

Index

- A**
- ABAQUS computer program**, 1111, 1112, 1945, 2001
- Acceptable risk, defined**, 2821
- Acetone (CH₃COCH₃), heat of combustion**, 143
- Acetylene**. *See* Ethyne (C₂H₂)
- Acid rain**, 688
- Action**, 15, 152, 158, 167, 181, 230–233, 273–274, 325, 329–330, 335, 344, 346, 450, 676, 681, 693, 1040, 1057, 1137, 1245, 1247, 1307, 1315, 1366, 1469, 1485, 1589, 1591, 1593, 1604, 1635, 1772, 1816, 1847, 1849–1852, 1864, 1865, 1872–1873, 1879, 1883, 1884, 1891, 1892, 1899, 1900, 1906, 1917, 1943, 1966–1968, 2013, 2021, 2023, 2039, 2040, 2071, 2076–2084, 2088–2095, 2097, 2103–2108, 2263, 2299, 2301, 2347, 2435, 2436, 2448, 2461, 2462, 2781, 2821, 2877, 2893, 2920–2924, 2926–2928, 2952, 2964, 2965, 3048, 3056, 3088, 3108, 3120, 3125, 3133, 3173, 3187–3190, 3194, 3198, 3321, 3331, 3352, 3384, 3391
- Active error**, 2921
- Adams-Bashforth method, solving initial value problems**, 1096
- Adiabatic flame temperature**
calculation, 147–149
and dissociation, 148
lower flammability limits (LFL), 536–538, 547
premixed flames, 388, 389
- ADINA computer program**, 1111
- Aerosol(s)**
defined, 1303
in smoke, 1343
- AFFF**. *See* Aqueous film-forming foam (AFFF)
- Aircraft hangars**
low-level application of AFFF, 1683–1685
new hangar design concepts, 1687
overhead sprinkler protection, 1681
video image flame detection, 1689
- Aircraft rescue and fire-fighting (ARFF) vehicles**, 1673, 1677, 1679
- Airport Services Guide (ICAO)**, 1663–1665, 1667, 1669, 1673, 1674
- Air, thermophysical properties of**, 95
- ALARM 1.0 fire risk indexing model**, 3178
- ALARM 2.0 fire risk indexing model**, 3178
- Alarms and alarm systems**
fire alarm audibility and intelligibility, 1368
scenarios, 1362, 1367, 1368
sound pressure level, 1360, 1362, 1363, 1367, 1368, 2031
fire alarm visibility, 1370–1374
hearing-impaired persons, 1372, 1373
voice alarm system, 1361
- ALARP (as low as reasonably practical) risk assessment method**
buildings, 2952
mass transportation, 3383
- Aliphatic hydrocarbons**, 1211, 2277, 2278
- Alkanes**, 198, 213, 337, 382, 530, 536, 542, 559, 913, 1168–1170, 1189, 1211, 1212, 2739, 2755, 3460, 3472
combustion of, 3460
- Alkenes**, 170, 182, 198, 199, 213, 214, 559, 913, 1211, 1212, 3460, 3461, 3472
- Alkynes**, 913, 1211, 1212, 3461, 3473
- ALOFT numerical model**, 1059, 1060
- Alumina trihydrate, arc tracking reduction with**, 673
- Aluminum**
combustion of, 662
electrical wiring overheating, 678, 680
- American Nuclear Society (ANS)**, 3334–3336, 3338, 3339, 3354
- American Society for Testing and Materials (ASTM)**. *See* ASTM entries
- Ammonia (NH₃), heat of formation**, 145
- Amorphous material**, 171, 177, 178, 278
- AnalyticaT decision analysis model**, 3025, 3026
- ANSI/AISC, Specification for Structural Steel Buildings**, 1889–1890
- ANSYS computer program**, 1055–1057, 1111, 2687
- Apparent stresses**. *See* Reynolds stresses
- Aqueous film-forming foam (AFFF)**
and aircraft hangar protection, 1680–1681
application rates, 1667–1673
aspiration, 1665, 1666, 1675, 1688
hybrids, 1647
portable fire extinguishers, 1709
protection of flammable/combustible liquid storage, 1691, 1695
protein foams compared, 1647, 1665, 1668, 1700
spill fire data, 1657, 1659, 1687, 1691, 1694, 1709
spreading coefficient, 1657–1659

- Arc fault circuit interruption (AFCI) devices**, 672
- Archimedes' principle**, 77
- Architectural Acoustics (Ginn)**, 1360
- Arcs, electrical**
- arc extinguishment, 669
 - arc flash, 668–669
 - arc tracking
 - and creepage, 673
 - dry/wet, 671
 - scintillations, 372
 - break-arcs, 668
 - defined, 666–667
 - make-arcs, 668
 - means of creating
 - arcing across carbonized path, 668, 671–673
 - contact arcs, 668
 - glow-to-arc transition
 - glow-to-arc transition: ionized gases between electrodes, 667, 668
 - glow-to-arc transition: raising voltage across electrodes, 667
 - temperature, 667, 696
- Area sample**, 2871
- Areas of refuge**, 1266, 1748, 2023, 2097
- Arenes**, 913, 1211, 3461, 3473
- Aromatic hydrocarbons**, 198, 220, 326, 1211, 2210, 2221
- Arrhenius expression, decomposition reactions**, 1041
- Arundel Park Hall fire (1956)**, 2099
- ASCE/SEI, Minimum Design Loads for Buildings and Other Structures**, 1889
- ASET**. *See* Available safe egress time (ASET)
- ASET-B zone fire model**, 3039–3040
- ASET zone fire model**, 1027
- ASME flow nozzle**, 1402, 1403
- ASME orifice meters**, 1402–1403
- ASTM D1331, Standard Test Methods for Surface and Interfacial Tension of Solutions of Surface-Active Agents**, 1657
- ASTM E2058 fire propagation apparatus**, 926, 1148, 1167, 1170, 1189–1191, 2242, 3471
- ASTM E691, Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method**, 3093
- ASTM E1546, Standard Guide for Development of Fire-Hazard-Assessment Standards**, 3212
- ASTM E1355, Standard Guide for Evaluating the Predictive Capability of Deterministic Fire Models**, 2039, 2919
- ASTM E1776, Standard Guide for the Development of Fire-Risk-Assessment Standards**, 3212
- ASTM E2067, Standard Practice for Full-Scale Oxygen Consumption Calorimetry Fire Tests**, 937
- ASTM E698-01, Standard Test Method for Arrhenius Constants for Thermally Unstable Materials**, 630
- ASTM E1529, Standard Test Method for Determining Effects of Large Hydrocarbon Pool Fires on Structural Members and Assemblies**, 1867
- ASTM E1354, Standard Test Method for Heat and Visible Smoke Release Rates for Materials and Products Using an Oxygen Consumption Calorimeter**, 925
- ASTM E1515, Standard Test Method for Minimum Explosible Concentration of Combustible Dusts**, 2791
- ASTM E2257, Standard Test Method for Room Fire Test of Wall and Ceiling Materials and Assemblies**, 935
- ASTM E84, Standard Test Method for Surface Burning Characteristics of Building Materials**, 791–792
- ASTM E119, Standard Test Methods for Fire Tests of Building Construction and Materials**, 1866, 1867
- time-temperature curves, 789, 1102, 1866, 1867, 1911, 1957
- ASTM, Standard Guide for Evaluating Predictive Capability of Computer Fire Models**, 3010
- Atria**. *See* Large-volume spaces, smoke management in
- Authority having jurisdiction**
- acceptable risk and, 2821
 - aviation fire protection, 1673
 - building fire risk assessment, 2976
- Autoignition**
- ASTM E698-01 and, 630
 - criticality concept
 - body size, 625
- Autoignition (cont.)**
- critical ambient temperature (CAT), 410, 411, 557, 604, 610, 629, 630
 - critical stacking temperature (CST), 605, 609, 626
 - examples, 572, 625, 649
 - Frank-Kamenetskii theory (*see* Frank-Kamenetskii theory, autoignition)
 - hot stacking problem, 609
 - iodine number, 576
 - liquids in porous materials, 575–578
 - and parallel reactions, 620–622
 - and presence of water, 620
 - reference texts, 2694
 - self-accelerating decomposition temperature (SADT), 629
 - Semenov theory (*see* Semenov theory, autoignition)
 - thermal runaway, 583, 605
 - time to ignition (TTI)
 - other chemically kinetic difficulties, 624
 - theoretical treatment, 623–624
- Autoignition temperature (AIT)**, 373, 531–537, 539, 554, 560, 561, 573, 574, 576, 578, 579, 607, 625, 648, 1569, 2225, 2226, 2693, 2779, 3450, 3451
- Automobiles**. *See* Motor vehicles
- Availability**
- equations for calculating, 2900
 - instantaneous/average, 2900
 - Markov modeling
 - characteristics, 2901–2902
 - developing, 2902–2903
 - solving continuous time model, 2907–2909
 - solving discrete time model, 2904–2907
 - transition matrix, 2903–2904
- Availability analysis**, 2876, 2877, 2900, 2928, 3202
- Available safe egress time (ASET)**, 1066, 1067, 1099, 2115, 3133
- impact of tenability on, 2145–2148
- Available time/time available**, 368, 1211, 1252, 1588, 2100, 2120, 2146, 2213, 2214, 2220, 2230, 2262, 2299, 2320, 2328, 2337, 2402, 2435, 2771, 2921, 2922, 2924, 2926, 2964, 2965, 2994, 3004, 3189, 3231, 3232, 3234–3237, 3359, 3360, 3373, 3389

Aviation fire protection

- agent quantities/standards, 1673–1679
- foam concentration, 1675–1679
- loam expansion and drainage, 1674–1675
- underlying principle, 1673

Avogadro's hypothesis, 140**B****Bagasse, spontaneous ignition**, 605, 628**Balcony spill plume**, 992, 1092, 1834–1839**Barriers**

- fire, analysis of, 3350
- smoke, 1750, 1786, 1813, 1817, 2022, 2413, 3167, 3170

Bayes's law, 2830, 2855**Beams**

- concrete, 1957, 1960
- critical stress in steel, 1941–1943
- critical temperature determination in steel, 1938–1939
- fire resistance in steel, 1931, 1985, 1994, 1996, 2001
- heat transfer to I-beams, 765, 766, 768, 769
- statically indeterminate, 270
- steel spandrel, 1929–1930

Bedding fires

- cigarette smoldering and, 2396
- heat release rates, 599, 2400

Behavioral response to fire/smoke.

See also Occupants

- altruistic behavior, 2073
- awareness of cues, 2106, 2108
- ambiguous cues, 2462
- British/U S. populations compared, 2104
- cognitive decision processes, 2077, 2928
- convergence clusters, 2097
- emotional instability, 2198
- emotional state, 2197
- fire-fighting behavior, 2072
- gender, response by, 2103–2105
- high-rise office buildings, 2087
- hotel fires, 2085–2087
- identified characteristics, 2084
- nonadaptive behavior, 2073
- panic behavior, 2072–2073
- anxiety/fear distinguished, 2073
- perception of incident stress model, 2916
- re-entry behavior, 2084, 2085

Bending, structural, moment, 1883**Bernoulli beam finite element**, 1904**Bernoulli distribution**, 2846–2847**Bernoulli equation**, 21–22, 67, 84, 1383, 1384, 1405**Beta distribution**, 2850, 2854**Beverly Hills Supper Club fire (1977)**, 675, 2072, 2077, 2096, 2406, 3143**Binomial distribution**, 2847–2849, 2863, 2867, 2930**Biot number**, 26, 31, 33, 34, 606, 618, 622–623, 640**Blackbody radiation**, 105, 2616**Boiling liquid expanding vapor explosion (BLEVE)**, 558, 2646, 2664, 2745, 2758, 2792–2814

defined, 2792

Boltzmann constant. *See* Stefan-Boltzmann constant**Bookcases, heat release rates**, 816, 2397**Bouguer's law**, 1081**Boundary layers, convection heat transfer**

- boundary layer approximation, 65, 66, 68, 70, 83
- laminar flow over flat surface, 67–71

Boundary layers, fluid flow thickness, 17, 18, 65, 69, 73, 76–79, 90**Bourbonnais (III.) grade crossing accident (1999)**, 3373**Bourdon gauge**, 1381–1382**Boussinesq approximation**, 64, 78, 98**Boxes, heat release rates**, 816, 837, 842–844, 846**Bradford stadium fire (1985)**, 706, 714, 2406**BRANZFIRE two-zone fire model**, 1028, 2968**Breathing effect, compartment fires**, 985**Brick**

- compressive strength, 305
- density, 305
- dilatometric/thermogravimetric curves, 305
- modulus of elasticity, 305
- specific heat, 306
- thermal conductivity, 288, 306

British Standards Institute (BSI). *See* BS entry**Browns Ferry nuclear plant fire (1975)**, 2923, 3328, 3331**BSI (British Standards Institute)**. *See* BS entry**BS 7974, "Part 7-Probabilistic Risk Assessment"**, *Code on the Application of Fire Safety Engineering Principles to the Design of Buildings (BSI)*, 2977–2979**Building aerodynamics****Building assemblies and frames, fire resistance**

- fire protection materials/systems
 - concrete/masonry, 1877
 - flame shielding, 1917
 - gypsum, 314, 315, 1817
 - intumescent/mastic coatings, 1817
 - spray-applied materials, 1915–1916
 - water-cooled columns, 919
- floor systems, 1885
- frames, 1884, 1890–1895
- heat transfer/temperature profiles
 - composite steel-concrete members, 1950
 - concrete members, 1949–1977
 - steel members, 289, 1112, 1909–1945
 - temperature variation along members, 1852
 - thermally protected steel members, 1917
 - timber members, 1979–2005
 - unprotected steel members, 1105, 1118
- high-temperature thermal degradation
 - concrete/masonry, 301, 311, 1877
 - steel, 1877
 - thermal strains, 1876
 - timber, 290
- individual members
 - bending along the span, 1883
 - bending strength in concrete sections, 1885
 - bending strength in steel-concrete sections, 1885
 - bending strength in steel sections, 1885
 - bending strength in timber sections, 1885
 - with concrete in compression, 1884
 - with concrete in tension, 1884
 - elements in compression, 1884
 - elements in tension, 1884
 - section bending strength, 1884
 - steel in compression, 1884
 - steel in tension, 1884
 - timber in compression, 1884
 - timber in tension, 1884
- input/modeling uncertainties
 - Bernoulli hypothesis, 1904–1905
 - boundary conditions, 1902
 - connections, 1905
 - fixed geometry, 1898–1899
 - lack of convergence, 1903–1904
 - limitations of tests, 1905–1906
 - localized fire effects, 1900–1901

Building assemblies and frames, fire resistance (*cont.*)

- mechanical calculations, 1901–1905
- perfect contact, 1899–1900
- spalling, 1902–1903
- thermal calculations, 1897–1901
- thermal properties, 1897–1898
- very large structures, 1901–1902
- limit states design
 - collapse prevention, 1874
 - fire exposures, 1866–1868
 - and heat transfer analysis, 1868–1871
 - reliability, 1865–1866
 - resistance, 1864–1865
 - and structural analysis (*see* Structural analysis and fire resistance)
- load combinations, 261, 1874–1875
- structural analysis
 - before fire, 1877–1878
 - during fire, 1878–1881
 - at required resistance time, 1881–1882
 - utilization of substructures, 1882–1883
- structural steel design criteria, 1889–1890
- walls, 1886–1889
 - load-bearing, 1886
 - separating function in fire conditions, 1886
 - separating function in normal conditions, 1886
 - thermal gradient across thickness, 1888

Building Code Requirements for Reinforced Concrete (American Concrete Institute), 1964**Building Envelope**

- exterior wall and enclosure systems, 3248
- exterior wall openings, 3272–3276
- Fire spread between buildings, 3242–3245
- loss history, 3276–3279
- risk assessment factors, 3279–3281
- vertical fire spread, 3245–3248

Building Fire Simulation Model, 2987**Building materials.** *See also specific materials*

- burnable/nonburnable, 279
- classification, 277–278
- composite materials
 - porosity, 286
- creep, 282–283
- density, 285–286
- elevated temperatures and, 280–281

Building materials. *See also specific materials* (*cont.*)

- fire performance groupings
 - Group I (insulating), 280
 - Group I/F (insulating/fuel), 280
 - Group L (load-bearing), 280
 - Group L/I (load-bearing/insulating), 280
 - Group L/I/F (load-bearing/insulating/fuel), 280
- homogeneous/heterogeneous, 277–278
- information sources, 291
- mass loss, 284–285
- material-specific properties, 281–283
- mixed composition, 279
- modulus of elasticity, 281–282
- moisture sorption, 278–279
- porosity, 278–279, 285–286
- and reference condition, 281
- specific heat, 286–287
- stress-strain relationships, 281
- structure-sensitive/-insensitive properties, 278, 288, 292, 293
- thermal conductivity, 287–288
- thermal diffusivity, 288
- thermal expansion, 284
- thermal properties, 284–288
- ultimate strength, 281–282
- yield strength, 281–282

Building Research Institute

(Japan). *See* National Research Institute for Fire and Disaster (Japan)

Buildings

- smoke movement in tall, 1789, 1791
- vent flows in, 474

Buildings, fire risk analysis,

- approaches/methods/models, 2957–2962
 - event tree analysis, 2960
- assessing probabilities, 2981
- data-gathering methods
 - causal relationship of initiating events/hazards/consequences, 2948–2949
 - consequence analysis, 2944
 - hazard assessment, 2944–2948
 - as low as reasonably practicable (ALARP), 2952
- fire risk characterization, 2943
- fire safety concepts tree, 2949–2950
- FN curves, 2951–2952
- guidance documents, 2975–2980
- risk-cost assessment models (*see also specific models*)
 - building fire safety evaluation method (BFSEM), 2973–2975
 - hazard/risk matrices, 2969–2970
 - performance matrix, 2970–2973

Buildings, fire risk analysis (*cont.*)

- uncertainty/variability/unknowns, 2956–2957
- Buoyancy forces**
- center of, 500
 - and convection heat transfer, 71–73, 77, 81, 98
 - fire plumes, 400
 - smoke movement, 1045
 - and vent flows, 467, 469, 470

- Burning rate**, 145, 151, 236, 354, 361–364, 378, 390, 398, 400, 403, 434, 490, 499, 508, 520, 524, 525, 740, 799, 800, 808, 813, 828, 830, 857, 867, 883, 920, 929, 931, 943, 985, 986, 996, 997, 999–1002, 1010, 1013, 1027, 1272, 1273, 1356, 1591, 1592, 1606, 1659, 1666, 1786, 1849, 1856, 2390, 2553, 2556–2558, 2571, 2572, 2574–2583, 2585–2587, 2593–2595, 2600, 2612, 2622, 2629, 2638, 2741, 2750, 2810, 2964, 3006, 3074, 3246, 3356
- Burning velocity, flames**, 376, 377, 2739, 2742

BURNSIM model, 2384**Burns, skin**

- classifications, 2380
- conducted heat, 2377
- consequences, 2379–2380
- convected heat, 2377–2378
- over large areas, 2379
- pain and, 2378–2379
- radiant heat, 2378

Bushes, heat release rates

- natural, 861–863
- plastic, 863

Business protection, goals, 1315**Butane, boiling point**, 537, 559**C****Calorimeters**

- industrial-scale, 937, 943, 946
- intermediate-/large-scale
 - furniture calorimeter, 932–934
 - intermediate-scale calorimeter (ICAL), 931–932
 - room/corner test, 934–936, 938
- single burning item test, 936–937
- standard hood/exhaust duct, 930–931
- open-burning calorimeters, 799–802, 852
- oxygen consumption calorimeter (*see* Oxygen consumption calorimeter)

Calorimeters (*cont.*)

- small-scale
 - comparative studies, 929–930
 - cone calorimeter (*see* Cone calorimeter)
 - fire propagation apparatus, 926–927
 - Ohio State University (OSU) calorimeter (*see* Ohio State University (OSU) calorimeter)
 - use/application of heat release rate data, 937–943

Calorimetry

- combustion bomb calorimeter, 142
- factors affecting small-scale measurements
 - airflow, 922
 - edge effects, 921–922
 - open/closed configuration, 918–919
 - other measurements, 922
 - specimen orientation, 922
 - specimen size, 920–921
 - type of heater, 919–920
 - type of ignition pilot, 920
- heat release rate measurement techniques
 - carbon dioxide generation, 926, 927, 1145–1147, 1149, 1183, 1187
 - compensation method, 911
 - oxygen consumption method, 911–915
 - sensible enthalpy rise method, 907–910
 - substitution method, 910–911
- oxygen bomb calorimeter test, 906
- gross/net heat of combustion, 906–907
- oxygen consumption, 146, 239, 896, 912–914, 917, 918, 924, 928, 934, 945, 952, 956, 1144–1147, 1182–1184, 1187, 1188
- uncertainty of heat release rate measurements, 943–945
- use/application of industrial-scale data, 943
- use/application of intermediate-scale data, 942
- use/application of small-scale data
 - analytical models, 938–939
 - physics-based models, 939–942
 - regression models, 938

Carbon dioxide (CO₂)

- asphyxiant, 1540
- CO and generation efficiency, 1206–1208
- fire concentrations
 - and hyperventilation, 1540
- fire product yield, 1196, 1199, 1200, 1210–1211

Carbon dioxide (CO₂) (*cont.*)

- heat of formation, 144, 145
- incapacitation from, 2243, 2244
- oxygen consumed and amounts generated, 1201–1202
- specific heat, 1537, 1539
- systems
 - fire extinguishing mechanisms, 1536
 - health and safety, 1540–1545
 - local applications, 1531, 1532, 1534, 1567–1573
 - nozzle selection, 1575–1584
 - thermal-physical properties, 1536–1540
 - total applications, 1554–1567

Carbon dioxide generation

- calorimeter**, 571, 1144–1147, 1149, 1183, 1184, 1187, 1188

Carbon monoxide (CO)

- CO₂ and generation efficiency, 1206–1208
- fire product yields, 1196, 1200, 1202, 1203, 1210, 1211, 1215
- fire ventilation and, 1202–1204
- heat of combustion, 143
- heat of formation, 145
- predicting uptake in humans, 2359
- and smoke generation efficiency, 1208
- smoke management and, 1826–1827
- smoldering fires, 595, 2287, 2355, 2392, 2393
- specific heat, 140, 141, 2667
- toxicity
 - Ct* product dose, 2332
 - fractional effective dose (FED), 2324, 2393, 2405, 2416
 - fractional incapacitating dose (FID), 2405
 - interaction with carbon dioxide, 2232
 - interaction with hydrogen cyanide, 2222
 - and low-oxygen hypoxia, 2292, 2370

Carbon tetrachloride, as early

- extinguishing agent**, 1451, 1452

- Carboxyhemoglobin (COHb)**, 1239, 2220, 2221, 2299, 2301, 2313, 2315, 2322, 2326, 2329, 2331, 2333, 2346, 2362, 2396, 2407
- predicting concentrations, 2419

- Carpeting, heat release rates**, 818, 866, 878

- Cars, passenger.** *See* Motor vehicles

- Case goods, heat release rates**, 816
- CEFICOSS computer program**, 1944

Ceiling fires

- CFD model application to coffered ceiling, 1059, 1060
 - corridor flame spread, 713–714
 - corridor heat transfer, 761–765
 - flame spread, 713–714
 - heat transfer beneath, 765–769
- Ceiling jet flows**
- buoyancy and, 429, 430, 449
 - confined ceilings
 - channel configuration, 445–446
 - general enclosure configurations, 447–449
 - convective heat transfer
 - ceiling jet region, 439
 - weak plume impingement region, 438
 - development in corridors, 449–451
 - entrainment and, 434, 445, 451
 - excess temperature, 430–435
 - excess velocity, 430–435
 - flame length, 437
 - friction factor, 439
 - heat release rates, 431, 432, 434, 435, 437–444, 446–450
 - nondimensional relations, 435–437
 - sloped ceilings, 439–441
 - steady fires
 - strong plume-driven flow field, 437
 - weak plume-driven flow field, 429–437
 - submerged/two-layer environment, 429, 431, 441, 443, 447, 449, 451
 - temperature, 429, 430, 435–437, 439–449
 - thickness, 430, 437
 - time-dependent fires
 - power-law fire growth, 442–445
 - quasi-steady assumption, 441–442
- Ceiling jet stage, compartment fires**, 1067–1068
- Ceiling layer, fire plumes**, 414. *See also* Compartment fires, two-layer system
- Ceiling linings.** *See* Wall/ceiling lining materials
- Ceiling temperature, polymer decomposition**, 199
- Cellulose, heat of combustion**, 143
- Cellulosics**, 172, 179, 227, 502, 581, 583, 591, 592, 600, 613, 615, 620, 622, 637, 662, 830, 890, 1001, 1003, 1137, 1174, 1264, 1301, 1456, 1511, 1533, 1589, 2235, 2237, 2240, 2246, 2250, 2277, 2281–2283, 2291, 2295, 2296, 2942, 3215, 3244, 3272, 3311
- thermal decomposition, 181

