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Sunil Kumar Sarangi , Ranjit Kumar Sahoo

National Institute of Technology

Rourkela 769008

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B) This is the only Indian journal where articles on cryogenic enginnering is encouraged. Editorial board encourages work on indigeneous development as an import substitution.

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FOREWORD

The National Symposium on Cryogenics (NSC) organized by the Indian Cryogenics Council is a biennial event. The Twenty Third National Symposium on Cryogenics, NSC-23 was hosted by National Institute of Technology, Rourkela during October 28 - 30, 2010. This Symposium, over the years, has grown steadily in terms of its character and diversity. Apart from traditional topics of cryogenic engineering, superconductivity, and low temperature physics, NSC-23 laid special emphasis on related subjects of cryomedicine and industrial gases. It was an attempt to bring together different streams of low temperature technology leading to fruitful discussions and promotion of inter-cultural knowledge.

We received a total of about 100 papers covering topics of Cryogenic processes, Cryogenic equipment, Cryogenic technology, Air separation and industrial gases, Low temperature physics & materials engineering, Cryogenics in biology and medicine. Apart from the contributed papers, there were two keynote lectures and eighteen plenary lectures. As per the convention of the Indian Cryogenics Council, selected full length papers of these abstracts are published in the Indian Journal of Cryogenics after a proper peer review process. The symposium was preceded by several short term courses conducted by the best known cryogenics teachers of the country.

It is our pleasure to present the full length papers to the Indian Journal of Cryogenics. The guest editors acknowledge the contributions made by the authors. We would like to thank all the reviewers for their excellent cooperation and services. We would also like to thank the Indian Cryogenic Council and all our friends and colleagues who contributed immensely to the successful completion of the symposium to the publication of the proceedings of the symposium in the IJC.

We sincerely hope that the articles published in the journal will serve as reference materials for researchers, professionals and the cryogenic community as a whole for a long time to come.

GUEST EDITORS

Prof. Ranjit Kr Sahoo	Convener, NSC-23
Prof. Sunil Kr Sarangi	Chairman, NSC-23

EDITORIAL

We have come a long way since the publication of the Indian Journal of Cryogenics (IJC) started some 36 years ago. This was soon after the Indian Cryogenic Council (ICC) was founded by a great visionary none other than Prof. A. Bose of the Indian Association for the Cultivation of Sciences (IACS) in the year 1975. The previous year 2011 happened to be the centenary year of Prof. Bose and on Dec. 23, 2011 Indian Cryogenic Council celebrated it by holding a "Workshop on Hundred Years of Superconductivity and the Birth Centinary Celebration of Prof. A. Bose, Founder President of ICC" at VECC, Kolkata.

We have great pleasure in bringing out this 37th Volume of the Indian Journal of Cryogenics. Your journal is on-time since 2006 when the ICC was reorganized. We have no back-log. This issue is the proceedings (Part-B) of the "23rd National Symposium on Cryogenics" held at NIT, Rourkela during October 28-30, 2010. It has three invited talks and 31 contributed papers duly reviewed by the peers. We are happy to note that the journal has become the mouthpiece of all the major institutions of India that are engaged in the area of cryogenics and applied superconductivity. Somehow we do not receive enough papers from several institutions engaged in high quality research in Low Temperature Physics. ICC is the body for the cryogenic engineers, scientists, cryogenic industry and low temperature physicist, all meeting under one umbrella. So is the IJC committed to publications from low temperature physicists, cryogenists and the industry. It will be our endeavour to attract papers from our institutions in the country engaged in high quality basic research. There is a good number of such institutions in India. Efforts will be made to raise the quality of publications to international standard so as to have it listed it as a SERC journal. We are also planning to regularise annual publication rather than Quarterly combining all 4 issues together. We thank Prof. Sunil Kumar Sarangi, Chairman (NSC-23) and Prof. Ranjit Kumar Sahoo (Convener NSC- 23) for their sincere and hard work to get about 66 papers for publication in volume 36 and 37. We are pleased to attach the foreward from the guest editors.

T S Datta & R G Sharma
(On behalf of Editorial Board)

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Growth of Cryogenics and Superconductivity in India

Tripti Sekhar Datta and Ram Gopal Sharma

Inter-University Accelerator Centre New Delhi – 110067

Cryogenics started in India as early as 1930 when a British company installed an oxygen plant. First low temperature experimental facility limited to 80 K was established at IACS Kolkata in 1937. Helium liquefier of capacity 4 litres/hr was installed in NPL in 1952 and that was the beginning of activity on superconductivity and low temperature physics down to 1 K. Many more institutes started activity at low temperature with minimum facility of helium refrigerator and PLA/PLN type laboratory liquid nitrogen plant during 1960- 1980. First Superconducting NMR arrived at IISc. Bangalore in 1976 and the first MRI unit with superconducting magnet was installed at INMAS. Delhi in 1986. During 1990 - 2000, many major national programmes in the field of cryogenics and superconductivity were taken up. Department of Science and Technology too enhanced funding to support research on High Temperature Superconductor (HTS), Low Temperature and High Field facilities. All these programmes fueled the growth of cryogenic facilities and manpower. Production capacity of single air separation plants rose from 100 tons / day to more than 1000 tons /day. The availability of cryocoolers going down to 4.5 K around the year 2000 led to the spread of low temperature research to many universities. This paper will summarize the growth of cryogenics in all its form including man power in the country and is based upon our study that we carried out for DST.

