

# **The Essential CANDU**

**A textbook on the CANDU Nuclear Power Plant Technology**

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CANDU (short for CANada Deuterium Uranium)

[www.unene.ca/education/candu-textbook](http://www.unene.ca/education/candu-textbook)

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## Dedication

This textbook is dedicated to the students of CANDU everywhere.

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## Table of Contents

### Volume 1

Preface

Acknowledgments

Prologue - CANDU in Context – Dr. William J. Garland

Chapter 1 - Introduction to Nuclear Reactors - Dr. Robin Chaplin

Chapter 2 - Genealogy of CANDU Reactors - Dr. Robin Chaplin

Chapter 3 - Nuclear Processes and Neutron Physics - Dr. Guy Marleau

Chapter 4 - Reactor Statics - Dr. Benjamin Rouben and Dr. Eleodor Nichita

Chapter 5 - Reactor Dynamics - Dr. Eleodor Nichita and Dr. Benjamin Rouben

Chapter 6 - Thermalhydraulic Design - Dr. Nikola K. Popov

Chapter 7 - Thermalhydraulic Analysis - Dr. William J. Garland

Chapter 8 - Nuclear Plant Systems - Dr. Robin Chaplin

Chapter 9 - Nuclear Plant Operation - Dr. Robin Chaplin

Chapter 10 - Instrumentation and Control - Dr. G. Alan Hepburn

Chapter 11 - Electrical Systems - Dr. Jin Jiang

Author Biographies

Abbreviations

### Volume 2

Preface

Acknowledgments

Chapter 12 - Radiation Protection and Environmental Safety - Dr. Edward Waller

Chapter 13 - Reactor Safety Design and Safety Analysis - Dr. Victor G. Snell

Chapter 14 - Nuclear Plant Materials and Corrosion - Dr. Derek H. Lister and Dr. William G. Cook

Chapter 15 - Chemistry in CANDU Process Systems - Dr. William G. Cook and Dr. Derek H. Lister

Chapter 16 - Regulatory Requirements and Licensing – Dr. Victor G. Snell and Dr Nikola K. Popov

Chapter 17 - Fuel - Mr. Mukesh Tayal and Mr. Milan Gacesa

Chapter 18 - Fuel Cycles - Mr. Mukesh Tayal and Mr. Milan Gacesa

Chapter 19 - Storage and Disposal of Irradiated Fuel - Mr. Milan Gacesa and Mr. Mukesh Tayal

Chapter 20 - Fuel Handling and Storage- Ms. Diane Damario

Chapter 21 - CANDU In-Core Fuel Management - Dr. Benjamin Rouben

Author Biographies

Abbreviations

## Preface

There has long been a need for a CANDU<sup>1</sup> nuclear power plant textbook suitable for students, educators, trainers and working professionals at a target level of senior undergraduate year university engineering and science. The aim is to provide a concise, and consistently told, root storyline that will enable those new to CANDU, whether a student, a manager, a teacher / trainer, a journalist or a discipline area specialist, to learn about CANDU as an overall system and to delve into any specific area as desired. This supports the agile deployment of personnel into the industry and redeployment throughout the industry. Early on it was decided that the textbook would be public domain available online in pdf form under the UNENE banner along with associated prerequisite material and further reading. This web material can be copied to CDs for distribution or printed in book form, yet is easily updated and expanded. It is to be a living document appearing in the form of editions for revision tracking purposes.

*The Essential CANDU* is a textbook about nuclear science and engineering pertaining to CANDU reactors using CANDU as the reference design. This distinguishes it from comparable textbooks based on PWR reactors. This is not a product description of CANDU per se. The book will emphasize theory over other aspects of nuclear science.

This is a textbook about CANDU nuclear reactor and power plant engineering, not just the reactor physics of the core. While it is true that the reactor is certainly the distinguishing feature of the plant, it is hardly the whole story. Within the Nuclear Steam Supply System (NSSS) there are some 225 systems, but only a few can be covered explicitly in the book. This is a book about the nuclear and related bits that constitute the key bits that define nuclear engineering, not the many associated disciplines per se.

CANDU 6 was chosen as the reference design. Specifically it was agreed that Pt. Lepreau (post refurbishment) would be used as the default reference design. This does not preclude reference to multi-unit designs, single-unit variants and future designs as appropriate.

