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INDIAN JOURNAL OF CRYOGENICS

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

Published by
Indian Cryogenics Council

Special issue
Proceedings of Twenty First
National Symposium on Cryogenics
National Physical Laboratory
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CONTENTS

On the Suitability of Monovalent (K & Na) Doped Lanthanum Manganite Perovskites as Refrigerant for Near Room Temperature Magnetic Refrigeration

T. K. Dey

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Polycrystalline samples of potassium and sodium doped lanthanum manganites of the types $La_{1-x}K_xMnO_3$ (0<x<0.15) and $La_{1-y}Na_yMnO_3$ (y=0.05, 0.10, 0.15) having nanometric crystallite size have been prepared by microwave processing. Pottasium and sodium addition in lanthanum manganite enhances the Curie temperature (T_C) of the system from 260K (x=0.05) to 309K (x=0.15) and from 196K (y=0.05) to 312K (y=0.15) respectively. A detailed structural analysis has been performed on all the samples using the Rietvald FULLPROF program and important structural parameters are estimated. Close to T_C a significant change in magnetic entropy has been observed in both K and Na doped lanthanum manganites. Maximum entropy change $\left|\Delta S_M^{Max}\right|$ in an applied field of 1T shows an enhancement by ~10% with increase in K content up to x=0.15. $La_{0.85}K_{0.15}MnO_3$ exhibits the largest value of 3.00 J/Kg-K at 310K amongst the compounds investigated. Moreover, the maximum magnetic entropy change in both systems exhibits a linear dependence with applied magnetic field. The adiabatic temperature change estimated at T_C and at 1T field also increases with both K and Na doping, being maximum of 2.8K for $La_{0.85}K_{0.15}MnO_3$ compound. The relative cooling power (RCP) of $La_{1-x}K_xMnO_3$ compounds is estimated to be about one third of the prototype magnetic refrigerant (pure Gd). $La_{1-x}K_xMnO_3$ compounds possess MCE around room temperature which is comparable to that of Gd. However, in case of $La_{1-y}Na_yMnO_3$ compounds MCE is ~67% of pure Gd. The temperature dependence of the magnetic entropy change (ΔS_M) measured under various magnetic fields is explained fairly well using the Landau theory of phase transition. Contributions of magnetoelastic and electron interaction are found to have strong influence in the magnetocaloric effect (MCE) of manganites. Our results indicate that apart from high and RCP value; tailoring of T_C, higher chemical stability, lower eddy current heating and lower cost of synthesis are some of the attractive features of $La_{1-x}K_xMnO_3$ compounds which are attractive as magnetic refrigerant.

Superconductivity of High Performance Nano-Diamond Doped MgB_2

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We studied the effect of nano-diamond addition on micro-structure, magneto-transport and magnetization of MgB_2:$(nD)_x$ system with x = 0.0 to 0.10. Superconductivity transition temperature (T_c), as determined from both resistivity and low field dc susceptibility measurements is nearly invariant up to x=0.05. This shows that added nano-diamond (C^{12}) is neither decomposed to C and eventually nor substituted at B site in MgB_2. R(T)H measurements showed higher T_c values

under same applied magnetic fields for the nano-diamond added samples, resulting in higher estimated H_c values for MgB_2:nD_x. Highest value for H_c is observed for 3% and 5% nano-diamond doped samples. Magnetization measurements showed the magnetic J_c of the order of 10^6 A/cm^2 for pristine sample, which is further increased 2 to 3 times for 3 and 5% nano-diamond doped samples in applied fields and is nearly invariant till 20 K under applied fields of up to 2 Tesla.

Impact of Al Substitution in $Mg_{1-x}Al_xB_2$ Superconductor with x = 0.0 to 1.0

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Impact of Al substitution is studied in detail for $Mg_{1-x}Al_xB_2$ system. In particular the results of phase formation, resistivity ρ(T), thermoelectric power S (T) and magnetization M (T) are reported. Al substitutes at Mg site in $Mg_{1-x}Al_xB_2$ with full solubility and results in lattice compression mainly in c direction. ρ(T) measurements exhibited suppression of superconductivity (T_c) with Al along with a decrease in q_D (Debye temperature). Decreasing q_D indicates the suppression of phonon interactions. Both thermoelectric power S (T) and magnetization M (T) measurements corroborated the ρ(T) behavior in terms of their T_c. Interestingly enough though the sign of S (T) is positive for MgB_2 the same is negative for AlB_2, indicating that the former is hole type conductor and the later is electron type.

