

ELEMENTS OF

Fuels, Furnaces & Refractories

O.P. Gupta

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ELEMENTS OF FUELS, FURNACES AND REFRACTORIES

Er. Om Prakash Gupta



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Operational Office :

4575/15, Onkar House, Opp. Happy School,
Ground Floor, Daryaganj, New Delhi 110 002
Phones : 011-45033819 • Mob. 09811541460
email : contactus@khannapublishers.in

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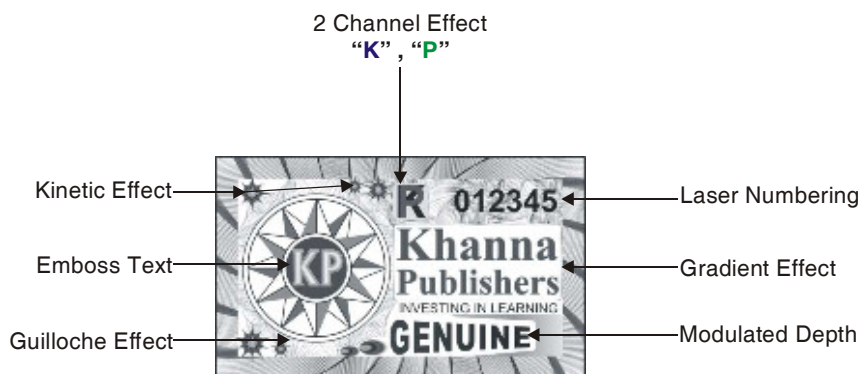
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ISBN No. 978-81-7409-088-6

First Edition : 1989

Seventh Edition : 2022

Preface to the First Edition

Fuels, Furnaces and Refractories are integral part of the degree diploma and postgraduate curriculum in Mechanical, Chemical, Ceramic and Metallurgical Engineering of Indian universities. Besides, it also forms a compulsory paper for various professional associate membership examinations conducted by various professional bodies like Institution of Engineers (AMIE), Indian Institute of Metals (AMIIM), Indian Institute of Chemical Engineers (AMIChE), Institute of Chemist (AIC) etc.

In absence of a single integrated book incorporating all these subjects as per the courses of study of these examinations, perplexed students were looking for these informations in a number of books and journals which are readily not available. In this present venture, I have taken the opportunity to combine all these informations from various sources in one book in condensed form thereby making the subject matter readily available without much waste of time to the students.

For ease of approach and clarity, the subject matter has been divided in different sections and only elementary treatment of the subject matter has been incorporated. In the subsequent editions, advanced treatment of the subject will be introduced as well as the coverage will be broadened to make it more useful to practising and design engineers also.

I am thankful to my wife Anita, daughter Jaya and son Manish who have spared time for me to complete the book.

Suggestions for further improvement are welcome.

26th January, 1990
Bokaro Steel City

Om Prakash Gupta
4F/2076, Bokaro Steel City-827004

Preface to the Sixth Edition

This new 6th edition of the book is being presented with some supplementary information added in different chapters of the book. Statistical information on fossil fuel reserves, production and consumption have been elaborated and updated. Few more solved numerical examples on combustion of fuels have been included in this edition of the book. Some more fuel related data and statistics have been included in Appendix.

I hope that the book in its present form will prove to be more useful to the readers.

Constructive criticisms and suggestions for further improvement of the book are solicited.

January 26th, 2014
Bokaro Steel City

Om Prakash Gupta
4B/1024, Bokaro Steel City-827004
op_gupta25@rediff.com

Preface to the Fifth Edition

This book being indispensable for the diploma, degree & postgraduate students of Chemical Engg., Metallurgical Engg., Mechanical Engg., Ceramic Engg., Aeronautical Engg., Petroleum Engg., Mineral Engg., Mining Engg. and Nuclear Engg. Over the last one and half decade needed another updating with the changing pace of time. Some chapters have been updated with relevant supplementary informations to make the book more useful to the concerned users. This book now can be assumed to be the universal *encyclopedia* or *Handbook*

of 'Fuels, Furnaces and Refractories Technology' capable of catering to the needs of all the diploma, degree, postgraduate and doctorate students, teachers and the practising engineers of the globe.

Suggestions for further enrichment and improvement of the book for broader coverage and enhanced utility are welcome from the concerned readers.

