INDEX

A
Absorber. See Cooling, absorption
Absorptance, absorptivity, absorption (of light) 1286–1287
Absorption cooling. See Cooling, absorption
Accumulator, refrigerant 1301. See Receiver, refrigerant
Acid dew point of fuels 1249
Acid dew point, flue gas definition 122–123
in boiler air preheaters 128 in boiler economizers. See Economizers, boiler
Acid dew point, of fuels 123
Active solar systems. See Solar cooling; Solar heating, active
Adjustable-pulley drives. See Drives, variable-pulley
Adjustable-speed drives. See Drives, variable-speed
Adsorbent air filters 541
Affinity laws (pumps) 1340
Air cleaning. See Filters, air
to reduce ventilation requirements. See Ventilation, outside air: reduce, by air cleaning
Air conditioners
compressor heaters, turn off 770
compressors, install efficient 767
condensing temperature, optimize 768–769
efficiency ratings. See Efficiency ratings, cooling
electric heat, eliminate 761
electric heating elements, eliminate 771
fan motors, install efficient 756
heat recovery from 773–774
heat rejection equipment control to minimize operation 772
drain seasonally 770–771
heat sinks, install alternative 775–778
design issues 777
options in new construction 775–776
options in retrofit 776–777
where to consider 775
infiltration around, prevent 757
install efficient 759–760, 767
cost, relative 760
efficiency ratings 759
other features 760
size, relative 760
maintenance for self-contained units 754–756
for split systems 765–766
motors, install efficient 766
ventilation, eliminate inefficient 758
Air conditioning. See Cooling
Air ejectors in vacuum condensate systems 140
Air handling systems & building pressure. See Pressure, building
air cleaning, to reduce ventilation. See Ventilation, outside air: air cleaning, to reduce amount
dampers, control. See Dampers, control
dampers, infiltration. See Dampers, infiltration
dual-duct reheat. See Air handling systems, dual-duct reheat
dual-duct VAV. See Air handling systems, VAV dual-duct economizer cycle. See Economizer, outside air
energy waste by, causes 499–500
envelope penetrations, improve 563–567
exhaust recirculation 566
exploit ambient temperature 566–567
freeze protection 571–572
pollutant sources 563–565
problems related to 563
wind, shielding from 565
fans, relief air 533
arrangement 524
capacity of 533–534
from spaces 537
fans, return air 532–533
arrangement 524
capacity of 533–534
control of space pressure 532–533
fans, supply air
control of output. See Air handling systems, by type
pressure requirements of filters 545
filters. See Filters, air
freeze protection, minimize energy for 568–572
& building penetrations. See Air handling systems: envelope penetrations, improve by antifreeze in coils 568
by draining coils 568
by preheat coils 569–570
coil valve leakage 572
during system shutdown 571–572
of steam coils 568–569
stratification, avoid. See Air handling systems: stratification, avoid
front end & economizer cycle 536, 548
& stratification 575–576
configurations 522–524, 532–537
dampers, control 532–533
definition 498
improvement of 532–537
functions 497–498
heat recovery. See Heat recovery, from building exhaust air induction. See Air handling systems, induction
maintenance access for 536
minimizing operation. See Air handling systems, minimize operation
multizone. See Air handling systems, multizone
once-through. See also Air handling systems, by type
provide recirculation for 538–539
purge cycle. See Purge cycle, air handling system
return air path
corridor 538
ducted 538
plenum 538
through void 538
single-duct reheat. See Air handling systems, single-duct reheat
single-duct VAV. See Air handling systems, VAV single-duct
single-zone. See Air handling systems, single-zone
stratification, avoid 536, 573–578
by damper arrangement 576
by damper turbulence 576
by duct configuration 575–576
by fan mixing 574–575
by mixing vanes 576–577
by preheat coils 575
how to minimize 574–578
how to visualize 574
problems caused by 573
thermostat installation 574
triangle-duct. See Air handling systems, triple-duct
types of air handling systems 498
VAV dual-duct. See Air handling systems, VAV dual-duct
VAV single-duct. See Air handling systems, VAV single-duct
ventilation by. See Ventilation, outside air
Air handling systems, dual-duct
reheat
coils, turn off to avoid reheat 643
& duct temperature reset 643
energy saving 643
when to do 643
comfort characteristics 637
convert to multi-speed fan 644
convert to VAV 644–650. See also
Air handling systems, VAV dual-duct
air circulation in space 648
building pressure control 650
conversion steps 646–650
diffuser performance 648
duct layout 649–650
duct temperature reset 649
economizer cycle 650
energy saving 645–646
fan modulation control 649
fan modulation methods 649
fan-induced resonances 650
isolation of unoccupied spaces 650
minimum-flow settings 648
purge cycle 650
space temperature deadband 648–649
space temperature setback 648
space warm-up 648
terminal conversion kits 647
terminals, reduce resistance 647–648
ventilation, outside air 649
description 637
duct temperatures, optimize 640–641
by automatic reset 642
cooling coils without valves 641
energy saving 640
how to adjust 640–641
humidity, effect on 640
load diversity limitations 640
placards 641
economizer cycle limitations 548–550
energy consumption 638–639
fan output, trim 644
humidity control 637
reheat
Air handling systems, induction
avoid discharge on surfaces 699
description 691–692
maintenance 698–699
primary air temperature, maximize 693–694
by automatic reset 694
energy saving 693
terminal condensate drainage 693
space temperature setback, install 696–698
energy saving 696
how to install 696–697
overrides 697
placards 697
where to apply 696
turn off air handling unit coil & primary air reset 695
energy saving 695
Air handling systems, minimize
operation
automatic control, prefer 506
by administrative staff 515
by annunciator panel 516
by clock control 507–508
how to select controls 507
override by occupants 508
where to consider 507
by optimum-start control 509–510
& control of other equipment 510
equipment options 509
how it works 509
outside air sensor, how to install 509
vs. setback temperature control 510
by personnel sensor 513–514
limitations 513
placards for 514
tailoring to space 513–514
types of sensors 513
by rundown timer 511–512
advantages 511
limitations 511–512
placards for 512
types of time switches 512
where to install 511
energy saving 506
override by occupants 506
temperature limits 506
vs. temperature setback 507
Air handling systems, multizone
coils, turn off seasonally 654
comfort characteristics 651–652
convert to multi-speed motor 655
convert to VAV 656–659
air flow, minimum settings 658
conversion steps 656–659
dampers, control of 657
dampers, how to modify 657
deck temperature reset 658
diffuser performance 658
economizer cycle 658
energy saving 656
fan modulation, control of 657–658
fan modulation methods 657
fan-induced resonances 658
humidity control 658
isolation of individual zones 658
purge cycle 658
retrofit difficulty 656
space air velocity 658
ventilation, outside air 658
zone layout 658
zone pressure variations 658
zone temperature deadband 658
zone temperature setback 658
damperless 653
deck temperatures, optimize 654
by automatic reset 654
description 651–653
economizer cycle limitations 548–550
fan output, trim 655
humidity control 651–652
reheat energy waste 651
three-deck 652–653
Air handling systems, single-duct
reheat
air blending terminals, block reheat
passage 614–615
energy saving 614–615
how to accomplish 615
limitations 614
where to consider 614
chilled air temperature, set to
minimize reheat 607–609
by automatic reset 610–611
energy saving 607–608
how to maximize 608
humidity, effect on 608
load diversity, limitation by 608
comfort advantages 606
convert to heating/cooling terminals
631–633
advantages 631
coops, how to install 632
control of space pressure 631
controls 633
cost 631
dehumidification at low load 633
disadvantages 631
energy saving 631
fan modulation 633
installation difficulty 631
isolation of unoccupied spaces 632
noise 631
outside air ventilation 631
piping 632
space air circulation 631
space requirement 631
vs. VAV 631
where to consider 631–632
zoning 632
convert to multi-speed motor 616–617
energy saving 616
motor, how to select 616
problems at low air flow 617
resonances, how to avoid 617
speed, how to control 616–617
vs. fan-coil units 631
vs. VAV 631
convert to room heating/cooling
units 634–635
advantages 634
disadvantages 634
energy saving 634
vs. VAV 634
convert to VAV 618–630. See also
Air handling systems, VAV
single-duct
chilled air temperature reset 628
control & adjustments 627–629
conversion steps 621
design challenges 619–621
diffuser performance 620, 626–627
duct layout 629
duct pressure reset 628–629
economizer cycle 629
energy saving 618–619
economizer cycle control 549
fan output, trim 615
fan output, VAV. See also Air
handling systems, VAV single-
duct
humidity, control of 606
reheat energy waste 605–606
turn off cooling coil to avoid reheat
612
energy saving 612
limitations 612
turn off reheat coils to avoid reheat
613
control changes required 613
energy saving 613
limitations 613
Air handling systems, single-zone
controls, placards for
energy saving 581
how to design 581–582
where to install 582
controls, temperature deadband
by adjusting valve actuators 603–604
by deadband thermostat 600–602
by manual heat/cool switching 597–599
by signal offset relay 603–604
deadband range 596
dehumidification, providing 596–597
energy saving 596
methods 596
thermostats, deadband 600–601
thermostats, heat/cool switching 597–598
thermostats, hesitation 601
controls, temperature setback 583–584
avoid forcing setback 584
energy saving 583
how to accomplish 583–584
override 584
placards 584
description 579
economizer cycle control 549
fan output, cycling 588–590
& deadband 590
energy saving 588–589
limitations 589–590
short cycling, avoiding 590
soft starting 590
where to consider 588
fan output, match to load 585–587
energy saving 585
factors to consider 585–587
methods 585
fan output, multi-speed motor 591–592
electric heating coils, with 592
energy saving 591
fan speed ratio 591
how to control 591–592
motor selection 591
placards 592
resonances, avoiding 592
fan output, trim 588
fan output, VAV 593–595
air distribution in space 594
building pressure control 594
controls 594
Air handling systems, triple-duct 639, 682

Air handling systems, VAV dual-duct air circulation in space 648
damper overlap, minimize 685
design steps 690
diffuser performance 648
duct layout 649–650
duct temperature reset 649
economizer cycle 650
economizer cycle, install 689–690
design steps 690
energy saving 689
ventilation, outside air 689–690
vs. waterside economizer 690
where to apply 689
energy saving 645–646
fan modulation control 649
fan modulation methods 649
fan modulation, optimize 688
humidity control 649
isolation of unoccupied spaces 650
maximize deadband 683–684
minimum-flow settings 648
optimize duct temperatures 687
by automatic reset 688
placards, thermostat 683
purge cycle 650
space temperature deadband 648–649
space temperature setback 648
space warm-up 648
temperature setback, install 684
terminals, how to select 647
turn off coils when practical 684
ventilation, outside air 649
zoning 649
Air handling systems, VAV single-duct 618–630
changeover control. See Air handling systems, VAV single-duct: terminals, heating/cooling changeover, install
thermostat deadband 676
thermostat operation 676
with electric heating coils 675–676
terminals, how to select 622–624
terminals, reduce minimum flow 670–671
energy saving 670
how to adjust 671
limitations 670–671
thermostats, install deadband 664–666
deadbond range 664
energy saving 664–665
humidity, effect on 664
placards 665
thermostat placards 668
types of deadband thermostats 665, 667–668
ventilation, effect on 664
where to apply 664
thermostats, install setback 667–668
energy saving 667
limitations 667
methods 667
overrides 668
turn off cooling coils 669
ventilation, outside air & front end design 620
& reheat 619–620
control 629
uneven distribution to spaces 620
with shutoff terminals 620
zoning for efficiency 629
Air pollution
& air-fuel ratio 60–61
flue sensors 48–49, 54
Air preheaters, boiler 126–128. See also Economizers, boiler
acid condensation in 128
cleaning requirements 128
draft requirements 128
energy savings 126–127
types of preheaters 127–128
heat pipe 127–128
parallel-plate 127
rotary 127
tubular 127
where to install 126–127
Air-cooled condensers. See also Heat rejection equipment
definition 1302
Air-cooled condensing units
definition 1302
Air-fuel ratio 59
& boiler maintenance 69–70, 111
& burner maintenance 73
& burner type 79
& flue draft 64
adjusting 60–64
atmospheric gas burners 62–63
basic procedures 61, 62–64
excess air 62
how often 64
linkages 69–70
modulating burners 63–64
automatic controls 65–69
actuators 66, 68, 69–70, 70
adaptability to load 68
adaptability to multiple fuels 68
alarms 66, 68
calibration 67–68, 70
components of 66
control response 68
data logging 68
displays 66, 68
energy savings 65
fail-safe features 68
how to select 66–69
installation 66
overrides 68
reliability 66
sensor types 67
what they sense 66–67
where to use 65–66
efficiency, effect on 60
optimum 60
problems related to 60–61, 61

Ammonia
in absorption cooling 1325
in cooling storage systems 420
superheat 387

Analog controls. See Controls, characteristics of

ANSI ballast codes 1075

Antarctic Circle 1285

Anticipators, thermostat
adjust to minimize standby losses 804
description 1379

Antifreeze
in hydronic systems 568

Arc, in lighting
definition 1459
in fluorescent lighting 1459–1460
in HID lighting 1471

Arc lighting. See Lighting, arc

Arctic Circle 1285

Argon
in fluorescent lamps 1461–1464
in high-pressure sodium lamps 1478
in incandescent lamps 1451
in low-pressure sodium lamps 1479
in mercury vapor lamps 1475
in metal halide lamps 1476

ASHRAE Standard 62-89 (ventilation) 522, 528, 529, 530

ASHRAE Standard 90. See Efficiency codes, laws & standards

Astragal 810

Astronomical timeclocks 1100–1101, 1200–1201

Attic insulation. See Insulation, for attics

Attic ventilation. See Ventilation, of attics

Awnings 920–921

Azeotropes 1335

Azimuth, how to determine 927
B

Back check 811
BACnet 1226
Baffle plate 577–578
Bagasse  
  fuel properties of 1247
Balconies, for shading 919
Ballast efficiency factor (BEF) 1061
Ballast factor 1060–1061
Ballasts, lighting. See Lighting, fluorescent; Lighting, high intensity discharge
Barometric dampers. See Draft, combustion: draft regulators
Baseboard radiators. See Radiators
Bellows traps. See Steam traps
Betz Coefficient (wind energy) 1275
Biomass combustion 1281–1282  
  applications 1281, 1281–1282  
  availability 1281  
  economics 1281  
  energy content 1281  
  environmental issues 1281–1282  
  equipment 1281  
  safety issues 1281
Bipolar junction transistor 1355
Black body 955
Bleed, cooling tower. See Water treatment, cooling water
Blinds, window. See Daylighting; Shading, to reduce cooling load
Blowdown, boiler 148  
  & total dissolved solids (TDS) 148–149  
  automatic controls for 157–158  
  bottom blow 154–155  
  definition 141, 153  
  effects of improper control 153–154  
  energy wasted by 155  
  hazards 155  
  heat recovery from. See Heat recovery: from blowdown  
  how to calculate rate 155  
  optimum control 153–156  
    of bottom blow 156  
    of top blow 155–156  
    surface blow 154–155  
    top blow 154–155  
  when shutting down boiler 118
Blower doors 1384–1385
Boiler capacity ratings 1294–1295

