

Index

- A**
- Absorption refrigeration cycle, 174–176
 - Accelerator, 305
 - Acetic acid, 399
 - Acid catalysts
 - of hydrochloric acid, 420
 - of sulfonic acid, 420
 - of sulfuric acid, 420
 - Activated carbon, 387, 431
 - Adiabatic heating, 328
 - Adsorbent, 178
 - Adsorption, 177
 - Adsorption refrigeration cycle, 177–180
 - Aerobic bacteria, 386
 - Aerobic process, 238
 - Affinity laws, 33–34, 112, 125–126
 - Air blast chilling/freezing, 257
 - Air compressor, 107–108
 - Air cycle, 173
 - Air impingement, 257
 - Air leak, 110
 - Albumin, 387
 - Algae, 412
 - Alkaline catalyst
 - of potassium hydroxide, 417
 - of sodium hydroxide, 417
 - of sodium methoxide, 417
 - Alkyl ester, 411
 - Ammonia, 387
 - α -Amylase, 366, 400
 - Anaerobic bacteria, 386
 - Anaerobic digestion
 - of by-products in grain mill, 238
 - pathways of, 386
 - process, 379
 - of slaughterhouse wastes, 284–285
 - of vegetable and fruit wastes, 261
 - Anaerobic filter, 389
 - Anemometer, 53
 - Energy, 39
 - Animal fat, 285, 411
 - Animal feeds, 260, 366
 - Annual implementation costs (AIC), 103
 - Annualized investment, 103
 - Apparent power, 118
 - Apple pomace, 262, 406
 - Ash slugging, 434
 - Aspergillus niger*, 400
 - Attenuation factor, 21–22
 - Available work, 39
- B**
- Baker's yeast, 400
 - Bakery production process, 289
 - Baking ovens, 292
 - Beef tallow, 412
 - Beet pulp, 248
 - Benefit to cost ratio, 75
 - Bentonite, 387
 - Bernoulli's equation, 26
 - Bile acids, 387
 - Biodiesel
 - from animal fats, 285
 - production process, 415–418
 - properties, 411–415
 - Biogas
 - production, 238, 261, 284–285
 - utilization, 387
 - Biological oxygen demand (BOD), 237
 - Biot number, 23, 220
 - Blanching, 254
 - Boiler
 - efficiency of, 91
 - heat loss from, 94
 - maintenance of, 98
 - types of, 88
 - Boiling heat transfer, 19
 - Bonds, 77
 - Boundary layer, 12
 - Bourdon pressure gauge, 53
 - Bran
 - as co-product, 371
 - ethanol fermentation from, 405
 - Brewer's yeast, 400
 - Broiler, 284
 - Butter, 269
 - By-products
 - in dairy processing facilities, 274
 - in fruit and vegetable processing facilities, 260
 - in grain and oilseed processing facilities, 237
 - in meat processing facilities, 284
 - in sugar and confectionary processing facilities, 247–248

C

Cabinet drying, 258
 Calcium methoxide, 420
 Calcium oxide, 420
 Canned fruits, 252
 Canned vegetables, 252
 Capacitance, 118
 Capacitor, 314
 Capital investment characteristics, 66
 Carbohydrates, 365
 Carnot factor, 39
 Cash flow diagrams, 72–73
 Cellulase, 403
 Cellulose, 403
 Cesium for food irradiation, 304
 Cetane number, 376
 Char, 431
 Cheese, 269
 Cholesterol, 387
Clostridium thermocellum, 400
 Cobalt-60 for food irradiation, 304
 Coconut oil, 376
 Co-digestion, 392
 Coefficient of performance (COP)
 of combined ejector-vapor-compression
 refrigeration cycles, 183
 of heat pumps, 160
 of mechanical energy-driving refrigeration
 cycles, 168
 of thermal energy-driving refrigeration
 cycles, 170
 Co-firing, 430
 Cogeneration
 in bakery processing facilities, 293
 benefits of, 103–104
 cycles, 189–195
 in sugar processing facilities, 247
 Cold flow properties, 412
 Combined heat and power (CHP),
 see Cogeneration
 Combined refrigeration cycles, 180–182
 Combustion
 efficiency, 94–95
 process, 378
 Composting process, 238
 Compressed air
 quality, 108
 system, 107
 Compressibility, 327
 Compression work, 327
 Concentrated milk, 269
 Condensate, 98
 Condensation heat transfer, 19
 Continuity equation, 25
 Continuously stirred tank, 389