Key words: Cryogenics, Superconductivity, Man Power, India, Present Status

Design and analysis of large-scale helium liquefiers/refrigerators: Issues with modeling and simulation

Parthasarathi Ghosh, Rijo Jacob Thomas, Rohan DuttaandKanchan Chowdhury

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Large-scale helium liquefaction/refrigeration plants have thermodynamically more involved configurations than Collins cycle that is the fundamental cycle for liquefaction and areused for cooling superconducting magnetsetc. Transient analysis helps in design of suchplants through improved understanding of the processes leading to optimaldesigns andappropriate strategies for mitigating the effects of fluctuating heat loads.Process simulator with appropriate Equation of State for thermodynamic properties of the fluid, appropriate models for transport and thermo-physical properties of helium and the structural materialshelps in modeling and simulationof such plants. In this paper, attempt has been made to bring out the features of helium liquefiers, to discuss the peculiarities of the properties of helium fluid and the materials of construction at temperatures near the normal boilingpointofheliumthat need to be addressed inperforming steady state and dynamicsimulation. Many of these aspects are not taken care of by the commercial process simulators like Aspen Plus®, Aspen Dynamics®, Aspen Hysys®, ChemCAD®etc. They have been compared on the basis of their suitability for addressing those issues. The areas, methodology and the extent of success that have been achieved in customizing the software, Aspen Hysys®, for simulation of helium systems have also been discussed.

Key words: Large-scale helium liquefier/refrigerator, Modeling and simulation, Aspen Hysys®

High Temperature Superconductor Applications in the field of Electricity: Present and Future

Jayateerth ManagoliAMSC

(American Superconductor Corp.), New Delhi

The discovery of High Temperature Superconductor (HTS) materials in 1986 by IBM hasbrought about revolution in applications in the field of electricity. The key power gridapplications of HTS include power cables, fault current limiters, generators, motors,transformers, etc. Power cables carrying hundreds of megawatts have been successfullydemonstrated and will change the complete scenario of bulk power transmission in theyears to come. Other promising applications of HTS include high power wind turbinegenerators, ship propulsion motors, warship degaussing systems, magnetic resonanceimaging magnets and current leads such as the ones used in the Large Hadron Collider atCERN.

Simulation tool for determining dynamic characteristics of high speed cryogenicrotor bearing systems by comparison with experiments

Arun S., Mohananand Jadhav, Anindya Chakravarty and Trilok Singh

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Most cryogenic turboexpander rotors are gas bearing supported high speed machines witha small size turbine at one end and a brake compressor at the other end. It is important tocorrectly predict the critical speeds of these rotors to enable them to quickly pass throughthese speeds during coasting up to design/service speed and also to define the stableoperation band sufficiently far from the critical speeds. The present paper describes thedevelopment of a simulation tool for correct determination of the dynamic characteristics ofa rotor bearing system. Transfer matrix method is used in the program for computing thedynamic characteristics.

Key words: Turboexpander, Critical speed, Stiffness, Transfer matrix method, Synchronousvibration response plot

Optimization Analysis of Liquefaction Cycles for Nitrogen

Balaji Kr Choudhury, S. A. Alur , R. K. Sahoo, Sunil Kr Sarangi

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Simulation is carried out on Claude cycle, modified Claude cycle eliminating last heat exchanger and modified Claude cycle eliminating first heat exchanger by process design software Aspen Hysys®. Modified Claude cycle eliminating last heat exchanger has been found suitable for a turboexpander based nitrogen liquefier with medium capacity. Analysis is carried out to access the role of different component efficiencies in predicting overall system efficiency at the design and off design conditions. In this analysis optimization has been done for maximum yield at the different operating pressures using same heat exchanger effectiveness and turboexpander efficiency. Optimum pressure of compression, heat exchanger effectiveness and mass fraction diverted through turboexpander and turboexpander efficiency was found out.

Key words: Steady State simulation, Liquefaction Cycles, Nitrogen refrigerator and liquefier, Parameter estimation.

