660.28427 CAO

Contact "Library Services" : info@dss.go.th

INDEX

A
Abdelsalam, M., 348
Absorbing media, radiation in, 426–437
  equivalent gray gas emissivity, 434–436
  gas energy-absorption mechanism, 426–428
  gases/inert gases, 426
  graphs for gas emissivity/absorption factor, 430–434
  heat exchange between gas and finite surface, 434
  heat transfer between surfaces in presence of absorbing gases, 436–437
  hemispheric monochromatic absorption factor, 428–429
  monochromatic hemispheric emissivity, 429
  total emissivity/total absorption factor, 429–430
Absorption coefficient, 396
Absorption-factor graphs, 430–434
Acetaldehyde, 535
Acetic acid, 535
Acetone, 535
Aceylene, 537
Acid rain, 455
Acoustic vibration, 142, 144
Addoms, J. N., 360
Air:
  effect of, in steam systems, 321
  natural convection in, at atmospheric pressure, 69, 70
  physical properties of, 72
  properties of, 70
Air coolers, 231–251
  components of, 231–236
  configurations of, 232, 235
  design procedure for, 242–251
    detailed design, 244–246
    example, 245, 247–250
    preliminary design, 242–244
    temperature control of process side, 250–251
Air coolers (*Cont.*):
  fans in, 233, 234
  forced draft vs. induced draft, 235, 236
  heat transfer in, 236–242
    fan power consumption, 242
    fin efficiency, 237, 238
    heat transfer area, 236
    heat transfer coefficient calculation, 240–241
    overall heat transfer coefficient, 236–237
    pressure-drop calculation, 241–242
    temperatures difference, 237–240
  LMTD correction factors for, 501–503
  nomenclature for, 236
  plenums in, 234
  structure of, 234, 235
  tube bundles in, 231–234
Air preheating system, 457
Air-fuel ratio, 458
All-radiant heaters, 450, 465–469
American National Standards Institute (ANSI), 115
American Petroleum Institute (API), 115, 367
American Society of Mechanical Engineers (ASME), 115, 173
Amine solutions, 540–541
  di ethanol amine, 540
  methyl di ethanol amine, 540, 541
  mono ethanol amine, 540
Aniline, 536
Annular flow, 289, 353
Annulus fluid, 96, 97
ANSI (American National Standards Institute), 115
API (*see* American Petroleum Institute)
API gravity, 442
API Standard(s), 116
  530, 462
  560, 448, 451, 455, 456
API Standard(s) (*Cont.*):
  RP 530, 452, 453
  RP 535, 454
Arbor-type heaters, 452
Arch, 450
Area, unit conversion for, 551
Argon, 538
ASME (*see* American Society of Mechanical Engineers)
ASME Code, 115
Asphalt, 525
Atmospheric distillation columns, 446
Atomizing steam, 440
Austenitic steels, 452
Average bulk temperature, 50–52
Axial-flow reboilers, 383–392
  examples, 389–392
  limitations to heat-flux density, 388–389
  liquid single-phase region of, 384–386
  saturated boiling region of, 386–387
  verification of recirculation rate, 387–388
  vertical thermosiphon reboiler design, 383–384

B
Baffle window, effect of, 179–182
Baffle window region, 143
Baffled heat exchangers, 149
Baffles, 117–121
  cuts in, 117–119
  disk and doughnut, 118, 119
  drain holes in, 120
  in horizontal condensers, 295, 296
  segmental, 117, 118
  spacing of, 120–121, 159
  tolerances for, 121
  type of, 159
  vibration damage to, 142
Bay, 235
Beer's law, 427
Bell, Kenneth, 148, 173, 177, 182

Bell method, 173–187
  applications of, 187
  of calculating shell-side heat transfer coefficient, 173–186
    bypass effects, 178–179
    effect of baffle window, 179, 182
    ideal-tube-bank data for, 173–177
    influence of number of tube rows, 177
    laminar flow, 180, 181
    leakage effect, 182–186
    pressure drop, 179–180, 182–184
    turbulent flow, 181
  fundamentals of, 173, 174
Benzene, 534
Bergelin, O. P., 64, 182
Birmingham Wire Gage (BWG), 121
Blackbody(-ies):
  cavity as, 398–399
  defined, 396
  intensity of radiation and emissive power of, 408–409
  radiant heat transfer among three, 414–415
  radiant heat transfer between, 409–412
  spectral radiant energy distribution for, 400–401
Blackbody emission, 406–407
Blanket insulation, 31–32
Blumenkrantz, A., 388
BMSs (burner management systems), 458
Boiler and Pressure Vessel Code (ASME), 115
Boilers, 319
  (*See also* Reboilers)
Boiling, 331–392
  defined, 331
  flow boiling in tubes, 352–367
    correlations, 358–367
    heat transfer mechanisms for boiling inside vertical tubes, 356–358
    two-phase systems, 352–356
  heat transfer coefficient for, 527
  mechanisms of heat transfer to boiling liquids, 331–344
    bubble diameter at detachment, 344
    formation of vapor bubbles in boiling liquids—equilibrium condition of bubble, 331–333
    nucleation into boiling liquids, 334–344
  of mixtures, 348
  pool boiling, 345–352
Boiling, pool boiling (*Cont.*):
    boiling-curve correlations, 346–349
    comparisons among nucleate boiling correlations, 349–352
    pool-boiling curve, 345–346
Boiling curve, 492–493
Boiling-curve correlations, 346–349
  boiling of mixtures, 348
  comparisons, 349–352
  maximum heat flux, 349
  nucleate boiling zone, 346–349
  onset of nucleation boiling, 346
  point of minimum heat flux, 349
  single-phase convection, 346
  stable film boiling zone, 349
  transition flux zone, 349
Boiling-range correction factor, 378–379
Boltzman, Stephan, 401
Bonnets, 132
Boundary layer(s):
  defined, 35
  development of, 37
  laminar, 37–39
  in nucleation, 337
  shear forces in, 36
  thermal, 39, 40
  turbulent, 37–38
  velocities distribution in, 37
  velocity, 11
Boundary-layer thickness, 37
Box-type heaters, 448, 450–452
Boyko, I. D., 290
Boyko-Krushilin correlation, 290
Br_2, 539
Brazed plate heat exchangers, 265
Brazing, 126
British thermal unit (Btu), 5
Bromley, L. A., 349
Bromley correlation, 349
Brown, G. A., 64
Btu (British thermal unit), 5
Bubble contact angle, 334–336
Bubble-point temperature, 275, 276
Bubbles:
  diameter at detachment of, 344
  equilibrium condition of, 331–333
  formation in boiling liquids, 331–333
  growth of, 336–339
Bubbly flow, 353
Bulk temperature, 50–52
Bundle entrance or exit areas, 122
Burner management systems (BMSs), 458
Burners, in fired heaters, 453–456
Burnout point, 346
Butyl rubber, 262
BWG (Birmingham Wire Gage), 121
BWG Standards, 122, 158, 529
Bypass effects, 178–179
Bypass streams, 135, 168–171

