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A yearly journal devoted to
Cryogenics, Superconductivity and Low Temperature Physics

Published by
Indian Cryogenics Council

Proceeding (Part-A) of
Twenty Fifth National Symposium on Cryogenics
(NSC-25)

Hosted by
University of Hyderabad, Hyderabad
December (8-10), 2014

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Indian Journal of Cryogenics

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All the papers received for publication in “Indian Journal of Cryogenics” are reviewed by a large number of Professors, Scientists and Engineers from Universities, Government Institutions and Corporate Sectors across the country in an honorary capacity. Papers are also sent to experts abroad for reviewing.

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Indian Journal of Cryogenics

A yearly journal devoted to Cryogenics,
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PREFACE

The University of Hyderabad got the privilege for hosting the Silver Jubilee of National Symposium on Cryogenics (NSC-25) during Dec. 8 – 10, 2014. The symposium provided a unique opportunity to Professors, Scientists, Engineers from research institutions and experts from the Industry & Corporate Sector and the young students to share their research work and development activities. The symposium focused on the growth of science & technology related to cryogenics, superconducting materials, cryo-systems & superconducting devices' in India. The NSC-25 was also importantin so far as it enabled scientists involved in international cryogenics and superconductivity to exchange their experiences and new developments with the young researchers.

In recent years, several universities and other institutions of research and higher education have installed cryogenic infrastructure facilities, mostly based on cryogen free technologies for the growth of research in the area of low temperature physics. Due to the depletion in helium gas sources, the dependence on cryogen free technologies is likely to growmore in the coming years. The conservation and recycling of helium with minimum losses is absolutely essential to cut down the running cost of helium liquefiers. The University of Hyderabad is one of the universities in the country which has installed cryogenics infrastructure and had been carrying out basic research in a variety of materials at low temperature.A large number of students have written their thesis and obtained Ph.D. degrees.

The Symposium attracted about 190 participants from the cryogenics & superconductivity community from universities, research institutes and from the industries. There were 6 plenary and 21 invited talks. The symposium had 69 oral presentations and 79 poster presentations. Quite a number of industries from India as well as from abroad showcased their products and made presentations on their activities atthe NSC-25.

Three distinguished scientists Prof.R.Srinivasan, Dr.R. G. Sharma and Dr. T. S. Radhakrishnan were conferred ICC Life Time Achievement Awards-2014 during NSC-25 for their outstanding contribution in the area of Low Temperature Physics, Superconductivity and Cryogenics.

The organising committee thanks all the participants of the NSC-25 for making the symposium a grand success.

Prof. Rajender Singh
Chair and Convener, NSC-25

EDITORIAL

The Indian Journal of Cryogenics (IJC) publishes the proceedings of the National Symposia and papers received directly from the authors. It is a matter of great satisfaction that IJC has become a popular journal with our Cryogenics / Applied Superconductivity community. This issue has been delayed slightly because of our involvement in the ICEC/ICMC Conferencebut there is no backlog. It is a matter of pride for all of us that the conference went wonderfully well albeit, with the cooperation of the entire Cryogenic Community in the country. We would like to take this opportunity to complement all our authors and the members of the Editorial Advisory Board for their help and cooperation. I thank Dr. RK Bhandari, Dr. TS Datta, Dr. SoumenKar and Shri Anup Choudhury who were always available for consultation and help which enabled us to bring out the Vol. 41 issue of the IJC. Ms. Tania Gupta worked hard in contacting reviewers and authors to have the final version of the manuscripts.

This issue of IJC contains 28 papers in all out of a total of 70papers submitted and presented at the '25th National Symposium on Cryogenics' (NSC-25) at the university of Hyderabad during 8-10 December, 2014. The remaining papers will appear in Vol. 42. All the papers appearing in Vol. 41 have been reviewed by our experts on our panel of referees in India and abroad.

