<table>
<thead>
<tr>
<th>Subject</th>
<th>Page Numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accelerated Degradation Testing (ADT)</td>
<td>368, 369, 415, 421</td>
</tr>
<tr>
<td>Acceleration factor</td>
<td>86, 374, 376,</td>
</tr>
<tr>
<td>Accelerated failure data models</td>
<td></td>
</tr>
<tr>
<td>degradation models</td>
<td>416, 419, 420</td>
</tr>
<tr>
<td>physics-experimental-based</td>
<td>372, 373, 412, 430</td>
</tr>
<tr>
<td>physics-statistics-based</td>
<td>372, 373, 404, 430</td>
</tr>
<tr>
<td>statistic-based nonparametric</td>
<td>276, 372, 373, 375, 386, 387, 389, 395, 396, 397, 398, 399</td>
</tr>
<tr>
<td>statistic-based parametric</td>
<td>375, 378, 380, 381</td>
</tr>
<tr>
<td>Accelerated failure time (AFT)</td>
<td>368, 369, 372, 373, 374, 400</td>
</tr>
<tr>
<td>Accelerated life testing (ALT)</td>
<td>plans, 276, 365, 368</td>
</tr>
<tr>
<td>use of, 368, 372</td>
<td></td>
</tr>
<tr>
<td>Accelerated Light Fading Test (ALFT)</td>
<td>435</td>
</tr>
<tr>
<td>Achieved availability</td>
<td>202</td>
</tr>
<tr>
<td>Acoustic emission (AE)</td>
<td>530, 539</td>
</tr>
<tr>
<td>Activation energy</td>
<td>384, 385, 392, 404, 405, 408, 412, 413, 414, 429, 430, 438</td>
</tr>
<tr>
<td>Active redundancy</td>
<td>138, 139, 140, 141, 181, 182, 213, 661</td>
</tr>
<tr>
<td>Additive hazards models (AHM)</td>
<td>395</td>
</tr>
<tr>
<td>Aeronautical earth station (AES)</td>
<td>640, 642, 643, 644, 645, 647, 648</td>
</tr>
<tr>
<td>Air route traffic control center (ARTCC)</td>
<td>641, 643, 646, 647, 648</td>
</tr>
<tr>
<td>Air traffic services (ATS)</td>
<td>640, 644</td>
</tr>
<tr>
<td>Alternating renewal process</td>
<td>187, 199, 465, 490, 664</td>
</tr>
<tr>
<td>Arrhenius model</td>
<td>373, 404, 406, 411, 421, 430</td>
</tr>
<tr>
<td>Asymptotic relative efficiency (ARE)</td>
<td>234</td>
</tr>
<tr>
<td>AT&amp;T</td>
<td>2, 232, 523, 532, 548</td>
</tr>
<tr>
<td>AT&amp;T Reliability Manual</td>
<td>273, 361, 362, 548</td>
</tr>
<tr>
<td>Atomic absorption</td>
<td>541, 549</td>
</tr>
<tr>
<td>Automatic dependent surveillance function</td>
<td>(ADSF), 640, 641, 642</td>
</tr>
<tr>
<td>Availability achieved</td>
<td>202</td>
</tr>
<tr>
<td>analysis and renewals</td>
<td>446, 452</td>
</tr>
<tr>
<td>average uptime</td>
<td>607, 609, 614</td>
</tr>
<tr>
<td>design objective</td>
<td>648, 649</td>
</tr>
<tr>
<td>importance of</td>
<td>198</td>
</tr>
<tr>
<td>inherent, 198, 202</td>
<td></td>
</tr>
<tr>
<td>instantaneous (point), 198, 199, 218, 220, 221, 228, 229, 232, 614, 649</td>
<td></td>
</tr>
<tr>
<td>mission-oriented</td>
<td>198</td>
</tr>
<tr>
<td>number of spares</td>
<td>517, 518, 519, 520, 521, 522, 523, 544</td>
</tr>
<tr>
<td>operational, 198, 203</td>
<td></td>
</tr>
<tr>
<td>pointwise, 190</td>
<td></td>
</tr>
<tr>
<td>repairable systems</td>
<td>187, 273</td>
</tr>
<tr>
<td>service performance</td>
<td>648, 649, 652</td>
</tr>
<tr>
<td>steady-state, 189, 198, 201, 202, 225, 447, 448, 490, 522, 549, 650</td>
<td></td>
</tr>
<tr>
<td>time-interval vs. downtime</td>
<td>198</td>
</tr>
<tr>
<td>work-mission, 205, 206</td>
<td></td>
</tr>
<tr>
<td>Average uptime availability</td>
<td>607, 609, 614</td>
</tr>
<tr>
<td>Bartlett’s test</td>
<td>279, 377, 625</td>
</tr>
<tr>
<td>Barlow–Proschan importance</td>
<td>149</td>
</tr>
<tr>
<td>Bathtub-shaped failure rate curve</td>
<td>15, 16, 17, 23, 42, 63, 64, 77, 84, 85, 86, 633</td>
</tr>
<tr>
<td>Bayesian approach</td>
<td>86, 234, 261, 262, 265, 271, 272, 314, 362</td>
</tr>
<tr>
<td>Bell Communications Research Reliability Manual</td>
<td>273, 274, 361</td>
</tr>
<tr>
<td>Bellcore Special Report</td>
<td>651, 656, 658, 663</td>
</tr>
<tr>
<td>Bellcore Technical Requirements</td>
<td>663</td>
</tr>
<tr>
<td>Bernard’s median rank estimator</td>
<td>12, 85</td>
</tr>
<tr>
<td>Best linear unbiased estimator (BLUE)</td>
<td>276, 297</td>
</tr>
<tr>
<td>coefficients, 302</td>
<td></td>
</tr>
<tr>
<td>for Rayleigh parameters</td>
<td>297</td>
</tr>
<tr>
<td>Beta model hazard function</td>
<td>41</td>
</tr>
<tr>
<td>Binomial distribution</td>
<td>65</td>
</tr>
<tr>
<td>likelihood function</td>
<td>241</td>
</tr>
<tr>
<td>Birnbaum importance</td>
