

**Proceedings of ASME Turbo  
Expo 2024: Turbomachinery  
Technical Conference and  
Exposition**

**(GT2024)**

**Volume 11**

**June 24-28, 2024  
London, United Kingdom**

**Conference Sponsor  
International Gas  
Turbine Institute**

**THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS**

© 2024, The American Society of Mechanical Engineers, 150 Clove Road, Little Falls, NJ 07424, USA  
(www.asme.org)

All rights reserved. “ASME” and the above ASME symbols are registered trademarks of the American Society of Mechanical Engineers. No part of this document may be copied, modified, distributed, published, displayed, or otherwise reproduced in any form or by any means, electronic, digital, or mechanical, now known or hereafter invented, without the express written permission of ASME. No works derived from this document or any content therein may be created without the express written permission of ASME. Using this document or any content therein to train, create, or improve any artificial intelligence and/or machine learning platform, system, application, model, or algorithm is strictly prohibited.

INFORMATION CONTAINED IN THIS WORK HAS BEEN OBTAINED BY THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS FROM SOURCES BELIEVED TO BE RELIABLE. HOWEVER, NEITHER ASME NOR ITS AUTHORS OR EDITORS GUARANTEE THE ACCURACY OR COMPLETENESS OF ANY INFORMATION PUBLISHED IN THIS WORK. NEITHER ASME NOR ITS AUTHORS AND EDITORS SHALL BE RESPONSIBLE FOR ANY ERRORS, OMISSIONS, OR DAMAGES ARISING OUT OF THE USE OF THIS INFORMATION. THE WORK IS PUBLISHED WITH THE UNDERSTANDING THAT ASME AND ITS AUTHORS AND EDITORS ARE SUPPLYING INFORMATION BUT ARE NOT ATTEMPTING TO RENDER ENGINEERING OR OTHER PROFESSIONAL SERVICES. IF SUCH ENGINEERING OR PROFESSIONAL SERVICES ARE REQUIRED, THE ASSISTANCE OF AN APPROPRIATE PROFESSIONAL SHOULD BE SOUGHT.

ASME shall not be responsible for statements or opinions advanced in papers or . . . printed in its publications (B7.1.3).  
Statement from the Bylaws.

For authorization to photocopy material for internal or personal use under those circumstances not falling within the fair use provisions of the Copyright Act, contact the Copyright Clearance Center (CCC), 222 Rosewood Drive, Danvers, MA 01923, tel:978-750-8400, www.copyright.com.

Requests for special permission or bulk reproduction should be addressed to the ASME Publishing Department, or submitted online at: <https://www.asme.org/publications-submissions/journals/information-for-authors/journalguidelines/rights-and-permissions>

