DRYDEN'S

Outlines of Chemical Technology

SECOND EDITION

EDITED & REVISED BY

M. GOPALA RAO

MARSHALL SITTIG

EWP EAST-WEST PRESS

OUTLINES OF

TECHNOLOGY

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Outlines of Chemical Technology

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On loan from The Ohio State University
Columbus, Ohio, U.S.A.
1963-1965

CHEMICAL

SECOND EDITION

EWP

Flow Diagrams and Graphs by D.S. Panesar

This edition is dedicated
to the memory of
Charles E. Dryden (1917-1967)
a great engineer, a great teacher,
a great person.

PREFACE TO THE SECOND EDITION

The two editors who have revised Professor Dryden's work started with a sense of deep respect for the uniqueness and thoroughness of the original edition.

The book "Outlines of Chemical Technology" was unusual in that it was essentially two intertwined books — one dealing with the state of chemical process technology on a world-wide basis, and the second dealing with the particular relevance of each specific process or industry to the Indian scene.

The first edition was comprehensive and very timely when it was published. However, six years have elapsed since its publication and the chemical industry is a fast-moving industry; also its place in the Indian economy has grown markedly in the last six years. Hence the new edition.

In addition to checking and updating, the editors have broadened the coverage of the book to include new material on

Cryogenics in chemical technology
Fertilizer industry
Chemicals from the sea
Air as a chemical raw material
Nuclear powered agro-industrial complexes (Nuplexes)
Paints and varnishes
Proteins from petroleum fermentation
Food industry
Coal and coal chemicals
Newer petrochemicals
Pesticides manufacture
Pharmaceutical industry
Metallurgical industry
Water and air pollution control

These are all important components of the chemical process industries, and are particularly important in the chemical industry in the developing economy of India.

Finally, a listing of over 800 chemical manufacturers in India has been added at the end of the book.

KANPUR, INDIA
AUGUST, 1971

M. GOPALA RAO
MARSHALL SITTIG

PREFACE TO THE FIRST EDITION

The curriculum in Chemical Engineering at the Indian Institute of Technology, Kanpur, is arranged so that a comprehensive study of the chemical process industries is given in the second semester of the fourth year. By then the students have had a suitable background in stoichiometry, thermodynamics, kinetics, rate processes, chemical engineering operations, organic and physical chemistry so that industrial chemical processes can be studied with the use of these fundamentals. Such a course thus furnishes adequate preparation for a more meaningful summer industrial experience and for the Ch.E. synthesis courses in process and plant design which follow in the fifth year.

A one-semester course which encompasses three one-hour lectures per week is so short that only the essential features of chemical process industries can be stressed. Standard industrial chemistry reference books are too detailed for reading assignments to obtain essential facts. Furthermore, there are no texts available which relate to the emerging chemical process industries of India. For these reasons, an outline series of notes was prepared for the course which analyze processes from industries classified as inorganic, natural products, synthetic organics, and polymers. Selection of industries and processes was necessary to keep within the time limits of one semester. The ones chosen are representative of each type of industry and furnish the basic principles of a particular technology. In many cases, these processes will be new in the Indian technology picture, but it is anticipated that these, or modifications thereof, will soon be operating in India. A portion of these notes was originally prepared by the author in 1961-62 for a similar course at Ohio State University. Supplementary material, plus revision and adaptation for Indian conditions, has been done while working at the IIT-Kanpur. A preliminary edition under the title "Chemical Technology Outline Series", Indian Edition, was printed at the IIT-Kanpur in October 1964. The present book is essentially the same book with some revisions.

I have resisted the temptation to write these notes in text prose style. Both this style and the outline form have been classroom tested. The results were strongly in favor of the outline form which stresses only the essential facts for students to comprehend, a necessary criterion for a short, concise study of a broad spectrum of industries. The most successful method of study is that of assigning material from these notes on an advanced schedule basis. The students are not expected to memorize factual material but should obtain general impressions and observe how chemical and engineering principles are used in each process and industry. They are given a ten-minute quiz on this assignment at the start of the class. The instructor then expands on material covered in the notes, preferably by introducing the latest developments with the knowledge that students have the necessary background.

