A publication of the International Cryocooler Conference

CRYOCOOLERS 11

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Preface

Over the last two years we have witnessed a continuation in the breakthrough shift toward pulse tube cryocoolers for long-life, high-reliability cryocooler applications. One class of pulse tubes that has reached maturity is referred to as "Stirling type" because they are based on the linear Oxford Stirling-cooler type compressor; they generally provide cooling in the 30 to 100 K temperature range and operate at frequencies from 30 to 60 Hz. The other type of pulse tube cooler making great advances is the so-called "Gifford-McMahon type." Pulse tube coolers of this type use a G-M type compressor and lower frequency operation to achieve temperatures in the 2 to 10 K temperature range. Nearly a third of this proceedings covers these new developments in the pulse tube arena.

Complementing the work on low-temperature pulse tubes is substantial continued progress on rare earth regenerator materials and Gifford-McMahon coolers. These technologies continue to make great progress in opening up the 2 - 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; the significant development here is the cost-effective incorporation of Oxford-like flexure spring piston supports so as to achieve an extended-life, low-cost product.

The objective of *Cryocoolers 11* is to archive these latest developments and performance measurements by drawing upon the work of the leading international experts in the field of cryocoolers. In particular, this book is based on their contributions at the 11th International Cryocooler Conference, which was held in Keystone, Colorado, in June 2000. The program of this conference consisted of 127 papers; of these, 98 are published here. Although this is the eleventh 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 fourth volume in this new series of hardcover texts for users and developers of cryocoolers.

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 11* is organized into 19 chapters, starting first with an introductory chapter providing summaries of major government cryocooler development and test programs. The next several chapters address cryocooler technologies organized by type of cooler, starting with regenerative coolers; these include Stirling cryocoolers, pulse tube cryocoolers, Gifford-McMahon cryocoolers, and associated regenerator research. Next, Turbo-Brayton, Joule-Thomson, and sorption cryocoolers, as well as sub-Kelvin refrigerators are covered in a progression of lowering temperatures. The technology-specific chapters end with a chapter on Optical Refrigeration; this provides a glimpse into the future with miniature solid-state refrigerators using advanced optical-based refrigeration cycles. The last four chapters deal with cryocooler reliability investigations, integration technologies, and experience to date in a number of representative space and commercial applications. The articles in these last four chapters contain a wealth of information for the potential user of cryocoolers, as well as for the developer.

The expanding availability of low-cost, reliable cryocoolers is making major advances in a number of fields. It is hoped that this book will serve as a valuable reference to all those faced with the challenges of developing and using cryocoolers.

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