

# INDEX

Additional page numbers with information about individual ASME Specifications (SA and SB numbers) can be found under the headings “American Society of Mechanical Engineers Ferrous Material Specifications” and “American Society of Mechanical Engineers Nonferrous Material Specifications.” Referrals to Code Paragraphs and Sections can be located by their alphabetical code (NA, NB, etc.).

- ABMA. *See* American Boiler Manufacturer’s Association.
- Abnormal occurrence reports (AORs), 592
- AC. *See* Alternating current.
- Acceleration drag, 584
- Acceleration drag force, 584–585
- Accelerometers, 602, 607, 620–621
- Acceptable damage, definition, 546
- Acceptance by the Inspector, definition, 95
- Acceptance criteria, for imperfections, 3
- Acceptance-rejection decisions, 4
- Acceptance-rejection levels
  - acceptable, 309
  - conditionally acceptable, 309
  - repair, 309
  - replacement, 309
- ACCP. *See* American Society for Nondestructive Testing Central Certification Program.
- Accreditation, 517, 531
  - globalization, 537–544
- ACI. *See* American Concrete Institute.
- Acme 105 vinyl ester resin, glass-reinforced, 252–253
- Acoustic analysis, to size and locate suction stabilizer and discharge dampener in piping, 596
- Acoustic compliance, 619
- Acoustic emission (AE), abbreviation, 307
- Acoustic emission (AE) continuous monitoring
  - component stressing, 22
  - coordination with plant system owner-operator, 22
  - general requirements, 22
  - noise interference, 22
  - objectives, 22
  - personnel qualification, 22
- Acoustic emission (AE) examination, 21–22, 327
  - application requirements, 21
  - applications, 235
  - calibration, 21
  - of Class II section X vessels, 251
  - continuous monitoring, 22
  - documentation, 21
  - environmental conditions, 21
  - equipment and supplies required, 21
  - evaluation, 21
  - of fiber-reinforced plastic vessels, 20–21
  - general requirements, 20–21
  - of light-water reactor plants, 393
  - of metallic vessels during pressure testing, 21
  - noise elimination or reduction, 21
  - of piping systems, 562–563
  - for RTP-1 vessels, 235
  - of Section X Class II vessels, 247
  - for Section X vessels, 235
  - sensor frequency, 22
  - sensors, 21
  - vessel conditioning requirements, 20
  - vessel stressing requirements, 21
  - written procedure, 21
- Acoustic-emission test report, 277
- Acoustic inertance, 619
- Acoustic modifications, 619–620
- Acoustical resistant element, 619
- Acoustic wave speed, 618–619
- ACRS. *See* Advisory Committee on Reactor Safeguards (USNRC).
- Active components, definition, 572
- Active failure, definition, 546
- Addenda to the Code, 389, 393–394
  - addenda to Section XI, 479
  - 1970 addenda to Section XI, 307–308
  - 1972 Addenda, 444
  - 1973 Addenda, 531
  - 1973 addenda to Section III, 525
  - 1973 addenda to Section XI, 311, 338, 383
  - 1974 addenda to Section XI, 313, 370–371
  - 1975 Addenda, 531
  - 1975 addenda to Section XI, 312, 323, 332, 340, 371
  - 1976 addenda to Section XI, 338–340, 345, 347, 351, 357–358, 360, 362, 367, 524
  - 1977 addenda to Section XI, 347, 370
  - 1978 addenda to Section XI, 314, 323, 339–341, 357, 365, 368–370, 374–375, 379, 382
  - 1980 addenda to Section XI, 341, 370, 379, 383
  - 1981 addenda to Section XI, 314, 340–341, 370, 379, 445
  - 1982 addenda to Section XI, 382
  - 1983 addenda to Section XI, 340, 342, 363, 371, 379, 409
  - 1985 addenda to Section XI, 352, 369–370, 375, 379
  - 1986 addenda to Section XI, 360, 370, 379
  - 1987 Addenda, Section VIII, Division 1, 140
  - 1987 addenda to Section XI, 339, 371–380

Addenda to the Code (*Continued*)

1988 addenda to Section XI, 316, 339, 345, 355, 371, 373, 376, 380, 383, 445

1989 Addenda, Appendix VIII, 318, 393

1989 addenda to Section III, 406

1989 addenda to Section XI, 316, 339, 340, 345, 347, 352, 371, 376, 380, 382, 385, 523

1990 addenda to Section XI, 340, 342, 347, 362, 371, 376, 380

1991 addenda to Section XI, 37, 347, 351–352, 356, 359, 371–373, 376, 380, 383, 385, 393, 407

1992 addenda to Section XI, 315–316, 340, 345–347, 376, 382, 523

1992 addenda to Section XI, Subsection IWA, 439

1992 addenda to Section XI, Subsection IWE, 439, 445

1992 addenda to Section XI, Subsection IWL, 439

1993 addenda to Section XI, 314, 339–340, 350, 359, 376, 381, 406

1994 Addenda, 531

1994 addenda to Section XI, 339, 356, 376, 378, 424

1995 addenda to Section XI, 254, 306, 339–341, 345, 347, 355, 356, 359–360, 362–363, 366, 368, 371

1996 addenda to Section III, 553

1996 addenda to Section XI, 323, 340, 347, 355, 357, 359–360, 363, 366, 371, 384, 524

1996 addenda to Section XI, Subsection IWA, 439, 446

1996 addenda to Section XI, Subsection IWE, 439, 446

1996 addenda to Section XI, Subsection IWL, 439

1997 addenda to Section VIII, 140

1997 addenda to Section IX, 206

1997 addenda to Section XI, Division 1, 255, 340, 341, 352, 359, 366, 368, 371, 373, 375, 377, 484

1998 addenda to Section XI, 439

1999 addenda to Section VIII, 138, 694

1999 addenda to Section IX, 197

1999 addenda to Section XI, 340–341, 345, 347, 352, 359, 362, 366, 368, 371, 375, 376, 380, 382–383, 401, 407

2000 addenda to Section VIII, Division 3, 177

2000 addenda to Section IX, 215–216

2000 addenda to Section XI, 345, 356, 360

Adhesives, use on nameplates, 173

Adiabatic heating, of nuclear reactor vessel materials, 141–142

Adjusted reference temperature, 427

Advanced reactors, 543. *See also* Generation IV reactors.

Advisory Committee on Reactor Safeguards (USNRC) (ACRS), 444  
acronym/abbreviation, 440

AE. *See* Acoustic emission.

AEC. *See* Atomic Energy Commission.

Africa, ASME companies holding B&PV certificates (including nuclear) as of June, 1999, 534, 538

AFW. *See* Auxiliary feedwater systems.

AI. *See* Authorized Inspector.

AIA. *See* Authorized Inspection Agency.

Air environments  
austenitic steels fatigue crack growth rate, 479, 480, 482  
ferritic steels fatigue crack growth rate, 479

Air-under-water method, 32

AISC. *See* American Institute for Steel Construction.

Algor post-processor, 247

Allowable bending stress, of reinforcing laminate, 258

Allowable bond shear stress, 265  
of lug assembly, 266

Allowable peel load, 265

Allowable stresses. *See* Stresses.

Allowable stress multiplication factor, 89

Allowable stress values, of pressure vessel materials, 126

Allowed outage times (AOTs), 562

Alloy CDA 954, 77

Alloy steels, weld cycle, 202

Alternating current (AC), 211, 220, 232

Alternating current (AC) welding, change in current, 232

Alternating stress component producing fatigue damage, 645

Alternating stress intensity, 648, 651

Aluminum  
as gasket materials and contact facings, 687, 688  
P-number, 203  
weld cycle, 202

Aluminum alloys, specific types  
3003-H112, 680  
5083, 87  
6061-T6, 627

Aluminum-base alloy, P-Number, 203

Aluminum-base electrodes, F-Number, 203

Aluminum-base rods, F-Number, 203

Aluminum electrodes, F-Number, 203

Aluminum rods, F-Number, 203

American Boiler Manufacturers Association (ABMA), 517

American Concrete Institute (ACI)  
acronym/abbreviations, 440  
referenced, 390  
standards for concrete pressure-retaining structures, 444  
Standard 201.1, 401  
Standard 201.1, R-68, 463–464, 709

American Institute for Steel Construction (AISC), 278  
code for supports, 338

American National Standards Institute (ANSI), 502. *See also*  
American Society of Mechanical Engineers Codes and Standards, specific types, USAS.  
acronym/abbreviation, 440  
/ASME PVHO-1, construction requirements of pressure vessels for human occupancy, 29  
/ASNT3, CP-189-1995 (Standards for Qualification and Certification of Nondestructive Personnel), 4, 26, 317–318, 393  
N45.2, 522  
N45.2 vs. ASME Section III and Section XI, 353  
N45.2-1977, N45.2.6 (Qualification of Inspection, Examination, and Testing Personnel for Nuclear Power Plants), 522  
N45.2-1977, N45.2.9 (Requirements for Collection, Storage, and Maintenance of Quality Assurance Record for Nuclear Power Plants), 522  
N45.2-1977, N45.2.10 (Quality Assurance Terms and Definitions), 522  
N45.2-1977, N45.2.11 (Quality Assurance Requirements for the Design of Nuclear Power Plants), 522  
N45.2-1977, N45.2.12 (Requirements for Auditing of Quality Assurance Programs for Nuclear Power Plants), 522  
N45.2-1977, N45.2.13 (Quality Assurance Requirements for Control of Procurement of Items and Services for Nuclear Power Plants), 522  
N45.2-1977, N45.2.23 (Qualification of Quality Assurance Program Audit Personnel for Nuclear Power Plants), 522  
N626-1990, 521  
N626, Part 4, accreditation, 533  
N626, Part 5, 533  
N626a-1991, 521  
N626.0-1974, 521  
N626.1 (Inservice Inspection), 521  
N626.2-1976, 521  
N626.4, 521  
/UL-969 (Marking and Labeling Systems), 676

American National Standards Institute (ANSI)/ASME Standard (Operation and Maintenance of Nuclear Power Plants), Part 3 (Requirements for Preoperational and Initial Start-up Vibration Testing of Nuclear Power Plant Piping Systems), 593