Electrochemical Synthesis of MnAs Thin Films

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Attempts have been made to synthesize room temperature magnetic refrigeration material like MnAs having large MCE in the thin film form by a novel ecofriendly electrochemical route. Electrochemical bath having 0.1 N $(CH_3COO)_2Mn$ and $AsCl_3$ were used for the deposition of the MnAs film on stainless steel (SS) substrates. These films were further heat treated at 225 ^oC in 10^{-2} torr pressure. XRD studies confirmed that the MnAs thin films were synthesized with the impurity phase of Mn_2As. A SEM study reveals the well covered growth of MnAs thin film.

Effect of Pr Doping on Transport Properties of $La_{0.7}Sr_{0.3}MnO_3$ CMR Material

Prem Vir Singh, Rahul Tripathi, Ravi Kant, Vijay Kumar,
H. K. Singh, A. K. Gupta, V. P. S. Awana and Hari Kishan

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Systematic studies were carried out on electrical transport properties of Pr doped $La_{0.7}Sr0_{.3}MnO_3$ manganites. Decrease in metal-insulator transition temperature (T_{MI}) from 373K to 313K is

observed as the doping percentage of Pr is increased . This effect can be explained on the basis of cation size mismatch as Pr is smaller than La. Magnetoresistance (MR) of these samples showing usual behavior of bulk polycrystalline samples except a peak near T_{MI}.

Thermoelectric power of polycrystalline Potassium doped Lanthanum Manganites at Cryogenic temperature

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The temperature dependence of the thermoelectric power of monovalent Potassium-doped $La_{1-x}K_xMnO_3$ polycrystalline pellets (x=0.05, 0.10 and 0.15) is reported between 50 and 300K. Reitveld analysis shows all the samples to be rhombohedral with space group $R\bar{3}C$. Curie temperature (T_C) of the samples increases from 260 to 309K as K-doping increases from 0.05 to 0.15. Both the resistivity and thermopower data of these compounds is governed by the adiabatic small polaron hopping in the high temperature ($T>T_C$). In the low temperature ($T<T_C$), the electrical resistivity is governed by polaron tunneling along with electron-electron, electron-magnon scattering whereas the thermopower can be well explained by the electron-magnon and spin wave fluctuation. Both, resistivity and thermopower data between 50 to 300K are further examined in light of a two-phase model based on an effective medium approximation. Our analysis confirms that the temperature dependence of the thermoelectric power of $La_{1-x}K_xMnO_3$ compounds computed using the expression derived using effective medium approach, gives a fairly good description of the observed thermal variation of thermoelectric power in monovalent (K) doped lanthanum manganites between 50 and 300K.

Inter-comparison of the Physical Properties of $YBa_2Cu_3O_7$ and MgB_2 Superconductors

Akshay Deshpande[1], Arpita Vajpayee[1,2], Monika Mudgel[1,2], , Anuj Kumar[1], V.P.S. Awana[1], Anurag Gupta[1], M. A. Ansari[1], R.B. Saxena[1], Rajeev Rawat[3], H. Kishan[1], G. L. Bhalla[2] and A. V. Narlikar[3]

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We synthesized two superconductors MgB_2 and $YBa_2Cu_3O_7$. We found striking differences in their physical properties besides having different critical temperatures of 39K and 90K respectively. MgB_2 is synthesized with a simple procedure of mixing the required samples, sealing them in quartz tube and then quenching them in N_2 atmosphere at 750°C after 2.5 hours. $YBa_2Cu_3O_7$ is synthesized by a conventional solid-state reaction. In case of $YBa_2Cu_3O_7$, its J_c at 20K under 2Tesla magnetic field is two orders of magnitude lower than MgB_2, but the H_{irr} seems to be much higher than 8 Tesla. The main aim of the work is to bring out the contrast in the two different superconductors in terms of their physical properties i.e. we present in this paper their intercomparison of properties.

