Subject Index

A

Absorptance, surface, thermal effect, 457-458 Absorption, water, 717 Active measurement strategy, thermal performance of walls, 92-93, 94(table), 96-97(tables) Adsorption, water, 717 Aerial thermography, 176, 178, 181-185 Air barrier, discussion, 625 Air change rates, Corry Field units, 386(tables) Air conditioning, 14-20, 560 Air exchange rates, domestic houses, 606(table) Air film resistance, 570 Air flow, 154, 158, 171 Air flow requirements for energy efficiency, 12, 545 Air flow visualization, 171 Air gap systems, 46 Air handler installations, 14, 15(fig.) Air infiltration (see also Air leakage) measurement by tracer gas, 175-176 of building envelope, 124, 125(fig.) Air infiltration tests, 377 Air layer, 283-286 thermal conductivity versus thickness, 290(fig.), 291 Air leakage building envelope, 34, 36, 38 field tests, 644 infiltration tests by tracer gas, sulfur hexafluoride, 377 R value accuracy limitations, 213 simulated experimental procedure, 642 test apparatus, 640, 641(fig.) Air leakage reduction (see also Insulating materials) cellulose wall insulation, 639 insulating materials, flow rate, 643(table) modular retrofit experiment, 647 retrofit, 645(table), 648 standards development

control requirements, 34, 36-37 infiltration, 32-33, 124 thermal transmittance, 683(fig.) thermographic inspections, 180 wood frame walls, 405 Air movements, thermal performance of building envelope, 124 Air permeability, 125 Air pressure changes, face wall, 127 Air space R values for Hi-Hat wall system, 727(table) Air temperature, 573 Air thermal conductivity, 287 Airtightness, 679, 680(fig.) building envelope, 124-125(fig.), 128-129, 616 heat loss reduction, 647 pressure versus air flow measurements, 644 Alarm systems, pressurized monitoring of conduit, 47 Alkalinity, underground pipe systems, 44-45 Aluminosilicate fibers, test specimens for radiation heat transfer, 687 Aluminum jacketing corrugated, vapor barrier design, 74 engineered specifications, 84 on foamed polyurethane insulation, 74, 77-79 Ammonia storage tanks, foam insulation systems, 80 Annual energy budget and usage, 16-18, 19(table), 20 Antifreeze protection, heat-traced systems, 85 Apparent thermal conductivity, 518, 522-523(table), 533(table) Application procedure checklist, thermal insulation materials, 87-88 Army buildings, energy conservation, 214-216 Ash, thermal conductivity, 271(table) ASHRAE handbook procedure, heat loss factor, 134-135 Asphalts application to foam test specimens, 438 roofing insulation, 434

ASTM Committee C-16 on thermal insulation, summary of approach on standards for burn hazard potential, 705 ASTM standardization work proposed standard test method for thermal performance of building components, 718-719 standards development, uniform definition of human burn hazard, 709 ASTM standards (see also Standards) C 76-82: 508 C 177-76: 108, 494, 588, 651, 656, 686 C 201-68: 68 C 202-71(1977): 687 C 236-80: 297, 310, 311, 326, 346, 508, 509, 567, 652, 724, 728 C 518-64T: 653 C 518-70: 651 C 518-76: 423, 478, 494. 521, 527, 656 C 518-80: 311 C 578-83: 520 C 653-70: 655 C 653-83: 652 C 680-82: 709, 710 C 755-73(1979): 75 C 976-82: 323, 346, 508, 567, 583, 586 C 1055-86: 709, 710 C 1057-86: 709, 711 D 9-81: 251 D 95-83: 436 D 226-82: 434 D 245-81: 251 D 250-84: 434 D 312-78: 434 D 1079-83a: 432 D 1165-80: 251 D 2126-75: 524 D 2395-83: 251 D 2555-781: 247, 251 E 84-84: 73 E 96-80: 74-75, 464, 716 E 230-83: 319 E 331-83: 378, 389 E 398-83: 463 E 741-83: 377 E 799-81: 644 ASTM Subcommittee C08.05, round robin analysis for ceramic fiber insulation,

- 686
- Attic air humidity ratios, 631, 632(fig.), 636(fig.)
- measured and predicted, 634, 635(fig.)
- Attic insulation, 210-213, 213-215(figs.)
 - field tests, 217-218, 494-500 standard deviations and means, 502, 503-504(tables)

impact on indoor formaldehyde concentrations, 231-232, 235 loose-fill, densities, 495 low levels, 637 test module, 716, 717(fig.) Attic ventilation, 635 guidelines, 637

Average computed conductivity, comparison of mean data, 248(table)

В

- Backfilling, 46
- Balance point temperature, 554
- Balloon frame construction, air leakage reduction after wall insulation retrofit, 644
- Basement air leakage, 644
- Basement wall/floor heat loss, 132 climatic sensitivity, 142(fig.) Washington, DC, 136-138(figs.), 144-151(appendix tables)
- Beadboard insulation (expanded polystyrene, EPS), 422, 518
- Biguarded thermal hot plate, 286
- Birch, thermal conductivity, 268-269(table)
- BLAST (see Building Loads Analysis and System Thermodynamics)
- Blistering, built up roofing membranes, 432-433, 447
- Block-molded polystyrene insulation, exposure studies, 524-529, 534, 582, 588, 589
- Blower-cyclone-shaker (BSC) test, 500, 501(table, fig.)
- Blown-in loose-fill insulation, 199
- BOCA (see Building codes)
- **Bubbling** phenomenon
- application of hot asphalt, 438
 - roof insulation, 433, 440, 443, 446
- Building codes, 721
 - Florida model energy efficiency code for building construction, 9, 12, 14-15, 20
- Building component characteristics, ASTM test methods for evaluation, 713
- Building component performance, domestic houses, 607
- Building components, test development simulators, 717
- Building component thermal, resistances, 179
- Building design for energy efficiency, 14, 15(table)
- Building design requirements and trade-off approaches, 29

Building design thermal insulation, 679 **Building diagnostics**, 179 Building energy requirements, 341 Building envelope, 29, 639 air infiltration, 124, 125(fig.) air leakage control, 34, 36-38 air movements, 124 air permeability, 125 BLAST program, 544 defects, 310, 680 openings for electrical installations, windows, doors, ventilation, etc., 682 design, 238 energy requirements, 341 exterior of office buildings, thermal resistance, 107 heat flow test procedures, 110-113 heat loads/gains, 203 heat loss, 179, 317 high-solar-gain house, 545 office buildings, 107 pressurization tests for measuring tightness, 175 thermal performance, 107-108, 124-131, 616.679 use of thermal insulating materials, 477 Building heat transfer, 154, 156, 169 Building Loads Analysis and System Thermodynamics (BLAST), 542, 544 Building materials, moisture performance, 616 Building performance optimization, 21-22 code compliance, 9, 29-34 energy analysis procedure, 27-28, 35-36, 341 parameter selection and analysis, heating and cooling, 28 Building Research Association of New Zealand, 94 Buildings heat transfer characteristics, masonry cavity wall, 319 moisture problems, 371 U.S. Army, R values, field investigations, 203 use of thermography to rank heat loss characteristics, 178 Building thermal analysis, 203-210 heat loss calculations, 132 **Building types** army, 205(tables) for energy calculations, 12, 13(table) Built-up roofing/insulation specimens, delamination, 437, 443, 444 Built-up roofing membranes, 432 Burn hazard evaluation, 704-711

design conditions, 710 potential, 705 Burn potential for heated surfaces, 711 Burn protection, 704

С

Calcium carbonate fill, treated in insulating envelope system, 48 Calcium silicate pipe insulation, 46 Calibrated hot box (see also Hot box), 163, 319-325, 346 design considerations, effect of environment, 358 testing, 582, 584(fig.) test apparatus, 585(fig.) vapor barrier, 615 Calibration, 576, 653-654, 658 instrumentation development, 659 Calibration constant versus thickness, R-Matic instrument, 660(fig.) Calibration specimen, 577(fig.) Calorimeter analysis, comparison between four and twelve data points, 694 Calorimeters, 175, 567, 569(fig.), 572 air temperature, 573 design, 573-575 heat flux, 119-120 portable, 108, 109(fig.) water, 686 Calorimeter test data ceramic fiber round robin, 690 thermal conductivity versus mean temperature, 698(fig.) Carrier pipes, cement, 47 Cavity walls, 319 heat transmission characteristics, 339 Cedar, thermal conductivity, 249(table), 268-269(table) Ceilings air leakage, 213 Ceilings (cont.) code requirements, 23(fig.) heat loss due to missing insulation, 120, 180 insulation, 610, 644 retrofit, 646 resistance variations, cause of differences in surface temperatures, 178 standards development, 29, 36 Cellular glass insulation, 48 Cellular plastic insulation, 421, 422-423, 432, 582, 720 Cellular polyurethane, 71 Cellulose insulation air leakage reduction, 643

