

Kiran R. Golwalkar

# Production Management of Chemical Industries



Springer

# Production Management of Chemical Industries

Kiran R. Golwalkar

# Production Management of Chemical Industries

Kiran R. Golwalkar  
Nagpur, Maharashtra  
India

ISBN 978-3-319-28251-0      ISBN 978-3-319-28253-4 (eBook)  
DOI 10.1007/978-3-319-28253-4

Library of Congress Control Number: 2015958843

© Springer International Publishing Switzerland 2016

This work is subject to copyright. All rights are reserved by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed.

The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

The publisher, the authors and the editors are safe to assume that the advice and information in this book are believed to be true and accurate at the date of publication. Neither the publisher nor the authors or the editors give a warranty, express or implied, with respect to the material contained herein or for any errors or omissions that may have been made.

Printed on acid-free paper

This Springer imprint is published by SpringerNature  
The registered company is Springer International Publishing AG Switzerland

*To the workers, design and shop floor engineers, and progressive managements who give priority to safety of all persons associated in any manner with their industries and products to control the environmental pollution, to maximise the efficiency, and to manufacture the products with the best possible quality.*

# Preface

Chemical industries are very important for our daily lives since we need various products for personal hygiene and health care, fuels for cooking and vehicles, paints and dyes, petrochemicals, synthetic fibres, water treatment chemicals, fertilisers, insecticides and pesticides for agriculture, etc. Chemical industries also make a large contribution to national economies. However, many of these industries produce or handle dangerous and highly polluting chemicals which must be very carefully controlled. Hence, the governments of all countries insist on compliance with the strict rules and regulations which are enacted to ensure the safety of personnel and the control of environmental pollution.

It is necessary that management, and all those shop floor engineers working in chemical industries (who are looking after the process and maintenance) should operate their plants in a safe, pollution free manner along with an all-around efficiency in order to keep the pollution and the production costs in control while meeting the required product quality and delivery schedules for their products.

Some of their main activities are given as follows:

- Market survey to estimate demand for the product mix
- Setting up new production units, expand/diversify running units, or revive idle units
- Ensuring safe operations and maintenance by Hazid and Hazop studies
- Compliance with statutory rules and regulations
- Procuring materials and machinery
- Environmental pollution control by minimising effluents and treating them properly
- Production of chemicals as per specifications of quality control checks
- Dispatch as per the delivery schedules agreed with clients

The author has attempted to present information generally needed by these engineers (and managers) about technical matters in a bullet format (rather than lengthy explanations) for an analysis of their plants and for proceeding further. It is seen that the main points are easily noted when checklists are given in this manner.

It is hoped this format will enable them to quickly prepare reports for plant expansion, diversification, and purchase of new equipment for presenting to the higher management for approval and sanctions.

Suitable explanatory notes instead of lengthy descriptions are added only at appropriate sections (in the relevant chapters of the book).

There are many excellent books available for researchers. However, I have placed more emphasis on safety, environmental pollution control, and energy efficiency while writing the book and hence request the persons carrying out research to always consider these issues while developing new processes and products.

The book is thus meant for use by production managements, shop floor engineers, and for students who wish to join the chemical industries.

Kiran R. Golwalkar

# Acknowledgements

I am grateful to my teachers at the technical institutes who taught the basic engineering principles, my senior colleagues for the training given to me at the beginning of my job in a chemical industry, the shop floor working personnel who were very cooperative and gave many practical suggestions, and to the design and shop floor engineers and progressive managements with whom I had opportunities to work.

I wish to especially thank respected Mr. Brian Halm, Project Coordinator and Mr. Michael Luby, Senior Publishing Editor, Engineering at Springer Science +Business Media, New York, USA for the encouragement and help in completing this work.

I am very thankful to Ms. Nicole Lowary, Assistant Editor, Applied Sciences, Springer Science+Business Media for the support and the Experts who have spent their valuable time, have taken the pains to review the book and made very encouraging positive comments.

I also specially wish to thank Ms. Nishanthi Venkatesan, Project Manager, Scientific Publishing Services (P) Ltd. for the great efforts made for preparation of the page proofs and kind support provided.



## **Sources of My Information**

My own experience of working in various chemical industries and consultancy organisations for the erection, commissioning, operation, modernisation, and diversification in India, Kenya, Thailand, and Indonesia, and visits to industrial exhibitions in India as well as discussions with various vendors of equipment during my professional career.

# Contents

|          |                                                                 |          |
|----------|-----------------------------------------------------------------|----------|
| <b>1</b> | <b>Introduction.</b>                                            | <b>1</b> |
| 1.1      | Typical Features of Chemical Industries                         | 1        |
| 1.2      | Modern Managements.                                             | 2        |
| 1.2.1    | Important Management Activities<br>for the Chemical Industry    | 2        |
| 1.2.2    | Estimation of Demand for the Products                           | 3        |
| 1.3      | Basic Engineering Documents                                     | 3        |
| 1.3.1    | Rated Capacity                                                  | 4        |
| 1.4      | Detailed Market Survey.                                         | 5        |
| 1.5      | Finalising the Product Mix.                                     | 5        |
| 1.5.1    | Future Product Mix and Product Life Cycle:<br>A Word of Caution | 6        |
| 1.5.2    | Overloading of Equipments                                       | 6        |
| 1.6      | Selecting the Process and Technology                            | 6        |
| 1.7      | Detailed Engineering Document                                   | 7        |
| 1.8      | Procurement of Plant Equipments and Machineries                 | 8        |
| 1.9      | Creating Infrastructure Facilities                              | 8        |
| 1.10     | Financial Arrangements (Cash Flow Planning)                     | 9        |
| 1.11     | Organisation of Structure for Industrial Administration         | 9        |
| 1.11.1   | Manpower Planning for Various Departments                       | 10       |
| 1.11.2   | Statutory Rules and Regulations                                 | 11       |
| 1.11.3   | Organisation Resource Planning and Allocation                   | 12       |
| 1.11.4   | Running on Contract                                             | 12       |
| 1.11.5   | Logistics                                                       | 12       |
| 1.11.6   | Communications                                                  | 13       |
| 1.12     | Technical Matters                                               | 13       |
| 1.12.1   | Procurement of Raw Materials and Other Items                    | 13       |
| 1.13     | Safety Management                                               | 13       |
| 1.14     | Process Control Laboratory                                      | 13       |
| 1.14.1   | Quality Control                                                 | 14       |

