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

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

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

June, 2017

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Indian Journal of Cryogenics

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Indian Journal of Cryogenics

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B) IJC is the only Indian journal which publishes research work in low temperature physics, superconducting materials, superconducting magnets and the cryogenics. IJC gives utmost importance to the publication of articles on cryogenic engineering. The Editorial Board encourages work on indigenous development of cryogenic and superconducting magnet systems as import substitutions and publishes in IJC.

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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 important in 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 grow more 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 at the 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

It is a matter of great pleasure that volume 42 of the “Indian Journal of Cryogenics” is out. Vol. 42 publishes the second part of the proceedings of the “25th National Symposium on Cryogenics” (NSC-25) held at the university of Hyderabad during 8-10 December, 2014. The first part of these proceedings has already been published in July 2016. This issue is on time in spite of our deep involvement in bringing out the proceedings of the ICEC/ICMC Conference held in Delhi in March 2016. As you already know the proceedings have been published by IOP titled “Proceedings of the 26th International Cryogenic Engineering Conference – International Cryogenis Material Conference 2016” (Editors: T. S. Datta, R. G. Sharma and S. Kar) as IOP Conf. Series Mater. Sci. Eng. Vol. 171 conference 1 (http://iopscience.iop.org/1757-899X/171/1/011001).The proceeding contains 156 papers out of a total of 234 manuscripts received.

This issue 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 other 28 papers have already been published in Vol. 41. All the papers of this issue were reviewed by our experts on our panel of referees from within and outside India. A list of papers published in Vol. 41 is also given in the last pages of this issue.

Like the previous issue (Vol. 41) this issue (Vol. 42) too begins with an invited review article written by Prof. M. D. Atrey, IIT Bombay, titled “Review of Cryocooler Technology – Moving towards Invisible and Reliable Cryogenics”. As we know, Prof. Atrey has made outstanding contribution to cryocooler technology in the country and has guided research for decades and trained a vast number of students who in turn spread this activity to several other institutions. The article gives the historical perspective of the development of this technology, different types of cycles used, present status of the capabilities of all such crycoolers, Indian efforts and describes systems developed using cryocoolers and doing away with liquid helium. I am sure the readers of the article will learn all about the cryocooler technology – fundamental to applications and understand all the intricacies involved in producing such a device.

I take this opportunity to complement all our authors and the members of the Editorial Advisory Board fortheir help and cooperation. I express my gratitude to the reviewers, who in spite of being busy with their academic work always found time to review multiple papers. Indeed during last one year they were burdened with huge review work for IJC papers as well as for the ICEC/ICMC conference papers. I also acknowledge the hard work that Ms. Tania Gupta has put in in keeping the line of communication alive between the authors, the reviewers, the Journal HQ and the printer to get the final version of the manuscripts before they were sent for printing. I thank Mr. Satish Gupta of the New United Process for taking good care of printing.

I thank all the members of the Editorial Advisory Board for their help and suggestions whenever needed. I thank Dr. RK Bhandari, Dr. TS Datta and Dr. SoumenKar who were always available for consultation and help which enabled us to bring out this issue (vol. 42) of the IJC.

Finally, we remain open to suggestions from all the authors and reviewers which can add value to IJC.

R.G. Sharma
Chief Editor

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Review of cryocooler technology – Moving towards invisible and reliable cryogenics

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Cryocoolers are refrigerators which produce cryogenic temperature in either a closed or open cycle manner. They can be developed for generating a wide temperature range depending on applications or demands. The understanding of these devices is essential from the design point of view. The cryocooler technology has undergone a major development in the last two decades and these devices have become quite reliable. They are used in, cooling of superconducting magnets, gas liquefaction, Infra-red detectors, scientific devices etc. This review paper highlights the working of various cryocoolers, their classification, the theory and the design aspects, for any general researcher or a user of cryogenics.

Key words: Cryocooler, Stirling, Pulse tube, Gifford McMahon, Joule Thomson, Recent advances, Indian context

Radiative cool down process of porous materials at cryogenic temperatures — design of test set-up

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A transient analysis has been presented in this paper for radiative cool down process of open cell metal foams subjected to liquid nitrogen temperatures. Similar to the lumped capacity analysis for a body immersed in a convective medium, a mathematical analysis has been carried out for a body held in vacuum inside an isothermal enclosure. Copper and aluminium foams, having a high porosity of 0.96 and 0.93 respectively, have been chosen for this study. In order to experimentally observe the cool down process, a test set-up has been designed. Preliminary tests have been conducted. The mathematical analysis together with the experimental data can be employed to determine a rough estimate of the radiative geometric feature, that is, view factor of metal foam. Nevertheless, few limitations need to be addressed so as to conduct accurate experimental analysis.

