

TABLE OF CONTENTS

MT-19 COMMITTEES	2
SPONSORS	3
CONGRESS CENTRE PLANS	4
EXHIBITION AREA	5
EXHIBITORS	6
GENERAL INFORMATION	8
GUIDELINES FOR PRESENTATIONS	9
GUIDELINES FOR MANUSCRIPT PREPARATION	10
GUIDELINES FOR SESSION CHAIRS	11
TECHNICAL TOURS	12
SOCIAL PROGRAM	12
POST CONFERENCE TOURS	12
IEEE AWARDS	13
MT-19 AWARDS	13
TECHNICAL PROGRAM AT A GLANCE	14
POSTER AREA – MONDAY 19 TH	17
POSTER AREA – TUESDAY 20 TH	18
POSTER AREA – WEDNESDAY 21 ST	19
POSTER AREA – THURSDAY 22 ND	20
ABSTRACTS	21
Monday, September 19, 2005	21
Tuesday, September 20, 2005	54
Wednesday, September 21, 2005	85
Thursday, September 22, 2005	118
Friday, September 23, 2005	149
	152

MT-19 COMMITTEES

International Organizing Committee

- L. ROSSI Italy (Chairman)
- C. A. BALDAN Brazil
- M. BARNES Canada
- E. D. BAYNHAM United Kingdom
- P. BRUZZONE Switzerland
- O. FILATOV Russian Federation
- L. GARCIA-TABARES Spain
- Z. JANU Czech Republic
- F. KIRCHER France
- H. KIRCHMAYR Austria

Local Organizing Committee

- R. MUSENICH (INFN Genova) Chairman
- S. FARINON (INFN) Vice-Chairman
- P. ALOTTO (University of Genova)
- E. CARNEVÀLI (INFN Genova)
- M. COROSU (INFN Genova)
- M. CONTE (INFN Genova)
- A. DELLACORTE (ENEA)
- G. DONATI (Outokumpu Italia)
- O. DORMICCHI (Ansaldo Superconduttori)
- P. FABBRICATORE (INFN Genova)

Scientific Program Committee

- P. FABBRICATORE (INFN-Genova IT) Chairman
- G. BELLOMO (INFN-Milano IT)
- A. BONITO OLIVA (Oxford Instruments UK)
- L. BOTTURA (CERN)
- A. DEVRED (CEA Saclay FR)
- S. FARINON (INFN-Genova IT)
- F. GÖMÖRY (Slovak Academy of Science SK)
- G. GRASSO (INFM IT)
- M. GRECO (INFN-Genova IT)
- M. GREEN (LBNL US)
- H. KRAUTH (EAS DE)
- D. KRISCHEL (ACCEL Instruments DE)
- M. LEGHISSA (SIEMENS DE)
- H. MAEDA (RIKEN JP)

- T. K. KO Korea P. KOMAREK- Germany R. MIKKONEN - Finland M. POLAK - Slovakia Y. C. SAXENA - India H. J. SCHNEIDER-MUNTAU - United States B. STRAUSS – United States H. TEN KATE - Netherlands H. WADA – Japan
- L. YAN China
- C. FERDEGHINI (INFM Genova)
- G. GEMME (INFN Genova)
- M. GRECO (INFN Genova)
- L. OPISSO (INFN Genova)
- R. PARODI (INFN Genova) Exhibition Manager
- M. PAVAN (INFN Genova)
- A. SECCI (Ànsaldo Superconduttori)
- S. SQUARCIA (University of Genova)
- R. VACCARONE (INFN Genova)
- G. VOLPINI (INFN Milano)
- T. ANTAYA (MIT US)
- R. MUSENICH (INFN-Genova IT)
- H. OHSAKI (University of Tokyo JP)
- R. PENCO (Ansaldo Superconduttori IT)
- L. ROSSI (CERN)
- E. SALPIÈTRO (ÉFDA)
- A. SATO (NIMS JP)
- H. SCHNEIDER-MUNTAU (NHMFL US)
- T. TAYLOR (CERN)
- G. VOLPINI (INFN-Genova IT)
- P. WANDERER (BNL US) A. YAMAMOTO (KEK JP)
- S. ZANNELLA (Èdison IT)

MAIN SPONSORS



BABCOCK NOELL NUCLEAR





SPONSORS





FURUKAWA ELECTRIC





GmbH



IEEE CSC Second council on superconductivity









ACKNOWLEDGMENTS





CONGRESS CENTRE PLANS





- 1 Entrance Hall Registration Desk, Manuscript Submission Desk, Wardrobe
- 2 Maestrale Room (Plenary and Parallel Oral Sessions)
- 3 Bar Area
- 4 Austro Room
- 5-7-8 Exhibition and Poster Areas
- 6 Ponente-Levante Room (Parallel Oral Sessions)
- 9 Libeccio-Scirocco Room (Parallel Oral Sessions)

EXHIBITION AREA





1	Furukawa Electric	2	Accel Instruments	3	Supercon
4	Hyper Tech Research	5	Esaote	6	Oxford Instruments Superconductivity
7	Forschungszentrum Karlsruhe	8	American Superconductor	9	HTS-110
10	Japan Superconductor Technology	11	Teco René Koch	12	Vector Fields
13	Alstom Magnets and Superconductors	14	Ansaldo Superconduttori	15	Babcock Noell Nuclear
16	Senis	17	Arcelor	18	Sumitomo Electric Industries
19	Outokumpu	20	Leybold Vacuum Italia	21	Space Cryomagnetics
22	Theva	23	Cryogenic	24	Ansoft Corporation
25	Sigmaphi	26	Tesla Engineering	27	EAS-EHTS
28	Jehier	29	Columbus	DC	SIMIC (displaying corner)
PO	poster area	I	Internet point	В	Coffee Break Table

5

DC

3

4

EXHIBITORS

ACCEL Instruments GmbH

Friedrich-Ebert-Straße 1 51429 Bergisch Gladbach GERMANY www.accel.de Contact Detlef Krischel krischel@accel.de

American Superconductor

2.Technology Drive 01581 Westborough, MA USA www.amsuper.com Contact: Dr Garry Ferguson htswires@amsuper.com

Ansoft Corporation

Piazzale Asia 21 00144 Rome ITALY www.ansoft.com Contact: Sondra Di Sabatino sondra@ansoft.com

Babcock Noell Nuclear GmbH

Alfred-Nobel-Strasse 20 97080 Wuerzburg GERMANY www.babcocknoellnuclear.de Contact: Michael Gehring michael gehring@bn-nuclear.de

Cryogenic Ltd

W3 7QE London UK www.cryogenic.co.uk Contact: Zakiya Khan info@cryogenic.co.uk

Esaote S.p.a

Via Siffredi 58 16153 Genova ITALY www.esaote.com Contact: Alessandro Trequattrini alessandro.treguattrini@esaote.com

Furukawa Electric

6-1, Marunouchi 2-chome, Chiyoda-ku Tokyo 100-8322 JAPAN www.furukawa.co.jp Contact: Hitoshi Shimizu shim@ho.furukawa.co.jp

Hyper Tech Research, Inc

1275 Kinnear Rd 43212 Columbus, OH USA www.hypertechresearch.com Contact: E.L Walley, Michael Tomsic elwalley@hotmail.com tomsic@voyager.net

Alstom Magnets and Superconductors

3 Bis Avenue des Trois Chênes 90018 Belfort FRANCE www.powerconv.alstom.com Contact. Claude Kohler claude.kohler@powerconv.alstom.com

Ansaldo Superconduttori

Corso Perrone 73r 16152 Genova ITALY www.as-g.it Contact: Roberto Cappellini cappellini.roberto@as-g.it

Arcelor

1, Place Kuborn 4100 Seraing BELGIUM www.arcelor.com Contact. Anne Taquet anne.taquet@arcelor.com

Columbus

Corso Perrone 24 16152 Genova ITALY www.columbus-sc.it Contact: Giovanni Grasso giovanni.grasso@infm.it

EAS-EHTS GmbH&Co KG

Ehrichstrasse 10 Hanau D-63450 GERMANY www.advancedsupercon.com Contact: Reinhard Dietrich reinhard.dietrich@advancedsupercon.com

Forschungszentrum Karlsruhe

Hermann-von-Helmholtz-Platz 1 DE-7644 Eggenstein-Leopoldshafenn GERMANY www.fzk.de Contact: Rolf Blattner, Johann Pappert rolf.blattner@map.fzk.de johann.pappert@map.fzk.de

HTS- 110 Ltd

PO Box 31-310, Lower hutt Wellington NEW ZEALAND www.hts-110.com Contact: Annalisa Devitt a.deviti@ivl.cvi.nz

Japan Superconductor Technology

5-9-12 Kitashinagawa, Shinagawa-ku 141-8688 Tokyo JAPAN www.jastec.org Contact: Kazuyuki Shibutani shibutani-jastec@kobelco.jp

Jehier

2, Rue de l'Erauderie BP 29 F 49120 Chemille FRANCE www.jehier.fr Contact: Tancrède Renault tancrede.renault@jehier.fr

Outokumpu

Via della Repubblica,257 Fornaci di Barga 55052 Lucca ITALY www.outokumpucopper.com Contact: Rauno Liikamaa, Guglielmo Donati guglielmo.donati@Outokumpu.com rauno.liikamaa@Outokumpu.com

Senis GmbH

Tecnnoparkstrasse 1 8005 Zurich SWITZERLAND www.senis.ch Contact: Dragana Popovic info@senis.ch

SIMIC

via Vittorio Veneto, 24 12072 Camerana (CN) ITALY www.simic.it Contact: Antonio Conte antonioconte 005@fastwebnet.it

Sumitomo Electric Industries Ltd

1-1-3, Shimaya, Konohana-Ku 554-0024 Osaka JAPAN www.sumitomo.com Contact: Yuichi Yamada yamada-yuichi@sei.co.jp

Teco René Koch

Chemin du Paradis 10 CH-1807 Blonay SWITZERLAND www.teco-rene-koch.com Contact: Rene Koch info@teco-rene-koch.com

Theva

Rote-Kreuz-Str.8 85737 Ismaning GERMANY www.theva.com Contact: Klaus Irgmaler irgmaler@theva.com

Leybold Vacuum Italia S.p.a

Via Tramesino 8 20128 Milano ITALY www.leybold.com Contact: Antonio Gonzato antonio.gonzato@leybold.com

Oxford Instruments Superconductivity

Tubney Woods, Abingdon, Oxon OX135OX UK www.oxford-instruments.com Contact: Neil Killoran neil-killoran@oxinst.co.uk

Sigmaphi

ZI DU PRAT Rue des Frères Montgolfier F – 56000 VANNES FRANCE www.sigmaphi.fr Contact: Jean Luc Lancelot contact@sigmaphi.fr

Space Cryomagnetics Ltd

E1 Culham Science Centre OX14 3DB Abingdon UK www.spacecryo.com Contact: Peter Penfold peterpenfold@spacecryo.co.uk

Supercon

830 Boston Turnpike 01545 Shrewsbury, Ma USA www.supercon-wire.com Contact: David Frost dfrost@supercon-wire.com

Tesla Engineering Ltd

Water Lane RH20 3EA Storrington West Sussex, UK www.tesla.co.uk Contact: Dr Michael Begg begg@tesla.co.uk

Vector Fields

24 bankside, Kildington Oxford OXS IJE UK www.vectorfields.co.uk Contact: Julie Shepherd julie.shepherd@vectorfields.co.uk

GENERAL INFORMATION

Weather

In September, the temperature in Genova is about 20-25° C (68-77° F) during daytime and 15-20° C (59-68° F) at night. Generally is sunny but showers are not infrequent.

Electricity

The electricity supply is 220 volts, 50 Hz. Official plug types are type C (round pin attachment plug), type F ("Schuko" plug) and type L (round pins with round in-line grounding plug). Adapters may be required.

Internet

Wireless and wired connections will be available at the Congress Center. In addition, a limited number of computer will be available for access to the internet during the Conference opening hours.

Currency

The official currency in Italy is Euro (€).

Time zone

Italy is located in the Central European Time Zone, GMT +1 (+2 during summer).

Tipping

Service charges are included in your restaurant bill, so you are not expected to tip. It is common practice, however, to leave a small amount but this is by no means compulsory. Tipping taxi drivers is not necessary.

Transportation

The conference badge is valid as pass for the Genoa public transits (bus and metro) valid from Sunday 18 to Friday 23. A desk for taxi reservation is available at the entrance hall of Congress Centre (special price to and from the airport).

Disclaimer

The MT-19 Organizing Committee accepts no liability for injuries, losses of whatever nature incurred by participants and/or accompanying persons, nor for losses or damage of their luggage and/or personal belongings.

Security

For security reasons the access to the conference site is controlled. Only people having their conference badge on are admitted.

CONGRESS SECRETARIAT

For information about:

- conference registration
- hotel booking
- optional tours
- post-conference tours
- companion program
- general information

please contact Promo-Est at the Help Desk or at the following address:

PROMO-EST S.R.L.

Barbara Colonnello and Elisa Cozza Via C. Barabino, 21/11 - 16129 Genova Ph. +39 010 5702228 - Fax +39 010 5702110 Mobile: +39 3486591678 e-mail: mt-19@promoest.com www.promoest.com

GUIDELINES FOR PRESENTATIONS

INSTRUCTIONS TO AUTHORS: ORAL PRESENTATIONS

Each **Contributed Oral** is permitted **20 minutes**. You should arrange your talk so that your presentation lasts 15 minutes, with 5 minutes available for questions.

Each **Invited Oral** is permitted **30 minutes**. You should plan for 25 minutes for the presentation and 5 minutes for questions. Each **Plenary Oral** is permitted **45 minutes**. You should plan for 40 minutes for the presentation and 5 minutes for questions.

You are expected to notify the session chair of your presence just before the start of the session so that he/she knows you are present. There will be no rearrangement of papers within an oral session to accommodate absences or cancellations, so the time you have been assigned within the oral session is fixed.

If you need to withdraw your presentation from the program, please contact the Scientific Secretariat desk.

All oral presenters are required to submit an electronic version of their presentation by 19:00 of the day prior to their presentation for the morning sessions and by 12:30 of the day prior to their presentation for the afternoon sessions. Presentations must be submitted in Microsoft Power Point format and should be turned in at the Speaker Preparation Room. These files are then checked and downloaded onto the computers in the session rooms. It is strongly recommended that presenters save their Power Point presentations with True Type fonts attached. Acceptable media include: CD and USB flash-drive.

Each presentation room is equipped with a PC connected to the projector. To minimize delays related to equipment troubles **authors are NOT permitted to use their own personal laptops.** Nor are they allowed to make changes to the file that has previously been submitted and has been downloaded to the computer in each session room.

Mac computers will NOT be available in any of the session rooms. Authors using a Mac platform will need to ensure that their files operate compatibly in the PC environment.

Authors are strongly encouraged to bring a duplicate copy of their presentation in the form of transparencies. You may also want to bring an additional electronic copy for added security against unanticipated software/hardware anomalies.

INSTRUCTIONS TO AUTHORS: POSTER PRESENTATIONS

If your paper appears in a poster session, you will want to take note of the following.

The poster boards are vertical. Each of them is 130 cm wide x 200 cm high.

Poster presenters are recommended to arrange their material before the morning parallel sessions and are expected to remove it within 18:00 (15:45 on Thursday). Adhesive tape will be available to post your material. The use of nail is not allowed.

Poster presenters are expected to be available from 13:30 to 15:30 to answer questions and discuss their papers with attendees. You may want to bring pre-prints for handout.

Only papers that are presented may be considered for publication. If a presenter is not available to answer questions and discuss the poster during the session, the paper written from this poster will not be published as part of the Transactions on Applied Superconductivity from the MT-19 conference. NOTE: It is NOT acceptable to merely post a copy of your paper. Such papers will be marked as 'no-show.'

Please note that MT19 accepts no responsibility for material that may be left behind, lost, stolen, or damaged.

How to decode the session number

MO, TU,	M/A	01, 02,	PO/OR/PL	01, 02, 03,
Day	Morning/Afternoon	Parallel Session Number	Poster/Oral/Plenary	Presentation number

Example:

MOA02OR03 means presentation No.3 of oral session 2 on Monday afternoon

GUIDELINES FOR MANUSCRIPT PREPARATION

The MT-19 Publication Desk is located in the entrance hall of the Conference Centre. THE MANUSCRIPT SUBMISSION DEADLINE IS AT 16:00 ON TUESDAY, SEPTEMBER 20, 2005.

OPEN FOR MANUSCRIPT SUBMISSION:

Monday, September 19, 2005, 9:30 - 18:00; Tuesday, September 20, 2005, 9:30 - 16:00;

1. MT-19 contributions will be published as a special issue in 2006 IEEE Transactions on Applied Superconductivity.

2. Your paper must be presented at the MT-19 conference and be recommended on the basis of peer-review in order to be accepted for publication in the IEEE Transactions on Applied Superconductivity.

3. You are requested to write your paper according to the instructions and guidelines posted on the following web sites : http://www.ieee.org/organizations/pubs/transactions/stylesheets.htm and http://www.ieee.org/organizations/pubs/transactions/information.htm Please download the TRANS-1011P_DOC template and two the assigned program number (example: MOA01PO10) (

Please download the **TRANS-JOUR.DOC** template and type the assigned program number (example: MOA01PO10) on the top right hand corner outside the text area on each page of your original manuscript.

4. The number of pages per paper is limited as follows:

Contributed papers:	4 pages
Invited papers:	6 pages
Plenary papers:	8 pages

If your paper exceeds the limit, you must pay 200€ per extra page at the On-Site Registration Desk PRIOR to submitting your paper.

5. The registration fee covers only one paper submission. When you register, you will get one paper submission voucher with your name at the Registration Desk. It will entitle to submit for publication one paper. The voucher is not transferable to other attendees. The name on the voucher must correspond with the name of one author on the paper being submitted. Authors submitting several papers must pay an extra charge of $300 \in$ for each additional paper at the On-Site Registration Desk PRIOR to submitting their papers.

6. The **deadline** for paper submission is **16:00 on Tuesday**, **September 20th 2005**. Authors are requested to submit 3 hard copies and an electronic copy in PDF format of their manuscript, the publication voucher and the signed <u>Copyright Form</u> to the Publication Desk at the Conference Site. Accepted media for the electronic copy of the papers are floppy disks, CD-ROMs, DVDs and USB pens.

7. Information on the submission of the final revised papers will be announced later.

GUIDELINES FOR SESSION CHAIRS

The following guidelines have been developed to help ensure the success of your session. Prior to the Conference, if you find you are unable to chair your session, please contact MT-19 organization (<u>mt-19@ge.infn.it</u>).

GENERAL INFORMATION FOR ORAL AND POSTER SESSION CHAIRS:

- Two Chairs are regularly assigned in every session.
- A Session Chair kit will be given to you at Registration that contains a list of the presentations in your assigned session, a Session Chair Report Form and any last-minute instructions or changes.
- Please contact your co-chair ahead of time to decide on the distribution of duties. Before the session, check the "Changes to Program" board near the registration desk for last minute additions and deletions.

ORAL SESSION INSTRUCTIONS

- Duration:
 - Contributed Oral is permitted 20 minutes. 15 minutes for the presentation plus 5 minutes for questions. Invited Oral is permitted 30 minutes. 25 minutes for the presentation plus 5 minutes for questions. Plenary Oral is permitted 45 minutes. 40 minutes for the presentation plus 5 minutes for questions.
- Be present in your meeting room at least 10 minutes before the start of your session to verify each author is present.
- All session rooms will be equipped with an LCD projector, a computer, and a screen. Presenters are required to submit a Power Point copy of their presentation to the Speaker Preparation Room prior to their presentation. These files are then reviewed and downloaded onto the computers in the session rooms. Presenters are not allowed to make changes to the file that has previously been submitted and has been downloaded to the computer in each session room.
- If a presenter has failed to submit his/her presentation, he/she will be required to give the presentation using transparencies and an overhead projector. Presenters are not allowed to use their own computers.
- Bring the session to order on time. Announce the title of the session, and introduce yourself and your co-chair.
- Announce a paper by title, speaker's name, and affiliation.
- Please, adhere to the time schedule and enforce the rules. Do not adjust the time schedule for no-shows and withdrawn presentations. Talks should be given at their scheduled time. Use your discretion in filling any gaps with longer discussions or questions from the audience. The discussion period must end in time for the next speaker to reach the podium, to be hooked up to the microphone, and to be briefed on your pre-arranged signals to indicate when a speaker's time is almost finished.
- Complete the Session Chair Report Form and submit it to the Publication Room. The form has space for documenting presenters and their paper numbers, no-shows, and withdrawals. Each submitted paper must have been presented at the Conference in order to be published in the Proceedings.

POSTER SESSION INSTRUCTIONS

- Please be in the Exhibition Areas at least 15 minutes prior to the session.
- Familiarize yourself with the displays and participate in discussions. Complete your Session Chair Report on presenters, no-shows, and withdrawals and submit it to the Publication Room. Each submitted paper must have been presented at the Conference in order to be published in the Proceedings.

TECHNICAL TOURS

Friday 23 technical visit to Ansaldo Superconduttori starting from 14:30. The reservation will be done on-site at the Registration Desk. The transportation is free of charge.
 Saturday 24 technical visit to CERN (leaving on Friday afternoon from Genoa) with the following program:

 8:30 Meeting at the Reception Building (33)
 9:00 Visit to CMS
 10:30 Visit to SM18
 11:30 Visit to ATLAS

13:00 End of tour

The transportation (bus or train) will be arranged on conference site depending on the number of participants. The cost of transportation + accommodation in Geneva is foreseen to be of the order of 200- $250 \in$.

SOCIAL PROGRAM

Social events and dinner

Sunday 18 evening:	Welcome Cocktail at the ground floor of the Congress Center (from 18:00 to 20:30)
Thursday 22 afternoon:	Riviera Tour and dinner at the Zeffirino restaurant on the Portofino Mount*. Buses are leaving
	from 15:30 to 17:30 in front of the Cogress Center entrance
Tuesday 20 at noon	Group photo on the pier in front of the Congress Center

*the Portofino Mount is about 400 m over the sea level and can be cool and windy. We suggest to take with you a warm cloth.

Optional program

Genoa Museums F	ass (3 days)		15€
Tuesdsay 20	(7:00 to 21:00)	Tuscany Wine Tour (min. 20 pers.**) A cultural and gastronomical tour in the land of Chianti	115€
Tuesdsay 20	(14:00 to 19:00)	Serravalle Outlet (min. 20 pers.**) A shopping experience in exclusive boutiques	26€
Wednesday 21	(8:30 to 14:00)	S.Fruttuoso-Portofino by boat (min. 15 pers.**) A tour to the famous villages of the Ligurian Riviera	60€
Thursday 22	(9:30 to 12:30)	Guided Tour of the Genoa Historic Center (old town) (the tour is included in the companion program fee)	13€

**Optional tours will be organized if the indicated minimum number of participants is reached. If the minimum number is not reached, pre-paid optional tickets will be fully refunded on-site.

POST CONFERENCE TOURS

Promo-Est, the MT-19 Official Agency, offers the following post conference excursions:

5 Terre by boat (September 24) Tuscany Wine Tour (September 25) Firenze (3 days) Roma (3 days) Venezia (3 days)

For information and reservation contact Promo-Est personnel at the Help Desk.

IEEE AWARDS

IEEE Award for LARGE SCALE SUPERCONDUCTIVITY

Romeo PERIN – CERN (retired)

For significant and continuous contributions in the field of large scale applications of superconductivity, in particular: for his many contributions in both design and construction of magnets for particle accelerators, including the design and construction of the pioneering project Intersecting Storage Ring (ISR) quadrupoles, the realization of the Large Hadron Collider (LHC) magnets at CERN from the design of the first models and prototypes through the difficult and critical phase of industrialization, and for the leadership of the magnet group responsible for developing magnets and superconductors at CERN.

IEEE Award for MATERIALS

René Louis FLÜCKIGER – University of Geneva

For outstanding and sustained contributions in the field of superconducting materials and conductors; in particular for his early seminal work on the electronic properties of the A15 compounds and the publication of the first phase diagram of Nb3Sn, for proposing the unique link between materials science and practical conductor engineering that led to the decisive enhancement of Nb3Sn for NMR applications at very high magnetic fields, for his significant researches in high temperature superconductors, namely BSCCO, and for training generations of students and young researchers in his laboratory at the University of Geneva.

MT-19 AWARDS FOR LARGE SCALE SUPERCONDUCTIVITY AND MAGNET TECHNOLOGY IN ITALY

Emilio ACERBI - Università di Milano and INFN

For his outstanding contribution to large scale superconductivity in Italy and to magnet technology developments in nuclear and high energy physics.

Francesco NEGRINI - Università di Bologna

For his leadership of the Superconducting MHD project in Italy and for his constant pursuing of superconductivity for power applications.

Nicola SACCHETTI - ENEA-Frascati (retired)

For his many years of leadership in large scale superconductivity in Italy and for his original contributions in Nb3Al developments and magnet technology for fusion.

Franco VIVALDI - Ansaldo Ricerche (retired)

For pioneering developments in magnet technology, large scale superconductivity and cryogenics in Italy for power and fusion applications.

TECHNICAL PROGRAM AT A GLANCE

The program ID numbers for each paper are made up of alphabets and numbers, for example TUA03PO01.

The first two digits, MO, TU, WE, TH, or FR, denote the day of the conference, from Monday 19 to Friday 23. The third digit, M or A, distinguishes between Morning and Afternoon sessions. The fourth digit is a number differentiating concurrent sessions. The next two digits, OR or PO, indicate the ORal or the POster sessions. The last digits denote your assigned slot. There are no concurrent oral and poster sessions.

Sunday, September 18, 2005		
18:00 - 20:30 Entrano	ce Hall Welcom	ne Cocktail

Monday, September 19, 2005		
08:30 - 09:15 Maestrale room	Introductory talks and IEEE Awards	
PLENARY SESSION		
09:15 - 10:00 Maestrale room	MOMPL (Speaker: Samuel Ting)	
10:00 - 10:30	Coffee break	
ORAL SESSIONS		
10:30 - 12:00 Ponente/Levante room	MOM10R (Motors, generators and transformers)	
10:30 - 12:10 Scirocco/Libeccio room	MOM2OR (High Tc superconductors)	
10:30 - 12:20 Maestrale room	MOM3OR (Magnets for high intensity machines)	
12:20 - 13:30	Lunch	
POSTER SESSIONS		
	MOA01PO (MgB2)	
	MOA02PO (Structural and magnetic materials & Insulation)	
	MOA03PO (Magnet design (I))	
	MOA04PO (Power supplies)	
	MOA05PO (Studies and simulations)	
13:30 - 15:30	MOA06PO (LHC main dipole magnets)	
	MOA07PO (Miscellaneous accelerator magnets (I))	
	MOA08PO (Magnet measurements)	
	MOA09PO (Power cables)	
	MOA10PO (Fault current limiters (I))	
	MOA11PO (Fusion present devices)	
	MOA12PO (ITER)	
15:00 - 15:50	Coffee break	
ORAL SESSIONS		
15:50 - 18:00 Scirocco/Libeccio room	MOA10R (Pulse magnets (I))	
15:50 - 18:10 Maestrale room	MOA2OR (Low Tc superconductors)	
15:50 - 17:40 Ponente/Levante room	MOA3OR (Magnet design)	

Tuesday, September 20, 2005		
PLENARY SESSION		
08:30 - 10:00 Maestrale room	TUMPL (Speakers: Alvaro de Rujula, René Flukiger)	
10:00 - 10:30	Coffee break	
ORAL SESSIONS		
10:30 - 12:00 Scirocco/Libeccio room	TUM1OR (Fault current limiters)	
10:30 - 11:40 Ponente/Levante room	TUM2OR (Fleld mapping)	
10:30 - 12:00 Maestrale room	TUM3OR (Challenging construction of large coils)	
12:00 - 13:30	Lunch	

POSTER SESSIONS	
	TUA01PO (MgB2 coils & New developments)
	TUA02PO (Low Tc superconductors (I))
	TUA03PO (Magnet design (II))
	TUA04PO (Field measurements and analyses)
	TUA05PO (AC losses (I))
13:30 - 15:30	TUA06PO (LHC miscellaneous magnets)
10.00 - 10.00	TUA07PO (Transfer lines magnets & Wigglers and undulators)
	TUA08PO (Miscellaneous accelerator magnets (II))
	TUA09PO (Fault current limiters (II))
	TUA10PO (Motors, generators and transformers)
	TUA11PO (Fusion magnet technology critical issues (I))
	TUA12PO (Industrial applications (I))
15:00 - 15:50	Coffee break
ORAL SESSIONS	
15:50 - 18:00 Maestrale room	TUA1OR (MgB2)
15:50 - 18:00 Scirocco/Libeccio room	TUA2OR (Nb3Sn accelerator magnets)
15:50 - 18:00 Ponente/Levante room	TUA3OR (High field magnets)
18:30 - 20:00	Round table on MgB2

Wednesday, September 21,	2005
PLENARY SESSION	
08:30 – 10:00 Maestrale room	WEMPL (Speakers: Ugo Amaldi, Xianrui Huang)
10:00 - 10:30	Coffee break
ORAL SESSIONS	
10:30 - 12:20 Maestrale room	WEM10R (Superconducting accelerator magnets)
10:30 - 12:20 Scirocco/Libeccio room	WEM2OR (Fusion magnets (I))
10:30 - 12:00 Ponente/Levante room	WEM3OR (Cooling systems & Temperature margins)
12:20 - 13:30	Lunch
POSTER SESSIONS	
	WEA01PO (Low Tc superconductors (II))
	WEA02PO (High Tc superconductors (I))
	WEA03PO (Cryogenics & Current leads)
	WEA04PO (Analytical design)
	WEA05PO (Stability)
13:30 - 15:30	WEA06PO (Permanent magnets)
10.00 - 10.00	WEA07PO (Nb3Sn accelerator magnets)
	WEA08PO (Detector magnets)
	WEA09PO (Energy storage (I))
	WEA10PO (High field magnets)
	WEA11PO (Industrial applications (II))
	WEA12PO (Fusion magnet technology critical issues (II))
15:00 - 15:50	Coffee break
ORAL SESSIONS	
15:50 - 18:20 Ponente/Levante room	WEA1OR (NMR and medical applications)
15:50 - 18:00 Scirocco/Libeccio room	WEA2OR (Industrial applications)
15:50 - 18:20 Maestrale room	WEA3OR (Detector magnets)

Thursday 22/9/2005	
PLENARY SESSION	
08:30 - 10:00 Maestrale room	THMPL (Speakers: Edward Bowles and Peide Weng)
10:00 - 10:30	Coffee break
ORAL SESSIONS	
10:30 - 12:30 Maestrale room	THM1OR (Fusion magnets (II))
10:30 - 12:20 Ponente/Levante room	THM2OR (Energy storage)
10:30 - 12:20 Scirocco/Libeccio room	THM3OR (Resistive magnets for accelerators and detectors)
12:30 - 13:30	Lunch
POSTER SESSIONS	
	THA01PO (Low Tc superconductors (III))
	THA02PO (High Tc superconductors (II))
	THA03PO (Protection systems & Special techniques)
	THA04PO (Quench)
	THA05PO (AC losses (II))
13:30 - 15:30	THA06PO (Electrical and mechanical computations)
10.00 - 10.00	THA07PO (FAIR accelerator magnets)
	THA08PO (ATLAS detector)
	THA09PO (Energy storage (II))
	THA10PO (Pulse magnets)
	THA11PO (Fusion future devices)
	THA12PO (NMR and medical applications)
15:00 - 16:00	Coffee break
16:00 - 22:30	Social program & Social dinner

Friday 23/9/2005							
ORAL SESSIONS							
8:30 - 10:20	Maestrale room	FRM1OR (Pulse magnets (II))					
8:30 - 10:40	Scirocco/Libeccio room	FRM2OR (LHC magnets)					
10:40 - 11:10		Coffee break					
PLENARY SESSION							
11:10 - 11:55	Maestrale room	FRMPL (Speaker: Hans Schneider-Muntau)					
11:55 - 13:00		Closure					

POSTER AREA – MONDAY 19TH



MT-19 2005, Genova

SEASIDE

- MOA07PO - MOA10PO - MOA11PO - MOA12PO



POSTER AREA – WEDNESDAY 21ST



2[™] FLOOR INNERSIDE MODULE 8 WEA04PO07 ESCALATOR WEA04PO06 SESSIONS: WEA04PO05 - WEA04PO - WEA06PO WEA04PO04 - WEA10PO WEA04PO03 WEA04PO02 WEA04PO01 -SEASIDE

2ND FLOOR MODULE 7

1^{s⊤} FLOOR

MODULE 8

SESSIONS:

- WEA08PO - WEA07PO

- WEA12PO

SESSIONS:

- WEA01PO - WEA02PO
- WEA03PO
- WEA05PO
- WEA09PO - WEA11PO



POSTER AREA – THURSDAY 22ND







2[™] FLOOR MODULE 7

SESSIONS:

- THA02PO - THA03PO
- THA05PO
- THA07PO
- THA09PO THA12PO

ABSTRACTS

Monday, September 19, 2005

PLENARY SESSION (Maestrale room)

9:15 - 10:00

MOMPL1

Superconductivity for space: physics experiments and technology

S. Ting, MIT.

A report will be given on the construction of the first large superconducting magnet for space applications. The Alpha Magnetic Spectrometer (AMS) magnet was done with the collaboration of ETH-Zurich, M.I.T., together with Space Cryomagnetics Ltd., ILK-Dresden, EADS-CRISA in Madrid, LINDE in Germany, H. Bieri in Switzerland. The applications of superconducting magnet technology in space for radiation protection, propulsion system, power generation and energy storage will be presented.

PARALLEL SESSION 10:30 - 12:00 (Ponente/Levante room) MOTORS, GENERATORS AND TRANSFORMERS

MOM10R1

High-Temperature Superconducting Rotating Machines for Ship Applications

M. Frank, H-W. Neumüller,W. Nick, B. Wacker,P. van Haßelt, P. Massek, P. Kummeth, Siemens AG, CT PS 3; G. Nerowski, Siemens AG, A&D LD; J. Frauenhofer, Siemens AG, A&D LD RD; R. Hartig, Siemens AG, I&S IP MAS; R. Wolfgang, Siemens AG, I&S IP MAS SP.

Main applications for rotating electric synchronous machines are given as generators and motors; a small niche can also be found in synchronous condenserapplications. HTS rotating machines show several significant advantages over machines built in conventional techniques. These are mainly increased efficiency, higher power density, and enhanced el. stability. Especially for onboard applications these properties may be decisive, to save fuel and space and improve the capabilities. In the past basic programs were carried out to demonstrate in principle the possibility to build such machines. Meanwhile these programs have shown great success and the feasibility of HTS machines for such applications has come into reach. For that reason developments for HTS machines in the megawatt-range are now being in progress, for propulsion purposes as well as for power generation applications. Started with the built of a 400 kW model motor that has operated for more than two years successfully, Siemens is now being engaged in the development of HTS machines for all electric ship application in the megawatt-range. A demonstrator for a 3600 rpm 4 MVA generator has been set up in the Nuremberg test facility for extended type and system testing. Results of tests with both machines will be presented. Technical implications of this new technology for ship-borne application will be discussed together with general economic assessments.

MOM10R2

Analysis Study on Superconducting Linear Driver for Electromagnetic Underwater Launching System Y. Peng, L. Zhao, R. Li, Y. Dai, C. Sha, A. Peng, Institute of Electrical Engineering, Chinese Academy of Sciences; T. Yang, T. Yang, Harbin Tech-Full Industry Co., LTD.

Electromagnetic underwater launcher system is expected to be quite, has high reliability and minimum maintenance requirement. In the system, a superconducting linear driver is used to generate a desired axial force to move a plunge to force water behind an object to be launched, such as a torpedo, and eject it from its tube. Design and simulation for a superconducting linear driver are presented in the paper. It is mainly consists of two components. One is a stationary superconducting magnet with opposite-poles solenoid coils to generate a constant magnetic field with the maximum radial field component of 0.75T, the other is a resistive coil, which is placed coaxially into the warm bore of the superconducting magnet, and is movable axially relative to the stationary superconducting magnet. A power supply system is connected to the movable coil, to provide current of desired magnitude and direction to the coil, so that energization of the resistive coil in the presence of the radial field component of the magnetic field creates an axial force on the movable coil. The axial force is controlled in magnitude and direction by controlling the magnitude and direction of the current supplied to the resistive coil with a controllable DC power. The linear driver can generate a desired axial force with the maximum of 10kN.

MOM10R3

Fabrication and Characteristics of HTS Induction Motor by the use of Bi-2223/Ag Squirrel-cage Rotor

T. Nakamura, H. Miyake, G. Morita, T. Hoshino, Kyoto University; I. Muta, Saga University.

We have fabricated and tested a High-Tc Superconducting (HTS) induction motor. A squirrel-cage type rotor is fabricated by using Bi-2223/Ag multifilamentary tape conductors, and then installed in the normal conducting stator, i.e., 3-phase and 4-pole. We have also developed the analysis method based on the electrical equivalent circuit that takes into account the nonlinear J-E relations. Tests are carried out after the fabricated motor is immersed in liquid nitrogen, i.e., 77.3 K. It is shown experimentally that there exists the minimum starting voltage for the generation of the torque, and this value agrees well with our theoretical study. Further experimental results will be presented and discussed.

MOM10R4

Experimental Study on Effect of In-Rush Current of Superconducting Transformer

T. İshigohka, K. Uno, S. Nishimiya, Seikei University.

In order to realize a superconducting transformer, it is essential to study its in-rush current characteristics. In a conventional transformer, usually the in-rush current becomes more than 7-10 pu. For such a large over-current, it would not be practical to design the transformer not to quench. Therefore, we should consider that the winding of a superconducting transformer may guench at the instant of the installation of the transformer into power system. The authors studied experimentally the problem of the in-rush current of a superconducting transformer using a small experimental model system. The experimental result shows that the superconducting winding recovers its superconducting state as soon as the initial large in-rush current decays.

PARALLEL SESSION	10:30 - 12:10
(Scirocco/Libeccio room)	
HIGH Tc SUPERCONDUCTORS	

MOM2OR1

Properties of Bi-2223/Ag-tapes and Y-123-coated conductors and ways of tayloring them for specific applications

T. Arndt, A. Aubele, M. Munz, B. Sailer, H. Krauth, EAS -European Advanced Superconductors GmbH & Co.KG; L. Kirchhoff, J. Knooke, A. Rutt, V. Selskij, A. Usoskin, EHTS - European High Temperature Superconductors GmbH & Co. KG.

High temperature superconducting tapes based on Bi-2223/Ag and later possibly on Y/RE-123 are more and more used in systems like Current Leads, Motors/ Generators, Power Transmission Lines, Magnets and Fault Current Limiters. These materials have to be tuned in design and properties to fulfill the different requirements of the specific application. The properties of the conductors are discussed as well as the design issues which should be addressed to trim them.

MOM2OR2

Progress in Bi-2212 Wires for High Magnetic Field Applications

K.R. Marken, H. Miao, M. Meinesz, B. Czabaj, S. Hong, Oxford Instruments.

The high field critical current density (Jc) and engineering current density (Je) in multifilament Bi-2212 round wires continue to improve. The critical current in these wires shows no anisotropy with respect to applied field. Recent efforts have focused on the effect of precursor composition combined with separate heat treatment optimization for each composition. Variations in the starting precursor cation ratios have several effects on conductor processing and properties, including the ceramic melt temperature, the relative sharpness of the melting event, the crystallization behavior including secondary phase formation and growth, and the peak Jc attainable. We systematically varied melt temperature, cooling rate, annealing temperature, and annealing time. Average Jc was determined from multiple samples for each parameter set. Dependence of Jc on cation ratio and these heat treatment parameters will be presented and discussed. Supporting characterization results include microstructural and microchemical SEM results and DTA analysis of the precursors. At 4.2K, self field Je has now exceeded 1600 A/mm2 (Jc > 6100 A/mm2), while at 25 T, Je has exceeded 500 A/mm2 (Jc > 1900 A/mm2) in 0.8 mm diameter wire. Issues and prospects for high field magnet application of this conductor will be discussed.

MOM2OR3

Advances in Bi-2212 high current Rutherford cable

Y. Hikichi, J. Nishioka, K. Tanimoto, T. Nakatsu, T. Hasegawa, Showa Electric Wire & Cable Co., Ltd.; K. Kidoguchi, N. Hirano, S. Nagaya, Chubu Electric Power Co., Inc.

The recent progress of Bi-family superconducting wire and tapes for practical applications is a reality generating enthusiasm to make devices larger. Large current capacity is an important requirement, because the excellent Jc-B characteristics of HTS conductors allow one to design compact electric power devices and energy efficient large-scale magnets. One of the advantages of Bi-2212 is that a high Jc value can be obtained in wires with various shapes and filament configurations. Realization of a high Jc round

wire made it possible to fabricate many kinds of cable developed for LTC applications. We successfully fabricated 30-strand Rutherford cable using 0.8mmd round wire. In this presentation, we will highlight the key factors to fabricate a Bi-2212 Rutherford cable that carried more than 10kA at 4.2K in self-field. We investigated the cabling parameters, electrical performance at 64K and 4.2K, and the mechanical properties. And the progress of the 200m class cable manufacturing activities will be presented.

MOM2OR4

Reel to Reel Coated Conductor Fabrication by Evaporation

W. Prusseit, C. Hoffmann, R. Nemetschek, G. Sigl, J. Handke, THEVA Dünnschichttechnik GmbH; A. Lümkemann, H. Kinder, TUM.

The latest development in superconductor wire technology are coated conductors, i.e. thin high temperature superconductor layers deposited on long, flexible metal substrates. We introduce a consistent reel-to-reel fabrication route for coated conductors with the potential of a future low cost production. The flexible substrate material is 0.1 mm thick and 10 mm wide electro-polished Hastelloy C 276. E-beam evaporation is used to deposit a highly oriented MgO buffer layer by inclined substrate deposition, the superconducting DyBCO - film, and additional metal layers, that serve as protective shunt and establish an electrical contact to the substrate. Currently, the processed tape length is increased from 10 m to 30 - 40 m. The ISD buffer enables critical current densities in excess of 2 MA/cm2 (77 K; s.f.). Due to improved tape handling the end-to-end transport current of the coated conductor tape has been gradually increasing from 150 to about 250 A/cm. In thicker films and over shorter distance even up to 500 A/cm are obtained. A major advantage of the coated conductor tape is the superior magnetic field performance. Measurements in magnetic field and under mechanical load will be presented. Although the available length is yet limited, superconducting current leads may constitute the first interesting application of coated conductors in magnet technology. They benefit from the low heat conductivity of the steel tape, which reduces the heat leakage considerably.

MOM2OR5

Fabrication and characteristic of Ho-123 Coated Conductors

M. Ueyama, S. Hahakura, K. Hasegawa, K. Ohmatsu, Sumitomo Electric Industries, LTD.

We have developed Ho-123 coated conductors on flexible metal tape substrates. Oxide buffer layers such as YSZ and CeO2 have been deposited on textured Ni-alloy tapes. A basic technique of the formation of buffer layer was and hetero-epitaxial buffer investigated. laver of CeO2/YSZ/CeO2 showed excellent in-plane alignment with the delta phi value in the range of 5 to 7 degrees. Surface roughness (Ra) was several nm and the surface was almost flat with few particles. Ho-123 deposition was conducted on the buffer layers by PLD method or MOD method. Sample less than 0.2 mm in thickness showed Jc (77.3 K, self field) over 2 MA/cm2. Sample with 1.3 mm in thickness showed Jc (77.3 K, self field) was 1.8 MA/cm2 near 2MA/cm2 and Ic (77.3 K, self field) was 231 A/cm-w. SEM photograph of Ho-123 layer revealed relatively smooth film morphology with some particles. Furthermore, Jc-B characteristics at 4.2 K under the high magnetic field up to 30 T were evaluated. Ic (4.2 K, 30 T) was 2,420A/cmw when the external magnetic field was applied parallel to the tape surface. A part of this work was supported by

NEDO as Collaborative Research and Development of Fundamental Technology for Superconductivity Applications. The authors would like to thank Dr. T. Takeuchi and Dr. N. Banno of NIMS for Ic measurement under low temperature and high magnetic field and Dr. I. Yamaguchi, Dr. T. Manabe, Dr. M. Sohma and Dr. T. Kumagai at National Institute of AIST for providing F-free coating solutions.

PARALLEL SESSION 10:30 - 12:20 (Maestrale room) MAGNETS FOR HIGH INTENSITY MACHINES

MOM3OR1

Test results of superconducting combined function prototype magnets for the J-PARC neutrino beam line

K. Sasaki, T. Nakamoto, N. Higashi, N. Kimura, Y. Ajima, T. Ogitsu, T. Tomaru, T. Okamura, Y. Makida, A. Yamamoto, KEK.

A next generation long base line neutrino oscillation experiment is planned to study fundamental nature of neutrinos. It will require the proton beam extracted from J-PARC 50GeV, 0.75 MW proton accelerator jointly built by JAERI and KEK. The beam line which guides the proton beam to the production target of secondary particles consists of 28 superconducting combined function magnets, SCFMs, currently developed at KEK. All the magnets are connected in series, cooled below 5 K by forced flow supercritical helium and operated DC. The unique feature of the magnet design is a left-right asymmetric structure with a single layer. This coil configuration enables to provide both a dipole filed of 2.6 T and a quadrupole field of 19 T/m with a current of 7350 A. The coil is encased in the glass- fiber reinforced phenolic plastic collars in stead of conventional metallic collars and iron yoke. The magnets have a large aperture of 173.4 mm, a magnetic length of 3.3 m and an outer diameter of 570 mm. The prototype SCFMs to investigate the magnet performance has been built and tested in a vertical cryostat at 4.2 K. In this paper, the results of guench tests and field measurement will be reported.

MOM3OR2

Design of a Radiation Resistant Quadrupole Using CICC

A. Zeller, J. DeLauter, NSCL/Michigan State University.

Several planned accelerator projects will produce very high radiation environments in the vicinity of superconducting magnets. The magnets will need to deal with both the heat deposited in the cold structure as well as long term damage to coils, insulation and support structure. CICC based coils provide the means for heat removal, but require some type of insulation and support for the large forces. Inorganic insulation provides radiation resistant insulation, but it's structurally weak. Two types of inorganicinsulated CICC coils have been considered for fabrication of radiation resistant coils: Aluminum conduit with internal anodization and a mineral oxide insulated CICC. The mineral insulated consists of an outer jacket with metal oxide between it and the inner jacket. Designs are presented that use each of these types of radiation resistant CICC.

MOM3OR3

The kicker magnet system of the RCS in J-PARC

J. Kamiya, T. Takayanagi, JAERI/J-PARC; E. Nakamura, T. Kawakubo, S. Murasugi, KEK/J-PARC.

The role of the kicker magnet in the J-PARC Rapid Cycling Synchrotron (RCS) is to extract the proton beam which is accelerated up to 3 GeV. The kicker magnet system is consists of a fast pulse power supply and a magnet. Their characteristic impedances are designed to match each other to prevent a reflection of fast pulse in their connections. The power supply is mainly composed of the charging unit, the pulse forming network, which is co-axial cables, and thyratrons as switching device. The maximum charging voltage is 80kV. The peak electric power throw the thyratron is very large. We suffered from selfbreakdown of the thyratrons without trigger signal. The energization as aging in several tens of hours was found to reduce the self-breakdown drastically. The magnet is a distributed twin-C type. The circuit parameters are designed to have the 10 ohm characteristic impedance. The measured characteristic impedance was close to 10 ohm. There will be no large mismatching between the power supply and the magnet. This magnet is installed in the vacuum chamber to prevent the electric discharge. We established the process to reduce the outgas from the components by baking them at appropriate temperature.

MOM3OR4

Opposite Field Septum Magnet System for the J-PARC Main Ring Injection

I. Sakai, K. Fan, Y. Arakaki, KEK.

The opposite field septum magnet system has been applied to the injection system of the J-PARC 50-GeV proton synchrotron. The features of the system are a forcefree structure, easy pulse excitation and the possibility of a large-aperture, thin-septum structure. The septum magnet has the structure of an inside-vacuum to eliminate the thickness of the vacuum-chamber walls and electricinsulation laver to make the septum thickness as thin as possible. However the magnet cores and return coils are outside of the vacuum to reduce the out-gassing rate of the vacuum system. Finally, the larger beam aperture than the full acceptance of the ring can be obtained at the septum magnet for low-loss injection. In this paper we will introduce the actual operation of the opposite field septum magnet and how to eliminate the error fields caused by fabrication errors and eddy current with pulse excitation.

MOM3OR5

Radiation Resistant Magnets for the J-PARC

K. Tanaka, J-PARC Promotion Office, High Energy Accelerator Research Organization (KEK); E. Hirose, H. Takahashi, Y. Suzuki, M. Takasaki, KEK; T. Birumachi, Hitachi Cable Ltd.; Y. Saitoh, K. Yahata, K. Kato, H. Tanaka, Tokin Machinery Corp.

A series of the R&D works on the radiation resistant magnets for the Japan Proton Accelerator Research Complex (J-PARC) has been continued. The main accelerator of the J-PARC is the 50 GeV-15 micro A proton synchrotron (50GeV-PS) the beam power of which reaches 750 kW. Then the radiation resistant magnet is the key technology to realize the external beam lines and experimental facilities of the J-PARC 50GeV-PS. The radiation resistant technologies we have selected for the J-PARC are; (1) Polyimide resin insulation for up to 10[^]8 Gy, and (2) Mineral Insulation magnet Cables (MICs) with larger cross sections for higher radiation dose than 10⁸ Gy. Approximately 20 polyimide insulation magnets and 10 MIC magnets have been designed for the external beam lines of the 50GeV-PS, and are now under fabrication. In addition to them, coils of more than 50 existing ordinary epoxy-insulation magnets will be replaced by polyimideinsulation coils or by MIC coils in order to increase their

radiation resistance to the J-PARC grade. These modifications will be completed by the end of March 2006. Then approximately 80 radiation resistant magnets will be prepared for the J-PARC 50GeV-PS. We have reported our R&D works on polyimide-insulation and MIC magnets in the previous MT conferences. At the coming MT-19, we will report the status of the mass production/preparation of these radiation resistant magnets for the actual construction of the J-PARC.

POSTER SESSION	13:30 - 15:30
MgB2	

MOA01PO01

Stability considerations of MgB2 superconductor

A. Stenvall, A. Korpela, R. Mikkonen, Tampere University of Technology / Institute of Electromagnetics.

Magnesium diboride, MgB2 is a tempting superconducting material in real technical applications due to its relatively simple structure and high critical temperature. It is widely believed that the MgB2 conductors could deliver the wire performance required for applications operating at 20-30 K in the \$1 to \$3 per kA-m range in the near future. The material is suitable especially at low field dc applications such in MRI devices and induction heaters. The stability analysis of MgB2 is however challenging. This is due to the fact that most conductors include ferromagnetic constituents in matrix metal. In addition the electromagnetic behaviour can be either isotopic or anisotropic depending on the conductor configuration. In this paper the numerical stability model is presented both for an individual MgB2 multifilamentary conductor and also for model solenoid. The results are compared to equivalent LTS and HTS magnets.

MOA01PO02

Bending Introduced Strain Effects on the In-situ Fabricated MgB2 Wire with Fe Sheath

X. Li, L. Xiao, Z. Zhang Institute of Electrical Engineering, CAS.

The effects of bending on Jc and Tc of MgB2/Fe monocore wire fabricated via in-situ PIT method were investigated. With the decreasing of the bending radii, Jc and Tc decrease significantly. The cracks in the superconductor were suggested to be the main reason of such degradation. The critical parameters of the bended wire were able to recover after post-annealing.

MOA01PO03

Fabrication of 130m-class MgB2/Fe/Cu wires and the results of small coil tests

H. Kitaguchi, K. Tanaka, H. Kumakura, NIMS; H. Yamada, M. Hirakawa, Central Japan Railway Co.; M. Okada, HRL, Hitachi Ltd.

We made 130m-long Fe/Cu-composite sheathed MgB2(Mg + amorphous B) wires through PIT route. The diameter of the wires is 0.8mm. Two small solenoid coils were fabricated using different batches of the wires and using wind & react process (heat treatment at 873-923 K for 1-10 h.) The test results of a coil using a 58m-long piece (459 turns) have been reported so far. In this paper, we report the test results of the other coil made of 86m-long piece (642 turns) and the comparison between these two coils. In the coil tests, we measured Ic of the coil under various external fields and temperatures. The Ic of the coil reached 195 A (engineering current density, Je, =390 A/mm2) at 4.2 K and in the external field of 1 T. The coil generated 1.95 T

(the center magnetic field, Bo), thus the total field reached 2.95 T. Je exceeded 100 A/mm2 in the external fields below 3.5 T, 2.5 T, and 1.5 T at 15 K, 20 K, and 25 K, respectively. These performances of 86m-coil are similar very much to those of 58m-coil. This indicates that the fabrication process of 130m-long wire and the heat treatment process are highly reproducible.

MOA01PO04

Self-field Loss in AC Transport Current for Ni-sheathed MgB2 Superconducting Tapes

S. Murase, M. lino, S. Kim, N. Nanato, Okayama University; Y. Yamada, K. Tachikawa, Tokai University. AC transport current loss (self field loss) of exsituprocessed MgB2 superconducting tapes with Ni sheath was measured under different conditions of transport current value. transport current frequency. and temperature. Experimental results were compared with Norris' theoretical curve, which were larger than the theoretical one and decreased with increasing frequency. Furthermore, loss – normalized transport current (transport current normalized by critical current) curves varied with temperature and the loss at 9 K was larger than that at 14 K. The frequency dependency of the loss is considered to be due to the skin effect. Although one of the loss origins is hysteresis of ferromagnetic nickel-sheath, the the hysteresis loss of Ni was to be negligibly small based on the estimation and measurement for loss of Ni. Main contributions to large loss are clarified by introducing a model of three concentric layers of MgB2 core in the wire caused by the inhomogeneity of critical current density and temperature. The measured curves critical and characteristics of loss - normalized transport current accorded with the calculated curves using above mentioned three-layered model.

MOA01PO05

Superconducting properties of MgB2 tapes fabricated with different alloys as sheath materials

V. Braccini, C. Fanciulli, M. Tropeano, M. Vignolo, A. Tumino, A. Malagoli, C. Bernini, G. Grasso, A.S. Siri, INFM-LAMIA.

At present, MgB2 appears suitable for niche applications at low and intermediate magnetic fields, and it has been shown to possess magnetic field capabilities that can be improved so as to overcome those of the best low Tc superconductors at 4.2K. At the same time, viable wire and tape technologies have been developed leading to samples with good superconducting properties over long lengths. We studied the influence of the deformation process, the sheath material and the precursor powders on the superconducting properties of ex-situ powder-in-tube processed MgB2 tapes. We used magnetic (Ni), slightly magnetic (Ni-W alloys) or non-magnetic (Ni-Cr alloys) sheaths. We used a commercially available Ni80-Cr20 alloy and we produced Ni-Cr and Ni-W alloys with different Cr or W percentages. We correlated their structural and physical properties with the different chemical compositions. Being these Ni alloys much harder than the Ni, their use induces a higher degree of stress improving properties such as the critical current density and the irreversibility field. On the other side, it is very hard to be cold-worked and cracks may occur in the phase, deteriorating the properties of the superconductor. We studied the influence of the pre-reacted MgB2 powders on the final properties of the tapes. We used powders with different granulometry, and doped in a different way, in order to increase the critical current density and improve the magnetic field capability of such tapes.

MOA01PO06

Preparation and characterization of superconducting MgB2 powders for powder-in-tube manufacturing

M. Vignolo, A. Tumino, V. Braccini, C. Bernini, G. Grasso, A. S. Siri, INFM-LAMIA.

Soon after the announcement of superconductivity in Magnesium diboride it appeared as a promising candidate for practical applications. At present, many efforts are focused on the development and manufacturing of long lengths MgB2 based conductors such as wires and tapes mainly for applications in low magnetic field, and in perspective for magnets as well. We produced tapes through the ex-situ powder in tube (P.I.T.) technique, thus allowing the use of pre-reacted MgB2 powders. This work regards the preparation, characterization and optimisation of MgB2 pure and doped powders to be used in superconducting tapes manufacturing in order to improve their properties such as the critical current density, the irreversibility line and the upper critical field. First of all, we developed an original method that allows the synthesis of large quantities (up to 1 Kg for batch) of MgB2 powders, needed for the production of long length tapes. We preformed a systematic study of their structural, morphological and superconducting properties both on the powders and on the tapes, with a comparison to those of commercially available powders. In addition we studied the pinning properties of the powders and the tapes in order to improve the tapes performances in presence of magnetic field. This was done following two ways: ball milling of powders in order to vary the granulometry and therefore the grain boundaries, and chemical doping, in particular with carbon and silicon carbide.

MOA01PO07

High Critical Current densities in Powder-in-Tube MgB2 Wires and Coils

A.C. Serquis, G. Serrano, M.T. Malachevsky, Instituto Balseiro - Centro Atomico Bariloche; L. Civale, B. Maiorov, LANL.

MgB2 is a promising material for making cheap and light magnets. The power-in-tube (PIT) method is one of the best procedures for processing brittle MgB2 into superconducting wires and tapes. Previous results indicate that low level of doping with AI, C and nano SiC powders improves the critical current density (Jc) of MgB2 bulk samples. Besides, the relatively low values for the upper critical field (Bc2) reported for MgB2 in the early days were rapidly overcome by the enormous progress achieved in bulk samples and thin films in the so-called dirty limit. Therefore, the optimization of the fabrication process for MgB2 long conductors should also include methods to enhance Bc2 and the irreversibility field (B*). In this paper we report on the fabrication and characterization of doped MgB2 wires and tapes prepared by PIT with commercial stainless steel and Ti sheaths. A series of samples have been prepared by different mechanic deformation procedures and sintered at different temperatures between 700°C and 950°C, in order to correlate their superconducting properties such as Jc, Bc2 and B* with the fabrication conditions and the doping content.

MOA01PO08

Properties of MgB2 Superconductor by doping impurity of SiC, Graphite, C60, and C nano-tube

K. Agatsuma, M. Furuse, S. Fuchino, National Institute of Advanced Industrial Science and Technology; W.J. Lee, J.M. Hur, Department of Metallurgy and Materials Engineering, Hanyang University.

Since MgB2 superconductor was discovered by Akimitsu,

many scientists has been studied this new intermediate temperature superconductor material. Recently Dou reported the critical current density and flux pining of MgB2 is enhanced by doping of SiC nano powder, and Fujii reported MgB2 superconductor made by the powder in tube ex-situ process using MgH2 as a precursor powder enhanced the critical current density especially under high magnetic field. Also Matsumoto reported the irreversibility field of MgB2 tape prepared by this the powder in tube insitu process using MgH2 as a precursor powder increased to 23T by the SiC doping. These results show MgB2 has high potential as a strong candidate for a practical use. We study the effects of doping nano carbon impurity because graphite has the same structure as the hexagonal Boron structure in MgB2. We added carbon impurities of graphite, C60, and open ended carbon nano tube respectively to MgB2 conductors made by powder in tube in-situ process. The experimental results will be presented.

MOA01PO09

Doping Effects of TiC and Mo2C on the Critical Current Properties of MgB2 tapes

A. Yamamoto, J-I. Shimoyama, S. Ueda, Y. Katsura, I. Iwayama, S. Horii, K. Kishio, University of Tokyo.

In our previous study, the MgB2 / SUS316-sheathed short tapes fabricated by the Powder-in-Closed-Tube method were found to exhibit excellent critical current properties with Jc of over 0.4 MA/cm2 and Birr exceeding 6 T at 20 K. On the other hand, moderately low level carbon substitution for boron site in MgB2 is well known to improve critical current properties particularly under high magnetic fields. The carbon substitution essentially accompanies a decrease of Tc and shortening of the a-axis length of MgB2. In the present study, TiC, Mo2C doped MgB2 tapes were synthesized in order to clarify effects of these carbon containing dopants on the microstructure and critical current properties of MgB2 tapes. Tc and the a-axis length of the TiC, Mo2C doped MgB2 tapes were systematically decreased with increasing nominal doping level x in Mg (1x)B_(2-x)(TiC)_x and Mg_(1-2x)B_(2-x)(Mo2C)_x while the c-axis lengths were almost unchanged. TiC or Mo2C doped MgB2 tapes showed distinct field and temperature dependence of Jc from undoped tapes. Improved high field Jc properties were observed for suitable amount of TiC, Mo2C doped samples both especially at low-temperatures around 5 K. Details of sample characterization and mechanism of enhanced Jc will be discussed including microstructural changes by doping of TiC and Mo2C.

MOA01PO10

Bulk MgB2 Doped with SiC and Diamond Nanopowders during Sintering by HP and HIP Techniques

D. Kuzmenko, A. Morawski, T. Lada, T. Mazur, D. Kolesnikov, Institute of High Pressure Physics, PASc; R. Diduszko, Institute of Electronic Materials Technology, Warsaw; A. Zaleski, Institute of Low Temperature and Structure Research, Wroclaw; K. Przybylski, University of Science and Technology (AGH), Cracow.

Bulk MgB2 was prepared by Hot Pressing (HP) and Hot Isostatic Pressing (HIP) techniques. Commercially available MgB2 powder (Alfa Aesar) milled in high energy mill was used as a precursor for sintering. Nanopowders of SiC and diamond were used as dopants to improve the superconducting properties of MgB2. HP was performed on the loose powder enclosed in the iron containers under 0.4 GPa of uniaxial pressure at different temperatures. HIP was carried out on the predensified samples packed into the soldered iron sheaths under up to 1 GPa of isostatic argon pressure. The dependence of sintered MgB2 morphology and superconducting properties (Jc, Hc2) on the sintering parameters and the dopant material and concentration was studied by X-Ray, EDAX, SEM methods and magnetization measurements.

MOA01PO11

High Hc2 and Hirr in MgB2 coated-conductor fibers

X.X. Xi, A.V. Pogrebnyakov, J. Chen, Q. Li, J.M. Redwing, Pennsylvania State University; V. Ferrando, University of Genoa/INFM-LAMIA; Ρ. Orgiani, University of Naples/INFM-Coherentia; J. E. Giencke, C. B. Eom, Department of Materials Science and Engineering and Applied Superconductivity Center, University of Wisconsin. MgB2 coated-conductor fibers were deposited on SiC fibers by hybrid physical-chemical vapor deposition (HPCVD). X-ray diffraction shows polycrystalline MgB2 with Mg2Si peaks. The clean MgB2 fibers have high Tc of ~ 40 K. When alloyed with carbon, the upper critical field Hc2 and irreversibility field Hirr of the fibers increase dramatically. The highest measured value of Hc2 is ~ 55 T and of Hirr is ~ 40 T at low temperatures. The results show that, first, epitaxy is not necessary in achieving the extraordinarily high values (over 60 T) previously reported in textured carbon-alloyed thin MgB2 films; and second, coated conductor using HPCVD is a viable approach for high performance MgB2 conductors for high-field magnets.

POSTER SESSION 13:30 - 15:30 STRUCTURAL AND MAGNETIC MATERIALS & INSULATION

MOA02PO01

Mechanical Properties of Zylon/Epoxy Composite at 295 K and 77 K

R.P. Walsh, C. Swenson, NHMFL-FSU; N. Bednar, Perseo Engineering.

Zylon fiber, poly(p-phenylene-2,6-benzobisoxazole) PBO has found recent use in high-field pulse magnet coil development because of this fiber's extremely high 295K ultimate tensile strength (>5.0 GPa) and elastic modulus (280 GPa). Although the fiber properties are well documented, there is limited data available with respect to its properties in fiber/epoxy composite form and at low temperatures. A test program has been conducted to investigate the properties one can attain from a Zylon/epoxy composite, produced using pulse magnet fabrication techniques (race track specimens are fabricated using various winding tensions and outside form techniques). The relationship between winding tension, ultimate tensile strength (UTS), and filling factor of the fibers is studied. The ultimate tensile strength (UTS), elastic modulus, and maximum strain at failure of a unidirectional Zylon/epoxy matrix composite are measured at both 295K and 77K. The thermal contraction of the composites are also measured and reported.

MOA02PO02

RF Magnetic Shielding Effects of the Compound Material Constructed from the Ferrite and Bincho-Charcoal Plates

H. Norikane, S. Gokyu, A. Omura, M. Itoh, Interdisc. Grad. School of Science and Engineering, Kinki University; Y. Hotta, EMC Engineering Laboratory Ltd.

RF magnetic shielding materials are used to reduce the influence of environmental electromagnetic waves, and to protect the environment from the leakage of any generated electromagnetic waves. In present study, RF magnetic

shielding degree SDh of a compound material, such as a bincho-charcoal plate superimposed by ferrite plate, is measured by use of the measuring cell for the near field (46 mm wide, 46 mm in height, 55 mm deep, 2 mm thick). The value of SDh for a ferrite plate was found to increase as the frequency increased over range from 1 MHz (SDh at 1 MHz: 20 dB) to 20 MHz (SDh at 20 MHz: 35 dB), and to decrease in frequency region from 20 MHz to 1 GHz (SDh at 1 GHz: 9 dB). However, it was found that the value of SDh for the bincho-charcoal plate is held at 0 dB in frequency range of 1 MHz - 8 MHz, and then increases over the frequency range of 8 MHz - 1 GHz (SDh at 1 GHz: 35 dB). Here, bincho-charcoal is obtained from very hard oak, sintered under high temperature conditions. The RF magnetic shielding characteristics were found to be improved by using the compound material, in the frequency region from 7 MHz to 1 GHz, that is, the value of SDh is held at approximately 35 dB on these wide frequency region. The present paper examines the effects of RF electromagnetic shielding on the compound materials. This includes the RF magnetic and electric shielding degrees, SDh and SDe, as a function of frequency, and the SDh and SDe as a function of RF power.

MOA02PO03

An innovating insulation for Nb3Sn Wind & React coils: electrical tests

L. Quettier, J.M. Rey, F. Rondeaux, CEA Saclay; A. Puigsegur, E. Prouzet, Institut Européen des Membranes - CNRS Montpellier.

If Nb3Sn is the best superconductor candidate for the realisation of high field magnets (>10-11 Teslas), its implementation remains delicate because of the great brittleness of material after the heat treatment necessary to the formation of Nb3Sn compounds. The conventional insulation for Nb3Sn Wind & React coils requires to perform, after the heat treatment, a vacuum resin impregnation, which adds to the cost and raises failure risk. We have proposed a one-step innovating ceramic insulation deposited directly on the un-reacted conducting cable. After the heat treatment necessary to the formation of the Nb3Sn, we obtain a coil having a mechanical cohesion, while maintaining a proper conductor positioning and a suitable electric insulation. We have shown that using this insulation in a coil manufacture process doesn't affect the electrical properties of the Nb3Sn wires. A solenoid of small dimensions (9 * 20 turns on an internal diameter of 22 mm) has produced a magnetic field of 3.8 T under 740 A. It was tested with success in high external magnetic fields: the quench limits have been imposed by the strand and the insulation was not damaged.

MOA02PO04

The Structure and Magnetic Properties of Hydroextruded Dysprosium

A. Bulatov, M. Lazareva, M. Tikhonovsky, N. Chernyak, National Science Center "Kharkov Institute of Physics & Technology" (NSC KIPT).

The low-temperature collinear ferromagnetic Dy that has high saturation flux density is a promising material for building magnetic flux concentrators for various cryogenic magnetic systems. An impediment for its employment in the polycrystalline isotropic state is the giant magnetocrystalline anisotropy. The problem has been resolved of crystalline structure control throughout the mass volume. The review of the experimental results indicated that: 1.As a result of the plastic strain obtained via the technique of Dy room temperature hydroextrusion, the favorable crystallographic grain orientation

{0001}<1010> was created along the direction of the extrusion. The degree of the spread of the axial grain orientation, according to the X-rays analysis, after the deformation of 60-75% is within the angular limits of 15-10 degrees, respectively. The grain size dispersion of the extruded samples does not exceed 1-2 microns. 2. The magnetic properties were studied in applied fields up to 15 T at T=4.2, 20.4 and 78 K. The dependence of magnetization on field value, its magnitude and saturation field are close to the respective parameters of single crystal (at 4.2 K the saturation magnetization is 3.7T). 3. Massive hydroextruded rods (d=16-40 mm) were employed to make a batch of magnetic flux concentrators for superconducting solenoids. The additional magnetic field in the gap of 1 mm is ~ 40% of the main solenoid one, the field homogeneity being at the level of 10(-4).

MOA02PO05

Production of austenitic steel for the LHC superconducting dipole magnets

F. Bertinelli, G. Peiro, A. Russo, CERN; S. Comel, P. Harlet, A. Taquet, ARCELOR Group.

The austenitic steel collars are an important component of the LHC dipole magnets, operating at cryogenic temperature under high mechanical stress. The required steel, known as YUS 130S, has been specifically developed for this application by Nippon Steel Corporation, followed in 1999 by a CERN contract for the supply of 11 500 tonnes. In 2005 - after six years of work - the contract is being successfully completed, with final production being ensured since October 2004 by Nippon Steel & Sumikin Stainless Steel Corporation (NSSC). The paper describes the steel properties, its manufacturing and quality control process, organization of production, logistics and contract follow-up. Extensive statistics have been collected relating to mechanical, physical and technological parameters. Specific attention is dedicated to measurements of magnetic permeability performed at cryogenic temperatures by CERN, the equipment used and statistical results. Reference is also made to the resulting precision of the fine-blanked collars. Finally new applications for this steel are described, as an example of technology transfer from the particle accelerator domain to Industry.

MOA02PO06

Production of low – carbon magnetic steel for the LHC superconducting dipole and quadrupole magnets

F. Bertinelli, G. Peiro, A. Russo, CERN; S. Comel, P. Harlet, A. Taquet, ARCELOR Group.

In 1996 CERN negotiated a contract with Cockerill Sambre - ARCELOR Group for the supply of 50 000 tonnes of low - carbon steel for the LHC main magnets: this was the first contract to be placed for the project, and one of the single largest. In 2005 - after nine years of work - the contract is being successfully completed. The paper describes the steel specifically developed, known as MAGNETIL, its manufacturing and quality control process, organisation of production, logistics and contract follow-up. Extensive statistics have been collected relating to mechanical, physical and technological parameters. Specific attention is dedicated to magnetic measurements (coercivity and permeability) performed at both room and cryogenic temperatures, the equipment used and statistical results. Reference is also made to the resulting precision of the fine-blanked laminations used for the magnet yoke. The technology transfer from the particle accelerator domain to Industry is ongoing: a new application for the screening of high voltage cables buried in the ground is described.

MOA02PO07

Curing of LHC main dipole coils insulated with all polyimide PIXEO® adhesive tape

P. Fessia, H. Kummer, D. Tommasini, CERN; F. Van de Velde, A. Kuribayashi, Kaneka High Tech Materials.

An all polyimide system made by plain and adhesive coated tapes has been adopted for the turn to turn insulation of the LHC coils. In this analysis we put in evidence how different parameters of the curing cycles affect the final bonding quality. Data for two different glue compositions are compared showing how the conjoint effort between CERN and Kaneka has helped to enlarge the window in which this material provides outstanding gluing making easier to keep under control bonding quality throughout the mass production in a real industrial environment.

MOA02PO08

Pulse Magnetic Characteristics of Ferrites at high rates of Magnetization for Pulsed Magnets

R.S. Schinde, P. Pareek, R.R. Yadav, S. Kotaiah, Head Ferrite Lab., MDL, CAT.

High frequency ferrites like NiZn,NiZnCo are used in high speed magnets for Accelerators. The magnetization rates are involved are up to about 5T/microsecond & reverses in the order of few ns.To design fast pulsed magnets, it is necessary to know how the ferrite magnetization under ns.To meet this requirement, a simple domain model has been used to explain fast flux reversal in Ni-Zn Systems. The model described here to predict electrical behaviour of ferrites at pulse conditions. The ferrite microstructure is represented by an effective spherical grain & effective domain wall collapsing inside the grain. The stimulated pulse response is compared with experimental results ferrites.To our knowledge,a systematic study of pulse magnetization of ferrites has not been reported in the literature.Since,ultimate utilization of ferrite compositions must be based on actual under pulse conditions. A pulse hystersisgraph set up has been built to measure the response of ferrite to fast, high rates of magnetization(~3 T/microsecond) so that these test results directly applied to the design of high speed magnets & magnetic devices for Accelerators.We have also developed a Coaxial fixtures to measure ns pulse response of ferrites. This paper presents ferrite domain model for pulse magnetization at high rates (dB/dt ~ 3 T/micosecond), modelled results comparision with experimentally obtained results. The measured pulse response nearly agrees with the stimulated pulse response from domain wall.

MOA02PO09

Dielectric thermal analysis as a tool for quantitative evaluation of the viscosity and the kinetics of epoxy resin curing

C.Y. Shigue, R. Santos, M. Abreu, C. Baldan, A. Robin, E. Ruppert-Filho, DEMAR/FAENQUIL.

Dielectric thermal analysis has been proved as a valuable tool for monitoring the epoxy curing process and the related rheological properties in the fabrication of polymermatrix composite materials. This technique has also the potential to be applied in the monitoring of magnet impregnation processes as well as in quality control. In this work we present the quantitative evaluation of the viscosity changing and the curing kinetics for the Stycast epoxy resin system at different temperatures using an impedance analyzer. The results show a very consistent correlation between the complex impedance and the reaction extent as well with viscosity measured by rotational rheometer. The results were also compared with the Differential Scanning Calorimetry (DSC) analysis and the kinetics parameters obtained from both methods showed an excellent agreement, pointing out the dielectric thermal analysis should be applied in quantitative measurement of curing reaction kinetics.

MOA02PO10

Thermal Conductivity with Various Temperatures and Dielectric Strength of the Impregnating Materials for the Bifilar Winding Type Superconducting Fault Current Limiter

S.E. Yang, D.K. Bae, M.C. Ahn, H. Kang, D.K. Park, T.K. Ko, Department of Electrical and Electric Engineering, Yonsei University; Y.S. Yoon, Ansan College of Technology; S.Y. Choi, Sungkyunkwan University; S.H. Kim, Department of Electrical Engineering, Gyeongsang National University; H.M. Chang, Department of Mechanical & System Design Eng., Hongik University.

The resistive type high temperature superconducting fault current limiter (HTSFCL) limits the fault current with the resistance generated by fault current. The generated resistance by fault current makes large pulse power which makes the operation of HTSFCL unstable. So, the cryogenic cooling system of the resistive type HTSFCL must diffuse and eliminate the pulse energy very quickly. Although the best way is to make wide direct contact area between HTS winding and coolant as much as possible, HTS winding also needs the impregnation layer which fixes and protects it from electromagnetic force. This paper deals with the thermal conductivity and dielectric strength of some epoxy compounds for the impregnation of high temperature superconducting (HTS) winding. The thermal conductivity of stycast® blue/catalyst 23LV that had better thermal characteristic property in liquid nitrogen was measured at 200K, 100K, 77K, 65K and 50K using conduction cooling method. The dielectric strength was measured in liquid nitrogen. The obtained data can be used in the optimal design of impregnation for HTS winding. Aluminar filling increased the thermal conductivity of epoxy compounds. Hardener also affected the thermal and electric characteristic of epoxy compounds,

MOA02PO11

Dielectric Characteristics of EPR for 66kV-class Power leads of High Tc Superconducting Fault Current Limiter.

M. Sakai, H. Kaneiwa, M. Urata, Toshiba corporation; H. Koyama, TMT&D; Y. Tokunaga, Tokyo elecric power company; K. Inoue, Super-GM.

66kV-class power lead insulation system has been developed. This power lead is insulated by ethylenepropylene rubber (EPR) without filler that has excellent crack resistance. Dielectric characteristics of this EPR were investigated. Breakdown voltage was measured against 1-10mm thickness at room temperature and liquid nitrogen temperature. And lifetime against electrical stress was measured. Therefore these characteristics were clarified, it came to be able to make the power lead insulation compact. And the power lead insulation verification model was made and electrical insulation property was evaluated. At result, this model satisfied a prescribed electrical insulation property. This work had been carried out as a part of Super-ACE (R&D of fundamental technologies for superconducting AC power equipment) project of METI, being consigned by NEDO.

MOA02PO12

Flux Dynamics in Inhomogeneous Bulk Superconductor during Pulsed Field Magnetization

R. Shiraishi, H. Ohsaki, The University of Tokyo.

Pulsed field magnetization (PFM) is one of the key technologies for magnetizing bulk superconductor as a strong flux source. Recently, various apparatuses using bulk superconducting magnets have been studied and developed. In these apparatuses, it is expected that the application of PFM would make the magnetization system much simpler than the other methods. However, the performance of PFM is dependent on the conditions of applied magnetic field, superconductive properties, etc. Efficient and effective magnetization is an essential issue for practical use of PFM for high-performance bulk superconductors. The bulk superconductor has inevitably more or less nonuniform distribution of superconductive properties. In PFM, this inhomogeneity greatly influences magnetic flux motion in the bulk superconductor and also the flux density distribution after PFM. In the local region with lower critical current density the smaller shielding current is induced and the magnetic flux penetrates more easily. Furthermore, the heat generation by the flux penetration causes the more lowering of critical current density. This paper discusses the relation between the inhomogeneous superconducting properties of the bulk and magnetizing properties of PFM. Then, better the magnetization conditions are examined in consideration of magnetic flux dynamics in the inhomogeneous bulk superconductor during PFM.

MOA02PO13

Electrical Properties of Ceramic Insulation Coatings for Magnet Technology

L. Arda, S. Aktas, Marmara University; O. Cakiroglu, Istanbul University.

Withdrawn.

MOA02PO14

Influence of heat treatment regime on magnetic properties of melt-spun Nd4.5Fe77B18.5 alloy

V. Cosovic, N. Talijan, J. Stajic-Trosic, A. Grujic, Institute of Chemistry, Technology and Metallurgy; T. Zak, Institute of Physics of Materials, Academy of Sciences of the Czech Republic.

Withdrawn.

MOA02PO15

Mössbauer study and thermomagnetic measurments of melt spun Nd-Fe-B alloys with different Nd content

J. Stajic-Trosic, N. Talijan, V. Cosovic, A. Grujic, Institute of Chemistry, Technology and Metallurgy; V. Menushenkov, Moscow State Institute of Steel and Alloys (Technological University); T. Zak, Institute of Physics of Materials, Academy of Sciences of the Czech Republic. Withdrawn.

POSTER SESSION	13:30 - 15:30
MAGNET DESIGN (I)	

MOA03PO01 Bump Magnet of CSRm

L. Ma, S. Han, Z. Zhou, Y. He, Y. Su, W. Liu, S. Zhang, P. Yuan, Y. Yuan, J. Xia, Institute of modern physics of CAS. CSRm is a new heavy ion storage ring just been constructed in Institute of modern physics, Chinese academy of sciences, lanzhou, China. Four Bump magnets are used for the ion injection of this storage ring. The electric-magnetic optimizing design, the field calculation, the test result will be described in this paper.

MOA03PO02

The Magnetic Septum System of CSR

L. Ma, Graduate School of CAS; S. Han, Y. He, P. Yuan, Y. Yuan, J. Xia, Institute of modern physics of CAS.

CSR, a new accelerator project at the Heavy Ion Research Facility in Lanzhou (HIRFL), is a multipurpose Cooling Storage Ring (CSR) system that consists of a main ring (CSRm) and an experimental ring(CSRe). In order to satisfy the requirements of the beam injection and extraction, four magnetic septa will be used in the injection and extraction for the two storage rings. The choice of the type, the electric-magnetic design and the field calculation will be introduced in this paper, including the construction and mechanic design, the fabrication and the test.

MOA03PO03

Design Methods of the Modified Spherical Quadrupole Magnet

Y. Bai, M. Yang, Q. Wang, Y. Yu, Institute of Electrical Engineering, CAS Withdrawn.

MOA03PO04

Superconducting Double Dipole High Field Magnet

V. Kashikhin, N. Andreev, V. Kashikhin, I. Novitski, A. Zlobin, FNAL.

Recent progress in Nb3Sn superconductor technology provides the base for increasing magnet field in accelerator magnets up to 15-16 T. The works on such magnet based on both block-type and shell-type coils are in progress at Fermilab, LBNL and elsewhere. One of the novel approaches to the design of this magnet is to split the magnet winding into two separate dipole windings powered in series or separately. Each winding generates a homogeneous magnetic field in the magnet aperture. The paper presents conceptual magnetic and mechanical designs of 15 T double dipole magnet and discusses several scenarios of magnet powering. The inner dipole winding is based on the 2-layer Nb3Sn coils previously developed and tested at Fermilab. The outer dipole winding is made of sub-sized Nb3Sn cable and has about two times higher current density. Both windings have the shell-type configuration. For the different powering scenarios the results of calculation of the field quality, coil magnetization effects, and the stress analysis are presented.

MOA03PO05

Excitation of superconducting coil made of Tareinforced Nb3Sn conductor in 14 T

T. Takao, K. Umekawa, Y. Fukasawa, T. Iwamura, S. Minowa, Sophia University; M. Umeda, M. Furuse, National Institute of Advanced Industrial Science and Technology.

We have studied mechanical property and Ic degradation of Ta reinforced Nb3Sn conductors. When the conductor is reinforced by Ta filaments, strain of the conductor against stress decreased and the Ic degradation also becomes small. We fabricated the coil made of the Nb3Sn conductor; and we excited the coil in the backup magnetic field of maximum 14 T. And the stress and quench current were measured. After warming up of the coil to room temperature, we cut the coil and observed cracks between the bobbin and the winding in the cross-section of the coil. In the paper, we present the detail of the experimental results, and analyze the stress applied to winding and the strain occurred in the winding.

MOA03PO06

Optimization of pole shapes by MULTIMAG

A.G. Kalimov, A. Potienko, St.Petersburg State Polytechnic

University; H. Wollnik, Giessen University.

The optimization of magnet poles is usually based on iterative procedures which include repited magnetic field calculation in nonlinear media. For this task we have used MULTIMAG a program that has been developed for the design and analysis of magnets used in particle ccelerators and spectrometers. This program uses finite element methods to determine magnetic fields characteristics and includes options for 2D and 3D modeling. First or second oder finite element techniques are used depending on the required solution accuracy. One of the important features of this program is that its calculation mesh is automatically generated without user interaction for any dipole or quadrupole magnet. Certain multi-step optimizations are also performed by MULTIMAG with minimal user interaction. Such optimizations are most useful for the design of high performance guadrupole magnets. This optimizing procedure is based on the reduction of undesired field harmonics in the area where good field quality is required. For a quadrupole magnet this goal is achieved by describing the pole surface as a sum of high order hyperbolas whose magnitudes are modified iteratively. This method has been applied successfully to find optimal poles shapes for a quadrupole magnet with superimposed six-pole harmonics of required magnitude.

MOA03PO07

Magnetic Field Distribution Control with Anisotropic Inter-Pole Magnetic Field

Y. Iwashita, ICR, Kyoto University.

A novel method to control a magnetic field distribution in a magnet is devised with use of inter-poles made of anisotropic magnet material. One can generate a gradient field in a constant gapped magnet with this technique; the effective length of the magnet can be constant independent of the entrance position. Such magnet can have not only constant gap but also smaller fringing field compared with a conventional one that controls its field distribution by changing the gap height. This technique should widen the recipe to design a magnet with a complex magnetic field distribution.

MOA03P008

3D FEM mechanical modeling of the head of the LHC Main dipole

P. Fessia, I. Rodriguez Canseco, CERN.

3D finite element mechanical model has been developed to simulate the complex geometry of the extremities of the coils for the LHC main dipoles. The final aim is to evaluate the importance of assembly induced defect of the coil end spacers and their possible impact on quench performances. In this paper we describe the first part of the work that has been carried out. This covers an analysis of the contribution of the mechanical properties of the different materials to the rigidity of the heads and the experimental validation of the model. For such validation we compared the computed stiffness with the values observed during production measurements in industry. The numerical results are in good agreement with the measured, however some results indicate that direction the modeling should be refined. The lines for further development are discussed too.

MOA03PO09

A non-linear finite element mechanical model for the LHC main dipole coil cross-section

M. Pojer, A. Devred, CERN.

The production of the dipole for the Large Hadron Collider is already at its final stage. Nevertheless, some mechanical instabilities are still observed for which no clear explanations have yet been found. A modelization of the dipole cold mass cross-section had already been developed at CERN, mainly for magnetic analysis, taking into account conductor blocks and a frictionless behavior. This paper describes a new ANSYS model of the dipole coil cross-section, featuring individual turns precise modeling inside the conductor blocks, and implementing friction and the mechanical hysteretic behavior of insulated cables. Preliminary results and development under way are discussed.

POSTER SESSION	13:30 - 15:30
POWER SUPPLIES	

MOA04PO01

The 100 kA DC Power Supply for a Staged Hadron Collider Superferric Magnet

S.L. Hays, B. Claypool, W. Foster, FNAL.

A 1.5 volt 100,000 amp DC switcher power supply was developed for testing a superferric magnet string at FNAL. This supply was used during testing as both the ramping supply and holding supply due to only a single magnet load with a total load resistance of 0.7u Ohms. The supply consists of a bulk power source which is filtered and regulated at 400 volts and 240kWatts and 10 switcher cells. The high current part of the supply consist of 10, 1.5 volt 10,000 amp forward converter cells connected in parallel at the input to the power lead. Each converter has a 7:1 turns ratio with the primaries of each of the 112 converters connected in series and the bridge outputs all connected in parallel. During these test each cell was operated as a constant power device without load current or field feedback. This paper will describe the design of the switcher cell and control system used during testing. We will also describes the next level of improvements to the current feedback system to improve the ramp control.

MOA04PO02

Low Temperature Characteristics of MOSFET Targeting Low-Voltage High-Current Power Source for Superconducting Magnets

R. Kawanami, T. Ishigouoka, Seikei University.

The authors propose a low-voltage/high-current DC power source using multi-parallel-connected MOSFETs for an excitation power source of superconducting magnets. The power source can operate at 77K in liquid nitrogen bath. The fundamental idea and some preliminary experimental results are presented. The preliminary experiment using 100 MOSFETs connected in parallel are carried out. The forward-direction voltage drop both at room temperature and 77K has been measured. The experimental results show good prospect for this type of DC power source in order to excite superconducting magnets.

MOA04PO03

A Study on Electrical Characteristics of Advanced Unipolar Power Electronics Devices for Their Application to Large Capacity AC/DC Converter

T. Matsukawa, M. Ishida, Department of Electrical and Electronic Engineering, Mie University; H. Chikaraishi, NIFS; Y. Sato, Daido Institute of Technology; R. Shimada, Tokyo Institute of Technology.

The switching device, which is applied to large capacity AC/DC converter, has been manufactured based on crystallized Si material, some of which are thyristor, ICBT, GTO, etc. For the power supply of future nuclear fusion

experimental system, like ITER, more capacity of AC/DC converter is required to energize the superconducting coils with high current. It is an important issue to reduce the operational loss of such large capacity AC/DC converter for high efficiency operation of the power supply. To achieve the high efficiency operation, the switching device of large capacity AC/DC converter is to have low on-state resistance. As the most promising device for lower on-state resistance than that of conventional Si-based device, advanced unipolar power electronics devices, including SiC-based one, has been under development. In this paper, based on some experimental results, the temperature dependence of electrical characteristics of advanced unipolar power device is mainly discussed. And, in comparison with conventional Si-based power device, it is also mentioned that the advantages of advanced unipolar power device will promote more efficiency improvement of large capacity AC/DC converter.

MOA04P004

Feasibility Study of a High-Precision Power Supply for the Ramping Dipoles of a Carbon/Proton Medical Machine Synchrotron Ring

M. Incurvati, C. Sanelli, INFN-LNF, I. De Cesaris, CNAO. A Protons and light Carbon ions accelerator for the therapy of deep tumours is in construction under the responsibility of the CNAO and INFN in Pavia (Italy). The feasibility study of the ramping Power Supply (PS) (3000A - 1600V, 1.6 seconds cycle period, maximum current error 30mA) for the 17 synchrotron bending dipoles is described in this paper. The magnets must follow a predetermined cycle between a bottom field/current level of injection and a top field/current level of extraction depending on the particular therapy cycle the patient must be subject to. This PS is requested to have, among others, a bipolar output voltage. Basing on reference cycle Fourier spectrum the PS bandwidth has been selected to be 100-200Hz to minimise transient tracking errors; passive filter and feedback loop design is presented. Simulations will be shown to analyse PS performance. Particular attention has been paid to the choice of the PS topology. A 24-pulses, 4 bridges seriesparallel connected, thyristors topology will be shown to be the best solution to meet the stringent requirement on the 10-5 of maximum current for the output current residual ripple and setting resolution. A suitable active filter that is under design in collaboration with PS builder, is foreseen to increase system performance and will be also analysed. The proposed PS design has been accepted by the winner of the tender that is going to build it in the next months.

MOA04PO05

A Cryogenic Power MOSFET Integrated Current Regulator for SMES Without Leads

C. Zhao, L. Xiao, L. Lin, Y. Yu, Institute of Electrical Engineering, CAS.

In this paper, a new concept of current regulator(CR) for SMES without leads is proposed. The cryogenic properties of power MOSFET for CR is tested in the liquid nitrogen first, then the principle of CR with soft-switching technology is presented. CR consists of a current converter, a high frequency & hybrid temperature transformer and a voltage converter. The current converter made of power MOSFETs and one side of the transformer are integrated in a liquid nitrogen Dewar together with the superconducting coil, so the leads of SMES can be cancelled. The principle of CR for SMES without leads is validated by the experiment on a SMES model with a HTS coil.

MOA04P006

Experiment for Pumping Current Control of Linear-Type Magnetic Flux Pump using Feedback Control Circuit System

Y. Chung, T. Hoshino, T. Nakamura, Department of Electrical Engineering, Kyoto University.

The fabricated small scale LTMFP, which is operated by DC and 3-phase currents, has been observed. The relations between pumping current and these power sources (DC and 3-phase currents) have been investigated. In this paper, the pumping current control by the feedback control system is described. As a preliminary test, the uniformed pumping current has been generated by the proposed feedback control circuit system. Detected voltage signal from the load coil, which is corresponded to superconducting loop current, is used as an input signal of the feedback control system. The feedback control circuit system is performed using a bang-bang control unit and detected voltage signal of pumping current. The bang-bang control unit mainly assists in turning on and off the 3-phase current, and aids in improving the switching speed. As the feedback control circuit system detects the voltage signal of the pumping current using a Hall probe, the control system directly turns on and off the 3-phase current by the detected voltage signal of the Hall probe. The LTMFP has been operated under the 6-coil toroidal Nb-Ti magnets of 0.543 H under the operating current of zero level and 10 A respectively. From these various investigations, the LTMFP and the proposed feedback control circuit system have been evaluated as one solution of current compensator for superconducting magnet.

MOA04P007

Superconductingpowersupplyforthinsuperconductingsolenoid of the CMD-3 detectorS.V. Karpov, A.V. Bragin, A.A. Ruban, Y.S. Popov, BINP.

Superconducting power supply is under development at BINP, Russia. It is assigned for energizing the thin superconducting solenoid, which is being constructed for the CMD-3 particle detector at VEPP-2000 collider. The power supply will rise up the solenoid current to 1000 A and provide long-term current stabilization. The power supply acts like a fullwave a.c.-d.c. rectifier. It consists of the air-core superconducting transformer and two thermally controlled superconducting switches used as rectifying elements. The rectifier is made of NbTi/Cu wires. It operates with 15 A primary a.c. current amplitude and provides output current up to 1500 A. This paper describes the construction of the rectifier as well as its characteristics achieved in testbed experiments. In case of quench in the superconducting magnet system some amount of energy stored in the solenoid could dissipate in secondary circuit of the rectifier. The problem of the rectifier protection against damage in such incident is also discussed here.

MOA04P008

Voltage Rating Reduction of Magnet Power Supplies using Magnetic Energy Recovery Switch

T. Isobe, T. Takaku, T. Munakata, H. Tsutsui, S. Tsuji-lio, R. Shimada, Tokyo Institute of Technology.

In this paper, a new concept of magnet power supplies that can reduce voltage ratings of the power supplies is proposed. A magnetic energy recovery switch (MERS) consists of four MOSFETs or IGBTs and a capacitor. The MERS is connected in series to a power supply and a coil. The MERS is a switch module and it has no power supply in itself. The MERS can absorb the magnetic energy stored in the coil and generate a high voltage in the capacitor. By applying the voltage to the coil, the MERS can raise current faster than the time constant of the coil. Because the MERS generates a voltage required for the inductance of the coil, the power supply only has to supply a voltage required for the resistance of the coil. Therefore, using the MERS can reduce a voltage rating and capacity of the power supply. By using the MERS with a power supply of a pulsed magnet, high-repetition pulsed current can be realized with a comparatively small capacity of the power supply. Some applications require a controlled current waveform. By controlling the MERS using PWM, the controlled current waveform is obtained. Operation principles and characteristics of the MERS are described. Some experiments were carried out. Experimental results confirm that the MERS can reduce voltage ratings of power supplies and generate high-repetition pulsed currents.

MOA04P009

Electric power systems for CNAO

R. Ricci, INFN-LNF; L. Frosini, Università di Pavia.

A synchrotron machine, capable to accelerate either Carbon ions or protons, will be the basic instrument of the medical centre dedicated to the cancer therapy, that is under construction in Pavia (Italy). The particles are injected into the synchrotron ring at low energy from a linac, and ramped up to the extraction energy, ranging from 60 ÷ 250 MeV/u for protons or 120 ÷ 400 MeV/u for Carbon ions, according to the medical treatment plane. Therefore the most of the magnets is cycled up and down with a period of about 1.6 s. Consequently, the reactive power required by thyristor converters fluctuates with an estimated peak value of about 10 MVAr. This strong variation represents a drawback both from flickering and equipment stability point of view, even if a dedicated 132 kV substation and an electrical network will feed the different kind of loads, among them the pulsed power supplies, typical medical devices, lighting and conventional loads. Load analysis, flicker effect and voltage fluctuation have been estimated with load flow simulations and different solutions, adopting various compensating devices, have been taken into account in order to comply with special equipment and public grid requirements. Different systems of dynamic reactive power compensation have been also evaluated both from technical and economical point of view.

POSTER SESSION 13:30 - 15:30 STUDIES AND SIMULATIONS

MOA05PO01

Comparison of HTSC and LTSC magnet efficiencies *E.Y. Klimenko, ISSSPh, RRC "Kurchatov Institute".* Withdrawn.

MOA05PO02

Analysis and simulation of the ITER-type NbTi Bus Bar III with THELMA code

F. Bellina, Università di Udine; M. Bagnasco, L. Savoldi, R. Zanino, Politecnico di Torino; L. Muzzi, ENEA Frascati; P.L. Ribani, Università di Bologna; E. Salpietro, EFDA Garching.

Bus Bar III (BBIII) is a curvilinear NbTi ITER-type multistrand superconducting cable-in-conduit conductor (CICC) 7 m long, made of 1152 strands inside a jacket, cooled with a forced helium flow. BBIII was developed in the framework of the ITER Toroidal Field Coil Task and tested in 2004 at Forschungszentrum Karlsruhe, Germany. In these tests, the sample was fed with different current

waveforms, and two different heaters were used to heat the jacket or the helium. The sample was equipped with many thermal-hydraulic (thermometers and mass-flow meters) and electrical (Hall probes and voltage taps) sensors, to acquire as wide as possible an experimental database, aimed at getting a benchmark for the validation of the THELMA code. THELMA is a computer tool for the analysis of CICC prototypes and magnets, recently developed and presently under validation. Starting from the object geometry, its CICC data and the waveforms of forced current and external heating power, THELMA can compute the current distribution among the cable elements used to represent the cable, taking into account their superconducting behaviour, as well as the temperature and the magnetic field distribution. The paper deals with the application of THELMA to some representative tests on BBIII and presents in detail the analysis setting-up, the results, its critical aspects and limits. A comparison is shown between the measured and the computed waveforms of the electromagnetic and the thermalhydraulic data.

MOA05PO03

The effect of geometry and location of suspension coils on magnetic levitation force for an electromagnetic suspension of a superconducting sphere

C. He, Q. Wang, Institute of Electrical Engineering, CAS.

In this paper, we present the calculation of magnetic levitation force of superconducting sphere suspended by coils. The influence on magnetic levitation force due to geometrical dimensions and relative locations of coils is analyzed. Theoretical computational results have been discussed by comparison with numerical simulation results. By the work it is a possible approach to achieve a stable suspension of superconducting sphere.

MOA05PO04

Modeling of Magnetic Force Control Device Based on the Inverse Magnetostrictive Effect

S. Cao, B. Wang, J. Zheng, W. Huang, Y. Sun, L. Weng, Hebei University of Technology.

A device using the inverse magnetostrictive effect of magnetostrictive materials (such as Terfenol-D) is called a magnetostrictve sensor. Magnetostrictve sensors have high energy coupling factors and fast response. Thus, the sensors have a wide range of applications in hydrophones, torque sensor, displacement and force sensor, etc. The difficulty for the sensors, however, lies in the hysteretic nonlinearity inherent to Terfenol-D. To design and use the sensors, it is necessary to establish an accurate model of Terfenol-D. The linear piezomagnetic equations (Clark, 1980) and related modeling techniques (Fenn & Gerver, 1994; Kleinke & Uras, 1996) provide adequate characterization of Terfenol-D sensing performance in quasi-linear regimes, hysteresis models for characterizing Terfenol-D sensing performance are still lacking. To address this problem, this paper first presents a hysteresis model of Terfenol-D, and then uses the model to found a magnetic force model for a magnetic force device (Ueno, Qiu and Tani, 2004). In the modeling of Terfenol-D, the magnetization of Terfenol-D is quantified under a magnetic field and a stress field. The field-induced component of magnetization is quantified with the ferromagnetic hysteresis model (Jiles & Atherton, 1986). The stressinduced component of magnetization is modeled with the law of approach (Jiles, 1995). It is found that the model results are in a good agreement with the experimental data.

MOA05PO05

Property of Mechanical Heat Generation inside the Superconductiing Coil installed in MAGLEV Inner Vessel

Y. Yoshino, Hachinohe National College of Technology; A. Iwabuchi, T. Suzuki, Iwate University; H. Seino, Railway Technical Research Institute.

n the JR MAGLEV system, trains are operated by the electromagnetic force between ground coils and on-board superconducting magnets (SCMs). However, SCMs are vibrated by the electromagnetic disturbance during the train runs. This phenomenon increases the mechanical heat load inside the inner vessel installed with а superconducting coil (SC- coil). One of the mechanical heat load is generated by the friction caused by the relative microscopic slips between fasteners and the SC-coil. The purpose of this study is to clear the mechanical heat generation inside the SC-coil. A frictional test was performed under fretting conditions against immersing SCcoil samples in liquid helium. Especially, we focused on the interface of the polyimide films which coated epoxy resinimpregnated SC-winding wires. Reciprocating slidings were provided between the fixed and vibrating specimens with the maximum peak-to-peak amplitude less than 30 microns by a vibration generator. Specimens were vibrated up to the frequency of 300 Hz. As a result, the mechanical heat generation increased with increasing of the number of polyimide films.

MOA05PO06

Rotation Loss Modeling in Superconducting Magnet Bearing

I. Masaie, K. Demachi, M. Uesaka, The University of Tokyo.

In superconducting magnet bearings there are 3 major physics problems, AC Loss, non-linear motion and irregular trap field of the superconductor. The effect of AC Loss and non-linear motion is reduced through the manufacturing techniques and the control systems. However the angular velocity loss increases as the rotation velocity increases or the irregular trap field is enhanced. We have considered that the angular velocity loss come of the Lorentz force between the irregular trap field of the superconductor and the current induced by the irregular field. Thus far the loss has been evaluated in our computer simulation method. In this study, we devised the rotation loss modeling in terms of the motion equation, and the model is demonstrated by the computer simulation and our experiment.

MOA05PO07

The study on the electromagnetic characteristics of the pilot-plant-scale linear electromagnetic stirrer using finite element method

M-K. Song, Vector Fields Korea. Inc.; S-J. Lee, E.E. Dept. Uiduk University; J-P. Park, Research Institute of Industrial Science & Technology. Withdrawn.

MOA05PO08

The study on the electromagnetic characteristics of square type EMC molds using finite element method *M-K. Song, Vector Fields Korea. Inc.; S-J. Lee, E.E. Dept. Uiduk University; B-M. Moon, J-S. Shin, KERI.* Withdrawn.

MOA05PO09

Computational Simulation of the interaction between PM and HTS bulk

M. Qiu, G.H. Yang, L.Z. Lin, Institute of Electrical

Engineering, Chinese Academy of Sciences.

Finite elements analysis (FEA) is widely used in solving electromagnetic problems. However, some materials such as superconductors or materials with a high anisotropy haven't been well characterized until now. In the latest decade, the interaction between permanent magnets (PMs) and high-Tc superconductors (HTSs) has been a subject of considerable interest because of various industrial applications including superconducting bearings, flywheel energy storage systems and motors. A convenient and simple FEA method is required to deal with complex configurations of magnetic fields and HTSs to optimize the engineering of these systems. Hence, the effective permeability of HTS bulk was tried to derive from different critical-state models. The interaction between PMs and HTSs was simulated by using commercial FEA programs. By comparisons with the experimental data, the feasibility of the method was discussed in the paper.

MOA05PO10

Boundary conditions for electric field on the interface of double strip composite conductor

V. Sobol, O. Mazurenko, Institute of Solid State and Semiconductor Physics NANB.

The most simple prototype of a composite cryoconductor is a two-layer plate combination of conductive materials. In an approach of short circuit model [Kaneko H., 1993] an effective resistance of a double plate conductor does not depend on widths of composite elements. That is the expression for a resistance contains only the thicknesses of elements. Here the model that assumes an existence of a transverse current being shorted via interface is discussed. In other words the new type of boundary conditions for a current density and an electric field taking into account the relation between widths and thicknesses of composite elements is supposed. This type of boundary conditions allows represent a physical picture of a current distribution and the resistive properties of a two-layer conductor in terms of Hall current and current skinning near the interface. The validity of this approach is followed from convergence of a received expression to a reasonable view of a resistance at a limit transition on geometric parameters. When the thicknesses of plates are much higher of widths the reversal resistance of a system consisting of two materials trends to sum of reversal diagonal components of their resistivity tensors. When the thicknesses and widths are of the same order the reversal resistance of a system is determined via diagonal components of conductivity tensors of materials.

POSTER SESSION	13:30 - 15:30
LHC MAIN DIPOLE MAGNETS	

MOA06PO01

Stability of the horizontal curvature of the LHC cryodipoles during cold tests

E. Fernandez Cano, F. Seyvet, J. Garcia Perez, A. Tovar-Gonzalez, A. Poncet, CERN, Accelerator Technology Department; B. Jeanneret, CERN, Accelerators & Beams Department.

The LHC will be composed of 1232 horizontally curved, 15 meter long, superconducting dipole magnets cooled at 1.9 K. They are supported within their vacuum vessel by three Glass Fiber Reinforced Epoxy (GFRE) support posts. Each cryo-dipole is individually cold tested at CERN before installation and interconnection in the LHC 27 km-circumference tunnel. As the magnet geometry under

cryogenic operation is extremely important for the LHC machine aperture, a new method has been developed at CERN in order to monitor the magnet curvature change between warm and cold states. It enabled to conclude that there is no permanent horizontal curvature change of the LHC dipole magnet between warm and cold states, although a systematic horizontal transient deformation during cool-down was detected. This deformation generates loads in the dipole supporting system; further investigation permitted to infer this behavior to the asymmetric thermal contraction of the magnet thermal shield during cool-down. Controlling the Helium flow rate in the thermal shield of the cryo-magnet enabled to reduce the maximal deformation by a factor of approximately two, thus increasing significantly the mechanical safety margin of the supporting system during the CERN cold tests. This paper describes the new measurement method, equipment and set-up, and presents the experimental data and corresponding analysis, along with recommendations and conclusions.

MOA06PO02

Long term stability of the LHC superconducting dipoles in their cryostats

F. Seyvet, G.A. Izquierdo, A. Bertarelli, M. Buzio, O. Denis, P. El-Kallassi, E.D. Fernandez Cano, P. Fessia, S.D. Ilie, D. Letant, A. Poncet, P. Pugnat, S. Sgobba, A. Siemko, E. Todesco, D. Tommasini, B. Vullierme, E. Wildner, CERN. The main superconducting dipoles for the LHC are being stored outdoors for periods from few weeks to several years after conditioning with dry nitrogen gas. Such a storage before installation in the 27 km circumference tunnel may affect not only the mechanical and cryogenic functionality of the cryodipoles but also their quench and field performance. A dedicated task force was established to study all aspects of long term behaviour of the stored cryodipoles, with particular emphasis on electrical and vacuum integrity, guench training behaviour, magnetic field quality, performance of the thermal insulation, mechanical stability of magnet shape and of the interface between cold mass and cryostat, degradation of materials and welds. In particular, two specifically selected cryodipoles stored outdoor for more than one year, were re-tested at cold. In addition, various tests have been carried out on the cryodipole assembly and on the most critical subcomponents to study aspects such as the hygrothermal behaviour of the supporting system and the possible oxidation of the Multi Layer Insulation reflective films. This paper summarizes the main investigations carried out and their results.

MOA06PO03

Impact of the First Powering on the LHC Superconducting Dipole Coil Geometry

M. Calvi, L. Bottura, S. Sanfilippo, E. Todesco, CERN.

The first powering of the LHC superconducting dipoles induces small changes of the coil geometry. Dedicated magnetic measurements have been performed to estimate the changes in the geometric component of the harmonics, caused by the last highest Lorentz force the coil has ever experienced. Several magnets have been powered at increasing current steps while the field quality has been measured to quantify the changes in geometry. The effect of thermal cycles has been also considered as well as the systematic differences between warm measurements before and after the training. The reconstruction of the coil geometry variations is discussed in terms of continuous modes of deformation as well as single block displacements.

MOA06PO04

LHC Superconducting Dipoles Production Follow-up: Results of Audit on QA aspects in industry

M. Modena, M. Bajko, M. Cornelis, D. Tommasini, P. Fessia, J. Miles, G. De Rijk, F. Savary, S. Sgobba, J. Vlogaert, C. Voellinger, E. Wildner, CERN.

The manufacturing of the 1232 Superconducting Main Dipoles for LHC is under way at three European Industries Alstom/Jeumont Consortium, Ansaldo Superconduttori Genova (ASG) and Babcock, Noell Nuclear (BNN). The manufacturing is proceeding in a very satisfactory way and in March 2005 we passed the mid production. To intercept eventually "weak points" of the production process still present and in order to make a check of the Quality Assurance and Control in place for the series production, an Audit action was launched by CERN during summer-fall 2004. Aspects like: completion of Production and QA documentation, structure of QC Teams, traceability, calibration and maintenance for tooling, incoming components inspections, were checked during a total of seven visits at the five different production sites. The results of the Audit in terms of analysis of "systematic" and "random" problems encountered as well as corrective actions requested are presented.

MOA06PO05

A correlation study between geometry of collared coils and normal quadrupole multipole in the main LHC dipoles

F. Bertinelli, S. Berthollon-Vitte, D. Glaude, I. Vanenkov, CERN; E. Boter-Rebollo, CELLS.

The quality control implemented at all LHC dipole manufacturers includes precise mechanical measurements of the geometry of collared coils. A cross-analysis performed between mechanical and magnetic measurements data shows a correlation between collared coils outer dimensions and the normal quadrupole multipole (b2) for one dipole manufacturer. The profile geometry of the single collars - as determined from 3D measurements at the collar suppliers and CERN - could not account alone for the significant left - right aperture asymmetry observed. This triggered a deeper investigation on different elements of the geometry of single collars. The results of this work show that the relative positioning of the collaring holes, allowing a small bending deformation of collars under the effect of coil pre-stress, is an important effect which generates a b2 multipole at the limit of specification. The study has deepened the understanding of the factors affecting collared coil geometry and field quality. The precision of 3D measurements at the collar suppliers and at CERN has been improved, and a tighter quality control has been introduced at the collar suppliers.

