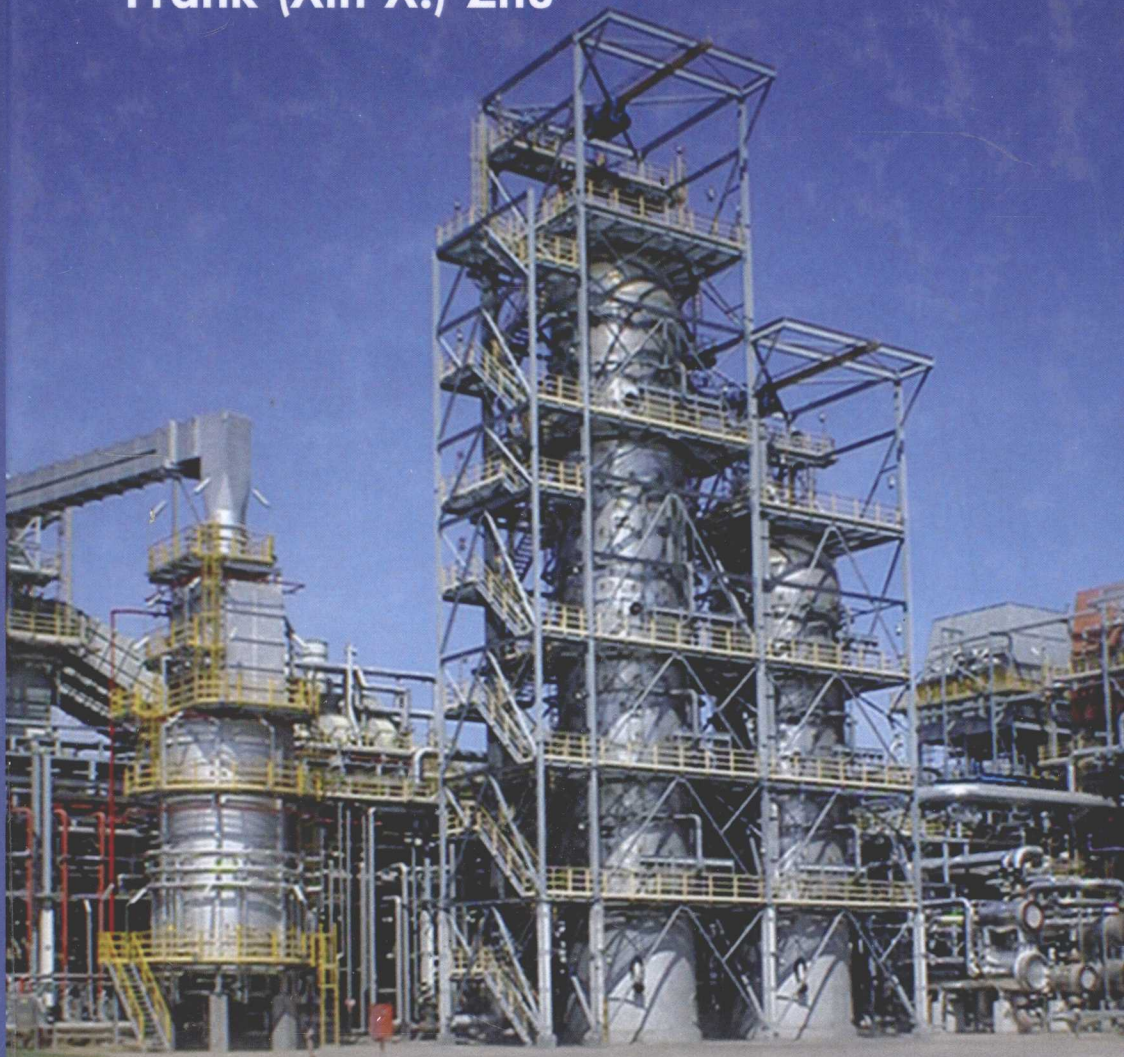
Energy and Process Optimization for the Process Industries

Frank (Xin X.) Zhu



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To Jane, Kathy, and Joshua

These three remain: faith, hope, and love.
The greatest of these is love.
1 Corinthians 13:13

PREFACE

In recent years, there has been an increased emphasis on industrial energy optimization. However, there are no dedicated books available to discuss basic concepts, provide practical methods, and explain industrial application procedures. This book is written to fill this gap with the following people in mind: managers, engineers, and operators working in the process industries. The book is aimed at providing practical tools to people who face challenges and wish to find opportunities for improved processing energy efficiency. I hope that this book is able to convey concepts, theories, and methods in a straightforward and practical manner.

With these objectives in mind, the focal discussions in this book center around five kinds of energy improvement opportunities. The first is minimizing heat losses via diligence. In reality, steam generated in the boiler house is distributed through an extensive network of steam pipelines to end users. The losses in steam distribution can be 10–20% of fuel fired in boilers. Hence, the net boiler efficiency could be 10–20% lower from the user's point of view.

The second is operation improvement opportunities, which occur due to the age of processes, the nature of operation variations. This usually involves establishing the best operation practices and optimizing process conditions. The third opportunity comes from improved heat recovery within and across process units, which requires design changes to process flow schemes and heat exchange schemes. The fourth is the use of state-of-the-art processes and equipment technology for enhanced processing efficiency. The fifth and final opportunity comes from better operation and planning of the energy supply system. In this book, these opportunities will be discussed and the methods for opportunity identification, assessment, and implementation will be introduced.

