

Advances in Cryogenic Engineering: Proceedings of the Cryogenic Engineering Conference (CEC 2021)

IOP Conference Series: Materials Science and Engineering
Volume 1240

Online
19 - 23 July 2021

Part 1 of 2

Editors:

**J.G. Weisend II
Jonathan Demko
Ram Dhuley
Michael DiPirro
Andrew May**

**Gregory Nellis
John Pfotenhauer
Seth Potratz
Al Zeller**

ISBN: 978-1-7138-5808-9
ISSN: 1757-8981

Printed from e-media with permission by:

Curran Associates, Inc.
57 Morehouse Lane
Red Hook, NY 12571



Some format issues inherent in the e-media version may also appear in this print version.

This work is licensed under a Creative Commons Attribution 3.0 International Licence.
Licence details: <http://creativecommons.org/licenses/by/3.0/>.

No changes have been made to the content of these proceedings. There may be changes to pagination and minor adjustments for aesthetics.

Printed with permission by Curran Associates, Inc. (2022)

For permission requests, please contact the Institute of Physics
at the address below.

Institute of Physics
Dirac House, Temple Back
Bristol BS1 6BE UK

Phone: 44 1 17 929 7481
Fax: 44 1 17 920 0979

techtracking@iop.org

Additional copies of this publication are available from:

Curran Associates, Inc.
57 Morehouse Lane
Red Hook, NY 12571 USA
Phone: 845-758-0400
Fax: 845-758-2633
Email: curran@proceedings.com
Web: www.proceedings.com

TABLE OF CONTENTS

PART 1

| | |
|--|----|
| Preface | |
| CEC Awards | |
| CEC Board of Directors | |
| CEC Technical Editors | |
| Acknowledgments | |
| Subject Index | |
| Author Index | |
| Peer Review Declaration | |
| Development of a Thermal Control Coating Optimized for Cryogenic Space Applications..... | 1 |
| <i>A Krenn, R Youngquist, T Gibson, S Snyder</i> | |
| Thrust Estimation for HTS-Magnet Based Magneto Plasma Dynamic Thrusters (MPDT) | 9 |
| <i>Lokesh Kumar Meena, A Anand, A S Gour</i> | |
| Liquid Nitrogen Removal of Lunar Regolith Simulant from Spacesuit Simulants | 17 |
| <i>I Wells, J Bussey, N Swets, L Reising, C Butikofer, G Wallace, S Kulsa, J Leachman</i> | |
| Improved Modelling of Magnetic Splitting in a Chrome Alum Below 300 mK | 25 |
| <i>C Gunderson, F Miller, T Chui, C Paine, T Prouve, W Holmes</i> | |
| Results of Use of Heat Flux Sensors on Liquid Hydrogen Tanks | 37 |
| <i>W L Johnson, R Balasubramaniam, R Hibbs</i> | |
| Development of a Space Irradiance Simulator for Advanced Studies and Materials Research..... | 45 |
| <i>A M Swanger, A Krenn, R Youngquist, T L Gibson</i> | |
| Experimental and Numerical Investigation of Self-Pressurization with Different Methods of Insulation for Ground and Space Applications..... | 53 |
| <i>S B Vishnu, T K Biju</i> | |
| Numerical Investigation of Two-Phase Fluid-Transient Induced Cavitation in the Cryogenic Propellant Feedlines | 61 |
| <i>A Garva, A Mishra, P Ghosh</i> | |
| Vapor Cooling of a Structural Skirt for a Large-Scale Hydrogen Tank | 69 |
| <i>W L Johnson, R Balasubramaniam, R Hibbs</i> | |
| Architectural Impacts of In-Situ Resource Utilization Production of Oxygen for Use as Propellant in a Mars Ascent Vehicle | 79 |
| <i>A Krenn, D Trent, G Sanders, S Hoffman, P Chai, E Hinterman</i> | |
| Development of a Surface Cryogenic Propellant Transfer Concept for Martian Operations | 87 |
| <i>J Congiardo, A Krenn, J Martinez, M Dupuis, A Swanger</i> | |

