Applications of Cryogenic Technology

Edited by

Robert W. Vance

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Robert W. Vance *Cryogenic Society of America and Aerospace Corporation*

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Preface

CRYO-68 represented a major effort to provide a large scale forum for the engineers and scientists who are involved in the day-to-day problems of cryogenic technology and who, in addition, are vitally interested in keeping abreast of the latest developments in this rapidly expanding field. There were three concurrent elements of CRYO-68, the Cryogenic Technology Symposia, the Cryogenic Clinics, and the Fourth Annual Cryogenic Equipment Exposition of the Cryogenic Society of America.

The Symposia, sponsored jointly by the Illinois Institute of Technology and the Cryogenic Society of America, were designed to offer current reviews of basic topics in cryogenic technology and to serve, in book form, as a reference for both engineers and students. The topics discussed included heat exchangers, heat transfer, safety, vacuum technology, plus discussions of important recent and projected developments in cryogenic applications—life support systems, liquefied natural gas, space communications, superconductivity, liquid hydrogen, medical and biological cryogenics. Each of the sessions featured a keynote address by a leading contributor to the topic under discussion, followed by a panel discussion with three or four other outstanding scientists and engineers. The remarks by the panelists were not recorded. However, the panels did augment the addresses and in some cases, pertinent comments have been included in the author's material. This book therefore is a compilation of these lectures and discussions. It should serve as a source of data and information for those engaged in cryogenic activities.

Special features of this text are "A Memoir of Russell B.

Scott," and the first annual Russell B. Scott Memorial Lecture, "The Second Century of Cryogenics." This lecture provided some amazing guidelines for cryogenic fuel utilization to eliminate smog and to provide ultra high speed vehicular systems. It served to point out that applications of cryogenic technology will become an important factor in our economy. As our gross national product continues to increase, that portion represented by the cryogenic and related industries will also increase, but we believe at a more rapid rate.

The overall goal of the two sponsoring organizations, the Cryogenic Society of America and the Illinois Institute of Technology, was to make CRYO-68 a truly educational experience. These proceedings should therefore become a source document meeting the needs of those engaged in applications of basic cryogenic technology including the research engineer, the designer, the manufacturer and the technical representatives.

It is a pleasure, therefore, to express our sincere appreciation to all of the authors who gave their time and effort to prepare their lectures and manuscripts.

We are also indebted to the panelists for providing lively discussions, and to the session chairmen and many secretaries who helped with the administrative details and conference arrangements.

We are also most grateful to the Cryogenic Society of America Program Committee, to their corporate members, to the exhibitors, and to the Illinois Institute of Technology—all of whom combined to create CRYO-68 and to make it successful.

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Los Angeles, California
1969

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Introduction

A MEMOIR OF RUSSELL B. SCOTT

Victor J. Johnson

As an Introduction to this volume on the *Applications of Cryogenic Technology*, we present a review of the career of the man to whom it is dedicated: Russell B. Scott, cryogenic physicist and cryogenic engineer at the National Bureau of Standards from 1928 to 1965. The memoir, which was first presented as an address at CRYO-68 in Chicago on June 11, 1968, includes a brief description of his early home, family, and education and of the first twenty-two years of his professional life at NBS in Washington in the Low Temperature Physics Laboratory. His career in conjunction with the development of the cryogenic industry is discussed in greater detail, as is the recognition he received as a cryogenic engineer and as Manager of the Boulder Laboratories.

It is indeed an honor for me to review briefly the career of a man with whom I had the privilege of close acquaintanceship for eighteen years—essentially the same eighteen years that span the birth and development of the field of cryogenic engineering in America. Russell Scott, or Scotty, as most of his friends affectionately called him, spent his entire professional lifetime of almost forty years in cryogenics. I cannot possibly relate all of his accomplishments or the many interesting things he did in a brief presentation. For this reason I have entitled this Introduction "A Memoir of Russell B. Scott." The dictionary defines a memoir as a biography without special regard for completeness.

I first met Scotty in 1948, shortly before he became Chief of the Low Temperature Physics Laboratory (later designated the

Cryogenic Physics Section of the Heat Division) of the National Bureau of Standards. I was at the Naval Research Laboratory in charge of installing a number of cryogenic facilities there. I needed some advice in regard to the liquefaction of helium and Mr. Scott was the obvious expert in the Washington area to consult on the matter. Later, I transferred to NBS in April of 1950, and worked rather closely with Scotty for the rest of his life.