Bokaro Steel City
1st November, 2004

Om Prakash Gupta
4F/2076, B.S. City-827004
Phone (R) — 06542-267573
e-mail : op_gupta25@rediff.Com
OPG 121@India Times.Com

Preface to the Fourth Edition

In view of the wide acceptability of this book by the students, teachers and practising engineers, I am presenting the fourth revised edition of this book. Most of the chapters have been updated and current/advanced information pertaining to the subject matter has been incorporated in this edition. Besides, two new chapters namely 'Furnaces Used in Steel Plant' and 'Rocket Fuels' have been added. Comprehensive data on fuels and their utilisation has been incorporated in the appendices.

I hope, that the book in its present form will serve still more useful purpose to those, for whom it is meant.

Suggestions for further improvement are welcome from the readers.

15th August, 2000
Bokaro Steel City

Om Prakash Gupta
4F/2076, Bokaro Steel City
PIN-827004

Preface to the Third Edition

The author is grateful to the readers for showing an overwhelming response to this book and is delighted to find the increasing popularity of this book. I, therefore, express my thanks and gratitudes to all its readers.

The book has been further revised by adding the recent developments in the field in the respective chapters.

The author is thankful to all the critics who had sent their suggestions for improvement of the book, as without their comments, it would not have been possible to bring out this edition.

—*Author*

Preface to the Second Edition

Encouraged by the wide acceptance of the first edition of the book by the students, teachers and practising engineers, I have this opportunity to present the second edition of the book in a short span of time. In this edition, a new section titled "Nuclear Fuels and their Utilisation" has been incorporated which makes the book complete in all respects, as it now includes both Chemical as well as Nuclear Fuels. This makes the utility of this book more comprehensive for the students of mechanical, chemical, metallurgical and ceramic engineering who all have to compulsorily study nuclear power engineering.

Most of the chapters have been updated by detailing advanced informations and some new chapters have been incorporated. Elaborate technical data on fuels furnaces and refractories have been given in the 'appendix', thereby enhancing its utility for the practising engineers too.

Finally, I hope that both the students and practising engineers will find this book more useful.

Suggestions for further improvement are welcome.

15th August, 1990

Om Prakash Gupta
Bokaro Steel City

This book is useful for the following courses and examinations :

1. Dip. Met. Engg. — Diploma in Metallurgical Engineering
2. Dip ChE. Engg. — Diploma in Chemical Engineering/Technology
3. Dip. Ceramic Engg. — Diploma in Ceramic Engineering/Technology
4. Dip. Mech. Engg. — Diploma in Mechanical Engineering
5. B. Tech./B.E. (Met. Engg.) — Degree in Metallurgical Engineering
6. B. Tech (Mining Engg.) — Degree in Mining Engineering
7. B. Tech/B.E. (Chemical Engg.) — Degree in Chemical Engineering and Chemical Technology
8. B. Tech/B.E. (Mech. Engg.) — Degree in Mechanical Engineering
9. B. Tech/B.E. (Ceramic Engg.) — Degree in Ceramic Engineering/Technology
10. B. Tech (Marine Engg.) — Degree in Marine Engineering
11. B. Tech/B.E. (Aeronautical Engineering) — Degree in Aeronautical Engineering
12. AMIE (Met. Engg.) — Associate Membership Examination of Institution of Engineers (Metallurgical Engg. Section)
13. AMIE (Chem. Engg.) — Associate Membership Examination of Institution of Engineers/Chemical Engg. Section)
14. AMIE (Marine Engg.) — Associate membership examination of Institution of Engineers/ Marine Engg. Section)
15. AMIIM — Associate Membership Examination of Indian Institute of Metals
16. IChE — Associate Membership Examination of Indian Institute of Chemical Engineers
17. AIC — Associate Membership Examination of Institute of Chemists
18. IME — Associate Membership Examination of Institution of Mechanical Engineers
19. B. Tech (Petroleum Engg.) — Degree in Petroleum Engineering of Indian School of Mines, Dhanbad
20. DISM (Fuel Engg.) — Postgraduate Diploma in Fuel Engineering of Indian School of Mines, Dhanbad
21. M. Tech (Nuclear Engg.) — Postgraduate Degree (M. Tech) in Nuclear Engg. of I.I.T. Kanpur
22. NIFFT — Courses run by National Institute of Foundary and Forge Technology, Ranchi
23. M. Tech (Fuel & Combustion) — Post graduate degree in Fuels & Combustion of B.I.T. Mesra, Ranchi
24. B. Tech (Mineral Engg.) — Degree Course in Mineral Engineering of Indian School of Mines, Dhanbad
25. Associate Membership Examination of Institution of Metallurgist, United Kingdom (U.K.)
26. Associate Membership Examination of Institute of Fuel, U.K.
27. Associate Membership Examination of Institution of Heat Treating & Ventillation Engineers, U.K.
28. Associate Membership Examination of the City and Guilds of London Institute, U.K.
29. The Swansea Education Committee Examination, U.K.
30. The University of Wales Examination, U.K.
31. Swansea College of Technology, U.K.
32. Researchers & Practising Engineers

