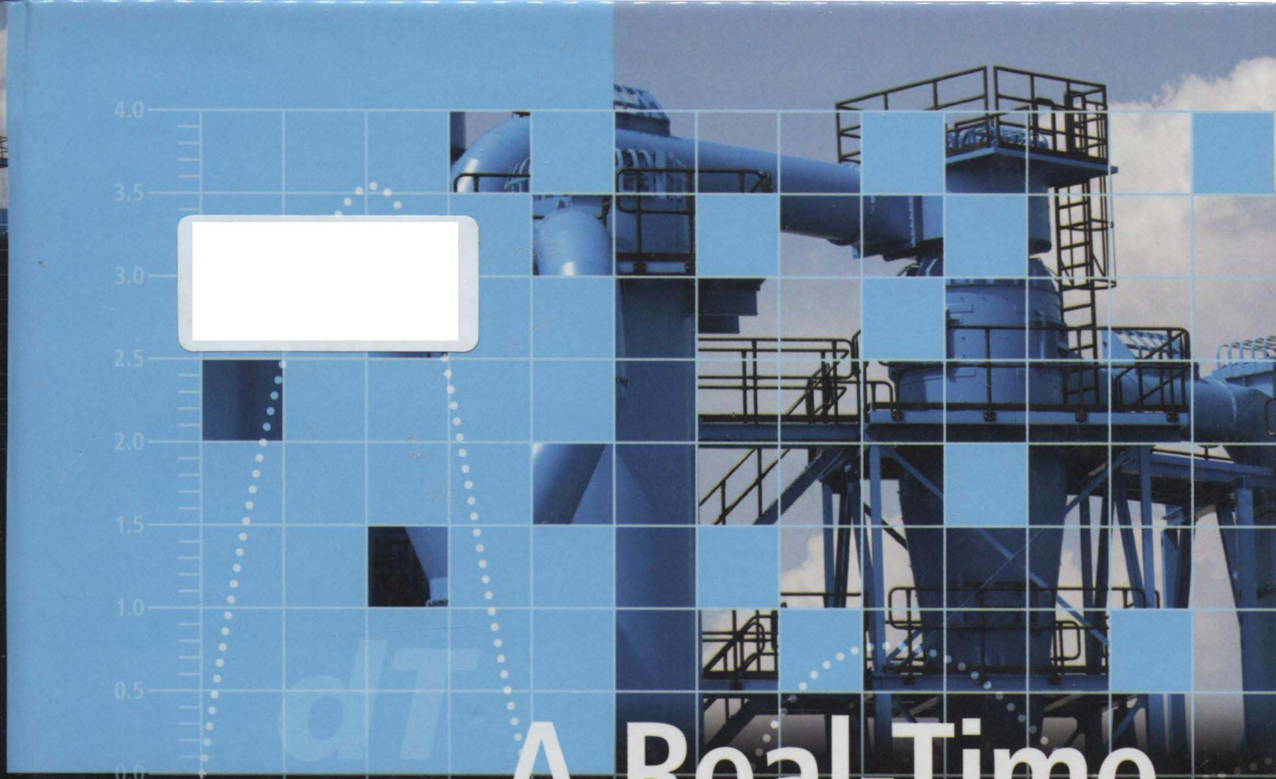

A Real-Time Approach to Process Control

Third Edition

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Donald P. Mahoney
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WILEY

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Author Biographies

William Svrcek is a retired (2009) professor of Chemical and Petroleum Engineering of the University of Calgary, Alberta, Canada, and is currently a professor emeritus of the University of Calgary. He received his B.Sc. (1962) and Ph.D. (1967) degrees in chemical engineering from the University of Alberta, Edmonton. Prior to joining the University of Calgary he worked for Monsanto Company as a senior systems engineer and as an associate professor (1970–1975) in the Department of Biochemical and Chemical Engineering at the University of Western Ontario, London, Ontario. Dr. Svrcek's teaching and research interests centre on process simulation control and design. He has authored or co-authored over 200 technical articles/reports and has supervised over 50 graduate students. He has been involved for many years in teaching the continuing education course titled 'Computer Aided Process Design – Oil and Gas Processing' that has been presented worldwide. This course was modified to include not only steady-state simulation but also dynamic simulation and control strategy development and verification. Dr. Svrcek was also a senior partner in Hyprotech, now part of Aspen Technology, from its incorporation in 1976. As a principal, director and president (1981–1993) he was instrumental in establishing Hyprotech as a leading international process simulation software company. He is currently providing leadership and vision in process simulation software as the president of Virtual Materials Group Inc. He is a registered professional engineer in Alberta and a member of professional societies that include the Canadian Society for Chemical Engineering, American Institute for Chemical Engineers and the Gas Processors Association of Canada.