MOA06PO06

Dependence of magnetic field quality on collar manufacturing and dimensions in the main LHC dipoles

B. Bellesia, F. Bertinelli, E. Boter-Rebollo, L. Rossi, C. Santoni, E. Todesco, CERN.

In order to keep the electro-magnetic forces and to minimize conductor movements, the superconducting coils of the main Large Hadron Collider dipoles are held in place by means of austenitic stainless steel collars. Two manufacturers provide the collars necessary for the whole LHC production, which has reached now more than 700 collared coils. In this paper we first assess if the different collar manufacturers origin a noticeable difference on the magnetic field quality measured at room temperature. We then analyze the measurements of the collar dimensions carried out at the manufacturers, comparing them to the geometrical tolerances. Finally we use a magneto-static model to evaluate the expected spread in the field components induced by the actual collar dimensions. These spreads are compared to the magnetic measurements at room temperature over the magnet production in order to identify if the collars, rather than other components or assembly process, can account for the measured magnetic field effects.

MOA06PO07

Electrical integrity tests during production of the LHC main dipoles

G. de Rijk, M. Bajko, M. Cornelis, P. Fessia, J. Miles, M. Modena, G. Molinari, F. Savary, J. Vlogaert, CERN.

For the LHC dipoles, mandatory electrical integrity tests are performed to qualify the cold mass at four production stages: individual pole, collared coil, cold mass before end cover welding and final cold mass. A description of the measurement equipment and its recent development are presented. After passing the demands set out in the specification, the results of the tests are transmitted to CERN where they are further analysed. The paper presents the most important results of these measurements. We also report a review of the electrical non-conformities encountered e.g. inter-turn shorts and quench heater failure, their diagnostic and the cures.

MOA06PO08

Identification of assembly faults through the detection of magnetic field anomalies in the production of the LHC dipoles

C. Vollinger, E. Todesco, CERN.

Magnetic measurements at room temperature have been used to monitor the production of the superconducting coils of the Large Hadron Collider main dipoles. They have made it possible to identify several assembly errors, e.g. cases of bad gluing of the coil layers, bad conductor positioning, missing pole shims and other problems related to faulty procedures. This paper reviews the experience accumulated so far considering almost 1000 dipoles. After a short outline of the method used to pin out field anomalies and deduce realistic deformation of the coil, an exhaustive list of the cases met during the production is given. A discussion follows on the findings after decollaring as compared to the predictions, including the still open cases.

MOA06PO09

Short circuit localization in the LHC main dipole with room temperature magnetic field measurements

B. Bellesia, E. Todesco, G. Molinari, CERN; C. Santoni, University of Clermont Ferrnad.

During the production of the LHC main dipole few cases of short circuits have been found, some of them detectable only under the collaring press. In this paper we present a method based on the analysis of magnetic measurement at room temperature which has allowed finding the position of the defect, repairing it, and reusing the coils. The presence of a short circuit strongly perturbs the magnetic field. The observed field pattern is compared to a library of standard perturbations that could arise from short circuits between turns and layers. The longitudianl sampling of the magnetic field allows identifying the position of the short circuit to within the length of the magnetic field measuring mole. The result of this localization procedure is presented and correlation with extensive electric investigations and actions to cure the short circuits are discussed.

MOA06PO10

Control of the LHC dipole cold mass geometry at CERN to optimize LHC performance.

E. Wildner, M. Bajko, J. Beauquis, R. Chamizo, D. Tommasini, M. La China, CERN.

The detailed shape of the 15 m long superconducting LHC dipole cold mass is of high importance as it determines three key parameters: the beam aperture, nominally of the order of 10 beam sigmas; the connectivity of the beam and technical lines between magnets; the transverse position of non-linear correctors mounted on the dipole ends. An offset of the latter produces unwanted beam dynamics perturbations. The tolerances are in the order of mm over the length of the magnet. The natural flexibility of the dipole and its mechanical structure allow deformations during handling and transportation which exceed the tolerances. This paper presents the observed deformations of the geometry of the geometry during handling and various operations and CERN, deformations which are interpreted thanks to a simple mechanical model. These observations have led to a strategy of dipole geometry control at CERN. based on adjustment of the position of its central support (the dipole is supported at three positions, horizontally and vertically) to recover individually or statistically their original shape as manufactured. Its implementation is discussed, with the goal of finding a compromise between conflicting requirements: quality of the dipole geometry, available resources for eventual corrective actions and magnet installation strategy whereby the geometry tolerances depend on the final magnet position in the machine.

MOA06PO11

Coil size variations in LHC superconducting main dipoles and their possible influence on the quench training behaviour

P. Pugnat, P. Fessia, I. Vanenkov, CERN.

The Large Hadron Collider (LHC) under construction at CERN will contain 1232 twin type superconducting dipole magnets build with very tight mechanical tolerances. The main part of these magnets is the coil wound with copper stabilized NbTi Rutherford type cables and surrounded by austenitic steel collars with dimensional tolerances of ±0.02 mm. The mechanical dimensions and properties of coil and collars are key parameters for the field quality and quench performance of these superconducting magnets. The collared coil sizes are carefully monitored in the three factories where dipoles are manufactured. Due to the high pre-compression stresses applied to the coils during the collaring process (up to 150 MPa), the coil geometry and the final pre-stress may be affected by some collar deformations mainly due to the statistical fluctuation of the coil sizes and of the collar dimensions. In this paper, the statistical analysis of coil sizes and collared coil dimensions will be presented and the importance of these parameters on the guench performance measured will be evaluated.

POSTER SESSION13:30 - 15:30MISCELLANEOUSACCELERATORMAGNETS(I)

MOA07PO01

Conceptual design of cryostat for the superconducting CR dipole magnet

Q. Wang, B. Zhao, Institute of Electrical Engineering, CAS; G. Moritz, GSI

The CR superconducting magnet is fixed field devices with field in beam-line from 0.1-1.6 Tesla. Actually, since the

magnet with relative large size and constant field to fill with beam, it is the large apertures that dictate the magnetic field strengths because high-field generates large forces associated with conductor being far from the beam. This forces one to use magnets that have iron to shape the field. On the other hands, the shape for superconducting coils determines the fabrication technology and operating environment. The magnet is assumed to be straight. That is why the good field area should be wider by approximately ±35 mm than the useable horizontal aperture, given in requirements to the CR dipole magnet. The evacuated CR cryostat with the attendant thermal shield provides the necessary cryogenics environment for operation of the superconducting CR dipole magnet. It consist of a liquid helium vessel and liquid helium reservoir, a thermal radiation shield cooled by liquid nitrogen, a vacuum vessel. Both liquid helium vessel and liquid helium reservoir are surrounded by thermal radiation shield and installed into vacuum vessel. The CR coil is immersed in the liquid helium. Upper service port for measurement, LHe filling tube etc. total weight of CR cryostat including CR coils are about 1260kg. This paper describes conceptual design for this cryostat.

MOA07PO02

Magnets Manufacture for CSR

B. Zhang, P. Yuan, Y. Zhang, L. Ma, Y. He, Institute of Modern Physics, CAS.

As a multipurpose Cooling Storage Ring (CSR) system in China,CSR project consists of CSRm(main ring) and CSRe(experimental ring). There are 16 H-type dipoles for CSRm and 16 C-type dipoles for CSRe. Also, there are 30 Ø 170mm and 22 Ø240mm quadrupoles. All of these magnets are laminated by 0.5mm thickness high induction cold rolled non-oriented electrical steel laminations. The whole process of the manufacture and the analysis of the various tolerances will be described in detail in this paper.

MOA07PO03

Development of a prototype superconducting magnet for the FFAG accelerator

T. Obana, The Graduate University for Advanced Studies; T. Ogitsu, T. Nakamoto, K. Sasaki, A. Yamamoto, M. Yashimoto, Y. Mori, KEK; T. Orikasa, TOSHIBA.

A superconducting magnet for the Fixed Field Alternating Gradient (FFAG) accelerator is proposed. The FFAG accelerator requires static magnetic field, and it is suitable for the superconducting magnet application, because problems associated with time varying magnetic field such as eddy current loss can be eliminated. superconducting magnet, which can generate The hiah magnetic field, is possible to realize a higher beam energy with a given accelerator size or the size to be smaller for a given beam energy. The FFAG accelerator magnet is required to have a non linear magnetic field that increases with k-th power of the orbit radius, where k is the field index in the accelerator. The coil end influences the magnetic field distribution because the ratio of the physical length of the coil end to that of the straight section is relatively large. The coil design was therefore evaluated by means of the integral magnetic field along a particle trajectory. By using a particle tracking code, we verified that the particle trajectory is stable in the accelerator with the magnetic field generated by the designed coil. The designed coil is going to be built as a prototype coil, which will be wound in terms of the developed winding machine that a superconducting wire of about 1mm in the diameter can be directly adhered to an insulated mandrel. The design study for the magnet and the magnetic field performance of the prototype coil
will be presented. The design study for the magnet and the magnetic field performance of the prototype coil will be presented.

MOA07PO04

Magnets for the PETRA-III Project

E. Bondarchuk, N. Doinikov, V. Ivkin, B. Kitaev, V. Kuligin, V. Muratov, V. Peregud, B. Krause, A. Petrov, K. Sinram, D.V.Efremov Institute (NIIEFA).

The work has been carried out at the Efremov Institute according to the new PETRA-III machine optic. Normalconductivity magnets (Quadrupole, Dipole and corrector magnets) for the PETRA-III Project were designed and calculated. Prototypes were built and magnetic measurements were carried out. Two precision quadrupole magnets of "eight" type with the lengths 0.44 m, 0.72 m were developed. Their gradient must be G=22.8 T/m and their apertures are 2ao=70 mm were. The tolerances for the integral gradient and the integral field nonlinearity in the reference radius zone ro<25 mm should be 0.001 and 0.0005, respectively. The deflecting magnets for the PETRA-III Project have H-shaped magnetic yoke with the length 1 m. In the good field region (GFR) area 60x36 mm**2 a magnetic field of Bo=0.873 T with the possibility of reaching Bmax = 1 T must be obtained. Within the GFR limits, the integral field nonlinearity should not exceed the value 0.0005, which is ensured by profiling the poles (longitudinal chamfers, slants and shims). Correction of the electron beam in the vertical direction will be done with a special dipole which has a horizontal magnetic field of Bx=0.062 T, its aperture is 112 x 50 mm**2 and its total length, including the coil end parts, should not exceed L=200 mm. The authors have designed two versions of such magnet, one with air-cooling and one with watercooling. Results of the magnetic measurements will be shown and be compared with the simulation.

MOA07PO05

Design, Construction and Measurements of Quadrupoles and Sextupoles for the SOLEIL Storage Ring

C. Benabderrahmane, F. Marteau, A. Dael, A. Madur, P. Brunelle, M. Soucaze, L. Bouillie, Synchrotron SOLEIL.

SOLEIL is the French third generation Synchrotron radiation Source. The energy of the machine is 2.75 GeV and it consists in a 354 m circumference electron storage ring, with 16 cells and 24 straight sections. The lattice is designed for a good dynamic acceptance even for large deviation (up to 6%) and requires very small multipolar components. All the magnets have been computed with 3D model on TOSCA code and the industrial production is finished. The paper describes the 160 quadrupole and 120 sextupole magnets.Full 3D magnetic computation has permitted to predict harmonic content. The page describes the construction technology, the measurement techniques especially for the absolute locating of the magnetic centre both for quadrupoles and sextupoles.

MOA07PO06

Variable Permanent Magnet Quadrupole

Y. Iwashita, T. Mihara, Kyoto University; M. Kumada, NIRS; C. Spencer, SLAC.

A compact, variable, superstrong permanent magnet quad (PMQ) has been fabricated and tested. The PMQ has inner and outer rings of NEOMAX and Vanadium Permendur poletips; the outer ring is subdivided along its length into 4 sections of various lengths and each section can rotate. By rotating different lengths from a zero position through 90 degrees one can vary the integrated strength in small steps. Because of the fixed inner ring and tight fabrication mechanical tolerances, the sensitivities of the magnetic center and quadrupole angles to errors in the rotation of the outer rings are largely suppressed. The observed small center (5-20 microns) and angle shifts were further reduced by adjustments to the stopping angles of the rotating rings and by shimming these rings. Measurements of multipole components at different strengths show little variation. Temperature compensation has been included. The design details and precise measurements of the PMQ will be presented.

MOA07PO07

Improvements in Mechanical Stability of Open-type Quadrupole Magnets with Peak Excitation for a 2.5 GeV SRS

K. Sreeramulu, V.K. Jain, K. Ruwali, M.G. Karmarkar, Govt. of India, CAT.

The open type Quadrupole magnets (16 T/m) for Indus-2 are made in C-configuration in which both of outer vertical sections of the steel are removed to take out the emerging synchrotron radiation beam lines, in the region immediately adjacent to main dipole magnets. This induces engineering complexity relating to mechanical stability that critically controls the deviations in field quality and magnetic centre. The magnet structure was initially designed by assuming the deflection of the poles near open end will be within 50 microns. However, after fabrication of prototype magnet, it was experimentally observed that the field quality and magnetic centre are changing drastically with excitation. Hence, there was a need to further reinforcement of the magnet structure for minimizing its deformation with excitation. We optimized the magnet structure reinforcement, without obstructing the emerging beam lines, for minimizing its deformation by simulation. using ANSYS. The measurement of deformation with excitations is done before and after reinforcement. The deformation in the optimized magnet structure is reduced to within 20 microns, when excited to maximum operating current. These results are consistence with simulation. Magnetic centre shift with excitations is observed within 15 microns. Higher order multipoles are low and their strength is not changing with excitations. The optimized mechanical structure is implemented in series production of open-type Quadrupole magnets.

MOA07P008

Importance of Coil position in SRS Dipole Magnet at higher field

S. Das, A. Valecha, R. Mishra, M. Karmarkar, Govt. of India, CAT.

Indus-2, a 2.5 GeV synchrotron light source is under construction at CAT, Indore, India. The Dipole Magnet of Indus-2 is designed for a maximum field of 1.5 T at the pole gap. The field quality in the good field region and the "magnet-to-magnet" variation in the field strength have an impact on the performance of the machine. For Indus-2 Dipole Magnets, field uniformity is observed in the rage of 8-10 x 10-4 at 2.5GeV. The relative variation in the field strength observed in most of the magnets (12 magnets out of total 16) is within +/- 1 x 10-3 from 0.27 T to 1.2 T field at the pole gap. Beyond 1.2 T "magnet-to-magnet" strength variations for few magnets deviate with excitation currents and the range of variations increases to +/- 3 x 10-3. It is well known that at the higher fields near core saturation, strength variation is caused by the variation in the magnetic property of the core laminations. The results of the Magnet simulation shows that the vertical position of the coils can play a major role in minimizing the magnet-to-magnet variation in such high field zone. Experiment done on the reference Dipole Magnet also shows that a significant field variation could be achieved by changing the vertical position of the coils at the higher field level whereas it has little impact in the low excitation as predicted. In this paper we present the role of coil position to compensate the strength variations related to the magnetic property of the core material at higher field.

MOA07PO09

Testing and Magnetic Measurements of the SOLEIL Booster Quadrupole Magnets

S.M. Gurov, B. Sukhina, BINP; T. Bouillie, A. Dael, A. Loulergue, SOLEIL.

The BINP has produced 52 quadrupole magnets for SOLEIL Booster. The results of testing and magnetic measurements are presented.

MOA07PO10

Eddy current reduction in fast ramped bending magnets

M. Negrazus, D. George, PSI Paul-Scherrer-Institute.

At the Paul-Scherrer-Institue (PSI/Switzerland) a new proton gantry for cancer treatment is planned. A fast 3 dimensional scanning technique of the tumour volume is part of the medical highlights of this new gantry. The gantry will be driven by the new COMET proton cyclotron, which will deliver a cw proton beam. The energy of this beam will be adjusted by a fast degrader device. All beam line magnets should follow the energy changes of the degrader as fast as possible to reduce the time of the cancer treatment. Therefore the eddy current effects in the laminated bending magnets of the beam line and the gantry had to be reduced by an appropriate magnet design. The poster shows measurements and numerical simulations of the dynamic behaviour of the fast switched bending magnets and design schemes for eddy current reduction in the bending magnets.

MOA07PO11

Eddy Current Effect in NiFe laminations on Pulsed Septum Magnet Response of Indus-22

R.S. Schinde, P. Pareek, R.R. Yadav, V. Gaud, R.K. Mishra, S. Kotaiah, Head Ferrite Lab., MDL, CAT.

A thin & thick active type Pulsed Septum Magnets has been developed for 700 MeV e beam injection into 2.5 GeV Storage Ring(2.5 GeV). A magnet yoke is made of 0.1 mm thick Ni-Fe laminations.Since the current flux lines close on it.the eddv current circulates confined within a lamination. This result in change in impedance due to incomplete cancellation of magnetic field. NiFe laminations (36%Ni+ bal Fe).Indian make have been oxidized so the pulse will penetrate into laminations at all during the pulse.A test bench has been built to measure pulse response of lamination at microsecond half sine wave.Magnetic simulation of septum magnets were performed using Flux 2D transient Software.A Septum magnets were excited by 50 microsecond half sine wave.A pulsed magnetic field of 1T & 0.5T for Thick & Thin Septm magnets were obtained.A Pulse field homogeneity in the order of 100 PPM & Integrated stray field 0.7 G-m has been obtained, which is less than allowed 2 G-m value. An excellent field stability on top 100 PPM has been observed. Measured response of the magnet are well satisfied with the design requirements.Our Measurement indicate no influence of the septum leakage field on the closed orbit of beam. This paper presents Eddy current effect in laminations on pulse magnetic field at working pulse frequency,,modeling of septum magnet, shield designs,

fabrication techniques, distribution of stray field outside of septum & pulse magnetic field homogenity in gap of Septum magnets.

MOA07P012

Fabrication and Testing of a Combined Superconducting Magnet for the TESLA Test Facility

F. Toral, P. Abramian, J.L. Gutierrez, E. Rodriguez, S. Sanz, C. Vazquez, CIEMAT; L. Garcia-Tabares, J. Calero, CEDEX; H. Brueck, W. Maschmann, DESY.

An international collaboration at DESY is currently studying the possibilities of a new type of particle accelerator: the superconducting linear collider, developed under the project name TESLA. The TESLA Test Facility is trying to establish a well-developed collider design, which will also be helpful for the design of a superconducting X-Ray Free Electron Laser facility, a project approved by the German Government and now in its initial stage. This paper is about the fabrication and testing of the first prototype of a combined superconducting magnet for focusing and steering purposes, in the framework of the Spanish contribution to TESLA project. It consists of a quadrupole and two dipole concentric coils, one horizontal and another one, vertical. The double pancake winding technique with a ribbon of eight pre-glued wires has been used in order to develop a cheap method for industrial scale, as the accelerator would need about 800 magnets. The coils were fully instrumented with voltage taps to study the quench starting location. The magnet has been successfully tested at DESY and the results are presented in this paper.

POSTER SESSION 13:30 - 15:30 MAGNET MEASUREMENTS

MOA08PO01

A Rotating Coil Apparatus with Sub-Micron Magnetic Center Measurement Stability

C. Spencer, S.D. Anderson, D. Jensen, Z. Wolf, SLAC.

A rotating double coil apparatus has been designed and built so that the relative magnetic center change of a quadrupole is measured to an uncertainty smaller than 0.02 micron for a single measurement. Furthermore, repeated measurements over about an hour vary by less than 0.1 micron and by less than 1 micron for periods of 24 hrs or longer. Correlation analyses of long data runs show that the magnet center measurement is sensitive to mechanical effects, such as vibration and rotating part wear, as well as to environmental effects, such as temperature and relative humidity. Evolving apparatus design has minimized mechanical noise and environmental isolation has reduced the effects of the surrounding environment so that sub-micron level measurement uncertainties and micron level stability have been achieved for multi-day measurement periods. Apparatus design evolution will be described in detail and correlation data taken on water-cooled electromagnet and adjustable permanent quadrupoles, which are about 350 mm in length, will be shown. These guads were prototypes for the linac quads of the Next Linear Collider (NLC) that had to meet the requirement that their magnetic centers change less than 1 micron during a 20% change in field strength. Thus it was necessary to develop an apparatus that could track the magnetic center with a fraction of a micron uncertainty.

MOA08PO02

Alignment and warm measurements of the J-PARC combined function magnets

T. Tomaru, K-I. Sasaki, T. Nakamoto, T. Ogitsu, Y. Ajima, N. Higashi, N. Kimura, K-I. Tanaka, A. Terashima, A. Yamamoto, KEK.

Superconducting combined function magnets (SCFMs) are under development for a neutrino beam line in Japan Proton Accelerator Research Complex (J-PARC), which is used to bring high intensity neutrino beam to the Super Kamiokande for neutrino oscillation experiment. The SCFMs provide a dipole magnetic field of 2.6 T and a quadrupole field of 19 T/m in a single coil. Therefore, high accuracy (< [0.3mm]) of the SCFM alignment is required to keep designed magnetic field. We have measured the dimensional distortion in alignment work of a prototype SCFM by using a laser tracker and a laser line marker, and confirmed that the distortion is within 0.3mm. This distortion was not induced by gravity but came from its internal stress most likely due to the outer shell welding. In next step, we are planning to measure the magnetic field of the SCFM with monitoring position of the sensor in warm condition. The magnetic field will be measured by a rotating coil, and position of the rotating coil will be measured by optical method, which consists of a laser, corner cube prism and position sensitive detector. In this paper, we will report the alignment work and warm measurement of the prototype SCFM with focusing on the optical and magnetic field measurement.

MOA08P003

The Beam-Handling Magnet System for the J-PARC Neutrino Beam Line

E. Hirose, K. Tanaka, H. Takahashi, H. Noumi, M. Takasaki, Y. Suzuki, Y. Kato, M. leiri, Y. Yamanoi, M. Minakawa, KEK.

The long baseline neutrino oscillation experiment using the J-PARC's 50GeV-0.75 MW proton beam is now under way. The primary proton beam line consists of three parts, i.e. the first preparation (PP) section with normal conducting magnets, the second arc (ARC) section with superconducting magnets and the third final focus (FF) section with normal conducting magnets. In the PP section, we have to clean the primary proton beam extracted from the 50 GeV-PS and transport halo-less pure beam only to the ARC section. In the FF section the magnets have to be placed very close to the pion production target and horns. Then one can understand that the normal conducting magnets have to work in the very high radioactive environment. The R&D works on the radiation resistant magnets for handling a high-intensity proton beam have already been continued at KEK as reported in MT18. Another important point regarding high-intensity beam handling is to realize easy maintenance of the beam line. Any magnet experiencing trouble can be easily removed from beam line and repaired remotely. For this purpose, we developed the new tools for the magnet maintenance. These are automatic sling apparatus, quick alignment and installation guide, and the quick disconnect devices of cooling water and electric power. In the MT19, we will report the beam line maintenance scheme developed for the neutrino beam line, as well as the design of normal conducting magnet sections.

MOA08PO04

Magnet Operation in Vacuum for High Radiation Environment near Production Target

H. Takahashi, K. Tanaka, Y. Yamanoi, H. Noumi, E. Hirose, M. Minakawa, Y. Suzuki, M. Takasaki, Y. Sato, Y.

Katoh, Institute of Particle and Nuclear Studies, KEK.

In a high-intensity proton beam facility, beam line elements downstream a production target are exposed to huge amount of radiation and heat. A water-cooled beam collimator must be located between the target and the magnets, and their yokes also have to be cooled by water. Beam ducts, however, are closer to beam than the magnet poles, and more difficult to cool sufficiently without Tritium production. Therefore, the magnets are placed in a large vacuum chamber, instead vacuum ducts located within the pole gaps. In order to reduce the residual radiation dose during the maintenance, the chamber lid and feedthroughs are 4-meter above the beam line, and radiation-shielding blocks are also inside the chamber. We have tested the magnet operation in vacuum using a dipole magnet with mineral-insulation-cable (MIC) coils and a nickel-plated voke. The magnets has worked successfully up to the current of 3000A. The magnetic field has been measured with a NMR probe and a Hole element. The difference between the field strength by the atmospheric operation and that by the vacuum operation was less than 0.1%. We have also developed a radiation-resistant quick-disconnect system of the feedthroughs on the chamber lid for ease of maintenance.

MOA08PO05

Design of thick septa based on 3D magnetic field calculation for 3 GeV rapid cycle synchrotron of J-PARC

M. Watanabe, Y. Irie, J. Kamiya, T. Shimada, T. Takayanagi, JAERI; H. Fujimori, S. Igarashi, T. Kawakubo, KEK.

Thick septa are used in the injection and extraction section of the 3 GeV rapid cycle synchrotron of the J-PARC. We have been designing seven thick septum magnets, two for injection, two for beam dump and three for extraction, respectively. These septa are required large aperture for low losses of high intensity beam and they work by direct current for the mechanical stability. The yoke is made of the soft-iron block. We have been designing them by using the three-dimensional magnet static field calculation code, TOSCA. In this presentation, we discuss about magnetic field flatness in the gap and effects of the leakage fields in the synchrotron. Moreover, we discuss about the design of the septum magnets based on the calculation.

MOA08PO06

Magnetic field measurements, 3D field calculation and heat measurements of a prototype thick septum magnet for 3 GeV rapid cycle synchrotron of J-PARC

M. Watanabe, Y. Irie, J. Kamiya, T. Shimada, T. Takayanagi, H. Suzuki, Y. Watanabe, JAERI; T. Kawakubo, KEK.

Septum magnets used in the injection and extraction section of the 3 GeV rapid cycle synchrotron of the J-PARC require large aperture for low losses of high intensity beam, protection against the high radiation and the high durability to avoid the maintenance after the high activation. Therefore the septum magnets have been designed to work by DC for the mechanical stability. And it works outside the vacuum to avoid a trouble due to the leakage of cooling water in the vacuum system. A prototype septum magnet was constructed. Magnetic fields in the gap of the core and leakage field outside of the magnetic shield were measured by a Hall device probe. The experimental results were compared with the 3D calculation by TOSCA. The measurements of the magnetic field in the gap agree well with a simple 3D model. On the other hand, leakage field of the measurements is larger than the one of the model.

After we made a more detailed model, it cleared that bolt holes which fasten a return yoke make effective sectional area and permeability small at the return yoke and therefore leakage field is larger. Because the thickness of the return yoke is not sufficient, magnetic flux density approaches saturation easily. Moreover, we discuss about the results of heat measurements of the magnet and efficiency of water cooling.

MOA08P007

Design of the injection bump system of the 3-GeV RCS in J-PARC

T. Takayanagi, Y. Yamazaki, Y. Irie, T. Shimada, J. Kamiya, M. Watanabe, JAERI; S. Izumi, T. Kawakubo, KEK.

The injection bump system of the 3-GeV RCS in J-PARC consists of the pulse bending magnets for the injection bump orbit, which are four horizontal bending magnets (shift bump), four horizontal painting magnets (h-paint bump), and two vertical painting magnets (v-paint bump). The shift bump magnets, which are connected in series in order to form a shift bump orbit, are not possible to adjust the magnetic field intensity individually. Therefore, the gap of the shift bump magnets has been adjusted to achieve a uniformed field of BL with less than 1.0 % in series connection of the four sets. The injection bump system needs the power supplies with the performance of high speed flexible current pattern. Furthermore, the tracking error is required less than 1.0 % for 1.0 microsecond pulse current. The power supplies with the IGBT chopper units, which are controlled by the switching frequency over 100 kHz, realize its performance.

MOA08P008

Magnetic field measurement of the kicker magnet in J-PARC RCS

J. Kamiya, T. Takayanagi, T. Ueno, JAERI/J-PARC; E. Nakamura, T. Kawakubo, S. Murasugi, K. Takata, H. Tazawa, KEK/J-PARC.

The kicker magnets are installed in the extraction section in the Rapid Cycling Synchrotron (RCS) of J-PARC and their pulsed magnetic fields extract the proton beams accelerated up to 3GeV. The magnetic fields of the kicker magnets have to meet three major requirements: a fast rise time, a time stable flat-top, and a uniform distribution. The magnetic field measurements were performed with a longsearch coil and a short-search coil. These coils were devised to reduce the electric noise by using the matching register. The rise time of the magnetic field is determined by the switching speed of the thyratron and the delav time in the magnet. Our magnet accomplished the faster rise time than the interval between the beam bunches. The flattop shape depends on the matching of the characteristic impedance between the power supply and the magnet. Therefore the simulation with the equivalent circuit was performed to identify the mismatching point. The distributions of the magnetic field were also measured. The wide aperture of our kicker magnet makes the uniform distribution of the magnetic field more difficult. Therefore we change the shape of the coil systematically and improve the uniformity of the distribution.

MOA08P009

Setup to Measure the Magnetic Center Behavior of an ILC Superconducting Quadrupole Prototype

C.M. Spencer, C. Adolphsen, S.D. Anderson, J. Chan, D. Jensen, R. Rogers, E-J. Thompson, T.B. Weber, J. Weisend II, SLAC; F. Toral, CIEMAT. Withdrawn.

MOA08PO10

Design and Fabrication of an RCS Magnet Coil using a Stranded Conductor of J-PARC 3-GeV Synchrotron

N. Tani, Y. Watanabe, H. Suzuki, J. Kishiro, Japan Atomic Energy Research Institute; T. Adachi, H. Someya, High Energy Accelerator Research Organization; K. Nakamura, T. Watanabe, Hitachi, Ltd.

The 3-GeV synchrotron now being constructed in the JAERI/KEK Joint Project (J-PARC) is a rapid-cycling synchrotron (RCS), which accelerates a high-intensity proton beam from 400-MeV to 3-GeV at a repetition rate of 25-Hz. Magnet coils of the RCS synchrotron are fabricated by using a stranded conductor. As a magnet coil, a hollow conductor that has a cooling water channel is widely used. However since RCS magnet is excited with a rapid cycle, heat of coil conductor caused by eddy current becomes a problem. Therefore, in order to reduce eddy current loss of coil conductor, we used a stranded conductor that consists of many electrically-isolated thin wires wrapped around a cooling water pipe as a coil conductor. This is a conductor developed at KEK as a coil conductor excited with a rapid cycle and was further developed to the stage of mass production. In this paper, we will report design and fabrication of an RCS magnet coil using a stranded conductor.

MOA08P011

Design of the bending magnets for the beam injection of the 3-GeV RCS in J-PARC

T. Takayanagi, Y. Yamazaki, Y. Irie, T. Shimada, J. Kamiya, M. Watanabe, JAERI; S. Izumi, T. Kawakubo, KEK.

The injection system of the 3-GeV RCS in J-PARC is composed of four main orbit bump magnets (shift bump) to merge the injection beam with the circulating beam. The magnetic field design and the structural analysis of the shift bump magnets have been performed using 3D magnetic and mechanical analysis codes. The shift bump has realized a uniformed field with less than 0.4 % in homogeneity over a wider aperture (380mm width and 250mm height), and the coil with flexibility has prevented the destruction by the thermal expansion.

POSTER SESSION	13:30 - 15:30
POWER CABLES	

MOA09PO01

Introduction of Cryogenic System for 75 m three-phase AC HTS Cables in China

Y. Fan, L. Gong, X. Xu, L. Zhang, L. Li, Technical Institute of Physics and Chemistry of CAS; L. Xiao, Institute of Electrical Engineering of CAS.

The 75 m 10.5kV/1.5kA three-phase AC high-temperature superconducting (HTS) power cable had been installed which was running in a live power grid in China in 2005. For cryogenic system, the liquid nitrogen decompression (LND) method was adopted in the 75 m cable facility, which is based on two reasons: one is that the LND method is simple and reliable; the other reason is that we have accumulated operation experiences from the test of 10 m cable prototype since 2003. By far, the 75 m HTS power cable facility with LND cooling method had completed the commissioning and electrical operation. The total running time was more than 1000 hours. In this paper we will mainly present the design and installation of cryogenic system, and show the result of commissioning and electrical operation.

MOA09PO02

Analysis of Balanced Three-phase Current Distributions in a Tri-axial Cable

T. Hamajima, T. Yagai, M. Tsuda, Tohoku University.

High Temperature Superconducting (HTS) cables have been studied because of low loss and compactness, compared with conventional copper cables. Three-phase cables are usually composed of three single-phase concentric cables. Recently, a tri-axial cable, composed of three concentric phases, has been intensively developed, because it has advantages such as reduced amount of HTS tapes, low leakage fields and low heat loss in leak, compared with the three single-phase cables. However, there is an inherent imbalance in the three-phase currents in the tri-axial cable due to the differences in radii of the three-phase current layers. The imbalance of the currents causes additional loss and large leakage field in the cable, and deteriorates the electric power quality. Therefore, it is important to find out cable construction parameters, such as winding pitches and radii of the three concentric phase layers, for the balanced three concentric phase currents in the tri-axial cable. We analyze the three-phase current distributions in the tri-axial cable as functions of winding pitches of three concentric phase layers. On the basis of the analysis, we propose the balanced three-phase current distributions in the tri-axial cable.

MOA09PO03

The Outgassing Test of the HTS Power Cable Cryostat D-Y. Koh, H-K. Yeom, Korea Institute of Machinery and

Materials; K-S. Lee, Hanyang University.

The reduction of outgassing in High Temperature Superconducting(HTS) power cable cryostat is very inportant to achieve a long interval vacuum pumping and to drop the minimum vacuum level. So, in order to reduce the outgassing from the cryostat surface, cleaning and baking are necessary porocess in manufacturing the cryostat. The outgassing surface of the cable cryostat is bigger than the vacuum space of the cable cryostat, therefore the vacuum level of the cable cryostat goes up quickly in small outgassing rate. In this paper, to analyse the vacuum characteristics of the HTS power cable cryostat, we have measured the outgassing rate of the sample HTS power cable cryostat in various structures of vacuum insulation (with or without multi layer insulation(MLI), filled or not filled with LN2) and predicted the trend of the vacuum level changes in our HTS power cable cryostat.

MOA09PO04

Robust Optimization of HTS Cable Multilayer Conductors By Means of PSO and Perturbation Analysis

S. Wang, J. Qiu, Z. Zhao, Department of Electrical Engineering, Xi'an Jiaotong University. Withdrawn.

MOA09PO05

The Effective Current and Magnetic Field Distributions for Reducing AC Loss in Coaxial Multi-layer HTS Transmission Cable

M. Tsuda, T. Fujisawa, T. Hiraoka, N. Harada, T. Yagai, T. Hamajima, Tohoku University.

We have investigated the relationship between current distribution and self-field loss of each layer in coaxial multilayer HTS transmission cable and clarified that the same layer current could reduce the self-field loss effectively. In the cable with the same layer current, however, the magnetic field in the outer layer is larger than that of the inner layer and the loss of external AC magnetic field from other layers, especially in the outer layer, becomes large. Therefore, we investigated the effective current and magnetic field distributions for reducing total AC losses, defined as the sum of the self-field loss and the loss of external magnetic field from other layers, in a 5 kA HTS transmission cable composed of three transport current layers and two shielding current layers. The loss of external magnetic field from other layers is much larger than the self-field loss; this means that the suitable cable parameters for reducing total AC losses could be determined by considering the loss of external AC magnetic field from other layers mainly. The total AC losses in the cable with the same magnetic field in all layers are much smaller than those of the same layer current. Since the same magnetic fields in all layers are realized by the larger layer current in the outer layer. This means that such the inhomogeneous current distribution is more effective on the reduction of the total AC losses than homogeneous current distribution.

MOA09PO06

Investigation on the thermal behavior of HTS power cable against fault current

S. Kim, J-W. Cho, K-D. Sim, J-H. Bae, J. H. Kim, H. J. Kim, KERI.

During the operation of HTS power cable, large fault current can be introduced to a HTS power cable due to several accidents. In this case, a circuit breaker limits the fault current to protect the HTS cable just as conventional power cables. However, heat is necessarily generated until the circuit breaker operates and sever performance degradation or even burn-out can occur at HTS tapes. To ensure the safety against the fault current, thermal analysis should be performed for the HTS tape. Considering the heat transfer in liquid nitrogen, the temperature and the resistance of HTS tape are estimated using numerical analysis assuming plausible fault current. To verify the analysis results, several experiments are performed with test samples using AC pulse power supply, which can simulate the short duration of the fault current. During the experiment, the increase of temperature and resistance are measured for the various fault current conditions. Through the experiments and the analysis, safety margin for the circuit breaker delay time and the allowable peak current are suggested. Moreover, the results can be used for the power system analysis by estimating the increased resistance, which acts as increased load.

MOA09PO07

Design and Experimental Results of a 3 Phase 30m HTS Power Cable

J. Cho, K-D. Sim, J-H. Bae, H-J. Kim, K-C. Seong, J-H. Kim, KERI; H-M. Jang, C-Y. Lee, LG Cables; D-Y. Ko, KIMM.

HTS power transmission cables appear to be the replacement and retrofitting of underground cable in urban areas and HTS power transmission cable offers a number of technical and economic merits compared to normal conductor cable system. A 3phase 22.9kV, 50MVA class HTS power transmission cable system have been developed by Korea Electrotechnology Research Institute (KERI), LG Cable Ltd. and Korea Institute of Machinery and Materials (KIMM) that is one of 21st century frontier project in Korea. The 30m long cable with 3 cores in 1 cryostat has been manufactured and installed to conduct long-term reliability test. The HTS power cable consists of two layers of phase conductor and two layers of shield used Ag/Bi-2223 tapes and polypropylene laminated paper is used in LN2 as electrical insulation. A HTS power cable

has been tested with DC and rated current and voltage in pressurized liquid nitrogen. The evaluation results clarify good performance of HTS cable and these results prove that the HTS power cable has the basic electrical properties for 22.9kV HTS power cable. This paper describes the results of developmental the 30m, 3 phase, 22.9kV, 50MVA HTS power cable in Korea.

MOA09P008

Influence of External Magnetic Field on Quench Characteristics of HTS Cable Conductor Transporting AC Current

S-W. Yim, K. Kishio, Department of Superconductivity, University of Tokyo; S-H. Lim, Research Center of Industrial Technology, Chonbuk National University; S-H. Shon, S-D. Hwang, KEPRI.

If an HTS cable transporting AC current is exposed to external magnetic field, current distribution among the strands becomes unequal, and the operation of the cable could be unstable, leading to the quench. Nevertheless, it is not easy to detect and analyze the quench phenomenon in this situation because the current is fluctuating and the configuration of magnetic field is complicated. In this study, a prototype of HTS cable conductor with 1 layer of 10 strands Bi-2223/Ag tapes was fabricated and the quench characteristics considering self and external magnetic field were investigated. Firstly, 60 Hz AC currents of which the peak values were up to around twice Ic were applied to a Bi-2223/Ag tape and the guench voltages were measured. These data were compared with the detected voltages of the HTS cable conductor after applying the currents beyond its critical current. When there were only self field, the influence of magnetic field was weak enough not to affect the transporting characteristics. On the other hand, in case that the external magnetic fields of 50 mT and 100 mT were applied to the cable conductor, the guench voltages of the strands were changed, due to the directional dependence on magnetic field. Finally, from the results, the variation of quench voltages with magnitude of the applied external magnetic fields was simulated and analyzed.

MOA09PO09

The research on the eddy current losses in the stabilizer and outer-cryostats for the high-Tc superconducting power cable system

M-K. Song, Vector Fields Korea. Inc.; S-J. Lee, E.E. Dept. Uiduk University; K-D. Sim, J-W. Cho, KERI.

The structure of high-Tc superconducting power cable system is composed by these parts; (From the outer section) liquid nitrogen cryostat, vacuum cryostat, multilayer high-Tc superconducting cable core and the stabilizer which is used as the current bypass during the quench period. In this paper, the eddy current losses in the stabilizer and both cryostats during the stable driving period of the high-Tc superconducting power cable system are calculated by the numerical method. And the optimal conditions of the stabilizer and both cryostats to minimize the eddy current losses are derived from the analyzed results. The optimal results can be applied to the design and manufacture of the high-Tc superconducting power cable system.

MOA09PO10

The research on the inductance calculations of the high-Tc superconducting power cable with new concept

M-K. Song, Vector Fields Korea. Inc.; S-J. Li, E.E. Dept. Uiduk University; K-D. Sim, J-W. Cho, KERI.

The inductance calculation of a multi layered high-Tc power cable is very important in order to design a stable high-Tc Superconducting power cable system. In this the conventional methods for inductance paper, calculations by using the go-&-return method and energy method are verified to be reliable or not in calculating the inductance of the multi-layered high-Tc superconducting power cable. And then these methods are compared to the newly derived inductance calculation method which uses Neuman's Formula and the concept of GMD(Geometric Mean Distance). And, in order to verify the new method, the inductances which are calculated from Neuman-GMD method and numerical method are compared using different twisted-pitch and inner-radius of high-Tc superconducting cable. In this procedure, the adequate inductance calculation method can be applied to the design and manufacture of the high-Tc superconducting power cable system

MOA09P011

3-D FEM Analysis of Effect of Twist Pitch and Shielding Layer on Multi-layered HTS Power Cable

D. Miyagi, S. Iwata, N. Takahashi, Okayama University; S. Torii, K. Ueda, CRIEPI; K. Yasuda, Super-GM.

A superconducting power cable is one of the most promising applications of high-Tc superconductor (HTS). Controlling the current distribution in each layer of a multilayer superconducting cable uniformly is important in order to realize a compact and large capacity HTS power cable. The phenomenon of current imbalance should be exactly investigated by the analysis, because the current unbalance occur the increase of AC loss. However, the report of the accurate 3-D analysis of AC loss of a HTS cable taking account of the E-J characteristic is few. This is mainly because the number of finite elements increases greatly in 3-D analysis. In this paper, in order to study the AC loss of multi-layered HTS power cable, 3-D finite element analysis taking account of the nonlinear E-J characteristic is carried out. By modeling such spirally wound superconducting tapes as conductors having an anisotropic conductivity and using the periodic boundary condition, the analysis region is considerably reduced. By using this model, the effect of the n value and twist pitch on the current distribution of multi-layered HTS power cable with shield layers is illustrated and the structure with little AC loss are discussed.

MOA09P012

Design and Fabrication of the Real-time Ac Loss Measurement System for a HTS Cable

J. Kim, K-D. Sim, J-W. Cho, H-J. Kim, H-J. Kim, K-C. Seong, J-H. Bae, D-S. Kwang, KERI.

There are many HTS cable project in the world such as LIPA, Albany, AEP, DAPAS program. For evaluation the HTS cable, correct AC loss measurement was to be developed. The hardware and software of the real-time Ac Loss measurement system were composed of theoretical design parameter. AC loss measuring system composed with cancel coil, Lock-in amp, and setp motor controller. AC loss measurement system is able to evaluate the real-time and calibrate automatically. Voltage and current data was analyzed and the measuring system was controlled by automatically. Real-time and automatic estimation is possible in ac superconducting power cable.

MOA09P013

Electrical Characteristics of Insulators for a Termination of HTS Cable

D-S. Kwag, H-G. Cheon, J. Lee, S-H. Kim, Gyeonsang National University; H-J. Kim, J-W. Cho, KERI.

As a energy demands increase and environmental concerns heighten, an underground high temperature superconducting (HTS) cable will provide the necessary alternative to meet power supply needs; Within conventional cable technology, the terminations are important components. A research on several characteristics such as volume breakdown and surface discharge of insulators for a termination of power transmission class HTS cable was performed. In this paper, we investigated the surface discharge of glass fibre reinforced plastic under air, cryogenic nitrogen gas, and nitrogen gas media. And the breakdown characteristics of these media were also studied. Experimental results revealed that flashover voltage greatly depends on pressure, temperature, the kinds of insulating media and voltages, but it is slightly affected by shape and material of electrode. The breakdown voltage of liquid nitrogen, cryogenic nitrogen gas, and nitrogen gas deeply depends on the shape and dimension of electrode, kinds of voltages, and pressure. Moreover, the breakdown voltage of cryogenic nitrogen gas and flashover voltage of glass fibre reinforced plastic in the cryogenic nitrogen gas is also influenced by temperature and vapour-mist density of the das.

MOA09P014

Design of HTS Transmission Cable with Cu Stabilizer

K-D. Sim, J-W. Cho, J-H. Bae, H-J. Kim, S-H. Kim, K-C. Seong, KERI.

More than three HTS cable development and installation projects are proceeded over the world. A 22.9kv/50MVA class HTS cable system has been developed in Korea during last 3 years. And the HTS cable system for commercialization will be developed and installed on the real or test power grid withinn 2 years ahead. Every HTS cable system has to satisfy the falult current specification of the power grid in order to protect the calble itself from the fault current. HTS cable composed of HTS tapes has its own capacity of enduring the fault current by bypassing the current through its Ag-sheath. But it may not be enough. So, some Cu stabilzer is generally introduced inside the conductor layers and outside the shield layers of HTS calbe core for some higer fault current grade. In this paper, the design method of HTS cable with Cu stabilizer will be intoduced. And the falult current capacity of HTS cable and its eddy current loss generated from the stabilizer will be calculated. And the impedence change of HTS cable in the fault current state will be calculated.

POSTER SESSION	13:30 - 15:30
FAULT CURRENT LIMITERS (I)	

MOA10PO01

Transient Numerical Simulation for Heat Transfer Characteristics on the Resistive Superconducting Fault Current Limiter

C.H. Kim, K. Rhyee, K. Lee, Seoul National University of Technology.

A transient numerical simulation was conducted to have variation of temperature on an element of resistive SCFCL (Superconducting Fault Current Limiter) under quenching condition. It is very important engineering information for an optimum design of cryogenic system for cooling of a resistive SCFCL element. A resistive SCFCL bifilar type coil for 10MVA that was developed by Nexans, Germany is incorporated in this study. The coil is made of 5-layer of different solid materials and is submerged into liquid nitrogen container at 77K, 1atm for cooling. As hot-spot occurs on the shunt material(CuNi) due to fault current in power line, very high temperature starts at the shunt and is transferred to the superconducting material(BISCCO-2212) by conduction. In this study, variation of the temperature distribution on the element of the bifilar type SCFCL was found with the change of time and hot-spot size generated on the shunt material. The average temperature on the shunt and BI-2212 element at 500Kw, 100ms is 711.1K and 198.4K respectively. The details of the temperature distribution on the SCFCL element obtained from this numerical study should be very valuable information for the decision of the cooling capacity of cryogenic system for the model SCFCL element.

MOA10PO02

Investigation of new bridge type superconducting fault current limiter

X. Liu, L. Xiao, Institute of Electrical Engineering, CAS.

A new bridge type high temperature superconducting fault current limiter (SFCL) with a limiting impedance of superconductor connected in the limiting circuit is proposed, which could limit the peak value and the stable value of the fault current. Under normal condition, the limiter is in low impendence as the limiting impedance and the inductance are both in superconducting state; when there comes a fault, the inductive coil keep the superconducting state to restrict the fault current from fast rising, while the limiting impendence change to the normal state so that the impedance is series-connected immediately to limit the stable part of the fault current. The principle of the current limiting was analyzed, and a system simulation was carried out. The results indicates the new hybrid bridge type SFCL using the inductance of the superconducting state and the impendence of the normal state of the superconductor could be more efficient in fault current limiting than the traditional bridge type SFCL .The proposed model and simulation results could be used as valuable references for the application.

MOA10PO03

Fundamental Characteristics of Superconducting Fault Current Limiter using LC Series Resonance Circuit

H. Arai, T. Ishigouoka, Seikei University; H. Tanaka, Hitachi Ltd.; K. Arai, M. Furuse, M. Umeda, AIST.

A new superconducting fault current limiter utilizing a series resonance circuit composed of a superconducting coil (L) and a capacitor (C) has been fabricated and tested. The amplitude of the fault current increases gradually by the transient characteristics of the LC series resonance circuit when a sudden short-circuit occurred. Therefore, we can reduce the capacity of a circuit breaker by suppressing the increase of a fault current with this fault current limiter. We carried out a small scale experiment with a model transmission system. By the experiment, the fundamental principle of this fault current limiter has been confirmed. Some numerical analyses are carried out. The numerical result agrees well with the experimental result. It is also shown that the fault current increase rate can be controlled arbitrarily by adjusting the value of the coil inductance L and the capacitance C.

MOA10PO04

Manufacture and Test of Small-scale Superconducting Fault Current Limiter by Using the Bifilar Winding of Coated Conductor

M.C. Ahn, D.K. Bae, S.E. Yang, D.K. Park, T.K. Ko, Department of Electrical and Electric Engineering, Yonsei University; C.J. Lee, Hyundai Heavy Industries Co., Ltd.; B.R. Seok, Heavy Industries Co., Ltd.; H.M. Chang, Hong Ik University.

Superconducting fault current limiters (SFCLs) have been developed in many research groups. However, there is no standard for current limiting device. Recently, YBCO coated conductor (C.C.) which is named as 2nd-generation wire has been developed rapidly. YBCO C. C. has many advantages for applying to fault current limiting material. In this paper, a bifilar winding type SFCL was manufactured using YBCO C.C. The bifilar coil was wound as pancake type and length of the used C.C. tape was 8 m. The shortcircuit test of the SFCL was performed successfully rated on 50V/100A. The SFCL has very low impedance in normal operation and limited the fault current effectively when a fault occurred. From the result, it could be confirmed that the bifilar winding type FCL using YBCO C.C. is feasible. Large-scale SFCL using C.C. should be developed in the future.

MOA10P005

Simulation Study on Operating Characteristics of Superconducting Fault Current Limiter in Power System

Y. Ye, Institute of Electrical Engineering, CAS.

Many studies have been reported on various types of superconducting fault current limiters (SFCLs). They were mainly about the characteristics of SFCLs themselves, and there are a few studies on SFCL as a power system apparatus. SFCLs are expected to improve reliability and stability of power system. In this paper, a detailed simulation model of a resistor type Superconducting fault current limiter was proposed. Simulation studies were performed in one-machine infinite bus system with parallel transmission lines. Power system operating characteristics of the SFCL were investigated and discussed by EMTDC simulation results. The rotor oscillation of generator was also analyzed with SFCL installed in power system. Simulation results show that SFCL can effectively protect synchronization both in a symmetrical three-phase fault and single-phase fault. Limiting fault currents means not only an improvement of circuit breaker abilities but also a protection of synchronism.

MOA10PO06

Test of LC Resonance type of fault current limiter

K. Arai, H. Tanaka, M. Furuse, M. Umeda, AIST; M. Inaba, H. Arai, T. Ishigohka, Seikei University.

A resonance-type superconducting fault current limiter (FCL) was developed and tested in order to demonstrate its concept and actual operations. The resonance type superconducting FCL was originally proposed by Seikei University, and after that, a large-scale experimental study using its modified FCL was started by National Institute of Advanced Industrial Science and Technology. This type of FCL can minimized the normal transition in Bi-2223 superconducting pancake coils in it in case of an over-current fault, and it can instantaneously return to steady state operation after the fault is cleared. The tested superconducting reactor has a toroidal configuration with 12 pancake-coil units where one unit includes 3 pairs of pancake coils. The inductance of the reactor can be variable from 5.5 to 50 mH by setting the combination of

the series and paralleled connections of those units. One combination in three-parallel and four-series mode makes a 200 A class FCL. The test result using 50 Hz alternating current shows the current increases exponentially to a saturated level of approximately 240 A, 1.3 times of steady state current level, while it can be estimated to be beyond 1000 A in the case of using no FCLs. The time constant to reach the saturation can be defined by the specifications of the arrester voltage and the normal voltage level in the superconducting reactor, which was experimentally measured and confirmed also using the FCL in a different connection of those units.

MOA10P007

Current Limiting Characteristics of Inductive Type SCFCL with ZnO Device and Resistor in Parallel

Y. Shirai, T. Morimoto, K. Furushiba, M. Shiotsu, Kyoto University; K. Fushiki, J. Baba, T. Nitta, The University of Tokyo.

Superconducting Fault Current Limiters (SCFCLs) can be classified into two types by the current limiting impedance, that is, inductive-type (L-type) and resistive-type (R-type) SCFCL. Both types have merits and demerits each other. The L-type SCFCL has good features in current limiting and recovery characteristics. The R-type one can consume the excessive energy of generators at a fault and it can improve power system stability. In this paper, we proposed a new FCL system which consists of a L-type SCFCL in parallel with a resistor and a ZnO device. The proposed system has good features of both L- and R-type ones. A model system was made and studied experimentally. The ZnO device is off-state in stand-by mode. When a fault occurs, the SCFCL turns into current limiting mode and has high impedance. The voltage across the SCFCL exceeds a threshold voltage of the ZnO device. During one cycle of the voltage, the ZnO device is on-state around the peak of the voltage, and the current flows through both the SCFCL and the resistor. A certain amount of excessive energy is dissipated in the resistor. The ZnO device is off-state around the peak of the current which is suppressed only by the L-type SCFCL. Finally the proposed FCL system toggles L-type and L+R-type in a cycle. Relations among the threshold voltage, the current limiting impedance and the resistance of the resistor were discussed. It was confirmed the proposed FCL system represents desirable current limiting characteristics.

MOA10P008

Study of a novel high-Tc superconducting fault current limiter

Z. Zhang, L. Xiao, Institute of Electrical Engineering, CAS. Withdrawn.

MOA10PO09

Investigation of Electrical Insulation Characteristics in the Simulated Quench Conditions of HTS FCL

B-Y. Seol, K. Nam, C. Lee, Electro-Mechanical Research Institute, Hyundai Heavy Industries Co., LTD. Withdrawn.

MOA10PO10

Design and Test of High-TC Superconducting Coils for a Three-Phase 10.5kV/1.5kA Fault Current Limiter

Z. Wang, J. Zhang, D. Zhang, H. Li, Y. Guan, Q. Bao, L. Lin, L. Xiao, ASCL, IEE.

The design of High Temperature Superconducting (HTS) coils for a three-phase 10.5kV/1.5kA HTS fault current limiter (FCL) is described. It is well known that the Ic of HTS materials is very sensitive to the orientation of fields.

In the design of the HTS coils, the value of Bperp should be reduced, and the coils should be wound and jointed easily. In order to enlarge the current carrying capacity of the coil, the double pancakes in the coils were connected in parallel. Based on the field distribution in the coils and the current distribution in each double pancake, the design of the magnet was optimized. Three coils wound with Bi-2223/Ag tape have been developed and tested.

MOA10PO11

Behavior Investigations of Superconducting Fault Current Limiters in Electric Power Systems

L. Ye, M. Majoros, A. Campbell, IRC in Superconductivity, Department of Engineering, University of Cambridge.

When electric power systems grow and become more interconnected, the fault current levels increase. Superconducting Fault Current Limiters(SFCLs) are being developed to prevent fault currents from exceeding clearance capacity of circuit breaker and voltage sags, thus improve power quality. SFCLs provide an attractive solution to the problem of fault currents in electric power systems. The behavior of the limiter depends on the characteristics of the material being using. In this paper the behavior of resistive SFCLs made of different material will be investigated from a system point of view. The simulation results of case study using Electromagnetic Transient program(EMTP) will be discussed. This paper outlined the basic application guidelines for SFCLs design, and some technical issues of the interaction between SFCLs and power grids are presented as well.

MOA10P012

Simulation of Thermal Instability in MgB2 Sample for Superconducting Fault Current Limiter Applications

L. Ye, M. Majoros, A. Campbell, IRC in Superconductivity, Department of Engineering, University of Cambridge.

A superconducting fault current limiter (SFCL) is considering to be one of the solution to control the fault current levels in fast growing power grids. The recent of superconductivity in discoverv magnesium diboride(MgB2) provides a possible new material for power application of SFCL. However, the implementation is still plagued by thermal instability related to defect, which leads to hot spots and melting of the conductor. In order to predict this weaknesses in a piece of MgB2 sample elements, which has proved to be a problem for a resistive types of SFCL. In this paper, we have developed and carried out numerical simulations of defect in MgB2 sample using FlexPDE which is a software tool for finding numerical solutions to systems of linear or non-linear partial differential equations. Results show the validity of the approach and will be valuable for future resistive SFCL designs.

MOA10P013

Finite Element Analysis of Thermal and Mechanical Behavior in Model Fault Current Limiter With QMG Bulk Superconductor

K. Kajikawa, Y. Takahashi, Y. Enpuku, K. Funaki, Kyushu University; H. Hayashi, Kyushu Electric Power Co., Inc.; M. Morita, H. Hirano, Nippon Steel Corp.

Various kinds of fault current limiters (FCLs) based on the transition from superconducting to normal states have been investigated all over the world, but there has been no superconducting FCL to be introduced into an electric power grid. In order to realize the FCLs, it is important to disperse the total energy dissipated during the fault condition efficiently. Up to now, our group has proposed a new concept for a resistive-type limiting device with bulk

superconductor to reduce a thermal shock due to the huge amount of Joule heating. Since two metal plates are soldered on each side of the superconductor, it is expected that the simultaneous thermal expansion resulting from the current sharing suppresses the stress concentration on the superconductor. This idea has already been confirmed with the experiments. In the present study, the current limiting process is numerically simulated with commercial software of finite element methods. In order to reproduce the experimental results with a QMG bulk superconductor, the distributions of current density and temperature inside the limiting device are numerically solved at each time step for a half cycle of an excess current. By using the obtained distributions, the analysis of internal stress is also carried out to validate the structure of metal reinforcement. Furthermore, the current limiting behavior for a voltage source is evaluated to simulate a realistic operation in the actual power transmission line.

MOA10P014

Quench properties of Bi-2212 bulk in magnetic field

J. Sim, H-R. Kim, O-B. Hyun, KEPRI; K-B. Park, H-M. Kim, Electrotechnology R&D Center of LS Industrial Systems. We have studied quench properties of Bi-2212 bulk for application to a resistive type superconducting fault current limiter. In order to protect the Bi-2212 bulk from hot spots during quenches, it had not only electrical bypass but also a magnetic field applied to it simultaneously with the quench. Due to the applied magnetic field, critical current density of the element was decreased and quench was accelerated. The coil to generate magnetic fields was connected in series or parallel to Bi-2212 bulk. We have measured electric field-current density characteristics of Bi-2212 bulk in applied magnetic field. We also have investigated the dependence of guench characteristics of Bi-2212 bulk on applied magnetic field. This work was supported in part by a grant from Center for Applied Superconductivity Technology of the 21st Century Frontier R&D Program funded by the Ministry of Science and Technology in Korea.

MOA10PO15

Quench characterisitcs of current limiting elements in a flux-lock type superconducting fault current limiter.

H-S. Choi, H-M. Park, Department of Electrical Engineering, Chosun University; S-H. Lim, C-R. Park, B-S. Han, School of Electronics and Information Engineering, Chonbuk National University.

We investigated quench characteristics of flux-lock type superconducting fault current limitier(SFCL) according to the winding directions of superconducting elements and the connecting method. The flux-lock type SFCL consists of two coils. The primary coil is wound in parallel to secondary coil through an iron core, and the secondary coil is connected with the superconducting elements in series. The operation of the flux-lock type SFCL can be divided into the subtractive and the additive polarity windings according to the winding directions between the coil 1 and coil 2. In order to increase the rated voltage and current grade of the SFCL, the superconducting elements should be connected in series. However, when it is simply connected in series, the quench is not generated simultaneously due to the slight differences of their intrinsic current. When we connected critical several superconducting elements in flux-Lock type SFCL, the quench was achieved simultaneously due to the flux linkage between the serial elements into secondary winding. Meanwhile, the line current are higher in the subtractive winding than that of the additive winding

because of the flux decrease and increase by the winding directions. This means that the capacity of the SFCL could be increased through the serial connection and the subtractive winding.

MOA10P016

Design of LTS Coil used for the Combined Device $\ensuremath{\mathsf{SMES}}\xspace{\mathsf{SFCL}}$

G. Zhu, M. Song, Z. Wang, Electrical Engineering Dept., Tsinghua University.

The paper presented the whole procedure of the LTS coil design which was to be used in the combined device SMES-SFCL. The optimization of the coil volume with the limitation of designated capacity and power was done at first. After the superconducting tape was chosen, the size of the coil, including the inner radius, outer radius and height, was determined. Since the coil was designed to be flown through by the short circuit current which was very quickly time-variant, its stress distribution would be quite different from that in the steady state. The numerical solution of the short circuit current flowing through the coil was calculated by Matlab, and this result was exported to ANSYS used as the transient condition to calculate the stress distribution of the coil, which was simulated using the electricity-magnetic-structure coupling model. The simulation results showed that the LTS coil was conditionally safe from both the electrical and mechanical point of views. These conditions can be satisfied by circuit breaker and protect circuit design.

POSTER SESSION	13:30 - 15:30
FUSION PRESENT DEVICES	

MOA11PO01

Effect of surface oxidation on stability of LHD conductor immersed in pressurized He II

M. Ohya, Y. Shirai, M. Shiotsu, Kyoto University; S. Imagawa, NIFS

In our recent study, stability tests were performed for a small test coil wound with a LHD (Large Helical Device) conductor immersed in He I and He II. The LHD conductor has a thick aluminum stabilizer and is stationary close to a perfect stabilized one. However, because of its long current diffusion time, the phenomenon was seen beyond a certain current that a short normal zone initiated by a thermal disturbance dynamically traveled along the conductor. If the stability limit of the LHD test coil was defined as such a dynamic minimum propagation current, the increasing rate of the stability limit of the LHD test coil by lowering the liquid helium temperature from 4.2 K to 2.0 K is guite smaller than that of a small test coil wound with a superconducting wire with the bare copper surface that is examined before. The LHD conductor surface is chemically oxidized, and the Kapitza conductance on the oxidized copper surface is known to be guite smaller than that on the bare copper surface. In order to confirm the influence of the Kapitza conductance on the stability of the LHD conductor, the stability tests of a new test coil wound with the bare LHD conductor (without oxidation) were performed. The stability of the bare LHD coil was improved as compared with that of the oxidized LHD coil at the time of He II cooling. It turned out that one of main factors that govern the stability of the LHD conductor cooled by He II is the Kapitza conductance.

MOA11PO02

Development of CICC for KSTAR Superconducting

Magnet System

B.S. Lim, J.Y. Choi, S.I. Lee, C.S. Kim, I.S. Woo, D.J. Kim, N.H. Song, W.W. Park, K.R. Park, H.K. Park, Korea Basic Science Institute.

The KSTAR (Korea Superconducting Tokamak Advanced Research) superconducting magnet system adopts a superconducting CICC(Cable-In-Conduit Conductor) type conductor. It consists of 16 TF coils and 14 PF coils and it also uses two different types of CICCs – Nb3Sn cable with Incoloy 908 conduit and NbTi cable with 316LN stainless-steel conduit. A special CICC jacketing system is developed for the KSTAR CICC fabrication and it uses the tube-mill process which consists of forming, welding, sizing and squaring procedures. The cabling process for TF and PF superconducting cable and the fabrication process of each CICCs (TF CICC and PF CICC) is described. The welding of conduit materials are also discussed. The fabrication results including the geometrical specification and the void fraction will be discussed.

MOA11PO03

Fabrication of the KSTAR TF Magnet

B.S. Lim, C.S. Kim, I.S. Woo, J.Y. Choi, D.J. Kim, N.H. Song, W.W. Park, K.R. Park, S.I. Lee, H.K. Park, Korea Basic Science Institute.

The KSTAR TF magnet system consists of 16 TF coils and 14 PF coils. Both of the TF and PF coil system uses internally cooled superconductors. The TF coil system provides a field of 3.5 T at a plasma center, with a peak flux density at the TF coils of 7.5 T. The stored energy is 470 MJ. TF coils use a Nb3Sn CICC(Cable-In-Conduit Conductor) with a 2.86 mm thick Incoloy alloy 908 (afterward, Incoloy 908) conduit. The Nb3Sn strand has KSTAR HP-III specifications in which the critical current density is greater than 750 A/mm2 at 12 T. 4.2 K. The nominal current of the TF coils is 35.2 kA with all coils in series. For the fabrication of CICC and TF magnet, a continuous CICC jacketing system is developed and the procedures of coil fabrication are established. The procedures of coil fabrication are CICC leak test, grit blasting winding, attachment of helium feed-throughs and joint terminations, heat treatment, insulation taping, ground wrapping and vacuum pressure impregnation. Each fabrication process is described and the fabrication results including the geometrical specification will be discussed.

MOA11PO04

Acceptance test of the first power supply and protection system module for W7-X

T. Rummel, T. Mönnich, Max-Planck-Institut für Plasmaphysik

superconducting magnet of the The system WENDELSTEIN 7-X (W7-X) experiment consists of 50 non-planar and 20 planar coils which are connected in series in seven groups of ten coils each. In order to be able to vary the magnetic configuration the five groups of nonplanar coils and two groups of planar coils will be powered individually resulting in seven independent power supplies. The selected concept is a twelve pulse thyristor-based converter with interphase transformers. The maximum output current per unit is 20 kA at a voltage of 30 V. It is necessary to equip each of the seven power supplies for the superconducting coils with a protection system to avoid overloading of the coils in case of a quench. The stored energy of up to 900 MJ during plasma experiments has to be removed very fast from the coils and dumped it into a discharge resistor. Load switches transfer the current into an intermediate circuit and D.C. breakers force it into the dump resistor circuit. During these switches high voltages

of up to 6 kV may be induced. The paper describes briefly the design of the power supplies and the protection system for W7-X and gives a detailed description of the component tests as well as the acceptance tests of the first module of the power supply and protection system. Acceptance tests were done without load, under short circuit conditions in order to simulate the superconducting coils and with a dummy load in order to simulate an inductive load.

MOA11PO05

Insulation of the coil and bus bar ends during assembly of W7-X

K. Rummel, A. John, Max-Planck-Institut für Plasmaphysik. of The superconducting magnet system the WENDELSTEIN 7-X (W7-X) experiment consists of 50 non-planar and 20 planar coils which are connected by 121 bus bars in series in seven groups of ten coils each. The terminal ends of the coils and bus bars are not insulated by the manufacturers and will be equipped with transition joints aluminium / stainless steel during coil and bus bar preparation. The transition joints are part of the joints which will be assembled after making the electrical connection between coils and bus bars. The insulation has to withstand a voltage of 13 kV DC for 1 min at Paschen conditions. Due to the complex 3 D shape of the coil and bus bar ends it is not possible to apply a vacuum impregnated insulation. Furthermore it has to be considered that the quench detection wires which were fed inside the insulation along the coil and bus bar ends have to be feed through the insulation near the joints. The paper describes the design of the insulation and focus of their application during assembly. The hand made insulation is a combination of wet wrap glass kapton epoxy insulation and GRP material. The qualification carried out on samples will be presented and tests to be performed. Besides the mounting of insulation at the first coil will be reported.

MOA11PO06

Improvement in the cryogenic stability of the model coil of the LHD helical coil by lowering the temperature.

S. Imagawa, N. Yanagi, S. Hamaguchi, T. Mito, K. Takahata, H. Chikaraishi, H. Tamura, A. Iwamoto, S. Yamada, O. Motojima, NIFS.

Helical coils of the Large Helical Device (LHD) are poolcooled superconducting magnets, in which propagation of a normal-zone have been observed several times at about 90% of the nominal current. It is planned to improve the cryogenic stability by lowering the inlet temperature. In order to estimate the effect, the cryogenic stability of a model coil of the helical coil was examined in saturated and subcooled helium. Liquid helium is supplied from the bottom of the model coil, and it is exhausted through the winding to the current-leads tank. The inlet helium is subcooled by a pre-cooler. A normal zone was initiated by a heater on the conductor. The propagation was detected by voltage taps. In the saturated helium of 4.4 K and 0.12 MPa, the minimum currents to begin propagation vary from10.7 to 11.2 kA in the four cases that are without or with additional thermal shields, and before or after cooling down to 3.5 K. The difference is considered to be caused by the change of quality of saturated helium due to the steady heat input into the winding. The propagation velocities at the same current are slower at the less heat input. The minimum currents are higher at the lower temperatures in the subcooled helium. It is raised up to 11.7 kA at 3.5 K of the temperature of the winding. The propagation velocity at each minimum current is almost same. Namely, the propagation velocities at the same

current are slower at the lower temperature in subcooled helium.

MOA11PO07

Analysis of the test results of the KSTAR Central Solenoid Model Coil

W. Chung, Y. Chu, S. Lee, S.J. Lee, S.H. Park, K. Park, Y.K. Oh, K. Kim, J.S. Bak, Korea Basic Science Institute; S. Jeong, KAIST.

The Korea Superconducting Tokamak Advanced Research (KSTAR) Central Solenoid Model Coil (CSMC) was tested during 2004 in Korea Basic Science Institute (KBSI) to validate the design of KSATR CS coil. In this paper, the results of measurement, which are AC loss, inlet and outlet helium temperature, helium mass flow rate and pressure drop, are presented. In addition, the test is simulated by the numerical code that is developed to simulate KSTAR operation. The results of the test are compared with those of the simulation. Some correlations, which are related to AC loss calculation and friction factor of the code, are modified predict to accurate thermo-hydraulic characteristics of KSTAR operation. The thermo-hydraulic characteristics of the KSTAR CS coil, which is calculated by the revised code, are also reported in this paper.

MOA11PO08

Paschen testing on W7–X coils and components in the BNN test facility

H. Scheller, H. P. Langenberg, M. Kühnberg, Babcock Noell Magnettechnik GmbH; J. Baldzuhn, B. Petersen Zarling, D. Gustke, Max Planck Institut für Plasmaphysik; H. Fillunger, Atominstitut der österreichischen Universitäten.

During the fabrication of the coils for the Wendelstein 7-Xexperiment the need for pressure dependent high voltage testing – Paschen tests – of the coils and components arose. These tests ensure the safety of the coils in case of an emergency shutdown due to a break in the vacuum of the experiment cryostat. For that purpose the vacuum test facility at Babcock Noell Nuclear was modified in order to perform these tests. It is now possible to test coils and their components up to 17 kV and for pressures below 1.0e-3 mbar. Completed coils, winding packs before insertion in the case and also several components have been tested up to now. It has been demonstrated that these Paschen tests are a powerful tool to detect insulation defects. The paper shows the effort which has been taken to set up the test facilities. It will show the preparation of the components under testing. We will present and discuss the results obtained up to now.

MOA11PO09

Recent Results of the cold tests performed on the Stellarator W7-X coils

J. Baldzuhn, H. Ehmler, A. Hoelting, C. Sborchia, K. Hertel, Max-Planck Institut fuer Plasmaphysik; L. Genini, T. Schild, CEA/DSM/DAPNIA Saclay.

The magnet system of the fusion plasma experiment W7-X consists of 50 non-planar and 20 planar superconducting coils. The particular magnetic field topology of the stellarator W7-X imposes strict constraints on these coils, because the stellarator field, i.e. the iota profile, the magnetic field shear etc., have to be maintained with a relative accuracy of better than 10-4. In addition, 25 years of reliable operation are envisaged, without the opportunity of access to the coil system. Therefore, all coils will be subject to an acceptance test at operational conditions at a cryogenic test facility at CEA Saclay, France. The program includes guench tests, thermo-hydraulic measurements,

AC and DC high-voltage tests, Paschen tests, vacuum leak tests of the superconductor and the cooling pipes, and a check of the mechanical deformations and stresses during cool-down and current ramp-up. One quench is performed in order to investigate the operational margin of the coil, and to study all electrical and mechanical parameters of the coil during and after the quench. During AC electrical tests, eddy currents are induced in the coil casings. Numerical studies of the results of these tests can be used for the detection of interlayer short-circuits. The mechanical stresses on the coil casings are measured by strain gauges. Extensive comparisons to numerical FE calculations are performed to study the behaviour of the coils under mechanical load.

MOA11PO10

Comparative analysis of impulse and AC tests to detect shorts and weak points between turns and layers within the W7-X magnets

H. Ehmler, H. Fillunger, R. K. Maix, T. Rummel, K. Risse, IPP; A. Jeckle, ABB; S. Parodi, Ansaldo Superconduttori; H. Scheller, BNN.

The magnet system of the W7-X Stellarator consists of 50 non-planar and 20 planar coils. In particular, the winding packs of the non-planar coils are densely packed and compressed in the area of interlayer joints and coil terminations, which brings some risk of turn and interlayer shorts. The paper will describe methods deducted from impulse and AC tests performed on the coils, which enable demonstrating the absence of shorts and weak points of low Ohmic inter-turn resistance. In the impulse test, frequency and damping are compared for coils with and without short circuits and coils with an external low-Ohmic bypass. In the AC test, a drastically reduced impedance clearly indicates a short circuit. Therefore both tests represent excellent QA tools for checking the uniformity of the electromagnetic performance of a serial production of magnet coils.

MOA11PO11

Effect of thermal contact between winding pack and casing on thermal behavior of SST-1 TF coil

A. Sahu, B. Sarkar, N.C. Gupta, J. Tank, P. Panchal, R. Bhattacharya, G. Phadke, G. Gupta, N. Shah, Y.C. Saxena, Institute for Plasma Research.

Super conducting magnets, especially toroidal field (TF) coil, which are large in size and used for magnetic confinement of plasma under steady state configuration, uses casing to house the winding pack due to various reasons. Active case cooling in such cases has been one of the point of debate. TF coils of SST-1 consists of six double pancakes of Nb-Ti based cable-in-conduit conductor (CICC), duly impregnated and encased in a tight fit stainless steel casing. A thermo-hydraulic experimental characterization has been made on a test TF coil while studying the cooling down behavior without active case cooling. The hydraulic paths have been uniformly cooled down to 4.5 K using a 1.3 kW helium refrigerator/liquefier. The temperature profile on the casing has been measured using cernox sensors. Strategic locations on the casing have been decided as per the mechanical configuration. The nose section, which is thicker than the rest of the places, has been scanned with due attention. The experimental results show a distributed temperature profile on the casing ranging from lowest temperature of 17 K to the highest temperature of 28 K,at the lowest operating temperature 4.5 K. The data obtained has been analysed using ANSYS on the basis of thermal contact and thermal resistance, taking into account all the material properties.

The paper will describe the experimental setup, thermohydraulic behavior of the CICC in winding configuration and the agreement of results with empirical analysis.

MOA11PO12

Safety Ground Scheme for Steady State Superconducting Tokamak (SST-1) Cold Structures R. Bahl, B. Sarkar, Y.C. Saxena, Institute for Plasma Research.

Grounding scheme for cold structures of TOKAMAK, which uses superconducting magnets requires special attention due to its cryogenic environment operation. The toroidal (TF,16 nos.) and poloidal (PF,9 nos.) coils are kept at isolated potential by means of electrical isolators at the cryogen feed/return points. During occurrence of a fault, high voltage, of the order of few KV is expected to appear across the coil terminal or floating structures causing overheating or arcing. These unwanted faults have been taken care of by providing a fault return path between the fault and the source. Protective ground path has been implemented for all potential places. The basis of our design scheme is as per the electrical engineering standard. Technical requirements are: 1. Limit of voltage difference of idle parts to ground 2. Low impedance path for possible fault current and over-voltage 3. Thermal load at 4.5 K and 80 K. The above have been accomplished by connecting all the potential cold (4.5K,80K) structures, to the ground potential using Kapton insulated 37 strand cu wires, ensuring a tree-type structure to avoid formation of ground loops. Ground grid at the ambient temperature acts like a heat source for all the cold structures; therefore, a metallic heat sink has been provided at 80 K so that dT/dX along the wires beyond the heat sink is negligible. The paper will describe the details of the technical design for the grounding scheme, thermal sink and the implementation procedure.

MOA11PO13

Quench Detection System for the KSTAR Central Solenoid Model Coil Test

S. Lee, Y. Chu, H. Yonekawa, S.H. Baek, Y.K. Oh, J.S. Kim, K. Kim, B.S. Lim, K. Park, W. Chung, Korea Basic Science Institute.

The superconducting model coils of central solenoids for Korea Superconducting Tokamak Advanced Research (KSTAR) have been assembled and current charging experiment has been conducted in cryogenic state. The systems for detecting unexpected quench conditions are the critical devices to guarantee the stable magnet system operation of tokamaks. Not only to verify quench detection scheme for KSTAR but also to protect model coils from the unexpected coil quenches, an integrated system has been developed. This system includes superconducting coil monitor modules and superconducting bus bar monitor modules. To detect quench of the coil, conventional quench detection methods using a bridge circuit has been applied. For superconducting bus bar, simple co-wound voltage tap sensors have been used. To combine each module signals, an integration device is used. This unit not only combine signal but also determine final quench state. A method for easy balancing of the quench detection system is proposed. Current charging test has been preformed, whose value is about 20kA and the guench detection system has detected a quench in coil at some wanted conditions.

MOA11PO14

AC Test of the KSTAR Central Solenoid Model Coil

Y. Chu, S. Lee, S.J. Lee, K.W. Cho, S. Baek, S.H. Park, J. Kim, H. Yonekawa, W. Chung, Y.K. Oh, National Fusion R&D Center, Korea Basic Science Institute.

Korea Superconducting Tokamak Advanced Research (KSTAR) Central Solenoid Model Coils (CSMC) were installed and tested in the form of split coils. The CSMCs were successfully charged up to 20 kA and down to zero at the various ramp rates. The AC losses were measured by a calorimetric method with the various types of AC currents up to 20 kA such as triangular wave, DC offset sinusoidal wave and so on. The hysteresis losses were measured by magnetization method and were below 250 mJ/cc during +3T to -3T operation. The coupling loss was then obtained by subtracting hysteresis loss from the total AC loss. The total AC losses were measured as a function of frequency from 0 to 0.7 Hz and various magnetic field amplitudes up to ~ 9T. Conclusively, the AC coupling time constant was estimated to be less than 40 msec at all current shot scenarios. This paper describes the experimental setup including the test facility, the sensors and control system and power supply, and presents the test results for various AC operations.

MOA11PO15

Thermo-hydraulic Friction Factor Measurement of KSTAR PF CICC

S.H. Park, Y.K. Oh, W. Chung, Y. Chu, S. Lee, S.J. Lee, H. Yonekawa, K.W. Cho, S. Baek, J.S. Kim, National Fusion R&D Center, Korea Basic Science Institute.

The objective of this work is to predict the hydraulic behavior of cable-in-conduit-conductor (CICC) for the Korea Superconducting Tokamak Advanced Research superconducting KSTAR (KSTAR) magnet. superconducting magnets consist of 16 TF coils and 14 PF coils. Each coil is made by a square CICC through continuous winding method. The length of CICC per coil is 610m for TF coil and maximum about 2500m for PF coil, respectively. Especially the maximum length of cooling channel is about 300m in PF coil. All the coils are cooled by supercritical helium at 4.5K and 6 bar of inlet pressure. The thermo-hydraulic friction factor is important because it is also closely related with helium supply system in KSTAR. It is needed to confirm the friction factor for the operational analysis and the estimation of PF coil operating stability through the experiments. The test facility consists of valves, sensors and straight 5m length CICC. After the measurement of pressure drop in CICC at room temperature, the friction factor could be evaluated using governing equations. The friction factor of KSTAR PF CICC can compare with the Katheder general correlation formula and ITER TFMC's tendency. Furthermore, the friction factor is useful to analyze the thermo-hydraulic parameters by simulation codes like the GANDALF or own developed one and helpful to operate KSTAR PF coil in the near future.

POSTER SESSION	13:30 - 15:30
ITER	

MOA12PO01

Control and Instrumentation for ITER Magnet System

K. Yoshida, Y. Takahashi, N. Mitchell, ITER Naka JWS. The ITER superconducting coil system consists of 18 Toroidal Field coils, six Poloidal Field coils, six Central Solenoid modules, 18 Correction Coils and their feeders. An extensive measurement and control system is required to monitor and to control these coils and feeders for safety and optimal operational availability. For each coil, both current and supercritical helium are supplied from external systems and are controlled from a central control system as part of the regular operation with plasma pulses. These allow adjustment of currents and, though a virtual model of coil thermo-hydraulic system continuously the benchmarked to the external instrumentation, allow smoothing of the cryoplant loads and optimization of the plasma pulse rate. Quench detection is provided as a separate, stand alone system. Finally, regular monitoring of the electric insulation system inside the coils is performed to detect incipient problems before serious damage can develop. ITER IT will procure directly all sensors, wires, electrical insulation breaks and cryogenic components for all the coils and feeders to a common specification. This will avoid duplication of qualification work and guarantee a common interface to the control circuits. This paper introduces the requirements and specifications of the control and instrumentation for the ITER magnet system.

MOA12PO02

Results of contact resistance distribution in ITER conductor termination

A. Anghel, P. Bruzzone, M. Vogel, CRPP Fusion Technology.

JORDI (JOint Resistance DIstribution), a dedicated test facility for the measurement of contact resistance distribution in full-size, ITER type conductor terminations, has been successfully commissioned at CRPP. In contrast to earlier attempts, where the contact resistance in terminations was measured in current unbalanced condition, in JORDI the contact resistance is measured under imposed balanced current distribution among all current-carrying elements of the termination. The current from a 10 kA power supply is split by precision, low temperature shunt resistors into 98 parallel channels, each connected to the first cable stage of a full size ITER conductor. The voltage drop, in the range of few nano-volt, is simultaneously sensed between each current carrying element (first cable stage) and the equipotential surface of the joint between the conductor termination and the facility current leads. We report first results of the contact resistance distribution in two prototypes of typical ITER terminations, made respectively of NbTi and Nb3Sn based cable-in-conduit conductors. The results of the measurements are analysed based on a simple statistical model.

MOA12PO03

Simulation of Quench Tests in the ITER Central Solenoid Model Coil

Y. Takahashi, K. Yoshida, M. Edaya, N. Mitchell, ITER International Team.

To investigate the conductor behavior during a quench, quench tests of Center Solenoid (CS) and Toroidal Field (TF) insert coils were carried out with various initial conditions (13 T, 30-46 kA) in the CS Model Coil Facility. Ramp rate limitation tests of the CS insert coil were also carried out. The conductors of both coils are cable-in-conduit conductors (CICC) with Nb3Sn strands. The superconducting cable of the conductor consists of about 1,000 Nb3Sn strands, each with an outer diameter of about 0.8 mm. The lengths of conductors of CS and TF insert coils are 140 m and 45 m, respectively. These coils were installed in the inner bore of the CS Model Coil and tested in the maximum background field of 13 T. The inductive heater, attached on the conductor at the center of the

length and the highest field region, initiated an artificial quench in the quench tests. A quench has also occurred during the pulse operation with the ramping rate of 0.4-2 T/s, in the ramp rate limitation tests of the CS insert. Simulations of electric, thermal and hydraulic behaviors of the conductor during quench and ramp rate limitation tests were carried out by using the "Gandalf" thermohydraulic simulation code. The experimental results were compared with the simulation and good agreement was obtained. These results are described and the implication for quench detection in ITER is discussed in this paper.

MOA12PO04

Demonstration of JK2LB jacket fabrication for ITER Central Solenoid

K. Hamada, H. Nakajima, K. Takano, F. Tsutsumi, K. Okuno, JAERI; N. Fujitsuna, Kobe Steel, LTD; A. Mizoguchi, Kobe Special Tube Co., LTD.

Japan Atomic Energy Research Institute has developed a jacket material called JK2LB for the Central Solenoid (CS) conductor in the International Thermonuclear Experimental Reactor (ITER). Mechanical properties of jacket material are required to be 0.2% yield strength of more than 1,000 MPa and fracture toughness (KIC(J))of more than 130 MPam0.5 at 4 K after Nb3Sn reaction heat treatment (650 °C x 240 hours). Dimensional requirements of jacket are as follows; accuracy of the outer dimension and inner hole diameter are within ±0.2mm, eccentricity of hole is less than 10% and minimum single length is 5m. As a jacket material, JK2LB (0.03C - 22Mn - 13Cr - 9Ni - 1Mo - 0.2N-B) has been developed. JK2LB billets having a diameter of 163 mm and total weight of 1.6 tons, were successfully produced by using conventional electric furnace followed by electroslag remelting (ESR) process. Good workability of JK2LB during hot work has been also demonstrated. Trial fabrication with the processes of hot extrusion followed by cold drawing of JK2LB billets was also performed to confirm achievable tolerances of dimension and unit length of the jacket. Target tolerance of within ± 0.2 mm for outer dimension and inner hole diameter, eccentricity of less than 5% and unit length of more than 7 m are achieved. As a result, the fabrication of JK2LB CS jacket has been demonstrated and mass production of the CS jackets became ready toward the ITER CS conductor procurement.

MOA12PO05

Pre-compression Requirements for the ITER Central Solenoid

Y. Fu, N. Mitchell, ITER IT Naka; C. Jong, ITER IT Garching; P. Michael, MIT, Cambridge, US.

The ITER Central Solenoid (CS) consists of 6 independent but identical coil modules. The modules are clamped together by top and bottom flanges that are linked by vertical tie plates. The plasma flexibility requirements for ITER produce several combinations of radial (or hoop) forces and a wide range of vertical forces on each of the CS modules. For example, during pre-bias energization the top three and bottom three CS modules are strongly drawn together in the axial direction. At start of the plasma burn the outermost CS modules are axially repelled by the innermost CS modules and other coils in the Poloidal Field coil system. Although the net vertical force on the CS stack is generally small, the modules in the CS stack must be pre-compressed to ensure that coils remain in contact during all stages of plasma operation, to avoid tensile stresses in the coil insulation or ratcheting of the relative coil positions. The required axial pre-compression must be determined by careful analysis of the CS stack under all

operating conditions. The allowable, room-temperature stresses in the vertical tie-plates generally limit the range of plasma scenarios that can be achieved. This paper provides details of the optimization analysis for the ITER CS stack, details for various material limits within the coils and structure, and the outlines the eventual range of supported plasma scenarios.

MOA12PO06

Simulations of the ITER Toroidal Field Coil Operation with the VINCENTA code

D. Bessette, ITER; N. Shatil, E. Zapretilina, Efremov Institute.

Time-dependent thermal-hydraulic analyses of the ITER Toroidal Field Coils have been performed with a guasi-3D model based on the VINCENTA code. Two primary cooling loops are considered for the case and the winding pack respectively, each of them including a circulation pump and a heat exchanger. The conductor pancakes are cooled in parallel in the winding pack loop, as are the cooling channels in the case loop. Temperature, pressure and velocity of the helium coolant are computed in these channels by the VINCENTA code. This provides boundary conditions for the thermal coupling to 2D heat diffusion carried out in the coil sections. This configuration is considered appropriate to simulate the heat exchange between the various channels. A range of plasma scenarios including plasma disruptions has been simulated. The deposited heat due to AC losses in the conductor, eddy current losses in the structure, thermal radiation, thermal conduction, and nuclear heating, are given as input data. The model has been updated according to recent design changes. It also includes new features such as the calculation of the local electric field along the conductor when operating in the current sharing regime. The related power is then treated as a local heat deposition. The main analysis results are presented showing the impact of design and operating parameters. The analysis has been applied to confirm that the range of strand losses and cable coupling losses are acceptable for the conductor.

MOA12PO07

From short sample to coil DC superconductor performance: ITER Central Solenoid Model Coil (CSMC) vs. Good Joint (GJ) sample

L. Savoldi, R. Zanino, Dipartimento di Energetica, Politecnico di Torino; N. Mitchell, ITER IT Naka.

One of the crucial problems in the design of large high field superconducting magnets using Nb3Sn superconductors is how to extrapolate from the performance of an isolated strand measured in the lab to the performance of the superconducting coil using multistrand twisted cables. The uncertainty can be covered by generous margins but of course this implies a cost penalty. Within the frame of the ITER activities, it is proposed to bridge the extrapolation gap through the test of short (few meters long) but full-size well-instrumented conductor samples in dedicated facilities, e.g., Sultan at Villigen PSI, Switzerland. However, the problem of how representative is the conductor sample for simulating conductor-in-coil conditions is still under discussion. It is addressed here by considering the particular case of the Central Solenoid Model Coil (CSMC), tested in 2001-2003 at JAERI Naka, Japan, and its associated Good Joint (GJ) sample (tested in 1999 at Sultan). While the basic thermal hydraulic conditions are interpreted from experimental data by the Mithrandir/M&M code, the sensitivity of the voltage - temperature characteristics to mechanical effects (due to the strain

sensitivity of the Nb3Sn) and non-uniform current distributions (due to the close proximity of the joint to the high field region in Sultan samples) is investigated by analysis. The results are used to assess the errors to be expected in predicting coil performance from measurements made on conductor samples.

MOA12PO08

The results of the Toroidal Field Conductor Insert (TFCI) non-destructive and destructive examinations

I. Rodin, S. Egorov, V. Korsunsky, T. Gurieva, A. Bursikov, E. Zapretilina, D.V. Efremov Institute (NIIEFA).

A single layer solenoid TFCI was tested in October 2001 at JAERI test facility (Naka, Japan) as a part of the ITER CSMC & Insert Test Program. During the test campaign the TFCI reached design operating current of 46 kA at background magnetic field of 13 T without any problems. However some results required non-destructive and destructive examinations of the TFCI to check the correspondence with the design specifications. These examinations were performed in 2004 by the manufacturing company - the Efremov Institute (NIIEFA), St. Petersburg, RF. This paper presents the overview of techniques and major results of examinations along with their analysis and interpretation.

MOA12PO09

Manufacturing Study and Trial Fabrication of Radial Plate for ITER Toroidal Field Coil

K. Abe, H. Nakajima, K. Hamada, K. Okuno, JAERI; H. Kakui, H. Yamaoka, Ishikawajima-Harima Heavy Industries Co., Ltd.

In the International Thermonuclear Experimental Reactor (ITER), a Toroidal Field (TF) coil is operated at 68kA and 11.8T. To support an electromagnetic force on conductor, the TF coil conductor is embedded in a groove, which is machined on stainless steel plate, called as Radial Plate (RP). The dimension of RP is 13.8m x 8.7m, with a plate width of 610mm and a plate thickness of 111.8mm. The RP is made of SUS316LN. Japan Atomic Energy Research Institute has studied to establish manufacturing processes of RP. In this study, estimations were made on the dimension and weight of available hot rolled plate, segmentation, machining method, tools and welding method. To estimate manufacturing time of RP, SUS316LN were machined by several cutting tools attached on a machining center and life time of tools were measured as a function of cutting feed and speed. For welding technology, TIG welding was employed to achieve high weld deposition rate and YAG laser welding was used to minimize shrinkage of welded joint. It was confirmed that characteristic of machining of SUS316LN was almost same as that of conventional SUS316L. Using the tools and conditions developed for the machining and welding, the trial fabrication of a small scale RP with the same groove dimension as that of the real one has been performed. Flatness of ±1 mm was achieved in the trial. The achieved flatness satisfied ITER requirement. Thus, essential technologies have been established for the manufacture of the ITER RP.

PARALLEL SESSION	15:50 - 18:00
(Scirocco/Libeccio room)	
PULSE MAGNETS (I)	

MOA1OR1 Performance of 75 T prototype pulsed magnet C.A. Swenson, W. Marshall, A. Gavrilin, NHMFL; D. Rickel, J. Schillig, NHMFL-LANL.

A new 75 T pulsed magnet design is now undergoing operational evaluation at the NHMFL Pulsed Field Science Facility. The magnet design incorporates improvements to the engineering template developed for the 65 T pulsed user magnets in operation at the NHMFL. The development of the 75T magnet is part of the NSF effort to develop insert magnets for the DOE 100T multi-shot (MS) magnet program. An important objective of the 75T project is to gain experience operating insert-like coils in the same temperature, stress, and strain range encountered at 100 T. The 75T magnet assembly is comprised of two solenoid coils nested together. The inner "A" coil is constructed with materials & techniques identical to those planned for the 100T inserts. We have successfully trained the 75T prototype to full field over 21 pulses of increasing intensity. The capacitor bank energy for a 75T pulse is 1.44 MJ. This paper presents a review of the magnet design, operational performance data, and the developments impact on the design of future pulsed field user magnets and inserts for the DOE 100T Multi Shot magnet program.

MOA1OR2

Stability aspects of the high strength high conductivity microcomposite Cu-Nb wires properties

V.I. Pantsyrny, A. Shikov, A. Vorobieva, N. Khlebova, N. Kozlenkova, I. Potapenko, M. Polikarpova, V. Drobishev, Bochvar Institute of Inorganic Materials.

Extremely high strength in microcomposite Cu-Nb wires is associated with ultra-fine-scale microstructure. The extended interfaces between ribbon-like niobium filaments and copper matrix contain the areas of semi-coherent interfaces that are apparently the main reason of significant level of residual stresses observed in microcomposite Cu-Nb wires. The analysis of non-equilibrity of such microstructure has been done. The issue of stability of nanostructured two-phase Cu-Nb materials in the form of winding wires for pulsed magnets has been considered in the present work. The results of measurements of mechanical properties and electrical conductivity carried out on the same samples after periods of time up to 7 years are presented. Different types of Cu-Nb microcomposites with cross sections from 0.07 mm2 to 21 mm2 were investigated. It was shown that microcomposite Cu-Nb wires maintained essentially unchanged combination of mechanical and electrical properties after many years aging at room temperature. The analysis has been done on the correlation of the mechanical and conducting properties with microstructure.

MOA1OR3

Coil design for non-destructive pulsed-field magnets targeting 100 T

S. Zherlitsyn, A. Bianchi, T. Herrmannsdoerfer, J. Wosnitza, S. Zvyagin, Hochfeld-Magnetlabor Dresden, Forschungszentrum Rossendorf.

A new pulsed magnetic field facility is under construction at the Forschungszentrum Rossendorf in Dresden that is planned to be opened for external users in 2007. This facility is placed near a free electron laser which offers unique opportunity to perform infrared spectroscopy in pulsed fields. In addition, further experimental techniques such as resistivity, magnetization, specific heat, ultrasound, and electron spin resonance will be available in pulsed magnetic fields in the range of 60 – 100 T. The typical pulse duration will be between 10 and 1000 ms with the magnet bores from 20 to \sim 50 mm. The pulsed magnets will be energized by a 50 MJ/24 kV modular capacitive pulsed-power supply. The current status of the magnet design and the magnet construction at the Dresden High Magnetic Field Laboratory will be reported. In our newly designed coils, so far we were able to reach pulsed magnetic fields above 65 T in a non-destructive manner built using regular copper wire reinforced by special organic fiber (PBO). The pulse duration was in the range between 20 and 50 ms. Different magnet failure modes have been analyzed and possibilities for an improvement of the magnet construction will be discussed. Numerical simulations for the design of pulsed magnets include analytical approximations and a finite element analysis using commercial software ANSYS and FEMLAB. Some numerical simulations of our pulsed magnets that ultimately are planned to reach 100 T will be presented.

MOA10R4

The Pulsed field facility at HFML, commissioning and first results

K. Rosseel, P.A.J. Dolron, U. Zeitler, J.A.A.J. Perenboom, S.A.J. Wiegers, J.C. Maan, High Field Magnet Laboratory, IMM, Radboud University Nijmegen.

To provide a large range of field strengths to outside users, the 20 MW DC installation of the Nijmegen High Field Magnet Laboratory (HFML) is complemented by a modular 2 MJ, 16 kV capacitor bank. In this contribution we report on the steps taken to commission the pulsed field setup and on the first results obtained with magnetotransport experiments on GaAs/AlGaAs structures. We will review the safety principles of the pulsed field installation, and highlight the current return path philosophy. Extensive short-circuit trials were performed to verify the safety of the surrounding DC - 220V AC environment. Using a Zylon reinforced soft copper wire wound coil a field of 54 T was obtained in 23 mm bore: the field has a rise time of 38 ms and a FWHH of 75 ms. It was found that oscillations of two times the charging voltage can occur due to the LRC circuit formed by the coaxial cable and the protection inductances of the capacitor bank; it will be shown that an efficient RC snubber can be dimensioned that will virtually eliminate these oscillations. Hall measurements on a GaAs/AlGaAs sample were successfully carried out; high performance preamplifiers were applied close to the sample to mininize pick-up and RC filter effects of the wiring. At this stage, experiments have been performed down to 4.2K in a 3DES system. Extension of the measuring capabilities to 3He temperatures and on 2DES bilayer structures are in progress.

MOA10R5

Powering Coil-in Coil-ex systems combining DC and Pulsed power supplies

J.A.A.J. Perenboom, K. Rosseel, P.A.J. Dolron, S.A.J. Wiegers, J.C. Maan, High Field Magnet Laboratory, IMM, Radboud University Nijmegen; P.H. Frings, Laboratoire National des Champs Magnétiques Pulsés.

The highest non-destructive fields are provided by pulsed field magnets. Monolithic coils are limited to 70-75 Tesla by mechanical and thermal constraints. These limitations can be circumvented through the use of multi-coil assemblies as shown e.g. by the EU funded project 'ARMS'. At the HFML, pulsed field magnets can be energized using either a 2 MJ, 16 kV capacitor bank or a state-of-the-art 20 MW DC power supply in pulsed mode; each of these sources is capable of delivering up to 20 kA under normal conditions. This would allow coilin-coilex operation at fields above 80 T. Extensive short-circuit tests, flash-over tests and pulsed mode operation have shown the viability of the concept. Currents of up to 60 kA are adequately shorted by the

crowbar circuitry designed to protect the DC installation from a coilin to coilex short-circuit. A coilex field of 25 T with a FWHH of 450 ms has been reached in a bore of 100 mm, with the 'ARMS' coil. To allow coilin-coilex operations, firing of the DC pulse mode from the pulsed field software will be implemented and a suitable coilin-coilex pair will be designed and commissioned in collaboration with the LNCMP, Toulouse.

MOA10R6

Development of a large bore long pulse magnet at GE Global Research Center

L. Li, X. Huang, P. Thompson, T. Laskaris, K. Amm, R. Ranze, A. Wu, GE Global Research Center.

A pulsed magnet wound with copper strips generating 3.5 Tesla in a 1.35 meter bore with inductive energy of 14 MJ at the peak field has been developed, successfully tested and used in the Global Research Center of the General Electric company. The rise time of the 3.5 T pulse is 9.4 seconds and the total pulse duration is about 45 seconds. The magnet is composed of 4 pancake coils in series, precooled with Liquid Nitrogen and powered by a 750 V, 8000 A DC power supply. This paper describes the design and construction of the magnet, its power supply and control circuit and the test results of the entire system.

PARALLEL SESSION	15:50 - 18:10
(Maestrale room)	
LOW Tc SUPERCONDUCTORS	

MOA2OR1

Latest Improvement of Current Carrying Capability of Nb3Sn

S. Hong, M. Field, J. Parrell, Y. Zhang, Superconducting Tech, Oxford Instruments.

Practical very high field superconducting magnets are exclusively built with Nb3Sn multifilamentary composites. Over the last few years there have been significant improvements in the current carrying capability of Nb3Sn strand. These improvements offer possibility to build more efficient and/or higher field strength magnets, and generally advance the high field superconducting magnet technology. The Nb3Sn composite requirements are somewhat different depending on the application, such as magnetically confined fusion, high energy physics accelerators, and solenoids for NMR or laboratory magnets. Hence the strands are designed differently for specific applications. We will present the current status of our Nb3Sn strand development efforts for these applications, along with magnet results.

MOA2OR2

Development and procurement of 7000 km of highcurrent Nb-Ti superconducting cables for the LHC *D. Leroy, CERN.*

The construction of the superconducting magnets for the LHC machine has required the supply of 7000 km of superconducting cables. The cables consist of 28 - 36 Nb-Ti strands. The delivery of cables that arrived at completion has made use of a large part of the worldwide production capacity. Contracts have been placed with firms in Europe, Japan and USA. The supply of Nb-Ti and the Nb materials has been ordered by CERN. Ten contracts have been placed according to a very demanding specification for an activity which spread over 10 years. Before tendering and placing the contracts, a long R&D programme has combined studies at CERN and orders of finished cables of

significant length to industry. This approach has allowed CERN to finalise the specification fulfilling the LHC machine requirements and has given to the firms a way of developing the industrial technology in order to optimize the yield and, consequently, to offer the best price in competitive tenders. The paper will include discussions: - of the characteristics and innovations of the LHC cables, - of the tools such as data bases and laboratory equipment created for a close follow-up of the production, - and of the encountered difficulties and the obtained contracts of the highly sophisticated industrial products such as the LHC superconducting cables.

MOA2OR3

Measurement of critical current and instability threshold of Rutherford-type Nb3Sn cables

G. Ambrosio, N. Andreev, E. Barzi, A. Zlobin, Fermilab; A. Verweij, C-H. Denarie, CERN.

In the frame of a FNAL-CERN collaboration, Nb3Sn Rutherford-type cables made of different wires (MJR, PIT or RRP) have been assembled in the sample holder at FNAL and tested at FRESCA (CERN). All cable samples had a trapezoidal cross-section with 0.9-1 degree keystone angle. The cables made of Modified Jelly Roll (MJR) or Powder In Tube (PIT) wire had 28 strands with 1-mm diameter. The cables made of Restacked Rod Process (RRP) wire had 39 strands with 0.7-mm diameter. All samples were tested at 4.3 and 1.8 K. Some samples were tested at constant current in sweeping field in order to characterize their stability. All samples showed signs of instability at low fields and several voltage spikes were detected and recorded. Critical current and instability threshold measurements are presented and compared with previous tests and with strand and magnet performances.

MOA2OR4

Measurement of Jc vs. Strain and Field on Nb3Sn Industrial Wires and Nb3AI experimental wires up 21 T

D. Uglietti, B. Seeber, V. Abaecherli, R. Flukiger, University of Geneva, Group of Applied Superconductivity; N. Banno, Supercond. Mater. Center, NIMS.

The critical current has been measured as a function of uniaxial tensile strain at fields up to 21T on two Nb3Sn wires prepared by the Bronze and the Internal Sn Technique, respectively, as well as on Nb3Al wires. Our device is based on the concept of the Walters spring (WASP), which allows to measure long wires (up to 80 cm) and to obtain an absolute measurement of the strain value. The long length of the conductors allows to measure the V-I relation under strain over three decades of electric field (down to 0.01 microV/cm). We show that the sharper criterion gives a new insight on the reversible behaviour of the Ic vs. strain curve as well as of the variation of the exponential factor n under uniaxial tensile strain. The Ic(B,epsilon) curves of the Nb3Sn wires have been fitted using the models of ten Haken and of Ekin. The values of the fitting parameters are discussed taking into account the wires design: it was found that even if the value of the upper critical field, Bc2, is comparable in both wires, the slope of Jc versus strain is markedly different. Calculations have been performed to explain the experimental results. The above models have also been adapted to describe the Ic(B,epsilon) behaviour in Nb3Al wires.

MOA2OR5

Magnetization measurements of Nb3Sn wires for the Next European Dipole (NED)

M. Greco, P. Fabbricatore, INFN-Sezione di Genova; C. Ferdeghini, INFM, Università di Genova; U. Gambardella,

INFN-LNF.

The Next European Dipole (NED) activity is developing a high-performance Nb3Sn wire (aiming at a non-copper critical current density of 1500 A/mm2 at 4.2 K and 15 T), within the framework of the Collaborated Accelerator Research in Europe (CARE) project. In the frame of the conductor development, magnetization measurements are carried out in parallel and transverse field, from low to fields as high as 10 T to qualify the conductor. Three Italian facilities are involved: INFN-Frascati (dc magnetization using a vibration sample magnetometer), INFM-Genova dc magnetization) and INFN-Genova (sauid (ac magnetization). In particular, measurements at low fields were performed to study magnetic instabilities (flux jumps) in strands with high critical current density. Experimental results, showing a correlation between instabilities at low fields and the residual non-reacted niobium, are presented.

MOA2OR6

Trial manufacture of a km class length of Cu cladding RHQT Nb3Al flat-wire

K. Tagawa, T. Takeuchi, H. Kitaguchi, Y. Iijima, N. Banno, A. Kikuchi, NIMS; Y. Sakurai, G. Iwaki, Hitachi Cable, Ltd. We have produced so far about a 400 m length of Cu RHQT (rapid-heating, stabilized quenching and transformation) Nb3AI flat-wire using a small-sized multibillet (10 kg). Although our goal is to make a 2.5 km unit length of Cu cladding flat-wire for high-field NMR uses, an attempt was made to fabricate a 1 km class unit-length of conductor as a milestone of commercialization. A longlength of precursor wire over 2.5 km was prepared by using a large-sized multi-billet (50 kg). Results of two times of RHQ operations and subsequent Cu-claddings over 1 km would be presented.

PARALLEL SESSION	15:50 - 17:40
(Ponente/Levante room)	
MAGNET DESIGN	

MOA3OR1

Towards integrated design and modeling of high field accelerator magnets

S. Caspi, P. Ferracin, LBNL.

The next generation of superconducting accelerator magnets will most likely use a brittle conductor (such as Nb3Sn), generate fields around 18T, handle forces that are 3-4 times higher than in the present LHC dipoles with stored energy that starts to make accelerator magnets look like fusion magnets. To meet the challenge and reduce the complexity, magnet designs will have to be more innovative and better integrated. The recent design of several high field superconducting magnets have now benefited from the integration between CAD (e.g. ProE), magnetic analysis (e.g. TOSCA) and structural analysis (e.g. ANSYS). Not only is it now possible to address complex issues such as stress along the magnet ends but the analysis can be better detailed and extended into new areas previously too difficult to address. Integrated thermal, electrical and structural analysis can be followed from assembly and cool-down through excitation and quench propagation. In this paper we report on the integrated design approach, discuss analysis results and point out areas of future interest.

MOA3OR2

The Inductive Coupling of the Magnets in MICE and its Effect on Quench Protection

M.A. Green, LBNL; H. Witte, Oxford University Physics Department.

The quench protection methods that result in safe quenching of the MICE focusing and coupling magnets are discussed The inductive coupling of various MICE magnets with the other magnets in the MICE is described. The consequences of this coupling on magnet charging and quenching are discussed. Calculations of the quenching of a magnet due quench back from circulating currents induced in the magnet mandrel due to quenching of an adjacent magnet are discussed. The conclusion of this report describes how the MICE magnet channel will react when one or magnets in that channel are quenched.

MOA3OR3

Comparison of 2-D Magnetic and Mechanical Designs of Selected Coil Configurations for the Next European Dipole

F. Toral, S. Sanz, CIEMAT; A. Devred, CEA-Saclay&CERN; P. Védrine, H. Felice, CEA-Saclay; J. Rochford, P. Loveridge, RAL; P. Fessia, CERN. Withdrawn.

MOA3OR4

Effect of Magnetic Instabilities in Superconductor on Nb3Sn Accelerator Magnet Performance

V.V. Kashikhin, A. Zlobin, Fermilab.

The performance of some superconducting model magnets built and tested at Fermilab and elsewhere based on the high-Jc state-of-the-art Nb3Sn strands suffered from electromagnetic instabilities in the coil. These instabilities led to a poor magnet quench performance and a significant degradation of the magnet quench current. Detailed theoretical and experimental studies of possible causes of the limited magnet quench performance allowed correlating it with the properties of superconducting strands and cables used in the magnets and the magnet design parameters. This paper reviews the recent progress in Nb3Sn strand and cable instability studies and analyzes the effect of magnetic instabilities in superconducting strands and cables on the quench performance and field quality of accelerator magnets of different designs. The results are compared with the magnet test data obtained at Fermilab and elsewhere.

MOA3OR5

Conceptual Design of the 12.5 T Superconducting EFDA Dipole

A. Portone, E. Salpietro, EFDA-CSU Garching; L. Bottura, CERN; P. Bruzzone, EPFL-CRPP; W. Fietz, R. Heller, FZK; J-M. Rifflet,; CEA-Saclay; J. Lucas, F. Toral, CIEMAT; S. Raff, ITP FZK; P. Testoni, Electrical and Electronics Eng. Dept., University of Cagliari.

