A publication of the International Cryocooler Conference

CRYOCOOLERS 22

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Preface

The objective of *Cryocoolers 22* is to archive the latest developments and performance measurements in the field of cryocoolers by drawing upon the work of leading international experts. In particular, this book is based on the 57 peer reviewed manuscripts that were prepared for the 22nd International Cryocooler Conference (ICC22) held as a hybrid on-site/virtual conference on June 27-30, 2022 in Bethlehem, Pennsylvania. Because the corona-virus epidemic that emerged in March 2020 extended into spring 2022, the original ICC22 all-on-site venue was adapted to also include virtual attendees from around the world. This led to slightly less papers than in past conferences, but to a larger attendance. A total of 172 cryocooler followers and researchers from around the world participated in the hybrid conference (108 on-site and 64 virtual), and 65 authors contributed slides and videos on the ICC website for viewing during and after the conference. Of those papers, 57 are captured here as formal manuscripts.

As with past conferences, following the book's publication, digital versions of all of the ICC22 papers will be available under the ICC website's Past Proceedings tab. This tab similarly provides access to digital copies (PDFs) of all ICC papers published since the first conference in 1980.

An activity, first introduced in ICC21, was the award of an ICC Exceptional Service Award and a Best Student Paper Award. The ICC22 Exceptional Service Award was awarded to Jeff Raab, a fellow editor of this proceedings. His award and the best student paper award are highlighted on the Awards pages directly following this *Preface*.

The content of *Cryocoolers 22* is organized into 10 chapters, covering the various types of cryocoolers and their applications. At the beginning is a chapter covering recent applications of cryocoolers in the aerospace arena with special emphasis on the 6 K MIRI cryocooler that was recently launched as an enabling part of the James Webb Space Telescope. This MIRI cooler was highlighted in the conference's opening plenary and two follow-on papers. Following this chapter on aerospace applications, a sequence of chapters covers the latest research covering Pulse Tube, Stirling, and GM cryocooler development and performance investigations.

Following these chapters on regenerative cryocooler technologies are two chapters covering Brayton coolers and low-temperature sub-Kelvin cryocoolers. A last cooler category, thermal electrics, draws attention to some new developments in this arena that may greatly extend the cooling range of this legacy all-solid-state cooler.

Two final chapters cover important information for users of cryocoolers. They cover cooler interface technologies such as drive electronics, heat transfer loops, superconductor magnet applications, and cryogen liquefaction technologies.

In reviewing the contributions contained in *Cryocoolers 22*, we note the significant number of very small (microcoolers) and some very large entering the marketplace. Example applications of cryocoolers include sensors for tiny CubeSat satellites, space infrared sensors for large space instruments, precooling for cryogen-free sub-Kelvin applications, cooling of HTS and LTS superconducting magnets and electronics, and helium and hydrogen liquefaction and control of cryogen boil-off.

Because the book's contents are designed for users of cryocoolers as much as for developers of cryocoolers, extra effort has been made to provide a thorough Subject Index that covers the referenced cryocoolers by type and manufacturer's name, as well as by the scientific or engineering subject matter. Contributing organizations are also listed in the Subject Index to assist in

finding the work of a known institution, laboratory, or manufacturer. To aide those attempting to locate a particular contributor's work, a separate Author Index is provided, listing all authors and coauthors.

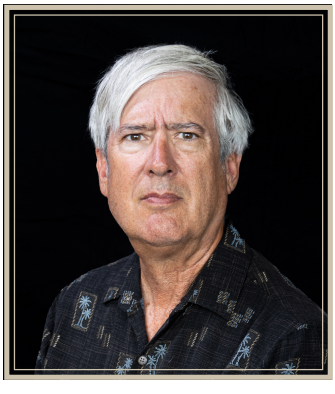
In summary, it is hoped that this book will serve as a valuable source of reference to all those faced with the challenges of taking advantage of the enabling physics of cryogenics temperatures. The expanding availability of low-cost, reliable cryocoolers continues to enable major advances in a number of fields.

The Editors

ICC Exceptional Service Award

In 2020, the International Cryocooler Conference Board established an ICC Exceptional Service Award to be awarded to a person exhibiting exemplary long-term service to the ICC and the cryocooler community. Sponsored by Sumitomo (SHI) Cryogenics of America, Inc., the award includes a plaque and monetary honorarium.

For ICC22, the Board is honored to bestow the ICC Exceptional Service Award to Jeff Raab (retired from Northrop Grumman Space Systems and an exceptional long-time contributer to the ICC and the cryogenic community.



Jeff Raab has been a leading researcher of cryocoolers since helping found TRWs cryogenics activities in 1987. Following his first ICC conference in 1992, he has published 25 papers covering the multiple TRW/NGSS cryocoolers being used throughout the cryogenic community. In direct support of the ICC, he has served on several ICC Program Committees, has been a member of the Conference Board for many years, and in 2012 co-chaired the 17th ICC Conference hosted by Northrop Grumman in Los Angeles. Key recent activities include serving as a co-editor of the the ICC proceedings since ICC20 and chairing of the ICC Student Paper Award Committee since ICC21.

Best Student Paper Award

In 2020, the International Cryocooler Conference Board established an ICC Best Student Paper Award for the best student paper submitted as a manuscript to each ICC Conference. The ICC Best Student Paper Award provides an incentive for students to participate and contribute quality papers to the ICC conferences and provides community recognition to assist them in pursuing their career goals in the field of cryogenics. Sponsored by Cryomech, Inc., the award includes a plaque and monetary honorarium.

The ICC Board is proud to announce the selection of the Best Student Paper delivered at ICC22 and published in Cryocoolers 22 as:

Optimizing Flow Uniformity through Regenerators of Large Cryocoolers Using CFD

by

A. Ghavami, A. Homa, S.M. Ghiaasiaan, and C. Kirkconnell

Formal presentation of the award to Mr. Ghavami and Mr. Homa will occur at the ICC23 Conference at the University of Wisconsin, Madison in 2024.

Acknowledgments

The International Cryocooler Conference Board wishes to express its appreciation to the Conference Organizing Committee, whose members dedicated many hours to organizing and managing the conduct of the 22nd ICC Conference. This was a particularly challenging conference given the persistance of the corona-virus epidemic into 2022. During the January 2022 call for papers it became clear that many persons in the cryogeic community would likely be unable to attend the ICC22 conference in person, as travel within parts of the world was severly limited. The result was adoption of a hybrid On-site/Virtual format that combined the complexities of an on-site conference, plus the issues of broadcasting much of the program to a virtual attendance via Zoom. We thank the 172 cryocooler attendees from around the globe (108 on-site and 64 virtual) that made this combined conference a rousing success and the 65 authors who contributed slides and videos for presentaion and viewing by our on-site and virtual attendees. Members of the conference Organizing Committee and Board included:

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In addition to the above Organizing Committee members, several groups deserve special mention for their extensive efforts in support of the conference. In particular, the Board is grateful to the Sumitomo (SHI) Cryogenics of America, Inc. members involved in planning and executing the conference, particularly the Engineering and Sales and Marketing teams. Special thanks go to the Program Committee for their work reviewing abstracts and organizing the program, and to the Session Chairs who managed each session and peer-reviewed all papers. Lastly, we appreciate the dedication of the event staffs at the Wind Creek Bethlehem, the ArtsQuest Center, and the National Museum of Industrial History. Their hard work ensured the success of ICC22's on-site activities.