Key words: Metal foams, Radiation heat transfer, Transient analysis, Experimentation

A low pressure cryogenic trap for cleaning of feed stream in dilution refrigerator

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Cryogenic traps are frequently used for removing impurities from gases and conventionally use the cryo-adsorption technique with activated carbon adsorbents. Such purification instruments are often operating at high pressure to aid the adsorption process to its maximum extent. In a system which operates at low pressure and low gas flow rates the residual concentration of the adsorptive gas is determined only by its vapor pressure in relation to the total pressure. In a dilution refrigerator the process gas circulates at sub-atmospheric pressure and it becomes a challenge to remove impurities by cryogenic trap at substantially low pressures. In this paper we describe a simple one column liquid nitrogen cooled cryogenic trap for entrapment of O_2 and N_2 from the circulating process gas. Two different types of adsorbents, LiLSX and activated carbon were investigated using volumetric adsorption approach and break-through studies.

Key words: Dilution refrigerator, Cryogenic trap, Helium, LiLSX

Helium liquefaction using a two stage Gifford McMahon Cryocooler

Srinivasan Kasthurirengan[1], Upendra Behera[1], Vivek.G.A[2], and Gautam Pal[3]

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This paper describes helium liquefaction using a commercial cryocooler with 1.5 W cooling power at 4.2 K, equipped with heat exchangers for pre-cooling the incoming gas. No external cooling of helium gas or Joule–Thomson stages have been utilized. In this typical liquefaction system, helium gas at room temperature is initially pre-cooled by the cooling power available at the first stage of the cryocooler. Thereafter, it is cooled by the special heat exchanger (with large surface area) mounted on the second stage of the cryocooler. The gas when passing over the cold surface areas, gets condensed into a liquid and this enters the collecting vessel which is also mounted on the second stage of the cryocooler.A pressure gauge is connected to the collection vessel through a long narrow stainless pipe to monitor the vapour pressure of the liquid. When the liquid touches the end of this stainless steel pipe, thermoacoustic oscillations are observed on the pressure gauge, which is used for monitoring helium liquefaction. This paper describes the experimental setup and studies of liquefaction of helium by the cryocooler.

Key words: Recondensation, Liquefaction, Heat exchanger, GM eryocooler, Thermoacoustic oscillations

Operational characteristics of NBI cryo-condensation pumps

B. Pandya, A.K. Sahu, V. Prahlad, S.K. Sharma, L.K. Bansal, B. Choksi, S.L. Parmar, N. Contractor, B. Sridhar, L.N. Gupta, P. Bharathi, V. Vadher, S. Rambabu, D. Thakkar, K. Qureshi, C.B. Sumod, P.J. Patel and U.K. Baruah

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Neutral Beam Injector (NBI) is used as an effective tool for heating plasma in magnetic confinement devices, namely the Tokamak. Cryo-condensation pump is an important component of the NBI system. These pumps are required to handle a high throughput of Hydrogen gas of 50-80 Torr.L/s. The Cryo-condensation pump comprise of panel cooled at ~4.2 K by flowing LHe (liquid helium). The required vacuum of ~10^{-5} torr is achieved by condensation of hydrogen gas on the panel. The panel is thermally shielded from ambient by a set of chevron baffles cooled by LN2 (liquid nitrogen) at ~80K. In IPR cryo-condensation pumps were developed indigenously for long duration pumping ~4000s. Two such cryo-condensation pumps are installed in the NBI's vacuum chamber. Recently an experiment has been conducted to obtain operational experience and to study its characteristic performance. The operation was carried out successfully for hydrogen gas feed up to 100 torr.l/s. In this paper we describe the experimental setup, the operational procedure and results of the experiments.