Within the framework of the European Fusion Programme

a design activity has been started in late 2004 by the EFDA Close Support Unit at Garching (FRG) to design a 12.5 T superconducting dipole magnet. The final goal of this activity is to define a "minimum cost" and "minimum risk" dipole to be built within the next 3 years by European industries. The newly built magnet shall be hosted in one of the existing cryogenic laboratories in the EU to test, in particular, the full size conductor samples that shall be produced during the ITER magnets procurement. As a result of this study - carried out in cooperation with several European laboratories - different concepts have been analysed and optimised. All designs are based on the use of high current density Nb3Sn strands (~ 2000 A/mm2 at 12 T/4.2 K). It is assumed that these strands can be cabled either as Cable In Conduit Conductors (CICC) or as Rutherford-type Cables (RC) and then wound as planar racetrack, non-planar (saddle) or cosg coils. The aim of this paper is to provide an overview of this study activity with particular emphasis to the optimisation steps followed in the design of each magnet concept. Four different types are described: a planar CICC/RC-based coil, a saddle CICC-based coil and a cosq RC-based coil. Each design is described together with the salient optimization steps that include electromagnetic, structure mechanic and thermohydraulic analyses as well as different manufacturing constraints.

MOA3OR6

Permanent Cyclotron Magnet

E. Antokhin, M. Kumada, JST/NIRS; S. Wasaka, AEC; T. Fujisawa, NIRS; Y. Iwashita, ICR Kyoto University; S. Matsumoo, AEC/Dokkyo University; Y. Matsuda, Osaka Pref. University; I. Bolshakova, R. Holyaka, V. Erashok, MSL.

Magnet for circular accelerator can be made as copper normal conducting electromagnet or superconducting magnet. The application of permanent magnet to the accelerator in the past, however, was only a storage ring of anti-proton at Fermilab. Here in this article we will report on a design, construction and field quality of a permanent magnet for a cyclotron application which can be used as a isotope production such as FDG in Positron Emission Tomography, s well as an injector of a cascaded accelerator complex. The design energy of the cyclotron is 10 MeV. Due to an ingenious configuration of magnetic circuit structure, a field strength can be varied from a 2.3 T maximum field to zero. The built in switching off capability of the magnetic field can make a field distribution adjustment to get isochronous field easier. In order to make a field mapping of the cyclotron magnet further efficient, a very accurate field mapper of 48 sensors were specially developed where a complete mapping of the magnet can be done in 3 hours. Interleaving of particle tracking and field shimming was done extensively. Temperature dependence was studied carefully. All of these details will be presented in the article.

Tuesday, September 20, 2005

PLENARY SESSION (Maestrale room)

8:30 - 10:00

TUMPL1

The really giant accelerator magnets: magnetic guns and rackets in deep space

Alvaro de Rujula, CERN.

Cosmic Rays were discovered almost 100 years ago. They have been observed up to energies above 100 million TeV, an awesome energy by our modest standards. The mechanism accelerating Cosmic Rays is still debated, it must be truly powerful, and is arguably very efficient. Relativistic beams of ordinary-matter neutral plasma are observed to be made by magnetized accreting black holes. The corresponding acceleration mechanism is not understood at all. I shall argue that these beams are magnetized plasmas that accelerate the interstellar matter they encounter by a very simple, purely "magnetic" mechanism, which explains all properties of Cosmic Rays. These neutral beams also "accelerate" the photons they encounter by Compton scattering, a simple mechanism that explains all properties of "gamma-ray bursts". Surely Nature has a lot to teach us about the production of magnets that are excellent accelerators.

TUMPL2

Superconducting materials magnet for large applications

R. Flukiger, Dépt. Phys. Mat. Condensée (DPMC), University of Geneva.

The current state of superconductors, including both, High Tc and Low Tc materials, is discussed in view of large magnet applications, i.e. magnets where the outer dimensions exceed 1 meter. The largest magnets are certainly the ATLAS magnet at CERN and the dipoles for accelerators, e.g. LHC. Various large size magnets are projected for future high field accelerator dipoles as well as for fusion magnets, i.e Tokamak, poloidal and central solenoid coils. Actually, the trend to NMR magnets producing 21 T and more leads to magnets of a considerable size, too. The field in industrial MRI magnets (actually 2 to 3 T) tends to increase, thus leading to larger sizes. With the availability of HTS superconductors, a new kind of large magnets is being developed: generators and motors (a ship motor of 36 MW is already under construction). Each application requires a particular superconducting material, but also a particular configuration, taking into account mechanical and thermal stability. In the present talk, a review is given of the properties and the actual state of the known superconducting materials, i.e. NbTi, Nb3Sn, Nb3Al, MgB2, Bi-2212, Bi,Pb-2223 and YBCO Coated Conductors. The overall critical current densities are reviewed as well as their behaviour as a function of applied tensile strain and transverse compressive stresses, which get more and more important with increasing fields, i.e. under higher Lorentz forces. Recent cost considerations are included. In view of future applications, there is still room for improvement in Nb3Sn wires, regardless of the technique (Bronze route, Internal Sn Diffusion, Powder in Tube). In MgB2 wires, the enhancement of both, irreversibility field and thermal stability still constitutes a challenge. With the future availability of longer length of Coated Conductor tapes, a replacement of Bi based tapes can be envisaged in a few years. The present state and future perspectives of Coated Conductors are presented.

PARALLEL SESSION (Scirocco/Libeccio room) FAULT CURRENT LIMITERS

TUM10R1

1st Phase Results and Future Plan of DAPAS Program Y-S. Jo, K-S. Ryu, M. Park, CAST.

At the end of July 2004 DAPAS (Development of the Advanced Power system by Applied Superconductivity technologies), which is the 10 year program, terminated the 1st phase among 3 phases. As the results of the 1st phase, the meter length of coated conductor and the core technologies of the distribution line voltage class HTS power devices; cable, transformer, SFCL, and motor, were developed. In this paper, the results of 1st phase and the target of 2nd phase will be described. In case of HTS cable project, a three-phase 50MVA/22.9kV class HTS cable of 30m length was developed and tested as the core technology development for the commercialization of HTS cable. And, the optimal design and manufacturing technologies of HTS transformer were developed. There were two kinds of SFCL developed during 1st phase DAPAS program; the reactive type and the resistor type. And, a 100hp class HTS motor was developed so that the essential parts of technologies for the utilization of superconducting motor could be obtained. Among the coated conductor projects, the batch process using Coevap. And R2R process using PLD gave us meter-length CC tapes. As the 2nd phase plan, the installation of HTS cable to the real utility network is in progress and also the alpha-prototype SFCL will be develop and install in the HTS power devices field test facility. In case of motor 1MVA class will be develop in the 2nd phase. And, the target of CC project is 100m length or more to supply power applications.

TUM10R2

Design and Test Results of 66 kV High-Tc Superconducting Fault Current Limiter Magnet

T. Yazawa, Y. Ohtani, M. Sakai, H. Koyama, M. Ohtsuki, M. Ono, M. Urata, T. Kuriyama, K. Nakamoto, N. Tachikawa, Toshiba Corporation; Y. Tokunaga, Tokyo Electric Power Company; K. Inoue, Super-GM.

One of the items in the Super-ACE project is development of a 66 kV high-Tc superconducting fault current limiter (FCL) magnet. This paper describes the design of the magnet and the test results obtained. The magnet mainly consists of a vacuum vessel, a nitrogen bath, a pair of current leads, cryocoolers, and six sets of coils wound with Bi2223 tape. The rated current is 750 Ap. The insulation voltage of the magnet is of the 66 kV class. In the final year of the project, all six sets of the coils are set connected in the cryostat and evaluation tests have been implemented. In the cooling test, sub-cooled nitrogen of 65 K was obtained, with homogenous temperature distribution in the cryogen. The rated current of 750 Ap was successfully obtained for both direct and alternating current tests. In addition, the magnet passed the simultaneous current and voltage application test. The dielectric test results showed that the magnet satisfied the insulation for 66 kV apparatus in the Japanese Electrotechnical Committee Standard standard. Finally, the magnet was combined with a rectifier bridge circuit to form an FCL. In a fault current limiting test with a short-circuit generator, the FCL successfully limited short circuit current up to 20kV applied voltage.

10:30 - 12:00

TUM10R3

Development and Demonstration Test of 10.5KV/1.5KA HTS Fault Current Limiter

D. Hui, L. Xiao, Z. Wang, J. Zhang, Z. Zhu, Institute of Electrical Engineering, CAS.

A 10.5KV/1.5KA 3-phase HTS fault current limiter was developed by IEE, CAS. This improved bridge-type SFCL with 7.5mH HTS magnet is being test for demonstrated long term reliable operation in a real 10.5KV substation located in Hunan, China. It can limit first half cycle short circuit current below 1200A, and can limit steady-state fault current below 1000A for 1 second. After fault ceases, it can reture to rated operation aotumatically.

TUM10R4

Design of LTS Coil used for the Combined Device SMES-SFCL

G. Zhu, M. Song, Z. Wang, Electrical Engineering Dept., Tsinghua University.

Moved to MOA10PO16.

TUM10R5

The Design and Tests of a three-phase 10.5 kV/1.5kA HTS fault Current Limiter

L. Xiao, Z. Wang, D. Hui, J. Zhang, C. Zhao, Z. Zhang, D. Zhang, H. Li, L. Lin, Institute of Electrical Engineering, CAS.

An improved bridge type superconducting fault current limiter (SFCL) is proposed. The current limiter consists of bridge rectifier, resistor and superconducting coil. At normal state, the resistor is shunt off by GTO, and at fault state, the GTO is switched off so that the resistor is connected in series with the superconducting coil, limiting the fault current. The improved bridge type SFCL can not only restrict the peak value but also the steady value of the fault current. A three phase 10.5 kV/1.5kA SFCL has been installed at a substation in Hunan. The coils are 6 mH in inductance and operated at 77 K. The test results show that the short-circuit current was reduced to 1.5 kA from 17 kA.

PARALLEL SESSION	10:30 - 11:40
(Ponente/Levante room)	
FIELD MAPPING	

TUM2OR1

Magnetic Measurement Techniques for the LHC

L. Bottura, M. Buzio, D. Cornuet, J. Garcia Perez, P. Sievers, L. Walckiers, CERN.

Precise and efficient measurement of the magnetic field is a mandatory step in the verification of the quality of the production of the normal- and superconducting magnets for the Large Hadron Collider (LHC), as well as a necessary preparation to the commissioning of the accelerator. Through the last years, and in anticipation of the series measurement phase, we have pursued a strong R&D program in magnetic measurement techniques. The program was staged through proof-of-principle experiments of various measurement concepts, the selection of the most practical and efficient methods, the engineering design and realisation of the instruments. We finally profited from interaction and feed-back during the measurement of the initial production, at a rate much lower than the present production, to adapt the measurement capability to the actual demands. In this paper we document the rationale behind the present measurement program and we give an overview of the magnetic

measurement techniques selected, mainly, but not exclusively, based on rotating coils. We summarise the instrument capabilities by giving a concise description complemented by exhaustive references, the estimated accuracy and precision, the typical turnover and availability, as well as cost figures for the instruments and their operation. The ultimate aim is to provide a term of comparison and a guideline of selection for future projects of scope comparable to the LHC.

TUM2OR2

Measurements of the Field Quality in Superconducting Dipoles at High Ramp Rates

A.K. Jain, J. Escallier, G. Ganetis, W. Louie, A. Marone, R. Thomas, P. Wanderer, BNL.

Several recent applications of superconducting magnets require the magnets to be operated at high ramp rates and at frequencies of several Hertz. Brookhaven National Laboratory (BNL) has recently designed and built prototypes of superconducting dipole magnets that can be ramped at a fairly high rate (1 T/s or more). In addition to the ability to ramp fast, it is also crucial that the magnets maintain good field quality, e.g., for accelerator applications. Well established techniques exist to measure the field quality of magnets under DC conditions. However, the field quality at high ramp rates may be substantially influenced by eddy currents induced in various magnet components. In order to characterize the field quality of these magnets at such high ramp rates, a new measurement system consisting of 16 printed circuit tangential windings has been developed. The coil system is held stationary while the magnet is ramped. The induced signals in all the windings are then analyzed to obtain the field harmonics. This paper will describe techniques used to overcome difficulties with some early measurements with this system, and present the results of measurements at different ramp rates in the prototype dipoles built at BNL.

TUM2OR3

A Fast Continuous Magnetic Field Measurement System Based on Digital Signal Processors

G.V. Velev, R. Carcagno, S. Kotelnikov, A. Makulski , R. Nehring, J. Nogiec, D. Orris, FNAL; D. Maroussov, CERN; O. Poukhov, F. Prakoshyn, JINR, Dubna.

In order to study dynamic effects in accelerator magnets, such as the decay of the magnetic field during the dwell at injection and the rapid so-called "snapback" during the first few seconds of the resumption of the energy ramp, a fast continuous harmonics measurement system was required. A new magnetic field measurement system, based on the use of digital signal processors (DSP) and Analog to Digital (A/D) converters, was developed and prototyped at Fermilab. This system uses Pentek 6102 16 bit A/D converters and the Pentek 4288 DSP board with the SHARC ADSP-2106 family digital signal processor. It was designed to acquire multiple channels of data with a wide dynamic range of input signals, which are typically generated by a rotating coil probe. Data acquisition is performed under a RTOS, whereas processing and visualization are performed under a host computer. Firmware code was developed for the DSP to perform fast continuous readout of the A/D FIFO memory and integration over specified intervals, synchronized to the probe's rotation in the magnetic field. C, C++ and Java code was written to control the data acquisition devices and to process a continuous stream of data. The paper summarizes the characteristics of the system and presents the results of initial tests and measurements.

PARALLEL SESS	SION :	10:30	- 12:00
CHALLENGING		OF	LARGE

COILS

TUM3OR1

Series production of challenging superconducting magnets. The experience of W7X non planar coils and LHC dipoles

F. Eyßelein, P. Lublow, W. Gärtner, E. Theisen, H. Schmidt, H. Scheller, P. Walter, E. Knoke, Babcock Noell Nuclear GmbH.

By the end of 1998, Babcock Noell Nuclear (BNN) as part of the Consortium Wendelstein was awarded with the fabrication of the non-planar modul field coils for the Wendelstein 7-X experiment to be built at Greifswald. In 1999 and 2002, BNN received orders for the production of LHC dipoles to be installed at CERN. Both projects are performed in parallel; therefore challenging tasks had to be solved not only from a technical but also from an industrial point of view. We present the solutions we found for the set-up of the production facilities, which include the development of tools suitable for series production and the recruitment of capable staff. An overview of the different production steps for both magnet types will be given as well as an outline about the quality measures that has been established. As in total 416 dipoles and 50 non-planar coils consisting of a lot of high-quality components are fabricated, logistics within the company and the consortial partners as well as to subsuppliers is an issue, too. Both types of magnets are on the forefront of what is technically feasible. Therefore feedback from test results and possible improvements of the fabrication processes are always an issue. Besides that, technical changes introduced for knowledge gained only at a later stage of the project had to be introduced in the fabrication process. We will summarise the present status of the fabrication and present some recent results of performance tests for both projects.

TUM3OR2

Application of learning curve analysis to the LHC Main Dipole Production

P. Fessia, S. Krog-Pedersen, L. Rossi, CERN.

Almost half of the LHC Main dipole has been delivered by the 3 companies in charge of the production. The training of the staff on the job and the natural improvement of the procedures with the acquired experience are the main factors that have driven the natural decrease of the time necessary for the assembly of a unit. The aim of this paper is to apply methodologies, as the cost based learning curves and the time based learning curves, to the LHC Main Dipole production. Finally the estimated learning percentage to the ones experienced in other industrial processes.

TUM3OR3

The G0 Spectrometer Superconducting Magnet System: From a challenging construction to reliable operations

P. Brindza, Thomas Jefferson National Accelerator Facility; D. Beck, K. Nakahara, D. Spayde, S. Williamson, University of Illinois Urbana-Champaign; T.A. Antaya, M.Trepanitis, T. Brandsberg, BWXT.

We report on the design, fabrication, commissioning and operation of a large superconducting magnet system that is an important element of the 8 sector super conducting toroidal G0 Spectrometer located at the Jefferson Lab in Newport News, VA. The purpose of the G0 experiment is the high precision measurement of polarized electron scattering by protons to isolate the strange quark content of normal baryonic matter by observing parity violation caused by the weak interaction. The G0 spectrometer has been operating for three years and first results are published. The G0 SC torus is 4 meters long and 4 meters outside diameter and produces 3 Tesla in the 8 gaps that are accessible to particles. To accomplish this required in part the development of an 8 sector superconducting magnet with a number of challenging large scale features including: large total open solid angle, high sector-sector field symmetry, the symmetry axis aligned perpendicular to gravity, the location of the liquid hydrogen (proton) target on axis in the magnet cryostat, and large surface area but thin titanium exit windows on one end of the cryostat. The cryostat consists of a super-alloy welded low permeability stainless steel shell (to minimize magnetization effects) and aluminum end caps. The 8 superconducting coils have unique characteristics including dry pancake wound copper stabilized NbTi conductors, encased in aluminum structure, mechanically preloaded and indirectly cooled by a set of parallel thermo siphon circuits. This magnet was built by BWXT under a fixed price performance contract that included fabrication to an ideal cold current distribution in space. The G0 Torus has been operating reliably for three years now at JLAB. The commissioning and operations will be discussed.

POSTER SESSION13:30 - 15:30MgB2 COILS & NEW DEVELOPMENTS

TUA01PO01

Compact design of cryogen-free HTS magnet for laboratory use.

L. Kopera, P. Kovác, T. Melišek, Institute of Electrical Engineering, Slovak Academy of Sciences.

compact high-temperature superconductor (HTS) magnet cooled by a single stage G-M cryorefrigerator was designed, manufactured and tested. The arrangement of the magnet was optimized to maximize cooling efficiency of the Bi2223/Ag winding and minimize heat generation by eddy current losses during high-speed excitation. To achieve wide angular access and good magnetic field homogeneity in the magnet centre a split-pair coil configuration was used. Maximum magnetic field in the magnet centre is 1.8 T @ 15 K, inner diameter of the magnet is 50 mm, outer diameter is 98 mm and total width of the magnet winding including 14.2 mm gap is 72 mm. Performance of the magnet was tested also at liquid Nitrogen, sub-cooled liquid Nitrogen and liquid Helium temperatures. Experimental results agree well with the magnet parameters obtained by FEM simulation.

TUA01PO02

Design and test results of a 4T BI -2223 coil.

R. Quarantiello, M. Ariante, V. Cavaliere, M. Cioffi, G. Masullo, A. Matrone, E.Petrillo, CRIS; M. Bocchi, L. Martini, V. Rossi, CESI.

In the framework of an Italian research project regarding the assessment of the performance of HTS conductor tape for high field magnet purpose, a 4T Bi2223/Ag coil with 50mm-bore has been designed and manufactured at CRIS. Magnetic field and quench analysis has been developed and results are shown. The double-pancake configuration was chosen in order to avoid damage of tape. The critical current of each double-pancake has been measured at 77K, in order to choose the best pancakes for assembling in higher magnetic field region. The magnet has been tested at 4.2K with a current of 163 A in a liquid helium bath, in a background field of 3 T for a total field of 7 T. In collaboration with CISE, magnet tests are in progress by using 65K sub-cooled liquid nitrogen and 27K liquid neon baths.

TUA01PO03

Test of a Variable-Field-Direction Superconducting Magnet

S. Matsumoto, T. Kiyoshi, NIMS Withdrawn.

TUA01PO04

A Solid-Nitrogen Cooled High-Temperature Superconducting Magnet for use in Magnetohydrodynamic Marine Propulsion

P.W. Hales, H. Jones, Oxford University; S. Milward, S. Harrison, Space Cryomagnetics Ltd.

A small high-temperature superconducting (HTS) magnet has been produced as part of a magnetohydrodynamic (MHD) propulsion unit to power a model boat. The magnet is wound from 6 pancake coils of Bi-Sr-Ca-Cu-O HTS tape (BSCCO-2223), and is conduction cooled using an onboard "thermal battery", containing 3 litres of solid nitrogen. The magnet is racetrack shaped, and aluminium electrodes are placed along the straights of the magnet to pass an electric current through the saltwater, perpendicular to the magnetic field. Power for the magnet and the electrodes is provided by onboard sealed lead acid batteries, resulting in a fully 'stand-alone' magnet system, capable of up to 1.25 hours of continuous operation on one battery pack. This system was integrated into a model boat hull (approx. 1.2m long x 0.6m wide), which was successfully launched on 29th March 2004 at the Culham Science Centre in Abingdon, England. A top speed of ~3cm/sec was reached during the first trial.

TUA01PO05

Properties of a YBCO pancake coil operating with AC current at frequencies up to 1000 Hz

M. Polak, E. Demencik, L. Jansak, Institute of Electrical Engineering - Bratislava; P. Barnes, Air Force Research Laboratory, Wright-Patterson AFB; G. Levin, National Research Council, Wright-Patterson AFB; C. Thieme, American Superconductors Corporation.

A small pancake coil wound using ~1.2m of YBCO coated conductor 10 mm wide and impregnated by epoxy resin was measured and tested. In the DC regime, we measured the I-V curve of the coil, the hysteresis of the magnetic field-current curve at liquid nitrogen temperature and the radial component of the coil field at the coil edges. AC losses in the frequency range from 100 Hz up to 1000 Hz at 77 K and at temperatures down to 66 K were also measured. The frequency dependence of losses and critical currents of a short sample at 77 K were also measured and compared with those for the coil.

TUA01PO06

Coils made from Monfilamentary and multifilamentary MgB2 strand

M.D. Sumption, M. Bhatia, F. Buta, S. Bohnenstiehl, E. Collings, LASM, MSE, Ohio State University; M. Tomsic, J. Phillips, Hyper Tech Research.

Three solenoidal coils have been wound and with MgB2 strand and tested for transport properties. Each coil was wound with a different strand. The first was a

monofilamentary strand with a pure Cu sheath, while the second and the third were seven filament strand with Nbreaction barriers, Cu stabilization, and an outer monel sheath. The wires were first S-glass insulated, then wound onto an OFHC Cu former. The coils were then heat treated (HT) at 675/30, 700C/20 min, and 700/20, for the first, second, and third coils, respectively. Smaller (1 m) segments of representative strand were also wound into barrel-form samples and HT along with the coils. After HT the coils were epoxy impregnated. Transport Jc measurements were performed between various pairs of taps along the coil lengths. Measurements were made initially in liquid helium, and then by conduction cooling as a function of temperature up to 30 K. Homogeneity of response along the coils was investigated and a comparison to the short sample results was made. The coil contained more than 100 m of 1.0 mm OD strand for first coil and 0.8mm OD strand for the second and the third coil. The 7 strand coil reached 222 A at 4.2 K, self field, with a Jc of 300 kA/cm2 in the SC and a winding pack Je of 23 kA/cm2. At 20 K the critical current density values were 175 kA/cm2 and 13.4 kA/cm2. Magnet bore fields of 1.5 T and 0.87 T were achieved at 4.2 K and 20 K, respectively.

TUA01PO07

A 0.6T/600 mm RT Solid Nitrogen Cooled MgB2 Demosntration Coil for MRI - A Status Report

J. Bascuñán, H. Lee, E. Bobrov, S-Y. Hahn, Y. Iwasa, MIT-Francis Bitter Magnet Laboratory; M. Tomsic, M. Rindfleisch, Hyper Tech Research Inc.

Aiming to demonstrate feasibility and practicality of a low cost superconducting MRI magnet system targeted for use in small hospitals, rural communities and underdeveloped countries, the MIT-Francis Bitter Magnet Laboratory has developed a 0.6T/600 mm room temperature demonstration coil wound with multifilament MgB2 conductor and cooled via an innovative cryogenic design/operation. The coil is to be maintained cold by solid nitrogen which in turn is solidified by a cryocooler. In the event of a power failure the cryocooler is automatically thermally decoupled from the system. In this paper we present details of the MgB2 conductor, winding process, and preliminary test results of the current-carrying performance of the conductively cooled coils in zero background field and over the 10 - 30 K temperature range.

TUA01P008

Relaxation of trapped magnetic field in 100m-long class MgB2 solenoid coil in persistent current mode operation

M. Takahashi, K. Tanaka, M. Okada, HRL, Hitachi, Ltd. We succeeded in the persistent current mode operation of 100m-long class MgB2 solenoid coil with persistent current switch (PCS). The coil was fabricated using metal-

sheathed MgB2 mono-core wires and using Wind & React process (heat treatment at 938K for 3600s). MgB2 wires were produced applying the in-situ PIT method consisting Mg and amorphous B powders. The PCS was fabricated with Cu-30wt%Ni sheathed NbTi multifilamentary wires. We confirmed the ability to trap 0.67T magnetic field with persistent current of 53.8A. From the relaxation of persistent current up to 28800s, relaxation times were estimated to be t > 15000s,showing resistance in overall current loop below 10-9 V/A. The average rate of magnetic relaxation was 7.5×10-5/h with inductance L of 8mH.

TUA01PO09

Feasibility of Hydrogen Cooled Superconducting Magnets

Y. Makida, H. Hirabayashi, T. Shintomi, KEK.

It looks feasible to realize hydrogen cooled superconducting magnets with HTS and MgB2 conductors. As is well known, hydrogen is an excellent refrigerant for cooling at the temperature range within 15 to 20 K. It can be applied to HTS and MgB2 superconducting devices. In the above temperature range, for example, HTSs have higher performance than in liquid nitrogen at around 77 K. Another possibility is that newly developed MgB2 conductor will become applicable to such devices with liquid and slush hydrogen cooling. Following our previous paper [1], in which accelerator and beam line magnets with MgB2 are discussed, feasibility of hydrogen cooled superconducting magnets in other fields is examined. Characteristics of liquid and slush hydrogen for these applications are summarized from the view point of environment and safety control. Utilization of evaporated hydrogen for Fuel Cells (FC) and a energy grid system are also breifly mentioned.

TUA01PO10

MgB2 coils for particle accelerators

R. Musenich, S. Farinon, M. Greco, INFN-Sezione di Genova; G. Bellomo, M. Sorbi, G. Volpini, INFN-Milano, LASA.

Soon after the discovery of the superconducting properties of MgB2, long lengths of wires became available opening the way to the construction of cryogen free magnets. The limit of magnesium diboride was the low irreversibility field which limited the possible applications to low field magnets like the ones for MRI. SiC doping of MgB2 enhances the irreversibility field to values in the order of 20 T. The present status of art of wires allows the design of magnets for several applications which can be competitive with iron/copper ones. In this work a tentative design of a MgB2 coil for application to particle accelerators is presented.

TUA01P011

The potential application of MgB2 superconducting magnets in space

M. Alessandrini, H. Fang, K. Salama, Department of Mechanical Engineering and Texas Center for Superconductivity University of Houston.

The intermetallic superconductor magnesium diboride (MgB2) has emerged as a strong candidate for superconducting wires and tapes owing to its relatively high transition temperature of about 40 K, almost more than double of Nb-based superconductors that are currently used as superconducting magnets. Among HTS, its coherence length is relatively long of about 5 nm that keeps the intergrain coupling from being a major impediment. Recent enhancement of both the upper critical field and the irreversibility field up to 20 - 30 T through alloying suggests that this compound can even be utilized at very high magnetic fields and at the temperature above 20°K, a temperature range at which it is reasonable to foresee the use of liquid hydrogen. Moreover, the low mass density of MgB2 makes it the ideal candidate for lightweight superconducting magnets that are pivotal for space applications. Significant progress in the processing of MgB2 tapes and wires has been achieved at the University of Houston. We have developed a modified powder-in-tube process to fabricate MgB2 wires and tapes by using an ultra-fine sized precursor prepared by high-energy ball milling. Several 10-meter long wires and tapes with JC, measured at 20°K, over 300 KA/cm2 at self-field and 100

KA/cm2 at 1.5 T, respectively, have been successfully manufactured. More important, the conductors fabricated using this method possesses a high core density of 2.55 g/cm3, very close to its theoretical value. We have also successfully manufactured several coils with different diameters and turns using the aforementioned wires and a winding-reaction process. Superior current carrying capability has been observed on a small size coil with a diameter of 12 mm and 12 turns. At 1 Tesla, the critical current is 159 A at 20°K, 110 A at 25°K, and 51 A at 30°K. This coil carries more than 1000 A at 4.2°K and self-field. For a large size coil with 14 cm diameter and 10 turns, the critical current density is 20 KA/cm2 at 6 Tesla and 4.2 K. At 20 K and self-field, the critical current density is 200 KA/cm2. We also demonstrated that the field dependence of MgB2 wires and tapes can further enhanced by introducing structural and chemical defects. These results reveal the promising of MgB2 wires and tapes for largescale space applications.

POSTER SESSION 13:30 - 15:30 LOW TC SUPERCONDUCTORS (I)

TUA02PO01

Stability Increase of NbTi Conductors Doped with Extremely Large Specific Heat Substances

V. Keilin, P. Alekseev, E. Kostrov, I. Kovalev, S. Kruglov, V. Lazukov, I. Sadikov, Kurchatov Institute; I. Akimov, M. Medvedev, A. Shikov, Bochvar Institute.

The comparative study of stability increase of NbTi conductors doped with extremely large specific heat substances (CeCu6 and HoCu2) was carried out. The short samples were made as follows. Mono- & multi- filamentary wires 0.85 mm dia with copper matrix and filaments made of CeCu6 and HoCu2, prepared by metallurgical methods, were soft-soldered to NbTi multifilamentary wire of the same diameter. For comparison the samples made of NbTi wires soft-soldered to a copper wire were used. The samples were placed in a perpendicular magnetic field and subjected to electromagnetic disturbances of different duration. The tests were carried out both in practically adiabatic conditions, and in well-cooled ones. It was shown that the stability of the doped samples is much larger than that of the samples without doping. Quantitatively the gain depends mainly on the disturbance time duration and cooling conditions. The tested samples can be considered as one of the possible prototypes of long-length superconductors with enhanced stability for practical windings.

TUA02PO02

Production review of 85 km of Al-Stabilized NbTi Cable for the ATLAS Toroids

G. Volpini, G. Baccaglioni, G. Cartegni, D. Pedrini, INFN-Milano, LASA; E. Baynham, RAL; C. Berriuad, CEA; B. Blau, I. L. Horvath, ETH Zurich; H.H.J. ten Kate, CERN.

The production of the conductor for the superconducting toroids of the ATLAS Experiment at the LHC (CERN) was successfully completed. The toroid system, comprising one Barrel Toroid (BT) and two End Cap Toroids (ECTs) operating at 20.5 kA and with 1.5 GJ stored energy, exploits aluminium-clad Rutherford-type NbTi conductors of very large size (57x12 mm2 for the BT; 42x12 mm2 for ECTs) and high critical current (58 kA for BT and 60 kA for ECTs @ 4.2 K, 5 T). Some 56 km of conductor were required for the BT, 26 km for the ECTs, and 3 km for the B0 model magnet. The whole production was equally split

between a German company and an Italian-Swiss consortium. The unusual large scale of this manufacture, the amount of material produced and the presence of two suppliers call for a systematic comparison of the conductor properties along the whole production, in terms of critical currents, degradation after cabling and extrusion, aluminium matrix RRR and bonding with the Rutherford cable. The main result is the confirmation that the technologies selected and the whole process are reliable and reproducible over large production quantities. Before starting the production, concerns were raised about reliability of the extrusion of the conductors of unprecedented length; for this reason a special technique was qualified to repair cables damaged during the extrusion. Only 3 out 67 extrusions failed, and in two cases out of three it was possible to repair and exploit the damaged units.

TUA02PO03

Development and test of a miniature novel Cable-In-Conduit-Conductor for use in fast ramping accelerators with superconducting magnets

V.E. Sytnikov, V.S. Vysotsky, A.V. Rychagov, A.V. Taran, Cable Institute of Moscow G. Moritz, M. Kauschke, E. Fisher, GSI; S.A. Egorov, Y.I. Rodin, Efremov Institute; L. Bottura, CERN; M.N. Wilson Consultant.

Superconducting magnets for future accelerators, such as the SIS 100 ring at GSI, Darmstadt or a superconducting injector at the LHC, require that the magnetic field is pulsed with high repetition rate and high reliability over periods of several years. Only a special conductor design can achieve this challenging task with reasonable compromise between performance and cost. Recently, a novel design of such a conductor was suggested. It will use the well known and proven CICC technology. This new design looks very attractive, with several possible advantages, such as increased conductor stability margin and better mechanical rigidity of the conductor. To verify design ideas and to optimize the design from the viewpoint of current carrying capacity, AC losses, cooling, pressure drop, and quench protection, an R&D project has been started by a consortium consisting of two Russian and two European Institutes, funded by INTAS. In this paper the results of the technology development and tests of the first sample of the novel CICC are presented and discussed. The miniature CICC sample consists of thirty 0.5 mm NbTi strands inside a conduit with an outer diameter of 6.4 mm and has a projected operating current not less than 6 kA. Comparison of the novel design with the similar conductors is presented.

TUA02PO04

Critical current studies on deformed LHC-type strands *V. Previtali, T. Boutboul, D. Leroy, L. Oberli, CERN.*

The NbTi superconducting conductors used in LHC dipole and quadrupole magnets are Rutherford cables composed of several tens of strands. During the cabling process, the strands are severely compacted especially at the thin edge of the cable. In order to assess, on the whole wire length, the deformation effect on the transport current of the wires, LHC type NbTi superconducting strands of various types were flattened by means of rollers. The critical current was then measured as a function of deformation degree and applied magnetic field at both 4.3 K and 1.9 K. The measurements were performed for both orientations (flat face perpendicular or parallel to magnetic field). For serious flattening, a critical current density degradation reaching several tens of percent was achieved in the case of perpendicular orientation. The critical current density anisotropy of such deformed strands and correlation with magnetization effects are discussed.

TUA02PO05

Critical current density in superconducting NbTi strands in the 10 mT to 8 T applied field range

T. Boutboul, S. Le Naour, D. Leroy, L. Oberli, V. Previtali, CERN.

The knowledge of the critical current density in a wide temperature and applied magnetic field range is a crucial issue for the design of a superconducting magnet, especially for determining both current and temperature margins. The critical current density of LHC type NbTi strands of 0.48 mm diameter was measured by means of critical transport current and magnetization measurements at both 4.3 K and 1.9 K and for a broad magnetic field range (up to 8 T). For the magnetic field range common to both measurement methods, critical current density values as extracted from transport current and from magnetization data are compared and discussed in this work. Our experimental data are compared to other sets from literature and scaling laws as well.

TUA02PO06

Residual Resistivity Ratio (RRR) measurements of LHC superconducting NbTi cable strands

Z. Charifoulline, CERN.

The Rutherford-type superconducting NbTi cables of the LHC accelerator are currently manufactured by six industrial companies. As a part of the acceptance tests, the Residual Resistivity Ratio (RRR) of superconducting strands is systematically measured on virgin strands to qualify the strands before cabling and on extracted strands to qualify the cables and to check the final heat treatment (controlled oxidation to control interstrand resistance). More than 12 thousands samples of virgin and extracted strands have been measured during last five years. Results show good correlation with the measurements done by the companies and reflect well the technological process of cable production (strand annealing, cabling, cable heat treatment). This paper presents a description of the RRRtest station and the measurement procedure, the summary of the results over all suppliers and finally the correlation between RRR-values of the cables and the magnets.

TUA02PO07

Production of superconductor for the LHC low-beta quadrupole MQXA

S-I. Meguro, I. Inoue, A. Kimura, M. Higuchi, A. Takagi, The Furukawa Electric Co., Ltd.; A. Yamamoto, K. Tsuchiya, KEK.

In the framework of a collaboration between KEK and CERN, KEK undertook to supply half of the high performance superconducting quadrupoles for the inner triplets of the low-beta insertions. Following a design and development stage at KEK, a series of twenty of these magnets, designated type MQXA, has been produced in industry and tested at KEK. Furukawa was entrusted with the supply of the 7.4 t of superconducting cable used in this project. The 11 mm wide Rutherford cable was of two types, made from two sizes of wire strand of multifilamentary NbTi in a copper matrix. The specifications of the conductors were established following in-depth discussion between KEK and Furukawa, and take into account the requirements of the accelerator magnet and the means available for guality control. In this paper we describe the manufacturing and quality control processes and present the results of measurements made on samples throughout the production, together with relevant statistical analysis.

TUA02P008

Annealing effect on microstructure and superconducting properties of the V-based Laves phase superconducting wire synthesized by a RHQ process

Y. Hishinuma, A. Nishimura, NIFS; A. Kikuchi, Y. Iijima, Y. Yoshida, T. Takeuchi, NIMS; K. Inoue, University of Tokushima.

Nuclear burning plasma reactors require high magnetic field to confine the D-T plasma and maintain the fusion reaction. A lot of fast neutrons are generated by D-T fusion reaction. V-based superconducting materials are interesting as a high field conductor for fusion reactor, because they show neutron irradiation resistance and low activation in the fusion neutron irradiation environment compared with Nb-based superconducting wires. We have studied V-based Laves phase compound multifilamentary superconducting wire using the Rapidly Heating and Quenching (RHQ) process and the simple precursor (Hf-Zr mixture powder/V matrix composite) in order to improve both workability and superconducting property. Recently, we reported that the reaction layer within 10 micron was formed between powder mixture filament and V matrix after the RHQ process, and then offset Tc values of asquenched and post-annealed samples were showed around 8.0 K up to 4.0 J/mm3 of heating energy density during RHQ process. The transport Jc values of samples post-annealed at appreciate temperatures for 10h were increased remarkably compared with as-quenched samples, and then Hc2 value calculated by Kramer's formula was increased from 14 T to 16 T by additional annealing. In this paper, the post-annealing effect on both microstructure and Jc-B property after RHQ process was investigated.

TUA02PO09

Test of superconductor of BESIII Magnet

Z. Zhu, L. Zhao, S. Huang, J. Zhou, H. Yang, J. Hu, Z. Hou, C. Yi, IHEP, Academia Sinica; Q. Xu, Technical Institute of Physics and Chemistry, CAS. Withdrawn.

POSTER SESSION	13:30 - 15:30
MAGNET DESIGN (II)	

TUA03PO01

3D Analysis of Stress Distribution in Force-Balanced Coils

H. Tsutsui, S. Nomura, S. Tsuji-lio, R. Shimada, Tokyo Institute of Technology.

Distributions of stress in force-balanced coils (FBCs) for the superconducting magnetic energy storage (SMES) are analyzed numerically by an element-free Galerkin method.

Recently, we had developed the FBC concept using the virial theorem, and derived a winding pitch of helical coils as a function of a coil aspect, where a distribution of stress is nearly uniform and working stress is minimized. A coil with the winding pitch were named as a FBC with the virial-limit condition or simply a virial-limit coil (VLC), and its excellent characters of stress were confirmed by experiments of a two-layered helical coil which can simulate arbitrary winding pitch numbers. Measurements of distributions of stress on the winding form of the coil proved that a minimum working stress and uniform stress were achieved under the VLC condition. Although stress

distributions in a FBC were investigated by the finite element method (FEM) in the previous work, a complicated structure of FBC requires huge computer resources and restricts detail calculations. In this work, detailed distribution of stress in a FBC are evaluated by an elementfree Galerkin method and compared with the experiments.

TUA03PO02

Laminar Windings

E.Y. Klimenko, ISSSPh, RRC "Kurchatov Institute"; E. Polulyakh, TRINITI, Troitsk. Withdrawn.

TUA03PO03

Study on an HTS Coil Cross Section for the Performance Improvement

S. Ishiguri, M. Yamaguchi, S. Fukui, J. Ogawa, T. Sato, Niigata University.

It is in particular of importance for HTS coils to secure a larger central magnetic field, a large stored energy, etc. with shorter length of HTS tapes. The critical current of an HTS tape depends on both the flux density and the flux angle with respect to tapes. In view of this, the performance improvement of HTS coils is taken into account with an analytical model. As a coil shape, the minimum volume coil derived from the Fabry Factor constant curve is taken up, which is often employed at low temperature coils. It is necessary to analyze the critical current of a high temperature superconducting coil in order to design the optimal cross section of the coil. Therefore authors measured the critical current and n value of Bi-2223/Ag tapes at 77 K. Fitting equations of the critical current and n value concerning any flux density and flux angle are obtained from the measured tape data. The performance of high temperature current а superconducting coil can be analyzed with these fitting equations. The electric field at the critical current is calculated in the cross section of the coil and the high electric field portions are taken off. As a result of this, the critical current and stored energy density of the coil are improved. The optimal coil cross section can be obtained by iterating the above calculation process.

TUA03PO04

Design, Numerical Analyses and Test of a 0.1 MJ SMES with Low Stray Field

Z.K. Wang, Z. Dong, Institute of Electrical Engineering, CAS.

A 0.1 MJ Superconducting Magnetic Energy Storage (SMES) is designed with low stray field by FEM. By applying a shield magnet, the stray field of SMES is reduced effectively. By analyzing the magnetic field of magnet, equipotential line, distributions of magnetic flux density are obtained. The SMES magnet is tested in the liquid helium and the calculated results and the measured results are compared. Based on above analyses, a design scheme, which has both acceptable technical performance and low stray field, is derived.

TUA03PO05

Electromagnetic System of the KTM tokamak

A.B. Mineev, A. Alexeev, E. Bondarchuk, E. Cherdakov, V. Korotkov, S. Krasnov, Y. Krivchenkov, A. Malkov, V. Yakubovski, D.V. Efremov Institute (NIIEFA); E. Azizov, Trinity Institute, Moscow.

The KTM magnet system consists of 20 Copper Toroidal Field (TF) Coils, 6 Poloidal Field (PF) Coils, a Central Solenoid (CS), 2 Feedback Control Coils and Support Structures. The TF coils produce a toroidal magnetic field of 1.0 T at the major radius 0.9 m, while CS and PF produce poloidal magnetic field, adequate for the plasma with nominal current 0.75MA and elongation k=1.7 . Each TF coil consists of 4 turns and has two dismountable joints (upper and lower). All PF coils are carried by outer supporting frame. This paper describes evolution of design solutions for the TF coil dismountable joints, and details of the TF and PF coils winding, insulation, supports and terminals. The supporting scheme is designed to withstand without damages all the EM loads at the normal and abnormal operating conditions, including various plasma disruptions and vertical displacement episodes (VDE's) with either symmetric or asymmetric distribution of the Halo current. The peak Halo current is assumed 0.35 MA

TUA03PO06

A New Robust Design Method for High-Field and Highly Homogenous Superconducting Magnets Using an Immune Algorithm

F. Campelo, S. Noguchi, H. Igarashi, Hokkaido University. When designing high-field superconducting magnets, such as nuclear magnetic resonance (NMR) equipment, one is often interested in using the minimum winding volume, in order to reduce the construction costs. On the other hand, a highly homogenous, highly regulated magnetic field is a crucial requirement for a good performance. Moreover, small variations in the design parameters, such as the radii or thickness of the coils, are unavoidable in the construction of any equipment. These variations can interfere in the field homogeneity, so requiring a costly and time consuming process of calibration after the device is built. Therefore, the design of robust devices, with low sensitivity to small variations in the parameters, is highly desired. Of course, the constraints of characteristics of superconductor (e.g. B-J characteristic) are taken into account. Optimization methods based in the Artificial Immune Systems paradigm are usually able to perform global as well as local exploration of the search space. This feature can be used to perform sensitivity analysis of the candidate solutions during the optimization process, and find robust configurations for a given problem. In this work, we explore the design of a high-field, highly homogenous superconducting magnets by using an AIS-based robust optimization algorithm. The algorithm is presented, and applied in the optimization of the device. The analysis of the results asserts the validity of the presented method.

TUA03P007

The heat load analysis of Superconducting wiggler with Semi-cold UHV beam duct

H-H. Chen, C-S. Hwang, C-H. Chang, F-Y. Lin, J-R. Chen, S-N. Hsu, G-Y. Hsiung, National Synchrotron Radiation Research Center.

A 3.2 T superconducting wiggler (SW6) have been installed in the NSRRC storage ring, and successful tested by an auto filling system with liquid helium and nitrogen at April 2004. The semi-cold UHV beam duct was made of Aluminum and welded a stainless steel with bimetal at both ends to reduce the room temperature conduction heat load. Meanwhile, the aluminum beam duct without Cu coating can rule out the heat load from the electron beam image current. The design temperature of the semi-cold UHV beam duct is 100 k to keep the vacuum in the ultra-high vacuum condition. The beam duct temperature will maintain within 120 k with total heat load at 400 mA electron beam current. The ANSYS code was used to calculate and analysis the total heat load, the temperature on beam duct, and on the superconducting coil. This article also describe the magnet design to keep the temperature

of the UHV beam duct at 100 k and to reduce the heat load from the beam duct to the superconducting coil.

TUA03P008

The Characteristics and Optimal Shape Design of a Superconductive Magnet for EMS-MAGLEV System

Y. Fang, Y. Yao, The College of Electrical Engineering, Zhejiang University.

In a hybrid EMS-Maglev system proposed in this paper, the propulsion is defined by a long stator linear synchronous motor (LSM) which stator (armature) is fixed all along the track and the moving poles with the excitation (suspending magnets) are on the vehicle. The attractive force between the motor stator and the moving poles creates the levitation forces, which is energized by high temperature superconductor (HTS) coils and adjusted by conductor coils. A linear generator supplies the on-board electric power. The static magnetic field energized by HTS and copper conductor coils is calculated and compared by 3D adaptive nonlinear FE code with nodal and edge element respectively. Design sensitivity analysis is combined with the 3D double nonlinear FE model for magnetic and superconductive materials. The design variables are the levitation gap length and the cross sectional dimensions of the HTS coil. As HTS Bi-2223 tape was applied to fabricate the HTS coil, the 3D shape of HTS magnet is optimized under strict restrictions to achieve the minimum volume and the largest air gap, while the perpendicular field along the outer surface of HTS coil is less than a specified value.

TUA03PO09

Development of High-Tc Superconducting Magnet System for Long-Run Operation Test in Sub-cooled Nitrogen

T.J. Kim, Seongnam Polytechnic College; H. Kang, D.K. Bae, D.K. Park, T.K. Ko, Yonsei University; H. Kim, NHMFL; C.J. Lee, B-Y. Seok, Electro-Mechanical Research Institute, Hyundai Heavy Industries, Co., Ltd; H.M. Chang, Hong Ik.

The applied superconducting magnets are usually operated in saturated liquid nitrogen system. But the several characteristics of superconducting magnet such as critical current, electrical insulation and thermal conductivity could be enhanced in sub-cooled nitrogen cooling system rather than in saturated liquid nitrogen cooling system. The main conditions for setting up a sub-cooled nitrogen cooling system are cooling down the temperature of liquid nitrogen to 64 K and adjusting the pressure of closed system as 1 atm. In this paper, the fabrication method of 84 mH superconducting magnet, the method of design and manufacturing for sub-cooled nitrogen system, and the results of long-run operation test of superconducting magnet system are described. And the minute matters such as how to measure the level and the temperature of liquid nitrogen, how to calculate the heat load of cooling system, how to connect the GM-cryocooler to the superconducting magnet and how to adjust the pressure of closed system as 1 atm were described in detail. The temperature and level of liquid nitrogen and pressure of closed system were not degraded not a bit in long-run operation test performed for about 600 hours. Moreover, the characteristics of this magnet system were not degraded by several over current tests and showed very reliable results. The possibility and merits of applying the sub-cooled nitrogen cooling system to large scale superconducting magnet were confirmed through this test.

TUA03PO10

Design Study of 300 MJ HTS SMES System

T. Dai, Y. Tang, J. Li, Huazhong University of Science and Technology.

This paper outlines a systematic procedure for the design of a toroidal coil and presents the optimum design of 300 MJ HTS magnet with finite element method. In this optimization, both the electromagnetic and mechanical design objects are considered. We carried out parameter surveys of the magnetic fields and circumference stress applied to the HTS-SMES magnets and studied a suitable magnet dimension with low inductance and high current.

POSTER SESSION 13:30 - 15:30 FIELD MEASUREMENTS AND ANALYSES

TUA04P001

Impacts of the Embedded Windings to the Field Quality of Dipole

Y. He, L. Ma, S. Han, W. Liu, B. Zhang, P. Yuan, J. Xia, Institute of modern physics of CAS.

The special C-type dipoles with embedded windings are used in the injection beam line of HIRFL-CSR (Heavy Ion Research Facility in Lanzhou - Cooler Storage Ring). They act as the prototype of dipole for Experimental Ring of CSR. The windings carrying current embedded in the dipole poles are used to improve the field quality by adjusting the currents value and direction. The currents are called trimming current. The impacts of such currents on the uniformity of field and multipole components are carefully investigated by using two kinds of magnetic measurements, the hall sensor and the long coil, respectively. It is proved that the uniformity of 1.0x10-3 can be reached easily by adjusting the magnitude of trimming currents. At the same time, the multipoles will also be changed. In our case, the quadrupole and sextupole components have decreased to a low level, and the octupole and dodecapole increased correspondingly, while the trimming currents reach to an optimized value.

TUA04P002

Magnetic Axis Measurement of Multipole Magnets for $\ensuremath{\mathsf{CSR}}$

Y. He, G. Cai, B. Zhang, L. Ma, W. Liu, Y. Su, S. Han, K. Man, P. Yuan, J. Xia, Institute of modern physics of CAS. Withdrawn.

TUA04PO03

Measurement and Analyse of Multipoles for CSRm

Y. He, B. Zhang, W. Liu, L. Ma, S. Han, S. Zhang, Y. Su, P. Yuan, J. Xia, Institute of modern physics of CAS. Withdrawn.

TUA04P004

Field Measurement and Analysis of Dipole magnets for HIRFL-CSR

Y. Su, Y. He, P. Yuan, L. Ma, W. Liu, S. Han, Q. Yao, S. Zhang, W. Wang, Institute of Modern Physics, CAS. Withdrawn.

TUA04PO05

A Configurable Component-Based Software System for Magnetic Field Measurements

J.M. Nogiec, E. Desavouret, J. DiMarco, S. Kotelnikov, K. Trombly-Freytag, D. Walbridge, FNAL.

A new software system to test accelerator magnets has been developed at Fermilab. It employs a single wire

measurement technique and is targeted at field angle and strength measurements. The software for the system is built on top of a flexible component-based framework, which allows for easy reconfiguration and run-time modification. Various user interface, data acquisition, analysis, and data persistence components can be configured to form different measurement systems that are tailored to specific requirements. The system can also be configured with various measurement sequences or tests, each of them controlled by a dedicated script. It is capable of working interactively as well as executing a pre-selected sequence of tests. Each test can be parameterized to fit the specific magnet type or test stand requirements. The system has been designed with portability in mind and is capable of working on various platforms, such as Linux, Solaris, and Windows. It can be configured to use a local data acquisition subsystem or a remote data acquisition computer, such as a VME processor running VxWorks. All hardware-oriented components have been developed with a simulation option that allows for running and testing measurements in the absence of data acquisition hardware.

TUA04P006

Current distribution identification in PF-FSJS *F. Bellina, Università di Udine.*

The Poloidal Field Full-Size Joint Sample (PF-FSJS) was built and tested jointly by ENEA and CEA in 2002 at SULTAN facility, to test two different types of full-size NbTi multistrand cables, and to assess a possible design for the ITER coil electrical joints. The sample was equipped with many sensors, to measure thermal-hydraulic and electromagnetic quantities. Among them, a set of magnetic field measurements was taken by means of pick- up coils located as close as possible to the cable. These signals can be used to reconstruct the current distribution among the main cable bundles, so that some information can be obtained about both the current redistribution along the cable and the effect of the non uniform electric contact between the cable bundles and the joint/terminations. The most common procedure of current distribution reconstruction is based on the Singular Value Decomposition (SVD), which has been applied to some other actual cases by several authors, using suitable techniques to minimise the effect of the measurement errors. However, a number of unresolved questions are still present as regards the procedure overall accuracy which, in some cases, may jeopardise the reconstruction results. Starting from its application to PF-FSJS, the paper presents a critical review of the SVD method, analysing in detail the procedure sensitivity, the effects of the singular values truncation and of the most usual geometrical approximations adopted in this types of analysis.

TUA04P007

Analysis of the Magnetic Field in Magnetic Fluid Acceleration Sensor

W. Yang, Q. Yang, H. Chen, S. Liu, J. Sun, W. Yan, Key Laboratory of Electromagnetic Field and Electrical Apparatus Reliability of Hebei University of Technology.

Magnetic fluid (MF) consists of ultrafine particles of ferromagnetic substance dispersed steadily in solvent using an interfacial active agent. It is a new function material and has both liquid and magnetic properties that make it be proper to develop many types of sensors. A simple and attractive application of magnetic fluid is an acceleration sensor which has good features compared to some traditional ones. This paper presents a magnetic fluid acceleration sensor, whose design principle is given and

the magnetic field is analyzed. MF membrane of the acceleration sensor is enclosed in a glass vessel and held in position thanks to an annular permanent magnet. The static deformation of MF membrane as a result of magnetic force and gravity. The deformation of membrane will change when system get the vertical acceleration. Outside the annular magnet we put a set of coils. An AC current is injected in the central one and the resulting voltage at the output of the other two coils is directly proportional to the vertical acceleration. The magnet of the acceleration sensor is uniformity magnetization so we calculate its magnetic field by equivalent surface current density method. The permanent magnet in the MF acceleration sensor is annular and axial symmetry radial magnetized so the equivalent current density is only circumferential. Boundary condition can be expressed a line integral of functional.

TUA04P008

Persistent Currents in the LHC Dipoles

L. Bottura, A. Devred, V. Granata, S. Le Naour, S. Sanfilippo, CERN. Withdrawn.

TUA04P009

The distribution and measurement of permanent magnet magnetic field

X. Wang, Y. Wang, G. Wang, L. Guan, Harbin Institute of Technology.

The distribution of permanent magnet magnetic field has a crucial effect on the performance of device using the permanent magnet. In this paper the finite element analyses and the measurements are taken on the magnetic fields of some familiar permanent magnets, and the structure of the measurement system is presented. The magnetic field distributions are described in the curves or the 3D images. The vector direction of magnetic flux density can be determined by the requirement of analysis or design. The sample of NdFeB permanent magnet was pulsed magnetized by a saturation magnetic field using a special designed magnetic yoke. The measurement of magnetic field distribution of the sample corresponds with the result of finite element analysis. The results from analyzing or measuring of magnetic field distribution can be referenced for improving the design of the permanent magnet and the magnetizing yoke to meet the requirement of high performance of the device using permanent magnet.

TUA04P010

Checking the Polarity of Superconducting Multipole LHC Magnets.

M. Buzio, L. Bottura, G. Fievez, J. Garcia Perez, R. Lopez, A. Masi, S. Russenschuck, N. Smirnov, CERN; A. Tikhov, IHEP, Protvino, Russian Federation.

The LHC will include about 1750 cold masses, up to almost 16 m long, housing several thousand superconducting magnets. To detect as early as possible costly errors the polarity of all magnets must be checked via cold bore tubes with diameters as small as 50 mm. For this, we have developed a probe called "Polarity Checker" to verify harmonic order, type (normal or skew) and polarity of all multipole magnets at room temperature. This paper describes the design and the operation of the probe and the results obtained on the first few hundred magnets. First we introduce the working principle, based on the harmonic analysis of the radial field component picked up by a rotating Hall sensor at different current levels. Then we describe the system hardware and software, which feature automatic powering, data acquisition and treatment. We show that the sensitivity to the transfer function of the main harmonic is better than 1% for fields as low as 100 T at 17 mm radius, which guarantees virtually no errors in the end results. We provide a summary of the test results, which consist of automatically generated reports that certify the conformity of the measurements to expectations for each magnetic element in an assembly. So far, polarity tests have identified several busbar inversions in both dipole and quadrupole assemblies. Finally, we outline the future developments of this activity, which include extending the polarity tests to the full range of superconducting cold masses.

TUA04P011

Magnetic Alignment Tests of LHC Short Straight Sections at Room and Cryogenic Temperature

M. Buzio, J. Beauquis, L. Bottura, M. Coccoli, G. Deferne, E. Laface, A. Ruccio, J. Garcia Perez, D. Missiaen, N. Smirnov, E. Wildner, CERN; P. Schnizer, GSI, Darmstadt, Germany.

The LHC will include 474 superconducting Short Straight Section assemblies, up to 12 m long, which contain various combinations of twin-aperture quadrupole magnets and multipole correctors that have to be aligned precisely. This paper is concerned with room- and cryogenic-temperature measurements of magnetic axis and field direction, which are essential tools to assess construction guality and guide the installation. First we give a short overview of the available instrumentation, which includes a Single Stretched Wire system, a fixed-coil traveling probe ("AC mole") and a harmonic coil scanning system ("Chaconsa bench"), describing capabilities and performance of each. In particular, we present the results of a series of crosschecks which support the essential equivalence of these systems within the required tolerance. Then we outline the overall testing strategy, which is based on 100% of magnets measured at room temperature, a statistical sample of cold tests to establish a correlation, and extrapolation of warm results to cryogenic temperature. In the following, we show some examples and a detailed statistical review of the results of the about 50 magnets tested so far, with special attention on the difference between mechanical and magnetic axes, the relative alignment of quadrupoles and correctors, and the thermal contractions between 300 and 1.9K. Finally, we discuss the results in terms of their implications for the installation and the commissioning of the machine.

POSTER SESSION	13:30 - 15:30
AC LOSSES (I)	

TUA05PO01

AC loss characteristics of large critical current YBCO coated conductors

Z. Jiang, N. Amemiya, Yokohama National University; Y. lijima, K. Kakimoto, T. Saitoh, Fujikura Ltd.; Y. Shiohara, ISTEC-SRL.

YBCO coated conductors are considered as next generation high temperature superconductors because of their high critical current density at liquid nitrogen temperature even in external magnetic field. One of the most important measures of the performance of YBCO coated conductors is their critical current density. However, the AC loss is another important measure of the performance of the coated conductors, because many electrical power devices will be operated at commercial

frequencies, and AC loss reduction is a critical issue for practical superconducting electrical power realizing The fabrication technologies for coated devices. conductors with high critical current density have been evolving in the last few years. The AC loss characteristics of the state-of-the-art coated conductors with large critical current are peculiar because of the large self magnetic field due to their high critical current density. In this work, the total AC losses of YBCO coated conductors with large critical current were measured electromagnetically at various amplitudes of transport current and various amplitudes of external transverse magnetic fields with various orientations. The measured total AC losses were compared with the numerically calculated total AC losses using the one-dimensional FEM model.

TUA05PO02

AC loss characteristics of REBCO coated conductors subjected to bending strains

H. Suzuki, A. Kataoka, N. Sekine, O. Tsukamoto, Yokohama National University.

REBCO coated conductors (CCs) have high potentials of low AC losses with high current density at high magnetic field. Therefore, CCs are promising HTS conductors for AC superconducting apparatuses such as power cables and transformers. AC losses in superconductors are the major losses generated in those apparatuses and dominate the efficiency and the economic feasibility of the apparatuses. Therefore, it is important to have data of AC losses. HTS conductors are used in those apparatuses in forms of coils and cables and subjected to bending strains. Ceramic nature of REBCO CCs and its high brittleness make these tapes very sensitive to degradation of the critical current due to various mechanical strains and stresses originated form, e.g., Lorenz forces, a thermal contraction/expansion. wires mechanical vibrations, The main reason for degradation of the critical current densities in the CCs is structural changes, i.e. destruction of a weak links between grains, formation of micro-cracks in superconducting layer. In the limit, for very severe deformations, superconducting property vanishes, and such deformed CCs behave like a normal conductor. All these, in turn, strongly influence AC power loss characteristics. In this work we experimentally investigate AC transport current loss characteristics of REBCO CCs subjected to bending strains.

TUA05PO03

AC transport current losses in REBCO coated conductors subjected tensile strains

N. Sekine, S. Odaka, H. Suzuki, O. Tsukamoto, Yokohama National University; M. Ciszek, Institute of Low Temperature and Structure Research.

We developed an equipment to measure AC transport current losses in HTS tapes subjected to tensile strains/stresses at 77 K. The tensile stresses are applied to HTS tapes by a pneumatic cylinder placed in room temperature region. Strains of the HTS tapes are measured by a gap sensor in the room temperature region and strain gauges attached to the HTS tape. The AC transport current losses are measured by a standard four terminal/lock-in amplifier method. When HTS tapes are applied to superconducting apparatuses, they are subjected to mechanical strains and stresses. Ceramic nature of HTS and its high brittleness make these tapes very sensitive to degradation of the critical current due to various mechanical strains and stresses originated from Lorenz forces and a thermal contraction/expansion. The main reason for degradation of the critical current densities in these materials is structural changes, i.e. destruction of a

weak links between grains, formation of micro-cracks within HTS materials. In the limit, for very severe deformations, superconducting properties vanish, and such deformed HTS conductors behave like normal ones. All these, in turn, strongly influence AC power loss characteristics. We measured the AC transport current losses in REBCO coated conductors together with Bi 2223/Ag sheathed tapes. In the paper, the dependence of the loss characteristics on the strains is studied in the relation to critical current degradations due to the stresses.

TUA05PO04

Simulation of the magnetization process in an MgB2/Fe wire

S. Farinon, P. Fabbricatore, M. Greco, INFN-Sezione di Genova; F. Gömöry, E. Seiler, IEE SAS - Bratislava. Withdrawn.

TUA05PO05

Numerical Evaluation of Total AC Loss in Parallel Tape Conductor with Transport Current in Oblique Magnetic Field

T. Hayashi, D. Nakamura, K. Kajikawa, M. Iwakuma, K. Funaki, Kyushu University.

When Bi-2223 Ag-sheathed tapes are applied to AC power devices, several pieces of them are arranged face to face in the form of a parallel conductor to keep the required current capacity. The parallel conductor is usually wound with optimum transposition to suppress the current imbalance among its strands and reduce the AC loss generated in the device. Under the condition of AC operation, the parallel conductor carries an alternating transport current and is simultaneously exposed to an AC external magnetic field with an arbitrary angle to the broadest faces of strands. Therefore it is important to evaluate the AC loss in the parallel conductor under these actual electromagnetic conditions for the design of the device. In this study, we numerically evaluate the AC loss in the parallel tape conductor by means of a finite-element method based on the direct analysis of the magnetic field distribution proposed by our group previously. We assumed that the parallel conductor carries the transport current in the oblique external magnetic field and that all strands in the conductor have the same branch current. It can be considered the electromagnetic behavior in this case corresponds to that in the parallel conductor with optimum transposition. It is found that the AC loss drastically depends on the number of strands in the range of the field amplitude smaller than the full penetration field but the loss is scarcely dependent on it in the range of larger amplitude.

TUA05PO06

Influence of mechanical vibration and losses in Bi-2223 tapes on thermal-expansion properties of structural materials

T. Takao, T. Higuchi, Y. Furumura, M. Arikawa, Sophia University; S. Fukui, Niigata University; A. Yamanaka, Tovobo.

We have experimentally studied relation between mechanical loss and thermal expansion property in superconducting coils. For the experiments, three kinds of structural materials (GFRP, DGFRP, and ZFRP) were used. A glass fiber reinforced plastic (GFRP) contracts with decreasing of temperature; on the contrary, a Dyneema and grass fiber reinforced plastic (DGFRP) and a Zylon fiber reinforced plastic (ZFRP) expand with decreasing of temperature. We used sample holders made of those plastics and measured AC loss of a Bi-2223 tape in liquid nitrogen. Even if the magnetic field applied to the tape and an AC transport current of the tape were same, the loss depended on the sample holder materials. When the sample holder is the GFRP, the loss was largest in the three kinds of plastics, and in case of the ZFRP, the loss was smallest. The ZFRP has the largest expansion property in the three materials, that is, the loss decreased with expansion of the sample holder's materials.

TUA05PO07

The nitrogen boil-off method of measuring AC losses in HTS coils

H. Okamoto, Kyushu Electric Power Co., Inc.; F. Sumiyoshi, Kagoshima University; K. Miyoshi, Furukawa Electric Co., Ltd.; Y. Suzuki, Taiyo Nippon Sanso Co.

The nitrogen boil-off method was developed for the measurement of AC losses in HTS coils. Generally the boiloff method is known to be useful for the measurement without any restrictions of external condition of magnetic fields and transport currents applying to the coil. Namely, the boil-off method is direct and convenient technique rather than electrical one. But the boil-off method with liquid nitrogen was not so easy as that with liquid helium. This is because there are some quite differences between the thermal properties of liquid nitrogen and liquid helium. So, we improved the precision and the sensitivity of the measuring system on the point of view of liquid nitrogen thermal properties. The main points of the improvement are the insulation of the sample housing to enclose the boiled nitrogen gas, and the control of heater power to keep steady gasification. The background of evaporation of liquid nitrogen inside the housing was reduced to about 50mW, and the sensitivity was about 0.1W. This performance is the best that the method with liquid nitrogen has been ever built. This improved method makes it possible to measure the absolute value of the AC losses of many applications preciously at liquid nitrogen temperature as well as at liquid helium.

TUA05PO08

Electrical and Mechanical Properties of Strands in Superconducting Bundle Conductors

K. Nakamura, T. Takao, Sophia University; A. Nishimura, NIFS.

Bundle cables made of hundreds of superconducting strands are twisted to reduce inter-strand coupling losses in cable-in-conduit conductors. The strands in the first subcable contact each other with line contacting regardless of twist pitches of the sub-cable. On the other hand, the strands in the second sub-cable made of the first subcables contact to the strands in the other sub-cables with point contacts at given intervals. Twist pitches of the subcables affect contact area, stress to the strands, and deformation of the strands at the contacting segments. Therefore, it is necessary to discuss the relation between the twist pitches and the contact resistance in the cables. In this study, we prepared sample cables made of the three strands with three different twist pitches. We fabricated experimental equipment that generated mechanical force for assuming electromagnetic force to the cable, and have measured the contact resistance between the strands in the cable in liquid helium. As a result, when the applied force to the wires is from zero to 100 N, the ranges of the surface resistance increased with decreasing of the twist pitches. The surface resistance is not a constant value but depends on the applied force. The results become fundamental data to simulate an electric circuit model consisting of more than one sub-cable, and also to estimate the inter-coupling losses in the cables.

TUA05PO09

Comparison between the experimental and numerical analysis of AC loss in a subdivided YBCO coated conductor considering the critical current distribution

J. Ogawa, S. Fukui, M. Yamaguchi, T. Sato, Niigata University; N. Sekine, M. Ciszek, O. Tsukamoto, Yokohama National University.

In previous work, we reported that the critical current density at the edge was decreased compared with the center, and that AC losses increase compared with a constant distribution. To reduce AC magnetization loss in YBCO coated conductors subjected to magnetic fields perpendicular to their faces, the YBCO tapes were subdivided into multiple filaments. We report the experimental results and the numerical analysis of the AC loss in subdivided superconducting strips due to the critical current density distribution. The YBCO coated conductor in the experiment shows the critical current density distribution is that of a gradually increasing slope from the edge to the center. The numerical analysis is based on the relation of the vector potential and the induction voltage. In this model each filament of the superconducting strips is decoupled and the AC losses are the main sources of hysteresis losses. Therefore, in the comparison between the experimental and numerical analysis of AC losses, the relation of the number of partitions and the critical current distribution is shown.

TUA05PO10

Dependence of AC loss with a Phase difference Between Transport Current and Applied Magnetic Field J. Ogawa, S. Fukui, M. Yamaguchi, T. Sato, Niigata University.

High temperature conductors in AC superconducting power instruments such as tri-axial power cables are exposed to external AC magnetic fields out of phase with the AC transport currents. We report an experimental and numerical analysis of the dependence of AC loss in Bi2223/Ag sheathed tape on the phase difference between the AC transport current and the external magnetic field applied perpendicular to the face. In the experiment, the AC loss was measured by the calorimetric method using the temperature rise of the HTS tape due to the AC losses. In the numerical analysis, using the relation of the vector potential and the inductive voltage, AC loss in the elliptical model such as the Bi2223/Ag sheathed tape was analyzed for the case of external AC magnetic fields out of phase with the AC transport currents. For these results, we report the increment and reduction of the AC loss compared with the in phase condition and we describe the mechanism of the findings.

TUA05PO11

Characteristics Measurements of HTS tape with Parallel HTS Conductors

J-H. Joo, S-W. Kim, K.J. Song, KERI; J-P. Hong, Department of Electrical Engineering, Changwon National University; S.B. Kim, Department of Electrical and Electronics Engineering, Okayama University.

After the discovery of HTS (High Temperature Superconductor), many HTS conductors are developed. Several BSCCO tapes fabricated by PIT (Powder In Tube) method became commercially available, and the transport current loss characteristics of BSCCO tapes are studied much by many research groups. The transport current loss characteristic is one of the typical properties of HTS tape and represents a uniform value in same tapes. It is used to evaluate the performance of HTS tapes in an ac operating and to design HTS power apparatuses. However, we

confirmed that the characteristics of an HTS tape could be varied certainly by neighboring HTS conductors. It is necessary to study the function of neighboring HTS conductors that do not flow current. This paper deals with measurement of the critical currents and the transport current losses of HTS tapes with neighboring HTS conductors. Measurement results and comparison will be presented with discussions.

POSTER SESSION	13:30 - 15:30
LHC MISCELLANEOUS MAGNET	5

TUA06PO01

Normal-Conducting Separation and Compensation Dipoles for the LHC Experimental Insertions

S. Ramberger, D. Gerard, D. Cornuet, G. de Rijk, CERN; I. Morozov, V. Petrov, O. Kiselev, A. Sukhanov, E. Ruvinsky, BINP.

The experimental insertions of the LHC employ normalconducting magnets to provide for part of the beam separation and to compensate the effect of two large spectrometer dipoles. In the interaction regions IR1 for the ATLAS experiment and IR5 for the CMS experiment, each of the optical elements D1 for beam separation on either side of the experiment consists of 6 MBXW dipoles. Each magnet has a core length of 3.4 m, a large single aperture with a gap height of 63 mm and will operate in the field range up to 1.5 T. The MBXWT and MBXWS magnets are shorter versions of the MBXW magnet and will be used as vertical and horizontal compensation dipoles for the spectrometer dipoles in IR2 for the ALICE and in IR8 for the LHCb experiments respectively. The MBXWT and MBXWS magnets have a core length of 1.5m and 0.75m respectively. Additionally one MBXW magnet serves as a main compensator for the LHCb experiment. The magnet design was done in collaboration between CERN and BINP and the dipole magnets are produced by BINP. So far all three MBXWS, all three MBXWT and thirteen of twentynine MBXW magnets have been manufactured and delivered to CERN. The report presents the main design issues and results of the acceptance tests including mechanical, electrical and magnetic field measurements.

TUA06PO02

Transient Thermal Analysis of Normal-Conducting Accelerator Magnets for the LHC

S. Ramberger, S. Bidon, D. Gerard, O. Hans, CERN.

The cleaning insertions of the LHC consist of a series of normal-conducting magnets. Their heat has to be extracted by water cooling and air ventilation systems to keep the tunnel temperature at the prescribed level. Plans to confine the collimation region including the magnets, called for a more detailed transient thermal model to evaluate the necessary ventilation within this area. This report investigates the thermal behaviour of the MQW double aperture quadrupole magnet in particular. A series of 6 magnets of this type establish optical an focusing/defocusing element in the LHC lattice of the cleaning insertions. The aim of this work is to set up a straightforward model that allows for the study of the transient temperatures of the coils, the cooling water, the yoke, the air, and the resulting heat flows. The basis for the model is an equivalent electric circuit which is evaluated by a SPICE circuit simulator. It is shown how to derive resistances and capacitances from analytic formulas for each of the circuit elements taking their shape and properties into account. The comparison of the simulation

results with temperature measurements on the coils and the yoke of the magnet confirm the lumped circuit model. It is also shown that the model reflects particular behaviour following transient current changes. It is therefore capable of predicting complex transient temperature profiles resulting from its environment.

TUA06PO03

Field Quality Change in Accelerator Magnets Due to Re-Magnetization of Superconductor

K. Sugita, The Graduate University for Advanced Studies; T. Ogitsu, N. Ohuchi, T. Nakamoto, K. Tsuchiya, C. Shintomi, A. Yamamoto, KEK.

A simulation program was developed to compute change of magnetic field quality originated by inter-strand current redistribution in Rutherford cables. The program was based on a hypothesis that the magnetic field quality is drifted by changing of superconductor filament magnetizations due to local field changes following imbalance current redistributions, especially during periods of beam injection. The imbalanced currents in cables were described by random zigzag currents within limited current variation. A sinusoidal magnetic field modulation, so called a 'periodic pattern', and the local field on the strand were computed. The variations of the filament magnetizations due to the local field changes, which cause the change of field quality in the magnet bore, were computed using a new model consisting of multiple layers of persistent current having cosine theta distribution. The computed results will be reported in comparisons with the measured results from 18 superconducting quadrupole magnets (MQXAs) for the LHC insertion regions.

TUA06PO04

Focusing strength measurements of the main quadrupoles

N. Smirnov, L. Bottura, M. Buzio, M. Calvi, G. Deferne, O. Dunkel, J. Garcia Perez, S. Sanfilippo, N. Sammut, CERN; J. DiMarco, FNAL.

The 474 twin aperture superconducting guadrupole magnets needed for the Large Hadron Collider (LHC) are assembled in up to 12 m long cryostats. Because of the 'warm-bore' insert, there is only 40 mm of roomtemperature measurement aperture available during cryogenic tests, making the integrated gradient of the quadrupoles challenging to measure both efficiently and with the required 0.1% absolute accuracy. This contribution describes the various systems used to perform magnetic field testing: Automated Scanner system, Single Stretched Wire system and Twin Coils system, concentrating mostly on the absolute accuracies of their integrated gradient (Gdl) measurements. Most of the possible inherent effects that can introduce systematic errors are discussed, along with their preventive methods. In understanding the systematic errors, a few samples of each of the several types of quadrupoles have been thoroughly measured with the different systems. The results of these intersystem cross-calibrations are presented. Also discussed are the qualification results for the measurement systems used in industry. This qualification is based on comparison of results for several quadrupole assemblies tested both in cold conditions at CERN and at room temperature at the manufacturer site.

TUA06PO05

Electrical and Magnetic Performance of the LHC Short Straight Sections

S. Sanfilippo, M. Buzio, M. Coccoli, N. Smirnov, N. Sammut, A. Stafiniak, L. Bottura, P. Pugnat, A. Siemko, P.

Hagen, CERN.

The Short Straight Section (SSS) for the Large Hadron Collider arcs, containing in a common cryostat the lattice quadrupoles and correction magnets, have now entered series production. Systematic cryogenic tests are performed at CERN in order to qualify these magnets with respect to their cryogenic and electrical integrity, the quench performance and the field quality in all operating conditions. This paper reports the main results obtained during tests and measurements in superfluid helium. The electrical characteristics, the insulation measurements and the guench performance are compared to the specifications and expected performances for these magnets. The field in the main quadrupole is measured at cryogenic temperature using two independent systems, 6m long, twin rotating coils (for field gradient and harmonics) and single stretched wire (for field gradient, direction and axis). The main results, as compared to warm data collected in industry are summarized. A particular emphasis is given to the integrated transfer function, which has a spread of around 15 units rms in the production and is a critical issue. Also the dodecapole harmonic component, that required trimming through a change in coil shims is discussed. Finally, the magnetic axis measurements at room temperature and at 1.9 K, providing the nominal vertical shift for installation are reported.

TUA06P006

Performance of the room temperature Systems for Magnetic Field Measurement of the LHC Magnets

J.J. Garcia Perez, J. Billan, M. Buzio, P. Ĝalbraith, D. Giloteaux, V. Remondino, CERN.

The LHC will be composed of 1232 horizontally curved, 15 meter long, superconducting dipole assemblies and 474 Short Straight Sections containing various types of quadrupoles. These magnets are manufactured by several European companies and half of them are currently produced. The field quality at room temperature is strictly monitored to guide and validate the assembly at different stages of the production in the industry. Dipoles and quadrupoles are measured with two different rotating coil systems. These "moles" travel inside the 50 mm aperture and accurately measure the field and gradient strength integrated over the length, the field direction and higher order harmonics. In this paper we describe these two systems, their performance and experience gained through the two first years of operation.

TUA06PO07

Production of the Superconducting Matching Quadrupoles for the LHC Insertions

H. Prin, N. Catalan Lasheras, G. Kirby, R. Ostojic, J. C. Perez, CERN.

The LHC insertions are equipped with individually powered superconducting quadrupoles comprising several quadrupole magnets and orbit correctors, and range in length from 5.3 m to 11.3 m. Following the initial experience in the assembly of the pre-series cold masses, the production has advanced well and about half of the total of 82 units has been produced at CERN. In this paper we present the experience in steering the cold mass production, in particular with respect to the alignment requirements. We also report on the field quality and other measurements made for assuring the quality of the quadrupoles.

TUA06PO08

Cold Test Results of the Inner Triplet Orbit Correctors for the LHC.

W. Venturini Desolaro, M. Karppinen, CERN.

The Inner Triplet Orbit Correctors for the LHC, MCBX and MCBXA, underwent acceptance tests at liquid helium temperature at CERN, before shipping to the FNAL for integration in the final cold masses. A total of 27 MCBX (Horizontal-Vertical Dipole Correctors), of which 9 MCBXA (with nested Sextupole-Dodecapole insert), are needed for the LHC, including spares. The paper discusses the test protocols for series and spare magnets, and reports the results of quench performance and cold magnetic measurements. The peculiarities of combined training and the hysteretic effects in the nested windings are presented and discussed, together with the search of the optimum setting procedure to minimize the persistent current effects on the beam dynamics.

TUA06PO09

Design, Performance and Series Production of the LHC Superconducting Trim Quadrupoles for the Large Hadron Collider.

M. Karppinen, J. Mazet, G. Mugnai, C. Boyer, V. Remondino, W. Venturini-Delsolaro, CERN; A. Puntambekar, CAT, Indore; L. Loche, G. Gaggero, M. Tassisto, Ansaldo Superconduttori.

The Large Hadron Collider (LHC) will be equipped with several thousands of superconducting corrector magnets. Among the largest ones are the superconducting trim quadrupoles (MQTL). These are twin-aperture magnets with a nominal gradient of 120 T/m at 1.9 K and a magnetic length of 1.3 m, weighing about 1800 kg. Sixty MQTL are required for the LHC, 36 operating at 1.9K in the dispersion suppressors and 24 operating at 4.5 K in the cleaning insertions. The paper describes the design features, and reports the measured quench performance and magnetic field quality of the first pre-series magnets. The MQTL magnet production is shared between CERN and industry. This sharing is simplified due to the modular construction, common to all twin-aperture correctors. We report on the present state of the production, and discuss some critical details of the fabrication.

TUA06PO10

The LHC Main Quadrupoles During Series Fabrication *T. Tortschanoff, P. Hagen, K-M. Schirm, E. Todesco, CERN; M. Durante, A. Payn, F. Simon, CEA-Saclay; R. Burgmer, U. Klein, D. Krischel, B. Schellong, P. Schmidt, ACCEL Instruments.*

Beginning of March 2005 about 235 of the 400 main LHC quadrupole magnets have been fabricated and about 140 of them assembled into their cold masses, together with corrector magnets. About 60 of them have been cold tested in their cryostats and most of the quadrupoles exceeded their nominal excitation, i.e. 12'000 A, after not more than two training quenches. During this series fabrication, the quality of the magnets and cold masses was thoroughly monitored by means of warm magnetic field measurements, of strict geometrical checking and of a number electrical verifications. A number of modifications were introduced in order to improve the magnet fabrication, mainly correction of the coil geometry for achieving the specified field quality and measures for avoiding coil insulation problems. Further changes concern the electrical connectivity and insulation of instrumentation and of the corrector magnets inside the cold masses. The contact resistances for the bus-bar connections to the quench protection diodes and the elimination of insulation problems of the main bus-bars required special attention. To this must be added actions for solving of interface problems to the neighbouring magnets in the machine and to the

cryogenic feed line.

TUA06P011

Steering the field quality in the production of the main quadrupoles of the Large Hadron Collider

P. Hagen, L. Bottura, S. Sanfilippo, K. Schirm, E. Todesco, T. Tortschanoff, CERN; F. Simon, CEA-Saclay.

In this paper we present the main issues concerning the field quality in the main quadrupoles of the Large Hadron Collider. The results concerning the correction of the coil layout to improve b6 at injection field level are presented. We then discuss the trend plots for the field gradient and multipoles at room temperature along more than two third of the production. Correlations to measurements in operational conditions are also discussed. A non-negligible fraction of the quadrupoles has been manufactured with collars featuring a magnetic permeability higher than the specified limits. Their impact on field quality, both at room temperature and at operational conditions is discussed. Other critical items like dependence of field quality on cable manufacturer are analysed.

TUA06PO12

Test Results of LHC Interaction Regions Quadrupoles Produced by Fermilab

G. Velev, R. Bossert, J. Carson, D.R. Chichili, S. Feher, J. Kerby, M.J. Lamm, T. Nicol, A. Nobrega, J. Nogiec, FNAL. Fermilab, as part of the US-LHC Accelerator Project, is producing superconducting low-beta quadrupole magnets for the Large Hadron Collider (LHC). These 5.5 m long magnets operate in superfluid helium at 1.9 K with a maximum operating gradient of 214 T/m in the 70 mm bore. Two quadrupoles are combined with a dipole orbit corrector to form a single LQXB cryogenic assembly, the Q2 optical element of the final focus triplets in the LHC interaction regions. We report test results for these magnets including quench performance, field measurement and field alignment.

POSTER SESSION			13:30 - 15:30	
TRANSFER	LINES	MAGNETS	&	WIGGLERS
AND UNDULATORS				

TUA07PO01

Superconductive in-vacuum undulators

R. Rossmanith, A. Bernhard, B. Kostka, T. Schneider, FZ Karlsruhe; M. Weisser, E. Steffens, University of Erlangen-Nürnberg.

During the last years the Research Center Karlsruhe developed novel high-field superconductive in-vacuum undulators with periods lengths of 3.8 and 14 mm. The undulators were tested with beam both in linac type accelerators (Mainzer Microtron MAMI) and storage rings (ANKA). Based on this experience a new generation of superconductive undulators is planned: undulators with electrically variable polarization direction and high brilliance for various accelerators. The talk gives an overview over the development.

TUA07PO02

Field Quality Measurements of a 2-Tesla Superconducting Transmission Line Magnet

G.V. Velev, W. Foster, V. Kashikhin, P. Mazur, A. Oleck, P. Schlabach, C. Sylvester, FNAL; M. Wake, KEK.

A prototype 2-Tesla superconducting transmission line magnet for future hadron colliders was designed, built and tested at Fermilab. The 1.5m long, combined function

gradient-dipole magnet has a vertical pole aperture of 20mm. In order to measure the magnetic field harmonics in such a small magnet aperture, a specialized rotating-coil probe with 15mm diameter and 0.69m length tangential coils was fabricated. Using this probe, a program of magnetic field quality measurements was successfully performed. Results of the measurements are presented and discussed.

TUA07PO03

Test Results of a 2 Tesla Superconducting Transmission Line Magnet obtained with 102 Sensors Array of Hall Station

V. Kashikhin, R. Carcagno, W. Folster, R. Nehring, H. Piekarz, P. Schlabach, FNAL.

A prototype of a 2 Tesla superconducting transmission line magnet for future hadron colliders was designed, built and tested at Fermilab. This combined function magnet with gradient 4%/cm and dipole field 1.96 Tesla has room temperature iron yoke with two horizontally separated air gaps for beam pipes. The magnetic field in both gaps is generated by a single-turn superconducting transmission line of 90 kA nominal current placed in the center of the iron yoke. The magnetic measurements were made simultaneously in both air gaps using a Hall Probe Station with 102 Hall sensors. The main parameters of Hall Station are briefly described. The magnetic design, pole tip and field quality optimization are presented. The iron saturation effects and their reduction with pole holes are also discussed. The results of magnetic measurements are compared with calculations, design parameters and the quality of magnetic field is discussed.

TUA07PO04

A Short Model Excitation of an Asymmetric Force Free Superconducting Transmission Line Magnet

M. Wake, H. Sato, KEK; R. Carcagno, W. Foster, S. Hays, V. Kashikhin, A. Oleck, H. Piekarz, R. Rabehl, FNAL.

The electromagnetic force on the conductor in a transmission line magnet is much suppressed due to symmetry of the core lamination design. Such a symmetry, with two beam spaces, is beneficial for the collider accelerator magnet but inconvenient for use in the beam line magnets where a single beam aperture is required. A short model of asymmetric force free magnet with a single beam aperture was made at KEK. The conductor position, asymmetric pole width and controlled holes in the pole play a role in the force balancing technique. The model magnet was excited together with the VLHC transmission line magnet in a common conductor loop. The testing was completed up to 104 kA current and the magnetic field distribution was found to be as expected,

TUA07PO05

Elliptical undulator HU256 for Synchrotron SOLEIL: magnetic design, computations and measurements

I.N. Churkin, P. Vobly, A. Steshov, A. Batrakov, E. Semenov, Y. Kolokolnikov, E. Rouvinski, BINP; A. Dael, O. Chubar, F. Briquez, Synchrotron Soleil.

The paper describes the design, magnetic computations and measurements of the elliptical undulator HU256 for Synchrotron Soleil (France): the new technology for insertion vacuum chamber has permitted the design of a Bx & Bz closed structure for an electromagnetic undulator This design has been realized on the basis of the 2-D, 3-D modeling (Mermaid and RADIA codes). The symmetric structure of the vertical magnetic field is formed by 27 laminated dipole magnets at nominal magnetic field of 0.44 T, and the asymmetric structure of the horizontal magnetic

field is formed by 28 dipole magnets at nominal magnetic field of 0.32 T. The undulator can work in standard mode as well as in a quasi-periodical mode while the modulation coils on the vertical field dipoles have been switched on. Auxiliary correction coils on the end dipoles make it possible to "zero" the first and second magnetic field integrals to avoid perturbation of electron trajectories in the Storage Ring. The model "undulator" configurations were investigated by means of 3D magnetic computations, and dependences of the magnetic field integrals from the main macroscopic parameters have been obtained. The magnetic measurements of the single dipoles were carried by the Hall probes. The undulator was magnetically measured by the Hall probes system and the Stretched Wire System, described in the paper. The results of magnetic measurements and computations are compared and analyzed.

TUA07P006

Mini-pole Superconducting Undulator for X-ray Synchrotron Light Source

C-S. Hwang, J-C. Jan, P-H. Lin, C-H. Chang, M-H. Huang, F-Y. Lin, T-C. Fan, H-H. Chen, National Synchrotron Radiation Research Center.

A mini-pole vertical winding racetrack coil undulator was studied for potential use as the hard X-ray source in a 3 GeV storage ring. A field strength of 1.5 T can be obtained for the superconducting undulator with a periodic length of 1.5 cm and a magnet gap fixed at 5 mm. The spectra of such a magnet cover the energies between 3 and 25 keV. The coil is NbTi superconducting wire whose diameter, including that of the insulator, is 0.44 mm. A spectrum shimming method has been developed to correct the magnetic field. A prototype superconducting undulator with 40 poles has been designed and will be constructed and cooled in a bath of liquid helium. The prototype will be tested and field measurements made in a vertical dewar. This article will discuss the design of the magnet circuit and the magnet structure, the field shimming method, the measurement of the magnetic field, and critical issues related to the construction process.

TUA07P007

Optimisation calculations for the KATRIN Magnet system

R. Gehring, FZ Karlsruhe; A. Osipowicz, FH Fulda; C. Weinheimer, University Münster.

The Karlsruhe Tritium Neutrino experiment aims to measure the the neutrino mass to extreme high precision by measuring the energy spectrum of the electrons of the tritium decay. A highly specialised magnet system is needed to transport the electrons from tritium beta decay along a more than 70 meter long path with differential and cryogenic pumping sections, pre- and main spectrometer to the detector plane. Each magnet group does not only provide a guiding field for the electrons but also serves additional purposes. The intermediate sections between magnet groups as well as the magnet design itself needs to be analyzed very carefully in order to work properly in the whole KATRIN experiment. This paper describes optimisation calculations performed to achieve this goal.

TUA07P008

Preliminary Test Results of the In Achromatic Superconducting Wiggler at NSRRC

C.H. Chang, C.S. Hwang, H.H. Chen, F.Y. Lin, M.H. Huang, T.C. Fan, J.C. Jan, NSRRC.

Three superconducting wigglers are fabricated to provide hard x-ray radiation for more x-ray users' needs at NSRRC.

The design effective wiggler field is 3.1 T for a 61-mm period at pole gap width of 19 mm. 16 racetrack-shaped coils, made of high performing NbTi, are enclosed and prestressed in an aluminum housing. The design of magnet and cryostat system is described in this work. The magnetic pole has important magnetic function. 5-pole prototype magnets with various pole materials from low carbon steel, vanadium permendure steel and holmium are tested and verified the magnetic field performance. We present the performances of the prototype of compact superconducting wiggler.

TUA07PO09

Manufacture and test of the 5T superconducting undulator for the LHC synchrotron radiation profile monitor

R. Maccaferri, D. Tommasini, W. Venturini Delsolaro, S. Bettoni, CERN.

NbTi superconducting undulators will be used in the LHC as a key part of the Synchrotron Radiation Profile Monitor System. Two undulators are needed, one per each circulating beam, providing 5 T in a 60 mm bore over two periods of 280 mm each. A full scale prototype has been designed and successfully tested in the end of 2004. In this paper, the electromagnetic and the mechanical design of the undulator are summarized. The fabrication of the prototype is described and the cold test results, both power test and field measurements, are reported.

TUA07PO10

Design of the PETRA III Damping Wiggler

P.D. Vobly, A. Utkin, N. Khavin, E. Levichev, N. Zubkov, BINP; M. Tisher, DESY.

The proposed upgrade of the PETRA storage ring will provide the horizontal emittance of ~1 nm if a number of damping wigglers with a total length about 80 m are installed in two long straight sections. The paper describes design concept of the damping wiggler, optimization of its parameters and results of the prototype magnetic measurements.

TUA07PO11

Extending Electromagnetic Wiggler/Undulator Magnet made with Sheet Copper Coils to Shorter Periods

G.H. Biallas, S. Benson, T. Hiatt, G. Neil, M. Snyder TJNAF.

Withdrawn.

TUA07P012

The bending magnets for the proton transfer line of CNGS

K.M. Schirm, CERN; Y. Pupkov, V. Anashin, A. Ogurtsov, E. Ruvinsky, K. Zhilyaev, V. Maraev, O. Kiselev, BINP; Y. Konstantinov, V. Peregud, EFREMOV.

The project "CERN neutrinos to Gran Sasso (CNGS)", a collaboration between CERN and the INFN (Gran Sasso Laboratory) in Italy, will study neutrino oscillations in a long base-line experiment. High energy protons will be extracted from the CERN SPS accelerator, transported through a 727 m long transfer line and focussed onto a graphite target to produce a beam of pions and kaons and subsequently neutrinos. The transfer line requires a total of 78 dipole magnets. They were produced in the framework of an in-kind contribution of Germany via (3)DESY to the CNGS project. The classical dipoles, built from laminated steel cores and copper coils, have a core length of 6.3 m, a 37 mm gap height and a nominal field range of 1.38 T – 1.91 T at a maximum current of 4950 A. The magnet was designed in collaboration between (2)CERN and (1)BINP.

The half core production was subcontracted to (4)EFREMOV Institute; the coil fabrication, magnet assembly and the field measurements were concluded at (1)BINP in June 2004. The main design issues and results of the acceptance tests including mechanical, electrical and magnetic field measurements are discussed.

TUA07PO13

Superconducting Undulators with Variable Polarization and Enhanced Spectral Range

S. Prestemon, D. Dietderich, S. Marks, R. Schlueter, BNL. A concept utilizing superconducting magnets for variable polarization insertion devices is presented. The iron-free concept provides full variable linear and elliptic polarization over a broad spectral range. With appropriate electrical switching the same device can access higher energies through period-halving, while continuing to provide variable-linear polarization; furthermore, separate switching will allow for period-doubling with full linear and elliptic polarization control. The performance, both in terms of field/spectral performance and in terms of polarization control, is compared to existing permanent magnet EPU devices. Engineering issues associated with the fabrication and implementation of the device are discussed.

TUA07P014

Design and development of a superconducting helical hundulator for a polarised positron source.

J. Rochford, CCLRC Rutherford Appleton Laboratory.

A method of producing a polarised positron beam from e+e- pair production in a target by circularly polarised gradiation is being investigated. Polarised photons are to be generated by the passage of a high energy electron beam through a helical undulator. For production of 20 MeV photons, an undulator with a period of 14 mm, a bore of approximately 4 mm and magnetic field on axis of 0.8 T is required. The first prototype of a superconducting undulator has been constructed and tested. This paper details the design, construction techniques and field measurement results for this prototype and compares the results with simulation.

POSTER SESSION 13:30 - 15:30 MISCELLANEOUS ACCELERATOR MAGNETS (II)

TUA08PO01

Researching the Reproducibility of Dipoles for Coolerstorage-ring

Y.L. Su, Y. He, L.Z. Ma, P. Yuan, F. Han, W.J. Liu, S.L. Zhang, W.J. Wang, Institute of Modern Physics, CAS.

The measurement method and principle of dipole magnet reproducibility for Cooling-storage-ring are introduced. How the position and number of steel sheet affect the reproducibility of magnet is investigated. In the end, the reproducibility of CSRm dipoles reaches to less than $\pm 2 \times 10$ -4, which can meet the acquirements of CSR. In addition, the measurement repeatability and the sources causing errors are also analyzed.

TUA08PO02

3-D calculations of wide aperture septum magnets and the estimation of the effects of nonlinear field on beam optics

K. Fan, Accelerator division - Tsukuba.

High intensity proton synchrotron requires wide aperture magnets system to reduce the space-charge effects of high

intensity charged particle beam. Especially, as for the injection and extraction system magnets, the beam passes close to the septum conductor. To get large beam separation effectively, septum magnet system is divided into several types of septum magnets. As a result, each septum magnet becomes shorter and the ratio of the magnet gap to the magnet length becomes large. In this case the end field of magnet core and conductor becomes very serious, and non-linear magnetic field is introduced, which affects the circulating beam quality. To get detail magnetic field distribution of the end field, 3D calculations are very important for the designing of wide aperture septum magnets and for the examining the magnet design. In this paper, the 3D calculations are presented, and the magnet measurement supports the calculation. Beam optics calculations based on the measurement are carried out.

TUA08PO03

Design and Construction of the LEIR Extraction Septum

J.C. Borburgh, M. Hourican, T. Masson, CERN.

The Low Energy Ion Ring (LEIR) is part of the LHC injector chain for ions. The LEIR extraction will use a pulsed magnetic septum, clamped around a metallic vacuum chamber which plays an important role in separating the high vacuum in the LEIR ring (dynamic pressure ~ 10-12 mbar) from that in the transfer line to the PS, where the vacuum requirements are less stringent. The major technical challenges and novel solutions related to the design of this magnet will be presented.

TUA08P004

The Physical Connection of the MICE Cooling Channel Magnets into a Superstructure Designed to Handle the Magnet Forces for Various MICE Operating Modes

M.A. Green, S. Virostek, LBNL; E. Baynham, Y. Ivanushenkov, CCLRC Rutherford Appleton Laboratory; P. Fabbricatore, S. Farinon, INFN-Genova; S.Q. Yang, W.W. Lau, Oxford University Physics Department.

A key issue in the construction of the MICE cooling channel is the magnetic forces between various elements in the cooling channel and the detector magnets. The detectors are separated from the cooling channel by a 50-mm thick lead shield assembly that is in place when the MICE RF cavities are being conditioned to operate at high acceleration gradients. The shield is needed to protect the MICE detectors from the x-rays produced by the RF cavities. The radiation shield forms a physical barrior between the MICE detector solenoids and the MICE cooling channel. This barrior means that it is difficult to transmit magnetic forces from the detector magnets to the cooling channel magnets. This report describes how the MICE cooling channel magnets are hooked to together so that the longitudinal magnetic forces within the cooling channel can be effectively connected to the base of the experiment. This report presents a magnetic force and stress analysis for the MICE cooling channel magnets, even when longitudinal magnetic forces as large as 500 kN (50 tons) are applied to various magnets within the channel. This report also shows that the detector magnets can be effectively separated from the MICE cooling channel magnets without damage to either type of magnet component.

TUA08P005

Electromagnetic Modelling Of The AGS A10 Injection Kicker Magnet

M.J. Barnes, R. Armenta, E. Blackmore, G. Wait, TRIUMF;

D. Norn. University of Victoria: C. Gardner, A. Zhang, BNL. The present AGS injection kickers at the A5 location were designed for 1.5 GeV proton injection. Recent high intensity runs have pushed the transfer kinetic energy to 1.94 GeV, but with an imperfect matching in transverse phase space. Space charge forces result in both fast and slow beam size growth and beam loss as the size exceeds the AGS aperture. A proposed increase in the AGS injection energy to 2 GeV with adequate kick strength would greatly reduce the beam losses making it possible to increase the intensity from 70 TP (70 * 10^12 protons/s) to 100 TP. However the integral of flux density over the length of the present AGS A5 injection kickers is insufficient for injection at 2 GeV. R&D studies are being undertaken by TRIUMF, in collaboration with BNL, to design two new kicker magnets for the AGS A10 location to provide an additional kick of 1.5 mrad to 2 GeV protons. The kick strength rise and fall time specifications are 100 ns, 3% to 97%; the design goal is to achieve a field uniformity of ±1% over 85% of the cross-sectional area of the aperture. TRIUMF has proposed a design for a 12.5 Ohm transmission line kicker magnet powered by a matched 12.5 Ohm pulse forming line. This paper describes the present status of the design including the results of detailed 2D and 3D electromagnetic modelling of the kicker magnet, a novel mathematical model of the magnet, and PSpice time domain analysis of the magnetic kick strength.

TUA08PO06

Fully superconducting magnets for the MS-ECRIS ion source

G. Ciavola, INFN-LNS, for the Ishibi collaboration.

Today the major infrastructures in Europe have adopted the technology of Electron Cyclotron Resonance (ECR) Ion Sources for the production of their ion beams. Most of them use 14 GHz ECRIS, except at INFN-LNS, where an 18 GHz superconducting ECRIS is in operation. In the past 5 years it was demonstrated, in the frame of the FP5 RTD project called "Innovative ECRIS", that the enhancement of performances requires a higher frequency (28 GHz and above) and a higher magnetic field (above 2 T) for the hexapolar field. This RTD project has defined the most salient features of the next generation of ECRIS. In this activity we plan to build and test an ECR ion source based on fully superconducting magnets able to satisfy the above mentioned conditions. The EU needs new generation ECRIS for its accelerators, comparable or even better than what is under development in the USA and Japan. Such a development represents a significant step further compared to existing devices, as an increase of a factor of ten typically of the performances is being planned. Our main priority is to develop a Multipurpose Superconducting ECRIS (MS-ECRIS), fully superconducting, in order to reach magnetic fields still never achieved in ECR Ion Sources, and hence very high performances. The maximum magnetic field will be higher than 4 T for the axial field and close to 3 T for the hexapolar field, which corresponds to values above 6 T within the conductor.

TUA08P007

Studies of Magnetic Field Coupling Between Various Magnets used in 2.5 GeV SRS Ring

G. Sinha, V. Thakur, A. Kumar, M.G. Karmarkar, Govt. of India, CAT. Withdrawn.

TUA08PO08

The superconducting magnets with cryocoolers for the ion sources DECRIS-SC

Y.A. Shishov, V. Drobin, V. Seleznev, V. Datskov, V. Bekhterev, S. Bogomolov, S. Dmitriev, A. Efremov, B. Iakovlev, Joint Institute for Nuclear Research; H. Malinowski, Electrotechnical Institute, Warsaw, Poland.

Two superconducting magnet systems (SMS) for the ECR ion source DECRIS-SC and DECRIS-SC2 were designed at the Joint Institute for Nuclear Research, Dubna, Russia. The first one was manufactured and successfully tested in 2004. The peculiarities of this system include the use of a GM cryocooler (1 W at 4.2 K) for the cryostabilization of the magnet and a special configuration of magnetic field required for the ion source. Four coils provide the magnetic field induction on the axes of the source of up to 3 T (the mirror ratio of approximately 6). Prepreg insulation is used for compounding of the magnet's windings which are indirectly cooled in the vacuum. A second SMS for ion source DECRIS-SC2 is currently being prepared. Due to the fact, that the microwave frequency of 14 GHz will be used for ECR plasma heating, the minimum of magnetic field in this region should be in order of 0.4 T. The maximum field on the axes are equal to the values of 1.9 T and 1.4 T in injection and extraction site respectively. The required axial magnetic field is created by a set of four solenoid coils with the inner diameter of 234 mm. The cryostat vacuum vessel will be made from carbon steel and will act as the system's magnetic shield.

TUA08P009

Design of air-core magnets to correct multipole error field leaking from large aperture septum magnets

T. Shimada, M. Watanabe, H. Hotchi, F. Noda, Y. Irie, JAERI. Withdrawn.

TUA08PO10

A High Intensity Superconducting Atomic Beam Source

M. Statera, M. Stancari, M. Capiluppi, G. Ciullo, M. Contalbrigo, P.F. Dalpiaz, P. Lenisa, Università di Ferrara and INFN; M. Wang, INFN.

The next generation of polarized high energy physics experiments at accelerators employing internal targets requires a significant increase in density of the target. In an atomic beam source (ABS) electron polarization is obtained from Stern-Gerlach separation by sextupole magnets and then transferred to nuclei by means of RF transitions. The Università di Ferrara and INFN group is developing a new ABS characterized by an high intensity beam, using superconducting sextupoles instead of a permanent magnet system. The R&D activities performed in Ferrara laboratory regarding an high flux microwave dissociator and a test bench for low temperature field measurement are presented. A preliminary design of the final high field (9 T) small bore (5-10 cm) superconducting sextupoles is presented. The system will be built and tested in Ferrara.

TUA08P011

A Levitated-Pole Superconducting Dipole for Use in the Beam Separators of LHC

P. McIntyre, A. Sattarov, Texas A&M University.

A superconducting levitated-pole dipole has been designed for use in separating beams in luminosity-upgraded insertion regions of LHC. In that application the dipole sweeps a large flux of energetic particles that were produced in beam-beam interactions so that they impact the side walls of the dipole with problematic doses of heat and radiation. In the levitated-pole dipole, the superconducting coil is bonded to a cold-iron pole tip that is in turn supported within a warm-iron flux return. With
appropriate magnetic design the coil/pole tip assembly can be levitated: the inward forces between the coils can be cancelled by the outward forces across a back-plane gap between pole tip and flux return. The benefit of this design for the beam separator is that there are no superconducting coils in or near the midplane, and the heat and radiation of the lost particles is deposited in warm steel. A design has been prepared that provides 8 Tesla dipole field with clear aperture of 56 mm throughout. Issues of field quality, mechanical support, and dynamic range will be discussed.

TUA08P012

15T Pulsed Magnet for Mercury Target Development

P. Titus, MIT Plasma Science and Fusion Center; H. Kirk, BNL; K. McDonald, Princeton University; P. Spampinato, V. Graves, Oak Ridge National Laboratory; D. Rakos, Everson Tesla Corporation; A. Fabich, J. Lettry, CERN.

MIT - PSFC is providing the design and analysis of a pulsed copper coil that can produce 15T with sufficient bore volume for use with mercury target experiments. A muon collider, or neutrino factory require intense beams of muons which are obtained from pion decay. Pion production from a proton beam interaction is maximized by use of a high Z target such as a mercury jet. A magnetic field is needed for particle confinement. The magnet used for the target development program will have a 15T maximum field. The R&D effort involves analytic simulation and experimental investigation of the mercury flow. Cost and power supply limitations dictated a compact, low inductance, high packing fraction design. A three segment, layer wound solenoid was chosen for the pulsed magnet. A 15 second pulse is needed to obtain the 15 Tesla flat top. The conductor is cold worked OFHC copper, inertially cooled with options for liquid nitrogen or gaseous Helium cooling between shots. The present intended cooling scheme is LN2 bath cooling. Coil Manufacture has been performed by Everson-Tesla in Nazareth PA. Mating with the cryostats is being done by CVIP in Emmaus PA. Preoperational testing of the magnet is being done at MIT in the PTF test facility in 2005. Testing with the mercury jet cassette is planned at MIT in 2006. Status of manufacture, and testing is presented. Configurations of the mercury system and the system installation at CERN are described.

TUA08P013

Optimization of Superconducting Focusing Quadrupoles for the High Current Experiment

G. L. Sabbi, A. Faltens, A.F. Lietzke, S. Mattafirri, P. Seidl, LBNL; N. Martovetski, LLNL; C. Gung, J. Minervini, J. Schultz, MIT; R. Meinke, AML.

The Heavy Ion Fusion (HIF) program is progressing through a series of physics and technology demonstrations leading to an inertial fusion power plant. The High Current Experiment (HCX) is exploring the physics of intense beams with high line-charge density. Superconducting focusing quadrupoles are being developed for magnetic transport studies at the HCX. A baseline design was selected following several pre-series models. Optimization of the baseline design led to the development of a first prototype that achieved a conductor-limited gradient of 132 T/m in a 70 mm bore, without training, with measured field errors at the 0.1% level. Based on these results, both the magnet geometry and the fabrications procedures were adjusted to improve the field quality. These modifications were implemented in a second prototype. In this paper, comparisons between the design harmonics and magnetic measurements performed on the new prototype will be presented and discussed.

POSTER SESSION 13:30 FAULT CURRENT LIMITERS (II)

TUA09PO01

Effect of Magnetic Saturation on the Current Limiting Characteristics of Transformer Type Superconducting Fault Current Limiter

T. Kataoka, Tokyo Denki University; H. Yamaguchi, National Institute of Advanced Industrial Science and Technology.

The transformer type superconducting fault current limiter (SCFCL) is one of the fault current limiters (FCLs) which have been proposed to reduce the fault currents in power transmission lines. It has many advantages such as design flexibility of the current limiting device. However, the transient behavior of this type of FCL when the transmission line fault occurs has not been analyzed in detail yet. Thus, in this paper the transient characteristics of the transformer type SCFCL are analyzed by simulation, considering the magnetic saturation of the transformer iron core. It is assumed that this FCL is applied to a simple transmission line where a short-circuit fault occurs. In the simulation analysis, the magnetization curve of the transformer core is expressed by Froelich's formula and the time-dependent resistance of the current limiting device during its S-N transition is represented by an expression containing an exponential function of time. The analysis is carried out using the parameters of an experimental SCFCL and transmission line. The transient current and voltage waveforms at various parts of the FCL at the shortcircuit fault are shown for different fault phase angles. It is shown that the transmission line fault current that has been reduced by the SCFCL will increase again considerably due to magnetic saturation of the transformer core. This has to be considered in the design of the transformer. Experimental results are shown to justify the analysis.

TUA09PO02

Test results of a Superconducting Fault Current Limiter using bifilar coil of BSCCO-2212

C.A. Baldan, C.Y. Shigue, D.S.S. Figueira, DEMAR/FAENQUIL; E. Ruppert Filho, R.C. Freitas, FEEC/Unicamp.

A single-phase superconducting Fault Current Limiter using a bifilar coil of BSCCO-2212 tube was tested in 220V -60Hz line during fault current between 1 kA to 4 kA, operating in 77 K. In this work are presented the current distribution and the magnetic field calculations used in the analysis of current limiter. The experimental setup is described and the test results are presented for the unit conducting a steady nominal AC current of 200 A, and also during the fault time (1 to 6 cycles). The performance of the bifilar coil to provide the limiting impedance associated with the dynamic resistance developed during the beginning of the fault was analyzed and compared with other types of superconducting current limiters.

TUA09PO03

Application of Superconducting Fault Current Limiter to Protection of High Temperature Superconducting Conductor

S-W. Yim, K. Kishio, Department of Superconductivity, University of Tokyo; S-H. Lim, Research Center of Industrial Technology, Chonbuk National University; S-D. Hwang, O-B. Hyun, KEPRI.