- Central Limit Theorem**, 2835, 2862
- CET89 computer code**, 2751
- CFAST multiroom zone model**, 942, 956, 1028, 1097, 1249, 1274, 1818, 2243, 2244, 3009, 3016, 3039, 3233–3235, 3356, 3364
- CFD**. *See* Computational fluid dynamics (CFD) models
- CFX Flow3D CFD model**, 1056, 1610, 1611
- Chain scission mechanisms, thermal decomposition**, 183, 213–216, 220
- Chairs**
heat release rates of lightly upholstered, 818
heat release rates of stackable, 818 upholstered, room effects on heat release rates, 800
- Chapman-Jouguet theory, detonations**, 2751, 2752
- Char(ring)**
building materials, 290–291
decomposition of polymers, 197
and ignition of solid fuels, 639
intumescent, 241, 247
rate, 290, 291, 309, 1984–1986, 1988, 1991, 1992, 1994, 1997–1999, 2002, 2003
wood, 265, 290, 291, 1985–1994
- Checklists**
evacuation computer models, 2088, 2174
fire risk analysis method, 2825, 2981
- Chemical equilibrium**
carbon formation in oxygen-deficient systems, 157–158
computer programs for calculations, 165–166
constant, 151–153
departure from equilibrium, 158
and dissociation, 151, 156
quantification of constants, 154–156
sample problems, 158–165
simultaneous, 153–154
- Chemical heat**, 1187, 1188, 1194
- Chemical heat of combustion**, 1182, 1185, 1186, 1188, 1192, 1193, 1196, 1209, 1210, 1218, 1224
- Chemical heat release rate**
determined by CO₂ generation
calorimetry, 1146, 1147, 1183
determined by oxygen consumption calorimetry, 1183–1184
and flame height, 398, 402
- Chemical reactions, exothermic/endothermic**, 377, 616, 1898, 3164
- c-Hexane (c-C₆H₁₂), heat of combustion**, 143
- Children, arousal by smoke detector**, 2463
- Chi-square distribution**, 2839–2840, 2854, 2866, 2867, 2869, 2915
- Chlorinated polyvinyl chloride (CPVC), thermal decomposition**, 1154, 3453, 3458
- Chlorine, heat of formation (atomic)**, 145
- α-chloroacetophenone (CN)**, 2233, 2250
- o-chlorobenzylidene malonitrile (CS)**, 2233, 2250
- Christmas trees, heat release rates**
artificial, 863, 864
natural, 859–863
- CIB**. *See* Conseil International du Bâtiment (CIB)
- Cigarette smoldering**, 592, 2342, 2392, 2999, 3214
- Class A foams**, 1300, 1737–1739, 3286
- Clean agent halon replacements**
characteristics, 1483–1485
environmental concerns
global warming potential, 1483–1485, 1503–1504
ozone depletion, 1502–1503
explosion inerting, 1498
explosion suppression, 1498–1499
extinguishing mechanisms, 1485–1486
flammable gas/liquid extinguishing concentration
cup burner apparatus, 1486–1492
opposed-flow diffusion flame apparatus, 1488, 1492, 1493
halocarbon compounds (*see* Halocarbon extinguishing agents)
inert gas mixtures (*see* Inert gas extinguishing agents)
solid fuel extinguishing concentration, 1492–1495
system design
agent hold time and leakage, 1526–1527
agent quantity, 1512
compartment pressurization, 1525–1526
and decomposition products, 1513–1516
design concentration, 1509–1512
discharge time, 1513
flow division at tees, 1519, 1521–1522
hydraulic flow characteristics, 1517–1520
- Clean agent halon replacements (cont.)**
nozzle area coverage/height limitations, 1524
pressure drop due to friction loss, 1522, 1523
testing/approval of design methods, 1522–1524
thermophysical properties, 1505–1508
toxicity, 1499–1502
use on energized cables/equipment, 1494, 1496–1498
- Cleanrooms, fire propagation index for polymeric materials**, 1162, 1163
- Cleveland open cup apparatus**, 566
- Clothing items, heat release rates**, 818–820
- Cluster sample**, 2871
- CMA wood charring model**, 1994
- Coburn-Forster-Kane (CFK) equation**, 2331, 2350, 2352, 2354, 2367, 2416, 2417, 2419–2421
- Codes**
design disadvantages, 1236–1237
design requirements, 2309
safety factors, 1137, 2309–2311, 3209
- Coffee makers, heat release rates**, 821
- COFRA fire risk indexing model**, 3178–3179
- Cognition**, 2078, 2921
- Cognitive error**, 2921
- Columns**
buckling, 265–267, 270, 1443, 1893, 1904, 1905, 1939–1941, 1996, 1999
critical stress in steel, 1941
critical temperature determination in steel, 288–289, 293, 294, 296, 312, 1938–1940, 2838, 2889
Euler equation, 1095–1097
failure, 264, 270
fire resistance in steel, 1910, 1911, 1913, 1916, 1919, 1936
fire resistance testing, 1910
heat transfer analyses, 1911, 1927–1936
liquid-filled, 1919, 1930
reinforced concrete, 1973–1974
slenderness ratio, 1939, 1941, 1974
- Combustion bomb calorimeter**, 142
- Combustion efficiency**, 145, 398, 399, 403, 424, 496, 522, 523, 582, 866, 909, 1001, 1013, 1014, 1137, 1139, 1159, 1182, 1186–1188, 1192, 1200, 1209, 1212–1214, 1221, 1223, 2289, 2291, 2394, 2640, 3038

Combustion kinetics

- branching, 329, 624
- chain-branching, 329, 340, 341
- chemical equilibrium in flame/
postflame gases, 328
- combustion products, 486, 493, 504,
511, 512, 514, 515, 517, 519,
520, 1181
- competition between elementary
reactions
 - and action of extinguishing/
retardant agents, 595
- oxidation rates and degradation of
fuel, 337–339
- rate of oxidation of CO by
hydroxyl radicals to that of
fuel molecules, 339–340
- rates of reaction between H atoms
and molecular oxygen,
340–341
- role of chain branching, 335, 336,
340, 341, 342, 344
- free radicals, 328–329
- fundamentals
 - concentrations, 332, 336, 344
 - order of reaction, 331
 - rate constant, 332
 - rate of reactions, 335, 1041
 - temperature dependence of
reaction rates/activation
energy, 333–335
- gas-phase reactions, 335, 336
- hydrocarbon oxidation mechanisms,
507, 509
- initiation, 1147–1150
- propagation, 1154–1156
- soot formation, 2640
- temperature range breadth, 627
- termination, 329

Combustion products. *See* Fire products; Species production, effect of combustion conditions on

Compartment fire modeling

- breathing effect, 985
- computational fluid dynamics
 - models (*see* Computational fluid dynamics (CFD) models)
- conduction heat transfer, 990
- conservation equations
 - energy, 984–985
 - mass, 983
 - species, 984
- convective heat transfer,
988–989
- door vent, 982
- entrainment, 981, 983, 987
- fire growth rate, 991
- forced flow effects, 991
- radiative heat transfer, 989–990

Compartment fire modeling (cont.)

- submodels
 - embedded, 991–992
 - mass/heat transport, 987–991
 - source term, 986
 - unresolved phenomena, 992, 993
 - upper/lower layers, 981, 982, 986,
989, 990
 - mixing between, 990–991
 - vent flows through horizontal
openings, 988
 - vent flows through vertical
openings, 987–988
 - volumetric expansion effect, 985
 - zone models (*see* Zone models)
- Compartment fires**
- conservation of energy and, 1002
 - conservation of mass and,
1000–1002
 - corner tests (*see* Room/corner tests)
 - defined, 996
 - energy generated, 999–1000
 - flame spread, 992
 - free-burning/fuel-controlled, 1000,
1015
 - heat release rates, 997, 1005, 1009,
1011, 1015–1018
 - equivalence ratio, 1010
 - ISO 9705 standard test, 504, 711, 712,
757, 788, 801–803, 848, 852,
853, 859, 891, 892, 935–938
 - and measurement of heat release
rates, 1014, 1015
 - predicting flashover
 - Babrauskas method, 1018–1019
 - comparison of methods,
1020–1021
 - McCaffrey et al method,
1019–1020
 - Thomas method, 1020
 - predicting postflashover
temperatures
 - Babrauskas method, 1010–1014
 - Law method, 1013–1015
 - Swedish method, 1016, 1017
 - predicting preflashover temperatures
 - Beyler and Deal method,
1006–1007
 - Beyler method, 1008–1009
 - Footo et al. method, 1005–1006
 - McCaffrey et al. method, 1002–1005
 - Peatross and Beyler method,
1007–1008
 - radiative heat transfer, 989–990, 1003
 - secondary/remote ignition, 1271
 - species product formation
 - compartment fire experiments,
499–505
 - full-scale studies, 504
 - hood experiments, 493–499

Compartment fires (cont.)

- stages
 - enclosure smoke-filling,
1068–1069
 - fire plume/ceiling jet, 1067–1068
 - postflashover vented, 1069, 1070
 - preflashover vented, 1069
 - temperature calculation, 998–999
 - temperature-time estimation
 - assumptions, 988, 989, 998
 - CIB data, 1001, 1013, 1014
 - duration of temperature, 1016, 1018
 - experimental results, 1013, 1014,
1020, 1021
 - factors affecting temperature rise,
998
 - heat release rate, 997, 1017–1019,
1132
 - increased fuel load, 1016
 - level of protection/location, 996,
1002
 - manner of ignition/enclosure
lining, 996
 - standards, 1017
 - temperature-time history, 146,
1017, 1018
 - ventilation, 997, 999–1002,
1004–1008, 1013, 1015–1020
 - transport to adjacent spaces
 - burning in unconfined adjacent
areas, 512
 - burning in confined adjacent
areas, 512–515
 - effects of burning outside
compartment, 511
 - effects of oxygen-deficient smoke
layers, 517–519
 - forced ventilation and, 519
 - predicting species levels, 515–517
 - two-layer system, 487, 489, 490,
500, 523
 - ventilation-controlled, 997, 999–1002
 - vent openings, 487
- Compartment fires, modeling
smoke filling**
- comparisons with experimental
data, 1097–1099
 - conditions in descending smoke
layer, 1085–1087
 - descending smoke layer analysis,
1082–1085
 - forced ventilation effects on smoke
layer
 - ceiling leakage path, 1093–1095
 - floor leakage path, 1091–1093
 - global effects, 1087–1091
 - smoke layer analysis, 1091
 - global (one-zone) analysis, 1088
 - concentrations of smoke/other
species, 1078–1080

Compartment fires, modeling**smoke filling** (*cont.*)

- leaky compartment, 1074–1075
- light attenuation/visibility through smoke, 1081–1082
- oxygen limitations on heat release, 1080–1081
- sealed compartment, 1073–1074
- temperature rise, 1075–1078
- modeling background, 1067
- numerical methods for solving initial value problems
 - Adams-Bashforth method, 1096
 - explicit or forward Euler method, 1095
 - Heun's method, 1096
 - Runge-Kutta methods, 1096
- phenomena associated with, 1070–1072

representative models, 1096–1097

COMPBRN III zone fire model, 1027**Compensation calorimeter**, 911**COMPF2 postflashover zone fire model**, 867, 1010, 1027, 1028**Components**

- mean time between failures (MTBF), 2789–2790, 2877, 2891, 2908, 2909
- mean time to failure (MTTF), 2877, 2880, 2929, 2930
- mean time to repair (MTTR), 2877, 2900, 2908, 2909
- nonrepairable/repairable, 2876

Composites, 29–30, 32–33, 121, 186, 189, 216, 222, 224, 273, 274, 278, 279, 285, 286, 309, 310, 313, 413, 585, 641, 707, 717, 774, 775, 785–787, 808–810, 831, 852, 890, 921, 969, 974–975, 1098, 1134, 1135, 1152, 1162, 1165–1167, 1170, 1190, 1362, 1370, 1673, 1869, 1871–1873, 1885, 1886, 1889, 1899, 1905, 1917, 1943–1945, 1950, 1956, 1957, 1974–1976, 1984, 1986, 1996, 2001–2002, 2004, 2185, 2296, 2538, 2962, 3022, 3094, 3248, 3250, 3252, 3257, 3265, 3268, 3371, 3379, 3453, 3454, 3469

Composites and fiberglass-reinforced materials, fire propagation index, 1164

Compressible fluid motion, 1380, 1382, 1624

Computational fluid dynamics (CFD) models

- applications
 - smoke filling, 1057, 1060
 - smoke movement, 1055

Computational fluid dynamics (CFD) models (*cont.*)

- computer hardware/software, 1049–1050
- explosion venting, 1056–1058
- finite volume method, 1048–1049
- fire spread, 1035, 1054, 1058
- general, 1035
- governing equations
 - assumptions, 1036–1037
 - conservation of energy, 1036
 - conservation of mass, 1036
 - conservation of momentum, 1036
- limitations, 1080–1081
- numerical solution
 - conservative/nonconservative, 1047
 - explicit/implicit, 1047
 - finite difference approximation, 1046–1047
 - order of accuracy, 1047–1048
 - spatial dimension, 1048
 - staggered/co-located variables, 1047
- outdoor applications/wind, 1059
- and quantifying fire scenarios, 1052–1054
- references, 1036, 1042, 1043
- smoke movement
 - example applications, 1055
 - fire source, 1037, 1058
 - large-volume spaces, 1055
 - open boundary conditions, 1045
 - visibility, 1045
- source terms and boundary conditions
 - combustion, 1041–1042
 - energy exchange at boundaries, 1044–1045
 - generation of species, 1042
 - mass exchange at boundaries, 1043
 - momentum exchange at boundaries, 1043–1044
 - radiation heat transfer, 1042–1043
- sprinkler activation with coffered ceilings, 1045
- tunnel applications, 1057–1058
- turbulence modeling
 - direct numerical simulation, 1037
 - isotropic turbulence assumed, 1039
 - large eddy simulation, 1039–1040
 - Reynolds-averaged Navier-Stokes approach, 1037–1039
 - verification/validation, 1050–1051
- visualization, 1050
- water mist fire suppression systems, 1591

Computer fire models, 981, 1000, 1024–1032, 1357, 1840, 2036, 2269, 2918, 2919, 3000, 3009, 3010, 3039, 3133. *See also* Computer simulation models; Zone models

Computers

- CPU heat release rates, 821, 822
- heat release rates of racks with equipment, 822, 823, 826, 827
- heat release rates of tapes, 821–822, 827
- keyboard heat release rates, 821, 822
- message passing interface, 1050
- mice heat release rates, 821
- monitor heat release rates, 821, 823–826
- parallel processing, 1049, 1050
- printer heat release rates, 821, 826

Computer simulation models. *See also*

- Evacuation computer models applications, 3125–3128 (*see also specific models*)
- compartment fires (*see* Compartment fire modeling)
- descriptive models, 3118
- Monte Carlo procedures, 3122–3123
- output analysis, 3132–3133
- physical models, 3118
- sensitivity analysis, 3122–3125
- simulation models
 - continuous, 3120–3122
 - discrete, 3119–3120
 - symbolic models, 3118
- uncertainty and, 3129–3132
- validation, 3128–3129

COMSOL computer program, 1127, 1994, 2001

Concrete

- aggregates, 1950, 1952–1953, 1955–1957, 1959, 1961, 1962, 1976
- bond with fiber-reinforced polymers, 1976
- compressive strength, 1949, 1950, 1952, 1961, 1962, 1969, 1973, 1976
- creep, 298, 299, 1880
- density, 1950, 1953, 1954
- fiber-reinforced (*see* Fiber-reinforced concrete (FRC))
- as fire protection material, 1949
- heterogeneous material, 278
- high-strength (*see* High-strength concrete (HSC))
- lightweight, 296, 299, 300, 1363, 1876, 1912, 1922, 1923, 1957, 1960, 1966
- mass loss, 285

Concrete (cont.)

- modulus of elasticity, 1950, 1951, 1953, 1954
- normal-strength (*see* Normal-strength concrete (NSC))
- properties,
 - modulus of elasticity, 1950, 1951, 1953, 1954
 - strength, 1950–1953
 - thermal expansion, 1965–1968
- reinforced, bond between rebar and concrete, 1951, 1970, 1975
- spalling, 1903, 1976
- specific heat, 1950, 1953, 1955
- thermal conductivity, 1950, 1955–1956
- thermal properties, 1951, 1953
- volumetric heat capacity/temperature relation, 298–300

Concrete members

- beams, 1950, 1961–1962
- bending strength, 1974, 1975
- composite steel-concrete construction, 1974–1975
- fire resistance determination by analytical methods
 - continuous one-way span example, 1962–1965, 1969
 - continuous unrestrained flexural members, 1962–1964
- heat transmission, 1956–1960
- members restrained against thermal expansion, 1965–1968
- simply supported slabs/beams, 1961–1962
- floor slabs, 1935
 - and thermal thrust force, 1965, 1966, 1968
- heat transfer/temperature profiles, 1949–1950
 - determination methods, 1949
- prestressed concrete assemblies, 1950, 1974
- recent developments
 - Eurocodes, 1950, 1961, 1974, 1975
 - fiber-reinforced concrete, 1976
 - high-strength concrete, 1976
 - hollow-core slabs, 1976–1977
 - spalling, 1976
 - temperature calculation, 1950, 1975
- reinforced concrete columns, 1973–1974
- reinforced concrete frames, 1974
- reinforced concrete walls, 1974
- thermal degradation at high temperatures, 1985

Concrete structures, temperature in fire-exposed

- fire-insulated, 1126–1127
- one-dimensional calculations, 1124–1126
- penetration depth in semi-infinite structures, 1122–1124

Conduction heat transfer

- compartment fire modeling and, 990
- Fourier's law and, 27
- heat diffusion equation, 1107
- integral (Duhammel's) analysis method, 40–42
- limitations on analytic solutions, 48
- modeling in materials, 29
- numerical techniques, 45
- models, 3009
- separation of variables analysis method, 38–39
- steady-state examples, 30
- thermally thin material, 33–34
- thick plates, 33–34
- through cavity walls, 3248–3250
- through laminated plates, 3271
- through pipe walls, 2747
- through plates, 38
- through solid wall, 1362, 3250
- through spherical solid with internal generation, 33, 40

Cone calorimeter

- additional gas analyzers, 972
- airflow, 962–963
 - exhaust system, 963
- calibration equipment, 961, 962, 971, 972
- controlled-atmosphere type, 977
- edge frame, 969
- features, summary of, 952–954
- means of ignition, 963–965
- measurements taken with, 975–976
- and nonambient pressures, 977
- operating principle, 956–957
- optical density measurement, 971
- orientation of heater/specimen, 960–962
- paramagnetic oxygen analyzer, 957
- radiant heater
 - choice of heater type, 957–958
 - conical shape, 958–959
 - convective fraction of heating flux, 959–960
 - design details, 958
 - emissivity of, 959
 - range of heat fluxes needed for testing, 957
 - uniformity of heating flux, 960
- repeatability/reproducibility of tests, 976
- ring sampler, 971, 973
- smoke measurement, 970–971

Cone calorimeter (cont.)

- specimen area, 965–966
- specimen thickness, 966, 967
- standard version, 925, 926
- testing specifications
 - edge effects, 969
 - intumescent samples, 969–970
 - load cell, 961, 962, 967–968
 - specimen orientation/holders, 966–968
- toxicity test, 2270, 2275
- wire grid use on specimens, 969, 970

Cone Calorimeter Annotated Bibliography (Babrauskas), 898**Confidence coefficient/limits, 295, 896, 2234, 2861–2862, 3238****Configuration factors, 120, 121, 2601, 2604, 2606–2609, 2613–2616, 2619, 2645, 2654, 2655, 3243–3246, 3476–3492****CONFIRE computer program, 1974****Conseil International du Bâtiment (CIB), compartment fire experiments, 1001****Consequence analysis, 1276–1277, 2758, 2943, 2944, 2948, 2949, 2969, 3185–3186, 3200****Consequences**

- decision analysis and, 3048, 3049, 3059
- defined, 3049

Conservation equations, convection heat transfer, 58–64. *See also* Energy, conservation of; Mass, conservation of; Momentum, conservation of**Consumer Product Safety Commission (CPSC), 675, 853, 3079, 3084, 3095, 3108, 3223****Consumer products, fire risk analysis. *See* Products (finished), fire risk analysis****CONTAM multizone fire model, 1027, 1029, 1788, 1791, 1794, 1797, 1799, 1801, 1804, 1807–1809, 1818****Contingency table, 2870****Continuity equation. *See* Mass, conservation of****Continuous probability distribution, 2831–2835, 2857, 3034, 3036****Control volume fire models. *See* Zone models**

- Convection heat transfer**
 boundary layer concept
 boundary layer approximation, 66–67
 heated, vertical plate, 71–75
 laminar flow over flat surface, 67–71
 laminar free convection, 71
 calculations
 electrical strip heater, 94–97
 fire door, 98–99
 glass-door fire screen, 97–98
 coefficient of
 basic laws and, 54–58
 experimental determination, 88–89
 compartment fire modeling and, 988–989
 complications in practical problems
 changes in fluid properties, 85
 complex geometry, 83–85
 effect of mass transfer, 85–86
 effect of turbulence, 80–83
 conservation equations for, 58–64
 simplifications, 64
 empirical relations, 86–94
 to fire-exposed structures, 1105–1107
 natural/forced, 53
 simple example, 53–54
- Convective heat release rate**, 406, 407, 409, 413, 415, 417, 424, 431, 432, 434, 435, 437–439, 442, 443, 926, 943, 1146, 1148, 1166, 1167, 1184, 1188, 1192, 1210, 1316, 1324, 1327, 1329, 1833, 1842, 1852
- Conversion factors**, 146, 2126, 2134, 2801, 3161, 3397–3424
- Conveyor belts, fire propagation index**, 1161
- Cook County Administration Building fire (2003)**, 901, 1065, 2113
- Copper pipes, properties**, 1389, 1392, 1408, 1430, 3491
- Corners**
 effect on ceiling jet flows, 434, 446–447
 effect on flame spread, 707, 712
 effect on plume, 396, 420–422
 heat transfer from fires in, 751–759
- Correlation coefficient**, 929, 944, 1203–1205, 1207–1209, 2620, 2622, 2836, 2857–2860, 3011, 3018, 3023, 3041, 3070
- Corridors**
 ceiling fire heat transfer, 450
 ceiling flame spread, 713–714
- Corridors (cont.)**
 development of ceiling jet flow, 449–451
 heat transfer in, 761–765
 transient flows, 992, 993
- Corrosion**
 measurement methods, 732–733
 nonthermal damage, 1219
- Cost-benefit analysis**
 air transportation risk management, 3382–3383
 engineering economies, 3137, 3143, 3146, 3148
 residential fire sprinklers example, 2818, 3025, 3026
 risk assessment example, 3184
- Cottonseed meal, autoignition**, 627
- Couette flow, liquids**, 720
- CPSC. See Consumer Product Safety Commission (CPSC)**
- CRC Handbook of Chemistry and Physics (Weast and Astle, eds.)**, 558, 1168
- Creepage, arc tracking and**, 673
- Creep, building materials**, 282–283
 concrete, 298, 299, 1880
 steel, 293
 in tension members, 264–265
- Cribs**
 center-ignited, 829
 heat release rates, 828–830
 ignited uniformly, 829
 room fire effects, 830
- CRISP II fire risk assessment model**, 3125
- CRISP risk assessment model**, 3125
- Critical heat flux (CHF)**, 211, 239, 586, 588, 1147, 1149, 1150, 1152, 1154, 1161, 1166, 1171, 1198, 1216–1217, 1256, 2656, 2722, 2724, 3243, 3451–3455, 3465, 3468
- Critical stress**
 steel beams, 1941–1943
 steel columns, 1941, 1942
- Critical temperature, algebraic equations for steel members**
 beams, 1938–1939
 columns, 1939
 computer programs, 1943–1945
- Cross-linking mechanisms, thermal decomposition**, 179, 182, 183
- Crowd management/control**, 2034, 2040, 2042–2044
- CRSI Handbook (Concrete Reinforcing Steel Institute)**, 1969, 1971
- CSTBZ1 postflashover fire model**, 1028
- Curisk risk assessment program**, 2968
- Curtains, heat release rates**, 830–832
- D**
- Daegu (Korea) subway fire (2003)**, 3374
- Damköhler number**, 369, 370
- Dangerous Substances and Explosive Atmospheres Regulations (U.K.)**, 571
- Darcy-Weisbach equation**, 1388, 1391, 1395
- Decile**, 2856
- Decision analysis**
 consensus
 alternative stability approach, 3069–3070
 comparative, 3070
 compound, 3070
 definitive, 3069
 decision classifications
 decision making under certainty, 3051
 decision making under risk, 3051–3052
 decision making under uncertainty
 Hurwicz paradigm, 3054
 Laplace paradigm, 3053
 Savage paradigm, 3053–3054
 Wald (minimax/maximin) paradigm, 3053
 fire safety attribute weighting
 effectiveness matrices, 3061–3062
 hierarchy approach, 3061
 measurement
 interval scale, 3066–3067
 nominal scale, 3066
 ordinal scale, 3066
 ratio scale, 3067
 multiobjective decisions
 additive weighting, 3057
 attributes, 3056
 disjunctive, 3056
 dominance, 3056
 illustration, 3057–3060
 objectives, 3055–3056
 satisficing, 3056
 values/utilities, 3056
 weighting, 3056, 3057
 panels of experts
 committee, 3067
 computer conferencing, 3068
 DACAM group, 3068–3069
 Delphi panel, 3068
 nominal group, 3067–3068
 payoff matrices, 3173–3174

- Decision analysis** (*cont.*)
 probability
 axioms of, 3050
 frequentists, 3049
 objective/subjective, 3049
 subjectivists, 3049
 subjectivity, 3049
 uncertainty, 3049
 weighting methods, fire safety
 evaluation
 analytic hierarchy process (AHP),
 3064–3065
 Edinburgh cross-impact analysis,
 3062
 hierarchical cross-impact analysis
 (HCIA), 3063–3064
- Decision tree**
 decision analysis, 2946, 3384–3385
 fire risk analysis, 2824, 2950, 3053
 risk decision making in rail
 transport, 3381
- Decks**
 fire resistance, 1999–2000
 heat release rates, 831
- Deep storage fires**
 flame height, 401
 virtual origin, 413, 414
- Deflagrations.** *See* Explosion
 protection, closed vessel
 deflagrations
- Degrees of freedom, distribution
 parameters,** 2915
- Delphi panels,** 3068–3070, 3086
- Deluge sprinkler system,** 1620,
 1686, 1767, 2029
- Density**
 building materials, 305–309, 314,
 316
 fluids, 1, 29, 64, 71, 77, 1378, 1408,
 1573, 1574
- Depolymerization,** 252
- Depropagation reactions, thermal
 decomposition,** 215
- Design for Fire Resistance of
 Precast Prestressed Concrete
 (Prestressed Concrete
 Institute),** 1974
- Desks, heat release rates,** 831–832
- DETECT-QS heat detector
 response program,** 943, 1325,
 1444
- Detact-t2 model,** 3235
- Detection system design**
 cost analysis, 1369–1370
 delay to detection, 1316
 design fire, 1316, 1317
 detection, 1317
 fire alarm audibility
 and intelligibility, 1368, 1369
- Detection system design** (*cont.*)
 scenarios, 1369–1370
 sound pressure level, 1360–1363,
 1365–1368
 fire alarm visibility, 1370–1374
 fire signature, 1317, 1318
 heat detection
 data selection, 1331–1334
 design examples, 1334–1343
 detector spacing, 1331–1333
 error sources, 1325–1326
 growing fires, 1324–1325
 power-law fires, 1326–1330
 response time index (RTI), 1321,
 1322, 1324, 1326
 steady-state fires, 1323–1324
 heat flux setting, calculating, 132
 precision/rounding off,
 1314–1315
 process goals, 1315
 radiant energy, 1357–1358
 example, 1358–1359
 smoke detector response
 calculation examples,
 1350–1357
 entry resistance, 1348–1350
 and forced ventilation systems,
 1351–1354
 modeling, 1344–1345
 and obscuration/attenuation,
 1344–1345
 temperature approximation theory
 and, 1356–1357
 system elements, 1317
 use of models, 1320, 1322, 1323,
 1328, 1330
- Detention/correctional occupancies,
 fire risk indexing model,**
 3178
- Deterministic fire models,** 1024,
 1031, 2039, 2919, 3364
- Detonations.** *See* Explosion
 protection, detonations
- D-Glucose (C₆H₁₂O₆), heat of
 combustion,** 143
- Diagnosis time,** 2899, 2922
- DIANA computer program,** 1974
- Diesel fuel, pool fire emissive
 power,** 1683, 2598, 2599
- Differential scanning calorimetry
 (DSC),** 178, 179, 184,
 186–188, 191, 192, 203, 218,
 246, 286, 299, 307, 606, 630,
 1168–1171, 1175
- Differential thermal analysis
 (DTA),** 178, 179, 184,
 186–189, 246, 287, 606
- Differential thermogravimetry
 (DTG),** 185, 186, 195, 206
- Diffusion flames**
 fire plumes and, 397, 398
 flammability limits, limiting oxygen
 index (LOI), 545, 546
 premixed flames distinguished, 145,
 235, 354
 reduction/oxidation zones, 1194
 wind effect on turbulent jet flames,
 396
- DIN 53 436 toxicity test,** 2273–2274,
 2289–2290
- Directional sounders,** 1365, 1366
- Discrete probability distribution,**
 2831, 2832, 2835, 2846–2850
- Discretization, conduction heat
 transfer analysis,** 1121
- Dishwashers, heat release rates,** 832
- Doors**
 effect of mechanism on evacuation
 time, 1259, 1751, 1752, 2021
 number of open and smoke control,
 478, 1001, 1030, 1043, 1057,
 1343, 1745, 1751, 1752, 1759,
 1768, 1799
- Dow Indices software,** 3179
- Dow's Fire and Explosion Index,**
 3162
- Draft curtains,** 1028, 1029, 1325,
 1843, 1844, 1849–1852, 2996
- Drag,** 53, 58, 77, 84, 726, 729, 1385,
 1386, 1444, 1598, 1655, 2528,
 2535–2537, 2562, 2596, 2753,
 3287, 3288
- Dressers, heat release rates,**
 833, 834
- Dry chemical fire extinguishers, static
 electricity and,** 687, 1302
- Dry pipe sprinkler system,** 1748,
 2780
- DSC.** *See* Differential scanning
 calorimetry (DSC)
- DTA.** *See* Differential thermal
 analysis (DTA)
- DTG.** *See* Differential
 thermogravimetry (DTG)
- Dublin Stardust disco fire (1981),**
 2405, 2406
- Ductility,** 170, 281, 301, 1865, 1873,
 1876, 1904, 1976
- Ducts**
 flame propagation in, 2777, 2787,
 2788
 fluid flow in
 hydraulic radius, 365
 laminar/turbulent, 20
- Duhammel's method, heat transfer
 analysis,** 41–42, 51
- Dupont Plaza hotel fire (1986),**
 2338, 2406, 2447

