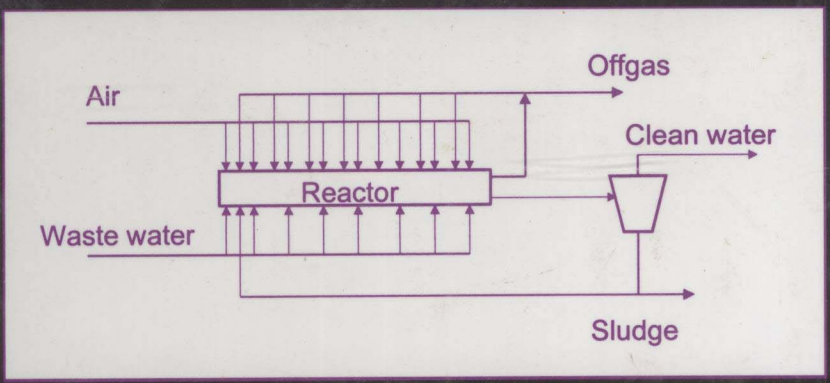
RE-ENGINEERING THE CHEMICAL PROCESSING PLANT

Process Intensification



edited by
Andrzej Stankiewicz
Jacob A. Moulijn

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DSM Research
Geleen, and
Delft University of Technology
Delft, The Netherlands

Jacob A. Moulijn

Delft University of Technology
Delft, The Netherlands

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Preface

The book you are about to read will introduce you to modern ways of re-engineering the chemical processing plant by means of Process Intensification (PI).

The story behind this book had begun with the paper *Process Intensification: Transforming Chemical Engineering*, which we published in the millennium issue of Chemical Engineering Progress (January 2000). After a pretty enthusiastic response to our paper by the chemical engineering community, Marcel Dekker proposed to us writing a book on that subject. After some discussions we came to the conclusion that it was not a good idea to write the entire book ourselves because, as you will see next, Process Intensification is a very broad discipline and includes many diverse expertise fields. So, instead of writing all chapters on our own, we have invited a number of prominent experts in various areas of Process Intensification, both from industry and from academia, to contribute to what now has become the world's first book on that subject.

The principal aim of this highly practice-oriented book is to illustrate the current developments and the frontline research in the area of Process Intensification. The book is primarily intended for engineers, technologists and researchers in chemical, biochemical and engineering companies, who are involved in process design and development and are interested in learning more about equipment and techniques that may bring quantum-leap improvements to their technologies. Also for others working in the forefront of process design and

development it is intended to be inspiring, in particular for the chemical engineering community in the universities and the National Laboratories. We hope that it will contribute to a better image of the chemical industry and even play a role in attracting more high-quality, motivated students to the discipline. The book may also be beneficial to R&D managerial personnel who wish to have a broader understanding of the principles and methodology of Process Intensification and gain the up-to-date knowledge of the emerging novel equipment and processing methods that could help to achieve technological breakthroughs in the processes at their companies.

The book has a certain logical structure that can be inferred from scanning the individual chapter headings. Chapter 1 introduces the reader into the genesis, philosophy and principles of Process Intensification and discusses its dimension and structure. It provides general information on process-intensifying equipment and methods and gives some examples of their application on the commercial scale. The three subsequent chapters describe selected types of the PI-equipment. Most of that equipment have already been successfully implemented on the commercial scale or is ready for implementation. Chapters 2 and 3 are devoted to the rotating equipment, *rotating packed beds* and *spinning disk reactors*, in which the use of high gravity fields leads to spectacular miniaturization of the processing units. Chapter 4 in turn describes the technology, design and application of *compact* and *multifunctional heat exchangers*. The next three chapters show how bringing certain structures in various scales of chemical processing environment can boost process efficiency, by dramatically improving mixing, heat and mass transfer. Various types and scales of such structuring are presented: *microreactors* in Chapter 5, large-scale *structured catalysts and reactors* in Chapter 6 and *inline mixing equipment* in Chapter 7. Following that "hardware" part of the book, its next four chapters focus on some important *methods* that can be used for intensification of chemical processes. Chapter 8 presents the application aspects of functional integration of reaction and separation into *reactive separation* systems, or integration of different separative techniques into *hybrid separations*. In Chapter 9 the modeling issues of the reactive separation systems are discussed. Chapter 10 discusses some aspects of the integration of reaction and heat transfer in *multifunctional reactors*, while Chapter 11 focuses on the application of *process synthesis* principles to the optimal design of integrated chemical processing plants. The final three chapters of the book address more general issues of Process Intensification. Chapter 12, based on the experiences within DSM, shows how the PI-principles can be applied in the industrial environment for redesigning and development of process-intensive chemical plants, while Chapters 13 and 14 focus respectively on safety and sustainability aspects of PI.