Boiler efficiency testing 43  
  assumptions involved 46–47  
  definition 44  
  errors 46–47  
    from extraneous air 51, 51–52  
    from sensing wrong gases 52  
    from steam leaks 52  
    from unburned fuel 48  
    in equipment 48, 49–51  
    flame appearance 48  
    how it works 46–47  
    how often to repeat 53  
  how to do 45–46, 51–52  
    load conditions 52  
    preparing the boiler 52–53  
    with air preheaters 52  
    with economizers 52  
    with flue gas recirculation 52  
  limitations 44–45, 46–47  
  reasons for 43, 44  
  test equipment  
    air casing pressure gauges 55  
    BTU meters 55  
    calibration 57  
    chemical 49, 50  
    digital 56  
    displays 55–56  
    electronic 49–51  
    for carbon dioxide 48, 49–50  
    for carbon monoxide 50–51  
    for oxygen 49–50  
    for smoke density 50–51  
    fuel flowmeters 54–55  
    fuel pressure gauges 55  
    fuel quantity indicators 55  
    Fyrite 49  
    how to select 49–51  
    install permanent 54–56  
    Orsat analyzer 49  
    pollutant sensors 54  
    recorders 55–56  
    smoke opacity sensors 54  
    steam meters 55  
    thermometers, flue gas 51, 54  
    thermometers, fuel oil 55  
  test for boiler defects 48  
  test for carbon dioxide  
    how to do 45–46  
    test for carbon monoxide 48  
    test for incomplete combustion 48  
    test for oxygen  
      check with carbon dioxide test 47–48  
      how to do 45–46  
      why better than carbon dioxide test 47  
  test for smoke opacity 48  
  test for specific pollutants 48–49  
  training for 58
Boiler feedwater systems  
  components 140–141  
  deaerating tank  
    for oxygen removal 141, 144, 146  
    functions 140–141  
    in feedwater system 146  
  for steam turbines 141  
  functions 137  
  pump characteristics 1342, 1344
Boiler horsepower (definition) 1294–1295
Boiler loading, optimum 34–37  
  automatic controls for 38–39  
    how to select 39  
    other functions 39  
    programming 39  
    where to consider 38  
  energy saving 34–35  
  how to calculate 35  
  start-stop sequence 35–37
Boiler plant layout  
  cross connect boiler plants 233–235  
    benefits 233  
    boiler sequencing 234  
    capacity, overall increase 234  
    compatibility of the plants 233  
    condensate return 234  
    disadvantages 233  
    feasibility factors 235  
    piping costs 234  
    pumping costs 234  
    reliability improvement 234  
    install lead boiler 226–229  
      cost 227  
      energy saving 226  
      feasibility factors 228  
    install local heaters to allow shut-down 230–231  
    feasibility factors 230–231  
    install local high-pressure boilers 232  
    overhead costs, effect on 228
Boiler plant maintenance  
  air preheaters 128  
  air-fuel ratio controls 69–70  
  blowdown. See Blowdown, boiler  
  boiler leaks 185  
  burners. See Burner systems, fuel
fireside cleaning
& air-fuel ratio 111
how often 110
how to minimize fouling 111
how to monitor fouling 110
methods of cleaning 111
turbulators, interference from 135
types of fouling 110
when to clean 111
leakage, monitoring 182, 183–184
leakage, repair 183–186
how to find leaks 184–186
how to repair joints 185–186
savings from 183
soot blowing. See Soot blowers
water treatment. See Water treatment.
boiler water
waterside cleaning 116–117
& water treatment 117
how to minimize fouling 117
methods 116–117
types of fouling 116
when to clean 116
when shutting down boiler 118
Boiler plant, minimize operation 20–21
auxiliary equipment 21, 31–32
control conditions 32
energy saving 32
interlock with boilers 33
spare pumps 34
by annunciator panel 27
by clock control 22
by optimum-start control 23–24
description 23
how to install 24
low-temperature protection 23–24
methods 24
where to use 23
by outside air temperature 25–26
energy savings 25–26
how to install 26
where to use 25
coordinate with cooling controls 21
energy saving 20
in cross connected plants 234
minimum shutdown intervals 20–21
placards 21
where to control 20
Boiler steam pressure, minimize 40–42
benefits 40
hazards 41
install local high-pressure boilers 232
limitations 41
staffing reduction 40, 41–42
steam metering error 41
Boilers
air preheaters. See Air preheaters, boiler
air-fuel ratio. See Air-fuel ratio
auxiliary equipment. See Boiler auxiliary equipment: boiler
plant equipment management: auxiliary equipment
burners. See Burners, fuel
cast iron sectional 1293–1294
& water treatment 145
coil boilers 1293
combustion chamber. See Burner systems, fuel
condensate. See Condensate systems
condensing 1294
draft. See Draft, combustion economizers. See Economizers, boiler; economizers, boiler
efficiency characteristics 34–35
efficiency testing. See Boiler efficiency testing
electric 1294
fans. See Burners, fuel
feedwater. See Boiler feedwater systems
firetube 1289
construction 1289
mud drums 154
pressure limitations 1289
fluidized bed 86, 1250
for superheated steam 1291
fuel selection. See Fuel selection, boilers
lead boiler. See Boiler plant layout: install lead boiler
leaks in 185
maintenance. See Boiler plant maintenance
effect of fuel choice 1250
operation. See Boiler plant equipment management
soot blowers. See Soot blowers
standby losses. See Standby losses, combustion equipment
turbulators for. See Turbulators, for firetube boilers
types of boilers 1289–1295
water treatment. See Water treatment, boiler water
watertube 1289
construction 1289–1293
steam drum 1293
water circulation 1291–1293
Brighton. See Lighting, design issues
BTU meters. See Heat meters
Bucket traps. See Steam traps
Buffer gas. See Lighting, fluorescent
Burner systems, fuel 71
air-fuel ratio. See Air-fuel ratio
characteristics 78–80
air pollution 79
auxiliary energy requirement 79
combustion chamber insulation 79
cost 80
draft requirements 79
efficiency 78
excess air requirement 78
flame pattern 78, 86–87
maintenance requirements 79–80
multi-fuel capability 80
standby losses 79. See also
Standby losses, combustion equipment
turndown ratio 79
combustion chamber, matching 79, 86–87
efficiency
& modulation 35
fan drive, install variable-output 90–92
efficiency
energy saving 90–91
how to install 91–92
how to select 91
where to consider 90
firing rate, reduce 75
flame appearance 48
install efficient 78–88
maintenance 72–74
motors 89
multi-fuel 80, 85
oxygen trim systems. See Air-fuel ratio
pilot flame, upgrade to electrical 89
problem diagnosis 73
problems related to 60–61, 73
air casing leakage 74
air pollution 60–61
clogged burner 73
dirty burner 73
efficiency loss 73
explosion hazard 61
fireside fouling 61
flare instability 61, 73
incomplete combustion 61
linkages loose 73
refractory damage 73, 86–87
smoke 73
soot in boiler 73
vibration 73
recirculation of flue gas 79
types of burners 81–86
cast iron boilers
flame retention 79
fluidized bed 86
gas, atmospheric 81–83
gas, power, modulating 83
gas, power, single-stage 83
gas, power, staged 83
air, atomizing 84
oil, pressure-atomizing, modulating 83–84
oil, pressure-atomizing, multi-stage 83
oil, pressure-atomizing, single-stage 83
oil, rotary cup 84–85
oil, steam-atomizing 84
retention head 79
stoker 85–86
whether to upgrade 87–88

C

Calcium, in boiler water 144, 145–146
Candela (definition) 1423–1424. See Lighting, measurements
Candlepower (definition) 1423–1424. See Lighting, measurements
Capacitors, power factor correction problems with VFD’s 1366, 1369–1370
Capillary tube refrigerant distributors 1318
Carbon dioxide test, combustion. See Boiler efficiency testing
Carbon monoxide sensors for. See Air-fuel ratio: automatic controls
Carbon tax 1250
Carnot efficiency for cooling 1302–1303
Carryover, in boilers. See Water treatment, boiler water
Cast iron boilers. See Boilers: cast iron sectional
Catalysts in fuel oil 178
Ceiling, suspended. See Insulation, for suspended ceiling

Cellulose insulation. See Insulation, types: cellulose
Certification. See Efficiency codes, laws & standards
Certified Ballast Manufacturers (CBM) 1063
CFC refrigerants. See Refrigerants
Changeover, heating/cooling. See Air handling systems, VAV single-duct: terminals, heating/cooling changeover, install
Chelants, in boiler water 146–148
Chilled water pumping. See Pumps, centrifugal: throttling output
Chilled water pumping. See Pumping, variable-flow, chilled water
Chilled water temperature, maximize 264–265, 265
by manual reset 265
compromise with fan power 264
compromise with pump power 264
potential for 264
when turning off CHW pumps 259
Chiller load, how to measure 242
Chiller loading, optimize 240–242
243–244
absorption/compression systems for modulating chillers 241
for multi-stage chillers 240
for single-stage chillers 240
how to measure load 242
load setting methods 241
with energy management system 243
with scheduling controller 243–244
how to select 243
where to consider 243
Chillers. See Cooling, by type
Chimney effect
avoiding air leakage from. See Section 6
cause of boiler draft problem 100–101
explanation of 1383–1385
in elevator shafts 872
Chlorine
in ozone depletion 1335–1336
in refrigerants. See Refrigerants
Chlorofluorocarbon refrigerants. See Refrigerants
Chromacity 1442–1443
CIE Chromacity 1442–1443
Clean Air Act
& refrigerants 1333
Clearance volume definition 1305–1306
in reciprocating compressors 1309

Clerestory windows
light shelves for 1005
Clock controls 1199–1204
astronomical 1200–1201
backup features 1202
cycle timers 1200
ease of use 1202
electrical features 1201
for air handling systems. See Air handling systems, minimize operation
for boiler plant. See Boiler plant, minimize operation
for heating & cooling units. See Heating & cooling units, minimize operation
for hot water recirculation 493–494
for lighting 1098–1099
astronomical controls 1100–1101
with photocontrols, exterior lighting 1102
with photocontrols, interior lighting 1105
installation 1204
optimum-start 1201
output signals 1201
overrides 1203–1204
physical features 1202
programmable thermostats 1202
scheduling features 1199–1201
Closed-loop controls 1381
Coal
environmental protection costs 1250
fuel properties of 1247–1249
Coanda effect 594
in air diffusers 626–627
Coefficient of performance. See Efficiency ratings, cooling. See type of equipment
Cogeneration 1329–1330
Cogging (variable-frequency drives) 1364
Coil boilers. See Boilers: coil boilers
Coils, heating & cooling control valves
in variable-flow systems 323
control valves, bypass 255–257
how to eliminate 257
Color
definition 1434
exterior surfaces, to reduce heat gain. See Shading, to reduce cooling load: by surface finish
interior surfaces. See Lighting, reflective space surfaces
interior surfaces, to enhance day-lighting 996–998, 1006
interior surfaces, to reduce lighting power 1116–1118
& fixture layout 1116
diffuse or specular? 1117–1118
energy saving 1116
esthetics 1117
of lamp light. See Lighting, by type; Lighting, design issues: lamp characteristics

Color printing 1434
Color rendering. See Lighting, design issues
Color rendering index (CRI) definition 1441
of lamp types. See Lighting, by type
Color television 1434
Color temperature (lamps). See Lighting, design issues: lamp characteristics
of lamp types. See Lighting, by type

Color vision. See Vision, human: color

Combustion efficiency test. See Boiler efficiency testing

Commodity charges, electricity 1253
Commutation, in variable-frequency drives 1355
Commutator (DC motor) 1370–1371
Compact fluorescent lamps. See lighting, fluorescent: compact fluorescent units

Compression ratio, cooling compressors
efficiency, effect on 1306
fixed vs. variable 1306

Compressor drivers 1315–1317
diesel engines 1317
electric motors 1315–1316
efficiency 1316–1317
hermetic 1315–1316
internal vs. external 1315–1316
open drive 1315–1316
semi-hermetic 1315
gas turbines 1317
how to select 1317
natural gas engines 1317
steam turbines 1317

Compressors, cooling, centrifugal 1307–1309
efficiency 1307–1309
false loading 1308
hot gas bypass 1308
impellers
diameter 1309
gear-driven 1309
number of 1309
speed 1309
in lead chillers 358
output modulation 1306, 1308–1309
condensing temperature, effect on 386
inlet guide vanes 1308
operating temperature limitations 1309
variable-speed drive 335–336, 1308–1309
with multiple compressors 1308
retrofit variable-speed drive 335–336
energy saving 335–336
limitations 335–336
potential chiller damage 336
surge limitations 1308

Compressors, cooling, in general
energy saving 335–336
limitations 335–336
potential chiller damage 336
surge limitations 1308

Compressors, cooling, reciprocating 1309–1315
efficiency 1309–1310
in lead chillers 358
output modulation 1306, 1310–1315
suction cutoff 1310
unloading cylinders 1310
variable-speed drive 1310
with multiple compressors 1310

Compressors, cooling, screw 1310–1313
efficiency 1309–1315
in lead chillers 358
output modulation 1306, 1310–1315
suction cutoff 1310
unloading cylinders 1310
variable-speed drive 1310
with multiple compressors 1310

Condensers, cooling system
air-cooled condenser 1302
auxiliary. See Heat recovery, from cooling equipment: by auxiliary or double-bundle condenser
cleaning air-cooled condensers 754, 765
cleaning water surfaces. See Condenser waterside cleaning condensate subcooling 1321
double-bundle. See Heat recovery, from cooling equipment: by auxiliary or double-bundle condenser
evaporative condensers 1302
heat transfer design 1320
fouling factor 1320–1321
methods of limiting cooling 269–270
temperature limits, minimum 268–269
temperature, optimize. See Condensing temperature, optimize

Condensing boilers. See Boilers: condensing
Condensing furnaces. See Direct-fired heating units

by automatic reset 272–273
control options 272
how to program 272
by manual reset 270–271
cautions 267–268
control accuracy 270
energy saving 268
how to calculate 269
in chiller heat recovery. See Heat recovery, from cooling equipment in lead chillers 358
in split systems 768–769
minimum temperature limits 268–269
with heat recovery storage 403

Conduction, of heat. See Heat, in general: how heat moves

Cone cells (vision) 1429, 1434

Control of equipment operation
for air conditioners. See Heating & cooling units, minimize operation for air handling systems. See Air handling systems, minimize operation

for boiler plants. See Boiler plant, minimize operation

for cooling plant. See Cooling plant, minimize operation

for direct-fired heating units. See Heating & cooling units, minimize operation

for furnaces. See Heating & cooling units, minimize operation

for heat pumps. See Heating & cooling units, minimize operation for heating & cooling units. See Heating & cooling units, minimize operation for lighting. See Lighting, control of for radiators. See Heating & cooling units, minimize operation for unit heaters. See Heating & cooling units, minimize operation for water heating. See Water heating for water pumping. See Pumping, service water pressure; Pumping, service water recirculation

Control signal polling 1227
signal discriminators 1227
using energy management computer for 1227

Controls, characteristics of 1377–1381

analog 1377, 1381
analog-to-digital converter 1377
anticipators 1379
automatic reset 1379–1380
closed-loop 1381
differential 1378
digital 1377, 1381
direct-acting 1377–1378
drift 1379
droop 1379
electric 1377
feedback 1381
fiber optic 1377
heat/cold changeover. See Air handling systems, VAV single-duct: terminals, heating/cooling changeover, install
hysteresis 1379
infrared 1377
offset 1379
on-off 1377, 1378–1379
open-loop 1381
pneumatic 1377
proportional 1377, 1379–1380
proportional-integral (PI) 1379–1380
proportional-integral-derivative (PID) 1380
reverse-acting 1377–1378
sensitivity 1378
setpoints 1377
signal offset relays 603
stability 1378, 1379
staged 1378
two-position 1378–1379

Convection
definition 1388

Convectors. See also Radiators (Same Measures apply.)
definition 719

Cooling, absorption 1323–1330
comparison with compression cooling 1329
components of 1323–1325
absorber 1323–1324
ammonia 1325
concentrator 1324
condenser 1324
corrosion inhibitors 1325
distiller 1324
economizer 1327–1328
evaporator 1323
float valve 1325
generator 1324
heat exchanger 1324–1325
lithium bromide 1325
orifice 1325
purge unit 1325
refrigerant pump 1325
solution pump 1325
crystallization 1326–1327
direct-fired 1326
efficiency 1325–1326. See also Efficiency ratings, cooling chilled water temperature, effect of 1327
condenser temperature, effect of 1327
economizer 1327–1328
effect of fuel heat value 1297–1298
number of stages, effect of 1325–1326
part-load 1327–1328
salt concentration, effect of 1327–1328
externally fired 1326
heat recovery from 387
heating capability 1328–1329
how it works 1323
in cogeneration systems 1329–1330
in combination systems 1329–1330
lead chiller, unsuitable as 358
number of stages 1325–1326
operating temperatures
capacity, effect on 1328
efficiency, effect on 1327
number of stages 1325
two-stage 1325–1326

Cooling, compression 1299–1321
components of system 1300–1301
accumulator 1301
compressor 1300. See also Compressors, cooling, by type
condenser 1300–1301. See also
Condensers, cooling system

crankcase heater 1301
evaporator 1300. See also
Evaporators, cooling system

expansion valve 1301
float valve 1301
purge unit 1301
receiver 1301
refrigerant metering device 1301
turbine, energy recovery 1301
efficiency. See also Efficiency
ratings, cooling
Carnot efficiency 1302–1303
compressors, effect on 1303
maximum theoretical 1302–1303
operating temperatures, effect of
1302–1303
refrigerants, effect on 1303
how it works 1299–1300
operating temperatures
capacity, effect on 1304
chilled water, optimum. See
Chilled water temperature,
maximize
condensing, minimum 268–
269, 1306
condensing, optimum. See
Chilled water temperature,
maximize
efficiency, effect on 1302–1303
factors that determine 1303–1304
refrigerants for 1300, 1331–1338
system layouts 1302
air-cooled condensing unit 1302
direct expansion 1302
hydronic 1302
split system 1302

Cooling cycle, definition 1299

Cooling plant layout
cross connect chiller plants 364–366
improve overall capacity 365
improve overall reliability 365
optimize overall control 365
piping design issues 364–365
reduce overall operating cost 365
efficient equipment sizing 357–360
auxiliary equipment load, mini-
mize 359
energy waste related to 355–356
how to select chiller size 358–
359, 359
install local cooling units to allow
shutdown 361–363
appearance 362
condenser cooling 362
cost saving 362
efficient control 362
electrical power for 362
energy saving 361–362
how to distribute 362
how to select local units 362
installation issues 362
noise 362
relative efficiencies 361–362
space requirements 362

Cooling plant, minimize operation 245, 246, 247–248, 249, 250
by annunciator panel 250
by clock control 249
by optimum-start control 249
by outside air temperature or
enthalpy 247–248
how to install sensor 247–248
where to consider 247
whether to use temperature or
enthalpy 247
by sensing cooling load 246
energy saving 245
heat rejection equipment. See Heat
rejection equipment, minimize
operation
pumps, chilled water 253–259
dangers 254
energy saving 253–254
how to control 256–257
how to eliminate bypass valves 257
isolate idle evaporators 257–258
use temperature reset 259
where to consider 253–254
with cooling coil bypass valves 255–257
with return water temperature
control 258
with system bypass valve 254–
257
pumps, spare 260
sump heaters, compressor 261
vs. local cooling unit control 245

Cooling, solar. See Solar cooling

Cooling system leakage
how to find refrigerant leaks 340–
341
by pressurizing system 352
dyes in oil 340
halocarbon torch 340
ionization detector 340
odor 340
soap bubbles 340
visible corrosion 340
preventing air leakage into idle
chillers 352–353
by inert gas pressurization 352
by warming refrigerant 352
preventing water leakage into idle
chillers 354
symptoms of leakage 340
types of leaks
air entry into system 338–339
loss of refrigerant 338
water entry into system 339
water vapor entry into system
338–339
where leaks occur 339–340

Cooling systems. See Cooling,
absorption; cooling, compression

Cooling tower, direct cooling with
by strainer cycle
system cleaning 279

Cooling towers. See also Heat
rejection equipment
COP (coefficient of
performance). See Efficiency
ratings, cooling
Correlated color temperature
(lamps)
definition 1441–1443

Cove lighting 1116, 1132, 1136–
1138

Crankcase heaters, compressor. See
Sump heaters, compressor

Crest factor 1061–1062, 1075

Crystallization, in absorption cooling
1326–1327

CSI (current source inverter)
drives. See Drives, variable-
frequency

Current source inverter (CSI)
drives. See Drives, variable-
frequency

CW/CWA ballasts, for HID lighting
1474–1475

Cycle timers 1200

Cycloconverter 1355
Damperless multizone systems  653

Dampers
boiler draft regulating. See Draft, combustion: draft regulators flue. See Flue dampers, automatic for air handling systems. See Dampers, control in burner systems. See Burner systems, fuel in heat rejection equipment  296