Cellulose insulation (cont.) density test, 495-498 new construction applications, 642 settling test (BSC test), 500 spray-applied laboratory/field tests, 362-366, 367(table) Cellulose wall insulation effect on leakage, 644, 646(table) retrofit reducing air leakage, 647 Cementitious coatings, vapor barrier design, polyurethane foam insulation, 74 Centre de Recherches Industrielles de Rantigny (CRIR), 161, 284 heat flux transducer, 656 Ceramic fiber insulations, heat transfer, 689 Ceramic fiber round robin, test results, 687, 690 Chlorosulfonated polyethylene (CSPE) mastic, 464 CH₂O (see Formaldehvde) Climate-heating-cost (CHC) parameters, U.S. Army energy savings program, 218 Climatic conditions cold climate studies, 406 effects on heat loss. Mitalas systems for calculating, 134-135, 144-151(tables) influence of airtightness and thermal insulation, 679 Climatic sensitivity, basement wall/floor heat loss, 142(fig.)Closed-cell cellular glass (Foamglas) insulated heat distribution systems, 43-44, 48 Coatings cementitious, 74 for insulated concrete, 45-46, 48 Code compliance procedures, 9, 29-34 Code requirements, comparative assessment. 23-24(figs.)Cold climate studies, 406 moisture levels in test wall panels, 415(fig.) in wood frame walls, 411, 413(table) Cold Regions Research and Engineering Laboratory (CRREL), 422, 428 Cold weather condensation hazard, 615, 625 Combustible cellular plastic thermal insulation. 720 Commercial construction, model energy code compliance procedures, 9, 29-34 Computer model description, TARP program, 542, 550, 565 Concrete cavity walls, 319 temperature and relative humidity, 379, 390 in insulating envelope system, 48

Concrete block cavities, influence on moisture movement, 379, 382, 383(table), 390

- Concrete block wall, uninsulated, thermal resistance, 594-596(table)
- Concrete block wall with drywall laminate system, thermal resistances, 594-595(fig.)
- Concrete block wall with exterior, insulated finishing system, thermal resistances, 589, 593-594, 596(table), 597
- Concrete masonry walls, 582
- Concrete sewer tile for pipe conduits, 48
- Condensation, 371, 395, 397
- attics. 633
- wood-frame walls, 405, 406
- Condensation hazard, 615

decay, 406 discussion, 625

- Condensation potential, metal window frames, 572

Condensation studies conclusions, 416

- data acquisition/recording, 410-411
- moisture levels, 407, 411, 412, 413(table)
- results. 411
- test methods/structures, 407 experimental structure, 408(fig.)
 - R values, wall panels, 409(fig.)
- Conductance, 284-285, 290, 567
- reduction after wall insulation retrofit, 646
- Conduction losses, efficiency measurements, 169-171
- Conductive/radiative heat transfer, 210, 284-285, 290, 639
- Conductivity of wood, North America, major research, 280
- Conduit systems alarm systems, 47 factory fabricated, 47-48
 - field fabricated, 47-48
 - pressurized monitoring, 47
 - underground pipe insulation, 46
- Consensus standard test methods, 713
- Conservation of energy army buildings, 214-216 energy efficiency, 639
 - engineered specifications, 82
- Construction materials (see also Wall system installation), 588
- Construction specifications, federal agencies, underground heat distribution systems, 43
- Contact burn potential, from heated surfaces, 711
- Convection, 284, 570, 572

cold air in attics, 210-211, 213, 214-215(fig.), 219

- from solar wall ducts, 606
- natural, 205, 209-210
- Convection heat transfer
- forced convection, 572
- hot box measurement, 347-349, 395 formulas, 349-354
- wet mineral wool insulation, 399
- Cooling (see Heating and cooling)
- Cooling load, 14-18
- comparison of measured/predicted, 548-549(figs.)
- Copper pipes, 47
- Corrosion cracking, insulated stainless piping, engineered specifications, 86
- Corrosivity, soil criteria for design of underground pipe systems, 44-45
- Corrugated aluminum jacketing, vapor barrier design, polyurethane foam insulation, 74
- Corry Field housing units air change rates, 386(table)
- moisture problems, 372
- Cost-effectiveness, 599
- Counterflow insulation systems (see also Dynamic insulation
- applications France, residential houses, 153
 - Scandinavia, industrial building roofs, 153
 - efficiency, 153, 154
- testing experiments, temperature measurement, 165-168(figs.)
- Cracking, corrosion, 86
- CRIR (see Centre de Recherches Industriele de Rantigny)
- CRREL (U.S. Army Cold Regions Research and Engineering Laboratory), 422, 428
- CSPE (chlorosulfonated polyethylene) vapor retarder mastic, 464

Cypress, 268-269(table)

thermal properties, 238-252, 252-253(table)

D

- Data acquisition, condensation, 410-411
- Data base design methodology, 239, 277-282 thermal properties of wood
 - data analysis, 277-278
 - experimental data, 240
- DBR (Canadian Division of Building Research) calorimeter design, 573-574, 575(fig.)

DBR wall calorimeter, comparison with window calorimeter, 576 Decay, condensation in wood frame walls, 406 Delamination built-up roofing/insulation specimens, 437, 443, 444 roofing membranes, 432 Delsante solution, slab-on-grade heat loss calculations, 132, 134 Density ceramic fiber round robin, 689(table) conductivity correlation, 251, 277 loose-fill attic insulation measurement in situ. 496. 497-499(tables) variations with time, 497 thermal properties of wood, standard deviation of mean, 243(table) Department of Defense (DOD), energy conservation investment program (ECIP), 214 Design criteria, underground piping systems, 44-45 Dew point/dry bulb temperatures, 379 **Domestic dwellings** air exchange rates, 606(table) building component performance, 607 design, 599-600 energy requirements, 607 Doors, standards development, 29, 36 Double glazing, 610 Double vapor barrier, 615 Douglas fir, thermal conductivity, 262(table) Draft barriers, 86 Drainage patterns, underground pipe systems, 44-45 Drainage tests, 377, 386, 387(table) Drywall installation, 588 TGIF and Z-furring, 720 Drywall laminate system, 589, 594-595, 597 Durability, insulating mineral fibers, 477 Dynamic flow of moisture, equation, 633 Dynamic insulation (see also Counterflow insulation systems) experiments test apparatus, 161-162 test wall, 162-163 measurements. 163 parietodynamic insulation, air circulating along wall, 154, 155(fig.) permeodynamic insulation, air circulating through mineral wool as a heat exchanger, 154, 160 temperature measurement, 166-169

theoretical efficiency, equations, 154, 156-161 Dynamic insulation (cont.) thermodynamic insulation, air circulating independent of ventilation system, 154-156 Dynamic performance, 449 Dynamic response behavior, long-term monitoring, 607 wall thermal performance, 91-92, 94-98, 99(table), 100 Dynamic tests test procedures, temperature cycles, 328 test results, 329 Dynamic thermal performance, 94-100 Dynatech R/D Co., R-Matic heat flow meter, 659

Е

Earth contact systems heat loss factor, 134-135 Mitalas heat loss calculations, 132-134 applied to U.S. climate, 143 Earth temperature, climatic conditions in U.S., 134-135 ECIP (see Energy conservation investment Program) Economic analysis, 214-216, 216(table) procedures, modeling parameters, 34 EERS (see Equipment energy efficiency ratios) Elastomeric coatings, polyurethane foam, vapor barrier design, 74 Elastomeric membrane, 422 Electrical installations, cause of building envelope penetrations, 682 Electrical resistance of wood, 617 Electric resistance heating, heat tracing medium, 85 Elm, thermal conductivity, 267(table) Emission rates, formaldehyde, 224 Emissivity, 284, 287, 291 effect on heat loss, 84 EMTL (see Energy Materials Testing Laboratory) **Energy analysis calculations** building types, 12-13 parameter selection and analysis, heating and cooling, 28 Energy analysis/performance criteria, 27-28, 30-36, 341 Energy audits, 179, 339 Energy balance equation, 323-324 Energy code compliance procedures for determining efficiency

building performance, 9 design standards, 9 point value system, 9 Energy codes, resulting in wide use of energy analysis methods, 31 point system approach, 31 systems analysis approach, 31-32 Energy conservation, 582, 639 analysis procedure, 34 army buildings, 214 consumption reduction, 713 control of air leakage, 32(fig.) cost savings, 652 counterflow insulation systems, 154-172 engineered specifications, 82 removable covers, 84 goals, 519, 541 use of thermal insulating materials, 477 Energy conservation investment program (ECIP) impact on mortgage costs, 26 U.S. Army, 202, 214, 216 Energy conservation standards, 25-26, 565 Energy conserving materials building applications, 662 test apparatus and test methods, 662 Energy consumption reduction, 713 Energy costs, 16-18, 20, 26-27 Energy efficiency air flow requirements, 12, 545 building codes, 9 design, 6, 14, 15(tables), 615 glazing, 14 improvement, U.S. Army, 214 optimization parameters, 26-28, 35 roofing systems, 431, 432, 449 thermal insulation, 69 Energy efficiency ratios, equipment, 20 Energy Materials Testing Laboratory (EMTL), 535 Energy performance standards, prescriptive approach, 29 Energy requirements, 21, 338-339 building envelope, 341 domestic houses, 607 Energy savings extra insulation, 610 solar house versus typical house, 607 solar wall, 608 thermal insulation, 69 Trombe-type solar wall, 608, 611 U.S. Army, 218 Energy savings measures cost effectiveness, 610 domestic dwellings, 599