As a prospective protecting method for high temperature superconducting (HTS) machines, superconducting fault current limiter (SFCL) has been expected. For the

application of SFCL, firstly, the guench characteristics of HTS tape are to be analyzed, and then, the switching power density of SFCL should be considered simultaneously. In this study, based on the electrical behavior of Bi-2223/Ag tape in transient state, the possibility of SFCL application was investigated as a basis study for the protection of HTS power machines. For the experiments, a Bi-2223/Ag tape having the critical current of 57 A and a resistive type SFCL fabricated using 3 elements of YBCO thin film were tested linked together. When the applied current exceeded the rated current of the SFCL, the current was limited completely. However, over 40 V could not be applied because of the restriction of the power density of the SFCL. On the other hand, as a method to increase the power density, a shunt resister was adapted to the SFCL and current limiting ability was tested. In this case, the results showed that the over-current was limited under the safe operation range for HTS tape and the SFCL was also safe, even though 100 V was applied to the tested circuit. In conclusion, the switching power capacity of SFCL could be increased using shunt resistor, protecting HTS tape safely according to the safty margin of Bi-2223/Ag tape.

TUA09PO04

An Analysis and Short Circuit Test of Various Types of Bi-2223 Bifilar Winding Fault Current Limiting Module

D.K. Park, M.C. Ahn, S. Park, H. Kang, D.K. Bae, S.E. Yang, T.K. Ko, Dept. of Electrical and Electronic, Yonsei University.

This paper deals with one of the feasibilities of fault current limiter (FCL) by using high temperature superconducting (HTS) wire. The HTS wires are very useful to apply to various superconducting equipments and have the highest productivity of all superconductors. The FCL using HTS wire has some advantages of stability, flexibility of structure and cost compared with existing superconducting FCLs using bulk or thin film. Even if the FCL using HTS wire has zero resistance in normal state, it needs to be wound as a bifilar winding for non inductance. In this paper, four types of FCL module with bifilar winding were suggested, manufactured and experimented with short circuit tests in 77K. The FCL modules have different fault current limiting characteristic and stability respectively. These types of module are solenoid, pancake, solenoid impregnated with epoxy resin and pancake impregnated with epoxy resin. The FCL module was applied by controllable AC bias during fault duration, 0.1s or 0.2s, from 0.5V to 22V. A process of fault occurrence in this test is very similar to a fault occurrence in real system. In results of tests, the pancake type was more effective to limit a fault current than the solenoid type. Also modules impregnated with epoxy resin showed more efficient current limiting characteristics than non-impregnated modules. The solenoid type has better characteristic of stability. The feasibility of the FCL by using HTS wire was verified by this paper.

TUA09PO05

Design and Manufacture of a Superconducting Fault Current Limiter with Bypass Reactor by Employing Two Different types of HTS wires

M.C. Ahn, D.K. Bae, S.E. Yang, D.K. Park, H. Kang, T.K. Ko, Department of Electrical and Electric Engineering, Yonsei University; Y.S. Yoon, Ansan College of Technology; K. Sim, KERI.

A resistive superconducting fault current limiter (SFCL) using Bi2223 wire and YBCO coated conductor has been developed. The SFCL has two coils; one is bifilar winding

coil wound using coated conductor, and the other is a typical coil using Bi2223 wire. The bifilar coil plays a role of switching when a fault occurs, while it has very small impedance in normal operation. On the other hand, the typical coil using Bi2223 wire has very small resistance but large inductance. The two coils were connected in parallel. A nominal current flows mainly thru the bifilar coil during normal operation. A partial fault current flows thru Bi2223 coil because the resistance of the C.C. bifilar coil rises. Two types of FCL were manufactured and tested; those were a conventional bifilar one which has only one coil using C.C. wire and the proposed one which has two coils. The proposed one has faster recovery than the conventional one.

TUA09PO06

A study on the optimal design of the stabilizer of coated conductor for the application to the superconducting fault current limiter

M.C. Ahn, D.K. Park, S.W.K. Park, D.K. Bae, M. Joo, T.K. Ko, Department of Electrical and Electric Engineering, Yonsei University; C.J. Lee, B.R. Seok, Hyundai Heavy Industries Co., Ltd.; H.M. Kim, LS Industrial Systems Co., Ltd.

A superconducting fault current limiter (SFCL) using high temperature superconducting (HTS) wire has been developing in Korea. While the first-generation wire has difficulty to adopt various matrices because that is made by PIT process, it is relatively easy to choose a matrix of the second-generation wire. In general, C.C. tape has a thick metal layer as a stabilizer above YBCO layer. In addition, the material of the metal layer has good electrical conductivity. However, SFCL plays role of limiting fault current using high resistivity when a fault occurs. Therefore, it is important for the design of this type SFCL to choose and design the stabilizer. In this paper, over-current characteristics of C.C. tapes which have various specifications of stabilizer were investigated experimentally. A simulation program for analyzing the quench characteristics was developed. Simulation results agreed with the experimental results. As a result, it was possible to design of the stabilizer of the C.C. by using the simulation. The design an SFCL using C.C. wire rated on 13.2kV/630A was performed using the optimal design of the stabilizer.

TUA09PO07

Quench Characteristics of HTSC Elements in Integrated Three-Phase Flux-Lock Type Superconducting Fault Current Limiter

C-R. Park, B-S. Han, Division of Electronics & Information Engineering Chonbuk National University; S-H. Lim, Research Center of Industrial Technology, Chonbuk National University; H-M. Park, H-S. Choi, Department of Electrical Engineering, Chosun University.

In this paper, we investigated the quench characteristics of HTSC elements in the integrated three-phase flux-lock type SFCL according to fault types such as the single-line-toground fault, the double-line-to-ground fault, the line-to-line fault and the three-line-to-ground fault. The integrated three-phase flux-lock type SFCL was an upgrade version of single-phase flux-lock type SFCL. The structure of the integrated three-phase flux-lock type SFCL consisted of three-phase flux-lock reactor wound on an iron core with the ratio of same turn between coil 1 and coil 2 in each phase. When the SFCL is operated under a normal condition, the flux generated between two coils of each single phase is canceled out. Therefore, the SFCL's impedance is zero, and the SFCL has negligible influence on the power system. However, if a fault occurs in any single one of three phases, the flux generated in the iron core is not zero any more. The flux makes HTSC elements of all phase to quench irrespective of the fault type, which reduces the current in fault phase as well as the current of sound phase. It was obtained that the fault current limiting characteristics of the suggested SFCL were dependent on the quench characteristics of HTSC elements in all three phases.

TUA09P008

Experimental and Numerical analysis of electrothermal and mechanical phenomena in HTS tube of inductive SFCL

S. Kozak, G. Wojtasiewicz, J. Kozak, B. Kondratowicz-Kucewicz, Electotechnical Institute in Warsaw, Laboratory of Superconducting Technology; T. Janowski, Lublin University of Technology.

The superconducting fault current limiter (SFCL) can be used to limit the short-circuit current level in electrical networks to 5 (or less) times of rated current level. The inductive SFCL works like transformer with shorted secondary winding in a shape of HTS tube. The physical model consists of superconducting Bi-2223 tube (critical current = 625 A at 77 K), iron core and copper primary winding. The numerical model using the "electro-thermal" physical domain which is the coupling of an "electric conducting" problem with a "transient thermal" problem of CAD package FLUX has been used to analyse of temperature distribution in HTS tube during fault. The numerical model using the "magnetodynamic" physical of FLUX package was used to analyse the mechanical force in HTS tube during fault. The paper tries to explain the reason why the HTS tubes guite often break during experiments.

TUA09P009

Fault Current Limiting Characteristics of Integrated Three-Phase Flux-Lock Type SFCL

S-H. Lim, Research Center of Industrial Technology, Engineering Research Institute; C-R. Park, B-S. Han, Division of Electronics and Information Engineering, Chonbuk National University; H-S. Choi, Department of Electrical Engineering, Chosun University.

The integrated three-phase flux-lock type superconducting fault current limiter (SFCL), which consisted of three-phase flux-lock reactor and high-TC superconducting (HTSC) elements connected in series with coil 2 of each single phase, was proposed and the short circuit analysis of the suggested SFCL was performed. In a normal condition, the flux generated in the iron core is zero because the flux generated between two coils of each single phase is canceled out. When a fault happens, however, the integrated three-phase flux-lock type SFCL shows the different fault current limiting characteristics from the threephase SFCLs with three isolated iron cores according to the fault types such as the single line-to-ground fault, the double line-to-ground fault, the line-to-line fault and the three lines-to- ground fault. In this paper, we investigated the fault current limiting characteristics of the integrated three-phase flux-lock type SFCL magnetically coupled among three phases through the computer simulations and the fault current limiting experiments. Through the analysis for the operational characteristics of this SFCL due to the design parameters such as the resistance of HTSC element, the winding direction and the inductance ratio between coil 1 and coil 2 in each single phase, the fault current limiting characteristics of it were compared.

TUA09PO10

Operational Characteristics of Hybrid-Type SFCL by the Number of Secondary Windings with YBCO films *H-S. Choi, Y-S. Cho, Electrical Engineering Chosun University; S-H. Lim, B-S. Han, School of Electronics and Information Engineering, Chonbuk National University.*

We investigated the operational characteristics of the hybrid-type superconducting fault current limiter (SFCL) according to the number of secondary windings. The SFCL consists of a transformer, which has a primary winding and several secondary windings with serially connected YBa2Cu3O7 films. In order to increase the capacity of the SFCL, the serial connection between each current limiting units is necessary. Resistive type SFCL has a difficulty in quenching simultaneously between the units due to slight differences of their critical current densities. The hybridtype SFCL could achieve the simultaneous guench through the electrical isolation and the mutual flux linkage among the units. We confirmed that the capacity of the SFCL was increased effectively by the simultaneous quench among the units. In addition, the power burden of the system could be reduced by adjusting the number of secondary windings and polarity directions between the primary and the secondary windings. We will investigate the method for capacity increase through serial and parallel connections of current limiting elements.

TUA09P011

Analysis on Current Limiting Capability of HTSC Elements in Hybrid Type SFCL

S-H. Lim, H-S. Choi, H-M. Park, O-B. Hyun, B-S. Han, Research Center of Industrial Technology, Engineering Research Institute.

The hybrid type superconducting fault current limiter (SFCL) has desirable operational characteristics to remove the power imbalance between high-TC superconducting (HTSC) elements with the different critical current. The power imbalance has been an obstacle to increase the voltage ratings of the resistive type SFCL. To solve this problem, the proper design of the transformer with the several secondary windings is required for lower power burden of HTSC elements and for more effective operation as the equal power balancer. In this paper, we investigated that the current limiting capability of the HTSC elements comprising the hybrid type SFCL could be improved with the occurrence of lower power burden for each HTSC element and higher limiting impedance of the system by adjusting the number of turns of the secondary winding. As design parameters to confirm it, the resistance and the power loss generated in each HTSC element and the limiting impedance of the system were derived from the electrical equivalent circuit in the sinusoidal steady state. It was confirmed through the analysis based on the fault current limiting experiments that the power burden of HTSC element in the hybrid type SFCL could be decreased with higher limiting impedance of the system by designing the number of turns of the secondary windings to be smaller.

TUA09P012

Comparison of the current limitation performance of Superconducting Fault Current Limiter components under the various operational temperature

H-M. Kim, K.B. Park, B.W. Lee, I.S. Oh, LS Industrial Systems; O.B. Hyun, KEPRI.

This paper deals with the current limitation characteristics of the unit component, which is high Temperature superconductor like BSCCO bulk, BSCCO tape, YBCO film, and so on for the superconducting fault current limiter(SFCL) under the change of its cooling condition. Cooling condition is from the bath cooling which is a 77K nitrogen temperature to the solid nitrogen temperature with around 50K. In the each operational temperature condition, the temperature and resistance rise are happened. The large voltages appear across the terminals of a sample during a fault current limiting. We are concluded that the potential across the component terminal has decreased when a cryogen temperature came down from 77K Liquid phase to solid state temperature of nitrogen.

TUA09P013

Fault Current Limiting Characteristics of DC Dual Reactor Type SFCL with Magnetic Coupling

S-H. Lim, Research Center of Industrial Technology, Engineering Research Institute; H-S. Choi, Y-S. Cho, Department of Electrical Engineering, Chosun University; D-C. Chung, Department of Information Engineering, Woosuk University; T-H. Sung, KEPRI; B-S. Han, Division of Electronics and Information Engineering, Chonbuk National University.

The fault current limiting characteristics of DC dual reactor type superconducting fault current limiter (SFCL) with magnetic coupling were analyzed. The suggested SFCL consists of a diode bridge, DC dual reactor with magnetic coupling and high-TC superconducting (HTSC) elements. Unlike the conventional bridge type SFCL, which requires the controller for the operation of the interrupter to prevent the continuous increase of fault current after a fault happens, the proposed DC dual reactor type SFCL can be operated without the interrupter and the controller for its operation. In addition, despite different critical currents after a fault accident, the balanced power burden between HTSC elements can be achieved by the magnetic coupling between two coils of DC dual reactor. It was confirmed through the experiments for the fault current limiting characteristics that the suggested SFCL performed the advantageous current limiting operations compared to the conventional bridge type SFCL using HTSC coil.

TUA09P014

Modeling and Simulation of Operational Characteristics for New Resistive Type SFCL using Flux Linkage

S-H. Lim, B-S. Han, Research Center of Industrial Technology, Engineering Research Institute; H-S. Choi, Department of Electrical Engineering, Chosun University.

paper, we investigated the operational In this characteristics of new resistive type superconducting fault current limiter (SFCL) through the computer simulations and the fault current limiting experiments. This SFCL has the similar fault current limiting characteristics to the fluxlock type SFCL. The limiting impedance of its is dependent on the inductance ratio of two coils connected in series and the inductance ratio of two coils affects the resistance of high-TC superconducting (HTSC) element as well as the fault current limiting characteristics of the SFCL. To confirm it, the operational characteristics of this SFCL were analyzed through the computer simulation based on its equivalent circuit considering the resistance generation of HTSC element, and the dependence of the fault current limiting characteristics on the ratio of the inductances between two coils was compared with the experimental results. The simulation results agreed well with the experimental ones.

TUA09P015

Analysis of fault current limiting characteristics according to design parameters in a flux-lock type

SFCL

C-R. Park, Division of Electronics & Information Engineering Chonbuk National University; S-H. Lim, B-S. Han, Research Center of Industrial Technology, Chonbuk National University; Y-S. Cho, H-S. Choi, Department of Electrical Engineering, Chosun University.

The flux-lock type SFCL consists of two coils which are wound in parallel each other through an iron core, and a HTSC thin film connected in series with coil 2. In a normal condition, the flux generated in the iron core is zero because the flux generated between coil 1 and coil 2 is canceled out. Therefore, the impedance of the SFCL is zero, and the SFCL has negligible influence on the power system. In a fault condition, if the current in the HTSC element exceeds critical current(Ic), the resistance of the HTSC element appears. It induces the magnetic flux in the iron core. Therefore, the fault current is limited by an instant rise in the impedance of the SFCL. In this paper, through the analysis of the equivalent circuit and short circuit test, we investigated the fault current limiting characteristics according to design parameters in the fluxlock type SFCL. In addition, the analysis of the equivalent circuit was compared to the one of the experimental results. From the comparison of both the results, analysis of the equivalent circuit results well agreed with the experimental ones.

POSTER SESSION	13:30 - 15:30
MOTORS, GENERATORS	AND TRANSFORMERS

TUA10PO01

Development of a 45kVA Single-Phase Model HTS Transformer

Y. Wang, FZ Karlsruhe; X. Zhao, J. Han, TBEA; H. Li, Y. Guan, Q. Bao, L. Xiao, L. Lin, Z. Zhu, X. Xu, IEE, CAS.

This paper presents design and test of a single-phase HTS transformer with capacity of 45kVA operated in liquid nitrogen of 77K for primary/secondary voltages of 2400/160V. The windings were wound stainless steelenforced multifilamentary Bi2223/Ag tapes. The structures of primary and secondary windings are solenoid and double-pancake respectively. The gas-cooling current leads of secondary windings were chosen in order to reduce heat input. Cryostat is made from electrical insulating materials with room temperature bore for iron core made of the commercial Fe-Si steel. Fundamental characteristics of the transformer are obtained by standard short-circuit and no-load tests. The AC losses were calculated and measured by calorimetric method with a mass flow meter of nitrogen gas at room temperature. The performances of the transformer in accidental cases of sudden short-circuit and lightning impulse were also tested.

TUA10PO02

The Design and Electromagnetic Analysis of a New Type Superconducting Motor

M. Shang, Y. Dai, Q. Wang, Institute of Electrical Engineering, CAS.

Study on Meissner effect of LTSC in ultra low temperature environment has been undertaken in this paper. In the design of the new superconducting motor(where stator is in the center of the rotor), rotor is driven by the diamagnetic force. The working principle of the motor and the different new designs are also described in this paper. Analysis of electromagnetic configuration on a two phase system design is carried out and the detail data on characteristic of the motor have been obtained as well.

TUA10PO03

Fundamental Design and Parameter Optimization Study of HTS Generators for Co-generation Systems *Y. Nanao, N. Maki, Tokai University.*

Superconducting generators (SCGs) for co-generation systems have potential benefits for use in practical applications. In such SCGs, high temperature superconductors (HTS) are more suitable for use because of their low cost, and easy manufacture and maintenance. Fundamental design studies of small-scale to large-scale HTS generators for co-generation systems have been carried out using a newly-developed design program. An output capacity of 0.5-10 MW for co-generation systems was selected so that a gasoline engine, diesel engine, or a gas turbine prime mover can be utilized. The basic preconditions for the design are a voltage of 6.6 KV, a frequency of 50 Hz, and a pole number of 4 considering popular utilization. The effects of parameters such as synchronous reactance, rotor diameter and maximum experienced magnetic flux density on the machine performance characteristics, such as weight and efficiency, were calculated. As a result, optimized parameters for 0.5-10 MW HTS generators were obtained in which their weight and efficiency are approximately one guarter lighter and 2 % higher compared to conventional generators, respectively. Furthermore, the influence of HTS generator capacity on the machine performance was also clarified.

TUA10PO04

Fundamental Design Study of HTS Motors for Industry Applications

N. Maki, H. Onodera, Tokai University.

In superconducting synchronous machines (SCMs), high temperature superconductors (HTS) are more suitable for use because of their low cost, and easy manufacture and maintenance. A fundamental design program in which the size of the components comprising the HTSMs and the performance of the HTS are taken into account, has been developed. Influence of the basic rotor structure, in which magnetic or non-magnetic materials are used, and air-gap or conventional (embedded in the iron core) armature winding are used, on HTSMs characteristics are clarified using the developed fundamental design program. As a result, it was found that adoption of the magnetic rotor and conventional armature winding are better than that of nonmagnetic rotor and air-gap armature winding. Fundamental designs of HTSMs for compression machines of thermal power generation systems, fans and blowers of thermal power generations, pumps of supply and drain water systems and rolling machines in steel industry, then carried out. Compress motors for thermal power generation systems and pump motors for supply and drain water systems have almost same efficiency as one of the conventional motors, but large advantage of machine weight reduction by more than 1/2 is obtained. In the motors for fans, blowers and rolling machines, motor weight reduction by about 1 [%] compared with the conventional motors is expected.

TUA10P005

Effect of Synchronous Reactance and Power Factor on HTS Synchronous Machine Design and Performance

S. Baik, M-H. Sohn, E-Y. Lee, S-H. Kim, Y-K. Kwon, Korea Electrotechnology Research Institute; T-S. Moon, H-J. Park, Y-C. Kim, Doosan Heavy Industries and Construction Co., Ltd.

The superconducting synchronous motor and generator have advantages over conventional synchronous machine due to small synchronous reactance of the armature coil. This small synchronous reactance comes from coreless structure of superconducting rotating machine, so that, as it becomes smaller, the machine shows smaller size and less weight physically. Moreover, in the view point of electrical engineering, the machine can get higher maximum output power and lower voltage variation. The power factor of a synchronous generator depends on the load connected, so if the type of the load is decided, it is fixed naturally. In the case of a synchronous motor, however, the power factor can be adjusted according to the excitation voltage. This paper also deals with the effects of power factor on the design parameters of a HTS synchronous motor.

TUA10PO06

Optimal Design of an Innovative High Temperature Superconducting Generator with the Evaporative Cooling Stator and the Distributed Dewar Rotor

G. Zhang, F. Song, B. Chen, S. Yu, H. Wang, H. Guo, G. Gu, Institute of Electrical Engineering, CAS. Withdrawn.

TUA10P007

Performance Test of High Temperature Superconducting Field Coils for a 1MW Motor

M-H. Sohn, S. Kim, S-K. Baik, E-Y. Lee, Y-K. Kwon, KERI; Y-S. Jo, Center for Applied Superconductivity Technology, Republic of Korea; T-S. Moon, H-J. Park, W-S. Kwon, Y-C. Kim, Doosan Heavy Industries and Construction Co., Ltd. A superconducting motor consisting of high temperature superconducting (HTS) rotor and air-core stator is under development in Korea Electrotechnology Research Institute. This HTS motor was designed for having the rated power of 1MW at 3600 rpm. HTS field winding is composed of sixteen HTS race track shaped coils wound with stainless steel-reinforced Bi-2223 tape conductor by react and wind fabrication method. Nomex paper was used for electrical insulation. Each of two magnet pole assemblies was constructed with six double and two single pancake sub-coils, mechanically stacked and electrically in series. Two magnet assemblies were fixed on an aluminum support structure to make effective heat transfer. Voltage terminals were attached to both ends of joints to measure joint resistances. HTS field winding was tested at 77K, also, each of Joule heats generated at the joints was calculated. Design, construction and testing of HTS field winding were carried out and Joule heat generated by the joint resistances was discussed.

TUA10P008

Consideration on Damper Cylinder Design for Effectiveness of Superconducting Generator

O. Skamoto, T. Nitta, The University of Tokyo.

Superconducting generators (SCGs) have many features such as high generation efficiency, small size, capability to enhance power system stability, and so on. Introduction of SCGs will offer great benefits to electric power systems. SCGs are steadily moving forward to practical use. For example, a 70 MW model SCG was successfully developed and R&D was conducted in 200 MVA and 600 MVA class machines in the Super GM project in Japan by 2004. Above-mentioned features originate in high magnetic flux density due to superconducting field winding. Appropriate design is necessary for SCGs to demonstrate these beneficial effects. There are some former studies on explicit expressions on relations between electrical or mechanical characteristics and structure-parameters of SCGs. Expressions were derived based on twodimensional electromagnetic analysis. Obtained expressions gave good view of generator characteristics.

Design of electromagnetic dampers is considered as one of key factors determining SCGs' characteristics. In a recent design of damper cylinders without damper support to get economical SCGs in simple structure, called monolayer type, an assumption in the former studies is inappropriate. In the paper, some modification of explicit expressions on SCGs' characteristics for recent design of damper cylinders will be described. Some considerations on design of damper cylinders for SCGs will be discussed as well.

TUA10PO09

Comparison of Insulation Test of Mini-Models with Different Winding for a HTS Transformer

H-G. Cheon, J. Lee, S-H. Kim, Gyeonsang National University; S-M. Baek, Changwon college.

Recently, universities and companies are developing a power distribution and transmission class HTS transformer that is one of the 21st century superconducting frontier projects in Korea. For the development of the HTS transformer, it is necessary to establish the dielectric technology at cryogenic temperature such as insulating design, cooling system, manufacture, compact, and so on. Also, verification of insulating stability is one of important dielectric technology. Thus, in order to the development of electrical insulation design of the HTS transformer with double pancake and Z continuous winding, we have been discussed insulation composition of the windings and investigated breakdown characteristics such as breakdown of LN2, polymer and surface flashover on FRP and breakdown-surface combination in LN2. Also we have been designed and manufactured a bobbin that has spiral slot for the Z continuous winding. The double pancake coil and Z continuous winding mini-models have been constructed from Kapton film insulated Cu tape which is simulated HTS tape for 22.9kV class HTS transformer using 0.1 % breakdown strength obtained by Weibull distribution. The winding models were measured insulation test such as ac (50 kV, 1min), impulse (154 kV, 1.2×50 ms full wave, 3 times) withstand test and PD (50 pC at 22.9 kV) test. And its excellent performance was confirmed.

TUA10PO10

Design of 100 MVA HTS Transformer with YBCO Coated Conductor Windings

S. Lee, W-S. Kim, S-Y. Hahn, Korea Electrical Engineering and Science Research Institute; T. Chang, K-D. Choi, H-G. Lee, G-Y. Hong, Korea Polytechnic University.

154 kV/22.9 kV, 60 MVA power transformer is one of standards for power system in Korea. In downtown, most of them are installed in basements of buildings. Though 150 % of current power load will be needed in 2017, it is hard to find a solution for increasing the capacity of facilities, especially for the power transformer. The idea which 100 MVA high-temperature superconducting (HTS) transformer can replace 60 MVA conventional one without volume increase is very attractive for the power company in Korea. We designed 154 kV/22.9 kV, 100 MVA, 3 phase HTS power transformer with YBCO windings for this purpose. So the main target of the design is for the HTS transformer to have same size and weight as the 60 MVA conventional one. In Korea, 154 kV class three phase power transformer is composed of 3 individual single phase one. The design criteria which are considered for the single phase one can be directly applied to the three phase one. We adopted shell type for the core and continuous disk type for the winding in order to limit the voltage stress within it. The coolant for the windings was sub-cooled liquid nitrogen and the cooling system for 3 phase transformer was designed also.

TUA10P011

Fabrication and Test of Multiple HTS Wire with Transposition for HTS Power Transformer

W-S. Kim, S. Lee, S-Y. Hahn, Korea Electrical Engineering and Science Research Institute; Y-I. Hwang, K-D. Choi, H-G. Joo, J-H. Han, H-G. Lee, Korea Polytechnic University. According to the recent design of an HTS (High Temperature Superconducting) power transformer whose capacity is hundreds MVA, the rated values of the low voltage side current is over thousands amps. Considering the performance of the recent HTS wires, it is inevitable to use several HTS wires in parallel for large rated current. Lots of stacked HTS wires were fabricated and tested so far, and the results have showed that we have to transpose each wire in order to reduce the AC losses as well as to increase the current capacity. But many development programs for HTS transformer reveal that the transposition of the several wires during the winding process is quite difficult not only in case of the layer windings but also in case of the pancake type ones. So, we need transposed multiple HTS wire which we can handle like single wire or cable for the HTS windings of large capacity power transformer. We fabricated many kinds of samples of multiple HTS wire with transposition to apply it to the HTS windings of power transformer. The electrical characteristics such as critical currents, distributions of current, breakdown voltages or AC losses are analyzed by experiments in case by case. Finally we present the finest design of a multiple HTS wire for power transformer.

TUA10P012

Continuous Disk Type HTS Winding for High Voltage Power Transformer

Y-I. Hwang, K-D. Choi, H-G. Joo, J-H. Han, G-W. Hong, Korea Polytechnic University; W-S. Kim, S. Lee, S-Y. Hahn, Korea Electrical Engineering and Science Research Institute.

High temperature superconducting (HTS) windings for an HTS transformer which have been developed have two kinds of type, one is the layer type and the other is disk type. The disk type windings have advantages over the layer type ones for a power transformer such as good insulation and limit of voltage stress. But this kind of HTS winding generates excessive AC losses caused by strong magnetic field component perpendicular to the surface of the HTS wire. Nevertheless, the layer type windings have adopted for an HTS power transformer so far because of the small AC losses of the HTS windings. We propose a new winding method for a high voltage HTS transformer which has advantages of both types of HTS windings, and we call it continuous disk type HTS winding. This new type of HTS winding consists of pile of lots of HTS disk windings which have no resistive joint between them. A prototype of an HTS winding was fabricated by the new winding method we proposed and characteristic test was carried out. The test result shows that the new type HTS windings can be applied to HTS power transformers, especially to the high voltage ones.

TUA10PO13

Performance Evaluation for a HTS Transformer

A. Formisano, R. Martone, Seconda Università Napoli; F. Marignetti, M. Scarano, Università di Cassino; G. Masullo, A. Matrone, R. Quarantiello, CRIS.

The adoption of High Temperature Superconductors (HTS) tapes is starting to become a suitable and interesting alternative to copper for windings in transformers, thanks to the improvement in performance and the lowering of costs. Of course, designs different with respect to usual layouts

must be considered (and optimized), due to the additional requirements of HTS tapes, such as minimization of orthogonal magnetic fields and consideration of additional losses in the HTS. In the framework of a scientific cooperation among some Italian Universities and a Private Company, a Finite Element model of a transformer with HTS secondary windings has been developed, and validated against a demonstrative device realized during the project. In the paper, the numerical model will be discussed, with particular attention to the HTS losses modelization, and the comparison to the experimental results will be presented.

TUA10P014

The Design and Tests of a three-phase 10.5 kV/400V/630 kVA HTS Transformer

L. Xiao, Y. Wang, X. Zhao, H. Li, J. Han, Z. Zhu, Y. Guan, Q. Bao, Institute of Electrical Engineering, CAS.

A three-phase high Tc superconducting power transformer has been made. The HTS transformer is operated at 77 K, the rated voltage is 10.5 kV/400V, the output current of secondary coil is up to 1 kA. The transformer has been installed at Tebian Electric Xinjiang Factories as power supply. In this paper, the design and test results will be presented.

POSTER SESSION 13:30 - 15:30 FUSION MAGNET TECHNOLOGY CRITICAL ISSUES (I)

TUA11PO01

"Flux Jumps" in Cable-in-Conduit Conductors Induced by Variable Magnet Field.

S.A. Lelekhov, V. Keilin, I. Kovalev, S. Kruglov, P. Naumov, V. Shcherbakov, Kurchatov Institute.

The jump-like temperature increasing that not is explained only by AC losses was observed during the tests of Nb-Ti CICC model samples in variable magnetic fields. The samples were placed between two racetracks that generate background variable magnetic field. The flux jumps occurred in CICC samples during the fast discharge of racetrack coils. The experiments were carried out at zero transport current. The physical model was developed to explain this phenomenon. According to this model, variable magnet field generates the screening currents in the loops formed by the superconducting strands and normal "matrix". In a real winding the additional currents can be either added to or subtracted from the transport current in superconducting strands depending on a mutual orientation of the varying magnet flux density vector and the transport current vector. The critical current of the strands can be exceeded as result of a simultaneous increase of the strands temperature due to AC losses and the screening current. After the sample reaches its critical state the energy stored in the loops quickly dissipates in the normal matrix. It results in a jump-like increase of the conductor temperature. The process duration and maximum temperature must depend on the smoothness of the voltage - ampere curve of the superconducting strands. This phenomenon can influence the stability margin and the ramp rate limitation of full size CICC.

TUA11PO02

A Conduction-cooled 4 T Superconducting Magnet System for Gyrotron with homogenous Regions of 150 and 250 mm

Q. Wang, Y. Dai, L. Yan, S. Song, B. Zhao, Y. Lei, Institute

of Electrical Engineering, CAS.

Development of a high frequency, high harmonic gyrotron using 4 T superconducting magnet is described. A conduction-cooled superconducting magnet with warm room of F 80mm and center field of 4 T was designed and fabricated. The superconducting magnet has two homogeneity regions with the lengths of 150 mm and 250 mm. The homogeneous regions are with the same starting point and the field is decayed to 1/6-1/7 from the front point of homogeneous region to 195 mm. The superconducting magnet is cooled by 1.5Watt 4 K GM refrigerator. In the paper, the design and fabrication of the superconducting magnet are presented.

TUA11PO03

Pressure Drop of the SST-1 Cable-in-Conduit Conductor

S. Pradhan, G. Govardhan, D. Bora, Y.C. Saxena, Institute for Plasma Research. Withdrawn.

TUA11PO04

Design of the Magnet System for a 42 GHz 200 kW Gyrotron

S. Pradhan, A.N. Sharma, U. Prasad, D. Bora, Y.C. Saxena, Institute for Plasma Research. Withdrawn.

TUA11PO05

Comparison of the DC Performance of Full- and Sub-Size NbTi Cable-in-Conduit Conductors

R. Wesche, B. Stepanov, P. Bruzzone, CRPP.

The DC performances of three full- and five sub-size NbTi cable-in-conduit conductors, measured in the SULTAN test facility, are compared. In general, the self-field effect was found to cause sudden take-offs at high currents. In most of the investigated conductors the transition to the sudden take-offs occurs for self-field contributions between 0.5 and 0.8 T. The take-off electric field increases with decreasing quench current. At currents below the threshold for the occurrence of sudden take-offs the normal power law E-J characteristic was observed providing the possibility to determine the critical current. The measured critical currents are typically close to the prediction that retains the peak field as operating field. In the region of the sudden take-offs, the quench currents of the full-size conductors were found to be far below the critical current expected for the peak magnetic field. This behavior can be attributed to current unbalance among the strands. Quench а simulations suggest that the current unbalance is more pronounced at higher currents. The comparison of the performances of the NbTi full- and sub-size conductors clearly indicates that the current carrying capacity of the NbTi strands is less effectively used in larger CICC's.

TUA11PO06

70 kA High Temperature Superconductor Current Lead Operation at 80 K – the Economic Strategy for ITER

R. Heller, W. Fietz, V. Tanna, G. Zahn, FZ Karlsruhe; R. Wesche, CRPP-EPFL; A. Vostner, EFDA-CSU.

For the superconducting magnet system of the International Thermonuclear Experimental Reactor, ITER, 60 current leads for a total current of more than 2500 kA are needed. To reduce the resultant large refrigerator load at 4.5 K, High Temperature Superconductors (HTS) could be used. Therefore, EFDA CSU Garching had launched a development program for a 70 kA HTS current lead demonstrator. The Forschungszentrum Karlsruhe and

CRPP developed and built this current lead which was optimized for 50 K Helium. In 2004 the current lead was successfully tested in the FZK test facility TOSKA. The very encouraging results asked to test this current lead with 80 K Helium because ITER provides a large cooling capacity of 1 MW for the thermal shields of ITER using 80 K Helium. If HTS current leads could be operated using this 80 K Helium the investment and operating costs of ITER could be decreased massively. At the end of last year, the test could be successfully performed demonstrating that high current capacity current leads can be stably operated at about 80 - 85 K. In this paper, the test results for the 80 K Helium cooling operation are presented and compared to the results obtained before at nominal conditions. The results are discussed and extrapolated to the ITER operation taking into account the cooling conditions and the cost issues.

TUA11PO07

A critical review of coupling current loss for cable-inconduit conductors

P. Bruzzone, B. Stepanov, EPFL-CRPP; E. Zapretilina, NIIEFA; A. Nijhuis, University of Twente.

AC loss curves measured for the same conductors at SULTAN in higher frequency range and at University of Twente (UT) in lower frequency range are normalized and compared to draw consistent results. From the unified curves, the coupling time constant (2tau) to be used in the loss formulae is drawn as a function of frequency. The envelope of 2tau versus frequency provides a practical basis to predict the coupling current loss under specific operating conditions for those cable-in-conduit conductors where a single value of 2tau is not adequate to describe the behavior over a broad range of frequency. The comparison of SULTAN and UT results is also extended to the case of cyclic load for NbTi CICC. At UT, the load is applied on the cable by a mechanical press. At SULTAN, the same load is obtained by a combination of operating field and current (body force).

TUA11PO08

A new model to simulate critical current degradation of a large CICC by taking into account strand bending

N. Koizumi, Y. Nunoya, K. Okuno, JAERI.

The ITER model coil experiments have revealed that degradation in critical current (Ic) and n index occurred in large Nb3Sn CICCs and the larger the electromagnetic force, the larger was the degradation. The most possible reason for this degradation is strand bending by a large Lorentz force. However, such degradation was not observed in the Nb3Al conductor, which was operated at similar condition to the Nb3Sn conductors. An approach to combine analytical model and small scale experiment was performed to interpret these results by developing a new model, in which the degradation in the Ic and n index of an individual strand was taken into account as follows: the Ic and n index of a single strand was measured as a function of transverse load; the transverse load in the CICC was evaluated by assuming a hydraulic pressure model; using these results, the Ic and n index of each strand in the conductor cross section was calculated; and finally the overall conductor Ic and n index could be estimated. The calculation results show that in case of the Nb3Sn conductor, the normal transition occurs at low field side, where the electromagnetic force is accumulated and transverse load is the largest, resulting in the large degradation in the Ic and n index. In contrast, in the Nb3AI conductor, the normal transition appears at high field side, where the transverse load is small, resulting in no

degradation in the Ic and n index. These results demonstrate the validity of our new model.

TUA11PO09

Irregular loops with long time constants in CIC conductor

T. Yagai, H. Sato, T. Hamajima, Tohoku University; Y. Nunoya, Y. Takahashi, K. Okuno, JAERI.

AC losses consist of both regular losses that are proportional to cable twisting pitch squared and irregular losses that could not be estimated from short conductor sample test results. It was explained from our previous works that irregular loops in conductor which are caused by asymmetric strand positions as a result of low void fraction of CIC conductor, produce the losses with long time constants up to several hundred seconds. The observed long time constant indicates that the typical loop length should be about LCM (Least Common Multiplier) of all substaged cable pitches, and that contact conditions between the two strands forming the loop should be line contact. In order to investigate the contact conditions in detail, we traced 81(= 3*3*3*3) strands every 11mm of CIC sample conductor with 1m in length whose strands are NbTi/Cu without any surface coating. The measured traces of 81 strands show that asymmetric strand positions, in other words, large displacements of strands from their original positions due to compressing the conductor provide many line contacts. It is found that the averaged line contact length reaches about 10mm that is three order of magnitude larger than the 10^-2 mm of point contact length.

POSTER SESSION 13:30 - 15:30 INDUSTRIAL APPLICATIONS (I)

TUA12PO01

DC Molten Metal Pump with Permanent Magnets *V.G. Kagan, Hazelett Strip-Casting Corp.*

Design of an Electro-Magnetic Pump (EMP)with permanent magnets for molten metals(particularly Aluminum)is described.Mathematical description of the EMP and analitical dependances of EMP output parameters on magnetic induction are given. A novel design of 3D magnetic concentrators with induction more then 1.5T in nonmagnetic gaps more then 5 sm are given. Examples of applications in continuous casting are brought.

TUA12PO02

Numerical Simulation of Marine Oil-Spill Recovery by MHD Method

G. Zhang, Y. Peng, L. Zhao, R. Li, C. Sha, Institute of Electrical Engineering, CAS.

A new method of recovering marine oil-spill based on electromagnetic force, the so-called MHD oil-spill recovery method is proposed in the IEECAS. It is based on the difference of electric conductivity and density between seawater and oil. Seawater floated with oil-spill is forced to move by electromagnetic force when it passes through the MHD channel, where there are electric field and magnetic field in perpendicular, and brings the floating oil moving in parallel. In the outlet of the MHD channel, there is a separating tank. The oil accumulates on the top of the tank due to MHD effect and different density between seawater and oil, where it is recovered through an automatically controlled valve when it gets to a certain thickness, while the seawater flows out from the bottom of the tank. This method is specially suitable for cleaning thin film on seawater, and have a good quality of separated oil with the containing water ratio less than 5%. An analysis model to describe the operating principle in MHD oil separation is presented in the paper. Multiphase flow with different components including oil, seawater and gas is considered in the model, and coupled fields of electromagnetic field and fluid are solved with finite-element method (FEM). The flow velocity, pressure, volume fraction distribution of each phase (water and oil) are analyzed, comparing with the data of demonstration test, the numerical simulation result is validated.

TUA12PO03

Experimental Study on AC MHD Pump

Y. Peng, S. Song, C. Sha, L. Zhao, R. Li, J. Ling, A. Peng, Institute of Electrical Engineering, CAS.

Theoretical and experimental investigations on AC MHD are carried out in the IEECAS. An experimental device to simulate a blood pump is manufactured. The system comprises a four-pole annular permanent magnet, channels with different parameters and motor with variable frequency controller. The magnet generates a field similar to sinusoid with the maximum of 0.75T along the circle to simulate an AC magnetic field when it is rotated up by motor. This moving magnetic field acts on the conductive fluid in the channel, and produces an electromagnetic force to move the fluid with the same direction as that of the magnet rotating. The rotate speed is changed in the range of 0 to 3500rpm. Four annular channels with different configurations are designed and tested in the test device. The electric conductivity of fluid is changed in 5 stages of 0.6, 1.2, 5, 10, 15s/m. In each case, the flow rate and pressure of fluid are measured. The results and discussion are presented in the paper. A 2-D simulation analysis on ACMHD driver is described in the paper. Coupled fields of magnetic field and fluid field are solved and simulated with finite-element method (FEM). Relationship of magnetic field, frequency, conductivity of the fluid, flow rate, and pressure are analyzed. The agreement between experimental values and analysis is satisfied.

TUA12PO04

New Type Superconducting Bulk Magnet by Pulse Field Magnetizing with Usable Surfaces on Both-sides in Open Space

H. Fujishiro, A. Fujiwara, M. Kaneyama, T. Tateiwa, Iwate University; T. Oka, IMRA Material R&D Co., Ltd.; H. Hayashi, Kyushu Electric Power Co., Inc.

For the practical applications of a high-Tc bulk superconductor (HTSC) as a high-strength bulk magnet in a magnetic separation system and so on, the HTSC bulk is usually cooled down below the liquid N2 temperature along the c-axis on the cold stage of the helium refrigerator and then magnetized by field cooled magnetizing (FCM) or pulse field magnetizing (PFM) along the c-axis. In this setup, only the upper surface of the bulk can be used as a magnetic pole in open space due to the restriction of the cooling procedure. If both the upper and lower surfaces of the bulk can be used effectively in open space, a new field of application should develop. In this paper, we propose and test a new type of the HTSC bulk magnet, where the bulk disk is cooled down from the side face (ab-plane) by thermal conduction and is magnetized by PFM along the caxis using a sprit coil. This cooling procedure is expected to reduce the cooling time and the recovering time in temperature after the heat generation by PFM because the ab-plane thermal conductivity k(ab) is much higher than caxis k(c). The vacuum sheath with two parallel surfaces is situated at 4 mm above the bulk surfaces. The magnetizing mechanism and the technical development for this type bulk magnet are discussed and compared with those of the bulk magnet which utilizes only the upper surface of the bulk.

TUA12PO05

Removal of Aerosol by Magnetic Separation

H. Okada, H. Okuyama, M. Uda, N. Hirota, NIMS.

Aerosol means suspended fine liquid or solid particles with a diameter from 1 nm to 100 mm in gas. Removal techniques of aerosol continue to be very important for a long time because fine particles in exhaust gas of cars and factory smoke are environment problems that are closest for us. Recently removal or capturing techniques of nanoparticles are widely noticed from nano-technology, too. They have to capture and separate nano-particles without damaging characteristics in any environment and condition, subsequently to fabricating nano-particles. We examined high gradient magnetic separation experiments of iron (ferromagnetic) nano-particles with a nominal diameter of 30 nm by a superconducting magnet. In the experiment we fabricated fine iron particles by thermal reactive plasma method in argon and hydrogen mixed gas and sent them to the magnetic separator directly. We present experimental results, functions of capture ratio on magnetic field and velocity of flow and so on. We conclude that high gradient magnetic separation is useful for nano-technology.

TUA12PO06

Industrial applications of HTSC coils using next generation BSCCO wire

T. Okazaki, K. Okura, T. Kato, K. Hayashi, K. Sato, Sumitomo Electric Industries.

Two examples of industrial applications of High-Temperature Superconducting (HTS) magnets/coils are presented. These applications employ newly developed "Drastically Innovative Bismuth-based HTS wire (DI-BSCCO wire)" which is commercially available using Sumitomo Electric's innovative fabrication process called Controlled-Over Pressure (CT-OP) sintering. The first application is the HTS coils for an electrical propulsion motor of a ship. The motor is designed to be used at the liquid nitrogen temperature to acquire economical operating conditions and durability. This motor employs iron cores to reduce magnetic field at the coils. Installation of air gaps hold off the saturation issue of iron cores. This motor has successfully demonstrated its performance in a test tank. The second application of the HTS coil is a cryocooler cooled high-field magnet for analysis and research works. Increasing applications of high-field magnetic field require handy and economical operating magnets. This magnet has a room temperature bore of 200mm and consists of 40km of DI-BSCCO wire. Two DI-BSCCO wires are bundled and wound in double-pancake shape without stainless steel enforcement. The DI-BSCCO wire has almost the same tensile strength as that of the usual copper wire. This condition is explained by existence of almost perfectly compressed superconducting filaments. This improved wire strength enables easier winding and stronger coil characteristics.

TUA12PO07

3D Electromagnetic Analysis of Levitating Transporter using Bulk Superconductor

H. Ueda, S. Tsuchiya, S. Azumaya, A. Ishiyama, Waseda University.

It is possible that the bulk superconductor (HTS bulk) is levitated without any fixed mechanical guides by the permanent magnet or electromagnet after a field-cooling

process. We have been constructed and demonstrated the levitating transporter composed of HTS bulks and permanent magnets. The dynamic characteristics of lift force, lateral force and magnetic stiffness are very important for the design of the superconducting applications such as levitation system. And the electromagnetic phenomenon should be investigated based on the accurate analyses on magnetic field and shielding current distributions. In this study, we newly developed a simulation program based on the threedimensional hybrid finite element and boundary element (the 3D hybrid FE-BE) method, which is combined the fast multipole method (FMM). By using the 3D hybrid FE-BE method, the electromagnetic phenomenon caused by movement or displacement can be treated without remeshing in the finite element region. This simulation program can also consider the anisotropic and nonlinear E-J characteristics of HTS bulks. The results of experiment and numerical simulation were good agreement. Therefore, we investigated the relationship between the levitation characteristics and shielding current profiles within the HTS bulk to find out the suitable conditions for stable levitation using the developed computer program.

TUA12PO08

Numerical analysis of levitating force using magnetic shielding effect of YBCO plates

T. Takao, A. Niiro, S. Suzuki, M. Hashimoto, J. Takeda, Sophia University; H. Kamijo, Railway Technical Research Institute.

We have studied a magnetic levitation system using a magnetic shielding effect of high Tc superconducting plates. In the previous work, we demonstrated the magnetic levitation whose experimental arrangement had three YBCO plates cooled by liquid nitrogen, and numerical analysis data were consistent with the experimental results. Extending the experimental arrangement, we proposed a new system having five YBCO plates and numerically analyzed a levitating force. According to the analytical results, the levitating force increased approximately thirty times as much as the force with the system of the three plates. Those results showed a possibility of scale-up to large-size model such as transportation systems for railways. Furthermore, we arranged positions of a permanent magnet and the YBCO plates, and tried to increase the levitation force. The analytical results of the arranged positions are also presented in the paper.

TUA12PO09

HTS Magnet for Maglev Applications: Coil Characteristics

T. Kuriyama, K. Tasaki, T. Tosaka, S. Hanai, K. Marukawa, T. Yamashita, Y. Yanase, M. Yamaji, H. Nakao, Toshiba Corporation; K. Nemoto, M. Terai, M. Igarashi, S. Kusada, S. Hirano, T. Okutomi, K. Kuwano, Central Japan Railway Company.

An HTS magnet for Maglev applications has been developed. The magnet consists of four persistent current HTS coils and is operated at a rated temperature of 20 K and a rated magnetomotive force of 750 kA for each coil. This paper describes fabrication and test results of each persistent current HTS coil. The HTS coil consists of 12 single-pancake coils wound with four parallel Ag-sheathed Bi2223 wires and a persistent current switch (PCS) made of YBCO thin films. The coil is conductively cooled by a cryocooler to approximately 20 K. Persistent current operating tests for four HTS coils at 750 kA were carried out and current decay rates of 0.37-0.68 %/day were obtained. Mechanical vibration applying tests up to ±15 G were carried out to investigate the mechanical properties of the HTS coils. Temperature increasing tests up to 25 K, which is 5 K higher than the rated operating temperature and higher magnetomotive force operating tests up to 800 kA were carried out to investigate the thermal stability of the coils and check the mechanical strength of the coils.

TUA12PO10

HTS magnet for Maglev Applications: Magnet Structure and Performance

M. Terai, M. Igarashi, K. Nemoto, S. Kusada, T. Okutomi, K. Kuwano, S. Hirano, Central Japan Railway Company; T. Yamashita, Y. Yanase, S. Hanai, K. Marukawa, T. Kuriyama, K. Tasaki, T. Tosaka, M.Yamaji, H. Nakano, Toshiba Corporation.

An HTS magnet for Magley applications has been developed. The HTS magnet is an actual device for a Maglev vehicle and consists of four persistent current HTS coils. The magnet is operated at a rated temperature of 20 K and a rated magnetomotive force of 750 kA for each coil. This paper describes structure and performance test results of the HTS magnet. These four HTS coils were installed in a cryostat for a Maglev vehicle and conductively cooled by two sets of two-stage GM type pulse tube cryocoolers below 20 K. Detachable current-leads, which consist of copper alloy leads and ultrasonic motors, are used to reduce heat leakage to the 1st stages of the cryocoolers. These four HTS coils were simultaneously charged up to the rated magnetomotive force. Persistent current operating tests were carried out and the current decay rates were measured. To observe the mechanical capability of the magnet, vibration tests were carried out. The HTS magnet will be installed to the vehicle of the Yamanashi Maglev test line.

PARALLEL SESSION	15:50 - 18:00
(Maestrale room)	
MgB2	

TUA1OR1

Development of MgB2conductors for AC applications G. Grasso, A. Malagoli, INFM-LAMIA & Columbus Superconductors srl; A. Tumino, V. Braccini, M. Tropeano, C. Fanciulli, M. Vignolo, A. S. Siri, INFM-LAMIA; M. Bocchi, L. Martini; CESI SPA.

In spite of its recent discovery, MgB2 conductors are already fabricated in very long lengths for low- to medium magnetic field generation in windings operated in DC condition. The possibility of using MgB2 in power applications is related to the capability of manufacturing superconducting wires with minimized AC losses, and with sheath materials showing mechanical, electrical, magnetic, and thermal properties desirable for a selected device. Considering the present behaviour of MgB2 in a magnetic field, the first power applications that is possible to target are Superconducting Fault Current Limiters (SFCL), and Transformers, that involve a conductor in self-field condition, and in a field of a few tenth of Tesla, respectively. In order to make the use of MgB2 attractive at low temperatures (20K-30K), it is vital to dramatically reduce its AC losses to minimize the extra cooling costs. The sheath material choice is much wider than for other HTS compounds, as MgB2 shows a much broader chemical compatibility with various elements. Nonmagnetic and high electrical resistivity alloys can be selected to constitute the sheath material. First results on the optimization of the filament configuration, twisting, and

high resistivity matrix choice will be presented. Critical currents larger than 500 A have been achieved on these conductors at 27K, in self field. Results will be discussed in terms of feasibility of long lengths, and application in SFCL prototypes.

TUA10R2

Magnesium diboride Superconducting Strand for Synchrotron Light Source Applications

E.W. Collings, M. Sumption, F. Buta, M. Bhatia, M. Tomsic, LASM, MSE, Ohio State University; S. Soltanian, S. Dou, ISEM, University of Wollongong.

The U.S Dept. of Energy's long term goal for magnesium (MgB2) strand intended for diboride accelerator applications includes current densities up to 1200 A/mm2 in 12-16 T. Such developments will take time, however, some near-term applications have been identified. Continually improving properties will enable MgBs, to be used in the windings of: (i) undulator magnet upgrades and replacements, (ii) light source bending magnet replacements, (iii) wiggler magnets, or even (iv) some of the lower field solenoids of a proposed muon collider. Hyper Tech Research has installed a manufacturing line to produce intermediate-to-long lengths of monocore and MF MaBs strand both with and without SiC doping to increase the ireversibility field, Birr. and the Jc. Values of Bc2 and Birr achieved recently in SiC-doped monocores are in the ranges 28-33+ T and 24-29 T, respectively. Values of Jc(4.2 K) achieved have been in the range 1.0-3.5 kA/mm2, 6-3 T (undoped 19-fil. strand) and 1.4-6 kA/mm2, 6-3 T (back-extrapolated, SiC-doped monocore); further improvements are expected. Recent superconducting undulator (SCU) magnets are calling for strands with Jc/B combinations such as 1.1 kA/mm2/1.2 T, 1.4 kA/mm2/3.8 T and 1.2 kA/mm2/5 T.. These specifications, in the light of the existing performance levels indicate MgB's potential for the windings of SCUs. Then next in line could be superconducting wiggler magnets with their higher field requirements, as the properties of MgB2 evolve.

TUA1OR3

Progress on the Commercialization of Magnesium Diboride Superconductors

M. Tomsic, M. Rindfleisch, J. Phillips, J. Yue, Hyper Tech Research Inc.; M. Sumption, M. Bhatia, E.W. Collings, Ohio University.

Hyper Tech Research will report on progress that has been made on developing long length magnesium diboride superconductor wires. Monofilament and multifilament wires will be discussed. The progress on making and the testing of MgB2 coils will be presented. The status of Hyper Tech Research current demonstration projects for making MgB2 coils for MRI, motors, transformers, and other applications will be presented.

TUA10R4

Behaviour of MgB2 reacted and wind coil from 15K to 35K in a criogenic free apparatus.

R. Marabotto, M. Modica, D. Nardelli, M. Tassisto, Ansaldo Superconduttori; G. Grasso, Columbus -Lamia; R. Musenich, INFN.

We have studied experimentally the behaviour of MgB2 reacted and wind pancake, made with Columbus Superconductors' tape, at several temperatures in a criogenic free apparatus. The coils made with different kind of Mgb2 tape (monocore, multifilamentary, twisted, not twisted ecc.) were built with different technique. Measurements of critical current of MgB2 short samples (taken from long lengh production) in a different criogenic

free test facility, with external magnetic field, are also shown. A comparison between short sample and pancake behaviour is reported. Analysis of the quench propagation for the different coils and for different protection circuit are also analysed.

TUA1OR5

Current density, Ic anisotropy and mechanical sensitivity of flat composite superconductors

P. Kovác, I. Hušek, Institute of Electrical Engineering of SAS.

Flattened composite superconductors have an advantage of increased fill factor and improved turn's stability in the magnet winding. Therefore, flat multifilament NbTi, Nb3Sn, Bi-2223 and MgB2 superconductors were measured in the external magnetic fields, at variable temperatures and different field orientations. Engineering current densities and angular dependences of critical currents are compared and discussed. Compared wires were subjected also to mechanical stresses and their critical current degradation was measured and analyzed. Obtained data show what magnetic fields can be generated by these materials used for the superconducting winding.

TUA1OR6

Simulation of the Effect of Fe-magnetization on MgB2/Fe Wires

Z. Zhang, X. Li, L. Xiao, Institute of Electrical Engineering, CAS.

The effect of Fe-magnetization on MgB2/Fe wires is very significant. The structures of the wires affect Ic, AC loss and stability, etc. In this paper, to improve the current carrying capability, the field distributions of several MgB2/Fe wires with different structures were simulated, and the results could be used to optimize the structures of MgB2/Fe wires in production.

PARALLEL SESSION	15:50 - 18:00
(Scirocco/Libeccio room)	
Nb3Sn ACCELERATOR MAGNETS	

TUA2OR1

Perspectives of Nb3 Sn in Future Accelerator Magnets P. Limon, FNAL

Practical Nb3Sn superconductor for magnets has been available since the 1960s. Although it has been used successfully in many types of magnets, its use in accelerators has been sparse and problematic, due chiefly to its difficult mechanical properties and the particular requirements of accelerator magnet design. Nevertheless, Nb3Sn has many features that make it attractive for the accelerators of the future, such as high critical field and high critical temperature. I will discuss the advantages of Nb3Sn conductor for use in future accelerator magnets; present a brief history of attempts at using it in model accelerator magnets; outline improvements in its properties over the past decade and recent increased understanding of its behavior as a practical magnet conductor; describe some recent technological improvements; and present recent results on R&D models of accelerator magnets.

TUA2OR2

A short period high field Nb3Sn undulator demonstration

H.W. Weijers, A. V. Gavrilin, K. R. Cantrell, J. R. Miller, NHMFL/FSU.

With the ultimate goal to develop a technology suitable for

a 2.4 m magnetic length superconducting undulator with 0.8 T on the beam and a 15 mm period for the IXS beam line at the Advanced Photon Source at the Argonne National Lab, USA, a 0.6-m Nb3Sn undulator demonstration magnet is under development at the NHMFL. The intent is to investigate the applicability of Nb3Sn superconductor, in combination with soft magnetic materials, for a 15 mm period planar superconducting undulator The demonstration requirements include a peak undulator magnetic field of at least 0.8 T and a vertical beam stay-clear aperture at least 7 mm wide at the center of the beam chamber. In concept, the beam tube is assumed to be thermally isolated from the windings and separately cooled at LN2 temperature to promote the system reliability. Liquid helium and nitrogen reservoirs provide conduction cooling and the former also acts as a basic structural element. A general description of the design and two options for the assembly procedure are presented along with the results of detailed FEA. Properties of small trial magnets, consisting of impregnated windings and magnetic yoke, are included as well.

TUA2OR3

Status of Nb3Sn Accelerator Magnet R&D Program at CEA/Saclay

A. Devred, CEA&CERN; M. Durante, H. Felice, D. Leboeuf, A. Puigsegur, J-M. Rifflet, M. Segreti, F. Simon, K. Sugita, F. Trillaud, CEA.

DSM/DAPNIA/SACM at CEA/Saclay has been involved for about 10 years in Nb3Sn accelerator magnet R&D. At present, the program is articulated around three main axes: (1) development and characterization of high performance Nb3Sn wires and Rutherford-type cables (in collaboration with Alstom/MSA), (2) conductor insulation development (in collaboration with Institut Européen des Membranes and Laboratoire de Céramique et Matériaux Avancés of CEA/DAM) and (3) design, manufacturing and test of a 58mm, single-aperture Nb3Sn quadrupole magnet model. We report here on the status of the different tasks and we summarize the most significant achievements.

TUA2OR4

Development and Test of Nb3Sn Cos-theta Magnets Based on RRP Strands

S. Feher, G. Ambrosio, N. Andreev, E. Barzi, R. Bossert, R. Carcagno, V. Kashikin, V. Kashikin, M. Lamm, I. Novitski, FNAL.

Fermilab is involved in the development of new generation high-field accelerator magnets exploring different design and technological options. One of the possible magnet designs is based on Nb3Sn cos-theta coils and the windand-react technology. The 1-m long magnetic mirror configuration and dipole model based on PIT Nb3Sn strand were fabricated and successfully tested at Fermilab last year reaching magnetic field of 10 T. To advance the maximum field in this magnet design to the level of 11-12 T, higher-Jc Nb3Sn strands produced using Restack Rod Process (RRP) technology were used. To provide strand stability in the expected current and field range, the strand diameter was reduced from 1 mm to 0.7 mm which resulted in smaller effective filament size. This paper describes the parameters of superconducting strands and cable used, the details of magnet design and fabrication procedure, and reports the results of RRP coil testing in magnetic mirror and dipole configurations.

TUA2OR5

Round and Extracted Strand Tests for LARP Magnet R&D

E. Barzi, D. Turrioni, A. Zlobin, Fermilab; A. Ghosh, BNL; D. Dietderich, S. Caspi, LBNL.

The first step in LARP magnet R&D is fabrication of technological quadrupoles TQ1a and TQ2a. These are two-layer quadrupoles which use cables of same geometry made of 0.7-mm RRP and MJR Nb3Sn respectively. Through strand billet qualification and tests of strands extracted from the cables, predictions on magnet performance were made. Strand tests included critical or quench current of both round and extracted strands at low and high magnetic fields using the voltage-current (V-I) and voltage-field (V-H) methods. Magnetization of round and extracted strands was measured at low (0-3-0 T) and high fields (10-13-10 T) using a balanced coil and a squid magnetometer. Measurements at high field were done in order to determine the effective filament size of strands. Measurements at low fields were performed to study magnetic instabilities (flux jumps). For both strands, effects of heat treatment were studied. This paper describes the Nb3Sn strand samples, the equipment and measurement procedures, and the results of the measurements. Based on these results, strand specifications are narrowed down for future LARP quadrupole models.

TUA2OR6

Magnet R&D for the US LHC Accelerator Research Program (LARP)

S.A. Gourlay, LBNL, for the LARP collaboration.

In 2004, the US DOE established the LHC Accelerator Research Program (LARP) with the goal of establishing a technology base for future luminosity upgrades of the LHC. The focus of the magnet program, which is a collaboration of three US laboratories, BNL, FNAL and LBNL, is on development of high gradient quadrupoles and high field dipoles using Nb3Sn superconductor. Other program components address issues regarding magnet design, radiation-hard materials, long magnet scale-up, quench protection, fabrication techniques and conductor and cable R&D. This paper presents an overall view of the program with emphasis on the current quadrupole project and outlines the long-term goals of the program.

PARALLEL SESSION	15:50 - 18:00
(Ponente/Levante room)	
HIGH FIELD MAGNETS	

TUA3OR1

Performance of a cryogen-free 30 T hybrid magnet

K. Watanabe, G. Nishijima, S. Awaji, K. Takahashi, K. Koyama, N. Kobayashi, Institute for Materials Research, Tohoku University; M. Ishizuka, T. Itou, T. Turudome, J. Sakuraba, Sumitomo Heavy Industries.

The world's first cryogen-free hybrid magnet, which was Laboratory developed at the High Field for Superconducting Materials in order to realize an easyoperational magnet system with no use of liquid helium and nitrogen, has achieved 22.7 T in a 52 mm room temperature bore. After this success, we started to construct a new cryogen-free 30 T hybrid magnet, consisting of an outer wide bore cryogen-free 11 T superconducting magnet and an inner water-cooled 19 T resistive magnet. Up to now, a NbTi outer section coil and a Nb3Sn inner one of a wide bore cryogen-free superconducting magnet were confirmed to generate an individual central field of 5.2 T at 350 A and 5.8 T at 300 A in a 360 mm room temperature bore, respectively. A wide bore cryogen-free superconducting magnet was energized up to 9.5 T as a total background field. A hybrid magnet mode was intended in a 8.5 T background field due to a cryogen-free superconducting magnet, and a cryogen-free hybrid magnet reached to generate a high magnetic field of 27.5 T in a 32 mm room temperature bore.

TUA3OR2

Investigation of ramp rate limitation on the superconducting magnet for the Grenoble 40-T hybrid system

A. Bonito Oliva, M. Biltcliffe, Oxford Instruments Superconductivity; S. Kramer, GHMFL.

The superconducting magnet for the Grenoble 40-T Hybrid system has been tested up to its guaranteed value of 7-T on its own and together with the resistive magnet. Although the superconducting magnet has been consistently operated at 7-T several times, it has shown ramp-rate limitation behaviour. In particular when trying to ramp to field in less than 3 hours, premature guenches have been observed. Subsequent measurement of the voltages across the sections of the superconducting coil has shown presence of anomalous voltage spikes during ramp-up and ramp-down of the magnet. These spikes have been attributed to the presence of a shorted turn in the superconducting magnet. A theoretical model based on the presence of a shorted turn has been developed and used to reproduce the observed magnet behaviour. In particular, by analysing the relative amplitude of the voltage spikes, we have determined the likely position of the short in the magnet and likely current induced in the shorted turn during ramp. In the this paper both theoretical and experimental aspects of the analysis are presented. Finally the plan of actions to fix the problem is reported.

TUA3OR3

Conceptual Design of a Superconducting Magnet System for a 21 T Fourier Transform Ion Cyclotron Resonance Mass Spectrometer

T.A. Painter, D. Markiewicz, J. Miller, I. Dixon, S. Kenney, S. Bole, NHMFL.

The National High Magnetic Field Laboratory (NHMFL) has identified as one of its next high-field persistent-magnet targets a 21 T superconducting magnet system to be used in a Fourier Transform Ion Cyclotron Resonance (FTICR) Mass Spectrometer. The required fundamental parameters of a 21 T central field and a 110 mm warm bore diameter are essentially the same as those already successfully demonstrated in the NHMFL's Ultra-Wide Bore 900 MHz Nuclear Magnetic Resonance magnet system. However, there are several ancillary requirements of the FTICR spectrometer that require technical attention such as fringe field restrictions requiring shielding, length of uniformity zone and magnitude of inhomogeneity, horizontal orientation of the magnet axis and a limitation on the length of the cryostat. This paper describes the overall system requirements and the conceptual design options explored meeting those requirements for for both the superconducting magnet and cryostat.

TUA3OR4

Improved Mechanical Clamping Construction for a 33 T Resistive Magnet at the Nijmegen HFML

S. Wiegers, J. Ros, J. Perenboom, J. K. Maan, High Field Magnet Laboratory, IMM, Radboud University Nijmegen. We present an improved mechanical clamping construction for the 33 T resistive magnets, which have been installed in 2003 at the Nijmegen High Field Magnet Laboratory. The premature failure of one of these 33 T magnets, and the near-failure of two others, were found to be caused by insufficient clamping of the innermost coil. The innermost two coils are electrically as well as mechanically in parallel, using only one set of tierods, to save conductor space for the innermost coil. We will show how we monitor the health of the coil, and how we have analysed its slow deterioration. It will be demonstrated that it is possible to reliably clamp parallel coils in high field resistive magnets with only one set of tierods, if one takes proper care of force transmission

TUA3OR5

Development of 15T cryogen-free superconducting magnets

R. Hirose, S. Hayashi, S. Fukumizu, Y. Muroo, H. Miyata, Y. Okui, A. Itoki, T. Kamikado, Japan Superconductor Technology, Inc.; O. Ozaki, Kobe Steel LTD.

The cryogen-free superconducting magnet is becoming popular because of its easy operation compared with the conventional liquid Helium cooled magnet. However, for higher fields such as above 14T, the cryogen-free magnet has not become popular yet, because it is difficult to design and manufacture since the critical current is markedly reduced at higher fields and higher temperatures. We developed two types of 15T cryogen-free superconducting magnets, which will be among the highest field magnets in operation as cryogen-free with a GM cryocooler. One magnet has a 52 mm room temperature bore with overall dimensions of 820 mm in diameter and 680mm in height. This magnet is designed so as to be simple in both operation and installation. Therefore, the magnet is cooled with a single 1W GM cryocooler. Also all coils are connected in series and charged with a single power supply. The magnet is successfully charged up to 15T in 30 minutes then also charged slowly to 15.5T without quench. The other magnet has a 170 mm room temperature bore with overall dimensions of 980 mm in diameter and 1015mm in height. This magnet is designed so as to be used with temperature controlled sample cryostats with an outer diameter of 168mm. The magnet is cooled with four 1W GM cryocoolers and charged with a single power supply. The magnet is successfully charged up to 15T in 120 minutes. Both magnets will enable high magnetic field research or application with very easy operation.

TUA3OR6

Fabrication of the Next Generation of Resistive Magnets at the NHMFL

M.D. Bird, S. Bole, J. Toth, NHMFL.

The National High Magnetic Field Laboratory in Tallahassee, Florida designs, builds and operates the world's highest field dc resistive magnets, providing fields up to 33 T in purely resistive systems and up to 45 T in resistive-superconducting hybrids. The next generation of magnets is presently being fabricated and will use technology developed for our hybrid magnet to upgrade the field in our various resistive magnets. Test results will be presented for the two new 20-MW magnets: the first providing 32 T in a 50-mm bore, the second 35 T in a 32-mm bore. Fabrication status will be provided for a third high-homogeneity magnet expected to provide 28 T with inhomogeniety of less than 50 ppm over a 10-mm diameter spherical volume in a 32-mm bore

Wednesday, September 21, 2005

PLENARY SESSION

8:30 - 10:00

(Maestrale room)

WEMPL1

Magnets for medicine: the increasing role of hadrontherapy

U. Amaldi, University of Milano Bicocca and TERA Foundation

Protontherapy is developing very fast. Five companies offer turn-key systems; three are based on synchrotrons, one on a normal conducting cyclotron and one on a superconducting cyclotron. Light ion therapy requires today the acceleration of carbon nuclei that carry six elementary charges to an energy that is more than twenty times larger than the one needed for the protons used in deep therapy which is 200 MeV. The two Japanese centres running in the Prefectures of Chiba and Hyogo and the two European centres, being built in Heidelberg and Pave, are based on the technically natural solution: synchrotrons having diameters of 20 meters and more. At present smaller synchrotrons are under study in Japan. The first issue to be discussed is the possible use of superconducting cyclotrons to bring carbon ions to an equivalent energy, about 4800 MeV i.e. 400 MeV/nucleon. The projects under study will be reviewed. Since 400 MeV/nucleon is an energy that implies large cyclotrons and heavy weights, the TERA design of a 'booster' linac capable of accelerating fully stripped carbon ions from 250-300 MeV/nucleon to 400 MeV/nucleon will be discussed. Superconducting cyclotrons would be more feasible if lighter ions could be used, as lithium or boron. This interesting possibility will also be explored. Gantries, especially light ion gantries, are another technical challenge. After a presentation of the solutions presently adopted, that are based on conventional magnets, the preliminary studies that consider superconducting magnets will be reviewed. Finally the difficulties and promises of the acceleration of 200 MeV protons in the interaction of short petawatt laser light pulses with thin foils will be shortly presented.

WEMPL2

Concepts and Development of Magnets for MRI X. Huang, P. Jarvis, General Electrics.

Magnetic resonance imaging (MRI) continues to be the most successful commercial application of superconducting magnet technology. The global installed base of ~30,000 systems grows by the addition of ~3000 new sockets each year. This talk reviews progress in MRI over 3 decades of development of cylindrical, open and niche systems. 1.5T systems continue to dominate the whole body (WB) market, however, the potential for increased signal-to-noise ration and/or patient productivity is fuelling a spectacular growth in the segment at >3T. We discuss design approaches and siting requirements for WB magnets up to 9.4T. At the other end of the field spectrum, we consider novel approaches to the design/manufacture of lower field WB permanent magnets and look at the developing concepts for the use of ultra-low field systems. Beyond full homogeneity WB systems, we review developed magnets and concepts for niche applications such as: interventional procedures, limb imaging, neo-natal imaging, the special considerations needed for multi-modality imaging such as MR/PET, and the addition of hyperpolarized applications. In a cost conscious industry, the drive for innovation in MR magnet technology, including the associated cryogenic systems and materials, continues unabated.

PARALLEL SESSION (Maestrale room) SUPERCONDUCTING ACCELERATOR MAGNETS

WEM10R1

Exotic Magnets for Accelerators P. Wanderer, BNL.

Over the last few years, several novel magnet designs have been introduced to meet the requirements of new, high performance accelerators. For example, the FAIR project at GSI requires superconducting magnets ramped at high rates (~ 2 T/s) in order to achieve the design intensity. Magnets for the RIA project in the US and for the next generation of LHC interaction regions will need to withstand high doses of radiation. Helical magnets are required to maintain and control the polarization of high energy protons at RHIC. In other cases, novel magnets have been designed in response to limited budgets and space. For example, it is planned to use combined function superconducting magnets for the 50 GeV proton transport line at J-PARC to satisfy both budget and performance requirements. Novel coil winding methods have been developed for short, large aperture magnets such as those used in the insertion region upgrade at BEPC. This paper will highlight the novel features of these exotic magnets.

WEM10R2

Simulation of Eddy-Current Losses in a Fast Ramped **Superconductive Dipole Magnet**

Koch, H. De Gersem, T. Weiland, Technische Universitaet Darmstadt; E. Fischer, G. Moritz, GSI.

For the synchrotron SIS-100 planned within the FAIR project at GSI Darmstadt, superconductive bending magnets are designed. These should be operated at fast ramp rates which give rise to eddy currents induced especially at the end plates of the magnets. Since the proposed design features cold iron at 4.5 K the resulting losses have to be calculated precisely to dimension the cryostats securely. The transient 3D simulation is performed using an implicit Runge-Kutta scheme for time integration and the Finite Integration Technique (FIT) for space discretisation. High flux densities of 2 T in the aperture require to consider the strongly non-linear material characteristics of the ferromagnetic yoke. Because of the skin depth being orders of magnitude less than the dimension of the whole magnet, a high mesh resolution is indispensable in order to determine the losses up to a sufficient accuracy. The laminated structure of the voke can not be resolved in the computational grid but is taken into account by an anisotropic material tensor for both the reluctivity and the conductivity. Results of the described simulations are presented and compared to measurements obtained at a test installation at GSI. Several design proposals for reducing the eddy-current losses are compared.

WEM10R3

New Results on Minimization AC Power Losses in a Fast Cycling 2T Superferric Dipole with a Cold Yoke

A. Kovalenko, H. Khodzhibagiyan, G. Kuznetsov, A. Smirnov, Joint Institute for Nuclear Research; E. Fischer, G. Moritz, GSI.

New results from the investigation of 2 T superferric model dipoles operating at 4 T/s, 1 Hz are presented. The works are performed within the R&D program on the design of the

10:30 - 12:20

SIS100 synchrotron at GSI in Darmstadt. One of the main research goals of the program is minimization of an overall AC power losses in the magnet at 4 K level. Different modifications of the dipole were proposed and tested experimentally. By the present time, the losses are reduced to 17 W per meter of the magnet length, while the reference Nuclotron dipole produce of about 38 W/m at the same operating mode. The essential design details of the model magnets are described. The futher R&D steps are discussed.

WEM10R4

Design, Fabrication and Test of a 2 Tesla Superconducting Transmission Line Magnet System

H. Piekarz, W. Foster, S. Hays, Y. Huang, V. Kashikhin, A. Oleck, R. Rabehl, P. Schlabach, G. Velev, FNAL; M. Wake, KEK.

A prototype of a superconducting transmission line magnet system proposed for an Injector Accelerator in a Staged VLHC P-P Collider has been built and successfully tested at Fermilab. A 1.5 m long, twin-aperture, combined function gradient dipole magnet of 2 Tesla field is excited by a single-turn 100 kA transmission line superconductor. The 100 kA DC current is generated in a switching converter consisting of 400 V, 240 kW bulk supply followed by 10 parallel, 10 kA each, DC-DC converter modules. A pair of 1.65 m long, horizontally placed conventional leads facilitates transfer of this current from the room temperature power supply poles to the magnet conductor lines operating at liquid helium temperature. The superconducting transmission line, the current leads and the power supply are all of original designs. The magnet features optimized pole configuration with saturation control pole holes. Fabrication of magnet components and magnet assembly technique are described and some implications for a large scale magnet production are briefly discussed. Results from the test magnet system operations and a summary of the magnetic field quality measurements are presented.

WEM10R5

Optimization of a 3x3 focusing array for heavy ion drivers

N.N. Martovetsky, LLNL; R. Menke, AML.

A heavy ion driver for inertial fusion will accelerate an array of beams through common induction cores and then direct the beams onto the DT target. An array of quadrupole focusing magnets is used to prevent beam expansion from space charge forces. In the array, the magnet fields from the coils embracing the beams are coupled, which reduces the cost of superconductor and increases the focusing power. The challenges in designing such an array are meeting the strict requirements for the quadrupole field inside the beam pipes and preventing stray fields outside. We report our optimization effort on designing such an array and show that 3x3 or larger arrays are feasible and practical to build with flat racetrack coils.

PARALLEL SESSION	10:30 - 12:20
(Scirocco/Libeccio room)	
FUSION MAGNET (I)	

WEM2OR1

Design, fabrication and test status of the coils for EAST Tokamak

P. Weng on behalf of EAST TEAM. Changed to plenary THMPL2.

WEM2OR2

30 Years of conductors for fusion. A summary and perspectives

P. Bruzzone, EPFL-CRPP.

Three decades of conductor R&D, prototypes, model coils and actual fusion devices are reviewed with special attention to the drivers of the design. The conductor options are affected by the boundary conditions typical of the fusion devices (large size, and stored energy, high field, heat removal rate). The mechanical loads, operating voltage, ac loss and stability further restrict the freedom of the designer. On the other hand, the evolution of the available technologies for cryogenics and superconducting materials opens new frontiers for performance, reliability and cost. The lessons learned from the a dozen of superconducting fusion devices are highlighted, starting from T-7, through MFTF, T-15, TRIAM, Tore Supra, LHD till the newest projects in construction, W-7X, HT-7U, SST-1, KSTAR. Some discussion is also devoted to the lessons that we keep refusing to learn.

WEM2OR3

A prototype superconducting magnet for 170 GHz Gyrotrons

M.I. Surin, V. Keilin, S. Miklyaev, S. Shevchenko, Kurchatov Institute; A. Fix, N. Kudriavsev, E. Sokolov, Jicom Ltd.

the frames of ITER Program a prototype In superconducting magnet for 170 GHz Gyrotrons was designed, manufactured and tested. The operating field 7.1 T in the center of 219 mm cold bore and 8.1 T at the winding corresponds to 183.5 A. In the final version of the magnet the operating field was reached without any training. A very specific field distribution along the axis was required with sharp decrease from both sides. To meet this requirement one of 5 subcoils has an opposite current direction. Both Nb3Sn and NbTi wires were used. Because of large axial forces (up to 40 Tons) a special support structure was used. For quench protection the subcoils were shunted with 16 resistive shunts. During the tests mechanical disturbances in the subcoils and support structure were observed by acoustic emission method. Axial field distribution measurements showed that it is in a good agreement with specification. Helium gas cooled 200 A HTS current leads for the magnet were designed and tested.

WEM2OR4

The ITER Central Solenoid Conductor

J.H. Schultz, T. Antaya, R.G. Ballinger, J. Feng, C-Y. Gung, H-H. Kim, P. Michael, J.V. Minervini, P. Titus, Plasma Science and Fusion Center, MIT; N. Martovetsky, LLNL.

The United States proposes to build the Central Solenoid for the International Thermonuclear Experimental Reactor (ITER), a fusion tokamak experiment with the goal of generating 500 MW of fusion power. The 6.4 GJ Central Solenoid (CS) provides most of the volt-seconds needed to induce and sustain a 15 MA plasma for burn times of > 400 s. The CS conductor has a peak field of 13 T and carries up to 45 kA. The five-stage cable has 1/3 copper and 2/3 advanced Nb3Sn strands in a thick superalloy conduit and is cooled by the forced-flow of supercritical helium through the cable space. Key design issues include the qualification of a conduit with adequate fatigue strength, minimizing performance damage from transverse Lorentz loads, and providing sufficiently rapid guench detection. Incoloy 908 was replaced by JK2LB as the reference conduit material in 2003. However, since that time, brittle equilibrium

phases have been discovered in JK2LB. Three US vendors are developing advanced internal tin Nb3Sn strands with 4.2 K, 12 T critical currents > 1,000 A/mm^2 and +/- 3 T hysteresis losses < 600 mJ/cc. 3D transient simulations, including transverse load effects, indicate a 1 K improvement in temperature margin, using Incoloy 908. One or two full-scale hairpin conductors will be tested in SULTAN to prove adequate cable performance under full transverse cyclic loads before solenoid testing.

WEM2OR5

Proposals for Cold Testing of the ITER TF Coils

P. Libeyre, D. Ciazynski, J-L. Duchateau, N. Dolgetta, C. Lyraud, Euratom-CEA Association; F. Kircher, T. Schild, CEA; W. Fietz, G. Zahn, FZK.

The ITER Toroidal Field (TF) magnet system will be made of 18 coils using Nb3Sn as superconducting material. These coils will operate at a maximum field of 11.8 T for a nominal current of 68 kA carried by a dual channel cablein-conduit conductor cooled by a forced flow of supercritical helium at 4.5 K. In each coil, seven 760 m conductor lengths wound in double pancakes will be connected to each other by low resistance joints. As a final step of the reception tests, it is proposed to perform cold tests of these coils at liquid helium temperature after completion of their manufacture. The testing shall include high voltage tests to check the quality of the insulation, leak tests and pressure drop measurements of the hydraulic circuits as well as measurement of the joint resistances. Testing the coils up to nominal current is a discussed option, addressing on one hand measurement of the electrical performances in self field and on the other hand the mechanical behaviour of the coils. To perform these tests, a dedicated test facility has to be built, allowing possible simultaneous testing of two coils, assembled together in a twin coil configuration, similarly to their assembly in the torus. The paper discusses the options, describes the outline design of the test facility, including a large cryostat, a 70 kA power supply and a dump circuit. In addition, details of the testing sequence are presented, which should allow to complete testing of two coils within about 100 days.

WEM2OR6

Progress in the Design, Manufacture and Testing of the Wendelstein 7-X Superconducting Magnets

C. Sborchia, J. Baldzuhn, K. Risse, T. Rummel, H. Viebke, Max-Planck-Institut für Plasmaphysik.

The W7-X machine is a low-shear stellarator of the Wendelstein line being assembled in Greifswald, Germany. magnet system of W7-X consists of 70 The superconducting coils integrated with the central support structure and intercoil elements, busbars, current leads and power supplies. The magnets are sub-divided into 50 nonplanar coils, which establish the basic magnetic confinement configuration, and 20 planar coils. They are manufactured with a superconducting NbTi cable coextruded in an Aluminium jacket. After insulation and pressure impregnation, are vacuum the windings embedded in stainless steel casings, which are then finishmachined and equipped with cooling systems. The manufacture of the magnets is in a well advanced phase. After the acceptance tests in the factory, the magnets are tested in cold conditions in a dedicated facility at CEA Saclay and, if successful, they are finally delivered to the assembly site. This paper will give an overview of the status of the manufacture of the W7-X coils, including the production of the superconductor, the windings and casings for the magnets, the final assembly and in-factory test procedures. Several design changes and re-work have

been implemented in the course of the manufacture due to more detailed engineering analyses or weaknesses found in the manufacturing procedures of some components. The status of the cold tests of the coils will also be presented with a general overview of the test results.

PARALLEL SESSION 10:30 - 12:00 (Ponente/Levante room) COOLING SYSTEMS & TEMPERATURE

COOLING SYSTEMS & TEMPERATURE MARGINS

WEM3OR1

A Desktop Cryogen Free Magnet For NMR and ESR J.A. Good, R. Mitchell, Cryogenic Ltd.

Cryogenic have built a miniature cryogen free magnet with 5 ppm uniformity at fields of 2.5 Tesla and 10-7 per hour in persistent mode. The magnet is cooled by a small refrigerator to 3K without the use of liquid helium. The overall dimensions of the cryostat are 260mm x 240mm x 540mm. The workspace is a bore of 51mm but other sizes are practical in the same geometry. For the lower field the system is designed to run with a 1 kilowatt air-cooled single-phase compressor making the magnet easy to use by non-specialists and to transport between locations. The magnet is intended for use in ESR as well as low field NMR experiments. It is thought to be the smallest high field superconducting NMR magnet yet built.

WEM3OR2

How the Performance of a Superconducting Magnet is affectedby the Connection between a Small Cooler and the Magnet

M.A. Green, LBNL.

As low temperature cryocoolers become more frequently used to cool superconducting magnets, it becomes increasingly apparent that the connection between the cooler and the magnet has an effect on the design and performance of the magnet. In general, the use of small coolers can be considered in two different temperature ranges; 1) from 3.8 to 4.8 K for magnet fabricated with LTS conductor and 2) from 20 to 35 K for magnets fabricated using HTS conductor. In general, both temperature ranges call for the use of a two-stage cooler. The best method for connecting a cooler to the magnet depends on a number of factors. There factors include: 1) whether the cooler must be used to cool down the magnet from room temperature, 2) whether the magnet must have one or more reservoirs of liquid cryogen to keep the magnet cold during a loss of cooling, and 3) the distance from the cooler cold heads and the magnet and its shield. Two methods for connecting low temperature coolers to superconducting magnets have been studied. The first method uses a cold strap to connect the cold heads to the loads. This method is commonly used for cryogen free magnets. The second method uses a heat pipe and liquid cryogens to make the connection between the load being cooled and the cold head. The two methods of transferring heat from the magnet to the cooler low temperature cold head are compared for the two temperature ranges given above.

WEM3OR3

Normal zone behavior of Y-Ba-Cu-O coated conductor with DC transport current

X. Wang, G. Zhang, Center for Advanced Power Systems, Florida State University; G. Merritt, U. Trociewitz, J. Schwartz, NHMFL; C. Adetu, FAMU-FSU Department of Electrical Engineering; M. Breschi, Department of Electrical Engineering, University of Bologna; C. Thieme, American Superconductor Corporation.

Normal zone initiation and propagation in an YBCO coated conductor with DC transport current is studied. The tape has a Cu stabilizer and NiW substrate and is conduction cooled in a vacuum environment. A heater made by NiCr wire is mounted on the Cu side of the tape to provide a localized heat pulse. Consecutive voltage taps and thermocouples along the tape monitor the voltage and temperature development after the heat pulse is applied. The temperature of the tape is adjustable by changing the temperature of the cold head where the tape is thermally anchored. The minimum quench energies and normal zone propagation velocities are measured as functions of the transport current with temperature of the tape ranging from 60 K to 80 K. The experimental results are reported and compared with the simulation results given by a onedimensional model.

WEM3OR4

Flow Visualization of Liquid Nitrogen during Quench and Recovery Processes of a Coated Conductor Sample for Fault Current Limiter Application

K. Nam, B-Y. Seok, S-W. Park, C. Lee, Electro-Mechanical Research Institute, Hyundai Heavy Industries Co., Ltd.

A flow visualization study of liquid nitrogen is performed to clarify two-phase flow patterns and related heat transfer characteristics during quench and recovery processes of high-Tc superconductor. A series of experiments are carried out using a YBCO coated conductor (CC) sample immersed in a liquid nitrogen bath. A pulse of DC or AC power input is applied to the CC sample to simulate the fault condition. The magnitude of the heat generation in the CC sample is extremely high (100~500 W/cm2) and the period of the heat generation is very short (50~100 msec), which are typical operating conditions of the large scale high-Tc superconducting fault current limiter (HTS FCL). Bubble and vapor film behavior is observed by recording their motions using a high-speed CCD camera during the quench and the recovery periods. Experimental results show that the nucleate boiling period is very short, and hence the film boiling region is dominant during the quench process. The thickness of the vapor film on the CC sample is observed and the correlations of the growth and the decay rate of the film are made, which is essential for the thermal design of the HTS FCL.

POSTER SESSION 13:30 - 15:30 LOW TC SUPERCONDUCTORS (II)

WEA01PO01

AC loss and contact resistance of Nb3Sn Rutherford cables in response to variation of surface condition and heat treatment

E.W. Collings, M. Sumption, LASM, MSE, Ohio State University; D. Dietderich, Berkeley National Lab; Y. Ilyin, A. Nijhuis, Low Temperature Division, Faculty of Applied Physics.

Calorimetric and magnetic techniques were used to measure AC loss in uncored Nb3Sn Rutherford cables the field-perpendicular and field-parallel orientations of the applied field. The five cables selected for study had widths of 8, 13, and 16 mm and strand counts of 20, 30, and 36, respectively. Under various surface conditions describable as "as-cabled", "solvent-rinsed", or "HCI-rinsed", they were reaction heat treated (RHT) then vacuum impregnated with resin in preparation for measurement. The calorimetric measurements were made at 4.2 K in sinusoidal fields of amplitude 400 mT and frequencies of 5 to 90 mHz, and the magnetic measurements over the same frequency range using the pick-up coil method on cable samples already installed in the calorimeter. The total per-cycle loss so obtained was also expressed in terms of the interstrand contact resistances (ICR). On some of the cables ICR data were also obtained using the four-terminal transport method for comparison with the calorimetric and magnetic results. Attention is focused on the ICR of one particular 8mm/20-strand cable measured under several pre-RHT/RHT conditions: (i) as-received plus mild RHT, (ii) asreceived plus plus standard RHT, (iii) acetone-degreased plus standard RHT, and (iv) acetone-degreased then HCIdeoxidized plus standard RHT.

WEA01PO02

Nb3AI Wire Development for Future Accelerator Magnet

K. Tsuchiya, A. Terashima, KEK; T. Takeuchi, N. Banno, S. Nimori, NIMS; T. Ikeda, T. Higuchi, Nomura Plating Co., Ltd; J. Obama, Y. Seki, T. Takao, Sophia University.

Recent developments in RHQ Nb3Al wire for accelerator magnet are presented and discussed. Two main items of the development are to increase the non-copper Jc and to find a good stabilization method. For the former item, several test wires with different Nb matrix ratio were made and the effect of the Nb matrix ratio on the Jc were investigated in correlation with the heat treatment and area reduction conditions after a RHQ process. For the latter item, we developed a special copper electroplating technique and succeeded to deposit a thick Cu layer on the surface of the wire. The mechanical bonding strength and the electrical characteristics of the Cu layer were studied by bending and drawing the wire, and by measuring its resistivity. Although the present piece length of the Cu stabilized Nb3Al wire is about 40 cm, we can draw and reduce the wire down to 50 % of the original diameter, without breaking the wire and damaging the bonding of the Cu stabilizer.

WEA01PO03

Design Optimisation of Superconducting Resistive-Core Cables

M. Calvi, L. Bottura, M. Coccoli, A. Siemko, CERN; P.P. Granieri, University of Bologna.

High field superconducting Nb3Sn magnets above 14T, for future high energy physics accelerators, call for improvements in the design of the protection system against resistive transitions. The longitudinal quench propagation velocity (vg) is one of the parameters defining the requirements of the protection. Up to now vq has been always considered as a physical parameter defined by the operating conditions (the bath temperature, cooling conditions, the magnetic field and the over all current density) and the type of superconductor and stabilizer used. It is possible to enhance the quench propagation velocity by segregating a percent of the copper stabilizer into the core of the cable and tuning the contact resistance between the superconducting strands and the core. The total amount of stabilizer remains constant. Computer simulations and analytical model are presented to explain the phenomenon. The consequences with respect to minimum quench energy are evidenced and the strategy to optimize the cable designed is discussed.

WEA01PO04

Superconducting Properties of Sn Added RHQT-Nb3Al Wires through the Clad-Chip Extrusion Method

S. Saito, N. Kodaira, Y. Kikuchi, T. Iijima, S. Takeuchi, S. Nimori, Ishikaga Institute of Technology.

Fabrication and superconducting properties of Sn added Nb3Al wires are presented. The adopted process consists of the clad-chip extrusion (CCE) method and the rapidheating, quenching and transformation (RHQT) treatment. The former (CCE) is characterized by the extrusion of thin chips of Nb/Al clad-rolled sheet and can produce the Sn added Nb/Al composite precursor wire with the intended chemical composition. The latter (RHQT) is a heattreatment method to transform the precursor wire into A15 intermetallic compound of Nb3AI. It can produce not only the nearly stoicheometric composition but also fine grain of Nb3AI which are favorable for upgrading the superconducting properties. The combined process of CCE and RHQT successfully fabricated several kinds of Snadded Nb3Al wires with Sn-concentration from 1.25 at% to 5at%. Sn-addition affected the RHQT treatment condition to transform to A15 phase from the precursor wire. The BCC supersaturated solid solution became unstable just after the RHQ-treatment and A15-phase became predominant with increasing Sn-addition. The RHQTtreated Nb3Al wire with nearly 2 at% Sn showed the maximum Tc. The Sn-addtion to the RHQT-Nb3Al wire enhanced the critical field of Bc2 (4.2K) though they showed decreasing Jc at lower magnetic fields than 20T comparing with binary Nb3Al wires.

WEA01PO05

Strain and Temperature Dependence of Nb3Sn Strands in Critical Current

S. Oh, J. Kim, C. Lee, K.W. Cho, K. Kim, Korea Basic Science Institute; P-Y. Park, Kiswire Advanced Technology.

A through understanding of the superconducting properties of Nb3Sn strands to strain is important for the proper performance prediction of large superconducting fusion magnets where the strands are used in large multi-strand cable-in-conduit conductors at high magnetic field. A variable-temperature WASP(Walter Spring) probe is developed for the critical current density measurement of Nb3Sn strands as a function of strain, field and temperature. Both the compressive and tensile strain can be applied up to 0.7 % while the temperature varies from 4.2 K to 16 K under the magnetic field up to 16 T. Several types of internal tin Nb3Sn strands (Jc > 900 A/mm2 at 12 T and 4.2 K) optimized for the ITER TF(Toroidal Field) coils are investigated for the comparative study on the axial strain and temperature dependence of the critical current.

WEA01PO06

Critical Current of Nb3Sn Strands under Axial and Transverse Stress

S. Oh, J. Kim, C. Lee, K. Kim, Korea Basic Science Institute.

In Nb3Sn cable-in-conduit conductors for large scale superconducting magnet applications, an axial stress is applied to the strand by the thermal contraction difference between the jacket material and the stand. During the high field operation, there is an additional transverse stress in the cable due to Lorentz force. In order to investigate the effect of the stress by two major causes, a new device is developed which can apply both the axial and transverse stress. The axial strain can be applied reversibly from -0.7

to 0.7 % to the strand soldered on a C-shape ring and the compressive transverse force is applied up to 4 kN. A preliminary result on the combined effect of axial and transverse stress on the critical current of Nb3Sn strands optimized for the ITER TF(Toroidal Field) coils is presented.

WEA01PO07

High field performance of bronze-processed Nb3Sn near Bc2

H. Kurahashi, K. Itoh, S. Matsumoto, T. Kiyoshi, NIMS; Y. Muramaki, H. Yasunaka, JASTEC; H. Wada, University of Tokyo; T. Miyazaki, Kobe Steel, Ltd.

The multifilamentary Nb3Sn superconductors made by the so called bronze process are now commercially available and a 930 MHz (=21.9T) high field NMR magnet wound by this type of Nb3Sn conductor was recently successfully manufactured. Meanwhile, there has been growing recognition that superconductors with high field performance are needed to manufacture high field magnets over 22 T. To improve the high field performance of Nb3Sn conductors, the addition of one or more third elements to the bronze matrix and/or Nb-core is well known to be quite effective. Previously, we have measured the upper critical magnetic field of bronze-processed Nb3Sn with and without the addition of various third-elements to the bronze matrix. In this study, we have investigated the effect of each element, reaction temperature and critical magnetic field on the critical current. The results will be discussed based on metallurgical observations by XRD, SEM, and EPMA.

WEA01P008

Prebending strain effect on CuNb/Nb3Sn superconducting wire during practical react-and-wind process

G. Nishijima, H. Oguro, S. Awaji, K. Watanabe, Institute for Materials Research, Tohoku University; K. Katagiri, Iwate University; K. Miyoshi, S-I. Meguro, The Furukawa Electric, Co., Ltd.

Prebending strain effect is that the repeated bending load at room temperature enhances superconducting properties of practical Nb3Sn wires. The authors are now focusing the application of the effect to practical superconducting coils fabricated by the react-and-wind method. The 1.0-mm diameter CuNb/Nb3Sn wire, which was heat-treated at 670 C for 96 hours, was insulated with polyimide tape wrapping. The insulated wire was pulled into the pulleys for the prebending process. The wire was repeatedly bent by using 10 pulleys. Prebending strain values were controlled by changing the pulley diameters; 100 mm for 1.0 % prebending, 125 mm for 0.8 % prebending, 200 mm for 0.5 % prebending, respectively. Finally, the prebent wire was wound on a 200 mm diameter stainless steel bobbin. To investigate the superconducting and mechanical properties, short samples were picked out in each process; after the heat treatment (HT), after the insulation wrapping (IW), and after the prebending process (PP). Magnetic field dependence of critical current (Ic) was measured at 4.2 K in the fields up to 25 T. Tensile stress/strain dependence of Ic was also measured at 4.2 K in 14 T. The measured Ic was 154 A, 183 A, 204 A for the samples HT, IW, and PP(1.0% prebending), respectively. The slope of the stress-strain curve for the sample PP was steeper than that for the sample HT, implying the effect of work hardening caused by the repeated prebending strains.

WEA01PO09

Fabrication of Cu stabilizer into long-length RHQTprocessed Nb3AI round wire

A. Kikuchi, T. Takeuchi, H. Kitaguchi, Y. Iijima, N. Banno, NIMS; Y. Sakurai, K. Tagawa, Hitachi Cable, Ltd.

For the practical conductors with large current capacity, the Cu stabilizer is necessary in order to obtain their fully performance. We successfully developed the reel-to-reel Cu ion-plating technique for fabricating the Cu stabilizer RHQT(rapid-heating/quenching into the and transformation)-processed Nb3AI round wires. Although stable Nb oxide layer is formed on the wire surface, the Cu ion-plating can continuously remove them and cover the Cu seed-layer of 1 micron in thickness. Then, the Cu stabilizer can be fabricated by the reel-to-reel Cu electroplating with an appropriate of Cu ratio. Because of good bonding between the Cu stabilizer and Nb3Al wire, it was possible to apply the wire drawing by conventional die after the Cu electro-plating. This is very attractive advantage for obtaining the severe homogeneity of the wire diameter in long-length. In this paper, we will also report results of RRR and Jc(4.2K)-B performance for Cu-stabilized RHQT-Nb3AI round wires having 1 mm in outer-diameter and about 1 of Cu/non-Cu ratio. A part of this study was financially supported by the Research Promotion Bureau of MEXT and by the Budget for Nuclear Research of MEXT.

WEA01PO10

Evaluation of the residual strain for the prebent bronze route (Nb, Ti)3Sn wires by a neutron diffraction

S. Awaji, H. Oguro, G. Nishijima, K. Watanabe, S. Harjo, T. Kamiyama, High Field Laboratory for Superconducting Materials, IMR, Tohoku University; K. Katagiri, Fac. Engineering, Iwate University.

We have found that a prebending treatment, i.e., a repeating bending load at room temperature, improves the superconducting properties such as Tc, Bc2 and Jc for the bronze route Nb3Sn wires. The enhancement of Jc due to the prebending strain comes from both a reduction of the axial prestrain and an increase of the maximum Jc in the strain dependence of Jc. These experimental results suggest that the three dimensional residual strain states were changed by the prebending treatment. In order to understand the residual strain states, we performed a neutron diffraction measurement for bronze route (Nb, Ti)3Sn wires. The axial and lateral residual strains of the (Nb, Ti)3Sn wire without a prebending treatment, which were determined by the comparison with the X-ray diffraction result for the (Nb, Ti)3Sn filaments of the same wires, were about -0.10 % and 0.03 % at room temperature, respectively. Here, the tensile strain is taken as a positive value in this study. By applying the prebending strain of 0.5 %, we found that the residual strains became 0.02 % for axial direction and 0.03 % for lateral direction. Hence, only axial residual strain was changed about 0.12 % toward tensile side by the prebending treatment. This residual strain change along axial direction is in agreement with the shift of the prestrain in the axial tensile strain dependence of Jc.

WEA01PO11

Superconducting properties of Nb/Al-Ge wire by pulsed ohmic heating in high pressure

Y. lijima, A Kikuchi, N. Banno, T. Takeuchi, M. Kosuge, M. Yuyama, NIMS.

Nb3(Al,Ge) is very promising as a high magnetic field superconducting material, because obtained is a higher Tc and Bc2 compared to a practical use superconducting wire including the binary RHQT processed Nb3Al. Since much higher cooling rate seems to be required for the ternary Nb3(Al,Ge) solid-solution formation, an attempt was made to rapid cool the Nb/Al-Ge precursor wire with a technique other than the common RHQ. A change of coolant material may enhance the cooling rate, and thus we have performed a pulsed ohmic heating of precursor wire in various coolants: Si oil, liquid nitrogen and vacuum as reference. In these coolants, the rapid heating was possible but we could not get enough quenching rate, probably because of the film boiling of coolant. We thought that the pressurization of coolant might suppress the film boiling and thus improve the cooling efficiency. In the present study, we performed a pulsed ohmic heating in Si oil pressurized up to 100MPa for the Nb/Al-20at%Ge wire prepared by RIT method. We will report the details of pulsed heat-treatments in the high pressurized Si-oil coolant to give excellent superconducting properties. Microstructures obtained would be also presented.

WEA01PO12

Field and strain dependence of critical properties in transformed Nb3Al conductors

N. Banno, T. Takeuchi, NIMS; D. Uglietti, B. Seeber, R. Flukiger, Univ. Geneva.

The Nb3AI wire could be still a candidate for high field accelerator magnets because of the strain tolerance. The critical current (Ic) - longitudinal strain characteristics for transformed Nb3Al conductors have been measured at fields up to 21 T at 4.2 K, using the modified Walters spring (WASP). The device allows to measure long length wires, which was helpful to precisely determine the n-value from the V-I curve. The n-value characteristics as a function of strain are also shown. A Nb matrix standard wire and a Cuclad stabilized wire were used for the measurement. The Ic - strain characteristics had a clear field dependence in the high magnetic field range. At the intrinsic compressive strain of 0.3 % at 4.2 K, the degradation of the critical current is about 7 % and 16 % at 17 T and 21 T, respectively. The measured data were scaled with an empirical scaling law with specifically given constants for the Nb3Al wires.

WEA01P013

A potential benefit of chromium plating on Nb3Sn/Cu composite wires used for wind-and-react magnet manufacture

D-W. Ha, J. Miller, K. Han, NHMFL.

A typical approach to building magnets with multifilamentary Nb3Sn/Cu composite wire is to wrap or overbraid the wire with glass fiber, wind the coil, perform the Nb3Sn-reaction heat treatment, and then impregnate the wound coil with epoxy resin to complete the insulation process. An important issue in this process is the removal (to the degree possible) of the sizing typically used on the glass fiber, which is reduced to carbon during the heat treatment and can compromise the insulation integrity. We explore the use of Cr plating on the wire, which would allow that carbon to be burned off by introducing oxygen (air) into the furnace during a final stage of the heat treatment without deleterious oxidation of the Cu in the superconducting composite wire. We present results of microstructure examination and RRR of Cr-coated Cu wires, heat-treated according to typical Nb3Sn-reaction schedules. We will also discuss the feasibility for using such a technique to wind magnet coils and the possibility of performing electrical and mechanical tests of small model coils processed in the proposed manner.

WEA01PO14

In-field Transport Properties of Nb3Sn Wire Samples under Strain

U.P. Trociewitz, B. Trociewitz, R. Walsh, V. Toplosky, K. Han, J. Miller, NHMFL.

A device to investigate axial strain in Nb3Sn wire samples has been built and tested to generate a data basis for the upcoming high field magnet projects of the NHMFL. The device allows measuring 130 mm long straight samples in the NHMFL 195 mm diameter large bore resistive magnet. With the use of a gear system very small strain steps can be applied. The samples are soldered on a stainless steel backing and the strain is measured using an extensometer that clips onto the sample backing thus eliminating strain gauge mounting issues on the samples. Lorentz-force induced strain contributions are eliminated by having the sample assembly move against a rigid steel support. Results of Ic(B,e) measurements at 4.2 K and n-values are presented.

WEA01P015

Scaling of the V-I Characteristics in the ITER Type Nb3Sn Strands in Relation to the Applied Strain and Magnetic Field

A. Vorobieva, N. Kozlenkova, A. Shikov, V. Pantsyrny, K. Mareev, Y. Konovalov, Bochvar Institute of Inorganic Materials; S. Nokikov, Kurchatovskiy Institute.

The knowledge of the scaling of voltage-current characteristics as a function of temperature, magnetic field and strain is a very useful additional tool (to scaling Jc (T, B, e)) for the design of superconducting magnets. The results of description of the experimental VCC (e, B, 4.2K) are presented in this work. VCC (e, B, 4.2K) have been measured in the range of the applied axial tensile strain from 0% to 0.4% at magnetic fields up to 12 T for ITER type bronze processed Nb3Sn strand. To describe experimental database V-C characteristics versus strain and magnetic field the relation is used containing four fitting parameters. Three parameters, namely: C, Tcm (0), and Hcm(0) describe Ic (T, B, e). Additional parameter characterizes the smoothness of VCcharacteristics. To determine these fitting parameters the experimental database of VCC obtained for Nb3Sn strands is transformed into computer program. Good agreement of experiment and calculation has been obtained.

POSTER SESSION	13:30 - 15:30
HIGH Tc SUPERCONDUCTORS (I)	

WEA02PO01

Susceptibility and high harmonics study in SnMo6S8 and YBa2Cu3Oy polycrystalline superconductors

I.R. Metskhvarishvili, M. Metskhvarishvili, Iv. Javakhishvili Tbilisi State University; S. Ginzburg, E. Tarovik, V. Khavronin, Petersburg Institute of Nuclear Physics, Russian Academy.

The ac susceptibility and high harmonics response of low and high temperature polycrystalline superconductors is measured in very weak ac and dc magnetic fields. The experimental results agree satisfactorily with the theory of the critical state in the framework of low-field electrodynamics. Experimental data show that the critical current density does not depend on the dc magnetic field for SnMo6S8 and squire dependence exists for YBa2Cu3Oy.

WEA02PO02

Distribution of mechanical properties in a single-grain Sm123 bulk superconductor at liquid nitrogen temperature

A. Murakami, H. Miyata, Faculty of Science and Technology, Hirosaki University; K. Katagiri, K. Kasaba, Y. Shoji, Faculty of Engineering, Iwate University.

In order to investigate the mechanical properties of a Sm123 bulk superconductor with 10 wt% Ag at liquid nitrogen temperature, 3-point bending tests by monotonic and repeated c-axis loadings of specimens cut from the bulk were carried out. As a result of the tests by monotonic loading, the Young's modulus and the bending strength scattered from 66 to 149 GPa and 38 to 107 MPa, respectively. The maximum strength obtained near the seed was equal to that of Y123 without Ag and slightly lower than that of Gd123 with 10 wt% Ag. This location of the maximum strength almost coincided with that in the previous result for the tensile test of Sm123 at room temperature. On the other hand, the minimum strength obtained at the location remote from the seed was significantly lower than that of Y123 and Gd123, 74 and 83 MPa, respectively. This is ascribed to the exceptional preexisting defects because the stress-strain curve for this specimen showed non-linear behavior. From the observations on the fracture surfaces, large voids were found in the tensile side surface region of this specimen. Except for specimen with non-linear curve, the minimum strength, 62 MPa, was comparable to that of the other bulks. The fracture stress by repeated loading up to 50,000 cycles scattered from 70 to 90 MPa. The fatigue endurance limit was estimated to be 60 MPa. Based on these results, techniques to cut and use the bulks for the application to practical devices such as current leads are discussed.

WEA02PO03

Low-Thermal-Conductive DyBaCuO Bulk Superconductor for Current Lead Application

H. Fujishiro, A. Fujiwara, M. Ikebe, Iwate University; H. Teshima, H. Hirano, Nippon Steel Co. Ltd.

The superconducting current lead using the melt-textured REBaCuO superconducting bulks is one of the exemplary models for practical applications, where both the low thermal conductivity k and the high critical current density Jc are the indispensable conditions. The REBaCuO bulk is a composite material and the temperature dependence of k(T) mainly depends on the quality of the RE123 phase, the content, size and dispersion of the RE211 phase. For the RE=Nd, Sm, Gd and YBaCuO systems, the k(T) data have been reported. However, there is no reports for k(T)of the DyBaCuO bulk. In this paper, we study the thermal properties (k(T), thermal diffusivity a(T), thermal dilatation dL(T)/L etc.) of the DyBaCuO bulk in the ab-plane and along the c-axis. The ab-plane k(T) is fairly lower than that of the YBaCuO and GdBaCuO bulks and is as small as that of the SmBaCuO bulk, in which Sm ions are partly substituted for the Ba site, acting as the strong phonon scattering centers. The Dy ions may be also substituted for the Ba site, although DyBaCuO is widely believed to be the non-substituting system. We fabricated the power current lead using the DyBaCuO bulk and measured the currentvoltage (I-V) characteristics and the endurance due to the quenching to liquid N2. The DyBaCuO lead shows an excellent electrical properties and the mechanical strength similarly to those of the YBaCuO lead. We discuss on the possibility of the DyBaCuO bulk to the power current lead application.

WEA02PO04

Transport Loss Characteristics of a Technical High Tc Superconductor in an External AC Magnetic Field

K.W. Ryu, Chonnam National University; H.J. Kim, K.J. Seong, Korea Electrotechnology Research Institute.

