Preface

Fusion energy is widely perceived as the ultimate terrestrial energy source. This appealing prospect has emerged by reason of scientific experiment, by the expectation of continuing scientific and technological progress, and by intriguing observations such as the following: life on earth is sustained as a consequence of fusion reactions in the sun; a medium-sized lake contains sufficient hydrogen fusion fuel to supply a nation with energy for centuries; the known diversity of fusion fuel cycles offers the eventual possibility of radiologically clean energy; fusion power appears essential for deep-space explorations; ... However, between this set of appealing notions and current scientific understanding and available technologies, there exists a barrier of considerable proportions. Both a broadly sustained community commitment and a high level of motivation by its participants is required for the realization of this ultimate source of energy.

As active research participants in several areas (both technical and geographic) of the fusion energy enterprise, we have long been sensitive to emerging technological perspectives related to this unique form of energy. In addition, as educators, we have repeatedly sought a conceptual and didactic framework for fusion lectures which would integrate the fundamentals of fusion phenomena with the successful experiences of the past and provide a link to the broader promise of emerging developments; additionally, and at a more subjective level, we have also sought an instructional balance between the pragmatic near-term educational role of a societal objective with the long-term inspirational value of a theme. Thus, while it is clearly essential to emphasize the well established concepts of magnetic and inertial confinement approaches to fusion, we believe it is also important to discuss topics such as spin-polarized fusion, advanced-fuel fusion reactions, muon-catalyzed fusion, and other related and emerging concepts. A synthesis which includes these and similar topics will, in our view, impart a most desirable perspective not only to the next generation of fusion scientists and nuclear engineers, but also to other professionals concerned with energy for the long term.

The writing of this text has been pursued, on and off, for nearly two decades. In retrospect, this has provided us with good time to accommodate the two divergent developmental paths which have become solidly established in the fusion energy community: the process of sequential tokamak development towards a prototype and the need for a more fundamental and integrative research approach before costly design choices are made. Our belief is that we have herein accommodated both interests in a coherent instructional format and the amount and level of material contained here allows for both avenues to be pursued.

In developing our subject we have found it useful to identify several distinct themes. The first is concerned with preliminary and introductory topics which relate to the basic and relevant physical processes associated with nuclear fusion. Then, we undertake an analysis of magnetically confined, inertially confined, and low-temperature fusion energy concepts. Subsequently, we introduce the important blanket domains surrounding the fusion core and discuss synergetic fusion-fission systems. Finally, we consider selected conceptual and technological subjects germane to the continuing development of fusion energy systems.

Our target group of interest is the senior undergraduate and beginning graduate university student in science or engineering. Familiarity with selected aspects of modern physics and a working knowledge of the differential calculus and vector algebra is assumed as a minimum prerequisite. In support of our pedagogical objectives, we have chosen to place considerable emphasis on the development of physically coherent and mathematically clear characterizations of the scientific and technological foundations of fusion energy specifically suitable for a first course on the subject. Of interest therefore are selected aspects of nuclear physics, electromagnetics, plasma physics, reaction dynamics, materials science, and engineering systems, all brought together to form an integrated perspective on nuclear fusion and its practical utilization. While the subject is of necessity broad, a focused pedagogical emphasis is consciously pursued: to identify and synthesize relevant physical concepts and their associated mathematical constructs and thereby provide a learning experience appropriate for subsequent more specialized work in any of the several areas of fusion energy.

In the course of our involvement in teaching and research in fusion energy, we sense a deep debt of appreciation to many with whom we have been in contact on matters of fusion energy. This includes numerous participants in various specific fusion energy programs at national and international research centres and colleagues at various universities. A particular word of thanks to Dr. D.P. Jackson (Chalk River Nuclear Laboratory, Canada), Prof. B. Lehnert (Royal Institute of Technology, Sweden), and Dr. G. Melese (General Atomics, USA) for their review of earlier drafts of this text. Additionally, we acknowledge those undergraduate and graduate students who, over the years, have passed on to us their comments on various versions of this work: A. Bennish, B. Bromley, B. Carroll, G. Cripps, B. Diacon, G. Gaboury, E. Hampton, X. Hani, T. Harms, S. Hassal, S. Ho, A. Hollen, M. Honey, J. Marczak, S. Mitchell, R. Ramon, P. Roberts, G. Sager, R. Scardovelli, A. Sguigna, P. Stroud, Y. Tan, D. Welch and J. Zielinski.

Our thanks to the several patient secretaries for typing the text and to the artists for the drawings. It is, however, with a particular sense of appreciation that we acknowledge two sterling co-ordinators for their accommodating disposition:

Jan Nurnberg (McMaster University) and Christine Stalker (University of Illinois).

To all we express our thanks.

A.A.H., K.F.S., G.H.M., D.R.K.
January 2000