Effect of Valve Opening on the Performance of Pulse Tube Refrigerator in OPTR Mode

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The Pulse Tube Refrigerator has no moving parts at its cold section. It is attractive in obtaining higher reliability, simpler construction, and lower vibration than any other small refrigerators. The experimental results of the G M type Pulse Tube Refrigerators are presented in this paper. In the present experimental investigation study of effect of valve opening on the performance of Orifice Pulse Tube Refrigerator was carried out. The Performance of Orifice Pulse Tube Refrigerator was evaluated for the frequency range of 2Hz to 6Hz and effect of orifice opening on no load temperature at the cold end was evaluated. The lowest cold end no load temperature was recorded as 74.5K at 3 Hz frequency. It was observed that with the increase in orifice opening the no load temperature at the cold end decreases and passes through minimum value.

Analysis of Inertance Pulse Tube Cryocooler Using Computational Fluid Dynamics

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Inertance pulse tube cryocoolers (IPTC) are a class of ragged and high-endurance refrigeration systems that operate without a moving part at their low temperature end and are capable of reaching very low temperature. Thermo-Fluidic processes in IPTC's are complicated and the details of mechanisms underlying their performance are in developing stage. Approaches like cyclic analysis, nodal analysis had been reported in literature [1, 2]. Computation Fluid Dynamics (CFD) is an art of replacing the integrals or the partial derivatives in the equations governing the fluid flow with discretized algebraic forms, which in turn are solved to obtain numbers for the flow field in contrast to a closed-form analytical solution [3]. Advances in Computational Fluid Dynamics and its wide application are proving for its stability. Hence CFD technique can be applied for analysis of IPTC.
CFD analysis approach is used to predict the performance of IPTC. Design methodology is developed for IPTC analysis. It is used to predict the performance of practical cryocooler reported by Gawali B. S. and Narayankhedkar [4]. Paper deals with the results obtained.

Investigations on Mixed Refrigerant Joule-Thomson (MR J-T) Cryocooler

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Development of mixed refrigerant Joule Thomson (MR J-T) cryocooler is under progress at IIT Bombay, Mumbai. In the recent years the mixtures formed with Nitrogen, Argon, light hydrocarbons, and some of HCFCs are used in MR J-T for getting higher refrigerating effect at

low temperatures. Use of high boiling components in mixtures has made it possible to operate closed cycle MR J-T at moderate pressures of about 20 -25 bar. An experimental set up to test such cooler has been developed in the laboratory. An efficient counter current heat exchanger has been fabricated. Single stage oil lubricated commercial air conditioning compressor is planned to be used to compress the gas with air cooled after-cooler and oil filters.

Theoretical Prediction and Experimental Investigation of Counter Flow Pulse Tube Refrigerator

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Interest in pulse tube has grown rapidly in the last few years because of mechanical simplicity, high reliability and no moving parts at the cold end, resulting in low vibrations. Many current and future commercial and military set-ups need a minimal vibration, long life and more capable active refrigerator to satisfy their requirements. In this context pulse tube refrigerators can play a vital role.
Matsubara and Miyake [1] introduced warm expander at the hot end of pulse tube to use the work of expansion in GM type Pulse Tube refrigerator. This is called the Warm expander Pulse Tube refrigerator. De Waele [2] proposed the concept of replacement of regenerator with recuperative heat exchanger. This is called the Counter Flow Pulse Tube Refrigerator. Cyclic analysis approach is applied to develop the theoretical model for the analysis of counter flow pulse tube refrigerator. Detailed analysis and predictions will be presented in the paper. Experimental model is developed to validate the predicted results.

Design of Rotary Valve for G-M Type Pulse Tube Refrigerator

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Pulse Tube Refrigerator (PTR) has become fast growing technology in Cryogenics. The G-M type PTR runs at frequencies less than 10 Hz. It has a Helium compressor, Pulse Tube expander and a Rotary valve. The rotary valve alternately connects high and low pressure ports of the compressor to the Pulse Tube Expander. It gives a pressure pulse which greatly affects the performance of the PTR. The present paper gives a methodology to design a rotary valve that yields stator and rotor dimensions; calculates net torque; and can be applied to generate a desired pressure pulse for a given PTR.

Effect of Working Fluid on Performance of Alpha Stirling Cryocooler Driven by a Novel Compact Mechanism

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An Alpha Stirling cryocooler driven by a solitary novel compact mechanism and which includes two cooling units operating simultaneously is analysed. The theoretical investigation consists of Second order thermodynamic analysis of the cryocooler, mechanical design of the drive mechanism and effect of parametric variation for optimum dimensions and cycle parameters. It is observed that at a fixed refrigeration temperature of 70 K, the power inputs of 93.76 W, 84.14 W and 95.27 W are required to provide the refrigeration effects of 4.894 W, 3.1387 W and 4.708 W using helium, hydrogen and neon respectively for the same mean pressure and rpm.

