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CRYOCOOLERS 20

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Preface

The objective of *Cryocoolers 20* 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 56 peer reviewed manuscripts that were prepared for the 20th International Cryocooler Conference held in Burlington, Vermont on June 18-21, 2018. Although this is the twentieth meeting of the conference, which has met every two years since 1980, the authors' works have only been made available to the public in hardcover book form since *Cryocoolers 8* in 1994.

Starting with *Cryocoolers 14*, we began publishing the series of *Cryocoolers X* books in-house at ICC Press using all-electronic manuscripts and digital printing. This allowed us to also freely distribute the book's contents on the Past Proceedings link of the ICC's website (http://www.cryocooler.org) as well as on a CD included within the back cover of each book. However, starting with *Cryocoolers 20* we have deleted the CD in the back of the book, in deference to the more accessible web-based paper access.

Because the book's content is 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.

Prior to 1994, proceedings of the International Cryocooler Conference were published as informal reports by the particular government organization sponsoring the conference — typically a different organization for each conference. A listing of previous conference proceedings is presented in the Proceedings Index, at the rear of this book. Most of the previous proceedings were printed in limited quantity and are out of print at this time. However, digital PDF copies of these past proceedings are available via the "Past Proceedings" link on the ICC web site.

The content of *Cryocoolers 20* is organized into 11 chapters, covering the various types of cryocoolers and their applications. At the beginning is a chapter on multistage cryocoolers to provide low-temperature cooling in the 4-40 K temperature range for space and military applications. This is followed by chapters on both very small and medium sized single-stage Stirling and Pulse Tube coolers for the common 50-200 K temperature range. Following them are chapters on Pulse Tube cooler modeling and performance investigations, on GM and GM-type pulse tube coolers, and on regenerator and recuperator investigations.

Following the chapters on regenerative cryocooler technologies, are two chapters covering recuperative cryocoolers, including Joule-Thomson, Sorption, and Brayton cryocoolers. These are followed by a chapter on unique sub-Kelvin and novel refrigerators. Applications requiring sub-Kelvin temperatures include space bolometers and x-ray sensors, and ground-based sensors in materials research, nuclear research, quantum materials research, quantum information technology, metrology, astronomy, and scanning tunneling microscopy (STM).

The last two chapters of the book deal with integration technologies such as use in liquefaction and zero-boil-off systems, lessons learned in representative applications, and vibration reduction

technologies. These articles contain particularly useful information for the potential user of cryocoolers as well as for the developer.

In reviewing the contributions contained in *Cryocoolers 20*, we note the continued strong interest in the development of pulse tube cryocoolers for a growing variety of long-life, high-reliability cryocooler applications. Pulse tube coolers can be driven by several competing compressor technologies. One class of pulse tube coolers is referred to as "Stirling type" because they are based on the linear Oxford Stirling-cooler type compressor; these generally provide cooling in the 10 to 100 K temperature range and operate at frequencies from 30 to 100 Hz. A second type of pulse tube cooler is the so-called "Gifford-McMahon or GM-type." Pulse tube coolers of this type use a GM-type compressor and lower frequency operation (~1 Hz) to achieve temperatures in the 2 to 10 K temperature range.

Also of note, is the significant number of very small (micro coolers) and very large (multi-kilowatt coolers) entering the marketplace...these expand the available operating capacity range to over three orders of magnitude!

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.

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