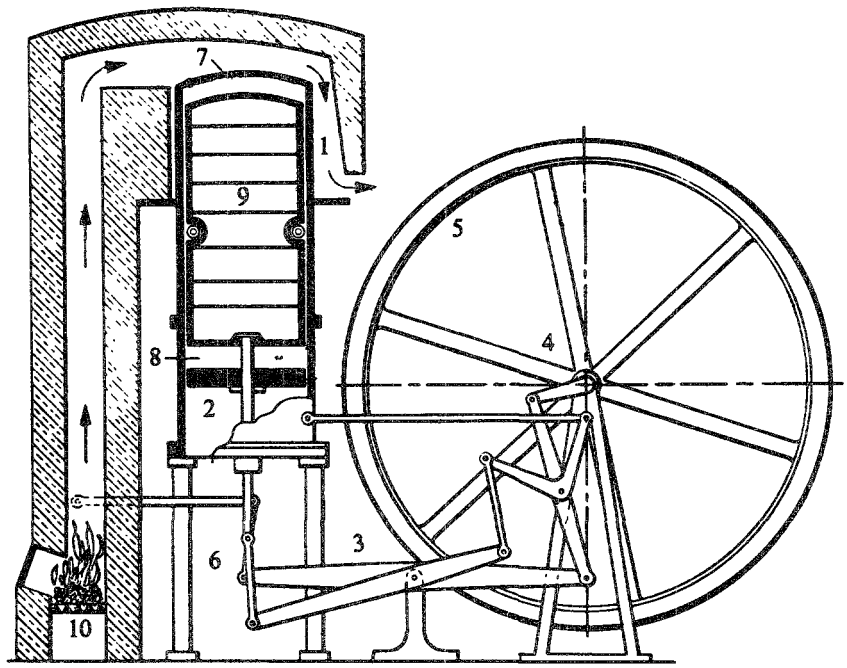
NBS SPECIAL PUBLICATION 607

U.S. DEPARTMENT OF COMMERCE / National Bureau of Standards

# Refrigeration for Cryogenic Sensors and Electronic Systems

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# Refrigeration for Cryogenic Sensors and Electronic Systems

Proceedings of a Conference held at the
National Bureau of Standards,
Boulder, CO, October 6-7, 1980

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Cryogenic Engineering Conference
National Bureau of Standards


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Issued May 1981

Library of Congress Catalog Card Number: 81-600038

National Bureau of Standards Special Publication 607
Nat. Bur. Stand. (U.S.), Spec. Publ. 607, 223 pages (May 1981)
CODEN: XNBSAV

U.S. GOVERNMENT PRINTING OFFICE
WASHINGTON: 1981

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402
Price $6.50
(Add 25 percent for other than U.S. mailing)

ABSTRACT

This document contains the proceedings of a meeting of refrigeration specialists held at the National Bureau of Standards, Boulder, CO, on October 6 and 7, 1980. Participation included representatives of industry, government, and academia. The purpose of the meeting was to discuss progress in the development of refrigeration systems which have been specialized for use with cryogenic sensors and electronic systems. The meeting focused primarily on the temperature range below 20 K and cooling capacity below 10 W. The meeting was jointly sponsored by the International Institute of Refrigeration-Commission A 1/2, the Office of Naval Research, the Naval Research Laboratory, the Cryogenic Engineering Conference, and the National Bureau of Standards.

Key words: Cryocoolers; cryogenic sensors; helium; refrigeration; superconducting devices.

# INTRODUCTORY REMARKS AND SUMMARY

This document contains the proceedings of the second of two conferences held at the National Bureau of Standards Boulder Laboratories on the subject of closed-cycle cryocoolers for small superconducting devices and electronic systems.