Dust(s)

- clouds
 - ignition by arcing, 670–671
 - minimum ignition energy, 670, 671, 684
 - minimum ignition temperature, 671
- explosion protection
- explosibility testing, 2766, 2767
- minimum explosible
 - concentration, 2771
 - particle size, 2766
- layers, minimum ignition
 - temperature, 2771
- lower flammability limits, 670
- particle size, 2766, 2768, 2769, 2771, 2772, 2784
- static electricity and, 671

E**The Economies of Fire Protection (Ramachandran), 3098****Eddy thermal conductivity**, 81**Eddy viscosity**, 15, 81, 367, 1038–1040, 1062**EFSES fire risk indexing model**, 3172**Egress**

- available safe egress time (*see* Available safe egress time (ASET))
- elevators, 2026–2027
- escalators, 2027, 2029
- exit capacity, 2012, 2014–2015
- exit width, 2014–2016
- fire escapes, 2019
- pedestrian walkways, 2029–2030
- protect-in-place, 1743, 2021–2022
- refuge floors, 2029
- required safe egress time (*see* Required safe egress time (RSET))
- scenarios, 2032
- trains, 2027
- vessels, 2153

Elastomers, 171, 179, 220–222, 224, 803, 1161, 1165, 1452, 1457, 2234, 2788, 3452, 3459, 3465**Electrical cables, fire propagation index**, 1160**Electrical fires**

- defined, 662
- electrical discharges
 - arcs (*see* Arcs, electrical)
 - breakdown, 663–664
 - defined, 663
 - dielectric strength, 666
 - dielectric strength of solid/liquid insulators, 666
 - in gas, 663
 - glow discharge, 667

Electrical fires (cont.)

- ionization, 663
- in liquids, 663
- Paschen's Law, 664–666
- self-healing media, 663
- in solids, 663
- sparks, 663
- electric current, 662–663
- ignition and values of voltage/
 - current/power, 693–694
- ignition modes involving electric
 - current
 - arcing across a carbonized path, 671–673
 - dust clouds, 670–671
 - ejection of hot particles, 681
 - excessive thermal insulation, 681
 - floating neutral, 675, 676
 - gases, 670
 - gross overloads, 674
 - high voltage into low voltage
 - wiring, 675
 - lightning, 675
 - minimum ignition energy, 670, 671
 - miscellaneous phenomena, 681
 - overheating connections, 678–681
 - overloads and related phenomena, 674–678
 - sparking/arcing, 670
 - stray currents/ground faults, 675
 - surface flashover, 673–674
 - voltage spikes, 676
- ignition modes involving electric
 - currents/solids, 670–681
- static electricity discharge
 - charge separation, 682
 - discharge types, 682–683
 - general, 681–682
 - granular materials, 687–688
 - liquids, 668–6899
 - persons, 686–687
 - solids, 685–686
- time for fire to initiate, 681

Electric cable trays, heat release rates, 834**Electronic equipment**

- heat release rates, 823
- heat release rates of cabinets, 827

Elevators

- and evacuation use, 3128
- safe for handicapped/impaired
 - persons, 3129

Elevator shafts, smoke control, 1807**Emergency flaring**, 2630**Empirical distribution, reliability analysis and**, 2886, 3162**Enclosure fires. *See* Compartment fires****End-chain scission, decomposition mechanism**, 197**Endothermic reactions**, 142, 155, 1992**Energy, conservation of**

- computational fluid dynamics
 - models and, 2668, 2669
- convection heat transfer, 81
- in flames, 985

EN, Eurocode 2: Design of Concrete Structures, 1950**EN, Fire Extinguishing Media-Foam Concentrates**, 1661**EN 1363, Fire Resistance Tests**, 1127**Engineering analysis**

- coding categories and, 3089–3090
- data half-truths/myths, 3083–3084
- data sources
 - incident/event data, 3096
 - laboratory data, 3093–3094
 - usage/exposure data, 3093–3094
- field observation data
 - incident/field data on systems
 - performance, 3088
 - inspections/testing, 3087
 - judgment/opinions, 3087
 - product life tracking systems, 3088–3089
 - simulations/laboratory studies, 3087–3088
- handling unknown data, 3079–3084
- incident data, sources, 3076, 3089
- types of analysis/data needs, 3073–3076
- usage and exposure data, 3095–3096

Engineering economics

- benefit-cost analysis, 3146
- cash-flow concepts
 - diagrams, 3138
 - interest calculations, 3138–3139
 - notation symbols, 3138
 - time value of money, 3147
- comparison of alternatives, 3145
 - annual cost, 3145
 - discount rate, 3143–3144
 - inflation and discount rate, 3143–3144
 - present worth, 3144–3145
 - rate of return, 3145–3146
- Cost-Effectiveness Tool, 3151–3153
- extreme events, 3149
- identifying relevant benefits/costs, 3146–3147
- interest factors
 - beginning-of-period payments, 3142
 - capitalized costs, 3142
 - capital recovery factor, 3142
 - compound amount factor, 3139
 - continuous cash flow, 3142
 - continuous interest, 3140
 - discounting, 3139

- Engineering economics** (*cont.*)
 gradients, 3142
 interest periods, 3140–3141
 interest tables, 3139, 3142, 3155
 nominal/effective interest, 3140
 present worth, 3139–3140
 present worth factor, 3140, 3142
 series compound amount factor, 3141
 series payments, 3141–3142
 series present worth factor, 3142
 simple/compound, 3141
 sinking fund factor, 3141
 maximum possible loss (MPL), 3147
 measurement of benefits/costs, 3146–3149
 selection of best alternative, 3147–3149
 software tools for interest calculations, 3143
 standards development, 3150–3151
 three-step protocol (NIST), 3149–3150
 treatment of uncertainty, 3149
- Engineering Guide on Pool Fire Radiation (SFPE)**, 2600
- Engineering thermoplastics**, 174, 227
- English Channel tunnel fire (1996)**, 3374
- Enthalpy**, 4, 8, 9, 57, 63, 139, 140, 142, 144, 150, 154, 159, 161, 165, 180, 187, 188, 198, 286, 320, 375, 378, 381, 389
- Entrainment**
 ceiling jet flows and, 429–451
 ceiling layer and, 451
 compartment fire modeling and, 981–993
 fire plumes, 396–425
 and species transport to adjacent spaces, 510–511
- Entropy**, 3, 154, 155, 166, 179–181, 183, 199, 1536, 1537, 1539, 1540, 2801, 2814, 3398
- Environmental Protection Agency (EPA)**, 1500, 1502, 1503, 1505, 1533, 1542, 1544, 1545, 1601, 1602, 1697, 2263, 2342
- Environmental protection concerns**
 contamination from runoff water, 1276
 e-folding lifetimes, 1503
 foam agents
 assessment methods, 1699–1701
 biodegradability, 1699–1701
 foaming/emulsification of fuels, 1701
 mitigation strategies, 1701–1702
 potential hazardous situations, 1699
 system discharge testing, 1699
- Environmental protection concerns** (*cont.*)
 toxicity, 1701
 training evolutions, 1699
 uncontrolled fires, 1698
 halocarbon extinguishing agents
 global warming potential, 1502
 ozone depletion, 1502
 halogenated agents, 1501
 statutes, 629
 toxic products of combustion, 1276
- EPA**. *See* Environmental Protection Agency (EPA)
- Epoxy resins, thermal decomposition**, 1276, 1277
- Equation of state, fluids**, 3–4
- Equivalence ratio**
 and fire products generation rates, 926
 heat release rates in compartment fires, 997–998
- Erlang distribution**, 2842–2843
- Error-forcing context**, 2921
- Error of commission**, 2921
- Error of omission**, 2921
- Ethane (C₂H₆)**
 heat of combustion, 143
 heat of formation, 145
- Ethanol (C₂H₅OH), heat of combustion**, 142, 144
- Ethene (C₂H₄)**
 heat of combustion, 143
 heat of formation, 145
- Ethylene 130**, 165, 174, 176, 181, 192, 193, 213, 368, 381, 382, 534, 540, 561, 625, 670, 773, 774, 1154, 1164, 1170, 1209, 1214, 1215, 1298, 1699, 2235, 2634, 2635, 2638, 2641, 2642, 2667, 2690, 2694, 2696, 2739, 2746, 2749, 2752, 3431, 3439, 3441, 3442, 3450, 3453, 3455, 3460, 3472
- Ethyne (C₂H₂)**
 heat of combustion, 143
 heat of formation, 145
- Euler column equation**, 1095
- Eulerian method, describing fluid motion**, 1610
- EUREFIC (European Reaction to Fire Classification) model**, 936
- Eurocode 4: Design of Composite Steel and Concrete Structures**, 1950
- Eurocode 2: Design of Concrete Structures**, 1950
- Eurocode 5: Design of Timber Structure**, 1979
- Evacuation**
 aircraft, 1587
 areas of refuge, 1266
 available safe egress time, 1066
 building characteristics, 1243
 before building collapse, 2806
 crowd movement and, 2034
 delay time to start, 2435
 calculating, 2091
 directional sound guidance system, 2202
 drill studies, 2441
 egress time model, 1067
 elevator use, 1343, 1752
 engineering data
 delay times, 2435
 pre-evacuation, 2448
 travel data, 2477, 2499
 escape guidance systems, 2204
 handicapped/impaired occupants, 2524
 high-rise residence building, 2176
 hydraulic model (*see* Hydraulic model, egress performance)
 incident studies, 221
 large retail store, 414
 models (*see* Evacuation computer models)
 movement in smoke, 1789
 movement of people and, 2042
 Fruin's level of service, 2016
 occupant characteristics, 1243–1244, 1257
 office buildings, 2087–2089
 perception of time available for, 2014
 premovement (*see* Evacuation, delay time to start)
 required safe egress time, 2053
 road tunnels, 2043
 underground rapid transit station, 2053
- Evacuation computer models**
 behavioral models, 2157
 computer models, 2152
 empirical engineering approach, 2152–2153
 manual engineering approach, 2153
 modeling process, 2154
 model selection
 age/generation, 2158
 checklist, 2176
 current models, 2157
 distribution/cost, 2158
 level of refinement, 2158
 model characteristics, 2156–2158
 modeling method, 2156–2157
 origin (development/validation) of model, 2155–2156
 output, 2157
 scope of representation, 2157

- Evacuation computer models** (*cont.*)
 movement models, 2156
 partial behavior models, 2156–2157
 project requirements, 2154
 deliverables of the project, 2155
 information availability, 2154
 nature/scope of project, 2155
 timing/funding, 2155
 scenario development
 additional building information, 2155
 behavior of occupants, 2037
 building configuration, 2169–2171
 checklist, 2177
 coarse network (building configuration approach), 2169–2171
 continuous network (building configuration approach), 2172–2173
 example, 2166, 2167
 fine network grid (building configuration approach), 2171
 fire information, 2167
 inclusion of emergency responders/building staff, 2176
 movement of occupants, 2165
 number of people, 2174
 occupant characteristics, 2164
 occupant route choice, 2166
 population configuration, 2163–2164
 pre-evacuation time, 2164–2165
 procedural configuration, 2166–2167, 2176
 structure generation/representation, 2162
- Events, sample space**, 2828
- Event trees**
 fire risk analysis, 2822
 fire risk assessment, 2822
 occupant response, 2462
 performance-based design, 2542
 releases of flammable material, 2592
 and selection of design fire scenarios, 1267–1268
- Exhibition Stadium crush (1980)**, 1755
- Exothermic reactions**, 142, 287, 374, 588, 620, 630
- Explicit (forward Euler) method, solving initial value problems**, 1095–1096
- Explosibility limits**, 2768
- Explosion hazard mitigation via water mist**, 1594
- Explosion prevention**, 1307
 clean agent inerting, 1524
- Explosion protection**
 blast waves, 2756–2763
 vapor cloud explosions, 2756–2763
 Chapman-Jouguet theory, 2751
 closed vessel deflagrations, 2741
 computer programs, 1943–1945
 deflagrations compared, 2692
 deflagration-to-detonation transition distance, 2754
 detonation cell width, 2753–2754
 detonations, 2750–2756
 dusts/powders
 explosibility testing, 2766–2768
 minimum explosible concentration, 2771
 minimum ignition energy, dust clouds, 2692
 minimum ignition temperature, dust clouds, 2771
 minimum ignition temperature, dust layers, 2771
 particle size, 2771
 vapors, 2763
 explosion suppression systems
 clean agent systems, 1522
 components, 2818
 explosion venting compared, 2781
 suppression sequence, 2566
 total suppressed pressure, 2784
 explosion venting
 standards, high-strength enclosures, 2744
 standards, low-strength enclosures, 2031
 test data/correlations, 2242
 theoretical models, 1992–1994
 vent area needed, 2781
 flammability/explosibility limits, 2738
 gases, 2738
 inerting, 2784
 isolation systems, 2788, 2789
 limiting oxidant concentration, 540, 541
 pressures, 812
 secondary explosions, 2812
- Exponential distribution**, 2840–2842, 2844, 2845, 2852–2854, 2880, 2881, 2883, 2885, 2886, 2900–2902, 2907, 2912, 2913, 2929, 2938, 3114
 reliability analysis and, 2875
- External burning, compartment fires**, 488, 511, 512, 515, 517–519
- Extinguishing agents**. *See* Aqueous film-forming foam (AFFF); Clean agent halon replacements; Fire protection mechanisms; *Foam entries*; Halocarbon extinguishing agents; *Halogenated entries*; *Halon entries*; Inert gas extinguishing agents; *Sprinkler entries*; Water; Water mist fire suppression systems
- Extraneous error**, 2921, 2924
- Extreme value theory**
 applications, 2210
 average loss, 2245
 building collapse example, 2415, 2418
 extreme order distributions, 2844–2846
 factors affecting fire damage, 2923
 fire protection measures, economic value of, 1240, 1459
 fire severity and fire resistance, 1029
 fire tests, analysis of, 2412
 large fire loss behavior, 1252, 1315
- F**
- FAA**. *See* Federal Aviation Administration (FAA)
- Factory Mutual Research Corporation (FMRC)**, 799, 842, 843, 846, 926, 956, 965, 981, 1145, 1157, 1158, 1185, 1186, 1318, 1334, 1496, 1511, 1667, 1681–1686, 1688, 1695. *See also* FM Global
- Factory Mutual Research Corporation Flammability Apparatus**, 956
- Failure mechanism**, 270, 271, 733, 2875, 2878, 2916, 3358
- Failure mode**, 264, 266, 267, 272, 273, 1786, 1815, 1816, 1884, 1893, 1939, 1941, 2793, 2877, 2878, 2945, 2949, 3184, 3256, 3350–3351
- Failure Modes and Effects Analysis (FMEA)**, 2878, 2945, 3183, 3184, 3209, 3388
- FASBUS-II computer program**, 1943
- Fault trees**
 fire risk analysis, 1269, 2920, 2927, 2932–2935, 2978, 3031, 3341, 3352
 reliability analysis, 2932–2935
 risk assessment, 2824
 system analysis, 2877, 2928, 2960

- F distribution**, 2840
- FDT fire modeling tool**, 3356, 3364
- Federal Aviation Administration (FAA)**, 194, 923, 924, 928–930, 1144, 1452, 1588, 1668, 1669, 1671–1673, 1677, 1679, 2406, 3104, 3371, 3373, 3381–3382
- Federal Railroad Administration (FRA)**, 2817, 2978, 3373, 3374, 3393
- Fiber-reinforced concrete (FRC)**
compressive strength, 296, 301, 302
polypropylene fibers, 296, 301, 304
steel fibers, 296, 1976
tensile strength, 301, 302
- Fiber-reinforced polymers (FRP)**
bond with concrete, 311
critical temperature, 312
fiber types, 312, 313
glass transition temperatures, 171, 172, 179, 187, 189, 190, 310, 311, 314, 642
mechanical properties, 310
modulus of elasticity, 310
stress-strain diagram, 311
thermal properties, 312
- Fibers, construction**, 278, 280, 285, 301–314
- Fick's law of mass diffusion**, 56
- Field models, turbulent flow**, 1609
- Film-forming fluoroprotein (FFFP) foam**, 1647, 1660, 1663, 1665, 1674, 1709
- Finite-differencing technique**, 1046–1048, 1935, 1983
- Fire**
categories, 1272
classes, 1024, 1025
stages
 decay stage, 997
 flashover, 997
 fully developed fire, 997
 growth stage, 996–997
 ignition stage, 996
 tetrahedron of, 1455
- Fire alarms**. *See* Alarms and alarm systems
- Fireballs**
point source model, 2654
radiation, 2654
size/dynamics, 2652–2654
spherical model, 2654–2655
- FiRECAM integrated computer modeling suite**, 3125–3127
design fires, 1271, 1277–1278
- Fire consequences, measuring in economic terms**
certainty monetary equivalent, 3113
costs/benefits based on level, 3104–3106
indirect loss estimation
 costs not usually calculated, 3104
 NFPA approach, 3099–3101
 private sector, 3102–3103
 unpublished U.K. study, 3101–3102
 U.S. examples, 3103–3104
insurance industry measurement
 approaches, 3106
 risk premium, 3106
monetary equivalents for
 nonmonetary costs/consequences
 deaths/injuries, 3106–3108
 donated time, 3108–3109
total national fire cost, 3100, 3101
utility theory
 cash equivalent, 3112, 3113
 expected monetary value, 3110, 3111, 3113, 3115
 probability distributions, 3114–3115
 risk averse behavior, 3109, 3111, 3115
 risk avoider/preferer, 3109, 3111–3113
 utility/disutility, 3111
 utility functions, 3112
- Fire Data Management System, calorimetry data**, 975
- Fire Dynamics Simulator (FDS), turbulent fire model**, 397
- Fire extinguishers**. *See also* Aqueous film-forming foam (AFFF); Clean agent halon replacements; Fire protection mechanisms; Foam entries; Halocarbon extinguishing agents; Halogenated entries; Halon entries; Inert gas extinguishing agents; Sprinkler entries; Water; Water mist fire suppression systems
dry chemical, 687, 1302–1306, 1646, 1648, 1662, 1680, 2899
portable foam, 1737
- Fire hazard analysis**, 805, 865, 1029, 1058, 2247, 2265, 2318–2321, 2584–2588, 2819, 3184, 3188, 3189, 3191, 3216, 3220, 3224, 3386, 3388.
See also Fire risk entries
- Fire load**
derated fire load, 1133, 1136
effective fire load, 1133, 1137
fire load density, 1131–1141, 1264, 1868, 1989–1992, 2838
- Fire plume(s)**, 399–400
balcony spill plume, 992, 1092, 1837–1839
calculation methods, 405–411
ceiling layer, 134, 451, 1194, 1200, 2746, 2747. *See also* (Compartment fires, two-layer system)
compartment fire stage, 499, 500, 505, 508–512, 982–983
diameter of fire source, 416
entrainment, 414–417
equivalent confined plume width, 1839
features, 397–399
flame height
 buoyancy and, 400–403
 momentum and, 403–405
flame pulsations, 421
heat release rates, 398
rise of plume front, 421
and species product formation, 508–509
strong, 415, 430, 436–439, 441, 446–447
strong plume relations, 407
temperatures, 2838, 2887, 2889
temperature-stratified ambients, 410–411
turbulence and, 409, 508, 3291
velocities, 405–410
virtual origin, 406, 407, 409, 411–414
wall/corner effects, 421–422
weak, 406, 407, 414
- Firepoint**, 555, 565–570
- Fire products**
enthalpies of, 161–165, 1538, 1540
nonthermal damage
 corrosion, 1219
 smoke, 1219
toxicity patterns, 2215
- Fire products, generation of**
concepts governing
 equivalence ratio and, 1208–1211
 fire propagation, 1154–1157
 flame heat flux, 1172–1174
 flaming/nonflaming fires, 1167–1174
 heat of gasification, 1168–1172
 heat release rate, 1181–1182
 ignition, 1147–1150
 relation between fire propagation rate, flame height, pyrolysis front, heat release rate, 1157–1159
generation of chemical compounds/consumption of oxygen

- Fire products, generation of** (*cont.*)
 efficiencies of oxygen mass consumption and mass generation of products, 1197–1200
 fire ventilation and, 1200–1201
 and mass loss rate, 1223–1224
 reduction/oxidation zones, 1194, 1201, 1205–1208
 halogenated polymers, 1152, 1154, 1209, 1210
 heat release rates and
 chemical heat release rate, 1183–1184
 CO₂ generation calorimetry, 1183
 complete/incomplete combustion, 1182–1184, 1186–1187
 convective heat release rate, 1184
 energy released in a fire, 1184–1185
 and fire ventilation, 1191–1193
 heat release parameter, 1185–1186
 oxygen consumption calorimetry, 1183–1184
 radiative heat release rate, 1184
 nonhalogenated polymers, 1209–1210
 and nonthermal damage (*see* Fire products, nonthermal damage)
- Fire propagation apparatus**, 926–930, 1144–1146, 1148, 1150, 1159, 1166, 1167, 1170–1173, 1175, 1178, 1181, 1183, 1187, 1189–1192, 1195, 1201, 1212, 1213, 1215, 1216, 1218, 1220, 1224, 2242
- Fire propagation index (FPI)**, 1159–1167, 1216
 application to classify materials, 1159–1167
- Fire propagation rates**, 1154–1157
- Fire protection engineering**
 quantitative risk assessment, 3207–3208
 risk-informed industrial, 3183–3185
 consequence analysis, 3185–3186
 evaluation method selection, 3186
 FPS-LOPA (*see* Fire protection system-layer of protection analysis (FPS-LOPA))
 hazard evaluation, 3183–3185
 qualitative risk analysis, 3186–3188
 treatment of uncertainty
 combining safety factors, 3004–3005
 derivation of safety factors, 3005
 with safety factors, 3002–3003
 selection of safety factor, 3003–3004
- Fire protection engineering** (*cont.*)
 uncertainties in
 behavior variability, 2996–2997
 and design process, 2998
 identifying, 2995–2998
 life-cycle use/safety of buildings, 2998
 providing for equity/incorporation of social values, 2998
 scientific, 2995–2296
 variability in risk perceptions/values, 2997–2998
- Fire Protection Equipment Directory (UL)**, 1660, 1661
- Fire protection mechanisms**
 active
 and firepoint theory, 1219–1221, 1224
 large-scale water extinguishment/suppression tests, 1603, 1667–1673
 by processes in gas phase, 1222–1223
 by reduced mass fraction of oxygen, 1223–1224
 small-scale water tests, 929–930
 water application rate, 943, 1689, 1713, 1720
 passive
 changing molten behavior of materials, 179, 181
 changing nature of fire products, 1219
 decreasing thermal response parameter/flame heat flux, 1218–1219
 increasing critical heat flux/thermal response parameter, 1150–1152, 1216–1217
- Fire protection system-layer of protection analysis (FPS-LOPA)**
 basics, 3188–3189
 conduct risk tolerance comparison, 3199
 definition/steps, 3189–3190
 determine likelihood of initiating fire event, 3192, 3193
 enabling event/probability of ignition, 3192–3194
 human error, 3192, 3193
 develop accident scenarios, 3190–3191
 estimate scenario risk, 3198–3199
 evaluate target vulnerability, 3197–3198
 example, 3200
 make decisions on risk reduction, 3204–3206
 monitor risk, 3206–3207
- Fire protection system-layer of protection analysis (FPS-LOPA)** (*cont.*)
 quantity performance of independent fire protection layers
 engineering assessment approach/model, 3195–3196
 engineering judgment/subjective probabilities, 3197
 fault tree analysis, 3196–3197
 reliability data/engineering design assessment, 3195
- Fire protection system selection**
 desired outcomes, 1294–1295
 identifying fire fighting agents, 1297–1298
 insurance company objectives, 1297
 stakeholders concerns, 1291–1292
- Fire Rated Wood Floor and Wall Assemblies (American Forest & Paper Assn.)**, 2000
- Fire Research Station (U.K.)**, 429, 435, 937, 1035, 2287, 2290, 2392, 2966, 3125
- Fire resistance**
 building assemblies/frames (*see* Building assemblies and frames, fire resistance)
 structural analysis and, 1871–1874
 structural members, 239, 260, 316, 317, 1910–1911
 test standards
 ASTM E119, 789–790
 ISO 834 and EN 1363-1, 789–790
- Fire Resistance Design Manual (Gypsum Assn)**, 1979
- Fire Resistance Directory (UL)**, 1920
- Fire risk analysis**
 buildings (*see* Buildings, fire risk analysis)
 computer simulation, 3117–3134
 health care facilities (*see* Health care facilities, quantitative fire risk analysis)
 industrial processes, 2952, 3212–3214
 methods, 2822–2824
 categories, 2822
 nuclear power plants (*see* Nuclear power plants, fire risk analysis)
 process, 2822–2824
 products (*see* Products (finished), fire risk analysis)
 resources, 2825–2826
 terminology, 2819–2822
 transportation vehicles (*see* Mass transportation)
 value judgments and, 2818, 2821