A shorter course than envisioned in this book can be set up by selecting topics from within the framework of the text. The book can also serve as introductory reading to become familiar with the scope and problems of a particular chemical process before making a detailed study of numerous sources.

In keeping with Indian Government adoption of the metric system, all conditions are given in terms of kg, metric tons, cubic meters, Kcal and atmospheres, although most of the literature and process engineering data are still recorded in the British system. I hope that the use of the metric system in teaching will aid in a more rapid switchover from the British system.

A three-hour per week laboratory for this course is utilised for making process calculations. Flow sheets of several processes are prepared using detailed material, energy, and equilibrium calculations with computer aids such as desk calculators and digital computers. In addition, several nearby chemical plants are visited and engineering inspection reports are prepared.

The compilation and summary of material was not possible without aid and information received from a number of sources both in the USA and India which are too numerous to acknowledge individually. Chemical engineers from the Chemical Branch, Directorate General of Technical Development, the Planning Commission, Government of India, from industry, and from educational institutions were quite helpful in supplying information on Indian conditions and critically reviewing the manuscript. In this respect, the assistance of the following persons in India and the USA is gratefully acknowledged : P. Adivarahan, E.P. Bartkus, S.K. Bhalla, S. Chandra, D.K. Dutt, J. Farst, R.K. Gupta, J.P. Kapur, N.R. Kuloor, C.R. Mitra, P.K. Seshan, and M.M. Sharma. The writer would also like to extend thanks to the Ohio State University and to the Indian Institute of Technology, Kanpur, for aid in publishing this material. In particular, the help of D.S. Panesar in careful preparation of drawings, and R.C. Gangal and B.S. Pandey for typing the manuscript is truly appreciated.

Last, but not least, the opportunity to teach and work in India was made possible by the U.S. Agency for International Development (AID) through their Kanpur Indo-American Program.

KANPUR, INDIA
MARCH, 1965

CHARLES E. DRYDEN

NOTES FOR TEACHERS

While this book is directed both to the student and to the practicing technologist, it was felt that some specific notes to teachers, based on classroom experience at the Indian Institute of Technology, Kanpur, would be helpful.

As noted in Professor Dryden's Preface to the First Edition, this book is used as a text in the second semester of the fourth year in a 5-year course.

Also, as noted, it has been the custom to start each lecture period with a ten-minute quiz. This helps to insure that a student does the assigned reading on which the quiz is based ; furthermore it helps to insure prompt arrival of students at the start of the class hour.

Now there is presented A Possible Course Outline. It is one which has been used successfully at IIT-Kanpur. It involves 3 lectures per week for 15 weeks.

Following the course outline is a discussion of Plant Inspection Trips which are viewed as a desirable and necessary adjunct to the proper teaching of this course.

A POSSIBLE COURSE OUTLINE

Topic	Class Lecture No.
I. Introduction	1
II. Inorganic Chemical Industries	
Sulfur and Sulfuric Acid	2
Fuel and Industrial Gases	3
Cryogenics in Chemical Technology	4
Fertilizer Industry	5
Nitrogen	6-7
Phosphorus	8-9
Electrochemicals	10-11
Chlor-Alkali	12
Chemicals from the Sea	13
Cement and Lime	14
Water and Air	15
Nuclear Materials	16-17
Explosives and Propellants	18
III. Natural Product Industries	
Oils ; Soaps and Detergents ; Glycerine	19
Paints and Varnishes	20
Carbohydrates and Fermentation	21-22
Food Industry	23
Pulp and Paper	24
Coal and Coal Chemicals	25
Petroleum	26-27
IV. Synthetic Organic Chemicals	
Petrochemicals and Chemicals from C_1 Comounds	28-29
Chemicals from C_2 Compounds	30-31
Chemicals from C_3 Compounds	32
Chemicals from C_4 Compounds	33
Chemicals from Aromatics (Including Dyes)	34
Pesticides	35
The Pharmaceutical Industry	36
V. Polymerization Industry	
Fundamentals	37-38
Polymerization Technology	39-40-41-42
VI. Metallurgical Industry	43-44
VII. You and the Indian Chemical Industry	45

PLANT INSPECTION TRIPS

Visual observation of actual chemical plant operations is one of the best ways of learning what goes on in a typical chemical industry. For this reason, several well-planned and coordinated plant trips should be taken to supplement the reading assignments and classroom discussions. Hard hats and safety glasses should be required for these trips.