C

Cabin heaters, 448, 450–452
CAD (computer-aided design) software, 147
Calcium silicate insulation, 30, 33
Carbon steel, 452
Carbon tetrachloride, 536
Carpenter, E. F., 290
Carpenter and Colburn correlation, 290
Catalytic re-former units, 446
Cellular foam insulation, 30
Cellular glass insulation, 30
Channels, 132
Chemical potential, 490
Chemical processing streams, 524
Chen, J., 360, 364
Chen correlation, 362–365
Chlorobenzene, 536
Chromium, 452
Churn flow, 353
Cl_2, 539
ClH, 539
Class B mechanical standards, 116
Class C mechanical standards, 116
Class R mechanical standards, 116
Clausius Clapeyron equation, 333
Cleaning:
  of fire-burner tubes, 453
  of gasketed plate heat exchangers, 264, 265
Cleaning balls (pigs), 453
CO, 538
CO_2, 431, 538
Coating moisture barriers, 30
Co-current configuration, 148
  (*See also* Parallel-flow configuration)
Coking unit streams, 525
Colburn, A. P., 290
Colburn coefficient (j factor), 175, 176
Colburn-type expressions, 286
Cold bodies, 395
Collision damage, 142
Column reboilers, 447
Combustion:
  complete, 439
  in process fired heaters, 439–447
    enthalpy balance, 442–446
    heating value, 441–442
    radiant convective arrangement, 446, 447
    stoichiometry, 439–441
Complete combustion, 439

Composite walls, conduction through:
cylindrical, 23–24
planar, 17–18
Computer-aided design (CAD) software, 147
Condensate-film thickness, 281
Condensation, 275–327
desuperheater condensers, 303–309
dropwise, 277
filmwise, 277
mechanisms of, 275–277
of single-component vapors, 277–292
effect of vapor velocity, 289–292
film condensation in turbulent flow, 288–289
filmwise condensation, 277–288
(*See also* Single-component vapors condensers)
steam as process heating medium, 318–327
process heating systems, 318–324
regulation of steam flow, 324–327
of vapor mixtures, 309–318
design of systems, 315
diffusional processes, 311–315
example, 316–318
Condensation curves, 309–311, 492–493
Condensation heat transfer film coefficient, 278–279
Condensation heat transfer coefficient, 282–283, 299
Conduction (in general):
defined, 10
description of, 9–10
Conduction (in solids), 15–33
general equation of, 15–16
steady-state, in multidimensional systems, 26–28
and thermal insulation, 28–33
through walls, 16–25
Conductivity:
of air, 70
factors affecting, 31
of insulation materials, 31
Constant-cross-section fired heaters, 450–452
Construction, of heat exchanger, 145
Contaminants, 454, 455
Continuous systems, 5–8
Control chamber, 323
Control systems:
for distillation, 487–488
in fired heaters, 457–458
Controlling resistance, 20, 86
Convection, 35–75
defined, 10
description of, 10–12
effects of, on radiant-zone model, 462
forced, 35–66
around submerged objects, 60–66
inside tubes, 44–60
over flat plates, 35–44
natural, 66–75
air at atmospheric pressure, 69, 70
combined convection-radiation coefficient, 69, 70
example, 68–69
heat loss, 71–75
heat transfer mechanism, 66–67
horizontal cylinders, 68
horizontal planar surfaces, 68
spheres, 68
vertical plates/cylinders, 68
Convection bank tubes, 470
Convection banks:
flue-gas pressure drop in, 472
heat transfer correlations for, with plain tubes, 472–473
heat transfer correlations for finned-tube, 470–471
Convection film coefficient, 12
defined, 40–42
effect of fluid velocity on, 42–43
in shell-and-tube heat exchanger design, 160
Convection heat transfer coefficient, 62–66
Convection section, 446, 470
Convection-radiation heat transfer coefficient, 69, 70
Convective boiling correlations, 358–367
Chen correlation, 362–365
critical pressure, 366–367
heat transfer in saturated boiling region, 360
in-tube film boiling, 366
limits to, 365–366
onset of subcooled nucleate boiling, 358, 359
single-phase liquid convection region, 358
start of saturated boiling, 359–360
subcooled nucleate boiling region, 358, 359
suppression of saturated nucleate boiling, 361
two-phase force-convection region, 362
Cooling leg, 322
Cooling-water flow rate, 305
Cordero, A., 239
Correlations for heat flow, 43–44
Corrugation angle, 268
Corrugations, 255, 260
COS, physical properties of, 539
Cosine law, 408
Countercurrent heat exchangers, 88–92
LMTD in, 148
with three shells, 155
two-pass heat exchanger transformed from, 158–159
Cover plate headers, 234
Cracking unit streams, 525
Critical pressure, 366–367
Cross-mixing hypothesis, 148–150
Crossover section, 446, 447
Crude oil, 524–525
CS_2, 539
Cylinders, conduction through, 22–25

D

Deaerator and condensate tanks, 319, 320
Decoking systems, 453
Delaware method (*see* Bell method)
Dengler, C. E., 360
Density:
of insulation materials, 31
unit conversion for, 551
Design changes, 103
Design pressure, 145
Design procedure:
for air coolers, 242–251
detailed design, 244–246
example, 245, 247–250
preliminary design, 242–244
temperature control of process side, 250–251
for double-tube heat exchangers, 102–111
changes to original design, 103
examples, 103–111
film coefficient calculation, 102
heat transfer area calculation, 103
LMTD calculation, 103
overall heat transfer coefficient calculation, 102
pressure drop calculation, 103
tube diameter selection, 102
tube length and number calculation, 103
for shell-and-tube heat exchangers, 145–146, 196–202
Design temperature, 145
Desuperheater condensers, 303–309

Detachment diameter, bubble, 344
Dew-point temperature, 275, 276
Di ethanol amine, 540
Differential Condensation Model, 493
Differential volume I, 35
Diffusional processes, 311–315
Dimensional analysis, 43
Dimensionless groups, 55–57
Dimensionless temperature, 52
Directional emissive power, 407–408
Disk and doughnut baffles, 118, 119
Distillation, 485–493
  column simulation of, 488, 489
  condensation and boiling curves for, 492–493
  control scheme for, 487–488
  heat transfer in, 79, 80
  mass and energy balances in, 490–492
  objective of, 369
  phase equilibrium in multicomponent system, 489–490
  total/partial condensers in, 488, 489
Distillation bottom product, 370
Distillation columns, simulation of, 488, 489
Doberstein, S. C., 64
Double-pass air coolers, 239
Double-split configuration, 371, 372
Double-tube heat exchangers (in general), 94–98
  annulus-fluid calculation, 96
  applications of, 97–98
  design procedure for, 102–111
  internal-tube fluid calculation, 95–96
  parallel-currents, 87
  pressure-drop calculation in, 96–97
  standard tube dimensions for, 98
Double-tube heat exchangers with longitudinal fins, 217–230
  about, 217–221
  with constant section, 221–224
  fin efficiency, 221–224
  friction factor for, 225
  heat transfer coefficient for, 225–226
  multipass heat exchangers with longitudinal flow, 226–230
  wall-temperature calculation for, 226
Double-tubesheet design, 138
Downcomers, 485
Draft, in fired heaters, 455–457
Drag coefficient (*see* Friction factor)
Drain holes, 120
Drew, T. B., 161
Dropwise condensation, 278
Dukler, A. E., 288
Dummy tubes, 169, 170