|          |                                                                              |           |
|----------|------------------------------------------------------------------------------|-----------|
| 1.15     | Utilities . . . . .                                                          | 14        |
| 1.15.1   | Energy Efficiency, Cogeneration, and Various<br>Methods of Heating . . . . . | 14        |
| 1.16     | Technical and Other Audits . . . . .                                         | 14        |
| 1.17     | Pollution Control and Disposal of Wastes . . . . .                           | 15        |
| 1.18     | Water Budgeting . . . . .                                                    | 15        |
| 1.19     | Electrical Installations . . . . .                                           | 15        |
| 1.20     | Maintenance Management . . . . .                                             | 15        |
| 1.20.1   | Some Quick-Fix Solutions . . . . .                                           | 15        |
| 1.21     | Management of Stores. . . . .                                                | 16        |
| 1.22     | Fire Fighting Systems . . . . .                                              | 16        |
| 1.23     | Innovation, and Research and Development . . . . .                           | 16        |
| 1.24     | Revival of Old Plants . . . . .                                              | 16        |
| 1.25     | Project Division for Expansion and Diversification . . . . .                 | 17        |
| 1.26     | Cost Reduction. . . . .                                                      | 17        |
| <b>2</b> | <b>Financial and Commercial Matters . . . . .</b>                            | <b>19</b> |
| 2.1      | Financial Costs. . . . .                                                     | 19        |
| 2.2      | Cost of Procurement . . . . .                                                | 20        |
| 2.3      | Cash Flow Planning for Site Jobs. . . . .                                    | 20        |
| 2.3.1    | Testing of Static Equipments . . . . .                                       | 21        |
| 2.3.2    | Testing and Mechanical Trial Runs<br>of Moving/Rotating Machineries. . . . . | 21        |
| 2.3.3    | Statutory Inspections . . . . .                                              | 21        |
| 2.3.4    | Pollution Control Facilities and Waste Disposal<br>Arrangements . . . . .    | 22        |
| 2.4      | Cash Flow Planning . . . . .                                                 | 22        |
| 2.4.1    | Typical Start-up Expenses . . . . .                                          | 22        |
| 2.4.2    | Sale of Products . . . . .                                                   | 22        |
| 2.5      | Investment of Own Funds by the Promoters. . . . .                            | 23        |
| 2.6      | Hooking up with Running Plant. . . . .                                       | 23        |
| 2.7      | Depreciation . . . . .                                                       | 24        |
| 2.8      | Government Assistance and Tax Concessions. . . . .                           | 24        |
| 2.9      | Marketing of Products. . . . .                                               | 25        |
| 2.9.1    | Production for Export/Prestigious Clients . . . . .                          | 25        |
| 2.9.2    | Selling the Product . . . . .                                                | 25        |
| 2.9.3    | Instruction Manuals. . . . .                                                 | 25        |
| 2.9.4    | Confirmation of Product Quality . . . . .                                    | 26        |
| 2.9.5    | Internal Records (For Manufacturer) . . . . .                                | 26        |
| 2.9.6    | Dispatch of Products and Storing at Client's<br>Site. . . . .                | 27        |
| 2.9.7    | Delivery Schedules . . . . .                                                 | 28        |
| 2.9.8    | A Word of Caution . . . . .                                                  | 29        |
| 2.10     | Agreements for Technical Consultancy . . . . .                               | 30        |
| 2.10.1   | General Conditions . . . . .                                                 | 32        |

|          |                                                                        |           |
|----------|------------------------------------------------------------------------|-----------|
| 2.11     | Running the Plant on Contract Basis . . . . .                          | 32        |
| 2.11.1   | Typical Options for External Assistance . . . . .                      | 32        |
| 2.11.2   | Agreement Between the Purchaser and External<br>Party . . . . .        | 33        |
| 2.11.3   | Important Jobs to Be Done by Purchaser . . . . .                       | 33        |
| 2.12     | Organisational Resource Planning . . . . .                             | 34        |
| 2.12.1   | Fulfilling of All Orders Accepted by the Sales<br>Department . . . . . | 34        |
| 2.12.2   | Tracking All Purchase Orders Issued . . . . .                          | 34        |
| 2.12.3   | Manufacturing/Production Operations . . . . .                          | 34        |
| 2.12.4   | Safety Issues . . . . .                                                | 35        |
| 2.12.5   | Effluent Treatment . . . . .                                           | 35        |
| 2.12.6   | Maintenance . . . . .                                                  | 35        |
| 2.12.7   | Effect of Weather Conditions . . . . .                                 | 35        |
| 2.12.8   | Manpower . . . . .                                                     | 36        |
| 2.13     | Resource Allocations for Increasing Revenue . . . . .                  | 36        |
| 2.13.1   | Cost of Idle Resources to the Organisation . . . . .                   | 36        |
| 2.13.2   | Some Typical Reasons for Resources Becoming<br>Idle . . . . .          | 37        |
| 2.13.3   | Remedial Actions . . . . .                                             | 38        |
| 2.13.4   | Allocation of Resources . . . . .                                      | 39        |
| 2.13.5   | Spare Capacity Available . . . . .                                     | 40        |
| 2.14     | Cost Reduction . . . . .                                               | 40        |
| 2.14.1   | Factors Contributing to Variable Cost<br>of Production . . . . .       | 40        |
| 2.14.2   | Some Tips for Reducing Variable Cost . . . . .                         | 41        |
| 2.15     | Total Quality Management (TQM) . . . . .                               | 43        |
| 2.15.1   | Quality and Other Goals . . . . .                                      | 43        |
| 2.15.2   | The Key Elements for Successful Implementation<br>of TQM . . . . .     | 43        |
| 2.15.3   | Suggestion Schemes . . . . .                                           | 46        |
| <b>3</b> | <b>Procurement of Equipments . . . . .</b>                             | <b>47</b> |
| 3.1      | Introduction . . . . .                                                 | 47        |
| 3.2      | Planning for Procurement . . . . .                                     | 47        |
| 3.2.1    | Common Equipments and Machineries . . . . .                            | 48        |
| 3.3      | General Guidelines . . . . .                                           | 48        |
| 3.3.1    | Purchaser's Obligations . . . . .                                      | 50        |
| 3.4      | Process Units/Machineries (Present Requirements) . . . . .             | 50        |
| 3.5      | Units Required in Future . . . . .                                     | 51        |
| 3.6      | Selection of Equipments . . . . .                                      | 52        |
| 3.7      | Some Miscellaneous Items for Making a Choice . . . . .                 | 53        |
| 3.7.1    | Vertical Submerged Pumps . . . . .                                     | 53        |
| 3.7.2    | Refractory Bricks . . . . .                                            | 53        |
| 3.7.3    | Caesium-Promoted Catalyst . . . . .                                    | 54        |

|          |                                                                                               |           |
|----------|-----------------------------------------------------------------------------------------------|-----------|
| 3.7.4    | Heat Exchangers . . . . .                                                                     | 54        |
| 3.7.5    | Pressurised Cooling Water Flow Arrangement . . . .                                            | 54        |
| 3.7.6    | Tangential Spray Scrubbing Towers . . . . .                                                   | 54        |
| 3.7.7    | Teflon Gaskets . . . . .                                                                      | 55        |
| 3.7.8    | Graphite Electrodes . . . . .                                                                 | 55        |
| 3.7.9    | Shaft Sealing Arrangements . . . . .                                                          | 56        |
| 3.7.10   | Centrifugal Blower . . . . .                                                                  | 56        |
| 3.7.11   | Water-Tube and Smoke-Tube Boilers . . . . .                                                   | 56        |
| 3.7.12   | Partition Rings . . . . .                                                                     | 57        |
| 3.7.13   | Demisters. . . . .                                                                            | 57        |
| 3.7.14   | Lower Portion of Towers as Circulation Tanks . . . .                                          | 58        |
| 3.7.15   | Protective Linings for Equipments. . . . .                                                    | 58        |
| 3.7.16   | Rubber/Fibreglass Reinforced Linings . . . . .                                                | 60        |
| 3.7.17   | Poly Tetra Fluoro Ethylene (PTFE) Lining. . . . .                                             | 60        |
| 3.7.18   | Glass Lining for Equipments . . . . .                                                         | 61        |
| 3.7.19   | Lead Lining and Lead Bonding . . . . .                                                        | 62        |
| 3.7.20   | Valves, Flanges, Gaskets, Expansion Bellows,<br>Bolts, and Nuts. . . . .                      | 63        |
| <b>4</b> | <b>Erection and Commissioning . . . . .</b>                                                   | <b>65</b> |
| 4.1      | New Process Plant . . . . .                                                                   | 65        |
| 4.1.1    | Future Expansion and Diversification. . . . .                                                 | 65        |
| 4.2      | Prerequisites for Erection. . . . .                                                           | 66        |
| 4.2.1    | Site Office Management: Important Activities . . . .                                          | 67        |
| 4.2.2    | Parallel Activities . . . . .                                                                 | 67        |
| 4.2.3    | Site Fabrication of Large Vessels (Storage Tanks,<br>Absorption Towers, Converters) . . . . . | 68        |
| 4.3      | Erection . . . . .                                                                            | 68        |
| 4.4      | Precommissioning Checks of Infrastructure . . . . .                                           | 72        |
| 4.5      | Items to Be Examined Before Commissioning<br>of Equipments . . . . .                          | 73        |
| 4.5.1    | General Checkpoints Common for All Equipments<br>(Prior to Their Commissioning) . . . . .     | 73        |
| 4.5.2    | Pumps. . . . .                                                                                | 74        |
| 4.5.3    | Blowers. . . . .                                                                              | 74        |
| 4.5.4    | Electrical Items. . . . .                                                                     | 74        |
| 4.5.5    | Heat Exchangers. . . . .                                                                      | 75        |
| 4.5.6    | Boilers. . . . .                                                                              | 75        |
| 4.6      | Pressure Vessels. . . . .                                                                     | 75        |
| 4.7      | Distillation Units . . . . .                                                                  | 76        |
| 4.7.1    | Condensers . . . . .                                                                          | 76        |
| 4.8      | Refrigeration Systems . . . . .                                                               | 76        |
| 4.8.1    | Cooling Towers . . . . .                                                                      | 77        |
| 4.9      | Reactor with Agitators . . . . .                                                              | 77        |
| 4.10     | Water Treatment Plant. . . . .                                                                | 77        |