Key words: Cryo-condensation pump, Hydrogen pumping, Pumping speed, Regeneration

Exergy based analytical investigation of cryogenic loop of test auxiliary cold box

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The test auxiliary cold box (TACB) has been designed for the qualification test of ITER cold circulator. The test loop in the TACB has been designed by incorporating various components and this test loop will undergo different operation modes. The exergy analysis has been performed for the test loop including all involved components to check their thermal performance and Irreversibility. The result shows the contribution of exergy destruction and exergy efficiency for the test loop as well as individual components during nominal operating case; cold circulator inlet pressure ~0.5 MPa and inlet temperature ~4.6 K. The analysis result has been captured the loop pressure variation between 0.5 MPa to 2 MPa in order to evaluate the balance between thermodynamically efficient process conditions and actual requirements, even though above 1 MPa pressure is not foreseen during the cold circulator test. The exergy based analysis approach for the cryogenic test loop show a path towards efficient process conditions at higher loop pressure and identify the inefficiencies in the various components.

Key words: Exergy analysis, Exergy destruction, Cold circulator (CC), Heat exchanger (HX)

Design of a mixed refrigerant Joule-Thomson cryopreservation chamber

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The process of cryopreservation involves the cooling of biological materials to a temperature in the range of 100 –150 K in an insulated chamber. The Mixed Refrigerant Joule-Thomson (MRJT) cryocooler technology, which is the focus of the present study, could be employed to cool the cryo-preservation chamber. The MRJT cryocooler uses a multi-component mixture of nitrogen-hydrocarbons as the working fluid. The design of the cryo-preservation chamber involves compressor selection with appropriate oil filter mechanism, MRJT cryocooler design and design of vacuum chamber. The heat exchanger design is a core aspect of the cryo-preservation chamber design. A tube-in-tube helically coiled heat exchanger is analyzed numerically to get an optimal design for the heat exchanger. Recently published correlations have been applied to estimate the boiling and condensation heat transfer coefficients. The predicted heat transfer coefficients are utilized by the algorithm to determine the temperature profile along the heat exchanger which is then used to compute the optimal design parameters of the heat exchanger. The estimated parameters are compared with the prevailing experimental data to elucidate the applicability of the model. After validation, the algorithm is used to design the heat exchanger for the cryopreservation chamber.

Key words: Cryo-preservation chamber, Mixed refrigerant Joule-Thomson cryocooler, Tube-in-tube helically coiled heat exchanger, Numerical model

Design and performance study of vortex tube for low temperature applications

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Unlike conventional systems which operate at discrete points on an operating line, vortex tube refrigeration systems offer a unique solution where the temperature and the cooling capacity of the system can be continuously varied by controlling the gas flow rate. An indigenous vortex tube operating at sub-zero temperatures is being designed and tested for study and analysis of different parameters governing its performance. A temperature difference of 60 ºC is achieved between the cold end and inlet in this specific design and refrigeration capacity of 100-150 W was observed in the whole operating range. This paper explains the different sets of experiments and their results obtained.

Key words: Vortex tube, Cryogenic, Experimental optimisation

Performance analysis of cryocoolers based on reverse Brayton cycle and its modifications for cooling HTS devices

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To maintain the superconducting state of high temperature superconductor (HTS) used for power application, higher refrigeration capacity cryocooler (>2 kW @ 70 K) is required. A reverse Brayton cycle based cryocooler with long-life and high reliability is one of the suitable candidates for cooling of HTS. The basic reverse Brayton cryocooler can be modified of basic configuration in order to achieve higher FOM. An analytical study focused on modified configurations of reverse Brayton cycle for HTS has been carried out. Neon is selected as working fluid since it has higher heat capacity than helium around 70 K. Six reverse Brayton based modified cycles are standard cycle, 2-stage compression, 2–stage series expansion, 2-stage parallel expansion (same pressure ratio), 2-stage parallel expansion (different pressure ratio), and modified cycle with intermediate cooling system for recuperator. The performances of the modified reverse Brayton cryocoolers are compared and reasons for performance variations are identified.

Key words: HTS, Reverse Brayton cryocooler, FOM

Design of 3-stream (He-He-He) compact plate-fin heat exchanger for helium plant

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Normally, in the helium Refrigerator/liquefier, to avoid high expansion ratio through the turbines, two turbines are used with series hydraulic connection, so that intermediate pressure is about 6 bar, while the helium inlet pressure to the 1st warmer turbine is about 13.5 bar. Before passing through the 2nd turbine, this medium pressure stream is also further cooled to about 15 K from ~27 K along with the hot high pressure helium stream of the same temperature range. 3-stream with counter-flow configuration type compact vacuum-brazed aluminium plate-fin heat exchanger is used for this purpose. Serrated type fins of thickness 0.2 mm have been used. Effects of fin parameters on the required size of the exchanger and pressure drop are analysed and considering manufacturing feasibilities, optimum parameters have been chosen. This paper will discuss details of these methods and results.