You will pleasantly find that the present issue begins with an invited review article written by Prof. Y.C. Saxena who initiated and led a large research team to successfully buildIndia's first superconducting tokamak, SST-1 at the Institute of Plasma Research, Gandhinagar, Ahmedabad. This article titled "Tokamak: A Device for Nuclear Fusion" describes all aspects of a fusion device starting from the fusion reaction, tokamak magnetic confinement, plasma heating, plasma shaping, different types of superconducting and normal magnet coils, and finally the ITER. I am sure the readers of the article will benefit a great deal and learn all the intricacies involved in building such a device. We hope to publish a similar invited review article authored by a very eminent professor/ scientist in each of our future volumes.

During last few months we have been sending abstracts and now the manuscripts of a very large number of papers submitted to the ICEC/ICMC conference for publication in the proceedings to our colleagues for review. Despite being busy with their academic work all of them responded admirably well. This review work is in full swing. Simultaneously we have been burdening them by sending papers for review for IJC Vol 41. Weexpress our gratitude to all our reviewers and thank them for their plentiful cooperation. We are open to suggestions whichcan addvalue to IJC.

R.G. Sharma

Chief Editor

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Tokamak: A device for nuclear fusion

Yogesh C. Saxena

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Tokamak is a plasma confinement device, which uses a combination of magnetic fields to confine hot plasma. Tokamak research has made rapid progress in terms of plasma confinement parameters and temperatures and it is a strong candidate for magnetic confinement based Nuclear Fusion Reactor. The paper gives introduction to tokama device, reviews the status to tokamak research with emphasis on tokamak research in India.

Key words: Nuclear fusion, Tokamak, Plasma, Confinement, Fusion reactor

Operational analysis and update on modifications to a helium liquefier under development at BARC

Anindya Chakravarty, Mukesh Goyal, Naseem Ahmed, Rajendran S. Menon, Mohananand Jadhav, Tejas Rane, Sandeep R. Nair, Jitendra Kumar, Naveen Kumar, Satish K. Bharti, Abhilash Chakravarty, Sandip K. Ghosh

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An experimental helium refrigerator/liquefier is being designed and developed by Cryo-Technology Division to be installed at Bhabha Atomic Research Centre, Mumbai. During first trial runs, certain limitations of the process were observed and some other fabrication/development issues came to light. After detailed steady state cycle simulation studies, it was decided to undertake some major modifications to achieve the target of about 200W refrigeration capacity at around 4.7K. The most significant modification involved changing the basic thermodynamic cycle from Collins to a modified Claude cycle which is more suited to turboexpanders. To this effect, simulation studies on the new cycle, with two turboexpanders in series interspaced with a multi stream heat exchanger, was taken up and the process computed. The present paper aims to describe in details different studies taken up on the helium refrigerator. It also aims to provide an update on the present status of development of the helium refrigerator/liquefier.

Key words: Helium liquefier, Modified claude cycle, Turboexpanders, Brazed plate fin heat exchangers

Performance Validation of a large scale helium turboexpander for cryogenic applications through CFD analysis

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The demand of low temperature for superconducting magnets used in high energy physics applications has necessitated the need for helium refrigeration and liquefaction cycles with improved efficiency. Any attempt of designing a plant with improved thermodynamic performance may call for improvement of efficiency of turboexpanders. Developing a design strategy for helium turboexpander with better efficiency demands in depth understanding of the complex flow physics. Computational Fluid Dynamics (CFD) is a useful tool to find the details of the flow and evolve a design strategy leading to improved performance of the machine. In the present work, 3D CFD analysis of a large scale cryogenic helium turboexpander designed and tested at BARC was performed using Ansys CFX®. Different aspects of computation procedure such as turbulence models, and models for rotor stator interface have been discussed. Results obtained from simulation were compared with experimental results for validation.

Key words: Helium turboexpander, Computational fluid dynamics

Development of experimental test facilities for validation of multistream plate fin heat exchanger design codes

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Compact plate-fin heat exchangers (PFHE) having very high effectiveness (>0.95) are key equipment of modern helium liquefaction / refrigeration systems. Effectiveness (ε) of these heat exchangers strongly influences the overall system performance. Apart from basic fluid film resistances, various secondary parameters such as axial heat conduction (AHC) through the heat exchanger metal matrix, parasitic heat in-leak from surroundings, variation in fluid/ metal properties and flow mal-distribution etc need to be considered while sizing/ rating such high effectiveness PFHE. Need of multiple streams in a single heat exchanger further complicates thermal designs. In-house codes are developed at BARC/ IIT Bombay for rating of such high effectiveness PFHEs. For experimental performance evaluation of PFHEs, their characterization at various operating conditions and validation of in-house developed numerical codes, a dedicated closed loop experimental test facility is developed. Development of the dedicated closed loop experimental test facility is presented in this paper along with initial test results.