<td>142, 143, 144, 145, 146, 148, 153, 160</td>
</tr>
</tbody>
</table>
Birnbaum–Saunders (BS) distribution, 230, 267, 272, 341, 342, 343, 362, 363, 425
Bivariate distribution, 56, 57, 58, 169, 589, 601, 602
Block replacement policy, 498, 542, 549
BLUE. See Best linear unbiased estimator
Boltzmann’s constant, 384, 404, 406, 408, 413, 414
Boolean truth table method, 124, 125, 126
Bottom-up heuristic (BUH), 101, 102, 103
Brownian motion, 42, 362, 420, 421
Burn-in test, 64, 237, 275, 317, 367, 368
testing, 275
CCITT (International Telegraph and Telephone Consultative Committee), 657, 664
Censoring
Type 1, 277, 278, 289, 307, 319, 340, 346, 423
Type 2, 277, 278, 281, 292, 307, 319, 329, 334, 340, 343, 346, 423
random, 277, 346
Challenger, 2
Check-weigher example, 256
Coefficient(s)
of best estimates of mean and standard deviation, 48
of correlation, 258
of determination, 258, 259
kurtosis, 50
skewness, 50
Cold standby, 138, 213, 218, 221, 222, 608
Collision-avoidance system for robot manipulators example, 112
Columbia, 2
Combination model, 411, 431, 438
Communications cables, example, 480
Communication management unit, 642, 644
Competing risk model, 59, 60, 86, 486, 493, 494
Complementary metal-oxide-silicon (CMOS) examples, 231, 232, 377, 410, 439
Complex reliability systems, 117
Boolean truth table method, 124
decomposition method, 118
event-space method, 123
factoring algorithm, 128
path-tracing method, 127
reduction method, 126
tie-set and cut-set methods, 121
Components
configuration, 100
doubling, 140
keystone, 118
optimal assignment in consecutive-2-out-of-n: F systems, 111
Components, methods for measuring importance of, 142
Barlow–Proschan importance, 149
Birnbaum’s importance measure, 142
criticality importance, 145
Fussell–Vesely importance, 148
upgrading function, 150
Compound events, 212
Computer tomography, example, 88
Condition-based maintenance, 154, 187, 420, 496, 535
Confidence coefficient, 239, 240
Confidence intervals, 239, 240, 262, 266, 287, 290, 292, 293
for censored observations, 301
Gamma distribution parameters and, 327
for noncensored observations, 300
renewal process and, 478
Weibull distribution parameters and, 327, 328
Consecutive-k-out-of-n: F systems, 104, 105
components in consecutive-2-out-of-n: F, 111
computer program for calculating, 674
consecutive-2-out-of-4: F systems, 106
consecutive-2-out-of-n: F systems, 105
consecutive-2-out-of-7: F systems, 107
generalization of, 106
optimal arrangement of components in consecutive-2-out-of-n: F, 111
reliability estimation, 108
Consistent estimator, 233
Constant failure rate examples, 18
Constant hazard function description of, 17
mean time to failure for, 17
mean time to failure in k-out-of-n systems, 183
mean time to failure in parallel systems with, 180
mean time to failure in series systems with, 179
Constant interval replacement policy (CIRP), 498
Continuous probability distribution, likelihood function for, 247, 248
Continuous time nonparametric renewal function estimation, 455
parametric renewal function estimation, 441
Convolution, 187
Corrosion, monitoring, 541
Cost minimization, 497
Covariates, 373, 387, 390, 395, 396, 397, 400, 401
Crane spreader subsystem, case study, 603
Creep fatigue, 414
Criticality importance, 145
Cumulative distribution function for gamma model hazard function, 35, 36
for normal model hazard function, 29
Cumulative downtime distribution, 649
Cumulative-hazard estimator (CHE), 347
Cumulative hazard function, 15
Cut-set method, 121
Cutters, example of end mill, 290
Debugging region, 16
Decomposition method, 99, 128, 163
Decreasing failure rates (DFR), 16, 61, 62, 63, 77, 82, 83, 84, 231
Degradation models
  hot-carrier, 419, 438, 439
  laser, 418
  resistor, 416
Degradation path, 420, 421, 536, 537
Delayed renewal process, 469
Dependent failure estimates
  compound events, 207, 212
  joint density function, 56, 207, 209, 212
  Markov model, 194, 196, 207, 212, 653, 655, 656
Detection system, case study of explosive, 617, 618, 619, 621, 622, 623
Digital signal processors (DSPs), 617, 619
Diodes, examples using, 82, 86, 132, 158, 161, 228, 269, 304, 460
Directed networks, 117
Discrete time