- American National Standards Institute (ANSI)/AWS Standard  
Welding Procedure Specification (SWPS), 204
- American National Standards Institute (ANSI) Committee, *Rules for Inservice Inspection of Nuclear Power Plant Components*, 444
- American National Standards Institute (ANSI) N-45 Committee  
(Reactor Plants and Their Maintenance), 522  
joint AEC-industry Code development program, 305
- American Nuclear Society (ANS), 392  
Standard 58.2 (1988), 545, 560  
Standard 58.3, 560  
Standard 58.3, Appendix B, 545
- American Petroleum Institute (API) Bulletin 2U, 152
- American Petroleum Institute (API) Pressure Vessel Inspection Code standards  
API 510, 27  
API 527, 676  
API 530, 27  
API 605, 681  
API 620, 360, 520  
API 650, 360, 520  
API 2000, 126  
API RP 520, 126  
API RP 579, 319, 324
- American Polymers Inc., spec. SP-GS-12 (Specifications for FRP Tanks and Vessels), 253
- American Public Health Association (APHA)  
referenced, 390
- American Society for Nondestructive Testing (ASNT), 3, 22  
acronym/abbreviation, 440  
document CP-189-1995 (Standard for Qualification and Certification of NDE Personnel) (ANSI/ASNT), 3–4, 26, 317–318, 393  
document SNT-TC-1A (Personnel Qualification and Certification in Nondestructive Testing), 3–4, 26, 62, 101, 135, 167, 306, 317–318, 393, 676  
Level III Certificate, 393  
personnel qualification processes, 310  
referenced, 390
- American Society for Nondestructive Testing (ASNT) Central Certification Program (ACCP), as alternative to NDE personnel qualification, 327
- American Society for Testing and Materials (ASTM), 139  
material specifications, 363  
pipe-and-tank standards, 254  
referenced, 390  
03.03 (Nondestructive Testing), 22
- American Society for Testing and Materials (ASTM) test methods, specific types  
D 56 (Standard test methods for flash point by Tag closed tester), 676  
D 93 (Standard test methods for flash point by Pensky-Martens closed tester), 676  
D 648 (Test Method for Deflection Temperature of Plastics under Flexural Load), 247  
E 8 (Methods of tension testings of metallic materials), 676  
E 83 (Methods of verification and classification of extensometers), 676  
E 125 (Reference photographs for magnetic particle indications on ferrous castings), 676  
E 140 (Hardness conversion tables for metals), 676  
E 208 (Drop weight test for nil ductility transition temperature of ferritic steel), 83, 143, 676  
E 647, 479, 481  
E 747 (IQI design requirements), 7  
E 1025 (IQI design requirements), 7  
E 1316 (Standard Terminology for Nondestructive Examination), 4
- American Society of Civil Engineers (ASCE)  
Standard 4-98, 545, 560  
Standard 7-95, 34
- American Society of Civil Engineers Committee on Impact and Impulse Loads, 545
- American Society of Mechanical Engineers (ASME)  
accreditation, globalization of, 534  
acronym/abbreviation, 440  
Criteria Document, 631  
Subcommittee IX, 197
- American Society of Mechanical Engineers (ASME) Board on Conformity Assessment, 276
- American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (Code)  
acronym/abbreviation, 440  
code cases and interpretations, 520, 522  
history, 137, 517  
Section III, Nuclear Components, 121  
Section III, Power Piping codes, 591  
Section XI File, 382
- American Society of Mechanical Engineers (ASME) BPVC Committee  
corrective action opinion, light-water reactor plants, 408  
design rules for openings in nuclear reactor vessels, 156  
requests for interpretations of design detailed, 31  
Special Committee to Review Code Stress Basis, 137
- American Society of Mechanical Engineers (ASME) B 31  
Mechanical Design Technical Committee, 638, 640
- American Society of Mechanical Engineers (ASME) Certificate of Authorization. *See* Certificate of Authorization.
- American Society of Mechanical Engineers (ASME) Certificate Holder (Code Stampholder), 307, 311, 329, 330  
Code cases for, 326–327  
interpretations, 329–330
- American Society of Mechanical Engineers (ASME) *Code Cases: Nuclear Components*, 398
- American Society of Mechanical Engineers (ASME) Code fatigue curves, 645
- American Society of Mechanical Engineers (ASME) Codes and Standards, specific types  
AM-105.1(b) (flange use), 677  
B 1.1 (Unified Inch Screw Heads), 676, 687  
B 1.20.1 (Unified Inch Screw Heads), 676  
B 16.1 (cast iron pipe flanges and flanged fittings), 79, 676–677, 680  
B 16.5 (flange standard), 31, 39, 82, 98, 128, 141, 153, 158, 675–680, 696, 705  
B 16.9 (Factory Made Wrought Steel Butt-Welding Fittings), 625, 627, 630, 676  
B 16.11 (forged fittings, socket-welded and threaded), 676  
B 16.15 (cast bronze threaded fittings, Classes 125 and 250), 676  
B 16.20 (gaskets), 676–677, 680  
B 16.24 (cast copper alloy pipe flanges and flanged fittings, Class 150, 300, 400, 600, 900, 1500, and 2500), 676, 680  
B 16.28 (wrought steel butt-welding short radius elbows and returns), 676  
B 16.34, 365  
B 16.42 (ductile iron pipe flanges and flanged fittings), 82, 676–677  
B 16.47 (large-diameter steel flanges, NPS 26 through NPS 60, also Series A and Series B flanges), 93, 141, 158, 675–676, 680  
B 18.2.2 (square and hex nuts [inch series]), 676  
B 31 Piping Codes, 203, 311  
B 31G (gas pipelines), 433, 437
- American Society of Mechanical Engineers (ASME) Codes and standards, specific types, B 31.1 Power Piping Code, 26, 211, 311, 316, 339–340, 345, 360, 382, 395, 493, 573, 592, 680–681, 703

- American Society of Mechanical Engineers (ASME) Codes and standards, specific types, (*Continued*)
- Appendix D, stress intensification factors, 638
  - branch connections, 639, 640
  - B 31.1-1983 (Power Piping), 622
  - B 31.1-1983, Appendix II, 560, 622
  - B 31.1-1988, 638
  - B 31.1-1998, 641
  - B 31.1-11, 638–639
  - B 31.1-12, 639–640
  - B 31.1-13, 639
  - criteria for piping, Classes 1 and 3, 570
  - flexibility factors, 638
  - piping system, nozzle flexibility, 640
  - repairs requirements, 329
  - stress intensification factors, 638–639
  - Table 112, 681
  - Table 126.1, 681
- American Society of Mechanical Engineers (ASME) Codes and Standards, specific types, B 31.3 Process Piping Code (formerly Chemical Plant and Petroleum Refinery Piping Code), 57, 178–179, 675, 679, 703–704
- Appendix D, stress intensification factors, 638
  - branch connections, 640
  - B 31.3-1999 (Process Piping), 639, 641
  - B 31.3-1b, 639
  - B 31.3-17, 639
  - B 31.3-18, 639
  - B 31.3-X, 639–640
  - B 31.3-Y, 640
  - check of branch end, no nozzle flexibility, 640
  - check of branch end of reducing-branch connection, 639
  - check of branch end with nozzle flexibility, 640
  - check of run ends, 639
  - check of run ends with nozzle flexibility, 640
  - fatigue checks, 639
  - flexibility factors, 638
  - load capacity check, 639
  - piping, nozzle flexibility, 640
  - stress intensification factors, 638–640
- American Society of Mechanical Engineers (ASME) Codes and Standards, specific types
- B 31.4 (Liquid Transportation Systems for Hydrocarbons, Liquid Petroleum Gas, Anhydrous Ammonia, and Alcohols), 675, 681
- American Society of Mechanical Engineers (ASME) Codes and Standards, specific types, B 31.7 (Nuclear Piping), 311, 316, 339, 355, 357, 360, 366, 573
- criteria for Class 1 and 3 piping, 570
  - criteria for Class 1 piping, 570
  - B 31.7-1969 (ANSI B 31.7), stress indices for pressure, moment, and thermal gradient, 629
  - B 31.7(a)-1971, 519
  - B 31.7b-1971, 519, 525
  - B 31.7c, 527
  - B 31.7(c)-1971, 519, 526, 527
- American Society of Mechanical Engineers (ASME) Codes and Standards, specific types
- B 31.8 (Gas Transmission and Distribution Piping Systems), 35, 675, 681
  - B 36.10M (welded and seamless wrought steel pipe), 676
  - NQA-1 (Quality Assurance Program Requirements for Nuclear Facilities), 392
  - NQA-1, Part II, 349
  - NQA-1, Part III, 349
  - NQA-1, QA Program Requirements for Other Certificate Holders, 531
  - NQA-1-1978 (Quality Assurance Program Requirements for Nuclear Power Plants), 522
  - NQA-1-1978, Supplement 2S-2, 522
  - NQA-1-1989, 522
  - NQA-1a-1989, 522
  - NQA-1b-1991, 522
  - PTC 25, 108
  - PTC 25 (pressure relief devices), 676
  - PVHO-1, 131
  - QAI-1, 356
  - QAI-1-1995 (Qualifications for Authorized Inspection), 532, 533
- American Society of Mechanical Engineers (ASME) Code Section III (Rules for Construction of Nuclear Power Plant Components), 131. *See also* Section III.
- definition, 442
- American Society of Mechanical Engineers (ASME) Code Section XI (Rules for Inservice Inspection of Nuclear Power Plant Components). *See also* Section XI.
- definition, 442
- American Society of Mechanical Engineers (ASME) Code Section XI File, Inquiry IN-99-10, 382
- American Society of Mechanical Engineers (ASME) Code Symbol RP, 247, 249
- American Society of Mechanical Engineers (ASME)-designated organization, manufacturer's quality control program, 99
- American Society of Mechanical Engineers (ASME) Ferrous Material Specifications (SA specifications), 360, 443
- SA 7, 137
  - SA 36, 67, 218
  - SA 50S, 228
  - SA 53, 139
  - SA 105, 228–229, 696, 698–699
  - SA 106, 218, 525, 627, 628, 631–633, 635, 639
  - SA 148, 74
  - SA 155, 529
  - SA 181-II, 635
  - SA 182, 114, 649
  - SA 193, 696
  - SA 193-B7, 699
  - SA 201, 647, 649
  - SA 216 WCB, 228
  - SA 225, 647
  - SA 234, 676
  - SA 263, 78, 164
  - SA 264, 78, 164
  - SA 265, 78, 164
  - SA 278, 76
  - SA 283, 67, 140
  - SA 285, 106, 112
  - SA 302, 328, 481, 647, 649
  - SA 320, 142
  - SA 333, 45, 83, 142, 525
  - SA 334, 45, 83, 142
  - SA 336, 114
  - SA 350, 45, 142
  - SA 352, 45, 142
  - SA 353, 83
  - SA 370, 141
  - SA 372, 63, 64, 106
  - SA 387, 71
  - SA 403, 329
  - SA 420, 45, 142
  - SA 476, 76
  - SA 500, 527
  - SA 501, 527
  - SA 508, 83, 114, 142, 426, 427, 481, 525
  - SA 516, 36, 44, 72, 112, 149, 150, 218, 228, 481
  - SA 517, 83, 149, 151