Key words: Plate-fin heat exchanger, Heat exchanger experimental test facility.

Analytical investigation of process pipe failure in cryo-line; impact of different crack sizes

Shukla Vinit, Vaghela H, Shah Nitin, ChoukekarKetan, Kumar Uday, Sarkar Biswanath

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Safety is important in cryogenic field dealing with liquid or supercritical state helium. Cryo-lines carrying helium at 4 K temperature level and equipped with thermal

compensation devices, like bellows, are prone todevelopment of cracksand its propagation after a number of expansion and contraction. Even after careful design, appropriate material selection and a strict quality control during manufacturing, probability of crack development in the Cryo-line cannot be avoided. An investigative study of failure of process pipe due to the development of crack has been carried out for a long Cryo-line laid in a confined space considering the space between two vacuum barriers is 10 meter.Study shows that minimum temperature of the Outer Vacuum Jacket (OVJ)goes down to 251 K in 540th second and the minimum temperature of the confined space reaches to 73 K in 37th second. As the crack size reduces, the OVJ pipe temperature approaches to the minimum value in longer time and confined space final temperature increases.

Key words: Cryo-line, Break of insulation vacuum, Helium, Cryogenics

Transient response of a two layer cryogenic compact plate fin heat exchanger

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In the present paper, a model for the transient simulation of a 2 layer plate fin heat exchanger having offset strip fins with helium as working fluid is formulated based on unsteady mass and energy conservation equations. The behaviour of the heat exchanger during start up from a given initial condition, cool down and during a step and ramp change in the inlet temperature of one of the fluids is studied with the help of this model. Initially, a model based on average helium properties is developed which is further extended to take into account the temperature dependence of helium properties along with axial heat conduction and variable thermal capacity of the metal separating plate. A computer code has also been developed to this effect.

Key words: Transient simulation, Plate fin heat exchanger

Numerical investigations on a pressure wave refrigerator

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A pressure wave refrigerator is an unsteady flow device which can transfer energy by pressure wave from one fluid to the other. Construction wise it has one or a set of inlet port and one or a set of receiving tubes. Hot high pressure gas enters the receiving tube through inlet port and compresses the existing low pressure gas inside the tube through a shock wave. While the shock wave moves forward, an expansion wave moves in the reverse direction and cools the gas at the inlet end of the receiving tube. This gas is further expanded and cooled when the tube is connected to the exhaust port of the rotor. The gas with shock wave dissipates thermal energy through the tube wall into the environment. In this paper a two-dimensional axisymmetric CFD model is presentedto understand wave interactions in an oscillating flowinside a receiving tube.Numericalinvestigations were carried outunder varying inlet pressureand length of the receiving tube. Effects of a shock absorber at the closed end of the tube for

minimizing the reflected shock wave were also studied.Isentropic efficiencies for various cases are computed and comparatively presented in the paper.

Key words: Unsteady flow, Wave rotor, Pressure oscillating tube, Shock waves, Numerical simulation.

Simulation studies on aerostatic thrust bearings with special reference to cryogenic turboexpanders

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The present paper details theoretical studies on aerostatic thrust bearings with special reference to cryogenic turboexpander rotors. A special case of 4.5K, 250W helium refrigerator has also been considered where both the turboexpanders are supported by aerostatic thrust bearings of similar dimensions. The bearings experience continuously changing ambient (discharge) pressure during the start-up and shut-down transients, thereby requiring a proper estimation of bearing characteristics for successful turboexpander operation at all times.Performance charts, in terms of load capacity, stiffness and bearing gas flow with respect to change in clearance have been presented for different bearing gas supply and discharge pressures.

