

# Contents

|  |         |
|--|---------|
| <i>Preface to Second Edition</i> ..... | (xxv)   |
| <i>Preface to First Edition</i> .....  | (xxvii) |
| <i>About the Author</i> .....          | (xxix)  |
| <i>Abbreviations</i> .....             | (xxxix) |

## CHAPTER 1

### Introduction

|  |   |
|--|---|
| 1.1 Dictionary Definitions.....                          | 1 |
| 1.2 Importance of Maintenance Function.....              | 2 |
| 1.3 The Three Dimensions of Maintenance .....            | 3 |
| 1.4 Scope of Maintenance Function.....                   | 5 |
| 1.5 Objectives of Maintenance Function .....             | 6 |
| 1.6 Responsibilities of a Maintenance Department.....    | 7 |
| 1.7 Responsibilities of Maintenance Engineer .....       | 8 |
| 1.8 Tero-Technology .....                                | 9 |
| 1.9 Integrated Maintenance Management System (IMMS)..... | 9 |
| 1.10 Conclusion .....                                    | 9 |

## CHAPTER 2

### Principles of Maintenance Planning

|  |    |
|--|----|
| 2.1 Planned Maintenance.....                     | 11 |
| 2.2 Why Maintenance Planning? .....              | 12 |
| 2.3 Advantages of Well Planned Maintenance ..... | 12 |
| 2.4 The Five to One Thumb Rule .....             | 13 |
| 2.5 Types of Maintenance Plans.....              | 13 |

|      |   |    |
|------|---|----|
| 2.6  | The Essentials of Maintenance Planning .....            | 14 |
| 2.7  | What is to be Maintained? .....                         | 14 |
| 2.8  | How is it to be Maintained? .....                       | 14 |
| 2.9  | When is it to be Maintained? .....                      | 15 |
| 2.10 | Priority Allocation of Maintenance Activity .....       | 16 |
| 2.11 | Objectives of Planned Maintenance .....                 | 16 |
| 2.12 | Benefits of Planned Maintenance .....                   | 17 |
| 2.13 | Basic Steps of Planning of Maintenance Activities ..... | 17 |
| 2.14 | Working Pattern of Maintenance Activities .....         | 19 |
| 2.15 | Principles of Planned Maintenance Activity .....        | 20 |
| 2.16 | Conclusion .....  | 24 |

## CHAPTER 3

### Categories of Maintenance

|     |  |    |
|-----|--|----|
| 3.1 | Different Approaches to Maintenance .....                                | 25 |
| 3.2 | Definitions of the Categories .....                                      | 25 |
| 3.3 | Maintenance Policies with Specific Reference to maintenance spares ..... | 30 |
| 3.4 | Nomenclature used in SAE Standard JA1011 .....                           | 31 |
| 3.5 | The Importance of Sound Maintenance Management .....                     | 32 |
| 3.6 | The Determination of a Maintenance Policy .....                          | 32 |
| 3.7 | Maintenance Procedure for Complex Replaceable Items .....                | 33 |
| 3.8 | Summary of Factors for Selection of the Policy .....                     | 34 |
| 3.9 | Conclusion .....   | 34 |

## CHAPTER 4

### Reliability and Machine Availability

|     |  |    |
|-----|--|----|
| 4.1 | Availability of a Machine .....        | 36 |
| 4.2 | Breakdown Time Distribution .....      | 37 |
| 4.3 | Bath Tub Characteristics .....         | 37 |
| 4.4 | Basic Definition of Availability ..... | 40 |

---

|  |    |
|--|----|
| 4.5 Factors of Availability .....                  | 40 |
| 4.6 Failure Rate and Probability of Failures ..... | 43 |
| 4.7 Other Indices of Maintenance Control.....      | 44 |
| 4.8 Numeric Examples .....                         | 45 |
| 4.9 Pareto Principle .....                         | 49 |
| 4.10 Note on Reliability based Maintenance .....   | 49 |
| 4.11 Conclusion .....                              | 49 |