- SA 522, 83  
 SA 533, 426–427, 481  
 SA 533B, 479  
 SA 537, 481  
 SA 541, 114  
 SA 542, 114  
 SA 543, 83  
 SA 553, 83  
 SA 578, 13  
 SA 592, 83  
 SA 609, 13  
 SA 645, 83  
 SA 658, 32  
 SA 671, 529  
 SA 672, 529  
 SA 688, 50  
 SA 691, 529  
 SA 723, 180, 185, 187, 190–191  
 SA 765, 45, 142  
 SA 832, 114
- American Society of Mechanical Engineers (ASME) Interview Team, 531
- American Society of Mechanical Engineers (ASME) Nonferrous Material Specifications (SB specifications), 360, 443  
 SB 162, 105  
 SB 163, 385, 423  
 SB 338, 106  
 SB 359, 106
- American Society of Mechanical Engineers (ASME) Nuclear Survey, 532
- American Society of Mechanical Engineers (ASME) Operations and Maintenance Code for Nuclear Power Plants (O&M Code), 308–309, 324, 378, 522, 564  
 Appendix I, valve Category C pressure-relief devices, 565  
 “IST”, Rules for Inservice Testing of Light-Water Reactor Power Plants, 307  
 OM-1987, Part 3, 622  
 OM-S/G-1990 (Operation and Maintenance of Nuclear Power Plants), Part 3, 545, 593  
 Part 3 Standard, 593  
 Part 3 Standard, allowable steady-state vibration, 594  
 Part 3 Standard, deflection equation for a fixed-guided beam model, carbon steel piping, 614  
 Part 3 Standard, stress reduction factor, 614  
 Parts 6 and 10 Standard, for pump and valve testing, 390  
 on piping vibration, 593  
 plant daily tours, 509  
 Reminder 424, 591  
 required action ranges included in acceptance criteria for SSCs, 562
- S/G (Standards and Guides for Operation and Maintenance of Nuclear Power Plants), 307–308, 522  
 standards, 308–309, 522  
 Subsection ISTB, figure ISTB-5200-1 (Fig. 35.1) (pump vibration limits), 566  
 Subsection ISTB, pumps, inservice test parameters and parameter ranges, 565  
 Subsection ISTB, subject pumps, inservice test parameters and parameter ranges, 565  
 Subsection ISTB-3000, vibration measurement and reference values, 566  
 Subsection ISTC, four categories of valves, 565  
 Subsection ISTC-3500, test requirements for valve categories, 565  
 Subsection ISTC-3600, leak-testing criteria, 565  
 Subsection ISTC-5000, stroke-time acceptance criteria for valves, 565  
 Subsection ISTD (Inservice Testing of Dynamic Restraints [Snubbers] in Light-Water Reactor Power Plants), 567
- American Society of Mechanical Engineers (ASME) Piping Codes, 637
- American Society of Mechanical Engineers (ASME) Section XI Task Group on Operability, 564, 569
- American Society of Mechanical Engineers (ASME) Special Working Group on High Pressure Vessels of Subcommittee VIII (SWG)  
 Bauschinger effect and mean stress in high-pressure vessels, 187  
 Section VIII, Division 3 development, 177  
 surface roughness correction factor reevaluation, 187  
 welding of high-pressure vessels, 193
- American Society of Mechanical Engineers (ASME) Specifications for Welding Rods, Electrodes and Filler Metal. (also ANSI/AWS specifications) (SFA specifications), 70, 210, 219, 230, 443  
 SFA-5.1, 210  
 SFA-5.4, 76  
 SFA-5.9, 76  
 SFA-5.11, 76  
 SFA-5.14, 76  
 SFA-5.22, 76
- American Society of Mechanical Engineers (ASME) Survey Team, 531  
 scope of Survey, 531
- American Society of Mechanical Engineers (ASME) Task Force, on postweld heat treatment of nuclear reactor vessels, 162
- American Society of Mechanical Engineers (ASME) Team Leader, duties, 532–533
- American Society of Mechanical Engineers (ASME) Working Group on Piping Design, 630
- American Standards Association (ASA). *See also* U.S.A. Standards (USAS).  
 B 16.5-1957, 518  
 B 31, 520  
 B 31.1-1955 (Code for Pressure Piping), 518, 627
- American Welding Society (AWS), 137, 203  
 A5.1, filler metal classification, 210  
 classification, 210, 219, 230  
 D1.1, 373  
 referenced, 390  
 specifications, 210, 362, 373  
 Subcommittee IX, 197
- Amplitude control linearity, 12  
 ultrasonic examination, 10
- Analog tape, 12
- Analytical evaluation. *See* Engineering evaluation.
- Angle beam calibrations, of welds, 12–13
- Angle beam scanning, 13  
 for reflectors oriented parallel to the weld, 13  
 for reflectors oriented transverse to the weld, 13  
 of ultrasonic examination, 10, 15
- ANI. *See* Authorized Nuclear Inspector.
- ANII. *See* Authorized Nuclear Inservice Inspector.
- ANIS. *See* Authorized Nuclear Inservice Inspector Supervisor.
- ANIS. *See* Authorized Nuclear Inspector Supervisor.
- Anisotropy, 238
- ANS. *See* American Nuclear Society.
- ANSI. *See* American National Standards Institute.
- A-Numbers, 203–204, 230  
 change, in base metals of welds, 203–204, 210  
 special process essential welding variables, 229
- AORs. *See* Abnormal occurrence reports.
- AOTs. *See* Allowed outage times.
- APHA. *See* American Public Health Association.
- API. *See* American Petroleum Institute.
- Apparent wave-propagation speed, definition, 546

## Appendices

- mandatory, notation, 521
- mandatory, purpose and designation, 306
- mandatory, scope, 521
- nonmandatory, changed to mandatory, 521
- nonmandatory, notation, 521
- nonmandatory, purpose and designation, 306
- nonmandatory, scope, 521
- Applied linings, in pressure vessels, 81–82
- Approved vendor lists, 528
- Appurtenance, definition, 442
- AQT material, 137, 147. *See also* Section VIII, Division 2, part AT.
- Aramid fibers
  - mechanical properties, 236
  - for reinforcing thermosetting resin vessels, 235
- Arc strikes, 84
- Arc welding, 191. *See also* Gas metal arc welding, Gas tungsten arc welding, Shielded metal arc welding.
  - of pressure vessels, 58
- Area replacement method, 103
- Artificial time history, 555
- ASA (American Standards Association). *See* U.S.A. Standards.
- Asbestos, as gasket materials and contact facings, 687
- ASCE. *See* American Society of Civil Engineers.
- ASME. *See* American Society of Mechanical Engineers.
- ASNT. *See* American Society for Nondestructive Testing.
- Aspect ratio of crack, 475, 476
- Assemblies for pressure vessels, dimpled or embossed, 103–105
- Assembly bolt load, 108
- Assess, definition, 442
- ASTM. *See* American Society for Testing and Materials.
- Atomic Energy Commission (AEC). (Later renamed U.S. Nuclear Regulatory Commission [U.S.N.R.C.]). *See also* U.S. Nuclear Regulatory Commission (U.S.N.R.C.).
  - acronym/abbreviation, 440
- Attachment
  - of Class MC containments, 439
  - definition, 442
  - of high-pressure vessels, 191
  - non-pressure-retaining, definition, 442
  - nonstructural, definition, 442
  - for nuclear reactor vessels, 158–159, 165
  - pressure-retaining, definition, 442
  - for pressure vessels, 42
  - structural, definition, 442
- Audits, of QSC organizations, 532
- Audit teams, 519
- Augmented Examination, of Class MC components and metal liners of Class CC components, 455
- Austenitic chromium-nickel stainless steels, for pressure vessels, 75–76
- Austenitic stainless steel all-position electrode, F-Number, 203
- Austenitic stainless steels
  - columbium (niobium) content limit in nuclear reactor vessels, 164
  - fatigue crack growth analysis in air environments, 481–484
  - fatigue crack growth analysis in water environment, 493
  - fatigue curves, 651
  - flaw acceptance standards in Class 1 components, 420–421
  - Heald fatigue tests, 627
  - liquid-penetrant examination, 16
  - piping, fatigue analysis, 631
  - piping, flaw evaluation, 333
  - piping, flaw evaluation, light water reactor plants, 430–433
  - piping, inservice inspection, 315
  - P-number, 203
  - for pressure vessels, 75
- Australia, ASME companies holding B&PV certificates (including nuclear) as of June, 1999, 538
- Authorized Inspection, 521–522
- Authorized Inspection Agency (AIA), 348, 530
  - accreditation, 521–533
  - approval for repairs to Class 1, 2, and 3 systems and components in nuclear power plants, 341
  - approval of Manufacturer's Quality Control System for welding done on nuclear reactor vessels, 341
  - contractual requirements, 532
  - definition, 442
  - inspectors of Class CC containments to have "C" endorsement to their certification, 454
  - interpretations, 329
  - involvement in repair/replacement activities at nuclear power plants, 356
  - involvement requirements in Repair/Replacement Program, 353
  - responsibilities (functions), 521
- Authorized Inspector (AI)
  - acceptance and adoption of nondestructive examination procedures, 4
  - approving adhesive-backed nameplate application, 4
  - definition in Section X, 275–276
  - inspection of brazed joints of pressure vessels, 65
  - inspection of nuclear reactor vessels, 160–161
  - manufacturer's quality control program, 100, 161
  - ovality tolerance of nuclear reactor vessels, 160–161
  - responsibilities for welded pressure vessels, 63
  - responsibility relating to construction of pressure vessels, 31
  - review of WPS at manufacturer location to check production welding, 207
  - third-party inspection waiver for Code-stamped (UM) vessel, 30
  - visual examination written procedure requirements for, 19
  - witnessing nameplate replacement for nuclear reactor vessels, 167
- Authorized Nuclear Inservice Inspector (ANII), 358, 392–393
  - access to records and reports of Owner, 410
  - acronym/abbreviation, 440
  - definition, 306, 442
  - duties at nuclear power plants, 356
  - interpretations used for clarification of requirements, 324
  - metal removal as repair/replacement activity, 345
  - responsibilities, 389
  - review of inspection plan before each inspection interval, 396
  - services, 351
  - and stamping of nuclear power plant items, 352
  - verification for small nuclear power plant items, 348
- Authorized Nuclear Inservice Inspector Supervisor (ANIIS)
  - assessing Owner's Code compliance for nuclear power plant items, 352, 356
  - duties at nuclear power plants, 356
- Authorized Nuclear Inspector (ANI)
  - acronym/abbreviation, 440
  - definition, 442
  - duties at nuclear power plants, 356
  - responsibilities, 521
- Authorized Nuclear Inspector Supervisor (ANIS), 521
  - role in nuclear survey, 532–533
- Authorized Observers,
  - ASME acceptance requirements, 173
  - conducting capacity certification tests, 178
- Autofrettage, of high-pressure vessels, 181–183, 187, 189–192, 194
- Autorefrigeration, 33
  - of nuclear reactor vessels, 144
- Auxiliary feedwater (AFW) systems, Class 3 components exempt from examination, in light-water nuclear plants, 399
- Availability
  - of SSCs, 509, 512–514
  - of SSCs, definition, 520