Key words: Aerostaticthrust bearing, Cryogenic turboexpanders

Optimum design of liquid helium dewar with vapour cooled shields

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The work presented aims to develop a numerical model which can be used to design a vapour shielded liquid helium (LHe) Dewar without LN_2 Shield. This model can compute the position of shields and the Net Evaporation Rate (NER) based on the capacity and number of vapour cooled shields (VCS) given by the user. The effect of neck dimensions on the heat in-leak is also given by this model. Heat in-leak design calculations are done using Finite Difference Method (FDM). A computer program is developed using MATLAB®. The results can be obtained either in graphical form or in terms of minimum NER and optimal positions of the VCS. The modelis validated against available results in literature and additional results are discussed in detail. This program can be extended to estimate the neck dimensions and position of shields for any given capacity, number of shields and allowable boil-off rate.

Key words: Optimum design, Liquid Helium Dewar, Vapour Cooled Shields, Finite Difference Method, Heat in-leak

Design and analysis of standing wave quarter wavelength thermoacoustic engine

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Thermoacoustics have been recent area of investigationsdue to its noticeable advantages like simplicity, structural stability, absence of moving component, high reliability, minimal or no maintenance etc. In addition to these, thermoacoustic devices can use different noble gases and their mixtures as working fluid as well as they can use low grade energy sources such as solar energy, exhaust gas of an automobile, waste heat etc.Incurrent work, design of quarter wavelength standing wave type thermoacoustic engine stack, using the linear thermoacoustic theory, is described. A set of dimensionless parameters has been used toreduce large number of dependent parameters. The design procedure followed here can be a guide fordesign and development of thermoacoustic engines. Various operating parameters such asmean pressure, frequency, driving ratio, hot and cold end temperatures of stack areused to investigate parameters such as length of stack, position of stack, and efficiency.

Key Words: Thermoacoustic engine, Design procedure, Length of stack, Position of stack, Efficiency

Investigation on thermal coupled three stage pulse tube cryocooler

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Pulse Tube Cryocoolers (PTCs) have been investigated in recent times with the focus on achieving much lower temperature and reliable operation. Lower temperatures can be obtained by cascading the stages of the PTC. These stages can either be gas coupled or thermal coupled. This paper presents the design and development of two different configurations of three stage thermal coupled PTC, one with room temperature phase shifting mechanism (PSM) and the other with cold phase shifting mechanism. For room temperature PSM, the first and second stage are provided with inertance tube, while that for the third stage is provided with inertance tube and a double inlet valve. For the cold PSM, only an inertance tube is used as a phase shifter. In case of PTC with room temperature PSM, a minimum temperature of 19.61 K is achieved with a refrigerating effect of 220 mW at 30 K at the cold end of the third stage pulse tube, with an input power of 600 W. While for the PTC with cold PSM, a minimum temperature of 32.41 K is achieved. A reliability test is carried out; the PTC performed well during the entire operation and the repeatability is established.

Key words: Phase shifting mechanism, Thermal coupled, Multi-stage, Pulse tube cryocooler

Parametric investigation of hybrid regenerator of a stirling cryocooler

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Stirling cryocoolers find applications in a variety of equipments installed in airborne, marine and vehicular platforms along with handheld and ground fixed applications. They are used for producing cryogenic cooling in the range of 60-80 K with the cooling power ranging from mW to a few watts. The performance of the cooler largely depends on the effectiveness of the regenerative heat exchanger used in the system. A study has been carried out using REGEN 3.3 to optimize a 3-mesh hybrid regenerator for a miniature Stirling cryocooler operating with a warm end temperature of 300 K and cold end temperature of 80 K. The investigation was carried out using #200, #250, #300, #400, and #450 Stainless Steel wire meshes and combinations of them. The output given by REGEN 3.3 includes the gross and net cooling power, thermal losses and associated pV work at the cold and warm ends of the regenerator. The optimization of regenerator is defined for a regenerator design that minimizes the required work supplied at the warm end to achieve a desired cooling power at the cold end. Thus the optimization is achieved by maximizing the COP, which is calculated from the net cooling power and pV work at the warm end of the regenerator. The COP is a function of length of each subsection of regenerator, mass flow and the phase between the cold end mass flow and pressure. The results obtained from the analysis are helpful for the complete design of a miniature Stirling cryocooler.

