

**ADVANCES IN
NUCLEAR SCIENCE
AND TECHNOLOGY**

VOLUME 16

ADVANCES IN NUCLEAR SCIENCE AND TECHNOLOGY

Series Editors

Jeffery Lewins

Cambridge University, Cambridge, England

Martin Becker

Rensselaer Polytechnic Institute, Troy, New York

Editorial Board

Eugene P. Wigner, *Honorary President*

R. W. Albrecht

F. R. Farmer

Paul Greebler

Ernest J. Henley

Norman Hilberry

John D. McKean

K. Oshima

A. Sesonske

H. B. Smets

Karl Wirtz

C. P. L. Zaleski

A Continuation Order Plan is available for this series. A continuation order will bring delivery of each new volume immediately upon publication. Volumes are billed only upon actual shipment. For further information please contact the publisher.

ADVANCES IN NUCLEAR SCIENCE AND TECHNOLOGY

VOLUME 16

Edited by

Jeffery Lewins

*Cambridge University
Cambridge, England*

and

Martin Becker

*Rensselaer Polytechnic Institute
Troy, New York*

PLENUM PRESS · NEW YORK AND LONDON

Library of Congress Catalog Card Number 62-13039

ISBN-13: 978-1-4612-9671-3

e-ISBN-13: 978-1-4613-2687-8

DOI: 10.1007/978-1-4613-2687-8

© 1984 Plenum Press, New York

Softcover reprint of the hardcover 1st edition 1984

A Division of Plenum Publishing Corporation

233 Spring Street, New York, N.Y. 10013

All rights reserved

No part of this book may be reproduced, stored in a retrieval system, or transmitted in any form or by any means, electronic, mechanical, photocopying, microfilming, recording, or otherwise, without written permission from the Publisher

PREFACE

John Maynard Keynes is credited with the aphorism that the long-term view in economics must be taken in the light that "*in the long-term we are all dead*". It is not in any spirit of gloom however that we invite our readers of the sixteenth volume in the review series, *Advances in Nuclear Science and Technology*, to take a long view.

The two principal roles of nuclear energy lie in the military sphere - not addressed as such in this series - and in the sphere of the centralised production of power, chiefly electricity generation. The immediate need for this latter has receded in the current era of restricted economies, vanishing growth rates and occasional surpluses of oil on the spot markets of the world. Nuclear energy has its most important role as an insurance against the hard times to come.

But will the demand come at a time when the current reactors with their heavy use of natural uranium feed stocks are to be used or in an era where other aspects of the fuel supply must be exploited? The time scale is sufficiently uncertain and the duration of the demand so unascertainable that a sensible forward policy must anticipate that by the time the major demand comes, the reasonably available natural uranium may have been largely consumed in the poor convertors of the current thermal fission programme. At that stage, the received wisdom of the fast breeder programme may prove, if not too little then at least too late to stretch out the depleted uranium stocks.

Fusion reactors are one promise of relief in such a situation. Significant work on the physical feasibility is now in progress with the commissioning of the Joint European Torus and the Princeton machine. But the direct exploitation of fusion at the engineering and economic stages presents a continuing challenge. The nature of this challenge in terms of insulating materials for the

extremes of high plasma and low cryogenic temperatures to be juxtaposed in such machines is indeed the subject of our first article by Banford, directing the attention of the research community to needs in this area.

If such machines, or their fission counterparts, are developed, then in the very long term (one suspects) the prospect of the direct exploitation of their energy via lasers is an intriguing one and we are grateful to Schneider and Hohl for their survey of the work already done and the prospects for nuclear pumped lasers.

It is however with sadness that we have to record the untimely death of one of our authors, Dr Frank Hohl, who passed away last year after a brief illness. He will be remembered for many things but we are glad that he should have been able to complete, with Professor Schneider, the substantial review of nuclear pumped lasers which this volume contains.

But if the problems of the economically viable fusion reactor raise too steep a barrier to be overcome immediately, then the symbiotic approach offers a new path forward. Readers of Greenspan's review of hybrid fission-fusion devices will be in a position to judge for themselves whether the combination of the advantages of both routes to nuclear power outweigh the combination of their joint disadvantages. Certainly it would be naive to think that fusion is free of the radioactivity problems associated with fission reactors, albeit of a different nature in exchanging say actinides for tritium. While the accident scenarios for both are distinct, both demand careful analysis.

In either case, accidents involve people as much as plant. The sound of escaping coolant from Three Mile Island reverberates still in the nuclear community and can be said to be a major cause for enforcing a longer and more penetrating look at nuclear power. The role of the nuclear operator has been thrown into sharper relief and here, in this present volume, we are glad to reflect the focus this has given to the design of the man-machine interface, an interface that in modern technology is too largely seen in the ubiquitous television screen or cathode ray tube. The short review by Danchak nevertheless embraces the many disciplines that must be brought together in the ergonomics of the operator-screen interface.

To look forward, we need a starting point. To survey both the ground near TMI and further horizons, we need a vantage point to cover our present ideas of radiation protection and health physics, given us here in the review by Roberts and Kelly. It is valuable in its historical perspective, in clarifying how we came to take up the ground we now stand upon, ready to look and, we may hope, move forward.

It remains for the editors to commend the volume as a whole to our audience who include we expect, both the tyro and the established professional in nuclear technology; to thank our Editorial Board for the assistance they have given to the Editors in selecting topics and writers for this volume; but chiefly of course to our authors for their labour in the vineyards. Vines for a fine vintage may take tens of years to develop. We should rather speak of planting walnut trees for a future generation in the breadth and depth of vision they have given us in this volume, allowing us to take a long and constructive view of the future.