A Bi-2223 tape has been developed for power applications such as a fault current limiter, a power cable and a superconducting magnetic energy storage system. In such applications, the Bi-2223 tape carries time varying transport current and in addition experiences time varying external magnetic field. It is well known that the external magnetic field not only causes magnetization loss in the Bi-2223 tape, but also drastically increases transport loss due to a so-called "dynamic resistance". We developed an evaluation set-up, which can measure transport loss in external ac magnetic field. Using this equipment, we measured the dynamic resistances for various amplitudes and frequencies of external ac magnetic field perpendicular to the face in the tape. Simultaneously we investigated the effect of external ac field on transport loss with different experimental conditions. This paper describes test results and discussions on correlation between the dynamic resistance and the transport loss for various technical Bi-2223 tapes.

WEA02PO05

Quench Propagation Characteristics of the Liquid Nitrogen Cooled HTS Wires by Externally Injected Heat Energy

K.Y. Yoon, D.K. Bae, H. Kang, M.C. Ahn, T.K. Ko, Yonsei University; S-J. Lee, Uiduk University; H.M. Kim, LG Industrial Systems; Y.S. Yoon, Ansan College of Technology.

With the successful commercialization of Bi-2223 powderin-tube wire, many attempts to the R & D of the high-Tc superconducting (HTS) magnets for high magnetic field applications are now being implemented actively. Although operating temperature of HTS magnet must be kept in the designed level, the magnetic energy and mechanical disturbance can make the operational temperature of HTS magnet unstable. Especially, generated heat energy of inner HTS winding is apt to accumulate, so the normal region appears in HTS winding. This paper deals with the quenching characteristic of reinforced Bi-2223 wire and two bare Bi-2223 wires in adiabatic condition. The minimum quench energy (MQE) of HTS wires was affected by the material and ratio of their matrix. In the same condition, the normal zone propagation (NZP) energy of non-reinforced HTS wire was smaller than that of reinforced HTS wire.

WEA02PO06

A new model of two directional Jc distributions for Bi2Sr2CaCu2O8 materials

K. Takahashi, S. Awaji, G. Nishijima, K. Watanabe, High Field Laboratory for Superconducting Materials, IMR, Tohoku University

E-J properties of the high-Tc materials are related to the distribution of the local critical current density Jc. From the previous results of Bi2212 thick films and practical Agsheathed Bi2212 tapes, we found that the distribution of the local Jc is much affected by microstructures, and the local Jc distribution becomes broad and asymmetric for well aligned plate-like Bi2212 grains. However, from a viewpoint of microstructures, the origin of the asymmetric Jc distribution remains unclear. In order to understand the relationship between the Jc distribution of Bi2212 materials and microstructure, we propose a "two directional Jc distribution is expressed by the sum of ab- and c-directional components. Since the ratio of the cross-sections for two directions is taken account in this model, we can consider the effect of an aspect ratio of a grain on the Jc distribution. In the case of plate-like Bi2212 grains with a large aspect ratio, we found that the c-directional component of Jc distribution becomes large and whole Jc distribution becomes asymmetric shape. The asymmetric Jc distribution gives the small n-value of E-J properties. Bi2212 materials are usually produced by melt growth process and the aspect ratio of each grain becomes large, compared with Bi2223 materials which produced by sintering process. Therefore, Bi2212 materials reveal essentially that the n-value becomes small even high Jc materials.

WEA02PO07

Effect of Critical Current Density on AC Loss Behavior of (Bi,Pb)2Sr2Ca2Cu3Ox Tapes

D. Nguyen, P. Sastry, G. Zhang, Center for Advanced Power Systems and Department of Physics, FSU; J. Schwartz, FAMU-FSU Department of Mechanical Engineering, CAPS and NHMFL.

According to Norris's model, self-field AC losses in superconducting wire with a given cross-section depend only on critical current. In this study, all samples are considered to have similar cross-section as they are all from the same conductor batch. The critical current, however, was varied in three different ways. In the first approach, mechanical stress was used, in the second approach the heat treatments were varied, and in the third approach DC magnetic fields were applied. As a result, critical current varied from 10 A to 120 A at 77 K. AC loss measurements were carried out by electromagnetic methods. Results of the three approaches are compared and the reasons for the effect of critical current on AC loss are explained.

WEA02PO08

Statistical Analysis of Electro-Mechanical Properties of AgMg Sheathed Bi2Sr2CaCu2Ox Superconducting Tapes Using a Weibull Distribution

A.L. Mbaruku, A. Lazic, J. Schwartz, FAMU-FSU College of Engineering, Center for Advanced Power Systems.

Studies on the Microstructural studies across sections of AgMg sheathed Bi2Sr2CaCu2Ox superconducting tapes have shown that the microstructure is often non-uniform. Consequently the mechanical properties and the electrical transport properties can vary from section to section. Here, we report the electro-mechanical properties of the tape at different sections at the critical strain where critical current degrades. Twenty samples have been studied at this strain and we report the probability of failure of these tapes by using a Weibull distribution.

WEA02PO09

Effects of Mechanical Fatigue on Bi2Sr2Ca2Cu3Ox Tape Conductors

A.L. Mbaruku, J. Schwartz, FAMU-FSU College of Engineering, Center for Advanced Power Systems; U. Trociewitz, NHMFL.

Superconducting materials are subjected to various loading in motors, transformers, generators and other magnet applications. The loading conditions include bending, tension, compression, and fatigue. Each of these loading conditions has an effect on the performance of the superconductor. It is important therefore to understand the properties of the superconducting material to optimize the design. Here we report the effects of fatigue loading at 77 K on the transport properties of Ag-sheathed Bi2Sr2Ca2Cu3Ox tapes. The effects of longitudinal tensile fatigue on critical current and n-value are reported. Fatigue studies include strains up to 0.1 %. Scanning electron micrographs of the fatigued conductors are used to identify the sources of failure in conductors.

WEA02PO10

Quench Behavior of YBa2Cu3O7 Coated Conductors with an AC Transport Current

J. Schwartz, U. Trociewitz, NHMFL; D. Knonll, D. Nguyen, P. Sastry, X. Wang, G. Zhang, Center for Advanced Power Systems, Florida State University; C. Thieme, American Superconductor Corp.

Normal zone creation and guench propagation measurements were performed on YBa2Cu3O7 coated conductors with AC transport current. The minimum quench energy and the quench propagation velocity were measured as a function of temperature, AC transport current and frequency. Self-field AC losses of the tapes were also measured at the same temperatures and currents to calculate the internal thermal loads. The samples were conductively cooled in vacuum using a cryocooler. A resistive heater was used to create a local normal zone whose propagation was followed through temperature and voltage measurements along the sample length. An analysis of the results is presented.

WEA02PO11

Temperature Dependence of Critical Currents and AC Losses of Bi2Sr2Ca2Cu3Ox and YBa2Cu3Ox Tapes

J. Schwartz, U. Trociewitz, NHMFL; D. Knonll, D. Nguyen, P. Sastry, X. Wang, G. Zhang, Center for Advanced Power Systems, Florida State University; C. Thieme, American Superconductor Corp.

Critical currents and AC transport losses of YBa2Cu3Ox and Bi2Sr2Ca2Cu3Ox tapes were measured between 40 K and 80 K. The AC losses were measured electrically at power frequency using the lock-in method. The samples were conduction cooled by a cryocooler and a temperature controller was used to maintain a constant temperature. AC losses were measured for transport current frequencies between 50 Hz and 500 Hz. Results of the analysis of the temperature and frequency dependence of critical current and AC losses are presented.

WEA02PO12

Optimization and Design of the Permanent Magnet Guideway with the High Temperature Superconductor

H. Song, J. Zheng, X. Wang, S. Wang, J. Wang, Southwest Jiaotong University.

To optimize the high temperature superconductor (HTS) and permanent magnet guideway (PMG) levitation system, the levitation and guidance forces were calculated for different kinds of the PMG. Given a cross section area of the permanent magnet and the superconductor arrays, the ratio between the thickness and width of the PMG has adverse influence on levitation and guidance force. It seems that, the more the thickness, the more the levitation force, the less the guidance force. Moreover the materials and geometries of the PMG were verified, it was found that the iron has great influence on the flux distribution and even the levitation or guidance force. Additionally, the cross section of the PMG was changed from rectangle to trapezium in size and its optimum design was present for the given HTS arrays in the end.

WEA02PO13

Alternating current characterization of the HTS Bi2223/Ag High Strength Tape under magnetic field

produced by direct current

E. Ruppert Filho, R. Cassiolato de Freitas, State University of Campinas; C. Alberto Baldan, C. Yujiro Shigue, Chemical Engineering Faculty of Lorena.

HTS tapes are commercially available for applications in power system devices. However to do that it is necessary to have the superconductor material characteristic curve which relates the values of the critical AC electrical current circulating in the material with the magnetic flux density at the material surface at 77K. This paper presents a methodology to construct the characteristic curve of the HTS Bi2223/Ag High Strength Tape, manufactured by the American Superconductor, under DC magnetic field using a short material sample. The DC magnetic field is produced by an electromechanical device constituted by a magnetic core with a small air-gap and an insulated copper wire coil wound on one of its columns carrying DC electrical current. The material sample is inserted in the air-gap firstly in perpendicular position, and after in parallel position, related to the air-gap magnetic field . Many different curves relating rms AC voltage between the sample terminals with the AC rms current in the sample are constructed for different values of the magnetic flux density. The critical current value for each magnetic flux density value is the one where the voltage on the sample reaches a defined value. Care must be taken with the measurements and positioning of the sample in the test assembly. The methodology, data test assembly, a lot of results for perpendicular and parallel position of the tape and the conclusions are completely reported in the paper.

WEA02PO14

Analysis of residual Bi-2212 in extracted Bi-2223/Ag filaments using X-ray diffraction

O. van der Meer, B. Metz, S. Harkema, B. ten Haken, H. ten Kate, University of Twente, Low Temperature Division; V. Vonk, H.Graafsma, ESRF.

Bi-2223/Ag superconducting tapes are made by a powderin-tube process in which the Bi-2212 phase is converted into the desired Bi-2223 phase during several heat treatments. The critical current density Jc of state-of-the-art Bi-2223/Ag tapes in self field is about 400 A/mm2, which is about 15-20% of the maximum local values found by magneto-optical imaging. Magnetization experiments indicate that the residual 2212 concentration is closely correlated to the Jc of the superconductor. However such experiments provide no spatial information about the location of 2212 still present in the tape. Quantitative information on the local amount of Bi-2212 and its exact location is obtained from X-ray diffraction measurements. A very small but powerful X-ray beam of 1.5x13 µm2 is used provided by the ESRF. We studied the variation in residual Bi-2212 concentrations in three different filaments extracted from one tape and also at different location within the single filament. Regions of 5-20 µm size with lower and higher Bi-2212 concentrations are observed. In the paper the experimental set-up is presented, characteristic results are presented and the results are interpreted in relation to the transport properties of the Bi-2223 filaments.

WEA02PO15

Critical current degradation of Bi-2223 composite tapes induced by cyclical deformation and fatigue-related effects

C.Y. Shigue, U. Oliveira, F. Carvalho-Junior, C. Baldan, DEMAR/FAENQUIL; E. Ruppert-Filho, State University of Campinas.

Superconductors based on the HTS Bi2Sr2Ca2Cu3Ox (Bi-2223) compound embedded in an Ag matrix have been

developed in an industrial production scale in which a combination of small diameter filaments and a ductile metal matrix results in a conductor with low crack formation and good tolerance against strain. The critical current and the n-index of Bi-2223/Ag composite tapes subjected to an initial bending strain as a function of number of thermal cycles were previously studied. The mechanical test essay of dependence of critical current in terms of number of thermal cycling is of great interest in the long term reliability evaluation of superconducting tapes aiming its use in power apparatuses. In this work we have been studying the mechanical and the superconducting characteristics of exsitu reinforced Bi-2223/Ag tapes subjected to cyclical bending strain applied through a mechanical testing machine and by thermal cycling between 77 K and room temperature. The microstructure of deformed samples were visualized by scanning electron microscopy and observed the formation and growth of cracks responsible by the critical current degradation. The results were analyzed in terms of critical current degradation and evaluation of n-index of I-V characteristic curves.

POSTER SESSION 13:30 - 15:30 CRYOGENICS & CURRENT LEADS

WEA03PO01

Characteristics of Cryogenic Temperature Sensors under Magnetic Fields

Y.P. Filippov, Joint Institute for Nuclear Research; Y. Dedikov, G. Kytin, VNIIFTRI.

Physical installations with superconducting magnets require efficient systems for monitoring the operation characteristics of the cooled devices and cryogens. The value of temperature is one of the main parameters to determine the state of the cryogen or cooled device. This report presents the information about four types of Russian commercially available cryogenic temperature resistive sensors investigated at cryogenic temperatures at the magnetic field up to 9 T. They are platinum (PRT), rhodium-iron (RIRT), carbon-glass (CRT) and carbon TVO-resistors. The equations to calculate the temperature shifts due to the magnetic fields for temperature sensors are given.

WEA03PO02

Experimental investigation of the heat transfer characteristics of liquid nitrogen in the capillary tubes *P. Zhang, X. Ren, W. Wang, Shanghai Jiao Tong University.*

In the present study, a thin wire heater (0.05mm in diameter) is confined in the capillary tubes to simulate the cable-in-conduit conductor cooled by the pool boiling of liquid nitrogen. The heat transfer characteristics are experimentally investigated. Two types of the capillary tubes with the diameters of 1.2mm and 3.8mm are used in the experiments. The experiments are conducted under the inclination angles of 0 degree to 90 degree with the interval of 30 degree. It is found that the presence of the capillary tube can enhance the nucleate boiling heat transfer to quite large extent. The temperature of the thin wire heater drops at the starting of the nucleate boiling, and this temperature drop increases with the decrease of the capillary tube diameter. It is shown by the visualization that many vapor bubbles detach from the thin wire heater and form a large vapor column on the upper side of the capillary tube, which induces the perturbation to the fluid inside the capillary tube and accelerates the natural convection close to the thin wire heater. Thus, the heat transfer is enhanced. Critical heat fluxes (CHFs) in both the capillary tubes and open bath are measured. The measurement results show that both the inclination angle and the capillary tube diameter affect the value of CHF. The maximum of CHF appears at the inclination angle of 30 or 60 degree in the capillary tubes; while it appears at 0 degree in the open bath.

WEA03PO03

Numerical study of the transient heat transfer in He II: a comparison to Gorter-Mellink equation

P. Zhang, M. Murakami, W. Wang, Shanghai Jiao Tong University.

Superfluid helium (He II) is frequently used for the cooling of the superconducting magnet. The prediction of the heat transfer characteristics of He II is very essential to guarantee the stable work of the instruments cooled by He II. In the present study, the heat transfer process is analyzed numerically by using Landau's two-fluid model and Vinen's vortex equation. It is found from the analysis results that second sound wave plays very important role in the transient heat transfer in He II. A rather large portion of the heat is transported by second sound wave in the case of the smaller heat flux; and as the heat flux increases, the amount of the heat transported by second sound wave decreases. The heat left un-transported by second sound wave accumulates in the thermal boundary layer resulting from the highly dense quantum vortices, which leads to the high temperature region close to the heater surface. This high temperature region is then diffused gradually. The numerical results are compared to that of Gorter-Mellink equation which is generally used to describe the heat transfer in He II by analogy to the diffusive heat transfer equation. It is revealed that Gorter-Mellink equation generally underestimates the transient heat transfer process and overestimates the steady heat transfer process. In the transient heat transfer cases, numerical analysis should be carried out.

WEA03P004

The 100 kA Current Leads for a Superconducting Transmission Line Magnet

Y. Huang, W. Folster, S.W. Kim, P. Mazur, A. Oleck, H. Piekarz, R. Rabehl, FNAL; M. Wake, KEK.

A pair of 100 kA conventional leads has been developed to pass a dc current from the room temperature power supply poles to the liquid helium temperature of the magnet's transmission line superconductors. Each current lead consists of 202 pieces of copper rods with diameter of 6.35 mm arranged horizontally. The effective length of the current lead is 1650 mm. The copper rods are softsoldered at both warm and cold ends. The liquid helium gas flow, guided by multiple baffles along the lead length, allows for relatively high heat transfer coefficient. As a result these current leads were successfully tested with a ramping current of up to 104 kA. The current lead design, construction work and the test results are presented.

WEA03PO05

Bi2212 HTS Conical Tubes Prepared by the Diffusion Process for Current Lead Application

Y. Yamada, M. Watanabe, J. Ohkubo, K. Tachikawa, Tokai University; H. Tamura, A. Iwamoto, T. Mito, NIFS.

Bi2212 HTS conical tubular conductors have been prepared by the diffusion process for current lead application. The Bi2212 HTS layers are synthesized through the diffusion reaction between a Sr-Ca-Cu oxide substrate and a Bi-Cu oxide coating with Ag addition. The

HTS diffusion layers about 150 micrometer in thickness are formed around both outside and inside of the conical tubes 37/29 mm in outside/inside diameter at the larger end, 27/19 mm in outside/inside diameter at the smaller end, and 200 mm in length. The Ag added to the coating enhances the diffusion reaction, and precipitates on the surface of the specimen decreasing the contact resistance. The transport current of the specimen exceeds 7,000A at 4.2K and self-field, which corresponds to the current density of 32,000A/cm2 for the Bi2212 layer. The transport current decreases with increasing temperature at the warm end of the conical specimen, and is about 4,600 A at 30 K, 3,200 A at 40 K or 2,000 A at 50 K. The total heat loads composed of heat leakage conducted through the tube and joule heating at the joint are estimated to be about 320 mW at 3,000 A between the warm end of 42 K and the cold end of 4.2 K, and is 400 mW at 2,000 A between 50 K and 4.2 K, respectively. Present Pb-free Bi2212 conical tubes seem to be promising as large transport current leads with small heat loads for superconducting magnets.

WEA03P006

Current leads design in conduction-cooled superconducting magnet

H. Liu, Q. Wang, Y. Yu, Institute of Electrical Engineering, CAS.

Current leads are the important component in the superconducting apparatus. Current leads are the main heat link to the low-temperature level of cryogenic systems. Its heat leakage is in the majority of total heat leakage. Without helium vapour cooled, heat leakage of current leads in conduction-cooled superconducting magnet is much more higher than in conventional liquid cooled magnet. At present, hybrid metal-high-temperature superconductor current leads are a mature technology for conduction-cooled superconducting magnet. The relationship between heat leakage and cryocooler capacity was investigated. The maximum allowable current that can charge the magnet system was obtained. Combining it with the characteristic of superconductors, the appropriate operating current for the magnet was chosen theoretically.

WEA03P007

AC Loss measurement System

J. Bae, K. Sim, J. Cho, K. Seong, Korea Electrotechnology Research Institute; C. H. Winter, B. Boucher, J. Montani. In order to measure the superconducting transition

temperature, the critical current and the Alternating Current (AC) magnet loss in short samples of superconducting tape a cryostat has been designed and built. Two closed-cycle coolers provide cooling with an ultimate sample temperature below 20K. Temperature regulation is provided by 50W of electrical heater that opposes the cooling power from the cold heads. Temperature control feedback (Channel A) is by means of a cernox temperature sensor co-located with the heaters on the second stage of the cold head. Additional temperature sensors are located on the sample mount (B1), on the CVI cold head (B2) and for customer mounting (B3)

WEA03P008

Simulation of the Cooling System of a High Temperature Superconducting Demonstrative Synchronous Generator

B. Chen, G. Gu, G. Zhang, F. Song, S. Yu, H. Wang, H. Guo, S. Dai, Institute of Electrical Engineering, CAS. Based on the commercial software ANSYS-CFX and FLUENT, the simulation analyses of the temperature field and the fluid field in the cooling system of a demonstrative high temperature superconducting (HTS) generator was performed. Because the HTS coils in most existing HTS generator prototypes were fully immersed in various coolants, such as gas helium (GHe), liquid helium (LHe), liquid neon (LNe), liquid nitrogen (LN2), liquid air (LAir) or solid nitrogen (SN2), the simulation focuses on the selection of the suitable coolant and the relevant cooling techniques. Both the static and the transient temperature distribution were calculated so as to improve the cooling efficiency by adjusting the configuration. Furthermore, thanks to the detailed simulation of the fluid field in rotor, frequency hydrodynamics oscillating the and characteristics of cooling system were discovered, that will be helpful for working status control and steady operation of rotor. Above theoretical analyses are beneficial to the optimal design of our innovative HTS generator prototype.

WEA03PO09

Installation of Peltier current lead for 90 A cryogen-free superconducting magnet

M. Hamabe, A. Sasaki, T. Kasukabe, M. Oue, K. Nakamura, S. Yamaguchi, Chubu University; A. Ninomiya, Seikei University; H. Okumura, Mie University; K. Kawakami, Mayekawa MfgB Co.Ltd.; I. Aoki, Jecc Torisha Co.Ltd.

Major heat leakage of cryogen-free superconducting magnet (CFM) comes from the current leads, and its reduction is a common problem in superconducting system. High-temperature-superconductor (HTS) is used in the low temperature side of the current lead of the CFM. We proposed to use Peltier current lead (PCL) in the high temperature side of the current lead for the reduction of the heat leakage through the current leads. We installed the PCL into the 90 A commercial CFM and measured the temperature profile of the current lead including both the PCL and the HTS to compare the heat leakage with the usual HTS current lead. There are two optimizations in designing the PCL. One is to minimize the heat leakage at the maximum current. The other is to minimize the heat leakage at 0 A while allowing the same heat leakage at the maximum current as the usual HTS current lead. Both types of the PCL were installed and the experimental data the numerical calculations. were analyzed by Consequently, the reduction of heat leakage was confirmed for the PCL.

WEA03P010

Conceptual Design of Cryogenic Cooling System for 21T ICR Magnet

D-L. Kim, H-S. Yang, B-S. Lee, Korea Basic Science Institute; Y.S. Choi, J. Miller, T. Painter, NHMFL.

An international collaborative research program directed to develop a next-generation 21 tesla ICR(Ion Cyclotron Resonance) superconducting magnet system is underway at the KBSI-NHMFL Research Collaboration Center. The cryogenic system for this magnet employs an innovative design primarily driven by the requirement of a user-friendliness and reliability. To accomplish this requirement, the superconducting magnet will be built horizontally, operating at 1.8 K by JT refrigeration system. The present paper describes the concept of cryogenic design for this unique system. The amount of thermal loads and required cryogen are estimated by a relevant heat transfer analysis, from which dimensions of cryogenic system are determined. The effects of the conduction at transfer line on the cryogen hold time are also discussed.

POSTER SESSION	
ANALYTICAL	DESIGN

WEA04PO01 Wavelet Analysis of Quench Precursors in the LHC Superconducting Dipole Magnets

M. Calvi, L. Bottura, A. Masi, A. Siemko, CERN; L. Angrisani, University of Napoli Federico II.

Premature training quenches are caused by transient energy released within the magnet coil while it is energised. Signals recorded across the so-called quench antenna carry information about these disturbances. A new method for characterizing those events is proposed which make use of the continuous time wavelet decompositions (CWT). Such approach brings information about the time of occurrence as well as the frequency content of the events. The choice of the optimised mother wavelet is discussed and several examples of high-frequency resolution signal are proposed. The criterion to recognise the interesting events is presented as well as the possibility to classify them in term of families.

WEA04P002

3D Calculation of the Magnetic Field and Force in a Hybrid EMS-MAGLEV System Taking Account of the Materials' Nonlinearity

Y. Yao, Y. Fang, The College of Electrical Engineering, Zhejiang University.

A hybrid EMS-Maglev system is proposed in this paper. The main magnet is energized by high temperature superconductors (HTS) in company with copper conductors. The HTS coils with constant DC provides main field. The copper conductor coils with variable current supplies adjustable field to compensate the disturbance from loads, gap and power system. Our researches in this paper focus on the computation of levitating field and force in three dimensions. As HTS Bi-2223 tape was applied to fabricate the HTS coil, a new FE model for three dimensional field calculations is deduced. The magnetic nonlinearity of the iron core and the anisotropic characteristic (Jc-Bc-Tc curve) of HTS coil are taken into consideration. The force distribution and total force is computed by local virtual work method. The force performance depending on input current is detail discussed in the paper.

WEA04P003

Optimal Design and Structural Stress Computation of High Temperature Superconducting Magnet in 100kVA High Temperature Superconducting Generator

F. Song, G. Zhang, B. Chen, S. Yu, H. Wang, H. Guo, S. Dai, Institute of Electrical Engineering, CAS.

Optimal design and structural stress computation of high temperature superconducting (HTS) magnet is presented in this paper. The magnet is the field windings of a 100kVA innovative HTS generator with the evaporative cooling stator and the distributed Dewar rotor. Magnetic rotor and nonmagnetic rotor can be adopted in this generator. At aim of decreasing the values of vertical component of the magnetic flux density through magnets, the magnets are optimized by electrical and magnetic field computation and structural optimization is also considered. The optimal results are that step structure magnet is adopted in nonmagnetic rotor and magnetic diverter rings are applied in magnetic rotor, and the comparison between these types of rotors is implemented about the values of vertical component of the magnetic flux density. For further research, structural stress distribution of the magnets is computed at rotation situation, and based on the stress distribution; the further optimization is beneficial to get reasonable stress distribution and the minimal value of vertical component of the magnetic flux density.

WEA04P004

Characteristic Analysis on the High Temperature Superconductivity Motor for Multi-pole and Low Speed Application.

K-C. Kim, J. Lee, Hanyang University.

This paper presents the design and analysis methods of a large scaled synchronous motor for ship which has field windings of HTS (high temperature superconductivity). The main characteristic of motor design for ship without gear system is low speed and the system needs multi-pole field HTS windings. However, the airgap of HTS motor is related to somewhat mechanical system, we can not reduce the length of airgap. Therefore, there is much more leakage magnetic flux in multi-pole HTS motor. In this paper, we analyzed the power and loss characteristics of multi-pole HTS motor according to the number of layer and distribution of HTS field windings by finite element method. The last we compared with power ratio between conventional synchronous motor with high power and low speed and HTS multi-pole motor which has same volume and stator dimension. And the power ratio of multi-pole HTS motor to four pole HTS motor also analyzed with same dimension. These are designed by considering critical magnetic flux intensity.

WEA04P005

Solution of Laplace equation on non axially simmetrical volumes.

V. Punzo, S. Besio, S. Pittaluga, A. Trequattrini, Esaote. The homogeneity of the magnetic field plays a fundamental role in MRI. Standard shimming techniques of the magnetic field are usually applied on volumes such as spheres or (less frequently) on surfaces of revolution (oblate and prolate spheroids) and are based on well-known solutions of the Laplace equation. We present a complete mathematical formalism for the solution of the Laplace equation with Dirichlet conditions defined on a tri-axial ellipsoid through the transformation of the equation in ellipsoidal coordinates. The importance of the ellipsoid lies in the fact that this surface can be more easily conformed to most districts of the human body (e.g. extremities) and are of interest for dedicated MRI systems.

WEA04P006

Estimation of Characteristic Satisfaction by EMF-Inductance Map in Superconducting Motor Design

J-Y. Lee, J-P. Hong, Changwon Naitonal University; S-K. Baik, M-H. Sohn, Y-K. Kwon, KERI.

Electric motors are kind of transfers changing electrical energy to mechanical energy. If the electric energy is estimated, the output characteristics are predicted. In the motors, there are input voltage, electromotive force (EMF), current, inductance, and resistance as commonly considerable electrical parameters. Input voltage is one of specifications rather than design variables. Current is dependant variable on other variables such as EMF, inductance, and resistance. Resistance does not mainly affect performances especially in synchronous motors because reactance is relatively bigger than resistance. However, the two rest parameters, EMF and inductance, are not only directly changed by design variables, but also changed. make motor performance considerably Therefore, this paper suggests EMF-Inductance Map, which will be called E-L Map, to effectively predict the

motor performance in design process. In the first step of motor design, the map is draw; Motor characteristics such as output power, efficiency, power factor, and current density will be mapped in EMF-inductance coordinates. According to limit or required performances, the map has contour lines. During designing a motor, the inductance and EMF will be shown as a point in the map. With the transition of the point, the design direction will be decided easily. This all process will be shown in 1MW superconducting motor design.

WEA04P007

Optimal Design of Superconducting Motor to Improve Power density using Experimental Design and Response Surface Methodology

J-Y. Lee, S-I. Kim, J-P. Hong, Changwon Naitonal University; S-K. Baik, M-H. Sohn, Y-K. Kwon, KERI.

This paper proposes an effective design process for 1MW HTS superconducting motor with experimental design (design of experiment; DOE) and Response surface methodology (RSM). DOE is used as the first step of optimization method, and in here main design parameters are decided. Between contradicted design variables, a small number which can improve power density is selected for optimal design. With the selected variables, RSM is used for the motor optimal design to improve power density. The utility of this method is verified through the comparison of the performances of the optimal geometry and those of the initial geometry.

POSTER SESSION STABILITY

13:30 - 15:30

WEA05PO01

Finite allowable temperature rise of high temperature superconducting composites before thermal runaway and its influence on stable states

V.R. Romanovskii, RRC Kurchatov Institute; K. Watanabe, G. Nishijima, S. Awaji, High Field Laboratory for Superconducting Materials, IMR. Withdrawn.

WEA05P002

Temperature-dependent electromagnetic behavior of high-Tc superconducting current-carrying elements Withdrawn.

WEA05PO03

Experimental Investigation of the Stability of Cu/NbTi Multifilament Composite Wires

F. Trillaud, CEA-Saclay; A. Devred, CEA-Saclay, CERN; F. Ajela, P. Tixador, CRTBT/CNRS.

The stability of Cu/NbTi multifilament composite wires remains an important data for magnet design. It has been characterized in helium bath cooling conditions. A new heating method based on fibered diode laser technology was developed to trigger localized heat disturbances of short durations. To compensate for the poor optical absorption of the copper stabilizer of composite wires, the wire surface was blackened by chemical oxidation. To back-up the measurements, various attempts at calibrating the energy delivered by the diode laser have been carried out and a study of the influence of the cryogenic environment on the optical fiber coupled to the diode laser has also been conducted. This new experimental technique led to a significant improvement in measurement reproducibility, yielding accurate estimates of Minimum Quench Energies (MQE) and Normal Zone Propagation Velocities (NPZ). In addition, the recorded data give deep insights on the early developments of the normal zone and help us understanding the mechanisms that are involved.

WEA05PO04

Detailed 3D ANSYS Quench Simulation of Superconducting Strands, Cables and Magnets with possible Quench causing Effects.

R. Yamada, FNAL; M. Wake, KEK.

The quench starting phenomena in strands are simulated in details in 3-D and in time using ANSYS and other FEM current sharing between programs. The the superconductor and copper stabilizer in strands at the beginning of a quench is clearly simulated and displayed in time sequence. This initial quench behavior is used to calculate the minimum quench energy, MQE, and minimum propagation zone, MPZ. They are calculated with different parameters of Jc, RRR, flux jump energy and others, for different kinds of Nb3Sn and Nb3Al strands. These calculated values are compared with experimental values. From these parameters, the stability for each strand is studied. Based upon the stability of the strand, the stability of the Rutherford cables is studied. The stability of magnets made of these cables is simulated for their quench behavior. For magnets the quench behaviors at the splice region and at high field regions are discussed with the stability of strands and with the supercurrent effects with different magnets.

WEA05PO05

Over-current pulse characteristics of YBCO Tapes

A. Ishiyama, Y. Ushiku, H. Naka, H. Ueda, Institute for Materials Research, Tohoku University; Y. Shiohara, ISTEC-SRL.

Coated conductors are expected to be used in future hightemperature superconductor applications, because it has better Jc characteristics in high temperatures and in high applied magnetic fields. For application to electric power devices, such as transmission cables, transformers, fault current limiters, the superconductors are subjected to short-circuit fault currents. In this study, the characteristics of the transition to the normal state and normal-zone propagation in YBCO sample tapes were examined experimentally and numerically subjected to over-current pulse. The YBCO sample tapes (20-cm long and 1-cm wide) were produced by IBAD/PLD and MOD/TFA methods. Measurements were performed as a function of the amplitude of an over-current pulse for operating temperatures of 55K, 60K, and 65K (Gifford-McMahon cryocooler was adopted) in a background magnetic field of 5T. The experimental results were compared with simulations using a developed computer program based on the finite element method (FEM). In the computer program, the I-V characteristics of the YBCO sample tapes were taken into account. The results of the simulations were in good agreement with the experiments. The influence of the thickness of Ag-stabilizer on the peak temperature and transient thermal behavior of YBCO tapes was also evaluated experimentally and numerically.

WEA05P006

Relation between mechanical losses and winding tensions at cryogenic temperature in AC superconducting coils

N. Sekine, Yokohama National University, S. Tada, T. Higuchi, Y. Furumura, T. Takao, A. Yamanaka, Sophia University. Withdrawn.

WEA05P007

Transient Thermal Characteristics of Cryocooler-Cooled YBCO Coil

A. Yshiyama, H. Naka, Y. Ushiku, H. Ueda, Dept. of Electrical Engineering, Waseda University; Y. Shiohara, ISTEC-SRL.

For the sake of the application of high-temperature superconducting (HTS) coil to practical use, establishment of a new thermal stability criterion for coil design is required. In the previous study, a small-sized cryocoolercooled Bi-2223/Ag coil has been constructed and tested to evaluate the electromagnetic and thermal behaviors of the HTS coil supposing SMES application. And the simulation by a newly developed computer program based on the finite element method agreed well with experiments. In this study, we simulated the transient thermal characteristics of a coil wound with YBCO tape by the developed computer program. In the numerical simulation, we considered the I-V characteristics of YBCO tape, which depend on the direction of applied magnetic field to the tape surface. YBCO tape is expected to be used in future HTS applications, because it has better Jc characteristic in high temperatures and in high magnetic fields. However, it is considered that YBCO tapes show a different thermal behavior from BSCCO tapes, since it has a laminated structure made by deposition of about 1mm YBCO thin film on a substrate. We compared the thermal behaviors of Bi-2223/Ag coil and those of YBCO coil. And the influence of thickness of stabilizer and substrate on the thermal stability of cryocooler-cooled YBCO coil was also investigated. This work was supported by NEDO as Collaborative Research and Development of Fundamental Technologies for Superconductivity Applications.

WEA05P008

Transient Stability Analysis Taking into Account Hall Effect for Large Aluminum Stabilized Superconductor

N. Kawawada, S. Noguchi, H. Igarashi, Hokkaido University.

Aluminum stabilized superconductors are used in fusion devices, SMES and so on. These superconductors have large cross-sectional areas of high purity aluminum to improve their stability. However, one of the important properties of these superconductors is the transient stability, which caused by a long duration of current transfer from the superconducting strands into the aluminum in a normal-state region. Once a normal-zone is initiated in such superconductors, excess joule heat is generated in a small region of the aluminum stabilizer near the superconducting strands during the current diffusion time. It hence deteriorates the transient stability. Recently, the experiments of the large aluminum stabilized superconductor show an asymmetrical propagation of normal-zone along the longitudinal direction of the conductor. Therefore, it is important to investigate the characteristics of the transient stability by numerical analysis. The phenomena such asymmetric normal-zone propagation are probably cased by the Hall effect. Therefore In order to simulate the normal-zone propagation in the superconductor more preciously and to clarify the cause of the asymmetric propagation, we have developed a 3D finite element analysis code considering the Hall effect and investigate the transient stability of large aluminum stabilized superconductors.

WEA05P009

A Modified Continuum Model for Stability Analysis of Nb3Sn Strands

J.R. McDonald, SAIC; E. Barzi, FNAL.

A continuum approach, based on the work of Duchateau and Turck, is used to predict the quench currents observed in multi-filamentary strands of composite superconductor being investigated at Fermilab and other labs and institutions. The size of the superconducting filaments does not enter as a parameter in the original continuum model; however, it has been shown that the effective filament size plays a major role in the stability phenomenon of Nb3Sn strands. As pointed out by Wilson, the original continuum model does not consider the local temperature distribution across a superconducting filament; when this temperature distribution is incorporated as a first-order correction, a modified continuum model results in which the stability parameter becomes dependent on the filament size. Experimental results for the quench currents of several Nb3Sn Restacked Rod Process, Modifield-Jelly-Roll and Powder-in-Tube strands, as well as CuNi NbTi strands are compared with the predictions of the modified continuum model, and the various implications are discussed.

WEA05P010

ASTEX: an experiment to study the effect of current distribution on the performance of a 36-strands NbTi CICC magnet

L. Muzzi, L. Affinito, E. Balsamo, S. Chiarelli, A. Della Corte, A. Di Zenobio, P. Gislon, A. Mauro, G. Messina, ENEA; J. Mayorga, O.C.E.M. S.p.A.

The current distribution is a crucial issue for the performance of multi-filamentary conductors during both steady state operation and current variations. The nonuniformity of the current within the cable section has been identified as the main cause leading to premature conductor quench phenomena or to current ramp-rate limitations. Within this framework, the experiment ASTEX (Advanced Stability Experiment) has been designed at ENEA, aimed at studying the influence of current distribution on conductor properties, such as critical current, AC losses, stability. A magnet has been coil wound with a sub-size NbTi 36-strands conductor, which has been opened at both terminations, and subdivided into different groups of strands. A system of external resistors allows to feed the magnet with a controlled non-uniformly distributed current and to measure separately the current flowing in each of the sub-stages. The results of preliminary measurements are presented here.

WEA05P011

Numerical Simulation of the critical current and n-value in the Nb3Sn strand Subjected to Bending Strain

M. Hirohashi, A. Ishiyama, H. Ueda, Dept. of Electrical Engineering, Waseda University; N. Koizumi, K. Okuno, JAERI.

To demonstrate the applicability of Nb3Sn CICCs to ITER coils, four Nb3Sn model coils have been constructed and tested. The experimental results showed that the measured critical current of the conductors degraded compared with those which are expected from the ability of the strands. In addition, the larger the electromagnetic force is applied, the larger the magnitude of the degradation is. The degradation in n-value was also observed. One of the explanations of this degradation is supposed to be a local strand bending. This consideration has been supported by the test results, in which the similar degradation in the critical current and n-value was observed when applying bending strains to a single strand. However, a general formula of the dependence of critical current on bending strain has not been clarified in this test since the experiments were carried out at a certain magnetic field, temperature and strain. Therefore, a numerical simulation

code was developed to study the general dependence of the critical current and n-value of the Nb3Sn strand on bending strain. The distributed constant circuit model is applied to simulate current transfer among the filaments in the strand. The simulation results agreed well with the experiment results and then the validity of our code was confirmed.

WEA05P012

Over current characteristics of YBCO coated conductor subject to perpendicular AC magnetic field

N. Amemiya, S. Umeda, Z. Jiang, Yokohama National University.

With respect to the stability characteristics of YBCO coated conductors, one of the major concerns is their response against the transport current more than their critical current (over current), which accidentally flows. Since YBCO coated conductors are very flat and wide usually, a large shielding current with large decay time constant might flow on their wide face when an AC external magnetic field which is perpendicular to their wide face is applied. The superposition of this shielding current on the transport current could result in a non-uniform current distribution on the wide face of an YBCO coated conductor and might affect its over current characteristics. In this paper, the authors report a numerical study on the over current characteristics of YBCO coated conductors subject to an AC perpendicular magnetic field. The current distribution on the wide face of an YBCO coated conductor is calculated using a two dimensional FEM model for electromagnetic field analysis based on a thin plate approximation where the influence of the parallel magnetic field component is neglected. A thermal equilibrium equation is solved to obtain the temperature distribution using a differential method. The electromagnetic field and thermal analyses are coupled together to simulate the quench process in the YBCO coated conductor carrying AC over current in an AC perpendicular magnetic field.

WEA05PO13

Thermal stability investigation of high-temperature microSMES model

P. Surdacki, T. Janowski, Lublin University of Technology; S. Kozak, G. Wojtasiewicz, H. Malinowski, B. Kondratowicz-Kucewicz, J. Kozak, Electrotechnical Institute, Warsaw.

A 5.8 kJ mSMES experimental model consisting of 14 pancake coils of outer diameter 300 mm, wound of high strength Bi-2223 tape with Ag matrix reinforced by steel sheath, has been designed. Due to use of contact cooling, operating current amounts to 135 A at 35 K. Contactcooled HTS magnet has advantages of easy operation, compact size and higher efficiency compared with liquid helium cooled magnets. However, a thermal instability of the system is possible when operated under high loading conditions. In order to manage it, a numerical model of thermal behavior based on two-dimensional time dependent heat diffusion equation in cylindrical coordinates has been developed for the experimental system. A numerical procedure based on Alternating Direction Implicit Method has been adopted to compute temperature distributions for various values of current. The numerical model results have been compared to experimental ones.

POSTER SESSION	13:30 - 15:30
PERMANENT MAGNETS	

WEA06PO01

A Field Distribution by the Dynamic-Link Magnetic Circuit

D.W. Lu, H.B. Wu, X.N. Xu, X. Jin, Department of Physics, Nanjing University.

The magnetic field of the gap in a typical permanent magnetic circuit(C-typed, e.g.) is usually constant. But we may get a changeable magnetic field in the gap of the magnetic circuit if we get the magnetic unit of the magnetic circuit moving out or in the circuit, or turning in the circuit. We call such a magnetic circuit as dynamic-link magnetic circuit. In the present paper, we proposed a method of generating an alternate magnetic field in a close space. In the close space the magnetic field varies with the rotary magnetic cylinder within the outer magnetic circuit. According to the above introduction, we designed and assembled an experimental dynamic-link magnetic array which is typed as the character O. The field distribution of the magnet was calculated and measured, respectively. Such a magnetic circuit may be useful in the room temperature magnetic refrigeration.

WEA06PO02

Magnetization Issues of 5 T Cryo-Permanent Magnets *M. Sander, Michael Sander Technologie-Beratung.*

Trapped peak magnetic fields beyond 15 T obtained for melt-textured 123-High-Temperature Superconductor (HTS) bulk cylinders, make these materials highly attractive for cryo-permanent magnets (CPM). The achieved level of accuracy for modelling the superconducting properties of 123-HTS allows already to melt-textured semiquantitatively study geometry- and size-related questions and to optimize designs and magnetization processes for larger size CPMs in the range of 5 T. To in-situ magnetize the HTS material using pulsed copper coils, and, in particular to reduce the required peak magnetic field, is a key issue for turning the proven materials performances into practical magnetic devices. To overcome the strong shielding properties and to enhance the flux penetration, a concept of injection-current (IC) assisted pulsed magnetization is proposed for ring-shaped CPMs. The high injection current is induced in an open HTS loop which is driven by the same magnetizing field as the HTS ring itself. The presented model calculations give clear indications that the trapped current and magnetic flux in the HTS loop then well exceeds the values that can be obtained in standard magnetization processes without injected current. At the same time this gives confidence that even trapped magnetic field profiles of <= 5 T over >= 10 cm can be achieved with pulsed copper coils.

WEA06PO03

Investigation of the Focusing Solenoid Magnets at LUE-200 Accelerator

V.K. Makoveev, V.M. Lachinov, V.K. Spodarets, A.P. Sumbaev, Joint Institute for Nuclear Research.

A linear accelerator of electrons (LUE-200) – a driver of the Intense REsonance Neutron source (IREN) of the booster type, has been constructed at Joint Institute for Nuclear Research (JINR) for several years. Physical peculiarities of the beam acceleration with a significant spatial charge of its own, put forward very strickt requirements to the quality of the beam focusing system. This work is dedicated to the topographical study of the magnetic fields of permanent current electromagnets - the coils composing the solenoid and providing the focusing magnetic field with a minimal value of the radial component (Br/Bz~1.0E-03) while beam accelerating in the first accelerating section. Methods and features of magnetic measurements of the focusing solenoid elements are discussed in the report, the results of measuring and field maps of the coils under investigation, are given.

WEA06PO04

Field property of ring arranged Halbuch PM

H. Wang, P. Xia, Q. Wang, Institute of Electrical Engineering, CAS.

The paper discribed the magnetic feild distributing propertis of the Halbuch PM ring arranged in plane. The analytical numerical and experimental results are gavin and analysed.

WEA06PO05

Hybrid quadrupole with variable gradient and precise regulation of the magnetic center

N.I. Doinikov, E. Bondarchuk, N. Kovrizhnykh, V. Muratov, T. Obidenko, V. Shangin, D.V. Efremov Institute (NIIEFA); B. Krause, A. Petrov, J. Pflueger, K. Sinram, Deutsches Elektronen-Synchrotron (DESY).

Two versions of hybrid quadrupoles 2ao=15 mm in aperture with shunting elements made of soft magnetic material (SMM) are analyzed. In Version 1 the possibility is shown to vary the gradient in the range of G=40 - 90 T/m and to regulate the magnetic center at Gmax during rotation of the external ring with shunting inserts. The possibility is also analyzed to regulate the position of the quadrupole magnetic axis by rotating additional rods made of hard magnetic material (HMM). In Version 2 radial displacement of shunts and components of their sections is shown to efficiently impact the magnetic parameters of the quadrupole. For the X-FEL (DESY) design a quadrupole prototype magnet without SMM elements has been developed in which adjustment of the gradient and magnet center is provided by horizontal movement of the poles.

WEA06PO06

Permanent magnets systems for the production of dense hot plasmas

S. Gammino, G. Ciavola, L. Celona, L. Andò, L. Torrisi, M. Presti, F. Consoli, INFN-LNS; S. Barbarino, G. Sorbello, University of Catania; A. Galatà, INFN-LNL. Withdrawn.

WEA06P007

Hybrid dipole and quadrupole with variable field strength

K. Ruwali, M.G. Karmarkar, Centre For Advanced Technology, India.

The use of permanent magnets has been investigated as an option for variable dipole and quadrupole field for the proposed electron based food irradiation facility and other fixed energy transportable charge particle accelerators at CAT. In order to vary integrated strength of the magnetic field, several techniques were studied such as varying the pole gap, shunts at entry-exit of magnet, varying the pole dimensions. Measurement results are in concurrence with computer simulations based on PANDIRA and Opera-3d.

WEA06P008

Sensitivity of the Field Trapped by Superconducting Bulks on the Parameters of the Pulsed Field Magnetization Process

A. Morandi, M. Fabbri, F. Negrini, P.L. Ribani, Department of Electrical Engineering, University of Bologna.

Bulk superconductors can trap a magnetic field whose magnitude is proportional to their critical current density. Recent developments in melt processing has enabled the fabrication of large SC bulks with high critical current density that can trap a magnetic field much stronger then that of conventional permanent magnets, thus opening the way to new applications in the field of power electric machinery. However, for high temperature bulk superconductors to find a broad use, a suitable magnetization process must be developed. Three main methods are used to magnetize an SC bulk: field cooling, zero field cooling and pulsed field magnetization. The latter has the advantages to be fast and suitable for in situ application, therefore it facilitates the assembling of the device and allows to recover partial demagnetizations following fault events. The profile of the trapped field induced by pulsed magnetization, its time evolution and its stability with respect to external disturbances is strongly influenced by the peak value and the waveform of the applied field pulses, the number of pulses and the operating temperature of the bulk. In this paper a numerical investigation of the pulsed field magnetization process of superconducting bulk is carried out and the sensitivity of the profile and the stability of the trapped field with respect to the above mentioned parameters is evaluated.

WEA06PO09

The Magnetic Net Model of a Dipolar Halbach Array

Y. Zhang, J. Chen, Institute of Electrical Engineering, Chinese Academy of Sciences.

This paper presents the magnetic circuit of dipolar Halbach array, which be constituted by some single magnet. Based on the magnetic circuit of single magnet, the paper constructs the magnetic network topology of dipolar Halbach array and gets magnetic network node equations. Base on the above, one set up the mathematics model of a dipolar Halbach array and calculates distribution of magnetic field in space by the solution of mathematic model. The result of calculation is verified by the experiment. There are some conclusions, as follow: 1. The magnetic network model of dipolar Halbach array is valuable, which is a method between numerical calculation and classical analytics. These methods are characteristic itself. The magnetic network model method is an engineering means. 2. The gap permeance of dipolar Halbach array is constant, from which we can sure that the gap permeance doesn't contributes to the symmetry of gap magnetic field.

3. The discreteness of radial magnetization contributes to the symmetry of gap magnetic field, as well as two magnetic potential (radial and curve) and different of permeance, so the conclusion is consistent with the conclusion from other methods.

WEA06PO10

Shift Dependent Skew Quadrupole in Advanced Light Source Elliptically Polarizing Undulators, Cause and Corrections

S. Marks, S. Prestemon, D. Robin, R. Schlueter, C. Steier, A. Wolksi, J-Y. Jung, LBNL; O. Chubar, Soleil.

Two elliptically polarizing undulators (EPU) are installed and operational at the Advanced Light Source (ALS); a third EPU has recently been installed. Operational experience has shown a variation in electron beam size which correlates with the EPU's magnetic quadrant shifts used to vary polarization. Storage ring electron dynamics studies pointed to the existence of a shift dependent skew quadrupole component generated within the EPUs. Detailed magnetic and mechanical measurements demonstrated that the field errors were the result of systematic magnetic block displacements which vary with quadrant shift. This paper will discuss the results of electron dynamics studies, magnetic and mechanical measurements, and the design of skew quadrupole compensation coils. A discussion of mechanical features to be included in future EPUs to minimize the generation of shift dependent skew quadrupoles will also be included.

WEA06PO11

Measure Undulator 10.0 With Pulsed Wire Method

Y. Li, H. Yan, Q. Zhou, SSRF, Shanghai Institute of Applied Physics, CAS, Shanghai, China. Withdrawn.

WEA06P012

Magnetic Fields Computation and Optimal Design of High Temperature Superconducting YBCO Flywheel Models

G. Zhang, S. Dai, Institute of Electrical Engineering, CAS; A.M. Campbell, A. Rastogi, T. Coombs, Cambridge University, UK.

The fundamental feature of the YBCO superconductors is the tendency to partially exclude magnetic flux from their interiors by developing a shielding current that flows near the surface. If the external field is lowered, the shielding current is induced only on the surface of the HTS and the original applied field is trapped in the center of HTS. However, if the change in the applied field is large enough, the shielding current flows in the whole volume of the HTS. Previously, the calculations of magnetic field in YBCO superconductors have been treated in ways similar to ferromagnetic materials. The critical-state models, such as Bean model or Kim model, have been successfully used to describe the hysteretic behavior of HTS and to predict the current distribution inside HTS bulks. However, finite to include ferromagnetic element software and superconducting materials is not readily available. A new calculation procedure, which can be called the Trapped Field Magnet (TFM) method, is proposed in this paper to predict the magnetic flux distributions and the stiffness of a flywheel model. The experimental results in field-cooled condition show that the proposed procedure can be used to get a reasonable field distribution when the displacement of the rotor is less than a few millimeters. The calculated stiffness in zero field-cooled condition is also presented.

WEA06PO13

Analysis and Design of Cyclinder Magnetic Separator with Permanent Magnet

Q. Yang, Hebei University of Technology.

Magnetic separator is widely used in metallurgy and other industries such as mineral separation, eliminate impurity and so on. It also can be used as special equipment for reclaiming heavy medium. Because traditional cylinder magnetic separator has the advantages of low operation cost, stable operation, fit for locale production, it takes up irreplaceable position in magnetic separators. In this paper, we analyze the force of magnetic separator reclaiming magnetism mineral grain in the condition of callback heavy medium, calculate magnetic intensity using finite element method, establish mathematics model of magnetic system, and study the effect of different magnetic system configurations. Magnetic circuit is the main portion of magnetic separator and decides the performance of magnetic separator. The magnetic system here is openended. In the paper, we study the impact of magnetic system height, breadth, radius, number of poles, magnetic difference of potential, pole span, ratio of magnetic pole breadth to airspace breadth, shape of magnetic pole, distance of magnetic pole to the center magnetic field, calculate parameter of magnetic system, analyze and verify

the different action of different magnetic series, design a kind of cylinder magnetic separator of permanent magnet with advanced, simple constitution and working reliable .

WEA06P014

Elliptically Polarizing Undulator End Designs

S. Prestemon, R. Schlueter, S. Marks, LBNL.

The magnetic end design of pure-permanent magnet Apple-II elliptically polarizing undulators (EPU) is discussed. Constraints on end block dimensions and positions are presented that guarantee steering and displacement free systems in both transverse directions and at all gaps for mu=1 material. For block material with mu>1 some beam steering (i.e. integrated dipole) may occur due to the ends; in particular, its strength varies with EPU phase. An optimization process is presented that assumes small perturbations about the mu=1 solution and minimizes the variation in steering with EPU phase. We present numerical and experimental results that quantify the reduction in integrated dipole variation with phase.

WEA06PO15

Development of Ferrite Sector Magnets for Magnetically Coupled Drives Use in Excimer Laser

R.S. Schinde, P. Pareek, R.R. Yadav, U. Nundy, S. Kotaiah, Head Ferrite Lab., CAT India.

Sr ferrite sector magnets has been developed for Magnetic drives for Excimer Laser Programme at CAT. To operate these lasers at high rep rate, blowers are used for gas circulation. The gas mixture contains Corrosive gases like flourine or Hydrogen chloride. The impeller of the blower has to be driven by a motor & no leaks can be tolerated.A magnetic drive totally avoids problem of dangerous leak developing.Outer & rotor magnetic assembly of drive system uses sector magnets in 4 pole configuration.A sector magnets of outer assembly subtend at angle of 38° at the centre so as to produce max torque.A pulse magnetizer has been built to magnetize the ferrite sector magnets.Magnetic moment of sector magnets were measured using Hemholtz coil system(3 degree rotation mechanism). This system provides precise & accurate measurements of magnetic moments of sector magnets.Sr ferrite magnet have positive coefficient of Hc & good magnet stability, therefore chosen for drive applications. A number of cylindrical & disc type magnetic drives has been developed & now in use for impeller blower drive system. An Excellent performance is obtained. This has proved stabilty & accuracy of magnet & drives. Magnet is operating at permeance coefficent, 1.4 & operating flux density in the magnetic circuit is 0.23 T. This paper describe the characterization of sector magnets& magnetic its conditioning, magnetic circuit analysis, magnet stability, modeling using FEA & performance results of devices.

POSTER SESSION 13:30 - 15:30 Nb3Sn ACCELERATOR MAGNETS

WEA07PO01

Magnetic and Mechanical Designs of 15T Nb3Sn Accelerator Dipole Based on 3-Layer Shell-type Coil

V.V. Kashikhin, N. Andreev, V. Kashikhin, I. Novitsky, A. Zlobin, FNAL.

Fermilab is working on the development of high field accelerator magnets for future hadron colliders. Several Nb3Sn dipole magnets and magnetic mirror models with the bore size of 43.5 mm based on 2-layer shell-type coil were manufactured and tested. Last year the nominal field

of 10 T was reached using Nb3Sn strand produced by PIT process. The work on advancing the field in this design to the level of 11-12 T using high-Jc Nb3Sn strand based on RRP process is in progress. This paper presents a new dipole magnet design, based on 3-layer shell-type coils optimized for the field quality, maximum field and stress in the coil. The proposed design allows increasing the maximum field in magnet aperture to the level of 15 T. It uses a 3-layer Nb3Sn coil wound without interlayer splices that up to now was a feature of 2-layer coils only. This approach reduces the magnet fabrication time and cost and improves the reliability against failure of internal splices. Magnet mechanical structure which provides the coil pre-stress and support up to the maximum field is also described. The magnet design concept along with the major parameters as well as magnetic and mechanical analysis will be presented and discussed.

WEA07PO02

The stress in graded high field Nb3Sn dipole magnets *S. Caspi, P. Ferracin, S. Gourlay, LBNL.*

Dipole magnets with fields beyond 16T will require superconducting coils that are at least 40mm thick, an applied pres-stress around 150MPa and a protection scheme for stored energy in the range of 1-2MJ/m. The coil size will have a direct impact on the overall magnet cost and the stored energy will raise new questions on protection. To reduce coil size and minimize risk, the coil may have to be graded. Grading is achieved by splitting the coil into several layers with current densities that match the short sample field in each layer. Grading, especially at high fields, can be significant; however it will also significantly raise the stress. In this paper we report on the results of a study on the coil size and field relation to that of the stress and stored energy. We then extend the results to graded coils and attempt to address high stress issues and ways to reduce it.

WEA07PO03

Design and construction of TQ1a - a 90-mm Nb3Sn quadrupole model for LHC luminosity upgrade based on a key and bladder structure

S. Caspi, D. Dietderich, P. Ferracin, S. Gourlay, R. Hafalia, A. Lietzke, G. Sabbi, LBNL; R. Bossert, V. Kashikhin, A. Zlobin, FNAL.

The US LHC Accelerator Research Program (LARP) is developing Nb3Sn accelerator magnet technology for the LHC luminosity upgrade. Two 90 mm "technology quadrupoles" (TQ1a and TQ2a) are being developed in close collaboration between LBNL and FNAL using identical coil design and two different support structures. The TQ1a structure was developed and successfully tested at LBNL where coils are assembled and supported by an outer aluminum shell using keys and bladders. In contrast the second model structure TQ2a is based on a more traditional approach using stainless steel collars and a thick SS skin.. This paper describes the TQ1a model magnet, the 3D ANSYS stress analysis, instrumentation and assembly procedure.

WEA07PO04

Development of Nb3Sn Sextupole Magnet for Neutron Beam Focussing

K. Tsuchiya, N. Ohuchi, KEK; J. Obama, Y. Seki, M. Ohno, K. Okamoto, K. Nakamura, T. Takao, Sophia University; H. Shimizu, RIKEN; J. Suzuki, JAERI.

In order to get high intensity neutron beam for neutron scattering experiment, strong sextupole magnets with large aperture are useful as a focusing element. We have started the development of the Nb3Sn sextupole magnet for this purpose. The design field strength of the sextupole is 10000 T/m2 and the aperture of the coil is 46 mm in diameter. As a first step of the development, several short model coils have been made to learn about Nb3Sn technology and to evaluate the fabrication techniques. Single pole tests of these coils have been performed to assess conductor stability and training behavior of the Nb3Sn coils. This paper presents the design of the magnet, fabrication of the model coils and the results of the single pole tests.

WEA07P005

Voltage Spike Studies using Strands, Cables and Magnets made from Nb3Sn Conductor

S. Feher, B. Bordini, E. Barzi, D. Turrioni, G. Ambrosio, N. Andreev, R. Bossert, R. Carcagno, V. Kashikin, V. Kashikin, FNAL.

High Field Magnet program at Fermilab utilizes Nb3Sn superconductor. Intrinsically stable high current Nb3Sn strands are still difficult to obtain with current "state of the art" superconducting technology. Performance of some magnets built using these type of superconductor have been limited by instabilities. In order to shed light on the origin of these instabilities, a series of tests were performed in which voltage spikes were detected to study flux change which might be associated with magnet or superconductor instabilities. Tests were performed on the strand, cable and magnet levels. This paper summarizes the test results.

WEA07P006

Mechanical designs of a shell-type quadrupole with 110-mm aperture and 230 T/m field gradient

G. Ambrosio, N. Andreev, FNAL. Withdrawn.

WEA07P007

Design Study of 15 Tesla Nb3Al Block Type Dipole Magnet

R. Yamada, A. Zlobin, E. Barzi, G. Ambrosio, Fermilab; M. Wake, KEK; A. Kikuchi, T. Takeuchi, NIMS.

The design study of the block type 15 Tesla Nb3Al dipole magnet, and its merits over Nb3Sn magnets are presented. Copper stabilized Nb3Al strand is now becoming commercially available for the application to the accelerator magnets. A 1 mm diameter Nb3Al strand with deff less than 40 microns, non-copper Jc about 2000 A/mm2 at 12 Tesla at 4.2 K, copper ratio of 50 %, can now be produced over several hundred meters. The stress and strain characteristics of the Nb3AI strand is superior to the Nb3Sn strand, and it is reported that Nb3AI strand can withstand over 500 MPa at 10 Tesla, while Nb3Sn can take up to about 150 MPa. Another advantage is that it can tolerate a longitudinal strain up to 0.55%. The Nb3Al Rutherford cable will have less chance of contamination of the stabilizer, compared to Nb3Sn cable. These characteristics of the Nb3Al will be beneficial for designing and producing 15 Tesla dipole magnets. The optimized magnet cross incorporating section will be presented coolina consideration. The heat treatment of the wound magnet has to be done at 800 C, but its duration is only 10 hours.

WEA07P008

Development of a 90-mm Nb3Sn Technological Quadrupole for LHC Upgrade based on SS Collar

R.C. Bossert, N. Andreev, E. Barzi, V. Kashikhin, I. Novitski, D. Turrioni, R. Yamada, A. Zlobin, FNAL; S. Caspi, D. Dietderich, LBNL.

As a first step towards the development of a large-aperture

Nb3Sn superconducting guadrupole for the Large Hadron Collider (LHC) luminosity upgrade, two-layer technological quadrupole models (TQ1a and TQ2a) with 90-mm aperture are being constructed at Fermilab and LBNL within the framework of the US LHC Accelerator Research Program (LARP). These models both use the same two-layer, shell type epoxy impregnated coil design, but have different coil support structures. The TQ1a structure was developed and successfully tested at LBNL where coils are assembled and reacted against an outer aluminum shell using keys and bladders. A short quadrupole model TQ2a based on stainless steel collars supported by an iron yoke and thick SS skin is being developed at Fermilab. A short 0.3 m long mechanical model was fabricated and tested to verify the results of the mechanical analysis. The model is instrumented with strain gauges installed on its main components. Stress distribution was monitored during model assembly at room temperature and after cooling down to liquid nitrogen temperature. This paper describes the TQ2a design, fabrication technology and summarizes its main parameters. The ANSYS 2D calculations are reported and compared with measurements on the mechanical model.

WEA07PO09

Nano and micro mechanical study of Nb3Sn wires for the Next European Dipole (NED)

S. Farinon, INFN-Sezione di Genova; C. Scheuerlein, S. Sgobba, P. A. Steinmann, CERN.

The Next European Dipole (NED) activity is aimed at the development of a large aperture, high field superconducting magnet relying on high performances Nb3Sn conductors. Part of the NED program is devoted to the mechanical study of the new generation of Nb3Sn wires and to predict and describe their behavior under the severe loading conditions of the cabling process. The deformation resulting from the cabling process was simulated through mechanical analyses by Finite Elements (FE). In order to set up the analysis, the mechanical properties of the various phases constituting the wire have to be provided. Due to the micrometric size of some of the constituents of the wire, the properties were assessed through microhardness and nanohardness measurements. Nanoindentation is a tool to measure not only hardness at a very local scale (lateral resolution is in the nanometric range and total indentation depths as small as 20 nm are resolved by the instrument), but also to measure local elastic properties of the individual phases based on the recorded force-displacement behavior. The results of FE analyses performed on the basis of the material properties assessed through the mentioned techniques are presented, allowing the wire behavior under simple uniaxial loads to be described.

WEA07PO10

Study of the protection system for cosine-theta Nb3Sn prototype of the NED dipole

M. Sorbi, D. Zamborlin, INFN-Sezione di Milano & Milan University; V. Granata, INFN-Sezione di Milano & CERN; G. Volpini, INFN-Sezione di Milano.

The Next European Dipole (NED) Collaboration has the scope to promote the study and development of a high magnetic field (15 T) and high aperture (88 mm) dipole prototype aimed to the LHC upgrade and to the next generation colliders. Among some other schemes, a classical cosine-theta solution is considered. This magnet will be based on a high current density (Jc around 1500 A/mm2 @ 15 T, 4.2 K in the non-copper section) Nb3Sn superconductor, and will have a high stored magnetic

energy (1.8 MJ/m i.e. 8 times higher than LHC dipoles), that makes the magnet protection extremely critical. For which we have investigated the quench propagation assuming different dump resistance values and operating conditions (quench heaters efficiency, delay time for the QDS), in order to optimize the discharge system in terms of peak temperatures in the coils and maximum voltage drop. The study is performed by using two quench propagation codes, which exploit different approaches, in order to further validate our conclusions.

WEA07PO11

Mechanical analysis of HD2, a 15 Tesla Nb3Sn Dipole Magnet with a 35 mm Bore

P. Ferracin, S. Bartlett, S. Caspi, D. Dietderich, S. Gourlay, R. Hafalia, A. Lietzke, S. Mattafirri, A. McInturff, G. Sabbi, LBNL.

After the fabrication and test of HD1, a 16 T Nb3Sn dipole magnet based on a flat racetrack coil configuration and with a 10 mm bore, the Superconducting Magnet Group at Lawrence Berkeley National Laboratory (LBNL) is developing the Nb3Sn dipole magnet HD2. With a central dipole field above 15 T, a 35 mm bore, and nominal field harmonics within a fraction of one unit, HD2 represents a further step of the block-type coil configuration towards future applications in high-field accelerator magnets. The design features tilted racetrack-type ends, to avoid obstructing the beam path, and a 4 mm stainless steel tube, to support the coil during the pre-stressing operation. The mechanical structure, similar to the one used for HD1, is based on an external aluminum shell pre-tensioned with pressurized bladders. Along the longitudinal direction, four axial rods and a stainless steel plate provide support to the coil ends during magnet excitation. A 3D finite element analysis has been performed in order to evaluate stresses and deformations of the structure from assembly to excitation, with particular emphasis on conductor displacements due to Lorentz forces. Numerical results are presented and discussed.

WEA07PO12

Assembly and Test of SQ01b, a Nb3Sn Racetrack Quadrupole Magnet for the LHC Accelerator Research Program

P. Ferracin, S. Bartlett, A. Lietzke, S. Mattafirri, G. Sabbi, LBNL; G. Ambrosio, B. Bordini, S. Feher, V. Kashikhin, M. Tartaglia, FNAL.

The US LHC Accelerator Research Program consists of four US laboratories (BNL, FNAL, LBNL, and SLAC) collaborating with CERN for an LHC luminosity upgrade and other LHC related goals. As part of the LARP magnet supporting R&D, in 2004 a large aperture Nb3Sn racetrack guadrupole magnet (SQ01) has been fabricated and tested at LBNL. The magnet implemented four subscale coils and was instrumented with strain gauges placed both on the support structure and directly over the turns. SQ01 exhibited training quenches in two of the four coils and reached a peak field in the conductor of 10.4 T at a current of 10.6 kA. After the test, the magnet was disassembled, inspected with pressure indicating films, and reassembled with minor modifications. A second test (SQ01b) was performed at FNAL and included training studies, strain gauges measurements and magnetic measurements. We report in this paper the inspection and test results, with a particular emphasis on mechanical and magnetic behavior. A comparison between strain gauges data, recorded during cool-down and excitation, and 3D finite element computations is performed, and a magnetic analysis, with experimental measurements and numerical predictions, is

presented and discussed.

WEA07PO13

Voltage Spike Observations in LARP Nb3Sn Coil Tests A.F. Lietzke, P. Ferracin, S.A. Gourlay, S. Mattafirri, M. Nyman, G. Sabbi, LBNL; G. Ambrosio, S. Feher, B. Bordini, FNAL.

LHC upgrades are being explored. A US LHC Accelerator Research Program (LARP) is developing a luminosity upgrade, in which high-field Nb3Sn magnets would replace present I-R magnets. Magnet designs are progressing, and proof-of-principle (POP) tests are exploring uncertainties. A recent POP (SQ01) tested the ability of LBNL's AI/Fe preloading technology to position and support four existing Nb3Sn racetrack coils as a large-bore quadrupole. An immediate erratic plateau was observed at ~0.85 lss. voltage-spikes, with "acceleration-deceleration-Sharp "slip-stick" conductor movements, were rings" of successfully recorded preceding most quench-onsets (conductor-motion-limited performance). Repetitive nonquenching spikes (repetitive slipping) was consistent with the erratic plateau. Fourier spectra have been examined. Slower non-quenching "flux-jumps" were observed between 0.2-0.4 Iss. After disassembly measurements also supported pre-load inadequacies, improvements were made. A re-test (SQ01b), this time at FNAL exhibited an immediate erratic plateau at 0.90 lss). While both kinds of voltage-spikes were observed at FNAL, sharp spikes were only seen while traversing virgin-stress territory. "Fluxjumps" were explored versus temperature (2.2- 4.5 K), ramp-speed and direction. Details will be presented and discussed.

WEA07PO14

A Structured-Cable Superconducting Quadrupole for High-Heat-Load Applications

P. McIntyre, A. Sattarov, Texas A&M University.

A superconducting quadrupole has been designed for use in the quadrupoles of an optimized IR design for LHC. The first quadrupole must operate in an environment of high heat load and radiation damage from particles produced in beam-beam interactions. A structured cable has been developed in which 6 round strands of Nb3Sn superconductor are cabled around an Inconel spring tube of the same diameter and the cable is then inserted within an outer sheath of Inconel. The cable is wound to form the coils of a quadrupole. The coil is vacuum-impregnated to fill the voids between cables but not the interior of each cable. The quadrupole is cooled by a manifolded flow of supercritical helium through the cable interiors. The turns are not insulated from one another in the coil, so that in quench current can distribute through the Inconel shells so that voltage cannot develop across the coil. This design uniquely provides volumetric cooling of the coil to compensate for the volumetric heating from particle interactions.

WEA07PO15

Mirror Configuration Assembly and Testing of a "Wind/React" Stress-Managed Block Coil

A. McInturff, LBNL; R. Blackburn, N. Diaczenko, T. Elliott, W. Henchel, A. Jaisle, P. McIntyre, P. Noyes, and A. Sattarov, Texas A&M University.

The second phase of a high field dipole technology development has been completed. This phase consists of a wind/react Nb3Sn/Cu cable "stress-managed" block winding fabricated with A&M's tooling, fixtures, modified procedures and technology. The Result, a fully impregnated ~0.7meter coil module, was assembled in a

"magnetic mirror" configuration and tested at LBNL in LHe to ascertain if the stress-management internal coil structure. Pre-stress springs, and metal filled bladders provided the proper load configuration and magnitude, compliance, and performance. After successful completion of the future phases, This concept verification should result in a cost effective simple process leading to a future high field hadron collider. The test results from special material spec.'s and procedures to the operational loads and performance will be presented. The present status of phase III will be presented as well as a couple of variation.

POSTER SESSION 13:30 - 15:30 DETECTOR MAGNETS

WEA08PO01

JINR Conceptual Design of the PANDA Magnet System E.K. Koshurnikov, N. Agapov, A .Efremov, Y. Lobanov, A. Makarov, A. Sissakian, A. Vodopianov, Joint Institute for Nuclear Research.

PANDA experimental facility at HESR (FAIR, GSI, Darmstadt, Germany) will include a target spectrometer with a 2 T solenoid and a large aperture 2 Tm dipole magnet - part of the forward spectrometer - that is downstream of the solenoid. The target solenoid consists of a superconducting coil with an inner radius of ~0.9 m and a length of 2.5 m. The maximum magnetic field in the operational area is 2 T and field homogeneity in the area of straw detector is better than ±4.9%. The superconducting solenoid of the PANDA magnet system is of split type to provide a warm hole 100 mm in diameter between coil unequal parts for Target System accommodation. Maximal stored energy in the winding is 18.4 MJ. The Dipole Magnet of the PANDA Forward Spectrometer is providing the bending momentum 2 Tm. The magnet is of "H-type" with a rectangle conical aperture and an AI water-cooled winding. Extensive TOSCA magnetic field and forces calculations as well as strength analysis were undertaken to verify the chosen concept of the magnet system. The description of the magnet system components and their implementation are presented on the base of the analysis. Finally the proposed PANDA magnet system concept is discussed in respect of economical efficiency.

WEA08PO02

Tolerances and Uncertainties versus Magnetic Performance in MECO Magnet System

A. Radovinsky, B. Smith, P. Titus, V. Fishman, Plasma Science and Fusion Center, MIT; W. Molzon, C. Chen, J. Guillochen, University of California, Irvine.

MECO, the muon-to-electron conversion experiment, requires a total of 96 solenoid superconducting magnets that will be constructed by industry and assembled in 4 separate cryostats after a full technical design is complete. The MECO magnetic field specifications have been designed to meet certain goals in order to maximize the sensitivity of the experiment. The objective of the tolerances and uncertainties sensitivity studies was to demonstrate the feasibility of building a MECO magnet system around the conceptual design that meets the performance requirements in the presence of expected material property variances, realistic manufacturing tolerances, and manufacturing and design uncertainties. It also presents a vehicle for minimizing manufacturing costs by setting adequate tolerances and using the most appropriate manufacturing and assembly procedures. Monte-Carlo magnetic modeling introduced field errors

from various possible deviations of the real structure from the nominal design, and correlated them with the field performance. The conclusion from the study is that the design is very robust. Easily achieved materials properties and machining and assembly tolerances result in the magnetic field meeting specification. This implies that the project may be able to accept field quality risk and ask the fabricator to accept only the responsibility for placing the coils with correct turn counts in their warm positions at reasonable tolerances.

WEA08PO03

An ultra-thin superconducting solenoid for cosmic-ray observation with ballooning at Antarctica

Y. Makida, T. Kumazawa, K. Tanaka, K. Abe, H. Fuke, T. Yoshida, A. Yamamoto, KEK.

An ultra-thin superconducting solenoid has been developed to provide a magnetic field of 0.8 T in a balloon-borne spectrometer for cosmic ray research, which is named BESS-Polar. The coil with a diameter of 0.9 m, a length of 1.4 m and a thickness of 3.5 mm was wound with a mechanically strengthened aluminum stabilized superconductor. The coil winding is stiff enough to omit the outer support cylinder which is necessary in the former thin solenoid type coils. Consequently the coil weight and thin material are 40 kg, and 2.52 g/cm2, respectively. The BESS-Polar was launched near the US McMurdo Station in Antarctica on December 13th 2004, floated for nine days on circulating air stream at an altitude of 37000 m, and then descended by a parachute. The solenoid was charged up on the ground and kept the field in a persistent current mode during launch and floating, and then was discharged in the sky after the observation completed. Any serious problems did not break out in the solenoid system. This report will describe the preparation and the operation of the solenoid system to contribute to the cosmic ray observation in Antarctica.

WEA08PO04

Quench Performance of Large Radial Build Solenoids in the MECO Detector Magnet

B.A. Smith, P. Titus, Plasma Science and Fusion Center, MIT.

The MECO detector magnet produces magnetic fields of 5 T to 1 T over a curvilinear volume with a 26 m axial length using a set of 96 NbTi solenoid coils in 4 cryostats operating at about 4.5 K. At the high field end of the magnet system, the solenoids have an inner radius of 0.88 m, and radial builds of about 0.125 m. In these relatively large radial build coils, guenches initiating at the high field region at the inner radius result in warm temperatures there, while the outer radial region can remain substantially cooler, even after 60 seconds when most of the current has decayed from the guench-protective dump. The warm inner zone of the winding places the cooler outer zone in axial tension that must be carried by the turn-to-turn insulation. This paper discusses the quench modeling process, which includes a 3-D solenoid quench code that provides element-by-element temperature data at each time point to ANSYS for structural analysis of the tensile strains. The paper also evaluates methods of managing the insulation surface-normal tensile strains, including use of copper sheets to generate eddy current heating and distribute the heat by thermal conduction to minimize the zonal temperature differences during the transient. I ocal cracking and debonding of the insulation layer affects the insulation voltage capacity. The choice of reasonable design criteria for the baseline insulation operating in this strain field, and the need for compressive preload are also

discussed.

WEA08PO05

Status of the KEDR superconducting magnet system

A.K. Barladyan, V.V. Anashin, L.M. Barkov, S.V. Karpov, V.F. Kulikov, A.B. Lobkov, S.G. Pivovarov, V.I. Plyusnin, A.A. Ruban, Y.A. Tikhonov, BINP.

Big superconducting solenoid of 2.84 m long and 3.1 m in diameter designed on magnetic field of 1.83 T is one of the main components of the KEDR universal detector at e+ecollider VEPP-4M. The detector is one of 5 large ones, which is operates in the energy region from psi to upsilon mesons, in the world. Two compact compensate superconducting solenoids of 0.433 m long and of 0.162 m in diameter designed on magnetic field of 6.55 T are situated on both poles of the main solenoid for minimize to zero an integral of magnetic field over the beam's trajectory in the detector. Iron yoke with total mass of 800,000 kg complete the KEDR' magnet system. Unique features of the main solenoid is the one-layer NbTi/Cu coil soldered by PbSn alloy into its supporting stainless steel helium cryostat for protect it from quenching and the power supply being a fluxpump type. The main solenoid being exploited since 2002 is only provides magnetic field of 0.7 T in the KEDR detector. After last run of the detector's job we will try to grown magnetic field in the detector up to 1 T and more, in the summer 2005. Experience of long time exploitation the superconducting magnet system of the KEDR detector as well as its cryogenic maintenance system based on helium refrigerator with an piston type expander machine with cooling power of 600 W at the temperature level of 4.2 K and last test results are described.

WEA08P006

Thin Superconducting Solenoid For CMD-3 Detector

A.V. Bragin, L. Barkov, S. Karpov, Y. Popov, N. Ryskulov, BINP.

The manufacturing status of the thin superconducting solenoid for the CMD-3 detector is described. The superconducting solenoid produces a 1.5 T magnetic field in the drift chamber of the detector. The dimensions of solenoid are 0.9 m length, 0.7 m diameter and 6 mm coil thickness. Its coil should contain minimal amount of matter in terms of radiation length in order to provide necessary accuracy of energy measurements of particles by outer calorimeters of the detector. The winding of the solenoid is made of two layers of the NbTi/Cu cable placed into the helical grooves of the aluminum support cylinder. The coil is quench protected by subdividing resistors having the total resistance about 40 mOhm. The solenoid is indirectly cooled using high purity aluminum strips. The radiation thickness of the coil is estimated to be 0.08 radiation length. The manufactured coil has being tested; the charging of the solenoid to operating current will be made in the second half of 2005 year.

WEA08PO07

Comparison between active and passive shielding designs for a large acceptance superconducting dipole magnet

B. Gastineau, C. Pes, CEA DSM DAPNIA SACM; J-E. Ducret, CEA DSM DAPNIA SPhN.

A large acceptance magnet is being designed at CEA (Saclay, France) for experiments using secondary relativistic radioactive beams at the future FAIR facility, in GSI (Germany). Two solutions are compared: A fully superconducting magnet with active shielding and a design combining superconducting coils and iron yoke. Both have

been studied to respect the new requirements of nuclear physics experiments: A momentum resolution of up to 10**-3 with 1 GeV/nucleon beams, a field integral of 5 T.m, a low fringe field, especially in the target region 1 meter upstream from the magnet entrance, and a large solid angle and momentum acceptance defined by a maximum bending angle of 40° (for protons) together with the transparency for neutrons and a vertical & horizontal angular range of +/- 80 mrad. The iron shielding needs a heavier mass of near 300 tons with respect to the active one, thus the total device volume is not so different (4 meter diameter) With iron the coil volume is divided by two (compared with the same current density value) but the stored energy is only decreased by less than 20%. The kinematical reconstruction algorithms show that both designs, either with iron pole & yoke or with innovative shielding coils, give results within the specifications, as shown by the given figures of merit. As a conclusion we could say that this study shows the limits of a traditional iron design, and that the physics requirements open the way of a non-usual active shielding solution.

WEA08P008

Design of a 5T Solenoid Magnet for the ILC

R.P. Smith, R. Wands, FNAL

The global design effort for the International Linear Collider is now underway. On a timescale that overlaps the operating period of the CERN Large Hadron Collider, the new linear collider will be brought into operation to provide collisions between electrons and positrons at energies of 500 -- 1000 GeV. A variety of detectors are proposed for the new machine and research and development for specific components of the detectors has begun. One such detector, the Silicon Detector (SiD), proposes to enclose a precision silicon tracking system in a 5T solenoidal magnetic field. The superconducting magnet must also provide a sufficiently large bore to enclose the tracking and the electromagnetic and systems hadronic of the detector. calorimeters External to the superconducting coil are the steel absorber layers of the muon system, which also provide the flux return for the magnet. In this paper a design study for a the 5 T SiD superconducting solenoid, storing 1.4 GJ magnetic energy, is presented. The results the mechanical analysis of the coil, based on a specific conductor and winding design, are highlighted.

POSTER SESSION	13:30 - 15:30
ENERGY STORAGE (I)	

WEA09PO01

Development of 10 kJ conduction-cooled high temperature superconducting magnet

Q. Wang, H. Huang, L. Yan, Y. Dai, S. Song, Y. Lei, Y. Yu, Y. Yuan, Institute of Electrical Engineering, CAS.

We are designing and fabricating a 10 kJ conductioncooled high temperature superconducting (HTS) magnet foe the Superconducting Magnetic Energy System. The magnet is made of Bi-2223 double pancake coils, and has inner and outer coil diameters of 120 mm and 211.2 mm, respectively and coil height of 202.8 mm. The superconducting magnet includes 20 double pancake coils. The operating current is about 87.8 A. This magnet is cryocooler-cooled with no liquid helium and should generate a magnetic filed of 3 T at a temperature of 20 K. We developed and tested a model Bi-2223 double pancake coil. The design and technique of the magnet is reported in the paper.

WEA09P002

3MJ/750kVA SMES System for Improving Power Quality

H.J. Kim, K.C. Seong, J.W. Cho, J.B. Bae, K.D. Sim, Korea Electrotechnology Research Institute; K.W. Ryu, Chonnam National University; S.H. Kim, Gyeongsang National University.

The purpose of this study is to develop a superconducting magnet energy storage system (SMES), which protects sensitive loads on the power system, when an interruption or voltage sag occurs. Industries also have many sensitive machines, and keeping the power in a good condition is very important for non-military machines also. Korea Electrotechnology Research Institute (KERI) has developed a 3MJ/750kVA SMES system to improve power quality in sensitive electric loads. It consists of an IGBT based power converter, NbTi mixed matrix Rutherford cable superconducting magnet, and a cryostat with HTS current leads. A computer code was developed to find the parameters of the SMES magnet which has minimum amount of superconductors for the same stored energy, and the 3MJ SMES magnet was designed based upon that. The SMES system is tested under short time power interrupt to verify the feasibility of the SMES system as a 750kVA uninterruptible power supply.

WEA09PO03

Design and Performance of a Bi-2223/Ag Coil Impregnated with Solid Nitrogen Based on Quantitative J-E Expressions

K. Higashikawa, T. Nakamura, Kyoto University; H. Okamoto, Kyushu Electric Power Company.

We have carried out an optimal design of a Bi-2223/Ag coil for SMES, and then investigated its performance. The objective of the design is the minimization of total length of the Bi-2223/Ag tape, on condition that energy loss of the coil does not exceed cooling capacity of a cryocooler at fixed operating temperature as well as stored energy. The design method consists of 3-dimensional finite element method (FEM) and genetic algorithm (GA). The FEM includes not only the electromagnetic analysis but also the thermal analysis in order to examine the effectiveness of impregnation with solid nitrogen. In addition, the FEM analysis also take into account quantitative J-E expressions based on percolation transition model, which agree very well with experimental data for wide rages of temperature (20-77 K), magnetic field (0.02-3 T) and its applied direction (arbitrary). That is, such analysis can precisely estimate the energy loss with consideration of temperature distribution inside the coil. On the other hand, GA is a particularly effective optimization method when the objective function has a number of local minimums. Thus, the design method introduced in this study is applicable even if complicate transport properties in the tape form local optimal solutions. We will show a design result of the coil as well as its performance, and then suggest also the availability of additional cryogens such as solid nitrogen for conduction cooled coil applications.

WEA09PO04

Low-temperature operation of a closed-loop buck converter with DC/DC transformer

G. Yang, M. Qiu, Institute of Electrical Engineering, CAS.

High-Tc Superconducting magnetic energy storage system (SMES) has been proposed for use in flexible AC transmission systems (FACTS) because of its high efficiency and rapid response to power demand. DC/DC

and DC/AC converters are the absolutely necessary parts in the system. Usually, High-Tc SMES requires liquid nitrogen for its operation. If these converters have the ability to work at the same cryogenic environment, it would bring lots of facilitation for the whole system. Hence, the electrical behaviors of some commercially available passive components for the converters were experimentally measured at low temperatures. As a trial, a closed-loop buck converter with dc/dc transformer was designed and investigated at 77 K. Performance characteristics, such as efficiency and regulation, were analyzed from 77 K to room temperature in the paper.

WEA09P005

Test Results on the Experimental SMES System with Normal conducting Shielding Coils

Y. Horiuchi, S. Inokuchi, M. Otsubo, T. Ezaki, Oita University; T. Imayoshi, Kyushu Electric Power Co., Inc. A shielding coil system, that is consisted of a main superconducting coil and a normal conducting shielding coil connected in parallel to it, is effective to reduce pulse losses of the superconducting coil of the SMES system for power system control, such as power line stabilization and compensation of power fluctuation, because the fluctuated current at energy in/output is diverted to the shielding coil and the only constant current flows in the main superconducting coil. For the shielding condition, however, it is necessary to compensate the voltage drop due to the normal resistance of the shielding coil. We are studying about this voltage drop compensator and have made an experimental shielding coil system to verify the operation of the voltage compensator. The experimental shielding coil system is composed of coaxial solenoid type coils which are a main .superconducting coil and a shielding coil. To achieve a shielding condition for their inductances. adjustable two correction coils are attached to the shielding coil. Here, results of performance tests on the shielding coil system including work of the voltage drop compensator will be presented.

WEA09P006

Design of a high energy-density SMES coil with Bi2212 cables

K. Koyanagi, K. Ohsemochi, T. Kurusu, M. Ono, S. Nomura, K. Shimada, Toshiba Corporation; K. Kidoguchi, H. Onoda, N. Hirano, S. Nagaya, Chubu Electric Power Company.

Development of HTS-SMES has been worked on as a Japanese national project since FY 2004 for four-year project as a sub-program of the Development of Superconducting Power Network Control Technology. Compared with the conventional LTS conductors, HTS conductors are promising for SMES application because of their superior characteristics in high magnetic fields. This results in higher overall system performance of SMES, such as dense stored energy of a superconducting coil. In this paper, a design of 5 MJ SMES using HTS high-field coils and a LTS outer coil is presented. The HTS coil is comprised of 16 double-pancake windings React and Wound techniques with Bi2212 Rutherford cables. The cable of 200 m length is used for each double-pancake windings, and reinforcing materials are co-wound. Winding inner diameter of 360 mm was set according to the bending tolerance of the cable, and outer diameter was restricted within 730 mm by the cable length. The coil is immersed in liquid helium and designed to generate a maximum field of 8 T within the backup field at an operating current of 1600 A. In the experiments, superconducting characteristics of the coil in a high magnetic field will be evaluated.

WEA09P007

Design and Test of a Series SMES (SSMES) With Fault Current Limiting Function

C. Zhao, L. Xiao, L. Lin, Y. Yu, Institute of Electrical Engineering, CAS.

Series SMES (SSMES) with fault current limiting function is a new kind of SMES (Superconducting Magnetic Energy Storage) for substation applications, and it is connected with the distribution system in series. A 0.1MJ/ 20kW SSMES model is developed in a 380V three-phase system for improving power quality and limiting the fault current. It mainly consists of a NbTi magnet with coaxial and homocentric configuration for reducing stray field, a threehalf-bridge inverter and a 1000A current regulator with a two- DSP control system. This paper describes the design and experimental results for the SSMES model.

WEA09P008

Design Considerations for SMES Systems Using MgB2 and/or High-Temperature Superconductors

S. Nomura, R. Shimada, Tokyo Institute of Technology; T. Shintomi, KEK.

MgB2 and high-temperature superconductors (HTS) are expected to reduce refrigeration energy requirements for superconducting coils. If MgB2 and HTS carry usable current densities at high magnetic fields, in contrast to NbTi superconductors, superconducting magnetic enerav storage (SMES) systems will be realized in smaller coil dimensions and shorter conductor lengths. This work discusses the design considerations for the SMES systems using MgB2 and/or HTS coils, and evaluates the required specifications of MgB2 and HTS as follows: (1) the critical current density of the superconducting materials should be higher than 1000 A/mm2 at 15-20 K and 5-10 T in order to improve small-sized SMES systems, (2) 50-kA class superconductors with lengths of 5-10 km are required from the view point of the coil construction. However, there still remains a problem of electromagnetic forces induced by coil currents and high magnetic fields. Then the SMES systems require special structural considerations to limit allowable tensile stresses. To cope with this problem, the concept of force-balanced coil (FBC) has been developed. The FBC is a helically wound hybrid coil of toroidal field coils (TFCs) and a solenoid. This coil can minimize the required mass of the structure for the energy storage. This work also estimates the operating current density within an allowable stress of the superconductor among the FBC, the TFCs and the solenoid.

WEA09PO09

A SMES based power supply for accelerator magnets

R. Gehring, K-P. Juengst, FZK; G. Kuperman, Ingeneurbüro Kuperman; F. Bordry, J-P. Burnet, F. Voelker, CERN.

As particle accelerator technology advances, rapid cycling machines become more common. An increase in ramping speed of the magnets will draw more pulsed power from the utilities grid up to non acceptable levels. An intermediate storage of active and reactive power with fast reaction times and excellent cycling capabilities becomes more and more important. A study has been performed for the conceivable replacement of the existing magnet power supply of the PS (Proton Synchrotron) of CERN. A possible solution is a SMES based modular compensator system which allows a step by step build-up of the system in turn with test operations during regular shut-down phases while continuing operation of the existing power supply.
WEA09PO10

Test results of power system control by the experimental SMES

H. Hayashi, T. Nagafuchi, Y. Hatabe, A. Taguchi, S. Taniguchi, Kyushu Electric Power Co., Inc.; K. Terazono, International Superconductivity Technology Center.

The authors have developed a solenoid model coil used for SMES for power system control, aiming at drastically reducing the costs of SMES system. The single solenoid model coil of 2.9MJ is designed with the rated current of 9.6kA, maximum magnetic field of 5.5T and coil charge rates equivalent to those of the practical 100MW/54MJ class SMES. The coil is characterized by the use of an aluminum stabilized NbTi CIC conductor. The experimental SMES was mainly consists of the 2.9MJ coil, the cooling system for CIC conductor and the 1MW class AC/DC converter. The SMES connected with the 6kV distribution lines at the substation. In the field tests, the SMES's 16 -17ms responses for the step input of active and reactive power were measured. Furthermore, its function for compensating load fluctuation of 6kV distribution line was confirmed. The test results show the realization of practical SMES system for power line control.

POSTER SESSION	13:30 - 15:30
HIGH FIELD MAGNETS	

WEA10PO01

Design and Fabrication of A Wide-bore Conductioncooled Superconducting Magnet

Q. Wang, Y. Dai, L. Yan, S. Song, B. Zhao, Y. Lei, Institute of Electrical Engineering, CAS.

A conduction-cooled magnet was designed, fabricated and tested. A two-stage 4 K Gifford-McMahon (GM) cryocooler with the second-stage power in 1 W is used to cool the superconducting magnet from room temperature to 4 K. The superconducting magnet has the operating current of 115A, the effective warm hole of f 180 mm, the maximum center field of 6 Tesla. The magnet can be rotated with a support frame to be operated with either horizontal or vertical position. A pair of Bi-2223 high temperature superconducting current leads was employed to reduce heat leakage into 4.2K level. The magnet system has f742 mm outside diameter, 558 mm height and 180 kg weight. The superconducting magnet was cooled and tested directly through cryocooler. It is reached to operating current of 115A without training effect to be observed during charge of the magnet. It shows that the training effect in the magnet directly cool-down by cryocooler and inter-winding support structure in magnet can be remarkably improved. The superconducting magnet was stably operating more than 275 hours continuously in full field. Further, a Nb3Sn coil insert to be installed, the magnet can provide the maximum center field of 10 Tesla with effective warm bore of f 100 mm. In this paper, the detailed design, fabrication, stress and quench protection are presented.

WEA10PO02

Development of A Conduction Cooled Superconducting Split Magnet

Y. Dai, H. Wang, B. Zhao, Y. Lei, Q. Wang, S. Song, Institute of Electrical Engineering, Chinese Academy of Sciences.

A superconducting split magnet is designed and fabricated as a laboratory test facility. Two superconducting coils are wound with NbTi superconducting wire and assembled into a rigid magnet structure. A pair of HTS current lead are integrated into the power supplying circuit to reduce heat leak from room temperature. The magnet is conduction cooled to 4K with the assistance of a 2-stage GM cryocooler. Magnetic design, quench simulation and heat leakage analysis of the magnet system are presented in this paper.

WEA10P003

A 13.4 MW Bitter Insert for a 37.9 T Hybrid Magnet

T. Asano, S. Matsumoto, T. Kiyoshi, H. Yoshioka, G. Kido, NIMS.

A new resistive insert magnet for a hybrid magnet was designed and constructed at the Tsukuba Magnet Laboratory (TML) of the National Institute for Materials Science (NIMS). This insert magnet successfully generated a magnetic field of 37.86 T in a 32 mm warm bore with a buck-up field of 14.02 T during the test operation. The maximum electric power for the coil was 13.35 MW during this operation. A parameter survey was carried out which led to the constitution of the four coaxial and axially cooled coils based on the scattered layout of the elongated cooling holes of the bitter disk. The two innermost coils are connected electrically in parallel, and the tie rods of the outer coil of the pair are also clamped to the innermost coil, which does not have its own tie rod. This parallel assembly is connected in a series, with the two outer coils connected in parallel. The bitter disks used in the coils, except the outermost coil, are made of Cu-Ag plates. The magnet is now in operation.

WEA10PO04

A 52 mm Warm-bore Bitter Insert for a 35.4 T Hybrid Magnet

T. Asano, S. Matsumoto, H. Yoshioka, T. Kiyoshi, G. Kido, NIMS.

A new 52 mm warm-bore resistive insert for a hybrid magnet was designed and constructed at the Tsukuba Magnet Laboratory (TML) of the National Institute for Materials Science (NIMS). This magnet successfully generated a magnetic field of 35.54 T at an operating current of 34.88 kA and a voltage of 367.5 V, with a buck-up field of 14.02 T. To supply high magnetic fields for a longer time, the constitution of the three axially cooled coaxial coils and the scattered layout of the elongated cooling holes were fixed by a parameter survey that was carried out considering the reduction in the operating electric power. The innermost coil is connected electrically in a series, with the two outer coils connected in parallel. The bitter disks used in the coils are made of Cu-Ag plates. The magnet is now in operation.

WEA10P005

Conceptual Design of a Split Resistive Magnet at the $\ensuremath{\mathsf{NHMFL}}$

M.D. Bird, S. Bole, J. Toth, NHMFL.

The National High Magnetic Field Laboratory in Tallahassee, Florida designs, builds and operates the world's highest field dc resistive magnets, providing fields up to 33 T in resistive solenoids and up to 45 T in resistive-superconducting hybrid solenoids. A new project is underway to develop a high field split magnet with radial ports. Conceptual design of the magnet will be presented. The field is expected to exceed 25 T while providing a uniquely large mid-plane scattering space for far-infrared scattering experiments.

WEA10PO06

Design of an 8 MW Water-Cooled Magnet for a 35 T

Hybrid Magnet at the HFLSM

K. Takahashi, S. Awaji, K. Koyama, K. Watanabe, High Field Laboratory for Superconducting Materials, IMR, Tohoku University.

We are now intending to construct a new water-cooled poly-Bitter magnet that will provide 35 T as a hybrid magnet with a backup field of 11.5 T by an outer superconducting magnet. The magnet was designed under the fully utilization of the electric power source of 8 MW and the cooling system installed in the High Field Laboratory for Superconducting Materials (HFLSM), Tohoku University. The designed magnet consists of four axial water-cooled Bitter coils which are electrically connected in series and all of cooling water flows from the bottom to the upper side of coils. The innermost coil diameter is 20 mm and a room temperature bore of 16 mm is available for experiments. According to our first design, the Bitter magnet will generate fields up to 22.8 T by 7.5 MW electric power and a hybrid magnet will achieve 34.3 T. A magnetic force field, B(dB/ dz), which is an important factor for magnetic levitation experiments, reaches to about -11100 T2/m at the central field of 34.3 T. This force field value is very large enough to levitate semiconductors such as silicon or germanium.

WEA10PO07

Mechanical Design of the Series Connected Hybrid Magnet Superconducting Outsert

I. Dixon, M. Bird, J. Miller, D. Knonll, NHMFL.

An innovative hybrid magnet configuration is being developed at the NHMFL, consisting of a Florida-Bitter resistive magnet nested within a cable-in-conduit conductor (CICC) superconducting magnet to provide high fields for less power than traditional hybrid magnets. The resistive and superconducting magnets, connected in series, will be capable of producing 20 T and 15 T respectively for a total central field of 35 T. The CICC uses a cable of multifilimentary Nb3Sn/Cu strands inside a superalloy jacket that confines flowing supercritical helium in direct contact with the cable strands. The design of the magnet system is presented along with the design criteria used to evaluate the superconducting magnet and its integral components. The results of a structural analysis performed using finite elements for normal operational and fault loads are discussed.

WEA10P008

Development of a 20 Tesla Superconducting Magnet

Y. Okui, R. Hirose, S. Fukumizu, S. Hayashi, K. Saito, JASTEC.

We designed and developed a 20T superconducting magnet for studying physical properties. Cryostats are open neck dewars with a liquid nitrogen reservoir and radiation shield. A lambda plate is built into the magnet support assembly. The operating temperature can be reduced from 4.2K to 2.2K by pumping liquid helium through a throttle valve under the lambda plate. The central magnetic field is 20T at 2.5K (18T at 4.2K). The field homogeneity is less than +/-0.1% at a 10mm sphere. The inner diameter of the cold clear bore is 52mm. The outer diameter of the coil is 349mm. The height of the coil, including the magnet protection circuit, is 560.5mm. The coil is wound with the specially developed wires for use in high magnetic fields. In the case of Nb3Sn wires, a marked increase of the critical current density is achieved with higher tin content in the bronze matrix together. The wires are more resistant external stress with a rectangular cross section. We hung the magnet into dewars and energized it. At first the magnet was operated at liquid helium

temperature 4.2K. As a result, the magnetic field rose to over 18T with no training quench. The maximum magnetic field was 18.5T. Then we energized after reducing the operating temperature to 2.2K. Finally, the magnetic field rose to over 20T with no quench. The result of this study shows that this magnet delivers a high magnetic field stably and easily.

WEA10P009

Design for a 50 mm bore 32 T Resistive and Hybrid Magnet at the Nijmegen HFML

S. Wiegers, J. Ros, J. Perenboom, J. K. Maan, High Field Magnet Laboratory, IMM, Radboud University Nijmegen. To accommodate experiments which need long exposure (several hours) to high and stable magnetic fields, we have designed a three-coil resistive 50 mm bore insert that can be fitted in the C coil (providing about 7.5T) of an existing 33 T magnet, as well as in the room temperature bore of our 8 T or 11 T superconducting hybrid outserts. Either combination provides magnetic fields in excess of 32 T, and using the 8 T hybrid combination only 10 MW power will sustain a magnetic field of 30.1 T. Because our cooling plant has a real-time cooling power of around 10 MW, this means we will be able to sustain 30 T for very long times and economically, in a 50 mm bore, facilitating e.g. NMR experiments. The design of the insert coil is so optimized that it needs only slight adaptation in stacking for the three possible outserts (C coil, 8 T or 11 T outsert), and otherwise is built with identical disks and other parts.

WEA10PO10

The Grenoble High Magnetic Field Laboratory (GHMFL) *E. Mossang, F. Debray, H. Jongbloets, W. Joss, G. Martinez, P. Petmezakis, P. Sala, C. Trophime, P. Wyder, GHMFL.*

The GHMFL, operated by the Centre National de la Recherche Scientifique (CNRS), is one of the leading laboratories pursuing research in the highest static magnetic fields technically feasible. During the last ten years, the GHMFL has kept on with a strong development related to magnet technology. Two 20 MW magnets are in operation and yield steady magnetic fields up to 30 teslas. The GHMFL has developed an extensive range of highly sophisticated instrumentation for specific use under high fields, including transport, magnetisation, visible and infrared optical measurements at low temperatures and/or high pressures, EPR and NMR investigations in high magnetic fields. The laboratory partly operates as a user facility for qualified external researchers. Scientists have access to the high field installation provided they have submitted a proposal for experiments in high magnetic fields and have obtained the Program Committee's approval to carry out their research work. Access for users to the high field facility is supported by the E.U., in the frame of the "Transnational Access to Infrastructures -Specific Support Action" contract. Resident scientists also use the facility to pursue their own research activities. We give an overview of the technical aspects and of the activities of the facility over the past few years. Statistics related to the scientific projects, the need for high field magnets and the breakdown between the different countries will be presented.

WEA10PO11

Preliminary Design of Cryostat Structure for 21T FT-ICR Magnet

B-S. Lee, D-L. Kim, H-S. Yang, J.S. Yoo, Korea Basic Science Institute; Y.S. Choi, T. Painter, J. Miller, NHMFL. The cryostat for the 21T FT-ICR superconducting magnet has horizontal type and the support system for this cryostat must be considered various aspects. Above all, Because the support length of horizontal type cryostat is shorter than the support length of vertical type cryostat, the issue for this system is reduction of heat invasion due to conduction and effective endurance for self weight and emergency within short working space for installation. The device for correction of position after cool-down and charge are discussed because horizontal type cryostat is generated transfer of magnetic field center due to thermal contraction of cryostats. For detailed information related on preliminary design, The simulation by using ANSYS is also performed and is considered in view of thermal and structural effect.

POSTER SESSION	13:30 - 15:30
INDUSTRIAL APPLICATIO	NS (II)

WEA11PO01

Dynamic Characteristics of HTS Bulk Magnetic Suspension System

Z. Wen, College of Astronautics, Beijing University of Aeronautics & Astronautics.

A world-wide conceptual design study has been carried out in support of highly reusable space transportation systems by using magnetic levitation as launch assistance. The magnetic levitation technique is regarded as a good alternative of the next generation of launcher system owing to its cost-effectiveness and perfect performance. Recently, a research plan was performed in our lab by constructing a scale-model suspension system with HTS bulks over a 7 Nd-Fe-B track for launch assistance. meter An experimental platform was built by means of a mechanical oscillator to investigate the dynamic stability of PM-HTS bulk magnetic suspension. The dynamic responses of the PM-HTS bulk suspension unit were experimentally recorded and analyzed with the theoretical simulations. Some technical considerations were discussed in the paper.

WEA11PO02

Construction and Performance of HTS Maglev Launch Assist Test Vehicle

W.J. Yang, Z. Wen, M. Qiu, Y. Liu, G.H. Yang, Y.F. Liao, College of Astronautics, Beijing University of Aeronautics & Astronautics.

Various maglev launch assist concepts were proposed in the world for the aim to find low-cost, safe, and reliable ways to get to space. Among them, high temperature superconducting (HTS) bulk magnetic levitation platform was considered as a better one for maglev launch assist because of its inherent stability both in the vertical and lateral directions. As a primary work, a demo HTS maglev launch assist test vehicle was designed and constructed in our laboratory. The system includes a vehicle body, permanent magnet guideway with the length of 7 m, the acceleration and braking parts. HTS bulks were located in LN2 vessels fixed below the vehicle body. The levitation force larger than 50 kg was provided by the interaction between HTS bulks and NdFeB guideway. The HTS bulk arrangement was optimized by measuring and comparing static and dynamic levitating characteristics of different HTS bulk units on NdFeB guideway. The acceleration part of the system was composed of rocket nozzle and gas pressure vessel to produce 3g acceleration. The braking was achieved by a set of linear motors. The experimental investigation was carried out in the system, and some results were presented in the paper.

WEA11PO03

ApplicationsofLowTemperature,ACSuperconducting Magnets for Material ProcessingH. Kasahara, CRIEPI; S. Taniguchi, K. Ueno, Tohoku

University; S-I. Shimazaki, JST.

We did a fundamental examination of an application for materials processing using AC superconducting magnets. Using AC magnets, applied two axis movement magnetic fields, and stiring melted metals. It can generate a high density alloy. To applicate AC Superconductor, it is necessary that (1) thermal insulation technology, (2) optimizing of magnet shapes, and (3) optimizarion of a magnet driving conditions. In this paper, we present a basic examination results.

WEA11PO04

The numerical analysis of magnetic stiffness in a magnetic levitation

X. Wang, S. Wang, J. Wang, H. Song, J. Zheng, Southwest Jiaotong University.

A two-dimensional numerical analysis, taking the voltagecurrent power-law characteristic of the high temperature superconductor into account, was proposed to calculate the associated stiffness on a YBCO bulk superconductor above a permanent magnet guideway when small movements were produced. The dependence of stiffness matrix upon the different field cooling position was extensively studied based on the finite element theory. Additionally, the numerical technology discussed the influence of the iron surrounding the permanent magnet, which is beneficial to the design and optimization of the high temperature superconductor Maglev system

WEA11PO05

The effect of magnetic force on oxygen bubble during the oxide crystal growth

J. Park, T. Shimomura, M. Yamanaka, S. Watauchi, I. Tanaka, Center for Science and Technology, University of Yamanashi; K. Kishio, The University of Tokyo.

Oxygen bubble in a crystal is inevitable during a conventional floating zone (FZ) growth of calcium aluminate (Ca12Al7O33; C12A7), a newly remarkable material as a transparent electrical conductor. We investigated the effects of magnetic force on the behavior of oxygen bubbles during crystal growth of C12A7 because of the extreme large paramagnetism of oxygen. For the crystal growth of C12A7 under magnetic field, the FZ furnace is specially designed and installed with a superconducting magnet. In this furnace, the size of melt for the crystal growth is small and the melt position is variable along the magnet bore; therefore, the direction of the magnetic force is changeable by the growth position. In this study, C12A7 crystals were grown at two different positions, where the magnetic force to oxygen bubbles works upward and downward, respectively. In the growth condition when magnetic force was upward, the grown crystals were half transparent and half opaque due to the segregation of oxygen bubbles. The number of the segregated bubbles was reduced as the applied magnetic force was increased. On the other hands, the crystals grown under the downward magnetic force were transparent under higher magnetic field than 5T. Our results show that the behavior of oxygen bubbles can be controlled by magnetic force even over 1392 degree of Celsius, the melting point of C12A7 and that the downward magnetic force is effective to obtain transparent C12A7 crystals.

WEA11PO06

Numerical Study on Magnetic Separation of Multiple Kinds Particles Using Narrow Channel Placed in Quadrupole Magnetic Field

M. Takahashi, S. Fukui, Y. Takahashi, M. Yamaguchi, J. Ogawa, T. Sato, M. Ooizumi, H. Imaizumi, Niigata University; T. Ohara, Kanazawa Institute of Technology; T. Watanabe, Tokyo Metropolitan University.

Magnetic separation combining with a high field superconducting magnet has been expected to apply for various industrial waste treatment processes. The magnetic separation is classified in the high gradient magnetic separation and the open gradient magnetic separation. In our previous study, we have proposed a new method of the open gradient magnetic separation using quadrupole magnetic field. In this study, we focus on the selective separation of multiple kinds of the particles with different magnetic susceptibility by using the fine narrow channels placed in the quadrupole magnetic field. The numerical study is conducted to evaluate the characteristics of separating the two kinds of particles with different magnetic susceptibility. The dependence of separation characteristics on the differences of magnetic susceptibility, the channel arrangement and the flow velocity in the channel is calculated and the validity of the proposed methods is discussed.

WEA11PO07

Vibration properties of Maglev vehicle module using bulk high-Tc superconductors

J. Zheng, J. Wang, S. Wang, Y. Zhang, G. Zeng, H. Song, Y. Huang, Southwest Jiaotong University.

It is proved that a most prospective application of bulk high-Tc superconductors (HTS) is for the superconducting Maglev vehicle. Such a multi-degree-of-freedom dynamical transportation system is coupled by the noncontact and nonlinear interaction between HTS bulks and the permanent magnet (PM) rail. Whether a vehicle using HTS bulks is statically levitated or running above the PM rail, complicated phenomena of nonlinear dynamics take place easily. A mini maglev vehicle module using YBCO bulks is set up in this paper. The oscillation characteristic of the vehicle module in the three directions is investigated in its free vibration and forced vibration by instantaneous exciter. The natural frequency is measured. Field-cooling height and maximum running height for stable levitation, decay time, safe load and drift locus are also measured as a function of the amplitude and position of the mechanical exciters. The paper aims to predict anti-interference and safe operation capability of the HTS maglev transportation system to some extent.