. **Key words: Stirling cryocooler, Regenerator, COP**

Experimental load map of two stage 1.5 W at 4.2 K (SRDK - 415D) GM cryocooler

Navneet Suman[1], Vijay Soni[1], Soumen Kar[2], Anup Choudhury[2], Sunil Kumar Sarangi[1], Tripti Sekhar Datta[2]

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Two stage GM cryocooler is one of the major components for development of any conduction cooled superconducting magnet system. Recently, IUAC New Delhi has developed a 6T conduction cooled NbTi magnet system using a two stage GM cryocooler (Sumitomo SRDK - 415D) of refrigeration capacity of 1.5W at 4.2K and 40W at 50K. The commercially available typical load map of the SRDK-415D cryocooler shows few 'discrete' points. The commercial load map most of the time is not sufficient to analyse the thermal characteristics of the NbTi magnet system. This paper briefly discusses the full scaled practical load map for the SRDK - 415D cryocooler generated using a test rig. This paper also gives the detail of the continuous load curves for both the stages of the cryocooler. Details of the test setup, measurement methodology to generate the practical load curves, parameters responsible for temperature fluctuation, have been described.

Key words: GM cryocooler, Refrigeration capacity

Steady state numerical analysis of a Joule-Thompson cryocooler for cryosurgical probe

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The Hampson-type Joule-Thomson cryocoolers are preferred for cryosurgical probes due to their small size and no moving parts. Due to substantial change of pressure and temperature along both the inlet and returning streams, property variations of the working fluid and pressure drop in the streams have to be realistically accounted for. Numerical analysis is the key to such demanding design applications. In the present work, steady state numerical simulation of the heat exchanger of the Joule- Thomson cryocooler is carried out. The model predicts the pressure and temperature profiles of the high pressure inlet and low pressure returning stream. These results are validated using various data available in literature. Once validated, the steady state model may be used for design of heat exchanger for Joule-Thompson cryocooler to be used in cryosurgical probe. Various key parameters of the heat exchanger that affect its performance are identified and their effects are studied.

Key words: Joule-Thompson cryocooler, Cryosurgical probe, Heat exchanger, Steady-state simulation, Temperature-dependent properties

Parametric study on thermal shield cool-down: effect of various flow conditions

Jotirmoy Das, Hitensinh Vaghela, Ritendra Bhattacharya, Pratik Patel, Ketan Choukekar, Vinit Shukla, Nitin Shah and Biswanath Sarkar

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Thermal performance criterion of the TACB (Test Auxiliary Cold Box) dictates the need for an effective thermal shield between the ambient temperature at 300 K and the cold mass at 4 K, in line with the maximum heat load limitation of the cryoplant at 4 K temperature level. This thermal shield, to be forced flow cooled and maintained at 80 K temperature level will screen direct thermal conduction and radiation heat loads from the ambient to the cold mass. The design objective is to attain cool-down of the shield within a desired time frame with least possible cryogen mass flow rate and pressure drop across the thermalization channel while adhering to the allowable heat load limit at 80 K temperature level. In the present paper, a transient thermal analysis is carried out by varying the process conditions, i.e. pressure and mass flow rate of the cooling fluid to compare time dependent thermal characteristics of the shield during cool-down and decide the optimum flow parameters from the available range.

Key words: Thermal shield, Cool-down time, Transient thermal analysis, ANSYS®

Test bench operation of a plasma fuelling device at IPR

J. Mishra, R. Gangradey, S. Mukherjee, P. Panchal, P. Nayak, J. Agarwal, P. Bairagi, H. Sharma, H. Patel, P Dutta and N Rastogi

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A single barrel pellet injection system has been developed at Institute for plasma research (IPR). It is an in-situ pipe gun type injector, in which, a solid hydrogen pellet formed at freezing zone is accelerated to high speed by using high pressure propellant gas. The pellet injection system is equipped with a GM-cycle cryogenic refrigerator for pellet formation, a fast opening valve for pellet acceleration and diagnostic system to measure the ejected pellet parameter. A pellet is formed in-situ in the gun barrel connected to cryogenic refrigerator maintained at a temperature < 10 K. With proper thermal heat load minimization on cryo region, solid hydrogen pellets are obtained. In test bench operation various sized cylindrical pellets of dimension (length x diameter) 1.6 mm × 1.8 mm and 4 mm × 4.25 mm are produced. The ejected pellet speed is varied over a range from 700 to 1000 m/s by regulating propellant pressure. Whereas, the speed of a pellet is measured by time of flight based light gate diagnostic system, pellet quality and its size are estimated from fast camera imaging system. The reliability of pellet formation and injection in present experimental system is greater than 95 %.