E
Eckert, E. R. G., 68
Eddies, 35, 177
Effective mean temperature difference, 152
Effectiveness, of heat exchangers, 205–213
  analysis of effectiveness graphs, 212–213
  outlet-temperature calculation, 205–210
  physical interpretation of, 210–211
Elastomeric gaskets, 255–259
Electric analogy, 414
Embedded tube bundles, 231, 233
Emissive power:
  of blackbody, 408–409
  directional, 407–408
  monochromatic, 399–400
Emissivity:
  of common materials, 70
  equivalent gray gas, 434–436
  gas, 430–434
  monochromatic hemispheric, 429
  and temperature, 398
  total, 429–430
Enclosures with gray surfaces, 419–422
Energy, unit conversion for, 552
Energy balance, in distillation, 490–492
Energy conservation law, 4
Energy units, 5
Enthalpy, 8
Enthalpy balance:
  in combustion, 442–446
  in condensation, 275
  and fluids heat transfer, 79–81
Equations of state, 8
Equivalent diameter:
  defined, 59
  example of, 60
  in shell-and-tube heat exchanger design, 166–167
Equivalent gray gas emissivity, 434–436
Equivalent gray-plane simplification, 458–462
Equivalent mean hemispherical beam length, 434, 463
Escoa Company, 470
E-shell heat exchangers, LMTD correction factors for, 495–500
  1–2 heat exchangers, 495
  2–4 heat exchangers, 496
  3–6 heat exchangers, 497
  4–8 heat exchangers, 498
  5–10 heat exchangers, 499
  6–12 heat exchangers, 500
Ethane, 532, 537
Ethyl acetate, 535–536
Ethyl chloride, 536
Ethylene glycol, 107, 541
Evaporation, 331
Expanded joints, 124–126
Expansion joints, 133
Externally sealed floating-head heat exchangers, 139
Extruded tube bundles, 231, 233

F
Fair, J. R., 354, 356, 366
Fan coverage, 233
Fan power consumption, 242
Fanning factor, 97
Fans, 233, 234
Fiberglass insulation, 30
Film boiling, 346, 366, 379
Film boiling zone, 349
Film coefficient(s):
  calculation of, 102
  in condensation, 278–279
  in convection, 12, 40–43, 53–55, 160
  in fluids heat transfer, 82–86, 102
  for plate heat exchangers, 268
  for shell-and-tube heat exchanger, 160
Film condensation:
  defined, 277
  of single-component vapors, 277–288
    condensate-film thickness, 281
    condensation heat transfer film coefficient, 278–279
    condensation heat transfer coefficient, 282–283
    condensation over horizontal tubes, 283, 286–287
    example, 287–288
    over vertical surfaces, 283–286
    velocity profile in descending film, 279–281
  in turbulent flow, 288–289
Film temperatures, 72
Fin efficiency:
  in air coolers, 237, 238
  defined, 220
  in double-tube heat exchangers with longitudinal fins, 221–224
  factors affecting, 224

Fin efficiency (*Cont.*):
of radiant-convection heaters, 471–472
Fin height, 224
Fin thickness, 224
Finned tubes, 217–251
in air coolers, 231–251
components of, 231–236
configurations of, 232, 235
design procedure for, 242–251
fans in, 233, 234
forced draft vs. induced draft, 235, 236
heat transfer in, 236–242
nomenclature for, 236
plenums in, 234
structure of, 234, 235
tube bundles in, 231–234
in double-tube heat exchangers, 217–230
about, 217–221
with constant section, 221–224
fin efficiency, 221–224
friction factor for, 225
heat transfer coefficient for, 225–226
multipass heat exchangers with longitudinal flow, 226–230
wall-temperature calculation for, 226
Finned-tube convection bank, 470–472
Fins, types of, 453
Fired heaters (*see* Process fired heaters)
Fired reactors, 447
First law of thermodynamics, 4
5-10 heat exchangers, 499
Fixed heads, 133
Fixed-tubesheet heat exchangers, 117, 133, 140
Flame color, 458
Flat plates, forced convection over, 35–44
boundary layers in, 35, 37–39
convection film coefficient in, 40–42
correlations for heat flow to moving fluid, 43–44
effect of fluid velocity on film coefficient, 42–43
heat transfer to moving fluid, 39–41
laminar/turbulent boundary layers in, 37–39
shear stress in moving fluid, 35–37
Floating heads, 133–140
outside-packed, 137–140
outside-packed lantern-ring, 139, 140
pull-through, 134–137, 140
split-ring, 135–137, 140
Float-type traps, 322, 323
Floor, heat loss through, 75
Flow boiling in tubes, 352–367
correlations, 358–367
Chen correlation, 362–365
critical pressure, 366–367
heat transfer in saturated boiling region, 360
in-tube film boiling, 366
limits to convective boiling correlations, 365–366
onset of subcooled nucleate boiling, 358, 359
single-phase liquid convection region, 358
start of saturated boiling, 359–360
subcooled nucleate boiling region, 358, 359
suppression of saturated nucleate boiling, 361
two-phase force-convection region, 362
heat transfer mechanisms for boiling inside vertical tubes, 356–358
two-phase systems, 352–356
flow patterns, 352–354
flow-pattern characterization, 354–355
frictional pressure drop, 355–356
liquid and vapor volume fractions, 354
Flow fractions, 171
Flow patterns, 352–355
Flue-gas pressure drop, 472
Fluid allocation, in shell-and-tube heat exchanger design, 158
Fluid flow, over submerged bodies, 60–62
Fluid velocity, effect on film coefficient, 42–43
Fluidelastic instability, 142, 144
Fluids heat transfer, 79–111
in double-tube heat exchangers, 94–98
and enthalpy balance, 79–81
heat transfer coefficient and area of, 81–82
and mean temperature difference between fluids, 86–94
overall heat transfer coefficient as function of film coefficients, 82–86
process specifications for, 98–101
Fluoroelastomers, 263
Flux zone, transition, 349
Footed tube bundles, 231, 233
Force, unit conversion for, 552
Forced convection, 35–66
around submerged objects, 60–66
defined, 12
inside tubes, 44–60
dimensionless numbers, 55
empirical correlations, 56
equivalent diameter, 59–60
example, 58–59
fluid velocity distribution, 44–46
heat transfer from wall to fluid, 53
heat transfer coefficient, 53–54
influence of wall temperature, 55–56
j_H dimensionless factor, 56–58
mean temperature difference, 54–55
nonisothermal flow, 49–52
pressure drop, 47–49
Stanton number, 56
temperature profile development, 52
over flat plates, 35–44
boundary layer, 35
boundary-layer development, 37
convection film coefficient, 40–42
correlations for heat flow, 43–44
effect of fluid velocity on film coefficient, 42–43
heat transfer to fluid in motion, 39–41
laminar/turbulent boundary layers, 37–39
shear stress in moving liquid, 35–37
Forced convective boiling, 345
Forced reflux return, 292, 293
Forced-circulation reboilers, 367–368
Forced-draft air coolers, 232, 233
Forced-draft gas burners, 454
Formic acid, 535
Forster, H., 347, 363
Forster and Zuber equation, 347, 348, 350–352, 364
Fouling, 147–148
Fouling correction:
in plate heat exchangers, 269–272
for radiant-convection heaters, 471–472
Fouling factors, 101, 148
Fouling resistance(s), 523–525
for chemical processing streams, 524
defined, 84–85
for industrial fluids, 524
for natural gas and gasoline processing streams, 524
for oil refinery streams crude oil, 524–525

Fouling resistance(s) (*Cont.*):
for plate heat exchangers, 269–272
for water, 523
4–8 heat exchangers, 498
Four-pass heat exchangers, 129
Fractionating column-feed preheaters, 446
Free-stream velocity, 35
Friction factor:
calculation of, 152–153
for combination of heat exchanger configurations, 156
as configuration-selection criterion, 153–156
convection, 47–48
defined, 38
for double-tube heat exchangers, 97, 225
and ideal tube-bank data, 175, 176
for inlet nozzle orientation, 157
Frictional pressure drop:
in shell-and-tube heat exchanger design, 161–164
in stack, 456–457
for two-phase systems, 355–356
Front (inlet) heads, 131–132
Fuel efficiency:
in combustion, 444–447
in fired heaters, 458
Fuel mixtures, 441, 442