ISBN: 978-0-7918-8804-9

## TABLE OF CONTENTS

Performance Evaluation of a Direct Air-Cooled Supercritical Recompression Brayton Cycle Using CO <sub>2</sub> /n-Butane As the Working Fluid Operating Under Off-Design Conditions .....	1
<i>Xurong Wang, Longwei Zhang, Jianhui Qi, Xiaowei Fan, Yiping Dai</i>	
Supercritical Carbon Dioxide Mixing Loss Characteristics Near the Critical Point.....	10
<i>Jinhong Wang, Teng Cao, Ricardo Martinez-Botas</i>	
Investigation of SPS Tungsten-Lithium Heat Pipe for Primary Heat Exchanger Applications .....	23
<i>Abhilash M. Prasad, Elena Torres, Nandhini Raju, Marcel Otto, Ladislav Vesely, Erik Fernandez, Zachariah Koyn, Jayanta Kapat</i>	
The sCO <sub>2</sub> Facility CARBOSOLA: Design, Purpose and Use for Investigating Geological Energy Storage Cycles.....	33
<i>Sebastian Unger, Stefan Fogel, Peter Schutz, Ricardo Chacartegui Ramirez, Andres Carro, Julio Carneiro, Uwe Hampel</i>	
Blade Designs for Improved Multi-Phase Performance in sCO <sub>2</sub> Compressors: Part I - Design and Numerical Evaluation at Application Relevant Conditions .....	42
<i>Ashvin Hosangadi, Timothy Weathers, Antonio Cepero, Paul Cooper, Erik Fernandez, Jayanta Kapat</i>	
Micro-PIV Investigation of Near-Critical and Liquid CO <sub>2</sub> Conditions Inside a T-Channel Setup .....	51
<i>Ritesh Ghorpade, Gihun Kim, Soroush Niazi, Yoav Peles, Subith Vasu</i>	
Experimental Investigation of Rotor Passage Loss in S-CO <sub>2</sub> Radial Turbine.....	59
<i>Seungkyu Lee, Jeong Ik Lee, Gihyeon Kim, Jeong Yeol Baek</i>	
Integration a Rotary Pressure Exchanger in Transcritical CO <sub>2</sub> Refrigeration System: Modeling and Annual Energy Saving Estimation.....	68
<i>Neelesh Sarawate, Arnav Deshmukh, Azam Thatte</i>	
Techno-Economic Analysis and Optimal sCO <sub>2</sub> Power Cycle Configuration for Novel CSP Plants Adopting Tubular Fluidized Particles Central Receivers.....	78
<i>Dario Alfani, Filip Sobic, Marco Astolfi, Marco Binotti, Paolo Silva</i>	
Numerical Investigation of the Axial Thrust Load of a Prototype Radial Turbine for Supercritical CO <sub>2</sub> Cycles.....	89
<i>Benedikt Lea, Francesca di Mare, Holger Franz</i>	
Performance of sCO <sub>2</sub> Cycles for Waste Heat Recovery and Techno-Economic Perspective As Gas Turbine Bottoming Cycle .....	99
<i>Vincent Thielens, Frederiek Demeyer, Ward De Paepe</i>	
Numerical Method for Investigating Non-Ideal Flow Demonstrated on a Centrifugal Compressor Operating Near the Critical Point of CO <sub>2</sub> .....	114
<i>Katharina Tegethoff, Carolina Borges de Almeida, Sebastian Schuster, Dieter Brillert</i>	
Compressor Development for CO <sub>2</sub> -Based Pumped Thermal Energy Storage (PTES) Systems .....	124
<i>Timothy J. Held, Jason Miller, Kyle Sedlacko, Joshua Cameron, Scott Morris, Jeongseek Kang, Mark Turner</i>	

Simultaneous Design Optimization of Binary CO <sub>2</sub> -Mixture-Based Power Cycles for Concentrated Solar Power Applications .....	134
<i>Balkan Mutlu, Kumar Patchigolla, Dhinesh Thanganadar</i>	
Topological Shape and Performance Optimisation of Microchannel Diffusion-Bonded Heat Exchangers Used in sCO <sub>2</sub> Brayton Cycle .....	142
<i>Shubham Kumar Vishwakarma, Adhip Srivastava, Pramod Kumar, Pradip Dutta, Nagendra Somanath</i>	
Thermodynamic Analysis and Optimization of a Supercritical CO <sub>2</sub> Power Cycle Driven by a SOFC-GT Hybrid System .....	155
<i>Runqing Cao, Youna Wang, Zhongliang Wu, Wenhe Liu, Yue Cao</i>	
The Investigation of Inlet Condition Effect on the Surge Recovery Process of a S-CO <sub>2</sub> Radial Compressor.....	167
<i>Gihyeon Kim, Jeong Ik Lee</i>	
Evaluation of Subfilter Model Performance for LES of Supercritical Fluids.....	175
<i>Dhruv Purushotham, Joseph C. Oefelein</i>	
Numerical Investigations on the Aerodynamic Performance of Supercritical Carbon Dioxide Centrifugal Compressor.....	185
<i>Run Cao, Rui Yang, Qinghua Deng, Jun Li, Liming Song, Tiejun Gao</i>	
Performance and Control of the Primary Heat Exchanger in a Closed-Loop sCO <sub>2</sub> Brayton Cycle With Solid Fuel Combustion .....	200
<i>Brian Schooff, Rajarshi Roy, Fletcher Smith, Daniel Tree, Brian D. Iverson, Andrew Chiodo, Timothy J. Held, Jason Miller, Brett Bowan, Kyle Sedlacko, Michael Johnson, Scott Montgomery, Andrew Fry</i>	
Vaneless Diffuser Modelling for Real Gas Supercritical Carbon Dioxide Flows- Need for a Data Driven Approach .....	209
<i>Lakshminarayanan Seshadri, Pramod Kumar</i>	
Off-Design Heat Exchanger Modelling for Transcritical CO <sub>2</sub> Heat Pump Cycles .....	223
<i>Leonhard Wolscht, Maxime Podeur, Martin Adams, Emmanuel Jacquemoud</i>	
Preliminary Characterization of the Desalination Project Demo Plant: Design and Off-Design Operability.....	233
<i>Ettore Morosini, Marco Astolfi, Michele Doninelli, Paolo Iora, Damien Serret, Jean-Michel Hugo, Giampaolo Manzolini</i>	
Numerical Modelling of a Primary Heat Exchanger in sCO <sub>2</sub> Power Cycles for Thermal Energy Storage Systems .....	244
<i>Alexandre Guille, Malini Bangalore Mohankumar, Sebastian Unger, Uwe Hampel</i>	
Numerical Investigation of Two-Phase Shock Waves in CO <sub>2</sub> Flows Using a Modified Hertz-Knudsen Model .....	254
<i>Giuseppe Petruccioli, Amir Momeni Dolatabadi, Aki Gronman, Teemu Turunen-Saaresti, Alberto Guardone</i>	
CO <sub>2</sub> Transcritical Turbines Stator Optimization for Refrigeration Applications .....	264
<i>Saugnac Renaud, Ortego Sampedro Egoi, Bouallou Chakib</i>	
Optimal Part-Load Performance of Supercritical Carbon Dioxide Brayton Cycles During Inventory Control.....	274
<i>Shrey Sahai Gupta, Pramod Kumar</i>	