Key words: Plasma fuelling, Pellet injection, Cryo cooler, Solid hydrogen, Pipe gun.

Performance assessment of the test facility for pre-series cryoline of ITER

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The Pre-series cryoline (PTCL) is a representative cryoline from the complex but indispensable network of intricate multi-process pipe ITER cryolines. A dedicated test facility has been developed for thermal performance measurements of the PTCL at cold temperature. This test facility is capable of supplying 80K gaseous helium at 6.5 bar(a) and maximum 37 g/s as well as 4.5 K liquid/vapor helium at maximum 2 bar(a) and 6 g/s which is required for carrying out the required tests. The test facility mainly consists of helium screw compressor, liquid helium Dewar, liquid nitrogen Dewar, 80K cold box and test valve boxes for distributing and controlling the flow of cold helium. The test facility has been successfully installed and recently commissioned in 80K temperature level. Further, the system was re-run with various modes of operation to ascertain its operational flexibility for the PTCL test. The present article describes the operational experience gained while carrying out the system performance measurement tests and results of the commissioning of the test facility.

Key words: Pre-series Cryoline test, Test infrastructure, ITER

Studies on an electrical isolator cum thermal conductor for a superconducting quadrapole magnet at IUAC

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IUAC has recently commissioned a superconducting quadrupole doublet magnet cryostat with zero boil off technology using 2 number of GM cryocooler each having refrigeration capacity 1.5 watt @ 4.2 K. Both the magnets are designed to be operated up to 84 Ampere for the required magnetic field gradient. To reduce the heat load to the 2nd stage of the cryocooler 4 number of high temperature superconductor (HTS) leads have been used to power the magnet in the cryostat. Each HTS lead requires two thermal stations cum electrical isolator for its efficient functioning. In the first design Aluminum Nitride (AlN) was used as electrical isolator cum thermal conductor. In the recently conducted cold test of the magnet, we have observed a temperature rise in the 2nd stage joint during current charging (From 4.4 K to 6.7 K). The quantum of temperature rise is not acceptable for the stable operation. To minimize the temperature rise in the 2nd stage an experimental study was conducted to select a design having better thermal conductivity. In the new design the thermal conductivity ratio improved by four times compared to the 1st design and when implemented the base temperature reduced from 4.4 K to 3.4 K. This paper will highlight the effort made to realize a better electrical isolator cum thermal conductor at low temperature & its implementation in the existing cryostat.

Key words: LTS, HTS, Superconductor, Quadrupole, Cryostat

Experimental studies on process parameters during loss of insulation vacuum in a cryoline

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Vacuum insulated cryolines serve as an efficient medium to transport cryogens. Insulation vacuum of these cryolines can degrade under various accidental scenarios. One such case is due to a major leak of ambient air inside the Outer Vacuum Jacket (OVJ) which cannot be compensated by vacuum pump. For an accurate estimation of the rate of pressurization in process pipe, precise heat transfer coefficients and heat fluxes are necessary. Hence, a small experiment on the representative cryoline of 0.5m OVJ diameter and 4m length has been performed. The Loss of Insulation Vacuum (LIV) is simulated by externally injecting dry nitrogen inside evacuated OVJ while process pipes are in cold condition. The present work indicates the assumptions, details of test scheme and the estimated convective heat transfer values based on mass and energy balance.