## CHAPTER 5

### Preventive Maintenance

|   |    |
|---|----|
| 5.1 Introduction.....   | 50 |
| 5.2 Definitions of Preventive Maintenance .....               | 52 |
| 5.3 History of Preventive Maintenance.....                    | 52 |
| 5.4 Objectives of Preventive Maintenance.....                 | 53 |
| 5.5 Elements of Preventive Maintenance.....                   | 54 |
| 5.6 Inspection and Check Up.....                              | 56 |
| 5.7 Frequency of Inspection.....                              | 57 |
| 5.8 Lubrication.....  | 58 |
| 5.9 Planning and Scheduling.....                              | 58 |
| 5.10 Dispatching and Executing.....                           | 58 |
| 5.11 Records and Analysis .....                               | 58 |
| 5.12 Training.....  | 59 |
| 5.13 Control of Spare Parts .....                             | 59 |
| 5.14 Reconditioning of Machine Tools.....                     | 59 |
| 5.15 Preventive Maintenance Program at Hyundai, Chennai ..... | 60 |
| 5.16 Appendices .....   | 64 |
| 5.17 How to Sell PM .....                                     | 64 |
| 5.18 Conclusion .....   | 65 |
| Appendix - I.....   | 66 |
| Appendix - II .....   | 67 |

|                      |    |
|----------------------|----|
| Appendix - III ..... | 68 |
| Appendix - IV .....  | 69 |
| Appendix - V(a)..... | 70 |
| Appendix - V(b)..... | 71 |

## CHAPTER 6

### Condition Monitoring

|  |    |
|--|----|
| 6.1 What is Condition Monitoring? .....                    | 72 |
| 6.2 Off-load vs On-load Condition Monitoring.....          | 74 |
| 6.3 Subjective or Objective Condition Monitoring.....      | 74 |
| 6.4 Signals Indicating Malfunctioning of Equipment .....   | 75 |
| 6.5 Condition Monitoring Techniques and Gadgets used ..... | 76 |
| 6.6 Signature Analysis.....                                | 87 |
| 6.7 Conclusion .....                                       | 88 |

## CHAPTER 7

### Logical Fault Location

|  |     |
|--|-----|
| 7.1 Introduction.....  | 92  |
| 7.2 Logical Fault Location.....  | 93  |
| 7.3 Basic Definitions.....   | 93  |
| 7.4 Faults and their Development.....                                    | 94  |
| 7.5 Six Step Procedure for Logical Fault Location.....                   | 96  |
| 7.6 Types of Logical Fault Location Systems .....                        | 97  |
| 7.7 Sequential Elimination Methods .....                                 | 99  |
| 7.8 Functional Block Diagram .....                                       | 100 |
| 7.9 The Midway Check Method or the Half Split Method.....                | 101 |
| 7.10 Assumptions made in the Half Split Rule or Midway Check Method .... | 103 |
| 7.11 Choosing the Best Method.....                                       | 103 |
| 7.12 Case Study .....  | 103 |
| 7.13 Conclusion .....  | 104 |

**CHAPTER 8****Wear Debris Analysis**

|  |     |
|--|-----|
| 8.1 Introduction.....  | 105 |
| 8.2 History of Wear Debris Analysis.....                                 | 106 |
| 8.3 Achievements of WDA .....  | 107 |
| 8.4 The Four Basic Types of Wear Particles.....                          | 107 |
| 8.5 Types of Debris .....  | 108 |
| 8.6 Factors for Excessive Wear .....                                     | 108 |
| 8.7 Wear Indicated by Debris Material Identified in the Oil Samples..... | 108 |
| 8.8 Wear Indicated by the Shape of the Debris Particles .....            | 109 |
| 8.9 Wear Indicated by Debris Size .....                                  | 110 |
| 8.10 Methodology for WDA .....   | 110 |
| 8.11 Normal Method of Collecting Samples .....                           | 111 |
| 8.12 Instruments for WDA.....  | 111 |
| 8.13 Software for Computer Aided WDA .....                               | 112 |
| 8.14 Side Benefits of WDA.....   | 112 |
| 8.15 Conclusion .....  | 113 |
| 8.16 References .....  | 113 |
| 8.17 Relevant Websites for Further Reference .....                       | 113 |
| Appendix .....   | 115 |