Conversion rate of microwave energy, 22
 Cooling, *see* Refrigeration
 Cooling degree days, 46
 Cooling energy storage, 164
 Co-solvent, 353
 Critical state, 353
 Crop residues, 373
 Crystallization, 246
 Culture media, 401
 Cultured butter, 269

D

Deaeration, 89
 Debt financing, 77
 Decomposition, 363
 Dehydration
 energy conservation in, 218
 of fruits and vegetables, 258
 of grains and oilseeds,
 235–236
 microwave-assisted, 338
 Delignification, 399
 Depolymerization, 399
 Depreciation, 70
 Dielectric constant, 335
 Dielectric loss factor, 335
 Dielectric properties, 335
 Direct dryer, 236
 Discounted payback, 74
 Distillation, 416
 Distillers' dried grains with
 solubles, 371
 Double-pipe heat exchanger, 129
 Dough, 289
 Drum drying, 258
 Dry milk, 269
 Dry milling, 371
 Drying, *see* Dehydration
 Dubinin–Askhov equation, 178

E

Economic life, 72–73
 Economizer, 88
 Effectiveness of heat exchangers, 140
 Ejector refrigeration cycle, 176–177
 Electric field strength, 315
 Electric potential, 313
 Electric load, 117
 Electricity bills, 46, 119
 Electrode, 315
 Electromagnetic energy, 21
 Electron beams, 303–304

Energy

- conservation, 65
- consumption, 205
- content, 37, 58
- conversion, 58
- cost, 203
- definition of, 3
- demand, 208
- forms of, 3
- indicator, 203
- loss, 3, 27
- management, 78
- measurement, 52–56
- quality of, 3, 59
- sources, 58, 204
- storage, 161
- systems, 48

Energy audit, 45

Energy analysis, 45, 57; *see also*

Energy audit

Energy balance in heat exchangers, 139

Energy efficiency

- calculation of, 62–63
- definition of, 40
- in food processing facilities, 210

Energy evaluation, *see* Energy audit

Energy Star program, 80

Energy survey, *see* Energy audit

Enhanced heat transfer surface, 145

Enthalpy, 36, 38

Entropy, 37–38

Enzymatic hydrolysis, 233

Equity financing, 77

Equivalent roughness, 28

Escherichia coli, 400

Ethanol

- from cheese whey, 274
- from food processing wastes, 367
- from grain and oilseed processing wastes, 238
- from sugar processing wastes, 248
- as transportation fuel, 397
- from vegetable and fruit processing wastes, 262

Eukaryote, 400

Excess air, 91, 97

Exergy

- analysis, 62, 140
- definition of, 3, 58
- degradation of, 60
- efficiency, 40, 62–63, 141, 210
- loss, 39, 60
- rate of, 38

Expeller press, 232

Extraction

- enhancement, 316
- process, 233

F

Facility inspection, 48–49

Facultative anaerobe, 386, 401

Falling film evaporator, 246

Far-infrared radiation, 237

Fatty acids, 376

FeCl₂, 387

Fed-batch culture, 407

Fermentation

- of carbon sources from food processing wastes, 399
- process, 379

Fiber, 237

Filtration, 231

Fischer–Tropsch liquids, 435

Flash pyrolysis, 431

Flue gas, 97

Fluid dynamics, 25

Fluid milk, 269

Fluid properties, 25

Fluidized bed

- combustor, 239
- digester, 389
- dryer, 236, 238
- gasifier, 433–434

Formic acid, 399

Fouling, 146, 273

Fourier's law of heat conduction, 4

Free water, 324

Freeze drying, 258

Freezing point, 324

Freezing point depression, 326

Freezing, *see* Refrigeration

Friction factor, 28–30

Frictional energy loss, 27–29

Fruits, 251

Fuel cells, 434

Fuels

- used in boilers, 89–90
- used in food processing facilities, 46

Funds, 77

Furfural, 399

G

β-Galactosidase, 274, 407

Gamma rays, 303–304

Gas antisolvent, 356

Gas engines, 434

Gas turbines, 191, 293, 434
 Gasification, 378
 Gasifying agents, 433
 Gasoline additive, 397
 Gelatinization, 402
 Generally recognized as safe (GRAS)
 microorganism, 400
 Germ, 371
 Glucoamylase, 400
 β -Glucosidase, 406
 Gluten, 371
 Glycerol, 416
 Glycosidic linkage, 399
 Grains
 composition of, 370
 processing residues, 238, 370
 Granshof number, 132
 Grapefruit peel, 262
 Gravity settler, 418
 Grease, 375
 Gross income, 71
 Gum formation, 376