WEA11PO08

Small-scale displacement performed on electro-maglev system composed of Y-Ba-Cu-O bulks and permanent magnets

T-Y. Yang, B-P. Lin, C-C. Wang, I-G. Chen, Department of Materials Science and Engineering, National Cheng-Kung University; S-Y. Chen, M-K. Wu, Institute of Physics, Academia Sinica, Taiwan. Withdrawn.

WEA11PO09

Experimental Study and Optimal Design of HTS Bulk Levitation on PM Guideway

M. Qiu, G.H. Yang, Institute of Electrical Engineering, CAS; W.J. Yang, Z. Wen, Y. Liu, Beijing University of Aeronautics & Astronautics.

Magnetic levitation and propulsion has been viewed as a

safe, reliable, and inexpensive launch assist for sending small payloads into orbit. In order to study the feasibility of HTS levitation system for the purpose, a experimental setup was designed and constructed to study the levitation force and guidance force of HTS bulks above PM guideway. The measurements were performed in zerofield-cooled and field-cooled conditions for differents configurations of HTS bulks and NdFeB arrangements. The results were compared with computional simulations. An optimal design was presented and discussed for the levitation system.

WEA11PO10

Application Design and modeling of Magnetostrictive thin film Actuator

H. Chen, Q. Yang, S. Liu, C. Fan, W. Yang, R. Yan, W. Yan, Hebei University of Technology.

There is a growing variety of micro-sensors and actuators that incorporate layered structures made of a magnetostrictive thin film (single layer or multilayer) deposited on a nonmagnetic substrate. The interest in the study and the exploitation of these structures, also known as bimorphs, arise from the potential advantages that they offer to the designer who is interested in remote operation, high-energy density, short response time and manufacturability. Unfortunately, the tools available for modeling and design of magnetostrictive layered structures are still not sufficiently developed. In this work we intend to contribute to these areas by presenting models and methods to design and calculate the deformation induced in film-substrate systems. The models currently used to determine the deflection are based on finite element method (FEM), with which the distortion of the elements will decrease the precision, just as mentioned in the reference . A magneto-mechanical strong coupling model of magnetostrictive thin film structures has been proposed and calculated by the Element Free Galerkin Method (EFGM) and the calculating precision is higher. At last, a film-substrate actuator model is realized and experiments are made. The computation results are compared with the experiment data to illustrate the performance of EFGM and examine the efficiency of the model which can be applied to forecast and simulate the real process of micro-sensor or actuators.

POSTER	SESSION	13	:30 - 15:30
FUSION	MAGNET	TECHNOLOGY	CRITICAL
ISSUES (II)		

WEA12PO01

Development and Manufacture of a PF Conductor Tail Mock-Up

N.A. Dolgetta, EURATOM/CEA; P. DeCool, CEA; A. Bourquard, ALSTOM; L. Moreschi, ENEA.

The ITER-PF winding pack's design consists of a stack of double pancakes made of NbTi CIC conductor, with a square section stainless steel jacket. At each electrical joint, and terminals, a structural element is required to react the operating hoop load on the conductor. In the present design, this is provided by a "conductor tail", welded to the conductor jacket and bonded to the adjacent turns. The operational hoop load is in this way transmitted to to the bulk of the coil, by shear stresses, through the interposed insulation. A FEM based design was previously developed based on a hollow profiled tail, with a length in the range 600-650 mm. The manufacturing of the prototype conductor tail has now been qualified with the production of

four tails, followed by tests to weld the conductor tail to the PF conductor jacket, bent at 500 mm radius, as for the PF pancake conductor exits. At present, a full-size mock-up of the conductor tail, simulating its working conditions, is in the process of being assembled. This includes two of the conductor tails previously manufactured and steel plates simulating the inertia of the adjacent conductors. The conductor tail and the adjacent parts are insulated with fiberglass - Kapton® tape, assembled with G10 filler blocks and impregnated, to form a mock-up in the shape of straight beam. The mock-up is to be subject to fatigue tests, at the laboratory of ENEA-Brasimone, at LN2 temperature, twice the nominal load for 60 000 cycles.

WEA12PO02

Numerical Simulations for Superconducting Cable in Conduit Conductor

K. Seo, NIFS.

We had been developing the numerical code simulating both electromagnetic and thermal phenomena in cable in conduit conductors (CICC). Here, the phenomena mean normal transitions, AC losses, current sharing among strands. It is difficult to comprehend and/or predict behaviors of CICC or coils without performing real experiments. Therefore the necessity of the numerical code predicting the conductor and/or coil performances is growing up. With that code, we will be able to design the conductors and coils in future. The CICC has the complicated electromagnetic and thermal systems consist of more than one thousand of strands; those are twisted by multiple stages. Electrical and thermal contacts between individual strands are random and this situation makes the phenomena complicated. On the other hand, mutual magnetic couplings between individual strands are determined by the tracks of these strands. Furthermore, the terminating joints of both conductor-ends affect current distribution among the strands in the cable. We need the numerical code, which involved mentioned complicated situations, to understand and predict the phenomena in the CICC precisely. In this paper, we reviewed the basic concept and algorithm of our latest numerical code and showed some results.

WEA12PO03

Electromagnetic Properties of Lap-Joint and its Influences on the Conductor Test Data *K. Seo, NIFS.*

The joint between superconducting cables is one of key elements in the large scale magnet. Joint-resistance induced non-uniform current distribution had been reported. The mechanism of this phenomenon is guite simple. The cable consists of the parallel superconducting lines. Therefore, in the DC condition, the current distribution is governed by the non-uniformity of individual joint-resistances between parallel strands, those are mainly determined by the joint configuration. When one strand carries larger current and it saturates at the critical current, flux flow resistance occurs and it functions as a current regulator. Once the current saturates in one strand, surplus current must go through other strands. Apparent n-value and current sharing temperature (Tcs) of the CICC are important parameters for magnet design. However these had been reported to degrade from the expected values based on the strand performances. We analyzed the nvalue and the Tcs of the cable considering the current nonuniformity introduced by the lap-joint quality.

WEA12PO04

THELMA code analysis of Furukawa Nb3Sn strand

bending effect on Ic

P.L. Ribani, Dipartimento di Ingegneria Elettrica, Università di Bologna; D.P. Boso, B.A. Schrefler, Dipartimento di Costruzioni e Trasporti, Università di Padova; M. Lefik, Technical University of Lodz; Y. Nunoya, JAERI; L. Savoldi, R. Zanino, Dipartimento di Energetica, Politecnico di Torino.

The ITER Central Solenoid Model Coil and Insert Coil experiments showed a significant degradation of the current-carrying capability of the Nb3Sn based cable-inconduit conductor, with respect to the expectations coming from experimental data on a single strand, subject to pure tensile/compressive stress. Such degradation is presently attributed to the deformation of the strands due to the bending effect of the Lorentz force and experimental investigations performed at JAERI Naka and elsewhere appear to confirm this. The THELMA code has been developed with the support of EFDA with the aim of simulating the main aspects of superconductors to be used in ITER coils. The code is based on a coupled electromagnetic and thermo-hydraulic model of cable and joints. An application of the code is presented here, where THELMA is used to simulate a single strand by considering, as cable elements, groups of superconducting (SC) filaments and the corresponding portion of the resistive matrix. One of the inputs required by the electromagnetic part of the code is the axial strain in the SC filaments. The filament strain is calculated by means of a finite element model of the strand which first computes the thermal strain and then the mechanical one due to the bending at 4.2 K. This approach is utilized to reproduce the voltage-current characteristic of the Furukawa strand measured at JAERI and in particular the effect of the applied mechanical load on the critical current of the strand.

WEA12PO05

Study of current distribution in TFMC NbTi Busbar III

L. Zani, D. Ciazynski, Association EURATOM-CEA; R. Heller, F. Wuchner, Association EURATOM-FZK; A. Vostner, EFDA-CSU Garching.

In the framework of the development of High Temperature Superconducting current leads (HTSCL), two prototype were tested at FZK in 2004, connected to each other by a short circuit conductor, referred as Busbar III (BBIII), used here for current distribution measurements. In addition to a 64 Hall Probe (HP) system, two additional 4-HP heads from CEA were assembled at both ends of the BBIII. This system, already successfully used during the TFMC test phase II, was now adapted by FZK to the present HTSCL-BBIII set-up. Electrical tests were performed in 2004 with conductor currents up to 80 kA without background magnetic field. In this paper, the analysis of the current distribution is presented using two methods: - First the current barycentre excursion was investigated in various runs. A comparative study is presented between resistive and inductive hypotheses where current is supposed to be uniformly distributed. In particular, we show that the two hypotheses lead to different results. - Second a global model of the current bundles distribution between four artificial subcables is investigated. More quantitative results show current imbalances between subcables to be either significant (>70% lavrg) or weak (<10% lavrg) depending on whether resistive or inductive hypothesis is considered. A discussion on why the second solution is thought to be the more likely is presented. Besides, a global comparison with results previously obtained from TFMC tests will be shown.

WEA12PO06

The effect of inter-bundle resistive barriers on the coupling loss and current distribution in ITER Nb3Sn and NbTi Cable-in-Conduit Conductors

A. Nijhuis, Y. Ilyin, H.H.J. ten Kate, University of Twente. The role of interbundle resistive barriers (wraps), introduced to drastically reduce the inter-bundle coupling loss in multistage cabled Cable-In-Conduit Conductors (CICC) for the International Thermonuclear Experimental Reactor (ITER) is evaluated based on the results gained recently on short sample experiments in the Twente Cable Press. The obvious benefit of effectively limiting the inter bundle coupling loss goes unavoidably together with the disadvantages of hampering redistribution of current to reduce the current non-uniformity introduced at the terminations as well as reduction of the heat exchange between the bundles. The impact of the sub-cable wraps and void fraction on the inter-strand and bundle contact resistance, the coupling loss and mechanical properties, is experimentally verified on a set of highly relevant Nb3Sn and NbTi conductors through cyclic loading up to 40,000 cycles. It is shown that wraps are efficient to limit AC loss, but at the same time can reduce the relevance of testing short samples on DC performance. In particular the effect of transverse loading is discussed in relation to the void fraction and possible strand deformations in Nb3Sn conductors. Preliminary

results of CUDI-CICC code simulations of the conductor in the Poloidal Field Coil Insert (PFCI) have shown that shortening the current transfer length (omitting wraps) can even degrade the DC performance of coils.

WEA12PO07

Effects of tensile and compressive strain on critical currents of Nb3Al strand and cable-in-conduit conductor

K. Kizu, K. Tsuchiya, K. Shimada, N. Koizumi, M. Matsukawa, K. Okuno, H. Tamai, JAERI; T. Ando, NAT; Y. Hishinuma, H. Nishimura, K. Seo, K. Takahata, S. Yamada, NIFS; Y. Miura, Osaka University.

The critical current (Ic) of Nb3AI strand is decreased by strain. In cable-in-conduit conductor (CICC), strands suffer thermal and bending strain. However, no decrease of Ic by bending strain of 0.4% was observed for a Nb3AI D-shaped coil made by react-and-wind method in the R&D campaign for the NCT, indicating that relaxation of bending strain in strands can be expected due to cabling effect. In order to evaluate the effect of bending on Ic of CICC, the effect of tensile and compressive strains on Ic of strand and the relaxation effect of strain on strands in the CICC were investigated. For this purpose, an apparatus to load tensile or compressive strain on a strand sample or a CICC sample wound on the surface of sample holder like a torsion coil spring made of CuBe was developed. The sample holder with a large diameter of 82 mm was manufactured to set up a CICC sample. A strand sample and a triplex-CICC sample with Nb3AI strands were supplied by Hitachi cable. The triplex-CICC sample consists of two Nb3AI strands and one Cu wire inserted into a stainless steel conduit. The Ic of strand sample at 4.2 K was measured in the range of magnetic field from 6 to 11 T and strain from -0.86% to +0.18%. The Ic of -0.86% at 11 T decreased to 0.65 of Ic at 0%. The empirical equation of Ic will be presented. The results of triplex-CICC sample will also be discussed.

WEA12PO08

Design and qualification of ITER CS and TF cooling inlets

P.F. Decool, H. Cloez, S. Nicollet, J. P. Serries, CEA.

In the ITER superconducting magnets, the CIC conductors cooling is insured by supercritical helium forced flow in the central and annular parallel channels. In the Central Solenoid, with a thick square jacket conductor, the helium inlet is in the highest field region at the inner bore pancake joggle, and it has to support the high hoop force stress level with a very low stress concentration factor. In the TF magnets, a thin jacket circular conductor is wound in double pancakes, inserted into radial plates, stacked and embedded into a steel case. The helium inlets are located at the inner bore, in the limited space between the radial plates and the coil casing. The PF coils helium inlets, not studied here, are similar to the CS ones, but with a lower stress level. A complete qualification work on the CS and TF helium inlets is presented. A design optimisation was performed, by FEM analysis, resulting in acceptable stress level in both helium inlets. The welding procedure was qualified and specific fatigue life mock-ups were designed, analysed and manufactured using representative jacket materials. Fatigue life qualification at 4K was performed in the FZK test facility appling the relevant loading and number of cycles. Hydraulic mock-ups were manufactured and gualified in the CEA test facility using GN2 at relevant Reynolds number. Pressure drop as well as flow repartition inside conductors' petals were measured. The mechanical and hydraulic results are presented.

WEA12PO09

The TFCI conductor examinations at the LIS-12 facility *E.R. Zapretilina, S. Egorov, I. Rodin, V. Korsunsky, A. Bursikov, A. Lancetov, S. Samoylov, D.V. Efremov Institute (NIIEFA).* Withdrawn.

WEA12PO10

Axial, and Through Thickness Insulation Tension Stresses in the ITER CS Coil

P. H. Titus, P. C. Michael, MIT Plasma Science and Fusion Center

Tensile strain, normal to the surface of insulation layers, is an issue in the ITER central solenoid. It has tensions which develop from flexure of the conductor jacket under axial self loads. Tensions also develop from quench behavior. Global components of tensile stress result from normal load interactions between the segmented coils. Global simulations of the segmented coil system are presented with parametric studies of frictional behavior and degree of axial preload. With lower preload, and appropriate modeling of slippage and separation, the global tensile stresses can be kept below 4 MPa. A design preload value will be recommended. Radial tensions due to normal operation vertical (axial) stresses are above 50 MPa, while quench tensile stresses are above 20 MPa. Exploring the nature of ITER's through thickness tensions and the consequences of local cracking and de-bonding, for all loading, will help in the evaluation of proposed insulation systems. While ITER's criteria puts limits on tensile strains, it does allow for qualification of larger strains, and the possibility of de-bonding via test. Previous tests and model coil loading are inadequate due to test temperatures or cyclic limits. More appropriate 4K testing will be proposed. The phenomena that produce through-thickness tensile stresses will be explained further via analytic models, and the status of efforts to qualify the tensile strains for specific insulation systems will be presented.

PARALLEL SESSION	15:50 - 18:20	
(Ponente/Levante room)		
NMR AND MEDICAL APPLICATIONS		

WEA1OR1

Superconducting magnets for cancer treatment accelerators

H-U. Klein, ACCEL Instruments GmbH.

Cancer treatment with converted photons from electrons with up to about 20 MeV energy by means of room sized hospital based linear accelerators is a standard clinical modality. In the last decade planning and establishment of Hadron (Carbon ion and/or proton) therapy systems have been steadily increasing despite their much larger dimensions and investment costs. While the basic concept for Hadron therapy systems is well established there are many considerations on the type and layout of the particle accelerator and delivery system with regard to e.g. treatment time, investment and operation costs, floor space, dimensions/weight of components, system availability, future development, etc. Superconducting magnets have been proposed to possibly using them on rotating ion therapy gantries predominantly because of potential weight savings. Within a newly developed superconducting medical 250 MeV proton cyclotron the superconducting magnet system is the key factor for many advantageous properties including compactness, beam stability and availability, extraction efficiency, low operation costs. A two coil NbTi magnet system with 2 m diameter, 2.4 T central field, and 2.5 MJ stored energy has been developed, which is actively cooled by a closed loop LHe system via cryocoolers providing 6 W @ 4.2 K. Two medical cyclotrons have been delivered with such magnet systems showing excellent cryomagnetic performances. In this paper emphasis is put on the reasoning for applying superconducting magnets and on one year of operational experience.

WEA10R2

A novel 0.25 T dedicated MRI apparatus

A. Trequattrini, S. Besio, S. Pittaluga, L. Satragno, Esaote. A new permanent magnet MRI apparatus is presented, in which the magnetic system is connected to a support enabling the rotation of the structure to perform patient examination under different weight bearing conditions.

WEA1OR3

Magnetic Field Homogeneity Optimization of GigaNMR Resistive Insert

C. Trophime, S. Kramer, G. Aubert, CNRS-GHMFL.

The Grenoble High Magnetic Field Laboratory is developing a GigaNMR magnet designed to provide 23.5 teslas in a 160 mm warm bore diameter. The magnet consists in a set of two resitive magnets and a supraconductor outsert developed by Oxford Inst. The inner resistive insert is made of a 8 helix insert. It is surrounded by two homogeneous bitter magnets designed to compensate for the supraconductor magnetic field inhomogeneity. The design of Polyhelix insert targets the ppm accuracy level whereas traditionnal PolyHelix magnets reach 1000 ppm in a 1 cm^3 diameter sphere volume. Preliminary Experiments of the GigaNMR resistive insert have been carried out. The insert is found to be less homogeneous than expected from the optimized design. Numerical modelling of the GigaNMR Polyhelix insert has been undertaken to investigate the magnetic field homogeneity. Changing the relative angular position of the helices is found to be a key to improve the magnetic field

homogeneity. A fair agreement with the field map measurements has been observed.

WEA10R4

Non-invasive measurement of the iron overload in the human body

M. Marinelli, B. Gianesin, E. Oliveri, Genoa University and INFN; G. Sobrero, INFN-Sezione di Genova.

We present a magnetic susceptometer to measure the iron overload in patients with pathology, like Thalassemia, producing iron store in the body. The output signal is the difference between the induced voltages in two pick up coils that are located symmetrically respect to an AC magnetic source. The overall dimensions allow the presence of the whole human body torso between the magnetic source and one of the pick up coil. All the apparatus components work at room temperature; the symmetry, stability and the temperature control, at the milliKelvin level, of the complete apparatus gives the sensitivity, better than 10-7, necessary to detect the iron quantity of interest for these pathologies. After the necessary authorizations of the ethic and scientific committees, the present susceptometer has been recently installed in the Center for Congenital Anemia of the "E.O. Ospedali Galliera" hospital in Genoa Italy. The apparatus description, its calibration with people without iron overload, and the preliminary results with patients are presented.

WEA10R5

The CEA/NeuroSpin Whole Body 500MHz MRI Magnet Project

T. Schild, G. Aubert, P. Bredy, F-P. Juster, B. Hervieu, F. Nunio, C. Pes, M. Segreti, P. Vedrine, P. Hagen, CEA-Saclay.

A neuroscience research centre with very high field MRI equipments is scheduled to be opened in 2006 by the CEA life science division. One of the imaging systems will require a 11.75 T magnet with a 900mm warm bore. Regarding the large aperture and field strength, this magnet is a real challenge as compared to the largest MRI systems ever built. The conservative MRI magnet design principles are not readily applicable and other concepts taken from high energy physics or fusion experiments, namely the Tore Supra tokamak magnet system, will be used. The coil will thus be made of a niobium-titanium conductor cooled by a He II bath at 1.8 K, permanently connected to a cryoplant. Due to the high level of stored energy, about 300 MJ, and a relatively high nominal current, about 1500 A, the magnet will be operated in a non-persistent mode with a conveniently stabilized power supply. In order to take advantage of superfluid helium properties and regarding the high electromagnetic stresses on the conductors, the winding will be made of wetted double pancakes meeting the Stekly criterion for cryostability. The magnet will be actively shielded to fulfil the specifications regarding the stray field.

WEA1OR6

A pulsed HTS coil cooled by heat pipes as part of a pre-polariser magnet system

M.P. Oomen, P. van Hasselt, N. Proelss, M. Leghissa, Siemens Corporate Technology; M. Kruip, S. Lister, A. Atkins, G. Gilgrass, Siemens Magnet Technology.

Future magnetic-resonance imaging (MRI) systems for medical diagnosis may work on the principle of prepolarisation. This requires a strong local magnetic field which can be ramped up and down in milliseconds. Such fields can be generated efficiently by compact coils made

with high-temperature superconductors (HTS). Copper conductors would be too bulky; low-Tc superconductors would give high AC loss at 4K. We have designed, constructed and tested an HTS double-pancake coil which generates 0.3T of pulsed field in a 200mm inner bore. An operating temperature of 30K was chosen as a compromise between efficient cooling and optimum use of the HTS tape. The coil is cooled by a single GM refrigerator via a heat-pipe system filled with liquid Neon. The heat pipes and supporting structure were designed for minimum eddy-current loss in the pulsed field. The design process had to account also for AC loss in the superconductor, heat transfer from the coil to the cooling fluid and Lorentz forces on the HTS tape. Initial experiments validated the winding process for the mechanically weak Bi-2223/Ag tape, and the glued connections under thermal contraction of the materials. The production process of the coil aimed at ensuring optimum thermal contact between winding and heat pipes. The critical current at 77K proved that there was no degradation of the HTS material. In tests at 30K, the coil carried 250A, 1Hz pulsed current during up to 20 minutes. Thus the coil fulfilled the design specs.

WEA1OR7

Perspective on a Superconducting 30 T/ 1.3 GHz NMR Spectrometer Magnet

D. Markiewicz, J. Schwartz, J. Miller, NHMFL.

The COHMAG report of the National Academy of Sciences, presently in progress, will provide an assessment of highfield magnet science and technology in the United States, and identify possible new initiatives for future high-field magnets. Regarding NMR, the report identifies high resolution NMR spectrometers in the range of 30 T/ 1.3 GHZ as having great scientific interest. The NHMFL has completed a 900 MHz ultra-wide bore spectrometer magnet and a 5 T HTS insert coil, and is prepared to address future high field magnets. This paper discusses technology issues associated with 30 T superconducting magnets. The enabling technology is HTS conductors and coil technology. Significant issues remain for application of HTS conductors to large coils, including long length quality, heat treatment, anisotropy and strain dependence. The outer LTS coil sections are large, with high stress and stored energy. Structural issues, including high strength conductor and reinforcement, and guench protection issues are significant. A review is given of present technology for NMR magnets and plans to address the technology development for 30 T magnets.

PARALLEL SESSION	15:50 - 18:00
(Scirocco/Libeccio room)	
INDUSTRIAL APPLICATIONS	

WEA2OR1

The R&D project of HTS magnets for the superconducting maglev

M. Terai, M. Igarashi, Central Japan Railway Company. This paper describes R&D project footmarks and progress of persistent current HTS magnets, which have been developing for the superconducting maglev trains since 1999. The first trial HTS magnet is operated with a very small current decay rate of 0.44%/day and can be cooled by a cryocooler below 20 K, using conduction cooling method. The HTS coil consists of 12 single-pancake coils, which were wound with Ag-sheathed Bi2223 tapes and insulation tapes. In order to minimize the current decay rate during persistent current operation, we have wound them carefully not to degrade the n-value characteristics of HTS wires. The HTS coil is connected with a PCS made of YBCO thin films, and cooled by a G-M type two-stage pulse tube cryocooler. Detachable current leads were used to reduce heat leakage to the 1st stage of the cryocooler and keep the HTS power leads adequately low temperature. This first trial HTS magnet is displayed in JR Central Pavilion at "The 2005 World Exposition", Aichi, Japan. On the other hand, the second HTS magnet for running tests at Yamanashi Maglev test line is being fabricated with the knowledge of the first trial magnet. The second magnet consists of 4 HTS coils and is cooled by 2 cryocoolers directly.

WEA2OR2

Open-gradient Magnetic Separator with Racetrack Coils Suitable for Cleaning Aqueous Solutions

T. Hartikainen, A. Korpela, R. Mikkonen, Institute of Electromagnetics, Tampere University of Technology.

Open gradient magnetic separation enables continuous operation of the separator without the need of matrixelements. Such a separator consisting of liquid helium cryostat and an interchangeable pair of NbTi and Nb3Sn coils were designed and constructed for testing the separation of various substances. Successful separation depends on experimentally optimized parameters, such as size and magnetic susceptibility of particles to be separated, applied magnetic force density, and flow velocity through separation zone. In isodynamic separation, high gradient and nearly constant and homogenous magnetic force density distribution in separation zone are created by magnet design. In this paper, the operation and quench analysis of both magnet systems are presented in detail. The performance of NbTi magnets was satisfactory, but Nb3Sn ones didn't meet their expectations, and reasons for that are discussed. Separation tests were ran with different waste waters, and results from these along with discussion are also presented here. Finally, proposals for developing the performance of racetrack magnets will be given.

WEA2OR3

Dual Magneto-Gravitational Chromatography (DMGC) *H. Sakaguchi, AIST; S. Nimori, NIMS.*

Under horizontal high magnetic field, even a feeble magnetic substance can move on a smooth horizontal surface. If a subatance is paramagnetic, it will go to the direction to the center of the magnetic field, and if the subatance is diamagnetic, it will go away from the center. Besides, as we live on the earth, a substance is pulled downward by gravitational force. Considering these two forces, when a substance is put on a gentle slope, where downward component force is smaller than upward component force, the substance moves upward. When the slope is steep, the substance stays at the bottom of the slope. The situation whether the slope is gentle or steep depends on the magnetic force applied on the substance, which is a multiplied value of the magnetic field strength, magnetic field gradient, magnetic susceptibility, and volume of the substance. Therefore, when a substance is put at the maximum magnetic force position in a horizontally kept helium-free superconducting magnet bore, with steps on both sides of the substance, first with a gentle angle and then with steeper angles, the substance will move to one or the other direction, climb over steps, stop at some point. And so, it is possible to recognize the magnetic property of the substance. When the substance is a mixture, it is possible to separate into components. We name this method as Dual Magneto-Gravitational Chromatography. Experiments and results will be shown and will be discussed.

WEA2OR4

Cryocooler-cooled Split-paired Magnet for Anisotropic Conductive Sheet Production

T. Kiyoshi, S. Matsumoto, Tsukuba Magnet Laboratory, NIMS; M. Yoshikawa, Kobe Steel, Ltd.; H. Konno, N. Shimoyama, M. Tobita, Polymatech Co., Ltd.

A magnet that allows horizontal access to the magnet center as well as vertical access is suitable for industrial applications. We designed and fabricated a split-paired magnet cooled with two G-M refrigerators. The magnet has a vertical room-temperature bore 400 mm in diameter and a horizontal room-temperature gap of 73 mm. Its design value of field uniformity around the magnet center is 0.53% in a space 200 mm in diameter and 50 mm in height. The magnet successfully operated up to 3 T. Its first application is production of anisotropic conductive sheets. Anisotropic conductive materials that are composed of dispersed contacts in polymer film are indispensable for mobile devices. They are used for electrical connections around LCDs. Anisotropic conductive sheets that have dense contacts and high reliability are expected to be produced using high magnetic fields and finely arranged ferromagnetic pins. The magnet was combined with a sheet forming device and has been used for the trial production of anisotropic conductive sheets. This study was performed through Special Coordination Funds of the Ministry of Education, Culture, Sports, Science and Technology of the Japanese Government.

WEA2OR5

Progress of the Maglev Transportation in China

L. Yan, Institute of Electrical Engineering, CAS.

The successful construction and operation of the Shanghai Maglev Demonstration Line shows the birth of maglev transportation in the world and China entered the new phase of maglev transportation development. In this new phase, we shall promote the application of maglev both for long line and for intercity and urban transport, promote the industrialization in close-connection with practical line construction and operation, and to promote the research and development of the new systems. The present paper describes shortly the corresponding progress.

WEA2OR6

Superconducting High Gradient Magnetic Separation for Purification of Wastewater from Paper Factory

S. Nishijima, S-I. Takeda, Graduate School of Engineering, Osaka University.

High gradient magnetic separation (HGMS) can be one of the promising ways for a new environmental purification technique because of producing no contamination such as flocculants and having possibility of treating large amount of wasted water within a short time. The magnetic separation system for purification of wastewater from the paper factory has been developed. The test plant of 500ton/day level was set up in the actual paper manufacturing process and a purification test of the wastewater was performed. The magnetic seeding of the organic pulp and dyes were successfully performed and the Chemical Oxygen Demand value of drainage was reached to less than 20 ppm after magnetic separation. The superconducting magnet for the system is 3T, 600mm long and 400mm bore NbTi solenoid. The system mainly consists of a mixing tank (magnetic seeding tank), a 1st separation tank, and a superconducting magnet. Floating magnetic flocks composed of magnetite particles and

organic polymers such as pulp and dye are captured by magnetic force in the superconducting magnet chamber. Some magnetic flock is sediment at the 1st separation tank by the gravity, which helps to reduce the amount of magnetic flocks going through the magnet chamber. The system has been successfully operated for several weeks.

PARALLEL SESSION	15:50 - 18:20
(Maestrale room)	
DETECTOR MAGNETS	

WEA3OR1

Evolution of Detector Magnets from CELLO to ATLAS and CMS and towards future developments

E. Baynham, CCLRC Rutherford Appleton Laboratory.

The evolution of physics with colliding beams has required ever increasing volumes of magnet field around the interaction points for effective particle detection. This has been the main driver for the development of detector magnet systems over the past 25 years. This paper traces the evolution of detector magnet technology through the engineering solutions developed to meet the increased scale and field strength. The paper will address all major aspects of detector magnet engineering from design and analysis to conductor and magnet fabrication technology. Advances in conductor design for stability, fabrication and protection will be described. The paper will evaluate the techniques developed to achieve high transparency, efficient cooling (direct vs. indirect) and magnetic force transfer. The current state of the art at both large (CMS and ATLAS) scale and small scale (BESS) will be reviewed. The future requirements for detector magnets will be reviewed.

WEA3OR2

The ATLAS Superconducting Magnet System: Status of integration and installation

H.T. Kate, CERN on behalf of the ATLAS collaboration.

The ATLAS particle detector in the Large Hadron Collider at CERN features a hybrid system of four superconducting magnets: a Central Solenoid providing the magnetic field for the inner detector, surrounded by 2 End-cap Toroids and a Barrel Toroid providing the magnetic field for the muon detectors. The magnet system with a stored energy of 1.6 GJ and dimensions of 22 m in diameter and 26 m in length actually is the largest superconducting magnet in the world. The construction of the magnets has started in 1998 and will end in 2006 with the completion of the installation and commissioning in the ATLAS cavern 100m underground. Currently, in August 2005, all magnet parts were manufactured and delivered to the integration site at CERN. The 8 coils for the Barrel Toriod were completed and successfully tested while the integration of both End Cap Toroids is progressing well. The Barrel Toroid and the Central Solenoid are already installed in the ATLAS cavern. Tests of the Toroids underground starts in autumn 05 after the connections to vacuum system, He cryogenics and power converters is completed. In the paper the main features of the various magnets, their common infrastructure and services are reviewed and the status of realization and installation is presented.

WEA3OR3

Completion of the Manufacturing of the ATLAS Barrel Toroid Magnet at CERN

P.N. Vedrine, M. Arnaud, C. Berriaud, B. Levesy, C. Mayri, J.M. Rey, CEA Saclay; A. Dudarev, H. Ten Kate, CERN; F.

Alessandria, G. Volpini, INFN-LASA.

The last two years have seen the completion of the integration and the cryostating of 8 superconducting coil windings for the ATLAS Barrel Toroid air-core magnet (BT). The Barrel Toroid is a 20 m in diameter, 25 m long and 5 m wide superconducting magnet for ATLAS, one of the two experiments dedicated to the search of the Higgs boson, which will be installed on the LHC ring at CERN in 2006. The paper presents the last steps of the integration progress which end with the cold acceptance tests. A special emphasis will be put on the installation of the thermal shields and superinsulation and the integration of the cold masses into their vacuum vessels. The integration of the windings in the coil casings has been completed in October 2003 and the last coil cryostating is foreseen in June 2005. The BT coils are now being installed in the ATLAS cavern at CERN.

WEA3OR4

On-Surface Test of the ATLAS Barrel Toroid Coils: Overview

A. Dudarev, J.J. Rabbers, S. Junker, R. Pengo, H.J.J. ten Kate, CERN; C. Berriaud, M. Arnaud, P. Vedrine, CEA-Saclay; F. Broggi, G. Volpini, INFN-LASA.

The Barrel Toroid provides the magnetic field for the muon detectors in the ATLAS experiment at CERN. The toroid is built up from eight superconducting coils. Each coil consists of two 25 m x 5 m racetrack shape double pancakes impregnated and pre-stressed inside an aluminium coil casing. The 40-tons casing is cooled by forced flow liquid helium circulating in aluminium pipes glued to the coil casing. The coils are tested on surface prior to their underground installation. The test program has been started in September 2004. This paper describes the test setup and various commissioning tests performed at the ATLAS Magnet test facility. It includes the aspects of the test preparation, vacuum pumping, leak testing, cooling down, powering and warming up. The coils passed the tests and are now being assembled into the toroid in the ATLAS cavern. The testing completes the production of the, so far, largest racetrack coils in the world.

WEA3OR5

The manufacture of modules for CMS coil

P. Fabbricatore, S. Farinon, M. Greco, R. Musenich, INFN Genova; C. D'Urzo, L. Loche, Ansaldo Superconduttori Genova; B. Levesy, F. Rondeaux, CEA Saclay; D. Campi, A. Gaddi. CERN.

CMS (Compact Muon Solenoid) is a general-purpose detector designed to run at the highest luminosity at the CERN Large Hadron Collider (LHC). Its distinctive features include a 4 T superconducting solenoid, composed of five modules, with a 6 m diameter by 12.5 m long free bore, enclosed inside a 10,000-ton return yoke. The construction of the five modules composing the coil was a very challenging task due to the large dimensions and weigth of each module (50 t) and to the severe requirements on tolerances. This paper describes the main technical issues related to the module construction, namely the winding, the vacuum impregnation (requiring 1100 I of epoxy resin for each module), the machinining operations (to get the proper tolerances on dimensions), the hydraulic circuit connections and the module to module mechanical coupling. Despite the limited number of modules, the manufacture was arranged as a series construction in a single large area. This area was subdivided in sectors for winding, impregnation, mounting and machining operations

and equipped with the required large tools such as two 100 t cranes, a huge lathe and an autoclave suitable for hosting a single module enclosed in its impregnation mold.

WEA3OR6

CMS Solenoid Assembly

B. Levesy, P. Bredy, F. Kircher, J. Y. Roussé, CEA-Saclay; D. Campi, A. Gaddi, H. Gerwig, CERN; P. Fabbricatore, M. Greco. INFN Genova; C. D'Urzo, Ansaldo Superconduttori. The CMS experiment (Compact Muon Solenoid) is a general-purpose proton-proton detector designed to run at the highest luminosity at the Large Hadron Collider (LHC). Distinctive features of the CMS detector include a high-magnetic-field solenoid (4 T) coupled with a multilayer active scintillating-crystal muon system, a fully electromagnetic calorimeter, a tile hadronic calorimeter. and a powerful inner tracking system. The superconducting solenoid (6 m diameter by 12.5 m long free bore) is enclosed inside a 10 000 t return yoke. The cold mass consists of 5 modules (7 m diameter, 2.5 m long, 45 t) manufactured at Ansaldo Superconductori Genoa. The assembly of the solenoid on CERN site starts with the pilling up, the electrical and hydraulic connection of the 5 coil modules. After instrumentation cabling, the outer thermal shield is mounted. The cold mass is then swiveled and inserted in the outer vacuum tank. The cold mass is supported inside the outer vacuum tank with a set of titanium tie rods. After inserting the inner vacuum tank and its thermal shield, both end of the cryostat are closed. In parallel, the current leads and the cryogenic chimney are connected to the coil. This paper describes all these activities and in particular the checks performed at each step of the coil assembly.

WEA3OR7

Toward an improved high strength, high RRR CMS conductor

S. Sgobba, D. Campi, B. Curé, P. El-Kallassi, CERN; P. Riboni, ETHZ; A. Yamamoto, KEK.

CMS (Compact Muon Solenoid) is a general-purpose detector designed to run at the CERN Large Hadron Collider (LHC), including a 4-layer superconducting solenoid with 6 m diameter by 12.5 m long free bore operated at 4 T and at 4.5 K. The Rutherford type superconductor, stabilized by high purity 99.998% aluminum, is reinforced by aluminum alloy sections welded to the superconductor by Electron Beam. Due to the high magnetic forces at nominal field inside the winding pack, the conductor itself represents a main structural component to get a self-supporting winding structure. In view of an upgrade oriented to a possible new project, an improvement of the mechanical performances of the reinforced conductor starting from the CMS concept has been considered, aimed to increase the reachable field based on an optimized layout. This improvement might be achieved by: 1) the replacement of the actual stabilizer by a cold drawn AlNi alloy, firstly developed for the ATLAS thin solenoid superconductor, allowing mechanical strength to be enhanced without excessive degradation in RRR compared to pure Al. 2) the replacement of the present reinforcement alloy EN AW-6082 by a higher strength AlZnMg alloy EN AW-7020. This alloy is readily extrudable and weldable and keeps even after curing high ductility and strength at 4.2 K. The withstanding mechanical properties and equivalent RRR of this improved CMS conductor are compared with the actual CMS conductor and conductors of other geometry.

Thursday, September 22, 2005

PLENARY SESSION (Maestrale room)

8:30 - 10:00

THMPL1

Integration of Electromagnetic Technologies into Shipboard Applications

E. Bowles, R.J. Thome, M. Reed, General Atomics-Electromagnetic Systems Division.

Progress in power electronics, computation speed, and control algorithms have led to the ability to manipulate energy transfer such that prior applications using mechanical or hydraulic energy conversion can be replaced by electromechanical methods. Many ships are being built with direct electrical energy transfer from the turbine/generators to electrical propulsion motors that are often mounted in pods external to the hull. The power generated is shared on a common bus with the ship service electrical system. The result is a flexible architecture for equipment arrangement and for operation, which allows optimization of fuel efficiency, redundancy for critical loads, and higher reliability. Computer aided design has led to the use of prefabricated solid bus sections that can be installed similar to piping rather than pulling power cables through long cable trays, thus leading to economies of installation and more compact designs. This paper reviews the development of electric propulsion motors and integrated power systems for ships. Examples are given for cruise ships, cargo ships and special applications like ice breakers and oceanographic exploration. Emerging technologies are described, for example, superconducting propulsion motors, superconducting bus, fuel cells, and autonomous unmanned vehicles for oceanographic mapping and studies. Special navy applications such as electromagnetic launchers and turboelectric arresting gear for aircraft carriers are also given.

THMPL2

Recent Developments of Magnet Technology in China: Large Devices for Fusion and Other Applications

P.D. Weng, Institute of Plasma Physics, Chinese Academy of Sciences.

The projects for large science device and industrial application are strongly driving the progress in the field of superconductivity and magnet technology in China. One example is the EAST Tokamak -- biggest superconductivity project in China. The magnet system of East consists twenty-eight large superconducting coils. All of coils are designed and manufactured in the Institute of Plasma Physics; the technology related with cable-in-conduitconductors (CICC) superconducting magnet and bus bar, current leads as well as cryogenic technology are well developed. Up to now, all of the 28 coils have been fabricated, except four big PF coils, 24 coils, have been tested in a test facility before assembling. The tokamak assembling is going on, all coils have been installed in the position. The first cooling down of the device will be carried out around the end of this year. At same time three projects for high-energy physics device are funded: the HIRFL -CSR project -- a cooling storage ring for the Heavy Ion Research Facility has been built and begin its commissioning and test operation now; the BEPCII High Double ring Collider is in progress, the Lumi. superconducting magnet winding for BESIII detector has been finished; The Shanghai Synchrotron Radiation Facility (SSRF) project has begun already, the R& D of prototype magnets are completed. One possible large project in the

next five years is 45 tesla high field magnet, the project has been proposed, part of R& D work is done. The R& D work for different prototype superconducting facility shows a good possibility using HTS for power industry. There are about 30 papers introducing the recent progress of power cable, transformer, fault current limiter, SMES as well as maglev transportation in China.

PARALLEL SESSION	10:30 - 12:30
(Maestrale room)	
FUSION MAGNETS (II)	

THM1OR1

From CS and TF model coils to ITER: lessons learnt and further progress

K. Okuno, H. Nakajima, N. Koizumi, JAERI

Central Solenoid (CS) and Toroidal Field (TF) model coil projects have been performed in order to establish technologies required to fabricate ITER magnets. The projects reached the development goals of 13 T, 46 kA in the CS model coil and 10 T, 80 kA in the TF model coil, respectively, and new design principles and fabrication concepts proposed to build the ITER magnets were verified. Further activities are now being performed to improve the performances of some components for design optimization and to mitigate technical risks during the manufacture of the ITER magnets. The coils tested in the projects used three different jacket materials of Incoloy 908, titanium and stainless steel, which enabled comparison of the conductor performances under different stress conditions. Detailed investigation of the conductor performance indicated that, in addition to the thermal and global hoop stresses, there was a significant stress effect due to transverse electromagnetic force acting on the strands. To interpret this effect, a lot of small to medium scale experiments and analytical studies have been performed internationally and new design criteria of the conductor have been proposed based on the results from these studies. Qualification of manufactures for this high performance Nb3Sn strands fulfilling the criteria is being performed in 2004 to 2005. Through these activities, preparation for the ITER magnet fabrication will become ready as required in the ITER project schedule.

THM10R2

Magnets of the superconducting Levitated Dipole Experiment

D. Garnier, M.E. Mauel, Department of Applied Physics and Applied Mathematics, Columbia University; A. Zhukovsky, J. Kesner, J.M. Minervini, P.C. Michael, J.H. Schultz, B.A. Smith, A. Radovinsky, Plasma Science and Fusion Center, MIT.

Incorporating three superconducting magnets, the Levitated Dipole Experiment (LDX) explores the physics of high-temperature plasmas confined by a dipole magnetic field. To remove plasma losses to supports, the magnetic dipole (a superconducting solenoid) is magnetically levitated for several hours at the center of a 5-m diameter, 3-m tall vacuum chamber. The Nb3Sn Floating Coil (F-coil), with a maximum field of 5.3 T, operates from an initial temperature of 4.3 K up to about 13 K at the end of the experimental run. The coil is cooled by retractable feeds and inductively charged/ discharged in a charging station below the experimental chamber. The NbTi Charging Coil (C-coil) surrounds the station and induces the current in the F- coil. After the F-coil is mechanically lifted to the center of

the chamber, the Levitation Coil (L-coil), made from high temperature superconductor, magnetically supports the Fcoil. Optical detection of the F-coil position is used to stabilize the levitation with a digital feedback control system. In the first year of operation, LDX has been operated with the F-coil supported while the cyrogenic operation of the coil is assessed and integration with the Ccoil is completed. Current work focuses on the integration of the F and L coils as we prepare for first levitation tests. An overview of the LDX coils will be presented, with emphasis on the interaction of the three coils in the levitated system.

THM1OR3

Implications of NbTi short-sample test results and analysis for the ITER Poloidal Field Conductor Insert (PFCI)

R. Zanino, L. Savoldi, Dipartimento di Energetica, Politecnico di Torino; E. Salpietro, EFDA-Garching; D. Ciazynski, CEA-Cadarache; N. Mitchell, ITER IT Naka; P. Bruzzone, PSI Villigen; A. Della Corte, ENEA Frascati; K. Okuno, JAERI Naka; N. Martovetsky, LLNL Livermore; E. Zapretilina, Efermov St. Petersburg.

Several short (few meter long) but full-size NbTi samples have been tested in the recent past within the frame of the ITER activities: the PF-FSJS, in 2002, and the PFCI-FSJS, in 2004, at the Sultan facility of CRPP Villigen, Switzerland; the BBIII, also in 2004, at the Toska facility of Forschungszentrum Karlsruhe, Germany. As the test of the PFCI is presently foreseen for 2006 at JAERI Naka, Japan, it is essential to consider in detail the lessons learned from the short sample tests, as well as the issues left open after them, in order to develop a suitable test program of the PFCI aimed at bridging the extrapolation gap between measured strand and future PF coil performance. Here we consider the DC performance assessment (Tcs/Ic test), the quench propagation and the calorimetry of conductor and joint AC losses, attempting to provide quantitative predictions for the behaviour of the PFCI during the corresponding tests, based on the results of the short samples. In particular, 1) the actual possibility to quench the PFCI conductor in the Tcs tests before quenching the intermediate joint will be addressed, taking into account the recent re-design of intermediate joint and lower termination, 2) the question of the so-called sudden or premature quench will be studied, based on Sultan sample results; 3) the quench propagation will be considered, based on the BBIII test results; 4) the feasibility of the AC losses calorimetry will be assessed quantitatively.

THM10R4

Progress in the Design, Manufacture and Testing of the Wendelstein 7-X Superconducting Magnets

C. Sborchia, J. Baldzuhn, K. Risse, T. Rummel, H. Viebke, Max-Planck-Institut für Plasmaphysik. Moved to WEM2OR6.

THM10R5

Design Changes and Impact on the Production of the Non-Planar Coils for the W-7X Experiment

K. Risse, R. Kairys, P. Rong, T. Rummel, C. Sborchia, J. Tretter, Max-Planck-Institut für Plasmaphysik; N. Valle, Ansaldo Superconduttori SpA; E. Theisen, Babcock Noell Nuclear GmbH.

The 50 non-planar coils of W7-X are currently manufactured by industry and use an especially developed NbTi cable-in-conduit conductor. The manufacture of the coils includes production of the superconductors and their forming into the winding pack, vacuum pressure

impregnation of the insulation and connection of the electrical joints with a resistance lower than 1 nOhm. Then, embedding into a cast steel casing, final machining, assembly of the helium cooling system and the diagnostics are performed. The coils are cooled by supercritical helium flowing through the conductors and the cooling systems on the casing surface. Design changes have been implemented during the production in the connection areas of the casings due to more detailed design and structural work. This has required the reinforcement of welds and remachining of the coils while production was already in progress. During the manufacture some improvements were required to the insulation and the welds in the termination area. New quench detection cables were qualified. The casings have been subjected to LINAC inspections and the detected defects were repaired. In order to guarantee the insulation guality, high voltage tests in vacuum under Paschen-minimum conditions have been added. This paper will give an overview on the status and schedule of coil fabrication and describe the design changes and improvements to the manufacturing techniques.

THM1OR6

Test results of a CICC with advanced Nb3Sn strands, prototype of the fusion dipole conductor

P. Bruzzone, B. Stepanov, R. Wesche, EPFL-CRPP; A. Portone, E. Salpietro, A. Vostner, EFDA-CSU Garching; A. della Corte, ENEA.

In the scope of the design activities for a 12.5 T superconducting dipole magnet, a short length of cable-inconduit conductor with steel jacket was prepared in spring 2005 as a pre-prototype of the high field dipole conductor. The small, rectangular CICC uses for the first time "advanced" Nb3Sn strands, with jc = 1100A/mm2 at 12T, 4.2K, also planned to be used in the gualification samples for the ITER conductors. At CRPP, a hairpin sample for SULTAN has been prepared from the short conductor length, heat treated and instrumented. The test program included pressure drop, ac losses and full dc characterization before and after cyclic load. To correctly assess the CICC performance, an accurate discussion of the available strand results and scaling law is presented. Opposite to other sub-size Nb3Sn CICC's tested in SULTAN, the performance of the prototype dipole conductor is roughly in line with the strand performance.

PARALLEL SESSION	10:30 - 12:20
(Ponente/Levante room)	
ENERGY STORAGE	

THM2OR1

Field testing of the largest Italian SMES

L. Ottonello, P. Albertelli, P. Ferrari, E. Picco, Ansaldo Ricerche spa; G. Masciarelli, S. Rossi, Outokumpu Copper Superconductors Italy spa; L. Martini, C. Pincella, CESI spa; E. Torello, Electrical Engineering Department, University of Genova; A. Martinolli, ELETTRA, Sincrotrone Trieste.

The industrial prototype of a Superconducting Magnetic Energy Storage (SMES), sized to deliver 1 MW for 1 second, was designed and constructed as result of a research project, partly funded by the Italian Ministry of Education, University and Research. After successfully undergoing factory test, the SMES was erected in 2004 at the Elettra Synchrotron Light facility in Trieste-I and is there achieving full operation as protecting device from

temporary voltage dips and interruptions, most frequent grid malfunctions causing fault of the beam magnetic confinement system. The innovative part of the prototype, which also includes several sophisticated power electronics items, is a 3 MJ stored energy magnet, wound with a new low-losses NbTi cable, cooled by liquid Helium at 4,2 K and adopting an electric insulation design solution to withstand 8 kV and obtain very close contact between coolant and coil. New design hybrid Current Leads, made of a resistive Copper stage and a High Temperature Superconducting one, cooperate together with a set of three cryocoolers and a multi-shield cryostat to keep negligible the Helium loss amount. Electrical insulation of the most critical components and the quench detection system is extremely accurate, because the voltage at coil-ends rises up to 2.500 V. The experimental results obtained at Elettra during the beginning of the SMES commissioning phase are presented.

THM2OR2

Validation of the High Performance Conduction-Cooled Prototype LTS Pulse Coil for UPS-SMES

T. Mito, H. Chikaraishi, R. Maekawa, T. Baba, NIFS; A. Kawagoe, F. Sumiyoshi, Kagoshima University; K. Okumura, R. Abe, Technova Inc.; T. Henmi, Graduate University for Advanced Studies; M. Iwakuma, Kyushu Univiersity.

We have been developing a 1 MW, 1 sec UPS-SMES for a protection from a momentary voltage drop and an instant power failure. A conduction-cooled low temperature superconducting (LTS) pulse coil has excellent characteristics, which is adequate for a short-time uninterruptible power supply (UPS). The LTS coil has better cost performance over the HTS coil and the conduction cooling has higher reliability and easier operation than the conventional cooling schemes. To demonstrate the high performances of the LTS pulse coil is a key technology of the UPS-SMES, we have fabricated a prototype LTS pulse coil with stored energy of 100 kJ and have conducted cooling and excitation tests. The coil was cooled from 300 K to 4 K within 3 days, which indicated the excellent thermal characteristics of this coil. Steady-state operation at the rated current of 1000 A was verified and over current test of 1230 A was also confirmed. Current shut-off test from 1230 A with a time constant of 1.37 s was successfully performed without normal transition. The temperature rise in the coil was limited to 0.8 K, which indicated a sufficient safety margin for the rated pulse discharge from 1000 A to 707 A in 1 sec. Repeated excitation of a triangular waveform with the peak current of 1000 A and ramp rate of 50 A/s was also tested. The temperature rise in the coil was limited to 1.1 K, which shows availability of continuous pulse operation because of the outstanding heat removal characteristics of this coil.

THM2OR3

Design Consideration of a High-Temperature Superconducting Magnet for Energy Storage in an Active Power Filter

C. Chao, C. Grantham, School of EE&T, University of New South Wales.

Installing active power filters (sometimes called active harmonic filters or line conditioners) in an electric power network can improve the quality of electricity supply. A shunt active power filter, with a current-source PWM inverter and a conventional copper inductor as its energy storage has a significant power loss. The power loss in this copper inductor can be substantially reduced by replacing the inductor with a high-temperature superconducting (HTS) magnet. Several solenoid design alternatives using silver-sheathed BSCCO-2223 tape have been made for the HTS magnet that has an inductance of 0.5H for this application. A liquid-nitrogen-cooled HTS magnet has been built and tested for use in an active power filter. The loss reduction effect of using the HTS magnet with the current-source active power filter has been investigated experimentally and the results are compared with those when using a conventional copper inductor. Practical issues such as air-core design versus iron-core design and using liquid-nitrogen cooling or a cryocooling are analysed and discussed.

THM2OR4

Superconducting Fault Current Limiter-Magnetic Energy Storage (SFCL-MES) for Substation Applications

C. Zhao, L. Xiao, L. Lin, Y. Yu, Institute of Electrical Engineering, CAS.

In this paper, a new concept of Superconducting Fault Current Limiter-Magnetic Energy Storage (SFCL-MES) for Substation Applications is proposed. By replacing the bias power source of bridge SFCL with the current regulator of SMES, SFCL and SMES are integrated into FCL-SMES with just one superconducting coil. The principle of FCL-SMES is analyzed first, then its configuration and operation mechanism are presented. FCL-SMES can not only limit the peak fault current, but also limit the steady fault current for long time. Moreover, it can provide high-quality power for the critical customers of the substation at the same time. Its effectiveness is verified by the numerical simulation and experiment.

THM2OR5

Flexible Power Interconnection with SMES

S. Nomura, H. Tsutsui, S. Tsuji-lio, R. Shimada, Tokyo Institute of Technology.

Electric power systems are usually interconnected with each other through a back-to-back direct-current (DC) link to increase reliability of electric power networks and to improve system operations. The objective of this work is to discuss the concept of a Superconducting Magnetic Energy Storage (SMES) system incorporated into a back-to-back interconnection. In this case, the back-to-back system is used as a power conditioning system for the SMES coils. Since the AC/DC converter can be designed independently of the frequency of the power system, a two-way switch is connected to the AC side of each converter. This two-way switch can select the interconnected power system. By using the two-way switches, this system can increase the availability factor of the back-to-back system during the SMES operations and also enables the economical power interchange between interconnected power networks with an optimal time interval for the power demand of each interconnected power network. This work discusses the system configurations and operations of the back-to-back interconnection with SMES that enables the replacement of a pumped hydro storage system. In this case, the SMES system is composed of a number of superconducting coils in order to reduce the cost of the superconducting coil by the effect of mass production. In this work, the SMES coils are optimized from the required mass of the structure and the leakage magnetic field.

PARALLEL SESSION10:30 - 12:20(Scirocco/Libeccio room)

RESISTIVE MAGNETS FOR ACCELERATORS AND DETECTORS

THM3OR1

Design and Construction of Conventional Accelerator Magnets

A. Dael, Synchrotron SOLEIL.

Even while new technologies are more often under the highlights, the so-called conventional technologies are making continuous progress. This law applies to the Accelerator Resistive Magnets. Over a long time period, significant changes have clearly appeared. The gap size and bore diameter are smaller and smaller. The field tolerances on homogeneity, identity, etc... are more and more severe. Both evolutions result in very tight mechanical requirements (in the range of factor 3 or 5 on twenty years...). Fortunately, on one hand, full 3D magnetic computation is now able to predict very precisely field maps and field harmonic content. And,on the other hand, the construction technologies are more and more accurate and assembly process is more and more effcient and precise. Other relevant aspects are: Interface with vacuum chamber which is more and more complicated; New possibilities from DSP power supplies to be analysed; Energy savings that play a major role taking advantage of the gap reduction but also requesting less power consumption and consequently a low average current density. Nowadays the companies are able to cover most of the design aspects and may often take full responsibility guarantee including magnetic with magnetic measurements and emerging industrial partners can play a good role. The paper gives "up to date" examples in different projects and illustrates the technological evolutions.

THM3OR2

Results from the ALICE Dipole Magnet Commissioning *D.K. Swoboda, C. de Almeida, A. Meynet, H. Taureg, A.*

Tournaire. CERN. The ALICE experiment is being installed in point 2 of the future LHC at CERN. The experimental hall was previously used by a LEP experiment of which ALICE reuses the big L3 solenoid as the central detector magnet. The single arm forward muon spectrometer requires in addition a new dipole magnet with a very large aperture. This magnet has been developed and constructed and has now been installed in its final position. Since this location adjacent to the large L3 solenoid leads to important interference between both devices the dipole has previously been assembled and tested in a pre-assembly location before the final assembly and commissioning in 2005. The techniques and results of geometrical, thermal, electrical, magnetic and mechanical measurements in the final location are presented. These values are also compared to obtained those measurements during the precommissioning campaign when the magnet was tested in a stand-alone position. To provide the necessary data for the particle track analysis, the magnetic field of both magnets has been mapped in the entire detector space and also in the surrounding region where field sensitive electronics will be installed. Some relevant results are summarized.

THM3OR3

LHCb dipole magnet tests and field mapping

M. Losasso, F. Bersgma, W. Flegel, P-A. Giudici, J.A. Hernando Morata, O. Jamet, R. Lindner, J. Renaud, F.

Teubert, CERN.

The LHCb experiment at the LHC at CERN is aimed to study CP violation and to measure the rare decays of Bmesons with exceptionally high precision. A 4 Tm dipole magnet is required for particle separation and momentum measurements. The 1600 ton warm magnet with sloping poles has been installed and fully commissioned end of 2004. It is the first detector magnet of the four LHC experiments having been aligned in its final position. In this paper the magnet installation in the underground cavern of Point 8 and its alignment on the beam line are shortly reviewed. Results of a first magnetic field mapping in the region of the magnet poles and the fringe field in the location of the RICH detectors are presented. The mechanical equipment used the for automatic displacement of the hall probe array is described together with the precision of measurements obtained and compared with TOSCA finite element calculations.

THM3OR4

Magnet Systems of CSR rings

P. Yuan, B. Zhang, X.Q. Zhang, G.P. Sun, Y. He, L.Z. Ma, Institute of modern physics, CAS.

The magnet design, fabrication and measurement of the experimental ring of HIRFL-CSR (Heavy Ion Research Facility in Lanzhou Cooling Storage Ring) are presented. All magnets will be laminated and welded with an armourcoated surface between two big endplates made of sticking glue 0.5mm-thick sheets. The dipole of CSRm was chosen an H type with an air circle on the pole to improve the field homogeneity, which was agreed between magnets measurement and OPERA code calculation. The dipole of CSRe was chosen the C type with an air circle and two air slots on the pole to improve the field homogeneity. Its reproducibility of magnet to magnet was adjusted with inserting small laminating pieces before remounted pole ends to reach less than ±2'10-4 at lower field. CSRm quadrupoles diameter is 170mm and has two different length and its endplates were made with punching pieces after coating epoxy glue, there is chamfered directly on the pole ends to reduce 12th order contribution of field and without the remounted pole end. CSRe main quadrupoles diameter is 240mm and has two different length and its endplates were also made with punching pieces after coating epoxy glue, there is also chamfered directly on the pole ends to reduce 12th order contribution of field and without the remounted pole end.

THM3OR5

Status report on the Centro Nazionale di Adroterapia Oncologica (CNAO)

M. Pullia, on behalf of CNAO collaboration.

The Centro Nazionale di Adroterapia Oncologica (National Center for Oncological Hadrontherapy, CNAO) will be the first Italian center for deep hadrontherapy. It is presently under construction in Pavia. It will be based on an evolution of the PIMMS synchrotron capable to accelerate carbon ions up to 400 MeV/u kinetic energy and protons up to 250 MeV, energies which are necessary to treat deep seated tumors. Four treatment lines, in three treatment rooms, are foreseen in a first stage. Space for two additional rooms eventually equipped with gantries has been left aside the center and the synchrotron has been designed to work with these two additional lines, but they are intended as a future upgrade. The beam is injected into the synchrotron from the inside, to allow positioning all the injection chain inside the synchrotron ring itself, and also to better exploit the two non-dispersive regions in the synchrotron. The injection chain is made by a 8 keV/u Low Energy Beam Transfer line

(LEBT), a RFQ accelerating the beam to 400 keV/u, a LINAC to reach the injection energy of 7 MeV/u and a Medium Energy Beam Transfer line (MEBT) to transport the beam to the synchrotron. This report describes the design and the performances of the CNAO, and reports about the status of the construction of the center.

POSTER SESSION	13:30 - 15:30
LOW Tc SUPERCONDUCTO	RS (III)

THA01PO01

Superconducting Properties of Nb3Sn Wires with Radially Arranged Filament

Y. Kubo, H. Egawa, T. Nagai, T. Sone, B. Ikeda, M. Hasegawa, Mitsubishi Electric Corporation; M. Kosuge, NIMS.

An internal-tin route Nb3Sn superconducting wire which has both remarkably low hysteresis loss (Qh) and high critical current density (Jc) was developed with a new design idea. The wire was constructed with arranging the filaments radially, enlarging the outer filaments along the radial direction, intentionally narrowing the filament spacing in the radial direction and enlarging the filament spacing in tangential direction. Thus, the electromagnetic combination among the filaments in tangential direction due to the bridging and/or proximity effect was suppressed without decreasing the volume fraction of Nb. As a result, excellent properties such as Jc(12 T)= 1150 A/mm2 and Qh=301 mJ/cm3 (for 1 cycle of B=±3 T) were obtained. We also evaluated the transition temperature (Tc) and upper critical field (Bc2) of the wire. The values for Tc and Bc2 were 17.3 K and 24.1 T, respectively, which were much better than those of usual internal-tin route wires. It was confirmed by electron probe micro-analyses that the good Tc and Bc2 were caused by the qualitative improvement of the Nb3Sn compound based on the effects of arranging Nb filaments radially, increasing the ratio of Sn-to-Nb and shortening the diffusion length for Sn due to the increase of the module number. This wire is promising for use with conductioncooled high-field magnets in which there is a need to decrease the load of the cryocooler, and also for the strands of fusion coils.

THA01PO02

Effect of prebending strain on CuNb/Nb3Sn superconducting coils using a React-and-Wind method H. Oguro, G. Nishijima, S. Awaji, K. Watanabe, High Field Laboratory for Superconducting Materials, IMR. Tohoku University; K. Miyoshi, S-I. Meguro, Furukawa Electric Co. Ltd.

We have found that Ic, Tc and Bc2 for practical Nb3Sn superconducting wires were enhanced by prebending strain, which means repeated bending load at room temperature. We applied the prebending treatment to fabricate a React- and-Wind processed coil and investigated the effect of prebending strain on the critical current for CuNb reinforced bronze route Nb3Sn superconducting coils. We prepared four kinds of monolayer coils with different prebending strain value of 1.0%, 0.8%, 0.5% and 0%. The prebending strain was applied by through 10 pulleys with each bending diameter. The number of turns of each coil is 49 and a diameter is 200 mm. We measured Ic and strain of the coils at 4.2 K in magnetic fields up to 11 T for both of the tensile and compressive hoop stress states. In the compressive stress state, Ic of the coil with 0 and 0.8% prebending strain at 10 T were 331 A and 353 A, respectively. Those values are larger than Ic = 284 A for short sample without prebending strain. At the hoop stress test, the Ic of four coils were similar value of about 260 A at 10 T. Therefore, it is considered that the Ic was limited by the large hoop stress of about 330 MPa for all coils in the tensile hoop stress states.

THA01PO03

Investigations of magnetic behaviour in various types of Nb3Sn multifilamentary wires by means of the 1st and 3rd harmonics of the AC magnetic susceptibility

M.G. Adesso, Università di Salerno & Université de Genève; D. Uglietti, V. Abächerli, R. Flükiger, Université de Genève, S. Pace, Università di Salerno.

The 1st and the 3rd harmonics of the AC magnetic susceptibility were measured as a function of the temperature, on three Nb3Sn multifilamentary wires, built by different processes: bronze route (home made), internal tin diffusion (Oxford) and powder-in-tube (SMI). These measurements were performed with and without a DC magnetic field, up to 19T. We observed that the magnetic response of the bronze route wire is mainly characterized by vortex dynamical phenomena, such as flux creep. This is in contrast to the internal tin wire, where the static hysteretic Bean model is sufficient to describe the magnetic behaviour. Thanks to a combined analysis of the 1st and the 3rd harmonics, it is possible to individuate, in this wire, the transition between quasi-ordered (BRAGG) and disordered phase. The H-T phase diagram from our measurements is very similar to that obtained for the previously analysed single crystal and bulk samples. The magnetic response of the "powder in tube" wire is more complex, showing two contributions possibly associated to Nb3Sn grains with slightly different Sn contents.

THA01PO04

Optimisation of Two-Step Heat Treatments of Bronze-Route (NbX)3Sn Conductors for High-Field Applications

H. Müller, T. Schneider, FZ Karlsruhe.

Up to now, the superconducting high field facility HOMER II of the Forschungszentrum Karlsruhe has been designed to reach magnetic field strengths of about 20 Tesla. To increase the field strength even further, two different methods are used. One is the building of a HTSC-insert coil, the other the fabrication of one or more (NbX)3Sn coils. These coils will operate in magnetic fields close to the upper critical field of the conductors, so special attention has to be focused on the heat treatment of the wires, which strongly influences the physical properties critical current and n-value. In our paper we will present results of two-step heat treatments on an alloyed bronze route Nb3Sn conductor. Differences between one- and two-step heat treatments will be discussed as well as the optimum heat treatment for different background magnetic fields.

THA01PO05

Studies of Electromagnetic Instabilities in Nb3Sn Strands and Cables

E. Barzi, G. Ambrosio, N. Andreev, L. Del Frate, V. Kashikhin, D. Turrioni, R. Yamada, A. Zlobin, FNAL.

Results of studies of electromagnetic instabilities in Nb3Sn strands and cables produced using the Modified Jelly Roll, Restacked Rod Process and Powder-in-Tube technologies are presented. The critical current of the strands was measured using the voltage-current and voltage-field methods. Magnetization was measured using a balanced coil magnetometer. Measurements at high field were done

in order to determine the effective filament size of strands. Measurements at low fields were performed to study magnetic instabilities (flux jumps) in strands with high critical current density and large effective filament size. Effects of strand deformation and heat treatment as well as test temperature and sample cooling conditions were studied. A superconducting current transformer with a maximum DC current of 28 kA was used for cable testing at self-fields under various experimental conditions. The cable tests confirmed that magnetic instabilities cause a significant reduction of current carrying capability at low fields. These results are in good agreement with magnet test data as well as with experimental studies of similar strands and cables. The strand and cable parameters and heat treatment procedures, equipment and measurement methods used, and the results of the measurements are herein described. The effect of magnetic instabilities is analyzed and compared to the predictions of an instability model.

THA01PO06

Composition analysis of Nb3Sn bronze wires by TEM and Auger spectroscopy

D. Uglietti, R. Flukiger, University of Geneva, Group of Applied Superconductivity; M. Cantoni, P. Buffat, CIME, Swiss Fed. Institute of Technology; A. Reginelli, H. J. Mathieu, Surface Analysis Group, Swiss Fed. Institute of Technology.

Multifilamentary Nb3Sn bronze route wires exhibit a gradient of the Sn concentration in the A15 layer, which affects the transport properties. Little is known about the microstructure and composition of the superconducting layer, the last investigation on this subject having been undertaken in the 80's: a better characterisation of the superconducting layer at nanometric scale is needed in order to improve the critical current density in these wires. In this work the composition gradient across the superconducting layer has been measured on different alloyed Nb3Sn bronze wires at the nanometric scale by means of TEM/EDX. The Sn, Ti and Ta composition gradients across the filaments and across the wire have been correlated to the grain morphology and to the transport properties. At the bronze/A15 interface the grains are equiaxed and the Sn content is close to 25 %, but decreases to a value of 18% at the A15/Nb interface, where the grain shape is columnar. Only the equiaxed regions of the A15 filaments have a sufficiently high critical field to carry supercurrents at high magnetic fields, while the Bc2 values of the columnar regions is lower and does not contribute to the current transport. At fields > 12 T, about 75% of the A15 area is superconducting, while less than half is superconducting at higher fields (>21T). It follows that the critical current of bronze wires can be drastically raised by enhancing the high Sn content section of the filaments.

THA01P007

Axial tensile stress-strain characterisation of a 36 strands cable

Y. Ilyin, A. Nijhuis, W.A.J. Wessel, N. van den Eijnden, H.H.J. ten Kate, University of Twente.

During the various manufacturing steps and operation of the Cable-In-Conduit Conductors (CICC) destined for the high field coils in the International Thermonuclear Experimental Reactor (ITER), the Nb3Sn wires of such cables are subjected to various (thermo-) mechanical deformations, originating from cabling and compaction, coil winding, heat treatment, cooling down to liquid helium temperature and finally electromagnetic forces. As the strain state of the Nb3Sn strands determines their critical properties, it is essential for optimal cable and magnet design to gain knowledge on the deformation of strands inside CICC's and its impact on the transport properties. The stress-strain and deformation of these cables is being analysed by computation. However, experimental verification is required at least on sub-cable level. For validation of existing mechanical models, a new set-up has been built, which allows the stress-strain testing of ITER relevant sub-size cables. The cable consists of 36 nonreacted Nb3Sn strands and the total effective length is four times the twist pitch of the last cabling stage (480 mm). A cable sample is subjected to tensile axial stress, while the axial effective elongation (strain) is being recorded using extensometers. The radial deformation is monitored at room temperature by a digital camcorder. The test results at room and liquid helium temperatures are reported together with the single strand mechanical characteristics.

THA01PO08

Axial tensile stress-strain characterization of ITER type Nb3Sn strands in TARSIS

N. van den Eijnden, A. Nijhuis, Y. Ilyin, W.A.J. Wessel, H.H.J. ten Kate, University of Twente.

Since the strain state of the Nb3Sn filaments in strands determines the transport properties, it is crucial for optimizing the cable and magnet design to investigate in detail the effective deformation state of the strand in CICC's and to determine the impact on the transport properties and superconducting transition. The stressstrain and deformation of ITER Nb3Sn cables is being modeled and analysed by computation and basic experimental verification is required on strand level. In order to validate the mechanical models, a new set-up is developed, which allows efficient tensile stress-strain testing of wires. This paper reports on the first axial tensile stress-strain measurements that were performed on several types of ITER Nb3Sn strands at liquid helium, nitrogen and room temperature in the TARSIS (Test ARangement for Strain Influence on Strands) setup. A double extensometer connected to the sample enables to determine the strain level whereas a load cell is used to determine the stress level. The details of the take-off origin of the measured stress-strain curves are discussed and the data are evaluated with respect to expressions for the stress-strain curves.

THA01PO09

Extended characterization of European advanced Nb3Sn strands for ITER

L. Muzzi, S. Chiarelli, A. della Corte, A. Di Zenobio, M. Moroni, A. Rufoloni, A. Vannozzi, ENEA; E. Salpietro, A. Vostner, EFDA CSU Garching.

Within the framework of ITER-related projects, new tasks have been recently launched by EFDA CSU Garching (European Fusion Development Agreement Close Support Unit Garching), for the definition and production on industrial scale of advanced Nb3Sn strands, to be used in the manufacturing of the ITER high field CS and TF magnets. We performed an extended characterization of the advanced Nb3Sn strands coming from different European companies, in terms of strand layout (diameter, thickness of Cr coating, Cu:non-Cu ratio, twist pitch length and orientation), critical transport current and n-value, RRR, and hysteresis losses. The results of the measurement campaign show that the upgraded strands meet the latest ITER requirements, with an overall critical transport current of at least 200A (at 12T, 4.2K), equivalent to a non-Cu Jc of about 800A/mm2, a Cu:non-Cu ratio of

about 1, a strand diameter of 0.81mm, and with non-Cu hysteresis losses limited to less than 1000 kJ/m3 on a \pm 3T field cycle at 4.2K.

THA01PO10

Internally Cu-stabilized RHQT Nb3Al superconductors with Ta matrix

T. Takeuchi, K. Tagawa, T. Noda, N. Banno, Y. Iijima, A. Kikuchi, H. Kitaguchi, NIMS; K. Tsuchiya, KEK; N. Koizumi, JAERI; A. Nishimura, NIFS.

Next generation nuclear fusion magnets would require a high-current and highly-strain-tolerant conductor in fields more than 16 T. A cable-in-conduit (CIC) conductor of the rapid-heating, quenching and transformation (RHQT) processed Nb3Al may be such a promising candidate. Good deformability of intermediately-formed hcc supersaturated-solid solution indeed allowed fabricating such a CIC conductor, which would be subsequently transformation annealed. Although the stabilizer should be incorporated into a thin and round strand, the established stabilization technique of Cu cladding is not available for a round wire. Thus, Ag has been internally included as a basic constituent of such a round strand so far, because Ag is almost non-reactive with Nb matrix during the RHQ. However, both of Ag and Nb are not suitable nuclei from the viewpoint of radioactivity when irradiated with neutrons. Recently, we have succeeded in replacing the Nb matrix with Ta that has the advantage of shorter half-life of radioactivity. In the present study, an attempt has been made to replace the Ag internal stabilizer with Cu, in the aim of further reducing radioactivity, based on anticipation that Ta would be less reactive with Cu than Nb did. A part of this study was financially supported by the Budget for Nuclear Research of the MEXT, the Research Promotion Bureau of the MEXT. and NEDO.

THA01P011

Development of high strength Nb3Sn superconducting wire with Ta reinforced filaments

G. Iwaki, Hitachi Cable, Ltd.; G. Nishijima, K. Watanabe, Tohoku University; K. Katagiri, Iwate University.

Although Practical applications of Nb3Sn superconducting magnets are expanding, the conventional magnet fabricating process, wind-and-react (W&R) method, restrict the applications to relatively small magnets due to complexity of the method. On the contrary, the react-andwind (R&W) method can make magnet fabrication process simple and large scale Nb3Sn magnets will be fabricated easily. To realize large Nb3Sn magnets by the R&W method, it is necessary to develop a specific Nb3Sn wire which will not deteriorate its property during winding process at room temperature and can withstand against a huge electro-magnetic force during the operation at low temperature. We are carrying out investigations of high strength Nb3Sn wires with Nb filaments reinforced by Ta suitable for the R&W method. The Nb3Sn wire with Ta reinforced filaments is expected to minimize the influence of the bending strain during winding and exhibit a high strength property with a Cu stabilizer enough to keep the magnet stability. A Nb3Sn wire with a volume fraction of Ta inside Nb filaments of 0.15 and a Cu ratio of 0.5 was developed for a magnet by the R&W method this time. The performances of the high strength Nb3Sn wire with Ta reinforced filaments will be introduced at this presentation.

THA01P012

Ways to Understand Scaling of Jc in Inherently Inhomogeneous Multifilament Nb3Sn Conductors

A. Godeke, University of Twente-University of Wisconsin-

Madison; A. Nijhuis, A. den Ouden, H.H.J. ten Kate, University of Twente; M. C. Jewell, P.C. Lee, D. Larbalestier, University of Wisconsin-Madison.

We analyzed thoroughly the scaling relations for Jc in Nb3Sn wires as used in magnet design and included recent findings on the variation of Hc2(T) with varying A15 composition. We showed earlier that a microscopic based description for Hc2(T) is valid for all available Nb3Sn data and thus represents an alternative to the empirical relation for the bulk average H*(T) as used in Summers/Ekin type descriptions. The alternative description for Hc2(T)/Hc2(0) can be approximated by 1-t^1.44, where 1.44 is a constant which follows from its full functionality and t=T/Tc. In addition, it follows that the GL parameter K(T)/K(0)=(1t^1.44)/(1-t^2), also yields an alternative to empirical versions. We further discuss how the presence of compositional or strain inhomogeneities can explain the often observed non-linearity in Kramer plots near Hc2. This can result in the validation of a Kramer type of pinning dependence in the field range 1 T<H<Hc2, provided the average grain size is above 100 nm. The above arguments can generalize scaling relations below the magnetic field where inhomogeneity effects start to appear. We will also present data emphasizing differences in strain sensitivity. These render general scaling descriptions not realistic for now, since the strain sensitivity as a function of composition is unknown. Overall we find that purely empirical descriptions do have better founded alternatives when the composition and strain variation within the A15 is addressed.

THA01P013

Jc(T, B) and V-I Characteristics of the Nb3Sn Strands with CuNb Reinforced Stabilizer

A.K. Shikov, V. Pantsyrny, N. Kozlenkova, A. Vorobieva, E. Dergunova, S. Sudyev, V. Sergeev, Y. Konovalov, M. Polikarpova, Bochvar Institute of Inorganic Materials. The Model Coil Program in ITER Project has revealed not

trivial correlation of the superconducting properties of the Nb3Sn strands in virgin state and in the scope of large CICC conductors where the strands are mechanically strained. That is why the evaluation of the voltage-current characteristics of the Nb3Sn strands with different mechanical properties has been done. Critical current density Jc(T, B), voltage-current (V-I) characteristics as a function of temperature and magnetic field, and voltagetemperature (V-T) characteristics have been measured on two Nb3Sn strands (internal tin and bronze route) with CuNb reinforced stabilizer. The measurements were carried out in the range of magnetic fields from 7 to 12 T at the temperatures from 4.2K to 13K. The Summers relations have been applied for evaluation of the experimental Jc(T, B). The fitting parameters C, Tcm (0), Bc2m (0) has been defined as giving the best fit to the experimental data. To describe experimental database V-C characteristics the relation is used containing four fitting parameters. Three parameters, namely: C, Tcm (0), and Hcm(0) describe Ic (T, B, e). Additional parameter characterizes the smoothness of VC- characteristics. The reasons determining the difference of these parameters for two kinds of strands are analyzed.

THA01P014

Critical current measurements on Niobium-Tin conductors for the NED project

A. den Ouden, University of Twente; T. Boutboul, V. Previtali, CERN; D. Pedrini, G. Volpini, INFN-Sezione di Milano.

The Next European Dipole (NED) project is a EU funded

program aiming at the realization of a 15 T accelerator-type Nb3Sn dipole magnet. The objective of NED phase one is developing high performance Nb3Sn conductor in collaboration with european industry. The envisaged Rutherford type of cable consists of 30-40 superconducting strands exhibiting a non-copper critical current density of 1500 A/mm2 at 4.2 K and 15 T. In the frame of conductor development, adequate critical current measurements in terms of accuracy and reproducibility should be ensured to qualify the ambitious strands produced. Therefore, representatives of several european institutes merged to constitute a working group aiming at the establishment and implementation appropriate and standardized of procedures for sample preparation and mounting, critical current measurement and data analysis. For this purpose, a cross-calibration program between the institutes involved has been performed by exchanging samples of Nb3Sn conductor from the same billet for critical current measurements, prepared and reacted at each institute. The experimental results of this program and the conclusive procedures for NED critical current measurements are presented and discussed.

POSTER SESSION	13:30 - 15:30
HIGH Tc SUPERCONDUCTO	DRS (II)

THA02PO01

Apparatus Designed to Detect the Homogeneity of Critical Current in HTS Tapes Using Contact-free Method

Y. Wang, FZ Karlsruhe; Y. Wang, X. Xu, L. Xiao, L. Lin, IEE, CAS.

High temperature superconducting (HTS) tapes are applied more and more frequently to equipments in area of electrical engineering. There is a great demand for homogeneity of critical current for HTS tapes in all of their applications. Longitudinal homogeneity of components and performances is the basic requirement. Making use of a contact-free method (Hall probe) is an applicable measuring method that can make longitudinal homogeneity examination of critical current in long HTS tapes

THA02PO02

Trapped Field distribution within a cylindrical hole in Sm-Ba-Cu-O bulk superconductor

M. Masuzawa, K. Egawa, K. Tsuchiya, KEK.

To study the possibility of HTS applications in the design of magnets for particle accelerators, trapped field distribution in a bulk superconductor was investigated. An array of Hall probes, calibrated at liquid nitrogen temperature, was used to monitor the trapped field distribution in a hole (10 mm in diameter) in a rectangular bulk superconductor (15 mm thickness) as a function of time. The bulk superconductor was placed in an external field created by a dipole magnet, where the field strength was varied up to about 1.3 T. The decay process of the trapped field was monitored using the Hall probe array. The decay speed was observed to be dependent on the thickness of the superconducting material, the distance from the edge of the material and the trapped field strength. The results are summarized in this report.

THA02PO03

Reduction of error in Jc distribution of coated conductors measured by magnetic knife method

O. Maruyama, P. Miyashita, J. Amemiya, Yokohama National University; E. Saitoh, Fujikura Ltd.; S. Yamada, C.

Shiohara, ISTEC-SRL.

The lateral critical current density (Jc) distribution of YBCO coated conductors can be determined using magnetic knife method which utilizes the magnetic field dependence of the Jc of YBCO coated conductors. The authors guessed that accurately placing the sample YBCO coated conductor at the center of the gap between two iron cores might be important to reduce an error in the determined Jc distribution. The position of the sample in the gap was varied, and the lateral Jc distributions were measured at the each position. The error was small when the sample was placed at the center of the gap, and the error increased with increasing displacement of the sample from the center of the gap. The measured profile of the magnetic flux density perpendicular to the wide face of the sample was hardly changed by a little displacement of the sample from the center of the gap. The component of the magnetic flux density parallel to the wide face of the sample (parallel B-component) is zero at the center of the gap. The numerical analysis showed that the parallel B-component appeared by a little displacement of the sample from the center of the gap. This parallel B-component was considered to the cause of the error. This work was supported by the Ministry of Economy, Trade and Industry through ISTEC as the Japan-U.S. Joint Study of AC Losses in High Temperature Superconductivity.

THA02PO04

Strain dependence of critical current in Bi2212 W & R wires under magnetic field up to 30 T

M. Sugano, K. Itoh, T. Kiyoshi, Tsukuba Magnet Laboratory, NIMS.

We developed a Walters spring (WASP) type apparatus to investigate strain dependence of critical current for relatively long superconducting wires under magnetic field. A 720 mm long Bi2212 wind-and-reacted (W & R) wire was soldered along the whole length on the Cu-Be spring with an outer diameter of 23 mm. Uniaxial tensile and compressive strain was applied by twisting the spring. The Probe was inserted in a variable temperature cryostat with He gas flow. In order to compensate the heating by current flow, temperatures at both of the current terminals were controlled. The probe and cryostat were inserted in the bore of a hybrid magnet in TML which can generate magnetic fields up to 30 T. An ultrasonic motor was equipped at the top of the probe where fringing magnetic field reached a few Teslas. From the result at 6 K and 30 T, critical current did not change largely up to a tensile strain of 0.45%, followed by rapid degradation. The strain value corresponding to the rapid degradation of critical current was discussed combining with measurement results of thermal expansion of the composite wires.

THA02PO05

Processing and properties of Re-Ba-Cu-O Bulk Superconductors

H. Fujimoto, Railway Technical Research Institute.

Melt-processed REBaCuO (RE: rare-earth) superconductors have a high Jc at 77 K and high magnetic field, and LRE (LRE: light rare-earth) BaCuO has a larger Jc than Y123 in high magnetic field. These materials are expected to be applied to high field applications such as a superconducting permanent magnet with the liquid nitrogen refrigeration, flywheels, current leads, motors and so on. In this study, we discuss DyBaCuO bulks melt-processed in and their characteristic superconducting air and mechanical properties. Slow cooling in air with oxygen annealing and a top seeded method were applied in DyBaCuOy/Ag system to seek the high-efficiency of

process and homogeneity of composition. Single-domain growth of superconducting phases of 48 mm in diameter and 15 mm in thickness was achieved using this technique. Superconducting and mechanical properties of the DyBaCuOy/Ag bulk were measured. The result implies that melt-processed in air applying a top seeded method and slow cooling in Dy system is feasible for producing larger bulks in large scale applications.

THA02PO06

Crystal Growth Direction Dependence of Microstructure and Superconducting Properties of Cylindrical RE123 Melt-solidified Bulks

T. Nakashima, J-I. Shimoyama, Y. Tazaki, Y. Ishii, S. Horii, K. Kishio, University of Tokyo.

Our previous study revealed that the c-growth region of the RE123 melt-solidified bulks exhibit huge second peak effect in their magnetization hysteresis loops, resulting in improved Jc properties under high fields compared with their a-growth region. In the present study, the cylindrical RE123 (RE=Sm, Gd, Dy, Ho, Y, Er) bulks containing Pt (0.5 wt%) and CeO2 (1 wt%) were synthesized by the meltsolidification method using cold-seeding technique. These bulks are composed of c-growth regions as major parts. Dispersion of RE211 particles, crystallinity of the RE123 matrix and Jc characteristics were systematically studied for the a- and c-growth regions of the bulks. In the c-growth region just below the seed crystal, the volume fraction of RE211 particles was lower than in the a-growth region, while this part showed huge second peak effect. This suggested that observed second peak was originated from oxygen defects. However, the c-growth region maintained higher Jc than that of the a-axis region even at the positions where the mean particle size and volume fraction of RE211 were almost identical in the a- and c-growth regions. These preferable Jc properties observed in the cgrowth region can be explained by excellent crystallinity of the RE123 matrix with few low-angle grain boundaries.

THA02P007

Texturing Behavior and Current Transport of Highly Textured Ag/Bi2212 PIT Monofilamentary Tapes After the Application of Different Heat Treatment Profiles and Silver Doping

D. Rodrigues Jr., E. Cursino, A. R. Bigansolli, Superconductivity Group, Department of Materials Engineering, FAENQUIL. Withdrawn.

THA02PO08

Deformation of Bi-2223 Superconducting Tapes under Pressurized Liquid Nitrogen and its Influence on Ic Degradation

H-S. Shin, J. Dizon, Andong National University; S-S. Ho, KERI.

The evaluation of endurance and reliability of HTS conductors are necessary for practical applications such as power transmission cables, motors and HTS coils adopting BSCCO tapes. The deformation and damage behavior and the bending strain effect on the critical current, Ic, of multifilamentary Bi-2223 superconducting tapes at pressurized liquid nitrogen (LN2) were investigated. Three different kinds of commercially available Bi-2223 tapes having different geometries were adopted in this study. BSCCO tapes were immersed and tested in LN2 pressurized to 1 MPa. After the immersion test, the diffusion and expansion of LN2 into the tapes, and the occurrence of ballooning or delamination at interface between the sheath and external reinforced layers at

differently pressurized LN2 levels were investigated. Simultaneously, the influences of damage on Ic degradation at specific bending strains were analyzed.

THA02PO09

Interstrand coupling losses in Bi-2212 Rutherford cables

F. Sumiyoshi, A. Kawagoe, S. Kawabata, Kagoshima University; N. Hirano, S. Nagaya, Chubu Electric Power Co. Inc.

Coupling loss measurements were carried out in liquid helium for Bi-2212 Rutherford cables in applied transverse magnetic fields. The cable is composed of 30 non-twisted strands with a diameter of 0.81mm; its cabling pitch is 87mm, its outer size of cross-sections is 13.4mm wide and 1.6mm thick. The current capacity is about 10kA at 4.2K and 0T. Short, straight sample composed of three or four stuck cables were set at the uniform field space inside the NbTi magnet of a race-track and split type. Measured frequency characteristics of ac losses were observed for transverse magnetic fields of both perpendicular and parallel to the flat face of cables. In case of higher amplitude, loss values are almost constant with the frequency; on the other hand, in case of lower amplitude, they have strong frequency dependences. From these frequency characteristic curves, the coupling time constant was obtained of the order of 10msec, which means that the inter-strand coupling current can be neglected compared with hysteresis losses in the sample for the practical conditions.

THA02PO10

Evaluation of Joint Resistance between Bi-2223/Ag Superconducting Tapes

J.H. Kim, J. Joo, H.S. Kim, S.B. Jung, School of Advanced Materials Science Engineering, Sungkyunkwan University; S. Choi, Division of Instrument Development, Korea Basic Science Institute; W. Nah, School of Information and Communications Engineering, Sungkyunkwan University. We fabricated resistive-joint of Bi-2223/Ag superconducting

tape and evaluated current carrying capacity and joint resistance from voltage-current characteristics at 77.3 K. In order to connect two tapes, 40Pb-60Sn solder was used and "shaking-hands" configuration was applied for the joint process. It was observed that current carrying capacity and joint resistance significantly dependent on contact length. When the contact length increased, the current carrying capacity improved and reached to peak value of 1 at the contact length of 5 cm. On the other hand, the joint resistance linearly decreased as the contact length increased. These results were closely consistent with the calculated current carrying capacity and joint resistance. Finally, we suggested the optimal condition to obtain low joint resistance for resistive-joint method.

THA02P011

Improved Superconducting Properties of Cation Composition Controlled Bi-Based Superconductors

J-I. Shimoyama, S. Uchida, T. Makise, Y. Miyahara, S. Horii, K. Kishio, University of Tokyo.

The Bi-based superconductors, such as Bi2212 and Bi(Pb)2223, have been well-developed as for wires and tapes. Critical current properties of these tapes are determined by two factors, microstructure of the superconducting layer and intrinsic nature of superconducting crystals. Recent progress on the Jc characteristics of these materials has been mainly achieved by the optimization of the microstructure. Further improvement of Jc properties can be expected by the

precise control of their chemical compositions, because the Bi-based superconductors have relatively large nonstoichiometry in cation and oxygen compositions. In the present study, we have systematically studied the relationship between chemical composition and Jc properties for single crystals of Bi2212 and Bi(Pb)2212 and polycrystalline Bi(Pb)2223 bulks and tapes. For Bi2212 single crystals, the Jc properties were found to be quite sensitive to the cation composition. The best performance was observed for a crystal with a cation composition close to Bi : Sr : Ca : Cu = 2 : 2 : 1 : 2. Similar results were obtained for Bi(Pb)2212 single crystals. Moreover, the record-high Jc properties were observed for very small amount of Y doped Bi(Pb)2212 single crystals. These results suggested that dilute disorders in good superconducting matrix is favorable for high Jc characteristics. Improvement of superconducting properties of Bi(Pb)2223 by control of cation composition will be also reported.

THA02PO12

Effect of the grain growth on the spatial distribution of nano-scale additives in Sm-Ba-Cu-O materials

C-C. Wang, K-M. Chen, I-G. Chen, Department of Materials Science and Engineering, National Cheng-Kung University; S-Y. Chen, M-K. Wu, Institute of Physics, Academia Sinica, Taiwan. Withdrawn.

Withdrawn.

THA02P013

Analysis on Alternating Over-Current Characteristics of HTSC Tape using DFT Technique

S-H. Lim, Research Center of Industrial Technology, Engineering Research Institute; S-W. Yim, S-D. Hwang, Korea Electric Power Research Institute; B-S. Han, Division of Electronics and Information Engineering, Chonbuk National University.

The quench characteristics of high-TC superconducting (HTSC) tape for alternating over-current application with different amplitudes were investigated and its quench developments by applying discrete fourier transform (DFT) technique for the voltage and the current waveforms of HTSC tape were analyzed. Generally, the HTSC tape shows a broad S/N transition region above its critical current due to the metal sheath unlike HTSC thin film or HTSC bulk. In addition, the voltage-current characteristics of HTSC tape for the alternating over-current application is complicated because the quench and the recovery between the superconducting state and the normal state are repeated. Therefore, the research to presuppose the quench developing process of HTSC tape is required for the effective quench sensing and protection from the quench generation of HTSC tape comprising the electrical machine. In this paper, the alternating over-current experiments for the HTSC tape were performed to analyze the quench developments of it. The fundamental frequency components for the current and the voltage waveforms of the HTSC tape were abstracted by applying with DFT From those fundamental frequency technique. components, the numerical formula for HTSC tape's resistance could be derived. By reflecting its numerical formula into circuit equation, the quench developments of HTSC tape dependent on alternating over-current could be estimated and well agreed with experimental ones.

THA02P014

Electric field in Bi-2223 tape carrying DC current and exposed to AC parallel magnetic field

A. Friedman, Y. Wolfus, F. Kopansky, S. Asulay, Y.

Yeshurun, Institute of Superconductivity, Bar-Ilan University.

Degradation of the critical current of Bi-2223 tapes under AC magnetic fields is of great importance for HTS power applications. In particular, in a common AC coil design, the field component parallel to plane of the tape is much stronger than the perpendicular component and cannot be reduced using field diverters. We present a study of the electric field in Bi-2223 tapes carrying DC transport current and exposed to AC magnetic field parallel to the plane of the tape. The observed I-V curves can be described as an additional voltage to the I-V curve superimposed on the zero-field curve. This additional voltage is evident already for small DC currents, peaks close to the zero-field critical current and decreases thereafter. Measurements of the time dependent electric field exhibit double-frequency features and strong dependence of the electric field on the amplitude and frequency of the AC magnetic field. The results are discussed and explained in the framework of models suggesting shaking of the pinned vortices under the application of a parallel AC field. Work supported by the Israeli Ministry of National Infrastructures.

THA02PO15

Y1Ba2Cu3O7-d superconducting tapes prepared via a continuous electrodeposition process.

S. De Biase, S. Ciaccia, G. Giunchi, Edison SpA R&D.

Our recent advancements about a continuous process for the production of electrochemical deposited Y-123 films on meters long silver tapes are presented. The process consists of alternate sequential elemental deposition steps and thermal treatments and, by the use of modular sections, the tape may be processed in a continuous way in order to produce hundred meters long tapes, useful for industrial applications. The Y-123 phase constituting elements (Cu, Υ, and Ba) were sequentially electrodeposited on both sides of an untextured 50mmthick silver tape. Following yttrium deposition step, an intermediate annealing transforms the precursor in a mixture of CuO and Y2Cu2O5. Barium electroplating and a final thermal treatment in pure flowing oxygen allow the formation of the Y-123 superconducting phase. A careful control of the deposit stoichiometry and of the thermal parameters seems to be crucial in order to achieve a good microstructure and high performances. The critical current density of our best specimens, measured by transport methods at 77K and 0T, was 25.000A/cm2, which is so far the highest reported value for this material obtained via an electrochemical process on untextured substrate.

POSTER SESSION 13:30 - 15:30 PROTECTION SYSTEMS & SPECIAL TECHNIQUES

THA03PO01

Electronic Systems for the Protection of Superconducting Elements in the LHC

R. Denz, CERN.

The Large Hadron Collider LHC, currently under construction at CERN, will incorporate an unprecedented number of superconducting magnets, busbars and current leads. As most of these elements depend on active protection in case of a transition from the superconducting to the resistive state, the so-called quench, a protection system based on modern, state of the art electronics has been developed. The paper presents a review of the various implemented designs such as quench detection and data acquisition systems. In addition it reports on the state of the protection system electronics with respect to production, test, installation and commissioning.

THA03PO02

Qualification and start of production of the ultrasonic welding machines for the interconnection of the LHC superconducting bus bars

A. Jacquemod, J.P. Tock, F. Laurent, CERN; J.M. Ballaguer, D. Eginard, IEG.

The Large Hadron Collider (LHC) is presently under installation at CERN, Geneva. The approximately 4000 superconducting corrector magnets required by the machine are powered through superconducting bus bars made of Nb-Ti in a copper matrix. To interconnect these bus bars carrying up to 600 A, about 48 000 joints with verv low resistance have to be performed in-situ. An ultrasonic welding technique has been developed and optimized by CERN which led to the development of a dedicated machine which was qualified during the assembly of the Test String, a fully functional 110-m chain of cryomagnets assembled and operated as a prototype of the LHC. The realization of the series interconnections together with the procurement of the tooling based on functional specifications have been contracted to an industrial consortium. Qualification tests and acceptance criteria in terms of electrical contact resistance, mechanical resistance, reliability and reproducibility have been defined by CERN. This paper presents the tests and some results of the qualification process relevant to the industrialized tooling provided by the contractor. Results of pre-series junctions done in the actual machine are presented, together with the perspective for the continuation of the work

THA03PO03

Measurement Test of Phase Difference in high Tc Superconducting Magnet

E. Mukai, A. Tada, Sojo University; S. Fukai, Saga University.

Superconducting magnets have been studied to extend the new technology region. At present, low Tc superconductive wire (LTSW) has almost reached the level of practical use. In contrast, high Tc superconductive wire (HTSW) is more advantageous than LTSW, because it is possible to use liquid nitrogen in the cooling. The HTSW of long-length multi filaments has recently been manufactured, and a shift from LTSW to HTSW is expected in the future. A grasp of ac loss for the superconducting magnet is very important, since the ac loss is essentially generated in the superconducting wire. In this paper, the phase difference measurement, which is related to the evaluation of the ac loss of the superconducting magnet, is described. A new electronic circuit using op-amps is proposed to measure the phase difference of the superconducting magnet and the measuring result is also presented. First, the superconducting magnet of a double pancake coil was constructed using HTSW with Bi-2223 multi filaments. Next, an exciting test of the magnet using the ac power supply was performed. As a result, it was confirmed that the phase difference between the voltage and the current of the magnet almost approximated 90°. Finally, the phase difference was measured using the new measurement circuit. This measuring result agrees with the result by a lock-in amplifier comparatively well, and thus it is considered that the measuring precision of the circuit is obtained.

THA03PO04

Thermal and stress analysis for the ITER magnetic feeders

Y. Song, Y. Zhang, J. Wang, S. Wu, P. Weng, Institute of Plasma Physics, CAS. Withdrawn.

THA03PO05

Fibre Bragg Gratings For Sensing Temperature And Stress In Superconducting Coils

R. Ramalingam, A. Nyilas, M. Süßer, K.P. Weiss, Institute of Technical Physics, FZK; W. Freude, Institute of High-Frequency and Quantum Electronics, Universität Karlsruhe; G. Kreig, Sensor System Technology, University of Applied Science, Karlsruhe; K.G. Narayankhedkar, Department of Mechanical Engineering, Indian Institute of Technology, Bombay.

We study the feasibility of employing fibre Bragg gratings (FBG) for measuring thermodynamic parameters of superconducting coils. The distributions of mechanical stress and temperature inside the coil are important for an optimized design. Standard sensors with electrical connections like resistance thermometer and strain gauges cannot be placed inside the coil. So it is impossible to access local stress and temperature data. Also, the sensor placement outside the coil adds an undue time delay. Fiber-based Mach-Zehnder interferometers were already used for temperature sensing inside a superconducting coil (QUELL report), however, the design requirements will make the task of measuring local quantities complex. Fibre Bragg gratings fabricated at different location in one single fiber is better suited for this purpose. Five mm long gratings with different spatial period are arranged at various positions along a singlemode fibre inside the coil. Coil temperature and stress will vary the gratings' periods, which can be read out with a tunable laser in a wavelength division multiplexing (WDM) scheme. The spectral position of the reflections may be correlated with the spatial position of the gratings. We specify the design and technology requirements to adapt the FBG sensor concept for low temperature near 4K. Initial experiments which demonstrate the properties of glass FBG at low temperatures are reported.

THA03P006

Production And Tests Of The Discharge Resistors For Wendelstein 7-X

T. Mönnich, T. Rummel, Max-Planck-Institut für Plasmaphysik.

One of the goals of W7-X is to demonstrate steady state operation which is an inherent property of stellarators and essential for a future fusion power plant. Magnetic confinement in W7-X will be achieved by 50 non-planar and 20 planar coils with diameters of up to 5 m and masses of typically 6 t. To achieve steady state operation, all coils are superconducting. The main field of W7-X is produced by 5 groups of 10 non-planar coils each. In addition 2 groups of 10 planar coils each allow varying the magnetic configuration. The electrical parameters of all groups of coils are quite similar with inductance being typically 1.1 H res. 0.4 H. The big amount of energy (up to 900 MJ) stored in the coils requires a fast and reliable protection system. In case of a quench or the need for a rapid shut-down the current in the coils has to be commuted to external discharge resistors (nickel 99.6) and ramped down within 10 s. In the design phase simulations on the basis of informations from data sheets and literature

were carried out in order to determine the active nickel masses. The real nickel data (specific resistance, temperature coefficient, specific heat capacity) were determined for the material used in W7-X, and compared with the values of literature. The final simulation of the electrical circuit was repeated with the measured data. After production all discharge resistors were tested under real operating conditions. The presentation will describe the results of the tests.

THA03P007

LHC Experiments Magnets Control Project

G.G. Maire, G. Olesen, E. Sbrissa, CERN; J.Y. Rousse, CEA-Saclay.

The MCP (Magnet Control Project) is a unified set of systems designed to protect and control the four experiment magnets. It consists of three parts: MCS (Magnet Control System), MSS (Magnet Safety System) and MDS (Magnet Diagnostic System) or CDS (Constructor Diagnostic System). The MCS system provides the process controls needed to execute automatically the various running modes of the magnet system. The process control layers are handled by the Process Control Unit (PCU), which may be composed of several PLC's. All data are stored in redundant data servers, which are connected to the PCU's and contain the dynamic variable data-base. The LMS(Local Magnet Supervisor), which is a part of MCS, ensures local supervision at the engineering level via an operator workstation located in the control room. To ensure the safety of personnel and the magnets themselves a common, harmonised safety system, the MSS, has been developed at CERN. Vital parameters of the magnets are constantly monitored and in case of a developing problem the MSS will initiate the appropriate actions to bring the magnet to a safe state. Emphasis is put on total reliability and availability. The system is fully redundant and a high degree of isolation is used at all levels. Several overlapping measurement techniques are employed for complementary detection. The system is versatile and can be used to protect both warm and superconducting magnets..

THA03P008

Study on the magnetic and current control of superconductive opening switch

X. Wang, L. Guan, Y. Zhao, Y. Wang, Harbin Institute of Technology.

The superconductive opening switch is the key component in the inductive energy storage system and the inductive energy storage discharge pulsed power. In this paper the characteristics of superconductive opening switch are contrastingly explained which controlled by various kinds of methods including heater, magnetic, current and laser pulse control. The operation principle of magnetic control and current control are analyzed and it is carried out the experimental study on the application circuits of the two kinds of superconductive opening switches. It is deduced the design parameters of the control circuit and magnetic field for realizing the state change from quenching to recovering superconductivity, and the generating pulse experiments are accomplished in the same of inductive energy storage discharge pulsed power using the two kinds of switches. Though contrasted the pulse shapes and the repeat frequencies, it is indicated the current control method was superior to the magnetic control method at reducing opening time. The current control method will have a good development prospect in the application of the superconductive pulse power.

THA03PO09

Cryogenic Experimental Investigation on Power MOSFET and IGBT

M. Qiu, G.H. Hu, Y.L. Zhang, G.H. Yang, Z.Y. Feng, Z.P. Qi, L. Kong, Institute of Electrical Engineering, Chinese Academy of Sciences.

In the recent years, there has been an increasing interest in semiconductor device behavior at low temperatures. A experimental investigation was carried out for some commercial Power MOSFET and IGBT devices from 77 K to 300 K. The results show a significant improvement on static and dynamic qualities at low temperatures. The qualitative simulation was presented and validated by comparison with the experimental data. Possible applications in superconducting power system were discussed in the paper.

THA03PO10

The quench detection technique of the resistive superconducting fault current limiter component using the Acoustic Emission signal

K.Y. Yoon, T.K. Ko, Yonsei University; H.M. Kim, LSIS; O.B. Hyun, KEPRI; H. Lee, Y. Iwasa, MIT.

This paper presents the quench detection technique of the high temperature superconductor(HTS) for superconducting fault current limiter(SFCL). Resistive SFCL is used to change the resistance of the superconductor, which is the superconducting state to the normal state. That is called "quench state" of superconductor. According to increasing the magnitude of fault current generated on the power grid recently, the fault current limitation machines like as SFCL was start to enlarge needs of power solution. In the study of the fault current limiting system, it is happen to a need of monitoring for stability of SFCL system. AE signals are generate from the surface of HTS components as the impedance and temperature of them raise. In this paper, we introduce the application method of AE sensor for the protection of the resistive SFCL system.

THA03PO11

Application of Orthogonally Polarized Two-Frequency Laser to Magneto-Optic Polarimeter

S. Tsuji-lio, T. Miyazaki, K. Hayakama, H. Tsutsui, R. Shimada, Research Laboratory for Nuclear Reactors, Tokyo Institute of Technology; T. Akiyama, NIFS. Withdrawn.

THA03P012

Characteristics analysis of a high-Tc persistent current system considering the n-value

Y.S. Yoon, M. Joo, Ansan College of Technology; H.K. Kang, M.C. Ahn, D.K. Bae, S.E. Yang, D.K. Park, T.K. Ko, Yonsei University.

This paper deals with characteristics analysis of a High-Tc (HTC) persistent current system considering the n-value, also presents its operational characteristics through experiments. A HTC persistent current system mainly consists of persistent current switch, HTC magnet load, and magnet power supply. The HTC magnet load was fabricated by connecting four double pancake coils in series. In these experiment three cases of the charging current period, which correspond to 0.1 A/sec, 0.3 A/sec and 0.5 A/sec. In order to measure the persistent current with respect to the magnet flux changes, a hall sensor was installed at the center of the pancake load. In the experiments, the initial current dropped rapidly in the persistent current mode. In order to analyze current decay during persistent current mode, we introduced a new

electrical equivalent model considering the n-value. Experimental results of the HTC persistent current system have been compared with the theoretical results by using finite deference method (FDM). It has been concluded that the characteristics of initial current decay were mainly determined by the voltages generated in the pancake load due to n-value, joint resistance, and charging current period.

POSTER SESSION	13:30 - 15:30
QUENCH	

THA04P001

Dependence of recovery current of multifilamentary NbTi superconductors on matrix purity

P. Usak, Institute of Electrical Engineering, Slovak Academy of Sciences. Withdrawn.

THA04P002

Quench and Recovery Characteristics of HTS Tapes under Pulsed Over-Currents with Different Frequencies Y. Zhou, Q. Song, B. Wei, T. Yao, J. Shi, J. Li, Y. Tang, Huazhong University of Science and Technology.

Quench and recovery characteristics of Bi-2223/Ag HTS tapes under pulsed over-currents with different frequencies have been observed. The experiment is carried out using a pulsed circuit consisted of capacitance and inductance, which produces pulsed currents with different frequencies. The HTS tape is immersed in liquid nitrogen bath. The frequencies of pulsed currents are 178.6 Hz, 333.3 Hz, 434.8 Hz, 757.6 Hz and 2632 Hz respectively. In order to confirm the critical current of the tape, DC and AC (50Hz) currents are fed to the tape respectively firstly. The magnitude of the pulsed over-current is from a small current to 200 A, which is about 3 times of the DC critical current of the tape. The experimental result shows that the normal voltage generated by the over-current disappears faster after the end of the over-current with the increasing frequency of the pulsed current, which shows that HTS tapes have better superconducting-to-normalcondcuting recovery characteristics under pulsed currents with high frequency than DC current. These experimental results will encourage the possibility of the important applications of HTS tapes in pulsed power.

THA04PO03

A Two-Stage Quench Protection Based on the Combined Quench Detection Method for HTS Magnets *Z. Zhang X. Li, L. Xiao, Institute of Electrical Engineering, CAS.*

Withdrawn.

THA04PO04

Quench Dynamics in Rutherford-type Cables J.R. McDonald, SAIC; E. Barzi, FNAL.

Since Nb3Sn magnet technology will play a vital role in the LHC and future accelerators, stability issues related to strands, cables, and magnets are being thoroughly investigated at Fermilab and other labs and institutions. Previously a Fast Multipole Method was implemented to evaluate the inductive voltages in an electrical-network model for Rutherford-type cables, and the resulting algorithm used to study the effect of electrical discontinuities on the current distribution in an increasing self field. The fast algorithm has now been combined with thermal-analysis, which allows for the modeling of quench

dynamics, including the effects of current redistribution, discontinuities and inhomogeneity. Results are presented for the minimum quench energy of a 28-strand cable, and its dependence on various parameters is discussed.

THA04P005

Developed the normal zone on the superconducting magnet

H. Malinowski, Electrical Institute in Warsaw.

This paper reports an experimental investigation of the propagation of the normal zone in superconducting winding magnet. A special superconducting magnet, which was equipped in many different sensors for measurement parameters of magnet on the quench process, has been taken. Main consideration was taking into on development the normal region on this case, when the value of destruction energy is compare to the minimum quench energy. This research work was carried out for sing coil and two coupled coils for different supply current. The experimental result enables to describe very accurate propagation quench process – speciality in first moment of their appeared.

THA04P006

Influence of technology insulation of superconducting magnets on the quench process

H. Malinowski, Electrical Institute in Warsaw.

The consequence of a long pause in the exploitation of superconducting electromagnet is the loss of superconducting state in the coil of electromagnet For electromagnets cooling by cryocooler the situation is very stressed because a time consuming of cooling process is long (even few days). In this reason is very important limiting (decrease) of probability of quench magnet. In the presented work the technology of isolation of winding magnet, which cause to more effective dissipation of heat energy was demonstrated. The analysis of temperature distribution in first stage of quench process and influence of the new technology of isolation on develop of normal zone is demonstrated too. Presented technology permits to reduce number of quenches.