**CHAPTER 9****Reliability Based Maintenance**

|   |     |
|---|-----|
| 9.1 Functional Reliability .....                              | 116 |
| 9.2 Quality vs Reliability .....                              | 117 |
| 9.3 What is RBM? .....  | 117 |
| 9.4 Nomenclature of RBM processes as used in SAE JA1011 ..... | 118 |
| 9.5 Principles of Reliability Based Maintenance .....         | 119 |
| 9.6 House of RBM .....  | 120 |

---

|        |  |     |
|--------|--|-----|
| 9.7    | When do you apply RBM?.....                      | 120 |
| 9.8    | Types of Failures.....                           | 121 |
| 9.9    | Severity of Failures .....                       | 121 |
| 9.10   | Statistical Distribution Curves of Failures..... | 121 |
| 9.11   | Probability Density Function .....               | 124 |
| 9.12   | Procedure of RBM.....                            | 125 |
| 9.13   | Reliability Prediction.....                      | 125 |
| 9.13.1 | Elements of Reliability Prediction .....         | 125 |
| 9.13.2 | Purposes of Reliability Prediction .....         | 125 |
| 9.14   | Monte Carlo Simulation.....                      | 126 |
| 9.15   | Markov Analysis.....                             | 127 |
| 9.16   | Conclusion .....                                 | 127 |

## **CHAPTER 10**

### **Lubrication**

|       |   |     |
|-------|---|-----|
| 10.1  | Introduction.....                       | 128 |
| 10.2  | Key Functions of Lubricants.....        | 130 |
| 10.3  | Aims of Planned Lubrication .....       | 130 |
| 10.4  | Characteristics of Lubricants.....      | 130 |
| 10.5  | Classification of Hydraulic Fluids..... | 132 |
| 10.6  | Mineral Oils .....                      | 134 |
| 10.7  | Glaze Formation.....                    | 135 |
| 10.8  | Fluid Types by Application.....         | 135 |
| 10.9  | Lubricant Additives.....                | 136 |
| 10.10 | Methods of Lubricant Application.....   | 138 |
| 10.11 | Lubrication Chart.....                  | 140 |
| 10.12 | GM Lubricant Coding.....                | 141 |
| 10.13 | Conclusion .....                        | 142 |
|       | Appendix .....                          | 143 |

**CHAPTER 11****Cutting Fluids**

|  |     |
|--|-----|
| 11.1 Introduction.....   | 147 |
| 11.2 Sources of Heat Generation during Metal Cutting Action .....    | 148 |
| 11.3 Cooling Action .....  | 149 |
| 11.4 Materials for Cutting Fluids .....                              | 150 |
| 11.5 Characteristics of Cutting Fluids .....                         | 151 |
| 11.6 Other Points to be noted while applying the Cutting Fluids..... | 152 |
| 11.7 Tramp Oil.....  | 152 |
| 11.8 Monday Morning Stench.....                                      | 152 |
| 11.9 Methods of Overcoming the Problem of Tramp Oils .....           | 153 |
| 11.10 Advantages of the Tramp Oil Remover.....                       | 155 |
| 11.11 Case Study .....   | 156 |
| 11.12 Conclusion .....   | 157 |