H

Halogen lamp, 292
 Heat
 definition of, 4
 latent, 36
 sensible, 36
 Heat exchanger
 design, 149
 with heat pipes, 188–189
 network retrofit, 149, 281
 types of, 129–131
 for waste-heat recovery, 158–159
 Heat pinch analysis, *see* Heat exchanger
 network retrofit
 Heat pipes
 applications of, 188–189
 principles of, 186–187
 for waste heat recovery, 292
 Heat pump
 dehumidifier, 185–186, 219, 236, 259, 272
 for drying, 185, 219, 236, 259, 272
 for pasteurization, 184, 215–216, 255
 principles of, 182
 for waste heat recovery, 159, 282, 358–359
 Heat recovery
 from bake ovens, 292
 in refrigeration plant, 282
 in supercritical fluid process, 358–359
 Heat transfer coefficient
 boiling, 20
 condensation, 20
 convective 13, 132

 overall, 15, 136, 146
 phase change, 20
 radiative, 17
 Heat transfer
 conductive, 4–12
 convective, 12–16
 definition of, 4
 enhancement, 142–146
 microwave, 21
 modes of, 4
 radiative, 16–17
 with phase change, 17–20
 Heat transfer rate
 conductive, 4, 10–11
 convective, 12–13
 overall, 15
 phase change, 19
 radiative, 17
 Heating degree days, 46
 Heterogeneous catalysts, 420
 Hexane, 232
 Hexose, 399
 High-efficiency motors, 109, 125
 High-energy electrons, 303
 High-pressure processing, 256, 323
 vessel, 352
 High-temperature and short-time
 pasteurization, 255
 Hot air drying, 258
 Hydraulic press, 233
 Hydraulic pressure, 324
 Hydrolysis, 399
 Hydroxymethylfurfural, 399

I

Ice cream, 269
 Incineration, 363
 Indirect dryer, 236
 Inductance, 118
 Inhibition, 387
 Inhibitor, 403
 Initial investment, 72
 Insulation, 100
 Integrated blancher/cooler, 254
 Internal combustion engine,
 190
 Internal rate of return, 75
 Irradiation, 256, 303
 Irradiation dose, 310
 Isothermal adsorption curves, 179

K

Kutateladze's correlation, 20

L

Lactic acid, 269
 Lambert's law, 337
 Landfill, 363
 Latent heat of fusion, 327
 Latent heat storage, 162–163
 Lauric acid, 376
 Le Chatelier's principle, 323
 Life cycle cost analysis, 76
 Lifetime of equipment, 76
 Lignocelluloses, 398
 Linoleic, 376
 Linolenic, 376
 Lipase, 420
 Living cell, 313
 Loans, 77
 Localized air delivery, 114
 Log mean temperature difference, 138
 Long-chain fatty acids, 387

M

Mass and energy flows, 57–58
 Maxwell's equation, 337
 Measurement
 of dimension, 52
 of electrical loads, 54
 of flue gas composition, 54
 of fluid flow, 53
 of pressure, 53
 of temperature, 52
 Meat products, 277
 Meat processing wastes, 373
 Mechanical compression refrigeration
 cycle, 172
 efficiency, 168
 Mechanical extraction, 232–233
 Mechanical vapor recompression evaporation,
 218, 273
 Membrane separation
 applications of, 300–301
 for concentrating juice, 258
 for concentrating sugar syrup, 246
 description of, 297
 for oil extraction, 234
 in wet milling process, 231
 Mesophile, 401
 Metabolic pathways, 386
 Methane, 261
 Methyl ester, 412
 Methyl tertiary butyl ether (MEBE), 397
 Methylene chloride, 358
 Microfiltration, 272, 298
 Microwave
 absorption efficiency, 343