High Speed Cryogenic Turboexpander Rotor for stable operation up to 4.5 kHz Rotational Speed

Rajendran Menon, Anindya Chakravarty, Mukesh Goyal, Mohananand Jadhav, Arun S., Satish Kumar Bharti and Trilok Singh

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BARC has been working towards the development of gas bearing supported high speed turboexpander rotors for use in indigenous helium liquefiers and refrigerators. Extensive experiments have been carried out to obtain the dynamic characteristics of the rotor both during coast-up as well as coast-down operations. The objective of these experiments is to identify the critical speeds of the rotor and relate it with the bearing clearance. This would enable design of radial bearings with proper clearance so as to avoid the occurrence of critical speed near the range of rated rotor operational speeds. The present paper documents the experience of stable rotation of several 16 mm diameter cryogenic turboexpander rotors during recent laboratory test runs. Snap shots from FFT analyzer during the experiments as well as synchronous response to unbalance for coast-up and coast-down operations have been included.

Key words: Cryogenic Turboexpander, Helium liquefier/ refrigerator plant, Gas Bearing, synchronous response to unbalance

Magnetic Abrasive Finishing (MAF) of Flat Thrust Bearing Surfaces and Cylindrical Shafts for Ultra High Speed Cryogenic Applications

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Nano-finishing of flat thrust bearing and cylindrical shaft surfaces employed in ultra high-speed cryogenic applications with Magnetic Abrasive Finishing (MAF) would reduce friction, minimize wear and increase service life. A magnetic field applied across the machining gap containing a homogeneous mixture of abrasive (diamond paste (5 µm) and ferromagnetic iron particles), aligns the ferromagnetic particles to form a flexible magnetic abrasive brush (FMAB). A novel MAF setup has been developed that can finish both cylindrical and flat surfaces. The FMAB can move in longitudinal direction as the workpiece rotates and can finish a cylindrical shaft to a roughness value of 0.023 µm (23 nm) Ra. A flat bearing surface was also finished to a roughness value of 0.029 µm Ra and flatness value of about 5 µm with transverse feed of FMAB. Effects of such improvements in surface finish and flatness values on the performance of the rotor-bearing assembly are being studied.

Key words: Magnetic abrasive finishing, MAF, ultra high speed shafts, thrust bearings

Development and Study of an Indigenous Helium Purifier based on Low Temperature High Pressure Adsorption of Impurities

Trijit K. Maiti[1], Ranadhir Dey[2], R. K. Sahoo[3],Sunil K. Sarangi[4]

[1,2]VECC/DAE, Kolkata [3,4] NIT, Rourkela

In collaboration with VECC, Kolkata, NIT, Rourkela has taken up the project of the development of cryosorption based helium purifier. The helium purifier has been designed for purifying helium containing 40% air impurities to a contaminant level below 50 ppm at a flow rate of 20Nm3/hr and operating pressure of 120 bar(g). Low pressure impure gas is recovered in gas bag from experimental set up. It is compressed, then purified by a shell & tube heat exchanger, a tube-in-tube heat exchanger, a subcooler, a liquid air separator and five LN2 cooled activated charcoal adsorber columns in series. Purity monitoring, regeneration system and gas storage manifold have been provided. All the major components have been fabricated, assembled and commissioned at NIT, Rourkela. It has been successfully tested with low percentage of impurities and detailed testing is underway.

Key words: Activated charcoal, Cryosorption, Grade 4.5 helium

Design and Development of HTS Magnet Insert to produce 12 T of Magnetic Field

J.Pradhan, U.Bhunia, Md. Z.A.Naser, A.Roy, S.K.Thakur, T.K.Bhattacharyya, A.De, S.Bandyopadhyay, U.Panda, M.Das, C.Mallik and S. Saha

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High Temperature Superconductor (HTS) magnet insert is designed and developed. This will be placed at the central bore of Low Temperature Superconducting (LTS) solenoid magnet operating at liquid helium bath. The combined magnet system produces about 12 Tesla of field at 60mm bore diameter. This will be used for different material testing, characterizations and also to develop state of the art HTS coil technology, aimed specifically for magnet for energy storage and beam line. This paper describes overview of the design and other critical aspect of the of the magnet system

Optimization for Solenoid-type Superconducting Magnetic Energy Storage Coil

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The operating cost of superconducting magnetic energy storage (SMES) system highly depends on the ac loss due to magnetic field transients and heat in-leak to the system. Therefore, reduction of ac loss and coil or cryostat surface area since it reduces heat in-leak into the system is an important design criteria for superconducting magnetic energy storage system. This paper presents a new and elegant optimization approach of finding geometrical parameters of a solenoid type superconducting magnetic energy storage coil that minimizes both ac loss as well as coil surface area for a given allowed hoop stress and stored energy. A fundamental prerequisite of the design is that if the initial design constraints such as stored energy and allowable circumferential or hoop stress in the winding are fixed and critical characteristics Jc(B) of the superconducting cable are given, the optimization technique using Differential Evolution (DE) method provides unique solution of design parameters and operating condition. For a given critical characteristics of the cable, dependence of optimized geometrical and operating point (Bm,I) in various stored energy levels has been investigated. Effect of allowed hoop stress on optimized parameters has also been investigated.