Improved Cryocooler For OnZ-board Applications

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A Split Stirling Cryocooler has been developed at ISRO Satellite Centre, Bangalore, sometime back for on-board application, performance of which is comparable to the cryocoolers made by other space agencies, except for the mass, which was higher. Apart from the thermal performance, mass of such cryocoolers is also one of the factors to be considered for on-board application. Hence the mass reduction of the cooler developed earlier was taken up.

Since the compressor is the main contributor to the total cooler weight, a new compressor is developed with a significantly lower mass. This unit has been built around a smaller magnet which results in significant weight saving, as the magnet assembly is the main contributor to the compressor overall mass. The weight of the new compressor is approximately 30% lower than that of the original design [2].
Keywords: *Cryocooler, Stirling Cycle, Thermal performance*

Development of Niobium Based Superconducting LINAC at IUAC

S.Ghosh, R.Mehta, G.K.Chowdhary, A.Rai, P.Patra, B.K.Sahu, A.Pandey, D.S.Mathuria, R.S.Meena, M.Kumar, S.Babu, S.S.K.Sonti, K.K.Mistri, S.Kar, A.Chowdhury, J.Chako, J. Zacharias, P.N.Prakash, T.S.Datta, D.Kanjilal and A.Roy

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Superconductivity brought a new era in the field of ion beam accelerators. With the increase in demand for ion beam energy from keV to GeV, room temperature accelerators were slowly replaced by superconducting accelerators. Among the various types of accelerators, superconducting (SC) linear accelerator based on Niobium Quarter Wave Resonator (QWR)

was chosen at IUAC as a booster to the existing Pelletron accelerator. The best accelerating electric field in a IUAC QWR achieved so far is 6 MV/m @ 6 watts of input power. Recently, 130 MeV 28Si ion beam from the Pelletron accelerator was further accelerated by five working resonators in the first linac cryostat of the SC linac and a beam of 148 MeV energy was delivered to conduct a nuclear physics experiment. The superconducting linac, with an emphasis on the niobium QWR, will be presented in the paper.

Liquid Helium Transfer Line for 10 kA Current Lead

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A 15 meter long liquid helium transfer line has been indigenously developed to supply 12 g/s of liquid helium flow rate at 4.2 K for the 10 kA conventional vapor cooled current leads test set up. Operating conditions of current leads require steady flow of liquid helium, with minimum pressure drop and minimum heat load. The optimized design of transfer line consists of vacuum barrier, MLI, spacer, process tube and outer jacket. Estimations show that this transfer line has total heat load of 10.3 W at 4.2 K. This paper covers the thermal design, flexibility analysis and pressure drop calculations of the transfer line.

Conceptualization and Realization of 20 K and 80 K Cryotarget System to meet Test Requirements of Imager and Sounder Payloads of Insat-3D Spacecraft at SAC, Ahmedabad

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Space Applications Centre, ISRO, Jodhpur Tekra, PO: SAC, Ahmedabad-380015

Thermal Vacuum Test is mandatory for evaluation of satellite payload and its subsystems for their onboard performance. Each payload requires specific test setup to test and evaluate its onboard performance. Insat-3D spacecraft consists of two payloads viz. Imager and Sounder. Detectors used in both these payloads require a target kept at 20K to validate their performance at 90 K to 100 K. Cryotarget system simulates deep space temperature and thereby cools the detectors of these payloads in radiative cooling mode. Patch in payload attains and provide required operating temperature range for IR detectors residing inside the payload. Cryotarget system maintains the patch temperature throughout the different phases of thermal vacuum testing of these payloads. With this objective, cryotarget system was configured, realized and installed in 5.5m Dia. Thermal Vacuum System at SAC, Ahmedabad.