The part of Mr. Scott's career that I am sure is of most interest is the part he played in launching and developing the field of cryogenic engineering. One of the first major projects in this country in which cryogenics was taken from the laboratory and applied to an industrial-sized operation was the construction and operation of the hydrogen liquefier facility at Boulder. Dr. Edward F. Hammel, Chief of the Cryogenic Research Section of the Atomic Energy Commission's Los Alamos Scientific Laboratory, arranged early in 1950 to have the National Bureau of Standards provide major assistance for programs in the area of liquid hydrogen technology because the greatest expertise in hydrogen technology was acknowledged to be at NBS.

The rather famous research report, RP 1932, on the properties of hydrogen and its isotopes by Woolley, Scott, and Brickwedde had just recently been published and was considered the "Bible" on hydrogen data for many years to follow.* It not only summarized the results of much of the work that Dr. F. G. Brickwedde and Mr. Scott had done during the previous twenty years in the Low Temperature Laboratory but also integrated it with the world-wide knowledge of hydrogen properties. The AEC assigned the entire hydrogen technology package to Dr. Brickwedde at NBS and set such a short time schedule that the project turned into what might be called a "crash program." Dr. Brickwedde started assembling a staff of engineers and physicists from within and from outside the Bureau, myself included, to

* H. W. Woolley, R. B. Scott, and F. G. Brickwedde, "Compliation of Thermal Properties of Hydrogen in its Various Isotopic and Ortho-Para Modifications," (National Bureau of Standards Research Paper RP 1932), *Journal of Research*, XLI (November, 1948), 98 pp.

design and construct what were then considered very large liquid hydrogen facilities and to plan for a future cryogenic engineering laboratory. Initially, Mr. Scott operated only as a consultant since he had a full-time assignment as Chief of the Low Temperature Physics Laboratory. It soon became evident, however, that we needed Scotty full-time on the AEC project. At first he agreed to a temporary leave from his then current post to lead us through the "crash" phase of the program. Later, as he became fully entrenched in the long-range aspects of the program, he accepted a permanent assignment and became Chief of the Cryogenic Engineering Laboratory.

Mr. Scott was always, first and foremost, an experimentalist. In accepting the position as Chief of the Cryogenic Engineering Laboratory he did so with the proviso that when the rush of the construction and development program was over he would be able to spend about half of his time in the laboratory. In order to make this more realistically possible, he selected Mr. B. W. Birmingham as his Assistant Division Chief. In spite of his urgent desire and plans, Scotty was never again able to spend any appreciable amount of time in experimental endeavor. However, I think he came rather close to achieving the desired satisfaction in this regard from the role he played in developing the program of cryogenic engineering and physics projects that built the Cryogenic Laboratory's world-wide reputation, particularly in the area of hydrogen technology. Although it was no longer possible for Mr. Scott to devote much time to an experimental project of his own, he kept in close touch with all of our projects and tried to visit with each of us at least weekly, sharing our experiences and offering suggestions where appropriate.

The true test of Mr. Scott's ability as a laboratory director, as well as of his and the Laboratory's reputation, came, I believe, after the big AEC program was essentially completed. The period from 1954 to 1956 was actually quite a crucial time in the development of the Cryogenic Engineering Laboratory. Up to that time the Laboratory had been totally funded by the AEC and its work was exclusively for the AEC program even though many of the

projects were of wide general interest. Now with the AEC program terminating rather suddenly, who was going to continue the support? The Laboratory could easily have folded at this time. Mr. Scott was determined that the Laboratory should survive because he was convinced that cryogenics had a great future and was in fact at the threshold of an explosion into a great number of different disciplines. Mr. Scott and his staff campaigned vigorously for support from all possible sources. They were successful, thus maintaining a good, sound program of research and development.

In 1956 a new interest in liquid hydrogen appeared on the scene. The Air Force and the National Aeronautics and Space Administration were interested in it for rocket propulsion and as a possible aircraft fuel. It was at this point that the real explosion in cryogenic technology started. There soon developed a wide outside interest in the Laboratory's projects and in the cryogenic information and data that had been accumulated. I would like to cite two aspects of this in which Mr. Scott played a key role. One was the need for basic cryogenic information in the Atlas and the Titan programs. Many personnel from the Air Force, NASA, and their contractors came to the Laboratory, starting in 1956 and 1957, for advice from Mr. Scott and his staff on the fundamental cryogenic problems of liquefying and handling the cryogens, for data on the properties of materials at low temperatures, and for information on numerous cryogenic processes and techniques. Mr. Scott was also quite concerned with the need to improve cryogenic insulations. He instituted research studies that led to a great improvement in powder insulations and to the development (by others) of multilayer insulations.

