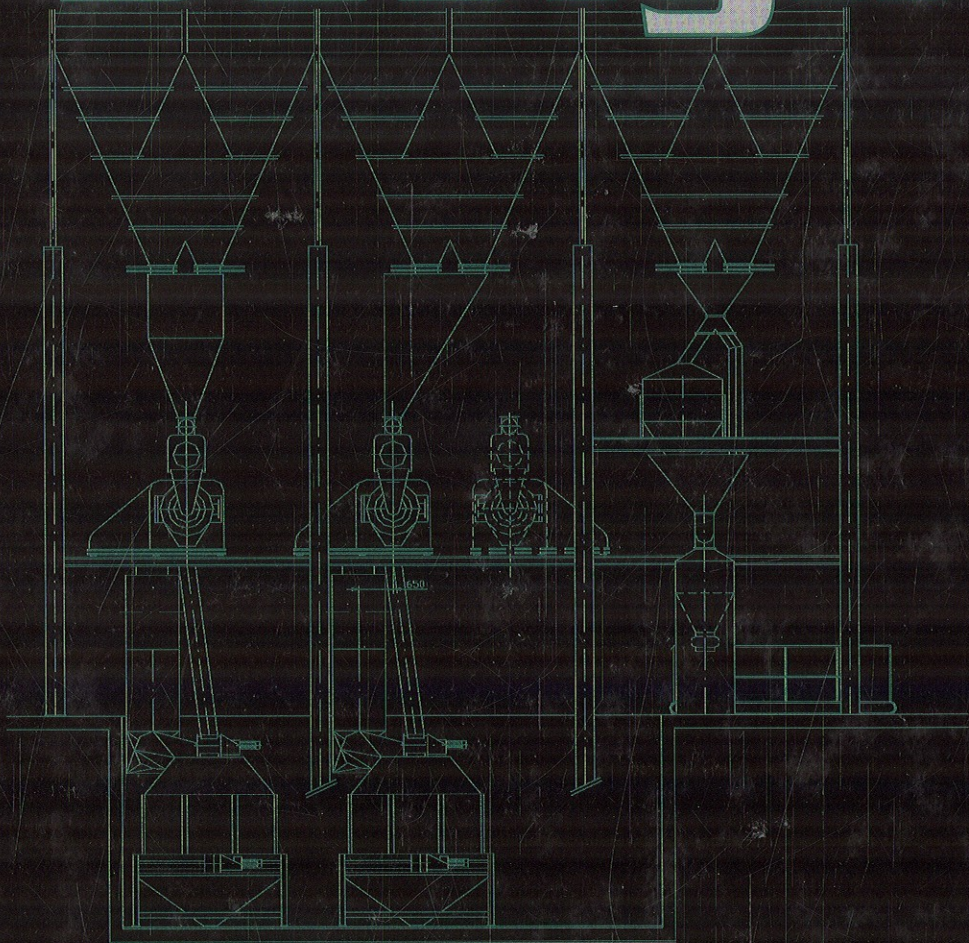


Food Plant Design



Antonio López-Gómez

Gustavo V. Barbosa-Cánovas

Contents

Chapter 1	Economic and Technical Context of Food Plant Design	1
1.1	Food Science, Technology, and Engineering	1
1.1.1	Historical Evolution	1
1.1.2	The Design Engineer in Food Engineering	9
1.2	Socioeconomic and Technical Context	10
1.2.1	Agro-Industrial System and the Food Chain	10
1.2.2	Food Processing Systems, Auxiliary Systems, and Food Plants	14
	References	28
Chapter 2	Mathematical Modeling of Food Processing Systems and Food Plant Simulation	31
2.1	Transfer Phenomena and Property Balance	31
2.1.1	Transfer Phenomena	31
2.1.2	Macroscopic Balances and Physical Properties	36
2.1.2.1	Mass Balance	36
2.1.2.2	Energy Balance	37
2.1.2.3	Momentum Balance	42
2.1.2.4	Physical Properties	47
2.1.3	Microscopic Balances and Transfer Phenomena	48
2.1.3.1	Microscopic Mass Balance; Fick's Laws	49
2.1.3.2	Momentum Balance: Newton's Law	53
2.1.3.3	Energy Balance: Fourier's Law	59
2.2	Transfer Properties: Viscosity, Conductivity, and Diffusivity	65
2.2.1	Viscosity	65
2.2.2	Thermal Conductivity	68
2.2.3	Diffusivity	69

2.3	Heat Transfer in Fluids	71
2.3.1	Individual Coefficients of Heat Transfer by Convection	71
2.3.2	Heat Transfer Coefficients in Newtonian Fluids	72
2.3.3	Heat Transfer Coefficients in Non-Newtonian Fluids	75
2.4	Mathematical Model of a Unit Operation: Hot Air Drying	77
2.4.1	Equations for General Model	84
2.4.2	Equations from This Model	85
2.4.3	Results of Experiment	89
2.4.4	Nomenclature	92
2.5	Mathematical Modeling of Refrigeration and Thermal Storage Systems	93
2.5.1	Modeling the Components of a Refrigeration System	95
2.5.1.1	Compressor	97
2.5.1.2	Condenser	103
2.5.1.3	Evaporator	106
2.5.1.4	Expansion Valve	112
2.5.2	Trends in Refrigeration Systems Modeling	116
2.5.3	A Case Study	117
2.5.3.1	Model Formulation	117
2.5.3.2	Heat Transfer Coefficients Analysis	120
2.5.3.3	Experiment Validation	121
2.6	Food Plant Simulation	127
2.6.1	Malting Plant	127
2.6.1.1	Knowledge-Based System Development	128
2.6.1.2	Simulation Results	131
2.6.2	Winery	131
2.6.2.1	Refrigeration Requirements Profile for Wineries	133
2.6.2.2	Thermal Behavior of the Fermentation Process	134
2.6.2.3	The Use of Thermal Storage Systems	135
2.6.2.4	The Use of Advanced Control Systems in Fermentation	136
2.6.3	Frozen Vegetables Plant	139
	References	141