Dampers, control  532–533 & freeze protection  571 & stratification  576 arrangements in air handling systems  498, 522–524, 523–524, 532–533 control accuracy  533 energy waste by  524, 533, 548 leakage  533, 548 need for tight closing  534

Dampers, infiltration  533, 534

Darlington transistor  1355

Daylighting, by light pipes  966–978. See also Daylighting, design issues advantages  966–967 diffusion, need for  970–971 disadvantages  966–967 electric lighting, compatible types  976 electric lighting, control of  975–976 energy saving  967 glare  971 heat loss  971–973 layout  969–970 materials  973 water leakage, preventing  975 where to use  966–967


Daylighting, by window diffusers  994–999. See also Daylighting, design issues & solar heat gain  998–999 condensation, avoiding  998 diffuser materials  995–996 energy saving  994 glare, avoiding  994–995 how to install  995–996 insulation value, exploiting  998 view, effect on  999 where to consider  994

Daylighting, design issues  1405–1413. See also Lighting, design issues; Solar heating, passive: design issues; Sunlight, characteristics avoiding visual desensitization  1410 brightness variations  1410 climate  1412 cooling load  1412 electric lighting. See also Section 9 circuit layout  1107 control issues  1410–1412 dimming, fluorescent  1066–1068 dimming, HID  1079–1080 lamp types  1410 energy available in sunlight  914 glare  1406 glazing area  950, 1412 glazing insulation value  1412–1413 glazing treatments  1412 intensity  1406 light pipes  1412–1413. See also Daylighting, by light pipes needed technology  1412–1413 passive solar heating effect  1412–1413 penetration  1405, 1406–1410 problems  1405–1406 reflective interior, exploiting  1006 sunlight, characteristics  1283–1287 tree shading, effect of  961 veiling reflections  1406 visual quality  1406

Deadband
in air handling systems. See Air handling systems, by type thermostats. See Thermostats: deadband
Deaerating feedwater tanks. See Boiler feedwater systems

Deballasting. See Lighting efficiency improvements, fluorescent; lamps & ballasts, remove excess

Dehumidifiers
to augment mechanical cooling 550

Delamping. See Lighting efficiency improvements, fluorescent; lamps & ballasts, remove excess

Demand charges, electricity. See Electricity pricing: demand charges

Demulsifiers
in fuel oil 179

Deregulation of utilities
effect on thermal storage 411

Desuperheater, cooling machine. See Heat recovery, from cooling equipment: by desuperheater

Detergents, low-temperature 461

Dial timers. See Timed-turnoff switches

Diffusers
for skylights. See Daylighting, by skylights
for windows. See Daylighting, by window diffusers

Digital controls
energy management systems. See Energy management control systems

Dimmers, lighting. See Lighting, fluorescent; Lighting, HID; Lighting, incandescent

Direct contact heat exchanger. See Economizers, boiler: water spray

Direct expansion cooling systems
definition 1302

Direct-current motors. See Drives, direct-current (DC)

Direct-fired heating units
anticipators, adjust 804
efficiency ratings 801
flue dampers for. See Flue dampers, automatic
flue gas condensing 800
install efficient 799–801
efficiency characteristics 799–800
flue gas condensing 800
multi-fuel 801
when to replace 799
maintenance 798–799
multi-fuel 801

Disc traps. See Steam traps

Discotheques 1118

Discriminators, control signal. See Control signal polling

Dispersants
in boiler water 148
in fuel oil 179

Dock levelers 856

Dock seals 854–857
damage during loading 856–857
door doors, compatibility 857
durability 857
ease of installation 857
ease of repair 857
height change during loading 856
pressure on wall 857
selection issues 856–857
types of dock seals 854–856
vehicle alignment with 857
vehicle dimensions 856
vehicle doors, type of 856
vehicle guides 857
vehicle tilt 856

Door closers, for personnel doors 811–812
desirable features 811
how to install 811–812

Door operators, powered
for large exterior doors 830–832, 835
how to connect to door 830–831
how to control 831–832
instructions for 832
types of operators 830
for personnel doors 812–813
& vestibules 812–813
types 812

Door switches
for lighting control 1113

Doors
abandoned, sealing 823
automatic. See Door operators, powered
bi-fold. See Doors, large exterior
close. See Doors, personnel closers. See Door closers
fabric. See Doors, impact
closing horizontally. See Doors, large exterior
closing vertically. See Doors, large exterior
clearance. See Doors, quick-acting powered
garage. See Doors, large exterior;
 Doors, quick-acting powered
garage. See Doors, large exterior
hangar. See Doors, large exterior
horizontal roll-up. See Doors: quick-acting powered
impact. See Doors, impact
industrial. See Doors, large exterior;
 Doors, quick-acting powered
loading dock. See Doors, large exterior;
 Doors, quick-acting powered
material handling. See Doors, quick-acting powered
operators. See Door operators, powered
panel. See Doors, large exterior person
personnel. See Doors, personnel powered
powered. See Door operators, powered
revolving. See Doors: revolving
powered
roll-up. See Doors: revolving
power
roll-up strip curtain. See Doors, quick-acting powered;
 Doors, strip curtain
seals for. See Weatherstripping
segmented. See Doors, large exterior
sliding. See Doors, large exterior
storm. See Doors, storm
strip curtain. See Doors, strip curtain
swing. See Doors, impact;
 Doors, large exterior;
 Doors, personnel vehicle. See Doors, large exterior;
 Doors, personnel vehicle
vehicle. See Doors, large exterior;
 Doors, personnel vehicle
Weightstripping for. See Weatherstripping

Doors, impact
collection to other types 839
fabric impact doors 842–843
characteristics 839, 842
signage for 842
rigid impact doors 843–845
characteristics 839, 843
how to select 843
signage for 845
where to consider 839–840
Doors, large exterior
- clearance when operating 836
- dead space required 835–836
- ease of installation 838
- ease of operation 836–837
- install efficient 833–838
- insulation 835
- man doors in 837–838
- operators for 835
- safety features 837
- security 838
- selection issues 834–838
- strength 837
- types of large doors
  - bi-fold 833
  - folding horizontally 833
  - folding vertically (bi-fold) 833
  - overhead sectional 833–834
  - overhead single-panel 833
  - roll-up 833
  - sliding 833
  - swinging 833–834
  - weatherstripping 834–835
- which type is best 838
- windows in 837–838

Doors, personnel
- closers. See Door closers
- install high-efficiency 814. See also Doors, revolving
- maintenance 808
- weatherstripping. See Weatherstripping: for personnel doors

Doors, quick-acting powered 846–853
- characteristics 839
- comparison to other types 839
- condensation, preventing 851–852
- dripage 852
- durability 848–849
- ease of repair 849–850
- frost, preventing 851–852
- guards for 853
- hazards 850–851
- impact resistance 849–850
- infiltration through 847–848
- installation issues 852–853
- insulation 848
- maintenance, need for 853
- roll-up strip curtains 841
- safety features 850–851
- security 852
- selection issues 846–852
- sensors for opening & closing 852–853
- signage for 853
- speed of operation 846–847
- types of quick-acting doors
  - folding horizontally 846
  - freezer 846
  - overhead sectional 846
  - roll-up horizontally 846
  - roll-up vertically 846
  - weatherstripping 847–848
  - where to consider 839–840
  - wind resistance 848
- Doors, revolving 815–816
  - need for standby door 816, 817
  - signage for 817
- where to consider 815–816

Doors, storm 818
- advantages 818
- disadvantages 818
- features to seek 818–819
- installation 819
- where to consider 818

Doors, strip curtain 840–841
- characteristics 839, 840
- comparison to other types 839
- how to install 840–841
- maintenance 841
- powered roll-up strip curtains 841
- where to consider 839–840

Downlights
- energy wasted by 1033
- install focussing extensions in 1039
- install reflective inserts in 1038
- lamps for
  - ellipsoidal reflector incandescent 1034
  - focussing 1033–1035
  - screw-in fluorescent 1025–1030, 1034
  - vertical-filament incandescent 1033
- remove excess 1132
- replace 1135–1136

Draft, combustion
- & burner type 94
- adjusting 94–98
- by convection 94
- by fans 94
- correcting problems 99–101
- building chimney effect 100
- defect in draft regulator 99
- excessive flue draft 99
- fan pressure in boiler room 101
- inadequate flue draft 99
- inadequate outside air 100–101
- soot obstruction 101
- wind effects on boiler room 100
- wind effects on flue 99–100
- definition 94–95
- draft regulators 95–97
- barometric dampers 96
- draft hoods 96
- motorized dampers 96–97
- variable-output fan 97
- how to measure 97–98
- overfire draft 97
- purposes 94
- stack draft 98
- when to check 98

Draft, in air distribution 620

Draperies
- avoid heat trapping against wall by fan-coil units 745–747
- by induction terminal units 699
- by radiators & convectors 727–728
- insulation value 727
- to reduce cooling load 931

Drip trap. See also Steam traps
- definition 188

Drivers, for cooling
- compressors. See Compressor drivers

Drives, direct-current (DC) 1370–1373
- advantages 1371–1372
- applications. See Drives, variable-speed
- bypass, emergency 1372
- efficiency 1371
- features to consider 1373
- how they work 1371
- maintenance 1372
- motors, direct-current 1370–1371
- commutator 1370
- how they work 1370–1371
- windings 1370
- power factor 1372
- problems and solutions 1372–1373
- speed precision 1371
- torque handling ability 1371–1372
- turndown ratio 1371

Drives, eddy current clutch 1374
- applications. See Drives, variable-speed
- efficiency 1374
- how they work 1374
- mounting methods 1374
- turndown ratio 1374

Drives, multi-speed motor. See also Motors, AC induction: multi-speed
- applications. See Drives, variable-speed
- for air handling system fans 591–592
Drives, multiple-motor 1349
applications. See Drives, variable-speed
cost 1349
efficiency 1349
for heat rejection equipment 299–300
retrofitting 1349
speed ratios 1349–1350

Drives, variable-frequency 1350–1370
advantages 1350–1351
applications, general. See Drives, variable-speed
applications, high-torque 1351–1354, 1363
how to accommodate 1352–1354
motor limitations 1351–1354
current source inverter (CSI) drives
braking 1369
carrier frequency 1356, 1361
design limitations 1352–1354, 1363
how they work 1354–1355
load-commutated inverter 1355
motors for
cooling limitations 1171–1172, 1352
1355–1356
comparison of (table) 1355

IR compensation 1367
multiple motors, ability to drive 1367
power factor 1369–1370
regeneration 1369
restart, automatic 1369
reversing capability 1369
speed increase capability 1368
speed precision 1368
speed range lockout 1368–1369
speed settings, fixed 1368
start moving motor 1369–1370
temperature limits 1370
torque characteristics 1351–1352, 1366–1367
turndown ratio 1368
voltage boost 1367
voltage-speed ratio adjustment 1367
how they work 1354–1355

bypass, emergency 1369
cable length limitations 1365–1366
capacitors, power factor correction 1366
cogging 1364
electrical interference, conducted 1364–1365
electrical interference, radiated 1365
electrical resonance in motor cable 1366
electrical resonance in power wiring 1366
fuses blown 1366
inefficiency in other equipment 1366
mechanical resonances 1364
motor efficiency loss 1363
motor insulation failure 1363–1364
motor overheating 1363
motor voltage stress 1361
noise, from drive 1364
noise, from motor 1364
notching 1364
overheating other equipment 1366
pulse width modulation (PWM) drives
braking 1369
carrier frequency 1356, 1361
design limitations 1352–1354, 1363
chopper circuit 1356
efficiency 1368
electrical interference 1361, 1364, 1365
fault protection, electrical 1370
filter 1356, 1360
harmonic distortion 1360, 1361
how they work 1356–1357
motor cable problems 1365–1366
motor failures with 1363–1364
motors, driving multiple 1367
noise 1361, 1364
power factor 1369
power system resonance 1366
pulse rate 1361
regeneration 1369
speed increasing capability 1368
turndown ratio 1368
voltage stress, in motors 1361, 1363–1364
waveform 1356, 1363
sizes available 1354

bipolar junction transistor 1355
commutation 1355
Darlington transistor 1355
gate turn-off thyristor (GTO) 1355
insulated gate bipolar transistor (IGBT) 1355
power transistor 1355
silicon controlled rectifier (SCR) 1355
thyristor 1355
turndown ratio 1351

types of variable-frequency drives 1355–1356
comparison of (table) 1355
variable-voltage input (VVI) drives braking 1369
cogging 1364
efficiency 1356
fault protection 1370
harmonic distortion 1360, 1361
how they work 1355–1356
mechanical vibration 1364
motors, driving multiple 1367
noise 1364
power factor 1369
power system problems 1366
speed increasing capability 1368
torque 1356
turndown ratio 1368
waveform 1355–1356
voltage-speed ratio 1367
waveform distortion, caused by VFD's caused by inverter 1360
cauised by rectifier 1360
harmonics of inverter frequency, PWM 1361
harmonics of line frequency 1360–1361
harmonics of motor frequency 1361
notching 1360, 1361, 1364
voltage-current phase shift 1361
waveform distortion, general current 1357–1358
effect of system impedance 1359
equipment causing 1357
harmonic analysis 1358–1359
how to calculate 1359
how to measure 1359–1360
input 1357–1358
output 1357–1358
standards for 1360
voltage 1357–1358

Drives, variable-pulley 1373–1374
Drives, variable-speed 1345–1375. See also Drives, direct current (DC); Drives, eddy current clutch; Drives, multiplemotor; Drives, variable-frequency; Drives, variable-pulley; Motors, AC induction: multi-speed; Motors, wound-rotor
consider overall efficiency 1346
for air handling systems. See Air handling systems, by type for centrifugal chillers 335–336
for centrifugal compressors 1308–1309
for centrifugal pumps 1340, 1342
for combustion fans 90–92
for heat rejection equipment 291, 295–297
calculation of compressor 1310
for VAV systems 627
not for service water 486
types of variable-speed drives 1345–1346

E 
Earth sheltered construction. See Insulation, types: soil
Earth-coupled heat pumps. See Heat pumps: earth-coupled
Economizers, absorption cooling 1327
Economizers, boiler & air preheaters 126–127
condensing 129–130
acid condensate, disposing 130
construction 129
cost 130
fuels used with 129–130
where to consider 129–130
conventional (non-condensing) 121–125
acid dew point limitations 122–125
construction 121
energy saving 121
fan and pump energy for 124
fuels used with 122–123, 124
how to protect from acid 123–124
where to consider 121
with multiple boilers 124–125
definition 1291
direct contact. See Economizers, boiler: water spray
install 120
water spray 131–133
construction 131
cost 131
environmental benefit 131
equipment 131
recovery temperature limits 131
temperature control
water condition 131
Economizers, cooling system 1305–1306
in screw compressors 1313
Economizers, outside air 547–550
control equipment 549
control sequences 549
ductwork requirements 548–549
energy saving 547–548
effect of internal heat gain 547
effect of system reheat 547
effect of weather profile 547
enthalpy control 549, 551–552
comfort effects 551
maintenance requirements 551–552
where to consider 551
how it works 547
limitations with dual duct systems 548–550
limitations with multizone systems 548–550
limitations with polluted outside air 548
Economizers, waterside. See Heat rejection equipment, direct cooling by: by waterside economizer
Eddy current clutch. See Drives, eddy current clutch
EDR (boiler rating) 1295
EER. See Efficiency ratings, cooling
Efficacy (lighting). See also Lighting, by type: Lighting, design issues: lamp characteristics: efficiency
definition 1437
maximum theoretical 1440
table of values 1437–1443
Efficiency codes, laws & standards
ANSI, for ballasts 1060, 1063
ASHRAE Standard 90 1168, 1445
CBM (Certified Ballast Manufacturers) 1063
construction efficiency codes 1445
BOCA 1445
CABO 1445
for ballasts 1063
for lighting 1445
   approaches used 1445
for motors 1167–1169
for water heaters 466
lighting equipment standards 1445
National Appliance Energy Conservation Act (US)
   fluorescent ballasts 1445
National Energy Policy Act (US)
   HID lighting 1480
   lamps 1445
National Energy Policy Act (US) 1168
NEMA (motors) 1167–1169

Energy analysis computer programs
   accuracy of 1242–1244
   data libraries 1241–1242
   how to debug 1244–1245
   how to select 1245
   how to use 1241–1242
   output of 1240–1241
   structure of 1239–1240
   technical support 1245

Energy efficiency ratio (EER). See
   Efficiency ratings, cooling

Energy levels, of atoms
   in fluorescent lighting 1459–1464, 1463
   in general 1447–1448
   in incandescent lighting 1447–1448

Energy management control systems 1219–1226
   advantages of 1219
   capabilities of 1219–1221
   configurations 1222–1223
   cost of 1223
   for complex control functions 1221
   for controlling many items 1220
   for creating reports 1219
   for limiting electrical demand 1221, 1222
   for monitoring 1219
   for system control 1220–1221
   inappropriate uses 1221–1222
   obsolescence 1226
   problems with 1223
   software issues 1225
   staffing requirements 1224–1225
   standards for 1226
   BACnet 1226
   LonMark 1226