| | |
|---|-----|
| Three-Dimensional Fluid-Structural Interaction and Thermal Analysis of a Large Diameter Horizontal Cryogenic Transfer Line..... | 95 |
| <i>Kailash Lohar, Keerthi Raj Kunniyoor, K.S. Ventateshwaran, Parthasarathi Ghosh</i> | |
| Analysis of Heat Transfer from a Local Heat Source at Cryogenic Temperatures..... | 103 |
| <i>W L Johnson, R Balasubramaniam, R Grotenrath</i> | |
| Integrated Modular Design and Analysis of Liquid Propellant Rocket Engine Working on Liquid Methane-Oxygen Expander Cycle..... | 111 |
| <i>Rajkumar P Desai, Biju T Kuzhivel</i> | |
| The Effect of External Heat Inflow to the Cryogenic Liquid Pressurized Discharge Process..... | 119 |
| <i>Seungwhan Baek, Youngsuk Jung, Kiejoo Cho</i> | |
| Development of a 2~4 K Closed-Cycle JT Cryocooler for Space Application..... | 127 |
| <i>Xiaoshan Pan, Shaoshuai Liu, Yinong Wu, Zhenhua Jiang, Lei Ding</i> | |
| Performance Testing and Temperature Fluctuations of a 4.5 K@150 mW Joule-Thomson Closed Cycle Cryocooler for Space Applications | 134 |
| <i>Zhichao Chen, Shaoshuai Liu, Yinong Wu, Zhenhua Jiang, Lei Ding</i> | |
| An 880 mW@15 K Thermal Coupled Pulse Tube Cryocooler with Active Phase Shifter..... | 142 |
| <i>Wang Yin, Shaoshuai Liu, Yinong Wu, Zhenhua Jiang, Lei Ding, Jiantang Song</i> | |
| Parasitic Heat Load in a Miniature Pulse Tube Cooler | 149 |
| <i>D Dherbecourt, J M Duval, M Garcia, D Lopes, D Guichard, M B C Branco, T Prouvé</i> | |
| Random Vibration, Exported Vibration, and Passive Isolation Testing of the Ricor K508N Cryocooler..... | 157 |
| <i>L Anderson, J Mork, C Swenson, B Zwolinski, A J Mastropietro, J Sauder, I McKinley, M Mok</i> | |
| The Effect of Transfer Line Length and Heat Rejection Temperature Distribution on the Thales Linear Pulse Tube (LPT) Cryocoolers..... | 165 |
| <i>I M McKinley, C D Hummel, J I Rodriguez</i> | |
| Experimental Study on a Helium-4 Sorption Cryocooler..... | 173 |
| <i>Xiaotong Xi, Biao Yang, Zhaozhao Gao, Liubiao Chen, Yuan Zhou, Junjie Wang</i> | |
| Helium Gas-Gap Heat Switch for Sub-Kelvin Refrigeration System..... | 180 |
| <i>Xiaotong Xi, Biao Yang, Zhaozhao Gao, Liubiao Chen, Yuan Zhou, Junjie Wang</i> | |
| Numerical Analysis and Experimental Research of a 2W/35 K Stirling-Type Pulse Tube Cryocooler..... | 186 |
| <i>Z Z Gao, B Yang, L B Chen, J J Wang</i> | |
| A Thermal-Coupled/gas-Coupled Hybrid High-Frequency Pulse Tube Cryocooler Attaining the Liquid-Helium Temperature..... | 193 |
| <i>Biao Yang, Zhaozhao Gao, Xiaotong Xi, Liubiao Chen, Junjie Wang</i> | |
| Investigation on the Dynamic Adsorption Characteristics of Activated Carbon to Helium-4 for 4-20 K Regenerator of Cryocoolers | 199 |
| <i>Biao Yang, Xiaotong Xi, Zhaozhao Gao, Liubiao Chen, Junjie Wang</i> | |
| Development of Adiabatic Demagnetization Refrigerator for Future Astronomy Missions | 205 |
| <i>H. Jin, J. Shen, C. Z. Li, C. Wang, F. Q. Yu, H. Y. Zu, P. Liu, J. Ding, K. Li, Y. N. Wang, W. Dai, Y. Zhou, W. Cui</i> | |

| | |
|--|-----|
| Status and Development Trends of the Space 2 K Mechanical Cryocooler | 211 |
| <i>Z Y Liu, Y X Ma, J Quan, Y J Liu, J Wang, J G Li, J T Liang</i> | |
| Theoretical Comparison of the Thermo-Mechanical Fatigue Characteristics of a Tension Rod and Coil Used as Dewar Supports | 219 |
| <i>B Nitin, Parmit Singh Virdi, Pavitra Sandilya, Goutam Chakraborty</i> | |
| Analysis of the Factors Influencing the Precooling Process of Cryogenic Compressed Hydrogen Storage Tank..... | 226 |
| <i>M He, Q M Jia, C Lv, J H Wu, Y Zhang, W P Zhu, M M Zhang, L H Gong</i> | |
| Dynamic Modeling and Analysis of Bunkering and Pressurization for Marine LNG Fuel Tank..... | 234 |
| <i>Cheng Wang, Yonglin Ju</i> | |
| Numerical Study on Pressure Variation of Marine Liquefied Natural Gas (LNG) Fuel Tanks Under Sinusoidal Sloshing Excitation..... | 242 |
| <i>Sixian Wu, Yonglin Ju</i> | |
| Numerical Computation of Boil off Rate (BoR) in Shipboard LNG Tanks | 250 |
| <i>A K Eswara, P Sandilya</i> | |
| Experimental Investigation of Valve Driven Transient Effect in Liquid Nitrogen Pipeline..... | 260 |
| <i>R G Bhuvana, Abhay Singh Gour, Parthasarathi Ghosh</i> | |
| Thermodynamic Analysis of Ideal Thermocompressor Based on Euler View..... | 268 |
| <i>S S Wu, J Wang, H C Zhang, C J Huang, L F Li, Y Zhou</i> | |
| Analysis of Radiation Energy Between Light Source, Optical Window and Cryogenic Sample | 276 |
| <i>S S Wu, J Wang, H C Zhang, F Z Shen, C J Huang, L F Li, Y Zhou</i> | |
| A Novel System for Measuring Effectiveness of Magnetic Shields in a Liquid Helium Dewar with a Fluxgate Magnetometer | 283 |
| <i>L Wei, G Wang, G Hong, L Wang, J Quan</i> | |
| Design of a Cryogenic Two-Phase Flow Visualization System for Cryogenic Pulsating Heat Pipe..... | 289 |
| <i>Bingkun Lyu, Dong Xu, Arata Nishimura, Laifeng Li</i> | |
| Analysis of Pump Tube and Orifice for a 4He sub-Kelvin Sorption Cooler | 297 |
| <i>Y L Lei, Y N Zhao, J Quan, G T Hong</i> | |
| Simulation and Experimental Research on the Thermal Resistance of Cernox Sensors in Different Bonding Ways Based on a High-Precision Cryogenic Temperature Measuring System | 304 |
| <i>H L Qin, G Zhou, Q Li</i> | |
| Visualization Study of a Cryostat with a Large Diameter Flow Channel for Flowing High-Pressure Cryogenic Fluid | 312 |
| <i>S Y Xie, Z Z Zhang, D Xu, B K Lyu, L F Li</i> | |
| An Innovative Approach for the Design of Cryogenic Electrical and Process Control Systems at CERN: The Cryogenic Continuous Integration Project..... | 318 |
| <i>T Barbe, M Pezzetti, S Martin, A Tovar-Gonzalez, C Fluder</i> | |
| Beam Induced Heat Load Instrumentation Installed in LHC During the Long Shutdown 2 | 325 |
| <i>B Bradu, K Brodzinski, J Casas-Cubillo, D Delikaris, J B Deschamps, S Le Naour, M Pezzetti, L Tavian, A Tovar, M Sisti, J Ph Tock, N Vauthier</i> | |

