Contents

Preface xi

Chapter 1 Introduction to Induction Heating 1
  1.1 The background to induction heating 1
  1.2 Induction-heating principles 2
  1.3 Applications 5
  1.4 Power systems 5
  1.5 Economics, safety, and environment 8

Chapter 2 Through-heating by Induction 10
  2.1 Introduction to applications of through-heating 10
  2.2 Temperature effects 17
  2.3 Heat radiation and convection 24
  2.4 Temperature distribution in induction through-heating 26
  2.5 Effects of current depth and radiated heat 27
  2.6 Temperature distributions in a heating cycle 28
  2.7 Selection of frequencies for induction through-heating 30
  2.8 Application specifications for coil design 33
  2.9 Equivalent circuit coil-design method 43
  2.10 Approximate coil-design method 49
  2.11 Mechanical construction of coils 55
  2.12 Slab reheating 58
  2.13 Travelling-wave induction heating 59
  2.14 Multi-layer coils 63
  2.15 Tapered heating for extrusion 64
  2.16 Scale-model analogue methods 65

Chapter 3 Surface Heating by Induction 67
  3.1 Metallurgical principles of heat treatment 71
  3.2 Quenches and quenching 77
  3.3 Selection of frequency in induction heat treatment 81
  3.4 Temperature distribution in induction surface hardening 87
  3.5 Application specifications for coil design 89
  3.6 Mechanical construction of coils 91
Chapter 4 Other Applications of Induction Heating 96
4.1 Soldering and brazing 96
4.2 Tube welding 109
4.3 Heating of resin kettles and other vessels 118
4.4 Paint drying 120
4.5 Induction heating in plastic working 121
4.6 Annealing and stress relieving 122
4.7 Longitudinal flux induction heating 124
4.8 Transverse flux heating 124
4.9 Semiconductor processing 126
4.10 Miscellaneous uses of induction heating 131

Chapter 5 Induction Melting 135
5.1 Principles of induction melters 135
5.2 The coreless induction furnace 142
5.3 The channel furnace 148
5.4 Comparison of coreless and channel furnaces 152
5.5 Special features in melting furnaces 155

Chapter 6 Supply-frequency Heating Systems 163
6.1 Advantages and limitations 163
6.2 Load matching 165
6.3 Control and switchgear 168
6.4 Solid-state power regulators 172
6.5 Measurements at supply frequencies 173
6.6 Workhandling equipment 174
6.7 Melting furnace system 177
6.8 Frequency multipliers 178
6.9 Dual-frequency systems 180

Chapter 7 Medium-frequency motor-alternator systems 181
7.1 Introduction 181
7.2 Principles of the medium-frequency generator 181
7.3 Mechanical features of inductor-alternators 187
7.4 Electrical behaviour of the generator 190
7.5 Load matching and tuning 194
7.6 Control systems 198
7.7 Automatic voltage regulators 200

Chapter 8 Medium-frequency Solid-state Systems 202
8.1 Derivation of medium-frequency solid-state static converters 202
8.2 Characteristics of medium-frequency induction-heating loads 202
8.3 Requirements of the static inverter 203
8.4 Silicon-controlled rectifier characteristics 204
8.5 Basic inverter systems 205
8.6 Swept-frequency systems 207
8.7 Load-resonant system 210
Chapter 13 Heat Transfer  341
13.1 Introduction  341
13.2 Relationship between power, mean temperature, and time  341
13.3 Temperature distribution in cylindrical billets  342
13.4 Cylindrical billets – soaking period  345
13.5 Cylindrical billets – effect of current density  346
13.6 Cylindrical billets – effect of radiation  350
13.7 Rectangular slab  351
13.8 Radiation  352
13.9 Heat transfer during surface hardening  356
13.10 Billet with initial axial temperature distribution  362
13.11 Water cooling in conductors  364

Chapter 14 Safety and Environmental Conditions  373
14.1 General and manufacturers’ responsibilities  373
14.2 Safety officers’, employers’, and employees’ responsibilities  374
14.3 International safety regulations  375
14.4 IEC safety recommendations  375
14.5 Environment and terminology  377

Appendix 1 Electroheating Terminology  379
A1.1 Classification of electroheat equipment according to frequencies  379
A1.2 Terminology  379

Appendix 2 Temperature Difference in a Slab  383
A2.1 Slab heated from one side only  383
A2.2 Soaking of slab previously heated from one side  385
A2.3 Slab heated from both sides  386
A2.4 Soaking of slab previously heated from both sides  388

Appendix 3 Effects of Induction-heating Equipment on Electricity Supplies  394
A3.1 Introduction  394
A3.2 Power plant – quality of engineering  394
A3.3 Choice of power plant for induction furnace  397
A3.4 Recommendations for connection of induction furnace loads to the public electricity supply system  398
A3.5 Connection of a proposed induction furnace load  403
A3.6 Inrush current. Calculation of voltage dip  405

Appendix 4 Unit Conversion Tables  407

Appendix 5 Resistivity, Specific Heat, and Thermal Conductivity as Functions of Temperature  410

References  412

Index  419