G

Gas(es):
fouling resistances for, 524
heat exchange between finite surface and, 434
heat transfer between surfaces in presence of absorbing, 436–437
heating value of, 441, 442
heat transfer coefficient for, 528
physical properties of, 537–539
physical properties of streams of, 227
radiation in absorbing, 426
Gas burners, 454
Gas emissivity, 430–434
Gas energy absorption, 426–428
Gas Processors Suppliers Association (GPSA), 367
Gaseous fuels, 440
Gasketed plate heat exchangers, 257, 260–265
components of, 260–265
configuration of, 258
frame of, 263–265
gaskets in, 262–263
general characteristics of, 264, 265
Gasketed plate heat exchangers (*Cont.*):
heat exchange plates of, 260–262
materials for, 261–262
pressure and temperature limitations of, 264, 265
Gaskets, plate, 262–263
Gasoline processing streams, 524
Geometric constraints, process specifications for, 101
Glycol solutions, 541
GPSA (Gas Processors Suppliers Association), 367
Grashoff number, 67
Gravity acceleration, 552
Gravity-return reflux system, 292, 293
Gray body(-ies):
defined, 402
emission spectrum of, 403
enclosures with, 419–422
generalized Kirchoff's law for, 404
heat transfer between surrounding body and, 422–424
Gray gas emissivity, 434–436
Gray-to-black transformation resistance, 420
Griffith, P., 342
Gross heating value, 441

H

Hairpin heat exchanger, 95, 98
Han, C. Y., 342
HCN, physical properties of, 538
Headers, in tube bundles, 233, 234, 453
Heat, 3
Heat balance:
of condenser and mean temperature difference, 298–299
defined, 91
of kettle reboilers, 376
Heat capacity ratio, 205
Heat exchangers:
with 2–4 configuration, 167, 168,
configurations of, 129, 156
construction of, 145
data sheet for, 547–549
defined, 79
effectiveness of, 205–213
process specifications for, 98–101
Heat flux, 9, 10, 349
Heat loss, natural-convection, 71–75
through floor, 75
through insulated wall, 71–74
through roof, 74–75
Heat transfer, 3–13
in air coolers, 236–342
to boiling liquids, 331–344
Heat transfer (*Cont.*):
in continuous/steady-state systems, 5–8
and first law of thermodynamics, 3–4
between fluids (*see* Fluids heat transfer)
mechanisms of, 9–13
in shell-and-tube heat exchangers, 184
and temperature/internal energy, 5
unit operations in, 3
variables of, 8–9
Heat transfer area:
in air coolers, 236
calculation of, 83, 103, 106–107
defined, 81
as design factor, 82
Heat Transfer Research, Inc. (HTRI), 186
Heat transfer to fluid in motion, 39–41
Heat exchange plates, 260–262
Heat exchanger cells, 186
Heat-flux density, 9
limitations to, 388–389
in radiant section, 448, 449, 462
unit conversion for, 553
upper limit to, 366
Heating value, of fuel, 441–442
Heat transfer coefficient(s):
for air coolers, 240–241
and area of fluids heat transfer, 81–82
in boiling, 527
bypass effects on, 178–179
calculation of, 105–106, 164–168
in condensation, 282–283, 299
in convection, 53–54, 62–66
for double-tube heat exchangers with longitudinal fins, 225–226
effect of baffle window on, 182
for finned-tube convection bank`, 470–471
for gas, 528
Kern method of calculating, 164–168
leakage effect on, 184
local film convective, 53–54
for plate heat exchangers, 266
in radiation, 70
in shell-and-tube heat exchanger design, 164–168
shell-side, 164–168, 173–186
tables of typical, 266, 527–528
unit conversion for, 553
for water-cooled condensers, 527
(*See also* Overall heat transfer coefficient(s))

Heat transfer correlations:
for convection bank with plain tubes, 472–473
for finned-tube convection bank, 470–471
Heat transfer mechanisms, 9–13
conduction, 9–10
convection, 10–12
radiation, 12–13
Heat transfer operations, 3
Heavier components, 309
Height of transfer unit (HTU), 211
Helium, 538
Hemispheric monochromatic absorption factor, 428–429
Herringbone corrugations, 260, 261
Heterogeneous nucleation over solid surfaces, 334–336
Hewit, G. F., 354, 355
Homogeneous nucleation, 334
Horizontal condensers:
design of, 315
with in-tube condensation, 295–297
with shell-side condensation, 295, 296, 299
Horizontal gravity-flow condenser, 292
Horizontal planar surfaces, natural convection on, 68
Horizontal thermosiphon reboilers, 371, 372, 383
Horizontal tubes:
condensation inside, 289–290, 299
condensation over, 283, 286–287
natural convection in, 68
Hot oil, 227
Hsu, Y. Y., 346
HTRI (Heat Transfer Research, Inc.), 186
HTU (height of transfer unit), 211
Hydraulic pressure test, 145
Hydraulic radius, 59, 225
Hydrogen, 537

I

I-butane, 537
Ideal gas constant (R), 552
Ideal-tube-bank data, 173–177
Impingement protection, 122, 123
Impingement protection plates, 122
Induced-draft air coolers:
advantages/disadvantages of, 235, 236
configuration of, 232
fans in, 233
Industrial fluids, 524
Inert gases, 294, 426
Inlet heads, 131–132
Inlet nozzles, 157, 255
Insulated walls:
heat loss through, 71–74
thermal radiation through, 415–419
Insulation (*see* Thermal insulation)
Integral Condensation Model, 493
Intensity of radiation (intensity of emission):
blackbody, 408–409
defined, 404–406
monochromatic, 406
Internal coefficient, 95–96
Internal energy, 4, 5
Internal reboilers, 374
Internal-tube fluid, 96–97
In-tube film boiling, 366
Inverted-bucket steam traps, 322, 323
I-pentane, 532
Isobutane, 532

J

j factor (*see* Colburn coefficient)
Jacketed vessels, 319–321
Jackson, W., 68
J_H dimensionless factor, 57–58
Joule (J), 5

K

Kcal (kilocalorie), 5
Kern, Donald, 58, 96, 148, 164, 167, 225, 290, 299, 306, 379, 388
Kern method, 164–173
for calculation of shell-side heat transfer coefficient, 164–168
equivalent diameter, 166–167
heat exchangers with 2–4 configuration, 167, 168
heat transfer coefficient correlation, 167
pressure drop, 167
shell-side Reynolds number, 164–166
criticisms of, 167–173, 187
Kettle reboilers, 371
arrangement of, 373–374
thermal design of, 376–383
examples, 380–383
heat balance, 376
Kern's recommendations for maximum heat flux, 379
maximum heat-flux density and film boiling, 379
reboiler area calculation, 376–379
shell sizing, 380
Kilocalorie (kcal), 5
Kinematic viscosity, 70
Kirchoff's law, 397–398, 403
Koo, E. C., 161
Krushilin, G. N., 290

L

Lambertians, 408
Lambert's law, 408
Laminar boundary layer, 37–39
Laminar flow:
convection in, 35, 56
defined, 11
effect of baffle window on, 180, 181
Laminar sublayer, 55
Laminar sublayer, temperature and thickness of, 42–43
Latent heat:
of condensation, 275
in reboilers, 376
of vaporization, 9
LCs (*see* Level controllers)
Leakage:
effect of, on pressure drop, 182–184
effect of, on shell-side heat transfer, 184
between shell and longitudinal baffle, 131
Leakage streams, 169–171
Length, unit conversion for, 551
Level controllers (LCs), 487, 488
Light end processing streams, 525
Liquid fuels, 440–442
Liquid single-phase region, 384–386
Liquid volume fraction, 354
Liquids, physical properties of, 72, 532–536
LMTD (*see* Logarithmic mean temperature difference)
LMTD correction factors:
for air coolers, 501–503
for E-shell heat exchangers, 495–500
for plate heat exchangers, 269, 270
for shell-and-tube heat exchangers, 151–157
Lobo-Evans method, 462–465
Local film convective heat transfer coefficient, 53–54
Local Nusselt number, 43, 54
Lockhardt, R. W., 354, 356
Lockhardt-Martinelli parameter, 354
Logarithmic mean temperature difference (LMTD):
calculation of, 103, 106, 148–150
in fluids heat transfer, 91–93
Longitudinal baffles, 129–131, 168
Lube oil processing streams, 525