Methodology of Introducing Flexibility in Cryogenic Distribution System

Rajiv Sharma, B. Sarkar, Hiten Baghela, A.K. Sahu, Girish Gupta, Satish R.B., S. Saradha and Y.C. Saxena

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The main cryogenic transfer of SST-1 machine consists of 3 supply and 3 return lines for hydraulic cryogenic distribution of magnet system. The high thermal stress induced in the cryogenic transfer line piping and critical component such as electrical isolators when machine is cooled from 300 K to 4.2 K. After analyzing, comparing different flexibility methods, specific cryogenic bellows have been developed, tested and incorporated in the cryogenic transfer lines. The developed bellows are capable of working under internal working pressure of 15 bars and simultaneous external working pressure of 10^{-5} mbar (vacuum). The two-ply bellow of 0.3 mm thickness has qualified all the tests under working temperature of 300 K to 4 K. The bellows are capable of providing 10mm compression/expansion under the operating condition; 2 mm lateral movement, 2-3 degree angular movement and also qualified for helium leak rate of $1X10^{-8}$ mbar lt/sec. This paper describes the design requirement, hydro test at 20 bars, helium leak test at LN_2 and LHe temperature, implementation methodology, experimental test results and analysis of bellows.

Cryogen-Free HTS Coil Based ECR Ion Source

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High temperature superconducting (HTS) tapes have been used for developing two identical solenoids for use in an electron cyclotron resonance ion source (ECRIS). This novel feature has many advantages in terms of savings in the power consumption and cooling requirements reduced by an order of magnitude, besides making the entire system in a cryogen-free compact form. The axial coils use Bi-2223 high strength HTS tapes wound in the form of pancakes which have critical bending diameter suitable for developing solenoids. The two coils are independently cooled using Gifford McMahon type cryo-refrigerators to ~ 23 K for optimum operation corresponding to a total heat load of 30 W. Since the maximum radial field at which the coils can operate is determined by the operating temperature, this particular single stage cryo-refrigerator was chosen for optimum performance. The entire HTS-ECRIS along with the cryo-cooler and associated beam extraction, vacuum and electrical systems are developed for operation on a 400 kV high voltage platform. The performance of the ion source matches all design goals. Various highly charged ions are produced using this source. Details of the working system and its performance is reported.

Prototype Testing Scheme for ITER Cryo-line

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The International Thermonuclear Experimental Reactor (ITER) cryogenic system consists of cryoplant, cryo-distribution system, cryo-lines and manifolds. These cryo-lines are used for supply and return of 4.5K SHe, 50 K GHe, and 80 K GHe to different applications. To suit this requirement cryo-line is designed with several internal tubes with MLI, bellows, fixed and sliding supports. A typical section of cryo-line for ITER Poloidal Field (PF) and correction coil (CC) including one Z, elbow, curved, and straight section has been taken for prototype testing. This paper presents the conceptual design and testing scheme of the typical segment of PF and CC cryo-line.

Materials for Coil Structure of Superconducting Magnet

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The material for coil structure of superconducting cyclotron magnet undergo drastic changes in their properties at 4.2K. High field of 5.5 tesla has been produced in 32mm pole gap of 100 tones magnet at VECC, Kolkata, when energized by 6.8 tones coil. High Lorenz force is acting radially outward on the composite coil structure. A high magnetic force (F=B^J) which produces a two-dimensional pressure ($B^2/2\mu_0 \approx$ 2000 PSI) along with the thermal stress due to cryo-shocking may destroy the coil structure. Safe performance of coil structures depends on the yield strength, stiffness, fatigue and fracture toughness, thermal conductivity, coefficient of thermal expansion, weld-deposit quality, and other physical properties at 4.2 K.

Applications of High Temperature Superconductors (HTS) for the Fusion Device

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The use of HTS materials in fusion devices could decrease the operational costs, but strong boundary conditions exist. To outline the prospects, challenges and problems, first the benefit of cryogenic power saving is discussed using HTS materials. High performance kA class HTS current leads, feeders and small-scale magnet are on the way for fusion applications. The development of HTS conductor would be the key design issue for the future fusion magnets. The R & D of such conductors based on Bi-2223 and YBCO are briefly discussed. Success of such conductors require to overcome AC loss problems and other challenges.

Operational Experience and Functional Control of Helium Cryogenic System of SST-1

Pradip Panchal, Ritendra Bhattacharya, B. Sarkar, A. K. Sahu, Jignesh Tank, Rohit Panchal, Rakesh Patel, Pawan Shukla, Manoj Singh, J.C. Patel, Dasarath Sonara, Girish Gupta, Ravi Duggar, Hiten Vaghela, Nitin Shah, Rajiv Sharma, Satish Badgujar, S. Sarada and Y. C. Saxena

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Fine tunings of overall helium cryogenic system become necessary after interfacing helium refrigerator/liquefier (HRL) with warm gas management, integrated flow distribution and control system (IFDCS) and current feeder system. Programmable logic controllers with supervisory control and data acquisition have been implemented to control functionality of helium distribution systems and bridge the various subsystems of SST-1 and the HRL. The performance of the distributed systems mainly depends on the control systems. The paper describes the operational experience, functional control logics and tuning of HRL and IFDCS during operation.