Key words: OVJ, Thermal shield, LIV, Heat load, Heat transfer coefficient

Thermal hydraulic analysis of two phase helium flow through hydro formed cryopanel

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In cryo-sorption cryopump developed at Institute for Plasma Research (IPR), hydro formed cryopanels are cooled down to 4.5K to adsorb hydrogen isotopes and helium gas. These panels are coated with activated carbon. To maintain continuous high pumping speed, panels require frequent regeneration to remove adsorbed gases. Regeneration comprises of two modes of operation, cool down from 300K to 4.5K and warm up from 4.5K to 100-300K. Thermal hydraulic characteristics were studied involving two phase flow of helium through a hydro formed cryopanel of size 500mm (l) ×100mm (w) with a sheet thickness of 1.5mm. Cool down time and transient parameters of two phase helium flow rate were estimated at real time operating conditions. The results are assessed and show good agreement with experiments.

Key words: Thermal hydraulics, Cryopump, Transient behavior of cryogenic fluid

Thermal impedance of electricaly insulated thermal joint for hybrid current leads

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Hybrid current lead is one of the important parts for the development of cryogen free superconducting magnet system. The thermal stability of the NbTi magnet is greatly dependent on the performance of the hybrid current lead. Hybrid current lead, which is a combination of the metallic (copper) lead and HTS lead, has some inter-lead joints which need to be electrically insulating and thermally conducting with the different stages of the cryocooler. A thermal anchoring block of oxygen-free high-conductivity (OFHC) copper is developed for inter-lead thermal joint. A detailed experimental study is carried out using Kapton and Aluminium nitride (AlN) as interlayer insulation material in the thermal anchoring block. The thermal resistance of the interface for 19 mm^2 contact surface area, is found to be ~7 K/W and ~15 K/W for Kapton and Aluminium nitride (AlN) respectively at 4.2 K temperature range and ~0.6 K/W (nearly similar) for both Kapton and Aluminium nitride (AlN) at 40 K temperature range. Dependency of the thermal impedance on the contact surface area is also discussed in details.

Key words: Hybrid current lead, Kapton, AlN, GM cryocooler, Thermal anchoring block

Measurement of outgassing rate of charcoal in a steel mesh

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For any material to be used in Ultra High vacuum, systems need to be checked for its outgassing rate. Activated charcoal is used as sorbent in a cryopump. Outgassing measurement of charcoal was carried out in Outgassing Measurement System(OGMS) at Institute for Plasma Research (IPR). OGMS(made of 304L steel) uses throughput method and has base outgassing rate (after baking upto 250 ^{0}C) less than 4x 10^{-12} mbar-liter/sec-cm^{2}. Charcoal is in the form of small granules hence placed in a pouch made up of SS mesh for finding its outgassing rate. In this article results from experiments carried out to find total gas load from the sample for various temperature cycle is presented.

Key words: Outgassing, charcoal, vacuum, sorbent

Prediction of differential joule–thomson inversion curves for cryogens using equations of state

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In many cryogenic applications, Joule–Thomson (J–T) effect is used to produce low temperatures. The isenthalpic expansion of gas results in lowering of temperature only if the initial temperature of the working fluid is below its characteristic temperature, called the inversion temperature. Inversion curves are helpful in studying the inversion temperatures. The prediction of inversion curves solely depends on the equation of state (EOS) for the working fluid. In the present work, various EOS are explored in order to predict the Joule–Thomson differential inversion curve for various commonly used cryogens viz. nitrogen, argon, carbon dioxide, helium, hydrogen and neon. The widely accepted EOS such as van der Waals, Redlich–Kwong and Peng–Robinson EOS are used for this purpose.

Key words: Inversion curve, Joule–Thomson effect, van der Waals, Redlich-Kwong, Peng-Robinson

Development of low noise amplifier and associated RF switching circuit for the penning ion trap

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In this paper we describe the design and development of cryogenic electronic instrumentation required for VECC cryogenic Penning ion trap facility. As a part of the development of cryogenic electronic instrumentation, a low noise amplifier based on GaAs technology is designed and room temperature testing of the amplifier is successfully accomplished. The equivalent input voltage noise density of the amplifier measured at room temperature is found to be in the range of HznV)2.08.1(*at the ion trap axial frequency of 63 MHz. Also a cryogenic switching and RC filtering circuit is developed in order to maintain proper switching of RF energy used to excite the motional amplitude of trapped electrons. These RC filtering circuits filter the noise in the DC supply lines. The performance of this circuit board has been tested successfully upto 90K.*