| | |
|---|-----|
| Study on Reducing the Impact to EAST Cryogenic System Caused by the Failure of Load Devices | 333 |
| <i>Q Yu, X F Lu, Z W Zhou, M Zhuang, Q Y Zhang</i> | |
| Liquid Helium Level Regulation Improvement in the LHC Electrical Distribution Feedboxes | 341 |
| <i>B Bradu, H Coppier, J Gery, M Pezzetti, A Tovar</i> | |
| Small Scale Time Projection Chamber Setup to Test the Purity of Liquid Krypton from the NA62 Experiment at CERN..... | 348 |
| <i>J Liberadzka-Porret, T Koettig, D Santandrea, R Kriboo, B Velghe, D Bryman, V Falaleev, H Danielsson, J Bremer</i> | |
| In-Flow Measurement of the Composition of a Binary Gas Mixture | 356 |
| <i>A.H. Tolboom, C.H. Vermeer, H.J. Holland, H.J.M. ter Brake</i> | |
| Drawn-Polymer Recuperative Heat Exchangers for Use in Cryocoolers | 364 |
| <i>J L Adams, K J Thompson, J Cummings, L Cantley, J G Brisson</i> | |
| Remote Cooling Systems with Mesh-Based Heat Exchangers for Cryogenic Applications | 372 |
| <i>A Onufrena, B Naydenov, T Koettig, J Bremer, T Tirolien, H J M ter Brake</i> | |
| A Research on Silver Powder Sinters for Dilution Refrigerator Heat Exchangers..... | 380 |
| <i>Z J Pan, L J Wei, M W Zheng, J T Liang, M G Zhao, Y J Liu</i> | |
| Design and Performance Analysis of the Thrust Gas Bearing with Single Orifice for Helium Turbine | 387 |
| <i>S S Li, B Fu, Q Y Zhang, S X Chen</i> | |
| Design of Cryogenic Test Platform for the Seal Structure in Superfluid Helium Temperature | 392 |
| <i>Z Li, Z Zhou, Q Zhang, G Wang, J Huang</i> | |
| Experimental Study of Different Structural Parameters on Gas Lubricated Spiral Groove Thrust Bearing for Cryogenic Turbo Expander | 400 |
| <i>X H Zhang, K R Li, H Yan, L W Zheng, C L Ke, B Dong, N Peng, L Q Liu, L H Gong</i> | |
| Effect of Trailing Edge Bending and Sweeping on Brake Impeller of Low-Temperature Turbo-Expander..... | 408 |
| <i>Y W Liang, N Peng, K R Li, C L Ke, J Li, B Dong, H Yan, X H Zhang, L W Zheng, L Y Xiong, L Q Liu</i> | |
| Design and Analysis of 5 kW Helium Turbine for EAST Cryoplant | 415 |
| <i>S X Chen, Q Y Zhang, B Fu, S S Li, C F Fan, C J Zhang, Y W Zong</i> | |
| Performance Study of Preloaded Cryogenic Bearings in Liquid Hydrogen Pump..... | 423 |
| <i>H Su, C Lv, J Shang, B H Huang, Y Feng, J H Wu</i> | |
| Analysis of the Effect of Friction of Hybrid Ball Bearings on Grease Evaporation in Cold Compressors | 431 |
| <i>H Su, J Shang, C Lv, J H Wu</i> | |
| Experimental Research on Performance of an Oil-Free Moving-Coil Symmetrical Dual-Piston Linear Compressor for the J - T Throttle Refrigerator | 439 |
| <i>Y L Liu, J Sun, Y Q Xun, H L Chen, Z J Huang, J H Cai, G T Hong</i> | |
| Mathematic Prediction and Experimental Research of Gas Thrust Bearing for High-Speed Turbo-Expander Involving Hydrogen, Helium, Nitrogen and Air Working Fluids | 447 |
| <i>H Yan, X H Zhang, N Peng, L W Zheng, C L Ke, K R Li, Y W Liang, L Y Xiong, B Dong, J Li, I Q Liu</i> | |