|          |                                                                                           |           |
|----------|-------------------------------------------------------------------------------------------|-----------|
| 4.11     | Effluent Treatment Plants . . . . .                                                       | 78        |
| 4.11.1   | Aeration System . . . . .                                                                 | 78        |
| 4.12     | Melters for Solids . . . . .                                                              | 78        |
| 4.13     | Calciners . . . . .                                                                       | 78        |
| 4.14     | Pipelines for Liquids and Ducts for Gases . . . . .                                       | 78        |
| 4.15     | Dry Compressed Air for Instrumentation . . . . .                                          | 79        |
| 4.16     | Precommissioning Checklist for Items: Case Study<br>of a Sulphuric Acid Plant . . . . .   | 79        |
| 4.17     | Preliminary Checking of Infrastructure: Case Study<br>of a Sulphuric Acid Plant . . . . . | 80        |
| <b>5</b> | <b>Procurement of Raw Materials and Other Items . . . . .</b>                             | <b>83</b> |
| 5.1      | Selection Criteria . . . . .                                                              | 83        |
| 5.2      | Rate of Consumptions and Inventory . . . . .                                              | 84        |
| 5.3      | Acceptance of Items Which Do Not Meet Specifications . . . . .                            | 85        |
| 5.4      | Storage of Raw Materials at Production Unit . . . . .                                     | 86        |
| 5.5      | Types of Packing for Procurement . . . . .                                                | 87        |
| 5.5.1    | Purchasing by Tankers . . . . .                                                           | 87        |
| 5.5.2    | Solids/Powders of Special Materials . . . . .                                             | 87        |
| 5.6      | Catalysts . . . . .                                                                       | 88        |
| 5.6.1    | Considerations for Purchase of Catalysts<br>from Manufacturer . . . . .                   | 88        |
| 5.6.2    | Fluidised Bed of Catalyst . . . . .                                                       | 88        |
| 5.6.3    | Process Conditions Leading to Loss of Activity . . . . .                                  | 89        |
| 5.6.4    | Initial Cost and Royalty . . . . .                                                        | 89        |
| 5.6.5    | Handling and Storage . . . . .                                                            | 89        |
| 5.6.6    | Performance Guarantees . . . . .                                                          | 90        |
| <b>6</b> | <b>Safety Management . . . . .</b>                                                        | <b>91</b> |
| 6.1      | Introduction . . . . .                                                                    | 91        |
| 6.2      | Preliminary Analysis . . . . .                                                            | 91        |
| 6.3      | Revised Detailed Engineering Document . . . . .                                           | 93        |
| 6.3.1    | Process Details . . . . .                                                                 | 93        |
| 6.3.2    | Properties . . . . .                                                                      | 93        |
| 6.3.3    | Procurement . . . . .                                                                     | 93        |
| 6.3.4    | Use of Guide Words . . . . .                                                              | 94        |
| 6.4      | Equipment Design and Construction . . . . .                                               | 94        |
| 6.5      | Process Vessels and Machineries . . . . .                                                 | 95        |
| 6.6      | Structural Stability of the Chemical Plant . . . . .                                      | 95        |
| 6.7      | Design of Plant Layout . . . . .                                                          | 96        |
| 6.7.1    | Receiving of Raw Materials . . . . .                                                      | 96        |
| 6.8      | Other Precautions . . . . .                                                               | 97        |
| 6.9      | Piping and Instrumentation Diagrams . . . . .                                             | 99        |
| 6.10     | HAZOP Study . . . . .                                                                     | 99        |
| 6.10.1   | Further Analysis . . . . .                                                                | 100       |

|        |                                                                                            |     |
|--------|--------------------------------------------------------------------------------------------|-----|
| 6.11   | Safe Erection and Mechanical Trials . . . . .                                              | 101 |
| 6.11.1 | Dispatch from Fabricator's Works. . . . .                                                  | 101 |
| 6.11.2 | Unloading at Site . . . . .                                                                | 102 |
| 6.11.3 | Site Erection . . . . .                                                                    | 102 |
| 6.11.4 | Mechanical Trials . . . . .                                                                | 103 |
| 6.12   | Safe Commissioning . . . . .                                                               | 103 |
| 6.13   | Standard Operating Procedures for Safe Working . . . . .                                   | 104 |
| 6.14   | Personal Safety Items . . . . .                                                            | 104 |
| 6.15   | Ensuring Safety After Expansion of Capacity. . . . .                                       | 105 |
| 6.15.1 | Plant Expansion . . . . .                                                                  | 105 |
| 6.15.2 | Diversification to New Products . . . . .                                                  | 106 |
| 6.16   | Safe Maintenance Practices for the Plant . . . . .                                         | 106 |
| 6.16.1 | Instructions for Safe Maintenance . . . . .                                                | 107 |
| 6.16.2 | Important Safety Precautions to Be Taken<br>Before Working Inside a Closed Vessel. . . . . | 107 |
| 6.17   | Some Examples from Industries . . . . .                                                    | 107 |
| 6.17.1 | Process Vessels with Heating Jackets or Coils . . . . .                                    | 108 |
| 6.17.2 | In Case of Vessels with Cooling Jacket . . . . .                                           | 109 |
| 6.17.3 | Multiple Safety Devices. . . . .                                                           | 109 |
| 6.18   | CASE Studies (Please See the Illustrations) . . . . .                                      | 110 |
| 6.18.1 | Ammonia-Based Chilled Water Plant. . . . .                                                 | 110 |
| 6.18.2 | Safety Interconnections for Oil Firing System. . . . .                                     | 110 |
| 6.18.3 | Falling Film SO <sub>3</sub> Condenser. . . . .                                            | 110 |
| 6.18.4 | Typical Unsafe Layout and Design . . . . .                                                 | 112 |
| 6.18.5 | Improved (Safer) Fittings for a Process Reactor . . . . .                                  | 112 |
| 6.18.6 | Pressurised Cooling System for Shell and Tube<br>Cooler. . . . .                           | 113 |
| 6.18.7 | Cooling System Under Siphon . . . . .                                                      | 114 |
| 6.18.8 | Precautions for Operation of Boiler. . . . .                                               | 114 |
| 6.19   | Safety Valves. . . . .                                                                     | 116 |
| 6.19.1 | Markings on Safety Valves . . . . .                                                        | 116 |
| 6.19.2 | Malfunctioning of Safety Valves. . . . .                                                   | 117 |
| 6.20   | Preparing for Some Likely Emergency Situations . . . . .                                   | 117 |
| 6.20.1 | Points for Discussions . . . . .                                                           | 118 |
| 6.21   | Safety Organisation. . . . .                                                               | 118 |
| 6.21.1 | Members (To Be Decided by Management) . . . . .                                            | 118 |
| 6.21.2 | Safety Policies . . . . .                                                                  | 119 |
| 6.21.3 | Design a Work Permit System . . . . .                                                      | 119 |
| 6.21.4 | Investigations and Corrections . . . . .                                                   | 120 |
| 6.21.5 | Follow-Up . . . . .                                                                        | 120 |