M
Marriot, J., 269
Marshall, W. R., 68
Martinelli, R. C., 354, 356, 362
Mass, unit conversion for, 551
Mass balance, in distillation, 490–492
Mass-transfer operations, 3
Material defect propagation, 142
Material requisition, 146
Maximum heat flux, 349, 379
Maximum heat-flux density, 379
Maxwell equations, 8
McAdams, W. H., 68, 69, 161
McNelly, M. J., 347
McNelly equation, 347, 350–352
MDEA (*see* Methyl di ethanol amine)
Mean Nusselt number, 43
Mean temperature difference:
  in condensers, 298–299
  for convection inside tubes, 54–55
  in countercurrent and parallel-flow configurations, 88–89
  between fluids, 86–94
    countercurrent and parallel-flow configurations, 88–89
    logarithmic mean temperature difference, 91–93
    thermal diagrams of heat exchangers, 89–91
  (*See also* Logarithmic mean temperature difference)
Mechanical design, 145
Mechanical standards, 116
Membrane moisture barriers, 30
Methane:
  heating value of, 441
  physical properties of, 537
Methyl di ethanol amine (MDEA), 540, 541
Microconvective effect, 358, 359
Microwaves, 396
Mineral wool insulation, 30
Minimum heat flux, point of, 349
Mist flow, 353
Mist flow region, 365
Mixing-cup temperature, 50
Mixtures boiling, 348
Moisture barriers, 30
Molecular transport of energy, 9
Molybdenum, 452
Momentum-transfer operations, 3
Mono ethanol amine, 540
Monochromatic absorption coefficient, 402–404
Monochromatic emissive power, 399–400
Monochromatic hemispheric emissivity, 429
Monochromatic intensity of radiation, 406
Monrad, C. C., 473
Moody, L., 48
Mostinsky, I. L., 348, 349, 379
Mostinsky equation, 348, 350–352, 365, 378
Movable pressure plates, 263
Moving fluid:
  correlations for heat flow from planar surface to, 43–44
  heat transfer from flat plate to, 39–41
  heat transfer rate from tube wall to, 53
  shear stress in, 35–37
  velocity distribution of, inside tubes, 44–46
Mueller, A. C., 291
Multicomponent distillation system, 489–490
Multicomponent mixtures, condensation of, 311–315
Multidimensional systems, steady-state conduction in, 26–28
Multipass heat exchangers, 126–128, 226–230
Multiple shell passes, 128–131
Multitube hairpin heat exchanger, 98
M-xylene, 534

N
N_2O, 539
Naphtha hydrotreater, 525
Natural convection, 66–75
  in air at atmospheric pressure, 69, 70
  combined convection-radiation coefficient, 69, 70
  defined, 12
  example of, 68–69
  heat loss by, 71–75
  heat transfer mechanism in, 66–67
  in horizontal cylinders, 68
  on horizontal planar surfaces, 68
  in spheres, 68
  with vertical plates/cylinders, 68
Natural gas, 524
Natural-draft gas burners, 454
N-butane, 532, 537
N-decane, 533–534
Net heating value, 441
NH_3, 538
N-heptane, 533
N-hexane, 533
Nitrile rubber, 262
Nitrogen, 537
Nitrogen oxides, 454, 455
N-nonane, 533
NO_2, 539
N-octane, 533
Nonisothermal flow, 49–52
Nozzle arrangements, 149
Nozzle entrance or exit areas, 143
N-pentane, 532–533
NTUs (*see* Number of transfer units)
Nucleate boiling, suppression of, 361
Nucleate boiling zone, 346–349
  Forster and Zuber equation, 347, 348
  McNelly equation, 347
  Motinsky equation, 348
  Rohsenow correlation, 346–347
  Stephan and Abdesalam correlations, 348
Nucleation:
  into boiling liquids, 334–344
    defined, 334
    example of, 342–344
    heterogeneous, 334–336
    homogeneous, 334
    in temperature gradient, 337–342
  in temperature gradient, 337–342
Number of transfer units (NTUs), 205, 211
Nusselt, W., 278
Nusselt equations, 283
Nusselt numbers, 43, 54, 55
Nusselt theory, 278, 279

O
Ohm's law of the electric circuits, 84
Oil refinery streams crude oil, 524–525
Oils:
  fouling resistances for, 524
  heat transfer coefficient for, 528
  hot, 227
Once-through circulation, 370, 371
One-pass cross-flow, both fluids unmixed, 501
1–2 heat exchangers, 495
Onset of nucleation boiling, 346
Onset of nucleation boiling temperature, 338
Onset of subcooled nucleate boiling, 358, 359
Operating pressure, 144
Organic solvents, 528
Othmer, D. F., 294
Outlet temperatures, 205–210
Outside-packed heat exchangers:
  floating-head, 137–140
  lantern-ring, 139, 140
Overall heat transfer coefficient(s):
  for air coolers, 236–237
  calculation of, 102, 106

Overall heat transfer coefficient(s) (*Cont.*):
for double-tube heat exchangers, 94–98
for fluids heat transfer, 81–86
for plate heat exchangers, 266
tables of typical, 266
Oxygen:
in combustion reactions, 439–440
physical properties of, 537
O-xylene, 534