  nonparametric renewal function estimation, 460
  parametric renewal function estimation, 452
  probability distributions, 64, 65
Downtime availability, time-interval vs., 198, 202, 203, 446
Downtime minimization, 506, 507
Dry bearings example, 348
Dynamic random access memory (DRAM) device, example, 388
Early failure region, 16, 17
Efficient estimator, 233
Electrical-discharge machining (EDM), example, 218, 219
Electrical resistance, measuring, 143
Electromigration
  examples, 54, 371, 381
  model, 412, 413, 417, 422, 432, 436
Equilibrium renewal process, 469, 470, 472, 473, 474, 476, 478
Erlang distribution, 36, 39, 224, 269, 357, 359, 473, 476, 484, 487, 489, 519, 580, 581, 600
Erlang loss formula, 522
Estimators
  consistent, 233
  efficient, 233
  point, 234, 239, 240
  sufficient, 234
Event-space method, 123, 124
Expected number of failures
  alternating, 465
  continuous time (nonparametric), 455
  continuous time (parametric), 441
discrete time (nonparametric), 460
discrete time (parametric), 452
Explosive detection system, case study, 617
Exponential distribution,
  acceleration model, 375
  Bartlett’s test, 279
  impact of Type 1 censoring on, 277
  impact of Type 2 censoring on, 277
  long failure times, testing for, 284
  maximum likelihood method for estimating, 234, 241, 247
  method of moments in estimating, 234
  parameter estimation, 234
  short failure times, testing for, 282
Extended hazards regression, 400, 437
Extended linear hazards regression
  model, (ELHR) 400
Extreme value distribution, 28
  with censoring, 329
Eyring model, 406
Factoring algorithm, 128
Failures
  abnormally long failure time, 234, 284
  abnormally short failure time, 282
Failure-dependent reliability, 170, 172
Failure rate(s)
  instantaneous, 5, 15
  mixture of, 59, 489
Failure time data, generation of, 265
Failure-time distributions, estimating parameters, 233
  least squares method, 256
  likelihood method, 241
  method of moments, 234
Fatigue failures model, 414
Fatigue limit, estimating, 23
Fisher information matrix, 254, 255, 269, 424
Fluid monitoring, 540
Fracking, 659
Freak failures, 282
F-ratio test, 283
Frechet distribution, 45, 46, 47, 48, 85, 338, 339, 340, 362
Fubini’s Theorem, 514
Full rebate policy, 564, 565, 567, 568, 569, 599, 600
Fundamental renewal equation, 442
Furnace tubes reliability, case study, 623
Fussell-Vesely importance, 148, 149
Gamma density, 36, 321, 358, 483, 484
Gamma distribution
  confidence intervals and, 327, 347
  method of moments in estimating, 234, 236
  parameter estimation, 322
  variance and, 326
  with censoring, 324
  without censoring, 321
Gamma function, table, 667
<table>
<thead>
<tr>
<th>Subject</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gamma model hazard function</td>
<td>36</td>
</tr>
<tr>
<td>Gas distribution system example</td>
<td>129</td>
</tr>
<tr>
<td>General hazard failure rate</td>
<td>77</td>
</tr>
<tr>
<td>Generalized Pareto model</td>
<td>54</td>
</tr>
<tr>
<td>Generator regulator example</td>
<td>211</td>
</tr>
<tr>
<td>Geometric distribution</td>
<td>66</td>
</tr>
<tr>
<td>Gold–aluminum bonds example</td>
<td>379</td>
</tr>
<tr>
<td>Gompertz distribution</td>
<td>28</td>
</tr>
<tr>
<td>Gompertz-Makeham model</td>
<td>54</td>
</tr>
<tr>
<td>Good-as-new repair policy</td>
<td>579, 580, 581, 582, 583, 584, 599</td>
</tr>
<tr>
<td>Government-Industry Data Exchange Program (GIDEP)</td>
<td>273</td>
</tr>
<tr>
<td>Gradient of likelihood method</td>
<td>253</td>
</tr>
<tr>
<td>Ground earth station (GES)</td>
<td>640, 641, 643, 646, 648</td>
</tr>
<tr>
<td>Group maintenance</td>
<td>524, 525, 544, 550</td>
</tr>
<tr>
<td>Half-logistic distribution</td>
<td>331, 332, 335, 337, 338, 358, 359, 360, 361</td>
</tr>
<tr>
<td>Hazard function(s)</td>
<td></td>
</tr>
<tr>
<td>beta model</td>
<td>41</td>
</tr>
<tr>
<td>constant</td>
<td>17</td>
</tr>
<tr>
<td>cumulative</td>
<td>15, 61, 171, 278, 346, 347, 348, 396, 400, 424, 574, 576</td>
</tr>
<tr>
<td>defined</td>
<td>5</td>
</tr>
<tr>
<td>exponential model/extreme value distribution</td>
<td>28</td>
</tr>
<tr>
<td>gamma model</td>
<td>35</td>
</tr>
<tr>
<td>generalized Pareto model</td>
<td>54</td>