|          |                                                                                   |     |
|----------|-----------------------------------------------------------------------------------|-----|
| <b>7</b> | <b>Pollution Control</b>                                                          | 121 |
| 7.1      | Reducing the Generation of Effluents                                              | 121 |
| 7.2      | Economic Benefits of Pollution Control                                            | 122 |
| 7.3      | Pre-operational Pollution                                                         | 122 |
| 7.4      | Some Typical Reasons for Environmental Pollution                                  | 123 |
| 7.4.1    | Incorrect Design of Process Units                                                 | 123 |
| 7.4.2    | Incorrect Operation and Improper Maintenance                                      | 124 |
| 7.5      | Preventive Actions for Pollution Control                                          | 125 |
| 7.5.1    | Modify the Process                                                                | 125 |
| 7.5.2    | Use of Better Catalyst                                                            | 125 |
| 7.5.3    | Use Better Equipment                                                              | 126 |
| 7.5.4    | Equipment Design with Adequate Margin<br>for Overload Operation                   | 126 |
| 7.6      | Standard Operating Procedures (SOPs)                                              | 127 |
| 7.6.1    | Confirm the Following Before Starting a Process<br>Plant                          | 127 |
| 7.7      | Condition Monitoring and Preventive Maintenance of Key<br>Equipment               | 128 |
| 7.8      | Contribution by Other Departments to Reduce Pollution                             | 128 |
| 7.8.1    | Better Selection of Process Equipment                                             | 129 |
| 7.8.2    | Stage Inspections During Procurement                                              | 129 |
| 7.8.3    | Procurement of Materials                                                          | 129 |
| 7.9      | Manpower Planning for Proper Plant Operation                                      | 131 |
| 7.10     | Electrical Power                                                                  | 131 |
| 7.11     | Transportation of Materials                                                       | 131 |
| 7.11.1   | Solids                                                                            | 132 |
| 7.11.2   | Liquids                                                                           | 132 |
| 7.11.3   | Gases                                                                             | 132 |
| 7.12     | Design of Plant Layout                                                            | 133 |
| 7.13     | Communications                                                                    | 133 |
| 7.14     | Errors in Sampling Leading to Errors in Process Control                           | 133 |
| 7.15     | Standard Input and Output Norms (SIONs)                                           | 134 |
| 7.15.1   | Disposal of Effluents                                                             | 135 |
| 7.15.2   | Disposal by CETP/CHWTSTD                                                          | 135 |
| 7.15.3   | Disposal of Solid Waste                                                           | 136 |
| 7.16     | Incineration of Solid Wastes                                                      | 137 |
| 7.16.1   | Waste Preparation and Feeding                                                     | 137 |
| 7.16.2   | Considerations for Installing/Procuring<br>an Incineration Plant                  | 137 |
| 7.16.3   | General Guidelines for the Construction<br>of Incinerators Stationary Kiln/Rotary | 138 |
| 7.16.4   | Air Pollution Control System                                                      | 138 |
| 7.17     | Disposal of Liquid Effluents/Wastewaters                                          | 139 |



|          |                                                                                 |            |
|----------|---------------------------------------------------------------------------------|------------|
| 7.18     | Details to be Submitted by Vendor for the Approval of Plant Engineers . . . . . | 141        |
| 7.18.1   | Removal of Sludge . . . . .                                                     | 142        |
| 7.19     | Lamella Clarifier (an Important Unit in the Effluent Treatment Plant). . . . .  | 142        |
| 7.20     | Tube Settler . . . . .                                                          | 142        |
| 7.21     | Dissolved Air Flotation . . . . .                                               | 143        |
| 7.21.1   | Consider for Selection After Examining the Important Components . . . . .       | 143        |
| 7.21.2   | Disposal of Skimmed Out Wet Solid Material . . . . .                            | 144        |
| 7.22     | Sequential Batch Reactor. . . . .                                               | 144        |
| 7.22.1   | Aeration Equipment and Air blowers. . . . .                                     | 144        |
| 7.22.2   | Effluent Removal Systems . . . . .                                              | 145        |
| 7.23     | Air Pollution Control . . . . .                                                 | 145        |
| 7.23.1   | Pollution Control System for Gaseous Effluents . . . . .                        | 145        |
| 7.23.2   | Inquiry for Gas Treatment/Scrubbing Systems . . . . .                           | 147        |
| 7.23.3   | Efficiency of Treatment Desired . . . . .                                       | 148        |
| 7.23.4   | Cyclone Separators . . . . .                                                    | 148        |
| 7.23.5   | Bag Filters . . . . .                                                           | 149        |
| 7.23.6   | Venturi Scrubber. . . . .                                                       | 150        |
| 7.23.7   | Packed Towers . . . . .                                                         | 150        |
| 7.23.8   | Jet Scrubber/Ejector Scrubber. . . . .                                          | 150        |
| 7.23.9   | Tower Packing Items. . . . .                                                    | 151        |
| 7.23.10  | Spray Nozzles . . . . .                                                         | 152        |
| 7.23.11  | Entrainment Separators and Candle Demisters . . . . .                           | 152        |
| 7.23.12  | General . . . . .                                                               | 153        |
| 7.23.13  | Electrostatic Precipitators (ESPs). . . . .                                     | 153        |
| 7.24     | Chimney for Final Discharge . . . . .                                           | 155        |
| <b>8</b> | <b>Maintenance . . . . .</b>                                                    | <b>157</b> |
| 8.1      | Condition Monitoring of Units and Machines. . . . .                             | 157        |
| 8.2      | Preventive Breakdown Maintenance Programme. . . . .                             | 158        |
| 8.3      | Facilities to Be Available in the Plant . . . . .                               | 158        |
| 8.4      | Inventory of Mechanical/Electrical/Instrument Spares . . . . .                  | 159        |
| 8.5      | Standardisation of Spares. . . . .                                              | 161        |
| 8.6      | Advancing the Plant Shutdown. . . . .                                           | 161        |
| 8.7      | Postponing the Plant Shutdown . . . . .                                         | 162        |
| 8.8      | Cost of Shutdown. . . . .                                                       | 162        |
| 8.9      | Restarting the Plant After Annual Shutdown . . . . .                            | 163        |
| 8.10     | Case Study: An Annual Shutdown of a Sulphuric Acid–Oleum Plant . . . . .        | 164        |

|          |                                                                    |     |
|----------|--------------------------------------------------------------------|-----|
| <b>9</b> | <b>Utilities</b>                                                   | 167 |
| 9.1      | Waste Heat Recovery Boilers (WHRBs)                                | 167 |
| 9.1.1    | Water-Tube Boiler                                                  | 169 |
| 9.1.2    | Smoke-Tube Boiler                                                  | 169 |
| 9.2      | Steaming Economisers                                               | 169 |
| 9.2.1    | Selection Criteria                                                 | 170 |
| 9.3      | Cogeneration of Power                                              | 171 |
| 9.3.1    | Planning for Cogeneration                                          | 171 |
| 9.3.2    | Options Which Shall Be Considered for Buying<br>a Steam Turbine    | 172 |
| 9.3.3    | Points to Be Included in the enquiries for Steam<br>Turbines       | 174 |
| 9.4      | Steam Superheaters                                                 | 174 |
| 9.5      | Steam De-Superheaters                                              | 175 |
| 9.6      | Electrical Equipments and Installations                            | 176 |
| 9.6.1    | Electrical Power Needed in Initial Phases—Before<br>Start of Plant | 177 |
| 9.6.2    | Electrical Power Need                                              | 177 |
| 9.6.3    | Sanctioned Maximum Demand                                          | 178 |
| 9.6.4    | Emergency Loads                                                    | 179 |
| 9.6.5    | In-House Power Generation                                          | 179 |
| 9.6.6    | Uninterrupted Power Supply for Critical Loads                      | 182 |
| 9.6.7    | Compliance with Statutory Rules<br>and Instructions                | 182 |
| 9.6.8    | Electrical Transformers                                            | 182 |
| 9.6.9    | Electrical Power Distribution in Plant                             | 184 |
| 9.6.10   | Electrical Motors                                                  | 185 |
| 9.6.11   | Diesel Generator Set                                               | 185 |
| 9.7      | Refrigeration Systems                                              | 187 |
| 9.7.1    | Essential Components                                               | 187 |
| 9.7.2    | Criteria for Selection/Procurement                                 | 187 |
| 9.8      | Cooling Towers                                                     | 189 |
| 9.8.1    | Selection Criteria                                                 | 189 |
| 9.9      | Air Drying Plant                                                   | 190 |
| 9.9.1    | Considerations for Procurement                                     | 190 |
| 9.10     | Nitrogen Plants                                                    | 191 |
| 9.10.1   | Pressure Swing Adsorption PSA Plant                                | 191 |
| 9.10.2   | Membrane Process for N <sub>2</sub> Gas                            | 192 |
| 9.11     | Water Budgeting and Management                                     | 193 |
| 9.11.1   | Quality of Water Required                                          | 194 |
| 9.11.2   | Sources of Water                                                   | 194 |
| 9.11.3   | Storage Facilities for Water                                       | 195 |