**CHAPTER 12****Maintenance Costs**

|   |     |
|---|-----|
| 12.1 What are maintenance costs? .....  | 158 |
| 12.2 The Cost Elements .....  | 159 |
| 12.3 Cost Categories .....  | 161 |
| 12.4 Effect of Condition Monitoring Integrated Preventive<br>Maintenance on the Maintenance Costs ..... | 162 |
| 12.5 Six Big Losses in Equipment Effectiveness .....  | 162 |
| 12.6 World Class Maintenance Requirements .....   | 163 |
| 12.7 Elements Needed for Effective Maintenance<br>with Optimal Cost Control.....                        | 163 |
| 12.8 Maintenance Benchmarking.....  | 163 |
| 12.9 Checklist for Benchmarking.....  | 164 |
| 12.10 Minimizing Total Maintenance Cost.....  | 164 |
| 12.11 Preparing Maintenance Budgets.....  | 165 |
| 12.12 Conclusion .....  | 165 |

**CHAPTER 13****Failure Modes and Effects Analysis**

|  |     |
|--|-----|
| 13.1 Importance of FMEA to Maintenance Management..... | 166 |
| 13.2 History of Development of FMEA .....              | 167 |
| 13.3 Types of FMEAs.....                               | 167 |
| 13.4 When to use FMEA.....                             | 169 |
| 13.5 Basic Terms of Reference in FMEA .....            | 169 |
| 13.6 Risk Priority Number .....                        | 172 |
| 13.7 Procedure for FMEA .....                          | 173 |
| 13.8 Responsibility for Action .....                   | 175 |
| 13.9 Benefits of FMEA .....                            | 175 |
| 13.10 FMEA Software .....                              | 177 |

**CHAPTER 14****Lean Maintenance**

|  |     |
|--|-----|
| 14.1 What is Lean Maintenance?.....  | 178 |
| 14.2 Original Concept of Lean Manufacturing System .....                     | 179 |
| 14.3 Increased Reliability with Lean Maintenance.....                        | 179 |
| 14.4 Improvement Opportunities Leading to Lean Maintenance.....              | 180 |
| 14.4.1 Manufacturing Reliability .....                                       | 180 |
| 14.4.2 Partnership between Operations -<br>Maintenance - Engineering.....    | 180 |
| 14.4.3 Elimination of Root cause of the Problem.....                         | 180 |
| 14.4.4 Storage.....  | 180 |
| 14.4.5 Integration and Application of Increased<br>Knowledge and Skills..... | 180 |
| 14.4.6 Over Manufacturing.....   | 181 |
| 14.4.7 Over Maintenance .....  | 181 |
| 14.4.8 Use of New Technology.....  | 181 |
| 14.5 Illustration of a Pit Shop Maintenance Situation.....                   | 181 |
| 14.6 Conclusion .....  | 182 |



**CHAPTER 15****Scientific Inventory Management**

|         |   |     |
|---------|---|-----|
| 15.1    | What is Inventory .....   | 183 |
| 15.2    | Types of Inventories .....  | 184 |
| 15.3    | Conditions Leading to Increased Inventory .....   | 184 |
| 15.4    | Disadvantages of Excessive Stocks.....  | 185 |
| 15.5    | Selective Control in Inventory Management .....   | 185 |
| 15.6    | Scientific Material Planning.....   | 186 |
| 15.7    | Classification and Codification.....  | 186 |
| 15.8    | ABC Analysis .....  | 187 |
| 15.8.1  | Procedure for ABC Analysis .....  | 188 |
| 15.9    | Inventory Control Parameters .....  | 189 |
| 15.10   | Inventory Carrying Costs or Costs Resulting from Owning the Item.....                                   | 191 |
| 15.11   | Stock-out or Down Time Costs .....  | 191 |
| 15.12   | Economic Order Quantity .....   | 191 |
| 15.13   | Inventory Models under Uncertainties .....  | 193 |
| 15.13.1 | Fixed Order Quantity (Q system) by varying the<br>Re-order Level.....                                   | 193 |
| 15.13.2 | Fixed Period Ordering (P system) by Varying the<br>Order Quantity.....                                  | 194 |
| 15.13.3 | Fixed Maximum Stock Ordering ( $I_{\max}$ system) by Varying Order<br>Quantity and Re-order Level ..... | 194 |
| 15.13.4 | Fixed Safety Stock Ordering ( $I_{\min}$ system) by<br>Varying Order Quantity and Re-order Level .....  | 194 |
| 15.14   | Two-bin Inventory Control System.....   | 194 |
| 15.15   | Recent Trends in Inventory Management.....  | 196 |
| 15.16   | Supplier Partnership.....   | 196 |
| 15.17   | Collaborative Planning, Forecasting and Replenishment (CPFR).....                                       | 197 |
| 15.18   | Conclusion .....  | 197 |
|         | Appendix .....  | 198 |

