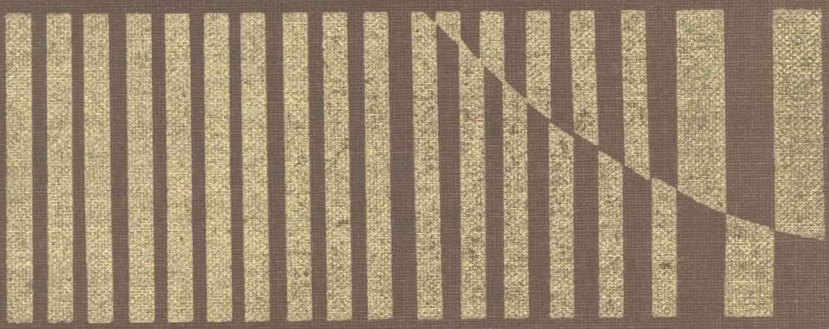
Critical Materials Problems in Energy Production



edited by
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PREFACE

As far as we know, man is the only animal both cognizant of and endowed with sufficient intellect to change his environment. However, man's ability to do so is heavily predicated on his ability to sustain his continued scientific and technological advance. In the main fields in which he conducts this struggle—agriculture, urbanization, medicine, and communications—the availability of huge supplies of energy has determined the rate at which man has been able to achieve his goals.

The problem of providing energy in such vast quantities, distributing it, and storing portions of it for later use during peak demand periods consists of several different but closely related aspects: sociological (priorities—who gets it and how much), ecological (at what price to our environment), economical (how much are we willing to pay for it), and technological (can we produce large amounts of energy, in a wide variety of forms, at an economically acceptable price). While there have recently been several excellent books and articles that address each of these problems, this volume is concerned with those technological phenomena which are limiting progress in energy production due to materials related inadequacies.

It is interesting to note that while progress in other fields depends on the close synergism between scientific discoveries and breakthroughs and the transformation of this knowledge into technologically useful systems, the production of new sources of large quantities of energy is more dependent on the extraction of technical knowledge from several traditional fields of engineering. For the most part, the need is to translate, advance, and utilize knowledge already on hand in the chemical engineering, metallurgical engineering, high-temperature ceramic engineering, corrosion engineering, and electrochemical engineering industries into solutions of problems in energy production.

Out of many technical problems encountered in the production of energy, this volume identifies and concentrates on the most challenging of the materials problems in the three areas of production, distribution, and storage of energy and treats them in seven sections: (1) nuclear power, (2) materials for high-temperature applications, (3) solar energy, (4) direct solar conversion, (5) coal and other fossil fuels, (6) superconducting materials, and (7) energy storage devices.

This volume is the result of a series of Distinguished Lectures sponsored by the Joint Center for Materials Science in New Mexico. The Center is a manifestation of an endeavor on the part of the Air Force Weapons Laboratory, the Los Alamos Scientific Laboratory, and Sandia Laboratories to cooperate with the New Mexico Institute of Mining and Technology, New Mexico State University, and the University of New Mexico to provide a program of continuing education in the field of materials science for the New Mexico scientific community. It was appropriate, therefore, that the list of guest lecturers be compiled from suggestions made by researchers working directly in the field of energy production. Consequently, the in-

dividuals invited to participate in this symposium represent the most distinguished scientists from both the United States and Western Europe, who are contributing to our present understanding of the fundamental materials problems that are limiting energy production.

As a part of the Joint Center's continuing educational program, the collected papers of the Distinguished Lecture Series on "Critical Materials Problems in Energy Production" have been edited and produced in a format suitable to be used as a text by both senior students and first-year graduate students in materials science. Each of the 28 chapters has sufficient introductory information to provide the student with the background and the context from which the materials problems in specific topics of energy production can be understood. In addition, a set of problems and recommended readings that are related to important technical points in each chapter is appended to the final section of the book. They are intended to help the instructor amplify materials science concepts and to offer the student an opportunity to augment the material presented with further, in-depth background information.

The Joint Center for Materials Science, which sponsored these lectures, gratefully wishes to thank and acknowledge the Air Force Weapons Laboratory; the European Office of Aerospace Research and Development, U.S. Air Force, London, England; the Los Alamos Scientific Laboratory; and Sandia Laboratories for their financial support of the Distinguished Lecture Series, and the University of New Mexico for their hospitality in providing lecture hall space.

The editor wishes to thank those who participated in the Distinguished Lecture Series and who contributed to this volume; and Mr. L. DeJohn, who provided the original graphic designs used to introduce each energy section.