Key words: Cryogenic instrumentation, LNA, Switch

Thermal and magnetic properties of GaV_4S_8

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A polycrystalline GaV_4S_8 was prepared by re-sintering the sintered compound at 500^0C for 10days. In this compound, we have found three anomalies around 179K, 43K and 13K. The 179K anomaly on GaV_4S_8 is noticed for the first time in resistivity, Seebeck coefficient and magnetization. According to the resistivity analysis, this is expected to be associated with the crossover from nearest neighbour to variable range hopping conduction. In comparison to previous results, this compound has a significantly large Seebeck coefficient within our measurement range. In addition to this, we have also found three Weiss temperatures i.e. +14.3K, -10.2K, +2.7K instead of two with effective paramagnetic moments $1.44_B\mu$, $1.35_B\mu$, $1.35_B\mu$ in 16 – 30K, 43 – 179K, 187 – 300K regions respectively from inverse susceptibility due to the existence of 179K anomaly.

Key words: Transition-metal compound; Disordered material; Seebeck coefficient; Magnetization; Hopping conduction

Granularity and annealing effects in superconductivity of the electron doped cuprate system $Nd_{1.85}Ce_{0.15}CuO_4$

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We have observed large granular effects in the superconducting behavior of the electron doped cuprate $Nd_{1.85}Ce_{0.15}CuO_4$ synthesized in polycrystalline form by solid state reaction. The resistive transition to the superconducting state reveals a staged behavior due to intra and inter-granular transitions, the former corresponding to superconductivity within the grains and the latter due to long range coherence between the grains. On the other hand the DC magnetization reveals the intrinsic behavior of the grains and a smooth transition from the paramagnetic state to the diamagnetic.Our investigations of electrical current dependence of inter and intra-granular transitions indicatesignificant changes in the former without any change in the latter. The behavior is in line with what is expected in granular superconductors which are related to intra granular and inter granular coupling. Scanning electron microscopy investigations provide morphological evidence of granularity in the material.

Key words: Cuprate superconductors, Electrical resistivity, Microstructure, Granularity.

Quench simulation of a 9T supercoducting solenoid magnet for VECC RIB facility beam line

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It is important to evaluate the peak temperature and voltage of superconducting magnet to ensure its safe operation. If the peak temperature and voltage exceed certain limit, it will impair the electrical integrity of the insulation material or even cause a meltdown of the cable. In this paper, temperature rise, voltage drop of high field superconducting magnet for VECC RIB facility have been discussed. The results obtained from simple and approximate theoretical formulation have been compared from results obtained from simulation using a quench solver computer code OPERA. The quench protection techniques and its effects on temperature rise and voltage drop has also been discussed in this paper for the optimum design of superconducting solenoid from quench point of view.

Key word: Superconductor, Superconducting solenoid magnet, Quench protection

Fault limitation characteristics of a lab-scale resistive type superconducting fault current limiter

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With the recent development of advanced YBCO based 2nd generation (2G) coated conductors (CCs), many researchers started developing superconducting fault current limiters (SFCLs) based on these conductors. We have used an electrically insulated CC developed by SuperPower to make a simplified laboratory scale resistive (i.e. non-inductive) type superconducting coil for SFCL technology in Indian power sector. This CC has unique thermal and electrical properties when compared to other commercially available HTS conductors. This YBCO based HTS tape has a silver over-layer and is made on Hastelloy®276 substrate which is highly resistive by nature. The conductor has polymide (kapton, 30% overlap) insulation for high voltage safety. Using this conductor, we made a small superconducting coil where adjacent turns carry equal and opposite currents to make it non-inductive. This SFCL coil is rated for 220 V_{rms} and 400 A_{rms} (single phase) operation. The former of the coil is fabricated in-house using G-10 Glass fiber and fine holes are made on the former for both-side cooling of the CC. In this paper, a simplified design of a resistive SFCL without bypass path is carried out using 2G CCs. After that, the continuous current performance of the coil and voltage drop are measured when 425 A_{rms} is applied. Over-current test on the coil is carried out to measure the effective fault limitation to verify the performance of the resistive SFCL without a bypass path.

Key words: 2nd generation, Coated conductors, Superconducting fault current limiters, Resistive.

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