**CHAPTER 16****Spare Part Inventory Control**

|       |  |     |
|-------|--|-----|
| 16.1  | Importance of Spare Part Inventory .....   | 204 |
| 16.2  | Categories of Maintenance Materials.....   | 205 |
| 16.3  | Maintenance Procedure for Complex Replaceable Items .....                            | 207 |
| 16.4  | Conditions Leading to.....   | 208 |
|       | Increased Maintenance Stores Inventory .....   | 208 |
| 16.5  | Spare Part Analysis.....   | 209 |
| 16.6  | Code Numbers for Spare Parts .....   | 209 |
| 16.7  | Inventory Control for Maintenance Items.....   | 210 |
|       | 16.7.1 What is Inventory? .....  | 210 |
|       | 16.7.2 Related Terms and Functions.....  | 210 |
|       | 16.7.3 Types of Inventories .....  | 211 |
|       | 16.7.4 Need for Inventory .....  | 211 |
|       | 16.7.5 Disadvantages of Excessive Stocks.....  | 211 |
|       | 16.7.6 Inventory Carrying Costs or Costs Resulting from .....                        | 211 |
|       | Owning the Item.....   | 211 |
|       | 16.7.7 Stock-out or Down Time Costs .....  | 212 |
| 16.8  | Inventory Control Systems for Production Materials vs<br>Maintenance Components..... | 212 |
| 16.9  | Selective Control in Inventory Management .....                                      | 213 |
| 16.10 | Layout of the Maintenance Stores .....   | 214 |
|       | 16.10.1 Plant Spares, Sub-grouped into .....   | 214 |
|       | 16.10.2 Tools, Sub-grouped into .....  | 214 |
|       | 16.10.3 Consumable Items, Sub-grouped into .....                                     | 215 |
| 16.11 | Centralised vs Decentralized Stores for.....   | 215 |
|       | Maintenance Department .....   | 215 |
| 16.12 | Reclamation of Spare Parts.....  | 216 |
| 16.13 | Spare Part Planning at the Tendering Stage.....                                      | 217 |
| 16.14 | Conclusion .....   | 217 |

**CHAPTER 17****Total Productive Maintenance**

|  |     |
|--|-----|
| 17.1 Introduction.....   | 218 |
| 17.2 The Meaning of TPM.....   | 219 |
| 17.3 History of TPM.....   | 219 |
| 17.4 Definitions of TPM .....  | 220 |
| 17.5 TPM is an Extension of TQM .....                                  | 221 |
| 17.6 Other Concepts of TPM .....                                       | 221 |
| 17.7 The Five Zeros of TPM.....  | 223 |
| 17.8 What can TPM Achieve?.....  | 223 |
| 17.9 The Three Levels of Autonomous Maintenance in TPM.....            | 224 |
| 17.10 The Five Goals of TPM.....                                       | 224 |
| 17.11 Procedure for the Implementation of TPM.....                     | 225 |
| 17.12 TPM, Tero-technology and Logistics – A Comparison .....          | 226 |
| 17.13 5S vs TPM.....   | 226 |
| 17.13.1 A place for Everything and Everything in its place (PEEP)..... | 227 |
| 17.13.2 Seiso (Shine, sweep or sanitize) .....                         | 227 |
| 17.13.3 Cleanliness in the Office Environment .....                    | 228 |
| 17.14 Quality Circles vs TPM .....                                     | 228 |
| 17.15 Maintenance Work Sampling.....                                   | 228 |
| 17.16 Conclusion .....   | 229 |
| Further Reference .....  | 229 |
| Appendix .....   | 230 |