- Energy Technology Support Unit (ETSU), U.K. Department of Energy, 600
- Energy transfer processes, modeling parameters, 34
- Energy usage calculations, 10-11
- Engineered specifications, 84-88
 - applications procedures, checklist, 87-88 corrosion cracking, 86 energy conservation, 82
 - expansion and contraction, 84-85
- Envelope systems, insulating underground pipe, 46, 48
- Envelope thermal test unit (ETTU), 92, 93(fig.), 94-97
- Environmental chamber tests, 224, 225-229
- Environmental criteria, temperature and humidity, 535
- Epoxy-lined cement carrier pipes, 47
- EPS (expanded polystyrene) foam sheathing insulation, 422-423, 582, 588, 589
- Equipment energy efficiency ratios (EERS), 20
- Equivalent leakage area (ELA), increased after ceiling insulation retrofit, 646
- Equivalent radiative thermal conductivity, 667, 668
- Error analysis, heat transfer measuring techniques, 355-357
- ETSU (see Energy Technical Support Unit)
- ETTU (see Envelope thermal test unit)
- Evaluation procedure, building components, 713
- Evaporation, 397
- Expanded polystyrene (EPS) insulation, 422, 518
- Expansion and contraction, engineered specifications, 84-85
- Expansion chambers, 45
- Expansion of piping, design considerations for underground systems, 44-49
- Experimental error, air flow measurement, 545
- Exposure study, EPS materials, 582, 588-589 experimental details, winter temperature/ humidity conditions, 524-529
- roof insulation tests, 428
- Exterior envelope, 107
- Exterior insulated finishing system, 592
- External relative humidity, 616
- Extinction coefficient, 665, 670(fig.), 671
- Extruded EPS sheathing, 588, 590, 592
- Extruded polystyrene sheathing, 518, 615 exposure study, winter conditions, 528, 534 moisture control performance, 625

F

Face wall, air pressure changes, 127

- Family housing, moisture problems, 371
- FCC (see Federal Construction Council)
- FCC guide specification, Section 15705, underground heat distribution systems, prefabricated/preengineered type, 44
- FCGS (see Federal construction guide system)
- Federal Construction Council (FCC) (see also National Academy of Sciences/ National Research Council, FCC technical reports), 43
- Federal construction guide system (FCGS), 43-44
- Federal Interagency Group, 44
- Felt, built-up roofing insulation, 443
- Fenestration

annual energy usage, 18(table)

solar, energy calculations, 11

Fiber batt insulation, new construction applications, 642

- Fiberboard sheathing, 412
- Fiberglass blowing wool, new construction applications, 642
- Fiberglass insulation spray-applied, 360 effect of moisture, 362-364
 - unbonded loose-fill, 310
- Fiberglass reinforced plastic pipe, 47
- Fiberglass wall insulation, 197
- Fibrous glass insulation, 223-224
- ceiling insulation, 236(table)
 - formaldehyde emissions, 224-227, 236
 - impact on indoor formaldehyde concentrations, 230-231
- Fiber insulation
 - heat transfer, 689
 - mass scattering coefficient versus temperature, 672(fig.)
- Fibrous insulation material, 394, 665, 674(fig.)
 - equations derived from radiation-conduction heat transfer, 666-668
 - mass scattering coefficient, 671 model, equation, 668
 - optical behavior model, 669
- Fibrous loose-fill insulation, quality control instrument for determining thermal resistance, 655
- Fick's law to describe formaldehyde transport, 233
- Field-fabricated systems, not pressure testable, 48

- Field experiments, effect of moisture in sprayapplied fiberglass insulation, 363-366
- Field measurement
 - attic insulation retrofit, 217-218
- heat loss in underground systems, 63, 66 Field studies, 615
 - space heating/cooling loads, effect of wall mass, 541
- Field tests, 108 attic insulation, 210-213, 213-215(figs.) heat flow through building envelopes, test procedures, 110-113
- Fills for insulating concretes, 49
- Filter coefficients, wall surfaces, 95
- FIP polyurethane foam (see Polyurethane foam insulation)
- Fire protection, polyurethane insulation systems, 73
- Fireplaces, air leakage standards development, 7
- Fir, thermal conductivity, 259(table)

Floors

- basement heat loss calculations, 132, 142 comparative assessment of code require-
- ments, 24(fig.)

insulation, 610

- Florida model energy efficiency code for building construction, 9, 12, 14-15(table), 20
- Flow for retrofit, insulating materials, 644(table)
- Flow of water into wood, model, 633
- Fluid mechanics of air leakage, 639 equation, 640
- Foamed polyurethane insulation, 47
- Foamed-in-place (FIP) polyurethane insulation, 71-73
- Foamglas, 43-44
- Foam insulation, 432
- storage tanks, 80
- Foam service life, 463
- Foam sheathing, 405, 422-428, 582, 588-589 test methods/structures, 407
- Foam test specimens, application of asphalt, 438
- Footing, water leakage, 387, 390
- Forced convection (see Convection heat transfer)
- Forest Products Laboratory, Madison, Wisconsin
- research on condensation in walls, 406
- Formaldehyde (CH₂O)-based resins, 223-227
- Formaldehyde concentrations, indoor attic insulation model, 235

diffusion model, 230-231

- impact of fibrous glass insulation, 230
- Formaldehyde emission measurements, 225-236
- Formaldehyde surface emission monitor (FSEM), 224-225, 236
- Formaldehyde transport model, equations, 233-235
- Formaldehyde vapor permeability data, 232(table)
- Fourier transforms, passive and active wall fluxes, 100-104(figs.)
- Frothing, polyurethane foam, 72, 434, 440
- FSEM (see Formaldehyde surface emission monitor)
- Fuel consumption, annual, computer program, 8
- Fuel energy program, calculation procedures, 12
- Full-scale thermal testing, 161–171, 583–586 Furring wall system installation, 588

G

- Gases, analysis of, in roofing blisters, 437, 444
- Glass fiber insulation, 223-224
 - cellular, 48 conductivity increased with moisture, 361-362
 - correlation between thickness, density, and temperature, 674(fig.)
 - laboratory/field experiments, 362-366
 - reinforced polyisocyanate test construction, 721-722
- Glass fibers, 154, 163, 477
- Glazing
 - considerations for energy efficiency, 9, 14 double, 610
 - standards development, 29
- Ground-based infrared thermography, 176-177, 180
- Ground drainage tests, Corry Field housing units, 377, 386, 387(table)
- Groundwater conditions Corry Field housing units, 377 soil criteria for design of underground pipe systems, 44-45, 52
- Guarded hot box, 506, 567, 571-572 design considerations, effect of environment, 358
 - imbalance analysis, 357(fig.)
 - principles of operation, 299
 - test measurements, 305, 311
 - test results for wall systems, 724-725(table)

tests of thermal resistance, wall construction components, 720-721 verification for thermal properties measurement, 297, 346 Guarded hot plate, 286(table), 287 apparatus, 288(fig.), 292 ceramic fiber round robin test data, 691(table)

evaluating thermal performance of insulations, 652, 686

heat transfer testing, 395

measurements on wet material, 397-398

performance, 302-303

thermal conductivity versus mean temperature, 697, 698(fig.)