- Fire risk assessment**
and fire scenarios, 2960, 2961, 2964, 2966, 2968–2970, 2973, 2977, 2979
mass transportation (*see* Mass transportation)
and software reliability, 2918–2919
- Fire risk estimation**, 2817, 2818, 2979, 2980
- Fire risk indexing**
computer models, 3178–3179 (*see also specific models*)
development/evaluation criteria for risk ranking, 3176–3178
Dow's Fire and Explosion Index
index calculation, 3163–3165
risk analysis, 3165
fire safety evaluation system (*see* Fire safety evaluation system)
hierarchical approach, 3173, 3175
application, 3176
attribute weighting/evaluation, 3175–3176
insurance rating, 3160–3162
Mond fire, explosion, and toxicity index, 3165
risk index
applications, 3159–3160
defined, 3158–3159
significance, 3160
- Fire risk management**, 2818, 2980, 3049, 3370, 3382, 3383
- FIRE-RISK risk-cost model**, 2962, 2963
- Fire safety concepts tree**, 2949–2950, 2980, 3174, 3177
- Fire safety evaluation system**
derivative applications, 3172–3173
equivalency concept, 3167
equivalency evaluations, 3168–3170
fire safety parameters, 3168
fire safety redundancies, 3168
fire zone concept, 3167
optimization, 3171–3172
risk, 3167–3168
supplemental requirements, 3168, 3171
- Fire scenarios**
characteristics
building, 1263–1264
fire, 1268–1269
occupant, 1266
clusters, 1269
consequence analysis
business interruption, 1276
damage to building/contents, 1276
environmental damage, 1276–1277
injuries/fatalities, 1276
- Fire scenarios** (*cont.*)
development of
building characteristics, 1263–1264
detection/suppression systems, 1265–1266
fire department actions, 1266
fuel loads, 1264
functions in building, 1265
identification of potential scenarios, 1263, 1266–1267
occupant actions, 1266
occupant load/characteristics, 1266
passive fire protection systems, 1265
types of combustibles, 1264–1265
fire risk analysis of finished products, 3212–3215
functions in building, 1265
identification, 1266–1267
performance-based design and, 1262, 1263
quantifying
decay phase, 1271–1273
design fires, 1271–1273
detection/suppression systems, 1274
fire department intervention, 1276
fire/impacts, 1273
impact on structure, 1274–1275
occupant response/evacuation, 1275–1276
postflashover fires, 1273
preflashover fire growth, 1271–1273
smoke movement, 1274
selection of
event trees, 1268–1269
examples, 1268
expected consequences, 1269
frequency calculation, 1269
risk ranking, 1269–1270
scenario selection, 1271
statistics and historical information, 1269
smoke management design in large-volume spaces, 1826–1827
and victim incapacitation
closed-room fires, 2396–2404
flaming fires, 2394–2395
fully developed fires, 2404–2406
mitigation of toxic hazard, 2406–2407
room-of-origin deaths, 2396
smoldering fires, 2392–2394
- Fire SERT Centre (University of Ulster), studies of evacuation capabilities of disabled persons**, 3135
- FIRE SIMULATOR zone fire model**, 1029
- FIRES-RC-II computer program**, 1974
- FIRE STATION simulation model**, 3125
- FIRES-T3 computer program**, 1931–1937
- First Interstate Bank building fire (1988)**, 3103, 3278
- FIRST zone fire model**, 1025
- FIVE fire modeling tool**, 3356, 3364
- Flame(s)**
adiabatic temperature, calculation, 147–148
burning velocity, 345, 347, 376, 377, 382, 383, 385, 389, 542, 2636, 2637, 2648, 2738, 2739, 2741–2743, 2746–2748, 2750, 2760
candle, 350, 351, 354, 366, 1069, 1080
composition profiles
distinct regions, 351–354
diffusion/premixed, 354, 373–377, 379, 386–391, 529–531
effect of additives on propagation, 2256, 2327, 2385, 2391
heat flux calculation, 131–133
premixed burning velocity, 391, 539, 2647
- Flame front**, 239, 352, 356, 384, 386, 387, 390, 529, 587, 708, 711, 785, 1154, 1256, 1467, 1498, 1499, 1533, 1594, 1595, 2553, 2580, 2649, 2664, 2693–2695, 2701, 2738, 2741, 2748, 2758, 2761, 2766, 2769, 2787, 3242, 3245, 3277, 3287, 3289, 3292
- Flame height**
buoyancy and, 365
and chemical heat release rate, 398, 1154, 1157, 1158
effect of wind, 422
fire plumes, 397, 399
mean, 397–399, 402–404, 407–409, 412, 413, 415–417, 419
momentum and, 403–404
and pyrolysis front, 1154–1158
wall/corner effects, 421–422
- Flamelets**, 367, 370, 421, 1042, 2596
- Flame radiation scaling technique**, 1173, 1188
- Flame radiation to external target, pool fires**
atmospheric absorption, 2615–2619
calculation methods
examples, 2622–2627
Mudan method, 2612–2615, 2620, 2624, 2625, 2628

- Flame radiation to external target, pool fires** (*cont.*)
 point source model, 2601–2605
 safety factor, 2601, 2603–2605, 2610–2611
 Shokri and Beyler correlation, 2601
 Shokri and Beyler detailed method, 2605–2610
 summary/recommendations, 2620–2628
 calculation steps, 2600–2601
- Flame retardants**
 combustion kinetics and, 231
 effect on thermal decomposition of polymers, 181, 229–231
- Flame spread, liquid fuels**
 empirical data, 2564–2570
 liquid/gas phase-controlled, 2559–2561, 2568
 theory
 flame spread regimes, 2559–2561
 pool dimensions, 2561–2562
 temperature effects, 2562–2563
- Flame spread, surface.** *See* Surface flame spread
- Flame trailing,** 422
- Flaming ignition of solids.** *See* Solids, flaming ignition
- Flammability diagrams,** 538–539, 2687, 2688, 2691
 stoichiometric limit and, 537, 542, 547
- Flammability limits**
 combustion outside limits, 530
 diffusion flames, 545–548
 dusts/mists, 544–545
 effect of temperature/pressure, 532
 explosibility limits compared, 2766–2768, 2771, 2774
 ignition energies and, 544
 ignition of liquids and, 554, 555, 559–565, 567–568, 570, 573
 and ignition of solids, 647
 limiting oxygen concentration (LOC) and, 539–540, 548
 lower (LFL)
 adiabatic flame temperature, 536–538, 542, 547, 551
 predicting, 531–532
 premixed flames, 529–531
 quenching diameters, 544
 upper (UFL), 529, 533–536
 vertical tube measuring apparatus, 529, 530
- Flaring,** 2629, 2630, 2644
- Flashover**
 electrical, 673–674
 predicting in compartment fires, 512–519, 1002
- Flashpoint**
 closed cup, 554, 555, 562, 564–570, 576, 1467, 2562, 2564–2569, 2587
 effect of atmospheric pressure on, 564–565
 and ignition of solid fuels, 650–651
 measurement of, 565
 open cup, 567–570
 spills and, 558, 574
- Floor coverings, heat release rates,** 816–818
- Floors**
 composite (concrete/steel)
 concrete-filled steel sections, 1917–1919
 heat transfer/temperature profiles, 1927–1936
 concrete slab, 273, 1935, 3277
 hollow-core, 1959, 1960, 1976, 1977
 fire resistance, 3255
- Fluent CFD model,** 956, 1032, 1035, 1037, 1044, 1045, 1050, 1056, 1061, 1066, 1252, 1605, 1610, 1611, 1817, 3234
- Fluid element,** 77, 1380, 1383
- Fluid motion, dynamics of**
 Bernoulli equation, 21–22
 boundary layers (*see* Boundary layers, fluid flow)
 dimensional analysis, 1383, 1401, 1869
 energy conservation equation, 1040, 1047
 flow in ducts (*see* Ducts, fluid flow in)
 flow in pipes (*see* Pipes, fluid flow in)
 Navier-Stokes equations, 1035, 1037, 1040
 turbulence, 1037
- Fluid motion, kinematics of**
 assumptions, 356
 circulation, 1434, 1919, 2034, 2035, 2053, 2063, 2157, 2566
 classification
 steady/unsteady, 5, 6, 11, 12, 1401
 turbulent, 12–21
 equation of continuity, 1383
 Eulerian method of describing, 1610, 1611
 flow concepts
 pathline, 1382, 1383, 1385, 1518, 1570
 stream filament, 4, 21, 22, 81, 83, 987
 stream function, 68, 73
- Fluid motion, kinematics of** (*cont.*)
 streamline, 4, 21, 22, 1383, 1386
 streamtubes, 4
 flow in a channel, 445
 flow similarity, 68, 73, 74
 Lagrangian method of describing, 1610, 2686
 rotational/irrotational, 1382
 velocity potential, 56, 57, 59, 81, 87, 99
- Fluids.** *See also* Liquids
 buoyancy, 9–10
 compressibility, 1407
 defined, 1
 incompressible, dynamics of, 5, 6, 14, 66, 1386, 1401, 1517
 properties
 density, 1
 physical, 1378
 pressure, 3, 1379–1380
 shear force, 54, 60
 shear stress, 1, 2, 6, 7, 9, 17, 54, 55, 58, 60, 61
 specific gravity, 1379
 specific volume, 1, 375, 1512, 1562, 1563, 2802
 specific weight, 1378–1379, 1381, 1383, 1418
 surface tension, 572, 719, 720, 1299
 thermal expansion, 72, 78, 189, 267, 271–274, 284
 vapor pressure, 558–565
 viscosity, 1–2
 specific heat, 2
 statics, 1380
- Fluid systems**
 body force, 60–62, 64, 71
 floating/submerged bodies, 429, 431, 441, 443, 447, 449, 451, 1382, 1825, 1839
 forces on submerged surfaces
 buoyant force, 431, 432, 449, 450
 plane-inclined and curved, 439–440, 2582, 3258, 3259
 hydrostatic equation, 458
 pressure at a point, 3
 statics and buoyancy, 9–10
 surface force, 60, 63, 64
- Fluoroprotein foam,** 1647, 1664, 1669, 1671, 1673, 1697, 1713, 1715, 1720, 1722, 1727, 2554
- FM fire products collector,** 937
- FM Global,** 646, 915, 921, 926, 943, 1035, 1144, 1146, 1160, 1162, 1165, 1166, 1168, 1170, 1425, 1445, 1446, 1593, 1594, 1613, 1614, 1621, 2781, 2785. *See also* Factory Mutual Research Corporation (FMRC)

- FMRC.** *See* Factory Mutual Research Corporation (FMRC)
- FMRC corner test,** 842, 843, 846, 847
- Foam(s)**
- aspiration
 - air-aspirated, 1665
 - non-air-aspirated, 1665, 1674, 1675
 - assessment of extinguishing/ burnback performance
 - comparison of small-scale tests, 1665, 1667
 - critical application rates/ correlation between small-/ large-scale tests, 1667–1673
 - EN, 1663–1665, 1667, 1674
 - ICAO *Airport Services Guide*, 1663
 - MIL-F-24385 specification, 1661–1662
 - standard test methods, 1659–1667
 - UL Standard, 1661, 1665, 1667
 - aviation fire protection
 - agent quantities/standards, 1673–1674
 - expansion and drainage, 1674–1675
 - foam concentration, 1675–1679
 - hangar protection (*see* Aircraft hangars)
 - nozzle design, 1680–1688
 - underlying principle, 1673
 - video image flame detection, 1689
 - Class A, 1330, 1737–1739
 - composite constituents, 1647
 - concentration determination
 - conductivity method, 1677–1679
 - refractive index method, 1677
 - depletion rate, 1650
 - design considerations
 - extinguishment and spreading theory, 1648
 - extinguishment modeling, 1656–1657
 - foam loss mechanisms, 1649–1653
 - spread over liquid fuels, 1653–1656
 - surface tension and spreading coefficient, 1657–1659
 - discharge device classifications, 1660, 1661
 - drainage, 1647–1653, 1657, 1662, 1663, 1674–1675, 1687, 1688
 - evaporation rate, 1649–1651
 - foam-water sprinkler systems (*see* Foam-water sprinkler systems)
 - high-expansion type
 - mass loss, 1649, 1652
 - warehouse protection calculations, 1646, 1688–1690
- Foam agents**
- AFFF (*see* Aqueous film-forming foam (AFFF))
 - environmental concerns, 1695–1697
 - film-forming fluoroprotein (FFFP)
 - foam, 1647, 1660, 1663, 1665, 1709
 - fluoroprotein foam, 1664, 1669, 1673, 1713, 1715, 1720, 1722, 1727, 2554
 - protein foam, 1647, 1656, 1665, 1668, 1669, 1673, 1681, 1682
- Foam systems**
- hazards/fires suitable for protection with, 1692, 1695
 - high-expansion foams, 1646, 1688, 1729–1737
 - incipient spill protection, 1709
 - objectives for evaluating protection with, 1707–1708
 - protection limitations, 1736–1737
 - for roof storage tanks, 1725–1728
 - storage tank protection, fixed roof
 - discharge outlets, 1710–1711
 - foam handlines, 1710
 - foam monitors, 1710
 - portable foam towers, 1709
 - semisubsurface injection of foam, 1725
 - subsurface application of foam, 1718
 - surface application of foam, 1710–1711
 - storage tank protection, floating roof
 - catenary system method, 1725
 - fixed foam maker, 1725–1726
 - portable nozzle method, 1725
 - storage tank protection, high-expansion foam, 1728
 - storage tank protection, low-expansion foam
 - fixed system calculations, 1711–1716
 - subsurface application calculations, 1718–1723
 - types
 - fixed, 1708
 - mobile, 1709
 - portable, 1709
 - semifixed, 1708–1709
- Foam-water sprinkler systems**
- codes/standards/regulations, 1689–1690
 - protection of stored flammable/ combustible liquids, 1691
 - drum/tank storage, 1691–1693
 - liquid spill and container storage, 1693–1695
- Fog, defined,** 1587, 2185
- Foodstuffs, heat release rates,** 834, 836
- Forest fires.** *See* Wildland fires
- Forest Products Laboratory (FPL),** 911, 924–925
- Formaldehyde (CH₂O),** 1205, 1207
- generated in pyrolysis of wood, 1206
- Forward Euler method, solving initial value problems,** 1095–1096
- FOSM (first-order second-moment) method, safety factor derivation,** 3005
- Fourier's law, heat conduction and,** 55
- steady-state examples, 55
- FPETOOL computer program,** 1029, 3360
- Frames.** *See* Building assemblies and frames, fire resistance
- FRAME works risk assessment model,** 2966, 2967
- Frank-Kamenetskii theory, autoignition**
- and Biot number, 606, 618, 622
 - experimental testing methods, 618, 619
 - and parallel reactions, 620–621
- Free-burning fires,** 486, 1000
- FREM fire risk evaluation model,** 3179
- FRIM-MAB risk index method,** 2967–2968
- Froude modeling,** 708, 1827, 1828, 2594
- Froude number,** 10–12, 365, 366, 399, 400, 403, 463, 468–470, 1051, 1052, 1603, 1827, 2596, 2597, 2632, 2636, 2650, 2684
- FSSIM zone fire model,** 1029
- Fuels, properties/combustion data,** 3437–3475
- Furniture.** *See* Upholstered furniture
- Furniture calorimeter,** 800, 844, 847, 852, 854, 885, 890, 932–934, 942–943, 946, 1337
- Furniture calorimeter tests,** 852, 932–933, 1331
- G**
- Gamma distribution,** 2842–2843, 2850, 2854, 2868, 2869
- Gas(es)**
- compressibility, 556, 557, 695, 697, 1484, 1536, 1573, 1612, 1620, 1623, 1624, 1626, 1634–1636, 2665, 2738, 2742, 2743, 2747, 2756, 2759, 2792, 2795, 2805

Gas(es) (*cont.*)

- explosion protection, 2751, 2752, 2811
- gray, 124, 750, 777, 941, 958, 1042
- ideal, 1, 3–4, 8, 56, 62, 64, 78, 138–140, 142, 146, 154, 155, 159, 329, 330, 335, 345, 352, 406, 459, 474, 494, 556, 558, 562, 697, 698, 983, 985, 993, 1073–1075, 1085, 1089, 1093, 1100, 1505, 1508, 1605, 1798, 1833, 1844, 1853, 2739, 2745, 2801, 3400
- ignition by arcing, 670, 2692
- molecular weights, 140, 390, 459, 460, 489, 556, 983, 1036, 1168, 1215, 2678, 2694, 2744, 2748, 2756
- nonscattering, 1042
- perfect, 402, 988, 1036, 1037
- properties, 56, 126, 127, 359, 371, 727, 1168, 1507, 1833, 2638, 2646, 2665, 2666, 2672, 2678, 2689, 2739, 3425
- vapor distinguished, 2665
- work done during expansion, 139, 140
- GASEQ computer program**, 165, 2740, 2751
- Gasoline**
 - enclosure fire example, 1084
 - pool fire emissive power, 2599
- Gas temperature rise calorimetry**, 1144, 1146, 1149, 1184
- Gaussian distribution.** *See* Normal distribution
- Gels, amorphous material**, 278
- General Services Administration**, 1235, 1778, 2043, 3223
- Geometric distribution**, 2848
- Geometric mean**, 125, 126, 730, 742, 2856
- Gibson (Calif.) Amtrak sleeping car fire (1982)**, 3374
- Glass**
 - amorphous material, 171, 179, 278
 - fire screen, 97
- Glass transition, phase change**, 314, 642
- Glass transition temperature, polymers**, 171, 172, 179, 310, 311
- Grashof number**, 11, 72, 81, 89, 93, 94, 100, 470, 484
- Gray body radiation**, 958
- Great Hanshin (Japan) earthquake and fires (1995)**, 717
- Gretner method, insurance rating**, 3161

Guidelines for Evaluating the Characteristics of Vapor Cloud Explosions, Flash Fires, and BLEVEs (AIChE Center for Chemical Process Safety), 2745, 2758

- Gypsum wallboard**
 - coefficient of thermal expansion, 314
 - dilatometric/thermogravimetric curves, 316
 - protection of steel members, 1916
 - specific heat, 315
 - thermal conductivity, 315
 - thermal properties, 314
 - types, 314

H

- Haber's rule, toxicity**, 2216, 2235, 2245, 2300, 2330, 2332, 2359, 2368
- Hagerbach tunnel research facility (Switzerland)**, 3321
- Halocarbon extinguishing agents.** *See also* Clean agent halon replacements
 - characteristics, 1301, 1302, 1450–1451, 1483, 1484
 - environmental concerns
 - global warming potential, 1301, 1503–1504
 - ozone depletion, 1301, 1502–1503
 - extinguishing mechanisms, 1301, 1485–1486
 - minimum extinguishing concentration, 1302, 1486–1498
 - thermophysical properties, 1505–1507
 - toxicity, 1302, 1499–1501
- Halogenated agent extinguishing systems**
 - agent delivery, 1462–1463
 - agent requirements
 - agent quantity, 1468–1469
 - application rate, 1469
 - compensation for leakage, 1470–1472
 - discharge time/soaking period, 1469
 - effects of ventilation, 1469–1470
 - liquid/gas fires, 1466–1468
 - solid fuels, 1465–1467
 - configurations, 1460
 - control panels
 - economics, 1461–1462
 - features, 1460–1461
 - modes of operation, 1461
- Halogenated agent extinguishing systems** (*cont.*)
 - design guidelines, 1463–1464
 - detection, 1460
 - flow calculations
 - guidelines/limitations, 1474
 - pipng theory and, 1471–1474
 - procedure, 1474–1479
 - halon zone, 1463
 - local application, 1464–1465
 - postdesign considerations, 1479–1480
 - total flooding, 1465–1471
- Halogenated agents.** *See also* specific agents
 - computer room protection, 1459
 - environmental issues, 1480–1481
 - halogens found in, 1451
 - history of use, 1451–1453
 - physical properties, 1454–1455
 - toxicity, 1457–1459
- Halogenated polymers, calculating combustion yields**, 1209
- Halon 122**, 1451
- Halon 1011**, 1451, 1452
- Halon 1211**, 1301, 1451–1454, 1456, 1458, 1464, 1673
- Halon 1301**
 - agent requirements
 - agent quantity, 1468–1469
 - application rate, 1469
 - compensation for leakage, 1470–1472
 - discharge time/soaking period, 1469
 - effects of ventilation, 1469–1470
 - liquid/gas fires, 1466–1468
 - solid fuels, 1465–1467
 - attributes/limitations, 1453–1454
 - combustion kinetics, 328
 - corrosive effects, 1456–1457
 - decomposition products, 1457–1458
 - design concentration, 1466–1468
 - environmental issues, 1480–1481
 - extinguishing effectiveness, 1456
 - physical properties, 1454–1455
 - protection of electronic data
 - processing equipment, 1453
 - total flooding systems, 1465–1471
 - toxicity, 1457–1459
 - water mist fire suppression systems
 - as replacement for, 1601–1602
- Halon 2402**, 1451–1453
- Halons.** *See* Halogenated agents
- Handbook of Military Infrared Technology (Office of Natl. Research)**, 2660

- Handicapped/impaired persons**
 alarm systems and, 2524
 areas of refuge, 2023
 buddy system, 2023, 2524
 evacuation response, 2023, 2524, 2525
 prevalence, 2524
 and signage, 2524
 wheelchair users, 2524
- Handrails, and effective evacuation width**, 2122–2124, 2132
- Harmonic mean**, 2856
- Harvard code**, 3217
- Harvard/NIST Mark VI zone model**, 987
- Harvard V5 program**, 1028
- Hazard(s)**
 defined, 572
 thermal/nonthermal, 2593, 2597–2600
- Hazard evaluation**, 1601, 2268, 2774, 3183–3186, 3191, 3201, 3205, 3208
- HAZARD I integrated computer modeling suite**, 3125–3127
- Health care facilities**
 fire risk indexing model, 3158, 3159, 3178–3179
 occupant response to fire/smoke, 2968, 2981
 handicapped/impaired persons, 2039, 2056, 2316, 2320, 2412
- Health care facilities, quantitative fire risk analysis**
 assumptions/limitations, 3227–3228
 available escape time, 3232–3234
 door open/closed, 3234
 calculation of consequences, 3236
 detection time, 3234, 3235
 event tree, 3232, 3233
 extended procedure, 3226, 3239
 facility conditions, 3228–3229
 fire frequency, 3230–3231
 fire growth, 3231–3232
 individual risk, 3237–3238
 model uncertainty, 3235
 movement time, 3235
 occupants, 2021, 2031, 2038, 2104, 2343, 2445, 2448, 2458, 3166, 3167
 patients/staff, 3229–3230
 societal risk, 3236–3237
- Hearing-impaired persons, alarm systems and**, 1746, 1747, 2031, 2039
- Heat capacity**. *See* Specific heat
- Heat detectors**
 ceiling jet flows and, 429, 430
 error sources, 1321
 fixed-temperature, 727, 1322
- Heat detectors (cont.)**
 rate-compensated, 1322
 rate-of-rise, 727, 1322
 response time index (RTI), 1321
 spacing, 1319
- Heat, exposure of fire victims to**
 convected heat, 1070, 2316, 2375, 2377–2378
 damage to respiratory tract, 2316, 2373, 2380–2381, 2418
 heat stroke (hyperthermia), 2373–2376, 2417
 predicting time to incapacitation, 2371–2374
 skin burns, 2373, 2376–2377
- Heat flux**
 to adjacent surfaces, 746
 boundary conditions, 43, 44
 burning parallel vertical surfaces, 782–785
 ceiling fires, 780–783
 corner wall fires, 774–780
 critical, 211, 239, 586, 588, 978, 1147, 1149, 1150, 1166, 1216, 1217, 2656, 2722, 2724, 3243, 3451
 effect of other variables, 793
 exposure fires
 adjacent to flat walls, 750–751
 beneath I-beams, 765–769
 beneath unconfined ceilings, 759–761
 corner fires, 751–756
 in corridors, 761–765
 effects of fire standoff distance, 757–759
 room environment effects, 756–757
 and flame spread, 789
 heat release rates and, 750, 753, 757, 758, 764, 765, 771, 773–778, 780, 783, 787, 788
 near ignition source, 211, 239, 655, 807
 objects immersed in flames, 749–750
 postflashover room fires, 808
 preflashover room fires, 807
 standard tests
 ASTM E84 tunnel test, 789, 791–792
 fire resistance, 789
 wall fires, 669–774, 807–808
 from windows, 787–789
- Heat generation**. *See* Fire products, generation of
- Heating equipment, database coding categories**, 3089–3090
- HEATING7 program**, 1934
- Heat of combustion**
 ambient/elevated temperatures, 142
 defined, 141–142
 effective, 238, 582, 799, 800, 837, 860, 866, 889, 908, 940, 952, 975, 976, 978, 999, 1001, 1002, 1021, 1041, 1185, 2242, 2269, 3074
 measurement, 141–144
 net/gross, 142
 selected fuels, 142, 143
- Heat of formation**, 144–145, 150, 287, 1182, 1374
- Heat Release in Fires (Babrauskas and Grayson, eds.)**, 814
- Heat release rates (HRRs)**
 bench scale measurement
 modeling with data from, 805–808
 predicting, 809–813
 burning foam sofa, 442–444
 bushes, 861–863
 ceiling jet flows, 449–451
 chemical heat release rate (*see* Chemical heat release rate)
 Christmas trees, 859–861
 compartment fires, 101, 997, 1005, 1009
 computer equipment, 821–828
 convective (*see* Convective heat release rate)
 dependence on heat flux, 808–810
 estimating for general combustibles, 895
 fire plumes, 828
 fires, 799–809, 811, 812, 814, 816, 818, 828–831, 833, 837, 839, 841, 842, 847, 848, 850, 852–855, 857, 860, 863, 865–867, 869, 872, 874–876, 879, 881–885, 887–892, 894, 896
 and generation of fire products, 814, 866
 intermediate scale measurement
 effect of ignition source on full-scale HRR, 804
 using full-scale HRR data, 802–803
 mattresses, 848–853
 measurement techniques
 compensation method, 911
 open-burning calorimeters, 799–800
 oxygen consumption method, 911–915
 room fire tests, 800–801
 sensible enthalpy method, 907–910
 substitution method, 910–911
 motor vehicles, 873, 943