Charles Stein

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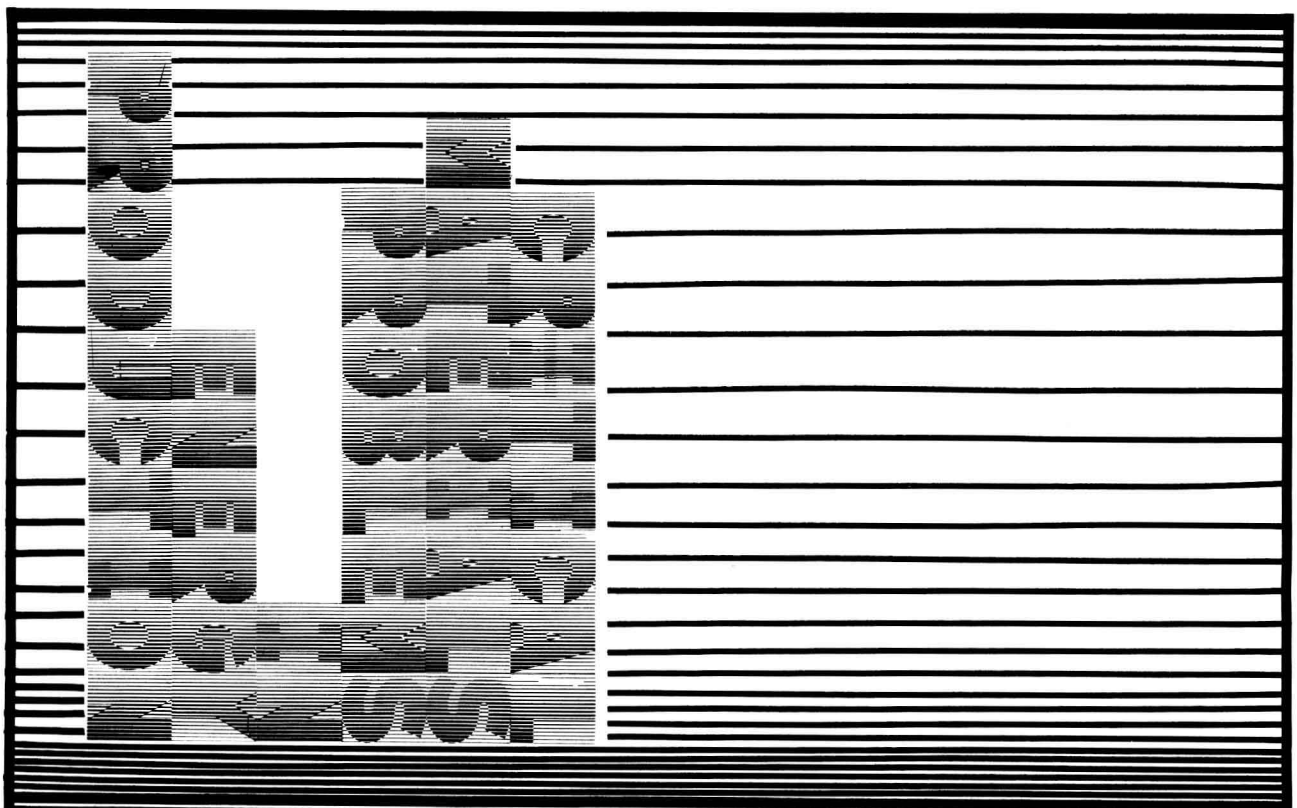

CHAPTER 1

A PERSPECTIVE ON MATERIALS IN THE ENERGY PROGRAM

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The production and consumption of energy, generally recognized by the technical community as a crucial program for the next few decades, will require significant advances in many areas of practice and knowledge. The Committee for the Joint Center for Material Science in the State of New Mexico feels that it is timely to address the question of contributions which the materials community may make to the energy program. Thus, we are embarking on this series of presentations entitled "Critical Material Problems in Energy Production." This introductory paper will serve to provide an overall perspective of the energy program within which the specific materials problems can be considered.

To many of us, the energy problem is most apparent through the rapid rise in fuel costs—gasoline for the car or fuel to heat the home. Therefore, people decry every day that energy is

getting more and more expensive. The interesting point is not so much that energy is getting more expensive but that energy has always been so cheap. This situation has given rise to a number of rather inconsistent but understandable behavior patterns.

For example, in Albuquerque the average homeowner's lot receives about 8800 million BTUs per year from the sun. For heating, hot water and cooking by natural gas, the average consumption is only 130 million BTUs a year(1)—considerably less than the energy received from the sun. And yet each Albuquerque homeowner will pay $177 on the average this year to have gas piped in from a well someplace far away. In our forests, enough timber matures to furnish nearly all the energy we need, but we drill holes four miles deep in search of more oil. We are planning construction of a whole series of incredibly complex and expensive nuclear power plants to provide even cheaper energy than these traditionally available forms.

We could propel our ships across the ocean with sails as we once did. The energy is free; but instead we fuel our tankers with inexpensive oil out of our own deposits so we can go overseas and import expensive oil from the Near East. The University of New Mexico closed down for three extra days during the Christmas holiday season to save energy; the result was a saving of 26 cents per day for each person who remained away from work.(2) It was not a favorable trade-off, precisely because energy is so cheap. Consequently, we may decide that we are willing to pay considerably higher prices for energy.

Energy and materials are closely linked in many ways. For example, the production of materials, which requires their recovery from natural resources, and the processing of them until they are ready for manufacturing, consume something like 17% of all energy used in this country. Conservation of energy in material processing is therefore an important problem for the materials community but there is not time in this Series to cover