Gypsum wallboard, 582

Н

Hardwoods, thermal conductivity, 240-241 Hazard potential from heated surfaces, 705 human exposure limits, 705 Heat and humidity, effect on inorganic insulating fibers, 477 Heat distribution systems, manholes, 45, 50 Heated surfaces, hazard potential, 704 Heat exchange, between test specimen and guarded hot box, equations, 571-572 Heat exchange coefficients, 307 Heat flow, 108 mineral fiber insulation, 394, 399 surface to surface temperature difference, 402(fig.) versus temperature difference, glass fiber, 403(fig.) Heat flow meter, 175, 652-653, 654(fig.) future needs, 662-663 historical development, 659 instrumentation, Dynatech R/D Co., 659 schematic, 658(fig.) standards, 656 Heat flow meter apparatus, product performance, 661 Heat flow resistance in situ measurement, 120 insulation air space leak testing, 48 Heat flow test procedure, 110-113 Heat flux density, 668 dynamic performance of wall, 92 measurement, 94 dynamic test results, 332-334(figs.)

thermal resistance of office building walls, 112-120 versus temperature difference, 289(fig.) Heat flux calorimeter, 108, 119-120 Heat flux sensors, 203, 207-208 calibration, 205-208 conversion factors, 208 Heat flux transducers, 108, 110, 119-120, 652-653, 656-657 Heating and cooling, energy analysis, 28 Heating and cooling equipment, 28 Heating and ventilation systems, solar houses, 604(fig.) Heating load correlations comparison of predicted/measured, 546-547(figs.) masonry walls, 556(table) wood frame walls, 554, 555(table) Heat load, 11, 14-15, 203 roof U values, 17(table) wall U values, 16(table) Heat loss, 679 basement walls and floors, 132 building envelope, 179, 317 heat loss eliminated from, 317 calculations, Mitalas system, 132-134, 134 - 135design characteristics, 600 due to missing insulation, 120 effect of emissivity, 84 in situ measurement, 52, 63, 108 insulation, permeodynamic systems versus conventional insulation systems, 171 office buildings, 108 reduction by airtightness, 647 scale model test results, pipe systems, 64-65(tables) thermal analysis, 132 thermography, 178 underground heat distribution systems, in situ measurement, 52-53, 63 Washington, DC, Mitalas system, basement walls/floors, 136-138(figs.), 144-151(tables) Heat loss coefficients, domestic houses, 604, 605(table) Heat loss factors earth contact systems, 134-135 Mitalas system, full basement, Washington, DC, 144-151(appendix table) Heat pump roof systems, 450 versus electric strip heating, 28 Heat sink, 397 Heat storage capacities, cavity walls, 341

Heat tracing mediums, 85 Heat transfer characteristics, 319 conductive/radiative, 169-171, 210, 284, 639 convection, 572 infrared inspection techniques, 178-179 masonry cavity wall, 319 measurement, 94-105, 169, 355-357 mineral fiber insulation, 399 model, 94, 156 radiative, 208-209, 219, 284, 292 wall thermal performance, 92-98, 129 Heat transfer behavior, low-density thermal insulation, instrument design, 656 Heat transfer calculations, 597 Heat transfer coefficients, 307(table), 570 Heat transfer energy, 666 Heat transfer factors, basement and slab floors, 143 Heat transfer from phase changes, 395-396 Heat transfer model, 666 Heat transfer properties BLAST program, 544 high-solar-gain house, 545 typical house, 545(table) Heat transfer reaction, source of high energy, 707 Heat transfer through fiber insulation, 689 Heat transfer U values equations, 569-572 windows, 567 Heat transmission, 160-162, 311, 582 characteristics, cavity walls, 339 coefficients, 325-326 mechanisms, 652 windows, 568 Hemlock, thermal properties, 260-261(table) High-solar-gain house, 542, 545 heat transfer properties, 545 reduction in space cooling loads, 562(table) reduction in space heating loads, 560, 561(table) High-temperature optical parameters, 665 High temperature tests, 685 Hi-Hat system air space R value, 727(table) R value comparisons, 726(table) test constructions, 722(fig.) Hot box method (see also Calibrated hot box) measuring technique, 346 Hot box tests, 507 measured thermal performance, 514(table) Hot, humid climates moisture levels in test wall panels, 412, 415(fig.)

moisture problems in family housing, 371-393 Hot plate and heat flow meter, 654 Hot plate, thermal biguarded, 286 House heat loss coefficients, 604 Housing construction details London, Ontario, 619(table) Regina, Saskatchewan, 619(table) St. John's, Newfoundland, 620(table) Winnipeg, Manitoba, 618(table) Housing units, field studies of moisture, 372 Human burn protection standards, 704 Human skin burns, contact resistance, 708 Humidity effects on inorganic insulating fibers, 477 effects on mineral fibers, 477 environmental criteria, 535 testing for moisture problems, 375, 379, 381(table) Humidity ratios, 630, 632(fig.) Hydrocarbon fill, granulated, insulating envelope systems, 48-49 Hygric experiments, 449, 458 Hyperthermia, 705 effects on human skin, 706

I

ICBO (see Building codes) Imbalance detection, heat transfer measurement, 354-357 Indoor air quality, 223 Indoor concentrations of formaldehyde, 223-237 Industrial roof insulation, Sweden, 153 Infiltration air, in building envelope, 124, 176 cause of air leakage, 32 standards development for energy efficiency, 29, 34 tests, 377 Inframetrics infrared unit, 197 Infrared imaging system, 177 Infrared inspection techniques, 178-179 Infrared scans, walls, 197 Infrared surveys, 175, 180-185 Infrared thermography applications, 176-177, 203 field investigations, army buildings, 205 review of insulated surfaces, 88 wall inspection, 197 Infrared thermometer (see Spot radiometer) Inorganic mineral fibers, durable for insulating applications, 477

Inside surface temperatures, 572 In situ insulation thickness and density, 495-496, 497-499(tables), 500 In situ measurement heat flow through composite walls, 120 heat loss, 52, 63, 108 R value measurement, 203, 209 thermal performance building envelope, 107-108 walls, 91-105, Inspection procedures, exterior envelopes of office buildings, 177 Inspection program, wall insulation, installation. 200 Installation and backfill, underground piping, 45-46 Installation problems, workmanship, 680 Instruments development, calibration, 659 Insulated concrete, 45-46 Insulated heat distribution systems, field investigations, 43 Insulated stainless steel piping, 86 Insulated underground piping systems, 45-49 Insulated wall systems, measured thermal resistance, 592, 593(table) Insulating concretes, 49 Insulating envelope systems, 48 Insulating materials and systems air leakage properties, laboratory measurements, 639 pressure drop versus air flow, 642(fig.) thermal resistances, 582 Insulating mineral fibers, 477 Insulation (see also Counterflow insulation, Dynamic insulation), 679, 685 air leakage reduction, 639 attics, 637 building envelope, 680 ceilings, 610 cellular glass, 48 cellular polyurethane, 71 cellulose, 362-367 density, 495-498 settling tests, 500 density, 495-498 effect of moisture, laboratory experiments, 362-363 gaps, 313-314 heat transfer reduction, 639 impact on thermal resistances, 597 wall systems, 588 moisture trapped in vapor barrier, 401 polyurethane foam, 71, 74, 431 protected membrane roofs laboratory tests, 423-425 wetting behavior, 428, 429

quality control instrument design, 655 quality of installation, 196, 314 standards development, 29, 36 retrofit, 202-220, 643, 646 thermal performance measurement, 652 ceilings, 644 wet mineral wool, 399 Insulation configurations, basement wall/ floor heat loss, Mitalas system, 144-151(appendix tables) Insulation densities, 495 Insulation efficiency, of polyurethane foam, 71.73 Insulation for energy efficiency, 9-16 Insulation for stainless steel surfaces, engineered specifications, 86 Insulation materials ceramic fiber round robin, 686 fiberglass, 197 new products, laboratory testing, 316 protective finish, 83-84 retrofit, 643(table) selection criteria, 70-71, 83, 87-88 testing for new construction cellulose, 642 fiberglass batt, 642 vermiculite, 642 Insulation panels, engineered specifications, 86 Insulation retrofit, 218 Insulation R values, 515(table) Insulation specifications, 82 Insulation specimens, roofing, 437, 443-444 Insulation systems application method, polyurethane-banded aluminum jacket, 78 banded tanks, 78 design objectives, 70, 73, 87 energy-saving thermal insulation, 70 ceilings, walls, floors, double glazing, 610 parietodynamic, 154-155 permeodynamic, 154, 160 polyurethane foam coatings/coverings, 73 fire protection, 73 shortcomings, 73 spray-applied fiberglass, 310, 360, 367-369 thermodynamic, 154-156 unbonded loose-fill fiberglass, 310 Insulation thickness, 45, 652 primary means of energy conservation, 83 Interior insulation system, 593 Interlaboratory comparison, 685 Interlaboratory reproducibility mean temperature versus thermal conductivity, 699(table)

Interlaboratory reproducibility (cont.)

thermal conductivity versus mean temperature, 700(fig.)