The chemical industry skyline in the 21st Century is changing. New highly efficient devices have already begun replacing the tens-of-meters high reactors and separation columns. In the still denser populated world inhabited by the still more

educated and environment-conscious society, there will be no room (literally and figuratively) for the huge, inefficient chemical factories of today, generating tens of tons of waste per each ton of the useful product. As a part of the society-driven changes miniaturization and, in general, intensification of chemical and biochemical plants, will become inevitable.

We are well aware that the present book does not cover *all* developments in the field of Process Intensification. It has not had such ambitions. With this collection of contributions by the leading experts in the field, we have tried to focus on the main developments and main issues only, hoping that they will give the reader sufficient flavor of PI and will encourage him/her to further studies on how to re-engineer a chemical processing plant basing on the "smaller-cheaper-safer-slicker" principles of Process Intensification. Both contributors and editors will be very glad to hear from the reader if we indeed have succeeded. Also suggestions for a possible next edition are welcome!

Andrzej Stankiewicz
Jacob A. Moulijn

Contributors

David W. Agar Lehrstuhl für Technische Chemie B, University of Dortmund, Dortmund, Germany

Remko A. Bakker DSM Fine Chemicals Austria, Linz, Austria

H.-J. Bart Institute of Thermal Process Engineering, University of Kaiserslautern, Kaiserslautern, Germany

A. A. H. Drinkenberg DSM Research, Geleen, The Netherlands

Wolfgang Erhfeld Ehrfeld Mikrotechnik AG, Wendelsheim, Germany

A. Górak Lehrstuhl für Thermische Verfahrenstechnik, University of Dortmund, Germany

Andrew Green BHR Group Limited, Cranfield, England

G. Jan Harmsen Delft University of Technology, Delft, The Netherlands

Dennis C. Hendershot Rohm and Haas Company, Bristol, Pennsylvania, U.S.A.

Freek Kapteijn Delft University of Technology, Delft, The Netherlands

E. Y. Kenig Lehrstuhl für Thermische Verfahrenstechnik, University of Dortmund, Dortmund, Germany

Antonis Kokossis University of Surrey, Surrey, England

Gijsbert Korevaar Delft University of Technology, Delft, The Netherlands

Saul M. Lemkowitz Delft University of Technology, Delft, The Netherlands

Patrick Linke University of Surrey, Surrey, England

Jacob A. Moulijn Delft University of Technology, Delft, The Netherlands

C. Ramshaw Department of Chemical and Process Engineering, University of Newcastle upon Tyne, Newcastle upon Tyne, England

Andrzej Stankiewicz DSM Research, Geleen, and Delft University of Technology, Delft, The Netherlands

B. Thonon Greth, CEA–Grenoble, Grenoble, France

P. Tochon Greth, CEA–Grenoble, Grenoble, France

David L. Trent The Dow Chemical Company, Freeport, Texas, U.S.A.

Henk van den Berg Faculty of Chemical Technology, University of Twente, Enschede, The Netherlands, and Ghent University, Ghent, Belgium

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Process Intensification: History, Philosophy, Principles

Andrzej Stankiewicz and
A. A. H. Drinkenburg
DSM Research, Geleen, The Netherlands

1. INTRODUCTION

Process intensification (PI) is currently one of the most significant trends in chemical engineering and process technology. It is attracting more and more of the attention of the research world. Four international conferences, several smaller symposia/workshops every year, and a number of dedicated issues of professional journals are clear proof of it. A number of commercial-scale applications of the PI principles have already taken place. But how did it all begin?