- Average bearing stress, of nuclear reactor vessels, 138–139. *See also* Stresses.
- Average scram rate, 505
- AWS. *See* American Welding Society.
- Axial bending moment in the shell under the lug, 267
- Axial normal stress in the wall under the lug, 259. *See also* Stresses.
- Axial stresses. *See also* Stresses.  
of piping in light-water reactor plants, 433–434
- BAC. *See* Board on Accreditation and Certification.
- Backfits, 591, 593
- Backfitting of new Code requirements on operating plants, 523
- Backing strips, 3  
for nuclear reactor vessels, 153  
in pressure vessel welds, 50
- Bag molding, 235, 240–242  
advantages, 241–242  
applications, 241–242  
concept, 241–242
- B&PV. *See* Boiler and Pressure Vessel (Code).
- BARC. *See* Board on Accreditation, Registration, and Certification.
- Barrier, 551  
definition, 546
- Bars, ultrasonic examination, 15
- Base material repairs, of nuclear vessels, ultrasonic examination, 15
- Base metal  
change in thickness, 229  
change to another material, 229  
ductility, 224  
welding, polarity, 231  
welding, type of current, 231
- Bath tub curve, 396
- Bauschinger effect, in high-pressure vessels, 182, 185, 187, 190–192
- BCA. *See* Board on Conformity Assessment.
- Beam-element models, 633
- Beam spread, of ultrasonic examination, 15
- Bearings, premature failures and piping fatigue, 591
- Bearing temperature monitoring, 512
- Bedding ply, 241
- Bellows manufacturer, 111
- Bellows material, of expansion joints, 108–111
- Bend ductility testing, 204
- Bending magnification factors, 475, 478
- Bending moment, 273
- Bending parameter ( $\beta$ ), 266
- Bending stress, 124. *See also* Stresses.  
correction factor for, 424  
general fabricating requirements, 43
- Bend testing, 217, 221, 224–225  
ensuring soundness of weldment, 205  
four-point bending tests, 627
- Benzoyl peroxide, 277
- Bernoulli equation, 577
- Bessel functions, 89
- “Best fit” equation, 643
- $B$  factor, 43
- Bilinear crack growth rate law, 479
- Bilinear fatigue crack growth rate curve, 479–485
- Biologically induced corrosion, as piping failure mode, 373, 562
- Biphase systems, 557
- Blach method, 703
- Blisters, of piping, 323
- BNC. *See* Board on Nuclear Codes.
- BNCS. *See* Board on Nuclear Codes and Standard.
- Board on Accreditation and Certification (BAC), 533
- Board on Accreditation, Registration, and Certification (BARC), 533  
formerly Board on Accreditation and Certification (BAC), 533  
renamed Board on Conformity Assessment (BCA), 530
- Board on Conformity Assessment (BCA), 522, 530, 533–534
- Board on Nuclear Codes (BNC), 529
- Board on Nuclear Codes and Standards (BNCS), 447, 521  
acronym/abbreviation, 440
- Board on Pressure Technology Codes and Standards, 529
- Boiler and Pressure Vessel (B&PV) certificates  
in Africa, 534, 538  
in Australia, 534, 538  
in Canada, 534–535  
in Eastern Asia countries, 534, 537  
in Europe, 534, 536  
in Middle East countries, 534, 537  
in North America, 534–535  
in South America, 534, 536  
in United States, 534
- Boiler and Pressure Vessel (B&PV) certificates  
list of, 541–542
- Boiler and Pressure Vessel (B&PV) Code  
acronym/abbreviation, 440
- Boiler and Pressure Vessel Code Main Committee, 446–447, 517–518  
Subcommittee IX, 197
- Boiler and Pressure Vessel Insurance, 46
- Boiler and Pressure Vessel Nuclear Code Cases, 338
- Boiler Construction Code, 1914 Edition*, 137
- Boiling water reactor (BWR), 439  
containment types in United States, 439–440  
environmentally-assisted cracking, 484  
flaw effect on integrity of nuclear components, 314  
hydraulic transient model of BWR control rod-drive system, 600–601  
pump makeup capability, 347
- Boiling water reactor (BWR) plants  
piping vibration case studies, 619–622  
piping weld examinations, 313–314
- Bolt-circle-aspect ratio, 699
- Bolted-Flange Joint Design Rules, 675
- Bolted-flange joints and connections, 631–637. *See also* Flanges.  
for nuclear reactor vessels, 169
- Bolt-hole-flexibility factor, 699
- Bolting, 329  
assembly efficiency, 707–708  
cast iron material not permitted, 76  
efficiency, 707  
elastic interaction, 708  
fatigue analysis, 679  
heat treatment effect, 646  
of high-pressure vessels, 181, 190  
impact-test exemption rules, Section VIII, Division 2, 141  
materials, 32  
for nuclear reactor vessels, 143  
of nuclear vessels, ultrasonic examinations, 15  
pressure-retaining, 422  
pressure-retaining, >2 in. diameter, 422–423  
removal and reinstallation, 329  
spacing requirements, 708  
ultrasonic examination, 15
- Bolt load, 88, 108
- Bolt preload, 128
- Bolt stress, 128
- Boric acid  
accumulation evident of reactor coolant system leakage, 408–409  
leakage testing, 423
- Bounding spectra, definition, 546
- Box headers, noncircular, corner joint detail, 113

- Branch connections, 631, 636–638
  - i*-factors, 637
  - “point spring” concept, 636–638
  - stress indices, 637
- Branch ends (Node 25), 636, 638
- Branch pipe connection welds, examination requirements, 404
- Brass, as gasket materials and contact facings, 687–688
- Braze repair, of pressure vessels, 65
- Brazing, 232–233
  - definition, 65, 232
  - filler metal application, pressure vessels, 65
  - filler metal, maximum design temperatures, 65
  - flow positions, 232–233
  - fluxes, 232
  - F-Number classification system, 232
  - joint clearance, 232
  - joint clearances at brazing temperature, pressure vessels, 65–66
  - joint design, 232
  - joints acceptable for pressure vessels, 65–66
  - of nuclear power plant items, 368–376, 380
  - P-Number classification system, 232
  - post-braze heat treatment, 232
  - of pressure vessels, 65–67
  - processes, 65, 232
  - sleeving of heat exchanger tubing, 385–386
  - tube-to-tubesheet joints, 111
  - variables covered in Section IX, 197
- Breaking-pin devices, 49
- Brinell hardness testing, of forgings of pressure vessels, 64
- British Standard BS-5500, 120
- Brittle fracture, resistance to, 72
- Broadband-response spectrum, definition, 546
- BS base metals, 118, 214
- B1 stress indices, 395
- Bubble test (direct pressure technique), 19
- Bubble test (vacuum box technique), 19
- Buckling, 35, 38, 44
  - of high-pressure vessels, 182, 186
  - of nuclear reactor vessels, 148–149, 151–153, 160–161
  - of RTP-1 F&D head, 262
  - of Section X vessels, 260
  - of straight pipe, 632
  - supports, 570
- Buckling-pin devices, 49
- Buckling stress
  - critical, for bending under wind moment, 263
  - critical, of Section X vessels, 260
- Building foundation, 545
- Building structure, 545
- Bulk flow, 582–584
- Bulk flow velocity, 584
- Burst pressure, 146
  - of nuclear reactor vessels, 148, 157
  - of Section X vessels, 249
- Burst strength, as design factor of pressure vessels, 121
- Butter-bead-temper bead welding, 383
- Butt joint, 83
  - brazing, 67
  - maximum allowable joint efficiencies for arc-and gas-welded joints, 51–52
  - Type No. 1, 161
  - Type No. 2, 161
- Butt lap joint, brazing, 67
- Butt weld, 51–53, 83, 87
  - nominal thickness, 67
  - radiographic examination, 68
- BWR. *See* Boiling water reactors.
- Calculated test pressure, 47
  - definition, 93
- Calibrated screen height, 11
- Calibration blocks
  - of ultrasonic examination, 15
  - for welds, 11, 15
- Calibration reflector(s), 11–13, 15
  - artificial, 12
  - defect-type, 12
  - for welds, 11–12
- Canada
  - ASME companies holding B&PV certificates (including nuclear) as of June, 1999, 534–535
  - Inspector certification, 46
- Canadian Provincial Inspectors, 392
- Cantilever bending tests, 627
- Capacity certification, tests, 108
  - of pressure-relief valves, 173
- Capacity conversions, of safety valve for pressure vessels, 100
- Capillary-type leak standards, 24
- Carbon, requirements for 2 $\Omega$  Cr-1Mo-1/3V weld metal composition, 114
- Carbon arc gouging, 375
- Carbon fibers
  - mechanical properties, 236
  - for reinforcing thermosetting resin vessels, 235
  - veil for nexus lamina, 237
- Carbon-fiber veil lamina, 237–239
  - isotropic in stiffness and strength, 237
- Carbon steel all position, low-hydrogen electrode, F-Numbers, 203
- Carbon steel cellulose-coated electrodes, F-Numbers, 203
- Carbon steel electrodes, F-Numbers, 203
- Carbon steels
  - cyclic stress-strain behavior, 650
  - fatigue curves, 646
  - Markl fatigue tests, 627
  - pipng endurance limit, 593
  - pipng, fatigue analysis, 631
  - P-Number, 202
  - postweld heat treatment of pressure vessels, 58–59
  - pressure vessel construction requirements, 67–73
  - stress allowables for pipng, 594
  - weld cycle, 202
- Carbon steels, specific types
  - EN-2, 647
  - SA-201, 647
- Carbon steel titania-coated electrodes, F-Numbers, 203
- Carbon steel vessels, postweld heat-treated to minimize stress-corrosion cracking, 31
- Cast ductile iron, for pressure vessels, 82–83
- Castings
  - metallic, radiographic examination of, 4
  - for pressure vessels, examination methods required, 98
  - repairs, acceptance of, 98
  - ultrasonic examination, 15
- Cast iron, for pressure vessels, 76, 78, 82–83
- Cast iron pressure vessels, weld repairs, 76
- Cast stainless steels, pipng, ferrite <20%, flaw evaluation, 430
- CAT. *See* Crack arrest temperature.
- Catalyst, 276
- Cavitation, 563, 595, 604
  - choking, 597
  - critical, 597
  - incipient, 597
  - incipient damage, 597
  - in pipng, 322, 595–597, 611, 623
  - supercavitation, 597
- CEN standards, non-ASTM materials, 319



