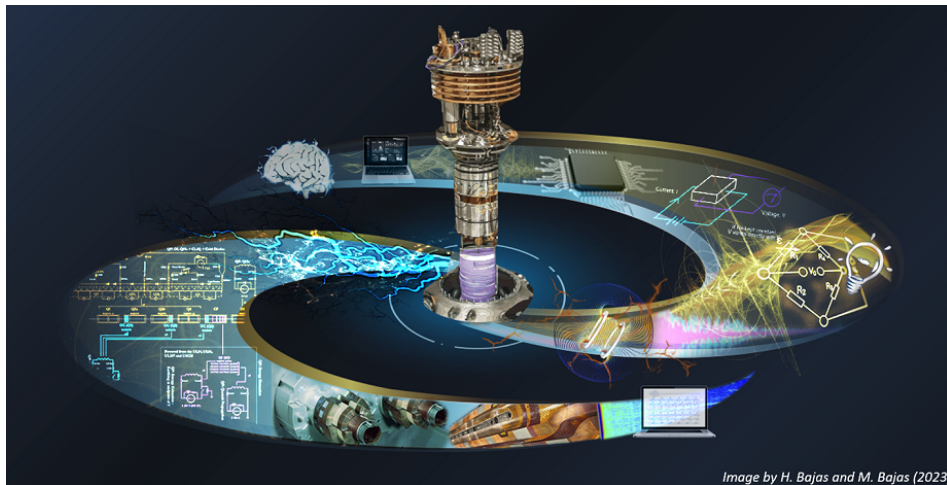


Lectures on Superconducting Magnet Test Stands, Magnet Protections and Diagnostics (as integral part of SMTF & IDSM Workshops)



Report of Contributions

Contribution ID: 1

Type: **not specified**

Superconducting magnets: why do we test ?

Tuesday 30 May 2023 16:30 (1 hour)

About the lecture:

In this talk we will review the main aims of test at cryogenic temperatures: electrical integrity, virgin training and performance, stability at flat-top, retraining after thermal cycle, power losses and field quality. We will outline the main strategies adopted for high energy colliders, with a special attention on the LHC and on the HL LHC cases.

About the speaker:

Ezio Todesco works at CERN, taking care of FQ in LHC dipole and then of the magnetic model of LHC. Since 2015 he is also in charge of the interaction region magnets for HL-LHC, including the Nb₃Sn triplet quadrupoles, to be installed in 2026-28.

Presenter: Dr TODESCO, Ezio (CERN)

Contribution ID: 2

Type: **not specified**

Phenomenology behind superconducting magnets training

Tuesday 30 May 2023 17:40 (1 hour)

About the lecture:

“Training” represents one of the most studied, analyzed, and debated phenomenon in superconducting magnets. It can be defined as the occurrence of premature quenches at progressively increasing currents during consecutive ramps. When a magnet requires a large number of quenches to reach the operational current, the training campaign can have a significant impact on the cost and time of a test. Therefore, the investigation of the possible causes of training and the identification of mitigation strategies constitute a major effort in superconducting magnet R&D. After a brief introduction of the quench process, the course will present magnet training by introducing the different possible triggering causes, and by describing modeling and measuring techniques aimed at its characterization. During the class, examples of training plots of recent magnets will be shown, and possible solutions currently explored by the magnet community toward the reduction of training quenches will be discussed.

About the speaker:

“In 2011, I joined the CERN Magnets, Superconductors and Cryostats (MSC) Group as a staff working on Nb3Sn superconducting magnets and in 2012 I started leading the development of MQXFB, the Nb3Sn low- β quadrupole magnet for the High Luminosity LHC (HL-LHC) project and the CERN activities of the Nb3Sn dipole magnet FRESA2. Since February 2020, I am the SMP Program Deputy at LBNL and in 2023 I started leading the LBNL activities for the US Magnet Development Program (MDP).”

Presenter: FERRACIN, Paolo (LBNL)

Contribution ID: 3

Type: **not specified**

Introduction to the cryogenics of large superconducting systems

Wednesday 31 May 2023 16:30 (1 hour)

About the lecture:

- Quick history of gas refrigeration and basic concepts of helium machines.
- Current general configuration.
- Main components of helium refrigerators.
- Efficiency.
- Integration in superconducting magnet cooling. Examples.