- Heat release rates (HRRs)** (*cont.*)
 predicting full-scale HRR from bench-scale data
 boundary conditions, 806
 effect of orientation, 811–812
 effect of thickness, 809–811
 other variables, 812–813
 overview, 805–806
 role of irradiance, 806–808
 radiative, 864–867
 for real products, 813–821
 uncertainty of measurements, 895–896, 943–945
 vehicle tires, 879, 882, 1686
- Heat stroke**, 2300, 2373–2376, 2381, 2417
- Helium (He), specific heat**, 141
- Heptane, pool fire velocities/temperatures**, 361, 399, 401, 408, 432, 934, 1514, 1739, 2597, 2598
- Herald of Free Enterprise ferry capsizes (1987)**, 3377–3378
- Hess's law**, 144
- Heun's method, solving initial value problems**, 1096
- Highly Flammable Liquids and Liquefied Petroleum Gases Regulations (U.K.)**, 570, 571
- High-rise evacuations**, 1743
- High-strength concrete (HSC)**
 compressive strength, 1976
 porosity, 303–304
 spalling, 289–290, 304
- Hillhaven Nursing Home fire (1989)**, 3231
- Hinsdale (Ill.) telephone exchange fire (1988)**, 3104
- Histogram**, 2373, 2374, 2384, 2385, 2850–2853, 2866–2868, 2873, 3068, 3069, 3133
- Historic structures**
 CFD smoke movement application, 1055, 1274
 Historic Fire Risk Index, 3172
- Hooke's law, stress/strain**, 189, 264, 265, 268, 274
- Horizontal-surface fires, flame height**, 398
- Hotel fires, occupant response**, 2085–2087, 2097, 2449, 3080, 3103, 3217, 3266
- HRR**. *See* Heat release rates (HRRs)
- Human action**, 2876, 2877, 2919, 2920, 2927, 2928, 2946
- Human error**, 2919–2925, 2928, 2932, 2947, 3087, 3189, 3191, 3192, 3208, 3280, 3326, 3329, 3351, 3352
- Human error probability (HEP)**, 2920, 2927, 3192, 3352
- Human factors**, 2920, 2997
- Human failure event (HFE)**, 2921, 3352
- Human reliability analysis**. *See* Reliability analysis, human
- Hydrants, discharge at opening**, 1405–1407, 1414
- Hydraulic model, egress performance**
 calculating escape time
 basic variables, 2133, 2137–2139
 factors influencing evacuation, 2119, 2137
 movement attributes of evacuees, 2138–2139
 routes available, 2138
 time taken to respond, 2139
 use of available routes, 2138
 establishing egress performance
 model approaches, 2118–2119
 model limitations, 2119–2120
 estimating evacuation time
 calculated flow, 2128
 consideration of door mechanism, 2126–2128
 effective width, 2122–2124
 effect of stairs, 2123, 2134
 example, 2132–2137
 fundamental movement
 calculations, 2121–2132
 intrusion of handrails, 2122, 2124
 population density, 2122–2124
 specific flow, 2126–2128
 speed, 2124–2126
 time for passage, 2128
 transitions, 2128–2132
 first-order hydraulic model, 2132, 2133
 high-density scenario, 2140
 impact of tenability on ASET/RSET, 2145–2148
 including effects of smoke, 2147, 2148
 low-density scenario, 2140
 modeling error, 2142–2143
 required safe egress time, 2115, 2116, 2121, 2137, 2139, 2141–2143, 2145–2148
 safety margin, 2143
 second-order hydraulic model, 2132, 2133
 use with other models, 2143–2146
- Hydraulics**
 conservation laws in fluid flows, 1382–1385
 energy losses in pipe flows
 boundary layer concept, 1385, 1386
- Hydraulics** (*cont.*)
 compound networks, 1400–1401
 critical zone, 1388–1389
 equations, 1387–1389, 1392, 1394
 Hazen-Williams-based data, 1391–1395
 laminar/turbulent, 1386–1387
 minor losses, 1395–1399
 pipes in parallel, 1399–1400
 pipes in series, 1399
 flow measurement
 ASME flow nozzle, 1402–1403
 ASME orifice meters, 1402–1404
 free discharge at opening, 1405–1407
 pitot tube, 1401–405
 Venturi flow meter, 1402
 fluid statics
 force on submerged plane areas, 1382
 gauge/absolute pressure, 1380, 1382, 1384
 pressure measuring devices, 1380–1382
 properties of fluids, 1378–1380
 static pressure head, 1380
 pumps
 centrifugal pump affinity relations, 1420–1422
 operating characteristics, 1416–1419
 selection, 1419–1420
 water hammer, 1407–1409
- Hydrocarbon fires, thermal radiation**
 event tree, 2591–2593
 hazards to personnel, 2655–2658
 pool fires
 emissive radiation, 2598–2600
 flame height/length, 2594–2595
 flame tilt angle, 2595–2596
 geometry, 2593–2594
 hazards, 2597, 2599, 2600
 radiation to external target (*see* Flame radiation to external target, pool fires)
 targets within the fire, 2628–2629
 trench/line fires, 2596, 2597
 wind effects, 2594
 turbulent jet flames
 aerodynamic effects, 2591, 2630, 2636–2638
 fire impingement exposure, 2645–2646
 flame diameter, crosswind, 2636–2638
 flame geometry, 2630
 flame height/length, crosswind, 2633–2636
 flame height, still air, 2630–2633

- Hydrocarbon fires, thermal radiation** (*cont.*)
 hazards, 2638–2640
 line/cylinder models, 2644–2645
 point source model, 2638–2640
 radiative fraction, 2640–2644
 unsteady thermal radiation analysis
 burning vapor clouds (*see* Vapor clouds)
 fireballs (*see* Fireballs)
 pressurized gas incidents, 2646
- Hydrocarbons**
 aliphatic/aromatic, 1211
 fire ventilation and yields, 1201, 1204
- Hydrogen**
 dissociation example, 159
 heat of formation (atomic), 145
- Hydrogen bromide (HBr), as inert diluent**, 1458
- Hydrogen chloride gas (HCl)**
 corrosivity, 732
 heat of formation, 145
 as inert diluent, 542
- Hydrogen cyanide (HCN)**
 fire yield, 2231, 2287, 2346
 generation efficiency, 1205, 1206
 heat of formation, 145
 toxicity
 fractional incapacitating dose (FID), 2373, 2417
 interaction with carbon dioxide, 2369
 interaction with carbon monoxide, 2369–2370
- Hydrostatic equation**, 9–10
- Hydroxyl (OH), heat of formation**, 145
- Hypergeometric distribution**, 848–849
- Hyperthermia**, 2300, 2374–2376, 2418
- Hyperventilation, and incapacitation from toxic effects**, 2366–2368
- Hypothesis testing**, 2861–2870
- Hypoxia**
 and carbon dioxide, 2369
 carbon monoxide and, 2370
- I**
- ICAO**. *See* International Civil Aviation Organization (ICAO)
- ICC Performance Coder® for Buildings and Facilities (International Code Council)**, 1235, 1238, 1242, 2022, 2035, 2041
- Ideal gas(es)**
 constant, 139, 556, 558
 law, 1, 3–4, 138, 142, 155, 159, 329, 330, 335, 406, 459, 474, 475, 556, 1073, 1085, 1798, 1843, 1844
- Ignition**
 autoignition (*see* Autoignition)
 defined, 554–555
 of liquids, 554–578, 635, 670, 1256, 3439, 3451
 modes involving electric current (*see* Electrical fires, ignition modes involving electric current)
 piloted, 389, 572, 649–650, 653, 707, 714, 920, 921, 1147, 1149, 1150, 1258, 3244, 3312
 secondary/remote, 151, 1272, 2592, 3219, 3312
 self-ignition (*see* Autoignition)
 solids, flaming ignition in (*see* Solids, flaming ignition)
 spontaneous combustion (*see* Autoignition)
 thermal radiation and, 572
 and values of voltage/current/power, 693–694
- Ignition Handbook (Babrauskas)**, 607, 665, 667, 668, 670–673, 676, 678, 680, 681, 683, 686, 694, 807, 955, 3194
- Ignition source, defining**, 892, 2570, 2691
- Ignition zone**, 1144, 1154, 1158, 1159, 1216
- IMO**. *See* International Maritime Organization (IMO)
- Implementation time**, 2922
- Incapacitation**
 fire scenarios and
 closed-room fires, 2396–2401
 flaming fires, 2394–2395
 fully developed fires, 2404–2406
 mitigation of toxic hazard, 2406–2407
 room-of-origin deaths, 2396
 smoldering fires, 2392–2394
 heat exposure
 predicting time to incapacitation, 2353, 2361, 2371–2373, 2387
 from toxic effects
 carbon dioxide, 2218, 2220
 carbon monoxide, 2218
 hydrogen cyanide, 2222, 2224
 hyperventilation and, 2220, 2223
 hypoxia, 2220, 2221
 predicting, 2215, 2219, 2220, 2225
- Incompressible fluid motion**, 5, 6, 14, 66, 483, 1386, 1401, 1517, 1624
- Independent fire protection layers**, 3188–3190, 3194–3197, 3200, 3202–3203, 3208, 3209
- Indexing, fire risk analysis method**, 2825, 2981
- Industrial fire protection**
 consequence analysis, 3185–3186
 fire risk evaluation, 3186
 FPS-LOPA, 3188–3207
 hazard evaluation, 3183–3185
- Inert gas extinguishing agents**
 characteristics, 1483–1485
 extinguishing mechanisms, 1485–1486
 minimum extinguishing concentration, 1492–1494
 thermophysical properties, 1505
 toxicity, 1499–1502
- Influence diagram, fire risk analysis**, 2824
- Information technology (IT) equipment, flammability concerns**, 1291, 1453
- Institute for Operations Research and the Management Sciences (InFORMS)**, 2826
- Insulation**
 thermal conductivity, 35, 1932
 thermal properties, 1105
- Insurance rating, fire risk indexing**
 class/schedule rates, 3160
 Gretener method, 3161–3162
 mercantile/Dean schedules, 3161
 Specific Commercial Property Evaluation Schedule, 3161
- Integral method, heat transfer analysis**, 75, 77
- Interior finish wall/ceiling materials, fire propagation index**, 1165–1167
- Intermediate-scale calorimeter (ICAL)**, 802, 803, 813, 896, 921, 931–932, 942, 3043
- International Building Code (ICC)**, 1304, 1742, 1753, 1776, 1808, 1819, 2000, 2027, 2030, 2042, 3172, 3254
- International Civil Aviation Organization (ICAO)**, 1663
- International Convention for the Safety of Life at Sea (SOLAS)**, 935, 1535, 1547, 1556, 1561–1566, 1614, 3377, 3379
- International Electrotechnical Commission (IEC)**, 235–237, 2269, 2270, 2284, 2772

- International Fire Engineering Guidelines (ICC)**, 1138, 1262
- International Foam-Water Sprinkler Research Project**, 1694, 1695
- International Maritime Organization (IMO)**, 621, 935, 956, 1535, 1588, 1589, 1613, 1614, 3377
- International Organization for Standardization (ISO)**. *See ISO entries*
- Interquartile range**, 2856
- Intumescent coatings**, 974, 1871, 3319, 3453, 3454
- Inviscid fluid**, 16, 65, 84, 992
- Ionization**, 194, 663, 695, 727, 1195, 1318, 1344, 1345, 1347–1349, 1353, 1356, 1460, 2398, 2401, 2402, 2692
- ISO (International Organization for Standardization)**. *See ISO entries*
- Iso-butane, heat of formation**, 130, 145
- ISO 834, Fire-Resistance Tests-Elements of Building Construction**, 789, 1102, 1105, 1116–1118, 1122, 1124–1129, 1866, 1928, 1949, 1956, 1988
time-temperature curves, 789, 1935
- ISO 5657, Fire Tests-Reaction to Fire-Ignitability of Building Products**, 235, 958, 959, 964, 976
- ISO 14520, Gaseous Fire Extinguishing Systems-Physical Properties and System Design**, 1486, 1494–1496, 1498, 1509–1511, 1527
- ISO Technical Specification 16733, Fire Safety Engineering-Selection of Design Fire Scenarios and Design Fires**, 1263, 1266, 1269, 2048, 2056, 2057, 2060, 2067
- ISO Technical Specification 16732, Guidance on Fire Risk Assessment**, 2826
- Isotropic materials**, 28, 278
- IT equipment**. *See* Information technology (IT) equipment, flammability concerns
- J**
- JASMINE CFD model**, 1035, 1048, 1609
- Jet flames**
flame height, 403
horizontal discharge, 396, 422–423
virtual origin, 413
- JET two-zone fire model**, 2566
- JP-5, flame spread rate**, 1669, 1683, 1687, 2564, 2566, 2567, 2569, 2582
- JP-8, flame spread rate**, 1687, 2564, 2566, 2567, 2569, 2582
- Judgment sample**, 2871
- K**
- Kinematic viscosity**, 2, 17, 18, 56, 351, 416, 438, 1321, 1375, 1379, 1393, 1655, 2750, 3398
- Kings Crossing fire (1987)**, 706, 1056, 2406
- Kiosks, heat release rates**, 846–847
- Kirchoff's law**, 119–120
- Kurtosis, probability distributions**, 2834
- L**
- Large eddy simulation approach**. *See* Computational fluid dynamics (CFD) models, turbulence modeling, large eddy simulation
- Large-volume spaces, smoke management in**
approaches to
analytical approach, 1827
factors affecting, 1832
scale models, 1827–1828
comparison of mechanical exhaust/natural venting designs, 1842–1851
computational fluid dynamics models, 1867–1868
draft curtains, 1843, 1844, 1849–1852
fire scenarios, 1824, 1827, 1829, 1831, 1843
hazard parameters
light obscuration, 1825–1826
smoke layer interface position, 1825
temperature/gas species concentration, 1826
limited fuel, 1857
mechanical venting systems, 1842–1843
design aspects, 1842–1843
natural venting systems
design aspects, 1843–1847
flow through vents, 1843, 1844, 1847
limitations, 1845–1847
makeup air supply, 1844–1845
smoke buoyancy and, 1843, 1844
wind conditions and, 1846, 1847
opposed airflow, 1857–1858
- Large-volume spaces, smoke management in (cont.)**
smoke filling period
empirical correlations, 1831–1833
smoke layer interface position, 1830–1831
steady fires, 1829–1830
t² fires, 1829, 1830, 1832
theoretically based approach, 1833–1834
transport lag, 1829–1830
special conditions
confined flow, 1852
intermediate stratification, 1852–1854
makeup air supply, 1856
plugholing, 1855–1856
sprinkler/vent systems
computer simulations, 1850–1851
consensus approach to design, 1851–1852
design considerations, 1849
interaction of spray and smoke layer, 1849–1850
past studies, 1848–1849
sprinkler skipping, 1851
vent skipping, 1851
thermal activation of vents, 1847–1848
vented period
axisymmetric plume, 1834–1836
balcony spill plume, 1837–1839
carbon monoxide concentration, 1841–1842
equilibrium smoke layer interface position, 1834–1839
light obscuration, 1841
properties of smoke layer, 1839–1842
temperature rise in smoke layer, 1839–1840
wall/corner plumes, 1836–1837
zone models, 1828–1830
- Latent error**, 2921, 2924
- LAVENT two-zone fire model**, 1029–1030
- Law of large numbers, probability distributions**, 2835
- Layer burning, compartment fires**, 488, 491
- Le Chatelier's rule**, 531–536, 547
- Lewis number**, 3, 9, 57, 351, 355, 358, 388, 569
- Life safety**
defend-in-place strategy, 1315, 2309, 2315, 2328
stay-in-place strategy, 1315
- LIFT (lateral ignition and flame spread test) apparatus**, 646, 717, 1155

- Lightning, ignition cause**, 691
- Limiting oxidant concentration, explosion prevention**, 540–541
- Limiting oxygen index (LOI)**, 234, 235, 237–238, 247, 545, 1165
test method, 235
- Liquefied natural gas (LNG)**, 398, 401, 422, 865, 2573, 2594–2596, 2646–2648, 2650, 2657, 2665, 2671, 2678, 2814
- Liquefied petroleum gas (LP-gas)**, 570, 571, 2638, 2645, 2646, 2648, 2651, 2653, 3091
- Liquid fuel fires. *See also* Pool fires**
blended fuels, 2573, 2574
fire growth rate
empirical data, 2564–2570
flame spread regimes, 2559–2561
pool dimensions, 2561–2562
temperature effects, 2562–2563
theory, 2559–2563
fire size
enclosure fires, 2582
flame height, 2582–2583
fuel burning regression rate, 2572, 2574
inclined/cluttered surfaces, 2582
pool tank lip height, 2582
wind speed, 2582
flame spread velocities and rate of pool/spill involvement, 2570–2572
liquid/gas phase-controlled flame spread, 2559, 2560, 2564
pool size, 2552–2558
porous surfaces, 2559, 2569
spill size, 2552–2558
- Liquids. *See also* Fluids**
autoignition, 573–575
liquids in porous materials, 575–578
classification of fuels, 570–572
ignition of
calculation of vapor pressure, 558–562
critical temperatures/pressures, 557
flashpoint (*see* Flashpoint)
latent heat of evaporation, 558, 561
phase diagrams, 555–557
vaporization process and, 555–558
vapor pressure of blends, 562–564
properties, 573
sustained ignition of, 572–573
effect of wick, 572, 573
- Livonia (Mich.) automotive plant fire (1954)**, 3147
- Log-normal distribution**, 1133, 1138, 1609, 2141, 2460, 2838–2839, 2844, 2846, 2852, 2854–2856, 2882, 2883, 2886, 2887, 2895, 2913, 3106, 3114
reliability analysis and, 2840–2853
- Lower flammability limits (LFL)**
adiabatic flame temperature, 148
dusts, 670
predicting, 570
- Luggage, heat release rates**, 848
- M**
- Magazine racks, heat release rates**, 848, 849
- MAGIC two-zone fire model**, 1030
- MAGIC zone fire model**, 3356, 3364
- Maintainability**
downtimes and, 2898–2900
inspections, 2910
maintenance, 2910
preventive, 2876–2879, 2898, 2899
quantification, 2899–2900
testing, 2910
- Maintainability analysis**, 2877–2879
process, 2877
- Making Hard Decisions (Clemen)**, 3024
- Malls. *See* Large-volume spaces, smoke management in**
- Manchester Airtours fire (1984)**, 2220, 2404
- Manchester Woolworth's fire (1979)**, 2406
- Manometer tube**, 1380–1381
- Marchioness collision/sinking (1989)**, 3378
- Marine transportation**
combustible materials, 3387–3388
cruise ships, 3377–3379
fire risk decision making
analytical hierarchy processes, 3392
NFPA 301 and, 3392–3393
USCG Safety Alert and, 3377, 3390–3392
fire safety objectives, 3380–3381
incidents, 3373, 3374, 3376, 3387
risk-informed decision making, 3379–3381
sources of ignition, 3392
- Markov model, fire growth**, 2901–2903, 2910
- Masonry**
as fire protection material, 1877, 1950, 3318
thermal degradation at high temperatures, 296, 3249
- Mass, conservation of**
computational fluid dynamics models and, 1036
continuity equation, 4–6, 59
convection heat transfer, 58–64
in flames, 375
- Mass flow rates, fire plumes**, 407, 414–417, 1000
- Mass fuel-to-air ratio**, 490, 491, 500, 1182, 1191, 1199, 1215
- Mass loss rate**, 200, 201, 203, 210, 211, 236, 361, 364, 431, 432, 489, 491, 499, 509, 593, 636, 773, 782, 799, 813, 837, 866, 922, 940, 941, 952, 975, 976, 986, 999, 1011, 1016, 1029, 1078, 1089, 1167, 1170–1174, 1179–1181, 1185, 1187, 1188, 1191, 1192, 1194, 1196, 1200, 1219–1224, 1649, 2209, 2210, 2226, 2242, 2243, 2246, 2286, 2319, 2385, 2387, 2394, 2411, 3074
- Mass optical density**, 1351, 1357, 1818, 1841
- Mass spectrometry (MS)**, 192–194, 203, 1700
- Mass transportation. *See also* Aviation fire protection; Marine transportation; Rail transportation**
decision-making methods, 3381
fire safety objectives, 3380–3381
risk-based decision making, 3379–3380
- Mathematical fire models**, 1024, 1848, 1851–1852
- Mattresses**
fire test method, 933
heat release rates, 848–853
room effects on heat release rates, 800
- McCaffrey-Quintiere-Harkleroad (MQH) correlation of temperature rise**, 1002–1005, 2860
- Mean**
geometric, 125, 126, 729, 2856
harmonic, 2856
testing, 295, 2862–2866
- Median, probability theory**, 2833
- Melting temperatures**, 179, 180, 187, 283, 1168
- Melting, thermal decomposition**, 179–181
- Mental model**, 2080, 2922
- Meshes, finite-differencing technique**, 1046, 1048
- Metals, properties**, 3432–3434

- Methane (CH₄)**
 heat of combustion, 143
 heat of formation, 145
 specific heat, 141
- Methanol (CH₃OH)**
 heat of combustion, 143
 heat of formation, 145
- MGM Grand Hotel fire (1980)**,
 2085–2087, 2097, 2449, 3103,
 3217
- Mica, dielectric strength**, 666
- MIL-F-24385 procurement/
 performance specification**,
 1661, 1662
- Milk-drying process, autoignition**,
 628
- Mode, statistical**, 2333
- Mole, defined**, 140
- Momentum, and flame height**,
 403–405, 422, 423
- Momentum, conservation of**
 computational fluid dynamics
 models and, 1036
 convection heat transfer, 59–62
- Mond Fire, Explosion, and Toxicity
 Index**, 3165–
- Mont Blanc tunnel fire (1999)**,
 1058, 2323, 2328, 2407
- Monte Carlo sampling/simulation**,
 2896, 2907, 2966, 3010–3011,
 3013, 3016, 3025, 3027, 3041,
 3125, 3133–3134, 3151–3153,
 3240, 3354
- Montreal Protocol**, 1301, 1450,
 1483, 1504, 1588
- Moody diagrams**, 20, 21, 1388,
 1389, 1391, 1393
- Motor vehicles**
 heat release rates, 943
 heat release rates of components, 943
 heavy goods vehicle cargo heat
 release rates, 881, 883
 tire heat release rates, 879
- MS.** *See* Mass spectrometry
- Multimodal data**, 2855
- Multinomial distribution**,
 2849–2850
- N**
- NanoMist**, 1625, 1626
- Narratives, fire risk analysis
 method**, 2822, 2823
- NARR2 computer program**, 1944
- National Building Code® (BOCA)**,
 3172
- National Bureau of Standards
 (NBS).** *See* National Institute
 of Standards and Technology
 (NIST); NBS toxicity text
- National Electronic Injury
 Surveillance System
 (NEISS)**, 3084, 3085, 3095
- National Fire Incident Reporting
 System (NFIRS).** *See* NFIRS
 fire incident database
- National Fire Prevention and
 Control Act (1974)**, 3084
- National Fire Prevention and
 Control Administration**,
 3084
- National Fire Protection
 Association (NFPA).** *See also*
 NFPA entries
 Fire Incident Data Organization
 (FIDO), 3085, 3086
 Fire Safety Concepts Tree, 1242,
 1291, 2038, 2825, 2949–2950,
 3052, 3174, 3177
 survey of fire departments, 2871,
 3076
- National Fire Protection Research
 Foundation (NFPRF)**, 1619,
 1694, 1695, 1737, 3380
- National Institute of Standards and
 Technology (NIST)**
 investigation of Station Nightclub
 fire, 2096
 investigation of World Trade Center
 terrorist attack, 1936
 radiant method toxicity test, 2275
 zeroth order sprinkler effectiveness
 model, 1447
- National Research Council of
 Canada (NRCC)**, 937, 1277,
 1798, 1806, 1981, 3272, 3276
- National Research Institute for Fire
 and Disaster (Japan)**, 855
- Navier-Stokes equations**, 7, 9–13,
 16, 17, 358, 1040, 3118
- NBS toxicity test**, 227–2272
- n*-Butane (n-C₄H₁₀)**
 heat of combustion, 143
 heat of formation, 145
- Negative binomial distribution**,
 2848
- NEISS.** *See* National Electronic
 Injury Surveillance System
 (NEISS)
- Net heat of complete combustion**,
 1182–1184, 1186, 1187, 1215,
 1219, 1224, 1225
- Newton's law of viscosity**,
 54, 55
- Newton's second law of motion**, 60,
 77, 1036. *See also* Momentum,
 conservation of
- NFIRS fire incident database**
 product categories, 2889–2891
 Version 5.0, 3077–3078
- NFIRS fire incident database (cont.)**
 errors/uncertainty in national
 estimates, 3081–3084
 unknown data issues,
 3080–3081
- NFPA.** *See* National Fire Protection
 Association (NFPA)
- NFPA 101A, Guide on Alternative
 Approaches to Life Safety**,
 3086, 3166
- NFPA 11A, Standard for Medium-
 and High-Expansion Foam
 Systems**, 1737
- NFPA 92A, Standard for Smoke-
 Control Systems**, 1785
- NFPA 12A, Standard on Halon 1301
 Fire Extinguishing Systems**,
 1453, 1509, 2899
- NFPA 30B, Code for the
 Manufacture and Storage of
 Aerosol Products**, 1425
- NFPA 92B, Standard for Smoke
 Management Systems in
 Malls, Atria, and Large
 Spaces**, 424, 1067, 1352
- NFPA 12B, Standard on Halon 1211
 Fire Extinguishing Systems**,
 1453
- NFPA 301, Code for Safety to Life
 from Fire on Merchant
 Vessels**, 3379, 3392–3393
- NFPA 231C, Standard for Rack
 Storage of Materials**, 1424
- NFPA 231D, Standard for Storage of
 Rubber Tires**, 1424
- NFPA 13D, Standard for the
 Installation of Sprinkler
 Systems in One- and Two-
 Family Dwellings and
 Manufactured Homes**, 1424
- NFPA 30, Flammable and
 Combustible Liquids
 Code**, 570, 1425, 1689,
 1691, 1692
- NFPA 231F, Standard for Storage of
 Roll Paper**, 1424
- NFPA 551, Guide for the Evaluation
 of Fire Risk Assessments**,
 1291, 2825, 2976–2977, 3380
- NFPA 325, Guide to Fire Hazard
 Properties of Flammable
 Liquids, Gases, and Volatile
 Solids**, 3163
- NFPA 550, Guide to the Fire Safety
 Concepts Tree**, 1242, 1291,
 2038, 2825, 2950, 3052
- NFPA 49, Hazardous Chemicals
 Data**, 3163
- NFPA 204M, Guide for Smoke and
 Heat Venting**, 1849