|           |                                                                                                              |            |
|-----------|--------------------------------------------------------------------------------------------------------------|------------|
| 9.11.4    | Elevated Storage Reservoirs (ESR) . . . . .                                                                  | 195        |
| 9.11.5    | Water Treatment Plants . . . . .                                                                             | 196        |
| 9.11.6    | Specifications of Treated Water . . . . .                                                                    | 198        |
| <b>10</b> | <b>Instrumentation . . . . .</b>                                                                             | <b>199</b> |
| 10.1      | Introduction . . . . .                                                                                       | 199        |
| 10.2      | Main Objectives . . . . .                                                                                    | 199        |
| 10.2.1    | For Operating Units . . . . .                                                                                | 199        |
| 10.2.2    | For Safety of Personnel and Plant Equipments . . . . .                                                       | 200        |
| 10.2.3    | For Pollution Control . . . . .                                                                              | 200        |
| 10.2.4    | For Energy Efficiency . . . . .                                                                              | 200        |
| 10.2.5    | For Ensuring Quality of Products . . . . .                                                                   | 201        |
| 10.2.6    | For Efficiency of Operations. . . . .                                                                        | 201        |
| 10.3      | Types of Instruments for Process Monitoring . . . . .                                                        | 201        |
| 10.4      | Selection Criteria for Plant Control Instruments . . . . .                                                   | 202        |
| 10.5      | Installation and Commissioning . . . . .                                                                     | 203        |
| 10.6      | Some Practical Suggestions . . . . .                                                                         | 203        |
| 10.6.1    | Float-Type Level Indicator. . . . .                                                                          | 204        |
| 10.6.2    | Suggestions . . . . .                                                                                        | 204        |
| 10.6.3    | Non-functioning of High-Level Alarms . . . . .                                                               | 205        |
| 10.7      | Ultrasonic Instruments for Level Indication . . . . .                                                        | 205        |
| 10.8      | Pressure Gauges . . . . .                                                                                    | 205        |
| 10.9      | Thermocouple/Dial Thermometer . . . . .                                                                      | 206        |
| 10.9.1    | Watching Carefully . . . . .                                                                                 | 206        |
| 10.10     | Rotameters. . . . .                                                                                          | 207        |
| 10.11     | Turbine Metres. . . . .                                                                                      | 207        |
| 10.12     | Vortex Metre . . . . .                                                                                       | 207        |
| 10.13     | Some More Suggestions . . . . .                                                                              | 208        |
| 10.14     | For Feeding Liquids to Small Process Units. . . . .                                                          | 208        |
| 10.15     | Gas Flowmeter Reading Incorrect. . . . .                                                                     | 209        |
| 10.15.1   | Precaution—Use a Roots-Type Blower<br>with Variable Frequency-Driven Motor . . . . .                         | 209        |
| 10.16     | Some Practical Tips if Thermocouples are Showing<br>Incorrect Temperature Readings . . . . .                 | 209        |
| 10.17     | Gas Leak Detection . . . . .                                                                                 | 210        |
| 10.17.1   | A Word of Caution . . . . .                                                                                  | 210        |
| 10.18     | Incorrect Readings by Weigh Bridge. . . . .                                                                  | 210        |
| 10.19     | Strength Indicator for Sulphuric Acid (Indicating Low<br>Strength But Actual Strength May Be High) . . . . . | 211        |
| 10.20     | Stack Gas Analyser for Sulphuric Acid Plant . . . . .                                                        | 211        |
| 10.21     | Stack Gas Analyser for Absorbed Exit for HCl Gas . . . . .                                                   | 211        |
| 10.22     | General . . . . .                                                                                            | 212        |
| 10.22.1   | Checking Purity of Filtered Liquids. . . . .                                                                 | 212        |
| 10.23     | Feed Control by Centrifugal Pump . . . . .                                                                   | 212        |
| 10.24     | Calibration Test Benches . . . . .                                                                           | 212        |

|           |                                                                                                                                                    |     |
|-----------|----------------------------------------------------------------------------------------------------------------------------------------------------|-----|
| <b>11</b> | <b>Energy Efficiency</b> . . . . .                                                                                                                 | 213 |
| 11.1      | Thermal Energy . . . . .                                                                                                                           | 213 |
| 11.1.1    | Modifications for Reducing Energy Consumption . . . . .                                                                                            | 214 |
| 11.1.2    | Better Heat Exchanger Designs. . . . .                                                                                                             | 216 |
| 11.2      | Changes in Plant Layout . . . . .                                                                                                                  | 216 |
| 11.3      | General Energy Saving Methods in the Plant Systems. . . . .                                                                                        | 216 |
| 11.4      | Reduce Energy Consumption for Material Transfer . . . . .                                                                                          | 217 |
| 11.5      | Saving Electrical Energy . . . . .                                                                                                                 | 218 |
| 11.5.1    | Variable-Frequency Drives for Speed Control. . . . .                                                                                               | 219 |
| 11.5.2    | Consider for Use. . . . .                                                                                                                          | 219 |
| 11.5.3    | Electrolytic Processes (Examples-Manufacture of NaOH, Aluminium, Electrical Grade Copper, Gold Refining, Electrolytic MnO <sub>2</sub> ) . . . . . | 220 |
| 11.6      | Heat Recovery and Cogeneration . . . . .                                                                                                           | 220 |
| 11.6.1    | Cogeneration of Power Through Waste Heat Recovery Boilers and Economisers . . . . .                                                                | 221 |
| 11.6.2    | Heat Recovery from Gases. . . . .                                                                                                                  | 221 |
| 11.6.3    | Heat Recovery from Hot Acid . . . . .                                                                                                              | 223 |
| 11.7      | Efficient Use of Steam. . . . .                                                                                                                    | 223 |
| 11.7.1    | Use for Power Generation . . . . .                                                                                                                 | 223 |
| 11.7.2    | Use as Heating Medium . . . . .                                                                                                                    | 224 |
| 11.7.3    | Selection of Steam Traps . . . . .                                                                                                                 | 224 |
| 11.7.4    | Steam Traps. . . . .                                                                                                                               | 225 |
| 11.7.5    | For Considerations by the Plant Engineers . . . . .                                                                                                | 225 |
| 11.7.6    | Some Typical Steam Traps. . . . .                                                                                                                  | 226 |
| <b>12</b> | <b>Methods for Heating</b> . . . . .                                                                                                               | 227 |
| 12.1      | Introduction . . . . .                                                                                                                             | 227 |
| 12.2      | Heating Load and Temperatures Required . . . . .                                                                                                   | 227 |
| 12.3      | Broad Selection of the Heating Method. . . . .                                                                                                     | 227 |
| 12.4      | Factors to Be Considered for Selection of Heating Method . . . . .                                                                                 | 228 |
| 12.4.1    | Types of Equipment . . . . .                                                                                                                       | 228 |
| 12.4.2    | Types of Processes . . . . .                                                                                                                       | 228 |
| 12.4.3    | Space Availability. . . . .                                                                                                                        | 229 |
| 12.4.4    | Operating Temperatures. . . . .                                                                                                                    | 229 |
| 12.4.5    | Temperature Control Required . . . . .                                                                                                             | 229 |
| 12.4.6    | Purity of Material to Be Maintained . . . . .                                                                                                      | 229 |
| 12.4.7    | Availability of the Heating Medium at Site . . . . .                                                                                               | 229 |
| 12.5      | Construction of the Equipment. . . . .                                                                                                             | 229 |
| 12.6      | Minimising the Loss of Heat from Process Units . . . . .                                                                                           | 230 |
| 12.7      | Methods for Conservation of Heat/Reducing Requirement of Heat . . . . .                                                                            | 231 |