</tr>
<tr>
<td>Gompertz–Makeham model</td>
<td>54</td>
</tr>
<tr>
<td>linearly decreasing</td>
<td>21</td>
</tr>
<tr>
<td>linearly increasing</td>
<td>19, 20</td>
</tr>
<tr>
<td>log-logistic model</td>
<td>39</td>
</tr>
<tr>
<td>lognormal model</td>
<td>32</td>
</tr>
<tr>
<td>mixed Weibull model</td>
<td>27</td>
</tr>
<tr>
<td>normal model</td>
<td>29</td>
</tr>
<tr>
<td>power series model</td>
<td>54</td>
</tr>
<tr>
<td>Weibull model</td>
<td>21</td>
</tr>
<tr>
<td>Hazard rate(s)</td>
<td></td>
</tr>
<tr>
<td>censoring</td>
<td>278</td>
</tr>
<tr>
<td>exponentially increasing</td>
<td>28</td>
</tr>
<tr>
<td>multivariate</td>
<td>55</td>
</tr>
<tr>
<td>roller-coaster</td>
<td>64, 86</td>
</tr>
<tr>
<td>High frequency radio (HF)</td>
<td>639</td>
</tr>
<tr>
<td>Highly accelerated life testing (HALT)</td>
<td>365</td>
</tr>
<tr>
<td>Highly accelerated stress screening (HASS)</td>
<td>366</td>
</tr>
<tr>
<td>Highly accelerated stress testing (HAST)</td>
<td>438</td>
</tr>
<tr>
<td>Homogeneous Poisson process (HPP)</td>
<td>481</td>
</tr>
<tr>
<td>Hot-carrier degradation model</td>
<td>419</td>
</tr>
<tr>
<td>Hot standby</td>
<td>138, 213, 218, 221, 230, 572</td>
</tr>
<tr>
<td>Humidity dependence failures model</td>
<td>413</td>
</tr>
<tr>
<td>Hypergeometric distribution</td>
<td>67</td>
</tr>
<tr>
<td>Importance measures</td>
<td></td>
</tr>
<tr>
<td>Barlow–Proshan importance</td>
<td>149</td>
</tr>
<tr>
<td>Birnbaum’s importance measure</td>
<td>142</td>
</tr>
<tr>
<td>criticality importance</td>
<td>145</td>
</tr>
<tr>
<td>Fussell–Vesely importance</td>
<td>148</td>
</tr>
<tr>
<td>upgrading function</td>
<td>150</td>
</tr>
<tr>
<td>Inactive redundancy</td>
<td>138, 139, 213</td>
</tr>
<tr>
<td>Incident beam collimators</td>
<td>317</td>
</tr>
<tr>
<td>Incomplete gamma function</td>
<td>36, 263, 589</td>
</tr>
<tr>
<td>Increasing failure rates (IFR)</td>
<td>61, 62, 63, 64, 77, 82, 83, 84, 231, 509, 510, 513, 524, 534, 540</td>
</tr>
<tr>
<td>Infant mortality region</td>
<td>16, 367, 586</td>
</tr>
<tr>
<td>Inherent availability</td>
<td>202</td>
</tr>
<tr>
<td>Inspection policy, periodic maintenance</td>
<td>527, 531, 546, 549</td>
</tr>
<tr>
<td>and,</td>
<td>on-line surveillance and monitoring, 537, 549</td>
</tr>
<tr>
<td>optimum</td>
<td>528, 529, 531, 534, 535, 545, 546, 628</td>
</tr>
<tr>
<td>Instantaneous availability</td>
<td>199, 218</td>
</tr>
<tr>
<td>Instantaneous failure rate</td>
<td>5, 15</td>
</tr>
<tr>
<td>Integrated circuits (ICs), examples</td>
<td></td>
</tr>
<tr>
<td>complementary metal-oxide-silicon (CMOS) examples</td>
<td>17, 55, 207, 244, 273</td>
</tr>
<tr>
<td>electromigration model</td>
<td>413, 432</td>
</tr>
<tr>
<td>fracture substrate example</td>
<td>381</td>
</tr>
<tr>
<td>gold-aluminum bonds example</td>
<td>379</td>
</tr>
<tr>
<td>humidity dependence failures model</td>
<td>413</td>
</tr>
<tr>
<td>Inverse Gaussian model (IG)</td>
<td>42, 43, 82, 85, 421, 436, 437</td>
</tr>
<tr>
<td>Jarvik heart</td>
<td>1</td>
</tr>
<tr>
<td>Joint density function (j.d.f.)</td>
<td>207, 209</td>
</tr>
<tr>
<td>Kaplan–Meier estimator</td>
<td>15, 346, 361, 435</td>
</tr>
<tr>
<td>Keystone component</td>
<td>118, 119, 121, 163</td>
</tr>
<tr>
<td>k-out-of-n systems, mean time to failure in</td>
<td>183</td>
</tr>
<tr>
<td>Laplace transform</td>
<td></td>
</tr>
<tr>
<td>of renewal density equation</td>
<td>187</td>
</tr>
<tr>
<td>state-transition equations and</td>
<td>196, 197, 199, 200, 201, 208, 218, 228, 229, 622</td>
</tr>
<tr>
<td>Ladder networks</td>
<td>131, 132</td>
</tr>
<tr>
<td>Largest restoration time</td>
<td>655, 664</td>
</tr>
<tr>
<td>Laser degradation model</td>
<td>418</td>
</tr>
<tr>
<td>Laser diodes (LD), example</td>
<td>418, 460</td>
</tr>
<tr>
<td>Laser printer example</td>
<td>89, 90, 165, 169</td>
</tr>
<tr>
<td>Least squares method</td>
<td></td>
</tr>
<tr>
<td>linear</td>
<td>256, 257</td>
</tr>
<tr>
<td>nonlinear,256, 257</td>
<td></td>
</tr>
<tr>
<td>L’Hôpital’s rule</td>
<td>194, 215</td>
</tr>
<tr>
<td>Likelihood method</td>
<td></td>
</tr>
<tr>
<td>Fisher information matrix</td>
<td>254</td>
</tr>
<tr>
<td>gradient of, 253</td>
<td></td>
</tr>
<tr>