| | |
|---|-----|
| Research on the Thermal Performance of a Heat Exchanger with Meso-Scale Twisted Helical Tube Bundles..... | 455 |
| <i>Y N Wang, J M Pfotenhauer, F K Miller</i> | |
| Stability Analysis on Gas-Lubricated Bearing for High Speed Cryogenic Turbo-Expander | 462 |
| <i>L W Zheng, X H Zhang, N Peng, H Yan, C L Ke, K R Li, Y W Liang, L Y Xiong, B Dong, J Li, I Q Liu</i> | |
| A Preliminary Study of 4He Convective Heat Switches | 470 |
| <i>F Q Yu, J Shen, A H Zou, K Li, C Wang, W Dai</i> | |
| Design of Cryogenic Heat Exchangers and Associated Sub-Systems for Controlled Cool-Down and Testing of Superconducting Magnets at FRIB | 476 |
| <i>N. Hasan, V. Ganni, A. Fila, F. Casagrande</i> | |
| Entropy Optimization of an Additively Manufactured Heat Exchanger with a Dual Stage Gifford-McMahon Cryogenic Refrigerator for Hydrogen Liquefaction..... | 484 |
| <i>J Raymond, C Bunge, L Pesek, J Leachman</i> | |
| Analysis of Oxygen Liquefaction with Transient Flow Rates for ISRU Systems | 493 |
| <i>R. Grotenrath, A. Kashani, D. Hauser, W.L. Johnson</i> | |
| Status of the PIP-II Cryoplant | 501 |
| <i>Y. Jia, B. Hansen, J. Creus Prats, O. Atassi, A. Klebaner, A. Chakravarty, M. Goyal, J. Kumar</i> | |
| Testing and Analysis of Stand-By Operating Modes for FRIB Helium Refrigeration System | 507 |
| <i>D Kroll, J Howard, P Knudsen, N Hasan, V Ganni</i> | |
| Preliminary Design of a Helium Cryogenic System for SAND Detector at LBNF-DUNE Near Site | 515 |
| <i>L Wang, D Montanari, J Creus-Prats, A Lawrence, G Cline, M Delaney, M Adamowski, M Leitner, F Maticichard</i> | |
| Commissioning of a Replacement Subatmospheric Cold Box for Jefferson Lab's Central Helium Liquefier | 523 |
| <i>B Mastracci, S Yang, J Creel, K Dixon, R Norton, S Thompson, J Wieliczko, T Wijeratne</i> | |
| Reconstruction and Operation of the Helium Purification System in the Cryogenic System for EAST Tokamak | 531 |
| <i>Z W Zhou, Q Y Zhang, P Zhu, K P Wu, Z G Zhu, L H Sheng, K Yuan</i> | |
| Dynamic Simulation of the Target Moderator Cryoplant and Cryogenic Transfer Line at the European Spallation Source | 539 |
| <i>Y Chao, J G Weisend, P Arnold, Z Gan</i> | |
| Process Analysis and Control Flow Design of the 1kW @ 4.5K Helium Refrigerator for NNBI..... | 547 |
| <i>J Q Li, Z W Zhou, Q Y Zhang, Z G Zhu</i> | |
| Large-Scale 20K Helium Refrigeration System for the European Spallation Source | 555 |
| <i>P Arnold, J Zhang, N Kolev, M Ressel</i> | |
| CFD Modelling of a Helium Cryogenic Pulsating Heat Pipe..... | 563 |
| <i>C Xu, J Pfotenhauer, F Miller</i> | |
| The Design of an Extended Length Helium Pulsating Heat Pipe Experiment | 570 |
| <i>L Kossel, J Pfotenhauer, F Miller</i> | |

| | |
|--|-----|
| Experimental Investigation of Vertical Neon Pulsating Heat Pipe for Superconducting Magnet Cooling Application | 576 |
| <i>T Dixit, G Autelet, C Mailleret, F Gouit, B Baudouy</i> | |

| | |
|---|-----|
| Design, Construction, and Commissioning of a Deployable Liquid Hydrogen Production and Fueling System for Unmanned Aerial Systems | 582 |
|---|-----|

I Richardson, J Raymond, D Boettner, G Saelid, Y Gitter, L Harfst, S Dimmer, J Kurtz, J Coleman, A Mei, H Gardner, J Leachman