Key words: Cryogenic, plate-fin, serrated, heat exchanger, helium

A novel liquid air energy storage in high-pressure state

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Compared with compressed air energy storage, liquid air energy storage has the advantage of higher energy density, smaller storage volume. In this study, it describes a novel liquid air energy storage system, the air is liquefied and stored with high pressure. The system uses a regenerator for air liquefaction and energy is recovered through throttled liquid air, so extra refrigeration process is unnecessary. Thermodynamic analysis of the system's performance is also presented. The results show that the efficiency of liquid air energy storage system is high and there is enough space for optimization with different working pressure.

Modification in charging composition in order to arrive at desired circulation composition in the context of sorption compressor based J-T cooler

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A sorption compressor based cooler works on thermal swing adsorption process followed by a Linde-Hampson cycle for producing the cooling effect. A mixed gas refrigerant provides low temperatures in the cryogenic range with pressure around 20 bar as compared to a high pressure of about 100 bar with a single pure working fluid such as Nitrogen. With gas mixture, the through put of individual gas in the sorption compressor varies from gas to gas. This is attributed to the different quantities of gases retained by the adsorbent at the end of desorption process. Therefore, in adsorption compressor, the mixture in circulation varies in composition when compared to the gas mixture composition while charging in the system. Necessary corrections in the mixture composition to be charged need to be incorporated so that the mixture in circulation has the desired composition. A mathematical model, based on the adsorption data for individual component gas is used to arrive at the correct composition of the gas mixture in circulation.

Key words: Sorption compressor, Mixed refrigerant, Charging composition, Circulation composition

Numerical investigation of multi-bypass type pulse tube cryocooler

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Multi-bypass has been experimental proved to be an effect configuration for pulse tube cryocooler to achieve a better cooling performance. However, at present, the understanding of its working mechanism is still ambiguous; sometimes, multi-bypass will just be viewed as a double-inlet working at a lower temperature, and sometimes, the multi-bypass configuration will be treated as a multi-stage structure. In the present work, the relations of multi-bypass and double-inlet will be numerical investigated. The numerical simulation shows that the functions of multi-bypass and double-inlet have some similarities to a certain extent, but the multi-bypass works more like a multi-stage. Compared with double-inlet, the opening of multi-bypass has a wider range for pulse tube cryocooler to achieve lower temperature. The hot end temperature has a very small effect on the cold end temperature when the opening of the multi-bypass is optimum; the effect of hot end temperature will be larger when the opening of multi-bypass deviates from its optimum value, especially when the multi-bypass opening is relative small.

CFD analysis of axial pump of lox booster turbo pump for a staged combustion cycle based rocket engine

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Computational fluid dynamics (CFD) is the present day state-of-art technique for simulating fluid flow and heat transfer analysis of turbo-machinery. In this paper, results of CFD analysis on liquid oxygen (LOX) pump (LPOT) used as a booster pump for a staged combustion cycle based rocket engine have been reported. Ansys CFX® has been used for the flow field analysis of the LOX pump. The computation technique involves discretized three-dimensional, Reynolds Averaged Navier-Stokes (RANS) based two-equation SST (Shear Stress Transport) k-ω turbulence model over an unstructured grid. Present effort is an attempt to find out flow field, temperature and pressure profile of fluid at different components of axial pump of LPOT system viz. inlet branch, inducer, straightening device for identifying the areas of recirculation, flow separation and cavitation. The data generated have been analyzed to study the performance of the pump at steady state. These results will be used as initialization conditions for unsteady, 3d cavitation modelling of pump with a view to critical analysis of complex flow pattern of LOX in the pump with cavitation-induced instabilities.

Key words: CFD, Axial pump, Staged combustion cycle, Cryogenic, Cavitation

Mathematical modeling of cryogenic propellant tank pressurisation system provided with heat exchanger

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Pressurisation of propellant tank during flight is required to maintain specified NPSP (Net Positive Suction Pressure) at pump inlet and also to ensure structural stability against buckling under flight loads. Selection of propellant tank pressurisation system plays a vital role in configuring a high performance propulsion stage. Heat exchanger is used to heat the pressurant gas so that overall mass of pressurization system is reduced considerably. When heated gas is used for pressurisation, it is imperative to quantify the mass of liquid attaining temperature higher than the acceptable value for cavitation free pump operation. Heat exchanger design is a trade-off between optimum pressurant gas temperature, the stratified propellant mass and pressurization system mass. The objective of this paper is to mathematically model the pressurization system for Liquid Oxygen (LOX) tank employed in a cryogenic propulsion stage.