International Refrigeration Institute, round robin test, 654

J

Jacketing, aluminum (see Aluminum jacketing) Jacket seam bonded aluminum jacket on foamed insulation, 80 design testing, 74 permeability, 74 polyurethane insulation, 74, 78-79 Joints, 679

L

experiments, Laboratory spray-applied fiberglass insulation, effect of moisture, 362-363 Laboratory measurement, 567 Laboratory tests, protected membrane roof, 425 Larch, thermal conductivity, 263(table) Leakage flow rate, insulation materials, 643(table) Leak testing, insulation air space, 48 Life cycle cost (LCC) principles, energy efficiency, 202, 214-215 Lighting loads, for energy calculations, 12 Loose-fill attic insulation, 493, 495 Loose-fill cellulose blower-cyclone-shaker (BSC) test, 500 wall insulation, 197, 199 Loose-fill thermal insulation, 494 Low-energy dwellings, design, 599 Low-frequency weather fluctuations, 103 Low-permeance foam sheathing moisture content, discussion, 625 versus other types of sheathing, 615 Low temperature design objectives for insulation systems, 70, 78-80 storage tanks, thermal insulation, 70, 76, 79

M

Maintenance, design criteria for tank insulation systems, 70 Manholes

Maple, thermal conductivity, 270(table) Masonry, moisture problems in family housing, 371-372 Masonry cavity walls, 319 thermal response, 341 Masonry securement systems, test constructions, 721-724 Masonry wall constructions, 582 heating load correlations, typical house, 554 Mass absorption coefficient (see Absorption coefficient) Mass scattering coefficient (see Scattering coefficient) Material degradation, thermal insulating mineral fibers, 477 Materials factors affecting choice, 83 insulation systems, 71 application procedure checklist, 88 types of materials, 83 Mathematical models data reduction, ceramic fiber round robin, 702(appendix) roof thermal performance, 449 Mean temperature comparison of averages of all water calorimeter and guarded hot plate tests, 702(table) versus thermal conductivity calorimeter tests, 698(fig.) guarded hot plate tests, 697(fig.) Mean values thermal properties of wood density, 243, 247(tables) moisture content, 244(table) thermal conductivity, 240-242(tables) use increasing design reliability, 280 Measuring techniques (see also Active measuring strategy) heat transfer, 355-357 hot box method, 349-354 tracer gas, 175, 176 Measurement/error analysis, 209 Mechanical properties of EPS materials, exposure study, winter conditions, 524-529, 531(table) Mechanical stress, in foam insulation systems, 75 equations, 76 Membrane blistering, roofing systems, 432 Metal jackets, securement, 84

design and maintenance, 50

pumping facilities and venting, 45

Metallic jacketing, 84

Metal window frames, condensation, 572 Metal Z-furring channel system, 590, 591(fig.) Metering box heat transfer coefficients, 307 space temperature difference behavior, 304(fig.) Metering chamber calibration, 584 temperature ranges, 586, 594 Mildew, on walls and furnishings, 371, 379 Mineral fiber bats, quality control instrument for thermal resistance, 655 Mineral fibers, 154 material disintegration, 480(table), 482-484 thermogravimetric analysis, 477 Mineral wool insulation. 399 material degradation, 477 wet thermal resistance, 396 Mitalas equations basement model, 133(fig.) climatic conditions, U.S. weather stations, heat loss calculations, 132-134 144-151(appendix Washington. DC. tables) Model building codes, 720 Model energy code compliance, 9, 29-34 Model, flow of water into wood, 633, 637 Modeling, 630 Modeling parameters development of energy transfer processes, 34 dynamic performance of a wall, 92 Modular retrofit experiment, 647 Module simulator, 713, 714(fig.) Module testing, 713, 715(figs.), 716 versus ASTM proposed standard test method for thermal performance of building components, 718-719 Moisture cavities, 379. 382. concrete block 383(table), 390 condensation studies, test methods/structures, 407 desorbed from roof sheathing, 632 from wood, 633 dynamic flow, 633 effect on family housing, 371-372 effect on loose-fill cellulose, laboratory experiments, 362, 368-369 effect on roofing, 432-434 effect on spray-applied fiberglass insulation, 360

effect on thermal insulation properties, 519 effect on thermal resistance, 360 literature survey, 361 effect on wood and wood products, 406 exposure studies, EPS materials, winter conditions, 528 main cause of insulation and pipe failure, 46 metal window frames, condensation, 572 polyurethane foam insulation, 431 protected membrane roof reducing thermal resistance of wood and wood products, 406 Moisture content foam insulation. 436 insulation board facings, 436 thermal insulation, 394, 399, 405 wall materials, 382, 385(table), 390, 405 wood, 634 data analysis. 277-278 standard deviation of mean, 244(table) test panels, 415 used for residential construction, 251, 252-273(tables) wood frame walls, 411, 413(table), 417 wood studs, 616 Moisture control, 405, 406 performance of extruded polystyrene, 625 Moisture detection, RTRA/ORNL roof systems, 452 Moisture gain, exposure study, EPS material, 524-528, 529(table), 530(table) Moisture migration, 395 Moisture monitoring, instrumentation, Delmhorst moisture elements, 616 Moisture performance of building materials, 616 Moisture permeance, urethane foam, 469 Moisture problems family housing, Corry Field units, 371-372, 378-379, 390-392 masonry cavity walls, 319 mineral fibers, 477 Moisture research, 618-620 Moisture resistance, 48 Moisture retarder paint, evaluated by module testing, 716 Moisture storage and release, 637 Moisture tests, 716 Moisture thermal performance, cellular plastic insulation, 518 Molded EPS materials, 521, 527 R values, 524 thermal conductivity, 524 Monitoring, long-term, domestic houses, 607

746 THERMAL INSULATION: MATERIALS AND SYSTEMS

Multilayer reflective insulation, 506, 511 heat flow, 515-516

N

National Academy of Sciences/National Research Council, Federal Construction Council (NAS/NRC/FCC) technical reports

- No. 30: Underground heat distribution systems, 43
- No. 39: Evaluation of components for underground heat distribution systems
- No. 47: Field investigation of underground heat systems, 43
- No. 66: Criteria for underground heat distribution systems, 44
- National Bureau of Standards (NBS) effects of thermal mass, 238
- design of thermesthesiometer, 709 National Program Plan

energy programs, 26

- insulation performance, 519
- thermal properties of wood, 238
- National Research Council of Canada, 108 environmental test facility, 568
- National Roofing Contractors Association (NRCA), 432-433

National Voluntary Laboratory Accreditation Program (NVLAP), 509

- proficiency testing on thermal insulation, 659
- Natural convection, 209-210
- New insulation products, laboratory testing, 316
- New Mexico Energy Research and Development Institute (NMERDI), 238-239
- New Zealand Building Research Association, 94
- Nonpressure testable systems, underground pipe installation, 47
- NRCA (National Roofing Contractors Association), 432, 447

0

- Oak Ridge National Laboratory (ORNL), 239, 449, 458
- Oak, thermal conductivity, 272-273(table)
- Occupant surveys, moisture and mildew, Corry Field units, 378-379, 389, 390, 391(table)
- Off-gassing, 432-433, 444

Office buildings

- building envelope, thermal resistance, 107
- calculation procedures for energy efficiency, 10
- construction details, 121-123
- description of test buildings, 181(table)
- thermal bridges, 182(figs.)

thermal resistance of exterior wall, 107-123

- thermographic inspections, 180-181
- anomalies, 182(table)
- On-site review, 87
- Opacity criteria, 674, 676
- Openings, air leakage
 - building envelope penetration caused by windows, doors, ventilation, etc., 682
 - standards development, 36
- Optical behavior, fibrous material, 669, 675
- Optical measurements, 671

Optical thickness, 665-666, 669, 673

- reference materials, 672, 676
- Optimization parameters for energy efficiency, 27-28, 35-36
- Outdoor storage tanks, behavior of water vapor retarders, 464-465
- Outside air film, 572
- Outside air humidity ratios, 632(fig.), 635

P

Parietodynamic insulation, 154, 155(fig.) Passive measurement, building walls, dynamic thermal performance, 94-97, 98, 99(table), 100

Passive solar construction, 30-31

Passive solar system evaluation with module testing, 715, 716(fig.)

- Peak energy load, building envelope, 336
- Penetrations of building envelope, 682

Periodic heat flux, wall thermal performance, 92, 94

Perlite fill, granular

in cavity walls, 319, 320

in insulating envelope systems, 49

Permeability

air, 125

building envelope, 125-127

- foamed polyurethane insulation aluminum jacket seam, 74-75
- Permeance values, exterior sheathing materials, 615, 616(table)
- Permeodynamic insulation systems, 154, 160, 171
- Personnel protection, 704
- Phase change, 395, 399

- Phenolic foam, exposure study, winter conditions, 528, 534
- Physical properties, exposure study, EPS materials, winter conditions, 528-529
- Physical testing versus theoretical modeling, 713, 716
- Pilkington Brothers, Research and Development Laboratories, U.K., guarded hot box facility, 297, 299(table), 301, 303, 307
- Pipe conduit, 46
- Pipe expansion, 45
- Pipe heat loss, 52-53, 63-65
- Pipe insulation, calcium silicate, 46
- Pipes, copper, 47
- Piping
 - fiberglass reinforced plastic, 47
 - insulated stainless steel, engineered specifications, 86
- Piping, underground design and installation criteria, 43 system failures, 43-51
- Plastic and metal jacketing materials, vapor barrier design, polyurethane foam insulation, 74
- Plastic insulation, cellular, 71
- Point system approach to energy analysis for standards development, 31-33, 38
- Polyethylene mastic, 464
- Polyisocyanurate foam insulation, 432 test construction, 721, 722
- Polystyrene beads, insulating concrete aggregate, 49 Polystyrene insulation
 - exposure study, 525-527
 - moisture distribution, 530(table)
- moisture resistance, 421, 422
- roofing, 432 Polystyrene sheathing, 412, 589
- Polyurethane foam
- bubbling, 440
- elastomeric coatings, 74
- field-installed (FIP) design, 71-73, 78-80
- froth systems, 72
- insulating efficiency, 73
- insulating envelope systems, 49
- pour system, 72
- resistivity, 71(fig.)
- spray system, 72
- thermogravimetric analysis, 437 vapor barrier design, 74
- water vapor retarders, 463-474
- Polyurethane foam specimens, thermogravimetric analysis, 437