About the speaker:

Philippe BREDY, cryogenic engineer at Accelerator, Cryogenics and Magnetism Department at CEA Saclay (France), in charge of helium cryogenics development and associated test platforms for Sc components like large superconducting magnets for physics (CMS) or medical detectors (High field IRM Iseult) and for superconducting RF cavities of accelerators.

Presenter: BREDY, Philippe (CEA Saclay)

Contribution ID: 4

Type: **not specified**

Protection against excessive pressure in He cryostats

Wednesday 31 May 2023 17:40 (1 hour)

About the lecture:

«Protection against excessive pressure in He Cryostats», aims to raise awareness of the risk of accidental overpressure in cryogenic devices. The main scenarios leading to this accident will be discussed, with particular emphasis on the breaking of the isolation vacuum. It is imperative that cryogenic equipment must be equipped with safety devices such as relief valves, rupture bursting discs, and that they are properly sized. The main points of the sizing method will be discussed and the differences with the ISO 21013-3 standard will be clearly explained.

About the speaker:

“I began my career at CEA as an instrumentation engineer in a thermohydraulic installation representing a model of a PWR (Pressurized Water Reactor) within the Nuclear Energy Department in Grenoble. Later, in the same department, I was in charge of a laboratory, specifically the mechanical and thermal design office.

In 2001, I changed departments to work in the field of cryogenics, taking on the role of project engineer in the design and development of cryostats. I also became the head of the design office in 2009 until the end of 2017.

At the same time, since 2006, I have been involved in cryogenic safety. I operated an experimental device that allowed quantifying the heat flux in supercritical helium following a vacuum rupture.

Alongside other colleagues, I contributed to the writing of a document published by “Techniques de l’Ingénieur” on the design of safety components TI 9814 and participated in the development of an EU standard (EU Prn17527) related to helium cryostats, where design aspects are extensively discussed.”

Presenter: PONCET, Jean-Marc (CEA)

Contribution ID: 5

Type: **not specified**

Current Leads for Accelerator Superconducting Magnet Test Stands

Thursday 1 June 2023 16:30 (1 hour)

About the lecture:

In this lecture an overview of the current leads operating on test stands that performing experiments with superconducting accelerator magnets will be presented. After a brief introduction about the basic principles of current leads –requirements and design challenges –a few test stand examples will be discussed. Then experience operating the current leads and issues that might arise will be reviewed.

About the speaker:

Senior Scientist of Fermilab. In late nineties he was in charge working with industry for the development of the 6kA HTS current leads and installing them into the Fermilab accelerator complex. The leads were successfully operated for 10 years. He was also in charge of bringing up a test facility that was dedicated to test HTS currents leads for the Tevatron and later for the HTS leads produced for the LHC IR distribution boxes (DFBX) and few years ago testing the ASC produced 6kA HTS current leads in a vacuum environment up to 10 kA operating current. These leads are being used for the Mu2e experiment.

Presenter: FEHER, Sandor (FNAL)

Contribution ID: 6

Type: **not specified**

Power Converter for Superconducting Magnets

Thursday 1 June 2023 17:40 (1 hour)

About the lecture:

Power converters play a central role in particle accelerators where both their performances are directly linked. As accelerator complexes develop towards higher beam energies and more towards a more sustainable nature, in response to the needs of physics research and of reducing the environmental impact, power converters are required to be on the forefront of technology. They have proliferated into accelerator complexes where thousands of them are used in modern complexes as at CERN. They must, therefore, achieve high reliability and in many cases cutting-edge precision. Hence, powering superconducting magnets for accelerators and test benches is a driving force for the development of high-performance power converters.

This lecture intends to introduce the requirements of power converters for superconducting magnets used in particle accelerators and magnet test benches. After showing the power conversion principles, it describes the role of power converters, the challenges and constraints when powering superconducting magnets. The principles of redundancy and modularity are discussed in this lecture in addition to the power converter control and high precision definition. More sustainable installations would need a better management of electromagnetic energies used in accelerator complexes. This lecture shows, therefore, the latest tendencies in terms of energy storage for power converters. Finally, it lists the key circuit parameters to be taken into consideration to properly specify a power converter for superconducting magnets.