- NFPA *National Fire Codes*[®], 2823
- NFPA 805, *Performance-Based Standard for Fire Protection for Light Water Reactor Electric Generating Plants*, 3334
- NFPA 5000[®], *Building Construction and Safety Code*[®], 1235, 1304, 1742, 3254
- NFPA 101[®], *Life Safety Code*[®], 1235, 1266, 2018, 2125, 2174, 3086, 3166, 3379, 3386
- NFPA 72[®], *National Fire Alarm Code*[®], 443, 451, 1318, 1689, 2899
- NFPA 403, *Standard for Aircraft Rescue and Fire-Fighting Services at Airports*, 1673
- NFPA 17, *Standard for Dry Chemical Extinguishing Systems*, 1305, 2899
- NFPA 412, *Standard for Evaluating Aircraft Rescue and Fire-Fighting Foam Equipment*, 1663, 1674, 1676
- NFPA 130, *Standard for Fixed Guideway Transit and Passenger Rail Systems*, 2027, 2043, 3385–3386
- NFPA 231, *Standard for General Storage Materials*, 1424
- NFPA 11, *Standard for Low-, Medium-, and High-Expansion Foam*, 1308, 1688, 1690
- NFPA 10, *Standard for Portable Fire Extinguishers*, 1533, 1709
- NFPA 502, *Standard for Road Tunnels, Bridges, and Other Limited Access Highways*, 1616, 2043
- NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems*, 2898
- NFPA 16, *Standard for the Installation of Foam-Water Sprinkler and Foam-Water Spray Systems*, 1425, 1689, 1690
- NFPA 13, *Standard for the Installation of Sprinkler Systems*, 1424, 1587, 1683, 1717
- NFPA 14, *Standard for the Installation of Standpipe and Hose Systems*, 1424
- NFPA 20, *Standard for the Installation of Stationary Pumps for Fire Protection*, 1424, 1630
- NFPA 75, *Standard for the Protection of Information Technology Equipment*, 1453
- NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection*, 1425, 1587
- NFPA 22, *Standard for Water Tanks for Private Fire Protection*, 1424
- NFPA 286, *Standard Methods of Fire Tests for Evaluating Contribution of Wall and Ceiling Interior Finish to Room Fire Growth*, 788
- NFPA 265, *Standard Methods of Fire Tests for Evaluating Room Fire Growth Contribution of Textile Coverings on Full Height Panels and Walls*, 935
- NFPA 251, *Standard Methods of Tests of Fire Resistance of Building Construction and Materials*, 1866
- NFPA 409, *Standard on Aircraft Hangars*, 1425, 1683, 1689, 1690
- NFPA 12, *Standard on Carbon Dioxide Extinguishing Systems*, 1496, 2899
- NFPA 2001, *Standard on Clean Agent Fire Extinguishing Systems*, 1453, 1494, 2899
- NFPA 69, *Standard on Explosion Prevention Systems*, 541
- NFPA 68, *Standard on Explosion Protection by Deflagration Venting*, 2811
- NFPA 750, *Standard on Water Mist Fire Protection Systems*, 1299, 1308, 1587
- NFPA 704, *Standard System for the Identification of the Fire Hazards of Materials (1990 ed.)*, 3163
- NFPA 259, *Standard Test Method for Potential Heat of Building Materials*, 906
- NFPA 70T, *National Electrical Coder*, 1751
- NIBS *toxicity test*, 2289
- NIST. *See* National Institute of Standards and Technology (NIST)
- Nitric oxide (NO), *heat of formation*, 145
- Nitrogen dioxide (NO₂)
generation efficiency, 1206
heat of formation, 145
- Nitrogen (N₂), *specific heat*, 141
- n*-Octane (n-C₈H₁₈), *heat of combustion*, 143
- Nonhalogenated polymers, *calculating combustion yields*, 1209, 1210
- Nonmetals, *properties*, 3435–3436
- Noodles, *autoignition of instant*, 627
- NORDTEST furniture calorimeter, 800
- Normal distribution, 2837
- Normal-strength concrete (NSC)
compressive strength, 297–299
spalling, 289–290
stress-strain curves, 296
- Nozzles
flow calculation, 472
flow coefficients, 458
hose, 456, 1298
sprinkler, 456
water mist fire suppression systems, twin-fluid/single-fluid, 1624
- n*-Pentane (n-C₅H₁₂), *heat of combustion*, 143
- Nuclear power plants
fire risk analysis, 3326–3365
historical view of assessments, 3331–3333
human error and, 3351–3352
incidents, 3358
probabilistic risk assessment assembly of results, 3352
current/future directions, 3361–3365
equipment damage probability, 3348
equipment response analysis, 3358
fire barrier analysis, 3360–3361
fire detection/suppression analysis, 3358–3360
fire environment analysis, 3355–3358
fire frequency analysis, 3342–3344
fire-modeling tools, 3355
plant response analysis, 3341–3342
process, 3336–3338
structure/methodology, 3331, 3360
- Nuclear Regulatory Commission, *risk-informed decision making*, 3028
- Null hypothesis, 2861–2867, 2869, 2870, 2893
- NUREG/CR-6738, *Risk Methods Insights Gained from Fire Incidents (Nuclear Regulatory Commission)*, 2922

- Nusselt number.** 70, 80, 84, 85, 87–89, 100, 361, 362
- Nylon(s)**
heat of combustion of Nylon 6,6, 143
thermal decomposition, 1165
- O**
- Occupants**
available safe escape time (ASET)
(*see* Available safe egress time (ASET))
dependent processes for escape, 2318
handicapped/impaired, 2039, 2524
movement through smoke, 1259, 2213, 2337
required safe escape time (RSET)
(*see* Required safe egress time (RSET))
response to fire/smoke
awareness of Cues, 2054
British/U.S. populations
compared, 3109
cognitive decision processes, 2082
commitment, 1243
convergence clusters, 2097
definition, 2070–2072
evaluation, 1244
fire-fighting behavior, 2084
gender, response by, 1244
health care facilities, 2021
high-rise office buildings, 2103
hotel fires, 2085–2087
nonadaptive behavior, 2073
panic behavior, 2072–2073
recognition, 2092
re-entry behavior, 2084
residential experience, 2038
stress model, 2916
validation, 2919
- Office workstations, heat release rates,** 854
- Ohio State University (OSU) calorimeter**
oxygen consumption versions, 924–925
thermopile version, 923–924
- One Meridian Plaza fire (1991),** 3103
- Open-burning calorimeters,** 799, 802, 852
- Optical density**
measurement with helium-neon laser, 970
measurement with turbidimeter, 728
- Orifices**
fire vents as, 456
flow coefficients, 457, 458
- Oxygen**
concentration effect on heat flux, 1071
heat of formation (atomic), 145
specific heat, 141
- Oxygen bomb calorimeter,** 905–907, 909, 912, 930, 945, 999, 1182, 3465
- Oxygen consumption calorimeter**
implementation of method
O₂, CO₂, and CO measured, 916–917
only O₂ measured, 915–916
practical considerations, 917–918
Thornton's rule, 912
volatiles/condensed phase, 912
- Oxygen index.** *See* Limiting oxygen index (LOI)
- P**
- Packaging, heat release rates,** 816
- Palletized storage**
heat release rates of other commodities, 1692, 1696
heat release rates of plastic-based commodities, 836
- Pallets, heat release rates of stacked idle,** 857–859
- PAN.** *See* Polyacrylonitrile (PAN)
- Paper, file storage arrangement,** 1559
- Pareto distribution,** 2846, 3114
- Pascal distribution,** 2848
- Pascal's law,** 1379
- Paschen's Law,** 664–666
- Passenger cars.** *See* Motor vehicles
- Passenger ships, sprinklers required,** 1589. *See also* Marine transportation
- PC.** *See* Polycarbonates (PC)
- PE.** *See* Polyethylene (PE)
- Pearson product-moment correlation coefficient,** 2857–2859
- Pedestrian Planning and Design (Fruin),** 2044, 2149, 2179, 2544
- Pensky-Martens closed cup apparatus,** 566
- Perceived risk, defined,** 2820
- Percentiles,** 1264, 1868, 1998, 2017, 2018, 2141, 2585, 2833, 2834, 2836, 2838–2840, 2843, 2856, 2889, 2893, 2969, 3006, 3037, 3238, 3240, 3346
- Perfect gas(es),** 402, 988, 1036, 1037, 2758
- Performance-based design**
advantages, 1236
application
use as stand-alone methodology, 1247
use with performance-based regulations, 1246
use with prescriptive-based regulations, 1246
attributes, 1242
defined, 1233
disadvantages, 1236–1237
fire scenarios
building characteristics, 1243
design fire curves, 1244
fire characteristics, 1244
occupant characteristics, 1243–1244
quantifying, 1243
hazard/risk
deterministic analysis, 1247
event trees, 1247–1249
risk-based analysis, 1247
historical developments, 1235–1236
performance types
component performance, 1233–1234
environment performance, 1234
risk potential performance, 1234–1235
threat potential performance, 1234
prescriptive-based design compared, 1236, 1238
process
define objectives, 1239
define project scope, 1237–1238
develop fire scenarios, 1240–1242
develop performance criteria, 1239–1240
develop trial designs, 1242
document design process, 1245–1246
evaluate trial designs, 1244–1245
fire protection engineering design brief, 1242–1243
identify goals, 1238
quantifying design fire scenarios, 1243
SFPE Handbook of Fire Protection Engineering and, 1255–1260
- Performance-based fire protection,** 1233, 1235–1245, 1247, 1255, 1257, 1260, 1262, 1277, 1315, 2032, 2035, 2825, 2960, 2998, 3013, 3023, 3189, 3207–3209, 3333, 3334, 3362, 3386

- Performance shaping factor**, 2921, 2924–2927, 3352
- PET**. *See* Polyethylene terephthalate (PET)
- Phase-Doppler anemometer (PDA)**, 1598–1600
- Phenolic resins, thermal decomposition**, 224–225
- Piezo-electrification, electric charge separation**, 682
- Piezometer tube**, 1381
- Pillows, heat release rates**, 589
- Piloted ignition**, 389, 572, 649–650, 653, 707, 714, 920, 921, 1147, 1149, 1150, 1258, 3244, 3312, 3358
- Pipe(s)**
 dimensions/weights of copper, 3491
 dimensions/weights of extra-strong, 3491
 dimensions/weights of red brass, 3491
 fluid flow in, 2, 98
 laminar/turbulent, 1382
 heat conduction through walls of, 3250
 properties of copper, 3490–3491
 properties of steel, 3483–3489
- Pipe flows**
 boundary layer concept, 65–75
 energy losses in
 compound networks, 1400–1401
 critical zone, 1389
 equations, 1387–1401
 Hazen-Williams-based data, 1393
 minor losses, 1395–1399
 pipes in parallel, 1399–1400
 pipes in series, 1399
 flow measurement
 ASME flow nozzle, 1402–1403
 ASME orifice meters, 1402–1403
 pitot tube, 21, 1403–1405
 Venturi flow meter, 1402
 laminar/turbulent, 1382
 water hammer, 1407–1409
- Pipe insulation, heat release rates**, 859
- Pitot tube**, 21, 407, 459, 1401, 1403–1405, 1438
- Planck constant**, 3400
- Planck mean absorption coefficient**, 124, 125, 128–130
- Planck's law**, 104
- Plastic-based commodities, pallet storage and heat release rates**, 836
- Plastics**
 arc tracking in, 671–673
 dielectric strength, 664, 666
 heats of combustion/properties, 1144
- Plate thermometers**, 749, 789, 790, 1105–1107, 1127–1129
- Plunge tests, detector sensitivity**, 1333
- PMA**. *See* Polymethyl acrylate (PMA)
- PMMA**. *See* Polymethyl methacrylate (PMMA)
- Pneumatic transport systems, static electricity and**, 687
- Poisson distribution**, 2842, 2844, 2847, 2915
 fire frequency analysis, 2844
- Polarization, electrical charge separation**, 682
- Polyacrylics**
 thermal decomposition, 167–247
- Polyacrylonitrile (PAN)**, 143, 168, 173, 185, 186, 197, 198, 217–218, 244, 673, 913, 2221, 2223, 2246, 2276, 2282, 2283, 2296, 2359, 2390, 3445, 3456, 3464
 arc tracking in, 671
 heat of combustion, 143
 thermal decomposition, 198, 217–218
- Polyamides**, 168, 170, 216, 227, 246, 3445
 thermal decomposition, 170, 216
- Polybutadiene, thermal decomposition**, 173
- Polycarbonates (PC)**
 heat of combustion, 143
 thermal decomposition, 215–216
- Polychloroprene**, 3453, 3457, 3465
 thermal decomposition, 3457
- Polycrystalline material**, 278
- Polyester, heat of combustion**, 143
- Polyesters**, 168, 170, 216–218, 228–229, 231, 246, 1164
- Polyethylene (PE)**
 calculating combustion yields, 993
 heat of combustion, 143
 thermal decomposition, 169, 182
 water application rate, 1689
- Polyethylene terephthalate (PET)**
 heat of combustion, 143
 thermal decomposition, 169, 216–217
- Polyisoprene, thermal decomposition**, 173, 220–223
- Polymeric materials**
 decomposition temperatures, 182, 222
 fire propagation/smoke development index, 1163
- Polymers**
 arc tracking in, 672, 673
 chain structure, 167
 classifying, 241
 composite construction, 1974
 effect of additives on
 decomposition, 28
 fiber-reinforced (*see* Fiber-reinforced polymers (FRP))
 fluorine-containing, 1301
 gasification, 167
 glass transition temperature, 171, 179, 642
 halogenated, 218–220, 1152, 2244
 nitrogen-containing, 2237, 2278, 2279
 oxygen-containing, 2255, 2282
 synthetic carbon-oxygen chain, 227
 thermal decomposition (*see* Thermal decomposition of polymers)
 thermally stable, 222
 vinyl-derived, 168
- Polymethyl acrylate (PMA), thermal decomposition**, 170, 198, 215
- Polymethyl methacrylate (PMMA)**
 calculating combustion yields, 993
 heat of combustion, 143
 thermal decomposition, 215
 water application rate, 169
- Polyolefins**, 887
 thermal decomposition, 884, 3459
- Polyoxymethylene (POM)**
 heat of combustion, 145
 thermal decomposition, 83, 173
 water application rate, 147
- Polypropylene (PP)**
 calculating combustion yields, 993
 decomposition products, 2255
 heat of combustion, 143
 thermal decomposition, 168, 170
- Polystyrene (PS)**
 calculating combustion yields, 993
 dielectric strength, 664, 666, 2692
 heat of combustion, 143
 thermal decomposition, 168, 170
 water application rate, 1689
- Polysulfides, thermal decomposition**, 810
- Polysulfones, thermal decomposition**, 810
- Polytetrafluoroethylene (PTFE)**
 dielectric strength, 220, 664
 thermal decomposition, 173, 178, 220
- Polyurethanes**, 168, 170, 224, 231, 246, 2246, 2255, 2256, 2288, 2291, 2296, 3452
 thermal decomposition, 224

- Polyvinyl acetate, thermal decomposition**, 168
- Polyvinyl chloride (PVC)**
arc tracking in electrical insulation, 220, 671
combustion yields, 993
dielectric strength, 666
heat of combustion, 143
thermal decomposition, 170, 191
- Polyvinylidene chloride (PVDC)**, 913, 3447, 3458, 3465
thermal decomposition, 93
- POM.** *See* Polyoxymethylene (POM)
- Pool fires.** *See also* Liquid fuel fires
fire size
blended fuel, 2573, 2574
flame height, 2582
fuel burning regression rate, 2572, 2574
pool tank lip height, 2582
wind speed, 2582
flame height/length, 2583
flame radiation to external target (*see* Flame radiation to external target, pool fires)
flame spread
empirical data, 2564
pool dimensions and, 2593
temperature effects, 2562
flame spread velocities and rate of pool involvement, 2570–2572
flame tilt, 2593, 2595–2596
geometry
flame height/length, 2594, 2595
flame tilt angle, 2595–2596
trench/line fires, 2596
heat release rates
room radiation and, 2600
rough surfaces, 2674
thin-layer, 866
pool defined, 2647
pool size, 2552–2558
pyrolysis rate, 2995
room effects on heat release rates, 2603
surface flame spread, 2569
thermal radiation hazards
emissive radiation, 107
external targets, 2600
targets within fires, 2628
virtual origin, 1835
wind and, 2595
- Porosity**
building materials, 278
high-strength concrete (HSC), 280, 289, 303
- Portable fire extinguishers**
dry chemical, 1302–1303
foam, 1299
- Portland Cement Association (PCA)**, 1965, 1966
- Powders.** *See* Dust(s)
- Power function of the test, statistics**, 2862
- PP.** *See* Polypropylene (PP)
- PRA.** *See* Probabilistic risk assessment (PRA)
- Prandtl number**, 3, 11, 18, 57, 65, 67, 72, 75, 78, 86, 89, 100, 351, 362, 438, 439, 451, 1062, 2670
- Preaction sprinkler system**, 1765
- Pre-heating zone, flames**, 3314
- Premixed combustion**
effect of additives on flame propagation, 2750
flame propagation, 2647
flame propagation mechanism, 2647, 2648
practical applications, 1031, 2910
pressure rise in closed vessels, 139, 2792
- Premixed flames**
adiabatic flame temperature, 388–389, 536–538
burning velocity, 2637, 2739
conical, 654, 958
diffusion flames distinguished, 237, 352
flammability limits, 546, 565
idealized (flat), 1800
turbulence, 12, 80, 389
- Pressure, fluids**, 1379–1380, 1382
- Primary reaction zone, flames**, 328
- Probabilistic fire models**, 1024, 2965
- Probabilistic methods, fire risk analysis**, 3226
- Probabilistic risk assessment (PRA)**, 2310, 2919, 2923, 2960, 2977–2979, 3326, 3333, 3365
nuclear power plants, 3326, 3329–3331
- Probability**
decision analysis and (*see* Decision analysis, probability)
defined, 2827
fire types, 3051
human error, 2920, 2927, 3192
in reliability analysis, 2840, 2876, 3351
- Probability distributions.** *See also specific distributions (cont.)*
discrete, 2831
discrete/continuous, 2831
failure/hazard rate, 2880, 2884
fire growth and (*see* Stochastic models of fire growth)
kurtosis, 2834
mean/median, 2855
moments, 2833
multivariate, 2836
parameters, 2841, 2845, 2854
populations, 2835
for reliability analysis, 2840, 2879
for significance tests
chi-square distribution, 2839, 2866
F distribution, 2840
Student's *t* distribution, 2839, 2864
skewness, 2834
uniform, 2834, 2850
- Probability measure**, 2828–2829
- Probability sample**, 2871
- Probability theory**
concepts, 2857
conditional probability, 2830
fire risk analysis and, 2888
formulas, 2829–2890
frequency interpretation, 2829
independent/dependent events, 2828, 2830
prior/posterior probabilities, 2830
probability distributions (*see* Probability distributions)
random variables, 2831
standard deviation, 2833
subjective interpretation, 2820
survival function, 2832
- Process flaring**, 2630
- Production flaring**, 2630
- Products (finished), fire risk analysis**
assumptions, 3212
data sources
code requirements, 2963
expert judgment, 3358, 3392
product/property surveys, 3220
importance of, 3326
process steps, 3013
relevant fire scenarios
building dimensions/geometry, 3219
exposure of people/property, 3220–3221
fire protection systems/features, 3221–3222
initiating fire, 3205
openings, 3219
room linings, 3218
scope of products included, 3212
specifying class of properties, 3212

- Products (finished), fire risk analysis** (*cont.*)
 specifying goals/objectives/measures of loss, 3212
 test methods/models
 calibration/sensitivity/uncertainty, 3222–3223
 ignition probability, 2846
- Propane (C₃H₈)**
 adiabatic burning, 147
 boiling point, 559, 735
 flammability limits, 537, 547
 heat of combustion, 143
 heat of formation, 144, 1182
 oxygen/air required for total oxidation, 141, 1182
- Property protection goals**, 3213
- Propylene (C₃H₆), compartment fire source examples**, 1079
- Protective action decision model**, 2076–2079, 2081, 2082
- Protein foam**, 1647, 1656, 1665, 1668–1670, 1673, 1681, 1682, 2554
- PS**. *See* Polystyrene (PS)
- PTFE**. *See* Polytetrafluoroethylene (PTFE)
- Pumps**
 brake horsepower, 1418, 1439, 1629
 centrifugal pump affinity relations, 1420–1422
 classes, 1426
 net positive suction head (NPSH), 1417–1419
 operating characteristics, 1416–1419
 parallel installation, 2930
 selection, 1419–1420
 series installation, 2930
 water horsepower, 1418
- PVC**. *See* Polyvinyl chloride (PVC)
- PVDC**. *See* Polyvinylidene chloride (PVDC)
- Pyroelectrification, electric charge separation**, 682, 689
- Pyrolysis**, 141, 167, 172, 177, 181, 183, 192–195, 197, 198, 200–206, 209–213, 215–217, 226, 227, 231, 239, 240, 244, 247, 290, 327, 396, 397, 502, 538, 582–585, 591, 593, 594, 600, 635–637, 639–644, 646, 647, 649–652, 655, 710, 712–715, 717, 721, 729, 805, 828, 830, 833, 928, 929, 932, 956, 964, 973, 977, 984, 986,
- Pyrolysis** (*cont.*)
 996, 997, 999, 1000, 1010, 1026, 1043–1045, 1081, 1135, 1146, 1150, 1154–1159, 1166, 1174–1175, 1178–1182, 1205, 1207, 1208, 1211, 1219, 1297, 1299, 1352, 1448, 1459, 1590, 1592, 1604, 1785, 1824, 1985, 1986, 1992–1994, 2005, 2208, 2210, 2212, 2221, 2223, 2253, 2255, 2271, 2273, 2274, 2284, 2302, 2303, 2321, 2390–2392, 2395, 2404, 2643, 2775, 2995, 3214, 3287, 3296, 3314
- Pyrolysis front**, 640, 641, 713, 714, 1154–1159, 1166
- Pyrolysis gas chromatography (PGC)**, 192–194
- Q**
- Quartile**, 2856
- Quenching distances**, 554
- Quota sample**, 2871
- R**
- RABT-ZTV fire resistance test**, 791
- Rack storage**
 ignition source location and fire development, 847
 quick-response sprinkler activation, 444, 1428, 1444
- Radiant energy detection**, 1257, 1357, 1358
- Radiant intensity**, 106, 107, 114, 117, 124, 1042, 1062, 2647, 3398
- Radiation blanketing**, 940
- Radiation blockage**, 3321
- Radiation heat transfer**. *See* Thermal radiation
- Radiative heat release rate**, 424, 1145, 1146, 1148, 1184, 1187, 1188, 1221, 1222
- Rail transportation**
 bridges, 3374
 car heat release rates, 3386, 3389, 3390
 fire risk decision making
 decision tree, 3381, 3384, 3385
 NFPA 130 and, 1753, 2027, 2029, 2043, 3374, 3385–3386
 regulation of combustible materials, 3384, 3387
 fire safety objectives, 3384, 3386–3389
 incidents, 3386
 subways, 3385
 tunnels, 3386, 3387
- Random-chain scission, decomposition mechanism**, 181
- Random sample**, 2870–2872, 3078, 3122, 3133, 3351
 simple/stratified, 2871, 3078
- Random variables**
 correlation, 2857–2859
 expected value/average, 2832
 regression analysis, 2857, 2859
 variance, 2857
- Range, data**, 2651
- Raoult's Law**, 562, 564
- Rayleigh number**, 11, 79, 89, 100, 366, 438, 452
- Refrigerators, heat release rates**, 867, 868
- Regression analysis**, 1150, 1171, 2107, 2518, 2857, 2859, 2861, 3117
- Reinforced Concrete Fire Resistance (Concrete Reinforcing Steel Institute)**, 1968
- Reliability**, 1865–1866, 2840–2850, 2875–2983
 software (*see* Software reliability)
- Reliability analysis**
 accelerated testing, 2879, 2915–2916
 complete/censored data, 2879, 2911–2913
 data collection, 2879, 2911, 2918
 human
 definitions, 2919
 models, 2920, 2927–2928
 process, 2923–2927
 value of, 2920
 models
 Arrhenius life-temperature relationship, 2916
 inverse power relationship, 2917
 probabilistic life-stress relationships, 2917
 nonrepairable items
 conditional distributions, 2834, 2884–2886, 2892, 2896, 2913
 empirical distribution, 2880, 2882–2884, 2886
 exponential distribution, 2840–2844, 2880–2881, 2885–2886, 2912–2913
 generic reliability values for fire protection systems, 2889–2891
 hazard rate, 2840, 2880, 2884–2887, 2918, 2919, 2929, 2930
 log-normal distribution, 2838–2839, 2882, 2883, 2886, 2887, 2895, 2913