PART 2

| | |
|--|-----|
| An Upgraded Cryogenic Test Stand for HL-LHC Cryo-Assemblies | 591 |
| <i>R Rabehl, O Al Atassi, G Chlachidze, S Feher, S Koshelev, S Ranpariya</i> | |

| | |
|---|-----|
| Commissioning and Cryogenic Performance of the UKRI STFC Daresbury Vertical Test Facility for Jacketed SRF Cavities | 598 |
|---|-----|

A J May, S Pattalwar, D Mason, K Middleman, M D Pendleton, P A Smith, S Wilde, A Akintola, A Bainbridge, R Buckley, G Collier, P Corlett, K Dumbell, M Ellis, M Hancock, J Hathaway, S Hitchen, C Hodgkinson, P Hornickel, G Hughes, C Jenkins, G Jones, M Lowe, P McIntosh, G Miller, J Mutch, A Moss, A Oates, N Pattalwar, P Sollars, A E Wheelhouse, A A J White, J Wilson

| | |
|---|-----|
| Cryogenic Accelerated Fatigue Tester for Additive Manufactured Polymer Composite Mechanical Property Measurement..... | 606 |
|---|-----|

R Adams, M Hunt, J Leachman

| | |
|---|-----|
| Design of the Cryostat for High Field Vertical Magnet Testing Facility at Fermilab | 614 |
| <i>S Koshelev, T Tope, J Theilacker, V Nikolic, G Velev, E Voirin, A J Marone, P E Kovach</i> | |

| | |
|--|-----|
| Cryogenic System Upgrade of Fermilab's IB1 Test Facility - Phase I..... | 620 |
| <i>B J Hansen, O Al Atassi, R Wang, J Dong, B Soyars, D Richardson, J Theilacker</i> | |

| | |
|---|-----|
| Design, Fabrication, and Installation of the Cryogenic Distribution System for FRIB Target and Fragment Pre-Separator Superconducting Magnets | 627 |
| <i>N Hasan, M Wright, V Ganni, F Casagrande, S Jones, C Nguyen, A Fila, N Joseph</i> | |

| | |
|--|-----|
| Status of LBNF/DUNE Near Site Liquid Argon Proximity and External Cryogenics Systems Development | 635 |
| <i>J Creus Prats, D Montanari, M Adamowski, G Cline, F Matichard, M Delaney, A Lawrence</i> | |

| | |
|---|-----|
| Overview and Status of the Long-Baseline Neutrino Facility Far Site Cryogenics System..... | 641 |
| <i>D Montanari, M Adamowski, J Bremer, M Delaney, R Doubnik, J Freitag, K Haaf, T Nichols, A Parchet, I Young</i> | |

| | |
|---|-----|
| Conceptual Design of DALS Test Facility Cryogenic System..... | 649 |
| <i>Z Sun, L Huang, X Shi, XL Wang</i> | |

| | |
|--|-----|
| Fabrication and Installation of the Mu2e Cryogenic Distribution System | 657 |
| <i>M White, M Lamm, A Hocker, D Arnold, G Tatkowski, J Kilmer, V Poloubotko, T Tope, Y Huang, L Elementi, K Badgley, E Voirin, I Young, J Brandt, S Feher, C Hess, D Markley</i> | |

| | |
|---|-----|
| Energy Efficient Large-Scale Storage of Liquid Hydrogen | 665 |
| <i>J Fesmire, A Swanger, J Jacobson, W Notardonato</i> | |

| | |
|---|-----|
| Introduction of the Liquid Nitrogen Transfer Line for TPS Beamline Endstation | 673 |
| <i>W R Liao, H C Li, P S Chuang, H H Tsai, F Z Hsiao, W S Chiou, S H Chang, D G Liu</i> | |