The first conference, whose proceedings are available from the Superintendent of Documents, U. S. Government Printing Office, Washington, DC, as NBS Special Publication 508, entitled "Applications of Closed-Cycle Cryocoolers to Small Superconducting Devices", was a meeting of about 40 invited speakers and participants. Its purpose was to review the state-of-the-art of small cryocoolers for temperatures below about 20 K, and to describe the needs of various prospective users of cryocoolers for superconducting and other cryogenic instruments used in biomagnetism, geophysics, magnetic anomaly detection, superconducting computers, Josephson voltage standards, space applications, millimeter-wave and infrared detection, and laboratory measurements. Also presented at this meeting were some new ideas for very-low-power low-interference cryocoolers, Stirling and Joule-Thomson types, particularly suited to many of the listed applications. A subject of special interest was a review of progress on high-$T_c$ superconductors, since the cost, complexity, and drive power of a cryocooler can be reduced considerably if the instrument can be operated at temperatures above 6 or 8 K rather than at 4 K or below. There are, of course, some applications where lower temperatures are required in any case.

In short, the purpose of the first conference was to define the problem. The present conference was organized quite differently. It was open to all interested participants, and most papers were contributed. Invited papers are those by Roubeau and by Nisenoff, the former being a rather free-ranging discussion of some unconventional approaches to cryogenic technology, and the latter a comprehensive review of recent developments in high-$T_c$ superconducting devices and materials. The contributed papers are on refrigeration concepts, systems and components suited to the support of cryogenic sensors and electronic systems below 20 K. Techniques and components developed for higher temperatures that are applicable to low-temperature refrigeration are included.

In reviewing the progress that has been made during the last three years, it is apparent that the desired goals have not been achieved. Nevertheless, there have been some notable developments. Several funding agenices, in particular the Office of Naval Research and Wright-Patterson Air Force Base, are now supporting conceptual studies and developments of low-power cryocoolers for superconducting instruments, and a number of such projects are underway. As described in this report, a helium liquefier-cryocooler for a superconducting computer has been built and is being tested. Also in this report are papers demonstrating increasing interest and emphasis on gas refrigerators using resonant mechanical systems driven by linear reciprocating electric motors and supported by gas bearings or magnetic suspensions. These systems offer the potential of ultimate simplicity, freedom from contamination, long life, and (eventually) low cost. Although the operation of such systems may at first glance appear somewhat subtle, we might point out the obvious, namely that the mathematical description of a resonant reciprocating cryocooler is identical (except for non-linearities) in all essentials to that of coupled electrical resonant circuits with a sinusoidal driving force, a system as familiar as sunrise to most electronic engineers (Probably even the non-linearities are analogous to a considerable extent). Finally, a book by Prof. G. Walker, Stirling Machines, has just been published by Plenum Press, and a companion book, Cryocoolers, is in press. These books are a very comprehensive source of information and references on the whole technology.

Approximatley one-half (57) of the participants at this meeting returned a questionnaire, distributed during the meeting, with answers to three questions. To the question "Has the conference been worthwhile?", 56 said yes and 1 said somewhat. To "Should it be held again?", the answer was yes, unanimously. To "At what interval?" 11 said 1 year, 33 said 2 years, 12 said 3 years, and 1 said 4 years.

There were several useful comments and criticisms. One was to allow more lead time and to provide for distribution of reprints at the meeting. Some comments concerning more industry participation are well taken and we suggest that an earlier planning meeting by an organizing committee made up of an even mix of industry, university, and government representatives might lead in the right direction. One should note that both government and industry papers were withdrawn because they could not be cleared by their organizations (proprietary considerations will certainly constrain some industry participation). We believe that the conference will be more lively and useful if the mix of participants provides for discussion of both new concepts and well conceived and engineered systems.

There were several suggestions that the papers should have been better screened. This is an oft-raised criticism with every conference. It is clear that papers can be rejected for obvious technical flaws or for failure to fit into the basic limits of the conference. However, judgments concerning the quality of a contribution are very difficult to make and many conferences have opted to exercise such judgment only in the published conference proceedings. This is what we chose to do in 1980. The next organizing committee will have to face the question again.

To conclude, and quite apart from the question of the usefulness of this meeting or similar meetings, it might be useful to repeat again the growing conviction that the ultimate fate of superconducting and other cryogenic instruments will depend heavily on the development of reliable, compatible, low-cost cryocoolers like those envisioned by the aurhors of the following papers.

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