<td>logarithmic values of</td>
<td>247</td>
</tr>
<tr>
<td>maximum</td>
<td>247</td>
</tr>
<tr>
<td>Newton’s iterative method</td>
<td>253</td>
</tr>
<tr>
<td>variance-covariance matrix</td>
<td>254</td>
</tr>
<tr>
<td>Linear least squares method</td>
<td>256, 257</td>
</tr>
<tr>
<td>Linear models, acceleration</td>
<td>374, 378, 379, 382, 426</td>
</tr>
<tr>
<td>thermal fatigue crack example</td>
<td>371, 380, 422</td>
</tr>
<tr>
<td>Inverse power rule model</td>
<td>408, 411, 431</td>
</tr>
<tr>
<td>Inverse Gaussian model</td>
<td>42, 43, 82, 85, 421, 436, 437</td>
</tr>
<tr>
<td>Subject Index</td>
<td></td>
</tr>
<tr>
<td>---------------</td>
<td></td>
</tr>
<tr>
<td>Linearly decreasing hazard function, 21</td>
<td></td>
</tr>
<tr>
<td>Linearly increasing hazard function, 19, 20</td>
<td></td>
</tr>
<tr>
<td>Mean time to failure, 179</td>
<td></td>
</tr>
<tr>
<td>Mean time to failure in k-out-of-n systems with, 184</td>
<td></td>
</tr>
<tr>
<td>Mean time to failure in parallel systems with, 180</td>
<td></td>
</tr>
<tr>
<td>Mean time to failure in series systems with, 179</td>
<td></td>
</tr>
<tr>
<td>Logarithmic values of likelihood method, 247</td>
<td></td>
</tr>
<tr>
<td>Log-logistic model hazard function, 39</td>
<td></td>
</tr>
<tr>
<td>Lognormal distribution acceleration model, 381</td>
<td></td>
</tr>
<tr>
<td>Acceleration model, 381</td>
<td></td>
</tr>
<tr>
<td>Parameter estimation, 314</td>
<td></td>
</tr>
<tr>
<td>With censoring, 319</td>
<td></td>
</tr>
<tr>
<td>Without censoring, 315</td>
<td></td>
</tr>
<tr>
<td>Lognormal model, 32</td>
<td></td>
</tr>
<tr>
<td>Lomax distribution, 59</td>
<td></td>
</tr>
<tr>
<td>Long failure times, testing for, 284</td>
<td></td>
</tr>
<tr>
<td>Lower confidence limit (LCL), 239</td>
<td></td>
</tr>
<tr>
<td>Lump-sum rebate, 560, 561, 562, 564, 597, 598, 600</td>
<td></td>
</tr>
<tr>
<td>Mean time to failure (MTTF) defined, 67</td>
<td></td>
</tr>
<tr>
<td>For k-out-of-n systems, 183</td>
<td></td>
</tr>
<tr>
<td>For other systems, 185</td>
<td></td>
</tr>
<tr>
<td>For parallel systems, 180</td>
<td></td>
</tr>
<tr>
<td>For series systems, 178</td>
<td></td>
</tr>
<tr>
<td>Mean time to replace, 20, 21</td>
<td></td>
</tr>
<tr>
<td>Mechanical fatigue, 74, 422</td>
<td></td>
</tr>
<tr>
<td>Median time to failure (MTF), 413, 417, 432</td>
<td></td>
</tr>
<tr>
<td>Membrane keyboard example, 205</td>
<td></td>
</tr>
<tr>
<td>Metal-oxide semiconductor (MOS), failure of, 207, 231, 383, 384, 464</td>
<td></td>
</tr>
<tr>
<td>Method of moments, 234</td>
<td></td>
</tr>
<tr>
<td>Microcasting example, 467</td>
<td></td>
</tr>
<tr>
<td>MIL-HDBK-217D, 273</td>
<td></td>
</tr>
<tr>
<td>Minimal repair policy, 579, 580, 583, 584</td>
<td></td>
</tr>
<tr>
<td>Mission-oriented availability, 198</td>
<td></td>
</tr>
<tr>
<td>Mixed-parallel, 97</td>
<td></td>
</tr>
<tr>
<td>Mixed repair policy, 583, 585</td>
<td></td>
</tr>
<tr>
<td>Mixed warranty policies, 564</td>
<td></td>
</tr>
<tr>
<td>Mixed Weibull model, 27</td>
<td></td>
</tr>
<tr>
<td>Mixture of failure rates, 59</td>
<td></td>
</tr>
<tr>
<td>Model identification, 276</td>
<td></td>
</tr>
<tr>
<td>Modified renewal process, 469</td>
<td></td>
</tr>
<tr>
<td>Monitoring, 537, 549. See also On-line surveillance and monitoring</td>
<td></td>
</tr>
<tr>
<td>Monte Carlo simulation, 308</td>
<td></td>
</tr>
<tr>
<td>Multicensored data cumulative-hazard estimator, 347</td>
<td></td>
</tr>
<tr>
<td>Product-limit estimator, 346</td>
<td></td>
</tr>
<tr>
<td>Multistate models/systems, 132</td>
<td></td>
</tr>
<tr>
<td>Parallel, 134</td>
<td></td>
</tr>
<tr>
<td>Parallel-series, 135</td>
<td></td>
</tr>
<tr>
<td>Series, 133</td>
<td></td>
</tr>
<tr>
<td>Series-parallel, 136</td>
<td></td>
</tr>
<tr>
<td>Multivariate hazard rate, 55</td>
<td></td>
</tr>
<tr>
<td>Naïve mean rank estimator, 12, 15, 75</td>
<td></td>
</tr>
<tr>
<td>NASA, 169, 369</td>
<td></td>
</tr>
<tr>
<td>Natrela-Dixon test, 234</td>
<td></td>
</tr>
<tr>
<td>Networks, directed/undirected, 117</td>
<td></td>
</tr>
<tr>
<td>Newton–Raphson method computer listing of, 722</td>
<td></td>
</tr>
<tr>
<td>Description of, 684</td>
<td></td>
</tr>
<tr>