- Polyurethane insulation, 47, 74, 77-79, 432-434
 - bubbling, with hot asphalt applications, 444
 - fire protection, 73
- Porous material, 665-668
- Portable calorimeter, 108, 109-110(figs.)
- Pouring, polyurethane foam, 72
- Predicted and measured attic air humidity ratios, 635(fig.), 636(fig.)
- Prefabricated pipe construction, underground heat distribution systems, 48
- Prescriptive approach, standards development for energy efficiency, 33
- Pressure differences, 679
- Pressure piping code, 46
- Pressure-testable systems, underground piping installation, 46
- Pressurization data, 642(fig.), 644, 647
- Pressurization tests, building envelopes, measuring tightness, 175
- Product variability, 651
- Project Pinpoint surveys, National Roofing Contractors Association, 432
- Propane tank shell, foam insulation, 76
- Protected membrane roof, 421, 422(figs.) exposure tests, 425, 426-427(figs.)
- Protected membranes, 422
- Protective coatings, insulated pipe, 46
- Protective finishes, insulation materials, 83-84

Q

Quality assurance, 655 Quality control infrared scans, 197 installation problems, 196, 199-200 instrument design, 655-659

R

- Radiant transfer, reduced by reflective insulations, 507 Radiation absorption, thickness dependent, 65 Radiation-conduction heat transfer, 666 Radiation heat flux density, 666-667 Radiation heat transfer, 208-209, 284-285, 354, 675-676 ceramic fiber insulations, 689 test materials for round robin, 687 thermal conductivity, 666 Radiation reference materials,
- Radiometer inspections, 176

Redwood, thermal conductivity, 254(table) Reference material, 674-676 thermal conductivity measurements, 283, 666 Reflectance, solar, 457-458 **Reflective insulation**, 506 data from hot box tests, 511, 512(table) Reinforced plastic pipe, 47 **Relative humidities** cavity walls, 379, 390 low-permeance sheathing walls, 620 maritime regions, 618-620 measurement for moisture problems, 375, 379. 381(table) thermal resistance of insulation, 394 Reproducibility (see also Interlaboratory reproducibility) interlaboratory, 699(table) mandate for standardization, 656 Residential building envelopes, 34, 36-38 Residential construction, model energy code compliance procedures, 9 Residential energy standard, ASHRAE 90A-80 versus new standard analytical tool selection, 26 basis for new standard, 22-25 economic approach, 25-26 economic parameters, 26 technical approach, energy analysis program criteria, 25 Residential housing insulation, France, 153 Residential insulation, 639 Residential space heating, 153-172 Residential walls, 615 Resistance, thermal insulation, 652 **Resistance** variations Resistivity (R values) of thermal insulating materials, 71(fig.) wall thermal performance, 91 Retrofit, 639, 643 army buildings, 218 effect of insulation on air leakage, 644 leakage data, 646(table) modular retrofit experiment, 647 return on investment (ROI), 317 spray-applied insulation, 360 wall insulation, 196-201, 316 reduction in air leakage heat loss, 645(table) **RIC/TIMA** (Roof Insulation Committee of the Thermal Insulation Manufacturers Association), 447 Ringwall-supported tanks, foam insulation systems, 79 R-matic instrument for calibration, 660(fig.)

wall securement systems, test results, 726(table) Rockwall wall insulation, 197 Rock wool, 477 Roof blisters, composition of gas, 446(table) Roofing blisters, 432-433, 447 analysis of gases, 437 Roofing/insulation specimens, 438, 443-444 Roofing membranes, delamination, 432 Roofing systems, 432 **Roof insulation** bubbling, 433, 438-440, 443 exposure tests, 428 heat storage effects, 453 Roof reflectance, 457-458 Roofs exterior membrane, 178 protected membranes, 421 reflectance, 449 R values, 213, 449 thermal efficiency of insulation systems, 172, 178 thermal performance, 449 U values, 17(table) Roof sheathing and trusses flow of water, 637 temperature, 632(fig.) wood moisture content, 631(figs.) Roof surface temperature, 452 Roof systems counterflow insulation, Scandinavia, 153 evaluation by aerial thermography, 181-182, 185, 186-187(figs.) moisture detection, 452 surface temperatures, 452, 454-455(figs.) thermal performance, 449 thermographic inspections, 178 Roof thermal research apparatus (RTRA), 449, 458 controlled by heat pump, 450 test panel construction, 450 Round-robin test. 283 ceramic fiber thermal conductivity, 685-696 expanded polystrene specimens, 535 hot plate and heat flow meter, 654 RTRA (Roof thermal research apparatus), 449, 450 R values (resistivity), 506, 515(table), 570 air leakage, 213, 377 buildings, measurement, 205, army 209(table), 210 earth contact systems, 135 loose-fill attic insulation, 494, 495(table), 500

measurement by spot radiometer, 187, 189, 190(tables) roofs, 449 test panels with foam sheathing, 407, 409(fig.) thermal insulation materials, 71(fig.) walls, 91, 219-220, 314

wall securement systems, test results, 726(table)

S

Sandbox, 53-54, 66 test results, 64-65(tables) Savings to investment ratio (SIR), life cycle costing, energy efficiency program, 214-215, 218 SBCC (see Building codes) Scale model, 55, 66 test results, 64-65(tables) Scanning electron microscopy, test data for insulating mineral fibers, 477-479(fig.), 482-485 Scattering coefficient, 665, 669, 671(fig.), 674, 676 correlation between density and thickness, 675(fig.) versus temperature, 672 Service life, design criteria for tank insulation system, 70 Settling, 494, 500 Shading of solar walls, 606 Sheathing, 412 Sheathing, low-permeance, 615 Sheathing, roof, 616 Silicate-coated perlite module, 717 Simplified thermal parameter (STP), 94 Simulated pipe system, small-scale test, 55, 56(fig.) sand temperatures, 57-62(figs.) Single-wall insulation systems, 70 Skylights, air leakage control, standards development, 36 Slab-on-grade-floor heat loss basement heat loss factor, 140-141, 143, 144-151(tables) Delsante solution, 132, 134 Slabs comparative assessment of code requirements, 24(fig.) standards development for energy efficiency, 29 Slag rock wool fibers, 477 material degradation, 482-491

Smoke test, air flow visualization, 171 Society of the Plastics Industry expanded/extruded polystyrene, 519 round robin study, EPS materials, 535 test materials black molded polystyrene, 520 extruded polystyrene, 520 phenolic foam, 520-521 Softwoods, thermal conductivity, 240~ 241(tables) data compared with standard, estimates of precision, 246(table) density/conductivity relationship, 279 (table) Soil condition criteria, design of underground pipe systems, 44-48 Soil corrosivity determination, by soil resistivity test, 45 Soil moisture content, 65 Soil thermal conductivity, 65-66, 135 Mitalas system, 144-151(appendix tables) Solar fenestration, energy calculations, 11 Solar heating and ventilation systems, 604(fig.) Solar houses, 600 Solar insulation, domestic houses, 607 Solar reflectance, on thermal performance of roof systems, 457 Solar wall ducts, convective contribution, 606-607 Solar walls, 599 shading, 606 Southern pine, thermal conductivity, 264-266(table) Space conditioning loads, predicted and measured, 550(table), 551-552 Space cooling load comparisons, masonry/ wood frame, 559(table) Space heating, 153-172 Space heating/cooling loads computer program (TARP) for predicting, 542 high-solar-gain house, annual reductions, 561(table) results of comparisons, 544 Space heating load comparisons, masonry/ wood frame, 558(table) Space heating, savings in energy consumption, 607 SPI (see Society of the Plastics Industry) Spot radiometer inspections, 176 thermal resistance measurement, 187, 189 used to measure interior surfaces, 178-179 Spray-applied fiberglass insulation, 310