- Reliability analysis** (*cont.*)
- stress/strength interference model, 2887–2889
 - Weibull distribution, 2881, 2882, 2886, 2898, 2912–2914
 - operational/test-generated data, 2879, 2911
 - parameter estimation
 - Bayesian analysis, 2914–2915
 - exponential distribution, 2912–2913
 - log-normal distribution, 2913
 - nonhomogeneous Poisson process, 2913
 - renewal process, 2913–2914
 - Weibull distribution, 2912–2913
 - probability and, 2880–2884
 - process, 2891, 2893, 2895, 2913, 2923
 - repairable items
 - chronological graphing of failure history, 2892
 - Laplace or centroid test, 2892–2893
 - nonhomogeneous Poisson process, 2895, 2896, 2913
 - numerical algorithm for failure prediction, 2896, 2913
 - probabilistic models for failure prediction, 2891
 - renewal process, 2891, 2893–2898
 - superimposed renewal process, 2895
 - trend concept, 2877, 2891–2893, 2897, 2928
 - system modeling/analysis
 - block diagrams, 2929–2932
 - cut sets, 2931
 - dependent/common cause failures, 2935–2937
 - fault tree quantification, 2935
 - fault trees, 2932–2935
 - modeling common cause failures, 2936–2937
 - other systems, 2930–2931
 - parallel systems, 2929
 - path sets, 2931
 - series systems, 2929
 - share load systems, 2930
 - standby systems, 2930
- Representative sample**, 1597, 2871, 2978
- Required safe egress time (RSET)**
- components, 2435, 2437
 - impact of tenability on, 2145–2148
- Residence dwellings**
- high-rise evacuation, 1743
 - occupant behavior, 1242, 1266, 2166
- Residuals, statistics**, 2859
- Resin**, 168, 170, 224, 309, 310, 313, 684, 810, 2771, 3105, 3267
- Resistance network analogy, thermal radiation**, 122
- Response time index (RTI)**, 1029, 1045, 1265, 1321–1326, 1328, 1329, 1331, 1334, 1336–1340, 1342, 1343, 1444, 1691, 3040, 3229, 3235
- Reynolds analogy**, 71
- Reynolds-averaged Navier-Stokes approach**. *See* Computational fluid dynamics (CFD) models; Reynolds-averaged Navier-Stokes approach; Reynolds-averaged Navier-Stokes approach/turbulence modeling; Turbulence modeling
- Reynolds number**, 10–20, 65–67, 72, 81, 86, 87, 89, 94, 96, 401, 416, 423, 438, 457, 463, 474, 725, 726, 988, 1320, 1321, 1387, 1388, 1391, 1393, 1399, 1401, 1446, 1574, 1827, 1828, 2632, 2637–2639, 2644
- Reynolds stresses**, 13, 1038, 1039
- RFIRES zone fire model**, 1025
- Risk analysis**
- defined, 3227
 - health care facilities, 2825, 3178
 - performance-based design, 1255, 1256
 - qualitative, 2822, 2957, 3186, 3207, 3341, 3364
 - quantitative, 3364
- Risk assessment**
- defined, 2831, 2888
 - hazard-based assessment compared, 1247, 3389
 - use of fault/event trees, 2823, 2929
- @RISK decision analysis model**, 3025
- Risk defined**, 2817, 2941
- Risk estimation defined**, 2818, 2821
- Risk evaluation defined**, 2821, 3186
- Risk identification defined**, 2083, 2821
- Risk-informed industrial fire protection engineering**. *See* Fire protection engineering, risk-informed industrial
- RiskPro fire risk model**, 82
- Roof assemblies, fire resistance testing**, 1910, 1911, 1913, 1917
- Room/corner tests**, 711, 712, 788, 789, 934–939, 942, 946
- standards, 788, 935–936
- Room fires**. *See* Compartment fires
- Rosland mean absorption coefficient**, 124–125
- RSET**. *See* Required safe egress time (RSET)
- Rubber, synthetic**. *See* Polyisoprene
- Runaway reaction**, 605, 616
- Runehamar test tunnel (Norway)**, 1616
- Runge-Kutta methods, solving initial value problems**, 1096
- S**
- Safety factors/margins**
- combining, 2992, 3004–3005
 - derivation of, 3005
 - FOSM method, 3005
 - implied/explicit, 3003
 - in prescriptive/performance codes, 3003
 - selection, 3003–3004
- Safety of Life at Sea (SOLAS) convention**, 935, 1535, 1547, 1556, 1561–1566, 1614, 3377, 3379
- SAFIR computer program**, 1111, 1127, 1957, 1994
- SAFIRE risk assessment method**, 2968–2969
- Sample design**, 1244, 2871
- Sample space**, 2828, 2829, 2831
- Sampling frame**, 2871
- Sampling theory**, 2870–2871
- San Pedro de Anes test facility (Spain)**, 1611, 1618
- Scatter plot/diagram**, 2457, 2857, 2860
- Schmidt number**, 3, 57, 351, 1038, 1040, 2669
- Secondary reaction zone, flames**, 216
- Self-heating, spontaneous combustion and**, 604–630
- Self-ignition**. *See* Autoignition
- Semenov theory, autoignition assumptions**, 611–614
- and Biot number, 618, 622–623
 - complex chemistry and, 615
 - inclusion of fuel consumption, 614–615
 - and reactions in continuously stirred tank reactor, 615–616
 - thermal runaway, 615–616
- Separation of variables, heat transfer analysis**, 38–39
- Set theory**
- set operators
 - complement, 2827–2828
 - formulas related to, 2829–2830
 - intersection, 2828
 - relationships among, 2828
 - union, 2828
 - sets/subsets, 2827

- SFPE Engineering Guide on Human Behavior in Fire**, 1243
- SFPE Engineering Guide to Fire Risk Assessment**, 1291, 2037, 2039, 2825, 3380
- SFPE Engineering Guide to Performance-Based Fire Protection**, 1233, 1235, 1237–1245, 1255, 1257, 1260, 1262, 2032, 2825, 2960, 2998, 3023
- SFPE Engineering Guide to Piloted Ignition of Solid Materials Under Radiant Exposure**, 1258
- SFPE Guide to Fire Exposures to Structural Elements**, 1909
- Shaft flows**, 992
- Shear and moment diagrams**, 263
- Shear force, fluids**, 54
- Shear stress, fluids**, 1, 54, 1379, 1385, 1654
- Shop displays, heat release rates**, 820, 836, 867–869
- Shopping malls**. *See* Large-volume spaces, smoke management in
- Side chain cyclization mechanism, thermal decomposition**, 217, 218
- Side chain elimination mechanism, thermal decomposition**, 213
- Signs**
- ability of handicapped/impaired persons to locate/read, 2181, 2203
 - escape guidance systems, 2200–2202
 - flashing light source, 2198–2200
 - light-emitting/-reflecting, 2187
 - traveling flashing light sources, 2181, 2200, 2202
 - visibility/conspicuousness, 2199
 - visibility of colored, 2188
 - visibility of light-reflecting, 2186, 2187
 - visibility through irritant smoke, 2188–2190
- Silver Spring (Md.) rail collision (1996)**, 3374
- SIMPLE numerical scheme for CFD models**, 1047
- Simultaneous thermal analyzer (STA)**, 188–189, 191, 192
- Situation assessment**, 2264, 2922
- Situation model**, 2922
- Skewness, probability distributions**, 2834
- Skin burns**
- correction factors, 2725–2729
 - human variability, 2707–2713
 - prediction, 2713–2724
 - statistics, 2713
- SMARTFIRE CFD model**, 1035, 1609
- Smoke**
- aerosols, 727
 - behavioral response in (*see* Behavioral response to fire/smoke)
 - buoyancy, 1785, 1787, 1789–1792, 1817, 1829, 1842–1845, 1848, 1849, 2310
 - and carbon monoxide generation efficiency, 2394
 - carbon particles in (*see* Soot)
 - coagulation of particles, 725, 727–729
 - decrease of visual acuity in irritant, 2188–2190
 - defined, 727, 732, 1785
 - detection (*see* Detection system design; Smoke detectors)
 - directional sounders, 2181, 2202–2204
 - escape guidance systems
 - directional sound, 2202–2204
 - flashing light source, 2198–2200
 - traveling flashing light source, 2181, 2200, 2202, 2205
 - fire ventilation and yields, 2396–2404
 - fractional effective concentration (FEC), 2318, 2324, 2338
 - incapacitation by, 2321–2323, 2349–2351
 - including effects into hydraulic model of egress performance, 1788, 2309
 - irritant, 2188–2190, 2196, 2336–2337, 2370
 - light obscuration, 1825–1826, 1841
 - modeling effects on visibility, 2187–2188
 - occupant movement through, 2320, 2412
 - optical density measurement, 2192, 2319, 2384, 2386, 2387, 2411, 2412, 2416
 - optically dense irritant, 2336–2345
 - tenability limits, 2342–2345
 - particle size, 729–730
 - particle size distribution, 729
 - measurement, 729
 - production of, 1824, 1848
 - properties, 724, 728
 - specific/mass optical density, 1841
 - spectral extinction properties, 2188, 2189
 - toxicity assessment model, 2309–2311
 - vapor/particulate phases, 2341
 - venting, 2404
- Smoke (*cont.*)**
- visibility in, 2187, 2189
 - smoke density and, 2186–2187
 - walking speed through, 2337
 - yields, 728, 729
- Smoke control**
- acceptance testing, 1820
 - barriers, 1786, 1799, 1813, 1817, 1824
 - compartmented stairwells, 1792
 - computer analysis, 1818
 - design parameters
 - airflow, 1787, 1790
 - number of open, 1087
 - pressure differences, 1790, 1799–1800
 - weather data, 1785
 - door opening forces, 1799
 - elevator shafts
 - piston effect, 1793–1794
 - pressurization, 1807–1808
 - flow areas, 1797, 1798, 1801, 1808, 1809
 - effective, 1794–1796
 - pressurization, 1787–1788, 1807–1808
 - pressurized stairwells, 1800–1806
 - analysis, 1800
 - principles of
 - airflow, 1787, 1790
 - pressurization, 1787–1788
 - smoke management (*see* Smoke management)
 - smoke movement (*see* Smoke movement)
 - symmetry concept, 1796–1797, 1801
 - tenability systems
 - fire scenario, 1817
 - smoke transport, 1817
 - smoke transport calculations, 1817–1818
 - tenability, 1817
 - tenability calculations, 1818–1819
 - tunnels, 1818
 - ventilation, 1789, 1793, 1826, 1830
 - zoned control, 1813–1814
- Smoke conversion factor**, 3397–3424
- Smoke damage**, 724, 725, 728, 733, 735, 738–740, 742, 1240
- Smoke detectors**
- activation times, 1061, 2327, 3235
 - audibility, 1257
 - ceiling jet flows and, 429
 - entry resistance, 1348–1350
 - and forced ventilation systems, 3356
 - ionization type, 1348
 - light-scattering (photoelectric) type, 1346–1348

- Smoke detectors** (*cont.*)
 modeling response, 1344–1345
 and obscuration/attenuation, 1345–1346
 occupant response to
 children, 2040, 2064, 2175
 sleeping occupants, 2040
 projected-beam type, 1345, 1351, 1356, 1854
 response functions, 1344–1350
- Smoke Development Index (SDI)**, 1162–1164
- Smoke layers, heat flux calculations**, 133–135
- Smoke management**, 1027, 1067, 1092, 1094, 1099, 1258, 1267, 1274, 1280, 1286, 1352, 1781, 1787, 1817, 1824, 1826–1827, 1829, 1843, 1855, 1857, 2034, 2043, 3260, 3315, 3316
 large-volume spaces (*see* Large-volume spaces, smoke management in)
- Smoke movement**
 buoyancy, 1792
 computational fluid dynamics models
 fire source, 1045
 open boundary conditions, 1045
 visibility, 1045
 design fire scenarios and, 1273, 1274
 expansion, 1789
 HVAC systems and, 1789
 reverse stack effect, 1789, 1790
 stack effect, 1789–1792
 in tall buildings, 1794
 wind effects, 1792–1793
- Smoke point**
 defined, 1211
 predicting fire properties with, 1214, 1215
- Smoldering**
 char oxidation, 582, 593, 599, 600
 defined, 581
 factors favoring, 1627
 in flammable liquids, 554, 1271
 self-sustained propagation
 forward propagation, 584, 585, 591, 600
 horizontal fuel layer, 591
 multidimensional spread, 584, 590
 one-dimensional spread, 584
 other fuel configurations, 592
 reverse propagation, 584
 transition to flaming, 598–600
 and victim incapacitation, 2391–2392
- Society for Risk Analysis**, 2819, 2826
- Society of Fire Protection Engineers (SFPE)**. *See* SFPE entries
- SOFIE CFD model**, 956, 1035, 1609
- Software availability**, 2918
- Software bug**, 2918
- Software error**, 2918
- Software failure**, 2918, 2919
- Software fault**, 2918
- Software maintainability**, 2918
- Software reliability**
 defined, 2875, 2918
 and fire risk assessment, 2919
- Software verification/validation**, 2919
- SOLAS**. *See* Safety of Life at Sea (SOLAS) convention
- Solids**
 flaming ignition (*see* Solids, flaming ignition)
 heat conduction in
 pipe walls, 35, 36
 plates, 38, 39
 spherical with internal generation, 30
 ignition by arcing, 670–671
- Solids, flaming ignition**
 fuels, 633–658
 gas phase
 autoignition, 647–649
 flashpoint/firepoint, 650–651
 piloted ignition, 649–650
 process of ignition, 634
 simplifications/standardization
 absorption of radiation and global properties, 653
 boundary conditions, 653–655
 ignition condition, 655
 inert solid assumption, 651–653
 solution, 656–657
 thermally thin materials, 657–658
 solid phase
 charring, 639
 melting/evaporation of water, 641–642
 production of gaseous fuel, 637–639
 pyrolysis/charring depth, 640–641
 pyrolysis process, 635–637
 semi-infinite solid, 640
 surface boundary conditions, 644–646
 temperature distribution, 642–644
 thermal depth, 639–640
 thermally thick/thin solids, 640
- Soot**
 agglomerates, 128
 defined, 325, 724
 formation, 151, 352, 353, 1035, 1042, 1172, 1175, 1211, 2640
 particle contribution to thermal radiation, 106, 353
 radiation properties of, 128–130
 smoke point and formation of, 241, 354, 1211, 1212
 yields, 915, 919, 971, 1079, 1080, 1090, 1348, 3005
- Sorption isotherm, building materials**, 279
- Southwest Research Institute**, 816, 937, 1692, 3254
- Spark, electric/mechanical distinguished**, 666
- Species production, effect of combustion conditions on**
 chemical kinetics, 505–508
 compartment fire experiments, 499–505
 engineering methodology, 520–526
 equivalence ratio, 489–493
 full-scale studies, 504
 hood experiments, 493–499
 overventilated conditions, 491, 494, 498, 499, 501, 506, 507, 509
 species yields, 488–489
 transient conditions, 509–510
 transport to adjacent spaces
 burning in confined adjacent areas, 512–515
 burning in unconfined adjacent areas, 512
 effects of burning outside compartment, 511
 effects of oxygen-deficient smoke layers, 517–519
 entrainment, 493, 499
 forced ventilation and, 519
 predicting species levels, 515–517
 underventilated conditions, 486–488, 491, 492, 496–500, 504–506, 509, 510, 521, 523
- Specific Commercial Property Evaluation Schedule, insurance rating**, 3161–3162
- Specific heat**
 brick, 305–306
 building materials, 286–287
 calculation of, 244
 concrete, 296–304
 defined, 140, 286
 gypsum wallboard, 314–315
 selected gases, 141
 wood, 306–309
- Specific surface, pore structure**, 278, 279
- Specific volume, fluids**, 1, 286, 299, 300, 314, 375, 376, 1512, 1554, 1562, 1563, 2802
- Spill(s)**
 confined/static, 2553
 continuously flowing, 2552, 2553, 2576, 2580, 2583
 defined, 2552
 estimating depth, 2553
 fire growth rate
 empirical data, 2564–2570
 flame spread regimes, 2559–2561
 pool dimensions, 2561–2562

Spill(s) (*cont.*)

- porous surfaces, 2559, 2569
- temperature effects, 2562–2563
- fire size
 - enclosure fires, 2582
 - flame height, 2582–2583
 - fuel burning regression rate, 2572, 2574, 2586
 - inclined/cluttered surfaces, 2582
 - wind speed, 2582
- flame spread velocities and rate of spill involvement, 2570–2572
- foam system protection, 1708–1709
- gasoline, 2554, 2556, 2576

Spontaneous combustion.

See Autoignition

Spontaneous ignition. *See*

Autoignition

Sprinklers

- ceiling jet flows and, 429, 430, 444
- K-factor, 1429–1431
- response time index, 27
- spacing, 1343, 1427, 1428, 1430

Sprinkler system calculations

- drawbacks of using water, 1423
- hanging/bracing
 - earthquake braces, 1443–1444
 - hangers/hanger supports, 1442
 - trapeze hangers, 1442–1443
- hydraulics considerations
 - density-based demand, 1426–1429
 - elevation losses, 1434
 - Hardy Cross method, 1434
 - Hazen-Williams method, 1430, 1431
 - loops and grids, 1434–1437
 - pressure losses through piping/fittings/valves, 1430–1432
 - pressure requirements for most remote sprinkler, 1429–1430
 - use of velocity pressures, 1432–1434
- limits of calculations, 1425–1426
- performance calculations
 - droplet size/motion, 1445–1446
 - dry system water delivery time, 1444–1445
 - spray density and cooling, 1446–1447
 - sprinkler response as detector, 1444
- standards, 1424–1425
- suppression by sprinkler sprays, 1447–1448
- water supply calculations
 - available supply, 1437–1439
 - pump selection/testing, 1439–1440
 - tank sizing, 1440–1442

Sprinkler systems

- required on passenger ships, 1622, 1637
- types, 1423–1424
- SPYVAP wood charring model**, 1993
- Stairs/stairwells**
 - compartmented, 2021
 - effect on evacuation time, 1816, 2022, 2107
 - pressurized, 1791, 1792, 1794, 1798, 1800–1802, 1804–1808, 1812, 1814–1817, 1820, 2058, 2066, 3260

- Standard deviation**, 260, 496, 729, 896, 915, 976, 1053, 1054, 1132, 1133, 1137–1141, 1179, 1671, 1868, 2335, 2339–2341, 2414, 2446, 2448, 2460, 2464–2468, 2478, 2479, 2484, 2487–2497, 2521–2523, 2525–2536, 2554, 2578, 2728, 2833, 2835–2840, 2843, 2845, 2854, 2855, 2857, 2860, 2862–2866, 2881, 2882, 2889, 3005–3007, 3009–3010, 3041–3042, 3044, 3115, 3134, 3153, 3230, 3234, 3235

Standard Methods for the Examination of Water and Wastewater (American Public Health Assn.), 1700

STANJAN computer code, 2740, 2752

Stanton number, 71, 89, 438, 445, 446

STAR-CD CFD model, 1609

STAR-Fire risk assessment method, 2968–2969

Star Princess cruise ship fire (2006), 3390

Static electricity. *See* Electrical fires, static electricity discharge

Station Nightclub fire (2003), 2096, 2405

Statistics

- basic concepts
 - descriptive, 2855–2857
 - inferences, classical/Bayesian, 2853–2855
- correlation, 2857–2859
- data characterization
 - data variability, 2871–2872
 - error, 2835, 2838, 2861–2863, 2872, 2873
 - precision/bias information, 2872
 - and propagation of uncertainties, 2852
 - repeatability/reproduceability, 2872
 - testing models for goodness of fit, 2872–2874

Statistics (*cont.*)

- hypothesis, 2861–2862
- hypothesis testing
 - confidence coefficient/limits, 2861
 - contingency test of independence, chi-square test, 2869–2870
 - error types, 2861–2862
 - nonparametric tests, 2870
 - power function of the test, 2862
 - test of difference between two means, z test, 2863
 - test of difference between two proportions, z test, 2863
 - test of goodness of fit to a distribution, chi-square test, 2866–2869
 - test of mean, t test, 2864–2866
 - test of mean, z test, 2862
 - test of proportion, z test, 2863
 - test of variance, chi-square test, 2866
- method of least squares, 2859
- parameters of descriptive mode, 2855–2857
- regression analysis, 2859
- regression coefficients, 2859–2861
- residuals, 2859
- sampling theory, 2870–2871

Steel

- cold-formed light-gauge/hot-rolled structural, 295
- creep, 282–283
- critical temperature, 288–289
- crystalline structure, 1913
- density, 1117
- modulus of elasticity, 281–282, 293–295, 1912, 1913, 1951, 1953, 1954
- pipes, properties, 1393, 1395, 1430, 1431, 1433, 1477, 1568, 1574, 1579, 1580, 1912–1914, 3483
- strength, 294, 1911, 1961
- stress-strain diagrams, 281
- thermal expansion, 284
- thermal properties, 284, 1112
- yield/ultimate strengths, 281–282

Steel members

- architecturally exposed, 1910
- bending strength, 1925
- in compression, 1925
- critical temperature (*see* Critical temperature, algebraic equations for steel members)
- design criteria, 1909
- fire resistance determination by analytical methods
 - beams, 1923–1924
 - columns, 1920–1923
 - empirically derived correlations, 1919–1927

Steel members (*cont.*)

- standard test, 1919, 1929
- time-temperature curve, 1910, 1911, 1935
- trusses, 1924–1927
- heat transfer analyses
 - computer-based analyses, 1934–1936
 - exterior columns, 1929–1930
 - graphical solutions, 1930–1934
 - Jeanes's graph, 1932–1934
 - liquid-filled columns, 1930
 - numerical methods, 1928–1930
 - protected members, 1928–1929
 - quasi-steady-state approach, 1933–1934
 - spandrel beams, 1929–1930
 - unprotected elements, 1928
- heat transfer/temperature profiles
 - thermally protected, 1917
 - unprotected, 1920, 1928
- methods of protection
 - board products, 1914–1915
 - concrete encasement, 1916–1917
 - concrete filling, 1917
 - flame shields, 1917
 - heat sinks, 1917–1919
 - insulation, 1914–1917
 - membrane, 1917
 - spray-applied materials, 1915–1916
- structural analyses
 - critical load, 1938
 - critical temperature, 1938
 - deflection, 1938
 - in tension, 1925
 - thermal degradation at high temperatures, 1876–1877

Steel structures

- temperature in fire-exposed
 - calculation example, 1112–1117
 - insulated steel, 1112–1114
 - shadow effects, 1118
 - unprotected, 1118

Stefan-Boltzmann constant, 646, 806, 1171, 2645, 2916, 3313, 3400

Steric hindrance, 333

Stochastic models of fire growth

- basic features
 - general model, 1030
 - probability distributions, 2834, 2895, 3012
 - spread to another object, 1030
- Markov model
 - Markov process, 2901
 - mathematical representation, 2907

Stochastic models of fire growth (*cont.*)

- state transition model, 2901–2903
- networks
- other models
 - fuel-state model, 1026
- stochastic differential equation
 - deterministic model, 1024, 1025
 - simulation/illustration, 1027, 1030
 - stochastic model, 2978

Stochastic process, 210, 2834, 2891, 2893, 2895, 2901, 3031, 3122, 3129

Stoichiometric mass fuel-to-air ratio, 490

Stoichiometry, 140–141, 160, 336, 347, 365, 513, 517, 522, 542, 912, 984, 1001, 1010–1011, 1078, 1182, 2647, 3437–3439

Storage units, heat release rates, 816

Stored commodities, FMRC classifications, 836–846

Strathclyde study (U.K.), 2214

Stream function, 68, 73, 2645

Streamline, fluid flow, 4, 21, 22, 81, 83, 865, 987, 1050, 1383, 1386

Streamtube, fluid flow, 4

Strength, 17, 170–172, 180, 189, 226, 231, 244, 255, 258, 259, 261, 264–270, 274, 275, 281–283, 289–291, 293–299, 301–307, 309–312, 315, 469, 596, 664–669, 674, 683–685, 966, 1102, 1121, 1127, 1162, 1272, 1371, 1438, 1498, 1506, 1548, 1567, 1612, 1636, 1662, 1663, 1863–1865, 1872–1876, 1878, 1879, 1884, 1885, 1889, 1890, 1892, 1897, 1899, 1904, 1906, 1911–1914, 1938, 1949–1964, 1966–1973, 1975, 1976, 1984, 1994–2003, 2005, 2092–2094, 2419, 2442, 2537, 2649, 2664, 2692, 2699, 2700, 2744, 2745, 2754, 2758, 2759, 2774, 2781, 2785, 2787, 2793, 2820, 2829, 2877, 2887–2889, 2994, 2996, 3003, 3011, 3049, 3193, 3252, 3257, 3291, 3386, 3398

Stress, 1, 2, 6–14, 17, 19, 54, 55, 58, 60, 61, 82, 86, 89, 171, 189, 190, 257–258, 264–266, 268, 269, 274, 281–283, 291–293, 296, 299, 310, 311, 719, 1036, 1037, 1063, 1379, 1380, 1385, 1418, 1442, 1499, 1654, 1656, 1864, 1876–1880, 1891, 1892, 1897, 1902, 1909, 1910, 1914,

Stress (*cont.*)

- 1938–1943, 1961, 1967, 1970, 1972, 1998, 1999, 2073, 2078, 2097, 2098, 2100–2101, 2106, 2108, 2254, 2505, 2707, 2806, 2844, 2876, 2877, 2887–2890, 2895, 2910, 2915–2918, 2921, 2925, 2932, 2957, 3002, 3192, 3257, 3271, 3398

Stress-strain diagrams

- fiber-reinforced polymers (FRP), 309–314
- steel, 291–296

Structural analysis and fire resistance

- building assemblies and frames, 1871–1874
- catenary action of composite floors, 1872–1873
- connection moment-rotation behavior, 1873
- floor slab effects, 1872
- local/member/frame instability, 1872
- material strength limit states, 1874
- nonuniform heating, 1873
- thermal strains, 1872
- thermophysical properties of fire protection materials, 1871

Structural Design for Fire Safety (Buchanan), 1950, 1974

Structural Fire Protection (Lie, ed.), 291, 293, 309, 1061, 1258, 1616, 1737, 1875, 1943, 2022, 2037, 2038, 2041, 2960, 3318

Structural mechanics

- control parameters, 258
- design process, 256
- engineering models, 261
- failure modes
 - compression members, 265–267
 - flexural, 264, 268–270
 - flexural members, 268–270
 - statically indeterminate beams, 262, 264, 272
 - tension members, 264–265
- fire conditions and, 260–261
- internal forces, statical analysis, 262–263
- loading conditions, 256–257
- reactions, statical analysis for, 261–262

Structural members

- fire resistance, 277
 - load-bearing/non-load-bearing, 277
- Structures, predicting temperatures in fire-exposed**
- concrete structures
 - fire-insulated, 1126–1127
 - one-dimensional calculations, 1124–1126