**CHAPTER 18****System Approach to Management Theory**

|  |     |
|--|-----|
| 18.1 Development of System Approach to Management Theory ..... | 234 |
| 18.2 What is a System? .....                                   | 235 |
| 18.3 Definition of a System .....                              | 235 |
| 18.4 Types of Systems.....                                     | 236 |

|        |   |     |
|--------|---|-----|
| 18.5   | Components of a System .....                          | 238 |
| 18.5.1 | Input .....   | 239 |
| 18.5.2 | Conversion Process .....                              | 239 |
| 18.5.3 | Output .....  | 240 |
| 18.6   | Elements of Control in System Approach .....          | 240 |
| 18.7   | Environment .....                                     | 240 |
| 18.8   | Open and Closed Systems .....                         | 240 |
| 18.9   | Systems and Subsystems .....                          | 241 |
| 18.10  | Relationship between the Systems and Subsystems ..... | 243 |
| 18.11  | Combination of Subsystems .....                       | 245 |
| 18.12  | The Management Cube .....                             | 245 |
| 18.13  | Planning Pyramid .....                                | 245 |
| 18.14  | Decision Theory .....                                 | 246 |
| 18.15  | Problem Analysis vs Decision Making .....             | 247 |
| 18.16  | Decision Tree .....                                   | 248 |
| 18.17  | Situations under which Decisions are taken .....      | 249 |
| 18.18  | Systematic Decision Making .....                      | 249 |
| 18.19  | Information Flow .....                                | 249 |
| 18.20  | Features of Management as a System .....              | 250 |
| 18.21  | Conclusion .....                                      | 251 |

## CHAPTER 19

### Organisation for Maintenance

|        |   |     |
|--------|---|-----|
| 19.1   | Why Organization .....                                      | 252 |
| 19.2   | What are to be Organized in the Maintenance Function? ..... | 253 |
| 19.3   | Principles of Organization .....                            | 253 |
| 19.4   | Classes of Organizational Structures .....                  | 255 |
| 19.4.1 | The Line Organization .....                                 | 255 |
| 19.4.2 | The Functional Organization .....                           | 255 |
| 19.4.3 | Line and Functional Staff Organization .....                | 256 |
| 19.4.4 | Committee Organization .....                                | 256 |

---

|       |   |     |
|-------|---|-----|
| 19.5  | Organization for the Maintenance Function.....                            | 258 |
| 19.6  | Centralised Maintenance Organization.....                                 | 258 |
| 19.7  | Decentralized Maintenance Organization.....                               | 259 |
| 19.8  | Matrix Type of Organization.....  | 261 |
| 19.9  | External Maintenance Services .....                                       | 263 |
| 19.10 | Factors shall be Considered for Deciding the<br>Manpower Requirement..... | 264 |
| 19.11 | Size and Type of Maintenance Organization.....                            | 264 |
| 19.12 | Manpower Planning for Maintenance Activities .....                        | 264 |
| 19.13 | Conclusion .....  | 265 |

## **CHAPTER 20**

### **Equipment Record**

|        |   |     |
|--------|---|-----|
| 20.1   | What is Equipment Record?.....  | 266 |
| 20.2   | Fixed Asset Register .....  | 267 |
| 20.2.1 | Objectives in Maintaining a Fixed Asset Register (FAR) .....            | 267 |
| 20.2.2 | Details to be Provided in a FAR .....                                   | 267 |
| 20.3   | Advantages of Equipment Record .....                                    | 268 |
| 20.4   | Enterprise Asset Management Systems.....                                | 268 |
| 20.4.1 | Asset Management .....  | 269 |
| 20.4.2 | Asset Knowledge Science (AKS) .....                                     | 269 |
| 20.4.3 | Asset Condition Assessment.....   | 269 |
| 20.4.4 | Asset Identification Label .....  | 269 |
| 20.4.5 | Asset Maintenance Management System.....                                | 269 |
| 20.4.6 | Asset Management Framework.....   | 269 |
| 20.4.7 | Asset Management Improvement Plan .....                                 | 269 |
| 20.4.8 | Enterprise Asset Management (EAM) Systems.....                          | 270 |
| 20.4.9 | Machinery Information Management<br>Open Systems Alliance (MIMOSA)..... | 270 |
| 20.5   | Some of the other Asset Management Software.....                        | 270 |
| 20.6   | Example of a Unit Record.....   | 270 |
| 20.7   | Documentation and Drawing Record.....                                   | 275 |
| 20.8   | Conclusion .....  | 275 |