- Spray-applied insulation systems, 360, 367-369
 - polyurethane foam, water vapor retarders, 463-474
 - thermal effects of moisture, field experiments, 363-366
- Spraying polyurethane foam, 72
- Spruce, thermal conductivity, 250(table)
- Stainless steel surfaces, insulation, engineered specifications, 86
- Standardization, 656
- Standards (see also ASTM standards) API 620: 76
 - ASHRAE Ad Hoc Standard 90-R: 29
 - ASHRAE cooling and heating load calculation manual, 10
 - ASHRAE Handbook of Fundamentals, 10, 721
 - ASHRAE SPC 119P: 34
 - ASHRAE Standard 62-81: 34
 - ASHRAE Standard 90: 21-22
 - ASHRAE Standard 90A-80: 22, 26-31
 - ASHRAE Standard 90B, Section 10-11: 29
 - ASME B31.1, Code for Pressure Piping, 46
 - British Standard 874: 346
 - California Energy Code, Title 24 (CEC), 22
 - Farmers Home Administration (FmHA), 22
 - French Standard, NFX 10-022, 346
 - German Standard DIN 52611: 346
 - Housing and Urban Development Minimum Property Standards (HUD-MPS), 22
 - housing industry dynamics (HID) survey, 22
 - International Organization for Standardization, Committee 163 on thermal insulation, 346
 - International Organization for Standardization, heat flow meter standards, 656
 - Pennsylvania Energy Code (PENN), 22
 - Swedish Standard (SS) 02 42 12: 346
- Standards assessment, 22, 31-34
- Standards development
 - air leakage, 32-33, 124
 - ASTM Committee C-16, human burn protection, 704
 - ceilings, 29, 36
 - energy analysis methods, 31
 - point system approach to energy analysis, 31-33, 38
- Standards methodology, 22, 25-35
- Standard test method, ASTM proposed, thermal performance of building components, 718

- Standing water during rain, 386-387
- State energy programs, 26
- Steam, heat tracing medium, 85
- Steel pipe, for hot water and steam installations, 47
- Still air layer, 283-286, 666
- Storage tanks, 69-70, 76-80
- STP analysis (see Simplified thermal parameter)
- Stress corrosion cracking, of insulated stainless steel piping, engineered specifications, 86
- Stress, thermal and mechanical
- equations, 75-76
- in foam insulation systems, 75-76
- Stud moisture content, 622-624
- Styrene insulation, 421
- laboratory tests, 423
- Sulfur hexafluoride tracer gas, 377
- Superinsulated buildings, 153, 216 Surface absorptance, thermal effect, 457
- Surface heat transfer coefficients, 308
- Surface humidity ratio, 634
- Surface temperatures
- hermetically sealed glazing unit, 568(fig.) hot box design, 356
- Sweden, National Testing Institute, classifying insulating materials, 395
- Systems analysis approach for energy conserving design, 31-33

Т

- Tanks, 78-80 outdoor storage, water vapor retarders, 464-466
 - thermal insulation, 70, 76
- TARP (see Thermal Analysis Research Program)
- Temperature
 - batt/sheathing interface, 627(fig.)
 - dynamic performance of wall, 92
 - office building walls, field tests, 111(fig.), 112
 - mass scattering coefficient, 672(fig.)
 - moisture problems in family housing, Corry Field units, 375, 379, 380(table)
 - roof sheathing and trusses, 632(fig.)
- Temperature and heat flux, dynamic test results, 329-334(figs.)
- Temperature baffle, 574(fig.), 577

Temperature measurement

cavity walls, 379, 390

counterflow insulation systems, 165–168 dynamic insulation, 166–169

dynamic temperature cycles, 329-331(figs.) for moisture problems, 375, 379, 380(table) glass, 567

- guarded hot box facility, 302-303
- roof thermal research apparatus (RTRA), 450
- versus moisture capacity, 628(fig.) Temperature/moisture profiles
- roof sheathing and trusses, 632(fig.) urethane foam in tanks, 469(fig.)
- Temperature profiles, 65, 67(fig.)
- Temperature/time relationship, human skin burns, 706-707(fig.)
- Temperature uniformity, 354-355
- Temp Guard insulation furring (TGIF) system, 590, 591(fig.), 597
- Test apparatus instrumentation and control, 583-585, 686 temperature sensing, 583
- Test constructions for masonry securement systems, 721-724
- Testing for air leakage, 377, 641-642
- Testing insulation, 642-643
- Test method and apparatus, 567
 - model parameters determined by least squares, ceramic fiber round robin, 693(table)
 - round robins, 699
 - thermal conductivities, ceramic fiber round robin, 691
- Tests for thermal resistance of wall constructions, 720-721
- TGIF system (see Temp Guard insulation furring system)
 - test construction, 721-722(fig.)
- Thermal analysis, heat loss calculations, 132
- Thermal Analysis Research Program (TARP), 542, 565
- Thermal and hygric measurements, roof systems, 449
- Thermal barrier, interior surface finish, 720
- Thermal bridges, 180, 182-185(figs.), 311, 592, 593, 602, 721
- Thermal capacity, walls, 11
- Thermal conductances (C value), 306, 506, 567
- Thermal conductivity (U value) (see also Average computed conductivity), 65, 66(table), 160, 169, 394
 - air, 287
 - ASHRAE recommendations, 570
 - building envelope, 127-129(fig.)
 - ceramic fiber insulation, round robin, 686 correlated with density, 251
 - decrease caused by convective heat transfer, 369

exposure studies, expanded polystyrene materials, winter conditions, 524-530, 531(table) glass-fiber insulation materials, 368 guarded hot box facility, 299, 306 loose-fill insulations, 494(table) mean temperature calorimeter tests, 698(fig.) guarded hot plate tests, 697(fig.) of wet material, 395, 400 polyurethane foam, 73 exposed to moisture, 75 protected membrane roof, 421 results, laboratory averages, 709(table) round robin analysis for ceramic fiber insulation, 686 insulation. 362-364, spray-applied 365(table) standard deviation of mean, 242(table) versus moisture content, 361 walls, 91, 94 wood, selected species, data analysis, 249, 268, 269(table) Thermal conductivity measurement, 668, 671, 675 mineral fibers, 485 Thermal conductivity tests, 695(table) Thermal conductivity versus density, 669(fig.), 670(fig.) Thermal effects of surface absorptance, 457 Thermal efficiency insulation materials, 720 measured by wet/dry thermal resistance, 424 roof insulation, 172, 178, 431 Thermal environment in buildings, module test used to evaluate, moisture retarder paint, 716 Thermal experiments, 450 Thermal hot plate, biguarded, 286 Thermal insulating materials, 477 Thermal insulation, 506, 541, 567, 582, 599 airtightness, 680(fig.) army buildings, 203, 207 ASTM Committee C-16, 705 basement heat loss factors, 144-151(tables) building envelope air movements, 124 cavity wall, 319, 338 cellular plastic, 518 combustible cellular plastic, 720 counterflow systems, 154-162 deterioration, due to groundwater ingress, 52 earth contact systems, 135 energy efficiency, 69 engineered specifications, 82-88

Thermal insulation (cont.) exterior envelopes of office buildings, 175-195 formaldehyde emissions, 223-237 heat loss factors, 144-151(tables), 286-287 hot box method for testing, 297-299, 303, 307, 346-347 installation, workmanship, 679, 680, 681(fig.) loose-fill attic insulation, 493 materials application procedures, 87-88 degradation, 477 thermal resistance values, 652 measuring techniques, hot box method, 345-359 metal furred wall systems, 720 mineral fiber, 394-395 module tests, 716 moisture problems in family housing, 371-372 new products, 310 office buildings, field measurement, 107-123 polyurethane foam insulation system, 69-81, 431 reference materials, 666 residential energy standards, 32-34 resistance, 652 basement heat loss factors. 144-151(appendix tables) retrofitted walls, 196-201 roof systems, 172, 178, 449 protected membranes, 421 slab-on-grade floor heat loss. 144-151(tables) spray-applied, 360, 367-369 stress, 75 equations, 75-76 underground heat distribution systems, 46, 49, 52 wall thermal performance, 92-98, 198-200 wall U values, 11-15, 92, 94 water vapor retarders, 463 wood data base 238-282 wood frame walls, 405 Thermal Insulation Manufacturers Association (RIC/TIMA), 447 Thermal mass effect 541, 542 dependent on internal heat gains, 563, 565 Thermal parameter theory, 92 Thermal performance, 567 army buildings, field investigations, 203 building components, ASTM proposed Standard test method, 718

building envelope, 107-108, 124-131, 616 guarded hot box facility, 297 conductance/transmittance, 301 energy measurement, 300(fig.), 301 in situ measurements of roof systems, 449 monitoring, 599 of insulation, heat flow meter technique, 652 reflective insulations, 506 related to poor application procedures, 314 roofs, 449 solar reflectance, 457 spray-applied insulation systems, 360, 367-369 walls active measurement strategy, 91-92 passive measurement strategy, 91-92, 94, 98-100 Thermal properties exposure studies, expanded polystyrene materials, winter conditions, 528, 531(tables), 532-534 measurement/verification, 297 of wood, data base, 238-282 Thermal resistance measurement future needs high-temperature heat flux transducers, 662 high-temperature reference materials of different thicknesses, 663 stability over a high-temperature range, 663 instruments calibrated hot box, 327(table) guarded hot box, 175-176, 311-313, 314(table) spot radiometer, 187, 189, 190(tables), 192, 193(figs.) Thermal resistances (R values) building envelope, 131, 310 concrete block wall, 593(table), 594, 596(table) decreasing with increasing moisture, 424 discussion, 592 hermetically sealed glazing, 568(fig.), 570(table) insulation materials, 71(fig.), 160, 310, 394-395 mean temperature for concrete block with wall laminate, 595 office buildings, 107 protected membrane roof, 421 quality control instrument, 655 reductions, 564(fig.), 565(table) reflective insulations, 506