Key words: SMES, Superconducting Magnet, AC Loss

Effective thermal conductivity of an axial groove cryogenic heat pipe

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A heat pipe is a device which transports heat at a high rate over considerable distance with a small temperature gradient. When the operating temperature of a heat pipe is less than 123 K, it is known as cryogenic heat pipes, and the working fluid used in the cryogenic heat pipes is any one of the cryogens like nitrogen, oxygen, hydrogen and helium depending on the operating temperature. This paper deals with development and studies of wire mesh wick and trapezoidal axial groove wick heat pipes with nitrogen and oxygen as working fluids. A special liquid nitrogen cryostat has been designed and developed for evaluating the performance of heat pipes. This consists of two main subsystems – a liquid nitrogen cryostat and instrumentation and accessory systems. Many investigators have carried out experiments on the cryogenic heat pipes, in which either the condenser is immersed in the liquid nitrogen or the condenser is connected to cryocooler whose operating temperature can be maintained at constant level by varying the cooling capacity. However, in most of the practical applications, where liquid nitrogen bath is used as the cold reservoir, it is very inconvenient to immerse condenser portion of the heat pipe into liquid nitrogen bath. The present study focus on the performance of trapezoidal axial groove wick heat pipe with the condenser connected to the reservoir externally. The performance of the heat pipe was determined at different temperatures between the triple point and critical temperatures of the working fluid. It is observed that the effective thermal conductivity of the heat pipe is about 2.9 times higher than that of equivalent diameter solid copper rod at about 100 K.

Key words: Axial groove cryogenic heat pipe, effective thermal conductivity.

Heat Transfer and Flow Friction Studies on Perforated Plates Using Fluent TM

S. Sunil kumar[1] and T. K. Nandi[2]

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Perforated plates usually find applications in matrix heat exchangers where heat transfer from one fluid to the other takes place by plate-fluid convection and plate conduction. The geometrical parameters that affect heat transfer and pressure drop characteristics are pore diameter, porosity, pore geometry and orientation of holes along the direction of fluid flow. In literature there are several correlations available for heat transfer and friction factor prediction. However, they differ significantly from one to other. In this paper an attempt has been made to obtain such correlations by modeling over a single perforated plate using Fluent TM solver. The model consists of a rectangular perforated test plate with two insulating spacers (one at the top and other at the bottom). Flow inlet and outlet are made through set of holes arranged either inline or offset with the perforated test plate. Studies have been done for varying Reynolds numbers from 100 to 1000. The results have been compared with the published data.

Key words: heat transfer, flow friction, Coburn factor, friction factor

Experimental Studies on Tube-In-Tube Compact Heat Exchanger

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Tube-in-tube compact heat exchangers with a new type of extended surface based on thin wire mesh are fabricated with a compactness of 1917.12 m2/m3 and 5847.56 m2/m3. Experiments are conducted in these compact heat exchangers with R-134a and mixture of hydro carbons (LPG). The effectiveness of the heat exchangers was calculated using the experiment data and it was found that the effectiveness of heat exchanger-1 is 78% and heat exchanger -2 is 83% for R-134a.The effectiveness of heat exchanger-1 is 61% and heat exchanger -2 is 79% for mixture of hydro carbons (LPG). In the case of heat exchanger-1 the temperature difference in the hot end is 10K to 20K and the cold end is 4K to 5K. The pinch point was occurred in the cold end. In the case of heat exchanger-2 the temperature difference in the hot end is 13K to 16K and the cold end is 12K to 14K. In this paper, details about the new tube-in-tube type compact heat exchanger, experimental setup, results and conclusions are discussed.

Key words: compact heat exchanger, effectiveness, pinch point, compactness

Quench Protection System for 1 MJ Superconducting Magnet Coil For SMES Project at VECC, KOLKATA

S. K. Thakur*, A. Bera, Y. Kumar, U. Bhunia, J. Pradhan, S. Saha

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This paper describes the indigenous development of a system which is used for quench detection, protection and monitoring the parameters of superconducting coil of superconducting magnetic energy storage (SMES) system. Resistive voltage measurement method is used for detecting the quench. The voltage across each current lead is also monitored and over voltage across the current lead is detected by comparing it with a set voltage limit. By using isolation amplifier and timer circuit, false quench trigging due to noise and spikes are minimized. If quench is detected a relay operated to turn-off the SMES power supply followed by the release of stored energy of the magnet to the external dump resistance by closing a switch.

Key words: SMES, Quench detection, Coil protection.

Development of Vapour Shielded Liquid Helium Dewar

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This paper describes the development of a 100L nominal capacity liquid helium (He) Dewar which uses multi-shield insulation system utilizing the cold from evaporated vapour of the stored cryogenic liquid. Heat in-leak design calculations are done using Finite Difference Method (FDM) by discretisation of Dewar neck into smaller elements and solving the energy balance taking care of variable neck material properties, variable vapour properties, heat in-leak through super-insulation, conductive heat transfer through neck and vapour, convective heat transfer from neck to vapour etc. A computer program is developed using Visual Basic Script of Microsoft Excel coupled with Gas property software package. Positions of He vapour cooled thermal shields are optimized for minimum heat in-leak to liquid helium (LHe). Mechanical design and fabrication of Dewar is done using ASME Boiler and Pressure Vessel code Section II, V, VIII Division-1 and section IX. Vacuum leak tightness of the Dewar is evaluated using He mass spectrometric leak detector (MSLD). Performance evaluation is done using liquid nitrogen (LN2).