 assisted extraction, 340–343
 baking, 292, 340
 cooking, 340
 drying, 259, 338–339
 heating systems, 334
 generation efficiency, 343
 pasteurization, 339
 thawing, 339
 Milk powder, 269
 Mill effluent, 238
 Minimum attractive rate of return
 (MARR), 76
 Modified accelerated cost recovery system, 70
 Modifier for solvents, *see* Co-solvent
 Moisture content, 365
 Molasses, 248, 407
 Moody chart, 29
 Motor efficiency, 109, 118, 120
 Moving boundary, 18
 Multi-stage compression, 113
 Multi-stage evaporation, 245, 258, 273
 Myristic acid, 376

N

Net benefits or savings, 75
 Nonthermal processes
 as alternatives to pasteurization and
 sterilization, 216
 of dairy products, 272
 of fruits and vegetables, 255
 of meat products, 284
 Normalizing energy consumption data, 47
 North American Industry Classification System
 (NAICS), 201
 Nusselt number, 132
 Nutraceuticals, 372

O

Obligate aerobe, 401
 Obligate anaerobe, 401
 Oil seeds
 milling of, 231–232
 oil contents, 368–369
 production of, 368
 Oilseed cakes, 369, 432
 Oleic, 376
 Olive husk, 237
 Organelle, 400
 Organic acids, 437
 Orsat analyzer, 54
 β -Oxidation, 387
 Oxidative stability, 412
 Oxygenates, 431

- P**
- Packaging materials for food irradiation, 307
 - Palm oil, 232
 - Palmitic acid, 376
 - Partial combustion, 433
 - Partial differential equation, 22
 - Partial oxidation, 433
 - Part-load efficiency, 121
 - Pasta, 293
 - Pasteurization
 - of dairy products, 271
 - energy conservation in, 215
 - of fruits and vegetables, 255
 - with heat pumps, 184
 - with high pressure, 326
 - with microwave, 334
 - with pulsed electric field, 317
 - Pathogenic bacteria, 261
 - Peak electricity demand, 122, 161
 - Pectin, 406
 - Pectinase, 406
 - Peel waste, 406
 - Penetration depth, 338
 - Pentose, 399
 - Permeability, 313
 - Permeate, 297
 - Permittivity, 335
 - Phase change, 18
 - Phase change materials, 163
 - Phenols, 399
 - Pipe hammering, 98
 - Plate heat exchanger, 129–131, 246
 - Plug flow, 389
 - Polar molecules, 333
 - Polymerization, 376
 - Polysaccharides, 399
 - Power factor
 - characteristics of, 121
 - definition of, 119
 - improvement of, 124
 - Power function, 67
 - Prandtl number, 132
 - Process integration, 149
 - Process optimization, 358
 - Process wastes, 363
 - Process wastewater
 - anaerobic digestion of, 392
 - from fruit and vegetable processing facilities, 364
 - from oilseed mills, 237
 - from starch processing plants, 372
 - Product of current and voltage (VAR), 118
 - Production route, 60
 - Prokaryote, 400
 - Proteolytic enzymes, 269
 - Psychrophile, 401
 - Pulsed electric field, 256, 272, 313
 - Pulsed microwave heating, 347
 - Pump
 - characteristic diagram, 33
 - energy requirement, 27
 - head, 27
 - net positive suction head, 27
 - types of, 33
 - Pyrolysis, 379
 - Pyrolytic oil, 431
- R**
- Rankine cycle, 192
 - Rapid chilling/freezing, 257
 - Ratchet clause, 122
 - Reactive power, 119
 - Real power, 118
 - Refrigeration
 - energy conservation in, 282–283
 - energy loss from, 219
 - load, 283
 - phenomena, 167–168
 - Renewable energy, 213–214
 - Rennet cheese, 269
 - Resistance, 118
 - Retained earnings, 77
 - Retentate, 297
 - Returns on investment, 72
 - Reverse osmosis
 - as an alternative to distillation, 234
 - for concentrating sugar syrup, 246
 - description of, 298
 - for recovering sugars from vegetable and fruit processing water, 262–263, 406
 - Reynolds number, 28, 132
 - Rotary dryer, 245
- S**
- Saccharomyces cerevisiae*, 274, 400
 - Safety equipment, 49
 - Salvage value, 72
 - Saponification, 387, 417
 - Scraped-surface heat exchanger, 131
 - Screw conveyor blancher, 254
 - Screw press, 232–233, 245
 - Sensible heat storage, 161–162
 - Shell and tube heat exchanger, 129, 246
 - Simple payback period, 74
 - Simultaneous saccharification and fermentation (SSF), 404
 - Skimming, 269
 - Slaughter wastes