| | |
|--|-----|
| Design and Analysis of the Helium Purification System for the NSRRC Cryogenic System | 681 |
| <i>P S Chuang, H H Tsai, H W Chiang, F Z Hsiao, W R Liao, H C Li, W S Chiou, S H Chang, P J Wang</i> | |
| Experiment and Optimization of a Large Scale Xenon/krypton Cryogenic Distillation System..... | 688 |
| <i>W Zhou, J Yonglin, C Xiangyi, J Xiangdong, L Jianglai</i> | |
| Conceptual Design of S3FEL Cryogenic System..... | 696 |
| <i>L B Hu, X L Wang, L Yang, B H Lai, X B Dong, G L Cui, Z Sun</i> | |
| Functional Analysis and Design of the Cryogenic System for the HL-LHC it String Test Bench at CERN | 703 |
| <i>G Rolando, M Sisti, O Duran Lucas, A Wanninger, J Mouleyre, A Perin</i> | |
| Design Aspects of the Feed Boxes of the Super-FRS Local Cryogenics System..... | 711 |
| <i>J Polinski, D Chadaj, M Chorowski, A Iluk, H Kollmus, L Pachnik, H Simon, F Wamers, M Winkler, Y Xiang</i> | |
| Conceptual Layout of a Helium Cooling System for the Einstein Telescope..... | 719 |
| <i>L Busch, S Grohmann</i> | |
| SNS Carbon Bed Research Project Design, Commissioning, and Initial Results | 727 |
| <i>B DeGraff, D Barnhart, S Gold, M Howell, S Kim, D Kraft, C McMahan, L Moore, T Neustadt, D J Vandygriff, D M Vandygriff</i> | |
| Sub-Atmospheric Re-Pressurization Analysis of FRIB Linac Segment 2 Cryogenic Distribution System | 733 |
| <i>J Howard, P Knudsen, N Hasan, V Ganni</i> | |
| Development of a Volatile Organic Compounds Cryogenic Condensation Recovery System Cooled by Liquid Nitrogen | 740 |
| <i>Hao Xu, Xiaotong Xi, Xiafan Xu, Jia Guo, Liubiao Chen, Wei Ji, Junjie Wang</i> | |
| Maintenance of the 1st NBI Vacuum System for the KSTAR Tokamak | 748 |
| <i>Young Ju Lee, Hyun Taek Park, Jong Su Kim, Jong Gu Kwak</i> | |
| Proton Improvement Plan II Cryogenic Distribution System Thermodynamic Design | 755 |
| <i>Ashish Kumar Shukla, Andrew Dalesandro, Ram Dhuley, William Soyars</i> | |
| Thermohydraulic Simulation of Quenches and Quench Recovery for the HL-LHC it String Test Bench at CERN | 761 |
| <i>G Rolando, A Wanninger, A Perin</i> | |
| Conceptual Design of Cryostat for Cryo-Cooled 37 Elements Phased Array Radar System for Space Surveillance..... | 769 |
| <i>A. Froehlich, H. Barbri, N. Ben Bekhti-Winkel, O. Grenz, F. Koenig, L. Naumann, S. Putselyk, M. Schneider, M. Tiesing, T. Wirths</i> | |
| Cryogenic Test Bench for the Experimental Investigation of Cryogenic Injection in Rocket Combusters Under High-Altitude Conditions | 777 |
| <i>Andreas Rees, Michael Oschwald</i> | |
| A Comparative Study of Two Liquid Air Energy Storage Systems with LNG Cold Energy Recovery..... | 785 |
| <i>W Ji, J Hu, L Guo, Z Gao, X Fan, L Chen, J Wang</i> | |

| | |
|---|-----|
| Study on the Selection Method of Solid Cold Energy Storage Medium for Liquid Air Energy Storage..... | 792 |
| <i>Luna Guo, Wei Ji, Zhaozhao Gao, Xiaoyu Fan, Jianying Hu, Liubiao Chen, Junjie Wang</i> | |
| Thermodynamic Analysis of the Non-Ideal Cryogenic Packed Bed Regenerator for the Liquid Air Energy Storage System..... | 800 |
| <i>L Guo, W Ji, Z Gao, X Fan, J Hu, L Chen, J Wang</i> | |
| Technical and Economic Evaluation of a Liquid Air Energy Storage System with Air Precooling for Compressor Inlet..... | 806 |
| <i>Z Gao, J Hu, W Ji, L Guo, X Fan, J Guo, L Chen, J Wang</i> | |
| Thermodynamic Analysis of a Liquid Air Energy Storage System with Off-Peak Electric Heat Storage and Reutilization | 814 |
| <i>X Fan, J Hu, W Ji, L Guo, Z Gao, J Guo, L Chen, J Wang</i> | |
| Preliminary Structural Design and Analysis of the Horizontal Cold Box for CFETR 25 kW@4.5 K Helium Refrigerator..... | 821 |
| <i>C J Zhang, Q Y Zhang, Z G Zhu, D M Yao, P C Yang, Y W Zong, S X Chen</i> | |
| Preliminary Analysis and Design of 4kW@4.5K Helium Refrigerator for CFETR Toroidal Field Magnet Test Facility..... | 827 |
| <i>X F Lu, Q Y Zhang, Z W Zhou, A Y Chen, P Zhu, S S Li</i> | |
| Dynamic Simulation of the Cool Down Process of Double-Pressure Helium Liquefaction Cycle..... | 832 |
| <i>H K Su, Z Y Li, L H Gong, W P Zhu, M M Zhang, Q M Jia</i> | |
| LCLS-II Warm Helium Compressor Commissioning | 838 |
| <i>V Ravindranath, A Apte, E Fauve, V Heloin, D Pflueckhahn, T Peterson, D Robinson, S Shririmal, D Arenius, R Bhattacharya, M Bevins, J Creel, J Hogan, R Norton</i> | |
| LCLS-II Helium Cryoplant and Cryo Distribution System Installation | 846 |
| <i>D Pflueckhahn, E Fauve, V Heloin, S Kaminski, T Peterson, J Pucci, V Ravindranath, J Sevilla, A Dalesandro², A Klebaner, A Martinez, W Soyars², D Arenius, M Bevins, J Hogan</i> | |
| Static and Dynamic Characteristics of Externally Pressurized Gas Bearing for High-Speed Hydrogen Turbo-Expander..... | 854 |
| <i>H Yan, C L Ke, N Peng, K R Li, X H Zhang, L W Zheng, Y W Liang, L Y Xiong, B Dong, J Li, I Q Liu</i> | |
| Failure Analysis of Leaks Due to Cracks in Hydrogen Transfer Lines of ESS Cryogenic Moderator..... | 862 |
| <i>H Tatsumoto, D Lyngh, P Arnold, M Segerup, P Tereszkowski, Y Beßler</i> | |
| Design of a Hydrogen Vent Line for ESS Cryogenic Moderator System | 870 |
| <i>H Tatsumoto, D Lyngh, P Arnold, M Segerup, P Tereszkowski, Y Beßler</i> | |
| Design of an In-Situ Measurement System for Ortho and Para Liquid Hydrogen Fractions at ESS | 878 |
| <i>H Tatsumoto, D Lyngh, Y Lee, M Hartl, H Sina, P Arnold, Y Beßler, H Kobayashi, Y Sakamoto, T Hasegawa</i> | |
| Operational Experience with the Proto-DUNE NP02 and NP04 Large Volume Liquid Argon Cryostats and Their Cryogenic Systems at CERN | 886 |
| <i>J. Bremer, M. Chalifour, J. Creus-Prats, C. Fabre, D. Montanari, M. Pezzetti, F. Resnati, M. Nessi</i> | |
| Automatic LHC Accelerator Warm-Up and Cool-Down Experience During the Long Shutdown 2 | 894 |
| <i>B Bradu, K Brodzinski, G Ferlin, M Pezzetti, A Tovar</i> | |