Key words: Liquid Helium Dewar, Multi-shield Insulation System, Heat in-leak.

Reliability and functional testing scheme for cold circulating pumps required to cool large size fusion grade superconducting magnets and cryo-pumps

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Forced flow cooling using supercritical helium is the most preferable method due to the distinct advantages over the other cooling procedures for the superconducting magnets and cryo-pumps in fusion research devices. The flow requirements are high to fulfill the stability requirement of the magnet system during all operational modes. The flow requirements are met with cold circulation pump at 4 K level. These pumps require state of the art design due to constraints from temperature and associated process requirements with a demand of high efficiency. The future requirement of the future fusion research reactor (ITER) is foreseen as ~2.7 kg/s mass flow rate with adiabatic efficiency > 70%. Against the future requirement, the maximum capacity ever built till now has a capacity of 1.2 kg/s mass flow with adiabatic efficiency ~60%. Therefore, the up scaling of existing cold circulating pumps with improvement of efficiency is necessary to meet the future requirement. This paper discusses the major risks associated with cold circulating pumps and a test proposal with basic testing scheme to validate the performance.

Key words: Cold circulating pump, testing scheme, risk

Design and Fabrication of Scan Tube for Field Measurement of Superconducting Magnet of Ion Trap Project at VECC

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A 5T Superconducting magnet for Ion Tran project has already been designed, fabricated and installed at VECC. The magnetic field measurement of the superconducting magnet has to be carried out to estimate the spatial field uniformity which has to be less than 1 x 10-6 over 1 cm DSV. For facilitating the magnetic field measurement, a scan tube has been designed and fabricated to house a NMR probe that would be inserted in the liquid helium filled bore of the magnet. The materials and thicknesses of different components of the scan tube have been optimized so that around room temperature would be maintained inside the scan tube when dipped in the liquid helium filled bore of the magnet and the heat load of the system would be minimum. Presently the scan tube was fabricated and cryoshocking test at 77K had been performed before vacuum leak test was carried out and helium leak rate was found to be less than 5 x 10-9 mbar.lit/sec. This paper describes the design and fabrication of the scan tube in detail.

Key words: Persistent mode superconducting magnet, Multilayer Insulation, NMR, DSV

Cryogenic Distribution System for ITER Proto-type Cryoline Test

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Design validation for ITER cryoline will be carried out by proto-type test on cryoline. The major objectives of the test will be to ensure the mechanical integrity, reliability, thermal stress and heat load as well as checking of assembly and fabrication procedures. The cryogenics system has to satisfy the functional operating scenario of the cryoline. Cryoplant, distribution box (DB) including liquid helium (LHe) tank constitute the cryogenic system for the test. Conceptual system architecture is proposed with a commercially available refrigerator/liquefier and custom designed DB housing cold compressor, cold circulator as well as phase separator with sub-merged heat exchanger. System level optimization, mainly with DB and LHe tank with options, has been studied to minimize the cold power required for the system. Aspen HYSYS® is used for the purpose of process simulation. The paper describes the system architecture and the optimized design as well as process simulation with associated results.

Cryostatforsuperconducting radio-frequency cavity program at VECC Kolkata

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cryostat is being designed for testing superconducting radio frequency (SCRF) cavity. The cryostat has an inner helium vessel where the scrf cavity will be immersed in a pool of liquid helium. A liquid nitrogen shield surrounds the liquid helium vessel. The liquid helium vessel and liquid nitrogen shield shall be enclosed inside a vacuum chamber to reduce heat load. Different designs for the test cryostat have been evaluated. The thickness of inner vessel, outer vessel, head and all the flanges for test cryostat have been calculated for external and internal pressure and for bolt load required for sealing. Garlock Helicoflex spring energized seal are planned to be used for sealing the flanges at 4.5 K. Thermal calculations have been carried out to access the heat leak in the designs. The paper presents the structural and thermal design of the test cryostat.

