GASIFICATION
GASIFICATION
Second Edition

Chris Higman and Maarten van der Burgt
## Contents

Notes on the authors, ix  
Preface to second edition, xi  
Preface to first edition, xiii

### 1 Introduction, 1  
1.1 Historical development of gasification, 1  
1.2 Gasification today, 6  
References, 9

### 2 The thermodynamics of gasification, 11  
2.1 Reactions, 12  
2.2 Thermodynamic modeling of gasification, 16  
2.3 Deductions from the thermodynamic model, 20  
2.4 Optimizing process conditions, 26  
References, 31

### 3 The kinetics of gasification and reactor theory, 33  
3.1 Kinetics, 33  
3.2 Reactor theory, 39  
3.3 Applications to reactor design, 43  
References, 44

### 4 Feedstocks and feedstock characteristics, 47  
4.1 Coals and coke, 47  
4.2 Liquid and gaseous feedstocks, 60  
4.3 Biomass, 75  
4.4 Wastes, 83  
References, 87

### 5 Gasification processes, 91  
5.1 Moving-bed processes, 93  
5.2 Fluid-bed processes, 104  
5.3 Entrained-flow processes, 120  
5.4 Oil gasification and partial oxidation of natural gas, 143
Contents

5.5 Biomass gasification, 163
5.6 Gasification of wastes, 174
5.7 Black liquor gasification, 178
5.8 Miscellaneous gasification processes, 180
References, 183

6 Practical issues, 193
6.1 Effect of pressure, 193
6.2 Pressurization of coal, 195
6.3 Coal sizing and drying, 206
6.4 Reactor design, 209
6.5 Burners, 215
6.6 Synthesis gas cooling, 216
6.7 Particulate removal, 224
6.8 Process measurement, 226
6.9 Trace components in raw synthesis gas, 232
6.10 Choice of oxidant, 243
6.11 Corrosion aspects, 248
References, 250

7 Applications, 257
7.1 Chemicals, 257
7.2 Synfuels, 278
7.3 Power, 286
References, 318

8 Auxiliary technologies, 323
8.1 Oxygen supply, 323
8.2 Synthesis gas treating, 328
8.3 Catalytic gas conditioning, 348
8.4 Cryogenic gas treatment, 354
8.5 Sulfur recovery, 357
References, 365

9 Economics, environmental and safety issues, 369
9.1 Economics, 369
9.2 Environmental issues, 377
9.3 Safety, 389
References, 393

10 Gasification and the future, 397
References, 399
Appendix A  Companion website, 401
Appendix B  Conversion factors, 403
Appendix C  Emissions conversions, 409
Appendix D  Guidelines for reporting operating statistics for
gasification facilities, 411
Appendix E  Basis for calculations, 415
Nomenclature, 417
List of names and abbreviations, 419
Index, 423
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Preface to Second Edition

The original idea for the first edition of this book grew out of an email exchange between the authors at the end of the year 2000. At that time neither of us had any idea of the growth in interest in gasification that would take place by 2007. In fact it was not even obvious in 2003, when the first edition appeared – even if we were both convinced that it would come some day. This growth of interest can be measured by the astonishing increase in attendance at the annual conferences organized by EPRI and the Gasification Technologies Council. At the 2003 conference in San Francisco, where we first presented this book, there were about 350 attendees. In 2006, the number was close to 1000.

Important events contributing to this interest include the following:

• There has been an increasing awareness of “greenhouse gas” issues and the role that gasification can play in CO₂ reduction strategies.
• The crude oil price has leapt from the $20–30 range to around $60–70 per barrel and higher raising the interest in all forms of coal-based technologies for energy conversion.

Reactions to these events have included the following:

• The passing of the US Energy Policy Act of 2005, providing for large incentives to gasification projects in the power industry, which offer the possibility of being retrofitted for CO₂ capture (CO₂ capture ready), and also in the industrial sector.
• Major US utilities such as AEP, Duke Energy and Southern Company have announced large gasification-based IGCC power plants.
• The oil major BP has announced two Carbon Capture and Storage (CCS) projects to utilize the CO₂ for Enhanced Oil Recovery (EOR), one in Europe and one in the US, with others to follow.
• Interest has been growing in other parts of the world, such as China, India and Australia, with each of these countries developing gasification processes tailored to the specific needs of their own national coal resources.
• Interest in gas-to-liquids operations has extended to coal-to-liquids. A number of such projects have also been announced.
Preface to Second Edition