Key words: Pressurisation system, Shell and coil heat exchanger, Cryogenic stage

Parametric studies of 2K cryogenic system for superconducting e-linac at VECC, Kolkata

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VECC is developing a 2 mA, 30/50 MeV continuous-wave superconducting electron linear accelerator (e-Linac) for the rare isotope beam facility upgrade. Presently a 10 MeV injector comprising a capture cryomodule (CCM) and an injector cryomodule (ICM) is being developed in collaboration with TRIUMF laboratory in Canada. The CCM and ICM will respectively house two single-cell and one 9-cell niobium superconducting radio-frequency (SRF) cavities operated at 1.3 GHz and 2 K. The 2K temperature is produced by expanding liquid helium from atmospheric pressure to about 30 mbar pressures through a Joule-Thomson (JT) valve. The sub atmospheric pressure is maintained by two roots pumps and a dry backing pump. A 4K-2 K test setup is being developed for testing the cryogenic parameters. A general model is formulated to construct parametric analysis comprising of different components making up the system. The numerical formulation is used for quantitative assessment of the flow requirements under different conditions of operation as well as abnormal scenarios like vacuum failure, rise of thermal shield temperature and so on. The results of the investigation provide a fundamental understanding of the system behaviour and flow requirements during operation. The paper also discusses the intricate relationships among different components of the system along with their desired performance characteristics.

Design of cryo-refrigerator assisted HTS steering magnet for K500 cyclotron beam line

U Bhunia*, Md Z A Naser, T Ghosh, Pankaj Kumar, C Nandi, A Agarwal, C Das, J Pradhan, J Debnath, M K Dey, G Pal and A Chakrabarti

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The steering magnet is required for the external beam line of K-500 cyclotron to provide corrective steering capabilities. A conventional copper based steering magnet for high rigidity beam (maximum up to 3.3 T-m) becomes very bulky and difficult to integrate in beam line if large steering (± 3 degree horizontal (X) and ± 1.5 degree vertical (Y)) is required. Recently, commercial availability of long length (more than 100 m) high temperature superconductor (HTS) tape along with availability of high power cryo-refrigerator has given opportunity to develop compact conduction-cooled HTS magnet operating at temperature of 20 K or even higher. Although many prototype magnets using HTS tape have been fabricated and evaluated, there are only few applications in the particle accelerator fields. The paper describes the physics design aspect of the X-Y steering magnet along with details of cryostat.

Key words: HTS magnet, Racetrack coil, Conduction cooled.

Measurement of equilibrium nitrogen adsorption capacity of granular activated carbon including detail error analysis

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Any adsorption based application needs information of equilibrium adsorption capacity of adsorbent (for any adsorptive). Measurement of equilibrium adsorption capacity and fitting the data into adsorption isotherm is not new in adsorption research, yet it is essential for every new adsorbent sample prepared. Accurate measurement in the cryogenic temperature domain needs special attention. Equilibrium nitrogen adsorption capacity of granular activated carbon prepared from coconut shell has been measured. Simple and cost effective volumetric method has been adopted for the measurement. Adsorption isotherms are measured from 300K to 175K with decrements of 25K. Experimental data are fitted into Langmuir equation. An exchange gas type cryostat has been used in the experiment to account the isotherms. Isosteric heat of adsorption has been calculated using Clausius-Clapeyron equation. The sources of error involving use of real gas equation and dead volume corrections particularly at low temperature and high pressure has been analyzed in details.

Key words: Equilibrium adsorption capacity, Isotherm, Exchange gas cryostat, Isosteric heat of adsorption.

Fault-diagnosis of an operating cryogenic air separation plant through steady state simulation

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Cryogenic air separation plant is expected to produce nitrogen, oxygen and argon in gaseous and/or liquid forms. Performance of such plants depend on number of components which may malfunction. When an operating plant has a reduced rate of production, increased power consumption and off-the-mark purity of products, the questions that haunt the operators are: which component is malfunctioning? Which parameters ought to be tuned? As the manufacturer almost never shares the geometric details of plant manufacturing, it becomes a challenge for the simulating person to guess the design details. However, once operating parameters match with simulated plant, it may be termed as recreation of the design. In the present work estimated design parameters were used for simulating plant in Aspen HYSYS® (a commercial chemical process simulator) platform until the results matched with output parameters. Results could serve as guidance to the operating engineers to preempt the decrease of plant performance.