|           |                                                                          |            |
|-----------|--------------------------------------------------------------------------|------------|
| 12.8      | Various Methods for Heating . . . . .                                    | 231        |
| 12.8.1    | Process Heating by Steam . . . . .                                       | 231        |
| 12.8.2    | Considerations for Buying a Coal-Fired Boiler . . . . .                  | 231        |
| 12.8.3    | Electrical Heating . . . . .                                             | 233        |
| 12.8.4    | Heating Directly by Flue Gases . . . . .                                 | 233        |
| 12.8.5    | Heating by Hot Process Gases . . . . .                                   | 233        |
| 12.9      | Factors to Be Considered for Selection of Fuel. . . . .                  | 234        |
| 12.10     | Accessories/Site Facilities Required for Using Various<br>Fuels. . . . . | 235        |
| 12.10.1   | Gaseous Fuels . . . . .                                                  | 235        |
| 12.10.2   | Liquid Fuels. . . . .                                                    | 237        |
| 12.10.3   | Use of Solid Fuels . . . . .                                             | 239        |
| 12.10.4   | Industrial Waste . . . . .                                               | 240        |
| 12.11     | Combustion Air for Firing Systems. . . . .                               | 240        |
| 12.12     | Safety Devices to Be Regularly Checked<br>by Senior Engineers . . . . .  | 241        |
| 12.13     | Heat Transfer Oils (Thermic Fluids) . . . . .                            | 241        |
| <b>13</b> | <b>Inventory Control . . . . .</b>                                       | <b>243</b> |
| 13.1      | Introduction . . . . .                                                   | 243        |
| 13.2      | Record of Past Consumptions . . . . .                                    | 244        |
| 13.3      | Use of Guide Words. . . . .                                              | 244        |
| 13.3.1    | Simplify . . . . .                                                       | 244        |
| 13.3.2    | Substitute. . . . .                                                      | 245        |
| 13.3.3    | Strengthen . . . . .                                                     | 246        |
| 13.3.4    | Safety Features. . . . .                                                 | 246        |
| 13.3.5    | Standardise . . . . .                                                    | 246        |
| 13.4      | Stocks for Emergency Use/Repairs . . . . .                               | 247        |
| 13.5      | Suggestions . . . . .                                                    | 247        |
| 13.5.1    | Minimum Stock Level to be Maintained . . . . .                           | 247        |
| 13.5.2    | Reorder Point. . . . .                                                   | 248        |
| 13.5.3    | Minimise the Time Required for Procurement. . . . .                      | 248        |
| 13.6      | General Considerations . . . . .                                         | 248        |
| 13.7      | Supply Chain Management . . . . .                                        | 249        |
| 13.7.1    | Coordination . . . . .                                                   | 249        |
| 13.7.2    | Example . . . . .                                                        | 250        |
| 13.8      | Planning and Management of Supply . . . . .                              | 250        |
| 13.8.1    | The Purchase Department . . . . .                                        | 251        |
| 13.8.2    | Production Department . . . . .                                          | 251        |
| 13.8.3    | Logistics . . . . .                                                      | 251        |
| 13.8.4    | Make or Buy . . . . .                                                    | 252        |
| 13.8.5    | Outsourcing . . . . .                                                    | 253        |
| 13.9      | Performance Measurement. . . . .                                         | 254        |
| 13.10     | Warehousing Management. . . . .                                          | 254        |
| 13.11     | Just-In-Time (JIT). . . . .                                              | 254        |

|           |                                                                                     |            |
|-----------|-------------------------------------------------------------------------------------|------------|
| 13.12     | Reverse Supply Chain . . . . .                                                      | 255        |
| 13.13     | Some Suggestions Which May Be Useful . . . . .                                      | 255        |
| 13.14     | Improve the Equipment Designs/Operating Methods . . . . .                           | 256        |
| 13.15     | FIFO—First In First Out . . . . .                                                   | 256        |
| 13.16     | LIFO—Last In First Out . . . . .                                                    | 257        |
| 13.17     | LIFO—Last In Last Out . . . . .                                                     | 257        |
| <b>14</b> | <b>General Administration . . . . .</b>                                             | <b>259</b> |
| 14.1      | Communications . . . . .                                                            | 259        |
| 14.1.1    | Internal . . . . .                                                                  | 259        |
| 14.1.2    | External . . . . .                                                                  | 260        |
| 14.1.3    | From Superiors (Seniors) to Subordinates<br>(Juniors) . . . . .                     | 260        |
| 14.1.4    | From Subordinates (Juniors) to Superiors<br>(Seniors) . . . . .                     | 261        |
| 14.1.5    | InterDepartment (Sideways Communication) . . . . .                                  | 262        |
| 14.2      | General . . . . .                                                                   | 262        |
| 14.3      | Advantages of Good Communication Practice . . . . .                                 | 262        |
| 14.3.1    | To Take Care . . . . .                                                              | 263        |
| 14.3.2    | To Avoid . . . . .                                                                  | 263        |
| 14.4      | Example of a Standard Operating Practice . . . . .                                  | 264        |
| 14.5      | Fire Fighting . . . . .                                                             | 265        |
| 14.6      | Logistics . . . . .                                                                 | 266        |
| 14.7      | Compliance with Statutory Matters . . . . .                                         | 267        |
| 14.7.1    | Technical . . . . .                                                                 | 267        |
| 14.7.2    | Inspection of Transport Vehicles . . . . .                                          | 270        |
| 14.7.3    | Legal and Commercial Matters . . . . .                                              | 270        |
| 14.7.4    | Operating Licences and Labour Laws . . . . .                                        | 271        |
| <b>15</b> | <b>Process Control, Product Quality, and Research and<br/>Development . . . . .</b> | <b>273</b> |
| 15.1      | Laboratory Facilities . . . . .                                                     | 273        |
| 15.1.1    | Investment in Laboratory Apparatus/Equipments . . . . .                             | 274        |
| 15.2      | Product Quality . . . . .                                                           | 274        |
| 15.2.1    | Visits to Clients' Work . . . . .                                                   | 274        |
| 15.2.2    | Factors for Ensuring Proper Quality . . . . .                                       | 275        |
| 15.3      | Process Control . . . . .                                                           | 278        |
| 15.3.1    | Some General Checks . . . . .                                                       | 278        |
| 15.3.2    | Supervision of Plant Operations . . . . .                                           | 279        |
| 15.3.3    | Selection of Sample Size for Examination<br>of Produced Items . . . . .             | 279        |
| 15.3.4    | Shelf Life of Items . . . . .                                                       | 281        |
| 15.3.5    | Confidence Level Required . . . . .                                                 | 281        |
| 15.3.6    | Sampling Errors . . . . .                                                           | 282        |