- Structures, predicting temperatures in fire-exposed** (*cont.*)
 penetration depth in semi-infinite structures, 1122–1124
 finite element calculations
 basic equations, 1109–1111
 computer codes/accuracy, 1111–1112
 heat transfer in fire resistance furnaces
 ASTM E119, 1128–1129
 ISO 834 and EN1363-1, 1127–1128
 heat transfer to structures
 adiabatic surface temperature, 1104
 calculation using plate thermometers, 105–1107
 convection, 1104
 radiation, 1103–1104
 total heat transfer, 1104
 modeling of conduction in materials
 measurement of thermal properties, 1108
 solid materials, 1107–1108
 steel structures
 calculation example, 1112–1121
 insulated steel structures, 1112–1114
 shadow effects, 1118
 thermal properties of steel, 1112
 unprotected, 1112
 timber structures, 1127
- Student's *t* distribution**, 2839, 2864
- Styrenics**, 116, 168, 169, 176, 198, 214, 535, 559, 688, 809, 1215, 2233, 2255, 3444, 3461, 3466, 3473
- Subcritical behavior**, 604, 605
- Subjectivity, decision analysis**, 2823, 3048, 3049
- Sublimation**, 85, 555, 1537, 1566, 1914
- Submerged surfaces, forces on**, 429
- SUPER-TEMPCALC program**, 1934, 1935
- Suppression**. *See* Aqueous film-forming foam (AFFF); Clean agent halon replacements; Fire protection mechanisms; Foam entries; Halocarbon extinguishing agents; Halogenated entries; Halon entries; Inert gas extinguishing agents; Sprinkler entries; Water; Water mist fire suppression systems
- Surface flame spread**
 flame spread process, 705–706
 opposed-flow
 mechanism, 714–717
 modeling, 717
- Surface flame spread** (*cont.*)
 over liquids, 719–721
 properties of materials, 711, 712
 research background, 706–707
 urban areas, 717
 wildland fires, 717–719
 wind-aided
 beneath a ceiling, 713–714
 upward turbulent wall flame, 708–713
- Surface tension**, 572, 719, 720, 1299, 1647–1649, 1655–1659, 1663, 1666, 1697, 1700, 2553–2556, 2559, 2667, 2668, 3428
- Survival function, random variables**, 2832
- Sustained burning**, 199, 231, 236, 555, 568, 662, 831
- Synthetic rubber**. *See* Polyisoprene
- System analysis**
 hardware/complex systems, 2877
 use of fault tree model, 2928, 2929
- Systematic sample**, 2871
- T**
- Tag tester, flashpoint measurement**, 561, 565
- Tanks**
 fire modeling, 1175
 floating roof perimeter seal, 1725
 flow of water under pressure from, 1423
 foam system protection
 fixed roof, 1710, 1712, 1716, 1725, 1726
 floating roof, 1718, 1725, 1726, 1728
- TASEF computer program**, 1111, 1112
- TASEF-2 computer program**, 1934–1936, 1957
- Television sets, heat release rates**, 869–870
- Terrestrial boundary layer, wind velocity**, 596
- 4910 Test Protocol**, 1162
- t*² fires**, 443, 1272, 1327, 1829–1834, 2242, 2243, 2571
- TGA**. *See* Thermogravimetric analysis (TGA)
- Thermal conductivity**
 brick, 288, 305, 306
 building materials, 287–288
 changes in, 288
 concrete, 29, 284, 287–288, 291, 296, 299, 1923
- Thermal conductivity** (*cont.*)
 gypsum wallboard, 1920, 1921
 insulation, 1932
 wood, 28, 309, 1994, 2003
- Thermal decomposition of polymers**
 chain scission mechanisms, 197–199, 247
 charring, 223, 224, 228, 240
 chemical processes, 181, 200, 247
 cross-linking mechanisms, 172, 182
 decomposition defined, 167
 degradation distinguished, 167, 210, 215
 effect of additives, 231–232
 fire performance, implications for, 234, 239
 glass transition temperatures, 179, 311
 interaction of chemical/physical processes, 178, 183
 kinetics of, 172, 199, 203
 melting temperatures, 179, 180
 physical changes during, 138
 physical processes, 167, 178, 183, 187
 side chain cyclization mechanism, 172, 197
 side chain elimination mechanism, 172, 197
 testing, 234, 236
- Thermal diffusivity, building materials**, 284, 288
- Thermal expansion**
 compressibility and, 1407
 concrete, 1976
 steel, 274
- Thermal radiation**
 calculation methods, 2600–2601
 combustion product properties and gases, 126–128
 gas-soot mixtures, 129–130
 soot, 128–129
 compartment fire modeling and, 981–993
 contribution of soot particles, 128–130, 133
 equation of transfer, 123
 flame heat flux, 1181, 1225, 2629
 fuel pyrolysis rate
 boundary layer combustion, 1208
 pool fires, 2604, 2622, 2658
 heat transfer to structures, 1102–1103
 ignition applications, 2729
 intensity and flux, 106–107
 nonparticipating medium, energy exchange in, 107, 134
 gray diffuse surfaces, 122–123
 resistance network method, 135
 one-dimensional analysis, 1383

Thermal radiation (*cont.*)

- participating media
 - mean absorption coefficient, 124–125, 128–130, 134
 - mean beam length, 125–126
 - spectral emissivity/absorptivity, 123–124
 - total emissivity, 110, 126, 127
- role in fires, 53
- smoke layer heat flux, 115, 116, 133–135

Thermal response parameter

- (TRP), 1149–1154, 1159–1162, 1167, 1216, 1217, 1225, 3451, 3456, 3458

Thermal runaway, 374, 588, 605, 606, 615–616, 621**Thermal volatilization analysis** (TVA), 194**Thermochemistry**

- calculation of adiabatic flame temperatures, 147–150
- enthalpy, 139–140
- heat release rates, equivalence ratio and compartment fires, 146
- heat release rates in fires, 145–146
- heats of combustion, measurement of, 141–144
- heats of formation, 144–145
- internal energy of a closed system, 138–139
- specific heat, 140

Thermodynamics, first law of, 7, 25, 26, 30, 62, 138, 142, 144, 908**Thermogravimetric analysis**

- (TGA), 183–186, 188, 191, 192, 196, 203, 210, 221, 246, 635–637, 1175

Thermomechanical analysis (TMA), 189**Thermophysical properties**, 95, 187, 358, 964–966, 1028–1030, 1505, 1871, 1950–1956, 1994**Thermoplastics**

- decomposition, 170
- deformability, 171
- glass transition temperature, 179

Thermosets

- decomposition, 170, 181
- glass transition temperature, 171, 179

Timber members

- bending strength, 1984, 1999
- charring, 1985
 - rate, 1984–1988, 1991, 1992, 1994, 1997–1999, 2002
- in compression, 1998, 1999, 2002
- connections, 2000
- direct protection, 1984

Timber members (*cont.*)

- fire resistance determination by
 - analytical methods, 1979–2005
 - component additive method, 1981–1983
 - composite models, 2001–2002
 - contribution of protective membrane, 1980–1981
- decks, 1999–2000
- effect of fire-retardants/adhesives, 1988
- Hadvig's equations, 1988–1992
- influence of char layer, 1983
- load-carrying capacity of uncharred wood, 1994–1996
- National Design Specification® for Wood Construction* (NOS®) method, 1979
- nonstandard fire exposures, 1988
- onset of char method, 1983
- property data, 2002–2005
- reduced cross-section area models, 1997–1998
- reduced properties models, 1996–1997
- theoretical models, 1992–1994
- T.T. Lie method, 1979
- fire resistance ratings, 1979–1982, 1988, 1999
- heat transfer/temperature profiles, 1983
- high-temperature thermal degradation, 1985
- membrane protection
 - asymmetrical wall assemblies, 1982
 - fasteners/spacing, 1981
 - models for light-frame construction, 1983
 - strength and grain direction, 1988
 - in tension, 1996, 1998, 1999, 2001

Timber structures

- shrinking/cracking, 189
- temperature in fire-exposed, 1127

TMA. *See* Thermomechanical analysis (TMA)**Toluene, spill/fire calculations**, 496, 2622**Toxicity**

- clean agent halon replacements, 1483
- combustion product atmospheres, 2225, 2232, 2266, 2390–2391
- Haber's rule, 2216
- halogenated agents, 1458
- major determinants of, 2287
- water mist additives, 1601

Toxicity assessment

- asphyxiants
 - predicting time to incapacitation, 2353, 2361, 2371, 2387
 - tenability limits, 2342–2345
 - tenability limits/hazard calculations, 2231, 2257, 2258, 2263, 2303, 2338, 2342, 2382
- asphyxiants, 2215, 2220, 2221, 2223–2226, 2228, 2230, 2231, 2232
- CO/CO₂ ratio, 595
- Ct product dose, 2231, 2232, 2234, 2247, 2265, 2332, 2416
- carbon monoxide, 2232, 2332, 2416
- dose/response relationships, concentration inhaled/duration of exposure/toxicity, 2216, 2269, 2329, 2949
- example, 2211, 2212, 2215, 2224, 2331, 2332
- foam agents, 1701
- fractional effective dose (FED), 1818, 2035, 2212, 2230–2231, 2324–2325, 2332–2333
- fractional incapacitating dose (FID), 194, 2247, 2300, 2332, 2355, 2373, 2374, 2383, 2384, 2386, 2405, 2417, 2419
- carbon monoxide, 2355, 2373
- fractional irritant concentration (FIC), 2231, 2261
- fractional lethal dose (FLD), 2232, 2247, 2332, 2388, 2416
- full-scale fire requirements, 2208, 2209, 2240–2244
- glossary of terms, 1743, 2298
- importance, 486
- incapacitating effects, 2214, 2218, 2249, 2269, 2308, 2345, 2367, 2378, 2405 (*see also* Incapacitation, from toxic effects)
- interactions between toxic gases, 2218, 2368, 2371
- irritants
 - animal models/extrapolation to humans, 2250
 - components of thermal decomposition atmospheres, 2255
 - concerns sensory, 2233, 2250, 2258, 2298, 2299, 2386
 - dense smoke as, 2218, 2250, 2294, 2317, 2320, 2327–2329
 - effects of concentration levels, 2222

- Toxicity assessment** (*cont.*)
- lung inflammatory reactions, 2254
 - predicting incapacitation, 2356
 - respiratory rate depression test, 2251
 - sensory/pulmonary, 2233, 2249, 2252, 2254, 2300, 2386
 - tenability limits, 2303, 2342–2345, 2386, 2387, 2413
 - materials-/combustion product-based approaches, 2211–2212
 - phases of fire effects on occupants, 2213–2215
 - models
 - effects of fire effluent/heat, 2224, 2230, 2285, 2411
 - FED methodology, 2335, 2414
 - and fractional effective concentration (FEC) smoke, 2322
 - smoke, 1345, 1769
 - tenability/hazard calculations for exposure to heat/burns, 2417–2419
 - nominal atmosphere concentration (NAC), 2217, 2235, 2253, 2258, 2260, 2296, 2298, 2302, 2386
 - nonflaming decomposition, 2217, 2256, 2267, 2274, 2342
 - postflashover conditions, 2246, 2294–2296
 - respiratory minute volume (RMV), 2253, 2300, 2302, 2330, 2331, 2350, 2357, 2365–2367, 2420
 - small-scale tests
 - adaptation of data, 2295
 - applications of data, 2266
 - conduct and application, 2296–2298
 - cone calorimeter, 2289
 - criteria for methods, 2268
 - development of FED expressions, 2266–2267
 - DIN test, 2270, 2290, 2294, 2295
 - measurement of toxic gas yield data, 2267
 - misuse of test data, 2242, 2257, 2270, 2283, 2284, 2296, 2568
 - NBS test, 2270, 2271, 2287
 - NIST radiant method, 2275
 - practical methods, 2269, 2332
 - product specification, 2207, 2209, 2210, 2266, 2267
 - second-generation test methods, 2242, 2274
 - toxic potencies in small-/full-scale tests, 2283–2287
 - tube furnace method, 2226, 2233, 2242, 2267, 2275, 2289, 2294
 - and type of fire, 2250, 2257, 2295
 - UPITT test, 2270
- Toxicity assessment** (*cont.*)
- susceptibility variations and, 2333–2334
 - toxic potencies, 2208, 2210, 2225, 2232–2240, 2283
 - under differing fire conditions, 2235, 2237
 - mass loss method, 2232, 2233, 2235, 2236
 - use of product yield data, 2242–2244
 - well-ventilated flaming conditions, 2240, 2246, 2256, 2285, 2289–2291
- Transient corridor flows**, 992
- Transportation vehicles, fire risk assessment**. *See* Mass transportation
- Trash bags/containers, heat release rates**, 882–885
- Trusses**
- fire protection methods, 1925, 1927
 - fire resistance in steel, 1911–1912, 1915, 1919, 1924–1927
 - interstitial, 1924, 1925
 - load-transfer, 1919, 1924
 - staggered, 1925–1927
- Tube furnace method toxicity test**, 2226, 2242, 2268, 2294
- Tunnels**
- CFD model applications, 1044, 1046, 1057–1058
 - fire testing, 1619
 - rail, 1616, 1637, 2406, 3314
 - time-temperature test curves, 2771
 - ventilation to mitigate fire hazard, 1692
 - water mist fire suppression systems, 1616–1620
- Turbulence**
- convection heat transfer, 54, 80, 81, 84, 85, 89, 97
 - field models, 1609
 - fluid flow, 1049
 - modeling, 15–16, 1037
 - premixed flames, 389
- Turbulent scalar flux**, 1038, 1039
- TVA**. *See* Thermal volatilization analysis (TVA)
- U**
- UL 263, Fire Tests of Building Construction and Materials**, 1866
- UL 1058, Halogenated Agent Extinguishing System Units**, 1513, 1523
- UL 1709, Rapid Rise Fire Tests of Protection Materials for Structures**, 790
- UL 162, Standard for Foam Equipment and Liquid Concentrates**, 1660, 1661
- Ultimate strength, building materials**, 277–320
- steel, 291–296
- Unavailability**, 805, 2890, 2900, 2901, 2906, 2907, 2910, 2936, 3086, 3194, 3336
- Uncertainty**
- aleatory/epistemic, 3033
 - benefit-cost analysis and, 3146
 - computer simulation models and, 2120, 2144
 - decision analysis
 - analytical model, 3033
 - @ RISK model, 3032
 - defining, 211, 258
 - design process
 - barriers to achieving fire safety, 2036
 - switchover, 2956
 - design process and, 3038
 - difficulties with, 3001–3002
 - fire protection engineering
 - behavior variability, 2096–2097
 - and design process, 2998–3001
 - identifying, 2995–2998
 - life-cycle use/safety of buildings, 2998
 - providing for equity/incorporation of social values, 2998
 - scientific, 2095–2096
 - variability in risk perceptions/values, 2997–2998
 - heat release rate measurements, 943–945
 - propagation of, 934, 3027, 3035, 3037, 3041, 3238
 - sources of
 - indeterminacy, 2993, 2994
 - linguistic imprecision, 2993, 2994
 - randomness, 2993, 2994
 - variability, 2993–2994
- Uncertainty analysis**
- completeness uncertainty, 3035
 - decision making and analysis of uncertainty, 3029–3032
 - comparison of PRA results/acceptance criteria, 3029
 - definition of problem, 3023
 - developing fire risk models, 3029–3032
 - identifying sources of uncertainty, 3032–3034
 - input uncertainty, 3034

Uncertainty analysis (*cont.*)

- interpreting results of PRA, 3028
- propagation of uncertainty, 3035
- risk-based approach, 3028
- risk-informed approach, 3028
- role of PRA, 3028–3029
- decision making and, 3024–3025
- model uncertainty
 - differential/direct method, 3010
 - fire models, 1249
 - Monte Carlo sampling, 3010–3011
 - response surface replacement, 3010
 - sensitivity of output predictions/ input values, 3010
- parameter uncertainty, 3032, 3034
- performance-based design process application
 - develop distribution of design fire scenarios, 3016–3017
 - develop/evaluate candidate designs, 3018
 - judge acceptability of design, 3023
 - probabilistic statement of performance, 3015–3016
 - scope/goals/objectives, 3024
 - selection/documentation, 3023
 - steps, 3016–3020
- quantitative treatment of uncertainty
 - bounding, 3007–3008
 - comparative analysis, 3008
 - expert elicitation, 3008
 - importance analysis, 3008
 - in measurement, 3008
 - in parameters/assumptions/values, 3007–3008
 - parametric analysis, 3008
 - sensitivity analysis, 3008
 - switchover, 3008
- Underwriters Laboratories Inc. (UL)**, 1318, 1334, 1512. *See also* UL entries
- UN Globally Harmonized System (GHS)**, 571, 572
- Unimodal data**, 2855
- United States Federal Safety Standards for Liquefied Natural Gas Facilities (49 CFR, Part 193, 1980)**, 2657
- University of Greenwich Dreadnought Building*, 2091
- University of Pittsburgh (UPITT) toxicity test*, 2271–2273
- Unzipping, decomposition mechanism**, 197–198
- Upholstered furniture**
 - cigarette smoldering and, 2342
 - heat release rates, 3212, 3213

UPITT toxicity test. *See* University of Pittsburgh (UPITT) toxicity test

Upper flammability limits (UFL), 567, 570, 1207, 1208

Urban areas, flame spread, 2674

U.S. Coast Guard (USCG) marine regulations, 1561
Star Princess Safety Alert, 3390

USFA. *See* U.S. Fire Administration (USFA)

U.S. Fire Administration (USFA), 3076, 3079, 3084, 3095

V**Vapor clouds**

- dispersion, 2664, 2679, 2686, 2746, 2762
- explosions, 2664, 2666, 2673, 2679, 2687, 2691–2697, 2699–2701, 2745, 2756–2763
- modeling, 2679–2688
- sources, 2664–2673
- thermal radiation from burning flame geometry model, 2648
- flame propagation velocity, 2647–2650, 2652
- thermal radiation, 2647, 2650, 2652

Vapor, distinguished from gas, 85, 412, 491, 919, 1620, 2374, 2560, 2568

Vaporization

- calculation of vapor pressure, 558–562
- critical temperatures/pressures, 557, 651
- and ignition of liquids, 554–558
- phase diagrams, 555

Vapor pressure, 290, 304, 345, 531, 555–558, 562–566, 570, 576, 578, 1417, 1418, 1454, 1511, 1517, 1518, 1524, 1535–1537, 1548, 1575, 1606, 1648, 1649, 1666, 1702, 2421, 2560, 2654, 2655, 2669, 2670, 2673, 2795, 2800, 2811, 3428

Variation, coefficient of, 1133, 1139–1141, 1875, 2857

Vegetation. *See* Bushes, heat release rates; Christmas trees, heat release rates

Vehicle tunnels

- fire characteristics, 3309
- full scale experiments, 3303–3304
- passive fire protection, 3318–3319
- ventilation, 3303–3318, 3321, 3322
- water spray systems, 3316, 3319–3322

Vena contracta, 467, 1402–1404, 1407

Venn diagrams, 2828

Vent flames, 992

Vent flows

- accuracy of calculations, 472–474
- in buildings, 455, 457–459, 464, 466, 470, 474, 475, 477, 478, 480, 483, 484
- buoyancy and, 467, 469, 470
- fire spread to second room, 463
- large-volume spaces, 1824, 1831
- measuring in fire experiment
 - hot/cold layer method (Method 4), 462
 - locating bottom of outflow in vent method (Method 3), 462
 - plane of vent method (Method 1), 459–461
 - pressure difference at floor method (Method 2), 461–462
- nonbuoyant, 455–457, 463, 472, 474
- room pressure
 - computation of, 480–483
 - equation to control pressure at steady state, 477–480
 - general equation to control, 477–480
- temperature distributions, 465, 484
- through horizontal vents, 466–472
- through vertical vents, 457–459

Ventilation

- effect on halogenated agent application, 1469
- effect on species production, 502, 508
- forced
 - CFD application, 1054
 - compartment fire modeling and, 981–993
 - effect on smoke movement, 1055–1061
- heat release rates and, 800, 801, 803, 827–829, 848, 892
- smoke management and, 1824, 1826–1827, 1829, 1843, 1855, 1857
- in tunnels, 3303, 3309, 3314, 3316–3318

Ventilation-limited fires, 486

Vents

- defined, 461, 467
- roof, 474, 478
- series of, 442, 459, 478

Venturi flow meter, 1402

Video games, heat release rates, 890–896

Video image flame detection (VIFD), 1684

Virtual stresses. *See* Reynolds stresses

- Viscosity**, 1–2, 4, 7, 11, 12, 15–18, 54–56, 64, 65, 81, 100, 166, 169, 170, 177, 190, 241, 278, 351, 367, 416, 425, 438, 457, 484, 649, 689, 720, 721, 725, 742, 1037–1040, 1062, 1063, 1251, 1321, 1359, 1375, 1379, 1385–1387, 1391, 1393, 1401, 1422, 1506, 1536, 1537, 1539, 1574, 1647, 1650, 1654–1656, 1659, 1663, 1665, 1666, 1699, 1702, 1716, 2557, 2569, 2571, 2638, 2670, 2750, 3398, 3410, 3428
- Volumetric expansion effect, compartment fires**, 985
- Volunteer fire fighters, value of donated time**, 3108, 3109
- Vorticity, fluid flow**, 1379, 1382
free vortex, 13, 84, 399
- VTT CFD model**, 827, 828, 830, 832, 833, 859, 867, 868, 870–872, 882, 892, 894, 895, 934, 1035, 1589, 2160, 2444, 2476
- VULCAN computer program**, 1945
- Vulnerability**, 1237, 1249, 1865, 2038, 2054, 2822, 2923, 3087, 3103, 3152, 3185, 3190, 3197, 3198, 3203–3206, 3220, 3355, 3371
- W**
- Wake**, 84, 85, 530, 624, 626, 1370, 2031, 2039, 2040, 2054, 2175, 2176, 2395, 2809
- Walking speed, through irritant smoke**, 2249, 2340
- Wall/ceiling lining materials, heat release rates**, 890–892, 1028
- WALL2D computer program**, 1983
- Wall function**, 1044
- Walls**
conduction heat transfer through cavity-type, 990, 1935
conduction heat transfer through solid, 990, 1935
effect on plume, 399, 424, 1092
fire resistance
load-bearing, 1886–1889
separating function in fire conditions, 1885–1887
separating function in normal conditions, 1886
testing, 789, 1906, 1980
thermal gradient across thickness, 185, 272, 640, 657, 1039, 1175, 1873, 1880, 1885, 1888, 1889, 1891
heat transfer to, 789–791
reinforced concrete, 1968
- Wardrobes, heat release rates**, 892–894, 1272
- Warehouses, high-expansion foam system calculations**, 1729–1732, 1734, 1736, 1737
- Washing machines, heat release rates**, 894–895
- Water**
bacteriological growth in stored, 1602
drawbacks as extinguishing agent, 595
extinguishment mechanisms, 1592, 1604
heat of formation, 144, 145, 150, 287, 1182, 1374
large-scale extinguishment/suppression tests, 1610
properties, 1298, 1378, 3429
small-scale extinguishment tests, 548, 1494, 1680
- Water hammer**, 1407–1409, 1686
- Water mist fire suppression systems**
acceptance testing, 1634–1636
development, 1589, 1603, 1609, 1611–1615, 1625, 1636
engineering details
application systems, 1615, 1621, 1622
methods of spray, 1624–1626
pressure regimes, 1626–1628
extinguishment/suppression mechanisms
enclosure effects/turbulent mixing/cycling, 1593–1594
explosion hazard mitigation, 1594–1597
gas phase cooling, 1590–1593, 1604, 1621
kinetic effects, 1590, 1592–1593
oxygen depletion and flammable vapor dilution, 1590, 1592
radiation attenuation, 1590, 1592
wetting/cooling of fuel surface, 1592
fire suppression modeling, field models (CFD models), 1608–1611
quasi-steady-state zone models, 1605–1607
transient zone models, 1607–1608
zone models, 1605–1609, 1612
fundamentals, 1590–1605
required extinguishing medium portion (REMP) parameter, 1591
spray characteristics
additives and health concerns, 1601
discharge rate, 1598, 1607, 1608, 1610, 1622
- Water mist fire suppression systems (cont.)**
drop size distribution, 1587, 1596–1601, 1604, 1609, 1625
measurement of drop size distributions, 1598–1599
spray cone angle, 1598, 1601
spray momentum, 1597, 1598
spray velocity, 1598–1601
spray heat absorption ratio, 1590
testing importance
development of fire test protocols, 1589, 1613–1615, 1618
protocols for tunnels, 1611, 1615–1622, 1637
types
high-pressure systems, 1626, 1627
local application systems, 1615, 1621, 1622
low-/intermediate-pressure systems, 1626, 1628
mist generation by flashing of superheated water, 1625
pre-engineered/engineered systems, 1623, 1624, 1627
total compartment application systems, 1620, 1621
twin-fluid/single-fluid nozzles, 1620, 1624, 1626, 1634, 1635
zoned application systems, 1620, 1622
water mist defined, 1595
- Water Mist Fire Suppression Systems Health Hazard Evaluation (Halon Alternatives Research Corp.)**, 1601
- Water vapor**
heat of formation, 144–145
specific heat, 2, 140
- Weber-Fechner's law**, 24
- Weibull distribution**, 2839, 2843–2844, 2846, 2854, 2873, 2881, 2882, 2886, 2895, 2896, 2898, 2912–2914, 2917, 2938
reliability analysis and, 2846, 2885, 2891
- Wet pipe sprinkler system**, 1687, 1748, 2890
- Wien's displacement law**, 104, 115, 920
- Wildland fires**
fire behavior, 3283, 3284, 3286–3294, 3296–3299
firebrands, 3285, 3291, 3298
fire impact, 3298, 3299
models, 3284, 3286, 3292–3296

Wind

buildings and, 23–24
 characteristics, 22–23
 effect on flame height, 422, 707–722
 effect on vapor cloud propagation, 2647
 effects generally, 18, 396, 987, 991, 1797, 1804, 1810, 1811, 1817, 1842, 1845, 1848, 2594, 3243, 3245, 3289, 3296
 effects on smoke movement, 1059, 1789, 1791, 1792
 flame trailing, 422
 and spill/pool fire size, 1847
 terrestrial boundary layer, 18, 22, 23, 2674

Windows

heat flux from, 812, 821, 848, 864, 892
 heat release rates of plastic, 895

Wisconsin Administrative Code, 3172

Wood

air required for complete combustion, 1182
 charring, 265, 290, 309, 639, 1137, 1983–1985
 coefficient of linear thermal expansion, 284, 307, 320
 components, 1988, 1997, 2000
 compressive strength, 307, 1874
 density, oven-dry, 2002
 dilatometric/thermogravimetric curves, 284, 285, 302, 305, 307, 308, 315, 316

Wood (cont.)

grain factor, 28, 290, 309, 1987
 heat of combustion, 1993
 members (*see* Timber members)
 modulus of elasticity, 264, 274, 307, 309
 properties, 1994, 2002
 specific heat, 1994
 structures (*see* Timber structures)
 tensile strength, 265, 282, 290, 307, 310, 2001
 thermal conductivity, 1994, 2003

Wood Handbook: Wood as an Engineering Material (Forest Products Soc.), 2002

Wool

heat of combustion, 143
 thermal decomposition, 167, 173, 174, 217, 227, 228, 240

Workstations, office, heat release

rates. *See* Office workstations, heat release rates

World Fire Statistics Centre

(WFSC), comparative data, 3098, 3099

World Trade Center bombing

(1993), 2024, 2040, 2099

World Trade Center fire (1975), 2216**World Trade Center terrorist attack**

(2001), 1874, 2054, 2073

WPI/FIRE zone fire model, 987,

1058, 1454, 1464, 1744, 1750, 1788, 1869, 2968, 3167, 3168, 3339, 3356

Y

Yates continuity correction, 2867

Yield strength, building

materials, 281, 282, 293, 295, 312
 steel, 265, 293, 295, 1892, 1961

Z

Zener-Hollomon parameter, 283, 320

Zone models

application, 1030–1032
 compartment fires, 1029
 smoke filling (*see* Compartment fires, modeling smoke filling)
 forced ventilation, 1030
 overview, 1026–1032
 pyrolysis/combustion products, 1026, 2036
 selection, 1030–1031
 smoke management in large-volume spaces, 1099, 1824
 submodels, 1026–1030
 upper/lower layers, 1025, 1026, 1028, 1029
 validation, 1030–1032
 vent flows, 447, 464, 483, 1026, 1069

Zone smoke control, 1750