Energy sources
   electricity 1251–1257
   fossil fuels 1247–1250
   free & renewable 1267–1282
   geothermal 1278–1280. See also
   Geothermal systems
   hydropower 1276–1278. See also
   Hydropower, local
   photovoltaic 1271–1273. See also
   Photovoltaic systems
   solar cooling 1268–1271
   solar heating, active systems 1268–1271. See also
   Solar heating, active
   solar thermal power systems 1274. See also
   Solar thermal power systems
   waste product combustion 1280. See also
   Waste product combustion
Exhaust air
definition 528
heat recovery from. See Heat recovery, from building exhaust air
Exit signs, install efficient 1041–1042
Expansion joints, air leakage at 865–866
Expansion valves, refrigerant 1301
capillary tube 1318
definition 1317
electronic 1318
limit condensing temperature 1318
superheat 1318
F
F&T traps. See Steam traps
Fan-coil units
3-pipe systems, convert to 2-pipe 748–750
to 4-pipe 751
control methods 741
thermostatic. See Heating & cooling units, minimize operation to minimize operation. See Heating & cooling units, minimize operation definition 741
electric heating, eliminate 752
heat trapping against wall, avoid 745–747
maintenance 742–743
motors, select efficient 744
Fan-powered VAV terminals. See Air handling systems, VAV single-duct: terminals, fan-powered
Fans
air handling system. See Air handling systems
dampers for 1190–1191
inlet vanes 1190
exhaust, air for 522
for burners. See Burner systems, fuel
output, adjusting 1188–1191
energy saving 1188
limitations 1189
with belt drive 1189–1190
with inlet vortex damper 1190
with variable-pitch propeller 1190
space air circulation 550
with VAV systems 621
variable-pitch for heat rejection equipment 297–298
Faucet aerators
efficiency standards for 443
maintenance 440–441
Faucets
efficiency standards for 443
for showers 446, 448–449
maintenance 440
Feedback (in controls)
definition 1381
Feedwater, boiler
definition 137–141
Feedwater systems, boiler. See Boiler feedwater systems
Fenestration. See Doors; Glazing
Fiberglass insulation. See Insulation, types: glass fiber
Film, solar control 944–948
& breakage of glazing 945
& shading devices 944–945
abrasion resistance 947, 948
& low-E coatings 946, 947
adhesive methods 946
appearance 946, 947
appearance defects 944
benefits, non-energy
breakage protection 945–946
improved building appearance 946
color 946, 947
economics 944
effect on appearance 944
effect on daylighting 945, 948
effect on heat loss 945, 946–947
effect on passive solar heating 945, 948
effect on solar heat gain 945
effect on view 947
energy penalties 945
energy saving 945
how it works 946–947
how to clean 948
how to install 947–948
how to select 947
limitations 944–945
low-E features 945, 946–947
& abrasion resistance 946
materials 946
on treated glazing 945
optical properties 946
reflection vs. absorption 946, 947
service life 944
ultraviolet absorption 946
Filters, air
- adsorbent 541
- chemical 541–542
- electrostatic 542
- HEPA 540–541
  to reduce ventilation requirements. See Ventilation, outside air: reduce, by air cleaning ultraviolet 542–544

Firetube boilers. See Boilers: firetube

Fixtures, service water
install efficient
- shower heads. See Shower heads: install efficient
- toilets. See Toilets: install efficient
- urinals. See Urinals: install efficient
- wash basins. See Wash basins: efficient fixtures, install maintenance 440–442
- basin stoppers 441
- faucet aerators 440–441
- faucets 440
- flushometer valves 441
- shower heads 441–442
- toilets 441
- valves 440

Flame spread, of insulation materials 1396

Flash intercooling 1305–1306

Float traps. See Steam traps

Float valve, refrigerant 1301

Flow measurement
equipment quality 1236
flowmeters 1233–1236
  calibration of 1237
  display features 1237–1238
  orifice 1235
  pitot tube 1234–1235
  propeller 1233–1234
  rotameter 1235–1236
  spring-loaded variable-area 1236–1238
  turbine 1233–1234
  ultrasonic 1234
  variable-area 1235–1236
  venturi 1235
  vortex shedding 1234
  for gases and vapors 1233–1238
  for liquids 1233–1238
  system components 1233
  totalizers 1236

Flow restrictors, shower head 447

Flowmeters 1233–1236

Flue dampers, automatic
energy saving 104
  for boilers 104–105
    where to consider 104
    where to install 105
  for direct-fired heaters 802–803
    energy saving 802
    where to consider 802
  for water heaters 469
    installation difficulty 469
    where to consider 469
    how to install 803
  okay with pilot lights 105
  safety certification 105, 803
  types of flue dampers 105, 802
    externally powered 105, 802
    self-powered 105, 802

Flue draft. See Draft, combustion

Flue gas
acid dew point
  definition 122–123
  limits heat recovery 121, 122–123
  values for typical fuels 123
  heat recovery from. See Air preheaters, boiler; Economizers, boiler recirculation, in burner systems 79
  scrubbers, cost of 1250
  temperature & boiler efficiency. See Boiler efficiency testing & economizers. See Economizers, boiler
    factors that determine 120

Fluidized bed boilers. See Boilers: fluidized bed

Flush valves
maintenance 441

Foam insulation. See Insulation, types: plastic foam

Foaming, in boilers. See Water treatment, boiler water

Footcandle. See also Lighting, design issues; Lighting, measurements definition 1423

Forgiveness clause, for cooling storage rates 413

Fossil fuels 1247–1250
  acid dew point of 1249
  and flue gas temperature 1249
  availability 1250
  coal 1248–1249
  combustion products 1248
  composition of 1247–1248
  contaminants 1248
  cost factors 1249–1250
  efficiency-related characteristics 1247–1249
  energy content of 1248–1249
    high heat value 1248–1249
    low heat value 1248–1249
  excess air requirements 1249
  fuel oil 1248–1249
  hydrogen content, effects of 1249
  natural gas 1247–1249
  storage and handling 80, 1250

Fouling factor
definition 1320
  in condensers 1320–1321
  in evaporators 1320–1321

Frederick the Great 1276

Free cooling. See Heat rejection equipment, direct cooling by

Free energy sources. See Non-fossil energy sources

Freeze protection
for steam coils 568–569
  in air handling systems. See Air handling systems: freeze protection
  in hydronic systems 568

Fuel oil. See also Fossil fuels additives 178–180
  alternatives to 180
  be skeptical about 179–180
  to catalyze combustion 178
  to improve atomization 178
  to prevent fuel system corrosion 179
  to prevent stratification 179
  to reduce fireside fouling 178
  to reduce sludge 179
  fuel properties of 1247–1249
  heating
    use most economical source 177
    with waste heat 177
  temperature. See Fuel oil: viscosity viscosity
    automatic control to optimize 176
    efficiency, effect on 174
    how to measure 175
    to optimize 174–175
    units of 175
    variation of 174–175, 175

Fuel oil systems
  functions 173
  motors, high-efficiency 180

Fuel selection, boilers 28–29, 30
  automatic 30
    how to install 30
    how to calculate 28
Glazing
Glass fiber insulation
Fuels. See Fossil fuels
Furnaces, forced-air. See Direct-fired heating units

G
Gate turn-off thyristor (GTO) 1355
Geothermal heat pumps. See Heat pumps: earth-coupled
Geothermal systems 1278–1280. See also Heat pumps: earth-coupled applications 1279
depths of wells 1279
development status 1279
economics 1279
environmental issues 1279
extraction techniques 1279
go thermal sources 1278–1279
life of source 1278
temperatures available 1278
Glare. See Daylighting, design issues; Lighting, design issues; Lighting, fixture layout
definition 1430
Glass. See also Glazing
absorption, far infrared 937
Glass fiber insulation. See Insulation, types: glass fiber
Glazing
appearance 942–943
area, reducing. See Shading, to reduce cooling load: by reducing glazing area
breakage & solar control films 945
protection by films 945–946
thermal 945
color 942
efficiency features absorption 939–940
frames, insulating properties 936–937
gap between panes 939
insulating fill gases 938
integral shading devices 940
low-E coatings 937–938
number of surfaces 936
reflection 939–940, 942
seal reliability 939
efficiency ratings 943
energy consumption effects 934
frames 936–937
avoid leakage around 941
thermal breaks 936–937
install efficient 934–943
for daylighting 941
for minimum air leakage 940, 941
for minimum heat gain 939–940
for minimum heat loss 936–939
for passive solar heating 940–941
how to plan 935–936
where to retrofit 934
install supplemental 908–910
condensation, preventing 909
energy saving 908–909
exterior glazing 909
how to install 910
interior glazing 909
ventilation, providing 909–910
vs. total window replacement 910
longevity 941–942
maintenance 860
privacy 943
shading for. See Shading, to reduce cooling load
storm windows. See Glazing: install supplemental thermal breakage, avoiding 941
view through 942
Global warming, & refrigerants 136–1338
Greenhouse effect, in global warming 136–1338
Greenhouse gases 136–1338
Greenhouses. See Daylighting, by translucent roof & walls; Solar heating, passive: by glazed enclosures
Ground source heat pumps. See Heat pumps: earth-coupled
Ground water
as heat sink and heat source. See Heat pumps: ground water source
Group relamping. See Lighting, maintenance

H
Halocarbon refrigerants. See Refrigerants
Halogen cycle (lamps) 1451–1452
Halogen lamps. See Lighting, incandescent: lamps, tungsten halogen
Hardness, water. See also Water treatment, boiler water
definition 145
Harmonic distortion. See Waveform distortion, electrical power
Hatches, roof. See Roof hatches
HCFC refrigerants. See Refrigerants
Heat
radiation 1229
Heat exchanger. See also Heat recovery
air-to-air 555–562
evaporative cooling of 560–561
flue gas. See Air preheaters, boiler; Economizers, boiler
heat pipe 556–557
heat wheel, latent 558–559
heat wheel, sensible 557–558
permeable medium 556
plate, for air 556
runaround loop 559
Heat, in general
definition 1387
how heat moves
conduction 1387–1388
convection 1388
mass transfer 1388
radiation 1388
infrared radiation 1387
latent heat. See Latent heat
Heat loss. See also Heat, in general: how heat moves
from buildings. See also Infrared thermal scanning
from hot surfaces 212
from wet insulation 212–213
Heat meters 1236
for boiler plants 55
Heat pipe. See Heat exchanger
Heat pump loop systems
advantages 780–781
cost 782
description 779–780
efficiency penalties 781
efficiency pitfalls 788–789
flaws, common 783
heat sinks 791–793
heat sources 780–784, 786–788, 791–793
loop isolation valves 789–790
optimize loop temperature 785–789
with thermal storage 788
separate high-/low-temperature headers 783–784
solar collectors for 781–784
cost advantage 792
space-to-space heat recovery 780–784, 782
temperature limits 786
thermal storage for 781, 794–795
energy & cost saving 794–795
where to consider 794

Heat pumps
air leakage around, prevent 757
compressors, install efficient 767
earth-coupled 1259–1261
advantages of 1260–1261
disadvantages of 1261
types of soil heat exchangers 1259–1260
efficiency ratings. See Efficiency ratings, cooling; Efficiency ratings, heating
fan motors, install efficient 756
for heat recovery 394–397
ground water source 1261–1262
advantages of 1261–1262
disadvantages of 1262
heat sinks for 1259–1264
heat sinks, install alternative. See Heat pumps: heat sources, install alternative
heat sources for 1259–1264
heat sources, install alternative 775–778
design issues 777
options in new construction 775–776
options in retrofit 776–777
where to consider 775
install efficient 759–760, 767
cost, relative 760
efficiency ratings 759
other features 760
size, relative 760
loop systems. See Heat pump loop systems
maintenance
for self-contained units 754–756
for split systems 765–766
motors, install efficient 766
solar collectors as heat source 1263–1264
advantages of 1263
disadvantages of 1263–1264
sump heaters, seasonal operation 770
surface water source 1262
advantages of 1262
disadvantages of 1263
ventilation, eliminate inefficient 758
waste heat as heat source 1264
well water source. See Heat pumps: ground water source

Heat recovery, from blowdown 140–141, 158–162
for heating feedwater 161
for heating makeup water 160
from blowdown water only 158
from flash steam 158
heat available 158–159
heat exchanger for 162
safety issues 162
with condensate heat recovery 161–162

Heat recovery, from boiler room air 218–223
comfort 223
energy saving 218
how to do 219–223
safety 223

Heat recovery, from building exhaust air 555–562
application restrictions 560
between multiple air streams 561
contamination between air streams 561
control 561
economizer cycle, with 562
efficiency 559–560
energy saving 560
fan energy requirement 559
fire hazard 561
freeze protection 561
heat exchanger
evaporative cooling of 560–561
heat pipe 556–557
heat wheel, latent 558–559
heat wheel, sensible 557–558
how to select 561
permeable medium 556
plate 556
runaround loop 559
types of heat exchangers 556–559
heat exchanger cleaning 561
heat recovery, latent 555, 559
heat recovery, sensible 555, 559
installation problems 561
pump energy requirement 559

Heat recovery, from condensate. See also Condensate systems: maximize condensate return
from discarded condensate 166
from high-temperature condensate 167–168
energy in flash steam 168

Heat recovery, from cooling equipment
adjusting load, recovery vs. non-recovery 388
amount of heat available 385
by auxiliary or double-bundle condenser 391–393
contamination by refrigerant 392
control 392–393
energy saving 392
leakage into refrigerant 392
recovery temperature 391
sizing 391
by desuperheater 397–399
contaminant isolation 399
equipment 398–399
from ammonia 387
heat recovery potential 397–398
limitations 398
refrigerants with high superheat 398
where to consider 397–398
by direct use of condenser cooling water 389–390
cost 390
efficiency 389
isolation from contaminants 389
by heat recovery chiller 394–397
from ammonia superheat 387
heat recovery potential, net 394–395
how to distribute cooling load 395
operation at low condensing temperature 395, 403
selecting type of compressor 395–396
sizing 395
use of chiller for cooling storage 396
condensing temperature, increasing 385–386
effect on cooling capacity 386
effect on COP 386
effect on equipment life 386
limitations of centrifugal compressors 386
from absorption chillers 387
from air conditioners 773–774
from ammonia superheat 387
from lead chiller 359
from screw compressor oil heat 386–387
from split systems 773–774
heat exchange losses 387–388
isolation from contaminants 387–388
matching application temperature 387
matching application timing 387
Heat recovery, from flue gas. See Air preheaters, boiler; Economizers, boiler
Heat recovery, from lighting 625–626, 626
Heat recovery, from steam vents 208–209
how to find leaks 208–209 methods 208
Heat recovery, in feedwater systems 140–141
Heat recovery, to heat fuel oil 177
Heat rejection equipment, direct cooling by
alternatives to 370
by chiller “free cooling” 371–373
advantages 372
disadvantages 372
how to control 372
where to consider 371–372
by heat exchanger in CHW system 373–375
advantages 373
disadvantages 373
how to control 374–375
installation 373–374
where to consider 373
by heat rejection unit in CHW system 382–383
freeze protection 383
how to control 382–383
type of cooler 382
where to consider 382
by strainer cycle 375–378
cleaning tower water 376
efficiency of 375
expansion tanks, adapting 377
flow rates, matching 377
how to control 377
system fouling hazard 375
water treatment 376–377
where to consider 375–376
by waterside economizer 379–381
efficiency 379–380
how to control 381
installation 380–381
where to consider 379
comparison of methods 369
where to consider 367–369
Heat rejection equipment, efficient installation
adjust water distribution 307
air recirculation, avoid 310
energy waste from 310–311
factors that cause 311–312
how to minimize 312–314
motors, install high-efficiency 315
secure access panels 309
to minimize debris 305–306
elevate units 305–306
install screens 305
Heat rejection equipment, efficient modulation
by dual/multi-speed fan motors 291–294, 299–300
control issues 299
cost 294
efficiency 292–293, 299
fan size range 293
gearbox lubrication 293
how to select 299
in multi-fan equipment 300
maintenance 294
noise reduction 294
resonances 293
retrofit, ease of 294
starting stress 294
by efficient fan sequencing 301–302
how it lowers condenser temperature 301
how it saves energy 301
by multi-speed fan motors
resonances 300
by variable-pitch fans 291–294, 297–298
control issues 298
cost 294
drive, belt vs. gear 298
efficiency 292–293
fan size range 293
maintenance 294
noise reduction 294
resonances 293, 297–298
retrofit, difficulty of 294
starting stress 294
turndown ratio 297
by variable-speed fan drives 291–294, 295–297
control issues 295–296
cost 294
efficiency 292–293
electrical interference 293, 295
fan size range 293
for multiple fans 293
gearbox lubrication 293
maintenance 294
motors, whether to replace 296
noise reduction 294
resonances 293, 295
starting stress 294
turndown ratio 295
by variable-speed fans retrofit, ease of 294
comparison of methods 292–294
condensing temperature, effect on 292
cooling efficiency, effect on 294
energy saving 291–292
other benefits 292
Heat rejection equipment, health hazards 564–565
Heat rejection equipment, maintenance
cleaning 302–304
energy saving 302
how to clean dry coolers 303
how to clean wet coolers 303–304
fouling, causes 302
keep air flow intact 308–309
seasonal shutdown 770–771
Heat rejection equipment, minimize operation 250–252, 772–773
energy saving 250–251, 772
how to control 251–252, 772
pumps, spare 260
where to consider 250–251, 772
Heat sinks, for heat pumps and cooling equipment 1259–1264
install alternative. See Air conditioners: heat sinks, install alternative
Heat sources
for heat pump loop systems 786–788
for heat pumps 1259–1264
fossil fuels. See Fossil fuels
free & renewable. See Non-fossil energy sources
free, for heat pumps
installation. See Heat pumps
Heat wheel. See Heat exchanger
Heaters
for cooling towers seasonal shutdown 770–771
Heaters, sump. See Sump heaters, compressor
Heating & cooling units, minimize operation
by clock control 711–713
applications 711
energy saving 712
how to install 712–713
how to select 712
override 712
by door & window switches 716
energy saving 716
how to install 716
placards for 716
by light switch 714
applications 714–715
how to connect 715
by personnel sensor 714
by placards 704–707
applications 704
energy saving 704–705
placard design 705
where to install 706
by setback thermostat 711–713
applications 711
energy saving 712
how to install 712–713
how to select 712
override 712
setback temperature 711–712

Heating equipment
absorption chillers 1328–1329
boilers. See Boiler plant; Boilers
direct-fired heating units. See
Direct-fired heating units
fan-coil units. See Fan-coil units
furnaces, forced-air. See Direct-fired
heating units
heat pump loop systems. See Heat
pump loop systems
heaters, direct-fired. See Direct-fired
heating units
minimize operation. See Heating &
cooling units, minimize operation
radiators. See Radiators