|           |                                                                                  |            |
|-----------|----------------------------------------------------------------------------------|------------|
| 15.4      | Material of Construction of Vessels and Containers . . . . .                     | 283        |
| 15.5      | Innovation, Research and Development . . . . .                                   | 283        |
| 15.5.1    | Aims of the Activities for Research<br>and Development . . . . .                 | 285        |
| <b>16</b> | <b>Smooth Running of the Production Plants . . . . .</b>                         | <b>287</b> |
| 16.1      | Process for Manufacture of Sulphuric Acid . . . . .                              | 287        |
| 16.2      | Batch Process for Manufacture of Papermaker's Alum<br>(Iron Free) . . . . .      | 288        |
| 16.3      | Process for Manufacture of Alum from Bauxite . . . . .                           | 290        |
| 16.4      | Process for Manufacture of Single Superphosphate . . . . .                       | 292        |
| 16.5      | Process for Manufacture of Caustic Soda and Chlorine . . . . .                   | 292        |
| 16.6      | Process for Manufacture of Nitric Acid by Oxidation<br>of Ammonia . . . . .      | 295        |
| 16.7      | Steam Generation by Coal-Fired Boiler . . . . .                                  | 297        |
| 16.8      | Some Useful Formats for the Production Managers . . . . .                        | 298        |
| 16.8.1    | Production Record of a Plant . . . . .                                           | 299        |
| 16.8.2    | Record of Consumption of Raw Materials . . . . .                                 | 299        |
| 16.8.3    | Record of Expenses Incurred on Maintenance<br>of the Plant . . . . .             | 299        |
| 16.8.4    | Record of Raw Material Stock Position . . . . .                                  | 300        |
| 16.8.5    | Record of Sale of Products . . . . .                                             | 300        |
| 16.8.6    | Rejected and Returned Products . . . . .                                         | 300        |
| 16.8.7    | Record of Stores Inventory . . . . .                                             | 301        |
| <b>17</b> | <b>Identifications of Hazards: Some Practical Examples . . . . .</b>             | <b>303</b> |
| 17.1      | Identification of Potential Sources of Hazards . . . . .                         | 303        |
| 17.2      | Case Study: Manufacture of Sulphuric Acid . . . . .                              | 304        |
| 17.2.1    | Identification of Some Hazards in Sulphuric<br>Acid Manufacturing Plan . . . . . | 305        |
| 17.3      | Illustration: Manufacture of Nitric Acid . . . . .                               | 307        |
| 17.3.1    | Identification of Some Hazards in Nitric Acid<br>Manufacturing Plant . . . . .   | 308        |
| 17.3.2    | Steam Supply to Ammonia Evaporators . . . . .                                    | 310        |
| 17.3.3    | Application of Some Typical Guide Words . . . . .                                | 310        |
| 17.4      | Manufacture of Caustic Soda (Membrane Process) . . . . .                         | 310        |
| 17.4.1    | Identification of Some Hazards in Caustic Soda<br>Manufacturing Plant . . . . .  | 311        |
| 17.4.2    | Application of Some Typical Guide Words . . . . .                                | 312        |
| <b>18</b> | <b>General Technical Matters . . . . .</b>                                       | <b>313</b> |
| 18.1      | Batch and Continuous Production . . . . .                                        | 313        |
| 18.1.1    | Salient Features of Batch Production . . . . .                                   | 313        |
| 18.1.2    | Cycle Time . . . . .                                                             | 314        |

|           |                                                                                   |            |
|-----------|-----------------------------------------------------------------------------------|------------|
| 18.1.3    | Idle Time. . . . .                                                                | 314        |
| 18.1.4    | Maintenance of the Process Units . . . . .                                        | 315        |
| 18.1.5    | Salient Features of Continuous Production . . . . .                               | 315        |
| 18.2      | Pressure Vessels . . . . .                                                        | 316        |
| 18.2.1    | Duty Conditions to Be Considered . . . . .                                        | 316        |
| 18.2.2    | General Arrangement Drawing . . . . .                                             | 317        |
| 18.2.3    | Finalise Detailed Arrangement . . . . .                                           | 317        |
| 18.2.4    | Mechanical Design . . . . .                                                       | 317        |
| 18.3      | Plant Operation at Different Pressures . . . . .                                  | 321        |
| 18.3.1    | Plant Operation Below Atmospheric Pressure . . . . .                              | 321        |
| 18.3.2    | Plant Operation Above Atmospheric Pressure . . . . .                              | 321        |
| 18.3.3    | Plant Operation at Above and Below<br>Atmospheric Pressures. . . . .              | 322        |
| 18.4      | Typical Checklist for Smooth Production Run . . . . .                             | 322        |
| 18.4.1    | Coordination with Marketing (Sales)<br>and Logistics Department. . . . .          | 322        |
| 18.4.2    | Availability of Items for Process<br>and Maintenance. . . . .                     | 323        |
| 18.4.3    | Daily Checks of All Important Equipment . . . . .                                 | 323        |
| 18.4.4    | Mechanical, Electrical, and Instrumentation<br>Spares . . . . .                   | 324        |
| 18.4.5    | Preventing Interruptions Due to Adverse<br>Situations. . . . .                    | 325        |
| 18.5      | Some Quick Fix Solutions for Plant Operation . . . . .                            | 325        |
| 18.5.1    | Items to Be Readily Available . . . . .                                           | 326        |
| 18.5.2    | A Word of Caution. . . . .                                                        | 327        |
| 18.6      | Equipment Modification for Adding Cooling/Heating<br>Capacity . . . . .           | 327        |
| 18.7      | Selecting the Process and Technology. . . . .                                     | 328        |
| <b>19</b> | <b>Technocommercial Matters. . . . .</b>                                          | <b>331</b> |
| 19.1      | Revival of Plants . . . . .                                                       | 331        |
| 19.1.1    | Setting Up a New Industry. . . . .                                                | 331        |
| 19.1.2    | Revival of a Plant. . . . .                                                       | 332        |
| 19.1.3    | Site Visit and Inspection . . . . .                                               | 333        |
| 19.1.4    | Further Planning . . . . .                                                        | 335        |
| 19.1.5    | Requirement of Funds . . . . .                                                    | 335        |
| 19.1.6    | Revival with Same Products: Process<br>and Equipment Modifications Only . . . . . | 336        |
| 19.1.7    | Raw Materials . . . . .                                                           | 337        |
| 19.1.8    | Cost-Cutting Without Compromising on Safety . . . . .                             | 337        |
| 19.1.9    | Revival with Expansion of Capacity . . . . .                                      | 338        |



|                        |                                                                       |            |
|------------------------|-----------------------------------------------------------------------|------------|
| 19.2                   | Technical and Commercial Audits . . . . .                             | 340        |
| 19.2.1                 | Planning, Design, and Fabrication Activities. . . . .                 | 340        |
| 19.2.2                 | Procurement and Purchase Activities—Legal<br>and Commercial . . . . . | 340        |
| 19.2.3                 | Regarding Implementation of the Project . . . . .                     | 341        |
| 19.2.4                 | Impact of the Project on the Organisation . . . . .                   | 341        |
| 19.2.5                 | Appointment of the Technical Auditor. . . . .                         | 342        |
| 19.2.6                 | Safety Audits . . . . .                                               | 342        |
| 19.2.7                 | Performance Audits. . . . .                                           | 343        |
| 19.2.8                 | Energy Audit . . . . .                                                | 343        |
| <b>Index . . . . .</b> |                                                                       | <b>347</b> |

# Chapter 1

## Introduction

Chemical industries play a very important role in our life by contributing various products using every day such as healthcare products, detergents, cooking gas, fuel for vehicles, pharmaceuticals, paints and dyes, plastics, petrochemicals, synthetic fibres, water treatment chemicals, fertilisers for crops, insecticides, and pesticides—the list is very large—almost endless. The chemical industries also make a very useful contribution to the national economies.