It was against this background that we decided that an update of *Gasification* would be appropriate. In particular, we wanted to do the following:

- Provide more detail on the integration issues for current generation, state-of-the-art IGCCs
- Discuss details of CO₂ capture in the IGCC context, addressing the issues of pre-investment and retrofitting, as well as defining what the term “CO₂ capture ready” might mean in practice
- Update data on plant reliability, availability and maintainability (RAM), including an evaluation of feedback from existing plants
- Include an update of all statistics, processes and projects, including descriptions of a number of processes not covered in the previous edition.

None of this will make the second edition into a radically new book; rather, the growth in interest in the subject will of necessity draw in many new people who could do with an up-to-date resource in a rapidly developing field.

We would like to thank all those who have provided feedback and comments, especially those who have pointed out errors, many of which have been posted on the *errata* slip on the website. Dave Heaven, in particular, made many helpful suggestions. We are grateful for the continued encouragement from the industry; in particular from Gary Stiegel of the US Department of Energy, Jim Childress of the Gasification Technologies Council, and Doug Todd, who gave one of us a great tutorial on gas turbines but who is not responsible for what we have made of it. Finally, we give renewed thanks to our wives, who continue to support our activities in the gasification field, despite the absences from home that these sometimes require.

*Chris Higman and Maarten van der Burgt*

*July 2007*
Gasification, at least of coal, is in one sense an old technology, having formed the heart of the town gas industry until the widespread introduction of natural gas. With the decline of the town gas industry, gasification became a specialized, niche technology with limited application. After substantial technical development, gasification is now enjoying a considerable renaissance. This is documented by the more than 30 projects that are in various stages of planning or completion at the present time. The reasons for this include the development of new applications such as gas-to-liquids (Fischer-Tropsch) projects, the prospect of increased efficiency and environmental performance including CO₂ capture through the use of Integrated Gasification Combined-Cycle (IGCC) in the power industry, as well as the search for an environmentally benign technology to process low-value or waste feedstocks such as refinery residues, petroleum coke, or biomass or municipal waste.

The literature of gasification is extremely fragmented, with almost all recent (post-1990) contributions being confined to conference papers or articles in the appropriate journals. In the coal literature it is mostly relegated to a single chapter, which is unable to do the subject proper justice.

The knowledge of the subject is mostly confined to commercial process licensors and the operators of existing plants. There is therefore little opportunity for outsiders to acquire an independent overview before embarking on a project of their own.

In discussing these issues between ourselves, we concluded that there was a need for a book that collected and collated the vast amount of information available in the public domain, and provided a “single point-of-entry” to the field of gasification without necessarily answering all the questions that might arise. In fact, we felt that the most important task is to communicate an understanding for the questions to ask in a given situation. This book may supply some of those answers directly; others will require further follow-up. This approach is no doubt colored by our own professional experience, where the very flexibility of gasification technology, with its differing feedstocks, differing end products, differing economic situations and the continual development has inevitably led to project-specific solutions for certain issues. Individual solutions will, we believe, continue to prevail in gasification technology, rather than a global standard after Henry Ford’s philosophy of “any color they want, so long as it’s black”. For gasification, standardization, which is certainly an indispensable requisite to its economic competitiveness, must, in our opinion, first of all be introduced as a structuralized approach to the issues to be faced. And in
Preface to First Edition

developing this book, we have aimed at providing a structure that we hope can help in this process.

We trust that in doing so we can be of assistance to a broad audience, including:

- Staff of companies who might want to build a plant and need to acquire know-how quickly in a compact form but independent of process licensors
- Engineers or potential project financiers or insurers wanting to have an understanding of the technical risks involved in such a project, or those working for government departments and agencies involved in the licensing and permitting of gasification projects
- People in the power industry who otherwise have little access to data on the subject of gasification
- Established workers in the field looking for a reference work with a broad theoretical and practical overview
- University students needing a book that combines the elements of academic theory and industrial practice.