<td>Newton’s iterative method for likelihood method, 253</td>
<td></td>
</tr>
<tr>
<td>Nondestructive testing (NDT), 536, 543, 576</td>
<td></td>
</tr>
<tr>
<td>Nondetection cost, 528, 531</td>
<td></td>
</tr>
<tr>
<td>Nonhomogeneous Poisson process (NHPP), 481, 482, 492, 575, 579</td>
<td></td>
</tr>
<tr>
<td>Nonparametric renewal function estimation continuous time, 455</td>
<td></td>
</tr>
<tr>
<td>Discrete time, 460</td>
<td></td>
</tr>
<tr>
<td>Nonrepairable products, warranties for, 553</td>
<td></td>
</tr>
<tr>
<td>Nonrepairable standby multiunit, 215</td>
<td></td>
</tr>
<tr>
<td>Simple, 214</td>
<td></td>
</tr>
<tr>
<td>Nonrepairable systems examples of, 170</td>
<td></td>
</tr>
<tr>
<td>K-out-of-n systems, 176</td>
<td></td>
</tr>
<tr>
<td>Parallel systems, 172</td>
<td></td>
</tr>
<tr>
<td>Series systems, 171</td>
<td></td>
</tr>
<tr>
<td>Normal distribution maximum likelihood method for estimating, 251</td>
<td></td>
</tr>
<tr>
<td>Method of moments in estimating, 237</td>
<td></td>
</tr>
<tr>
<td>Table for, 741</td>
<td></td>
</tr>
<tr>
<td>Operational availability, 203</td>
<td></td>
</tr>
<tr>
<td>Operational life testing (OLT), 18, 274, 275</td>
<td></td>
</tr>
<tr>
<td>Optimal arrangement of components, 111</td>
<td></td>
</tr>
<tr>
<td>Optimal assignment of units, 100</td>
<td></td>
</tr>
</tbody>
</table>
Optimum inspection policy, 529, 544, 546
Optimal replacements for items under warranty, 569
Ordinary free replacement warranty, 551, 552
Ordinary renewal process, 469, 478, 572, 573, 574
Outliers, 234, 272
Parallel-series system
description of, 95
multistate components in, 135
Parallel systems
description of, 93
mean time to failure in, 180
multistate components in, 134
nonrepairable, 172
Parameter estimation
least squares method, 256
likelihood method, 241
method of moments, 234, 236
Parametric reliability models
censoring, types of
Type 1, 277, 278, 289, 307, 319, 340, 346, 423
Type 2, 277, 278, 281, 292, 307, 319, 329, 334, 340, 343, 346, 423
exponential distribution, 248
extreme value distribution, 28
gamma distribution, 35
half-logistic distribution, 331, 332, 335, 337, 338, 358, 359, 360, 361
linear models, 344
lognormal distribution, 32
multicensored data, 346, 347
random, 277, 346
Rayleigh distribution, 19, 21, 22, 23, 24, 77, 84, 249, 250, 266, 294, 295, 296, 297, 298, 299, 300, 302, 380, 381, 689
Weibull distribution, 21, 27
Parametric reliability models,
approaches to
accelerated life testing, 275
burn-in testing, 275
failure data, use of, 273
operational life testing, 274
Parametric renewal function estimation
continuous time, 441
discrete time, 452
Pareto distribution of the second kind, 59
Pareto model, generalized, 54
Partial-fraction-expansion formula, 197, 449, 455
Partial redundancy, 228
Path-tracing method, 127
Pearson Type V, 69, 77
Pearson Type VI, 59
Permanent magnet synchronous motor (PMSM), example, 450
Physics-experimental-based models
electromigration model, 413, 432
fatigue failures model, 414
humidity dependence failures model, 413
Physics-statistics-based models
Arrhenius model, 373, 404, 406, 411, 421, 430
combination model, 411, 431, 438
Eyring model, 406
inverse power rule model, 408, 411, 431
Point availability, 188, 189, 199, 201, 494
Point estimator, 234, 240, 347
Point Pleasant Bridge, 2
Pointwise availability, 190
Poisson distribution, likelihood function for, 243, 247
Poisson processes
homogeneous, 481
nonhomogeneous, 481, 482, 492, 575, 579
Power series model hazard function, 54
Preventive maintenance, replacements, and inspection (PMRI)
constant interval replacement policy, 498
cost minimization, 497
downtime minimization, 506
group, 524
inspection policy, 527
minimal repair, 509
number of spares, determining, 517, 518, 519, 520, 521, 522, 523, 544
on-line surveillance and monitoring, 537, 549
optimum for systems subject to shocks, 513
replacement at predetermined age, 503, 504, 505, 569, 570
Printed Circuit Boards (PCBs), 260
Probability density function
exponential, 4, 17, 39, 55, 61, 63, 65, 71, 72, 189, 235, 236, 248, 266, 279
of gamma distribution, 35
of log-logistic model, 39
of lognormal distribution, 32