About the speaker:

Samer Yammine has obtained his master's and PhD in electrical engineering from ENSEEIHT, Toulouse. He has joined the Electrical Power Converter group at CERN working on various projects related to the powering of the LHC accelerator complex and its HL-LHC upgrade and is now responsible for the HL-LHC IT String experimental test program.

Presenter: YAMMINE, Samer (CERN)

Contribution ID: 7

Type: **not specified**

Electrical integrity tests and electrical failure diagnostics in superconducting circuits

Friday 2 June 2023 16:30 (1 hour)

About the lecture:

Electrical failures in superconducting circuits can cause severe damage to the equipment and even lead to personal injury due to high operating currents. Often a significant energy stored in the magnetic field generated by the superconducting magnets becomes an additional risk factor.

The training course will cover various topics related to electrical integrity tests and electrical failure diagnostics, using examples gathered by Electrical Quality Assurance Team during more than 15 years of experience in electrical testing and nonconformity investigations of the Large Hadron Collider superconducting circuits.

Participants will learn about commonly used types of electrical tests, selection of test parameters, proper management of measurement data, how to troubleshoot electrical failures, and develop a comprehensive plan for electrical testing and diagnosis.

This training course is designed for people working with superconducting circuits, as well as those involved in the design, manufacture, and maintenance of equipment that utilizes superconducting magnets and bus bars. By the end of the course, participants will have a thorough understanding of electrical integrity tests and electrical failure diagnostics and will be able to implement them effectively in their work.

About the speaker:

Jaromir Ludwin is an electrical engineer with background in physics. He's working in the Institute of Nuclear Physics in Krakow, Poland. He's a member of the Electrical Quality Assurance Team at CERN since 2006.

Presenter: LUDWIN, Jaromir (HNINP)

Contribution ID: 8

Type: **not specified**

Introduction to quench detection

Friday 2 June 2023 17:40 (1 hour)

About the lecture:

The notion of quench protection and detection in superconducting magnets will be introduced, along with detection requirements and where they come from. Standard for the accelerator magnet field approaches to quench detection will be described, main obstacles and solutions will be presented. Modern hardware/firmware/software implementations and examples will be mentioned. Alternative or under development methods for quench detection will be discussed and reasons for their search explained.

About the speaker:

Scientist at FNAL since 2015; working on facility and magnet diagnostic improvements, magnet testing and data analysis; recognizable involvements include support for HL-LHC at FNAL and “15 Tesla” demonstrator magnet.

Presenter: STOYNEV, Stoyan (FNAL)

Contribution ID: 9

Type: **not specified**

Quench protection with external energy extraction

Monday 5 June 2023 16:30 (1 hour)

Topics to be discussed during the lecture:

1. Various techniques to protect the superconducting magnet during quenching.
2. When and why, we need energy extraction.
3. Different configuration of Energy Extraction Circuits.
4. Engineering considerations of Energy Extraction system including power circuit, energy absorbing resistors and high current switches.
5. Detail design of 10kA Energy Extraction Switch using IGBTs in parallel.

Presenter: PIYUSH, Joshi (BNL)

Contribution ID: 10

Type: **not specified**

Quench protection with strip heaters

Monday 5 June 2023 17:40 (1 hour)

In the design and use of superconducting magnets one must always ensure the safe dissipation of the stored magnetic energy after a quench. External energy extraction is relatively simple to implement, and it has the advantage of dissipating the energy outside of the cryostat. However, its capacity is limited by the maximum allowed voltage across the magnet terminals, which limits the dump resistor size. When external energy extraction is not enough, a common method is to apply electrical strip heaters on coil surfaces. After quench detection these heaters are activated, and they will bring the superconducting coils to normal state thus increasing the coil resistance, increasing the magnet current decay rate and limiting the peak temperature. In this lecture, we will discuss practical guidelines for designing and using strip heaters for magnet quench protection. We will cover topics such as performance requirements, strip heater parameters, and potential safety concerns. These include risks of heater delamination, bubble formation, and electrical shorts. We will also discuss testing methods for evaluating heater functionality and compare the pros and cons of strip heaters to other quench protection methods.