The major test of knowledge acquired on a plant visit is the report submitted within the time limit of one week after the plant is visited. To insure good reports, familiarize yourself with the industrial processes to be seen and study the suggestions given next.

Report Form

Type of Report : The instructor will discuss the type of report to be submitted. One type of report can be based on the assignment given to a typical engineer inspecting industrial facilities for possible purchase by his company.

The student is free to submit the report in any style he desires. However, the important information must be included.

Type of Material to be Included in Report :

Introduction

- Name of plant
- Address
- Inspection date
- Person (s) contacted and titles
- Type of plant and history of plant and the industry

Description of process(es)

- Flow sheet
- Raw materials
- Chemical reactions
- Process controls
- Products
- Unusual engineering features
- Safety aspects

Economics

- Cost of raw materials
- Products (manufacturing cost and selling price)
- Labor
- Capital investment
- Competitive aspects locally and nationally

Summary

- Potential of the plant and the industry
- Engineering improvements required
- Recommendations for purchase

Hints when making inspection trip

- Study the industry ahead of time
- Ask questions in a loud voice so all can benefit from the discussion
- Take plenty of notes

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I
ORIENTATION

IA. INTRODUCTION

The chemical and allied industries in India rank amongst the top of all manufacturing industries both in capital assets and importance to the nation. A great number of their products are used in manufacturing industries in India. These chemical industries also supply vital materials for preparation of drugs and growth of agricultural food products.

The nature of the chemical industry is different from much of the rest of industry. Its basic purpose is to start from an ore or other chemical raw material and end up with a consumer product through series of chemical and physical changes. In this, it differs from many manufacturing industries which are assembly industries and not creative industries in the same sense as are the chemical and allied industries.

It is of interest to compare the position of the chemical industry in the Indian economy with the position of the chemical industry in the U.S. economy.

The gross national product (GNP) of India is about Rs. 26,500 crores ($35 billion). The value of chemicals and allied products produced is about Rs. 1,000 crores or 4% of the GNP.

The gross national product for the USA was approximately $1,000 billion in 1970 of which about $60 billion was accounted for by chemical and allied products alone. This is about 6% of the GNP.

Thus, the contribution of the chemical industry to GNP is not so different in terms of percentages of GNP in USA and India but the absolute size of chemical products production alone in the USA is about 70% greater than the total Indian GNP.

For further comparison, chemical sales in West Germany and in Japan approximate $10 billion each.

The top 13 chemical companies in India and their estimated sales figures have been given in *Chemical Age of India*, **21** (10) : 864 (Oct. 1970) as follows :

	Sales	
	Million $	*Rs. Crores*
Imperial Chemical Industries (ICI)	86.1	65.4
Fertilizer Corp. of India Ltd.	57.1	43.4
Glaxo Laboratories Ltd.	26.4	20.1
Fertilizers & Chemicals, Travancore Ltd.	25.1	19.1
Gujarat State Fertilizer Co. Ltd.	22.1	16.8
Indian Oxygen Ltd.	19.2	14.6
Indian Explosives Ltd.	18.5	14.0
Pfizer Ltd.	17.7	13.5
Synthetics & Chemicals Co. Ltd.	16.1	12.2
Coromandel Fertilizers Ltd.	14.8	11.2
Tata Chemicals Ltd.	14.4	10.9

	Sales	
	Million $	*Rs. Crores*
Atul Products Ltd.	11.8	9.0
Indian Dyestuff Industries Ltd.	11.1	8.4

Chemical engineers are trained primarily to work in chemical industries. Of those having technology and graduate degrees in chemical engineering, approximately 95% work in some phase of the industrial chemical business : for example — research, design, development, production, technical sales and service, or management, both in the private and public sector.