Key words: superconducting radio frequencycavity, cryostat,

Static and Dynamic Behavior of Cryogenically Cooled Hydrostatic Journal Bearings for Space Applications

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Externally pressurized cryogenically cooled (using LOX or LH2 as coolant) hydrostatic bearings are being considered as an alternative to the conventional ball bearing system of a cryogenic rocket engine turbopump. Comparing with ball bearing system, hydrostatic journal bearings (HJBs) offer several advantages like, higher load capacity, higher stiffness with low coefficient of friction, good damping characteristic and vibration stability. Because of very low viscosity of cryogenic liquids, compared with oil (as lubricant), modeling of cryogenic HJBs, is complicated by factors like: turbulent fluid film, inertia effect, compressibility and variation of cryogenic liquid properties. In this paper a finite difference based numerical model is presented for prediction of static and dynamic performances of LOX/LH2 lubricated hydrostatic journal bearings. Pressure distribution in the fluid film is obtained by solving relevant Reynolds equation. Dynamic behavior is studied through the determination of stiffness and damping coefficients by using finite disturbance method. Sample results have been presented both for static and dynamic conditions.

Keywords: Hydrostatic bearing, numerical modeling, static and dynamic study

Experiences in the commissioning of new helium liquefier at VECCand the respective remedial actions

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A new liquefier of 415 W refrigeration capacity at 4.5K has been installed at VECC alongwith a new compressor of 50 g/s flow rate. It has been interfaced with the existing liquefierand cryogenic loads. During commissioning of this liquefier the following problems havebeen faced: (i) Space constraints for installation (ii) Flanged section of pipelines at theinterfacing point of the cold box and the compressor (iii) Cleaning of pipelines to ensure thatno metal chips are present (iv) Testing of each and every components of the cold box andcompressor (v) Failure of a number of components and their replacement (vi) Failure tomeet refrigeration and liquefaction capacity (vii) Parallel run of two compressors (viii) Shut-down of cold box for every trip of compressors (ix) LP and HP control to reduce the pressurefluctuation (x) Attenuation of the turbo-expanders (xi) Cool down of the cold box along withthe cryostat (xii) Sub-cooler liquid helium level control (xiii) LP isolation of the two ORSs Inthis paper the measures taken for rectification of the above problems are discussed withresults.

Key words: Helium Liquefier, Control, turo-expander

Design Approach Of Seismic Interface For Cryoline With Tokamak Building For ITER

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ITER Tokamak building is designed with seismic isolation pads to protect the Tokamak components from seismic events. Two main cryolines, designated as cryolines between buildings (Mg & CP), runs from interconnection box in cryoplant building to the Tokamak building. The lines outside Tokamak building are supported by seismically non-isolated supports. The cryoline design at the interface between seismically isolated and non-isolated support systems needs to be studied to fulfill the functional requirements. One of the options for interface, universal expansion joint has been modeled in CATIA with actual thickness of each ply and inter-ply distance, analyzed in ANSYS using contact definition, as a part of the preliminary study. The bellows have been checked by design calculation as per EJMA standard for the specified movements.The paper will present approach for conceptual design of interface, problem definition & boundary conditions, methodology for analysis and preliminary results of stress pattern for expansion joints.

Key words: ITER, Tokamak, Cryoline, Seismic, multi-ply bellows, CATIA, ANSYS

Cryogenic pump at 4 K temperature level – basic hydro-dynamic design approach

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Cryogenic cold circulating pump, an essential and critical component of fusion research reactor needs a systematic study due to future large pumping capacity requirements of the order ~2.7 kg/s of helium fluid for the cooling of large superconducting magnets and cryo-adsorption vacuum pumps. Design of cryogenic cold circulating pump for helium at 4 K temperature level is diverse from the conventional pump design in some aspects due to distinct fluid properties and issues related to the very low temperature. The complex three dimensional geometries of the pump impeller, suction passage and volute restrict to achieve the complete design solution based on two dimensional design theories. Based on the input data for the future requirements of cryogenic cold circulating pump for helium, a basic design of its impeller is obtained. Suction passage and discharge passage of the pump is designed. Impeller blade profiles as well as volute profile are developed for the future application.

Key words: Cold circulating pump, hydro-dynamic design, blade profile

Phase Angle and Flow Pattern studies for Inertance Tube Pulse Tube Refrigerator

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The phase angle between mass flow rate and pressure and the flow patterns in a Pulse Tube Refrigerator (PTR) are important factors which affect the performance of the refrigerator. Various modifications have been made to the PTR in order to reduce the phase angle and secondary flow, to increase the refrigeration effect. Secondary flow emerges due to the change in the cross-section and the direction of the flow. Flow straighteners and tapered pipes are used to avoid the formation of secondary flows. These secondary flows disturb the temperature profile in PTR, which in turn deteriorate the refrigeration effect. The present paper highlights the emergence of secondary flow in Inertance Tube Pulse Tube Refrigerator, especially near the cold end heat exchanger, and correlates it with the phase difference. The analysis further studies the effect of change in cross-section area on secondary flow and its effect on the performance of the PTR. The modelling of the ITPTR is done using commercial CFD software, FLUENT 6.2. From the analysis, it has been observed that, the phase difference between the mass flow rate and the pressure is responsible for the secondary flow. The duration of secondary flow per cycle is directly proportional to the phase difference. Hence reduction in the phase difference amounts to reduction in secondary flow.