Design and Development of Coil Winding Machine for Super Conducting Quadrupole Magnet

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A wide bore(200mm) cold iron superconducting quadrupole doublet magnet for the Hybrid Reaction Analyzer(HYRA) project is being developed at Inter University Accelerator Centre (IUAC). Conventional winding machines are not capable of giving the required cross-sectional shape and also the winding has to be done without the pole tips in position. But the shape of the coil after winding must match with pole tips shape and angle. One side of the coil has an angle of 45 degree and the winding former has to flip exactly that much while rotating to get the desired shape. The winding machine is designed in such a way that it flips 45 degree either side while rotating. Coating of the super conducting wire with Stycast Epoxy also has to be done during the winding operation. In this paper, design and development of the machine is presented.

The Control System for the Linac Cryogenics

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The Superconducting Linear Accelerator at TIFR presently has five working accelerating modules, each module consisting of four lead plated OFHC copper cavities. The resonators are operated at liquid helium temperature in order to use the superconducting properties of lead for the generation of high accelerating fields with low RF power dissipation in the cavities. Therefore, for the stable operation of the LINAC, an efficient cryogenic system is required. The cryogenic plant and distribution system is operated remotely from control room. For this purpose, one needs various monitoring and controlling instruments at proper locations, supporting electronics for its remote operation and well designed program for its automatic operation. This paper describes the present and on-going efforts in this direction to automate the cryogenic distribution system.

Status of Indigenously Developed Closed Cycle Refrigerator Based Cryopump of 1000 Lit/S Pumping Speed

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Closed cycle refrigerator based cryopump of 1000 lit/s pumping speed for nitrogen was already developed using indigenous two stage GM-cryocooler. Exhaustive tests were carried out for the performance measurement of cryopump with respect to its cool-down time, ultimate pressure, pumping speed, cross-over rating, maximum throughput and gas capacity. In this paper, different cryopump characteristics are discussed, particularly recent test results for measurement of pump gas capacity with nitrogen by continuous pumping nitrogen at constant flow-rate. The performance of cryopump was repeatable in attaining second stage temperature of 12 K, base pressure of the order of 10^{-8} mbar and pumping speed of 1000 lit/s. in all trials. This cryopump has already completed more than 4000 hrs of operation. There is no performance degradation so far.

Development of a Cryogenic Turbo-expander using Herringbone-grooved Journal Bearings

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Instability of the rotor caused by high rotational speed is the major concern in the development of a cryogenic turbo-expansion device. Externally pressurized gas lubricated (aerostatic) bearings consume process gas and are suitable only at low and medium rotational speeds. Herringbone-grooved bearings are one type of self-acting (aerodynamic) bearings which do not need any external gas supply and can perform without any speed limitation. This paper highlights some of the theoretical and practical works carried out towards the development of this type of bearing system. Theoretical performance prediction using FEM analysis and some trial run results are presented.

A 7 Tesla Insert-Superconducting Magnet System

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The paper describes the design, fabrication and the operation of a 7 Tesla insert type superconducting(SC) magnet with a working bore of 46 mm and a field uniformity of ± 0.1% (in 10mm diameter spherical volume). The magnet is wound using a NbTi multifilamentary conductor and produces a field of 7.1 T at a current of 210 A. The magnet is of insert type and suitable for operation in a standard 100 mm neck liquid helium storage vessel. Hence, the preparation time required to start a magnetic field measurement is thus drastically reduced.
Key Word: superconducting magnet, current leads, quenching

Development of a test-set up for Ineffectiveness Measurement of Cryogenic Regenerators

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A test setup is proposed for the measurement of ineffectiveness of a regenerator at 77 K at the cold end. The setup has some unique features compared to the ones described in literature. Detailed design aspects of the test setup and some of its critical components are discussed. A new type of 4-way rotary valve is designed and developed. The valve is fabricated in house and tested for its desired performance. Isothermalizers should ensure very high heat transfer coefficient, so that the gas can be cooled to liquid nitrogen temperature instantaneously. Design of the isothermalizers is also presented.