Donald Mahoney is vice president and global head of chemicals for SAP, the world's largest enterprise software company. Mr. Mahoney earned a bachelor's degree in mechanical engineering from Penn State, a master's degree in control theory from Purdue University and an MBA from the University of Delaware's Lerner College of Business and Economics. Mr. Mahoney has held research and teaching positions at the US Navy's Applied Research Lab at University Park, and at Purdue University, where he was awarded the department's highest honour for outstanding teaching. He has also lectured extensively on process simulation and control topics and has published a number of journal articles in the field. Prior to joining SAP, Mr. Mahoney was a business software entrepreneur and vice president with Hyprotech Ltd, where he led the introduction and launch of more than half a dozen process design, modelling and optimization software products. He also held industrial positions at General Motors and DuPont as a control systems engineer and process modelling and control consultant. While at DuPont, Mr. Mahoney was involved in the development and support of the chemical industry's first object-oriented dynamic simulation package, TMODS™.

Brent Young is a professor in the Department of Chemical and Materials Engineering at the University of Auckland and is currently the head of department. He also holds the position of chair in Food and Process Engineering and is the director of the Industrial Information and Control Centre. He received his B.E. (1986) and Ph.D. (1993) degrees in chemical and process engineering from the University of Canterbury, New Zealand. Prior to his graduate studies, he worked as a chemical engineer for Ravensdown Fertilizer Coop's Super Phosphate Plant in Christchurch. In 1991, he joined the University of Technology in Sydney, Australia, as a lecturer, continuing his research in the areas of modelling and control of processes, particularly industrial processes. He was then an associate professor of Chemical and Petroleum Engineering at the University of Calgary from late 1998 to the end of 2005. He joined the University of Auckland in January 2006. He is a registered professional engineer and a fellow of the Institution of Chemical Engineers. His research, teaching and practice are centred on two major areas, process simulation and control, and process design and development.

Foreword and Endorsements

As plants are pushed beyond nameplate, it is increasingly obvious that the importance of process control has grown to the point where it is the single biggest leverage point for increasing manufacturing capacity and efficiency. The process engineer, who is best posed to use his process knowledge for getting the most from better control, typically has had just a single course in control. Furthermore, the approach was based on theory rather than on practice, and was immersed in the frequency domain. Real processes are diverse and complex and the view into their behavior is by means of real time trend recordings. This book provides a building block real time approach to understanding and improving process control systems. Practical examples and workshops using models drive home the points and make the principles much more accessible and applicable.

—Gregory K. McMillan, Principal Consultant, CDI Process & Industrial, Emerson

At the undergraduate chemical engineering level, the traditional, highly mathematical approach misses the point of what knowledge of control and dynamics the practicing process engineer requires. If BS graduates in chemical engineering simply understood the basics of time based process dynamics and control (capacitance, dead time, PID control action and controller tuning, inventory, throughput, and distillation control), the impact on process design and plant operations throughout the CPI would be immense. Today, these skills are among the least developed in BS chemical engineering graduates, despite having taken the requisite traditional process control course. This text is particularly suitable for any college, university, or technical training program seeking to provide its graduates with a truly practical and applied background in process dynamics and control. With today's widespread commercial availability of high fidelity process simulation software, the understanding gained from this text can be immediately and directly applied.

—Thomas C. Hanson, Senior Process Modeling and
Advanced Process Control Specialist, Praxair, Inc.

Several years ago, a recruiter from a major chemical company told me that his company was hesitant to interview students that indicated a first preference in the area of process control because his company 'did not have any jobs that made use of Laplace transforms and frequency domain skills'. This was an excellent example of the mismatch between what is frequently taught in universities, and what often gets applied in industry. After teaching chemical process control for over 30 years, I feel strongly that good process control is synonymous with good chemical engineering. Industry would be well served if all chemical engineering graduates, regardless of career paths, had a better, more practical working knowledge of process dynamics and control. I think the approach taken in this text is right on target, and is consistent with how we teach at the University of Tennessee. It provides a good hands-on feel for process dynamics and process control, but more importantly, it presents these concepts as fundamentals of chemical engineering. For undergraduate programs looking to transition away from the traditional mathematical-based approach to a more applied, hands-on approach, this text will be an invaluable aid.

—Charles F. Moore, Professor of Chemical Engineering, University of Tennessee

What BS degree chemical engineers need is a base level understanding of differential equations, process dynamics, dynamic modeling of the basic unit operations (in the time domain), basic control algorithms (such as PID), cascade structures and feed forward structures. With these basic tools and an understanding of how to apply them, they can solve most of their control problems themselves. What they do not need is the theory and mathematics that usually surround the teaching of process control such as frequency domain analysis. Graduate education in process control is the place to introduce these concepts.