- anaerobic digestion of, 391
 - from poultry slaughterhouses, 284, 374
 - Soap, 419
 - Solid residues, 364
 - Solid state fermentation, 263, 404
 - Solubility
 - of chemicals in supercritical CO₂, 357
 - of oil in supercritical CO₂, 354
 - of water in supercritical CO₂, 235
 - Solvent extraction, 232–233
 - Soxhlet extraction, 343
 - Soybean oil, 232
 - Specific energy, 317
 - Specific heat, 36
 - Spray drying, 258, 273
 - Stack heat recovery, 97
 - Starch, 398
 - State changes, 35
 - Steam
 - blowdown, 89, 96
 - distribution, 98
 - enthalpy of, 92–93
 - generation, 88
 - leaks, 99
 - system, 88
 - trap, 87, 98–99
 - turbine, 191
 - Stearic acid, 376
 - Steeping, 230
 - Stefan–Boltzmann law, 16
 - Sterilization, *see* Pasteurization
 - Stocks, 77
 - Subcritical pressure, 357
 - Sucrose, 398
 - Sugarcane bagasse, 248
 - Sugars
 - from grain processing residues, 238
 - production process of, 243–244
 - from sugar beet, 243
 - from sugarcane, 243
 - from vegetable and fruit processing residues, 365
 - Sulfur dioxide, 387
 - Supercritical fluid
 - drying, 236, 355–356
 - extraction 232, 234, 354–355
 - liquefaction, 436
 - particle formulation, 356
 - properties, 351–352
 - Supplemental heat, 235
 - Sustainability, 65
 - Synergetic sterilization, 328
 - System, 34
- T**
- Tar, 434
 - Taxable income, 71
 - Tax rates, 71
 - Thawing, 326
 - Thermal conductivity
 - definition of, 4
 - measurement techniques for, 5
 - prediction of, 7–8
 - of selected food products and materials, 6
 - Thermal damage, 234
 - Thermal diffusivity, 23
 - Thermal properties, 9
 - Thermal resistance, 10, 13, 136
 - Thermal storage, 161
 - Thermochemical conversion
 - of by-products in food processing facilities, 238
 - via combustion, 429, 430
 - via gasification, 429, 432
 - via pyrolysis, 429, 431
 - via thermochemical liquefaction, 380, 429, 436
 - types of, 429
 - Thermodynamic cycles, 167
 - Thermodynamics
 - definition of 34
 - first law of, 35
 - second law of, 37
 - Thermometer, 52
 - Thermophile, 401
 - Thermosyphon, 292
 - Thin layer drying, 237
 - Time value of money, 67
 - Total dissolved solids (TDS), 89
 - Toxicity, 387
 - Transesterification, 380, 416
 - Triacylglyceride, 411
 - Trichoderma reesei*, 400
 - Tunnel drying, 258
- U**
- Ultrafiltration
 - as an alternative to distillation, 234
 - description of, 298
 - for nonthermal food pasteurization, 256
 - for recovering solids from waste water, 238
 - Unsteady-state heat transfer, 22
- V**
- Vacuum drying, 258
 - Vacuum spray chamber, 356

Variable speed drive, 126
Vegetable, 251
Vegetable oil, 231, 411
Viscosity, 25
Voltmeter, 54
Volt-ohm-ammeter, 55

W

Waste heat
 quality of, 154
 quantity of 154–156
 utilization of, 157
Waste-heat recovery, 113, 153
Water immersion chilling, 257
Water spray chilling, 257
Water treatment, 89
Water washing of biodiesel, 416
Wattmeter, 54

Weight loss, 282
Wet milling, 228–230, 371
Wet solid residue, 238
Whey, 269, 274, 407

X

X-rays, 303–304

Y

Yeast extract, 401

Z

Zein, 372
Zymomonas mobilis, 400