Some Critical Aspects of Designing the J-T Heat Exchangers for Helium Liquefier/Refrigerator

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J-T heat exchanger is one of the important components of any helium liquefier/refrigerator. The lowest achievable temperature in the system is largely dependent on thermal and pressure drop design of heat exchanger of this stage. In any helium liquefier/refrigerator, the typical operating temperature range of J-T heat exchanger is 6-10 K. Therefore, this heat exchanger operates near the critical region where thermo physical properties of fluid vary immensely with the temperature and pressure. The conventional design methods may not be accurate enough to predict the thermal performance of the heat exchangers working in this region. The temperature profiles with the length of heat exchanger may vary with the operating pressures in this temperature range due to the variation in thermo physical properties. These temperature profiles become highly non-linear (shape of concave, convex or both may appear) depending on the working pressure and temperature of fluids. Therefore, the hot and cold end temperature difference may change accordingly. This may result in change of the design parameters because small change in the end temperature difference may reduce or increase the length significantly. Hence, the sizing of this heat exchanger can affect the overall cycle performance. The design based on conventional methods may not be suitable. In the present paper, some of these critical issues will be presented regarding the design of J-T heat exchangers.

Low Frequency NQR Using Squid Sensors

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NMR and NQR studies at low frequencies have gained considerable importance due to their application towards the detection of Nitrogen based explosives, as well as for the determination

of the structure of biological molecules through ^{14}N NMR and NQR. However, the low frequency NMR / NQR (upto about 5 MHz) using conventional Faraday detection technique has the disadvantage of very low sensitivity since the induced voltage in the detector scales as w^2/T. Hence, alternate detection techniques have been considered. Using Superconducing Quantum Interference Devices (SQUIDs) as a detector for NMR / NQR has emerged as the best alternative for the above, since SQUID can detect extremely small magnetic fields of the order of 10^{-15} Tesla along with the advantage that SQUID detects directly the magnetization rather than its rate of change as in the case of Faraday detection technique used in the conventional NMR / NQR.

The instrumentation aspects of using DC SQUIDs for NMR / NQR detection upto 200 kHz are discussed here. This includes the following: (a) Development of the necessary cryogenic experimental setup, (b) Magnetic shielding for SQUID, (c) Development of the electronic circuits for the Flux locked Loop (FLL), SET ZERO and RESET circuits etc. Using the above, NQR signals of nitrogen nuclei ^{14}N in NH_4ClO_4 has been observed at 4.2 K with a commercial DC SQUID.

Cryogenic Temperature Measurement And Data Acquisition For SST-1

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Special design, implementation and operational techniques of Data Acquisition system have been developed for low temperature measurement using resistance temperature detector type temperature sensors for the superconducting magnets and 80 K thermal shield of SST-1. Two different ways have been implemented for the helium temperature data acquisition on the basis of measurement location criticality. The real time data is also made available at dedicated computer through local area network using Network Dynamic Data Exchange protocol. The paper describes the accurate temperature measurement scheme with different components of temperature data acquisition of SST-1.

Development of compact low cost ppm level nitrogen detector at IUAC

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A low level (less than100ppm) impurity monitor for nitrogen in helium gas has been developed at IUAC. The essential feature of the detector is that mixture of helium and nitrogen gas is passed through an arc cell where plasma is created with the help of a high voltage DC source. The light output of a particular frequency is chosen (after the analysis of the whole arc spectrum) and the chosen light is filtered out with appropriate optical filter and converted to electrical signal by photodiode and high gain amplifier circuit. A gas mixture setup was also made to obtain gas for calibration purpose.

Instrumentation Setup for Current Lead Test at IPR

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A conventional type helium vapor cooled current leads have been designed, developed and tested at IPR. A complete instrumentation system is developed using programmable logic controller (PLC) and supervisory control and data acquisition (SCADA) system. The performance testing of current leads requires accurate measurement of parameters. PLC has been used for data acquisition and controls. The mimic pages for P&ID, auto-manual interface, trends and history trends, alarm pages using SCADA were developed for test. Necessary interlocks were implemented with Helium liquefier/refrigerator and power supply. This paper describes the design of instrumentation setup and control sequence of current lead operation.