TITANIUM SCIENCE AND TECHNOLOGY
1968—Refractory Metal Alloys: Metallurgy and Technology
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1969—Research in Dental and Medical Materials
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TITANIUM SCIENCE AND TECHNOLOGY

Proceedings of the Second International Conference organized by The Metallurgical Society of AIME, the American Society for Metals, and the Institute of Metals in association with the Academy of Sciences of the USSR and the Japan Institute of Metals, held at the Kresge Auditorium, Massachusetts Institute of Technology, Cambridge, Massachusetts, May 2-5, 1972

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VOLUME 1

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To

DR. MAX HANSEN,

whose pioneering work in the physical metallurgy of titanium in the United States and Germany truly exemplifies the international nature of the research on titanium, which is described in these proceedings circa 1972.
PREFACE

The Second International Conference on Titanium was held in Cambridge, Massachusetts, four years after the inaugural conference in London in 1968. There were many similarities and differences between the two conferences and the status of the titanium industry at the time.

In 1968 the production of titanium in the United States was close to its historic peak of about 30 million pounds of mill products. Projections of applications in commercial and military aerospace and the civilian economy indicated continuation of the ten-year growth pattern of about 20 percent annually. A great feeling of enthusiasm pervaded that conference.

In 1972 this growth pattern for titanium had been interrupted for at least two years, and the industry is now in a decline expected to be at least 20 percent off of its peak year. The U.S. supersonic transport, largely to be built of titanium, had been cancelled. The U.K.-French and Soviet supersonic transports were designed and constructed to operate at about Mach 2, to eliminate the requirement for extensive use of titanium. The largest titanium market, commercial aircraft, was in a period of consolidation after the rapid expansion in the 1960's.

The organizers for the Second International Conference seriously considered whether it was opportune to have a second conference in this period of decline in the industry. With considerable trepidation, calls for papers were sent out. We were amazed and delighted to find a tremendous outpouring of offers of papers from all parts of the world. Most of these papers reported new research and development, many applied to new areas of application not covered in the London Conference. After screening, a core of close to 200 worthwhile papers were accepted for the conference. Despite the poor economic condition of the industry, and shortages of travel funds, the attendance at the conference was also a pleasant surprise. About 350 participants from all over the world attended the conference, roughly the same number who participated in the original London Conference. We must conclude that the charisma of titanium has remained intact.

Other differences apparent to us between London and Cambridge were greater concern for economics in production and utilization, a search for new areas of application, particularly for nonaerospace uses, and an increasing attention to reliability as the
aerospace applications became more demanding and titanium was utilized in airframes and primary aircraft structures instead of primarily in engine applications.

The scientific aspects of titanium research continued at the high level of quality displayed at the London Conference. We now see how to better relate the structure of titanium in its various aspects from electronic structure, dislocation structure, and grain structure to mechanical behavior and other properties. We saw examples of how this scientific knowledge was put to practical use. This is a new subdivision of titanium science and technology, metallurgical synthesis, which relates the creation of appropriate structures to achieve desired properties.

The trend for titanium application to move from military to civilian, from aerospace to terrestrial, and from high cost to low cost has continued apace. In Europe and Japan, it is apparent that these trends, particularly in nonaerospace applications, have proceeded further than in the United States, but the U.S. market trend should follow a similar course if reductions in the cost of titanium continue. At present we view this as an extremely favorable factor for turning the utilization of titanium upward again. We are not discouraged about the future application of titanium, including aerospace, and believe the current economic decline of titanium is temporary and related to a depression in the total aerospace utilization of materials.

To stimulate the transfer to actual use of the rapidly growing body of scientific knowledge on titanium and to provide the information necessary to support the reliable use of titanium in new applications, we felt that particular attention during the conference should be paid to coupling between those working in the science with those working in practical applications. Thus, the entire spectrum from basic research to service experience was covered, and many speakers addressed themselves to various aspects of this coupling.

In order to handle the large number of papers in a four-day period, it was necessary for us again to use the rapporteurial system of presentation. To stimulate discussion and interplay among the attendees at the Conference, we added for each session the presentation of a critical review of the field by an invited lecturer who was well-known for his work on titanium. After the critical review and rapporteur's presentation, the authors were given an opportunity to add further comments and clarification of the highlights of their papers. The remaining time for each session was devoted to discussion of the overall topic led by two co-chairmen. Sense reports on this discussion follow each of the sections of the proceedings. We think they are well worth reading to gain an idea of the interplay that went on during the Conference itself.
The Organizing Committee is listed below:

Mr. Stanley Abkowitz  
General Chairman

Dr. Harris M. Burte  
U.S. Technical Co-Chairman

Prof. Nicholas J. Grant  
U.S. Technical Co-Chairman

Mrs. M.K. McQuillan  
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Institute of Metals

Japan Institute of Metals

Academy of Sciences U.S.S.R.

The Metallurgical Society of AIME

Unfortunately, Prof. Glazunov was not able to attend. In his place Dr. L. Petrova served ably as head of the Soviet delegation. We also wish to thank the Titanium Committee of The Metallurgical Society of AIME who assisted us in the review of abstracts and organization of the program. These included:

S. Abkowitz  
H. Margolin

H.B. Bomberger  
R.E. Newcomer

J.D. Boyd  
I. Perlmutter

R. Broadwell  
C.M. Pierce

E.W. Collings  
T. Redden

F.A. Crossley  
R.A. Sprague

H.L. Gegel  
B.V. Whiteson

R.F. Malone  
J.C. Williams

All of these also had active roles in the conduct of the Conference as authors, co-chairmen, or rapporteurs.

Thanks are due to Mr. Abkowitz and Prof. Grant for handling the arrangements in Cambridge for the Conference and to Dr. M.K. McQuillan for coordinating the overseas program input and participants. The Titanium Conference was truly international in that there were papers from many countries represented.
In particular we wish to thank the rapporteurs who did a notable job of introducing often as many as 15-20 papers in a particular session, interrelating one paper with the other and commenting on its relationship to the overall field. Much of the success of the ensuing discussion must be attributed to these efforts.

We wish to comment on the dedication of this book to Dr. Max Hansen. This course follows the tradition established in the first proceedings, which were dedicated to Dr. Wilhelm Kroll as the father of titanium. We believe Max Hansen also embodies the international character of titanium research and development. He was trained in metallurgy in Germany. His work on titanium originated in the United States at the Armour Research Foundation (presently the Illinois Institute of Technology Research Institute, IITRI). Later he returned to Germany where he instituted extensive titanium research at the Metallgesellschaft, A.G. in Frankfurt-Main, Germany. Max Hansen is now retired in Kronberg, Germany.

Lastly, we wish to express our hope that there will be a third and continuing international conferences on titanium held every four years to record and stimulate progress on this remarkable metal.
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