- Center of pressure (CP), 576
- Centrifugal casting, 235, 240, 242  
 applications, 242  
 curing process, 242  
 schematic diagram, 242
- Certificate Holder, use of Code symbol stamp, 167
- Certificate of Accreditation, 530–531  
 corporate, 534  
 issuance and renewal of, 532  
 replacing Interim Letter, 531
- Certificate of Authorization, 329, 361, 530–531  
 application for issuance or renewal, 531  
 for bellows manufacturer, 112  
 Construction Code requirements, 361  
 of manufacturers, diminishing number, 529  
 for Manufacturer to apply Code symbol to nuclear reactor vessel, 167, 172  
 NA-Certificate, repair/replacement requirements, 329, 351, 531  
 N-Certificate, outside U.S., 534  
 N-Certificate, repair requirements, 327, 329, 531  
 not required to perform repairs, 351  
 for nuclear reactor vessels, information guidance, 176  
 of pressure vessels, information included, 130–131  
 as property of ASME, 168–169, 172
- Certificate of Authorization Number for the Fabricator, 519
- Certificate of Compliance (COC), 46, 334, 528, 530  
 definition, 527  
 definition in Repair/Replacement Program, 352  
 Material Manufacturer's ASME Section III, 526  
 with Material Specifications, 528  
 of nuclear reactor vessels, 159  
 of Southeastern Electric Cooperative (SEC) Example Nuclear Plant, 528
- Certification, 517  
 interpretations, 329–330  
 limited, of personnel for nondestructive testing, 4  
 of personnel, 3  
 as unstructured program, 518
- Certification of Capacity, for relief valves, 166
- Certification of Inspection, for nuclear reactor vessels, 166
- Certified Design Report, 316
- Certified Design Specifications, 316
- Certified Individual (CI), 261–262  
 definition, 262, 540
- Certified Material Test Reports (CMTRs), 527, 529
- Certified Stress Report, 357  
 for Class A and B vessels, 357
- CFR. *See* United States Nuclear Regulatory Commission Code of Federal Regulation.
- CGD. *See* Commercial Grade Dedication.
- CGI. *See* Commercial grade items.
- C-glass fibers, weight, 237
- Change-in-flow test, 408
- Charpy V-Notch (CVN) impact testing, 69, 70, 83, 217  
 of high-pressure vessel materials, 181
- Check valves, 578–580
- Chemical analysis  
 of materials, 32  
 of welds, 228, 230
- Chemical energy missile, definition, 559
- Chemical Manufacturers, composition of resins and resin choice, 251
- Chemistry factor, 427
- Chicago Bridge and Iron Company, 146, 148
- Chlorendic bisphenol-A fumarate resins  
 cost, 236  
 curing process, 236  
 high-temperature properties, 236  
 properties, 236
- CHR. *See* Containment heat removal system.
- Chrome (4%–6%), as gasket materials and contact facings, 687–688
- Chromium, requirement for  $2\frac{1}{2}$  Cr-1Mo- $\frac{1}{3}$  V weld metal composition, 114
- Chromium-alloy stainless steels, for lining nuclear reactor vessels, 164–165
- Chromium-molybdenum low-alloy steels (with Cr between  $2\frac{1}{4}$ % and 3%; <85,000 psi minimum tensile strength), P-Number, 203
- Chromium-molybdenum low-alloy steels (with Cr between  $\frac{3}{4}$ % and 2%; total alloy content < $2\frac{3}{4}$ %), P-Number, 203
- Chromium-molybdenum low-alloy steels (with Cr <3% and <85,000 psi minimum tensile strength), P-Number, 203
- Chromium-molybdenum low-alloy steels (with >3%Cr and <85,000 psi minimum tensile strength, P-Number, 203
- Chromium-molybdenum steels, for pressure vessels  
 $2\frac{1}{4}$  Cr-1Mo steels  
 forgings, material specifications, 114  
 plates, material specifications, 114  
 $2\frac{1}{4}$  Cr-1Mo- $\frac{1}{4}$  V steels  
 forgings, material specifications, 114  
 plates, material specifications, 114  
 3Cr-1Mo- $\frac{1}{4}$  V-Ti-B steels  
 forgings, material specifications, 114  
 plates, material specifications, 114
- Chromium-vanadium steels, P-Numbers, 203
- CI. *See* Certified Individual.
- Circumferential butt joint, single-welded, radiograph of, 3
- Circumferential welds  
 examination requirements, 404
- CIT. *See* Computerized imaging techniques.
- Cladding  
 attachments, for nuclear reactor vessels, 158  
 of Class 1 components, 334  
 depth in a flaw, 422–423  
 for high-pressure vessels, 181  
 of light-water reactor plants, 398  
 for nuclear reactor vessels, 164–165  
 temper bead welding, 384  
 ultrasonic examination, 332  
 ultrasonic examination interference, 309  
 ultrasonic examination techniques, 15  
 weld-metal-overlay, 13–14
- Clamp connections, 676  
 of high-pressure vessels, 196  
 of pressure vessels, 107–109
- Clamping devices, 328  
 for Class 2 and 3 piping pressure boundary, 317
- Class A piping, 527  
 certification requirements for integral attachments and component standard supports, 527
- Class A pressure vessels, 357, 527  
 Section III, 518–520  
 Section VIII, Division 2, 519
- Class B impact-tested piping, 527  
 certification requirements for integral attachments and component standard supports, 527
- Class B pressure vessels, 357  
 for Class 1 Nuclear Piping, 527  
 Section III, 519  
 Section VIII, Division 2, 519
- Class C impact tested piping, 519  
 certification requirements for integral attachments and component standard supports, 519
- Class C pressure vessels  
 Section III, 519  
 Section VIII, Division 2, 519

- Class D impact tested piping, 527
  - certification requirements for integral attachments and component standard supports, 527
- Class 1 components, 391–392
  - additional examinations, light-water reactor plants, 402
  - allowable stresses, 678
  - alternate requirements for small items, 349
  - alternative requirements for NPS 1 piping, tubing, 523
  - ASME Code requirement development, 444
  - ASME design stress intensity allowable, 571
  - austenitic stainless steel piping, 385
  - bolting, 678
  - carbon and low-alloy steel piping, 368
  - Component Examination Categories, 403–405
  - criteria for piping, designed to ANSI B 31.1, 570
  - criteria for piping, designed to ANSI B 31.7, 570
  - design-by-analysis approach, 678
  - Design Report certification, 357
  - examination and inspection, light-water reactor plants, 400
  - examination and radiation levels, 392
  - examination exemptions, light-water reactor plants, 398–399, 402
  - examination method of choice, 393
  - examination of manways, 330
  - examination of only integrally welded attachments that meet size requirements, 330
  - examination of piping safe-end welds, 330
  - examination of repair/replacement welds, 330
  - fatigue evaluation, 631–632
  - ferritic vessels, evaluation of flaws, 423
  - flaws, acceptance of, 416–423
  - heat exchangers, plugging by explosive welding, 384
  - heat exchanger tubing, mechanical plugging, 385
  - hydrostatic pressure testing, 406
  - inservice inspection reports, 409
  - inspection summary reports, 409
  - instrument tubing of 1 in. diameter and smaller, 329
  - integrally welded components, 330
  - IWA-4000 requirements, 372
  - mechanical tube plugs, 385
  - nonductile failure prevention, 420
  - nozzles, examination of, 330
  - penetration requirements with MC containments, 446–447
  - peripheral control rod-drive housing weld examination, 332
  - piping, 628
    - piping analysis, 436
    - piping, “as welded” girth butt welds, 636–637
    - piping, “B” equation identification, 625
    - piping, branch connections, 638
    - piping, C&K stress indices, 629
    - piping, Certified Stress Report for, 357
    - piping, check of branch end, 637
    - piping, elbows, 636–637
    - piping, fatigue evaluations, 632
    - piping, flange design, 679
    - piping mechanical joints, 366
    - piping, nozzle flexibility, 640
    - piping, number of welds, 335
    - piping, pressure-testing exemptions, 383
    - piping requirements in Code for Nuclear Piping, 519
    - piping, seismic analysis, 633
    - piping, stresses caused by thermal gradients, 631
    - piping, stress indices for moment loading, 630
    - piping subject to thermal stratification, 493
    - piping welds internal counterbores for ultrasonic examination, 392
  - preservice examination, 494
  - preservice inspection, 378
  - pressure-retaining bolting, 329
  - pressure testing requirements, 333
  - pumps and valves, Design Report for, 357
  - pumps and valves, examination and pressure test requirements, 404–405
  - repair of damaged threads, 376
  - Repair/Replacement Program, 353
  - requirements for pressure-retaining components, welded attachments, and supports, 398
  - requirements, local membrane stresses on pipe wall-thinning, 433
  - requirements of Section XI for repairs, 341
  - restructuring of Code paragraphs/terminology, 339
  - size exemption, 331
  - successive inspections, light-water reactor plants, 402
  - supports, IWF subsection, 329
  - supports, repair/replacement by welding or brazing, 368
  - system leakage test, pressure testing, 380
  - systems, regulatory requirements specified makeup criteria, 346
  - systems, Section XI rules for repair, 334
  - systems, start-up functional testing, dynamic effects, 593
  - systems, testing should include verification by observation and measurement, 593
  - test pressurization boundaries, 407
  - vessels, modification rules, 334
  - visual examination standards, 436
  - visual examination (VT-1), 392
  - volumetric and surface examination exemption (during pressure test), 331
  - welds, conditioning for examination, 315
- Class 2 components, 391–392
  - acceptance standards, 437
  - additional examinations, light-water reactor plants, 402
  - ASME Code requirement development, 444
  - ASME design stress allowable, 571
  - austenitic stainless steel piping, 387
  - carbon and low-alloy steel piping, 369
  - construction, Safety Guide 26, 520
  - criteria for piping, designed to ASME Section III, 570
  - design-by-formula approach, 677
  - Design Report certification, 358
  - Design Reports for, 365
  - examination and inspection, light-water reactor plants, 400
  - examination exemptions, 329
  - examination exemptions, light-water reactor plants, 399, 400
  - examination method of choice, 330
  - examination of manways, 331
  - examination of only integrally welded attachments that meet the size requirement, 331
  - flaw evaluation, 436
  - heat exchangers, plugging by explosive welding, 383
  - heat exchanger tubing, mechanical plugging, 385
  - hydrostatic test alternative, 406
  - hydrostatic tests, 405
  - inservice inspection reports, 409
  - inspection summary reports, 409
  - instrument tubing of 1 inch diameter and smaller, 329
  - integrally welded components, 330
  - IWA-4000 requirements, 372
  - mechanical tube plugs, 385
  - penetration requirements with MC containments, 447–448
  - pipe fittings, longitudinal weld examination, 329
  - piping, 385, 386, 628
    - piping, allowable stresses, 638–639, 679
    - piping, branch connections, 637–639
    - piping, “C” equation identification, 625
    - piping, check of run ends, 637
    - piping, code equation compliance, 637
    - piping, code equations as a fatigue check, 635, 637
    - piping, elbows, 636–637
    - piping, evaluating thermal stresses, 630–631