2. A BIT OF HISTORY

According to *Miriam-Webster's Collegiate Dictionary*, the word *intensive* has probably its origins somewhere in 15th century. And it was not many years later, right at the peak of the Renaissance, when Georgius Agricola published his famous book *De Re Metallica* (1), the book that is commonly regarded as the first comprehensive textbook on the *engineering* of mining and metallurgy. *De Re Metallica* is richly illustrated with woodcuts showing equipment and processing methods used in the times of Agricola. In many of those woodcuts clear elements of process intensification–oriented thinking can be found. One example is shown in Figure 1,

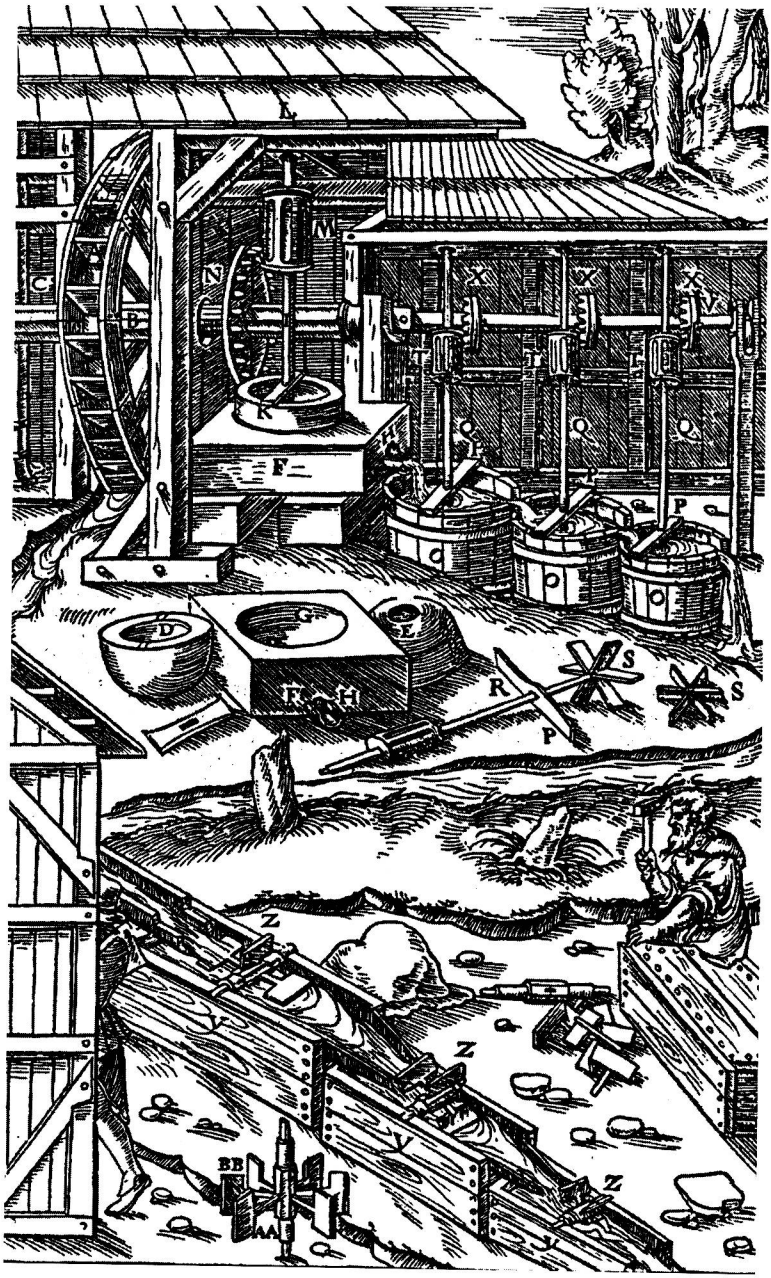

FIGURE 1 Sixteenth century technology of gold retrieval from gold ore. (From Ref. 1.)