THA04P007

Numerical Simulation of Thermal Properties of a Cryocooler-Cooled Bi2223 Superconducting Pulsed Coil

H. Miyazaki, I. Tanaka, M. Iwakuma, K. Funaki, Reserch Institute of Superconductor Science and Systems, Kyushu University; H. Hayashi, Kyushu Electric Power Co., Inc.; A. Tomioka, Fuji Electric Advanced Technology Co., Ltd.

Since oxide superconducting coil can usually be operated at higher temperature than liquid helium one, the cooling efficiency and the reliability of the system should be much improved and the cost of cooling equipment can be reduced. Therefore, it may be advantageous to design cryocooler-cooled superconducting pulsed coil by using oxide superconducting wires as compared with the case of low-Tc ones. We fabricated a 1 T cryocooler-cooled oxide superconducting pulsed coil with Bi2223 multifilamentary flat wires in order to study the thermal stability of the cryocooler-cooled system. We have already measured the temperature dependence of thermal runaway current of the coil in DC or AC operation. We found that the thermal runaway of the coil does not break out when the total heat generation of the coil exceeded the cryocooler capacity but it is induced when the local heat generation due to the fluxflow loss becomes larger than the effective cooling due to thermal diffusion. In this study, we evaluated the heat generation due to flux-flow loss and AC loss in the winding

and measured the average thermal conductivity of the winding, and investigated the stability of the coil by simulating the thermal conduction inside the coil.

THA04P008

Analysis and design of the CMS magnet quench protection

P. Fazilleau, F. Kircher, CEA-Saclay; B. Curè, A. Hervè, G. Maire, D. Campi, C. Martins, CERN; C. Lesmond, ETH.

The CMS experiment (Compact Muon Solenoid) is a general-purpose detector designed to run at the highest luminosity at the CERN Large Hadron Collider (LHC). Its distinctive features include a 4 T superconducting magnet with 6 m diameter by 12.5 m long free bore, enclosed inside a 10000-ton return yoke. The magnetic field is achieved by a 4-laver superconducting solenoid made of a reinforced Rutherford type superconductor with a hybrid configuration and wound inside an external aluminum cylinder. The coil is indirectly cooled at an operating temperature of 4.5 K by a thermo-siphon, and it is designed to run at a nominal current of 19.5 kA. The corresponding maximum stored magnetic energy reaches 2.67 GJ with an E/M ratio of 12 kJ/kg. The quench protection is achieved by discharging the magnet on an external resistor in a fast mode, with a peak voltage in the coil kept at 600 V and a voltage to ground of +-300 V during the discharge. 50% of the stored magnetic energy is then dissipated by joule effects in the dump resistor. The coil design takes benefit of the guench back effect to limit the temperature gradients inside the winding pack in case of quench. The design and the characteristics of the quench protection system are described. Then, the computational results of the guench protection for several operating currents are presented. Finally, the behaviour of the magnet in case of faulty conditions on the protection system is analyzed.

THA04P009

Study on Thermal Stability of YBCO-coated Conductor

S. Tabe, T. Okamura, Tokyo Institute of Technology; K. Tasaki, T. Kuriyama, Toshiba Corporation.

A YBCO-coated conductor is expected to be a next generation superconducting wire with superior Jc characteristics in high temperatures and/or high magnetic fields. The theory of thermal stability of a YBCO-coated conductor, however, has not been specifically established yet. We focused on the thermal runaway phenomena of a YBCO-coated conductor. Thermal behaviors of the YBCOcoated conductor, which was conductively cooled by a cryocooler, investigated experimentally was and numerically. In experiments, the temperature distributions of the conductor in longitudinal direction were measured. In numerical calculations, we reviewed the characteristics of the thermal runaway condition of the YBCO-coated conductor.

THA04P010

Analysis and validation of a numerical model for superconducting magnets quench evolution.

V. Cavaliere, M. Cioffi, G. Masullo, CRIS Consorzio Ricerche Innovative per il Sud; A. Formisano, R. Martone, Dipart. Ingegneria dell'Informazione, Seconda Università di Napoli.

The superconducting (SC) magnets for Magnetic Resonance Imaging (MRI) are called for producing strong fields with high homogeneity and stability. The energy stored in the SC coils composing the magnet is then quite high; as a consequence, any possible quench could heavily damage the device, and suitable protection schemes must be considered as early as the design phase. Typical

protection schemes require the subdivision of the SC magnet in a number of sections, each shunted with suitably sized dumping resistors. The tuning of the protection circuit parameters is a quite difficult task due to the complex dynamics involved in the phenomenon. Therefore, a suitable simulation tool is required, able to check the robustness and the effectiveness of the protection system for different choices of the parameters. To this purpose, a possible FEM model of the magnet, taking into account magnetic, thermal and circuital equations, has recently been developed. The model is able to treat the evolution of both electrical and thermal quantities. In this paper, in order to validate the model, a 2T MRI magnet, built up in the Ansaldo-CRIS laboratories, is numerically analysed and its simulated quench behaviour is critically compared to experimental data.

THA04P011

An experimental study of quench characteristics in jointed HTS tape

S. Choi, School of Information and Communications Engineering, Sungkyunkwan University; W. Nah, Sungkyunkwan University; J.H. Kim, J. Joo, School of Advanced Materials Science Engineering, Sungkyunkwan University; M-H. Sohn, J-K. Kwon, KERI. Withdrawn.

THA04P012

ANSYS Quench Simulation of high field solenoid magent for FT-ICR

B-S. Lee, D-L. Kim, H-S. Yang, J-S. Yoo, Korea Basic Science Institute.

To investigate more approximated quench behavior of high field solenoid magnets for FT-ICR analysis program is composed with ANSYS macro code. The simulation program is considered winding effect, wire shape, epoxy impregnation and is used to estimate structural stress, thermal stress, effect of Lorentz force and effect due to quench. We can deal with complex problem, according as we use ANSYS and obtain more detailed quench behavior. But we need more quench study for practical design.

THA04P013

Numerical Simulation of Thermal Properties of Bi2223 Conduction-Cooled Pulse Coil for SMES

M. Iwakuma, H. Miyazaki, K. Tanaka, K. Funaki, Kyushu University; A. Tomioka, Fuji Electeric Systems Co., Ltd; H. Hayashi, Kyushu Electric Power Co., Inc.

We fabricated a 1T cryocooler-cooled pulse coil with a 4strand parallel conductor composed of Bi2223 silveralloysheathed superconducting multifilamentary wires. We succeeded to operate it continuously in a triangularwaveform mode at 1Hz. The operating temperature was around 40K. We investigated the ac loss and critical current characteristics and also the thermal properties of the pulse coil. We clarified that the thermal runaway current exceeded the critical current at every temperature and it decreased monotonically with increasing temperature independently of the operating frequency, i.e. the induced ac loss power. In addition, the thermal runaway was induced even though the cooling capacity of the cryocooler was larger than the total heat generation which was composed of ac loss and flux-flow loss. This result suggests that the thermal runaway of conduction-cooled superconducting coils is induced when the local heat generation by flux-flow loss, which increases non-linearly if the operating current becomes larger than the critical current at the local tempearature, exeeds the thermal diffusion rate inside the winding. So we estimated the

thermal conductivity of the winding and the constituent materials and numerically simulated the thermal properties of the coil to clarify the mechanism of thermal runaway quantitatively. On the basis of the obtained result, we discussed how to design the conduction-cooled superconducting magnets.

POSTER SESSION	13:30 - 15:30
AC LOSSES (II)	

THA05PO01

Theoretical estimation of electromagnetic loss at the movement of superconducting coil in the W7-X stellarator

F. Gömöry, S. Takacs, Institute of Electrical Engineering SAS Bratislava; A. Werner, M. Sochor, MPI für Plasmaphysik Greifswald.

Generation of heat due to the dissipation, occurring when a superconducting coil experiences a transient in the magnetic field generated by other coils, was investigated. Such mechanism could be relevant during energizing the main magnetic field in the W7-X machine, when the mutual forces between superconducting coils could lead to their deformations or movements. In these cases, the heat will be generated by different kinds of screening currents, induced in the complex structure of the cable. Significant paths for current loops have been identified, and the formulas allowing the estimation of dissipated heat derived. From the hierarchy of current loops in space and time, it was possible to break the process in several stages that could be treated individually. Thus, all the contributions to the heat generation (eddy current, coupling and hysteresis losses) could be included into the calculations. Finite element simulations have been used to determine the typical transient of magnetic field that could be expected inside the W7-X coil due to mechanical movement. It was found that one can foresee magnetic field changes of about 20 mT occurring during 40 milliseconds. Applying the formulas derived for transient loss for the case of such field change, the maximum dissipation connected with one such event was estimated to be less than 0.16 mJ/cm3, which is tolerable for the magnet design of W7-X.

THA05PO02

Electromagnetic field analysis of an YBCO coated conductor in multi-layer superconducting cables

S. Sato, N. Amemiya, Yokohama National University. AC loss reduction is one of the key issues for the applications of YBCO coated conductor to electrical power devices. Understanding AC loss characteristics of YBCO coated conductor is required for AC loss reduction, and numerical electromagnetic field analysis by finite element method (FEM) is a very useful tool for this purpose, electromagnetic because the phenomena inside superconductors resulting in AC loss generation can be visualized. In superconducting power cables, YBCO coated conductors are often assembled in multi-layers in order to increase their current carrying capacity. In this work, electromagnetic field analysis of YBCO coated conductors in multi-layer superconducting power cables with practical configuration was carried out. The electromagnetic fields in the YBCO coated conductors of superconducting cable carrying an AC transport current were calculated using a numerical model that employed FEM. The AC losses of multi-layer superconducting power cables were estimated from the temporal evolutions of the electromagnetic fields. The number of conductors in each layer and the gap between the conductors were varied to study their influence on the AC loss of the cables. The numerically calculated AC losses were compared with the analytical values. This work was supported by the New Energy and Industrial Technology Development Organization (NEDO) Collaborative Research and Development as of Superconductivity Fundamental Technologies for Applications.

THA05PO03

Measurement of the Cryogenic Loss in Superconducting Magnet System by using Calorimetric Method

H. Kang, S.W. Park, M.C. Ahn, S.E. Yang, T.K. Ko, Yonsei University; S.Y. Choi, Sungkyunkwan University; C.J. Lee, B-Y. Seok, Electro-Mechanical Research Institute, Hyundai Heavy Industries, Co., Ltd; T.J. Kim, Seongnam polytechnic college; Y.S. Yoon, Ansan College of Technology.

There are some ways to measure the AC loss of superconducting material such as magnetization, transport current and calorimetric method. Especially, the calorimetric method is very useful for measuring the AC Loss of large scale superconducting magnet. The cryogenic loss of superconducting magnet system measured by mass flow meter (MFM) includes not only AC loss of superconducting magnet but also background loss such as conduction loss through current leads and electrical wires and radiation loss through cryostat. The cryogenic loss contains AC loss and background loss is very important in effective operation of cryogenic superconducting magnet system. To design and manufacture the applied superconducting magnet system such as superconducting transformer and fault current limiter, this total cryogenic loss should be taken into consideration carefully. In this investigation, we fabricated pancake, solenoid and bifilar type the double superconducting magnet and measure the AC loss of them. The cryogenic loss was experimentally measured and separated into background loss and AC loss. The experimentally measured background loss and AC loss were compared with the calculated losses by using simple heat equation and finite element method (FEM), respectively. These calorimetric measurement method and calculation method could be very useful to design the applied superconducting magnet system with pertinent loss to operate the superconducting magnet system reliably for a long time.

THA05PO04

Characteristics of Magnetization Loss and Shield Effect in Multi-stacked Tapes According to Stacking Geometry

J-K. Lee, Woosuk University; M. Park, H. Lim, H. Lee, G. Cha, Soonchunhyang University; S. Lee, Korea Electrical Engineering and Science Research Institute.

AC loss is one of major topics in large AC power high temperature superconductor(HTS) applications such as power tranformer, transmission cable and fault current limiter because it is closely related with operation efficiency. Multi-stacked tapes conductor should be used to transport the large current in those power applications. A research of various arrangements of HTS tapes for multistacked tapes has been performed to increase a capacity of transport current in HTS power applications. In this paper, we studied magnetization loss and shield effect by a different several arrangements of HTS(BSCCO) tapes such as Face-to-Face type, regular matrix type(m×2) and irregular matrix type. As a result, we get the result that the magnetization loss of Face-to-Face arrangement was lower than those of the other matrix types under the conditions of the same stacking numbers. We think that the result was due to shield effect by demagnetization of adjacent HTS tapes which located face to face.

THA05P005

Analysis of AC Loss and Current Distribution Characteristics of Multi-Layer Tri-Axial HTS Cable for 3-Phase AC Power Transmission

S. Fukui, T. Noguchi, J. Ogawa, M. Yamaguchi, T. Sato, Niigata University; T. Takao, Sophia University; O. Tsukamoto, Yokohama National University.

Superconducting power transmission cable is one of the most promising applications of high temperature superconductors (HTS). For three phase transmission cable, the tri-axial HTS cables that the HTS conductors of each 3-phase are axially assembled have been proposed. This configuration of the 3-phase cables has the advantage of the increase in the current capacity and/or the reduction of the necessary amount of the HTS tape compared with the three single-phase cables. Generally in the multi-layer cable, because of the difference of the magnetic coupling between the inner and outer layers, the inter-layer current distribution becomes uneven. The uneven current distribution consequently increases the AC losses in the cables. Therefore, the equalization of the inter-layer current distribution and the reduction of the AC loss are the key technical issues for the development in the HTS transmission cables. In this study, we develop a numerical model to analyze the inter-layer current distribution and AC loss in the tri-axial 3-phase HTS cable. The relation between the cable structures, such as the twist pitch and the twist direction, and the AC transport characteristics of the tri-axial 3-phase cables with the 2-laver / phase and 4layer / phase arrangements are analytically studied. Based on the numerical model, the twist pitch combinations to achieve uniform current distribution of the 2-layer tri-axial cable are obtained and the AC loss characteristics are discussed.

THA05P006

Numerical Study on AC Loss Characteristics of HTS Coils with Various Cross Sections and Optimization of Coils Cross Section

S. Abe, T. Nishijyo, S. Fukui, J. Ogawa, M. Yamaguchi, T. Sato, Niigata University; M. Furuse, K. Araki, AIST; T. Takao, Sophia University.

With recent progress of fabricating technology for long length and high critical current high temperature superconducting (HTS) tapes, their application to the winding of AC electric power apparatuses such as fault current limiters, transformers and AC reactors. For the development of low AC loss HTS winding technology for AC power devices, it is important to clarify their AC loss properties. In our previous study, a method to calculate the AC loss in the HTS coil has been developed. In this study, the AC loss characteris¬tics of the HTS coils is numerically studied by using the model. The AC losses in the HTS coils with various cross sections are calculated and the relation between the AC loss characteristics and the coil cross section is evaluated. A possible design of coil cross section is studied in terms of the AC loss minimization.

THA05P007

Numerical Analysis of AC Losses characteristics of Cable Conductor Assembled by HTS Tapes in Polygonal Arrangement

S. Fukui, R. Kojima, J. Ogawa, M. Yamaguchi, T. Sato,

Niigata University; O. Tsukamoto, Yokohama National University.

Since the current capacity of a HTS tape is at most hundred ampares, the conductors for AC power apparatuses should be assembled by multiple HTS tapes to gain the necessary current capacity. When the cable conductor assembled by the HTS tapes is used in the AC apparatuses, the electromagnetic condition of the HTS tapes in the conductor is different from that of the single tape. Therefore, it is important to precisely understand the AC loss characteristics in the cable conductor assembled by multiple HTS tapes. In this study, we focus on cable conductors that are assembled by multiple HTS tapes in a polygonal arrangement on a cylindrical former. A numerical model to analyze the AC losses in the assembled conductor of multiple HTS tapes in the polygonal arrangement is developed. Based on the model, the influences of tape gap length, tape width, former radius and tape number on the AC loss characteristics are numerically studied.

THA05P008

Comparison of AC Losses of Multi-Stacked YBCO Coated Conductors and BSCCO Tapes

H. Lim, M. Park, K. Lee, G. Cha, Soonchunhyang University; J-K. Lee, Woosuk University.

Multi-stacked HTS tapes are needed to conduct large current in the power application. In this paper, magnetization losses of the multi-stacked YBCO coated conductor and the BSCCO tape have been measured and compared. Magnetization losses of single tape, 2-stacked and 4-stacked HTS tapes have been presented in this paper. Multi-stacked tapes have been fabricated using face-to-face type stacking method. Measurements of magnetization loss were performed under various angles of external magnetic field to consider the anisotropic characteristics of HTS tapes. Test results show that loss density per unit volume decreased for both YBCO coated conductors and BSCCO tapes when the stacking number of tapes is increased. As the external magnetic field decreased, the ratio of decrement has risen because the full penetration magnetic field(Bp) of the multi-stacked tape is larger than that of the single tape.

THA05PO09

Transport and Magnetization AC Losses on Y-123/CeO2/NiW Coated Conductors

L. Gianni, M. Bindi, F. Fontana, S. Ginocchio, E. Perini, S. Zannella, Edison SpA; L. Martini, CESI.

Modelling and design of superconducting power devices, based on second generation HTS tapes (e.g. fault current limiters), requires accurate evaluation and prediction of AC losses in in the range of temperatures achievable by liquid nitrogen (65 K - 77 K). Transport and magnetization AC loss measurements were performed on samples of Y-123/CeO2/NiW coated conductors, immersed in liquid nitrogen, as a function of current, field and temperature. The results were compared with classical analytical models for AC losses calculation, based on Norris and Bean formulae; the role of the magnetic substrate and metallic cap layer was also evaluated.

THA05PO10

AC loss of HTS coil reinforced by negative thermal expansion fiber material

M. Furuse, M. Umeda, AIST; T. Takao, Sophia University; A. Yamanaka, Toyobo Co.,Ltd.

High power density coils manufactured from HTS tape without any reinforcements have high mechanical loss due

to inelastic deformation, which dominate the total loss. Previously we derived a relation between stiffness of a pancake type HTS coil and its mechanical loss, and also experimentally confirmed total loss reduction of Bi2223 coils reinforced by stainless steel tape co-winding. In this presentation, we show AC loss measurement results for HTS coils reinforced by various fiber materials having negative thermal expansion coefficient, data are compared to SUS reinforcement case.

THA05P011

Influence of non-uniform current distribution on AC transport current loss in Bi-2223/Ag tapes

H. Hwangbo, S. Choi, W. Nah, School of Information and Communications Engineering, Sungkyunkwan University; J.H. Kim, J. Joo, School of Advanced Materials Science Engineering, Sungkyunkwan University; K-W. Ryu, Department of electrical engineering, Chonnam National University; S-J. Suh, Advanced Materials and Process Research Center for IT, Sungkyunkwan University; M-H. Sohn, J-K. Kwon, KERI.

In the power apparatuses of superconductivity such as HTS power cables, superconducting tapes are generally stacked and layered to carry large currents. The nonuniform current distribution at each tape or layer in multistructure conductor often causes the degradation of machine performance as well as significant effect on ac loss. This uneven current distribution in multi conductor is important factor for exact ac loss analysis. In this paper, we describe the influence of different current distribution on AC transport current loss in multi-structure HTS conductor. The HTS conductor composed of a number of Bi-2223/Ag tapes is fabricated and ac loss is measured in different ratio of current distribution. A numerical code is developed to investigate the transport loss taking account of actual magnetic field dependent E-J characteristics. The validity of the numerical and experimental results is discussed.

POSTER SESSION 13:30 - 15:30 ELECTRICAL AND MECHANICAL COMPUTATIONS

THA06PO01

Theoretical and Experimental Study on Loss in HTS Magnet

B. Zhang, Y. Yu, Q. Wang, Institute of Electrical Engineering, CAS.

characteristic of high-temperature The loss superconducting (HTS) magnet carrying DC transport current was theoretically and experimentally studied. A HTS magnet is designed with Bi2223 superconductors wound including 20 double-pancake coils. The index loss of the HTS magnet carrying DC transport current is analyzed using numerical simulation and experiment. The index losses of every double-pancake coil and turn are calculated. The trend of the index loss of the magnet with increasing current is studied. The index loss of a double pancake coil in the liquid nitrogen temperature is obtained by experiment. The measured data reasonably agree with the simulation results. The implemented nonlinear model of HTS tapes takes into account the B-dependence of the critical current density Jc and the power index n. The AC loss of the HTS magnet during rapid current excitation was calculated using the numerical method on the basis of the nonlinear model of HTS tapes.

THA06PO02

Study of stress, strain in super-conducting magnet by Fiber-Bragg Grating

Q. Wang, Z. Fan, Institute of Electrical Engineering, CAS. Stress and strain are one of the sophisticated problems in superconducting magnet system. Although some simulation can be done to predict its performance, great concerns are taken about the real action. In this paper the performances of the Fiber Bragg Grating are investigated in liquid nitrogen temperature and are applied to measure the strain in the superconducting magnet. The experiment result agrees well with simulation result.

THA06PO03

Multi-objective Optimization Approach Based on Improved Genetic Algorithm for Transverse Flux inductor

X. Yang, Y. Wang, F. Liu, Q. Yang, Hebei University of Technology.

Transverse flux induction heating (TFIH) has considerable advantages for continuous heating of metal strips. A uniform temperature distribution on the surface of work piece is essential for this heating process, and moreover, electrical efficiency of the inductor is expected to be the highest. But the two objectives are conflict with each other. An optimization procedure based on genetic algorithm is presented, which results in the population can evolve to the best trade-off of the two objectives by means of chromosome selection with different probabilities. The individual fitness is evaluated by computation of electromagnetic-thermal problems in a quick coupling method. To improve the convergence speed and local searching ability for genetic algorithm, subpopulation competition and data exchange with basic population method is proposed. Subpopulation is constructed close to best individual of basic population and limited in a subspace, where the searching speed is highly increased because of the greatly reduced searching space and competition population size. Through between subpopulations, the resulted quality individual is introduced into basic population, which leads to the searching speed in the whole space greatly increased. After optimization the inductor is improved, i.e., the temperature distribution becomes more uniform and the electrical efficiency becomes higher. The results show that the proposed optimization procedure is suitable for design of inductor.

THA06PO04

Study on weight functions of Element-Free Galerkin Method in electromagnetic field calculations

S. Liu, Q. Yang, Hebei University of Technology.

The weight function plays an important role in the performance of the Element-Free Galerkin Method (EFGM). It can impose a tremendous influence on the accuracy of solutions, the complexity of computation and the rate of convergence. The smoothness of weight function governs the smoothness of shape function. Therefore, it becomes particularly urgent to select an appropriate weight function suited to electromagnetic field calculations.

THA06PO05

Solving Boundary Value Problem for Static Electromagnetic Field by Support Vector Regression

W. Yan, X. Shen, K. Fu, H. Chen, Hebei University of Technology; H. Yan, Zhejiang University.

Being high generalization performance, support vector regression (SVR) is an effective machine learning method. The approach based on the synergy of the support

vector regression(SVR) and radial basis function (RBF) network is proposed of dealing with the boundary value problem (BVP) of 2D static electromagenetic field, thereinto SVR as the basic approximation element within the domain of BVP and the RBF network used to satisfy the boundary conditions. More specifically, the SVR problem is for solving the dual problem contained a large size discrete working sets, as the traditional quadratic programming algorithms are not suitable for large size problem, and that sequential minimal optimization algorithm is proposed to put the work to the extreme by iteratively selecting working sets of size two and optimizing the target function . The SVR-RBF synergy method has been tested on the 2D BVP of leakage electromagnetic field for transformer. As the result ,there are 24 support vectors, the distribution of the magnetic vector potential and comparison of quantity of magnetic vector potential between finite element method and the SVR-RBF synergy method are shown in two figures. The proposed method based on the machine learning algorithm is different from the traditional numerical computation methods such as finite element and finite difference method, which will be useful to solve high dimensional BVP of electromagnetic field with irregular boundary.

THA06PO06

Thermal and bending strain analysis of Nb3Sn based strands

D. Boso, B. A. Schrefler, Department of Structural and Transportation Engineering, University of Padova; M. Lefik, Technical University of Lódz.

Recent experimental results on ITER Central Solenoid Model Coil and Insert Coil have shown that the critical characteristics measured on a single strand are significantly different from those of a cabled conductor. This cable degradation seems to be due mostly to the bending effects on the strands subjected to the electromagnetic forces: a strand inside the cable behaves like a beam supported by the neighbouring strands and loaded by the transversal Lorentz force. Recently some experimental tests are being performed to study this effect. Here we analyse the strand strain field resulting from the cool down and the successive bending loads. Due to material non linearity it is not possible to calculate the two effects separately. To analyse the strain field of a strand experiencing an electromagnetic load at 4.2K it is hence necessary to follow the evolution of the deformation from the strand reaction temperature to its working conditions. For the analysis of a single multifilamentary strand we propose a method which makes use of equivalent material characteristics obtained with homogenisation methods. To recover the strain inside each single component, i.e. in the bronze and Nb3Sn filaments, a suitable unsmearing technique is then applied. The results are compared to the outcomes of the experimental tests above mentioned. The procedure has a general character and can also be applied to upper cable stages.

THA06P007

A New Approach to Calculate the Torque Transmitted by Permanent Magnetic Coupling

F. Liu, Q. Yang, X. Yang, W. Yan, Hebei University of Technology.

Based on the principle of virtual work, a new approach to calculate the torque transmitted by a permanent coaxial synchronous coupling is presented. The three-dimensional magnetic scalar potential finite element method is used to calculate the permanent magnetic field distribution. After the magnetic flux density in every element is determined, the stored energy of the permanent magnetic field can be obtained as the integral of the coenergy density over the entire system. With the virtual work technique, by giving a virtual angular displacement, the torque can be obtained by calculating the variety of the energy of the permanent magnetic field in the two positions of the permanent magnetic couples. The method is applied to calculate the torque transmitted in a four poles magnetic coupling. The results are in very good agreement with measured data.

THA06P008

A New Dynamic Performance Analysis Model of Coupled Field-Circuit-Movement by Incorporating Finite Element Method into Bond Graph

Y. Yao, Y. Fang, The College of Electrical Engineering, Zhejiang University.

In EMS-Maglev system, the propulsion is defined by a Long stator linear synchronous motor (LSM) which armature is fixed all along the track and the moving poles with the excitation are on the vehicle. The attractive force between the motor stator and the moving poles creates the levitation forces. The LSM windings are energized by three-phase alternating voltage over a power supply section. And linear generator supplies the on-board electric power. Obviously the excitation current has to satisfy an accurate levitation force and a high power factor. However, the dynamic performance of this complex system is hardly obtained by analytical method. With ordinarily transient finite element method, it is also difficult to consider the external power supply of LSM and the working status of linear generator. In this paper, a new model for the performance analysis of magnetically levitated vehicles of electromagnetic type is proposed. It uses power bond graph combined with finite element analysis to construct the nonlinear state equations. The method to express the FE equations in the forms of Bond Graph is discussed. The dynamic characteristic is simulated with the help of Rung-Kuta method. The algorithm is easier to incorporate field computation and external power system into vehicle's movement equations. Using this method, the factors affecting levitation and propulsion forces can be easily investigated. It is shown that the algorithm is time saving and gives reasonable results.

THA06P009

Force Separation Scheme of Each Part in AC Machines J-H. Lee, Duke University; H-S. Choi, I-H. Park, Sungkyunkwan University.

The analysis of accurate and consistent force component of electromagnetic devices is an essential part of the design of many electromagnetic devices. The force component can be used for the prevention of mechanical fractures in some sections, the evaluation of mechanical bonding strength between different parts, and the basis for reinforcing design change. However, most of studies have focused on the total force or force density on the whole body surrounded by air. In other words, there has been no method for calculating individual force component of machine parts. We proposed a force separation scheme of each part in AC machines. It is based on the general formulation of the equivalent magnetic charge method for magnetic materials and the Lorentz force density for conductor transport current. The proposed scheme can consider the total forces of each part in contact with different or same materials. To show the validity of the proposed scheme, we applied it to two induction motors which are a canned conductor and a squirrel bar conductor rotor types. We calculated torque components of stator core, windings, rotor core and conductor bars. The stator

torque which is the summation of torque components of stator core and windings and rotor torque which is the summation of torque components of rotor core and conductor bars are compared. The stator torque and the rotor torque are also compared to the total forces which are calculated by conventional total force methods.

THA06PO10

Development of a Current Fit Function for NbTi to be Used for Calculation of Persistent Current Induced Field Errors in the LHC Main Dipoles

N. Schwerg, C. Vollinger, CERN.

A new fit function for the critical current density of superconducting NbTi cables for the LHC main magnets is presented. Existing fit functions usually show a good matching of the very low field range, but produce a current density which is significantly too small for the intermediate and high field range. Consequently the variation of the values of multipoles measured at cold is only partially reproduced and loops from current cycling do not match. The presented function is used as input for the field quality calculation of a complete magnet cross-section including arbitrary current cycling and all hysteresis effects. This way allows tracing a so-called finger-print of the cable combination used in the LHC main bending magnets. The finger-print pattern is a consequence of the differences of the measured superconductor magnetization of cables from different manufacturers. The simulation results have been compared with measurements at cold obtained from LHC main dipoles and a very good agreement for low and intermediate field values could be observed.

THA06PO11

Force Calculation of Magnetized Bodies in Contact using Kelvin's Formula and Virtual Air-gap

H-S. Choi, I-H. Park, Sungkyunkwan University; S-H. Lee, MIT.

Conventional methods such as Maxwell stress tensor, virtual work, equivalent magnetizing current, and equivalent magnetic charge are widely used for total force calculation. But, their limitation is that they can only be used for the bodies surrounded by air or vacuum. In order to use these methods for the body which is inserted into or contacting with some other bodies, it is necessary that a thin air-gap should be inserted between materials, or that H and B should be estimated imprecisely for the force calculation. These approaches intrinsically have numerical errors. To overcome this difficulty in force calculation of materials in contact, this paper proposes a newly approached Kelvin's formula based on virtual air-gap. The virtual air-gap was derived from the generalized magnetic charge method that is a prior work done by the authors. The concept of total field and the continuum approach is adopted for the application of Kelvin's formula. Numerical tests show that this new approach gives valid result for the interaction and contacting forces between two diamond-shaped ferromagnetic bodies, and an axi-symmetric actuator having a moving core. They are also compared with the ones of other three methods of Maxwell stress tensor, virtual work, and equivalent magnetic charge.

THA06P012

Hysteresis Compensation Algorithm in Variable Load System of Magnetostrictive Actuators

Y. Sun, B. Wang, W. Huang, L. Weng, S. Cao, Q. Xing, Hebei University of Technology.

In the design of smart actuators employing active materials like Terfenol-D, hysteresis is particularly significant and

cause undesired effects in the control system and they show either dynamic and memory effects mixed together. Therefore, no matter what model of the actuator is employed, the availability of efficient procedures for hysteresis and non-linearity compensation are required. In any of applications, actuators should drive a mechanical load. Then there is a variable force exerted on the mechanical load. When the system is working, there are dynamics influences between the actuator and the mechanical load each other. These increase the difficulty and trouble in the control system. Therefore, this paper proposes fast dynamic compensation algorithm in the variable load system. The compensation procedure should reduce computational costs but not reduce accuracy. Through tracking the errors for a sine wave reference signal, the procedure should show a good performance.

POSTER SESSION 13:30 - 15:30 FAIR ACCELERATOR MAGNETS

THA07PO01

Optimization of Dipole with Partial Keystone Cable for the SIS300

L. Tkachenko, I. Bogdanov S. Kozub, P. Shcherbakov, V. Zubko, IHEP; C. Muehle, G. Moritz, GSI; S. Russenschuck, D. Tommasini, CERN.

The last stage of the GSI Fast-Pulsed Synchrotron Project is the SIS300 ring, which will use su-perconducting dipoles with 100-mm aperture, 6-T magnetic field amplitude and 1-T/s field ramp rate. Stringent requirements on physical parameters and on the dependable service of the dipole necessitated using a cable with increased current carrying capability and low dynamic losses. A suitable geometry of the superconducting cable was found in that used for the outer layer of the LHC superconducting main dipole and supplemented by a stainless steel core for the reduction of the transverse contact resistance between the strands. The shape of the partially keystoned ca-ble demands numerical methods for the optimization of the geometry in adaptation to the wide-aperture dipole. The main characteristics of the optimized 2D and 3D geometry of the dipole are presented. Two sorts of iron yoke steel grade were analyzed in view of the field quality. Thermal analysis of the dipole was carried out.

THA07PO02

Tests of Straight and Bent Superconducting Dipoles

S.S. Kozub, I. Bogdanov, V. Pokrovsky, P. Shcherbakov, L. Shirshov, V. Sytnik, L. Tkachenko, V. Zubko, Institute for High Energy Physics, Protvino; J. Kaugerts, G. Moritz, GSI. An important part of the FAIR (Facility for Antiproton and Ion Research), being developed in GSI, Darmstadt, Germany, is the fast-ramping heavy ion synchrotron SIS 300. The main elements of the SIS300 magnetic system are 6 T, 2.6 m long superconducting dipoles with a 50 m curvature radius. The superconducting dipole. manufactured for the UNK project, was chosen for study of the influence of bending effects on magnet characteristics. The straight collared coil was tested, then bent with a 50 m curvature radius, and then retested. Main measured and calculated characteristics of the coil for both tests are presented. Test results showed similar characteristics, both in training and in ramp rate dependence, as well as in field quality of the straight and bent coils. There is a good agreement between measured and calculated results of the completed study.

THA07PO03

Status of the Super-Conducting Magnet Design for the HESR at FAIR

R. Eichhorn, S. Martin, D. Prasuhn, F. Esser, A. Gussen, FZ Juelich.

The Forschungszentrum Juelich has taken the leadership of a consortium being responsible for the design of the HESR going to be part of the FAIR project at GSI. The HESR is a 50 Tm storage ring for antiprotons using superconducting magnet technology. On basis of the RHIC Dipole D0 (3.6 T), the magnet design for the HESR has started recently. The principle layout of all magnets, showing the coil arrangement and the expected field quality, calculated with ROXIE will be reported. One key issue will be a very compact layout because of the rather short magnets (being 1.82 m for the dipoles and 0.5 m for the other magnets). Additionally, the need and possible solutions for a bent dipole magnet with a radius of curvature of 13.2 m will be discussed.

THA07PO04

Design of a superferric quadrupole magnet with a high field gradient

C. Muehle, G. Moritz, GSI; A. Kalimov, St.Petersburg Polytechnic University, Russia.

A new international accelerator complex is now being developed now by GSI (Darmstadt, Germany). The synchrotron SIS100, which is a part of this complex, will be equipped exclusively with fast-cycling superferric magnets. The magnet system of this accelerator includes 180 identical quadrupoles with a maximum gradient of 33.4 T/m in an elliptical aperture of 120 mm * 65 mm. One of the most important requirements of the quadrupole design is a field gradient uniformity better than ±0.06% for the flux density variation range of 0.2 T - 2 T. This goal is achieved by introducing slots in the central part of the magnet poles, which create the effect of artificial saturation. These slots also help to reduce eddy currents in the yoke, induced during the current ramp in the magnet coil. This is very important because the whole magnet will be operated at liquid helium temperature and therefore power losses in the yoke should be reduced as much as possible. To provide the necessary integral field quality, the shape of the quadrupole pole ends was also optimized.

THA07PO05

A test facility for fast-ramped superconducting magnets for FAIR

G. Walter, C. Schroeder, G. Hess, F. Klos, S. Berlinghof, P. Schnizer, M. Kauschke, G. Moritz, GSI.

For testing fast-ramped superconducting magnets for the FAIR project (Facility for Antiprotons and Ion Research) a test facility is set up at GSI to test model and prototype superconducting magnets for the different planned machines (SIS100, SIS300, SFRS and the storage rings). The following magnet tests are planned: measurements of losses, quenches and training, magnetic measurements, temperature distributions in the magnet, and long-term stability tests. The facility accommodates forced-flow cooled model dipoles (Nuclotron-, RHIC-, and UNK-type) with a max. length of 1.4 m, prototype magnets (dipoles, quadrupoles, corrector magnets) with a maximum length of 2.6 m, and bath-cooled magnets for the planned CR, SFRS, and NESR/RESR. The facility will consist of the following components: refrigerator (400 W at 4 K); a distribution box for the different cooling schemes

(supercritical for the RHIC-/UNK-type magnets and twophase helium for the Nuclotron-type window-frame magnet); 2 feedcans providing electrical and cryogenic supply for the magnets; an all-purpose horizontal magnet cryostat which can be used for all kinds of different magnets; an AC Power supply including the quench protection system; a quench detection system adapted from the LHC-series test facilities. We will present the technical layout of the facility, the planned testing programme and also first testing results from a Nuclotrontype model magnet.

THA07PO06

3D Transient Process Calculations For Fast Cycling Superferric Accelerator Magnets

E. Fischer, G. Moritz, GSI; R. Kurnyshov, "Elctrozavod", Moscow, Russia; P. Shcherbakov, IHEP, Protvino, Russia. Fast cycling superferric magnets are planned to use in the new International Accelerator Facility (FAIR) at GSI, Darmstadt. The efficiency of this magnets is basically defined by the AC loss at helium temperatures in the construction elements of the dipoles and quadrupoles (iron yoke, coil, beam pipe restrain, suspension). A detailed knowledge of the 3D magnetic field, the eddy current distributions and their transient behaviour is necessary to minimize the hysteresis and the eddy current losses with help of an appropriate design. Methodical problems are considered for finite element calculations (ANSYS) of eddy currents in a laminated iron yoke. The results for a windowframe dipole of the Nuclotron-type are given. We present the influence of nonlinear and anisotropic magnetic and electrical properties of laminated steel and of bulk restrain elements. The effect of eddy currents on dynamical magnetic field nonlinearities is also discussed.

THA07PO07

Cable Design for SIS 300

M.N. Wilson, Consultant; A. Ghosh, BNL; J. Kaugerts, G. Moritz, GSI; I. Bogdanov, P. Shcherbakov, L. Shirshov, L. Tkachenko, IHEP, Protvino; A. Den Ouden, University of Twente.

Withdrawn.

THA07P008

New Design for the SIS100/300 Magnet Cooling

H.G. Khodzhibagiyan, A. Kovalenko, Joint Institute for Nuclear Research; E. Fischer, GSI.

Two superconducting synchrotrons SIS100 and SIS300 are planned for the new International Accelerator Facility of Antiprotons and Heavy Ions (FAIR) at GSI, Darmstad. The both accelerator rings, operating at liquid helium temperature, are placed in one tunnel of 1100 m length. The SIS100 structural superferric dipoles and guadrupoles are based on the Nuclotron-type hollow NbTi composite multi wire cable and cooled in parallel with two-phase helium flows. The peak operating mode for the SIS100 dipoles is correspond to Bm = 2 T, dB/dt = 4 T/s, and f = 0.58 Hz. Fast-ramped 6 T dipoles (dB/dt = 1T/s, f = 0.05 Hz) are required for the SIS300 ring. Supercritical helium is used as coolant in the existing concept of the SIS300. We propose two-phase helium cooling also in the SIS300 case. The necessary modifications of the magnet cooling scheme are presented and discussed. General optimization of the SIS100/300 cryogenic system, including helium transfer lines and refrigerator loads for different operating regimes, is considered also. The new design will make it possible to reduce the FAIR project cost.

THA07PO09

Progress in the Design of a Superconducting Synchrotron Dipole Magnet with a Pulse Repetition Rate up to 20 Hz

A.D. Kovalenko, N. Agapov, V. Bartenev, H. Khodzhibagiyan, G. Kuznetsov, P. Nikitaev, A. Smirnov, Joint Institute for Nuclear Research.

The works on the design of a superconducting synchrotron magnets with a pulse repetition rate up to 20 Hz are continued at the JINR Laboratory of High Energies. A cold iron (T = 4.5 K) window-frame Nuclotron dipole with a single-layer coil made from the new high current hollow NbTi composite cable was constructed. The magnet was tested at the pulse repetition rates from 3 to 5 Hz. Operating current and the current ramp, limited by the power supply voltage, have reached the level of 6 kA and 37.5 kA/s respectively. Maximum magnetic field in the gap did not exceed of 1 T at that tests. Upgrade of the power supply was performed and the new current leads, aimed at operating current up to 15 kA, were manufactured and installed at the test facility as well. Modification of the magnet from the 4K yoke option to the 50 K one will be made also. The new tests are planned in July-August. Possibilities of the using MgB2 superconductor are discussed.

THA07PO10

A Detailed Mechanical and Thermal Evaluation of the Hollow Cable Conductor for the Fast Cyclic SIS 100 Synchrotron

E. Bobrov, FBML, MIT; E. Fischer, J. Kaugerts, G. Moritz, GSI.

Several conductor designs have been considered as alternatives for the fast cycling superferric magnets to be used in construction of the SIS 100 synchrotron for the new International Accelerator Facility (FAIR) at GSI, Darmstadt. The original Nuclotron conductor designed at JINR, Dubna, still remains however the conductor of choice for the SIS 100 accelerator. The paper presents a detailed and comprehensive evaluation of the hollow cable conductor cooled with two-phase helium. The evaluation includes both mechanical and thermal aspects of conductor performance and its transient stability. Special attention is given to mechanical/thermal contact zones between individual components of the cable and the coolantcarrying conduit. The latter requires a solution of non-trivial problems associated with "point" contacts of round and oblong bodies. Certain modifications are proposed.

THA07P011

Radiation Resistant Quadrupole Magnet behind the High-Power Production Target of the Super-FRS at FAIR

M. Winkler, K.H. Behr, H. Geissel, H. Iwase, G. Moritz, C. Mühle, H. Weick, GSI; M. Svedentsov, Inst. for Analytical Instr., St. Petersburg, Russia.

The planned new international accelerator facility FAIR at GSI will provide primary beams of all projectiles up to uranium with energies up to 1.5 GeV/u for nuclear structure physics. The maximum intensities of these projectile beams will be (1-3) 10^12 /s, leading to a maximum beam power of approximately 60 kW. 10-20% of the primary beam will react in a high-power production target at the entrance of the Super-FRS. The Super-FRS is a large-acceptance two-stage fragment separator which will provide spatially separated isotopic beams. The non-reacting primary beam will be dumped at dedicated beam catchers, located at well defined places in the first part of the Super-FRS. The target area as well as the beam dump

area is in high fluxes of high-energy particles, mainly neutrons and protons. Since magnetic elements located in these areas have to be reliably operated for the lifetime of the facility (~20 years) their design has to be radiation resistant. In this paper we present specification, radiation issues, and a first magnetic design of the first quadrupole magnet placed 1 m downstream of the production target.

POSTER SESSION	13:30 - 15:30
ATLAS DETECTOR	

THA08PO01

Suspension system of the Barrel Toroid cold mass

C. Mayri, P. Vedrine, C. Berriaud, M. Reytier, Y. Pabot, S. Cazaux, CEA Saclay; A. Foussat, A. Dudarev, Y. Zaitsev, H. ten Kate, CERN.

The ATLAS Barrel detector is constituted by 8 coils symmetrically placed around the LHC beam axis. The coil dimensions are 25-m of length, 5-m of width and 1-m of thickness. Each coil cold mass is maintained in its cryostat by three types of supports. The first ones are the tie rods which take the magnetic forces of 1500 tons and accommodate the thermal shrinkage of 45-mm at each extremity during the cool down phase. The second ones are the cryogenic stops which support the cold mass weight of 45 tons. They have also to take in account the thermal shrinkage. The last ones are the fixed points which locate longitudinally the cold mass inside the vacuum vessel. The solution used for each item is relatively different. The tie rods are made in titanium alloy and take the thermal shrinkage by flexion. The cryogenic stops are made in epoxy resin-glass fibre composite and take the displacement of the cold mass by a dedicated sliding system. The fixed points are done in a G11 bar. Each of these systems was designed to support the mechanical solicitations and to minimize the thermal loads. Some elements were tested individually on test bench and the final pieces in real conditions during the coil test. The paper will describe the design, the tests and the behaviour of each element in the real conditions of the Barrel Toroid coil cold tests.

THA08P002

ATLAS Barrel Toroid Warm Structure design and manufacturing

Z. Sun, B. Levesy, M. Massinger, C. Mayri, Y. Pabot, P. Vedrine, CEA Saclay; I. Zaitsev, A. Dudarev, H. Ten Kate, CERN.

The ATLAS barrel toroid magnet is a large air-core toroid that provides magnetic field needed for the ATLAS muon spectrometer. The barrel toroid structure, named warm structure, holds the eight superconducting coils evenly positioned around the beam axis with an outer diameter of 20 m. The warm structure supports not only the coils but also muon detectors, services and access for the ATLAS experiment. The warm structure withstands about 1400 tons of weight and strong magnetic forces. Physics performance of the muon detectors, and the fact that many design aspects of the toroid and of other related subsystems of the ATLAS experiment are intertwined, impose stringent requirements on the warm structure design. The design has been achieved along with extensive finite element analyses. Manufacturing feasibilities and facilities have been also considered in the design. The main components of the warm structure including 64 Voussoirs, 64 Connection Boxes, 64 Struts and 16 Wedges are in large dimensions that are made of aluminum alloy. The

Russian company RusAl was qualified for the warm structure manufacturing. Most of the components production processes have been implemented at Samara Metallurgical Plant - fabricating facility. This paper gives an overview on the design and manufacturing of the ATLAS Barrel Toroid Warm Structure.

THA08PO03

Quench Characteristics of the ATLAS Central Solenoid

R. Ruber, G. Olesen, H. ten Kate, CERN; Y. Makida, M. Kawai, A. Yamamoto, KEK; S. Mizumaki, Toshiba Co.

A thin superconducting solenoid magnet has been constructed for ATLAS, one of the four LHC experiments at CERN. The single layer coil wound with an AI stabilized NbTi superconductor, with overall dimensions of 5.3 m length and 2.6 m diameter and operating at 7.6 kA provides the 2 T magnetic field for the inner detector. The coil was successfully tested at the company before shipment and re-tested at CERN on surface in its final configuration before commencing the installation in the ATLAS cavern 100m underground. The tests include an extensive study of the quench evolution and in particular the normal zone propagation through the coil windings and in the superconducting bus-lines. A special feature of this coil is the use of AI quench propagation strips glued to the inner surface. The solenoid is equipped with voltage taps, temperature sensors, superconducting quench detectors and pick-up coils. A test current of up to 8.4 kA was applied and the coil went through almost thirty quench cycles including four training quenches. The normal zone propagation speed varies between 2.4 m/s in the bus-lines to 16 m/s in the coil windings. With a stored energy of 38 MJ and 5.4 tons cold mass the maximum temperature in the windings went up to about 110 K. In the paper the quench characteristics including normal zone propagation, temperature rise and distribution, internal voltage as well as and comparison to theory are presented.

THA08PO04

ATLAS End Cap Toroid Cold Mass and Cryostat Integration

E.D. Baynham, E. Towndrow, S. Carr, E. Holtom, CCLRC Rutherford Appleton Laboratory; J. Buskop, NIKHEF; A. Dudarev, R. Ruber, H. ten Kate, CERN.

The ATLAS experiment at LHC, CERN will utilise a large, superconducting, air-cored toroid magnet system with a long Barrel Toroid and two End Cap Toroids. Each End Cap Toroid will contain eight racetrack coils mounted as a single cold mass in a cryostat vessel of approximately 10m diameter. This paper presents the design principles and realisation of the cold mass assembly. The procedures for integration of the full cold mass, 120 tonnes, into the vacuum cryostat are described. The overall status of toroid magnet integration and planning for test and installation is reviewed.

THA08P005

Experience report of the manufacture of the 25 m long superconducting coils for the ATLAS Barrel Toroidal Magnet.

G. Drago, P. Gagliardi, A. Laurenti, R. Penco, Ansaldo Superconduttori; L. Rossi, CERN& University of Milan; E. Acerbi, M. Sorbi, INFN-Sezione di Milano & University of Milan; A. Leone, G. Volpini, INFN-Sezione di Milano.

The magnet system of the ATLAS detector, which presently is being installed in the LHC accelerator at CERN, is composed by four components: the inner Solenoid, two End Cap Toroids and the Barrel Toroid (BT). The Barrel Toroid has a length of 25 m and an external

diameter of 20 m; it is composed by 8 separated superconducting coils, race-track shaped, 25 m long and 5 m large. At the present time all the 8 coils have been completed and independently tested on surface under nominal conditions, and the final assembly of the toroid in the ATLAS cavern is in progress. The construction of such huge coils has required a great effort in order to match the design dimensional tolerances and to obtain a good impregnation quality. In this report we summarize the results obtained in the BT coils, and the tests performed to assess the quality of the impregnation and the electrical insulation. These data can be now considered as the "status of the art" for large size superconducting coils.

THA08P006

Data Acquisition System for Large Superconducting Magnets.

F. Broggi, A. Paccalini, INFN-LASA; G. Rivoltella, University of Milan and INFN.

Data acquisition systems play an important role in any scientific apparatus, especially if superconducting. While small magnets can be tested and operated in small laboratory, large magnets need to operate in large and industrial environment with many noise source (power supplies and lines, cryogenic plants, cranes, etc.). In addition the dimension itself of the magnet can increase the noise problems, because of the inductive coupling with the coil. In this paper the LASA data acquisition system for the ATLAS Barrel Toroid test station is described. The problems encountered during the design and final realization of the system are discussed. In particular the LASA laboratory, after the tests on two isolation cards developed at CERN for LHC, has designed a new card for better answer to BT acquisition requirements. The h/w and s/w solutions to reduce common mode voltage, ground loops, electromagnetic noise and to protect the electronics from quench overvoltages are presented. Validation of the system design is provided by the tests performed on the magnet models (B00 and B0) and on the final Barrel Toroids

THA08PO07

Experimental and theoretical investigation of the ramp losses in the conductor and coil casing of the ATLAS Barrel Toroid Coils

J-J. Rubbers, A. Dudarev, R. Pengo, H.H.J. ten Kate, CERN; C. Berriaud, CEA-Saclay.

Each of the eight huge coils of the Barrel Toroid of the ATLAS detector consist of two double pancakes which are embedded in an aluminium coil casing. The 12 mm x 57 mm sized conductor is a Rutherford cable with NbTi/Cu strands co-extruded with a high purity aluminium stabiliser. The very large race track coils with overall dimensions of 25 m x 5 m, have a mass of 42 ton and the length of the conductor in the windings is 6.7 km per coil. The coils are conduction cooled using forced flow helium flowing in cooling tubes attached to the cold mass. The nominal operating current is 20.5 kA, the nominal ramp rate is 4 A/s. The peak field on the conductor in the windings is almost 4 T. During the test program of the individual coils the ramp losses are measured to confirm that they do not exceed the design cooling capacity of the ATLAS cryogenic system. The losses are determined form the amount of evaporated helium in the return flow. The ramp losses in the conductor consist of the hysteresis and coupling current losses in the Rutherford cable and eddy current loss in the pure aluminium stabiliser. Ohmic losses are also generated in the aluminium alloy coil casing which acts as a low resistive secondary turn of a transformer formed by

the coil and the casing. In this paper the results of the loss measurements on the different coils, with different RRR, are presented. Measurements are performed at various ramp rates. The results are in good agreement with the calculated losses.

THA08P008

Cold mass integration of the ATLAS Barrel Toroid Magnets at CERN

J-M. Rey, M. Arnaud, C. Berriaud, S. Cazaux, M. Humeau, R. Leboeuf, C. Mayri, P. Vedrine, CEA-DSM-DAPNIA-SACM; A. Dudarev, H. Ten Kate, CERN.

The ATLAS Barrel detector is constituted by 8 coils symmetrically placed around the LHC beam axis. The coil dimensions are 25-m of length, 5-m of width and 0.4-m of thickness. Each coil cold mass consist of 2 double pancakes of aluminium stabilized NbTi conductor held in an aluminium alloy casing. The magnet being conduction cooled a good bonding between the superconducting winding and the coil casing is a strong requirement. Due to the high load level induced by the Lorentz forces on the double pancakes a prestressing technique has been developed for the assembling of the double pancake windings in the coil casing. This prestressing technique uses inflatable bladders made of extruded aluminium tubes filled with glass microballs and epoxy resin and cured under pressure. The paper will describe the design of the system as well as the problems occurred during the assembling of the 8 superconducting ATLAS coils and the ATLAS B0 prototype coil, and the behaviour of the Barrel Toroid coil with respect to this prestress during the cold tests.

THA08P009

On-Surface Test of the ATLAS Barrel Toroid Coils: Acceptance Criteria and Results

C. Berriaud, CEA; A. Dudarev, J.J. Rabbers, S. Junker, R. Pengo, E. Adli, S. Ravat, L. Deront, E. Sbrissa, G. Olesen, CERN.

Each superconducting coil of the ATLAS Barrel Toroid has to pass a commissioning test on surface before the installation in the underground cavern of the ATLAS experiment at CERN. Particular acceptance criteria have been developed to characterise the individual coils during the on-surface testing. Based on these criteria and a limited time for the tests, a compressed test program was proposed and realised. In only a few cases additional tests were required to justify the coil performance. In this paper a detailed analysis of the test results is presented and discussed on the basis of the acceptance criteria. Some differences in the parameters are found between the identical coils. They are analysed with the link to coil production features. The main results are also compared to the results obtained for the B0 prototype coil, which has been tested at CERN two years ago.

THA08P010

Quench Behaviour of the ATLAS Barrel Toroid Coils

A. Dudarev, J.J. Rabbers, H.J.J. ten Kate, CERN; C. Berriaud, CEA-Saclay; F. Broggi, INFN-LASA.

The superconducting Barrel Toroid of the ATLAS detector accumulates about 1 GJ of stored energy. The toroid is built up from eight 25 m x 5 m racetrack coils and operates at 20.5 kA. In the case of a quench this energy has to be dissipated internally to guarantee a low voltage in the detector. When a quench is detected the internally implemented heaters initiate a quench in all other coils and the stored energy dissipates homogeneously. At various fault scenarios the normal zone propagation within the coil windings plays an important role to minimise the peak temperatures in the coils. Before the final assembly in the ATLAS cavern the coils have been tested separately on surface and a few quenches per coil were initiated to check the efficiency of the quench protection heaters and the quench propagation behaviour. The experimental results of the quenches at different currents up to 22 kA are presented in this paper. The performed calculations of the average coil temperature confirm the design values and they are in good agreement with the results of the model B0 coil where the quench behaviour has been studied intensively.

THA08PO11

Design, Manufacture and Commissioning of the ATLAS Magnet Run Down Unit

G. Baccaglioni, G. Volpini, INFN-Milano, LASA; G. Cartegni, F. Cataneo, Università Statale di Milano.

The ATLAS Experiment at the LHC (CERN) has a Magnet System composed by one Barrel Toroid (BT) and two End Cap Toroids (ECTs) powered in series at 20.5 kA with an overall stored energy of 1.5 GJ and one Central Solenoid, operated at 7,600 A with a stored energy of 39 MJ. During the discharge the stored energy is dissipated inside external resistors and diodes (globally referred as Run Down Unit, RDU). Being critical for magnet safety the RDU was designed so as to operate also in case of severe fault conditions. The Toroid RDU has 20 parallel branches, each comprising ten diodes in series with a 8 mohm resistor. The number of branches has been dictated by the request to keep the diode current at a safe value, also under very unfavourable conditions, while the number of diodes was aimed to linearize as much as possible the discharge current slope. The resistors are made with welded stainless steel tubes filled with water. Although in normal operating conditions their temperature rise does not exceed 20 °C, they have been designed to operate also in case of a complete loss of coolant. The Solenoid RDU is based on the same criteria, with ten parallel branches, each with four diodes in series to a 1.9 mohm resistor. This paper presents the details of the design and the tests performed to develop each component and to assess their behaviour under normal and fault conditions. The results of the final test after commissioning inside ATLAS underground cavern are reported.

THA08P012

Assembly concept and technology on the ATLAS Barrel Toroid Magnet

A.A. Foussat, M. Raymond, H.J.J. ten Kate, CERN; B. Levesy, C. Mayri, P. Vedrine, Z. Sun, Y. Pabot, CEA-Saclay.

The ATLAS detector for the LHC accelerator at CERN requires a huge superconducting Barrel Toroid (BT) with overall dimensions of 25m length and 22m diameter and is installed in the ATLAS cavern 100m underground at CERN. The toroid is assembled from 8 flat race track coils of dimensions 25m x 5m. The ATLAS Barrel Toroid has been designed by CEA-Saclay in collaboration with the ATLAS Magnet group at CERN. Following the on surface acceptance test of the 8 BT coils, they are successively inserted in the underground cavern and assembled as a full toroid by using 16 supporting structural rings to form a rigid and stable structure. The total mass of the toroid is 850 tons. The toroid is also used as mounting frame for the various muon detectors with a total mass of about 450 tons, which brings the total mass to be supported at 1300 tons. Particular problems are that the axis of the toroid is horizontal and the final shape of the toroid has to be

cylindrical with a tolerance of 10mm with respect to an overall system diameter of 22m. The shape of the toroid can only be controlled by installing the 8 coils in their theoretical elliptical shape using high strenght bolting, and then release the structure under its self weight. This paper presents the concepts of the assembly of the toroid, highlights the FEA calculations performed to predict the shape, summarizes the tooling required and reviews the experience gained during the installation.

POSTER SESSION	13:30 - 15:30
ENERGY STORAGE (II)	

THA09PO01

Manufacturing and Testing of a 200 kJ Nb-Ti mSMES

M. Fabbri, A. Morandi, F. Negrini, P.L. Ribani, Department of Electrical Engineering, University of Bologna; R. Penco, *M.* Perrella, Ansaldo Superconduttori. Withdrawn.

THA09P002

Breakdown Characteristics in Vacuum for a Conduction-Cooled HTS SMES

J. Lee, H-G. Cheon, S-H. Kim, Gyeonsang National University; S-M. Baek, Changwon college; H-J. Kim, K-C. Seong, KERI.

The commercial application of many HTS coil, however, requires refrigeration at temperatures below 77 K, in order to take advantage of a greater critical current density of HTS and reduce considerably the size and weight of the system. The magnet is operated in vacuum condition. Thus, for the development of the coil, cryogenic insulation design should be established to accomplish miniaturization that is a big advantage of HTS SMES. Recently, research and development concerning application of the conductioncooled HTS SMES that is easily movement are actively progressing in Korea. Electrical insulation under cryogenic temperature is a key and an important element in the application of this apparatus. However, the behaviors of insulators for cryogenic conditions in air or vacuum are virtually unknown. In this paper, we present and discuss very fist results in this field, focused on several insulators such as Al2O3 and AIN which have high thermal conductivity and electrical. We summary the insulation factors of a coil for HTS SMES. And we experiment the spacer configure effect in the dielectric flashover characteristics. Before we experiment the spacer configure effect, we have been investigated a surface flashover with several insulators as well as breakdown in air and vacuum. From the results, we confirm that our research established basic data in the insulation design of the coil.

THA09PO03

On-Line Measurement of Real Parts of Eigenvalues in Multi-Machine Power System by Use of Superconducting Magnetic Energy Storage

T. Yonezu, T. Nitta, The University of Tokyo; Y. Shirai, A. Nakamaru, Kyoto University; K. Shibata, The Kansai Electric Power Co., Inc.

Small signal stability of power systems is evaluated by eigenvalues of state equations derived from system models. The eigenvalues are currently given by off-line computer analyses. However, parameters of power systems used in the computation may not be obtained accurately. If the eigenvalues can be measured directly from operating power systems, it will contribute to make power systems more stable and more economical than

they are now. Therefore, on-line measurement of the eigenvalues by use of Superconducting Magnetic Energy Storage (SMES) has been proposed. The eigenvalues of power systems can be measured by analyzing the output power of generators and transmission lines for small power changes generated by SMES. It can give small power changes without affecting operating conditions of the power systems. For the waveforms of power changes from SMES, sinusoidal signals and chirp signals have been studied. In case of sinusoidal signals, the imaginary parts of the eigenvalues can be measured in any power systems. However, the real parts of them can be measured only in one-machine infinite bus system. A new method using power change of sinusoidal waveform for measurement of the real parts of the eigenvalues of multi-machine power system will be described in the paper. Some simulations were carried out in order to examine the method by use of analogue type power system simulators. The results of simulations will be also described.

THA09PO04

Design of HTS Magnets for a 600 kJ SMES

W-S. Kim, S. Lee, S-Y. Hahn, Korea Electrical Engineering and Science Research Institute; S-Y. Kwak, H-K. Jung, Seoul National University; K-D. Choi, J-H. Han, Korea Polytechnic University; J-K. Lee, Woosuk University; K-C. Seong, Korea Electrotechnology Research Institute.

Development of a 600 kJ SMES system is in progress by Korean Electric Research Institute (KERI). High temperature superconducting wires are going to be used for the windings of the system, and the design of the HTS windings for the system is presented in this paper. We considered BSCCO-2212 wire for the HTS windings which is preferred in lower temperature environment to BSCCO-2223 wire. The operating temperature of the winding was decided to be 20K which will be accomplished by conduction cooling method using cryo-coolers. Four stacked BSCCO-2212 wire were used for design process of the HTS windings, and the objective function of the optimal process was the total amount of the HTS wire. This HTS windings is going to be applied to the SMES system whose purpose is stabilization of the power grid.

THA09P005

Design study of a 54MJ class magnet of a SMES for Power System Stabilization

H. Hayashi, T. Nagafuchi, Kyushu Electric Power Co., Inc.; S. Okitsu, K. Takeuchi, Hitachi Ltd.

We have developed a SMES system for power system stabilization, aiming at reducing the costs of the system. The multi-pole solenoid coils of Bi2212 conductor for the 100MW/54MJ class SMES was designed with the rated current of 3kA and maximum magnetic field of 10T. Our study revealed that the maximum magnetic field applied to the magnet is effective to reduce the magnet size and volume, and in terms of magnetic stress applied to the Bi2212 conductor and the support structure. The AC loss mainly depending on histeresis loss was also calculated. Thus, the authors confirmed the possibility of 54MJ class SMES's magnet for power system stabilization in a power system.

THA09PO06

Heat transfer properties of a conduction cooled prototype LTS pulse coil for UPS-SMES

A. Kawagoe, H. Yamamuro, F. Sumiyoshi, Kagoshima University; T. Mito, H. Chikaraishi, T. Baba, NIFS; T. Henmi, Gradient University for Advanced Studies; K. Okumura, R. Abe, Technova Inc.; M. Iwakuma, Kyushu

University.

We have been developing a 1 MW, 1 sec UPS-SMES for a protection of production lines of an industrial plant or largescale experimental devices such as a fusion device from a momentary voltage drop and an instant power failure. A conduction cooled prototype LTS pulse coil of 100 kJ class was developed as a key component of the UPS-SMES. The prototype coil has demonstrated its excellent thermal characteristics during the cooling and excitation tests. In this paper, measurements of the temperature in the coil during experiments and thermal analysis by using twodimensional finite elementary methods were compared to clarify quantitatively the high heat transfer properties of this prototype coil. This coil was wound with a NbTi/Cu Rutherford cable, which is extruded with aluminum. In order to realize the conduction cooled LTS pulse coil, Dyneema FRP and Litz wires were used as spacers. Dyneema FRP improves the heat transfer from layer to layer in the windings. Litz wires increase the heat transfer from turn to turn in the windings and enable conduction cooling of the coil by attaching the end of the Litz wires directly to the cold heads of the cryocoolers. It was clarified that these spacers were very effective and the coil has sufficient stability margin compared with the design values. Possibilities for reducing the size and the cost of a 1 MJ LTS pulse coil are also shown.

THA09P007

Superconducting magnet energy storage (SMES) for the power nets application

S.A. Egorov, O. Filatov, V. Belyakov, M. Astrov, V. Korsunsky, S. Fedotova, I. Rodin, E. Zapretilina, D.V. Efremov Institute (NIIEFA).

Withdrawn.

THA09P008

SMES for electric power compensation of the J-PARC high intensity proton synchrotron

T. Shintomi, H. Sato, KEK; S. Nomura, Tokyo Institute of Technology; T. Ise, Osaka University; S. Akita, CRIEPI. The new proton accelerator complex for high intensity

beam (Japan Particle Accelerator Research Complex - J-PARC) is under construction at the Tokai campus of Japan Atomic Energy Research Institute as a joint project between KEK and JAERI. The accelerator complex, which is composed of a 400 MeV linac, a 3 GeV booster synchrotron, and a 50 GeV main synchrotron, will be used for particle and nuclear physics, neutrino experiment, research with neutron and muon, and others. In phase I, the main proton synchrotron will be operated at energy of 40 GeV with pulse operation. The proton energy is to be increased up to 50 GeV at phase II, and a large amount of electric power, which is + 110 MW and - 60 MW peak-topeak with 3.4-second repetition, will be demanded for the operation. Such large pulse power will give un-allowed disturbances to an electric power network to which the complex will be connected. Some measure will be required for compensating the pulse electric power and reducing such disturbances. A SMES system will be one of the promising measures for the purposes. The SMES system is proposed and described in detail.

THA09P009

Field Test Results of 5 MVA SMES System for Bridging Instantaneous Voltage dips

Shigeo Nagaya, N. Hirano, T. Noda, H. Moriguchi, E. Adachi, K. Shikimachi, Chubu Electric Power Co., Inc.; S. Hanai, J. Inagaki, S. Ioka, S. Kawashima, Toshiba Corporation.

A power storage apparatus capable of instantly outputting considerable power is required to compensate for the lack of power in the event of instantaneous voltage dips. We developed 5 MVA SMES system to bridge instantaneous voltage dips, rendering it sufficient to cover the whole plant. The SMES system includes superconducting coils, a protective circuit, a high-speed switch for swift shutdown of the system-side power in the event of any instantaneous voltage dip, and a power converter that converts the energy stored in the coils to A/C and then supplies the power to the load. The SMES system must be capable of high speed switching, and offer a high capacity. To achieve such aims, the development of a power converter and high speed switch respectively was essential. The SMES system was installed at an advanced large plant in Japan, and field test began in July 2003. During operation, the intervention of the SMES system in performing the compensatory action rapidly upon the occurrence of instantaneous voltage dips within the actual system was confirmed. The test system underwent successive instantaneous voltage dips due to successive faults caused by repeated lightning strikes, and the compensation functioned perfectly by sustaining bridging action during the period. Through the test operation, the technological proficiency of the specification requested to provide effective compensation to counter instantaneous voltage dips was proven in the case of the SMES system.

POSTER SESSION	13:30 - 15:30
PULSE MAGNETS	

THA10PO01

Design of a Prototype Repetitively Pulsed Magnet at the NHMFL

M.D. Bird, Y. Eyssa, A. Gavrilin, S. Gundlach, NHMFL.

The National High Magnetic Field Laboratory in Tallahassee, Florida has undertaken a program to design and build high-field, split-pair, Repetitively Pulsed Magnets (RPM) for neutron-scattering experiments. RPM systems have the advantages of lower average power and lower construction costs than dc magnets. The best magnets of this type presently available worldwide are those built by Motokawa et al. in Sendai, Japan. The NHMFL RPM program intends to build magnets with higher field and larger scattering space than other existing systems. Details of the design of these systems are presented.

THA10PO02

Fabrication and Testing of a Prototype Repetitively Pulsed Magnet at the NHMFL

M.D. Bird, K. Han, C. Swenson, NHMFL-FSU; D. Rickel, NHMFL-LANL.

The National High Magnetic Field Laboratory in Tallahassee, Florida develops, builds and operates the most intense dc and pulsed resistive magnets in the world. NHMFL user facilities provide fields up to 45 T in a dc hybrid and 75 T in a 15 ms pulsed magnet. A new project is underway to develop a repetitively pulsed magnet for neutron scattering experiments. The goal is to provide 30 T for a few milliseconds about once per second in a split magnet with an aluminum alloy mid-plane. The fatigue life of the various materials and components drives the design process. We intend to build several prototype systems prior to designing the final user magnet system. The first prototype has been designed and fabricated as a singlelayer system at the Tallahassee branch of the NHMFL. Device testing will be performed at the NHMFL Pulsed

Field Science Facility at Los Alamos National Laboratory. Fabrication and test results are presented.

THA10PO03

Investigation of Reinforced, Magnet-Coil Support Shells for the NHMFL 100 Tesla Multi-Shot Magnet

C. Ammerman, J. Sims, J. Schillig, H. Coe, J. Bacon, K. Kihara, M. Pacheco, J. Michel, R. Parker, Los Alamos National Laboratory. Withdrawn.

THA10PO04

Pulsed Magnets - Coil Optimization using Finite Element Analysis

H. Witte, H. Jones, University of Oxford; A. Gaganov, N. Kozlova, J. Freudenberger, IFW Dresden, Institute for Metallic Materials.

For a successful pulsed magnet design, the sensible choice and combination of materials is crucial. User magnets with a long lifetime and record coils mainly relied on the mechanical strength of the materials in the past, the conductor itself or in combination with reinforcement fibres. User coils for the Nikolas Kurti High Magnetic Field Laboratory are traditionally made of the copper stainless steel conductor (pioneered in Oxford), which shows good mechanical properties in combination with reliability, leading to a long coil life. Novel conductors, made of copper-silver, are also used, because of their enhanced mechanical properties. For higher fields it became evident that a better understanding of the processes going on during a discharge is necessary. In Oxford, finite element software (FEM) is used for this purpose. FEM is now used on a standard basis, not only for the mechanical design of the coils, but also for calculating the temperature distribution during the discharge. We report on the progress in this area on the basis of our latest coil design. Another important aspect for which FEM has shown to be useful is the minimization of the cooling time of pulsed magnets. We are concentrating on developing magnets with cooling times reduced to about 20 minutes. Using FEM, this seems to be possible without decreasing the coil efficiency; first results are shown in this paper...

THA10P005

Inspection and fault analysis of pulsed magnet prototypes after short and long term operation

C.A. Swenson, W. Marshall, K. Han, NHMFL; D. Rickel, NHMFL-LANL.

The NHMFL is now operating a new pulsed-science user magnet. The first technical implementation of this technology was the 65T magnet developed in 2003. This design is also a insert magnet development platform for the DOE 100T Multi Shot Magnet Program. We have, after two years, experienced the first electrical faults associated with long term operation. The first 65T magnet assembly failed after 470 full field science shots. The 65T insert construction was based upon the poly-layer assembly technique developed at NHMFL. The fault was unique in that the entire magnet assembly was intact save for the winding layer that failed. Inspection and analysis of the assembly presented an opportunity to examine all internal interfaces to evaluate structural performance of components after long term service. Such inspection and design review is critical to the practical improvement of pulsed magnets. We have also experienced electrical faults in the external "outsert" coil windings during the development and refinement of theses assemblies for our 65T and 75T magnet projects. This paper presents our physical observations and fault analysis associated with

long term insert operation. Additionally we will present our technical data, analysis, and operational experience concerning the development of reliable high field pulsed outsert magnets

THA10PO06

Nanocomposite Copper-Based Conductors for Pulse Magnets

M.A. Tikhonovsky, A. Kupriyanov, A. Pikalov, National Science Center " Kharkov Institute of Physics & Technology".

The methods of manufacturing high-strength nanocomposites wires and sheets from two-phase alloys with both ductile phases (Cu-Nb, Cu-Fe, Cu-Ta, Cu-Cr) have been developed. The initial two-phase billets were produced by controlled solidification or by powder metallurgy. Severe plastic deformation of billets were made by rolling and drawing. The diameter of finished wires was 0.1-3mm and the thickness of ribbon-like fibres of second phase (Nb, Fe, Ta, Cr) was 10- 1000nm. Mechanical properties and electrical resistivity of nanocomposites were investigated in the range 77- 1000K. It has been found that starting from certain degree of deformation, dependent on the initial billet dispersion, the sharp increase in strength take place. At high degrees of drawing deformation we found a discrete character of yield strength change. This is accompanied by appearance of certain peculiarities in the structure of nano- scaled fibres. Firstly, the narrow knife like boundaries along the fibres are observed. Secondly, significant tensile elastic stresses appear in the fibres. The resistivity of nanocomposites is determinated by the interface scattering but scattering factor can change when the drawing deformation increases. The reasons for the structural features observed and the condition of obtaining the optimum of mechanical and electrical properties in nanocomposites are discussed.

THA10P007

Insert development program for DOE 100T multi-shot magnet

C.A. Swenson, A. Gavrilin, J. Toth, Y. Viouchkov, NHMFL; W. Marshall, D. Rickel, J. Schillig, J. Sims, NHMFL-LANL. The US-NHMFL DOE-NSF 100T Multi Shot magnet will ultimately generate pulsed fields for science with an intensity of 100 T. The 141 MJ outsert magnet structure is now in assembly at the NHMFL Pulsed Field Science Facility at Los Alamos National Laboratory. The final design of the first operational 90T insert is completed and construction preparations are underway. There has been an extensive technology development program to develop the materials and engineered structures required to build insert magnets for this program. This development required an extensive prototype program to gain operational experience with such structures. The insert prototype program entails the development of three prototype pulsed magnet systems before construction of the first 90T operational inserts. This paper will report our progress on the 65T-user, 75T, and 80T prototype pulsed magnets. We will also present a review of the design of 90T insert and its electro-mechanical integration into the 100T outsert assembly.

THA10P008

77 K Axial Fatigue Test Results for Two High Strength Pulse Magnet Conductors

R.P. Walsh, V. Toplosky, C. Swenson, J. Sims, NHMFL-FSU.

High strength conductors, used for the construction of pulsed magnets at NHMFL, must withstand demanding
stress, strain and cyclic fatigue requirements. The safe design and operation of pulse magnets requires an understanding of the expected conductor performance as determined from design-specific low-cycle fatigue tests. Here we report the fatigue tests results for two commercially available micro-composite conductors; CuNb and GlidCop Al60. The fatigue tests simulate the in-service fatique stress regime (non-symmetric axial tension/compression) at 77 K with the application of axial tension and compression in a stress or strain control mode. The conductors are rectangular wire composites that must be tested in their as-produced condition thus careful specimen design is required and reviewed here. The fatigue test results for the two conductors are presented and compared. The effect of fatigue parameters such as test control mode, applied stress range, mean cyclic stress and r-ratio are also discussed.

POSTER SESSION	13:30 - 15:30
FUSION FUTURE DEVICES	

THA11PO01

Design and Manufacturing of In-vessel Magnets of SST-1 Tokamak

S. Pradhan, Y.C. Saxena, R. Prakash, R. Bahl, Institute for Plasma Research; D.P. Ivanov, Nuclear Fusion Institute, Russian Research Center, Kurchatov Institute, Moscow. Withdrawn.

THA11PO02

Cooling system operation of the levitated dipole experiment floating coil

A. Zhukovsky, MIT, Plasma Science and Fusion Center; D. Garnier, Columbia University.

The Levitated Dipole Experiment (LDX) is an innovative facility to study plasma confinement in a dipole magnetic field, created by a superconducting solenoid (floating coil), which is magnetically levitated in the center of a 5 m diameter by 3 m tall vacuum chamber. This persistent mode, floating coil (F-coil) consists of a Nb3Sn magnet installed inside a high pressure vessel filled with 12.5 MPa helium gas at room temperature. It is surrounded by a high heat capacity fiberglass-lead composite radiation shield and by a toroidal vacuum shell. The built-in tube heat exchanger serves to cool the magnet, the helium vessel, and the thermal shield. When positioned at the lower part of the vacuum chamber the F-coil is cooled by retractable cryogenic transfer lines to about 4.5 K and it is charged inductively by the charging coil installed outside of the vacuum chamber. Then the helium flow is interrupted, the heat exchanger is pumped out, retractable lines are disengaged from F-coil ports, the ports are plugged, and the F-coil is lifted to the middle of the chamber to initiate and study plasmas. After several hours and just before the F-coil warms up to about 10 K it is lowered down for the next re-cooling or for discharging. This paper describes the F-coil cooling system and inductive charging system operation and performance.

THA11PO03

Fabrication of the Toroidal Field Superconducting Coils for EAST Device

W. Chen, Y. Pan, S. Wu, P. Weng, D. Gao, J. Wei, J. Yu, S. Chen, Institute of Plasma Physics, CAS.

EAST is a large fusion experimental device. It will be built at the Institute of Plasma Physics of Chinese Academy of Sciences in the end of this year. The superconducting magnet system of EAST device consists of sixteen toroidal field (TF) coils arrayed toroidally and fourteen poloidal field (PF) coils installed symmetrically about the plasma equator. The TF coil includes the winding pack used a square cable-in-conduit (CIC) type base on NbTi superconductor and cooled by a force flow of supercritical helium, the "weld-up plate" case structure, the gravity support which is composed of pedestals with flexible plates, the coil joint with low resistance at high current and so on. AT present, the production of all TF coils has been finished and the assembly of the TF coils is under way. This paper describes mainly the special fabrication processes of TF coil in detail. Meanwhile, in this paper, some test results of single TF prototype coil in the test cryogenic facility will be introduced.

THA11PO04

A 3 T Magnet System for Magnum-psi

H.J.N. van Eck, W.R. Koppers, G.J. van Rooij, W. Goedheer, B. de Groot, P. Smeets, J.C. Wolff, N. Lopes Cardozo, A.W. Kleyn, FOM-Institute for Plasma Physics Rijnhuizen, Association EURATOM-FOM; A. den Ouden, University of Twente, Faculty of Science and Technology; D. Schram, Eindhoven University of Technology.

The FOM-Institute for Plasma Physics Rijnhuizen is preparing the construction of Magnum-psi1, a magnetized (3 T), steady-state, large area (100 cm2) high-flux (up to 1024 H+ ions m-2s-1) plasma generator. The aim of the linear plasma device Magnum-psi is to provide a controlled, highly accessible laboratory experiment in which the interaction of a magnetized plasma with different surfaces can be studied in detail. Plasma parameters can be varied over a wide range, in particular covering the high-density, low-temperature conditions expected for the detached divertor plasma of ITER. A vital part of the Magnum-psi experiment will be the 3 T superconducting magnet system. Room for diagnostic access to the experiment is essential. In this contribution, we will explain the requirements on the magnet system, which is now in the pre-design phase. The present design consist of 4 cylindrical, conduction cooled NbTi coils which generate an axial field of 3 T in a 1.3 meter room temperature bore. The discrete coils are supported by a 2.5 meter long single cylinder in a shared cryostat with 12 room temperature view-ports. The field is passively shielded by an iron dome at 3 meters from the cryostat. As background, we will discuss the global pre-design of the Magnum-psi experiment; i.e. vacuum system, plasma source, target manipulator and additional plasma heating.

THA11PO05

Development of persistent-current mode HTS coil for the RT-1 floating magnet

T. Tosaka, Y. Ohtani, M. Ono, T. Kuriyama, S. Mizumaki, K. Nakamoto, M. Shibui, Toshiba Corporation; J. Morikawa, Y. Ogawa, Z. Yoshida, Tokyo University.

A magnetically levitated magnet has been constructed, for the RT-1 apparatus for advanced high-beta plasma and fusion research at Tokyo University. The high-temperature superconducting (HTS) magnet is levitated inside the plasma vacuum chamber in which the plasma is confined by its magnetic dipole field. The magnet consists of an HTS coil, an HTS persistent current switch (PCS), a pair of retractable current leads, detachable transfer line for the cooling circuit, a thermal shield and a vacuum vessel. The HTS coil is cooled below 20K by cold helium gas provided through the transfer tube and operated in persistent current mode. The magnet is designed to levitate in the magnetic field of a normal conducting magnet while the HTS coil temperature is kept in the range of 20K-30K after current leads and transfer tube are detached. This paper describes design, construction and test results of the HTS coil and the PCS.

THA11PO06

Optimization Study of Poloidal Field Coil Configuration for Improving Plasma Shaping Capability and the Flexibility in NCT

M. Matsukawa, JAERI, on behalf of NCT Design Team. High-beta steady-state operation is a key to realize the nuclear fusion power plant economically competitive to other energy sources, because the fusion power is approximately proportional to the square of normalized plasma beta value and the cost of electricity is determined dominantly with the capital investment of the machine construction. Therefore, it is very important to control the normalized plasma beta close to its ideal MHD limit over the no-wall limit. Since the plasma shaping parameter S(=q95*lp/a*Bt) is considered to be correlated to the achievable plasma beta value, choosing the plasma aspect ratio and shape is a still important issue for the machine design. The national centralized tokamak (NCT) is one of the next major domestic programs in Japan and it is aiming at contributing DEMO as well as ITER. Then, NCT has to cover larger operational region of the plasma shape and aspect ratio than ITER. For this purpose, optimization study of poloidal field (PF) coil configuration was carried out. As a result, the wide aspect ratio in the range of 2.6-3.4 and the maximum plasma shaping parameter S~7 will be obtained in the case of double null divertor configuration while S~6 for single null divertor. It was also concluded that two additional PF coils would much enhance the flexibility of plasma shaping capability especially for the squareness control. In this paper, the latest PF coil and in-vessel sector coil designs of NCT will be presented.

THA11P007

Development of the Magnetically Floating Superconducting Dipole in the RT-1 Plasma Device

S. Mizumaki, T. Tosaka, Y. Ohtani, M. Ono, T. Kuriyama, K. Nakamoto, N. Tachikawa, Toshiba Corporation; J. Morikawa, Y. Ogawa, Z. Yoshida, The University of Tokyo. A high-temperature superconducting coil floating in the magnetic field of a normal conducting coil has been developed for the RT-1 plasma confinement apparatus at the University of Tokyo. The RT-1 device consists of the floating superconducting coil, a lifting coil made of normal conductor, a plasma vacuum vessel and detachable services for the floating coil. The floating coil is made with 181 turn X 12 layer single pancake windings of Bi-2223 tape, has a diameter of 500mm and is operated at a current of 115A. The floating coil is cooled down to 20K by a flow of helium gas supplied through detachable cooling line joints in the coil vacuum vessel. It is then excited to nominal current by retractable current leads at the bottom of the plasma vacuum vessel. After the cooling lines and electrodes are detached the coil is elevated to the experimental position with a lifting system. The floating coil is designed to levitate in persistent current mode for up to eight hours of operation. This paper presents the design concept and operating scenario of the floating coil as well as the required services such as a HTS persistent current switch necessary to realize this scenario.

THA11P008

A Study of Ferritic Steel Utilization on Full Superconducting Coil Tokamak NCT *M. Matsukawa, JAERI.* Withdrawn.

THA11PO09

Stress analyses of the support structure and winding pack of the superconducting TF coil in National Centralized Tokamak

K. Tsuchiya, K. Kizu, H. Takahashi, M. Matsukawa, H. Tamai, JAERI; T. Ando, Nippon Advanced Technology.

The design optimization of the support structure for the toroidal field coil (TFC) in the National Centralized Tokamak (NCT) is performed with FEM analysis from viewpoints of stiffness of the coil case and shear panels considering the shear keys and bolts. It is found that the displacement of TFC is effectively suppressed by thickening of the coil case and enforcement of shear panels especially near the lower midplane of TFC. As a result, the maximum displacement is reduced up to less than 6 mm in the case of the largest electromagnetic (EM) force. The self EM force of TFC and the out-of-plane force comes from the poloidal field coils cause the strain on the winding pack of TFC, which may induce the degradation of critical current (Ic). The transverse stress at the wedge part loaded from the neighboring TFC by the centripetal force may also cause the Ic degradation. Therefore, the accurate evaluation of these stresses and strains is required taking the profile of the magnetic field on a TFC into consideration. Even in the case that the largest EM force appears, the transverse stress is still lower than the level (= 60 MPa) that may induce the Ic degradation of Nb3AI cable that is adopted for a TFC in NCT. In the longitudinal direction, tensile strain is dominant with the range of -0.02 0.08% in this case. Tensile strain mitigates the constriction (= -0.7%) from the conduit covering the cable. Therefore, it is considered that Ic degradation by the EM force is negligible.

POSTER SESSION 13:30 - 15:30 NMR AND MEDICAL APPLICATIONS

THA12PO01

Field homogeneity optimization of iron-free MRI magnet system

A. Korpela, R. Mikkonen, Tampere University of Technology / Institute of Electromagnetics.

Commercial Magnetic Resonance Imaging (MRI) systems have typically the homogeneity of few ppm in a spherical volume with a radius of about 10 cm. In order to fulfil the magnetic field homogeneity requirements, most of the commercial MRI systems utilize iron. However, the trend in MRI systems is towards considerably higher magnetic fields. In that case iron can no longer be utilized. On the other hand, if the system is iron-free, its weight is significantly reduced. In this paper, the design of an ironfree MRI system consisting of several solenoidal coils is carried out. In the design procedure the field computations by means of Finite Element Method are coupled with the optimization algorithm Sequential Quadratic Programming. According to results, the magnetic field homogeneity requirements of today's commercial MRI devices can be met with solenoidal iron-free magnet system.

THA12PO02

The Optimal Design Method of Completely Open Architecture Superconductive Magnet for Magnetic Resonance Imaging

Y. Yao, G. Ni, Y. Fang, The College of Electrical Engineering, Zhejiang University.

A lot of efforts to enlarge the "open" degree of traditional MRI equipments have been done in order to provide convenient access to the imaging region and a better imaging quality. However, existing open architecture designs include double iron pole pieces with intervening support members so that they all can hardly be utilized for interventional diagnostic or surgical procedures. In this paper, a completely open architecture magnet is proposed, which is structured by several superconductive coils. To enhance the magnetic intensity and homogeneity in the imaging region, an open iron shell with special terminal shape is designed for magnetic compensation. A new flexible design method is proposed to facilitate the construction of a completely open MRI magnet by combining the magnetic dipole pair model and optimization algorithm. Based on the magnetic dipole pair model and saddle point rule, the initial structure of the magnet is constructed by several superconductive coils, which specially located and energized in different currents and turns. Then an algorithm is used to adjust the coils' parameters. At last, genetic algorithm is used to design the dimensions of the compensative parts and get a magnetic field with higher homogeneity and field strength in the imaging region. A numerical implementation shows that the new design provides a main magnetic field having sufficient homogeneity and strength in the imaging region, which is defined outside of the magnet structure.

THA12PO03

Design and analysis of a novel test tube shape magnet of Mobile NMR

J. Chen, Y. Zhang, Institute of Electrical Engineering, CAS. This paper presents a novel test tube shape magnet of Mobile NMR, which is composed of a dipolar Halbach array. The magnet, which compensates the axis magnetic field distribution of cylindrical Halbach magnet, suits well to measure the sample in the test tube with mobile NMR devise. Halving a cylinder and a spheres through cylindrical coordinate an angle of ninety degrees and sphere coordinate an angle of ninety degrees, one get a hemi cylinder and a hemispheres. They compensate respectively the axis magnetic field of the cylindrical Halbach magnet bottom, so the whole magnet has the test tube shape. These compensations are simulated with two-dimensional and three-dimensional finite-element methods. The axis magnetic field homogeneity, which is in the hollow of compensated cylindrical Halbach magnet, corresponds with the homogeneity of no compensated magnet with the double axis size. If the homogeneity is consistent, the whole volume and weight decrease almost 50%, the field of test tube shape magnet is better for the measure of the sample in the test tube. Therefore, the design improves the performance of cylindrical Halbach magnet in the application of mobile NMR magnet.

THA12PO04

A High Field Gradient Magnet for Magnetic Drug Targeting

W. Schmidt, P. Henninger, R. Röckelein, Siemens AG, Corporate Technology; C. Alexiou, H. Iro, Hals-Nasen-Ohrenklinik der Universität Erlangen-Nürnberg; H. Weber, Siemens AG, Medical Systems.

Magnetic drug targeting (MDT) is one of the new regional

drug therapies presently investigated for cancer treatment. The striking advantage of MDT is the reduction of side effects of chemotherapeutic agents for the patient due to applying the agents mainly to the desired target volume at the tumor. MDT is based on anticancer agents bound to ferromagnetic nanoparticles with biocompatible starch coating suspended in a fluid. The suspension is injected intra-arterially close to the target volume. A magnet, positioned close to the tumor, draws the particles out of the bloodstream and concentrates them in the tissue to be treated. The magnetic field has to be applied for a certain time, until the bond between the drug and the magnetic particle decays and the drug has penetrated the tumorcells. A magnet was designed, built and tested, which fulfills the requirements of high magnetic force in the application volume around and inside the tumor, low mass, size and appropriate geometry for easy handling and positioning, and a surface temperature below 40°C at the patient. The gradient of the magnetic field, which determines the magnetic force for small single-domain ferromagnetic particles, ranges from 100 T/m at the pole tip to a minimum of 10 T/m in an application volume of (20 mm)[^]3 and points inwardly.

THA12PO05

Fiber Tracking Method by Correlative Vector Weighting with Magnetic Resonance Diffusion Tensor Imaging Data

X. Zhao, M. Wang, W. Gao, Tianjin University, H. Liu, University of Minnesota, Tianjin University; D. Li, Northwestern University. Withdrawn.

THA12PO06

Computed Modeling of The Brain and Magnetic Coil Design with Transcranial Magnetic Stimulation

G. Xu, Tianjin University, Hebei University of Technology; M. Wang, Tianjin University; Q. Yang, S. Yang, H. Wu, Y. Chen, Hebei University of Technology.

Transcranial magnetic stimulation (TMS) is a powerful, noninvasive tool for investigating functions in the brain. Brain stimulation with TMS can either excite the cortex or disturb its function, and has numerous applications in the study, diagnosis and therapy of the brain. The observed excitatory effects are normally muscle twitches or phosphenes. In TMS, excitation is achieved by driving intense pulses of current I(t) through a coil located above the head. The source of activation is the electric field E induced in the tissue, obtained from Faraday's law. This paper presents the TMS computer modeling of the brain with low-frequency magnetic field based on finite element method (FEM). Its attempts have been made to employ the computer simulation in order to evaluate the current that flows throughout the brain tissues and to predict the system parameters. The effective calculation of the field in the region of interest (cerebral cortex of the human head) is the crucial point of simulation. Magnetic coil (MC) design also is one of the most important aspects of the TMS technique. The primary goal of this study was to determine the governing parameters in the MC design, such as coil configuration, diameter, and number of turns in one loop of the coil. By varying these parameters, our approach is to design, construct, and evaluate the induced electric field distributions of magnetic coils.

THA12P007

A 700 MHz LTS/HTS NMR Magnet - A Status Report

J. Bascuñán, H. Lee, E. Bobrov, S-Y. Hahn, Y. Iwasa, MIT-Francis Bitter Magnet Laboratory. Phase II of our three phase program to develop a 1 GHz High Resolution LTS/HTS NMR Magnet, entails the design, construction and testing of a 700 MHz LTS/HTS NMR magnet. Here we report on the design and construction of a 100 MHz HTS Insert magnet, its interface to a 600 MHz LTS magnet, and testing of the LTS/HTS assembly. Immersed in 4.2 K LHe at atmospheric pressure, the coils are connected in parallel with the HTS Insert operating at 97.3 A while the background LTS coil carries 240 A. Details of the cryogenic and magnetic features of the system are presented.

THA12PO08

A 500 MHz/200 mm RT Solid Neon Cooled Nb3Sn MRI Magnet - A Status Report

J. Bascuñán, H. Lee, E. Bobrov, S-Y. Hahn, Y. Iwasa, MIT-Francis Bitter Magnet Laboratory.

We report here on the status of our program aimed to build and operate a dry MRI magnet. The system incorporates a new design/operational concept that we believe it will be eventually adopted by manufacturers of the next generation of superconducting magnets. System features include: a) liquid-free; b) if required by the user, cryocooler microphonics free over a period of time; c) ability to maintain a constant operating field over a specified period of time, even in the event of a power outage or during cryocooler maintenance. The basis of this new design/operation concept, among other features, is the presence of solid cryogen, solid neon for this system, in the cold body that also contains the magnet to enhance significantly the cold body's heat capacity. Details of the system design - magnetic and cryogenics are presented in this paper.

THA12PO09

Three-Dimensional Motion Control System of Ferromagnetic Particle for Magnetically Targeted Drug Delivery System

F. Mishima, T. Hamajima, S-I. Takeda, Y. Izumi, S. Nishijima, Department of Nuclear Engineering, Graduate School of Engineering, Osaka University.

Development of 3-dimensional navigation system of the ferromagnetic particle in a static and/or flow systems were performed. In order to advance from the practice of using externally-applied magnetic fields to target in situ magnetic particles to a circumscribed body region, a 3-dimensional navigation system by utilizing external magnetic field was proposed and the feasibility of the present system was investigated. A 3-D theoretical model was established and used in order to evaluate the degree of the navigation/retention of magnetic particles. Furthermore, an experimental model system was made and the efficiency of a prototype system was examined. Comparisons of experimental and corresponding modeling data were made to verify the theoretical predictions. The obtained results suggest that the 3-D model of calculation and the experimental system for magnetically targeted drug delivery system can be used as a platform for an effective magnetic drug-targeting tool with a multitude of medical applications.

THA12PO10

Development of Magnetic Force-Assisted New Gene Transfer System using Biopolymer-Coated Ferromagnetic Nanoparticles

S-I. Takeda, F. Mishima, B. Terazono, Y. Izumi, S. Nishijima, Department of Nuclear Engineering, Graduate School of Engineering, Osaka University

Development of a simple method for converting the lipid

envelope of an inactivated virus to a gene transfer vector was achieved in the medical school of Osaka University. Hemagglutinating virus of Japan (HVJ; Sendai virus) envelope (HVJ-E) vector introduced plasmid DNA efficiently and rapidly into various cell lines, including cancer cells and several types of primary cell culture. Efficiency of gene transfer was found to be greatly enhanced by application of a magnetic field. In the present study, we developed a new type of magnet for magnetically enhancing and targeting gene transfection system by using vectors associated with ferromagnetic particles coated with positively/negatively charged biopolymers, which can help to enhance and target gene delivery with higher efficiency. For the transfection experiment in vitro, the HVJ-E vector was mixed with ferromagnetic particles coated with biopolymer and this mixture was added to cultured cells which were set up under the various types of magnetic fields. The effect of the strength and gradient of the magnetic field on the efficiency of the transfection was discussed. The accuracy of the targeted size was also examined with a comparison of the calculation of the magnetic fields.

THA12PO11

Development of a Superconducting Joint for High Field NMR

T. Fukuzaki, H. Maeda, RIKEN Genomic Sciences Center; T. Kiyoshi, S. Matsumoto, S. Nimori, NIMS

A high sensitivity and high resolution NMR magnet is constructed with multiple superconducting magnets. Each magnet is joined in a series by a superconducting joint between the NbTi conductor and the Nb3Sn conductor (or the NbTi conductor), and the magnet is usually operated in the persistent mode. An NMR magnet with sufficient magnetic field stability (for example, field decay <10 Hz/h) is required for NMR measurement. It is necessary for the persistent current decay by the superconducting joint resistance to be low. For a new high field NMR magnet such as a 1 GHz NMR, the inner coil is designed by a new superconductor instead of the bronze processed Nb3Sn conductor. It is therefore important that a superconducting joint between the new conductor and the NbTi conductor be developed. Nb3Al is an effective superconductor for the inner coil of a 1 GHz NMR magnet. We have developed a method for constructing a superconducting joint between the Nb3Al conductor and the NbTi conductor.

THA12PO12

Transient Response of Permanent Magnet MRI Magnet to Gradient Pulses

K. Sivasubramaniam, X. Huang, W. Barber, K. Amm, E. Laskaris, GE Global Research Center; T. Havens, B-X. Xu, J. van Oort, GE Healthcare.

Open MRI magnets are generally designed with ferromagnetic poles to contain and shape the magnetic flux and to reduce conductor requirement. Permanent magnet MR magnets have blocks of PM material on or close to the pole face. These electrically conducting regions are sources of eddy currents that affect the image quality because of their relatively large time constants and close proximity to the imaging volume. The impact on image quality can be minimized by appropriate segmentation and/or lamination of these components. Detailed eddy current diffusion models are necessary to quantify the field distortion and time constants of the resulting field to perform design studies. The three dimensional frequency or time domain models required to accurately predict effect of eddy currents due to gradient fields is not computationally economical. This paper describes

modeling of a PM imaging system using simplified 2D models with appropriate assumptions to evaluate the impact of these eddy currents. Experimental validation of some of the results with a prototype magnet is provided.

THA12PO13

The CNAO syncrotron magnetic elements

C. Priano, M. Pullia, S. Rossi, L. Vuffray, G. Bazzano, Fondazione CNAO; C. Sanelli, INFN-LNF; G. Drago, Ansaldo Superconduttori; D. Cornuet, L. Bottura, CERN; J-M. Beconto, Laboratory for Subatomic Physics and Cosmology (LPSC). Withdrawn.

Friday, September 23, 2005

PULSE MAGNETS (II)	
(Scirocco/Libeccio room)	
PARALLEL SESSION	8:30 - 10:00

FRM1OR1

ARMS: A successful European programme for a 80 T user magnet

H. Jones, University of Oxford; P. Frings, O. Portugall LNCMP, Toulouse France; M. von Ortenberg, Humboldt University at Berlin; A. Lagutin, F. Herlach, Katholieke Universiteit Leuven; L. Van Bockstal, Metis Instruments and Equipment nv, Belgium.

ARMS is the acronym for Advanced Research Magnet Systems - a project under the European Union's 5th Framework Research Infrastructures programme. Eight partners co-operated to produce a coil-ex / coil-in pulsed field magnet, the two components of which were energised by separate capacitive power supplies. The location of the finished magnet was LNCMP, Toulouse, whose 14 MJ capacitor bank powered the coil-ex. A small 100 KJ, fast bank powered the coil-in. In this paper, the evolution of the coils and the conductors and other materials is described as well as the testing and final useage for condensed matter experiments in fields up to 76 T. The future direction of high fields in Europe, post - ARMS, will also be addressed.

FRM10R2

Accuracy and Uncertainty of the Material Testing Data for Magnet Design

K. Han, R. Walsh, Y. Xin, NHMFL. Withdrawn.

FRM1OR3

Magnetic Misalignment Matrix and Current Lead Configuration Study for the NHMFL 100 Tesla Pulsed Magnet System

J. Toth, C. Swenson, Y. Viouchkov, NHMFL. Withdrawn.

FRM1OR4

Development of high strength conductors for pulsed high field magnets

J. Freudenberger, A. Gaganov, E. Botcharova, L. Schultz, IFW Dresden. Withdrawn.

FRM10R5

Experimental and theoretical analysis of the heat distribution in pulsed magnets.

F.C. Herlach, K.U. Leuven - Natuurkunde - LVSM; T. Peng, HUST, Wuhan; J. Vanacken, LNCMP, Toulouse.

Joule heating is a critical issue with pulsed magnets; it determines the feasible combination of pulse duration and peak field with respect to the power supply, as well as the durability of the magnet. It is straightforward to calculate the average heating from the energy that is dumped into the magnet during the pulse. There are two effects that result in shifting the heating from the outer layers towards the inner radius of the winding: magneto-resistance and the skin effect. This is because both effects depend on the magnetic field that is of course stronger at the inner layers. The temperature difference could easily be of the order of 100 K for fields in the range above 50 T. For magnetoresistance, the magnetic field dependence is not precisely known for many of the conductors used in the coils. Calculation of the skin effect requires in principle the solution of partial differential equations governing the current distribution in the wires, but approximations can be made that permit analytical calculation. We measured the temperature distribution by means of a series of thermocouples embedded in the winding and compare the results with our calculations. These measurements also are useful for the optimization of the cooling process after the pulse. This optimization could considerably shorten the cool-down time between pulses.

FRM10R6

Spheroidization effects on the electrical and magnetic properties of a Cu15%Nb composite

M.J.R. Sandim, H. Sandim, R. Renzetti, Department of Materials Engineering - FAENQUIL; D. Stamopoulos, Institute of Materials Science, NCSR; M. das Virgens, L. Ghivelder, IF-UFRJ.

We report on the microstructural evolution in Cu15%Nb multifilamentary conductors upon annealing and the corresponding effects on their electrical and magnetic properties. Vacuum annealing of the composite was performed from 300 to 1000 "C at times varying from 1 to 120 min. The microstructure of niobium filaments was investigated using scanning electron microscopy (SEM) and Vickers microhardness. Electrical resistance versus temperature curves of as-drawn and annealed specimens were determined using the four-probe technique between 5 and 12 K. The variation in the resistivity ratio r295 K/r77K was also determined. The DC magnetic measurements as a function of magnetic field were performed at 4.2 K and at magnetic fields up to 2 T. A closer inspection in SEM reveals important microstructural changes in annealed niobium ribbons in terms of morphology (spheroidization). Concerning the annealed samples, in the normal state it was observed an increase in the electrical resistivity with increasing annealing temperature. The annealing strongly affects the shape of the magnetization loops, which display a double-peak feature. The kinetics of spheroidization exhibited by niobium ribbons is mirrored in the changes of the characteristics of magnetization curves with annealing time. The aim of the present work is understanding the microstructural changes associated with spheroidization in Cu15%Nb, as well as its influence on the electrical and magnetic properties.

PARALLEL SESSION	8:30 - 10:40
(Maestrale room)	
LHC MAGNETS	

FRM2OR1

Trends in field quality along the production of the LHC dipoles and differences among manufacturers

E. Todesco, C. Vollinger, P. Hagen, CERN.

More than two thirds of the dipoles of the Large Hadron Collider have been manufactured and their field content measured at room temperature. In this paper we make a review of the trends that have been observed during the production. In some cases, the trends have been traced back to the displacements of conductors with respect to the nominal layout. The analysis allows detecting the most delicate zones in the superconducting coil as far as field quality is concerned. The second part of the paper makes the point of the observed differences in field quality between the three manufacturers. The analysis allows evaluating which multipoles are more affected, what orders of magnitudes are necessary to justify these differences (the manufacturers all producing the same baseline), and what could be the origin of such differences.

FRM2OR2

Status Report on the Series Production of the Main Superconducting Dipole Magnets for LHC

F. Savary, M. Bajko, M. Cornelis, P. Fessia, J. Miles, M. Modena, G. De Rijk, L. Rossi, J. Vlogaert, CERN.

The LHC accelerators, at present under construction at CERN Geneva, will make use of 1232 superconducting dipole magnets. The coils are wound with Rutherford type cable using NbTi alloy surrounded by a copper matrix for electrical and mechanical stabilization. The LHC machine will be operated at 1.9 K in superfluid helium. The unprecedented mass production of the superconducting dipole magnets, which involves three main contractors in Europe, is running steadily according to plan. This paper reports the outstanding technical issues encountered throughout the execution of the main manufacturing steps, which are the coil winding and curing, the 15-m long computer controlled welding, the high precision positioning operations for the cold mass finishing and the helium leak testing. The achieved production rates are discussed as well as the CERN plan for the completion of these important contracts.

FRM2OR3

The LHC dipole geometry as built in industry

M. Bajko, C. Rocio, C. Charrondiere, F. Savary, CERN. The LHC dipoles are produced with different production rate in 3 sites in Europe. The production is well advanced and more then half of the total quantity has been delivered to CERN. One of the most important characteristics of the dipoles is their geometry. To achieve the requested mechanical tolerances on the magnets, which are 15m long and approximately 28t-weight, the final assembly operations are submitted to precise optical measurements. To assure the good quality and the high rate of production, the final assembly procedure has been automated as much as possible. The author will report here about the assembly procedure, the features of the software that guides the optical measurements (and consequently the assembly operations) and the results obtained on the geometry in the 3 companies.

FRM2OR4

Modeling the structural behavior of the LHC superconducting dipole

M. La China, W. Scandale, CERN.

In superconducting magnets for particle accelerators the geometry of the cold mass is a crucial parameter to guarantee the field quality needed by beam dynamics. The issue is made even more challenging in the two-in-one LHC superconducting dipole where tolerances in the 0.1 mm range shall be guarantied over a length of 15 m, taking into account a weight of 30 tons. To reach this goal a large amount of geometrical checks and analyses are constantly carried out during all the stages of magnet assembly, handling, installation and operation. In this paper we present the structural models of the dipole by which the checks and the analysis are performed, the nature of the geometrical imperfections identified and the temporary or permanent shape modifications predicted. Comparison with the measured data are also discussed.

FRM2OR5

The Production of the low-beta Triplets for the LHC *R. Ostojic, M. Karppinen, T. Taylor, W. Venturini Delsolaro,*

CERN; A. Nobrega, C. Sylvester, G. Velev, J. DiMarco, J. Kerby, J. Strait, M. Lamm, M. Tartaglia, P. Schlabach, R. Bossert, R. Rabehl, S. Feher, T. Nicol, T. Page, T. Peterson, FNAL; A. Yamamoto, K. Tsuchiya, N. Kimura, N. Ohuchi, T. Nakamoto, T. Ogitsu, T. Shintomi, KEK.

The LHC performance depends critically on the low-beta triplets, located on either side of the four interaction points. Each triplet consists of four superconducting guadrupole magnets, which must operate reliably at up to 215 T/m, sustain extremely high heat loads and have an excellent field quality. A collaboration of CERN, Fermilab and KEK was set up in 1996 to design and build the triplet systems, and after nine years of joint effort the production has been completed in 2005. We retrace the main events of the project and present the design features and performance of the low-beta quadrupoles, built by KEK and Fermilab, as well as of other vital elements of the triplet. The experience in the tunnel installation of the first triplet and plans for commissioning in the LHC are also presented. Apart from the excellent technical results, the construction of the LHC low-beta triplets has been a highly enriching experience combining harmoniously the different competences and approaches to engineering in a style reminiscent of physics experiment collaborations, and rarely before achieved in accelerator building.

FRM2OR6

Quench Antenna Studies of Mechanical and Quench Performance in Fermilab Interaction Region Quadrupoles

M.A. Tartaglia, S. Feher, A. Hocker, M. Lamm, P. Schlabach, J. Tompkins, Fermilab; T. Ogitsu, KEK.

As part of the US-LHC collaboration, Fermilab has built and tested eighteen high gradient quadrupole magnets, assembled into nine cryostats, for installation at the Large Hadron Collider Interaction Regions. Most of these magnets have only quarter coil voltage taps for quench characterization, but the magnetic measurement warm bore is instrumented with a quench antenna for quench localization and characterization. We report on studies using the quench antenna for the pre-production prototype (with extensive voltage taps) and 18 production magnets. These include a summary of quench localization and development characteristics, as well as general features of flux changes observed during training ramps.

PLENARY SESSION (Maestrale room)

11:10 - 11:55

FRMPL1

Magnet Technology Beyond 50 T

H.J. Schneider-Muntau, NHMFL.

The highest continuous magnetic field generated today is 45 T. It is routinely made available with a hybrid magnet consuming 30 MW of electrical power. The step to 50 T is planned, and the development of a 60 T magnet has been recommended. There is no principal limit to the generation of even higher continuous fields; however power requirements soon become excessive because of insufficient strength and conductivity of the available materials. Fields of this strength can also be obtained with

pulsed magnets during milliseconds. Only modest investments are necessary, and may university laboratories have such a facility. Magnet technology above 50 T is dominated by the challenging task of handling the Lorentz forces. The induced stresses exceed by far the strength of all conductors. Design innovations and the use of reinforcement materials within the winding have pushed the limit to 80 T. 100 T multi-coil magnets, energized by energy storage systems of a 50 MJ capacitor bank or a 600 MJ generator, respectively, are in the planning or construction stage. At present, it appears not possible to generate fields above 100 T because of the lack of suitable materials. Magnet longevity is limited because the conductors undergo heavy plastic deformation and cyclic strain hardening. These magnets are, therefore, an excellent test bed for new concepts and materials. Above 100 T the Lorentz forces are so high, that the magnet necessarily explodes. Up to 300 T can be generated during microseconds by fast discharges into single-turn coils. Even higher fields are achieved by flux compression with electromagnetic fields (500 T) or explosives. The world record of 2800 T has been achieved in Sarov, Russia, with a three-stage cascade system and 170 kg of explosives. We present the single-turn coil and flux compression devices and their techniques. It is followed by a detailed description of the "multi-shot" magnets generating fields in the millisecond time range, and the technologies and solutions, which have been developed so far to cope with the Lorentz forces. We underline the urgent need for better high-strength, high-strain conductors, such as macrocomposites and/or nanocomposites with improved microstructure, and stronger high-modulus reinforcement materials, such as multiphase alloys and fibers.