Presenter: SALMI, Tiina-Mari (Tampere University)

Contribution ID: 11

Type: **not specified**

Quench protection with CLIQ and eCLIQ

Tuesday 6 June 2023 16:30 (1 hour)

About the lecture:

Coupling-Loss Induced Quench (CLIQ) is a quench protection method for superconducting magnets developed at CERN, which relies on a capacitive discharge unit introducing an oscillation of the transport current in the superconducting cable of the coil. The resulting fast change of the local magnetic field introduces a high coupling-current loss, which, in turn, causes a fast quench of a large fraction of the coil due to enhanced temperature.

The External coil CLIQ (E-CLIQ) relies on a capacitive discharge through a resistive coil magnetically coupled with the solenoid but external to it. Various versions of this method (with other naming) were proposed in research institutes, and also at CERN.

This training will introduce the working principles of the CLIQ and E-CLIQ methods, evaluate their advantages and disadvantages, and highlight the key parameters affecting their performances. Furthermore, a selection of past applications will be presented to identify different CLIQ configurations and electrical circuits. Finally, practical recommendations will be provided to magnet test engineers preparing a test facility including CLIQ and testing magnets with a CLIQ unit.

About the speaker:

Emmanuele Ravaioli defended his PhD in applied physics at the University of Twente in 2015. He has worked on superconducting magnet quench protection, multi-physics modeling, and circuit design since 2009, at CERN and at the Lawrence Berkeley National Laboratory. He is currently co-owner of the STEAM project.

Presenter: Dr RAVAIOLI, Emmanuele (CERN)

Contribution ID: 12

Type: **not specified**

Aspects of quench detection and protection for HTS

Tuesday 6 June 2023 17:40 (1 hour)

About the lecture:

The course will cover various aspects of quench detection and protection for HTS. These include the methods used to detect quenches in HTS, the types of quench protection systems commonly used, and any challenges or limitations associated with these systems.

About the speaker:

Tim Mulder did his PhD in ATLAS magnet group at CERN via the University of Twente on the development of ReBCO CORC cables, followed by a fellowship at CERN working on several different HTS applications. He briefly worked at RWTH Aachen on the design of the large HTS magnet system for the AMS-100 experiment. After which he returned to CERN, where he now works in the Machine Protection group on the R&D of new protection concepts for both LTS and HTS magnets.

Presenter: Dr MULDER, Tim (CERN)

Contribution ID: 13

Type: **not specified**

Fiber Optic Sensors for temperature monitoring and quench detection

Wednesday 7 June 2023 16:30 (1 hour)

About the lecture:

This course is dedicated to the use of fiber optic sensors (FOS) as novel quench detection systems in superconducting coils. The various existing techniques (Fiber Bragg Grating, Rayleigh scattering, etc...) will be presented together with their different working principles. A focus will be made on Fiber Bragg Grating technology giving the details on the constitutive equation describing the behavior of the sensor. Methods to increase the sensitivity of the sensor at cryogenics temperature will be also presented. The necessary hardware will be exposed with their technical specification and practical examples will be given.

About the speaker:

Hugo Bajas have done is PhD with ITER and CEA on the mechanical optimization of Nb3Sn cable-in-conduit conductor with his design now use for the Central Solenoid conductor. He then worked at CERN as fellow then staff during 11 years on HL-LHC magnet testing in the Test Facility Section. He is now part of the Swiss Plasma Center at EPFL and work on fusion conductor design and testing. He is also in charge of the fiber optic development for quench detection.

Presenter: BAJAS, Hugo (EPFL)

Contribution ID: 14

Type: **not specified**

Mechanical measurements in superconducting magnets: practice and theory

Wednesday 7 June 2023 17:40 (1 hour)

About the lecture:

High-energy accelerator or detector projects demands a sustained R&D effort to implement advanced technologies for the development of a new generation of superconducting magnets, high-energy proton beam dumps, powerful particle physics detectors and cryogenic radio-frequency cavities. During the research and developments phases, mechanical measurements is paramount to validate Finite Element Analysis (FEA) and confirm the mechanical response of complex structures in harsh environments such as cryogenic temperatures, high magnetic and electric fields, high radiation level or the vicinity of high energy proton beams.