Heating Seasonal Performance
Factor (HSPF). See Efficiency
ratings, heating

Heating, solar. See Solar heating,
active; Solar heating, passive

Heating storage. See Thermal storage,
heated water

Heating surface (boiler rating) 1295

Helical rotary compressors. See
Compressors, cooling, screw

HEPA filters 540–541

Hermetic compressors
definition 1315

HFC refrigerants. See Refrigerants

High-frequency ballasts. See Lighting,
fluorescent; Lighting, high
intensity discharge

Hoods
draft hoods. See also Draft, combus-
tion: draft regulators
ventilation air for
how to reduce 522

Horsepower (boiler rating), definition
1294–1295

Hot gas bypass
in centrifugal compressors 1308

Hot water temperature 458–460
& recirculation 460
energy use, effect on 458
hazard, infection 458–459
& type of water heater 459
hazard, scalding 459, 475
how to select 459–460
in storage heating systems 475
low-temperature detergents, to
reduce 461
storage capacity, effect on 460, 475
thermometers for 460

Hour charges, for electricity 1255

House wraps 1393–1394

HSPF. See Efficiency ratings, heating

Hydrazine, for water treatment 146

Hydronic cooling systems
definition 1302

Hydronic heating systems
advantages 734
convert steam to 733–735

Hydropower, local 1276–1278
applications 1277
connection to public utilities 1278
development status 1277
economics 1278
energy availability 1277–1278
environmental issues 1278
high-head and low-head 1277
PURPA, effect of 1278
system components 1277
terrain preparation 1277

Hypersensitivity pneumonitis 565

Hysteresis, in controls 1379

I

IBR ratings (for boilers) 1295

Identification. See Placards
IEEE Standard 519 (waveform
distortion) 1360

Igniters. See Lighting, high intensity
discharge

Illuminance. See also Lighting, design
issues: illumination level
definition 1423

Impedance
of power systems 1359
of transformers 1359

Impeller, pump. See Pumps, centrifu-
gal

Impeller trimming, pump. See
Pumps, centrifugal: impeller
trimming

Induction loop sensors 852

Infiltration. See Air leakage, building
envelope

Infrared radiation. See also Infrared
thermal scanning
definition 1387
from incandescent lighting 1450
in sunlight 1283–1284
& emittance of opaque surfaces
955–956
& solar control films. See Film,
solar control
absorption by opaque surfaces
955–956
amount 955–956
selective absorption by glazing
934, 939
intensity vs. source temperature
1229
long-wavelength
& low-E coatings. See Low-
emissivity coatings
absorbed by glass 937
heat gain 935
heat loss from buildings 935
origin 1229
wavelength vs. source temperature
1229

Infrared switches. See Personnel
sensors: infrared

Infrared thermal scanning 1229–1232
capabilities 1229
estimating air leakage heat loss
1232, 1384
estimating conductive heat loss
1231–1232
for heating plant insulation 214
for steam trap testing 201
limitations 1229
survey conditions 1231
types of scanners 1230
where to get equipment 1232

Inlet guide vanes
for centrifugal compressors 1308
for fans. See Fans: dampers for:
inlet vanes

Insulated gate bipolar transistor
(IGBT) 1355

Insulation, economics 1396–1399

Insulation, for attics 876–878
appropriate types 876–877
blankets & batts, installing 877
loose fill, installing 877
protecting 877
vapor barrier for 877
venting moisture from attic 877

Insulation, for condensate pipe 164

Insulation, for doors. See Doors, by
type
Insulation, for heating plant equipment 212–216
condensate system 214
heat loss from bare surfaces 212
heat loss from wet insulation 212–213
how to find defective 214
in pipe tunnels 213, 216–217
installation 215
materials 214–215
what not to insulate 213–214
what to insulate 213–214

Insulation, for hot service water pipe 493
effect on pump power 493

Insulation, for roofs
exterior rigid insulation 879–882
advantages 879
drainage 881
types of roof insulation 880
exterior sprayed foam 882–883
advantages 882
disadvantages 882–883
drainage 883
protection 883
for interior surface 884–885
advantages 884
attachment 885
moisture damage, how to avoid 884–885
moisture damage, risk of 884
to reduce solar heat gain 954

Insulation, for suspended ceiling 886–887
applications, cooling 886
applications, heating 886–887
reducing space volume 887

Insulation, for walls
for curtain walls 903–905
air leakage, avoiding 905
materials 905
panel design 905
retrofit feasibility 904–905
with other improvements 905
for exterior surface 901–902
advantages 901
convection loss, avoiding 901–902
moisture problems, avoiding 902
protection for 902
types of exterior insulation 901
for interior surface 896–900
air leakage, avoiding 899
materials 896
moisture damage, avoiding 896
with impermeable walls 899
with permeable walls 896–899
for wall cavities 890–895
energy saving 890
fire safety 895
retrofit, in masonry walls 893–895
retrofit, in stud walls 890–893
vapor barriers 895
to reduce solar heat gain 954

Insulation, for water heaters 465–466, 475

Insulation, for windows
high-efficiency glazing. See Glazing: install efficient
low-E coatings 937–938
low-E retrofit films 912, 944–948
storm windows. See Glazing: install supplemental
supplemental glazing. See Glazing: install supplemental
thermal shutters 911–912
security benefit 911
vs. storm windows 911

Insulation, how it works 1387–1390
fiber insulation 1387–1388
foam insulation 1388
gases in insulation 1388
granular insulation 1387–1388
mass effects 1389
preventing conduction 1387–1388
preventing convection 1388–1390
preventing heat radiation 1388
preventing mass transfer 1388
reflective insulation 1389–1390
time lag in conduction 1389

Insulation, how to install 1401–1402
avoiding conduction paths 1401
avoiding convection 1402
batt insulation 1402
loose fill insulation 1402
rigid insulation 1402
avoiding moisture damage 1389
vapor barriers 1391–1394
venting 1402
water drainage 1402

Insulation, movable. See Movable insulation

Insulation, selection issues 1395–1399. See also Insulation, types
aging characteristics 1397
care required in installation 1396
cost 1396
density 1388
ease of installation 1396
emissions 1397
fire characteristics 1396
microorganism growth 1397
moisture resistance 1389, 1397
orientation 1389
permeability 1397
physical damage, resistance to 1397
R-value 1395
settling tendency 1396–1397
temperature 1389
temperature range 1397
vermin resistance 1397
void filling 1396

Insulation, types 1397–1399. See also Insulation, selection issues
ceilings, loose dry 1399
composition 1399
fire characteristics 1399
installation 1399
moisture degradation 1399
R-value 1395
settling tendency 1397, 1399
vermin 1399
ceilings, wet sprayed 1399
application 1399
fiber, generally 1387
foam, generally 1388
glass fiber 1388, 1397–1398
batts 1397–1398
blankets 1397–1398
boards 1397–1398
care required in installation 1396
density & R-value 1398
fire characteristics 1396
health hazards 1398
loose fill 1397–1398
R-value 1395, 1397
vapor barrier, attached 1398
vapor barriers for 1392
glass foam 1388
granular, generally 1387
lightweight concrete 1399
composition 1399
R-value 1395
mineral fiber 1398
R-value 1395
perlite 1399
composition & manufacture 1399
in lightweight concrete 1399
R-value 1395
plastic foam, beads 1398
fire characteristics 1398
in lightweight concrete 1398
plastic foam, boards 1398
aging 1398
ease of handling 1398
permeability 1398
polyisocyanurate, extruded 1398
polystyrene beadboard 1398
polystyrene, extruded 1398
polyurethane, extruded 1398
R-value 1395, 1398
temperature ranges 1398
vapor barrier, as its own 1393
plastic foam, generally
fire characteristics 1396, 1398
impact resistance 1397
permeability 1397
R-value degradation 1397
sunlight degradation 1397
plastic foam, sprayed 1399
application 1399
impact protection 1399
puddling 1399
sunlight protection 1399
reflective 1389–1390
for hot surfaces 215
soil 1399
cost of use 1399
problems 1399
urea formaldehyde
chemical emissions 1397
vermiculite 1388, 1399
composition & manufacture 1399
fire characteristics 1399
handling 1399
in lightweight concrete 1399
R-value 1395, 1399
Inverted bucket traps. See Steam traps
Inverter drives. See Drives, variable-frequency
Ion exchange (water treatment) 145–146
Ionization
definition 1460
in fluorescent lighting 1460, 1463
Isocyanurate insulation 1398

L

Latent heat
definition 1299, 1332
in building air
recovery by exhaust air heat recovery system 555–562
in flue gas
recovery in condensing boilers 1294
recovery in condensing economizer 129
recovery in condensing furnaces 800
recovery in direct-contact heat recovery unit 131–133
recovery in high-efficiency water heaters 463–467
in heat pipes 556–557
in steam
recovery from boiler blowdown 158–162
recovery from discarded condensate 166
recovery from high-temperature condensate 167–168
recovery from steam vents 208–209
of refrigerants 1332
Latent heat wheels 558–559
Leakage, refrigerant. See Cooling system leakage
Legionnaires’ Disease 565
Light
how it originates 1447–1448
Light beam switches 1206–1207
Light meters 1423
Light pipes. See Daylighting, by light pipes
Light shelves. See Daylighting, by light shelves
Lighting, arc 1449, 1450, 1451
Lighting, control of
by assigning staff for 1090
by door switches 1113
by key switches 1095
by personnel sensors 1109–1110
overrides, avoid 1109–1110
survey & planning 1109
types of personnel sensors 1109
where to use 1109
by photocontrol, for exterior 1101–1103
current capacity 1102
durability 1101
how to install 1102
how to select 1101–1102
mounting methods 1101
response delay 1101–1102
sensitivity settings 1101
with other controls 1102
by photocontrol, for interior 1104–1108
circuit layout 1107
HID limitations 1105
mounting methods 1106
number of sensors 1106
sensitivity settings 1106–1107
where to consider 1104–1105
with other controls 1105
by programmable controller 1144
to avoid duplication 1140
user instructions 1144
by pullcord switches 1147–1149
how to install 1147–1149
where to use 1147
by relays 1143
by timeclock 1098–1099
astronomical timeclocks 1100–1101
how to select 1099
where to consider 1098–1099
by timed-turnoff switches 1111–1112
overrides, avoid 1111
safety limitations 1111–1112
types of timer switches 1111
circuits. See Lighting, fixture layout convenience 1145–1146
at activity areas 1145–1146
at exits 1145
for transit 1146
distinguish special switches
by contrasting switch color 1094
decal 1094
by lighted toggle 1094
by separate mounting 1091, 1094
telltale lights 1093
task lighting 1129
from multiple locations 1143
placards for. See Placards: for lighting controls
to avoid duplicated lighting 1140
with programmable controller 1140
with transfer switch 1140
toggle switches, install properly 1091
when substituting single-tube ballasts 1051

J

Jackshaft (boilers) 63

K

Kelvin temperature (lamps) 1442–1443
Kinematic viscosity 175
Krypton
in fluorescent lamps 1463
in incandescent lamps 1025, 1451
Lighting, design issues 1425–1435. See also Daylighting, design issues; Lighting, layout area lighting 1428–1429
background lighting 1429–1430
& energy efficiency 1430
& visual comfort 1429–1430
& visual efficiency 1429
island of light 1430
partitions 1430
surface colors 1430
brightness
& glare 1424
& visual comfort 1425
& visual efficiency 1425
definition 1424
do background 1429–1430
do task area 1428
of various objects (table) 1430
color rendering 1434–1435
& color vision defects 1435
& illumination level 1435
how humans see color 1434, 1435
how lamps reveal color 1434
loss, in dim light 1435
of lamps 1435. See also Lighting, fluorescent; Lighting, high intensity discharge; Lighting, incandescent
of sunlight 1434–1435
design approach, overall 1018–1019
design methods, conventional 1019–1020
economics, overall 1018
efficiency. See specific topic
efficiency standards. See Efficiency codes, laws & standards
energy saving potential, overall 1017–1018
esthetics 1429–1430
glare
& age of viewer 1431
& background lighting 1429
& brightness 1430–1431
& visual comfort 1430
duration of exposure 1430
from light sources 1083, 1119, 1430–1431
from reflections of light source 1122–1123, 1433
from veiling reflections 1431. See also Lighting, design issues: veiling reflections
position of light source 1430
size of light source 1430
heat recovery. See Heat recovery, from lighting
illumination level 1425–1427
& color rendering 1435
& visual comfort 1427
& visual efficiency 1426–1427
age of viewer 1426
contrast in task 1426
office work 1427
recommendations 1426
size of details 1426
illumination, uniformity of 1427–1428
in task lighting 1119–1121
lamp characteristics 1437–1443.
See also Lighting, fluorescent; Lighting, high intensity discharge; Lighting, incandescent; Lighting, low-pressure sodium
ability to substitute lamps 1440–1443
ballast energy requirement 1440–1443
color, lamp 1441–1443
color rendering index (CRI) 1441–1443
decorative options 1443
dimming ability 1440–1443
efficiency 1437–1443
electrical interference 1443
harmonic distortion 1443
lamp & ballast noise 1443
light distribution pattern 1442–1443
lumen degradation 1437–1443
lumen output 1437–1443
mismatch potential 1440–1443
mounting position limitations 1443
power factor 1443
service life 1437–1443
temperature, effect on output 1442–1443
temperature, starting 1442–1443
time to restart 1442–1443
time to start 1442–1443
layout. See Lighting, fixture layout
light intensity, measuring 1423–1424
luminance. See herein brightness photography 1441
shadowing, by the viewer 1429
in task lighting 1121
shadowing, within the task 1428–1429
harsh lighting 1428
in task lighting 1122
surface area of fixtures 1428–1429
task lighting. See Task lighting
veiling reflections 1431–1434
& reflected glare 1433
conditions that cause 1432
definition 1431
discomfort from 1431
energy waste 1431–1432
how to avoid 1433
in task lighting 1119
polarization of light 1433–1434
smoothness of surface 1432–1433
strength of 1432–1433
visual comfort 1425
& background lighting 1429–1430
& glare 1430
& illumination level 1427
eye strain 1427
in task lighting 1121
measuring 1425
visual comfort probability 1425
visual efficiency 1425
& background lighting 1429
& illumination level 1425, 1426–1427
age of viewer 1426–1427
contrast within task 1425, 1426
desensitization by glare 1429
in task lighting 1121
size of task details 1425, 1426
visual quality 1425–1435
Lighting efficiency improvements, fluorescent. See also Lighting, fluorescent
ballasts, disconnect unused 1053
ballasts, substitute lower wattage 1057–1063
ballasts, or both? 1057–1058
retrofit applications 1058
selection factors 1060–1063
types of ballasts 1058–1060
current limiters, install 1064–1065
compatibility 1064–1065
how to install 1064–1065
where to consider 1064
lamps & ballasts, remove excess 1046–1049
ballast connection limitations 1046–1047
benefits 1046
disadvantages 1046
fixture labeling 1049
how to disable ballasts 1049
how to remove lamps 1048–1049
illumination levels 1047–1048
outer or inner tubes? 1048
planning 1047–1048
public relations 1048
rewire ballasts between fixtures 1052
socket adapters 1048, 1070
substitute single-tube ballasts 1051
visual quality 1048
where to delamp 1046
See Dummy lamps, fluorescent lamps, substitute dummy lamps 1050
how to install 1050
problems 1050
lamps, substitute lower wattage fixture labeling 1056
selection factors 1054–1056
where to consider 1054
reflector retrofits 1069–1070
energy saving, actual 1069–1070
diffusers, effect of 1481–1482
for downlights 1038
how they don't work 1069
materials 1070
socket adapters for 1070
Lighting efficiency improvements, incandescent. See also Lighting, incandescent
dimmers, install 1042–1043
efficiency limitations 1042
electrical interference 1043
placards for 1043
types of dimmers 1042–1043
exit signs, replace with fluorescent or LED 1041–1042
fixtures, improve shades 1036–1037
fixtures, install flexible extensions in 1039
fixtures, install reflective inserts 1038
fixtures, replace with fluorescent or HID 1040
lamps, reduce wattage 1023–1024
fixure labeling 1023
lumen degradation, account for 1023
planning 1023
with dimmers 1024
lamps, substitute compact fluorescent 1025–1030
energy saving 1025, 1026
fixture labeling 1030
limitations 1026
selection factors 1026–1030
service life 1025
lamps, substitute to minimize light loss 1033–1035
fixture labeling 1035
lamp options 1033–1034
selection factors 1034–1035
lamps, substitute tungsten halogen 1031–1032
applications 1031
fixture labeling 1032
limitations 1031
selection factors 1031
rheostats, eliminate 1091–1092
Lighting, efficiency standards. See Efficiency codes, laws & standards
Lighting, fixture layout
& reflective space surfaces. See Lighting, reflective space surfaces accommodate all activities 1139–1141
applications 1139–1140
avoid duplication 1140
area lighting 1131