Mr. Scott was greatly interested in the development of the cryogenic industry and took an active part in promoting such development. In 1954 he promoted the first Cryogenic Engineering Conference and was an active supporter of subsequent conferences. Also, in 1958 he established the Cryogenic Data Center to better serve industry's needs for information and data. Both of these activities have flourished and grown in stature and they are now internationally recognized. Throughout the rest of his life,

Mr. Scott maintained a deep and personal interest in the welfare of the Cryogenic Data Center and it has been very satisfying to me to be so closely associated with it.

I feel I must give you a more complete picture of Scotty's life than simply my personal association with him. He was born near Ludlow, Kentucky, on April 17, 1902, to Burton and Carrie Riggs Scott. He received his early education in the local schools. After two years at the University of Cincinnati he transferred to the University of Kentucky where he received his bachelor of science (*cum laude*) in physics in 1926. He stayed on and received a master of science in the same field in 1928, while serving also as an instructor in physics. One of his sophomore physics students was a lovely young girl, Leonora Downing, whom he married on June 13, 1928. Soon afterwards they moved to Washington, D.C., where Scotty was employed by the Bureau of Standards* in the Low Temperature Laboratory. The Scotts bought a home in Garrett Park, a beautifully wooded suburb just northwest of Washington. They lived in this home for twenty-one years and there raised their two children, Marian and Burton. Marian is now the wife of Dr. William F. Kenkel, who teaches at the University of Kentucky in Lexington. They have five children, four boys and a girl. Burt, who has a Ph.D. in physics, married Betty Lu Mitchel, whom he met while attending the University of Colorado. They live in the Malibu section of Los Angeles and have two children, a girl and a boy. Mr. Scott adored his grandchildren and visited them often.

When Mr. Scott joined the Bureau in 1928, the total staff was less than 1,000 and the staff of the Low Temperature Laboratory was three—Dr. Brickwedde, Mr. Cook who operated the liquid air plant, and Scotty. Scott and Brickwedde actually started cryogenic research at the Bureau (and for that matter in this country) because prior to 1928 the only cryogenic work was the liquefaction and distribution of liquid air for cold traps in vacuum

*It became the National Bureau of Standards in 1933, with Dr. Lymon J. Briggs as Director.

systems and the like. Some of the major accomplishments in which Mr. Scott was primarily involved during those early years in the Low Temperature Laboratory at NBS were the following: (1) the first liquefaction of helium in the United States—that was in 1931—and the first research with liquid helium in the United States; (2) the first concentration of deuterium, which made possible the discovery of deuterium with a spectroscope by Urey at Columbia University (also, the first measurements of differences in thermodynamic properties of H_2 and D_2 were made in the Bureau's Low Temperature Laboratory); (3) the establishment of a scale of temperatures from 273°K (0°C) down to 10°K for the calibration of thermometers at the NBS for other laboratories needing this service; and (4) the design and construction of the most precise and accurate low temperature calorimeters of the time for measurements of low temperature specific heats down to solid-hydrogen temperatures. There were many other accomplishments too, which by the time of World War II had given the Laboratory world-wide fame.

I am indebted to Dr. Brickwedde for much of the information I have on Scott's early career as a cryogenic physicist. I would like to quote a paragraph from Dr. Brickwedde's remarks made at Scotty's retirement banquet. He said, "As was to be expected of low temperature laboratories in those early days, we had our little explosions—there were two of them—they were not cryogenic explosions—and I should not even mention them except that both involved Scotty and they are the best evidence I can offer you that it was Scotty who was doing the laboratory's important research. Both explosions were freaks. One was an explosion of a ten-gallon glass demijohn which served as a ballast on the line for evacuating a liquid hydrogen cryostat. It had had some gaseous hydrogen in it and, on standing, some air had diffused into it, making an explosive mixture. Scotty had finished some glass blowing on a completely separate part of the system and was testing the excellence of his glass seal with a tesla coil, customarily used for this purpose. The explosion in the demijohn was caused by a high electrical potential transferred by