P

Palen, J., 187
Palen, J. W., 378, 379
Parabolic distribution function, 45–46
Parallel corrugations, 261
Parallel-flow configuration, 87–90, 255
Partial condensers, 297, 488
Pass partitions, 128
Passes, in fired heaters, 450
Pass-partition flow, 169
PCs (*see* Pressure controllers)
Perforated-trays column, 485, 486
Petroleum refineries, 446
Phase equilibrium, 489–490
Phenol, 536
Physical constants, unit conversion for, 552
Physical properties, 531–546
of amine solutions, 540–541
of gases, 537–539
of glycol solutions, 541
of liquids, 532–536
Pignotti, G., 239
Pigs (cleaning balls), 453
Pilots, 454
Pipelines, pumping stations of, 447
Piping, 31–32
Planck, Max, 400
Planes, conduction through, 16–22
composite walls, 17–18
controlling resistance, 20
example of, 20–22
wall separating two fluids, 18–20
Plate heat exchangers, 255–273
components of, 255, 257
disadvantages of, 265–266
fouling resistances in, 269–272
gasketed, 260–265
components of, 260–265
frame of, 263–265
gaskets in, 262–263
general characteristics of, 264, 265
heat exchange plates of, 260–262
pressure and temperature limitations of, 264, 265
Plate heat exchangers (*Cont.*):
heat transfer and pressure-drop correlations for, 267–269
film coefficients, 268
pressure drop, 268–269
Reynolds number, 267–268
heat transfer coefficients for, 266
limitations of, 255
LMTD correction factor for, 269, 270
number of transfer units and specific pressure drop for, 272–273
operating principles and general description of, 255–258
schematic drawing of, 256
series-parallel combination in, 258–260
welded/semiwelded, 265
Plenums, 234, 454
Plug headers, 234, 453
Point of minimum heat flux, 349
Pool boiling, 345–352
boiling-curve correlations, 346–349
boiling of mixtures, 348
comparisons, 349–352
maximum heat flux, 349
nucleate boiling zone, 346–349
onset of nucleation boiling, 346
point of minimum heat flux, 349
single-phase convection, 346
stable film boiling zone, 349
transition flux zone, 349
pool-boiling curve, 345–346
Pool-boiling curve, 345–346
Portholes, 255
Potential energy, 4
Potential flow regime, 37
Power-heat flux, unit conversion for, 552
Prandtl number, 55
Premix burners, 454, 455
Pressure, unit conversion for, 552
Pressure controllers (PCs), 487, 488
Pressure drop:
in air coolers, 241–242
calculation of, 103, 107–109, 165
in double-tube heat exchangers, 96–97
effect of baffle window on, 179–182
flue-gas, 472
frictional (*see* Frictional pressure drop)
heat transfer correlations for, with plain tubes, 472–473
inside tubes, 47–49
Pressure drop (*Cont.*):
Kern method of calculating, 165
leakage effect on, 182–184
in plate heat exchangers, 268–269, 272–273
process specifications for, 101
in shell fluid, 167
in shell-and-tube heat exchangers, 185–186
in 2–4 heat exchangers, 167, 168
in water, 107–109
Process fired heaters, 439–482
applications of, 446, 447
combustion in, 439–447
convective arrangement, 446, 447
enthalpy balance, 442–446
heating value, 441–442
stoichiometry, 439–441
components of, 452–458
air preheating system, 457
burners, 453–456
control systems, 457–458
draft, 455–457
stack, 455–457
tubes, 452–454
constant-cross-section, 450–452
design/verification of capacity of, 458–482
all-radiant heaters, 465–469
correction for fouling and fin efficiency, 471–472
flue-gas pressure drop in convection bank, 472
heat-flux density in radiant section, 462
heat transfer correlations for convection bank with plain tubes, 472–473
heat transfer correlations for finned-tube convection bank, 470–471
Lobo-Evans method, 462–465
radiant-convection heaters, 470–482
radiant-zone model, 458–462
schematic drawing of, 440
vertical cylindrical, 448–450
Process heating systems (steam), 318–324
air in, 321
installations of, 319–321
steam traps in, 321–324
Process specifications, 98–101, 145
fouling-factor, 101
geometric-design, 101
pressure-drop, 101
thermal-performance, 99–101
Process streams, 79
Propane, 532, 537
Propane refrigeration cycle, 303

Propane-refrigerated condensers, 296–297
Pseudo-critical pressure, 367
Pull-through floating-head heat exchangers, 134–135, 137, 140
Pumping stations, 447
Pure-fluid-condenser design, 297–302
  condensation heat transfer coefficient, 299
  example, 300–302
  heat balance of condenser and mean temperature difference, 298–299
P-xylene, 534
Pyrolosis heaters, 447

R

Radiant convective arrangement, 446, 447
Radiant energy, 395–396
Radiant section, 462
Radiant shields, 425–426
Radiant-convection heaters, 470–482
  correction for fouling and fin efficiency, 471–472
  efficiency of, 446, 447
  flue-gas pressure drop in convection bank, 472
  heat transfer correlations for convection bank with plain tubes, 472–473
  heat transfer correlations for finned-tube convection bank, 470–471
  rating of, 473–482
Radiant-zone model, 458–462
  convective effects, 462
  equivalent gray-plane simplification, 458–462
  radiation to shield tubes, 462
Radiation, 395–437
  in absorbing media, 426–437
    equivalent gray gas emissivity, 434–436
    gas energy absorption mechanism, 426–428
    gases/inert gases, 426
    graphs for gas emissivity/absorption factor, 430–434
    heat exchange between gas and finite surface, 434
    heat transfer between surfaces in presence of absorbing gases, 436–437
    hemispheric monochromatic absorption factor, 428–429
    monochromatic hemispheric emissivity, 429
    total emissivity/total absorption factor, 429–430
Radiation (*Cont.*):
  defined, 13
  description of, 12–13
  to shield tubes, 462
  through transparent media, 395–426
    absorption/reflection/transmission coefficients for, 396
    blackbody emission distribution, 406–407
    blackbody intensity of radiation and emissive power, 408–409
    and cavity as blackbody, 398–399
    directional emissive power, 407–408
    electric analogy, 414
    emission from surfaces, 401–402
    enclosures with gray surfaces, 419–422
    gray surfaces, 402–404
    heat transfer among three blackbodies, 414–415
    heat transfer between blackbodies, 409–412
    heat transfer between gray body and surrounding body, 422–424
    insulating walls/refractories, 415–419
    intensity of radiation, 404–406
    and Kirchoff's law, 397–398
    monochromatic absorption coefficient, 402–404
    monochromatic emissive power, 399–400
    monochromatic intensity of radiation, 406
    radiant shields, 425–426
    spectral radiant energy distribution for blackbody, 400–401
    view-factor algebra, 413–414
  wavelength spectrum for, 395
Radiation heat transfer coefficient, 70
Radiation-convection coefficients, 74
Radiosity, 419
Ranz, W. E., 68
Rating, of heat exchangers, 193–195
Raw-gas burners, 454
Reactor-feed preheaters, 446, 447
Reboiler area calculation, 376–379
Reboilers, 367–392, 485
  applications of boiling heat transfer equipment, 374, 375
Reboilers (*Cont.*):
  axial-flow reboilers, 383–392
    examples, 389–392
    limitations to heat-flux density, 388–389
    liquid single-phase region, 384–386
    saturated boiling region, 386–387
    verification of recirculation rate, 387–388
    vertical thermosiphon reboiler design, 383–384
  defined, 79
  forced-circulation reboilers, 367–368
  horizontal thermosiphon reboilers, 371, 372, 383
  internal reboilers, 374
  kettle reboilers, 371, 373–374, 376–383
    examples, 380–383
    heat balance, 376
    Kern's recommendations for maximum heat flux, 379
    maximum heat-flux density and film boiling, 379
    reboiler area calculation, 376–379
    shell sizing, 380
  thermal design of
    general aspects, 375–376
    kettle reboilers, 376–383
  vertical thermosiphon reboilers, 368–372
Recirculation rate, 387–388
Refinery hydrocrackers, 446
Reflashing, 305
Reflection coefficient, 396
Reflux, 485, 487
Reflux countercurrent condensers, 315
Reflux ratio, 487
Refractories, 415–419
Regulation, of steam flow, 324–327
Removable-bundle heat exchangers, 133–139
  externally-sealed floating-head, 139
  outside-packed floating-head, 137–138
  outside-packed lantern-ring, 139
  pull-through floating-head, 134–135
  split-ring floating-head, 135–137
  U-tube, 136–137
Residuum, 525
Resistance(s), 82–86
  controlling (*see* Controlling resistance)

Resistance(s) (*Cont.*):
effect of controlling, 352
example of, 85–86
fouling (*see* Fouling resistance(s))
to heat transmission, 84
individual heat transfer, 82–84
Reynolds number, 55
for plate heat exchangers, 267–268
shell-side, 164–166
Roberts, D. N., 354, 355
Rohsenow, W., 346
Rohsenow correlation, 346–347, 350–352
Roof, heat loss through, 74–75
Roughness, 59