circuit layout 1141–1143
cost 1142–1143
for convenient control 1145–1146
for daylighting 1107, 1142
methods 1142–1143
relay systems 1143, 1144
with programmable controller 1144
cove lighting 1132
downlights 1132, 1135–1136, 1139
eergency lighting 1139
exterior lighting 1132
glare, avoiding 1431
glare shields 1431
indirect lighting 1136–1138
inside ceiling plenum 1138
light distribution pattern 1481–1482
maintenance lighting 1140
relocate fixtures 1133–1134
remove excess fixtures 1130–1132
appearance 1131
applications 1131–1132
visual quality 1130–1131
substitute more efficient fixtures 1135–1138
task lighting. See Task lighting
transit lighting 1139, 1142
wall washers 1132
Lighting, fluorescent 1443, 1459–1469. See also Lighting efficiency improvements, fluorescent & daylighting 976
ballasts, electronic
& lamp efficiency 1464, 1468
dimming with 1468
efficiency 1059–1060
electrical interference 1062, 1443
frequency of lamp current 1061
harmonic distortion 1062–1063, 1443
how they work 1467–1468
lamp connections 1061
noise 1062, 1443
power factor 1062
reliability 1063
retrofitting 1060
service life 1063
ballasts, hybrid 1060, 1467
ballasts, in general 1467–1468
ballast efficiency factor (BEF) 1061
ballast factor 1060–1061
certification 1063
crest factor 1061–1062
efficiency 1061
energy losses 1440–1443
filament operation 1061
harmonic distortion 1062–1063
lamp compatibility 1060
purpose of 1467
temperature, starting 1062
wattage rating 1060
ballasts, magnetic
capacitor, power factor correction 1467
capacitor, starting 1467
efficiency 1467
how they work 1467
lamp connections 1061
noise 1062, 1443
power factor 1062, 1443, 1467
reduced-wattage 1059
reliability 1063
service life 1063
color rendering 1441–1443
phosphors, effect on 1461
compact fluorescent units
ballast efficiency 1440–1443
color, lamp 1441–1443
color rendering 1029, 1441–1443
dimensions 1028
efficiency 1027, 1437–1443
electrical interference 1029, 1443
for task lighting 1128
harmonic distortion 1029–1030, 1443
light distribution pattern 1028, 1442–1443
lumen degradation 1437–1443
lumen output 1026–1027, 1437–1443
noise 1443
power factor 1443
quality 1027–1028
reflector lamps 1034
replacing incandescent lamps 1440. See also Lighting efficiency improvements, incandescent: lamps, substitute compact fluorescent
screw-in extension lamps 1034
service life 1027–1028, 1437–1443
temperature, effect on output 1029, 1442–1443
temperature, starting 1029, 1442–1443
time to restart 1442–1443
time to start 1442–1443
tube replacement 1029
dimming 1066–1068, 1440–1443
ballasts for 1061
equipment for 1067–1068
how it works 1067
lamp compatibility 1067–1068
reliability 1068
turndown 1066–1067
where to consider 1066
evapor pressure 1045, 1468–1469
for task lighting 1128
frequency of lamp current 1463–1464
how it works 1459–1464
lamp components 1459–1464
activators 1461
argon 1461
buffer gas 1461–1464
electrodes 1459–1460, 1463–1464
filaments 1061
krypton 1463
mercury 1459–1460
phosphors 1459, 1460–1461, 1463
starting gas 1463
lamps
ballast compatibility 1055
color, lamp 1055–1056, 1441–1443
color rendering 1435, 1441–1443
cost 1056
efficiency 1055
filament operation 1055
high-efficiency, characteristics 1054–1056
light distribution pattern 1442–1443
lumen degradation 1437–1443
lumen output 1055, 1437–1443
mercury in 1460
mounting position 1443
names for 1465
reduced-wattage, characteristics 1054–1056
service life 1056, 1437–1443
substitution & mismatch 1440–1443
temperature, operating 1056
temperature, starting 1056
time to restart 1442–1443
time to start 1442–1443
types of lamps 1464, 1465
voltage sensitivity 1056
wattage 1055
light output 1460
maintenance. See Lighting, maintenance
mercury in 1460
socket types 1155
spectrum
effect of phosphors 1460–1461
of typical lamps 1461
ultraviolet 1459–1460
visible 1460–1464
starting aid 1468
starting methods 1468
instant-start 1463, 1468
preheat 1463, 1468
rapid-start 1463, 1468
starter 1468
trigger-start 1468
temperature, effect on output 1442–1443
temperature, operating
effect on efficiency 1464
effect on output 1464
temperature, starting 1442–1443
Lighting, HID 1471–1480. See also Lighting efficiency improvements, HID
& daylighting 976
ballasts
& capacitors 1076
& ignitors 1076
ANSI code 1075
capacitor, power factor correction 1475
color rendering, incandescent: lamps, substitute compact fluorescent
tube replacement 1029
constant wattage autotransformer (CWA) 1075, 1474–1475
control connections 1076
conversion kits 1073
crest factor 1075
distance from lamp 1076
efficiency 1076
electrical interference 1443
electronic 1076
emergency lighting connections 1076
ergy losses 1440–1443, 1480
fixtures per circuit 1075
harmonic distortion 1443
lamp compatibility 1075
lamps per ballast 1075
noise 1443
power factor 1076, 1443, 1475
purpose of 1474
reactor 1075, 1076, 1474
service life 1076
temperature, starting 1076
voltage sensitivity 1075

capacitors 1076
dimming 1079–1080, 1440–1443
applications 1079
controls for 1080
effect on color 1080
effect on mounting position 1080
effect on operating temperature 1080
efficiency 1080
electronic dimming 1079
step dimming 1079
turndown ratio 1079–1080
efficiency, of ballasts. See herein
ballsast

efficiency, of lamps. See herein
lamps, by type
environmental problems 1468–1469
fixtures
labeling 1077
selection factors 1076–1077
for task lighting 1128–1129
how it works 1471
ignitors 1076, 1475
lamps, high-pressure sodium 1476–1478
& igniters 1478
color, lamp 1441–1443
color rendering 1074, 1441–1443, 1479
construction 1471–1474
efficiency 1074, 1476–1478, 1479
light distribution pattern 1442–1443
lumen degradation 1437–1443
lumen output 1074, 1437–1443
mounting position 1074–1075, 1443, 1478
service life 1075, 1437–1443
spectrum 1471, 1476–1478
starting gases 1471, 1478
substitute for mercury vapor 1078–1079
substituting for mercury vapor 1478
temperature, operating 1075
time to restart 1442–1443, 1475
time to start 1442–1443

lamps, mercury vapor 1475
color, lamp 1441–1443
color rendering 1074, 1441–1443, 1479
color rendering index 1475
color temperature index 1475
construction 1471–1474
efficiency 1074, 1475, 1479
hazard, ultraviolet 1474
light distribution pattern 1442–1443
lumen degradation 1437–1443
lumen loss 1475
lumen output 1074, 1437–1443
mounting position 1074–1075, 1443, 1478
service life 1075, 1437–1443
spectrum 1471, 1475
starting electrode 1475
starting gas 1471, 1475
substitute for mercury vapor 1078–1079
substitution & mismatch 1440–1443
temperature, operating 1075
time to restart 1442–1443, 1475
time to start 1442–1443

lamps, metal halide 1475–1476
& igniters 1476
color, lamp 1441–1443
color rendering 1074, 1435, 1441–1443, 1479
construction 1471–1474
efficiency 1074, 1475, 1479
hazard, explosion 1476
hazard, ultraviolet 1474
light distribution pattern 1442–1443
lumen degradation 1437–1443
lumen loss 1476
lumen output 1074, 1437–1443
metal vapors used 1475–1476

mounting position 1074–1075, 1443, 1476
phosphors 1471, 1475
service life 1075, 1437–1443, 1476
spectrum 1471, 1475
starting gas 1471, 1476
substitute for mercury vapor 1078–1079
substitution & mismatch 1440–1443
temperature, operating 1075
time to restart 1442–1443, 1476
time to start 1442–1443

lamps, not requiring ballast 1475
photocontrol, limitations with 1105
socket types 1155
temperature, effect on output 1442–1443
temperature, starting 1442–1443

Lighting, incandescent. See also Lighting efficiency improvements, incandescent advantages 1021
color, lamp 1451
color rendering 1435, 1449–1450
compared to sunlight 1449–1450
definition 1447–1448
dimming 1042–1043, 1440–1443
efficiency limitations 1042
electrical interference 1043
rheostats, eliminate 1091–1092
types of dimmers 1091–1092
temperature, effect on output 1442–1443
temperature, starting 1442–1443

filament materials 1450–1453
filament temperature, effects 1450–1451
service life 1451
filament type 1453, 1457
& focussing 1453
& light distribution pattern 1453
low-voltage 1452–1453, 1453
shock resistant 1453
vibration resistant 1453
how it works 1447–1448, 1448
lamps, all types
base types 1457
bulb shapes 1457
color, lamp 1441–1443, 1451
color rendering 1441–1443
color-corrected 1024
decorative options 1443
gases in 1451
light distribution pattern 1442–1443
lumen degradation 1437–1443
lumen output 1437–1443
mounting position 1443
naming of 1457
service life 1437–1443
substitution & mismatch 1440–1443
tinted 1024
lamps, conventional
Class B & Class C 1453–1454, 1457
krypton filled 1025
lamps, reflector
ellipsoidal reflector 1034
PAR (parabolic) 1033–1034
R-series 1033
lamps, tungsten halogen 1451–1452
cleaning 1152
color temperature 1032
efficiency 1032, 1452
infrared reflecting coatings 1452
krypton in 1025
light distribution pattern 1032
safety hazards 1452
service life 1032, 1452
low-voltage 1452–1453
lumen degradation 1453–1454
service life 1451, 1453–1454
comparison (table) 1454
socket types 1155
spectrum 1449
ultraviolet 1451
Lighting, low-pressure sodium 1478–1479
ballasts
electrical interference 1443
energy losses 1440–1443
harmonic distortion 1443
noise 1443
power factor 1443
lamps
buffer gas 1479
color, lamp 1441–1443
color rendering 1077, 1441–1443, 1479
construction 1479
efficiency 1077, 1478–1479, 1479
light distribution pattern 1442–1443
lumen output 1437–1443
operating temperature 1479
service life 1075
starting gas 1479
substitution & mismatch 1440–1443
time to restart 1442–1443, 1479
time to start 1442–1443, 1479
temperature, effect on output 1442–1443
temperature, starting 1442–1443
Lighting, maintenance
cleaning 1152–1153
& group relamping 1152
energy saving 1152
halogen lamps 1152
how often 1152
materials for 1152
safety 1152
fixture labeling 1155–1157
methods 1156
what to do 1156
where to do it 1156
why to do it 1155
fluorescent fixtures 1083
group relamping 1437–1443
replace darkened diffusers 1153–1154
changing light distribution pattern 1153–1154
diffuser materials 1153
energy saving 1153
where to find replacements 1154
task lighting 1121
Lighting, measurements 1423–1424
brightness 1424
candela 1423–1424
candle 1423–1424
candlepower 1423–1424
footcandle 1423
footlambert 1424
illuminance 1423
lumen 1423
luminance 1424
lux 1423
Lightweight concrete, as insulation. See Insulation, types: lightweight concrete
Lithium bromide 1325
Load calculations 1240
Load shedding
with photovoltaic systems 1272
Load-commutated inverter 1355
Loading dock seals. See Dock seals
LonMark 1226
LonWorks 1226
Louvers, for air handling
systems. See Air handling systems: envelope penetrations, improve
Louvers, for shading. See Shading, to reduce cooling load
Low-emissivity (low-E) coatings
for glazing 937–938
for solar control films. See Film, solar control
Low-temperature distribution systems
disadvantages of 432–433
with cooling storage 432–433
Low-voltage lighting. See Lighting, incandescent: low-voltage
Lumen (definition) 1423. See also Lighting, measurements
Luminance
definition 1424. See also Lighting, measurements
Lux. See also Lighting, design issues; Lighting, measurements definition 1423
M
Magnesium, in boiler water 144, 145–146
Makeup air. See Ventilation, outside air
heat recovery. See Heat recovery, from building exhaust air
Makeup water, boiler. See Condensate systems
Marking. See Placards
MCA ratings (for boilers) 1295
Mercury
characteristics, for lighting 1460
environmental hazard 1045, 1468–1469
in fluorescent lighting 1045, 1459–1460
in HID lighting 1471
in low-pressure sodium lamps 1479
in mercury vapor lamps 1475
in metal halide lamps 1475
Metering, electricity. See Electricity pricing
Methane
fuel properties of 1247–1249
Microwave personnel sensors. See Personnel sensors: microwave
Midgely, Thomas 1332, 1335
Mineral wool insulation. See Insulation, types: mineral fiber
Montreal Protocol 1333–1334
Motion sensors. See Personnel sensors
MotorMaster computer program 1166
Motors, AC induction
- efficiency
  - & operating temperature
  - & starting current
  - & voltage
  - comparative characteristics
  - estimating, for existing motors
  - in new construction
  - part-load
  - standards
- enclosure types
- energy consumption by fractional-horsepower
- frame types
- high-efficiency
  - construction features
  - cost premium
  - savings potential
- how to select
- insulating, for existing motors
- in new construction
- part-load
- standards
- test methods
- types of multi-speed motors
- NEMA Designs
- operating temperature
  - & altitude
  - & ambient temperature
  - & dirty environments
  - & efficiency
  - & frequent starts
  - & load
  - & phase balance
  - & power quality
  - & variable-frequency drives
- power factor
- rewinding
- service factor
- single-phase
- sizing
- speed of induction motors
  - & number of poles
  - & power frequency
  - full-load
  - slip
  - synchronous
  - starting current
  - temperature ratings
- of insulation
- torque characteristics
  - & full-load speed
  - & NEMA Designs
  - & service factor
  - breakdown torque
  - full-load torque
  - locked-rotor torque
  - pull-up torque
  - starting torque
  - variable-frequency drives
  - voltage
- voltage stress

Motors, direct-current (DC)
- See Drives, direct-current (DC)

Motors, dual drives
- See Drives, multiple-motor

Motors, high-efficiency, install
- See also Motors, AC induction

Motors, multi-speed
- See Motors, AC induction: multi-speed

Motors, wound-rotor
- efficiency
  - how they work
  - slip energy recovery
  - speed control
  - turndown ratio
  - windings

Movable insulation
- description

Mud room
- 819

Multi-speed motors
- See Drives, multi-speed motor; Motors, AC induction: multi-speed

N

National Fenestration Rating Council
- 943

Natural gas
- & fireside cleaning
- See Boiler plant maintenance: fireside cleaning; Soot blowers
- burners for
- See Burner systems, fuel
- cleaning of gas-fired furnaces
- See Economizers, boiler fuel for high-efficiency boilers
- fuel for high-efficiency furnaces
- fuel for high-efficiency water heaters
- fuel properties

Navy showers
- 450

NEMA motor efficiency ratings
- 1167–1169

Net output (boiler rating)
- 1295

Non-fossil energy sources
- See Biomass combustion
- See Geothermal systems
- See passive solar heating
- See Solar heating, passive
- See Photovoltaic systems
- See Solar cooling
- See Solar heating, active
- See Solar thermal power generation
- See Solar thermal power systems
- waste product combustion

Notching, in variable-frequency drives
- 1360, 1361, 1364
Optimum-start controls
Orifice flowmeters
Open-loop controls
Passive infrared motion sensors
Orifice traps. See Steam traps
Orifice, refrigerant metering
Orifice, refrigerant purge units
Passes, in boilers
Passive infrared motion sensors. See Personnel sensors: infrared
Passive solar heating. See Solar heating, passive
Peak shaving
with cooling storage
Perlite. See Insulation, types: perlite
Personnel sensors 1205–1212
adaptability 1211
audible sound 1206–1207
coverage pattern 1208–1209
daylight override 1210
delay in turning off 1210
electrical characteristics 1211–1212
false activation 1210
for air handling systems 513–514
for heating & cooling units 714
for lighting control 1109–1110, 1208
for quick-acting vehicle doors 852–853
for urinals 453
how to cover large areas 1211
how to install 1207–1212
how to limit area of control 1210
how to select 1207–1212
infrared 1205–1206
light beam 1206–1207
microwave 1206
mounting location 1209–1210
overrides for 1211
passive infrared 1205–1206
placards for 1212, 1215
range 1208–1209
safety issues 1207–1208
sensitivity 1208–1209
sensitivity to space layout 1211
sound sensing 1206–1207
tread switches 1206
types 1205–1207
ultrasonic 1206
where to use 1205
Petroleum. See Fuel oil
Phase balance, electrical power
& motor failure 1172, 1173–1174
causes of imbalance 1173–1174
Phosphors. See Lighting, fluorescent; Lighting, high intensity discharge
Photocontrols
for exterior lighting. See Lighting, control of: by photocontrol, for exterior
for interior lighting. See Lighting, control of: by photocontrol, for interior
Photoelectric controls. See Photocontrols. See also Light beam switches
Photography, lighting for 1441
Photons
in incandescent lighting 1447–1448
in light emission 1447–1448
Photovoltaic systems 1271–1273
applications 1272
connection to public utilities 1273
development status 1272
economics 1273
environmental issues 1273
generating capacity 1272–1273
photovoltaic cells 1272
PURPA, effect of 1273
system types 1272
Pilot light. See Burner systems, fuel
Pipe tunnels
limit ventilation to conserve heat 216–217
pipe insulation in 213
Placards 1213–1217
appearance 1089, 1216
ccontent of 1214
coordination 1089
examples of 1214–1215
for air handling system controls 584, 641, 643
for air handling system time controls 512, 514, 515
for boiler heat collecting hoods 223
for boiler plant scheduling controls 21, 32
for chilled air temperature setting 608
for chiller plant scheduling controls 248
for door openers 832
for door stops 812
for door switches 716
for efficient water use 450
for evaporator isolation valves 258
for fan speed controls 592
for flushing water heaters 471
for heat pump loop systems 790
for heating & cooling units 704–707
for hot water temperature 460
for interruptible water heating 475, 478
for kitchen fan 1214
for light fixtures 1023, 1030, 1032, 1035, 1049, 1050, 1053, 1056, 1063, 1065, 1077, 1078–1079, 1130, 1155–1157, 1215
for light shelves 1005
for lighting controls 1086–1089, 1094
appearance 1089
for daylighting 1107
for photocontrols 1107
for programmable controllers 1144
for timed-turnoff switches 1112
how to design 1086–1087
materials 1089
where to install 1086, 1087–1089
why needed 1086
for lighting dimmers 1043
for motion sensor controls 1215
for openable windows 1214
for passive solar heating 1011
for personnel sensors 1212
for quick-acting vehicle doors 853
for radiator controls 723
for refrigerant controls 723
for refrigerant liquid level indicator 343
for refrigerant purge units 351
Preheat coils. See Air handling systems: freeze protection

Pressure, building
& building penetrations. See Air handling systems: envelope penetrations, improve
ability of air handling system to control 522, 524, 533, 548
improvement of 532–537
effects of 519–521
how to measure 525

Priming, in boilers. See Water treatment, boiler water

Programmable lighting controls. See Lighting, control of
Programmable thermostats 1202

Propane
fuel properties of 1247

Propeller flowmeters 1233–1234

Proportional-integral-derivative (PID) controls. See Controls, characteristics of: proportional-integral-derivative (PID)