### 1.1 Typical Features of Chemical Industries

- They have large thermal and electrical energy changes (consumption/generation).
- Their operations are mostly automatic. Very careful continuous monitoring is necessary in most of them—(but less manpower is required).
- They do not produce much noise generally (except where crushing and grinding are done).
- Effluents are generated in considerable quantities (toxic, harmful substances), and they can pollute the environment since their disposal is not easy.
- There could be fire hazards or long-term health hazards.

There are a large number of chemical industries in operation and new ones are being added all over the world. However, the general perception is that though very useful, chemical industries pollute the environment and could be very dangerous some times.

Governments of all countries are fully aware of this and have made stringent rules and regulations to monitor their operations to ensure safety of personnel and control of environmental pollution.

## 1.2 Modern Managements

Modern responsible and successful managements make efforts to operate the chemical industries without any accidents (completely safe for plant personnel as well as outsiders), without causing any environmental pollution (minimising generation of waste and proper treatment of all the effluents) in a highly energy efficient manner and minimising consumptions of raw material while delivering the products as per specified quality and quantity required by the clients.

The revenues generated are used very judiciously for necessary maintenance of safety devices, effluent treatment, process units and machinery; procuring supplies of raw materials and other inputs; paying taxes and duties to the government, welfare of all working personnel, carrying out innovation for improvement and research for new technologies; and return of capital with interest as per terms of agreement with all creditors and stakeholders.

Reasonable amounts are set aside for replacement of old (corroded) process units and worn out machinery, and as a contingency fund for any unforeseen situation. This is very important for a chemical industry because the rate of corrosion is much more than general fabrication shops or engineering industries. The distribution of profits to the promoters/owners (and the equity shareholders) is generally done after above allocations.

### 1.2.1 *Important Management Activities for the Chemical Industry*

Modern managements with a progressive and practical outlook apply their knowledge, experience, and resources for executing their main functions of planning, organising, staffing, coordinating, directing, and controlling the activities essential for the successful establishment, operation, expansion, modernisation, and revival of idle units.

*They are able to perform these important managerial functions by employing professionals with knowledge and experience in their respective fields.*

There can be a certain overlap among these functions and the activities during execution. Though the activities are allotted to different departments, no sharp divisions are generally made. All departments and sections are supposed to work as one well-oiled machine with clear communication and cooperation with each other; though some demarcation could be made for convenience of working by using the individual expertise for meeting the aims of the organisation.

Broadly these activities are arranged to suit the nature of business (manufacturing or trading), geographic area of operations, whether running on a low-volume, high-unit-price basis or high-volume, low-unit-price basis; dependence on local or imported technology, or materials; producing items for mass consumption; healthcare products, or industrial use; producing goods which need safe and careful handling, and so on.

The main activities typically required for setting up a chemical plant are as follows:

- Market studies and finalising the product mix,
- Basic and detailed engineering (*please see below*),
- Hazid and Hazop studies,
- Incorporating safety devices and revising P and ID, operating procedures, etc.,
- Obtaining statutory permissions and necessary licences,
- Creating site infrastructure and carrying out site activities,
- Procuring plant and machinery,
- Erection and commissioning of the process plant,
- Stabilising safe and efficient operation and maintenance of the plant,
- Minimising generation of effluents and ensuring their proper treatment in-house or disposal through common disposal facilities run by statutorily authorised parties,
- Production of chemicals as per specifications given by customers,
- Quality control checks before dispatch,
- To meeting the delivery schedules agreed with clients.

*Production management has to look into all these and ensure that the plant runs safely, without causing any environmental pollution while complying with all statutory rules and regulations, and generates sufficient revenues to get a satisfactory rate of return. These essential activities are briefly described below and elaborated elsewhere in this book.*

### ***1.2.2 Estimation of Demand for the Products***

An initial estimation of demand for various products is carried out to shortlist them. This is necessary for planning a new industry or for diversifying to additional products from the existing running plant. It can be entrusted to a professional agency if it cannot be done by the organisation itself. It should be a reasonably reliable estimate of demand for the products and their specifications generally required by clients. The products are shortlisted accordingly and the production planning is based on these estimates.

## **1.3 Basic Engineering Documents**

It shall be prepared for deciding further in the matter (*as it gives more information*):

- Production capacities to be planned for the product mix (*at present and in future*);
- Process flow sheet (*for selecting process and technology*);

- Issues related to safety and environmental pollution control;
- Expected running days per year and stoppage for annual overhaul;
- Rated capacity of the plant for various products (continuous operation) or number of batches per year if it will be a batch type operation;
- The expected total investment required;
- Layout for the product mix (*at present and in future*);
- Infrastructure required (land, approach roads, storage);
- Raw material and utilities consumptions (water, power, and steam);
- Engineers, technicians, and workforce required;
- Maintenance requirements and other expenses;
- The expected **return on investment**;
- Time required to implement the project;
- Shortlisted locations based on availability of raw materials, power, water, geographic and climatic conditions, proximity to clients, existence of approach roads, etc.;
- It is important to look into the suitability of climate for safe storage, handling of various raw materials, the products, and safe operation of the process plant. The decision to set up the process industry or for adding more products to existing industry can be taken on the basis of above information.

### 1.3.1 Rated Capacity

This shall be based on annual production and not on daily production. It should take into consideration the plant stoppages due to annual overhaul, and occasional breakdowns/process problems.

#### Example

A continuously running plant can produce 100 MT per day of sulphuric acid.

It needs about 20 days of complete stoppage for annual overhaul and maintenance. It is also estimated that the plant would be stopped for a total of about 15 days due to various reasons during the year such as sulphur spray gun choking, air blower maintenance, repair to control valves in acid lines, etc.

This leaves  $365 - 20 - 15 = 330$  days of actual running period.

The annual production would be  $330 \times 100 = 33,000$  MTs and not 36,500 MTs.

The sales volume would be 33,000 MTs, and revenues will be obtained from these only.

However, certain expenses on security, stores management, plant lighting, salaries of supervisory staff, maintenance crew, water supply, etc., will be incurred even when the plant is not producing. Money is spent on all these matters throughout the year for 365 days.

The plant shall be rated as 33,000 MT/annum therefore, and cost of production per MT shall be calculated by dividing total annual costs by 33,000 and **not by 36,500 MT** as this can give an incorrect figure.

In case of plants operating with complicated technologies or handling very corrosive products, the running days per year shall be considered even lower—say, 300/310 only.

The profit per MT and return on investment shall be estimated on these figures. It is obvious that all efforts shall be made to minimise the annual shutdown period and other stoppages during the year.

However, the plant shall not be operated at overload condition *beyond safe limits* during the running days to achieve higher production for getting more profits.

## 1.4 Detailed Market Survey

This is to be done now to obtain reliable information through an experienced marketing organisation. This is necessary before finally deciding to proceed further on the basis of the basic engineering document.

It should cover all the aspects of the demand for the product—the product quality generally specified by clients (minimum purity required, tolerance limits for impurities), the types of containers preferred (carbouys/tankers); quantities of products required and the delivery schedules convenient to them; the present producers of the products, the demand–supply gap in the market, whether demand for the product is seasonal or all through the year, in domestic market or overseas.

## 1.5 Finalising the Product Mix

- The initial planning for the production unit may be for only one product or more products with a certain capacity for each of them.
- The future product mix (with more products) and the corresponding production capacities can also be planned in the beginning itself while setting up the industry.
- Expansion of production capacities in the future may also be planned in the beginning.
- This will enable design of process scheme and the list of equipments *to be installed at present*. Planning for the site infrastructure for the present and for the future shall also be done accordingly.
- Some of the process units and machinery from the plant can be used **as such** in future also, while some additional equipments may be required for the product mix and production capacities planned for the future. Some existing units may need only upgradation.

*A plant for manufacture of sulphuric acid can produce 98.3 % technical grade acid only or can also produce 25 % oleum by addition of an absorption tower with accessories for circulation system. An oleum boiler can then be added to produce*