**CHAPTER 21****Work Order Systems**

|        |  |     |
|--------|--|-----|
| 21.1   | What is a Work Order? .....                    | 276 |
| 21.2   | Categories of Work Orders.....                 | 277 |
| 21.3   | Objectives of Work Orders .....                | 277 |
| 21.4   | Work Order Priorities.....                     | 278 |
| 21.4.1 | Emergency Priority-1 .....                     | 278 |
| 21.4.2 | Rush Priority-2 .....                          | 278 |
| 21.4.3 | Code Compliance Priority-3.....                | 279 |
| 21.4.4 | Routine Priority-4 .....                       | 279 |
| 21.5   | General Procedure for Work Order System.....   | 279 |
| 21.6   | An Illustration of Work Order Flow Chart ..... | 280 |
| 21.7   | Conclusion .....                               | 285 |

**CHAPTER 22****Computerised Maintenance Management System**

|      |   |     |
|------|---|-----|
| 22.1 | Introduction.....   | 286 |
| 22.2 | CMMS.....   | 287 |
| 22.3 | Benefits of CMMS .....                                    | 288 |
| 22.4 | Specific Software Available for Maintenance Function..... | 289 |
| 22.5 | Future of CMMS .....                                      | 290 |
| 22.6 | System Integration.....                                   | 290 |
| 22.7 | Conclusion .....  | 291 |
| 22.8 | Websites on CMMS .....                                    | 291 |

**CHAPTER 23****Replacement of Machinery and Equipment**

|      |   |     |
|------|---|-----|
| 23.1 | Why Replacement? .....                          | 292 |
| 23.2 | Basic Strategies of Repair/Replacement.....     | 293 |
| 23.3 | When to Recondition instead of Replacement..... | 293 |

---

|        |   |     |
|--------|---|-----|
| 23.4   | When Replace Machinery and Equipment.....   | 294 |
| 23.5   | Factors for Investment Decision on Facilities .....                                 | 295 |
| 23.6   | Phases of Replacement Analysis.....   | 295 |
| 23.7   | Methods of Evaluation.....  | 296 |
| 23.8   | Traditional Methods.....  | 296 |
| 23.8.1 | Payback Period Method.....  | 296 |
| 23.8.2 | Total Life Average Method .....   | 297 |
| 23.8.3 | Average Rate of Returns Method .....  | 297 |
| 23.9   | Discounted Cash Flow Methods.....   | 297 |
| 23.9.1 | Net Present Worth (NPW) or Net Present Value (NPV).....                             | 297 |
| 23.9.2 | Profitability Index Method .....  | 298 |
| 23.9.3 | Internal Rate of Returns Method .....   | 298 |
| 23.9.4 | Differences between Net Present<br>Worth and Internal Rate of Returns Methods ..... | 299 |
| 23.10  | MAPI Method.....  | 299 |
| 23.11  | Markov Analysis.....  | 300 |
| 23.12  | Conclusion .....  | 300 |
|        | Appendix I.....   | 301 |
|        | Appendix II .....   | 305 |