Optimization of a CO <sub>2</sub> -Free Offshore Power Plant Using Supercritical CO <sub>2</sub> .....	285
<i>Kjartan Pedersen, Marcin Pilarczyk, Rainer Quinkert, Stefan Glos, Martin Kuhn</i>	
Impact of Different Equations of State in the Turboexpander Design for Allam Cycle .....	293
<i>Emanuela Alfano, Vittorio Michelassi, Francesco Fantozzi</i>	
A Method to Develop Radial Inflow Turbine Performance Maps for Off-Design and Dynamic Simulation Studies of sCO <sub>2</sub> Cycles.....	311
<i>Colin du Sart, Pieter Rousseau, Ryno Laubscher</i>	
CO <sub>2</sub> -Based Power Cycles: What Effect Does Additive Molecular Complexity Have on the Cycle Layout?.....	321
<i>Omar Aqel, Martin White, Abdulnaser Sayma</i>	
Development of Thermo-Mechanical Service-Like Testing for Supercritical CO <sub>2</sub> Expanders.....	330
<i>Federico Bucciarelli, Damaso Checcacci, Giuseppe Macoretta, Bernardo Disma Monelli, Leonardo Bertini</i>	
Design of a Scroll-Centrifugal Compressor for Supercritical Carbon Dioxide Power Cycles .....	337
<i>Zimu Yang, Zhenbo Lu, Hongsheng Jiang, Weilin Zhuge, Panpan Song, Yuping Qian, Yangjun Zhang</i>	
Study on the Casing Recess Design Method for a Supercritical Carbon Dioxide Axial Turbine .....	347
<i>Zhuo Hu, Hongsheng Jiang, Weilin Zhuge, Yuping Qian, Yangjun Zhang</i>	
Thermal Performance Characterization of Dry Gas Seals in a sCO <sub>2</sub> Compressor .....	356
<i>Rahul A. Bidkar, Uttara Kumar, Xiaohua Zhang, Nora Molino, Joshua Neveu, John Klaerner, Jeremy Johnson, J. Jeffrey Moore</i>	
Pulsations and Vibrations in the Discharge Piping of a Throttled Supercritical CO <sub>2</sub> Turbine .....	369
<i>Jason Wilkes, Abhay Patil, Jon Bygrave</i>	
Experimental Investigation on Laser Ignition and Flame Stabilization in an Oxygen/Methane CO <sub>2</sub> - Diluted Combustor at Elevated Pressures.....	379
<i>Francesco Di Sabatino, Kendyl Partridge, Brian Connolly, Steve White</i>	
Transient Thermo-Structural Analysis of a Throttle Valve Operated With sCO <sub>2</sub> .....	389
<i>Cosimo Bianchini, Davide Bertini, Simone Sandrin, Vanessa Mariotti, Nicola Maceli, Lorenzo Arcangeli</i>	
Real Gas Effects on Autoignition Delay and Laminar Flame Speed Predictions for Direct-Fire sCO <sub>2</sub> Combustion .....	400
<i>Cory Kinney, Carlos Velez, Scott Martin, Annalisa Forte, Pier Carlo Nassini, Alessandro Zucca, Subith S. Vasu</i>	
Blade Designs for Improved Multi-Phase Performance in sCO <sub>2</sub> Compressors; Part II - Optical Diagnostics in sCO <sub>2</sub> and Experimental Evaluation With Particle Image Velocimetry.....	409
<i>Erik Fernandez, Emmanuel Gabriel-Ohanu, Ladislav Vesely, Jayanta Kapat, Ashvin Hosangadi, Paul Cooper</i>	
Numerical and Experimental Comparison of a Single Stage Axial sCO <sub>2</sub> Compressor.....	423
<i>Saugat Ghimire, Justin Holder, Matthew Ha, Mark Turner, Jeongseek Kang, Scott C. Morris, Kyle Sedlacko, Timothy J. Held</i>	
Dynamic Performance and Control Analysis of a Supercritical CO <sub>2</sub> Recuperated Cycle.....	442
<i>Swatara Tucker, Simone Maccarini, Luca Mantelli, Alberto Traverso</i>	