After a brief historical introduction to gasification and its relevance to the development of our modern technological society in Chapter 1, there follow two chapters of theory. In order to have a good understanding of the practicalities of gasification, it is necessary to have a sufficient theoretical background. Chemical engineers will have this anyway, but many project engineers who become involved in gasification projects may have an educational background in mechanical or some other branch of engineering, and for such readers a brief summary is sure to be of use. The main emphasis of Chapter 2 is on thermodynamics, since this is sufficient for understanding and calculating the results of synthesis gas generation processes. But the development of computational fluid dynamics is beginning to make kinetics accessible in a manner hardly thinkable 20 years ago, so we have included a basic treatment of kinetic aspects of gasification in Chapter 3.

Chapter 4 reviews the wide variety of feedstocks that can be gasified, ranging from coal, through oils and gas to biomass and waste. It discusses their properties as these affect both the gasification process itself and the downstream synthesis gas treatment and end usage.

The heart of the book lies in Chapters 5, 6 and 7. Chapter 5 discusses actual processes. The emphasis is on processes in commercial use today, such as those of Shell, GE, Lurgi, Siemens, and others such as the circulating fluid-bed processes of Foster Wheeler and Lurgi. It includes brief mentions of some of the important forerunner processes, such as Winkler and Koppers-Totzek. A number of promising new processes, such as the Japanese MHI and EAGLE gasifiers, are also handled.

Chapter 6 looks at a broad selection of practical issues, including the drying and pressurizing of coal, syngas cooling and particulate removal, equipment issues, process control, trace components in synthesis gas, choice of oxidant, and corrosion aspects.
Typical applications are reviewed in Chapter 7. These include the production of chemicals ranging from ammonia and methanol through hydrogen to carbon monoxide, and synthesis gas for the production of oxo-alcohols. The section on synfuels production covers gas-to-liquids (GTL) and Substitute Natural Gas (SNG). The discussion on power applications includes state-of-the-art IGCCs, as well as a look at the potential for increasing efficiency with advanced cycles.

No gasification plant stands alone. Most processes require a source of oxygen, and the product synthesis gas needs treating and conditioning before it can be used. The principle auxiliary technologies for these tasks and the principal issues surrounding their selection are discussed in Chapter 8.

Every project stands or falls on its economics. Gasification is no exception, and economic aspects are addressed in Chapter 9. This chapter also looks at the environmental impact of gasification, particularly its superior performance in power generation. Its innate ability to provide a means of CO₂ capture with only minor additional cost is an important aspect of this subject. This chapter also addresses those safety issues that can be considered specific to the technology.

By way of an epilogue, we have tried to look into the crystal ball, to see what part gasification can play in our futures. We discuss the potential contribution that gasification of fossil fuels can make to the transition to a hydrogen economy. Even in an ideal “fully sustainable” world, gasification of biomass may help us in the provision of some of the petrochemical products we so take for granted today.

At a number of different points in the text we have deliberately questioned current practice or thinking. We hope that the one or other idea produced may stimulate others and help further the technology as a whole.

COMPANION WEBSITE

As an accompaniment to this book we have built a website (www.gasification.higman.de), which includes a number of computer programs arising out of the work involved in preparing this book. They include a complete gasification calculation based on the content of Chapter 2, and also a literature databank with keyword search capability.

TERMINOLOGY

A preliminary word on terminology may be in order. Gasification has a place in many industries, each with its own specific linguistic tradition. Recognizing this, we have not tried to impose our own language on the reader, but have used whatever synonym appears appropriate to the context. Thus the words fuel, feed and feedstock are used interchangeably without any attempt to distinguish between them. Similarly, oxidant, blast, or gasification agent are used with the same meaning in different places.
Preface to First Edition

We would like to thank all our friends in the industry who have helped and encouraged us in this project, in particular Neville Holt of EPRI, Dale Simbeck of SFA Pacific and Rainer Reimert of Universität Karlsruhe. We would also like to thank Nuon Power Buggenum and Hydro Agri Brunsbüttel (now Yara) for the use of the cover photographs. A complete list would be too long to include at this point, but most will find their names somewhere in the bibliography, and we ask them to accept that as a personal thank you. Chris would also like to thank Lurgi for the time and opportunity to research and write this book. We would both like to thank our extremely tolerant wives, Pip and Agatha, who have accompanied us through our careers and this book, and who have meanwhile come to know quite a lot about the subject too.

Finally, we hope that this book will contribute to the development of a better understanding of gasification processes and their future development. If it is of use to those developing new gasification projects, then it will have achieved its aim.

Chris Higman and Maarten van der Burgt
January 2003