Rayleigh distribution, 19, 21, 22, 23, 24, 77, 84, 249, 250, 266, 294, 295, 296, 297, 298, 299, 300, 302, 380, 381, 689
for standard normal distribution, 29, 42, 240, 286, 421, 454, 478, 504, 539, 741
Production line design, case study, 609, 612
Progressive testing, 278, 362
Product-limit estimator (PLE), 346, 347, 348, 359
Proportional hazards model (PHM), 373, 389, 393, 430
Proportional Mean Residual Life (PMRL), 401, 435
Proportional Odds Model (POM), 373, 395, 396, 397, 398, 437, 438
Pro rata warranty, 551, 552, 553, 554, 560, 561, 562, 564, 567, 568, 569, 570, 588, 598, 599, 600
Prot method, 23
Pump engine, 660
Qualification and certification, 632
Random censoring, 277
Random variates, 265, 266, 272, 363
Rayleigh distribution
acceleration model, 380
best linear unbiased estimator for
parameters, 297
description of, 10
maximum likelihood method for
estimating, 249
parameter estimation, 249
variance, 294
with censored observations, 296
without censored observations, 297
Reduction method, 126
Redundancy
active, 138, 139, 140, 141, 181, 182,
213, 661
allocation for a series system, 100
cold standby, 138, 213, 218, 221,
222, 608
defined, 138
difference between active and
inactive, 138
hot standby, 138, 213, 218, 221,
230, 572
inactive, 138, 139, 213
partial, 228
system, 138, 213
warm standby, 138, 213, 218, 221,
231
Redundancy and standby
cold standby, 138, 213, 218, 221,
222, 608
examples of, 213
hot standby, 138, 213, 218, 221,
230, 572
nonrepairable, 214
nonrepairable multiunit, 215
nonrepairable simple, 214
repairable, 218
warm standby, 138, 213, 218, 221,
231
Relative efficiency, 234
Reliability
acceptance test (RAT), 365, 367,
440
block diagrams, 87, 88, 89, 90, 93,
118, 119, 120, 121, 127, 154,
155, 159, 160, 161, 164, 605,
606, 607, 613, 645, 660, 661
definition, 3
demonstration test (RDT), 266
estimating, 3
demonstration test (RGT), 365
importance of, 1, 2, 3
k-out-of-n balanced system, 115,
116, 117, 163
k-out-of-n system, 113, 115
objectives, 648
Reliability function
for exponential model hazard
function, 28
for gamma model hazard function,
36
for linearly increasing hazard
function, 19, 20
for log-logistic model hazard
function, 39
for mixture of two increasing failure
rates (IFR), 61, 62, 63, 64, 77,
82, 83, 84, 231, 509, 510, 513,
524, 534, 540
for normal model hazard function,
31, 32
for power series model hazard
function, 54
Renewal
alternating renewal process, 187,
199, 465, 490, 664
availability analysis and, 446
confidence intervals, 239, 240, 262,
266, 287, 290, 292, 293
delayed renewal process, 469
density equation, 187
equilibrium renewal process, 469,
470, 472, 474, 476, 478
estimating, 441
fundamental renewal equation, 442
process; see Renewal processes
remaining life at time, 70
time approach, 441
variance of, 193, 471
Renewal function estimation,
nonparametric
continuous time, 445
discrete time, 460
Renewal function estimation,
parametric
continuous time, 441
discrete time, 452
Renewal processes
alternating, 187, 199, 465, 490, 664
equilibrium, 469, 470, 472, 473,
474, 476, 478
modified/delayed, 469
ordinary, 469, 478, 572, 573, 574
Renewal theory approach, 441
Repair, minimal, 509
Repairable products, warranties for, 574
Repairable standby, 218
Repairable systems
alternating renewal process, 187,
199, 465, 490, 664
Markov models, 196
Poisson processes; see Poisson
processes
Repeaters/bipolar transistors, examples,
72, 207, 208, 280, 281, 285,
287, 379, 385, 412, 419, 464
Replacement
age, 503, 504, 505, 569, 570
block, 498, 542
constant interval replacement policy
(CIRP), 498
for items subject to shocks, 513
for items under warranty, 569
optimal, 569
periodic (time-dependent cost), 516
at predetermined age, 502
under minimal repair, 509
unlimited free, 551, 552
Reserve fund, 553, 554, 555, 556, 557,
558, 559, 560, 562, 563, 590,
597, 598, 599, 600, 601
Resistance, measuring electrical, 143
Resistor degradation model, 416
Reverse-biased second breakdown
(RBSB), 431
Root mean square (RMS), 276, 538
Runge–Kutta method, 198, 200, 682
Satellite communications, 642
Satellite data unit (SDU), 642, 644,
645
Scattered beam collimators, 619, 621
Semi-Markov process, 199
Sensors, examples using, 3, 112, 298, 488, 536, 537, 540, 541, 542