Evaluation of Cold Flow Test Conditions and Test Fluid Selection for a 60-kW Radial Inflow Supercritical CO <sub>2</sub> Turbine.....	453
<i>Syed Jiul Hoque, Shrey Sahai Gupta, Pramod Kumar</i>	
STEP 10 MWe sCO <sub>2</sub> Turbine Commissioning.....	468
<i>J. Jeffrey Moore, John D. Klaerner, Jonathan L. Wade, Jason Mortzheim, Giridhar Jothiprasad</i>	
High Temperature Industrial-Scale CO <sub>2</sub> Heat Pumps: Thermodynamic Analysis and Pilot-Scale Testing .....	478
<i>Timothy J. Held, Jason D. Miller, Jason A. Mallinak, Luke Magyar</i>	
The Design, Fabrication, and Installation of the Inconel 740H Piping System for a 10 MW sCO <sub>2</sub> Pilot Plant .....	490
<i>Seth Cunningham, Mitchell Rhodes, Fernando Karg Bulnes, Jonathan Wade, George N. Khawly</i>	
Comparison of Geothermal Power Systems in Texas.....	500
<i>Owen Pryor, Cole Replogle, Reese Roddy</i>	
Design and Simulation of a Blowdown Facility for Supercritical Carbon Dioxide.....	508
<i>Mohsen Ghavami, Martin T. White, Hicham Chibli, Abdunaser I. Sayma</i>	
Design and Integration of a Microtube Precooler Into an Aircraft Engine Waste Heat Recovery and Fuel Systems.....	521
<i>Claire-Phonie Bury, Ladislav Vesely, Jayanta Kapat, Mingxuan Shi, Michael Stoia</i>	
sCO <sub>2</sub> Cycle Selection for Waste Heat Recovery From Aircraft Engine.....	532
<i>Ladislav Vesely, William Andress, Guillermo Paniagua, Marcel Otto, Jayanta Kapat, Claire-Phonie Bury</i>	
Commissioning and Operation of an Inventory Management System .....	544
<i>Joshua Warren, George Khawly</i>	
Experimental Study of the Real Gas Effects of CO <sub>2</sub> on the Aerodynamic Performance Characteristics of a 1.5-Stage Axial Compressor .....	551
<i>Jeongseek Kang, Alex Vorobiev, Joshua D. Cameron, Scott C. Morris, Mark G. Turner, Kyle Sedlacko, Jason D. Miller, Timothy J. Held</i>	

**Author Index**