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THE HISTORY OF THE COUNTY OF MIDDLESEX

...the first year of the reign of King Henry the Second, the Countess Matilda, who was the daughter of King Henry the First, and the wife of Count Geoffrey, was driven from the throne of England by King Richard the First, who was the son of King Henry the First, and the brother of King Matilda. King Richard the First was a very brave and valiant king, and he was very much beloved by his subjects. He was also a very generous and merciful king, and he was very much respected by his subjects. He was also a very wise and prudent king, and he was very much admired by his subjects. He was also a very just and equitable king, and he was very much loved by his subjects. He was also a very brave and valiant king, and he was very much respected by his subjects. He was also a very generous and merciful king, and he was very much beloved by his subjects. He was also a very wise and prudent king, and he was very much admired by his subjects. He was also a very just and equitable king, and he was very much loved by his subjects.

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1

Introduction and Classification of Fuels

A substance which produces heat is called a fuel. The heat may be produced either by combustion or by nuclear fission & fusion. Heat generated by the combustion of fuel is utilised either directly or is converted into mechanical or electrical energy. Fuels are the major source of energy for industries. Those fuels which produce heat by the combustion are termed as simply '*fuels*' whereas those which release heat by fission or fusion are called *nuclear fuels*.

Fuels are classified mainly in four general classes namely *fossil*, *by-products*, *chemical* and *nuclear fuel*. Out of these, first three release heat by combustion in presence of air or oxygen. Nuclear fuels release heat by nuclear fission or fusion by converting mass into energy.

Fossil fuels are those which have been derived from fossil remains of plant and animal life and are found in the crust of the earth e.g. coal, petroleum, natural gas etc.

By-product fuels are the co-product of some regular manufacturing process and are of a secondary nature. As for example, coke oven gas and blast furnace gas are the by-product fuels in the process of coke and iron making respectively.

Chemical fuels are of an exotic nature and normally not used in conventional processes. Examples are hydrazine (a rocket fuel), ammonium nitrate, flourine etc.

Nuclear fuels which release heat by fission are uranium, plutonium etc. and those generating heat by fusion are deuterium and tritium (both are isotopes of hydrogen) etc. In both the situations, the mass is converted into energy.

Depending upon the state of occurrence, the fuels are classified as solid, liquid or gaseous fuels.

Fuels in each general division are further classified as *Primary* and *Secondary fuels*. Primary fuels are those which occur in nature *viz.* coal, wood, petroleum, natural gas etc. Secondary fuels are those which are derived from primary fuel e.g. fuel oil & kerosene (derived from petroleum), coke oven gas (derived from coal) etc.

Secondary fuels are further classified into *manufactured* and *by-product fuels*. Manufactured fuels are those which are made for some specific purpose e.g. coke (made for iron making), gasoline (made for internal combustion engines), producer gas (made for industrial heating) etc. By-product fuels are those which are a co-product/side product (unavoidable product) of a regular manufacturing process e.g. bagasse, tar, refinery gas etc. By-product fuels help industries in conserving primary fuels.

Table 1.1 gives the classified list of important fuels (excluding chemical & nuclear fuel).

Nuclear fuels are of two types. One type can release heat by its fission by neutron bombardment. Such fuels are called fissile fuel e.g. uranium-233, uranium-235, plutonium-239. There are some nuclear fuels e.g. thorium-232 and uranium-238 which can not be fissioned directly, but they can be converted into fissile material e.g. uranium-233 and plutonium-239 respectively. Such nuclear fuels are called fertile fuels.