- mechanical tube plugs, 385
  - moderate-energy piping, flaws in, 334
  - moderate-energy piping, acceptable leakage, 334
  - nonmetallic Cured-In Place Piping, 386
  - pipe and tube, 368
  - piping, acceptable defects in, 368
  - piping, allowable stresses, 639, 679
  - piping, branch connections, 637–638
  - piping, “C” equation identification, 625
  - piping, check of branch ends, 637
  - piping, check of run ends, 637
  - piping, code equation compliance, 638
  - piping, code equations as a fatigue check, 635, 637
  - piping, elbows, 636–637
  - piping, evaluating thermal stresses, 631
  - piping, fatigue checks, 639
  - piping, fatigue evaluations, 633
  - piping, girth butt welds, 636–637
  - piping, leakage, evaluation justification, 436
  - piping, nozzle flexibility, 640
  - piping, pressure testing exemptions, 396
  - piping, stress-intensification factor, 627
  - preservice examination, 394
  - repair of damaged threads, 376
  - requirements for pressure-retaining components, welded attachments, and supports, 398
  - requirements of Section XI for repairs, 343
  - restructuring of Code paragraphs/terminology, 341
  - rupture disk device, 533
  - successive inspections, light-water reactor plants, 402
  - supports, IWF subsection, 329
  - supports, repair/replacement by welding or brazing, 368
  - system leakage test, pressure testing, 394
  - systems, pressure testing, 333
  - systems, regulatory requirements lacking makeup criteria, 346
  - systems, Section XI rules for repair, 334
  - systems, start-up functional testing dynamic effects, 593
  - systems, testing should include verification by observation and measurement, 593
  - test pressurization boundaries, 407
  - upgrading, safety criteria, 329
  - vessels, local stress analysis of shell, 569
  - visual examination (VT-3), 392
  - volumetric examination, 406
  - welds, examination of, 394
- Class CC components/containments
  - ASME Code requirement development, 444
  - component types, 439–441
  - examination and inspection, light-water reactor plants, 400
  - examination exemption, light-water reactor plants, 399
  - free water documentation, 468
  - inaccessible surface areas, 449
  - inservice inspection, 315–316
  - items covered by IWA-4000, 372
  - IWA-4000 requirements, 372
  - liners, additional examinations light-water reactor plants, 404
  - liners, successive inspections, light-water reactor plants, 403
  - metallic liners, ASME Code requirements for, 444–446
  - metallic liners, general requirements for, 446
  - metallic liners, regulatory requirements for containments, 444
  - metallic liners, requirements for metal containments, 446
  - metallic liners, scope and responsibility, 446
  - penetration liners for, 340
  - pressure testing, 392
  - requirements for concrete containments, 446
- Class 3 components, 392
  - additional examination light-water reactor plants, 402–403
  - allowable stresses, 637
  - ASME Code requirement development, 444
  - ASME design stress allowable, 571
  - austenitic stainless steel piping, 385
  - carbon and low-alloy steel piping, 368
  - circumferential welds, 407
  - construction, Safety Guide 26, 520
  - criteria for piping designed to ANSI B 31.1, 570
  - criteria for piping designed to ANSI B 31.7, 570
  - criteria for piping designed to ASME Section III, 570
  - design-by-formula approach, 677
  - Design Reports for, 365
  - examination and inspection, light-water reactor plants, 400
  - examination exemptions, light-water reactor plants, 398–399
  - examination of integrally welded attachments, 331
  - flaw evaluation, 436
  - heat exchangers, plugging by explosive welding, 384
  - heat exchanger tubing, mechanical plugging, 385
  - high energy, carbon steel piping, 385
  - high energy, piping, 386
  - hydrostatic test alternative, 406–407
  - hydrostatic testing, 406
  - instrument tubing of 1 in. diameter and smaller, 329
  - IWA-4000 requirements, 372
  - liquid penetrant examination, 406–407
  - low-energy piping, acceptable leakage, 334
  - low-energy piping, flaws in, 334
  - piping, fatigue checks, 639
  - piping, fatigue evaluations, 631–632
  - piping, girth butt welds, 636, 637
  - piping, nozzle flexibility, 640
  - piping, pressure-testing exemption, 383
  - piping, Section III, 679
  - piping, stress indices for moment loading, 630
  - piping, stress intensification factors, 627
  - piping weld, internal counterbores for ultrasonic examination, 392
  - preservice examination, 395
  - preservice inspection, 376
  - pressure testing, 405
  - repair of damaged threads, 395
  - requirements for pressure-retaining components, welded attachments, and supports, 399
  - requirements of Section XI for repairs, 341
  - restructuring of Code paragraphs/terminology, 339
  - rupture disk device, 533–534
  - size exemption, 331
  - successive inspections, light-water reactor plants, 402
  - supports, IWF subsection, 329
  - supports, repair/replacement by welding or brazing, 368
  - system leakage test, pressure testing, 380
  - systems, inservice volumetric examination, 331
  - systems, pressure testing requirements, 333
  - systems, regulatory requirements lacked makeup criteria, 346
  - systems, Section XI rules for repair, 334
  - systems, start-up functional testing dynamic effects, 593
  - systems, testing should include verification by observation and measurement, 593
  - test pressurization boundaries, 407
  - upgrading, safety criteria, 329
  - vessel examination Category C-A, 329
  - Vessels, Design Report, 357
  - vessels, local stress-analysis of shell, 569
  - vessels, Section III, 679
  - visual examination (VT-2), 392
  - volumetric examination, 407
  - welds, conditioning for examination, 315

- Class CC components/containments (*Continued*)  
 requirements for pressure-retaining components, welded attachments, and supports, 398  
 requirements overview, 439  
 responsible individual inspection, 401  
 restructuring of code paragraphs/terminology, 339  
 rules and requirements, 446  
 scope and responsibility, 446
- Class MC components/containments  
 alternative welding methods, 383  
 ASME Code requirements, development, 444–445  
 coated surfaces, examination requirements, 450  
 containment boundaries, 448  
 containment types, 439–441  
 examination and inspection, light-water reactor plants, 400  
 examination and pressure test requirements, 445–446  
 examination by responsible individual, 450–451  
 examination exemption, light-water reactor plants, 399  
 flaw evaluation, 436  
 inservice inspection, 315  
 inservice nondestructive examination, acceptance and evaluation, 445–446  
 Inspection Programs A and B, 452  
 IWA-4000 requirements, 372  
 painted or coated surfaces, examination requirements, 454  
 penetration requirements with MC containments, 444  
 preservice examination, 445–446  
 pressure testing, 378  
 repair of metal components, 446  
 repair/replacement of metal containments and metal shells, 340  
 repairs and replacements, 452  
 requirement overview, 439  
 requirements, 443–446  
 requirements for pressure-retaining components, welded attachments, and supports, 398  
 responsible individual inspection, 401  
 restructuring of code paragraphs/terminology, 339  
 scope and responsibility, 446, 448  
 successive inspections, 452  
 successive inspections, light-water reactor plants, 402  
 supports, IWF subsection, 329  
 vessels, additional examination, light-water reactor plants, 403  
 vessels, modifying, 334
- Class NF components  
 flaw evaluation, 436  
 visual examination, 436
- Class 600 component, 679
- CLB. *See* Current licensing basis.
- Clevis pins, 608
- Clinch River nuclear power plant, 315
- Closed-form classical discontinuity analysis method, 91
- “Close-in” nozzle-reinforcement requirement, 91
- Closures, of high-pressure vessels, 190
- CMTR. *See* Certified material test report.
- Coated ferritic materials, eddy-current examination, 18
- Coatings  
 of Class MC containments, documentation of reapplication in preservice examination records, 450  
 magnetic-particle examination of, 317  
 of MC containments, examination requirements, 453  
 of nuclear reactor vessels, 167  
 pigmented gel, for fiber-reinforced plastic vessels, 253  
 for pressure vessels, 123  
 preventing atmospheric corrosion of pressure vessels, 119  
 surface-contrast enhancement, 17  
 ultraviolet inhibitors for fiber-reinforced plastic vessels, 252–253
- CODAP (French code), 148
- Code. *See* American Society of Mechanical Engineers Boiler and Pressure Vessel Code.
- Code-allowable stress tables, 137
- Code Bolted-Flange Joint Design Rules, 675
- Code Case index, used in determining suitable material replacements, 529
- Code Cases, 389  
 Construction, 360  
 history, 137  
 of nuclear power plant items, 383–385  
 purpose, 103, 338  
 and Repair/Replacement Plan content, 354  
 Section XI, 352  
 S-Numbers, 203  
 as technical inquiry subject, 1  
 use and content for Section XI, 323
- Code Cases, specific types  
 10, 517, 520  
 141, 679  
 1644, 527  
 1828, 130  
 2211, 168, 195  
 2235, 52, 195  
 2260, 148  
 2261, 148, 149  
 2286, 36, 151–153  
 2311, 48  
 N-7, 520  
 N-9, 520  
 N-71, 527  
 N-122, 571  
 N-236, 334, 444  
 N-249, 527  
 N-284, 152  
 N-318, 571  
 N-335, 324  
 N-335-1, 324  
 N-391, 571  
 N-392, 571  
 N-411, 568  
 N-411-1, 572  
 N-416, 333, 406  
 N-416-1, 380–381, 406  
 N-432, 328, 383  
 N-458-1, 327  
 N-460, 327  
 N-463, 433  
 N-463-1, 327, 437  
 N-471, 327  
 N-480, 324, 433–434, 437  
 N-481, 326  
 N-491-1, 326  
 N-496, 364  
 N-496-2, 364  
 N-498, 406  
 N-498-1, 328, 406  
 N-504-2, 328  
 N-504-2, 385  
 N-508-1, 348  
 N-512, 319  
 N-513, 323, 326–327, 334, 338, 366, 368, 434, 437, 567, 573  
 N-516-1, 384  
 N-517, 326, 334  
 N-517-1, 361  
 N-523, 525  
 N-523-1, 323, 326, 328, 338, 349  
 N-526, 418  
 N-528, 326