Public Utilities Regulatory Policies Act (PURPA)
and hydropower 1278
and photovoltaic systems 1273
and wind power 1276

Pulse width modulation (PWM) drives. See Drives, variable-frequency

Pump curves. See Pumps, centrifugal

Pumping, hot water recirculation 492–494
how to control 493–494
insulation, effect on pump power 493
pump energy requirement 492–493
purpose 492

Pumping, service water pressure 480–483, 484–487, 488–491
analysis of system energy use 481
exploit utility pressure 482–483
for hot water 483
improving, with multiple pumps 484–487
adapting to changing water usage 484–485
adapting to various pressure needs 485–486
minimizing pressure fluctuation 484–485
pump sequencing 484
reserve pumps 484
variable-speed pumps, not 486
improving, with pressurizing tank 488–491
cost 488
efficiency 488
freeze protection 491
how to select capacity 490
how to select pumps 490
pressure fluctuations 489–490, 490
tank, closed pressurizing 490
tank, gravity 489–490
pressure requirements 482
where to improve 480

Pumping traps 165

Pumping, variable-flow, chilled water 319–329
CHW temperature reset, effect of 325
control of chiller loading 324, 326–327
energy saving 321–322
higher chiller efficiency 321–322
less pump energy 321
reduced cooling load 322
layout, basic 319–321, 322–325
bypass line 324
distribution pumps, control of 324–325
evaporator check valves 323
evaporator circulation pumps 323
features of 319–321
starting & stopping, chillers & pumps 323–324
throttling valves on loads 323
layout, variations 325–329
chiller ahead of bypass line 327–328
chiller in return line 328
diverse load pressures, accommodating 325–326, 326
ganged evaporator pumps 325
mixed chiller types 325
preferential chiller loading 327–328, 328
when connecting chiller plants 328–329
whether to install 319, 322
Pumps, centrifugal 1339–1345
affinity laws 1340
efficiency 1340–1341
& impeller compromises 1344
& internal leakage 1345
& liquid viscosity 1344
& mechanical friction 1345
& pump size 1344
& specific speed 1180, 1344
& surface roughness 1345
how to select for efficiency 1344–1345
flow rate 1339
how they work 1339
how to adjust output 1340
impeller 1339
pump characteristics, effect on 1339–1340
impeller trimming 1178–1182, 1340
& system improvements 1182
analysis of 1178
for chilled water pumps 318
for service water pumping 495
how to accomplish 1182
how to calculate 1181–1182
where to consider 1178, 1180
multi-stage 1339
names of types 1339
operating point 1340–1341
power input 1339
formula for 1342
pressure output 1339
pump curves 1342
flatness of 1342
specific gravity, effects of 1339–1340
specific speed 1344
suction head (NPSH) 165
system curves 1180, 1343–1344
throttling output 1183–1185
analysis of 1183
for chilled water pumps 319
how to measure saving 1185
how to set 1185
valves for 1183–1185
where to consider 1185
Pumps, steam-powered condensate movers 165
Purge cycle, air handling system 553–554
how to control 553–554
humidity problems 553
in VAV systems 554
where to consider 553
Purge units, refrigerant 1301
for ammonia 350–351
how they work 348–349
install efficient units 350–351
advantages of 350
operate properly 347–350
energy saving 347
how to check 349
refrigerant loss from operation 349
system damage from neglect 347–348
with idle chillers 349
where they are needed 347
PURPA. See Public Utilities Regulatory Policies Act
PWM (pulse width modulation) drives. See Drives, variable-frequency
Pyrolytic coatings. See also Low-emissivity (low-E) coatings
description 938
durability 938, 942
efficiency 938
Pyrometers 1230–1231
Quartz lamps. See Lighting, incandescent: lamps, tungsten halogen
R-value. See Thermal conductivity
Radiation, heat. See Heat: radiation
Radiator air flow, ensure adequate 725–727
control, of steam units
vacuum condensate system. See Vacuum condensate systems
why difficult 731–732
control, provide localized 738–739
control, to minimize operation. See Heating & cooling units, minimize operation
control valves, manual improve access 724
replace with thermostatic. See Radiators: control valves, thermostatic
control valves, thermostatic accommodate vacancy 722
energy saving 721
location 722
maintenance requirement 723
types of thermostatic valves 721–722
definition 719
electric, eliminate 736–738
alternative heating equipment 737–738
cost saving 736
fuel availability 736–737
heat trapping against wall, avoid 727
insulate from wall
energy saving 729
how to do it 730
where it matters 729
knocking, cause of 731
steam, convert to hydronic 733–735
alternative heating units 734
benefits 734
energy saving 733–734
expansion tank 735
pumps 735
thermostatic controls 735
using existing boilers 734
using existing piping 734
using existing radiators 734–735
with VAV systems 622
Radon
building pressure, effect on intake 520
danger of 565
description 565
entry through air handling systems 565
from soil 565
from water sources 565
reducing, by increased ventilation 521
removal, by carbon filter 541
where it occurs 565
Ratchet charges, electricity 1255
Rate schedules, electricity 1251–1253
Reactor ballasts, for HID lighting 1474
Receiver, refrigerant
adding to system 345–346
description 1301
in liquid overfeed systems 1317
liquid level indicator in 343
purposes of 345
Recirculation, hot water. See also Pumping, hot water recirculation & water temperature 460
infection hazard 459
Recirculation, in heat rejection equipment. See Heat rejection equipment, efficient installation: avoid air recirculation
Reflectance, reflectivity (of light) 1286–1287
Refrigerants  1331–1338
  Refrigerant charge
  effects of improper  342
  how to measure  342–345
  condensate subcooling  345
  evaporator line sight glass  345
  refrigerant level indicators  342–343
  refrigerant pressures  343–345
  suction superheat  345
  maintain proper  342–346
  how to add refrigerant  346
  whether to add receiver  345–346
Refrigerants  1331–1338
  availability  1334–1335
  CFC (chlorofluorocarbon)  1333–1335
  azeotropes  1335
  charge. See Refrigerant charge
  chlorine in  1333–1334
  definition  1299, 1332
  efficiency characteristics  1303, 1305
  energy efficiency  1337
  & global warming  1337
  environmental issues  1331–1338
  explosion potential  1337–1338
  flammability  1337–1338
  global warming potential (GWP)  1336–1338
  halocarbon  1332–1338
  HCFC (hydrochlorofluorocarbon)  1333–1338
  HFC (hydrofluorocarbon)  1333–1338
  how to select  1334–1338
  latent heat  1332
  leakage. See Cooling system
  leakage
  factors causing  1336
  in ozone depletion  1336
  mixtures  1335
  naming system  1332–1333
  ozone depletion potential (ODP)  1335–1336
  phase-out of chlorine-containing
  1333–1334
  Clean Air Act schedule  1333
  Montreal Protocol schedule  1333–1334
  pressure, condensing  1338
  pressure, evaporating  1338
  properties of  1331–1332
  purge units for. See Purge units, refrigerant
  selecting  1300
  specific heat  1332
  substitution of types  1333–1334
  when replacing compressor  334
  superheat  398
  toxicity  1337
Refrigeration. See Cooling
Reheat, in air handling systems. See also Air handling systems, by type
  economizer cycle, effect on savings  547–548
  Relief air. See also Exhaust air
  definition  528
  heat recovery. See Heat recovery, from building exhaust air
Renewable energy sources. See Non-fossil energy sources
Reserve equipment. See Standby equipment
Rod cells (vision)  1429, 1434
Roller shades. See Shading, to reduce cooling load: by internal fixtures
Roof hatches, install efficient  869–870
  ease of use  869
  how to install  869
  how to select  869
  maintenance  870
  signage for  869
Rotameters  1235–1236
  Rotary cup burners. See Burner
  systems, fuel: types: oil, rotary cup
Runaround loop  559. See also Heat recovery, from building exhaust air
Rundown timers. See Timed-turnoff switches
S
  Sample cooler, boiler water  149
Saybolt Seconds  175
Screw compressors. See Compressors, cooling, screw
Scroll compressors. See Compressors, cooling, scroll
Scroll housing dampers, for fans  1191
Scrubbers, flue gas  1250
Seasonal energy efficiency ratio (SEER). See Efficiency ratings, cooling
SEER. See Efficiency ratings, cooling
Sensors
  air flow, to control air handling systems  525, 534–536
  enthalpy. See Enthalpy
  flue gases
  for boiler efficiency testing. See Boiler efficiency testing
  for controlling air-fuel ratio. See Air-fuel ratio: automatic controls
  for flow measurement. See Flow measurement
  indoor air pollutant, to control ventilation  530
  motion. See Personnel sensors
  outside air
  how to install  247–248
Series-connected evaporators  1320–1321
Service factor (motors)  1169
Service water. See Water, service
Setback thermostats. See Thermostats: setback
Setpoint. See Controls, characteristics of
Sex, safe  51
Shading coefficient
  definition  932
  of internal shading devices  932
Shading, to reduce cooling load
  azimuth, need to determine  927
  by external fixtures  919–929
  & daylighting  922
  & fire egress  927
  & passive solar heating  923
  & property lines  927
  appearance  923
  attachment  925
  awnings  920–921
  balconies  919
  controls for movable  925
  design issues  921–927
  eaves  919–920
  energy saving  919
  horizontal shelves  919
  longevity  923–925
  louvers  920, 921
  mesh materials  921
  methods  919–921
  orientation  927
  overhangs  919–920
  penetrations of wall  927
  removable  925
  roll-up blinds  921
  sheathing  956
  vertical fins  920
  view, effect on  921
  where to consider  919
by internal fixtures 930–933
& daylighting 930, 932
& fire egress 932
& heat loss 930
& passive solar heating 930–932
appearance 932
controls for movable 932
design issues 932
draperies 931
ergy saving 930, 932
glare 932
installation 932
longevity 932
louvers 931
methods 931–932
orientation 932
roller shades 931
venetian blinds 931–932
vertical blinds 931–932
view, effect on 932
where to consider 930
within glazing units 940
by reducing glazing area 949–951
& daylighting 950
& passive solar heating 950
appearance 950–951
ergy saving 949
how to plan 949–951
security benefit 951
view 950
where to consider 949
by solar control film. See Film, solar control
by surface finish 954
absorption 955–956
emittance 955–956
energy saving 955
how to select 956
sheathing 956
where to use 954–955
by trees & foliage 961–964
& daylighting 961
& passive solar heating 961
appearance 961
disadvantages 961–962
energy saving 961
energy saving, delay 961
how it works 962–963
how to preserve 964
how to select species 963
maintenance required 962
subsidies for 964
usable space, increasing 961
where to consider 961
where to plant 963
reflection from adjacent features 928
shading by adjacent objects 928
to reduce demand charges 917
Shower heads
& efficient faucets 446
flow restrictors, avoid 447
install efficient 445–448
cost 445
ease of use 446
how to select 447
integral valve, avoid 446
personal preferences 445–446
spray characteristics 445–446
water saving 445
maintenance 441–442, 447
Showers
encourage efficient use 450
faucets, efficient 448–449
Sick building syndrome
& envelope insulation 1397
& envelope penetrations. See Air handling systems: envelope penetrations, improve & ventilation 521
air cleaning to avoid 539–546
microorganism growth in cooling coils 544
microorganism growth in cooling towers 564–565
Signs. See Placards
Silicates, in boiler water
144, 145, 148
Silicon controlled rectifier (SCR) 1355
Skylights. See Daylighting, by skylights. See also Glazing passive heating with. See Solar heating, passive
Slip energy recovery, wound-rotor motors 1375
Slip, in AC motors 1347
Sludge
in boilers 143, 144
in fuel oil storage 179
Slurry ice storage systems 424–426, 426–427
Smart building controls. See Energy management control systems
Smoke production, of insulation materials 1396
Socket adapters
for fluorescent fixtures 1048, 1070
Soda-lime process 146
Soft start
in variable-frequency drives 1367
Softening, water. See Water treatment, boiler water
Soil
as heat sink and heat source. See Heat pumps: earth-coupled as insulation. See Insulation, types: soil
Solar collectors 1268
flat plate 1268
focussing 1268
types of collectors 1268
insulated 1263–1264, 1268
used for heat rejection 1263–1264
used with heat pumps 787–788, 1263–1264
cost advantage 792
used with heating storage 403
Solar cooling 1269–1271
Solar heating, active 1268–1271
applications 1269–1270
development status 1270–1271
economics 1270–1271
environmental issues 1271
freeze protection 1269
heating capacity 1271
rejection of excess heat 1269
solar collectors 1268
stagnation temperature 1269
sunlight, characteristics 1283–1287
system components 1268
Solar heating, passive
& tree shading 961
by glazed enclosures 1012–1016
cost advantage 1012
cooling costs, unexpected 1012
design guidelines 1012–1015
economics 1012
heating costs, unexpected 1012
by interior skylight fixtures 1009–1011
design guidelines 1010–1011
economics 1010
by interior window fixtures 1009–1011
design guidelines 1010–1011
economics 1010
comparison with active solar 1415
design issues 1415–1422
appearance 1422
condensation, limiting 1419–1420
development, conventional heating & cooling 1421
control, conventional heating & cooling 1421
control, electric lighting 1421
control, heat output 1421
conventional heating & cooling 1421–1422
cost 1422
daylighting 1415, 1421
distribution of sunlight 1419
electric lighting 1421
energy saving potential 1417–1419
glazing area 1419
glazing location 1419
heat loss, limiting 1419–1420
heat storage, control of 1421
heat storage, location 1421
heat storage, mass 1420
heat storage, materials 1420
longevity 1422
maintenance 1422
snow 1422
system components 1415
thermal lag 1421
water leakage 1422
where to use passive solar 1415–1417
wind 1422

glazing area 950
sunlight, characteristics 1283–1287

Solar thermal power systems 1274
and conventional utilities 1274
capacity 1274
development status 1274
economics 1274
environmental issues 1274
equipment 1274

Solstice 1284–1285

Soot blowers 112–114
& fuel type 112–113
compressed air blowers 113–114
environmental problems 114
for firetube boilers 113
for watertube boilers 113
optimize usage 115
how to schedule 115
steam blowers 112–113
where to install 112–113
with economizers 113

Spare equipment. See Standby equipment

Specific speed (pumps) 1344

Split systems
definition 1302

Split systems (cooling). See also Air conditioners

Sputtered coatings 938. See also
Low-emissivity (low-E) coatings

Stack effect. See Chimney effect

Stack gas. See Flue gas

Stagnation, in air distribution 620

Stagnation temperature (solar collectors) 1269

Standards. See Efficiency codes, laws & standards

Standby equipment, avoid unnecessary operation
by power switching automatic 1195
for more than two units 1194–1195
for two units 1194
rotary switch 1194–1195
transfer switch 1194

Standby losses, combustion equipment 79
& boiler damage 102
explanation 102
convection losses 102
purging losses 102
how to minimize 102
by changing burner type 106
by installing flue damper 104–105. See also
Flue dampers, automatic
by minimizing burner cycling 106–107
minimizing by installing flue damper 802–803
turbulators, effect of 134–135

Standpipe, service water. See also
Pumping, service water pressure:
improving, with pressurizing tank
definition 489

Starter (fluorescent lighting) 1468

Starter, motor
soft starting 590

Starting aid (fluorescent lighting) 1468

Starting gas
in fluorescent lighting 1463

Steam drum (boiler) 1293

Steam pressure. See Boiler steam pressure, minimize

Steam traps
capacity range 195
construction, operation & leakage tendencies
bellows 192–193
bimetallic 192
disc 193–194
float & thermostatic (F&T) 189–190
inverted bucket 191
orifice 194–195
thermodynamic 193–194
therostatic 192–193

cost 196
don't share 197
effects of malfunction 188, 198
energy waste from leakage 188, 198
failure, causes of 188, 198–199
freezing, vulnerability to 196
functions of 138, 187–188
how to select size 196
install most efficient types 187–197
piping details 193, 196
pressure differential 195
pressure, maximum 195
pumping traps. See Pumps, steam-powered condensate movers
reliability 195
repair regularly 198–202
group repair 201–202
how often 201–202
procedures 202
training for 202
size 196
strainers for 196
superheated steam, operation with 196
surge capacity 196
test regularly 198–202
at start-up 201
during warmed-up operation 201
hire testing service 207–208
how often 201
training for 202
testing methods 199–201
audible sounds 199–200
check condensate vents 199
gauge glass on trap 200, 205
infrared imaging 201
permanently installed devices 203–206
preferred test methods 201
proprietary devices 205–206
stethoscope 199–200
temperature 200
test valves 199, 203–205
ultrasonic stethoscope 200
types of steam traps 188–195
venting, cold system 195
venting, warmed-up system 195–196
water hammer, vulnerability to 196

Stefan-Boltzmann Law 1229, 1449

Stoke (viscosity unit) 175

Storm windows. See Glazing: install supplemental

Strainer cycle. See Heat rejection equipment, direct cooling by: by

Stripping. See also Flushing, softening, water conditioning
Strainers, cooling water. See Water treatment, cooling water

Stratification
in air handling systems. See Air handling systems: stratification in fuel oil storage 179

Strip curtains. See Doors, strip curtain

Suction cutoff, reciprocating compressors 1310

Sulfites, for water treatment 146

Sulfur
& acid dew point 1249
& flue gas temperature 1249
as fuel contaminant 1248
heat content of 1247, 1248

Sump heaters, compressor
minimize operation 261, 770

Sun shading. See Shading, to reduce cooling load

Sun trackers, for daylighting. See Daylighting, by light pipes

Sunlight, characteristics 1283–1287
atmosphere, effects of 1283, 1285
color rendering 1434–1435
difficulty in using 913
energy content 913, 917, 1283, 1405
glazing materials, effects 1284, 1286
glazing orientation, effects 1285–1286
infrared component 1284
motion of sun 1284–1285
reflection from exterior surfaces 1287
reflection from smooth surfaces 1287
spectrum 1283–1284
ultraviolet component 1284
visible component 1284
wavelengths 1283
weather, effects of 1285