S
Saturated boiling, 340
defined, 331
illustration of, 332
start of, 359–360
Saturated boiling region, 360, 386–387
Saturated nucleate boiling, suppression of, 361
Saturation curve, 385
SBR (styrene butadiene rubber), 262
Sealing strips, 169, 178
Segmental baffles, 117, 118
Semiannular flow, 353
Semiwelded plate heat exchangers, 265
Sensible heat, 275, 376
Series-parallel plate heat exchangers, 258–260
Serrated fins, 453
7–8 heat exchangers, 209
SH_2, 538
Shape factor, 26–27
Shear stress, in moving fluid, 35–37
Shell entrance or exit areas, 122
Shell number, 158
Shell passes, 158
Shell sizing, 380
Shell-and-tube condenser, 276
Shell-and-tube heat exchangers, 115–146
baffles in, 117–121
comparison of, 139, 140
components of, 116–117
design/construction of, 145–146
design/construction standards for, 115–116
fixed-tubesheet, 133
front heads in, 131–132
LMTD correction factors for, 495–500
multipass, 126–128
Shell-and-tube heat exchangers (*Cont.*):
with multiple shell passes, 128–131
nomenclature for, 116
overall heat transfer coefficients for, 527
plate heat exchangers vs., 265–266
removable-bundle, 133–139
specification sheet terminology, 144–145
TEMA Standards, 139, 141
tube failure regions, 143
tube vibration in, 140–144
tubes/tube distribution in, 122–124
tube-to-tubesheet joints in, 124–126
Shell-and-tube heat exchanger design, 147–214
convection film coefficient, 160
and cross-mixing hypothesis, 148–150
design parameters of, 157–159
design procedure in, 196–202
effectiveness of, 205–213
analysis of effectiveness graphs, 212–213
outlet temperature calculation, 205–210
physical interpretation, 210–211
physical interpretation of, 210–211
frictional pressure drop, 161–164
heat transfer coefficient and pressure drop at shell side, 164–193
accuracy of correlations, 187–193
Bell method, 173–186
computational techniques, 186–187
Kern method, 164–168
performance factors, 167–173
LMTD calculation in, 148–150
LMTD correction factors, 151–157
rating of existing units, 193–195
software design programs for, 202–204
techniques for, 147–148
Shell-side condensation:
horizontal condensers with, 295, 296, 299
vertical condensers with, 294–295, 299
Shell-side heat transfer coefficient, 164–168
Shell-side Reynolds number, 164–166
Shield tubes, 450, 462, 470
Shields, radiant, 425–426
Sieder, E., 56
Silicium, 452
Silicones, 262–263
Single cylinders in cross-flow, 64
Single phase, heat transfer coefficient for, 527
Single-component vapors condensation, 277–292
effect of vapor velocity on, 289–292
film condensation in turbulent flow, 288–289
filmwise condensation, 277–288
condensate-film thickness, 281
condensation heat transfer film coefficient, 278–279
condensation heat transfer coefficient, 282–283
example, 287–288
over horizontal tubes, 283, 286–287
over vertical surfaces, 283–286
velocity profile in descending film, 279–281
inside horizontal tubes, 289–290
inside vertical tubes, 290–291
outside tubes with high vapor velocities, 291–292
Single-component vapors condensers, 292–302
design of, 297–302
horizontal, 295–297
partial, 297
vertical, 294–296
Single-pass air coolers, 239
Single-phase convection, 332, 346
Single-phase liquid convection region, 358
6–12 heat exchangers, 500
Slug flow, 353
Small, W. M., 379
SO_2, 538
SO_3, 538
Software, 1–2, 202–204
Soils, conductivity of, 27
Solid fins, 453
Solids, conduction in (*see* Conduction, in solids)
Specific heat:
at constant pressure, 8, 9
at constant volume, 8
unit conversion for, 552
Specification sheet, 144–145
Spectral radiant energy distribution, 400–401
Spheres, 64, 68
Split-ring floating-head heat exchangers, 135–137, 140

Square tubes pattern, 158
Stable film boiling zone, 349
Stacks, in fired heaters, 455–457
Stage-air burners, 455, 456
Staggered arrays, 177
Stagnant point, 60, 63
Standards, design and construction, 115–116
(*See also specific standards;* e.g. API Standard(s))
Stanton number, 56
Stationary tubesheets, 133
Steady-state conduction, 26–28
Steady-state convection, 35
Steady-state systems, 5
Steam flow, regulation of, 324–327
Steam generators, 319
Steam heaters, 527
Steam systems, 318–327
effect of air in, 321
installations of, 319–321
regulation of steam flow in, 324–327
steam traps in, 321–324
Steam traps, 321–324
float-type trap, 322, 323
inverted-bucket steam trap, 322, 323
thermodynamic trap, 323–324
thermostatic Bellows trap, 321, 322
Steam-hydrocarbon reformer heaters, 447
Stephan, K., 348
Stephan and Abdesalam correlations, 348, 349
Stephan correlation, 350–352
Stratified flow, 289
Streams, physical properties of, 227
Structural moisture barriers, 30
Styrene, 535
Styrene butadiene rubber (SBR), 262
Subcooled boiling, 331, 332
Subcooled nucleate boiling, onset of, 358, 359
Subcooled nucleate boiling region, 358, 359
Sublaminar layer, 38
Submerged objects, forced convection around, 60–66
fluid flow over submerged bodies, 60–62
heat transfer coefficient, 62–66
Sun, temperature of, 401
Supercritical pressure, 366
Superheat correction factor, 334, 335
Suppression factor, 364, 365
Surface area, heat exchanger, 193

T
Taborek, J., 187, 378
Tanks, insulation of, 32
Tate, G., 56
Technical specifications, 145–146
TEMA (*see* Tubular Exchanger Manufacturers Association)
TEMA Standards, 115, 116, 139, 140
Temperature(s):
defined, 5
of insulation materials, 31
and internal energy, 5
of sun, 401
unit conversion for, 551
viscosity as function of, 161
Temperature control, 250–251
Temperature profile, 52
Temperature-profile distortion, 172–173
Temperatures difference, 237–240
(*See also* Mean temperature difference)
Tension-wrapped tube bundles, 231, 233
Theoretical tray, 489
Thermal boundary layer, 39, 40
Thermal conductivity:
defined, 10
of fin material, 224
unit conversion for, 553
Thermal conductivity units, 10
Thermal design, 145
Thermal diagrams, 89–91
Thermal energy, 5
Thermal equilibrium, 398
Thermal expansion coefficient, 67
Thermal insulation, 28–33
characteristics of, 28–29
factors affecting, 31
installation of, 31–32
materials for, 29–30
moisture barriers with, 30
rationale for using, 28
thickness of, 32–33
water permeability values for, 29
Thermal performance, 99–101
Thermal radiation (*see* Radiation)
Thermodynamic state, of system, 8
Thermodynamic traps, 323–324
Thermodynamics, first law of, 4
Thermosiphon reboilers:
horizontal, 371, 372, 383
thermal design of, 383–384
vertical, 368–372, 383–384
Thermosiphon steam generators, 375
Thermostatic Bellows traps, 321, 322
Three shell passes, 131
Three-pass cross-flow, both fluids unmixed, 503
3–6 heat exchangers, 497
Tie rods, 120, 121
Toluene, 534
Total absorption factor, 429–430
Total condensers, in distillation, 488, 489
Total emissivity, 429–430
T-Q diagram, 90, 91
Transition flux zone, 349
Transition regime, 56
Transmission coefficient, 396
Transparent media, radiation through, 395–426
absorption/reflection/transmission coefficients for, 396
blackbody emission distribution, 406–407
blackbody intensity of radiation and emissive power, 408–409
and cavity as blackbody, 398–399
directional emissive power, 407–408
electric analogy, 414
emission from surfaces, 401–402
enclosures with gray surfaces, 419–422
gray bodies, 402–404
heat transfer among three blackbodies, 414–415
heat transfer between blackbodies, 409–412
heat transfer between gray body and surrounding body, 422–424
insulating walls/refractories, 415–419
intensity of radiation, 404–406
and Kirchoff's law, 397–398
monochromatic absorption coefficient, 402–404
monochromatic emissive power, 399–400
monochromatic intensity of radiation, 406
radiant shields, 425–426
spectral radiant energy distribution for blackbody, 400–401
view-factor algebra, 413–414
Transversal baffles, 129
Transversal corrugations, 261
Trays, schematic of, 490
Triangular tube arrays, 158
Tube bundles:
in air coolers, 231–234
convection, 64–66
in reboilers, 378
Tube count tables, 505–508
1-in tubes on square array, pitch 1 in TEMA type S, 508
1-in tubes on square array, pitch 1.25 in TEMA type U, 508