| | |
|---|------|
| Cryogenic Performances of a Heat Exchanger Prototype Suitable for the Superconducting HL-LHC Recombination Dipole D2 | 901 |
| <i>B Rousset, F Bancel, N Besson, M Bon-Mardion, S Claudet, T Goy, F Millet, P Nivelon, A Perin</i> | |
| Assessment of the Operation Safety Margin of the HL-LHC Superconducting Recombination Dipole D2 in Case of Helium Filling Failure | 908 |
| <i>B Rousset, F Bancel, N Besson, M Bon-Mardion, S Claudet, T Goy, F Millet, P Nivelon, A Perin</i> | |
| 43+T Grenoble Hybrid Magnet: Commissioning Tests of the Current Leads and Cryogenic Satellite Producing the Pressurized Superfluid He at 1.8 K | 916 |
| <i>P Pugnat, R Barbier, C Berriaud, T Boujet, P Graffin, C Grandclément, B Hervieu, J Jousset, F P Juster, F Molinié, M Pelloux, R Pfister, L Ronayette, E Yildiz</i> | |
| Heat Loads Measurements at the XFEL Cold Linac | 924 |
| <i>R Ramalingam, Y Bozhko, S Barbanotti, T Schnautz</i> | |
| Advanced Exergy Analysis of Reverse Brayton Cryocooler for 10 kW Cooling Capacity at 65 K | 932 |
| <i>Aman Kumar Dhillon, Parthasarathi Ghosh</i> | |
| The Development Status of Sunpower DS 10 Cryocooler | 940 |
| <i>Yongsu Kim, Josh Collins</i> | |
| The GTLT Cryocooler, a Low Temperature Variant of CryoTel® GT | 945 |
| <i>Yongsu Kim, Doug Mansfield</i> | |
| Requirement of the On/off Ratio of Superconducting Heat Switch Used for the Continuous Stage of cADR..... | 950 |
| <i>Ping Liu, Ke Li, Chang Wang, Fangqiu Yu, Jun Shen, Wei Dai</i> | |
| Thermodynamic Process and Analysis of Dilution Refrigerator | 957 |
| <i>M W Zheng, L J Wei, Z J Pan, J T Liang, M G Zhao, P Lin</i> | |
| Characteristics of Reciprocating Speed of a Low Power Consumption 4 K G-M Cryocooler | 965 |
| <i>S Masuyama, K Kamiya, T Numazawa</i> | |
| Comprehensive Optimization Design of Low Temperature Insulation System of Regeneration Cryocooler | 970 |
| <i>Z K Wang, L F Li, Y Zhou</i> | |
| Optimal Absorption of Distributed and Conductive Heat Loads with Cryocooler Regenerators | 976 |
| <i>Ryan Snodgrass, Joel Ullom, Scott Backhaus</i> | |
| Investigation of Regenerator Mesh Characteristics for a Pulse Tube Cryocooler | 988 |
| <i>Derick Abraham, Biju T Kuzhiveli</i> | |
| Application of Stirling Pulse Tube Cryocoolers in High Temperature Superconducting Filters Subsystems | 996 |
| <i>Y B Duan, J Wang, S S Wu, W Wang, R J Huang, L F Li, Y Zhou</i> | |
| Development of a 20K Two-Stage Stirling Type Pulse Tube Cryocooler with Pre-Cooling Inside Second-Stage Pulse Tube | 1004 |
| <i>Z. W. Li, X. T. Wang, Y. N. Wang, W. Dai</i> | |
| Numerical Simulation of Three-Stage Gas Coupled Pulse Tube Refrigerator | 1012 |
| <i>Chushu Fang, Yanbo Duan, Zekun Wang, Hongyu Dong, Laifeng Li, Yuan Zhou</i> | |

