BOOK REVIEW

Selection of books for review is based on the editor's opinions regarding possible reader interest and on the availability of the book to the editor. Occasional selections may include books on topics somewhat peripheral to the subject matter ordinarily considered acceptable.

Engineering Aspects of Thermonuclear Fusion Reactors

Editor	G. Casini
Publisher	Harwood Academic Publishers for the Commission of the European Communities (1982)
Pages	639
Price	$97.00
Reviewer	Kenneth R. Schultz

This book consists of the formal notes from a series of 17 lectures presented at a course on the engineering problems and technological requirements related to the development of fusion energy. The course was organized by the Joint Research Center of the European Communities at Ispra, Italy and took place in June 1980. The course was intended for engineers and scientists who wanted to acquire general information on the trends of fusion development.

The book focuses for the most part on the tokamak concept of magnetic fusion and is best suited for engineers and scientists working in the fusion field. The book is too long and detailed to serve as a general introductory article on fusion engineering and the various chapters presuppose some level of knowledge about fusion. There generally is not sufficient depth on any one subject to serve as a textbook. The chapters are of mixed scope. Some are rare gems of lasting value, others are descriptions of the present status of projects or designs and will be of limited time value.

The book was edited from lecture notes and as such is not a fully polished product. Some of the figures are a bit rough, a few typographical errors exist, and on occasion the English syntax is a bit unusual. These points, however, do not detract from the overall clarity of the book.

The various chapters are written by the leaders of the European fusion community and make the book a good window on the European fusion program and the references an introduction to the European fusion literature. The 17 chapters are reviewed briefly below.

1. *Basic Principles of Fusion Power—H. Knoepfel*

This chapter starts with nuclear binding energy and gives a brief sketch of the history of fission and fusion. Knoepfel shows how they have alternated being in the forefront of progress and suggests that it is now fusion's turn for significant strides. He presents 24 (!) possible fusion reactions before focusing on deuterium-tritium fusion. A series of point model plasma engineering equations is given with no derivation that the uninitiated would find difficult to follow. The closing section on fusion "chain reactions," that Knoepfel acknowledges are of no practical interest, appears out of place.

2. *The Tokamak Concept and Its Physics—H. Knoepfel*

This chapter gives a brief history of the tokamak concept, describes the configuration, and then defines a number of the familiar key plasma parameters, including q, j_{crit}, β, $\beta_{T_{max}}$, and plasma elongation. Also described are a number of the various plasma instabilities. I found it a very useful introduction to tokamak physics.

3. *Magnetic Field Evaluations—S. Bobbio*

Bobbio defines the magnetic fields of a tokamak—toroidal and poloidal—and derives simple models to calculate these. He derives the conditions for plasma equilibrium and the expressions for the vertical field needed to maintain the location of the plasma. Although he does a great deal of derivation, he does not start at a sufficiently basic level for the uninitiated to be able to follow easily. Because the equations are fundamental to tokamak fusion, I found this chapter to be very useful.

4. *Electromagnetic Systems—S. Bobbio*

Bobbio discusses each of the magnetic systems of a tokamak. He derives the power consumption for normal copper toroidal field coils, showing this to be very high for conventional fields and geometries. He derives the equations to design the equilibrium field (EF) and describes a technique to apply this within the other EF coil design constraints. Like Chap. 3, I found this to be a useful chapter of lasting value.

5. *Additional Heating at Reactor Level—M. Haegi*

Haegi shows the need for additional heating in tokamaks and then discusses the various options to get it—neutral beams, adiabatic compression, ion cyclotron resonance heating, and lower hybrid heating. Most of the discussion centers on neutral beam hardware. The discussion of radiofrequency heating is very brief. Generally, I found this chapter did not give enough discussion of either the physics or the engineering of heating methods and gives virtually no comparison of advantages and disadvantages among the various options.

6. *The Large Tokamaks—E. Bertolini*

Bertolini gives a very good introduction on the entire fusion energy subject—the need for energy, nuclear power, fusion, and tokamaks. He then gives a brief description of the present set of large tokamaks: Tokamak Fusion Test Reactor (TFTR), JT-60, Joint European Torus (JET), T-20, and International Tokamak Reactor. This includes tables of the major parameters (a, R, I_p, B_T, t_{pulse}) that are useful for future reference, and a number of pictures of various aspects of these machines, most of which are not.

7. *The JET Project–P. H. Rebut and B. J. Green*

They summarize the JET goal to produce a reactor level plasma, the plasma conditions this requires, and the means by which these can be achieved. They then summarize the present status of all the various components and systems. Some of these are pretty mundane but this did serve to make me more aware of the tremendous number of details that must be worried about for a large fusion project. They conclude with a discussion of the JET R&D needs. The chapter is interesting and has a lot of pictures of JET hardware, but will rapidly become dated.