Keywords: Inertance Tube Pulse Tube Refrigerator, CFD, Flow Pattern, Secondary Flows

Development and Performance Tests of Miniature Stirling Cryocooler

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This paper is about development of a gamma-type integral Stirling cryocooler. The cryocooler consists of piston, displacer, regenerator, Dewar, clearance seals, and rotary BLDC motor. The design was targeted for applications such as night vision device where compactness and light weight design are prime requirements. These requirements make design of piston, cylinder, and clearance seals very critical. Assembly procedures require particular attention while handling precise components. Helium filling requires a special fixture and procedures to avoid contamination.A BLDC motor was developed to be used as prime mover for miniature cryocooler. Compactness and high efficiency make BLDC a proper choice. The prototype Stirling cryocooler has been tested and parameters such as power consumption, coefficient of performance are investigated under various rotating speeds and charged pressure, which will help us in further developments and optimization of cryocooler.

Key words: Stirling Cryocooler,Infrared, Night vision,Piston-Cylinder, BLDC Motor

Motoring test of a stirling cycle engine system while acting as a cooler

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A lot of work is done on the Stirling coolers of various configurations at IIT Bombay. This includes the development of nitrogen liquefier, with a capacity of 5-6 liter/h, as a higher capacity cooler to miniature coolers, with capacities as low as 1 W at 80 K, for IR detector cooling onboard satellite. Presently work on "Development of Stirling Engine for 1.5 kW electrical power output" is in progress with the intention of making use of the experience gained in the process. It is of Beta-type with rhombic drive mechanism. This paper presents the results of a cooling system which has not been designed as a cooler but has been designed for providing power in the form of an engine. It also discusses the experience during motoring test and initial trials on Beta type Stirling engine with Rhombic drive mechanism as cooler. Initially, the Stirling cycle engine setup is tested by welding single tube to the cylinder head and charging at slightly higher pressure than ambient. Further, four tubes are welded to the cylinder head to provide the sufficient flow passage through heat receiving tubes, which was not case with single tube. The condensation at the top of cylinder head and around the tubes is observed in three minutes after starting, with Helium as working fluid and charging pressures of 3.1, 4 and 5 bar. The pressure ratio, which is ratio of the maximum pressure to the minimum pressure in the cycle system, is around 1.72. The system is operated without any substantial load and let some of the dimensional mismatch reduce by way of wearing out unmatched components. Then it is operated repeatedly, in this fashion so that every time the system is restarted, it should need less power. After testing and conducting trials cylinder head is inspected visually. No scratches or rubbing impressions are observed at contact the contact surfaces.

Keywords: Stirling engine, Rhombic drive mechanism, Motoring test

Dynamic Analysis of a Free Piston Free Displacer Split Stirling Cryocooler with pressure losses

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Free piston free displacer cryocoolers in the small capacity miniature range, used for cooling infrared sensors, have a long operating life without maintenance. This paper shows the complete dynamics and thermodynamics of the free piston free displacer miniature cryocooler including the pressure loss due to the flow through the regenerator and the variation of the pressure in the bounce space.

Comparison of different numerical models for the analysis of two stage pulse tube cryocooler

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In the recent years, for several applications such as cooling of sensors, super conducting magnets, cryo-pumping etc., there are worldwide efforts to replace cooling with liquid helium by cooling with closed cycle cryocoolers. The internal working processes in pulse tube cryocoolers are quite complex due to unsteady, oscillating compressible gas flow in the pulse tube. Although, considerable theoretical studies have been carried out, as on date, phenomena occurring in pulse tube are still to be understood. Three different numerical models namely isothermal model, adiabatic model and energy equation model are compared to analyze a two stage pulse tube cryocooler. The various experimental parameters have been incorporated in the models to carry out the analysis. The various losses of the pulse tube cryocooler are being calculated separately and incorporated into the models. The numerical results are compared with the experimental results obtained for a two stage pulse tube cryocooler for validation.

Key words: Cryocoolers, Numerical models, Energy equation model, Isothermal model, adiabatic model

Data logging, Graphical Process Visualization of Cryogenic Plant Parameters through PLC

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The objective is to monitor the operation of cryogenic plants effectively, as the available skilled manpower is much limited and also the operation being at very low temperatures and also from safety point of view (due to involvement of high pressure). Even though, the current helium liquefiers are fully automated, still there are large numbers of plant operative parameters, arising from auxiliary equipments which needs to be monitored and controlled for the smooth & trouble free plant operation. Further, the important task in the cryogenic facility is to keep a watch on the plant healthiness, advance indication about the possibility of problem progressiveness by means of pre-warning or alarms, so that the remedial action can be taken well before the actual failure affects the plant operation, so that the plant down time is kept almost negligible. Our paper will describe our work carried out at TIFR, Mumbai.