| | |
|---|------|
| Final Design of the Cryostat for the High Luminosity LHC Magnets..... | 1019 |
| <i>D Ramos, A Vande Craen, H Prin, Y Leclercq, L Williams, M Struik, G Barlow, O Rio Martinez, B Wong Luis, V Parma, F Savary, E Todesco</i> | |
| 50 kJ SMES Magnet Design Optimization Using Real Coded Genetic Algorithm..... | 1028 |
| <i>A Anand, A S Gour, T S Datta, V V Rao</i> | |
| Comparative Study on HTS Magnet Coil Design Approach for 1.0 T @ 65 K with 10 Ppm Field Homogeneity at 80 Mm DSV | 1036 |
| <i>S K Chand, A S Gour, T S Datta</i> | |
| Methods of Speeding Up the Cool-Down of Superconducting Magnets that Are Cooled Using Small Coolers at Temperatures Below 30 K | 1044 |
| <i>Michael A Green</i> | |
| Short Review on Cryostats with Superconducting Magnets..... | 1052 |
| <i>S Putselyk</i> | |
| Cryogenic System Design and Performance Test of Calibration Magnet | 1060 |
| <i>H Zhao, H S Feng, R Hu</i> | |
| A Cryostat for a 6 T Conduction-Cooled, No-Insulation Multi-Pancake HTS Solenoid | 1068 |
| <i>J Barkas, Y Zhai, M Safabakhsh</i> | |
| Numerical Analysis of Delamination Degradation of Epoxy-Impregnated Superconducting Coils Wound with REBCO Tapes Caused by Thermal Stress..... | 1076 |
| <i>M Ohya</i> | |
| Effect Analyses of Thermal Deformation on Magnetic Performance of the CPMU Prototype in SSRF..... | 1084 |
| <i>Jian Wang, Li Wang, Yiyong Liu, Wei Zhang</i> | |
| Feasibility Study of Capacitance Based Quench Detection Technique for HTS Power Transmission Cables | 1090 |
| <i>Harris K. Hassan, Pankaj Sagar, Abhay Singh Gour, V. V Rao</i> | |
| Cryogenic Design of the Crab Cavity Modules for the High Luminosity LHC at CERN..... | 1098 |
| <i>K Brodzinski, O Capatina, T Capelli, S Claudet, L Delprat</i> | |
| Development of a Cryocooler Conduction-Cooled 650 MHz SRF Cavity Operating at ~10 MV/m Cw Accelerating Gradient | 1105 |
| <i>R.C. Dhuley, S. Posen, M.I. Geelhoed, J.C.T. Thangaraj</i> | |
| Cryogenic Testing of a 25 kV RIS Bushing | 1114 |
| <i>Stefan Fink, Uwe Fuhrmann, Volker Zwecker</i> | |
| Improvement of Magnet and Cavities Cooling at Heavy Ion Or Rare Isotopes Accelerators Due to Application of Sub-Cooled Superfluid Helium | 1121 |
| <i>S Putselyk</i> | |
| Design of Injectors and Stay-Alone Cryostats with Superconducting Cavities for High RF Powers Applications..... | 1126 |
| <i>S Putselyk</i> | |

| | |
|--|------|
| Low Level RF Development for ESS High Beta Cavity Test | 1133 |
| <i>K Dumbell, J Lewis, A Wheelhouse, S Pattalwar, A Moss, P Corlett, P Goudket, S Hitchen, C Jenkins, M Ellis, M Pendleton, P Smith, A May, S Wilde, A Oates, K Middleman, J Wilson, M Lowe, D Mason, P Sollars, N Pattalwar, P Hornickel, J Mutch</i> | |
| A Review on Liquid Hydrogen Pool-Boiling Correlations | 1141 |
| <i>M Shenton, J Leachman</i> | |
| Experimental Study on the Pool Boiling Heat Transfer of Slush Nitrogen Under Triple Point to Atmospheric Pressure..... | 1149 |
| <i>Q D Wang, Q K Jiang, T Jin</i> | |
| Two-Phase Pressure Drop Study for Cryosurgical Probes Using One-Dimensional Homogeneous Model | 1156 |
| <i>Anish Gunjal, Milind D. Atrey, Atul Srivastava</i> | |
| Flow of Neon-Nitrogen-Hydrocarbon Mixture Through Adiabatic Capillary Tube at Cryogenic Temperatures | 1164 |
| <i>Darshit Parmar, M. D. Atrey</i> | |
| Numerical Simulation of Sinusoidal Corrugated Fins and Serrated Fins Performance at Low Temperature..... | 1172 |
| <i>Z G Zhu, H Wang, Q Y Zhang, Z Y Zou</i> | |
| Heat and Mass Transfer During Levitation of a Liquid Nitrogen Leidenfrost Droplet on a Water Pool..... | 1179 |
| <i>Z Zhang, RMA Spijkers, M Schremb, S Vanapalli</i> | |
| Numerical Study on the Flow and Heat Transfer Characteristics of Natural Convection in CFETR Cryostat | 1187 |
| <i>J H Huang, J J Wei, S M Liu, J Ge, Y T Song, T Jin</i> | |
| Vapor-Liquid Equilibrium of the Nitrogen-Argon System at 100 K..... | 1194 |
| <i>J Tamson, M Mair, S Grohmann</i> | |

Author Index