Series systems
description, 91
mean time to failure in, 178
multistate components in, 133
nonrepairable, 171
redundancy allocation for, 139

Series-parallel systems, 136
description, 96
multistate components in, 136

Shakedown region, 16

Short failure times, testing for, 282

Silicon controlled rectifier (SCR), 81

Sinusoidal-cyclic stress, 370

Smart cards, 629

Sound recognition, 539
Spectrographic emission, 541

Standard Brownian motion, 42, 362, 420, 421
Standard normal distribution, 42, 362, 420, 421

Steady-state availability, 189, 198, 201, 202, 225, 447, 448, 490, 522, 549, 650

Strain-gauge technique, 530

Stress
cconstant, 369, 370, 371, 421
electrical, 367, 371
environmental, 363, 371, 372, 390, 404
loading, 369, 371
mechanical, 59, 85, 371
ramp, 368
ramp-soak-cycle, 370
step, 370, 371, 437

Structure function, 142, 143, 144, 145

System redundancy, 138
reliability block diagrams used to evaluate, 87, 88, 89, 90, 93, 118, 119, 120, 121, 127, 154, 155, 159, 160, 161, 164, 605, 606, 607, 613, 645, 660, 661
structure function, 142, 143, 144, 145

System configurations, 146, 170, 213, 368, 640, 663. See also types of systems
complex reliability, 117, 185
consecutive-k-out-of-n: F, 104, 105
k-out-of-n, 113, 115
mixed-parallel, 97
multistate models, 132
optimal assignment of components, 100
optimal assignment of components in consecutive-2-out-of-n: F, 111
parallel, 93
parallel-series, 95
series, 91
series-parallel, 96

System design using reliability objectives, case study, 648

TAFT, 364
Taylor’s expansion, 253
Telecommunication networks
reliability, case study, 640
Telecommunication system example, 114, 117, 131

Temperature acceleration testing, examples, 373, 391, 406, 423, 428, 430
Arrhenius model, 373, 404, 406, 411, 421, 430
Eyring model, 406
Temperature monitoring, 540
Test censoring time, 277
Test duration, 277, 422, 631, 632
Test plan formulation, 424

Therac-25, 5
Thermal fatigue crack example, 371, 380, 422
Thermocouple example, 215, 216
Thin layer activation, 541

Thresher, 1

Tie-set method, 121

Time-dependent dielectric breakdown (TDDB), 207, 384, 464
Time-dependent equations, computer program for solving, 682
Time-dependent reliability estimates, 87, 170, 194. See also Mean time between failure
alternating renewal process, 187, 199, 465, 490, 664

Markov models
nonrepairable systems, 194
repairable systems, 196

Time-interval versus downtime availability, 198, 202, 203

Time to failure (TTF), 176
Time to first failure (TFF), 71, 282
Top down heuristic (TDH), 101, 102, 103

Transistors, example of testing, 72, 207, 208, 280, 281, 285, 287, 379, 385, 412, 419, 464

Truth table method, Boolean, 124, 125, 126

Turbine example, 284

Two-dimensional warranty, 553, 588, 590, 600

Type 1-Type 2 censoring, impact on estimation, 277

Unbiased estimator, Weibull distribution parameters and, 308, 310, 312
Unbiasing factor, 308, 336, 337
Undirected networks, 323
Uniform random variable, 73
Unlimited free replacement warranty, 551, 552
Upgrading function, 150
Upper confidence limit (UCL), 239
Variance-covariance matrix, 254
Variance
   of MLE estimate, 307
   of number of renewals, 193, 471
   of parameters, 264, 326
   of system reliability, 98, 168
Variates, 265, 266, 272, 363
Very large-scale integrated (VLSI) circuits, 419
Vibrations
   analysis of, 537
   excessive, 29
Warm standby, 138, 213, 218, 221, 231
Warranties, 3, 356, 551, 552, 553, 588, 599, 602
   estimating warranty cost, 440
   for fixed lot size (arbitrary failure-time distribution), 578
   for fixed lot size (good-as-new repair policy), 580
   for fixed lot size (minimal repair policy), 579
   for fixed lot size (mixed repair policy), 583
   full rebate policy, 564, 565, 567, 568, 569, 599, 600
   lump-sum rebate, 560, 561, 562, 564, 597, 598, 600
   mixed policies, 564, 565, 566, 567
   for nonrepairable products, 553
   one-dimensional warranty, 553, 588
   optimal replacements for items under, 569
   ordinary free replacement, 551, 552
   pro-rata, 551, 552, 553, 560, 561, 562, 564, 567, 568, 569, 570, 598, 600
   for repairable products, 574
   reserve cost, 554, 555, 560, 598
   two-dimensional, 553, 588, 590, 600
   unlimited free replacement, 551, 552
Warranty claims
   for grouped data, 596
   with lag times, 592
Wear-out region, 16, 17, 23, 26, 27, 64, 84, 633
Weibull distribution, 266, 302
   acceleration model, 378
   confidence interval and, 239, 240, 262, 266, 287, 290, 292, 293
   parameter estimation, 302
   unbiased estimates for parameters, 308
   variance of maximum likelihood estimates, 307
   with censoring, 307
   without censoring, 302
Weibull hazard, 26, 171, 172, 175, 176, 178, 179, 180, 182, 184, 344
   mean time to failure in k-out-of-n systems with, 184
   mean time to failure in parallel systems with, 182
   mean time to failure in series systems with, 179
Weibull model
   mean time to failure for, 21
   mixed, 27
Work-mission availability, 205, 206
X-ray generator, 617, 621
Yorktown, 3
Yule process, 514, 515
$\chi^2$, critical values of, 279, 280, 281, 288, 625, 747