EPICS Based Control System For Cryogenic Plant At VECC

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Cryogenic Plant of Variable Energy Cyclotron Centre consists of two Helium refrigerators (250W and 415W @ 4.5K), valve box with sub-cooler and associated sub systems like pure gas storage, helium purifier and impure gas recovery etc. The system also consists of 3.1K liters of liquid Nitrogen (LN2) storage and delivery system. Many of the systems are procured from different suppliers and some are also developed in house. Due to the variety of systems and suppliers the control philosophy, communication protocols and component is also different. So the Supervisory control and data acquisition (SCADA) module has to be such that it can take care of the variance and bring everything into a common control platform. To solve this purpose EPICS (Experimental Physics and Industrial Control System) architecture has been adopted. EPICS is having the advantage of being open source, flexible and unlimited as compared to the commercial SCADA packages.

Key words: Cryogenics Automation, SCADA, EPICS

Magnetic properties of Ni-Mn-Sn Heusler Alloy

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We report the magnetism and magnetic entropy change in the Mn-rich Ni48Mn39Sn13 Heusleralloy system. The excess Mn content stabilizes the cubic austenite phase at roomtemperature. The shift of Martensitic transition temperature to low temperature with theapplication of higher magnetic field. A magnetic entropy change ("SM) of 12.12 Jkg-1K-1 hasbeen achieved for a field change of 5 T for this alloy.

Keywords: Heusler alloy, Martensitic transformation, Magnetocaloric effectTopic code: 75.50.Cc, 81.30.Kf, 75.30.Sg, 75.30.Kz

Effect of cryotreatment on the wear performance of Tungsten carbide tools

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Success in metal cutting depends upon the selection of the proper cutting tool for a given work material. While, large varities of tools are available, High Speed Steel (HSS) tools and carbide inserts are popularly employed for machining operations. The tool life plays a critical role in the machining operation with regard to quality, time and cost. Cryogenic treatment is being extensively employed to enhance tool life, in particular for HSS tools. In this experimental work, wear resistance properties of tungsten-carbide tool inserts for machining bearing steel (En31) have been studied. After determining the cutting forces, surface roughness and flank wear for different cutting speeds and feed rates, the carbide inserts were cryotreated at 98K for 24 hours in a cryotreatment system followed by tempering at 448K.The tools after cryotreatment have resulted in reduced tool-work interface forces, better surface finish of work piece and increased wear resistance properties.

Key words: Cutting tools, Wear, Temper, Liquid Nitrogen

Low Temperature Magnetization and Resistivity Studies on 3d-TM substituted at Mn site Bi – Manganite

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Manganites are known to be potential candidates in various applications like magnetic refrigeration, sensors, memory storage devices etc. Low temperature studies on these materials provide information about various transitions that the materials undergo caused by the evolution of different magnetic correlations. In this paper the effects of doping 3d – transition elements (TM) (V, Cu and Zn) at the Mn site of Bi0.5Ca0.5Mn0.95M0.05O3, on the ordered states of the material are presented. The data provides the value of Charge Ordering temperature, TCO,and the long range antiferromagnetic (AFM) ordering temperature, TN. Cu and Zn substitution decreases the TCO and melts AFM transition. Whereas, the TCO and TN values remain unchanged in the case of V- substituted sample. Below T ≈ 40 K the temperature independent magnetization is attributed to the freezing of FM inhomogeneities. The temperature dependent resistivity is analyzed using the Mott's and Efros - Shklovskii (ES) variable range hopping (VRH) models. Mott's VRH model is found to provide reasonable values of the model parameters. The data is also analyzed in view of the phase separation (PS) model.

Key words: Manganties, Transition elements, Magnetization, Resistivity, Phase Separation Topic Code: 502

Synergetic effect of 200 MeV Ag ions and Y_2O_3 inclusions oncritical current density in Y_{1-x} $Ca_xBa_2Cu_3O_{7-d}$ thick film

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$Y_{1-x}Ca_xBa_2Cu_3O_{7-\delta}$ (x = 0.1) +Y_2O_3 (10 wt.%) composite thick film prepared by diffusion reactiontechnique is irradiated with 200 MeV Ag ions. Micro Raman reveals the microstructuralchanges. Beans critical state model was employed to calculate the critical current densityestimated from the width of magnetization loops obtained at 40 K. The enhancement of J_c from 1.4x10^{4}Acm^{-2} to 6.7x104 Acm^{-2} with irradiation upto fluence 5x10^{11}ions-cm^{-2} in YCaBCOsamples is observed indicating that flux pinning increases due to the creation of columnardefects induced by irradiation. Addition of Y_2O_3 increases the J_c in the pristine sample to8.3x10^4 Acm^{-2} but decreases with increasing fluence. The insulating inclusions Y_2O_3 causesJc increment by the process of flux pinning. Combined effects of inhomegenity and columnardefects due to irradiation have degraded the superconducting volume. The interaction energybetween vortex and defects dominate over the pinning energy. Hence the pinning sites arenot used effectively and Jc starts decreasing with irradiation.

Key words: SHI irradiation, Pinning energy, Critical current density