AUTHOR INDEX

A

Abächerli, V. Abe, K. Abe, R. Abe, S. Abramian, P. Abreu, M. Acerbi F Adachi, E. Adachi, T. Adesso, M. Adetu, C. Adli, E. Adolphsen, C. Affinito, L. Agapov, N. Agatsuma, K. Ahn, M. C. Aiima, Y. Akimov, I. Akita, S. Akiyama, T. Aktas, S. Albertelli, P. Alekseev, P. Alessandria, F. Alessandrini, M. Alexeev, A. Alexiou, C. Amaldi, U. Ambrosio, G. Amemiya, N. Amm, K. Ammerman, C. Anashin, V Anderson S Andò, L. Ando, T. Andreev, N. Anghel, A. Angrisani L. Antaya, T. Antokhin, E. Aoki, I. Arai. H. Arai, K. Arakaki, Y. Araki, K. Arda, L. Ariante, M. Arikawa. M. Armenta R Arnaud, M. Arndt, T. Asano, T. Astrov, M. Asulay, S.

MOA2OR4, THA01PO03 MOA12PO09, WEA08PO03 THA09PO06, THM2OR2 THA05PO06 MOA07PO12 MOA02PO09 THA08PO05 THA09PO09 MOA08PO10 **THA01PO03** WEM3OR3 THA08PO09 MOA08PO09 WEA05PO10 THA07PO09, WEA08PO01 **MOA01PO08** MOA10PO04, TUA09PO05, TUA09PO06, MOA02PO10, THA03PO12, THA05PO03, TUA09PO04, WEA02PO05 MOA08PO02, MOM3OR1 TUA02PO01 THA09PO08 THA03PO11 MOA02PO13 THM2OR1 TUA02PO01 WFA3OR3 **TUA01PO11** TUA03PO05 THA12PO04 WEMPL1 MOA2OR3. THA01PO05 WEA07PO06 WEA07PO05. WEA07PO07. TUA2OR4 WEA07PO12, WEA07PO13 WEA05PO12, THA05PO02. THA02PO03. **TUA05PO01** MOA1OR6, THA12PO12 THA10PO03 TUA07PO12, WEA08PO05 MOA08PO01, MOA08PO09 WEA06PO06 THA11PO09, WEA12PO07 MOA03PO04, MOA2OR3, THA01PO05, TUA2OR4, WEA07PO01, WEA07PO05, WEA07PO06, WEA07PO08 MOA12PO02 WEA04PO01 TUM3OR3, WEM2OR4 MOA3OR6 WEA03PO09 MOA10PO03, MOA10PO06 MOA10PO06, MOA10PO03 MOM3OR4 THA05PO06 MOA02PO13 **TUA01PO02** TUA05PO06 TUA08PO05 THA08PO08, WEA3OR3, WEA3OR4 MOM2OR1 WEA10PO03, WEA10PO04 THA09PO07 THA02PO14

Atkins, A. Aubele, A. Aubert, G. Awaji, S.

Ayela, F. Azizov, E. Azumaya, S.

В

Baba, J. Baba, T. Baccaglioni, G. Bacon, J. Bae. D. K. Bae. J. Bae, J-H. Baek, S. Baek, S-M. Bagnasco, M. Bahl, R. Bai. Y. Baik, S. Baik, S-K. Bailey, I. R. Bajko, M. Baldan, C. A. Baldzuhn, J. Ballaguer, J. M. Ballinger, R. Balsamo, E. Banno, N. Bao, Q. Barbarino, S. Barber, D. P. Barber, W. Barkov, L. Barladyan, A. Barnes, M. Barnes, P Bartenev, V. Bartlett S Barzi, E. Bascuñán. J. Batrakov, A. Baynham, E. Bazzano, G. Beauquis, J. Beck. D. Beconto, J-M. Bednar, N. Behr, K. Bekhterev, V. Bellesia, B. Bellina, F. Bellomo, G. Belyakov, V. Benabderrahmane, C. Benson, S.

WEA1OR6 MOM2OR1 WEA1OR3, WEA1OR5 WEA01PO10, THA01PO02, TUA3OR1. WEA02PO06, WEA05PO01, WEA01PO08. WEA10PO06 WEA05PO03 TUA03PO05 TUA12PO07 MOA10PO07 THA09PO06, THM2OR2 THA08PO11, TUA02PO02 THA10PO03 MOA02PO10, MOA10PO04, THA03PO12, TUA03PO09, TUA09PO04, TUA09PO05, TUA09PO06, WEA02PO05 WEA03PO07 MOA09PO06, MOA09PO07, MOA09PO12, MOA09PO14, WEA09PO02 MOA11PO13, MOA11PO14, MOA11PO15 THA09PO02, TUA10PO09 MOA05PO02 MOA11PO12, THA11PO01 MOA03PO03 **TUA10PO05** TUA10PO07, WEA04PO06, WEA04PO07 TUA07PO14 FRM2OR3. FRM2OR2 MOA06PO04, MOA06PO07, MOA06PO10 TUA09PO02, MOA02PO09, WEA02PO13, WEA02PO15 MOA11PO09, MOA11PO08, WEM2OR6 **THA03PO02** WFM2OR4 WEA05PO10 WEA01PO12, MOA2OR4, MOA2OR6, WEA01PO02, THA01PO10. WEA01PO09. WEA01PO11 MOA10PO10, TUA10PO01, TUA10PO14 WEA06PO06 TUA07PO14 THA12PO12 WEA08PO05, WEA08PO06 WEA08PO05 **TUA08PO05 TUA01PO05** THA07PO09 WEA07PO11, WEA07PO12 THA01PO05, TUA2OR5. MOA2OR3, THA04PO04, TUA2OR4, WEA05PO09, WEA07PO05, WEA07PO07, WEA07PO08 THA12PO07, THA12PO08, TUA01PO07 TUA07PO05 THA08PO04, WEA3OR1. TUA02PO02 TUA07PO14, TUA08PO04 MOA11PO07 MOA06PO10, TUA04PO11 TUM3OR3 **THA12PO13** MOA02PO01 THA07PO11 **TUA08PO08** MOA06PO06, MOA06PO09 MOA05PO02, TUA04PO06 **TUA01PO10** THA09PO07 MOA07PO05 TUA07PO11

TUA07PO01 Bernhard, A. MOA01PO05, MOA01PO06 THA08PO09, THA08PO01. THA08PO10, THA08PO08 WEA3OR3, WEA3OR4 Bersgma, F. THM3OR3 MOA06PO02 Bertarelli, A. Berthollon-Vitte, S. MOA06PO05 MOA02PO05, MOA02PO06, MOA06PO05, MOA06PO06 WEA04PO05, WEA1OR2 Bessette, D. MOA12PO06 TUA07PO09 TUA01PO06, TUA1OR2, TUA1OR3 MOA11PO11 Bhattacharya, R. TUA07PO11 MOA10R3 **TUA06PO02** Bigansolli, A. THA02PO07 TUA06PO06 TUA3OR2 **THA05PO09** THA10PO01. THA10PO02. WEA10PO05, WEA10PO07 Birumachi, T. MOM3OR5 WEA07PO15 Blackburn, R. TUA08PO05 Blackmore, E. TUA02PO02 THA07PO10. THA12PO07, TUA01PO07 TUA01PO02, TUA1OR1 THA07PO01, THA07PO02, THA07PO07 Bogdanov, I. TUA08PO08 Bogomolov, S. TUA01PO06 Bohnenstiehl, S. TUA3OR3, TUA3OR6, WEA10PO05 Bolshakova, I. MOA3OR6 MOA07PO04, TUA03PO05, WEA06PO05 Bondarchuk, E. TUA3OR2 Bonito Oliva, A. TUA11PO03, TUA11PO04 Borburgh, J. **TUA08PO03** WEA07PO05, WEA07PO12, WEA07PO13 WEA09PO09 THA06PO06 WEA12PO04 WEA07PO08. FRM2OR5. TUA2OR4, WEA07PO03, WEA07PO05 Botcharova, E. FRM10R4 Boter-Rebollo, E. MOA06PO05, MOA06PO06 TUA04PO08, TUM2OR1, MOA3OR5 TUA02PO03.TUA04PO10. TUA06PO04 TUA06P005 WEA01PO03, WEA04PO01 WEA03PO07 MOA07PO05, MOA07PO09 WEA12PO01 Bourquard, A. Boutboul. T. TUA02PO05, THA01PO14, TUA02PO04 TUA06PO09 THMPI 1 MOA01PO05 MOA01PO06 TUA10R1 TUA07PO14 Bradshaw, T. WEA08PO06, MOA04PO07 Brandsberg, T. TUM3OR3 WEA1OR5, WEA3OR6 WEM3OR3 TUM3OR3 TUA07PO05 THA08PO06, THA08PO10, WEA3OR4 MOA07PO12 MOA07PO05

THA07PO05

THA08PO07.

TUA02PO02,

TUA3OR6.

THA12PO08,

TUA06PO12.

MOA06PO03,

THA12PO13,

TUA04PO11.

TUA06PO11.

Berlinghof, S.

Bernini, C

Berriaud, C.

Bertinelli, F.

Besio, S.

Bettoni, S.

Bhatia. M.

Biallas, G.

Bianchi, A.

Bidon, S.

Billan, J.

Bindi, M.

Bird. M.

Blau, B. Bobrov, E.

Bocchi, M.

Bole S

Bora, D.

Bordini, B.

Bordry, F.

Boso, D.

Bossert. R.

Bottura, L.

Boucher, B.

Bouillie, L.

Boyer, C.

Bowles, E.

Braccini V

Bragin, A.

Bredy, P.

Breschi. M.

Brindza, P.

Briquez, F.

Broggi, F.

Brueck, H.

Brunelle, P.

Biltcliffe, M.

Bruzzone, P. Buffat P Bulatov, A. Burgmer, R. Burnet, J-P. Bursikov A Buskop, J. Buta. F. Buzio, M. С Cai, G. Cakiroglu, O. Calero, J. Calvi, M. Campbell, A. Campelo, F. Campi, D Cantoni, M. Cantrell, K. Cao, S. Capiluppi, M. Carcagno, R. Carr, S. Carson, J. Cartegni, G. Carvalho-Junior. F. Caspi, S. Catalan Lasheras, N. Cataneo, F. Cavaliere, V. Cazaux S Celona, L. Cha. G. Chamizo, R. Chan, J. Chang, C. Chang, C-H. Chang, H. M. Chang, T. Chao, C. Charifoulline, Z. Charrondiere, C. Chen, B. Chen. C. Chen. H. Chen, H-H. Chen, I. Chen, J. Chen, J-R. Chen, K-M. Chen, S. Chen, S-Y. Chen, W. Chen, Y. Cheon, H-G. Cherdakov, A. Chernyak, N. Chiarelli, S. Chichili, D. R.

THM1OR6, TUA11PO07, WEM2OR2, MOA3OR5, MOA12PO02, THM10R3. **TUA11PO05** THA01PO06 MOA02PO04 TUA06PO10 WEA09PO09 MOA12PO08, WEA12PO09 THA08PO04 TUA01PO06, TUA1OR2 TUA04PO10. TUA04PO11 MOA06PO02 TUA06PO04, TUA06PO05, TUA06PO06. TUM2OR1 TUA04PO02 MOA02PO13 MOA07PO12 MOA06PO03, WEA01PO03. WEA04PO01, TUA06PO04 MOA10PO11, MOA10PO12, WEA06PO12 TUA03PO06 THA04PO08, WEA3OR5, WEA3OR6, WEA3OR7 THA01PO06 TUA2OR2 MOA05PO04, THA06PO12 TUA08PO10 TUA07PO03, TUA07PO04, TUA2OR4, TUM2OR3, WEA07PO05 THA08PO04, TUA07PO14 TUA06PO12 THA08PO11, TUA02PO02 WEA02PO15 MOA3OR1, WEA07PO02, WEA07PO03, TUA2OR5, WEA07PO08, WEA07PO11 Cassiolato De Freitas, R. WEA02PO13 TUA06PO07 **THA08PO11** THA04PO10, TUA01PO02 THA08PO01, THA08PO08 WEA06PO06 THA05PO04. THA05PO08 MOA06PO10 MOA08PO09 **TUA07PO08** TUA03PO07, TUA07PO06 MOA02PO10, MOA10PO04, TUA03PO09 TUA10PO10 THM2OR3 TUA02PO06 FRM2OR3 WEA03PO08, TUA10PO06, WEA04PO03 WEA08PO02 WEA11PO10, THA06PO05, TUA04PO07 TUA03P007, TUA07P006, TUA07P008 THA02PO12, WEA11PO08 THA12PO03, MOA01PO11, WEA06PO09 TUA03PO07 THA02PO12 **THA11PO03** THA02PO12, WEA11PO08 **THA11PO03** THA12PO06 TUA10PO09, MOA09PO13, THA09PO02 TUA03PO05 MOA02PO04 THA01PO09, WEA05PO10 TUA06PO12

MOA04PO03, MOA11PO06, THA09PO06, Chikaraishi, H. THM2OR2 MOA09PO07 Cho. J. MOA09PO06, MOA09PO09, MOA09PO10, Cho, J-W. MOA09PO12, MOA09PO13, MOA09PO14, WEA03PO07, WEA09PO02 Cho, K-W. MOA11PO14, MOA11PO15, WEA01PO05 Cho, Y-S. TUA09PO10, TUA09PO13, TUA09PO15 Choi, H-S. MOA10PO15, THA06PO11, TUA09PO10. THA06PO09, TUA09PO07 TUA09PO09. TUA09PO13, TUA09PO11 TUA09PO14, **TUA09PO15** Choi, J. Y. MOA11PO02, MOA11PO03 THA09PO04, TUA10PO10, TUA10PO11, Choi, K-D. **TUA10PO12** THA04PO11. THA02PO10, THA05PO03. Choi, S. THA05PO11 WEA10PO11, WEA03PO10 Choi, Y. S. MOA11PO14, MOA11PO07, MOA11PO13, Chu, Y. MOA11PO15 Chubar, O. TUA07PO05, WEA06PO10 Chung, D-C. **TUA09PO13** Chung, W. MOA11PO07, MOA11PO13, MOA11PO14, MOA11PO15 MOA04PO06 Chung, Y. Churkin, I. TUA07PO05 THA02PO15 Ciaccia S Ciavola. G. TUA08PO06 WEA06PO06 Ciazynski, D. THM1OR3, WEA12PO05, WEM2OR5 Cioffi, M. THA04PO10, TUA01PO02 TUA05PO03, TUA05PO09 Ciszek, M. TUA08PO10 Ciullo. G. Civale. L. MOA01PO07 TUA07PO14 Clarke, J. Claypool, B. MOA04PO01 WEA12PO08 Cloez, H. TUA04PO11, TUA06PO05, WEA01PO03 Coccoli, M. THA10PO03 Coe, H. TUA1OR2, WEA01PO01, TUA01PO06, Collings, E. TUA10R3 Comel, S. MOA02PO06 Consoli, F. WFA06PO06 TUA08PO10 Contalbrigo, M. TUA07PO14 Cooke, P. Coombs, T. WEA06PO12 FRM2OR2, MOA06PO04, MOA06PO07 Cornelis, M. Cornuet, D. THA12PO13, TUA06PO01, TUM2OR1 MOA02PO14. MOA02PO15 Cosovic. V. THA04PO08 WEA3OR7 Cure B THA02PO07 Cursino, E. Czabaj, B. MOM2OR2 D Daël, A. THM3OR1. MOA07PO05, MOA07PO09, **TUA07PO05** WEA03PO08, WEA04PO03, WEA06PO12 Dai, S. Dai, T. **TUA03PO10** WEA10PO02, MOM10R2, TUA10P TUA11PO02, WEA09PO01, WEA10PO01 TUA10PO02 Dai. Y. Dainton, J. B. **TUA07PO14** TUA08PO10 Dalpiaz, P. F. FRM10R6 Das Virgens, M. MOA07PO08 Das S TUA08PO08 Datskov, V. THM3OR2 De Almeida, C. **THA02PO15** De Biase, S. MOA04PO04 De Cesaris, I.

WEM10R2

THA11PO04

TUA06PO01

MOA06PO07,

FRM2OR2

De Rujula, A. Debray, F. Decool, P Dedikov, Y. Deferne G Del Frate, L. Delauter, J. Della Corte, A. Demachi, K. Demencik, E. Den Ouden, A. Denarie, C. Denis, O. Denz, R. Dergunova, E. Deront, L. Desavouret. E. Devred, A. Di Zenobio, A. Diaczenko, N. Diduszko, R. Dietderich, D. DiMarco, J. Dixon, I. Dizon, J. Dmitriev, S. Doinikov, N. Dolgetta, N. Dolron, P. Dong, Z. Dou. S. Drago, G. Drobin, V. Drobishev, V. Duchateau, J-L. Ducret J-F Dudarev, A. Dunkel, O. Durante, M. D'Urzo, C. Ε Edaya, M. Efremov, A. Egawa, K. Eginard, D. Egorov, S. Ehmler, H. Eichhorn, R. El-Kallassi, P. Flliott T Enpuku, K. Fom C Erashok, V. Escallier, J. Esser, F. Evssa, Y. Eyßelein, F. Ezaki, T. F Fabbri, M.

TUMPL1 WEA10PO10 WEA12PO08, WEA12PO01 WEA03PO01 TUA04PO11, TUA06PO04 **THA01PO05** MOM3OR2 THA01PO09, THM1OR3, THM1OR6, WEA05PO10 MOA05PO06 **TUA01PO05** THA01PO14 THA01PO12. THA07PO07. **THA11PO04** MOA2OR3 MOA06PO02 **THA03PO01** THA01PO13 **THA08PO09** TUA04PO05 TUA2OR3, MOA03PO09, MOA3OR3, TUA04PO08, WEA05PO03 THA01PO09. WEA05PO10 WEA07PO15 MOA01PO10 TUA07PO13, TUA2OR5, WEA01PO01, WEA07PO03, WEA07PO08, WEA07PO11 FRM2OR5, TUA04PO05, TUA06PO04 WEA10PO07, TUA3OR3 **THA02PO08** TUA08PO08 WEA06PO05, MOA07PO04 WEA12PO01, WEM2OR5 MOA1OR4, MOA1OR5 TUA03PO04 TUA10R2 THA08PO05, THA12PO13 TUA08PO08 MOA10R2 WEM2OR5 WEA08PO07 THA08PO10, WEA3OR4, THA08PO01, THA08PO02 THA08PO04 THA08PO07, THA08PO08, THA08PO09, WEA3OR3 TUA06PO04 TUA06PO10, TUA2OR3 WEA3OR5, WEA3OR6 **MOA12PO03** TUA08PO08, WEA08PO01 THA01PO01, THA02PO02 THA03PO02 THA09PO07. MOA12PO08, TUA02PO03, WEA12PO09 MOA11PO10, MOA11PO09 **THA07PO03** MOA06PO02, WEA3OR7 WEA07PO15 MOA10PO13 MOA01PO11 MOA3OR6 TUM2OR2 THA07PO03 THA10PO01 TUM3OR1 WEA09PO05

THA09PO01, WEA06PO08

De Gersem, H. De Groot. B.

De Rijk, G.

MOA06PO04.

Fabich, A. Faltens A Fan, C. Fan, K. Fan, T. Fan, Y. Fan, Z. Fanciulli, C. Fang, H. Fang, Y. Farinon, S. Fazilleau, P. Fedotova, S. Feher, S. Felice, H. Feng, J. Feng, Z. Ferdeghini, C. Fernandez Cano, E. Ferracin, P. Ferrando, V. Ferrari P Fessia, P. Field, M. Fietz, W. Fievez, G. Figueira, D. S. S. Filatov, O. Filippov, Y. Fillunger, H. Fischer, E. Fishman, V. Fix, A. Flegel, W. Flükiger, R. Fontana, F. Formisano, A. Foster, W. Foussat A Frank, M. Frauenhofer, J. Freitas, R. Freude, W. Freudenberger, J. Friedman, A. Frings, P. Frosini. L. Fu K Fu, Y. Fuchino, S. Fudanoki, F. Fujimori, H. Fujimoto, H. Fujisawa, T. Fujitsuna, N. Fujiwara, A. Fukai, S. Fukasawa, Y. Fuke, H

Fabbricatore, P.

WEA3OR5 MOA2OR5, TUA05PO04, TUA08PO04, WEA3OR6 **TUA08PO12 TUA08PO13** WEA11PO10 TUA08PO02. MOM3OR4 TUA07PO06 TUA07PO08 MOA09PO01 THA06PO02 MOA01PO05, TUA1OR1 **TUA01PO11** TUA03PO08, THA12PO02, THA06PO08. WEA04PO02 TUA05PO04, WEA07PO09 TUA01PO10 TUA08PO04, WEA3OR5 **THA04PO08** THA09PO07 TUA2OR4, WEA07PO05, FRM2OR5, FRM2OR6 TUA06PO12. WEA07PO12, WEA07PO13 MOA3OR3, TUA2OR3 WEM2OR4 THA03PO09 MOA2OR5 MOA06PO01, MOA06PO02 WEA07PO11, WEA07PO12, MOA3OR1. WEA07PO02, WEA07PO03, WEA07PO13 MOA01PO11 THM2OR1 MOA02PO07, MOA03PO08, TUM3OR2 MOA06PO02, MOA06PO04, FRM2OR2, MOA06PO07, MOA06PO11, MOA3OR3 MOA2OR1 MOA3OR5, TUA11PO06, WEM2OR5 TUA04PO10 **TUA09PO02** THA09PO07 WEA03PO01 MOA11PO08, MOA11PO10 THA07PO06, THA07PO08 THA07PO10 TUA02PO03, WEM10R2, WEM10R3 WEA08PO02 WEM2OR3 THM3OR3 TUMPL2, MOA2OR4, THA01PO03, THA01PO06, WEA01PO12 THA05PO09 TUA10PO13, THA04PO10 MOA04PO01, TUA07PO02, TUA07PO03, TUA07PO04, WEA03PO04, WEM1OR4 THA08PO12, THA08PO01 MOM10R1 MOM10R1 TUA09PO02 THA03PO05 FRM10R4, THA10PO04 THA02PO14 FRM1OR1, MOA1OR5 MOA04PO09 THA06PO05 MOA12PO05 MOA01PO08 MOA02PO05 MOA08PO05 THA02PO05, TUA12PO04, WEA02PO03 MOA09PO05, MOA3OR6 MOA12PO04 TUA12PO04 WEA02PO03 THA03PO03 MOA03PO05 WEA08PO03

Fukui, S.

THA05PO05,

TUA03PO03,

THA05PO07,

TUA05PO06.

THA05PO06,

TUA05PO09.

Fukumizu, S. Fukuzaki, T. Funaki, K.

Furumura, Y. Furuse, M.

Furushiba, K. Fushiki, K.

G

Gaddi, A. Gaganov, A. Gaggero, G. Gagliardi, P. Galatà, A. Galbraith, P Gambardella, U. Gammino S Ganetis. G. Gao, D. Gao, W. Garcia Perez. J. Garcia-Tabares, L. Gardner. C. Garnier. D. Gärtner, W. Gastineau, B. Gaud, V. Gavrilin, A. Gehring, R. Genini I George, D. Gerard, D. Gerwig, H. Ghivelder, L. Ghosh, A. Gianesin, B. Gianni. L. Giencke, J. Gilgrass, G. Giloteaux, D. Ginocchio, S. Ginzburg, S. Gislon, P. Giudici. P. Giunchi, G. Glaude, D. Godeke, A. Goedheer, W. Gokyu, S. Gömöry, F. Gong, L. Good. J. Gourlay, S. Govardhan, G. Graafsma, H. Granata, V. Granieri, P. P. Grantham. C. Grasso. G. Graves, V.

TUA05PO10, WEA11PO06 TUA3OR5, WEA10PO08 **THA12PO11** MOA10PO13, THA04PO07, THA04PO13, TUA05PO05 TUA05PO06, WEA05PO06 THA05PO10, MOA01PO08, MOA03PO05. MOA10PO03, MOA10PO06, THA05PO06 MOA10PO07 MOA10PO07 WEA3OR5, WEA3OR6 FRM10R4, THA10PO04 TUA06P009 THA08PO05 WEA06PO06 TUA06PO06 MOA2OR5 WEA06PO06 TUM2OR2 THA11PO03 THA12PO05 TUA06PO06. MOA06PO01. TUA04PO10. TUA04PO11, TUA06PO04, TUM2OR1 MOA07PO12 TUA08PO05 THM1OR2, THA11PO02 TUM3OR1 WEA08PO07 MOA07PO11 MOA10R1, THA10PO01, THA10PO07, TUA2OR2 TUA07PO07, WEA09PO09 MOA11PO09 MOA07PO10 TUA06PO01, TUA06PO02 WEA3OR6 FRM10R6 THA07PO07, TUA2OR5 WEA10R4 **THA05PO09** MOA01PO11 WEA1OR6 TUA06PO06 THA05PO09 WEA02PO01 WEA05PO10 THM3OR3 THA02PO15 MOA06PO05 **THA01PO12** THA11PO04 MOA02PO02 THA05PO01, TUA05PO04 MOA09PO01 WEM3OR1 TUA2OR6 WEA07PO02, WEA07PO03, WEA07PO11, WEA07PO13 **TUA11PO03** WEA02PO14 TUA04PO08, WEA07PO10 WEA01PO03 THM2OR3 TUA1OR1, MOA01PO06, MOA01PO05. TUA10R4 TUA08PO12

Greco, M. Green, M. Greenshaw, T. Grujic, A. Gu, G. Guan. L Guan, Y. Guillochen, J. Gundlach, S. Gung, C. Guo. H. Gupta, G. Gupta, N. Gurieva, T. Gurov, S. Gussen, A. Gustke, D. Gutierrez J

Η

Ha, D-W. Hafalia, R. Hagen, P. Hahakura, S. Hahn, S. Y. Hahn, S-Y. Hales, P. Hamabe, M. Hamada, K. Hamaguchi, S. Hamajima, T. Han, B-S. Han, F.

Han, J. Han, J-H. Han, K.

Han, S.

Hanai, S. Handke, J. Hans, O. Harada, N. Harjo, S. Harkema S Harlet P Harrison, S. Hartig, P. Hartikainen, T. Hasegawa, K. Hasegawa, M. Hasegawa, T. Hashimoto, M. Hatabe, Y. Havens, T. Havakawa, K. Hayashi, H. Hayashi, K. Hayashi, S. Hayashi, T. Hays, S. He, C.

THA03PO11

TUA12PO06

TUA05PO05

MOA05PO03

TUA3OR5, WEA10PO08

THA09PO05,

WEA09PO10, MOA10PO13,

THA04PO07, THA04PO13, TUA12PO04

MOA04PO01. TUA07PO04. WEM10R4

MOA2OR5, TUA01PO10, TUA05PO04. WEA3OR5, WEA3OR6 MOA3OR2, TUA08PO04, WEM3OR2 **TUA07PO14** MOA02PO14, MOA02PO15 TUA10PO06, WEA03PO08 THA03PO08 TUA04PO09 MOA10PO10, TUA10PO01, TUA10PO14 WEA08PO02 THA10PO01 TUA08PO13, WEM2OR4 TUA10PO06, WEA03PO08, WEA04PO03 MOA11PO11 MOA11PO11 MOA12PO08 MOA07PO09 THA07PO03 MOA11PO08 MOA07PO12 WEA01PO13 WEA07PO03. WEA07PO11 TUA06PO11, FRM2OR1, TUA06PO05, TUA06PO10 MOM2OR5 THA12PO07, THA12PO08, TUA01PO07 THA09PO04, TUA10PO10, TUA10PO11, **TUA10PO12** TUA01PO04 WEA03PO09 MOA12PO04, MOA12PO09 MOA11PO06 MOA09PO02, MOA09PO05. THA12PO09. **TUA11PO09** MOA10PO15, THA02PO13, TUA09PO07, TUA09PO09, TUA09PO10, TUA09PO11, TUA09PO13, TUA09PO14, TUA09PO15 **TUA08PO01** TUA10PO01. TUA10PO14 THA09PO04, TUA10PO11, TUA10PO12 FRM10R2, THA10PO02, THA10PO05, WEA01PO13, WEA01PO14 MOA03PO01, MOA03PO02, TUA04PO01, TUA04PO02, TUA04PO03, TUA04PO04 THA09PO09, TUA12PO09, TUA12PO10 MOM2OR4 TUA06PO02 MOA09PO05 WEA01PO10 WEA02PO14 MOA02PO06 TUA01PO04 MOM10R1 WEA2OR2 MOM2OR5 THA01PO01 MOM2OR3 TUA12PO08 WFA09PO10 THA12PO12

Healey, D. Heller, R. Henchel, W. Henmi, T. Henninger, P. Herlach. F. Herrmannsdoerfer, T. Hertel, K. Herve, A. Hervieu B Hess, G. Hiatt. T. Higashi, N. Higashikawa, K. Higuchi, M. Higuchi, T. Hikichi, Y. Hirabayashi, H. Hirakawa, M. Hirano, H. Hirano, N. Hirano, S. Hiraoka, T. Hirohashi, M. Hirose, E. Hirose, R. Hirota. N. Hishinuma, Y. Hocker, A. Hoelting, A. Hoffmann, C. Holtom, E. Holyaka, R. Hong, G-W. Hong, J-P. Hong, S. Horii, S. Horiuchi, Y. Horvath I Hoshino, T. Hotchi, H. Hotta. Y. Hou. Z. Hourican, M. Hsiung, G-Y. Hsu, S-N. Hu. G. H. Hu, J. Huang, H. Huang, M. Huang, S. Huang, W. Huang, X. Huang, Y. Hui, D. Humeau M Hur. J. Hušek, I. Hwang, C-S. Hwang, S-D. Hwang, Y. Hwang, Y. I. Hwangbo, H.

He. Y.

TUA04PO02, TUA04PO01. TUA04PO03. MOA03PO01, MOA03PO02, MOA07PO02. THM3OR4, TUA04PO04, TUA08PO01 WEA03PO07 TUA11PO06, MOA3OR5, WEA12PO05 WEA07PO15 THA09PO06, THM2OR2 THA12PO04 FRM10R5 FRM10R1 MOA10R3 MOA11PO09 THA04PO08 WEA10R5 THA07PO05, THA07PO11 TUA07PO11 MOA08PO02, MOM3OR1 WEA09PO03 TUA02PO07 TUA05PO06, WEA01PO02, WEA05PO06 MOM2OR3 TUA01PO09 MOA01PO03 MOA10PO13, WEA02PO03 MOM2OR3, THA02PO09, THA09PO09, WEA09PO06 TUA12PO09, TUA12PO10 MOA09PO05 WFA05PO11 MOA08PO03, MOA08PO04, MOM3OR5 TUA3OR5 WEA10PO08 TUA12PO05 TUA02PO08, WEA12PO07 FRM2OR6 MOA11PO09 MOM2OR4 THA08PO04 MOA3OR6 TUA10PO10, TUA10PO12 TUA05PO11, WEA04PO06, WEA04PO07 MOA2OR1, MOM2OR2 MOA01PO09, THA02PO06, THA02PO11 WEA09PO05 TUA02PO02 MOA04PO06, MOM10R3 **TUA08PO09** MOA02PO02 TUA02PO09 **TUA08PO03** TUA03PO07 TUA03PO07 THA03PO09 TUA02PO09 WEA09PO01 TUA07PO06, TUA07PO08 TUA02PO09 MOA05PO04, THA06PO12 WEMPL2, MOA1OR6, THA12PO12 WEA03PO04, WEA11PO07, WEM10R4 TUM10R3, TUM10R5 THA08PO08 MOA01PO08 TUA10R5 TUA07PO06, TUA03PO07, TUA07PO08 MOA09PO08, THA02PO13, TUA09PO03 **TUA10PO12** TUA10PO11 **THA05PO11**

Hyun, O-B.

Ι

lakovlev, B. leiri, M. Igarashi, H. Igarashi, M. Igarashi, S. lijima, T. lijima, Y. lino, M. lkehe M Ikeda. B. Ikeda. T. llie, S. D. llyin, Y. Imagawa, S. Imaizumi, H. Imayoshi, T. Inaba, M. Inagaki, J. Incurvati, M. Inokuchi, S. Inoue. I. Inoue, K. loka, S. Irie, Y. Iro, H. Ise, T. Ishida, M. Ishigohka, T. Ishigouoka, T. Ishiguri, S. Ishii, Y. Ishiyama, A. Ishizuka, M. Isobe T Itoh, K. Itoh, M. Itoki, A. Itou, T. Ivanov, D. P. Ivanyushenkov, Y. lvkin V Iwabuchi A lwaki. G. Iwakuma, M. Iwamoto, A. Iwamura, T. Iwasa, Y. Iwase, H. Iwashita, Y. Iwata, S. Iwayama, I.

J

Jacquemod, A. Jain, A. Jain, V. THA03PO02

MOA07PO07

TUM2OR2

Izquierdo, G. A.

Izumi, S.

Izumi, Y.

MOA10PO14, THA03PO10, TUA09PO03, TUA09PO11, TUA09PO12

TUA08PO08 MOA08PO03 TUA03PO06, WEA05PO08 TUA12PO09, TUA12PO10, WEA2OR1 MOA08PO05 WFA01PO04 WEA01PO11, MOA2OR6, THA01PO10. TUA02PO08, TUA05PO01, WEA01PO09 MOA01PO04 WEA02PO03 THA01PO01 WEA01PO02 MOA06PO02 THA01PO07. THA01PO08, WEA01PO01. WEA12PO06 MOA11PO06, MOA11PO01 WFA11PO06 WEA09PO05 MOA10PO06 **THA09PO09** MOA04PO04 WEA09PO05 TUA02PO07 MOA02PO11, TUA02PO08, TUM1OR2 THA09P009 MOA08PO05, MOA08PO06, MOA08PO07, MOA08PO11. TUA08PO09 THA12PO04 THA09PO08 MOA04PO03 MOM10R4, MOA10PO06 MOA04PO02, MOA10PO03 TUA03PO03 THA02PO06 WEA05PO05, WEA05PO07, MOA04PO08, TUA12PO07, WEA05PO11 TUA3OR1 MOA04PO08 THA02PO04, WEA01PO07 MOA02PO02 TUA3OR5 TUA3OR1 THA11PO01 TUA07PO14, TUA08PO04 MOA07PO04 MOA05PO05 THA01PO11, MOA2OR6 THA04PO13, THA04PO07, THA09PO06. THM2OR2, TUA05PO05 MOA11PO06, WEA03PO05 MOA03PO05 THA03PO10, THA12PO07, THA12PO08, TUA01PO07 **THA07PO11** MOA03PO07, MOA07PO06, MOA3OR6 MOA09PO11 MOA01PO09 MOA06PO02 MOA08PO07, MOA08PO11 THA12PO09. THA12PO10

Jaisle, A. Jamet, O. Jan, J. Jang, H. Janowski, T. Jansak, L. Jarvis, P. Jeanneret, B. Jeckle, A. Jensen, D. Jeong, S. Jewell, M. Jiang, Z. Jin, X. Jo, Y. Jo, Y-S. John, A. Jones, H. Jong, C. Jongbloets, H. Joo, H-G. Joo. J. Joo, J-H. Joo, M. Joss, W. Juengst, K. Jung, H-K. Jung, J-Y. Jung, S. B. Junker, S. Juster, F. Κ Kagan, V. Kairys, R. Kaiikawa. K. Kakimoto, K. Kakui, H. Kalimov, A. Kamijo, H. Kamikado, T. Kamiya, J. Kamiyama, T. Kaneiwa, H. Kaneyama, M. Kang, H. Karmarkar, M. G. Karpov, S. Karppinen, M. Kasaba, K. Kasahara. H. Kashikhin, V. Kasukabe, T. Katagiri, K. Kataoka, A. Kataoka, T. Kato, K. Kato, T. Kato, Y. Katoh Y

WEA07PO15 THM3OR3 TUA07PO06, TUA07PO08 MOA09PO07 TUA09PO08, WEA05PO13 **TUA01PO05** WEMPL2 MOA06PO01 MOA11PO10 MOA08PO01, MOA08PO09 MOA11PO07 **THA01PO12** TUA05PO01, WEA05PO12 WEA06PO01 TUA10PO07 TUM10R1 MOA11PO05 FRM10R1, THA10PO04, TUA01PO04 MOA12PO05 WEA10PO10 TUA10PO11, TUA10PO12 THA02PO10, THA04PO11, THA05PO11 TUA05PO11 THA03PO12, TUA09PO06 WEA10PO10 WEA09PO09 THA09PO04 WFA06PO10 THA02PO10 THA08PO09, WEA3OR4 WEA10R5 TUA12PO01 THM10R5 MOA10PO13, TUA05PO05 TUA05PO01 MOA12PO09 MOA03PO06, THA07PO04 TUA12PO08 TUA3OR5 MOA08PO08, MOM3OR3, MOA08PO05, MOA08PO06, MOA08PO07, MOA08PO11 WEA01PO10 MOA02PO11 TUA12PO04 THA05PO03, MOA02PO10, THA03PO12, TUA03PO09, TUA09PO04, TUA09PO05, WEA02PO05 MOA07PO07, MOA07PO08, TUA08PO07, WEA06PO07 MOA04P007, WEA08P005, WEA08P006 TUA06PO09, FRM2OR5, TUA06PO08 WEA02PO02 WEA11PO03 MOA03PO04, MOA3OR4, TUA07PO03. WEA07PO01, THA01PO05, MOA03PO04 TUA07PO02, TUA07PO04, TUA2OR4 TUA2OR4, WEA07PO01, WEA07PO03, WEA07PO05, WEA07PO08, WFA07PO12 WEM10R4 WEA03PO09 THA01PO11, WEA01PO08, WEA01PO10, WEA02PO02 TUA05PO02 **TUA09PO01** MOM3OR5 TUA12PO06 MOA08PO03 MOA08PO04

MOA01PO09 Katsura, Y. THA07PO02, THA07PO07, THA07PO10 Kaugerts, J. Kauschke, M. THA07PO05, TUA02PO03 Kawabata, S. THA02PO09 Kawagoe, A. THA09PO06, THA02PO09, THM2OR2 Kawai, M. THA08PO03 Kawakami, K. WEA03PO09 MOA08PO05, MOA08PO06, MOA08PO07, Kawakubo, T. MOA08PO08, MOA08PO11, MOM3OR3 Kawanami, R. MOA04PO02 Kawashima, S. THA09PO09 WEA05PO08 Kawawada, N. TUA02PO01, TUA11PO01, WEM2OR3 Keilin. V. Kenney, S. TUA3OR3 FRM2OR5, TUA06PO12 Kerby, J. THM10R2 Kesner, J. Khavin N TUA07PO10 WEA02PO01 Khavronin, V. MOA10R2 Khlebova N THA07PO08, THA07PO09, WEM1OR3 Khodzhibagiyan, H. WEA10PO03. WEA10PO04 Kido, G. MOM2OR3, WEA09PO06 Kidoguchi, K. Kihara, K. **THA10PO03** WEA01PO09, MOA2OR6, THA01P TUA02PO08, WEA01PO11, WEA07PO07 Kikuchi, A. THA01PO10, WEA01PO04 Kikuchi, Y. Kim, C. S. MOA11PO02, MOA11PO03 MOA10PO01 Kim, C-H. MOA11PO02, MOA11PO03 Kim, D. J. WEA03PO10, THA04PO12, WEA10PO11 Kim, D-L. TUA03PO09 Kim, H. Kim, H. J. MOA09PO06, WEA02PO04 **TUA09PO12** Kim, H. M. Kim, H. S. THA02PO10 Kim, H-H. WFM2OR4 WEA09PO02, MOA09PO12 MOA09PO07 Kim, H-J. MOA09PO12. MOA09PO13, MOA09PO14, THA09PO02 Kim, H-M. MOA10PO14, THA03PO10, TUA09PO06, WEA02PO05 Kim, H-R. MOA10PO14 MOA09PO12, MOA11PO14, WEA01PO05, Kim, J. WEA01PO06 Kim, J. H. THA02PO10, THA04PO11, THA05PO11 MOA11PO13, MOA11PO15 Kim, J. S. MOA09PO06, MOA09PO07 Kim, J-H. MOA11PO07, MOA11PO13, WEA01PO05, Kim, K. WEA01PO06 Kim, K-C. WEA04PO04 MOA09PO06, TUA10PO05. WEA04PO07. Kim, S. WEA09PO02 MOA01PO04, TUA05PO11 Kim, S-B. MOA02PO10, MOA09PO13, MOA09PO14, Kim, S-H. THA09PO02, TUA10PO07, TUA10PO09 Kim, S-W. TUA05PO11, WEA03PO04 TUA03PO09 Kim, T. THA05PO03 Kim, T. J. THA09PO04, TUA10PO10, Kim, W-S. TUA10PO11. **TUA10PO12** Kim, Y-C. TUA10PO05, TUA10PO07 Kimura, A. TUA02PO07 FRM2OR5, MOA08PO02, MOM3OR1 Kimura, N. Kinder, H. MOM2OR4 TUA06PO07 Kirby, G. Kircher, F. THA04PO08, WEA3OR6, WEM2OR5 Kirchhoff, L. MOM2OR1 Kirk, H. **TUA08PO12** TUA06PO01, TUA07PO12 Kiselev, O MOA01PO09, MOA09PO08, THA02PO06, Kishio, K. THA02PO11, TUA09PO03, WEA11PO05 MOA08PO10 Kishiro, J.

Kitaev, B. Kitaguchi, H. Kiyoshi, T. Kizu, K. Klein, H-U. Kleyn, A. W. Klimenko, E. Klos, F. Knoke, E. Knonll, D. Knooke, J. Ko, T. K. Kobayashi, N. Koch, S. Kodaira, N. Koh, D. Koh, D-Y. Koizumi, N. Kojima, R. Kolesnikov, D. Kolokolnikov, Y. Komori T В Kong, L. Konno. H. Konovalov, Y. Konstantinov, Y. Kopansky, F. Kopera, L. Koppers, W. Korotkov, V. Korpela, A. Korsunsky, V. Koshurnikov, E. Kostka, B. Kostrov, E. Kosuge, M. Kotaiah, S. Kotelnikov, S. Kovác P Kovalenko, A. Kovalev, I. Kovrizhnykh, N. Koyama, H. Koyama, K. Koyanagi, K. Kozak, J. Kozak S Kozlenkova, N. Kozlova, N. Kozub, S. Kramer, S. Krasnov, S. Krause. B. Krauth, H. Krieg, G. Krischel. D. Krivchenkov, Y. Krog-Pedersen, S. Krotov, N.

MOA07PO04 MOA01PO03 THA01PO10, MOA2OR6, WEA01PO09 WEA2OR4, THA02PO04, THA12PO11, TUA01PO03, WEA01PO07, WEA10PO03. WEA10PO04 WEA12PO07, THA11PO09 WEA1OR1, TUA06PO10 THA11PO04 MOA05PO01, TUA03PO02 THA07PO05 TUM3OR1 WEA02PO10, WEA02PO11 MOM2OR1 MOA02PO10, MOA10PO04, THA03PO10, THA03PO12, THA05PO03, TUA03PO09, TUA09PO04, TUA09PO05, TUA09PO06, WEA02PO05 TUA3OR1 WEM10R2 WEA01PO04 MOA09PO07 MOA09PO03 TUA11PO08, THA01PO10, THM10R1. WEA05PO11, WEA12PO07 THA05PO07 MOA01PO10 TUA07PO05 MOA02PO05 Kondratowicz-Kucewicz, TUA09PO08, WEA05PO13 THA03PO09 WEA2OR4 THA01PO13, WEA01PO15 TUA07PO12 THA02PO14 TUA01PO01 THA11PO04 TUA03PO05 THA12PO01, MOA01PO01, WEA2OR2 MOA12PO08, THA09PO07, WEA12PO09 WEA08PO01 TUA07PO01 TUA02PO01 THA01PO01, WEA01PO11 MOA02PO08, MOA07PO11, WEA06PO15 TUA04PO05, TUM2OR3 TUA1OR5, TUA01PO01 THA07PO09, WEM1OR3, THA07PO08 TUA02PO01. TUA11PO01 WEA06PO05 MOA02PO11, TUM10R2 TUA3OR1, WEA10PO06 WEA09PO06 TUA09PO08, WEA05PO13 TUA09PO08. WEA05PO13 MOA10R2, THA01PO13, WEA01PO15 **THA10PO04** THA07PO02, THA07PO01 TUA3OR2, WEA1OR3 TUA03PO05 MOA07PO04 MOM2OR1 THA03PO05 TUA06PO10 TUA03PO05 TUM3OR2 TUA04PO11 TUA02PO01, TUA11PO01

Kruglov, S.

Kruip, M. Kubo, Y. Kudriavsev, N. Kühnberg, M. Kuligin, V. Kulikov, V. F. Kumada, M. Kumakura, H. Kumar, A. Kumazawa, T. Kummer, H. Kummeth, P. Kuperman, G. Kupriyanov, A. Kurahashi, H. Kuribayashi, A. Kuriyama, T. Kurnyshov, R. Kurusu, T. Kusada S Kuwano, K. Kuzmenko, D. Kuznetsov, G. Kwag, D-S. Kwak, S. Kwang, D. Kwon, W-S. Kwon, Y-K. Kytin, G. L La China, M.

Lachinov, V. Lada, T. Laface F Lagutin, A. Lamm, M. Lancetov, A. Langenberg, H. Larbalestier, D. Laskaris F Laskaris, T. Lau, W. Laurent, F. Laurenti, A. Lavrov N Lazareva, M. Lazic. A. Lazukov, V Le Naour, S. Leboeuf, D. Leboeuf, R. Lee, B. W. Lee, B-S. Lee, C. Lee, C. J. Lee, E-Y. Lee. H. Lee, H-G. Lee, J.

Lee, J-H. Lee, J-K. WEA1OR6 THA01PO01 WEM2OR3 MOA11PO08 MOA07PO04 WEA08PO05 MOA07PO06, MOA3OR6 MOA01PO03 TUA08PO07 WEA08PO03 MOA02PO07 MOM10R1 WEA09PO09 THA10PO06 WEA01PO07 MOA02PO07 TUA12PO09, THA04PO09. THA11PO05. THA11PO07, TUA12PO10 THA07PO06 WFA09PO06 TUA12PO09. TUA12PO10 TUA12PO09, TUA12PO10 MOA01PO10 THA07PO09, WEM1OR3 MOA09PO13 THA09PO04 MOA09PO12 TUA10PO07 THA04PO11, THA05PO11, TUA10PO05, TUA10PO07, WEA04PO06, WEA04PO07 WEA03PO01 FRM2OR4, MOA06PO10 WEA06PO03 MOA01PO10 TUA04PO11 FRM10R1

FRM2OR5, FRM2OR6, TUA06PO12,

TUA2OR4

WEA12PO09

MOA11PO08

THA01PO12

THA12PO12

TUA08PO04

THA03PO02

THA08PO05

WEA05PO02

MOA02PO04

WEA02PO08

TUA02PO01

TUA2OR3

THA08PO08

TUA09PO12

WEM3OR4

THA09PO02.

WEA04PO04

THA06PO09

TUA02PO05, TUA04PO08

TUA03PO09, TUA09PO06

TUA10PO05, TUA10PO07

THA12PO08, TUA01PO07

TUA10PO10, TUA10PO11

THA04PO12, WEA03PO10, WEA10PO11

MOA10PO09, WEA01PO05, WEA01PO06,

MOA09PO07, MOA10PO04, THA05PO03,

THA03PO10, THA05PO04, THA12PO07,

THA05PO04, THA05PO08, THA09PO04

MOA09PO13 TUA10PO09

MOA1OR6

Lee, K. Lee, P. J. Lee, S. Lee, S. J. Lee, S-H. Lee, S-J. Lee. W. J. Lefik, M. Leghissa, M. Lei, Y. Lelekhov. S. Lenisa, P. Leone, A. Leroy, D. Lesmond, C. Letant, D. Lettry, J. Levesy, B. Levichev, E. Levin G Li, D. Li, H. Li, J. Li, L. Li, R. Li, X. Li, Y. Liao, Y. Libeyre, P. Lietzke, A. Lim, B. Lim, B. S. Lim, H. Lim, S-H. Limon, P. Lin, B. Lin, F-Y. Lin, L. Lin, P. Lindner, R. Ling, J. Lister, S. Liu, F. Liu, H. Liu, S. Liu W Liu, X. Liu, Y. Lobanov, Y. Lobkov, A. Loche, L. Lopes Cardozo, N. Lopez, R. Losasso, M. Louie, W. Loulergue, A.

Lee, J-Y.

WEA04PO06, WEA04PO07 MOA09PO03, MOA10PO01, THA05PO08 **THA01PO12** MOA11PO13, TUA10PO10. MOA11PO02. MOA11PO03, MOA11PO07, MOA11PO14, THA05PO04, MOA11PO15, THA09PO04, TUA10PO11, TUA10PO12 MOA11PO07, MOA11PO14, MOA11PO15 THA06PO11 MOA05PO07, MOA05PO08, MOA09PO09, MOA09PO10, WEA02PO05, MOA01PO08 **MOA01PO08** THA06PO06, WEA12PO04 WEA10R6 TUA11PO02, WEA09PO01, WEA10PO01, WFA10PO02 **TUA11PO01** TUA08PO10 THA08PO05 MOA2OR2, TUA02PO04, TUA02PO05 **THA04PO08** MOA06PO02 TUA08PO12 WEA3OR6, THA08PO02, THA08PO12, WEA3OR3, WEA3OR5 TUA07PO10 TUA01PO05 THA12PO05 MOA10PO10, TUA10PO01, TUA10PO14, TUM10R5 THA04PO02, TUA03PO10 MOA10R6, MOA09PO01 MOM10R2, TUA12P002, TUA12P003 MOA01PO02, THA04PO03, TUA10R6 WEA06PO11 WEA11PO02 WEM2OR5 WEA07PO13, TUA08PO13, WEA07PO03. WEA07PO11, WEA07PO12 MOA11PO13 MOA11PO02, MOA11PO03 THA05PO08, THA05PO04 THA02PO13, TUA09PO09, TUA09PO11. TUA09PO13, TUA09PO14, MOA09PO08, MOA10PO15, TUA09PO03. TUA09PO07. TUA09PO10, TUA09PO15 TUA2OR1 WEA11PO08 TUA03PO07, TUA07PO06, TUA07PO08 MOA04PO05, MOA05PO09, MOA10PO10, THA02PO01, THM2OR4, TUA10PO01, TUM1OR5, WEA09PO07 TUA07PO06 THM3OR3 TUA12PO03 WEA10R6 THA06PO07, THA06PO03 WEA03PO06. THA12PO05 THA06PO04, TUA04PO07, WEA11PO10 MOA03PO01, TUA04PO01, TUA04PO02, TUA04PO03, TUA04PO04, TUA08PO01 MOA10PO02 WEA11PO02, WEA11PO09 WEA08PO01 WEA08PO05 TUA06PO09, WEA3OR5 THA11PO04 TUA04PO10 THM3OR3 TUM2OR2 MOA07PO09

Loveridge, P. Lu, D. Lublow, P. Lucas, J. Lümkemann, A. Lyraud, C.

Μ

Ma, L.

Ma. L. Z. Maan, J. C. Maan, J. K. Maccaferri, R. Madur, A. Maeda. H. Maekawa, R. Maiorov, B. Maire, G. Maix, R. Majoros, M. Makarov, A. Maki, N. Makida. Y. Makise, T. Makoveev, V Makulski, A. Malachevsky, M. Malagoli, A. Malinowski, H. Malkov, A. Malyshev, O. Malysheva, L. Man, K. Marabotto, R. Maraev. V. Mareev, K. Marignetti, F. Marinelli, M. Marken, K. Markiewicz, D. Marks S Marone, A. Maroussov, V. Marshall, W.

Marshall, W. Marteau, F. Martin, S. Martinez, G. Martini, L. Martinolli, A.

Martins, C. Martone, R. Martovetsky, N.

Marukawa, K. Maruyama, O. Masaie, I. Maschmann, W. Masciarelli, G. Masi, A. Massin, A. Massek, P. Massinger, M. Masson, T. Masullo, G. Masuzawa, M. MOA3OR3 WEA06PO01 TUM3OR1 MOA3OR5 MOM2OR4 WEM2OR5

MOA03PO01, MOA03PO02, MOA07PO02, TUA04PO01, TUA04PO02, TUA04PO03, TUA04PO04 THM3OR4, TUA08PO01 MOA1OR4, MOA1OR5 TUA3OR4, WEA10PO09 TUA07PO09 MOA07PO05 THA12PO11 THM2OR2 MOA01PO07 THA03PO07, THA04PO08 MOA11PO10 MOA10PO11, MOA10PO12 WEA08PO01 TUA10PO04. TUA10PO03 TUA01PO09, WEA08PO03, MOM3OR1, THA08PO03 THA02PO11 WEA06PO03 TUM2OR3 MOA01PO07 MOA01PO05, TUA1OR1 THA04PO05. THA04PO06 TUA08P008 WEA05PO13 TUA03PO05 **TUA07PO14** TUA07PO14 TUA04PO02 TUA10R4 TUA07PO12 WEA01PO15 TUA10PO13 WEA10R4 MOM2OR2 WEA1OR7, TUA3OR3 WEA06PO10, TUA07PO13, WEA06PO14 TUM2OR2 TUM2OR3 MOA1OR1, THA10PO05, THA10PO07 MOA07PO05 **THA07PO03** WEA10PO10 THA05PO09, THM2OR1, TUA01PO02, TUA10R1 THM2OR1 THA04PO08 THA04PO10, TUA10PO13 WEM10R5. THM1OR3, TUA08PO13, WEM2OR4 TUA12PO09, TUA12PO10 THA02PO03 MOA05PO06 MOA07PO12 THM2OR1 TUA04PO10, WEA04PO01 MOM10R1 THA08PO02 TUA08PO03 THA04PO10, TUA01PO02, TUA10PO13 THA02PO02

Mathieu, H. Matrone, A. Matsuda, Y. Matsukawa, M. Matsukawa, T. Matsumoo. S. Matsumoto, S. Mattafirri, S. Mauel, M. E. Mauro, A. Mayorga, J. Mayri, C. Mazet J Mazur. P. Mazur, T. Mazurenko, O. Mbaruku, A. Mcdonald, J. Mcdonald, K. Mcinturff, A. Mcintyre, P. Medvedev, M. Meguro, S. Meinesz, M. Meinke, R. Melišek, T. Menushenkov, V. Merritt, G. Messina, G Metskhvarishvili, I. Metskhvarishvili, M. Metz. B. Meynet, A. Miao, H. Michael, P. Michel, J. Mihara, T. Mikkonen, R. Miklyaev, S. Miles, J. Miller, J. Milward, S. Minakawa M Mineev. A. Minervini, J. Minowa, S. Mishima, F. Mishra R Missiaen. D. Mitchell, N. Mitchell, R. Mito, T. Miura, Y. Miyagi, D. Miyahara, Y. Miyake, H. Miyashita, M. Miyata, H. Miyazaki, H. Miyazaki, T. Miyoshi, K.

THA01PO06 TUA01PO02, TUA10PO13 MOA3OR6 THA11PO06, THA11PO09. THA11PO08, WEA12PO07 **MOA04PO03** MOA3OR6 TUA01PO03, THA12PO11, WEA01PO07, WEA10PO03, WEA10PO04, WEA2OR4 TUA08PO13, WEA07PO11, WEA07PO12, WEA07PO13 THM10R2 WEA05PO10 WEA05PO10 THA08PO01, THA08PO02, THA08PO08. THA08PO12, WEA3OR3 TUA06PO09 TUA07PO02, WEA03PO04 MOA01PO10 MOA05PO10 WEA02PO08, WEA02PO09 THA04PO04, WEA05PO09 TUA08PO12 WEA07PO15, WEA07PO11 TUA08PO11, WEA07PO14, WEA07PO15 TUA02PO01 TUA02P007, THA01P002, WEA01P008 MOM2OR2 TUA08PO13, WEM10R5 TUA01PO01 MOA02PO15 WEM3OR3 WEA05PO10 WEA02PO01 WEA02PO01 WEA02PO14 THM3OR2 MOM2OR2 MOA12PO05, THM10R2, WEA12PO10, WEM2OR4 **THA10PO03** MOA07PO06 MOA01PO01, THA12PO01, WEA2OR2 WEM2OR3 FRM2OR2, MOA06PO04, MOA06PO07 TUA2OR2, TUA3OR3, WEA01PO13, WEA01PO14, WEA03PO10, WEA10PO07, WEA10PO11, WEA10R7 **TUA01PO04** MOA08PO03, MOA08PO04 TUA03PO05 THM10R2, TUA08PO13, WEM20R4 MOA03PO05 THA12PO09. THA12PO10 MOA07PO08, MOA07PO11 TUA04PO11 MOA12PO01, MOA12PO03, MOA12PO05, MOA12PO07, THM10R3 WEM3OR1 THM2OR2 MOA11PO06, THA09PO06. WEA03PO05 WEA12PO07 **MOA09PO11** THA02PO11 MOM10R3 THA02PO03 TUA3OR5, WEA02PO02 THA04PO07, THA04PO13 THA03PO11, WEA01PO07 THA01PO02, TUA05PO07, WEA01PO08

Mizumaki, S. Modena, M. Modica, M. Molinari. G. Molzon, W. Mönnich, T. Moon, B. Moon, T. Moortgat-Pick, G. A. Morandi, A. Morawski, A. Moreschi. L. Mori. Y. Moriguchi, H. Morikawa, J. Morimoto, T. Morita, G. Morita. M. Moritz, G. Moroni, M. Morozov, I. Mossang, E. Motojima, O. Mugnai, G. Mühle, C. Mukai, E. Müller, H. Munakata. T. Munz M Murakami A Murakami. M. Murakami Y Murase, S. Murasugi, S. Muratov, V. Muroo. Y. Musenich. R. Muta, I. Muzzi, L.

Mizoguchi, M.

Ν Nagafuchi, T.

Nagai, T. Nagaya, S. Nah, W. Naka H Nakahara, K. Nakajima, H. Nakamaru, A. Nakamoto, K. Nakamoto, T. Nakamura, D. Nakamura, E. Nakamura, K. Nakamura T Nakano, H. Nakashima, T. Nakatsu, T. Nam, K. Nanao, Y. Nanato, N. Narayankhedkar, K. MOA12PO04 THA11PO07, THA08PO03, THA11PO05 MOA06PO04 ,FRM2OR2, MOA06PO07 TUA10R4 MOA06PO07, MOA06PO09 WEA08PO02 THA03PO06, MOA11PO04 MOA05PO08 TUA10PO05, TUA10PO07 TUA07PO14 WEA06PO08, THA09PO01 MOA01PO10 WFA12PO01 MOA07PO03 THA09PO09 THA11PO05, THA11PO07 MOA10PO07 MOM10R3 MOA10PO13 MOA07PO01, THA07PO01, THA07PO02, THA07PO04, THA07PO05, THA07PO06, THA07PO07, THA07PO10, THA07PO11, TUA02PO03, WEM10R2, WEM10R3 THA01PO09 TUA06PO01 WEA10PO10 MOA11PO06 TUA06PO09 THA07PO04, THA07PO01, THA07PO11 THA03PO03 **THA01PO04** MOA04PO08 MOM2OR1 WFA02PO02 WEA03PO03 WFA01PO07 **MOA01PO04** MOA08PO08, MOM3OR3 MOA07PO04, WEA06PO05 TUA3OR5 TUA01PO10, TUA10R4, WEA30R5 MOM10R3

THA01PO09, WEA05PO10, MOA05PO02 THA09PO05, WEA09PO10 MOM2OR3, THA02PO09, THA02PO10, THA04PO11, THA05PO11 WEA05PO05, WEA05PO07 MOA12PO04, MOA12PO09, THM1OR1 THA11PO05, THA11PO07 FRM2OR5, MOA07PO03, MOA08PO02, MOM3OR1, TUA06PO03 MOA08PO08, MOM3OR3 TUA05PO08, MOA08PO10, WEA03PO09, MOM10R3, MOA04PO06, WEA09PO03 TUA12PO09, TUA12PO10 WEM3OR4, MOA10PO09

THA01PO01

THA09PO09,

WEA09PO06

THA01PO01

THA09PO03

TUA05PO05

WEA07PO04

THA02PO06

TUA10PO03

MOA01PO04

THA03PO05

MOM2OR3

Nardelli, D. Naumov, P. Negrazus, M. Negrini, F. Nehring, R. Neil, G. Nemetschek, R. Nemoto, K. Nerowski, G. Neumüller, H. Nguyen, D. Ni. G. Nick, W Nicol T Nicollet, S. Niiro, A. Nijhuis, A. Nikitaev, P. Nimori, S. Ninomiya, A. Nishijima, G. Nishijima, S. Nishijyo, T. Nishimiya, S. Nishimura, A. Nishioka, J. Nitta, T. Nobrega, A. Noda, F. Noda, T. Nogiec, J. Noguchi, S. Noguchi, T. Nomura, S. Norikane, H. Norn, D. Noumi, H. Novikov, S. Novitski, I. Noyes, P. Nundy, U. Nunio, F. Nunoya, Y. Nyilas, A. Nyman, M. Obama, J. Obana T Oberli, L. Obidenko, T. Odaka, S. Ogawa, J. Ogawa, Y. Ogitsu, T. Oguro, H. Ogurtsov, A. Oh, I. Oh, S.

TUA10R4 TUA11PO01 MOA07PO10 THA09PO01, WEA06PO08 TUA07PO03, TUM2OR3 TUA07PO11 MOM2OR4 TUA12PO09. TUA12PO10 MOM10R1 MOM10R1 WEA02PO07, TUA08PO12, WEA02PO10, WEA02PO11 THA12PO02 MOM10R1 FRM2OR5 TUA06PO12 WEA12PO08 TUA12PO08 WEA12PO06, THA01PO07, THA01PO08, THA01PO12, TUA11PO07, WEA01PO01 THA07PO09 THA12PO11, WEA01PO02, WEA01PO04, WEA2OR3 WEA03PO09 WEA01PO08, THA01PO02, THA01PO11, TUA3OR1, WEA01PO10, WEA02PO06, WEA05PO01 WEA2OR6, THA12PO09, THA12PO10 THA05PO06 MOM10R4 THA01PO10, TUA02PO08, TUA05PO08, WEA12PO07 MOM2OR3 MOA10PO07, THA09PO03, TUA10PO08 FRM2OR5, TUA06PO12 TUA08PO09 THA01PO10, THA09PO09 TUA04PO05, TUA06PO12, TUM2OR3 TUA03PO06, WEA05PO08 THA05PO05 THM2OR5, WEA09PO08, THA09PO08, TUA03PO01, WEA09PO06 MOA02PO02 TUA08PO05 MOA08PO03, MOA08PO04 WFA01PO15 MOA03PO04, TUA2OR4, WEA07PO01, WEA07PO08 WEA07PO15 WEA06PO15 WEA10R5 TUA11PO08, TUA11PO09, WEA12PO04 THA03PO05 WEA07PO13

WEA01PO02, WEA07PO04 MOA07PO03 TUA02PO04, TUA02PO05 WEA06PO05 TUA05P003 TUA05PO09, TUA05PO10, THA05PO05, THA05PO06, THA05PO07, TUA03PO03, WEA11PO06 THA11PO05, THA11PO07 FRM2OR5, FRM2OR6, MOA07PO03, MOA08PO02, MOM3OR1, TUA06PO03 THA01PO02, WEA01PO08, WEA01PO10 TUA07PO12 TUA09PO12 WEA01PO05, WEA01PO06, THA02PO08

Ohara, T. Ohkubo J Ohmatsu, K. Ohno, M. Ohsaki H Ohsemochi, K. Ohtani, Y. Ohtsuki, M. Ohuchi, N. Ohya, M. Oka. T. Okada, H. Okada, M. Okamoto, H. Okamoto, K. Okamura, T. Okazaki. T. Okitsu, S. Okui. Y. Okumura. H. Okumura, K. Okuno, K. Okutomi, T. Okuyama, H. Oleck, A. Olesen, G. Oliveira, U. Oliveri, E. Omura, A. Ono, M. Onoda. H. Onodera, H. Ooizumi, M. Oomen, M. Orgiani, P. Orikasa, T. Orris, D. Osipowicz, A. Ostojic, R. Otsubo, M. Ottonello, L. Oue, M Ozaki, O.

Oh. Y. K.

Ρ

THA08PO01, THA08PO02, THA08PO12 Pabot Y Paccalini. A. THA08PO06 Pace, S. **THA01PO03** THA10PO03 Pacheco, M. FRM2OR5 Page, T. Painter, T. TUA3OR3, WEA03PO10, WEA10PO11 THA11PO03 Pan, Y. Panchal, P. MOA11PO11 MOA10R2 ,THA01PO13, WEA01PO15 Pantsyrny, V. MOA02PO08, MOA07PO11, WEA06PO15 Pareek P Park, C-R. TUA09PO07, TUA09PO15, MOA10PO15, TUA09PO09 TUA09PO04, MOA02PO10, MOA10PO04, Park, D. K. THA03PO12 TUA03PO09, TUA09PO05. TUA09PO06 MOA11PO02, MOA11PO03 Park, H. K. Park H-J TUA10PO05, TUA10PO07 MOA10PO15, TUA09PO07, TUA09PO11 Park, H-M.

MOA11PO07, MOA11PO13, MOA11PO14,

THA11PO05, THA11PO07, TUM1OR2

FRM2OR5, TUA06PO03, WEA07PO04

MOA11PO15

WEA11PO06

WEA03PO05

WEA07PO04

MOA02PO12

WEA09PO06

TUM10R2

MOA11PO01

TUA12PO04

TUA12PO05

WFA07PO04

TUA12PO06

THA09PO05

WEA03PO09

THM10R1.

THM10R3

TUA12PO05

WEM10R4

WEA02PO15

MOA02PO02

WEA09PO06

WEA09PO06

TUA10P004

WEA11PO06

WEA1OR6

MOA01PO11

MOA07PO03

WEA09PO05

WEA03PO09

THM2OR1

TUA3OR5

FRM2OR5. TUA06PO07

TUM2OR3 TUA07PO07

WEA10R4

MOA01PO03 TUA01PO08

TUA05P007. WEA09P003

MOM3OR1, THA04PO09

WEA10PO08. TUA3OR5

THA09PO06, THM2OR2

WEA05PO11, WEA12PO07

TUA12PO09, TUA12PO10

MOA12PO04,

TUA11P008

TUA07PO02, TUA07PO04, WEA03PO04,

THA03PO07, THA08PO03, THA08PO09

THA11PO05, THA11PO07, TUM1OR2,

MOA12PO09,

TUA11PO09.

MOM2OR5

Park, I-H. Park, J. Park, J-P. Park, K. Park K R Park, K-B. Park, M. Park, P-Y. Park, S. H. Park, S. W. Park, S-W. Park, W. W. Parker, R. Parodi S Parrell, J. Payn, A. Pedrini, D. Peiro, G. Penco R Peng, A. Peng, T. Peng, Y. Pengo, R. Peregud, V. Perenboom, J.A.A.J. Perez, J. Perini, E. Perrella. M. Pes, C. Petersen Zarling, B. Peterson, T. Petmezakis, P. Petrillo, E. Petrov A Petrov, V. Phadke, G. Phillips, J. Picco, E. Piekarz, H. Pikalov, A. Pincella. C. Pittaluga, S. Pivovarov, S. Plyusnin, V. Pogrebnyakov, A. Pojer, M. Pokrovsky, V. Polak, M. Polikarpova, M. Polulyakh, E. Poncet, A. Popov, Y. Portone, A. Portugall, O. Potapenko, I. Potienko, A. Poukhov, O. Pradhan, S. Prakash, R. Prakoshyn, F. Prasad, U. Prasuhn D Prestemon. S. Presti, M. Previtali, V. Priano, C.

THA06PO09, THA06PO11 WEA11PO05 MOA05PO07 MOA11PO07, MOA11PO13 MOA11PO02, MOA11PO03 MOA10PO14, TUA09PO12 THA05PO04, THA05PO08, TUM1OR1 WEA01PO05 MOA11PO15, MOA11PO07, MOA11PO14 THA05PO03, TUA09PO04, TUA09PO06 WEM3OR4 MOA11PO02, MOA11PO03 THA10PO03 MOA11PO10 MOA2OR1 TUA06PO10 THA01PO14, TUA02PO02 MOA02PO05, MOA02PO06 THA08PO05, THA09PO01 MOM10R2, TUA12P003 FRM10R5 MOM10R2, TUA12PO03, TUA12PO02 THA08PO07, THA08PO09, WEA3OR4 MOA07PO04, TUA07PO12 MOA1OR5, WEA10PO09 MOA10R4. TUA3OR4, TUA06PO07 THA05PO09 THA09PO01 WEA08PO07, WEA1OR5 MOA11PO08 FRM2OR5 WEA10PO10 TUA01PO02 MOA07PO04 TUA06PO01 MOA11PO11 TUA01PO06, TUA1OR3 THM2OR1 WEM10R4, TUA07PO03, TUA07PO04, WEA03PO04 **THA10PO06** THM2OR1 WEA04PO05, WEA10R2, WEA08PO05 WFA08PO05 WEA08PO05 MOA01PO11 MOA03PO09 **THA07PO02** TUA01PO05 MOA1OR2, THA01PO13 TUA03PO02 MOA06PO0, MOA06PO02 MOA04PO07, WEA08PO06 MOA3OR5, THM1OR6 FRM1OR1 MOA10R2 MOA03PO06 TUM2OR3 THA11PO01, TUA11PO03, TUA11PO04 THA11PO01 TUM2OR3 **TUA11PO04** THA07PO03 TUA07PO13, WEA06PO14, WEA06PO10 WEA06PO06 TUA02PO04, THA01PO14, TUA02PO05 **THA12PO13**

Qi, Z. Qiu, J. Qiu, M.

Quarantiello, R. Quettier, L.

R Rabbers, J-J.

Rabehl. R. Radovinsky, A. Raff, S. Rakos, D. Ramalingam, R. Ramberger, S. Ranze, R. Rastogi, A. Ravat, S. Raymond, M. Redwing, J. Reed, M. Reginelli, A. Remondino, V. Ren. X. Renaud, J. Renzetti, R Rey, J-M. Reytier, M. Rhvee, K. Ribani, P. L. Riboni, P. Ricci, R. Rickel, D Rifflet. J. Rindfleisch, M. Risse, K. Rivoltella, G. Robin, A. Robin, D. Rochford, J. Rocio, C. Röckelein, R. Rodin, I.

Rodrigues Jr., D. Rodriguez Canseco, I. Rodriguez, E. Rogers, R. Romanovskii, V. Rondeaux, F. Rong, P. Rook, J.

 TUA06P007

 WEA10R6

 MOA02P003

 MOM20R4

 MOA01P010

 MOA06P011, MOA06P002, TUA06P005

 TUA06P009

 WEA04P005

 TUA07P012

THA03P009 MOA09P004 **MOA05P009, THA03P009, WEA11P009**, WEA09P004, WEA11P002 **TUA01P002**, TUA10P013 **MOA02P003**, THA01P014

THA08PO07, THA08PO09, THA08PO10. WEA3OR4 FRM2OR5, TUA07PO04, WEA03PO04, WEM10R4 WEA08PO02, THM1OR2 MOA3OR5 **TUA08PO12** THA03PO05 TUA06PO01, TUA06PO02 MOA10R6 WEA06PO12 THA08PO09 THA08PO12 MOA01PO11 THMPL1 THA01PO06 TUA06PO06, TUA06PO09 WFA03PO02 THM3OR3 FRM10R6 THA08PO08, MOA02PO03, WEA3OR3 THA08PO01 MOA10PO01 WEA12PO04, MOA05PO02, THA09PO01, WEA06PO08 WEA3OR7 **MOA04PO09** MOA10R1, THA10P002, THA10P005, THA10PO07 MOA3OR5, TUA2OR3 TUA01PO07 TUA10R3 THM10R5, MOA11PO10, WEM20R6 THA08PO06 MOA02PO09 WEA06PO10 TUA07PO14, MOA3OR3 FRM2OR3 THA12PO04 MOA12PO08, THA09PO07, TUA02PO03, WEA12PO09 THA02PO07 MOA03PO08 MOA07PO12 MOA08PO09 WEA05PO01, WEA05PO02 MOA02PO03, WEA3OR5 THM10R5

TUA3OR4, WEA10PO09

Rosseel, K. Rossi, L.

Rossi S Rossi, V. Rossmanith, R. Rousse, J. Rouvinski, E. Ruban, A. Ruber, R. Ruccio, A. Rufoloni A Rummel, K. Rummel, T. Ruppert Filho, E. Russenschuck, S. Russo, A. Rutt, A. Ruvinsky, E. Ruwali, K Rychagov, A. Ryskulov, N. Ryu, K. Ryuichi, S.

Sabbi, G. L.

Sadikov, I. Sahu. A. Sailer, B. Saito, K. Saito, S. Saitoh, T. Saitoh, Y. Sakaguchi, H. Sakai, I. Sakai M Sakamoto, O. Sakuraba, J. Sakurai, Y. Sala, P. Salama, K. Salpietro, E. Sammut, N. Samoylov, S. Sander, M. Sandim, H. Sandim, M. J. Sanelli, C. Sanfilippo, S. Santoni. C. Santos, R. Sanz, S. Sarkar, B. Sasaki, A. Sasaki, K. Sastry, P. Sato, H. Sato, K. Sato, S. Sato, T. Sato, Y.

MOA10R4, MOA10R5 FRM2OR2, MOA06PO06, THA08PO05, TUM3OR2 THA12PO13, THM2OR1 TUA01PO02 TUA07PO01 THA03PO07, WEA3OR6 **TUA07PO05** MOA04PO07, WEA08PO05 THA08PO03, THA08PO04 TUA04PO11 THA01PO09 MOA11PO05 MOA11PO04, MOA11PO10, THA03PO06, THM1OR5, WEM2OR6 WEA02PO13, TUA09PO02, MOA02PO09. WEA02PO15 THA07PO01, TUA04PO10 MOA02PO06 MOM2OR1 TUA06PO01, TUA07PO12 WEA06PO07. MOA07PO07 TUA02PO03 WEA08PO06 WEA02PO04, THA05PO11, TUM1OR1, WEA09PO02 MOA04PO08 TUA08PO13, WEA07PO03, WEA07PO11, WEA07PO12, WEA07PO13 TUA02PO01 **MOA11PO11** MOM2OR1 **WEA10PO08**

THA02PO03, TUA05PO01 MOM3OR5 WEA2OR3 MOM3OR4 MOA02PO11, TUM10R2 **TUA10PO08** TUA3OR1 MOA2OR6, WEA01PO09 WEA10PO10 TUA01PO11 MOA05PO02, MOA3OR5, THA01PO09, THM1OR3, THM1OR6 TUA06PO04, TUA06PO05 WEA12PO09 WEA06PO02 FRM10R6 FRM10R6 MOA04PO04, THA12PO13 TUA06PO05, MOA06PO03, TUA04PO08, TUA06PO04, TUA06PO11 MOA06PO06, MOA06PO09 MOA02PO09 MOA07PO12, MOA3OR3 MOA11PO11, MOA11PO12 WEA03PO09 MOM3OR1, MOA07PO03, MOA08PO02 WEA02PO07, WEA02PO10, WEA02PO11 THA09PO08, TUA07PO04, TUA11PO09 TUA12PO06 THA05PO02 THA05PO05, THA05PO06, THA05PO07, TUA03PO03, TUA05PO09, TUA05PO10,

WEA01PO04

WEA11PO06

MOA04PO03, MOA08PO04

Satragno, L. Sattarov, A. Savary, F. Savoldi, L. Saxena, Y. Sborchia, C. Sbrissa, E. Scandale, W. Scarano, M. Scheller, H. Schellong, B. Scheuerlein, C. Schild, T. Schillig, J. Schirm, K. Schlabach, P. Schlueter, R. Schmidt, H. Schmidt, P. Schmidt, W. Schneider, T. Schneider-Muntau, H. Schnizer, P. Schram, D. Schrefler, B. Schroeder, C. Schultz, J. Schultz, L. Schwartz, J. Schwerg, N. Scott, D. Seeber, B. Segreti, M. Seidl, P Seiler, E. Seino, H. Seki Y Sekine, N. Seleznev, V. Selskij, V. Semenov, E. Seo, K. Seok, B. R. Seok, B-Y. Seong, K-C. Sergeev, V. Serquis, A. Serrano, G. Serries. J. Sevvet F Sgobba, S. Sha, C. Shah, N. Shang, M. Shangin, V. Sharma, A. Shatil, N. Shcherbakov, P.

WEA10R2 TUA08PO11, WEA07PO14, WEA07PO15 FRM2OR2, FRM2OR3, MOA06PO04, MOA06PO07 MOA12PO07, MOA05PO02, THM1OR3, WEA12PO04 MOA11PO11, MOA11PO12, THA11PO01, TUA11PO03, TUA11PO04 WEM2OR6, MOA11PO09, THM10R5 THA03PO07, THA08PO09 FRM2OR4 TUA10PO13 MOA11PO08, MOA11PO10, TUM3OR1 TUA06PO10 WEA07PO09 WEA1OR5, MOA11PO09, WEM2OR5 MOA1OR1, THA10PO03, THA10PO07 TUA07PO12, TUA06PO10, TUA06PO11 FRM2OR5, FRM2OR6, TUA07PO02, TUA07PO03, WEM10R4 TUA07PO13, WEA06PO10, WEA06PO14 TUM3OR1 TUA06PO10 **THA12PO04** THA01PO04, TUA07PO01 FRMPL1 THA07PO05, TUA04PO11 THA11PO04 THA06PO06, WEA12PO04 THA07PO05 WEM2OR4, THM1OR2, TUA08PO13 FRM10R4 WEA02PO10, WEA02PO11, WEA02PO09, WEA02PO07, WEA02PO08, WEA10R7, WEM3OR3 **THA06PO10** TUA07PO14 MOA2OR4, WEA01PO12 TUA2OR3, WEA1OR5 TUA08PO13 TUA05PO04 MOA05PO05 WEA01PO02, WEA07PO04 WEA05PO06, TUA05PO02, TUA05PO09 TUA08PO08 MOM2OR1 TUA07PO05 WEA12PO02, WEA12PO03, WEA12PO07 MOA10PO04, TUA09PO06 THA05PO03, TUA03PO09, MOA10PO09. WEM3OR4 MOA09PO07, MOA09PO12, MOA09PO14, THA09PO02, THA09PO04, WEA02PO04, WEA03PO07, WEA09PO02 **THA01PO13** MOA01PO07 MOA01PO07 WEA12PO08 MOA06PO02, MOA06PO01 **WEA3OR7**, WEA07PO09 MOA06PO02. MOA06PO04. MOM10R2, TUA12P002, TUA12P003 MOA11PO11 **TUA10PO02** WEA06PO05 TUA11PO04 MOA12PO06 THA07PO01, THA07PO02, THA07PO06, THA07PO07

Shevchenko, S. Shi, J. Shibata, K. Shibui, M. Shigue, C. Y. Shikimachi, K. Shikov, A. Shimada, K. Shimada, R. Shimada, T. Shimazaki, S. Shimizu, H. Shimomura T Shimovama, J. Shimoyama, N. Shin, H. Shin, J. Shinde, R. S. Shintomi, T. Shiohara Y Shiotsu M Shirai Y Shiraishi, R. Shirshov, L. Shishov, Y. Shoji, Y. Shon. S-H. Siemko, A. Sievers, P. Sigl, G. Sim, J. Sim, K-D. Simon, F. Sims, J. Sinha, G. Sinram, K. Siri, A. Sissakian, A. Sivasubramaniam K Smeets, P. Smirnov, A. Smirnov, N. Smith, B. Smith, R. Snvder, M. Sobol. V. Sobrero, G. Sochor, M. Sohn, M-H. Sokolov, E. Soltanian, S. Someya, H. Sone, T. Song, F. Song, H. Song, K. J. Song, M. Song, M-K. Song, N. H.

WEM2OR3 THA04PO02 **THA09PO03** THA11PO05 MOA02PO09, WEA02PO15, TUA09PO02, WEA02PO13 THA09PO09 THA01PO13, MOA10R2, TUA02PO01, WEA01PO15 WEA09PO06, WEA12PO07 MOA04PO03, THA03PO11, THM2OR5, TUA03PO01, WEA09PO08 TUA08PO09, MOA08PO05, MOA08PO06 MOA08P007, MOA08P011 WFA11PO03 WFA07PO04 WEA11PO05 THA02PO11, MOA01PO09, THA02PO06 WFA2OR4 THA02PO08 MOA05PO08 MOA02PO08, MOA07PO11, WEA06PO15 THA09PO08, FRM2OR5, TUA01PO09, TUA06PO03, WEA09PO08 THA02PO03, TUA05PO01, WEA05PO05, WEA05PO07 MOA10PO07, MOA11PO01 MOA10PO07, MOA11PO01, THA09PO03 MOA02PO12 THA07PO02, THA07PO07 TUA08PO08 WEA02PO02 MOA09P008 MOA06PO02, TUA06PO05, WEA01PO03, WEA04PO01 TUM2OR1 MOM2OR4 MOA10PO14 MOA09PO14, MOA09PO06, MOA09PO07. MOA09PO10, MOA09PO12, MOA09PO09. TUA09PO05, WEA03PO07, WEA09PO02 TUA06PO10, TUA06PO11, TUA2OR3 THA10PO03, THA10PO07, THA10PO08 **TUA08PO07** MOA07PO04 MOA01PO05, MOA01PO06, TUA1OR1 WEA08PO01 **THA12PO12 THA11PO04** THA07PO09, WEM1OR3 TUA06PO04 TUA04PO10. TUA04PO11. TUA06PO05 WEA08PO04, THM1OR2, WEA08PO02 WEA08PO08 TUA07PO11 MOA05PO10 WEA10R4 THA05PO01 TUA10PO07, THA04PO11, THA05PO11, TUA10PO05, WEA04PO06, WEA04PO07 WEM2OR3 TUA10R2 MOA08PO10 THA01PO01 WEA04PO03. TUA10PO06. WEA03PO08 WEA02PO12, WEA11PO04, WEA11PO07 TUA05PO11 MOA10PO16 MOA05PO07, MOA05PO08, MOA09PO09, **MOA09PO10** MOA11PO02, MOA11PO03

TUA11PO01

THA06PO05

Shcherbakov, V.

Shen, X

Song, Q. Song, S. Song, Y. Sorbello, G. Sorbi, M Soucaze, M. Spampinato, P. Spayde, D. Spencer, C. Spodarets, V. Sreeramulu, K. Stafiniak A Stajic-Trosic, J. Stamopoulos, D. Stancari, M. Statera, M. Stef, W. Steffens, E. Steier, C. Steinmann, P. Stenvall. A. Stepanov, B. Steshov, A. Strait, J. Su, Y. Sudyev, S. Sugano, M. Sugita, K. Suh, S Sukhanov, A. Sukhina B Sumbaev A Sumiyoshi, F. Sumption, M. Sun, G. Sun, J. Sun, Y. Sun, Z. Sung, T. Surdacki, P. Surin, M. Süßer, M. Suzuki, H. Suzuki, J. Suzuki, S. Suzuki, T. Suzuki, Y. Svedentsov M Swenson, C. Swoboda, D. Sylvester, C. Sytnik, V.

THA04PO02

THA03PO04

WEA06PO06

MOA07PO05

TUA08PO12

WEA06PO03

MOA07PO07

TUA06PO05

FRM10R6

TUA08PO10

TUA08PO10

TUA07PO01

WFA06PO10

WEA07PO09

MOA01PO01

TUA07PO05

TUA04PO04,

THA01PO13

THA02PO04

THA05PO11

TUA06PO01

MOA07PO09

WEA06PO03

THA02PO09,

TUA05PO07 TUA01PO06

WEA01PO01

TUA04PO07

TUA09PO13

WEA05PO13

WEM2OR3

THA03PO05

TUA05PO02

TUA05PO03

WEA07PO04

TUA12PO08

MOA05PO05

TUA05PO07

THA07PO11

MOA1OR1,

FRM10R3

THM3OR2

FRM2OR5

THA07PO02

TUA02PO03

THA10PO08

THA06PO12, MOA05PO04

THA08PO02. THA08PO12

THM3OR4

TUA04PO02, TUA04PO03

TUA06PO03, TUA2OR3

FRM2OR5

TUA3OR4

TUM3OR3

TUA11PO02, TUA12PO03, WEA09PO01,

WEA07PO10, THA08PO05, TUA01PO10

MOA08PO01, MOA08PO09, MOA07PO06,

THM10R6, TUA11PO05, TUA11PO07

TUA08PO01,

THA09PO06,

TUA10R2.

MOA08PO06.

MOA08PO03, MOA08PO04, MOM3OR5,

THA10PO05,

MOA02PO01,

MOA03PO01,

THM2OR2,

TUA1OR3.

MOA08PO10

THA10PO07.

THA10PO02.

WEA10PO01, WEA10PO02

MOA02PO15, MOA02PO14

T

Sytnikov, V.

 Tabe, S.
 THA04P009

 Tachikawa, K.
 MOA01P004, WEA03P005

 Tachikawa, N.
 THA11P007

 Tada, A.
 THA03P003

 Tada, S.
 WEA05P006

 Tagawa, K.
 MOA2OR6, THA01P010, WEA01P009

Taquchi, A. Takacs, S. Takagi, A. Takahashi, H. Takahashi, K. Takahashi M Takahashi, N. Takahashi, Y. Takahata. K. Takaku. T. Takano, K. Takao. T. Takasaki, M. Takata. K. Takayanagi, T. Takeda, J. Takeda. S. Takeuchi, K. Takeuchi, S. Takeuchi, T. Talijan, N. Tamai, H. Tamura, H. Tanaka, H. Tanaka, I. Tanaka, K. Tang, Y. Tani, N. Taniguchi, S. Tanimoto, K. Tank, J. Tanna, V. Taquet, A. Taran, A. Tarovik, E. Tartaglia, M. Tasaki, K. Tassisto, M. Tateiwa, T. Taureg, H. Taylor, T. Tazaki, Y. Tazawa, H. Ten Haken, B. Ten Kate, H. Terai M Terashima, A. Terazono, B. Terazono, K. Teshima, H. Testoni, P. Teubert, F. Thakur, V. Theisen, E. Thieme, C.

WEA09PO10 THA05PO01 TUA02PO07 MOA08PO04 MOA08PO03, MOM3OR5, **THA11PO09** WEA02PO06, WEA10PO06, TUA3OR1 TUA01PO08, WEA11PO06 MOA09PO11 MOA12PO03, MOA10PO13, MOA12PO01, TUA11PO09, WEA11PO06 MOA11PO06, WEA12PO07 MOA04PO08 MOA12PO04 MOA03PO05, TUA05PO06, TUA12PO08 THA05PO05. THA05PO06. THA05PO10. TUA05PO08, WEA01PO02, WEA05PO06, WFA07PO04 MOA08PO03, MOA08PO04, MOM3OR5 MOA08PO08 MOA08P007, MOA08P011, MOA08P005, MOA08PO06, MOA08PO08, MOM3OR3 **TUA12PO08** THA12PO10, THA12PO09, WEA2OR6 THA09PO05 WEA01PO04 THA01PO10 MOA2OR6 TUA02PO08 WEA01PO09, WEA01PO02. WEA01PO11. WEA01PO12, WEA07PO07 MOA02PO14, MOA02PO15 THA11PO09, WEA12PO07 MOA11PO06, WEA03PO05 MOA10PO03, MOA10PO06, MOM3OR5 THA04PO07, WEA11PO05 MOA01PO03. MOM3OR5 MOA08PO02 MOA08PO03, MOA08PO04, THA04PO13. TUA01PO08, WEA08PO03 THA04PO02, TUA03PO10 MOA08PO10 WEA09PO10, WEA11PO03 MOM2OR3 MOA11PO11 TUA11PO06 MOA02PO06 TUA02PO03 WEA02PO01 FRM2OR6, FRM2OR5, WEA07PO12 THA04PO09, TUA12PO09, TUA12PO10 TUA10R4, TUA06PO09 TUA12PO04 THM3OR2 FRM2OR5 THA02PO06 MOA08PO08 WEA02PO14 WEA3OR2. THA01PO07. THA01PO08. THA08PO01. THA08PO02. THA01PO12 THA08PO03, THA08PO04, THA08PO07, THA08PO08, THA08PO10, THA08PO12, TUA02PO02 WEA02PO14, WEA12PO06, WEA3OR3, WEA3OR4 TUA12PO10, WEA2OR1, TUA12PO09 MOA08PO02, WEA01PO02 THA12PO10 WFA09PO10 WEA02PO03 MOA3OR5 THM3OR3 **TUA08PO07** THM1OR5, TUM3OR1 TUA01PO05, WEA02PO10, WEA02PO11, WEM3OR3 TUM2OR2

Thomas, R.

Thome, R. Thompson, E. Thompson, P Tikhonov, Y. A. Tikhonovsky, M. Tikhov, A. Ting, S. Tisher, M. Titus, P. Tixador, P. Tkachenko, L. Tobita. M. Tock, J. Todd, B. Todesco, E. Tokunaga, Y. Tomaru, T. Tomioka, A. Tommasini, D. Tompkins, J. Tomsic, M. Toplosky, V. Toral, F. Torello, E. Torii, S. Torrisi, L. Tortschanoff, T. Tosaka, T. Toth. J. Tournaire A Tovar-Gonzalez, A. Towndrow, E. Trepanitis, M. Trequattrini, A. Tretter. J. Trillaud, F. Trociewitz, B. Trociewitz, U. Trombly-Freytag, K. Tropeano, M. Trophime, C. Tsuchiya, K. Tsuchiva. S. Tsuda. M. Tsuji-lio, S. Tsukamoto, O. Tsutsui H Tsutsumi, F. Tumino, A. Turrioni, D. Turudome. T.

U

THA02PO11		
TUA12PO05		
TUA12PO07, WEA05PO11	WEA05PO05,	WEA05PO07,
MOA09PO11		
	THA02PO11 TUA12PO05 TUA12PO07 , WEA05PO11 MOA09PO11	THA02PO11 TUA12PO05 TUA12PO07 , WEA05PO05, WEA05PO11 MOA09PO11

THMPL1 MOA08PO09 MOA10R6 WEA08PO05 THA10PO06, MOA02PO04 TUA04PO10 MOMPL1 TUA07PO10 TUA08PO12, WEA12PO10, WEA08PO02, WEA08PO04, WEM2OR4 WEA05PO03 THA07PO01, THA07PO02, THA07PO07 WFA2OR4 THA03PO02 TUA07PO14 FRM2OR1. FRM2OR1 MOA06PO02. MOA06PO03, MOA06PO06, MOA06PO08, MOA06PO09, TUA06PO10, TUA06PO11 MOA02PO11, TUM10R2 MOA08PO02, MOM3OR1 THA04PO07, THA04PO13 MOA02PO07, MOA06PO02, MOA06PO04, MOA06PO10, THA07PO01, TUA07PO09 FRM2OR6 TUA1OR3, TUA01PO06 TUA01PO07, TUA10R2 THA10PO08, WEA01PO14 MOA07PO12, MOA3OR3, MOA08PO09, MOA3OR5 THM2OR1 MOA09PO11 WFA06PO06 TUA06PO10, TUA06PO11 THA11PO05, THA11PO07, TUA12PO09 FRM10R3. THA10PO07, TUA3OR6, WEA10PO05 THM3OR2 MOA06PO01 THA08PO04 TUM3OR3 WEA10R2, WEA04PO05 THM10R5 WEA05PO03, TUA2OR3 WFA01PO14 WEA01PO14, WEA02PO09, WEA02PO10, WEA02PO11, WEM3OR3 **TUA04PO05** MOA01PO05, TUA1OR1 WEA10R3, WEA10PO10 THA11PO09, WEA01PO02, WEA07PO04. FRM2OR5, THA01PO10, THA02PO02, TUA02PO07, TUA06PO03, WEA12PO07 TUA12PO07 MOA09PO05, MOA09PO02 THA03PO11, THM2OR5 MOA04PO08. **TUA03PO01** TUA05PO03, THA05PO05, THA05PO07, TUA05PO02, TUA05PO03, TUA05PO09 TUA03PO01, MOA04PO08, THA03PO11 THM2OR5 MOA12PO04 MOA01PO05, MOA01PO06, TUA1OR1 THA01PO05, TUA2OR5, WEA07PO05, WEA07PO08 TUA3OR1

Ueda, S. Ueno, K. Ueno, T. Uesaka, M. Ueyama, M. Uglietti, D. Umeda, M. Umeda, S. Umekawa, K. Uno. K. Urata, M. Usak, P. Ushiku, Y. Usoskin, A. Utkin, A. Valecha, A. Valle, N. Van Bockstal, L. Van De Velde, F. Van Den Eijnden, N. Van Der Meer, O. Van Eck, H. Van Haßelt, P. Van Oort J Van Rooij, G. Vanacken, J. Vanenkov, I. Vannozzi, A. Vazquez, C. Vedrine, P. Velev, G. Venturini Delsolaro, W. Verweij, A. Viebke, H. Vignolo, M. Viouchkov, Y. Virostek, S. Vlogaert, J. Vobly, P. Vodopianov, A. Voelker, F. Vogel, M. Vollinger, C. Volpini, G. Von Ortenberg, M. Vonk, V. Vorobieva, A. Vostner, A. Vuffrav. L. Vullierme, B. Vysotsky, V. W Wacker, B. Wada, H. Wait G

MOA01PO09 WEA11PO03 MOA08PO08 MOA05PO06 MOM2OR5 THA01PO03, MOA2OR4. THA01PO06. WEA01P012 MOA03PO05, MOA10PO03, MOA10PO06, THA05PO10 WEA05PO12 MOA03PO05 MOM10R4 MOA02PO11, TUM10R2 THA04PO01 WEA05PO05, WEA05PO07 MOM2OR1 TUA07PO10 MOA07PO08 THM10R5 FRM10R1 MOA02PO07 THA01PO08, THA01PO07 WEA02PO14 **THA11PO04** MOM1OR1, WEA1OR6 THA12PO12 **THA11PO04** FRM10R5 MOA06PO05, MOA06PO11 **THA01PO09** MOA07PO12 WEA3OR3 THA08PO02, THA08PO12, WFA10R5 WFA3OR4 MOA3OR3. THA08PO01. THA08PO08 TUA06PO12, TUA07PO02, TUM2OR3, FRM2OR5, WEM10R4 TUA06PO08, FRM2OR5, TUA06PO09, TUA07PO09 MOA2OR3 WEM2OR6 MOA01PO06, MOA01PO05, TUA1OR1 FRM10R3, THA10PO07 TUA08PO04 FRM2OR2, MOA06PO04, MOA06PO07 TUA07PO10, TUA07PO05 WEA08PO01 WEA09PO09 MOA12PO02 MOA06PO08, MOA06PO04, FRM2OR1, THA06PO10 TUA02PO02. THA01PO14 THA08PO05 THA08PO11, TUA01PO10, WEA07PO10, WEA3OR3, WEA3OR4 FRM10R1 WEA02PO14 WEA01PO15, MOA1OR2, THA01PO13 THA01PO09, THM1OR6, TUA11PO06, WEA12PO05 **THA12PO13** MOA06PO02 TUA02PO03 MOM10R1

WEA01P007 TUA08P005 **TUA07P004**, TUA07P002, WEA03P004, WEA05P004, WEA07P007, WEM10R4

Wake. M.

Walbridge, D.	TUA04PO05	
Walckiers, L.	TUM2OR1	
Walsh, R.	MOA02P001, THA10P008 , WEA01P014	FRM1OR2,
Walter, G.	THA07PO05	
Walter, P.	TUM3OR1	
Wanderer, P.	WEM1OR1, TUM2OR2	
Wands, R.	WEA08PO08	
Wang, B.	MOA05PO04, THA06PO12	
Wang, C.	THA02PO12, WEA11PO08	
Wang, G.	TUA04PO09	
Wang, H.	WEA06PO04, TUA10PO06,	WEA03PO08,
- U	WEA04PO03, WEA10PO02	
Wang, J.	THA03PO04, WEA02PO12, WE WEA11PO07	A11PO04,
Wang, M.	THA12PO05, THA12PO06, TUA	08PO10
Wang, Q.	MOA07PO01, THA06PO02,	TUA11PO02,
	WEA09PO01, WEA10PO01, MOA05PO03 MOA07PO01	
	THA06PO02. TUA10PO02.	TUA11PO02.
	WEA03PO06, WEA06PO04,	WEA09PO01,
	WEA10PO01, WEA10PO02	
Wang, R.	WEA03PO02, WEA03PO03	
Wang, S.	MOA09P004 , WEA02PO12,	WEA11PO04,
	WEA11PO07.	
Wang, W.		
Wang, W.J.	TUA08PO01	
Wang, X.	THA03PO08, TUA04P009, WEM3OR3, WEA02PO10,	WEA02PO11,
Wong V		
wang, r.	THA03PO08, THA06PO03, TUA10PO14	TUA04PO09,
Wang, Z.	MOA10PO10, TUA03PO04 , TUM10R3, TUM10R5	MOA10PO16,
Wasaka, S.	MOA3OR6	
Watanabe K	TUA3OR1, THA01PO02,	THA01PO11,
	WEA01PO08, WEA01PO10,	WEA02PO06,
	WEA05PO01, WEA10PO06	
Watanabe, M.	MOA08PO05, MOA08PO06,	MOA08PO07,
Watanaha T	MOA08PO10 WEA11PO06	A03F003
Watanaba Y		
Watanabe, Y.		
Watauchi, S.	WEATIPO05	
Weber, H.	THA12PO04	
Weber, T.	MOA08PO09	
Wei, B.	THA04PO02	
Wei, J.	THA11PO03	
Weick, H.	THA07PO11	
Weijers, H.	TUA2OR2	
Weiland, T.	WEM10R2	
Weinheimer, C.	TUA07PO07	
Weisend II, J.	MOA08PO09	
Weiss, K.	THA03PO05	
Weisser, M.	TUA07PO01	
Wen. Z.	WEA11PO01, WEA11PO02, WE	EA11PO09
Weng I	MOA05PO04, THA06PO12	
Weng P	THMPL2, THA03PO04, THA11F	2O03
Werner A	THA05PO01	
Wesche R	TUA11PO05 THM1OR6 TUA1	1P006
Wessel W		
Wiegers S		1005
Wiegers, S.		
Wildher, E.	MOA06PO10, MOA06PO02, TUA04PO11	MOA06PO04,
Williamson S	TUM3OR3	
Wilson M	THA07PO07 TUA02PO03	
Winkler M	THA07PO11	
Witto H		
	TUADODOO MEADEDOAD	
wojtasiewicz, G.	NOA09DO01	
vvolt, ∠.		
Wolff, J.	THA11PO04	
	MOM1OR1	

Wolfus, Y. Wolksi, A. Wollnik, H. Woo, I. Wosnitza, J. Wu, A. Wu, H. Wu, M-K. Wu, S. Wuchner, F. Wyder, P. Х Xi, X. Xia, J. Xia, P. Xiao, L. Xin, Y. Xing, Q. Xu, B. Xu, G. Xu, Q. Xu, X. Υ Yadav, R. Yagai, T. Yahata, K. Yakubovski, V. Yamada, H. Yamada, R. Yamada. S. Yamada, Y. Yamaguchi, H. Yamaguchi, M. Yamaguchi, S. Yamaji, M. Yamamoto, A. Yamamuro, H. Yamanaka, A. Yamanaka, M. Yamanoi, Y. Yamaoka, H. Yamashita, T. Yamazaki, Y. Yan, H. Yan, L. Yan, R. Yan, W. Yanagi, N. Yanase, Y. Yang, G. Yang, H. Yang, M.

THA02PO14 WEA06PO10 MOA03PO06 MOA11PO02, MOA11PO03 MOA1OR3 MOA1OR6 THA12PO06, WEA06PO01 THA02PO12, WEA11PO08 THA03PO04, THA11PO03 WEA12PO05 WEA10PO10 MOA01PO11 MOA03PO01, MOA03PO02, TUA04PO01, TUA04PO02, TUA04PO03 WEA06PO04 TUA10PO14, TUM1OR5, MOA01PO02, MOA09PO01, MOA10PO10, MOA04PO05, MOA10PO08, MOA10PO02. THA02PO01, THA04PO03, THM2OR4, TUA10PO01, TUA1OR6, TUM1OR3, WEA09PO07 FRM10R2 THA06PO12 THA12PO12 THA12PO06 TUA02PO09 MOA09PO01, THA02PO01, TUA10PO01, WEA06PO01 MOA02PO08, MOA07PO11, WEA06PO15 TUA11PO09, MOA09PO02, MOA09PO05 MOM3OR5 TUA03PO05 MOA01PO03 WEA05PO04, WEA07PO07, THA01PO05, WEA07PO08 MOA11PO06, WEA12PO07 WEA03PO05, MOA01PO04, THA02PO03 **TUA09PO01** THA05PO05, THA05PO06, THA05PO07, TUA03PO03, TUA05PO09, TUA05PO10, WEA11PO06 WEA03PO09 TUA12PO09, TUA12PO10 MOA01PO09, FRM2OR5, MOA07PO03, MOA08PO02, MOM3OR1, THA08PO03, TUA02PO07, TUA06PO03, WEA08PO03, WEA3OR7 THA09PO06 THA05PO10, TUA05PO06, WEA05PO06 WEA11PO05 MOA08PO03, MOA08PO04 MOA12PO09 TUA12PO09, TUA12PO10 MOA08PO07, MOA08PO11 THA06PO05, WEA06PO11 WEA2OR5 WEA09PO01, TUA11PO02. WEA10PO01 WEA11PO10 THA06PO05, THA06PO07, TUA04PO07, WEA11PO10 MOA11PO06 TUA12PO09, TUA12PO10 WEA09PO04, MOA05PO09, THA03PO09, WEA11PO02, WEA11PO09 THA04PO12, TUA02PO09, WEA03PO10, WEA10PO11 MOA03PO03

Yang, Q. Yang, S. Yang, S. E. Yang, S. Q. Yang, T. Yang, T-Y. Yang, W. Yang, W. J. Yang, X. Yao, Q. Yao, T. Yao, Y. Yashimoto, M. Yasuda, K. Yasunaka H Yazawa, T. Ye, L. Ye, Y. Yeom H Yeshurun, Y. Yi, C. Yim, S. Yim, S-W. Yonekawa, H. Yonezu, T. Yoo, J. Yoon, K. Y. Yoon, Y. S. Yoshida, K. Yoshida, T. Yoshida, Y. Yoshida, Z. Yoshikawa, M. Yoshino, Y. Yoshioka, H. Yu, J. Yu, S. Yu, Y. Yuan, P. Yuan, Y. Yue, J. Yuyama, M.

Ζ

Zahn, G. Zaitsev, Y.

WEA06PO13, THA06PO03, THA06PO04, THA06PO07, THA12PO06, TUA04PO07. WEA11PO10 MOA02PO10, THA12PO06 MOA10PO04, THA03PO12, THA05PO03, TUA09PO04, TUA09PO05 TUA08PO04 MOM10R2, MOM10R2 **WEA11PO08** TUA04PO07, WEA11PO10 WEA11PO02, WEA11PO09 THA06PO03, THA06PO07 TUA04PO04 THA04PO02 THA06PO08, THA12PO02, WEA04PO02. TUA03PO08 MOA07PO03 MOA09PO11 WEA01PO07 TUM10R2 MOA10PO11, MOA10PO12 MOA10PO05 MOA09PO03 THA02PO14 TUA02PO09 **THA02PO13** MOA09PO08, TUA09PO03 MOA11PO13, MOA11PO14, MOA11PO15 THA09PO03 THA04PO12, WEA10PO11 THA03PO10, WEA02PO05 THA03PO12, MOA02PO10, THA05PO03, TUA09PO05, WEA02PO05 MOA12PO01, MOA12PO03 WEA08PO03 TUA02PO08 THA11PO05, THA11PO07 WFA2OR4 MOA05PO05 WEA10PO03, WEA10PO04 **THA11PO03** TUA10PO06, WEA03PO08, WEA04PO03 MOA03PO03, MOA04PO05, THM2OR4, WEA03PO06, WEA09PO01, WEA09PO07 MOA03PO01, THM3OR4. MOA03PO02. MOA07PO02, TUA04PO01, TUA04P TUA04PO03, TUA04PO04, TUA08PO01 TUA04PO02. MOA03PO01, MOA03PO02, THA06PO01, WEA09PO01 TUA1OR3 WEA01PO11

TUA11PO06, WEM2OR5

THA08PO01, THA08PO02

Zak, T. Zaleski, A. Zamborlin, D. Zani, L. Zanino, R. Zannella, S. Zapretilina, E. Zeitler, U. Zeller. A. Zena. G. Zhang, A. Zhang, B. Zhang, D. Zhang, G. Zhang, J. Zhang, L. Zhang, P. Zhang, S. Zhang, X. Zhang, Y. Zhang, Z. Zhao, B. Zhao, C. Zhao, L. Zhao, X. Zhao, Y. Zhao, Z. Zheng, J. Zherlitsyn, S. Zhilyaev, K. Zhou, J. Zhou, Q. Zhou, Y. Zhou, Z. Zhu, G. Zhu, Z. Zhukovsky, A. Zlobin, A. Zubko, V. Zubkov. N.

Zvyagin, S.

MOA02PO14, MOA02PO15 MOA01PO10 WEA07PO10 WEA12PO05 THM1OR3, MOA05PO02, MOA12PO07, WEA12PO04 THA05PO09 WEA12PO09, MOA12PO06, MOA12PO08, THA09PO07, THM10R3, TUA11PO07 MOA10R4 MOM3OR2 WEA11PO07 TUA08PO05 **MOA07PO02, THA06PO01**, THM3 TUA04PO01, TUA04PO02, TUA04PO03 THM3OR4. MOA10PO10, TUM10R5 TUA10PO06, TUA12PO02, WEA06PO12, WEA02PO07. WEA02PO10. WEA02PO11. WEA03P008, WEA04P003, WEM30R3 MOA10PO10, TUM10R3, TUM10R5 MOA09PO01 WEA03PO02, WEA03PO03 MOA03PO01, TUA04PO03, TUA04PO04, TUA08PO01 MOA07PO02, THM3OR4 WEA06PO09, MOA2OR1, THA03PO04, THA03PO09, THA12PO03, WEA11PO07 MOA10PO08, THA04PO03, TUA1OR6, MOA01PO02, TUM1OR5 MOA07PO01, TUA11PO02, WEA10PO01, WEA10PO02 MOA04PO05, THM2OR4, WEA09PO07. TUM10R5 MOM10R2, TUA02P009, TUA12P002, TUA12PO03 THA12P005, TUA10P001, TUA10P014 THA03PO08 MOA09PO04 WFA11PO07 MOA05PO04, WEA02PO12, WEA11PO04 MOA1OR3 TUA07PO12 TUA02PO09 WEA06PO11 THA04PO02 MOA03PO01 **MOA10PO16** TUA02PO09, TUA10PO01. TUA10PO14. TUM1OR3 THA11PO02 THM10R2 MOA03PO04, MOA2OR3, MOA3OR4, THA01PO05, TUA2OR5, WEA07PO01 WEA07PO03, WEA07PO07, WEA07PO08 THA07PO01, THA07PO02 TUA07PO10 MOA1OR3