8. *Power Supply Requirements–E. Bertolini*

Bertolini presents a very handy set of approximate equations for deriving the major characteristics of fusion reactor power supply systems, focusing on flywheel generators and transformer converters. He discusses energy storage and describes the power supply systems for JT-60, TFTR, and JET. He finishes with mention of future options, homopolar generators, and magnetohydrodynamic generators. This chapter has a lot of useful information but is the longest chapter in the book and is somewhat rambling and repetitive.

9. *First-Wall and Blanket Problems–G. Casini*

Casini discusses the first-wall and blanket requirements to breed tritium, recover energy, and withstand plasma exposure. He gives several examples that are design specific and should be qualified to avoid misunderstanding. He mentions materials damage by displacements per atom and gas production, but does not discuss the potentially serious effects they can have on material properties. Breeding material and coolant options are discussed and three recent designs are presented. A concern with this chapter is the very limited number of references. A great deal of material is covered in one chapter. This should be expanded in the future to two or three chapters.

10. *Technology of Superconducting Magnets–P. Komarek*

Komarek starts with the principles of superconductivity and stabilization techniques. I felt the need for more basics and explanation, however. He then discusses practical application of superconducting materials and summarizes developments in progress. He gives the specifications of all six coils of the Large Coil Project and also describes other projects, such as Torus 2 Supra, the Japan Atomic Energy Research Institute Cluster Test, and S/C poloidal field coils. This is a good chapter with excellent references and lasting value but could use more explanation of the basics.

11. *The Fuel Cycle–J. Darvas*

This chapter presents a clear description of the processes involved in the fuel flow system and the blanket tritium recovery system, with good references. Darvas, however, does not give many specifics; there are no basic equations describing tritium behavior and very few numbers. More specifics are needed.

12. *Remote Operations–J. T. D. Mitchell*

This chapter describes the servicing operations and the servicing machines fusion reactors will need, using the Culham Mark II design as an example. It contains good, solid, well thought-out advice on how to design a reactor for remote maintenance. A good set of references is given.

13. *Systems Integration–F. Farfaletti-Casali*

"Systems integration is the basis for producing a consistent and congruent configuration." This chapter is a very methodical step-by-step layout of the system design process. Farfaletti-Casali introduces a 16×16 matrix interface chart of the main fusion reactor systems and then focuses on the eight most critical interfaces. This chapter is a rare gem, a guideline that can be used to help ensure that reactor designs are fully integrated and self-consistent.

14. *The NET Experimental Reactor–R. Toschi*

The overall development of fusion includes the need for proof of scientific, technological, and engineering feasibility. The role of the Next European Torus (NET) is to satisfy the first two of these three needs. The NET objectives are defined, and its design guidelines and main parameters are derived. It is clear from the tentative nature of this chapter that the ideas for NET are still in the formative stages.

15. *Mirror Reactor Concepts–M. A. Hoffman*

This chapter gives an overview of the engineering aspects of mirror reactors. The plasma configuration of the tandem mirror has been changing rapidly in recent years so some of this material is already dated. An extensive list of references is given, most of them Lawrence Livermore National Laboratory reports.

16. *Inertial Confinement Fusion Reactors–M. A. Hoffman*

Hoffman focuses on the reactor aspects of inertial fusion, leaving the driver and pellet designs completely alone. The very complex energy deposition behavior and its effects on solid and liquid wall designs is described in some detail. An excellent set of references is given.

17. *Safety and Environmental Aspects–P. Rocco*

Rocco cites some of the International Commission on Radiological Protection general rules for radioactive material and then gives a very general discussion of safety design guidelines for tokamak reactors. He develops "safety requirements" for various containment barriers without any numerical justification for these requirements. While the outline of safety issues is very useful, it is important that we not attempt to impose safety requirements on fusion without firm reasons, based on numerical analysis, for doing so.

In summary, this book is interesting and useful. It presents in one place a reasonably complete overview of fusion engineering and would be an excellent place for someone to obtain an overall perspective. Several of the chapters have basic information that will be of lasting value on the fundamentals of fusion reactor engineering. The book presents the European Community fusion program and is valuable for non-European readers just to get that viewpoint. At $97.00 the book is not inexpensive, however, and I could not recommend that everyone rush out and buy one for their personal library.

Kenneth R. Schultz is manager of the Fusion Development and Technology Branch at GA Technologies in San Diego, California. He received BS and MS degrees in mechanical engineering from Stanford University and a PhD in nuclear engineering from the University of Florida in 1971. He has worked on the core physics design of high-temperature gas-cooled reactors and since 1975 has been involved with fusion reactor design studies and fusion technology experiments. He is the 1982/1983 chairman of the ANS Fusion Energy Division.