—James J. Downs, Senior Engineering Associate, Eastman Chemical Company

The control engineering profession has produced shelves of books. For the most part they have been written to support academic courses and are authored by lecturers who teach the subject using theory not relevant to the process industry and mathematics that most students find daunting. This book belongs on the shelf labelled 'Process Control for Process Engineers'. It is one of a hopefully growing collection written by authors who recognize that the practical application of control techniques in the process industry is a quite different subject.

The money invested in process control by the process industry has grown substantially over the last few decades. Now around a quarter of the construction cost of a modern plant is associated with its control and optimization. The industry needs professionals that properly understand the technology and what it can achieve. But highly theoretical courses dissuade most process engineering graduates from entering the control engineering profession. Those that do find rewarding that they can have an almost immediate impact on process performance.

This book provides a valuable introduction. It will help students appreciate the true nature of the subject and enable them to make an informed decision about whether to follow it in depth.

—Myke King, Director WhiteHouse Consulting, England

Preface

For decades, the subject of control theory has been taught using transfer functions, frequency-domain analysis and Laplace transform mathematics. For linear systems – like those from the electromechanical areas from which these classical control techniques emerged – this approach is well suited. As an approach to the control of chemical processes, which are often characterized by non-linearity and large doses of dead time, classical control techniques have some limitations.

In today's simulation-rich environment, the right combination of hardware and software is available to implement a 'hands-on' approach to process control system design. Engineers and students alike are now able to experiment on virtual plants that capture the important non-idealities of the real world and readily test even the most outlandish of control structures without resorting to non-intuitive mathematics or to placing real plants at risk.

Thus, the basis of this text is to provide a practical, hands-on introduction to the topic of process control by using only time-based representations of the process and the associated instrumentation and control. We believe this book is the first to treat the topic without relying at all upon Laplace transforms and the classical, frequency-domain techniques. For those students wishing to advance their knowledge of process control beyond this first, introductory exposure, we highly recommend understanding, even mastering, the classical techniques. However, as an introductory treatment of the topic, and for those chemical engineers not wishing to specialize in process control, but rather to extract something practical and applicable, we believe our approach hits the mark.

This text is organized into a framework that provides relevant theory, along with a series of hands-on workshops that employ computer simulations that test and allow for exploration of the theory. Chapter 1 provides a historical overview of the field. Chapter 2 introduces the very important and often overlooked topic of instrumentation. In Chapter 3, we ground the reader in some of the basics of single input/single output (SISO) systems. Feedback control, the elements of control loops, system dynamics including capacitance and dead time and system modelling are introduced here. Chapter 4 highlights the various PID control modes and provides a framework for understanding control loop design and tuning. Chapter 5 focuses specifically on tuning. Armed with an understanding of feedback control, control loop structures and tuning, Chapter 6 introduces some more advanced control configurations including feed forward, cascade and override control. Chapter 7 provides some practical rules of thumb for designing and tuning the more common control loops found in industry. In Chapter 8, we tackle a more complex control problem: the control of distillation columns. As with the rest of this text, a combination of theory and applied methodology is used to provide a practical treatment to this complex topic. Chapter 9 introduces the concept of multiple loop controllers. In Chapter 10, we take a look at some of the important issues relating to the plant-wide control problem. New in the third edition, Chapter 11 provides an introduction to Model Predictive Control (MPC). Also in this third edition, we have included a brief overview of the Fieldbus industrial network system, included in the Appendix. Finally, up-to-date information on computer simulation for the workshops and powerpoint slides can be found on the book web site http://www.wiley.com/go/svrcek-real-time-3e.

While this text is designed as an introductory course on process control for senior university students in the chemical engineering curriculum, we believe this text will serve as a valuable desk reference for practicing chemical engineers and as a text for technical colleges.

We believe the era of real-time, simulation-based instruction of chemical process control has arrived. We hope you'll agree! We wish you every success as you begin to learn more about this exciting and ever-changing field. Your comments on and suggestions for improving this textbook are most welcome.

Acknowledgements

It would be impossible to mention all of the individuals who contributed to the ideas that form the background of this text. Over the past 5 years, we have interacted with many students, academics and, perhaps most importantly, practitioners in the field of process control. This, combined with the more than 50 years of cumulative experience among the authors, has led to what we believe is a uniquely practical first encounter with the discipline of chemical process control.

Some who deserve special mention for their influence include Björn Tyréus and Ed Longwell from DuPont and Paul Fruehauf from Applied Control Engineering. These gentlemen share a passion for the field and a commitment to the practical approach to both teaching and practicing process control.

As with any text, many more names were involved in its creation than the three printed on the cover. To those who put in such generous effort to help make this text a reality, we express our sincerest of thanks.

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