Tube count tables (*Cont.*):
1-in tubes on triangular array, pitch 1.25 in TEMA type L, 507
3/4-in tubes on square array, pitch 1 in TEMA type S, 506
3/4-in tubes on square array, pitch 1 in TEMA type U, 507
3/4-in tubes on triangular array, pitch 1 in TEMA type L, 506
pass-partition arrangement diagrams, 505
Tube diameter:
selection of, 102, 104–105
in shell-and-tube heat exchanger design, 158
Tube dimensions (BWG standard), 529
Tube distribution patterns, 122–124
Tube layouts, 509–522
1-in tube distribution in 1.25-in square pattern
two-pass configuration, rear head type S, 519
two-pass configuration, rear head type U, 521
four-pass configuration, rear head type S, 520
four-pass configuration, rear head type U, 522
1-in tube distribution in 1.25-in triangular pattern
one-pass configuration, rear head type L, 516
two-pass configuration, rear head type L, 517
four-pass configuration, rear head type L, 518
3/4-in tube distribution in 1-in square pattern
two-pass configuration, rear head type S, 512
two-pass configuration, rear head type U, 514
four-pass configuration, rear head type S, 513
four-pass configuration, rear head type U, 515
3/4-in tube distribution in 1-in triangular pattern
one-pass configuration, rear head type L, 509
two-pass configuration, rear head type L, 510
four-pass configuration, rear head type L, 511
Tube length, 103, 159
Tube numbers, 103, 158–159
Tube passes, 158–159
Tube patterns:
illustration of, 166
in shell-and-tube heat exchangers, 122–124, 158, 171, 172
Tube pitch, 122–124
Tube rows, 177
Tube vibration, 140–144
corrective measures for, 144
damage from, 141, 142
failure regions with, 143–144
mechanisms of, 142
treatment of, 143–144
Tubes:
centrally mounted, 465
condensation outside, with high vapor velocities, 291–292
in fired heaters, 452–454
flow boiling in, 352–367
correlations, 358–367
flow-pattern characterization, 353–355
frictional pressure drop, 355–356
heat transfer mechanisms for boiling inside vertical tubes, 356–358
two-phase flow patterns, 352–354
forced convection inside, 44–60
dimensionless numbers, 55
empirical correlations, 56
equivalent diameter, 59–60
example, 58–59
film heat transfer coefficients, 55
fluid velocity distribution, 44–46
heat transfer from wall to fluid, 53
heat transfer coefficient, 53–54
influence of wall temperature, 55–56
j_H dimensionless factor, 56–58
local film heat transfer coefficient, 53–54
mean temperature difference, 54–55
nonisothermal flow, 49–52
pressure drop, 47–49
Stanton number, 56
temperature profile development, 52
impingement protection for, 122, 123
materials for, 122
in shell-and-tube heat exchangers, 122–124
Tubesheet clamping effect, 142
Tubesheets, 143, 453, 454
Tube-to-tubesheet joints, 124–126
Tube-wall dryout, 358
Tubular Exchanger Manufacturers Association (TEMA), 115, 173
Tubular heat exchangers, correction factors for, 177–178
Turbulent boundary layers, 37–39
Turbulent buffeting, 142, 144
Turbulent flow:
convection in, 35, 56
effect of baffle window on, 182
film condensation in, 288–289
in shell-side heat transfer, 181
2–4 heat exchangers:
LMTD correction factors for, 496
pressure drop in, 167, 168
temperatures evolution in, 130
with two shells, 156
Two-pass cross-flow, both fluids unmixed, 502
Two-pass heat exchangers, 127, 158–159
Two-phase flow patterns, 352–354
Two-phase force convection region, 358, 362
Two-phase (boiling-in-tubes) systems, 352–356
flow patterns, 352–354
flow-pattern characterization, 354–355
frictional pressure drop, 355–356
liquid and vapor volume fractions, 354
T-x diagram, 90

U
Undisturbed free stream, 37
Unit conversions, 551–553
area, 551
density, 551
energy, 552
force, 552
heat-flux density, 553
heat transfer coefficients, 553
length, 551
mass, 551
physical constants, 552
power-heat flux, 552
pressure, 552
specific heat, 552
temperature, 551
thermal conductivity, 553
viscosity, 553
volume, 551
Unit operations, 3
Unsupported spans, 120, 159
Utility streams, 79
U-tube bends, 143, 144, 453
U-tube heat exchangers, 136–137, 140

V
Vapor mixtures condensation, 309–318
  design, 315
  diffusional processes, 311–315
  example, 316–318
Vapor velocity, 289–292
Vapor volume fraction, 354
Vapors:
  condensation of (*see* Condensation)
  fouling resistances for, 524
Velocity boundary layer, 11
Velocity distribution (forced convection inside tubes), 44–46
Velocity heads, 457
Velocity profile, 279–281
Vertical condensers, 294–296, 299
Vertical cylindrical fired heaters, 448–450
Vertical plates:
  condensation over, 283–284
  natural convection on, 68
Vertical thermosiphon reboilers, 368–372, 383–384
Vertical tube bundles, 285–286
Vertical tubes:
  boiling heat transfer inside, 356–358
Vertical tubes (*Cont.*):
  condensation inside, 290–291, 299
  condensation over, 284–285
  natural convection in, 68
Vessels, insulation of, 32
Vibration, tube, 140–144
View factor, 410–412
View-factor algebra, 413–414
Visbreaker, 525
Viscosity, 56, 70, 161, 553
Viscous fluids, 447
Visible radiation, 395
Volume:
  measurement of, 8
  unit conversion for, 551
Von Karman turbulence, 142
Vortex shedding, 142–144

W
Wall temperatures:
  calculation of, 226
  influence of, on convection in tubes, 55–56
Wallis, G. B., 291
Wall-mounted burners, heaters with, 451–452
Walls:
  conduction through, 16–25
    cylindrical, 23–25
Walls, conduction through (*Cont.*):
    planar, 17–22
    two fluids separated by wall, 18–20
  natural-convection heat loss through insulated, 71–75
Washboard corrugations, 260, 261
Water:
  fouling resistances for, 523
  heat transfer coefficient for, 528
  pressure drop in, 107–109
Water permeability values, 29
Water vapor, emissivity of, 432, 433
Water-cooled condensers, 527
Water-treatment units, 319, 320
Weierman, C., 470, 472
Welded joints, 126
Welded plate heat exchangers, 265
White bodies, 396
Whitley, D. L., 187
Wien's displacement law, 401
Wispy annular flow, 353
Work, 4
Wrapped tube bundles, 233

Z
Z parameter, 243, 244
Zuber, N., 347, 349, 363
Zuber equation, 349