Key words: Cryogenic air separation, Fault diagnosis, Aspen HYSYS®, Geometrical parameters, Simulation

Studies on pumping behavior of a test cryopumping facility

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Since more than a decade cryopumps are used as one of the reliable vacuum pump to get clean ultra-high vacuum. The pumping performance of a cryopump is always depends on the type of sorbent used, operating temperature of pumping surface and the type of gases. There is always a variation of the reported pumping speed towards the actual experimental pumping speed. Hence the actual pumping speeds were measured as per the American Vacuum Society (AVS) standard for the different gases and compared with the reported values for the test cryopump Marathon® CP-12. Experiments were performed for the operating pressure range of 5E-7 mbar to 1E-4 mbar with a calibrated throughput varying from 1mbar-ltr/s to 1E-3 mbar-ltr/s. It was observed that the pumping speed for a particular gas always depends on the working pressure and the operating temperature. Measured pumping speed values are in good agreement with the catalogue value for the operating pressure range of 3E-5 mbar to 4E-5 mbar.

Key words: Cryopump, Pumping, Vacuum, Throughput

Study of fluid flow parameters of cryogen distribution system for E-Linac facility of RIB Project at VECC, Kolkata

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The cryogenic infrastructure for the e-Linac will have LHe liquefier, LHe distribution lines and liquid nitrogen (LN_2) distribution lines. LN_2 distribution lines supply liquid nitrogen to the LHe liquefier, 80K thermal shields of the cryomodules and LHe distribution system. The total heat load to the nitrogen system has been estimated. Study was carried out for both series and parallel flow connections for LN_2 circulation. Various flow parameters e.g. mass flow rate, fluid quality, pressure and temperature at different locations of the helium distribution systems were calculated by considering two phase fluid flow. These flow parameters are very crucial to ensure the optimum operation of cryogenic distribution system. Provision of using the return cold helium vapour (40K/ 80K) as a coolant of thermal shield of the cryomodules were studied to rule out the LN_2 flow requirement to the cryomodules.

Key words: Capture cryomodule, Injector cryomodule, Homogeneous flow

Thermohydraulic analysis of hydroformed radiation shield plate

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Hydroformed panels are widely used in fusion reactor components as a thermal radiation shield, for cryopumps and cryostats. In a cryopump, the pumping surface area is cooled down below 5K and is shielded from direct outer thermal radiation by using radiation shield panel cooled at 80K. Therefore, high cryogenic operational mass flows are required and thus pressure drop and heat transfer characteristics are important aspects of study. CFD analysis for radiation shield plate (2045 mm x 1800 mm x 3 mm) has been carried out when gaseous helium at 15 bar and 80K was inserted under heat flux of 365 W/m_2. Further analyses were made for variable mass flow rate (i.e. 20 g/sec to 50 g/sec) to obtain optimum value of pressure drop with accurate thermal distribution on hydroformed shield plate.

Key words: Cryopump, Radiation shield, Pressure drop, Heat transfer

System for adsorption isotherm studies of porous carbon materials down to 4.5 k

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In order to characterize different type of adsorbents for cryopumping specific application at low temperature down to 4.5 K, a facility for adsorption study (FADS) is set up at Institute for plasma research (IPR). This system comprises of a standard micro-pore analyser for sample characterization at 77 K and a GM cryocooler with sample holder cell for sample analysis at a temperature < 77 K. The use of temperature control unit enables to study the porous characteristics of adsorbents at any temperature between 4.5 K and 77 K. Using this system various activated carbons were characterized by studying their adsorption isotherms for nitrogen and helium gas. The surface area of the activated carbons were found to be varied from ~ 1000 m_2/s to ~ 3000 m_2/s for temperature range 77 K to 4.5 K. A complete detail of the system and the results of experimental studies on some specific adsorbents

Key words: Cryopump, Fusion, Activated carbon, Adsorption isotherm, Cryocooler

Design and development of experimental setup to measure the RRR values of a thin film coated superconducting sample

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Bulk Niobium cavities are currently used in superconducting radio frequency applications. Superconducting thin films can replace them as they have great potential to overcome the fundamental limitation of the bulk cavities. For thin films to be successfully implemented, systematic studies on structural properties are necessary. Superconducting Radio Frequency (SRF) technology is widely adopted in particle accelerators. Here we use residual resistance ratio (RRR) value as a measure to determine the purity of metal, which is defined as ratio of resistivity of metal at 300K to residual resistivity at 4.2 K. This paper discusses about design and development of an experimental setup and data acquisition system and its validation with standard resistor. This will be used for measurement of RRR values of niobium coated samples in future experiments. The measurement of resistance is carried out using NI-DAQ and LabVIEW 11.0 software. Cold electronics pre-amplifier used for signal conditioning also is discussed.