## **CHAPTER 24**

### **Environmental Issues**

|      |   |     |
|------|---|-----|
| 24.1 | Introduction.....                                       | 309 |
| 24.2 | Basic Environmental Concepts .....                      | 310 |
| 24.3 | Sustainable Development .....                           | 310 |
| 24.4 | Global Environmental Issues .....                       | 311 |
| 24.5 | International Initiatives on Environmental Issues ..... | 311 |
| 24.6 | Environmental Scenario of India .....                   | 313 |
| 24.7 | Oil Spills .....  | 313 |
| 24.8 | Environmental Impact Assessment.....                    | 314 |
| 24.9 | Engineer's Role in Environment Protection.....          | 315 |

|       |   |     |
|-------|---|-----|
| 24.10 | Environmental Engineering .....                             | 315 |
| 24.11 | Green Design .....  | 315 |
| 24.12 | Principles of Green Design .....                            | 316 |
| 24.13 | Environmentally Conscious Manufacture.....                  | 316 |
| 24.14 | Basic Approaches for Resolving Environmental Problems ..... | 316 |
| 24.15 | Conclusion .....  | 318 |

## CHAPTER 25

### Industrial Safety

|        |  |     |
|--------|--|-----|
| 25.1   | Introduction.....                                  | 319 |
| 25.2   | Essentials of a Machine Guard.....                 | 320 |
| 25.3   | Mechanical Power Transmission.....                 | 320 |
| 25.4   | Characteristics of Safe Industrial Buildings ..... | 322 |
| 25.5   | Eye Protection.....                                | 322 |
| 25.6   | Supervision and Training .....                     | 323 |
| 25.7   | Safety Inspection.....                             | 325 |
| 25.7.1 | Principal Function .....                           | 325 |
| 25.7.2 | Objectives.....                                    | 326 |
| 25.7.3 | Purpose of Safety Inspections .....                | 326 |
| 25.7.4 | What to Inspect .....                              | 326 |
| 25.8   | Plant Safety Tours.....                            | 328 |
| 25.9   | Conclusion .....                                   | 330 |
|        | Appendix .....                                     | 331 |
| 1.0    | HEALTH.....  | 331 |
| 1.1    | Cleanliness.....                                   | 331 |
| 1.2    | Temperature .....                                  | 331 |
| 1.3    | Sanitary Conditions .....                          | 331 |
| 2.0    | SAFETY .....                                       | 331 |
| 2.1    | Floors .....                                       | 332 |
| 2.2    | Electricity Regulations .....                      | 332 |
| 2.3    | Horizontal Milling Machine Regulations.....        | 332 |
| 2.4    | Woodworking Machinery Regulations .....            | 332 |
| 3.0    | AIR RECEIVERS .....                                | 332 |



**CHAPTER 26****Job Hazard Analysis**

|   |            |
|---|------------|
| 26.1 Why Accident Free Work Environment .....                         | 333        |
| 26.2 What is a Hazard .....   | 334        |
| 26.3 OSHA Definition on JHA .....                                     | 334        |
| 26.4 OSHA Regulations.....  | 334        |
| 26.5 How Accidents are Caused .....                                   | 334        |
| 26.6 Definition and Purpose .....                                     | 335        |
| 26.7 Methodology .....  | 335        |
| 26.7.1 Select.....  | 336        |
| 26.7.2 Record.....  | 337        |
| 26.7.3 Examine and Evaluate.....                                      | 338        |
| 26.7.4 Develop .....  | 340        |
| 26.7.5 Install and Maintain .....                                     | 340        |
| 26.8 Some Suggestions for making a Job Hazard Analysis.....           | 341        |
| 26.9 Use and Follow up of Job Hazard Analysis.....                    | 341        |
| 26.10 Advantages of Job Hazard Analysis .....                         | 341        |
| 26.11 Checklist for Job Hazard Analysis .....                         | 342        |
| 26.12 Software for JHA.....   | 343        |
| 26.13 Conclusion .....  | 344        |
| 26.14 References .....  | 344        |
| Appendix .....  | 346        |
| <b>Annexures I: University Syllabi Referred to in this Book .....</b> | <b>347</b> |
| <b>Annexures II: Syllabi of International Universities .....</b>      | <b>362</b> |
| <b>Bibliography.....</b>  | <b>369</b> |
| <b>Index.....</b>   | <b>373</b> |