It is the root story line that glues a textbook together and guides what material is to be emphasized or deemphasized. The steam generator (and the associated heat duty diagram) is the central node of the station. It is the steam generator that dominates the overall plant dynamics. The primary side temperature floats on top of the steam drum temperature with just enough  $\Delta T$  to transfer the heat from the primary side to the secondary side as discussed in Chapter 6. If the drum pressure (hence temperature) jumps, the primary side jumps to suit, affecting primary temps, fuel temps, margins, reactivity feedbacks, etc. But clearly the overall system behavior is very much dependent on the characteristics and limits of the various sub-systems and components. In short, reactor physics – the inevitable focus of typical reactor texts – is important to be sure and is covered herein. But there is so much more to a nuclear plant than reactor physics that we would be remiss in telling the CANDU story if we were to overlook the broader

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1 CANDU (short for CANada Deuterium Uranium)

picture.

There are a number of existing documents and products that cover significant parts of the CANDU story. UNENE itself hosts a dozen or so graduate level courses that are significant resources for preparing a CANDU textbook. See [www.unene.ca](http://www.unene.ca) for details on those courses. And of course there are many other existing university nuclear and nuclear related courses in Canada and elsewhere (see for instance <http://nuclearcanada.ca>). The CANTEACH repository at <http://canteach.candu.org> contains a large number of legacy CANDU documents, albeit largely descriptive. Significant training, design, analysis and operation documents exist within AECL (and now Candu Energy) , Ontario Power Generation, Bruce Power, the CNSC and other organizations comprising the Canadian nuclear enterprise. *The Essential CANDU*, with its educational focus is complementary to all that.

As Editor-in-Chief it has been my pleasure to work with the authors as they laboured well beyond expectations. I have worked for years on course development with Ben Rouben and Dorin Nichita on reactor physics, Nik Popov on thermalhydraulics, Victor Snell on safety, and George Bereznai on plant systems and operations. It is truly satisfying to see the fruits of that labour appearing in the form of this text. On a more administrative level I have worked with Robin Chaplin (thermodynamics), Derick Lister and Willy Cook (Chemistry and Corrosion), Jin Jiang (Electrical) as they developed and delivered courses for UNENE. From its inception in 2000, UNENE has been a world class and world leading nuclear network. The aforementioned people are part of the UNENE team. Their research and educational contributions are a big part of that success. Guy Marleau (reactor physics), Al Hepburn (I&C), Ed Waller (Health Physics), Milan Gacesa and Mukesh Tayal (Fuel topics), and Ms. Diane Damario (Fuel Handling) are all well known in their areas. It was a pleasure to work with them on this project. Old and new colleagues and friends - it is an honour to have worked with them all.

Of course it is not just the authors that deserve special mention. As they would readily attest, it took many creative and hard working professionals to build our Canadian Nuclear Enterprise – generations of them going all the way back to the early roots of CANDU. They are the past and present colleagues, professors, managers, researchers, students and others that form our foundation and upon whose work we are but modest reporters. Two particular subsets of those are the reviewers of this text and the Working Group for this project. Scholars and authors in their own right, they have overseen and guided the development of this work. It was a comforting ‘defense in depth’. The reviewers are acknowledged at the end of each chapter. We wish to sincerely thank the following Working Group members for their guidance and technical oversight:

- George Bereznai (University of Ontario Institute of Technology)
- Basma Shalaby (UNENE)
- John Luxat (McMaster University)
- Mahesh Pandey (University of Waterloo)
- Jatin Nathwani (University of Waterloo)
- Esam Hussein (University of Regina)

I have worked with each of the Working Group members as colleagues on and off over the years going back to the 70’s. George, Basma, others and I bemoaned the lack of a comprehensive

CANDU textbook from the beginning. George and I even mapped out our vast plans (with half-vast ideas) and did manage over time to guide a number of courses through to completion, as did other professors. The interactions and the innumerable chats with these and many other colleagues through the years collectively set the backdrop for this textbook. But it was Basma, when stepping in as President of UNENE as I stepped out, who said: “Come on Bill. Let’s go.” And so, we did. Thanks Basma for that final prod.

This textbook, as large and comprehensive as it is, is far from complete. Each topic is a book, perhaps several books, on its own. I hope it at least encourages others to build on this modest start. It is worth noting too that the written word, try as we might, does not capture well the tacit knowledge, the working knowledge, that the working professionals have. This textbook is but a humble complement to that. The very process of creating this textbook, however, creates a learning environment for the authors and we found a considerable sharing of expertise as we prepared the chapters. This will apply to future authors as well. So, “Come on, let’s go.”

Finally, what can we say of our long suffering families but a truly heartfelt thanks. We shall be forever in your debt. Thank you all.

Bill Garland  
Professor Emeritus  
Department of Engineering Physics  
McMaster University



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