test results, 592

- walls, 91, 112-113(fig.), 326
- wet mineral wool, 396-397
- Thermal response dynamic tests, test procedures/results, 328-329
- Thermal sensations, range of temperatures compatible with tissue life, 708(table)
- Thermal shorts, 316-317
- Thermal testing, 92–97, 161–171 calculation techniques, 511 reflective insulations apparatus and test panels, 509 laboratory test plans, 508 test results and discussion, 511 test specimens, 510
- Thermal transfer test facility, 298(fig.)
- Thermal transmission data, 597
- Thermal transmission properties, test wall, 584
- Thermal transmittance air flow along insulation, 682(fig.)
 - air leakage around electrical outlet, 683(fig.) guarded hot box, 299
 - increase due to pressure and air flow,
 - 130(fig.)
- Thermesthesiometer, new NBS tool for evaluation of hazardous conditions, 709 Thermistors, 110
- Thermodynamic insulation, 164 Thermographic inspections, 176-177, 180-182, 194, 196-201, 207
- Thermographic survey of solar houses, 602
- Thermography, infrared aerial and ground-based, 176 review of insulated surfaces, 88
- Thermography scans, wall insulation, cost effectiveness, 200
- Thermogravimetric analysis insulating mineral fibers, 478-479, 482-
 - 485(figs.), 488-489(figs.) polyurethane foam specimens, 437, 441,
 - 442(fig.)
- Thermometer, infrared (see Spot radiometer)
- Thermophysical properties of wood, data base, 238-282
- Thermo-Stud system, 589-590, 597
- Thickness effect, 671, 675
- cellular plastic insulation, 518
- heat flow meter use for quality control, 661-662(table)
- Thickness, loose-fill attic insulation measurement *in situ*, 496, 497-499(tables) variations with time, 497

- Thickness measurements, before/after round robin testing by calorimeter, 688(table) by guarded hot plate, 688(table) Thickness versus calibration constant, R-Matic instrument, 660(fig.) Time constant, wall thermal performance, 91, 96-99(tables) Tissue life, after hazard exposure, 708(table) Tools for evaluation of hazardous conditions, thermesthesiometer, testing the thermophysical reaction of human skin to a heated surface, 709 Tracer gas, air infiltration measurement. 175-176.377 Transducers, heat flux, 108, 110, 119-120 Transducer signals, 583 Transfer standards, 651 Trench systems, insulated underground pipe, 46 Trombe-type solar wall (U.K.), substantial energy saving, 608
 - Trusses, roof, 631-632, 637
 - Tunnel systems, buried, for housing underground piping, 50

U

- Ultraviolet light, vapor barrier design, aluminum jacketing, 74
- Unbonded loose-fill fiberglass insulation, 310
- Underground heat distribution systems, 43
- Underground insulated piping systems alkalinity, 44-45
 - conduit systems, 46
 - design and installation criteria, 43
 - drainage, 44-45
 - failures. 43-44
 - Tallures, 43-44
 - maintenance and performance, 50
- Underground water conditions, classification, 44(table)
- Uniform temperature convection heater, 575(fig.), 577
- Urea-formaldehyde foam insulation (UFFI) walls, 199
- Urethane foam insulation, 421 laboratory tests, 423
- temperature/moisture profiles, 469(fig.)
- U value (see Thermal conductivity)

V

Vapor barrier, 615, 679, 682 coating, 74, 423 design, 74 Vapor barrier (cont.) effect on airtightness, 133 effect on pressure drop, 129 efficiency, 75 polyurethane foamed insulation, 47 design, 74, 79, 80 trapped moisture, 401 Vapor compression air conditioning, 560 Vapor movement effect on conductivities, 369 effect on heat transfer, 361 Vapor pressure gradients, laboratory wetting test. 428 Vapor proofing, engineered specifications, 84 Vapor retarder, 406, 412, 464, 466-467 Vapor retarder coatings, 463 Vapor retarder paint tests, 716-717(fig.) Vapor sealing membranes, 46 Ventilation attic. 635 new rationale required, 637 building envelope, 125 exchanges, 605 fresh air, 18, 19(table) insulation efficiency, 154-156, 160-171 load, energy efficiency, 9, 12, 14 whole-house, versus vapor-compression air conditioning, 560 Ventilation systems, solar houses, 604(fig.) Verification procedures guarded hot box facility performance, 308 measurement/verification, 302-304 thermal properties, 297 Vermiculite insulating concrete aggregate, 49 new construction applications, 642 Vitrified clay, for pipe conduits, 48 Voids roofing insulation, 434, 444, 445(fig.), 446(fig.) wall insulation, 198-199, 314

W

Wall cavities, excessive moisture, 405
Wall conductance, reduction after wall insulation retrofit, 646
Wall constructions

discussion of test results, 592
interior insulation systems, 587
St. John's, Newfoundland, 621(fig.)
surface-to-surface R values, measured concrete block wall, 592, 593(table)

Wall dynamic thermal performance, 335
Wall fluxes, Fourier transforms, 100-104
Wall heat loss, 108

Wall heat transfer, measurement strategies, 94 - 100Wall insulation, 14-17, 197, 610 fiberglass, 197 installation problems, 197-200 quality control, 199-200 on-site inspection program, thermography scans, 200 retrofit, reduction in air leakage heat loss, 644-645(table) void areas, 198-199 Wall materials, moisture content, 375 Wall orientations, 10(table) Wall relative humidity, 626(fig.) Walls air leakage, 213 basement heat loss calculations, 132, 142 code requirements, 23(fig.) convection, army housing units, 209 dynamic thermal response, 92-98 heat flow, 120 inside surface temperature, 571 insulation efficiency, 171, 196 infrared thermography scans, 197 residential. 615 R values, 213, 219-220(table) standards development, 29 thermal performance, measurement strategies active, 92-94, 96-98 passive, 94-96 thermal resistances, 112, 114-116(table), 117, 120 measurement period, 119 tests, 721 U values, 16(table) water vapor permeance, 616 Wall surface temperatures, hot box measurement, 355 Wall systems, 311, 312-313(figs.) cavity walls, 319 comparison of measured and calculated Rvalues, 728(table) discussion, test results, 592-597 drywall laminate system, 589 exterior insulated finishing system, 592 guarded hot box test results, 725(table) installation, 588 metal Z-furring channel system, 590 R values, 313 Temp Guard insulation furring (TGIF) system, 590 test results of R values, 726(table) Thermo-Stud system, 589-590 Washington, DC, basement wall/floor heat loss, 144-151(appendix tables)

Water absorption of foam, 467-468(tables) Water calorimeter, 686 Water flow rate inside attic, 633, 637 Water leakage at footing, 387 in family housing, 377, 390 Waterproof coatings, underground pipe systems, 45-46 Water spray tests, moisture problems, 378. 388-389 Water table, ground drainage tests, 377 Water vapor diffusion, 463 Water vapor movement rate, 405 Water vapor permeability, 232 of wall materials, 372 vapor barrier design, aluminum jacketing, 74 Water vapor permeance of walls, 616 Water vapor pressure, in insulation systems, 73.390 Water vapor retarders, chlorosulfonated polyethylene mastic, 464, 466-468 Water vapor transport, preventive use of vapor retarders, 716 Weather fluctuations, 103 Weatherization, walls, 196-201 Weather side air film, 572 Wet bulb temperature, 12 Wet insulation in walls, after condensation, 406 Wetting behavior of insulations, 428-429, 456(fig.) protected membrane roofs, 424, 428 exposure tests, 425-427(figs.) White pine, thermal conductivity, 251, 255-258(tables) Wind flow around tanks, 77 Wind loading, estimations of pressure differ-

- ences, 127
- Wind loads and pressure, 679
- Wind machine, Canadian Division of Building Research, 572, 573(fig.)
- Window frames, metal condensation, 572

Windows evaluation program, 578 heat transfer equations, 569-572 standards development, 36 surface temperature, hermetically sealed glazing unit, 568(fig.) tests using DBR wall calorimeter apparatus and test setup, 578-581 thermal performance, 567 Wind protection, 679, 681 building envelope, 124-125, 127-128 Wind resistance, design criteria for tank insulation systems, 70, 76-77(fig.) Wind speed, 636(fig.) Winter temperatures, humidity conditions, 524-529 Wood data analysis electrical resistance, 617 moisture content, 634-635, 636(fig.) specimen preparation/test conditions, 274-275(table). 277 surface film humidity ratio, 634-635 thermal conductivity, 277-278, 280 used for domestic residential construction mean density compared with mechanical property data, 247(table) thermal properties, 251, 252-273(tables) Wood frame walls condensation, 405, 410-416 decay, 406 Workmanship, deficiencies in installation, 679-680

Y

Yellow pine, mechanical/thermal properties, 251

Z

Z-furring test construction, 724(fig.)