FUEL CELLS

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C. A. McAuliffe

ENERGY ALTERNATIVES SERIES

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by

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First published 1976 by

THE MACMILLAN PRESS LTD

London and Basingstoke

Associated companies in New York, Dublin,

Melbourne, Johannesburg and Madras

SBN 333 18408 4 (hard cover)

333 18409 2 (paper cover)

ISBN 978-0-333-18409-7 ISBN 978-1-349-15693-1 (eBook)

DOI 10.1007/978-1-349-15693-1

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EDITOR'S FOREWORD TO THE SERIES

The so-called 'energy crisis' is misnamed. There is certainly a serious problem regarding reserves of gaseous and liquid hydrocarbons, but immense fossil fuel reserves exist in the form of coal. If we take the United States of America alone and assume that only 50% of their known coal deposits are recoverable, then this would still be enough to last them for 2000 years at current rates of consumption. A similar situation applies in the Soviet Union.

However, crisis or not, the short oil embargo by the O.P.E.C. countries in 1973 did make us aware that we had not been giving due attention to our most important basic resource, energy. For example, the trend towards the use of naturally occurring hydrocarbons in most developed countries had been taking place without any thought of the long-term economic and social issues. It was also realised that although fossil fuels may be plentiful in the immediate future, complacency about energy is an irresponsible attitude and that we should be directing our efforts to seeking to use it more efficiently and to developing alternative sources.

Thus there has been in recent years a great deal of discussion and research into all aspects of energy sources and their utilisation. The questions considered range from the straightforward analysis of the efficiency of various energy-generating processes now in current use, through the possibilities raised by more unconventional sources such as solar energy and geothermal energy, to the demands which society has and will continue to make for greater supplies of energy to support itself in increasing comfort.

Within this range, it seems to me that there is a place for a series of books which sets down the essential scientific facts about the many different energy alternatives open to us once we look beyond current practice. With this in view, a number of experts have been approached and each asked to write a short account of his specialist subject and to outline its possible contribution to our future energy strategy. The choice of subjects must reflect to some extent my own prejudices about what may be considered important and relevant, but at the same time I believe that there is general agreement about what the major possibilities are. These will certainly be covered by the series. In scope each volume is principally restricted to the

scientific and technological aspects of the subject, but it has occasionally proved impossible to avoid introducing broader social and political questions. This has not been discouraged, since discussion about the energy problem, although properly based upon a thorough appreciation of the factual background, must inevitably be conducted in a more general forum.

The series is intended to be open-ended, and thus will be better able to respond to changes in both technology itself and also in society's attitude towards it. It is not aimed at the specialist research worker—there are many books and articles which satisfy the needs of this market—but rather it is intended for university or polytechnic students, for engineers, planners, architects, policy-makers, and indeed anyone with a basic grounding in science who feels the need to be equipped with the facts before joining the debate about the future of energy.

Manchester, 1976

C. A. McAuliffe

FOREWORD TO THE BOOK

by

P. G. Ashmore (Professor of Physical Chemistry, University of Manchester
Institute of Science and Technology)

Fuel cells seem to have been on the verge of capturing world markets as well as the imagination ever since my postwar years in Cambridge, when F. T. Bacon's researches were turning a backroom idea into a practical power unit. Admittedly, those were days when fuel was scarce in England, and electricity distribution networks were frequently overwhelmed by demand. Steady improvements in the efficiency of electricity production were achieved by bigger and better boilers, turbines and generators, and corresponding advances were made in the distribution system by reducing power losses, smoothing peak demands, and switching in and out parts of the national grid. In transport, it proved hard to find any competitor for the incredibly flexible and versatile petrol and diesel engines for road transport, and when diesel ousted steam locomotives it seemed that the internal combustion engine would be the dominant free power unit. Electrification of many intercity railways, however, has allowed the indirect methods of producing electricity to win back some business from diesel power. Can the direct production of electricity by fuel cells oust the internal combustion engine in any large market in the future?

In this book, a bold attempt is made to present the scientific and technical background to research and development of fuel cells, and to examine the economic and social factors that affect the use of fuel cells as primary producers of electricity in various parts of the world. It is surely a tribute to mankind's perpetual search for alternatives that research has gone as far as described into the properties of low-temperature and high-temperature fuel cells, into possible and practicable fuels, into improvements in efficiency and power-for-weight, into longer-lived and cheaper electrodes. All this work used fundamental researches on the kinetics and thermodynamics of electrode processes, and these are clearly outlined in the early chapters, at sufficient length to satisfy those with scientific training but not so deeply as to confound those whose science stopped when they left school. The last

four chapters look at current practice, present costs, and possible future developments and uses of fuel cells. In presenting objectively 'the facts of the present and the aims of the future', this book certainly fulfils one of the main aims of the series.

Manchester, 1976

P. G. Ashmore

PREFACE

In the world of today the 'energy crisis' is frequently mentioned. It is widely assumed that we are being profligate with present-day sources of power and that eventually there will not be enough energy left in the world to provide for the predicted rapid increase in human population. In these circumstances it is not surprising that attention has been turned to ways of using our present resources of energy more efficiently, that is to say with less waste. The direct conversion of chemical energy into electricity by means of the fuel cell is an outstanding example of such a process, and much research effort has been expended in recent years in an attempt to develop the fuel cell for commercial use.

This book provides a discussion of the background to the use of the fuel cell as a source of electrical power, showing the advantages and constraints of the system and illustrating the attempts that have been made to produce commercially viable fuel batteries. Emphasis has been placed on general principles, which are discussed in the first four chapters, and on their application to particular designs of cell, described in the remainder of the book. Economic considerations are outlined briefly in chapter 12 and a review of future prospects appears as chapter 13. Although detailed descriptions, both of the scientific basis of fuel cell operation and of the technological development of fuel battery construction, have been reduced to a minimum, and there has been no attempt to describe the research methods used, references are made to suitable sources of further information on these points.

It is hoped that this book will provide a useful introduction to a subject of considerable interest today for a person having some knowledge of physics and chemistry but little other experience in the field. With a view to its ready acceptance in the modern educational environment, I have adopted, so far as possible, the methods of quantity calculus and the units of the *Système Internationale* throughout the book.

I should like to thank my colleagues and friends who have helped me during the writing of this book. I am particularly grateful for the encouragement, assistance and advice given by Professor P. G. Ashmore, Dr J. H. R. Clarke, Dr B. J. Tyler and Mr P. Wiseman, and especially Dr J. Lee who has read every word I have written and whose clear minded criticisms and suggestions I have rarely been able to ignore. I must also thank Chloride

Technical Ltd who have very generously provided much information, several of the diagrams and all of the photographs which appear in this book, and my typist, Mrs H. P. Robinson, who has coped splendidly with much unfamiliar scientific material.

Manchester, 1976

A. O. McDougall