This course will provide an overview of the mechanical measurement techniques performed under harsh environmental conditions. Furthermore the seminar will focus on the experimental stress analysis based on standard electrical strain gauges and optical fibre strain measurements. Disturbances on the measurements will be also carefully treated with some corrective solutions and compensation techniques. The measurement of the dynamic behaviour of structure will also be discussed with some examples.

About the speaker:

Michael Guinchard graduated Engineering studies in the instrumentation –measurement field at the Conservatoire National des Arts et Métiers at Strasbourg in France. He worked for General Motors in the Noise and Vibration Laboratory of the European Technical Centre during 6 years before to join CERN in 2005 to develop and lead the Mechanical Measurements Laboratory in the Engineering Department.

The lab is composed by 10 persons, it is specialized in measurement of mechanical stresses and strains, displacements, pressures and vibrations applicable to a wide range of components and devices for present and future high energy physics projects. The measurements are carried out in a large variety of environments, including cryogenic and high temperatures, high radiation environment and high magnetic fields. The laboratory is also equipped with a full set of equipment to perform thermo-mechanical analysis from cryogenic.

Presenter: GUINCHARD, Michael (CERN)

Contribution ID: 15

Type: **not specified**

Magnetometers theory

Thursday 8 June 2023 16:30 (1 hour)

About the lecture:

Magnetometers are the most important tools for accurately evaluating the performance of superconducting magnets. A magnetic field at any point in the space is a vector quantity, meaning that measuring the magnetic field requires knowledge of both its direction and strength. However, there is no single magnetometer that can measure magnetic field vectors with high accuracy and sensitivity across all magnetic field ranges. Therefore, it is necessary to select the appropriate technique from a variety of different options in order to properly evaluate magnet performance. This talk will provide an overview of some of the most widely used magnetometers, such as Hall sensors, fluxmeter and NMR, as well as their principles of operation. When discussing magnet performance, unique expressions may need to be used to represent the magnetic field distribution. For instance, accelerator magnets use a two-dimensional multipole expansion of a field, while three-dimensional spherical harmonic expansion is typically used to express the special uniformity of magnetic fields in MRI magnets. These two expressions will also be introduced in the talk. Additionally, the importance of calibrating magnetometers will be emphasized.

About the speaker:

“I joined Cryogenic science center KEK since 2004, and was involved the construction of superconducting combined function magnets for Neutrino experiment at J-PARC, Japan. I was in charge of cooling test of magnets and commissioning of beam line. I’m also member of cryogenic section, J-PARC, now, and engaged on the superconducting magnet development for physics experiment in J-PARC, COMET, g-2/EDM, and so on.”

Presenter: SASAKI, Ken-ichi (KEK)

Contribution ID: 16

Type: **not specified**

Magnetic measurements in accelerator magnets

Thursday 8 June 2023 17:40 (1 hour)

About the lecture:

Magnetic measurements are required throughout all the development phases of superconducting magnets: from short models and prototypes to series units both at ambient and cryogenic temperature. Depending on the measurement requirements and on the test conditions, different instruments are exploited.

In this talk the instruments typically used for the magnetic characterization of superconducting magnets are presented. The design principles, the technologies, and the actual implementation of rotating coils, stationary coils, and stretched wire are discussed. Example of results from real tests are given, with emphasis on their interpretation as well as on the achieved accuracy.

About the speaker:

In 2008, Lucio joined the CERN Magnets, Superconductors and Cryostats Group as PhD student working on the development of a magnetic measurement system for the characterization of dynamic effects in superconducting magnets. From 2012, he has been in charge of magnetic measurements for various projects and, in particular, he has followed the magnetic tests on short models and prototypes magnets for HL-LHC. Within this context, he designed and built different systems such as rotating-coil probes, rotating-coil chains, and quench antennas. More recently he has been involved in the development of the new superconducting magnets for the “High Field Magnets” program.

Presenter: FISCARELLI, Lucio (CERN)

Contribution ID: 17

Type: **not specified**

Acoustic diagnostics for superconducting magnets

Friday 9 June 2023 16:30 (1 hour)

About the lecture:

High-field superconducting magnets operate during operation and exhibit transient releases of elastic energy associated with epoxy cracking or conductor motion. These events cause premature magnet quenching and training. Acoustic emission (AE) diagnostics is a unique way of probing transient magnet mechanics in a non-invasive way. It allows for measuring mechanical energy releases during magnet operation and performing localization of quenches and quench precursors. In this lecture, I will introduce the basics of the AE technique, and discuss AE sensor hardware and data analysis. Examples of AE diagnostics for quench localization in various magnets tested at LBNL will be presented.