Chapter 3	Documentation of Food Plant Design	153
3.1	Introduction	153
3.2	Preliminary Studies of Food Products and Raw Materials	154
3.3	Literature Review and Laboratory Studies on Food Processing Technology and Engineering.....	155
3.4	Pilot Plant Studies	156
3.5	Food Processing Systems and Food Plant Preliminary and Final Projects	157
3.5.1	The Food Processing Plant Preliminary Project.....	157
3.5.2	The Food Processing Plant Final Project	162
3.5.2.1	Food Processing System Final Project.....	163
3.5.2.2	<i>Auxiliary System Final Project</i>	166
3.5.2.3	Buildings and Services Final Project.....	168
3.6	Information Handling in Flowchart Form.....	171
3.6.1	Basic Modules General Flowchart	171
3.6.2	Flowcharts.....	172
3.6.3	Mass Balance in the Process	176
3.6.4	Energy Balance in a Food Processing System	187
3.6.4.1	Energy Accounting in Food Processing Plants	187
3.6.4.2	Measuring Energy Flow Rates	189
	References	194

Chapter 4	Processing System Alternatives: Process Synthesis	213
4.1	Introduction	213
4.2	Synthesis Methods	215
4.2.1	Evolutionary Methods	215
4.2.1.1	Basic Modules Method	215
4.2.1.2	Evolutionary Design Method.....	218
4.2.2	Methods Based on Problem Solving.....	220
4.2.3	Heuristic Design Methods	223
4.2.4	Algorithmic or Mathematical Programming Methods	224
	Nomenclature	227
	References	228

Chapter 5 Food Processing System Alternatives Analysis.... 231

5.1	Outlining the Problem	231
5.2	Selecting Design Variables	232
5.2.1	Process Subsystems.....	233
5.2.1.1	Degrees of Freedom and Information Flow Diagram	233
5.2.1.2	Inversion of Information Flow.....	237
5.2.1.3	Algorithms for Selecting Design Variables.....	240
5.2.2	Process Systems.....	243
5.2.2.1	Information Flow through Subsystems ...	243
5.2.2.2	Inversion of Information Flow.....	249
5.2.2.3	Algorithm for Selecting Design Variables.....	251
5.3	Alternative Analysis by Means of Simulation	256
5.4	Design Economic Criteria	257
5.4.1	Static Criteria	257
5.4.2	Dynamic Criteria	259
5.4.2.1	Net Present Worth.....	260
5.4.2.2	Net Present Worth/Initial Investment Ratio	261
5.4.2.3	Payback Period	261
5.4.2.4	Internal Rent Share	262
5.5	Cost Estimation	263
5.5.1	Initial or Capital Investment Estimation.....	263
5.5.1.1	Cost Estimation of Food Processing Equipment.....	263
5.5.1.2	Auxiliary System Cost Estimation.....	269
5.5.2	Operating Cost Estimation	269
References		282

Chapter 6 Experimentation in Pilot Plant..... 285

6.1	Introduction	285
6.2	Size and Structure of the Pilot Plant	286
6.2.1	Basic Principles of Scaling.....	286
6.2.2	Minimum and Maximum Size.....	287
6.3	Types and Applications	288
6.4	Pilot Plant Design	292
6.5	Experimentation Strategies.....	293
6.6	Capital Investment and Operation Cost	296
References		297

Chapter 7 Materials for Construction of Food Equipment ... 299

7.1	Characteristics of Suitable Construction Material	299
7.2	Types of Materials and Applications	301
7.2.1	Stainless Steel	301
7.2.1.1	Surface Finish	303
7.2.1.2	Corrosion	309
7.2.2	Aluminum	311
7.2.3	Nickel and Monel	311
7.2.4	Plastic Materials	312
	References	314

Chapter 8 Hygienic Design of Processing Systems and Auxiliary Systems 315

8.1	<i>Basic Principles for Hygienic Design of Food Equipment</i> ...	315
8.2	Hygienic Design of Auxiliary Systems in Contact with Foods	318
8.2.1	Tanks	318
8.2.2	Pumps	322
8.2.3	Valves	325
8.2.4	Pipes	328
8.3	External Design of Processing Equipment and Auxiliary Systems	333
8.4	CIP (Clean-in-Place) System Design	335
8.4.1	Single-Use or Single-Tank Systems	337
8.4.2	Multiple-Use or Multitank Systems	340
8.4.3	Compact Systems and Foam-Cleaning Systems ...	341
8.4.4	CIP System Design Details	345
8.4.4.1	Spray Distribution Devices	346
8.4.4.2	Pumps, Heat Exchangers, and Valves	349
	References	350

Chapter 9 Food Processing Plant Design Considerations 351

9.1	Designing the Food Plant	351
9.1.1	Legal Aspects	352
9.1.2	Functional Aspects	354
9.1.3	Plant Layout	357
9.2	Selecting Food Plant Site	360
9.2.1	Land Conditions and Location	360
9.2.2	Distribution of Zones at the Site	361

9.3	Hygienic Design of the Food Processing Plant	362
9.3.1	Resistant Structure	362
9.3.2	Building Enclosure and Interior Divisions.....	362
9.3.3	Floors	366
	References	372
	<i>Index</i>	373