- N-528-1, 361
- N-532, 353, 392
- N-540, 531
- N-541, 323, 326
- N-544, 326, 329, 334–335, 385
- N-549, 533–534
- N-552, 327
- N-554-1, 358
- N-555, 397
- N-556, 356
- N-557-1, 385
- N-560, 311, 323–324, 326
- N-561, 328
- N-561-1, 385, 388
- N-562, 328
- N-562-1, 385, 388
- N-567-1, 328, 363
- N-569, 385
- N-573, 326, 373
- N-575, 326
- N-576, 385
- N-577, 323, 326
- N-578, 323, 326
- N-587, 376
- N-588, 327
- N-589, 388
- N-592, 327
- N-593, 326–327
- N-594, 433
- N-594-1-3, 437
- N-597, 324, 327, 366, 368, 433–435, 437
- N-605, 327
- N-606, 328
- N-606-1, 384
- N-613, 327
- N-618, 328
- N-619, 330
- N-622, 327
- N-629, 327
- N-638, 328, 384
- N-640, 326, 568, 573
- N-643, 498, 501
- Code Certification of Authorization, needed for welding organization, 32
- Code compliance, of piping system examples, 637
- Code Data Report, pressure boundary material in nuclear power plants, 343
- Code decisions, 521
- Coded marking, 525
- Code editions, 389
- Code equations, for example piping system, 635
- Code Interpretations. *See* Interpretations.
- Code N-2 Data Report, stamping of bolting, 329
- Code N-5 Data Report, stamping of welds, 329
- Code of Federal Regulations (CFR), acronym/abbreviation, 424. *See* United States Nuclear Regulatory Commission Code of Federal Regulations (USNRC-CFR) for information.
- Code of Record, 528
  - for a component, 530
- Code Partial Data Report for Welded Construction (Form U-2 or U-2A), 32
- Code reconciliation, 517, 524
- Code requirement, explanation of, 3
- Code rules
  - as technical inquiry subject, additional or new, 1
  - as technical inquiry subject, proposed revision of, 1
- Code Stampholder (ASME Certificate Holder), 307
- Code-stamping, of bellows expansion joint, 111
- Code status, maintenance of, 27
- Code symbols
  - U, 48
  - UM, 48, 129
  - UV, 166
- Code Symbol Stamp, 517
  - application on pressure vessels, 129
  - application, significance of, 27
  - establishment of, 519
  - for light water-cooled nuclear power plants, 391
  - not provided with Certificate of Accreditation, 531
  - as property of ASME, 168
  - securing of, from ASME, 517–518
- Code Symbol Stamps, specific types
  - B construction stamp, for brazed construction, 48
  - N-stamp, 477, 531
  - NA symbol stamp, 311, 329, 334, 351, 361
  - ND stamp, 533
  - NPT-stamp, 329, 368, 530–531
  - NV-symbol stamp, 363
  - P-construction stamp, 48
  - RP Symbol Stamp, 249, 276
  - RTP-stamp, 277
  - W construction stamp, 48
- Code terms, 4
- Code Working Group on Piping Design, 628
- Code Z-factor, 703
- Coherence, definition, 546
- Coherence functions, 555
- Collapse load, of nuclear reactor vessels, 171–172
- Columbium. *See* Niobium.
- Combined axial compression and bending, of linear type supports, 571
- Commercial Grade Dedication, 528
- Commercial grade items (CGI)
  - acceptance as is for Section XI, 528
  - USNRC guidelines for, 529
- Commercial grade materials, 527–528
- Committee on Nuclear Quality Assurance, 522
- Committee on Qualification for Authorized Inspection (QAI) (QAI Committee), 533
- Committee on Quality Assurance Program Requirements, 522
- Committee to Review Generic Requirements (USNRC) (CRGR) acronym/abbreviation, 441
- Compact area, of RTP-1 vessels, 251
- Component
  - definition, 306, 442
  - data package inclusions, 530
- Component standard supports, short-term operability acceptance criteria, 570
- Component support, definition, 442
- Composite ferrous electrode, F-Number, 203
- Composite ferrous rods, F-Number, 203
- Compound-bore nozzle, 525
- Compressive strength, of laminae, 238
- Computer programs, for stress analyses of nuclear reactor vessels, 170
- Concrete, missile penetration formulas, 559
- Concrete containment. *See also* Class CC components/containments.
  - definition, 442
- Concrete expansion anchors, short-term operability acceptance criteria, 571
- Concrete vessels, inspection schedule, 402
- Condensate-return lines, thermal shock, 557
- Cone-cylinder junctions, of nuclear reactor vessels, 147–150, 152
- Conical sections, 39
- Connections, of pressure vessels, 57
- Construction, definition, 443, 640

- Construction and maintenance type missiles, definition, 558
- Construction Code Cases, 354
- Construction Codes, 218, 339
  - AISC, supports, 339
  - for Class CC containments, 446
  - definition, 349
  - definition, revision in 1993 Addenda, 339
  - D1.1, supports, 339
  - Draft Pump and Valve Code, 339
  - interpretations on use of requirements, 360–361
  - for light-water reactor plants, 395
  - of light-water reactors, knowledge by Registered Professional Engineer, 446
  - material specifications, changes, 364
  - and mitigation of defects by modification, 366
  - nondestructive examination, 313
  - for nuclear power plant items, 343, 347, 349, 354, 356, 358, 364, 366, 370, 372–373, 376, 379, 384–385
  - referred to by repair and replacement plans, 523
  - for Section III, 316, 332
  - for Section IX, 316, 332
  - for Section XI, 307
  - Section XI, and Owner's Requirements, 358–360
  - of Section XI, compliance with requirements, 528
  - welding, 197, 218, 220
- Construction of pressure vessels. *See also* Pressure vessels.
  - bolted flange connections with ring-type gaskets, 91, 98–101
  - box headers for air-cooled heat exchangers, 113–114
  - brazing fabrication requirements, 65
  - of carbon and low-alloy steels, material requirements, 67, 70–72, 74
  - of cast ductile iron, 82–83
  - of cast iron, 78–79
  - of chromium-molybdenum steels, welding and heat treatment requirements, 114
  - clamp connections, 106–108
  - deflagration, loadings accommodations, 121
  - design, 32–43
  - design and construction details not covered, 31
  - drilled holes not penetrating wall, 113
  - expansion joints, 96–97
  - of ferritic steels with tensile properties enhanced by heat treatment, 83–84
  - flanges, design of, 675–679
  - forging fabrication requirements, 63–64
  - glass-lined, requirements, 111
  - half-pipe jackets, 130–132
  - helically wound, introducing strip-layered steel bars of special section for, 113–114
  - of high-alloy steels, 74–76
  - horizontal vessels, 120
  - hubs of tubesheets and flat heads machined from plate, 105
  - inspection and tests, 44–49
  - integrally forged construction, 106–107
  - jacketed pressure vessels of work-hardened nickel, 99
  - jacketed steam kettles, electrically heated or gas-fired, 105
  - jacketed vessels, 99–101
  - of layered construction fabrication, 84–85
  - linings, 119
  - materials, 32
  - of materials having higher allowable stresses at low temperature, 86–87
  - noncircular cross section, 99, 101
  - of nonferrous materials, 71, 74
  - nonglass-lined, 111
  - nozzle attachment details, 157–158
  - quality control system, 99
  - referenced standards, 31
  - responsibilities, 30–31
  - Section VIII, Division 1, forward, 27
  - Section VIII, Division 1, scope, 27–28, 30
  - temperature protection, 129
  - tubesheet design, 89–92
  - tube-to-tubesheet joints, 116–119
  - vertical vessels, 120
  - welding of material with corrosion-resistant integral cladding, weld metal overlay, or with applied linings, 78–79
  - welding fabrication requirements, 49–58, 60–63
- Construction permit, 531
  - for nuclear power plants, 520, 523
- Contact molding, 235, 240
  - applications, 240
  - chopper gun schematic diagram, 240
  - curing process, 240
  - definition, 240
  - hand lay-up method, 240
  - quality control, 240
  - of shell, 268
  - spray-up method, 240
- Contact wedges, for ultrasonic examination, 10
- Contained fluid energy missile, definition, 558
- Containment heat removal (CHR) system, Class 2 components
  - exempt from examination, 399
- Containment In-Service Inspection Program, 439
- Containment Inspection Program, 439
- Containment pressure tests, 445
- Containment spray system, 505
- Containment surfaces
  - examination requirements, 445–446
  - requiring augmented examination, examination requirements, 455, 457–458
- Containment system, definition, 442
- Containment Type A leakage test, 460
- Containment Type B leakage test, 460
- Containment Type C leakage test, 460
- Containment vessels, examination and pressure testing, 406
- Continuous-monitoring data-acquisition system, for vibration in piping, 608
- Contraction coefficient, 578
- Contract requirements, 3
- Controllers, 530
- Control valves, 620
  - and vibration, 620–621
- Control-volume fluid-dynamics computer codes, 546
- Copper
  - as gasket materials and contact facings, 697–698
  - P-Number, 203
- Copper-base alloy, P-Number, 203
- Copper-base electrodes, F-Number, 203
- Copper-base rods, F-Number, 203
- Copper rods, F-Number, 195
- Core closure welds in castings, 398
- Corner joints, 46
- Corporate certificates, extended to sites, subject to site audit, 531
- Correction factors (Z factors), 431
- Correlation coefficient, 555
  - definition, 547
- Correlation coefficient function, 547
- Corrosion
  - atmospheric, 119
  - of Class MC containments, 445
  - flow-accelerated, 313, 319–320, 324, 368, 562–563
  - microbiologically induced, 373
  - of nuclear power plant items, 319
  - of nuclear reactor vessels, 159