Superheat, refrigerant
how it reduces COP 1318–1319
in expansion valves 1318

Superheat, steam
economizer selection, effect on 120
interferes with measuring condensate to find leaks 214
steam trap issues
bellows traps, do not use with 192, 196
disc traps, chattering 196
inverted bucket traps, running dry 191, 196
orifice traps, leakage through 194–195, 196, 198
to avoid steam line condensation 214

Superheaters, boiler 1290–1291

Surface water, as heat sink and heat source. See Heat pumps: surface water source

Surge, in centrifugal compressors 1308
limitation on heat recovery 386

Survey, heat loss. See Infrared thermal scanning

Suspended ceilings. See Insulation, for suspended ceiling

Swamp coolers. See Evaporative space coolers

Switches
for heating & cooling units. See Heating & cooling units, minimize operation
for lighting. See Lighting, control of for standby equipment. See Standby equipment, avoid unnecessary operation: by power switching timed-turnoff. See Timed-turnoff switches

System curves, pumping
in general 1343–1344

T

Tank, pressurizing, service water. See Pumping, service water pressure: improving, with pressurizing tank

Task lighting 1119–1129. See also Lighting, design issues: Lighting, fixture layout & lighting of adjacent space 1121, 1122
accommodate all activities 1129
adaptability 1121
advantages 1121
aiming 1124–1126
with fixtures 1124–1125
with reflector panels 1126–1127
as fundamental approach 1020
avoid duplication 1129
bounce lighting 1123–1124
& reflector panels 1124
challenges 1119–1121, 1121–1122
to avoid shadowing at task 1122
cost 1121, 1122
definition 1119
design effort 1122
efficiency 1121
esthetics 1122
fixture mounting 1126–1128
distance from task 1127
for bounce light 1128
on ceiling 1127
on task 1127–1128
requirements 1126–1127
for office work 1128

Sunlight, characteristics 1283–1287
atmosphere, effects of 1283, 1285
color rendering 1434–1435
difficulty in using 913
energy content 913, 117, 1283, 1405
glazing materials, effects 1284, 1286
glazing orientation, effects 1285–1286
infrared component 1284
motion of sun 1284–1285
reflection from exterior surfaces 1287
reflection from smooth surfaces 1287
spectrum 1283–1284
ultraviolet component 1284
visible component 1284
wavelengths 1283
weather, effects of 1285

Supervisors, cooling water. See Water treatment, cooling water

Surfaces, cooling water. See Water treatment, cooling water

Survey, heat loss. See Infrared thermal scanning

Sweat, by water treatment. See Water treatment, cooling water

Temperature
air handling unit discharge
to minimize reheat. See Air handling systems, by type

Superheat, compressor
minimize operation 261, 770

Sun shading. See Shading, to reduce cooling load

Sun trackers, for daylighting. See Daylighting, by light pipes

Sunlight, characteristics 1283–1287
atmosphere, effects of 1283, 1285
color rendering 1434–1435
difficulty in using 913
energy content 913, 917, 1283, 1405
glazing materials, effects 1284, 1286
glazing orientation, effects 1285–1286
infrared component 1284
motion of sun 1284–1285
reflection from exterior surfaces 1287
reflection from smooth surfaces 1287
spectrum 1283–1284
ultraviolet component 1284
visible component 1284
wavelengths 1283
weather, effects of 1285

Superheat, refrigerant
how it reduces COP 1318–1319
in expansion valves 1318

Superheat, steam
economizer selection, effect on 120
interferes with measuring condensate to find leaks 214
steam trap issues
bellows traps, do not use with 192, 196
disc traps, chattering 196
inverted bucket traps, running dry 191, 196
orifice traps, leakage through 194–195, 196, 198
to avoid steam line condensation 214

Superheaters, boiler 1290–1291

Surface water, as heat sink and heat source. See Heat pumps: surface water source

Surge, in centrifugal compressors 1308
limitation on heat recovery 386

Survey, heat loss. See Infrared thermal scanning

Suspended ceilings. See Insulation, for suspended ceiling

Swamp coolers. See Evaporative space coolers

Switches
for heating & cooling units. See Heating & cooling units, minimize operation
for lighting. See Lighting, control of for standby equipment. See Standby equipment, avoid unnecessary operation: by power switching timed-turnoff. See Timed-turnoff switches

System curves, pumping
in general 1343–1344

T

Tank, pressurizing, service water. See Pumping, service water pressure: improving, with pressurizing tank

Task lighting 1119–1129. See also Lighting, design issues: Lighting, fixture layout & lighting of adjacent space 1121, 1122
accommodate all activities 1129
adaptability 1121
advantages 1121
aiming 1124–1126
with fixtures 1124–1125
with reflector panels 1126–1127
as fundamental approach 1020
avoid duplication 1129
bounce lighting 1123–1124
& reflector panels 1124
challenges 1119–1121, 1121–1122
to avoid shadowing at task 1122
cost 1121, 1122
definition 1119
design effort 1122
efficiency 1121
esthetics 1122
fixture mounting 1126–1128
distance from task 1127
for bounce light 1128
on ceiling 1127
on task 1127–1128
requirements 1126–1127
for office work 1128
glare
from light sources 1119
from reflections of light source 1122–1123
glare shielding 1128
& reflector panels 1128
appearance 1128
geometry of 1128
on fixtures 1128
illumination, uniformity of 1119–1121
lamp types for task lighting
compact fluorescent 1128
efficiency 1128–1129
HID 1128–1129
not incandescent 1128
layout
accommodate all activities 1129
aiming fixtures 1124–1126
bounce lighting 1123–1124
do not duplicate fixtures 1129
fixture mounting 1126–1128
glare shielding 1128
reflector panels 1126
"standard" layout 1119–1121
surrounding area, relationship to 1122
to avoid shadowing at task 1122
maintenance 1121
reflector panels 1126–1127
& glare shielding 1128
shadowing, by the viewer 1121
shadowing, within the task 1122
veiling reflections 1119
visual quality 1121

Temperature
air handling unit discharge
to minimize reheat. See Air handling systems, by type
chilled water
  maximize, to increase chiller efficiency. See Chilled water temperature, maximize
combustion air
  air preheater, increase with 126–128
condensing
  chiller heat recovery, effect on. See Heat recovery, from cooling equipment
  lower, to maximize chiller efficiency. See Condensing temperature, optimize
definition of 1229–1230
flue gas
  boiler turbulators, effect of. See Turbulators, for firetube boilers
  flue gas heat recovery, effect on. See Air preheaters, boiler; Economizers, boiler
  for boiler efficiency measurement. See Boiler efficiency testing
for rating cooling equipment. See Efficiency ratings, cooling: rating temperatures
of fuel oil
  adjust, to control viscosity 174–175
of combustion air
  recover boiler room heat 218–223
of hot service water. See Hot water temperature
of pipe tunnels
  maximize, to minimize heat loss 216–217
outside air
  for free cooling, in chilled water systems. See Heat rejection equipment, direct cooling by
  for free cooling, through air handling system. See Air handling systems: purge cycle; Economizers, outside air
to control air handling system running. See Air handling systems, minimize operation: by optimum-start control
to control boiler plant running 25–26
ratings of motors. See Motors, AC induction: temperature ratings setback. See Thermostats: setback supply air setting. See Air handling systems, by type
wet-bulb. See Wet-bulb temperature

Tempering valve, hot water 475
Terminal units. See also Air handling systems, by type
Thermal breaks, glazing 936–937
Thermal conductivity
  of materials. See Insulation, types
  R-value
    definition 1395
    of common materials (table) 1395
  U-value
    definition 1395
Thermal shutters. See Movable insulation
Thermal storage, cooling 405
  applications 406
  benefits 407–409
  chiller capacity, reduced 407–408
  condensing temperature, lower 408
  distribution equipment, smaller 408
  electricity cost, reduced 407, 412
  heat recovery, increased 409, 414
  reserve cooling capacity 408
  chiller capacity for 415
  chiller types for 415
  control strategy 414
deregulation of utilities, effect of 411
design issues, general 431–435
  alarms 416
  charging storage vs. direct cooling 433
  controls 416, 433–435
  distribution system pressure 431–432
  matching distribution temperatures 432–433
disadvantages 409–411
  economic risk 411
  energy losses 409–410
  operational burden 410–411, 411, 412, 416
  space requirement 410, 416
electric vehicles, effect of 411
  evaporator configuration 415, 417–418
  how to approach 411–416
  in heat pump loop systems 781, 794
  load profiles 411
  low-temperature distribution, use with 432–433
  maintenance 416
negotiating with electric utility 412–413
  forgiveness clause 413
  metering arrangements 413
  rates 412
  not an energy conservation measure 406, 409–410
  ownership options 412
  peak shaving with 407
  staffing 416
  status of 406–407
  storage capacity, cooling 407, 414–415
  storage capacity, heat recovery 415
  storage equipment 415, 416
  system connections 416
  system layout 416
  systems, eutectic storage media 430–431
  charge, difficulty of measuring 431
  development status 430
  disadvantages 431
  efficiency 430
  for pre-cooling 431
  heat exchanger limitations 431
  phase change temperature 431
  storage tank 430–431
  volume required 430
  with absorption cooling 431
  with free cooling 431
  systems, ice capsules 423–424
  advantages 424
  capsule freezing problems 424
  discharge characteristics 424
  systems, ice on coil, coil melt 422–423
  advantages & disadvantages 422
  storage unit construction 423
  system connections 423
  systems, ice on coil, external melt 419–422
  advantages 419–420
  alternate use for heat storage 422
  DX storage units 420
  efficiency 419–420
  ice bridging 420
  irregular melting 420–422
  systems, ice shedder 417–419
  advantages 417
  efficiency 418
  evaporator 417–418
  heat exchanger 419
  storage tank 418–419
  systems, ice storage, in general 416–417
systems, liquid chilled water 427–430
combination with heat recovery storage 430
economy of scale 428
efficiency 427
how to measure charge 430
storage using diaphragm in tank 430
storage using multiple tanks 428–429
storage using siphon baffles 429
storage using stratification 429
storage volume required 427–428
temperature matching to distribution system 428
Thermal storage, heated water 400–404
cost saving 400–401
equipment for 401
energy saving 400–401
with solar collectors 403
for cooling equipment heat recovery 400–404
demand charges, effect on 400–401
for preheating service water 402
for space heating 402–403
load profiles 400
storage capacity, how to estimate 401
storage capacity vs. condensing temperature 403
in heat pump loop systems 781, 794
Thermodynamic traps. See Steam traps
Thermos bottle 1387
Thermostatic control valves. See Valves, control
Thermostatic traps. See Steam traps
Thermostats
anticipators 804, 1379
covers, avoid 663
deadband 600–602
& fan cycling 590
in VAV systems 664–666
types 665
hesitation 600–602
let occupants adjust 582
manual heat/cool switching 597–599
placards 1214
programmable 1202
setback
for heating & cooling units 711
for single-zone air handling units 583–584
for VAV systems 667–668
in digital control system 583
individually programmable 583
overrides 668
pneumatic central control 583
types 667–668
space temperature
how to install 739
thermometers with 582
Three-deck multizone systems 652–653
Three-pipe systems. See Fan-coil units: 3-pipe systems, convert
Thyrister 1355
Time controls. See Clock controls
Timeclocks. See Clock controls
Timed-turnoff switches
for air handling systems. See Air handling systems, minimize operation
for heating & cooling units 714
for lighting 1111
types 512, 1111
Toilets
install efficient 451–452
actual performance 451–452
how to select 452
maintenance 441
water usage standards 452
Ton (cooling), definition 1297
Total dissolved solids (TDS)
control with blowdown 148–149
definition 148
in condensate 149
testing for 148–149
Total internal reflection 978
Totalizers 1236
Transfer switch
for lighting
to prevent duplicate lighting 1140
for standby equipment. See Standby equipment, avoid unnecessary operation
Transformers
impedance 1359
Transmittance (of light) 1286–1287
Transpiration 962–963
Tread switches. See Personnel sensors: tread switches
Trees
air pollution, effect on 961
carbon dioxide, effect on 961
for shading. See Shading, to reduce cooling load: by trees & foliage transpiration 962–963
Triple-duct air handling systems. See Air handling systems, triple-duct
Trochoid compressors 1314–1315
Tropic of Cancer 1285
Tropic of Capricorn 1285
Truck dock seals. See Dock seals
Tube sheets, boiler 1289
Tungsten
as lamp filament 1450–1451, 1451, 1451, 1452, 1453–1454
as refrigerant metering device 1301, 1319–1321
Turbine
flowmeters 1233–1234
Turbulators, for evaporator tubes 286–287
effect on flow rate 287
energy saving 286
hazards 287
where to consider 286
Turbulators, for firetube boilers 133–135
cost 133
damage to boiler 135
draft, effect on 134
fireside cleaning, interference 135
how they work 133
standby losses, effect on 134–135
where to consider 134
VVI (variable voltage input) drives. See Drives, variable-frequency.

W

Wall washers (lighting)
eliminate unnecessary 1132
replace with direct lighting 1136–1138
replace with reflective surfaces 1116

Wash basins
confused with urinals 444
efficient fixtures, install 443–445
for private use 443
for public use 443–444
stoppers, maintenance 441

Waste heat
as heat source for heat pumps 787, 1264

Waste product combustion 1280
applications 1280
availability of material 1280
economics 1280
energy content 1280
environmental issues 1280
equipment 1280
types of combustible waste 1280

Water, domestic. See Water, service

Water heaters
anode rods 467
booster heaters 462
direct-contact construction 464
economics 464
efficiency 464
flue 465
water condition 464–466
efficiency characteristics 463–465
efficiency ratings 466
electric efficiency 463–465
energy source, select lowest-cost 462
fast-recovery 466
flue dampers. See Flue dampers, automatic: for water heaters
flues 465, 467
flush scale 471–472
for interruptible heating 475
for storage heating 475
fuel-fired efficiency 463–464
maintenance 470

infection hazards 459
install efficient 463–467
install with lowest-cost energy source 463–467
insulation 465–466
maintenance access 466–467
power venting 467
recovery rate 460
separate, for high-temperature uses 462
steam-powered efficiency 463
tank, non-metallic 467

Water heating
control to reduce demand charges 477–478
interruptible 473
capacity vs. temperature 475
disadvantages 473
electricity rate benefit 473
how often interrupted 473
how to exploit 473–475
informing occupants 475
safety 475
utility motivation for 476
water heaters for 475
recirculation. See Pumping, service water recirculation
solar 1270
storage 473

Water power. See Hydropower, local

Water, service fixtures. See Fixtures, service water pressurization. See Pumping, service water pressure recirculation. See Pumping, hot water recirculation; Recirculation, hot water
temperature setting. See Hot water temperature
water heating. See Water heaters; Water heating

Water testing, boiler water 148–149
for alkalinity 148
for hardness 148
for iron 148
for oxygen 148
for pH 148
for silica 148
for total dissolved solids (TDS) 148–149, 155
sample cooler 149
who should accomplish 151

Water treatment, boiler water 142–149
& blowdown. See Blowdown, boiler & cooling tower water treatment 149
& hydronic system water treatment 149
benefits 142–143
consultant for 150–151
functions of 150
how to select 150
contractor for 150–151
functions of 150
how to select 150
effects of neglect 144–145
carryover 145
corrosion, acid 145
corrosion, alkali 145
corrosion, oxygen 144
damage to sealing materials 145
foaming 145
priming 145
reduced heat transfer 144
scale 144
sludge obstruction 144
tube damage 144
tube fouling 117
equipment for 152–153
chemical feeders 152–153
how to control 152
maintenance 152–153
for hot water boilers 141
hazards 145
methods of water treatment 141, 145–148
to limit carryover
corn starch 148
to limit condensate system corrosion
amines 148–149
dealkalizing 148–149
neutralization 148–149
to prevent acid corrosion
chromates 148
neutralization 148
nitrites 148
to prevent oxygen corrosion
daeraating tank 146
hydrazine 146
sodium sulfite 146
to prevent scaling
chelants 146–148
dispersants 146–148
ion exchange 145–146
phosphates 146
precipitation 146
soda-lime process 146
softening 145–146
zeolite 145–146
to remove dirt
alum 145
coagulants 145
filtration of makeup water 145
what determines need for 143–144
when shutting down boiler 118
who should accomplish 151
Water treatment, condensate. See
Water treatment, boiler water
& boiler water treatment 281
by bleed 280, 283–284
automatic control for 285–286
cost of 283
how to calculate bleed rate 283
by chemicals 280
automatic equipment for 282
by strainers 280
causes of fouling 280–281
consultant for 282
contractor for 282
testing makeup water 284
Waterside economizer. See Heat
rejection equipment, direct
cooling by: by waterside economizer
Watertube boilers. See Boilers: watertube
Waveform distortion, electrical
power
& motor overheating 1172
by fluorescent ballasts 1062–1063, 1443
by HID ballasts 1443
by variable-frequency drives 1360–1361
introduction to 1357–1360
Weatherstripping
for large exterior doors 827–829, 834–835
for personnel doors 809–810
how to install 809–810
for storm doors 819
for windows 861, 940
Well water. See Ground water

Wet-bulb temperature
for control of heat rejection
equipment. See Condensing
temperature, optimize
how to measure 270–271
Wheeling (electricity rates) 1257
Wien’s Displacement Law
1229, 1449
Wind
& building air leakage 1383
effect on air handling systems 565
Wind energy systems 1274–1276
applications 1274–1275
Betz Coefficient 1275
capacity of machines 1275
connection to public utilities 1276
development status 1275
economics 1276
energy availability 1275–1276
environmental issues 1276
equipment 1274–1275
from tethered blimps 1276
ground friction limitations 1276
PURPA, effect of 1276
topographical requirements 1276
wind speeds required 1275–1276
Window treatment. See Shading, to
reduce cooling load
Windows. See also Glazing
for cooling ventilation 550
inset, for shading 920
maintenance 860
openable
types of openable windows 940
weatherstripping 940
passive heating with. See Solar
heating, passive
storm. See Glazing: install supple-
mental
Wood
combustion of. See Biomass
combustion
fuel properties of 1247, 1281
Wound-rotor motors. See Motors, wound-rotor
Z
Zeolite 145–146
Zone changeover controls 749–750