Keywords: Residual resistivity ratio, Cold electronics, Superconductor, Data acquisition

Low temperature electrical and magnetic behaviour of Sr Doped LCMO manganites

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To understand the complex conduction mechanism and electrical transport properties of manganite materials a series of strontium doped LCMO manganites with compositional formula $La_{0.67}Ca_{0.33-x}Sr_xMnO_3$ have been synthesized. The samples were characterized structurally by XRD and AC susceptibility measurements were undertaken to determine T_C. A systematic investigation of electrical resistivity over a temperature range 5-300 K was done to determine metal-insulator transition temperature (T_P). Anomalies were observed at temperatures below 50 K and the observed behavior has been explained using electron-electron interactions, Kondo like scattering and electron- phonon interactions.

Key words: Colossal magnetoresistance, Conduction mechanism, Electron-magnon scattering, Electron-electron scattering

Artifacts suppression using independent component analysis from the measured magnetocardiogram

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Magnetocardiography(MCG) is a non-invasive technique, complimentary to the electrocardiography (ECG), and measures the magnetic field associated with the electrical activity of the heart using Superconducting Quantum Interference Devices (SQUID) which have unparalleled sensitivity for the detection of weak magnetic fields. But a detailed analysis of MCG data is often limited by interference from extraneous noise, which may even dominate the MCG data. In most previous works, the step involving the elimination of noise was implemented using filtering. Conventional filtering cannot always fully address the problem of signal processing in terms of extracting specific signals due to particular biological sources of interest such as human heart. In this paper, we demonstrate the use of independent component analysis (ICA) to suppress the artifacts from the MCG recordings acquired using SQUID sensors coupled to axial gradiometers.

Key words: Superconducting quantum interference devices, Magnetocardiography, Artifact suppression, Independent component analysis

Tribological properties of polytetrafluoroethylene at cryogenic temperatures

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Many cryogenic applications like bearings, pumps, valves, seals etc cannot be lubricated by conventional means with oils and grease because the cryogenic temperature range is far below the pour points of these lubricants. For these applications, solid lubricants like poly tetra fluoro ethylene (PTFE), molybdenum disulphide (MoS2), amorphous carbon, polymers, etc. are used. In this study, experiments are carried on plain and carbon filled PTFE materials to study their tribological properties at cryogenic temperature. A cryotribometer has been designed and developed which works on the principle of pin on disc wear type tribometer according to ASTM standard (ASTM G 99-95).Both plain and carbon filled PTFE pins were made to slide for 10 minutes over an abrasive surface rotating at 400 rpm under the applied load of 10N. Experiments were carried both at room and cryogenic temperatures. The effect of cryogenic temperature on the wear, frictional force and coefficient of friction are presented.

Key words: Wear, Coefficient of friction, Fictional force, Tribology, Liquid nitrogen

Simulation optimization on quench analysis of wide aperture superconducting quadrupole magnet

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Wide aperture superconducting magnets are used in different accelerator laboratories as spectrometer magnets. These magnets are used in the accelerator facilities like ANURIB project, Kolkata, newly constructed BIGRips facility in Japan and FAIR project in GSI, Germany. Quench simulation is an important part of the design of superconducting magnet. The present simulation has been carried out using QUENCH code and QUENCH-ELECTRA coupled code of Vector Fields software for wide aperture superconducting quadrupole magnet. Since the quench calculation is highly nonlinear in nature, Computation time is generally high. As increased computation time increases cost of design, choosing proper mesh size and time stepping tolerances play an important role during quench calculation. This paper will discuss about convergence of hot spot temperature and maximum voltage on mesh size, tolerance criteria. Computation time for each case, effect of delay in actuation of quench circuit will also be discussed.

Key words: Superconducting magnet, Quench simulation, Over voltage