As the book covers a wide range of topics, I have attempted to organize the materials in such a way that aids the reader to locate the relevant materials quickly, to be able to understand them readily, and to apply them in the right context. Furthermore, the structure of the book is carefully designed to help readers avoid losing sight of the forest for the trees. The book starts with a provision of an overall context of the process energy optimization, followed by concepts and theory to gain a basic understanding of the energy metrics, gradually transitions to practical assessment methods from equipment- to system-based evaluations, and culminates in establishing an effective energy management system to sustain the benefits. Therefore, the features of material organizations need to be explained:

- An overview of process energy optimization is provided in Chapter 1. Basic concepts for process energy efficiency are introduced in Chapters 2–4 in Part 1. These concepts include energy intensity for determining process-specific energy use, energy benchmarking for setting the energy baseline and identifying the improvement gap, and key energy indicators for determining what operating parameters to monitor and what are their operating targets.
- Energy assessment methods are presented in Part 2. Chapter 5 focuses on reliable and efficient operation for process-fired heaters, while Chapter 6 discusses process energy loss analysis. Chapters 7 and 8 are dedicated to heat exchanger performance assessment as well as fouling mitigation. Methods for heat recovery targeting and retrofit design are explained in Chapters 9 and 10, while process integration methods are illustrated in Chapter 11.
- Part 3 is dedicated to process assessment. The concept of operating window for fractionation is introduced in Chapter 12 where the calculation methods for determining the operating window are explained. Fractionation system assessment and optimization are discussed in Chapters 13 and 14.
- The steam and power system must supply energy in an efficient manner if one wishes to achieve high energy efficiency for an overall processing site. Thus, methods for steam and power system assessment and optimization are provided in Part 4. Steam and power system modeling is explained in Chapter 15. Chapter 16 covers steam and power balances. Chapter 17 discusses practical steam pricing methods. Chapter 18 focuses on steam system benchmarking. By putting the models and opportunities together, Chapter 19 discusses how to build mathematical models for steam and power optimization.
- Finally, Part 5 is dedicated to techno-economical analysis of energy modifications as well as establishing an effective energy management system. To avoid bad investment, true benefits must be determined by considering outside system battery limit conditions and process variations, which are discussed in Chapters 20 and 21. The goal of the capital project evaluation is to achieve minimum investment cost. The key to achieving this goal is to explore alternative design options for each improvement idea and find economical solutions to overcome process/equipment limits. Detailed discussions are given in Chapter 22. The last chapter, Chapter 23, condenses the ideas presented in the other

chapters by explaining how to establish an effective energy management system to sustain the benefits gained from implementation through a case study.

It is my sincere hope that readers will find the methods and techniques discussed herein useful for analysis, optimization, engineering design, and monitoring, which are required to identify, assess, implement, and sustain energy improvement opportunities. More importantly, I hope that this book can help readers build mental models in terms of key parameters and their limits and interactions. You can then revisit these methods whenever you need them.

Clearly, it was not a small effort to write this book; but it was the strong need of practical methods for helping people to improving industrial energy efficiency that spurred me to writing. In this endeavor, I owe an enormous debt of gratitude to many colleagues at UOP and Honeywell for their generous support to this effort. First of all, I would like to mention Geoff Miller, vice president of UOP, who has provided encouragement and support. I am very grateful to many colleagues for constructive suggestions and comments on the materials contained in this book, and I apologize if any names are unmentioned. I would especially like to thank John Petri for his critical readings of Chapter 4, Darren Le Geyt and Dennis Clary for Chapter 5, Phil Daly and Lillian Huppler for Chapter 6, Zhanping (Ping) Xu for Chapter 12, and Chuck Welch for Chapter 15; their comments have improved these chapters. Tom King provided meticulous line-by-line reading of the entire first draft and identified pedagogical lapses, typos, better expressions, and better sources of information. My sincere gratitude also goes to Charles Griswold, Margaret (Peg) Stine, and Mark James for their review of the book. I would like to thank all of my colleagues for their help with the book and my debt to them is very great, but I would like to stress that any deficiencies are my responsibility. This book reflects my own opinions and not that of UOP and Honeywell.

I would also like to thank my co-publishers, AIChE and John Wiley, for their help. Special thanks go to Steve Smith at AIChE and Michael Leventhal at John Wiley for guidance. The copyediting and typesetting by Vibhu Dubey at Thomson Digital is very helpful in polishing the book.

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FRANK ZHU

Long Grove, Illinois, USA
May 7, 2013

CONTENTS

PART 1

BASIC CONCEPTS AND THEORY

1

OVERVIEW OF THIS BOOK

1.1 INTRODUCTION

Energy management is a buzzword nowadays. What is the objective of energy management in the process industry? It is not simply energy minimization. The ultimate goal of energy management is to control energy usage in the most efficient manner to make production more economical and efficient. To achieve this goal, energy use must be optimized with the same rigor as how product yields and process safety are managed.

The time of "let the plant engineers do their technical work" is long gone. The reduction of the technical workforce due to automation and technology advances has also increased the level of responsibility on business management of plant operations, often resulting in fewer workers taking on more tasks. Furthermore, it is often the case that plant managers and engineers are ill-prepared to take on widespread responsibilities, particularly when working under time pressures. This in turn results in their devoting less time on plant operation and equipment reliability and maintenance. Therefore, the current challenge for energy optimization is: How can we develop effective enablers to support engineers and management?

In addition, plant management and engineers are presented with modern management concepts and techniques. Not all these methods are easily translatable or applicable to any given company. Even if implemented, some of these methods require tailor-made revisions to fit into specific applications. The challenge here becomes: Which methods should be selected and how to implement them for specific circumstances?

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