As an aid to the description of some of the various positions which a chemical engineer may assume, and as an aid to the reader of this book in helping him to fit the position to his own personality and capabilities, the following table is presented :

TABLE IA-1. QUALIFICATIONS REQUIRED FOR VARIOUS JOBS

Qualifications / *Jobs*	*Verbal Ability*	*Social Intelligence*	*Analytical Mindedness*	*Numerical Ability*	*Mechanical Interest*	*Forcefulness*	*Self-sufficiency*	*Sociability*	*Self-confidence*	*Imagination Resourcefulness*	*Frustration Perseverance*	*Supervising*	*Persuading*	*Helping Others*	*Working with Data*	*Working with Instruments*
Teaching	××	×				×				×		×		××		
Pure research			××		×		××		×	××	××				×	××
Commercial research			××		×	×				××					×	××
Applied research	×	×	××		××		×	×		××	×			×	×	××
Pilot plant		×	××	×	××					×	×	×	×		×	××
Design			××	××	××			×		×	×	×	×		××	×
Production	×	×			××	××	×					××	×		×	××
Market research	×	×	××	××		××	×		×	×	×				××	
Market development	××	×	×			××	×	×	×	××	××		××	×	×	
Sales	××	××				××	××	×	××	××	××		××	××		
Technical service	×	×	××		××	×			×	×				××		×
Analytical			××	×	×		×									××
Patents—Law	×	×	××						×	××			×		×	
Personnel	×	×	×					×					×	××		•
Purchasing	×	×						×	×	×				×	×	
Accounting			××	××			×		×							

Column heads originally suggested by Arthur Atkin, psychologist and specialist in aptitude testing. (By permission of *Chem. & Eng. News.*)

Taken from the article "Happiness as a Goal" by Carl Pacifico, *Chem. & Eng. News*, 37 (4) : 1-13 (Jan. 26, 1959).

Check your talent against the needs of the job and see what the future may hold for you.

It is essential that chemical engineering students have a comprehensive picture of the chemical industries, particularly as to the reasons and the basis for the many and diverse operations which are carried on. It will be shown in the study of a number of types of chemical industries that the fundamentals of chemistry, thermodynamics, kinetics, engineering, and economics are always valid, even though the operations may appear complex at times.

A selected series of outline notes will be used to show how these fundamentals have been applied. These will be divided into five categories for ease of study :

1. Inorganic chemical industries
2. Natural product industries
3. Synthetic organic chemical industries
4. Polymerization industries
5. Metallurgical industries.

Additional study is recommended in terms of plant inspection trips and a computation laboratory in which detailed material, energy, and equilibrium calculations are submitted with flow sheets for several industrial processes.

IB. CHEMICAL INDUSTRIES—FACTS AND FIGURES

1. The Production Picture for India

The introductory section (IA) has pointed out the importance of chemical industries in the Indian economy. The basis for the economic development of India is government planning through a series of 5-year plans. The First Plan was implemented in 1951 by the Planning Commission of the Government of India. Rapid industrialization has been the continued aim of planning, both through public and private enterprise.

In Table IB-1, a comparative set of statistics is given for the more important chemical and allied industries. These data have been classified as inorganic or heavy chemicals, natural products, organic, and metallurgical. The heart of the present Indian chemical industries is the inorganic sector since it is the oldest and best established group. The organic chemical industries have not yet taken hold to the same extent that is prevalent in other countries. The principal reason for this is a lack of cheap and abundant raw materials, petroleum in particular.

The chemical industries have a relatively high growth rate as measured by yearly growth percentages. Values in the 30-50% range compare with the fastest growing U.S. industries. Furthermore, metals, paper products and cement have established growth rates at least twice that of the USA, indicating the intense activity of the Indian chemical industries. The per capita production in India is about 1% of that in the USA for most chemicals which is a clue to the possibilities which lie ahead for India. The emphasis placed on growth is reflected in the perspective of the Fourth Plan period (1969-1974). The ultimate aim of the Planning Commission is to produce a healthy economy in which both public and private sector can function effectively to supply India's population with the essential needs of food, clothing, housing, transportation plus some of the luxury items which will characterize Indian living in the future.