

A publication of the International Cryocooler Conference

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# **CRYOCOOLERS 10**

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## Preface

The last two years have witnessed a continuation in the breakthrough shift toward pulse tube cryocoolers for long-life, high-reliability cryocooler applications with the development of mature products addressed to a wide variety of operating temperatures. On the commercial front, Gifford-McMahon cryocoolers with rare earth regenerators continue to make great progress in opening up the 4 K market. Also in the commercial sector, continued interest is being shown in the development of long-life, low-cost cryocoolers for the emerging high temperature superconductor electronics market, particularly the cellular telephone base-station market. At higher temperature levels, closed-cycle J-T or throttle-cycle refrigerators are taking advantage of mixed refrigerant gases, spearheaded in the former USSR, to achieve low-cost cryocooler systems in the 65 - 80 K temperature range. Tactical Stirling cryocoolers, the mainstay of the defense industry, continue to find application in cost-constrained commercial applications and space missions, but continue to shrink in numbers as the defense industry continues its consolidation.

To archive the latest developments and performance of this expanding stable of cryocoolers, this book draws upon the work of many of the international experts in the field of cryocoolers. In particular, *Cryocoolers 10* is based on their contributions at the 10th International Cryocooler Conference, held in Monterey, California, in May 1998. The program of this conference consisted of 128 papers; of these, 101 are published here. Although this is the tenth 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 1994. This book is thus the third volume in this new series of hardcover texts for users and developers of cryocoolers.

As a significant addition to this proceedings, *Cryocoolers 10* contains ten articles highlighting cryocooler developments that have taken place in the former USSR over the past 20 years. Eight of these cover key accomplishments of the Special Research and Development Bureau (SR&DB) in Cryogenic Technology of the Institute for Low Temperature Physics and Engineering of the National Academy of Sciences in the Ukraine; they are listed in the subject index under: SR&DB of the Ukraine. Also, two articles authored by staff of the Kharkov State Polytechnic University in the Ukraine are included; they cover more recent research activities on pulse tube type coolers and provide insight into the teaching of cryocooler design in the Ukraine. The ten Ukrainian articles reflect a significant increase in collaboration between the cryocooler research centers in the former USSR and the broader worldwide cryocooler community.

Because this book is designed to be an archival reference 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. Extensive referencing of test and measurement data, and application and integration experience, is included under specific index entries. 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.

The content of *Cryocoolers 10* is organized into 15 chapters, starting first with an introductory chapter providing cooler overviews and summaries of major government cryocooler development programs. The next few chapters address cryocooler technologies organized by type of cooler, starting with Stirling cryocoolers, pulse tube cryocoolers, and associated research. Next, Brayton, Joule-Thomson, hybrid J-Ts, and sorption cryocoolers are covered in a progression of lowering temperatures. Gifford-McMahon cryocoolers and low-temperature regenerators in the 4 to 10 K range are covered next, followed by a glimpse into the future with miniature solid-state refrigerators and advanced refrigeration cycles. The last three chapters deal with cryocooler integration technologies and experience to date in a number of representative applications. The articles in these last three chapters contain a wealth of information for the potential user of cryocoolers, as well as for the developer.

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 is making major advances in a number of fields.

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