J. D. Lewins
M. Becker

July 1983

CONTENTS

Electrical Insulation and Fusion Reactors

Hamish MacKinnon Banford

I.	Introduction.	1
II.	Fusion Environment.	2
III.	Materials and Radiation	19
IV.	General Discussion and Conclusion	54
V.	Acknowledgements.	60

The Human Factors of CRT Displays for Nuclear Power Plant Control

Michael M. Danchak

I.	Introduction.	75
II.	The Human Operator in Nuclear Process Control	77
III.	Fundamentals of CRT Display Systems	90
IV.	Effective CRT Display Design for Nuclear Process Control	100
V.	Summary	115
	References.	116

Nuclear Pumped Lasers

R. T. Schneider and F. Hohl

I.	Introduction.	123
II.	Physics of Nuclear Pumping.	133
III.	Experimental Research	149
IV.	Modelling of Nuclear-Pumped Lasers.	204
V.	Reactor Laser Systems	229
VI.	State-of-the-Art of Nuclear-Pumped Lasers	262
	References.	266

Fusion-Fission Hybrid Reactors

E. Greenspan

- I. Introduction.289
- II. Range of Characteristics Attainable from Hybrid Reactor Blankets295
- III. Blanket Design Considerations320
- IV. Hybrid Reactor Designs.383
- V. Alternative Fuel Hybrid Reactors.428
- VI. Multi-Purpose Hybrid Reactors446
- VII. Hybrid Reactors and the Energy Economy. . .454
- VIII. Concluding Remarks.475
- Acknowledgements.478
- References.479
- Appendix.494

Radiation Protection Standards: Their Development and Current Status

G. C. Roberts and G. N. Kelly

- I. Introduction.517
- II. Basic Standards for Radiological Protection.518
- III. The Practical Application of Standards. . .538
- IV. Current Issues.549
- V. Future Developments558
- References.561
- Glossary of Dosimetric Quantities and Units566

- Index569

CONTENTS OF VOLUME 10

- Optimal Control Applications in Nuclear Reactor Design and Operations, *W. B. Terney and D. C. Wade*
- Extrapolation Lengths in Pulsed Neutron Diffusion Measurements, *N. G. Sjöstrand*
- Thermodynamic Developments, *R. V. Hesketh*
- Kinetics of Nuclear System: Solution Methods for the Space-Time Dependent Neutron Diffusion Equation, *W. Werner*
- Review of Existing Codes for Loss-of-Coolant Accident Analysis, *Stanislav Fabic*

CONTENTS OF VOLUME 11

- Nuclear Physics Data for Reactor Kinetics, *J. Walker and D. R. Weaver*
- The Analysis of Reactor Noise: Measuring Statistical Fluctuations in Nuclear Systems, *N. Pacilio, A. Colombina, R. Mosiello, F. Morelli and V. M. Jorio*
- On-Line Computers in Nuclear Power Plants - A review, *M. W. Jervis*
- Fuel for the SGHWR, *D. O. Pickman, J. H. Gittus and K. M. Rose*
- The Nuclear Safety Research Reactor (NSRR) in Japan, *M. Ishikawa and T. Inabe*
- Practical Usage of Plutonium in Power Reactor Systems, *K. H. Peuchl*

CONTENTS OF VOLUME 11 (Continued)

Computer assisted Learning in Nuclear Engineering,
P. R. Smith

Nuclear Energy Centers, *M. J. McNelly*

CONTENTS OF VOLUME 12

Characteristic Ray Solutions of the Transport Equation,
H. D. Brough and C. T. Chudley

Heterogeneous Core Designs for Liquid Metal Fast Breeder
Reactors, *P. W. Dickson and R. A. Doncals*

Liner Insulation for Gas-Cooled Reactors,
B. N. Furber and J. Davidson

Outage Trends in Light Water Reactors, *E. T. Burns,*
R. R. Fullwood and R. C. Erdman

Synergetic Nuclear Energy Systems Concepts, *A. A. Harms*

Vapor Explosion Phenomena with Respect to Nuclear Reactor
Safety Assessment, *A. W. Cronenberg and R. Benz*

CONTENTS OF VOLUME 13

Radioactive Waste Disposal, *Horst Böhm and Klaus Kühn*

Response Matrix Methods, *Sten-Orjan Linkahe and Z. J. Weiss*

Finite Approximation to the Even-Parity Transport Equation,
E. E. Lewis

Advances in Two-Phase Flow Instrumentation, *R. T. Lahey*
and S. Benerjee

Bayesian Methods in Risk Assessment, *George Apostolakis*

CONTENTS OF VOLUME 14

- Introduction: Sensitivity and Uncertainty Analysis of
Reactor Performance Parameters, *C. R. Weisbin*
- Uncertainty in the Nuclear Data used for Reactor
Calculations, *R. W. Peeble*
- Computational Methodology and Associated Uncertainties,
E. Kujawski and C. R. Weisbin
- Integral Experiment Information for Fast Reactors,
P. J. Collins
- Sensitivity Functions for Uncertainty Analysis,
Ehud Greenspan
- Combination of Differential and Integral Data, *J. H. Marable,
C. R. Weisbin and G. de Saussure*
- New Developments in Sensitivity Theory, *Ehud Greenspan*

CONTENTS OF VOLUME 15

- Eigenvalue Problems for the Boltzmann Operator,
V. Protopopescu
- The Definition and Computation of Average Neutron Lifetimes,
Allen F. Henry
- Non-Linear Nuclear Stochastic Theory, *K. Saito*
- Fusion Reactor Development: A Review, *Weston M. Stacey, Jr.*
- Streaming in Lattices, *Ely M. Gelbard*

Volumes 1-9 of *Advances in Nuclear Science and Technology*
were published by Academic Press, New York.