Besides AE, I will also discuss “active” ultrasonic methods developed recently for monitoring stress and temperature variation in magnets and quench detection.

About the speaker:

Maxim Marchevsky received Ph.D. in Physics (with honors) from Leiden University, Netherlands (1997). He held appointments at NEC Research Institute in Princeton NJ, Syracuse University, and SuperPower, Inc., working on various aspects of general and applied superconductivity. In 2010 he joined LBNL and supervised superconducting magnet testing and analysis for the US LARP. Presently, he leads the diagnostics and instrumentation development effort for the US Magnet Development Program and a number of magnet technology projects.

Presenter: MARCHEVSKY, Maxim (LBNL)

Contribution ID: **18**Type: **not specified**

Design of the DAQ systems for the LHC superconducting magnet test benches

Friday 9 June 2023 17:40 (1 hour)

The LHC superconducting magnet test benches controls were designed in 1996. They were based on VME data acquisition systems, Siemens PLCs control and interlocks systems. After a review of renovation of superconducting laboratories at CERN in 2009, it was decided to replace the VME systems with a PXI based systems and the ageing Sun/Solaris workstations with Linux PC's. This lecture covers the process of designing a new DAQ system for superconducting magnets, from gathering requirements, signal conditioning, hardware and software architecture and finally the lessons learned after 14 years of operation.

Presenter: JANKOWSKI, Patryk Dawid (CERN)

Contribution ID: 19

Type: **not specified**

Quench detection and protection of fusion magnets

Monday 12 June 2023 16:30 (1 hour)

About the lecture:

Quench protection in fusion magnets is based on external energy extraction, due to the large stored energy. The external resistor system is arranged such as to adjust the maximum voltage to the ground to an acceptable level.

The quench propagation is slowed down due to the helium circulating in the cable in conduit, classically used in fusion magnets.

The quench detection is classically ensured by voltage detection in fusion magnets. The balance of the inductive voltage is more difficult to perform in comparison with Particle Physics or NMR magnets. This is due the simultaneous independent operation of several magnet systems together.

About the speaker:

Jean-Luc Duchateau is presently Scientific Adviser at CEA Institute for Magnetic Fusion Research.

Presenter: DUCHATEAU, Jean-Luc (CEA)

Contribution ID: 20

Type: **not specified**

AC losses in superconductors: theory and methods of measurements

Monday 12 June 2023 17:40 (1 hour)

About the lecture:

The course tries to summarise over 60 years of theory and experiments on AC losses in LTS and HTS magnets. The participants will learn definitions, where to find and how to use analytical tools for loss calculations. The course provides a list of references (past courses, publications and books) for deeper studies and further reading. Several examples for both low and high temperature superconductors are provided. The participants will find the tools to solve specific problems, but substantial amount of time should be then dedicated to master these tools.

Course plan:

- Definitions and historical development of AC loss research. Why AC losses matter in magnets design?
- Losses in superconducting magnets and losses in superconducting electro-technical devices (motors, cables, transformers,...).
- AC losses as magnetisation: M-H diagram and examples for hysteretic, coupling and eddy current losses
- Analytical models and example of application (LTS and HTS) for hysteretic, coupling and eddy current losses.
- Numerical methods to compute AC losses.
- AC losses in strands, cables and magnets: how to scale up in complexity?
- Loss map: a simple way to draw the complex landscape of hysteretic, coupling and eddy current losses in strand and cables.
- Survey of electrical and calorimetric methods for measuring AC losses.

About the speaker:

Two years as junior researcher at Pirelli —AC loss in Bi223 power cables

University of Geneva PhD in Physics —electromechanical characterization and microstructure of Nb3Sn

NIMS, Japan —development of high field magnet with coated conductors

EPFL —research on HTS (mainly coated conductor but also Bi2223 and Bi2212) for high field solenoids and cables for fusion magnets

Presenter: UGLIETTI, Davide (EPFL)