Still another type of nuclear fuels release heat by fusion, e.g. deuterium & tritium (both are isotopes of hydrogen), hydrogen etc. But in both the cases whether the fuel undergoes fission or fusion, conversion of mass into energy takes place to release heat.

Depending upon the usage, fuels are classified as *domestic fuel*, *illuminating fuel*, *industrial fuel*, *rocket fuel* etc.

Table 1.1. General Classification of Fuels

General Division	Primary Fuels		Secondary Fuels	
	Natural	Manufactured	By-product	
Solid	Wood Coal	Semi-coke Coke Charcoal Briquettes Pulverised Coal	Charcoal Wood refuse Bagasse Coke breeze Waste material from grain	
Liquid	Petroleum	Petrol Kerosene Alcohol Colloidal fuels Fuel oil Naptha Vegetable Oil	Tar Pitch Benzol Paper pulp mill waste	
Gaseous	Natural gas	Producer gas Water gas Carburetted water gas Coal gas Oil gas Gober gas Reformed natural gas Butane Propane Acetylene Hydrogen LPG	Blast furnace gas Coke oven gas Oil refinery gas Sewage gas L.D. converter gas	

Domestic fuels supply heat for cooking and space heating. *Illuminating fuels* e.g. kerosene, town gas etc. supply light in darkness. *Industrial fuels* supply heat for process heating, steam and electricity generation etc. *Rocket fuels* e.g. hydrazine are used for producing enormous thrust for the propulsion of rocket.

As per another general classification system, the fuels which generate heat by combustion are called '*Chemical Fuels*' and the fuels which generate heat by nuclear fission or fusion are called '*Nuclear Fuels*'.

Features and characteristics of a good fuel:

- It should be readily available at cheap rate.
- It should be easy & safe to handle, store and transport and at a low cost.
- Storage cost of the fuel should be low.
- It should have high heating value (Calorific value).
- Its moisture content should be low, as it reduces the heating value.
- It should have moderate ignition temperature as low ignition temperature fuel will catch fire easily and one with high ignition temperature will present difficulty in igniting it.
- Its non-combustible matter content should be low.
- It should not produce on burning harmful products of combustion.
- It should possess moderate rate of combustion. If rate of its combustion is low, the required high temperature may not be attained as part of heat generated will be lost. Too high combustion rate of fuel may be uneconomical and uncontrollable to achieve the desired effect.

ELEMENTS OF Fuels, Furnaces and Refractories

This book deals with every aspect of fuel, furnaces and refractories in details, in a single volume. The main aim behind presentation of this book has been to assimilate the scattered information on the interrelated topics in one volume for the benefit of students and practicing engineers. This book begins with the basics which are the tools for efficient fuel utilization alongwith the advanced treatment and latest practices in the field to give more broader coverage of the subject matter. The text matter has been presented with lots of self-explanatory illustrations, flow charts and solved examples for the better understanding of different topics. The text contains eighty chapters, which are classified into following sections:

- + General Topics
- + Solid Fuels
- + Liquid Fuels/Petroleum Refinery Engg.
- + Gaseous Fuels
- + Combustion
- + Furnaces
- + Refractories
- + Topics Related to Fuel Technology
- + Nuclear Fuels and Their Utilization
- + Appendices

In the end detailed appendix presents the practical data in the form of tables, mathematical derivations, glossary of terms and classified information as is generally needed by practicing engineers.

The concise treatment of the various topics will help the students of the engineering degree/diploma and professional examinations (e.g. AMIE, AMIIM, AMIICHE, AIC etc.) to prepare for the examinations with little effort in short time. Moreover, it will act as a reference book for practicing engineers.

Basically being a chemical engineer, Mr. Om Prakash Gupta has a practicing experience of efficient fuel utilization in steel industry for about more than two decades. Privileged to be the youngest writer of technical books in the country (for he had written his first book at the age of 24 years while doing M.Tech. at I.I.T., Kanpur in 1979), he has also authored a number of technical papers.

Besides, being the regular faculty member in technical courses for graduate engineers trainees, he has also visited England and France on a study tour sponsored by United National Development Programme (UNDP) to study the scope of energy conservation steel plants in 1987.



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4575/15, Onkar House, Opp. Happy School,
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