

# Contents

PREFACE

ix

## Chapter 1. Xenon in Nuclear Reactors. Dynamic Programming I

1.1. Introduction and Historical Review	1
1.2. Xenon Spatial Oscillations	3
1.3. Fission-Product Poison Production	4
1.4. Absorption Cross Section of Xenon	6
1.5. Thermal-Reactor Xenon Difficulties	7
1.6. Conventional Approaches to Circumvent Xenon	11
1.7. Dynamic Programming	12
1.8. Principle of Optimality and Two Examples	13

## Chapter 2. Reactor Poisons. Dynamic Programming II

2.1. Long-Term Fission-Product Poisons	21
2.2. Poison Reactivity	23
2.3. Xenon Spatial Oscillations Revisited	24
2.4. Discrete Optimal Control	25
2.5. Averaged Control and Terminal Control	27
2.6. Impact on Linearized Control Theory	30

### Chapter 3. **Poison Kinetics and Xenon Shutdown. Dynamic Programming III**

3.1. Reactor-Poison Kinetics Equations	34
3.2. Immediate Flux Shutdown	39
3.3. Xenon and Samarium after Protracted Shutdown	41
3.4. Xenon Minimum and Minimax Problem	
Statements	43
3.5. Constraints	44
3.6. Dynamic Programming. Absolute Value and Minimax Criteria	47

### Chapter 4. **The Maximum Principle**

4.1. Introduction	52
4.2. Two Examples	56
4.3. Bang-Bang Control	59
4.4. Continuous and Bang-Bang Control	61
4.5. Optimal Orbital-Rendezvous Control	63
4.6. Simplified Xenon Shutdown Control	64
4.7. The Two-Point Boundary-Value Problem	67

### Chapter 5. **Minimum and Minimax Xenon Shutdown**

5.1. Mathematical Restatement of Optimal Xenon Shutdown	69
5.2. Mathematical Restatement of Constraints	71
5.3. Dynamic-Programming Functional Equation	73
5.4. Derivation of Bellman's Equation	75
5.5. Bang-Bang Control Dilemma	77
5.6. Dynamic-Programming versus Maximum-Principle Optimal Shutdown Solutions	80

**Chapter 6. Computational Aspects**

6.1. Introduction and Calculation of $F_k$ Tables	87
6.2. The Xenon Override Constraint	90
6.3. DYNPROG and COAST Input-Data Format	91
6.A. Appendix to Chapter 6	93

**Chapter 7. Experimental Verification**

7.1. Introduction and IRR-1 Reactor Description	102
7.2. Immediate Shutdown of IRR-1 to Zero Flux	103
7.3. Shutdown to Nonzero Power Levels	107
7.4. Xenon and Iodine Buildup and Decay	109
7.5. Experimental Results	115
7.A. Appendix to Chapter 7	118

**Chapter 8. Results and Conclusions**

8.1. Introduction and Xenon Unconstrained Extremals	121
8.2. Xenon Constrained Extremals	124
8.3. Interdependence of Flux and Xenon Constraints	126
8.4. Two Types of Optimal Shutdown Payoffs	127
8.5. Short Allowable Shutdown Durations	129
8.6. Strongly Limited Xenon Override Shutdown	130
8.7. Conclusions of Experimental Investigation	136

**Chapter 9. Summary and Equivalences**

9.1. Reprise	140
9.2. Equivalence between the Optimality Principle and the Maximum Principle	143

9.3. Comparison of Optimal Shutdown Criteria	147
9.4. Other Equivalences	149
9.5. Higher-Order-System Formulations	152

<b>References</b>	155
-------------------	-----

**Bibliography**

Document Glossary	157
Xenon Bibliography	158

INDEX	165
-------	-----