- of piping, 321
- pump casings and valve bodies, 423
- of steam-generator tubing, 328–329
- Corrosion allowance
  - for flanges, 682
  - of nuclear reactor vessels, 172
  - of pressure vessels, 119–120
  - of welds at openings, 57
- Corrosion barriers, 239, 246, 277
  - air bubbles in, 276
  - for Section X, Fabricator's responsibility, 252
  - from Section X vessels, 252
- Corrosion/erosion allowance
  - construction of pressure vessels, 30
  - of nuclear reactor vessels, 139
- Corrosion fatigue
  - of high-pressure vessels, 189
  - of pressure vessels, 664
- Corrosion-resistant integral cladding, of pressure vessels, 81–82
- Corrosion-resistant material, for pressure vessels, internal structures of, 119
- Corrosion-resistant overlay cladding, 398
- Corrosion-resistant weld metal overlay, 227–232
  - welder performance qualification, 232
- Corrugated metal, as gasket materials and contact facings, 687–688
- Coulomb functions, 262
- Counterbores, 312, 315
- Coupled, definition, 547
- Coupled system, 555–556
- Covers
  - flat, 39–41, 70
  - flat, of nuclear reactor vessels, 158
  - spherically dished, 91
  - unstayed flat, 695
- Crack. *See also* Flaws.
- Crack arrest, 87
  - in light-water reactor plant components, 428, 430
- Crack arrest fracture toughness, 428–430
- Crack arrest temperature (CAT), 70
  - stress limit, 70
- Crack depth, 474–478
- Crack growth cycle-by-cycle integration algorithm, 476
- Crack initiation, 648
- Cracklike flaws, acceptance standards developed, 310
- Crack propagation technology, 651–652
- Crack shape factor, 478
- Crack tip stress intensity factor, 189
- Creep, 138
  - of tube or tubesheet material, 118
- Creep-fatigue behavior, of vessels in cyclic service, 138
- Creep resistance, 74
- Crevice corrosion cracking, of piping, 321
- CRGR. *See* Committee to Review Generic Requirements (USNRC).
- Critical crack size, of high pressure vessel, 179, 183, 188
- Critical heat removal systems, 308
- Critical length, of cylindrical shell of Section X, 255
- Critical mass flow rate through the valve, 578
- Critical mass flux for gases, 578
- Cross-bore intersection, 193
- Cryogenic operation, of carbon and low-alloy steel pressure vessels, 70–72
- Cryogenic service, process piping, 680
- Cryogenic temperatures, pressure vessels constructed of materials
  - having higher allowable stresses, 86–87
- C1 stress indices, 395
- Cumulative usage factor, 648
- Cured-in place piping, 386
- Curing
  - of joined RTP-1 vessel parts, 242
  - of resins, 236
- Current checks, 512
- Current licensing basis (CLB), definition, 571
- Cut-and-try method
  - calculating lug dimensions, 265
  - determining thickness of head, 255
- Cutoff frequency, 555
  - definition, 547
- Cut sets, definition, 504
- C-veil lamina, 242
  - compressive strength, 238
  - density, 238
  - fiber content by weight, 238
  - glass content, 237
  - isotropic in stiffness and strength, 237
  - Poisson's ratio, 238
  - reinforcement, C-glass fibres, 238
  - reinforcement weight, 238
  - shear modulus, 238
  - shear strength, 238
  - tensile strength, 238
  - thickness, 237–238
  - Young's modulus, 238
- CVN. *See* Charpy V-Notch impact testing.
- Cycle, definition, 547
- Cycle life, 98
  - of bellows expansion joints, 111
- Cycles, allowable number, of bellows expansion joints, 111
- Cycle-to-cycle numerical integration scheme, 478
- Cyclic loading, 545
  - cumulative damage, 648
  - cyclic stress-strain response of pressure vessel alloys, 650
  - equations of motion and time-dependent loading functions, 549–550
  - exemption from fatigue analysis, 648–649
  - experimental verification of design fatigue curves, 649–650
  - fatigue data for pressure vessel alloys, 650–651
  - fatigue evaluation procedure, 646–648
  - fatigue failure data, 646
  - mean stress effect, 644–646
  - for nuclear reactor vessels, 139
  - stress-strain concentration factors, 644
  - vibratory, 556
- Cyclic motion, 551
- Cyclic softening, 650
- DAC. *See* Distance-amplitude correction, Distance-amplitude curve.
- Damage states, definition, 547
- Damage Tolerant Design Handbook* (U.S. Air Force), 473
- Damping, 545, 547, 549–552, 555, 617–618
  - Coulomb, 555
  - geometric, 555
  - impact, 555
  - material, 555
  - structural, 555–556
  - and vibration in piping, 601–604
  - viscous, 555
  - and vortex shedding, 597
- Damping coefficient, 549
- Darcy friction factor, 577
- Dashpots, 577
- Data package, for components, 530
- Data Report
  - for light water-cooled nuclear power plants, 391
  - of nuclear reactor vessels, 139
  - of nuclear reactor vessels, access openings exemptions noted, 159
  - repair/replacement activities, 351

- Data Report (*Continued*)  
 weld repairs of nuclear reactor vessels noted, 164  
 weld repairs of pressure vessels, 68
- Data Report forms  
 Form A-1, for a Division 2 vessel, 169  
 Form A-2, for part stamping, 169  
 Form N-2, 329  
 Form U-2, for welded construction, 32  
 Form U-2A, for welded construction, 32
- DC. *See* Direct current.
- DED. *See* Division of Engineering Design.
- Default curves, of Section VIII, Division 2, 141
- Defect  
 definition, 411, 307  
 of nuclear power plant items, mitigation by modification, 367–368  
 removal by metal removal, 341  
 removal, in nuclear power plant items, 368–375  
 test failure, 227
- Defining reflector sizing technique, 310
- Definition of Reactor Coolant Pressure Boundary (10CFR50.2), 392
- Deflagration, 31, 34  
 definition, 121  
 internal, 96  
 loadings produced by accommodation, 121–122
- Degradation mechanisms, of piping, 321, 324
- Degraded condition, definition, 368
- Degreasing, in liquid-penetrant examination, 16
- Delta ferrite, limits in pressure vessel stainless steels, 87
- Densitometer, 9  
 calibration, 8
- Density, of laminae, 238
- Deoxidation, 204
- Department of Energy (DOE), Standard 3014, 560
- Derakane 470 resin, 238, 261  
 as matrix for laminate constructed, 245
- Design  
 of assemblies for pressure vessels, dimpled or embossed, 103–105  
 of Division 2 pressure vessels, 138  
 flange-design methods, 680–703  
 flange for external pressure, 697  
 flange joints, for external loads, 703–705  
 of flanges, 92–93  
 flanges for piping, 679–680  
 flanges for pressure vessels, 675–679  
 flange standards, 680  
 of high-pressure vessels, 181–193  
 of integral flat heads for pressure vessels, 103  
 of nuclear power plants, associated with repair/replacement activities, 364–367  
 of nuclear reactor vessels, 143–145  
 of nuclear reactor vessels, flat heads and bolted connections, 158  
 of nuclear reactor vessels, for internal pressure, 146–151  
 of nuclear reactor vessels, shell buckling, 151–153  
 piping, 601–604  
 of pressure vessels, clamp connections, 106–108  
 of pressure vessels, corrosion allowance practice, 119  
 of pressure vessels, deflagration accommodation, 121  
 of pressure vessels, expansion joints, 108–112  
 of pressure vessels, internal structures, 119  
 of pressure vessels, linings, 119  
 of pressure vessels, nonferrous materials, 74  
 of pressure vessels, seamless condenser and heat-exchanger tubes  
   with integral fins, of copper, copper alloy, or titanium alloy, 106  
 of pressure vessels, supports and attachment, 119  
 of pressure vessels, tubesheets, 89, 97, 130, 134  
 RTP-1 qualifications of vessels, 243–247, 249, 251, 260–275  
 Section X Class II vessels, 243–247  
 Section X qualifications of vessels, 249–251  
 of Section X vessels, 249–260  
 of Section X vessels, calculations, 256–260  
 of welded joints in pressure vessels, 49–53
- Design basis, definition, 571
- Design basis accident pressure (Pa), 463
- Design-basis dynamic loads, as consideration in operability evaluation, 564
- Design-basis earthquake, definition, 547
- Design-basis events, 572
- Design-by-analysis, 97
- Design-by-rule analysis, 35, 91  
 of RTP-1 vessels, 251  
 of Section X vessel, 250
- Design-by-stress analysis, 243–246  
 of RTP-1 vessels, 251  
 of Section X vessel, 250
- Design change, 334–345
- Design codes, for light-water reactor plants, 401
- Design condition, 696–697
- Design fatigue usage factor, 493
- Design-ground acceleration, definition, 547
- Design ground-response spectrum, definition, 547
- Design length, 271
- Design life, 649  
 and vibratory loads, 546
- Design life/design lifetime, definition, 442
- Design margin  
 of high-pressure vessels, 183  
 of high-pressure vessels, design cycle calculation, 188–189  
 of light-water reactor plants, 395  
 of nuclear reactor vessels, 172  
 reduction of, 137  
 for stress intensification factors, 625–627
- Design metal temperature, of high-pressure vessels, 182
- Design pressure (MAWP), 36. *See also* Maximum allowable working pressure.  
 of high-pressure vessels, 179  
 of nuclear reactor vessels, 143  
 for pressure vessels, 46  
 of Section X vessels, 240
- Design Report, 277, 357, 362  
 Certified, 315  
 certified by Registered Professional Engineer, 521  
 definition, 442  
 of nuclear reactor vessels, 139  
 prepared by Manufacturer of Division 2 vessels, 138  
 and Repair/Replacement Plan, 355  
 revision and updating, 365  
 Revisions, recertification of, 521
- Design Specifications, 357  
 Certified, 316  
 and Construction Code documentation, 359  
 definition, 442  
 for Division 2 vessels, 138  
 of high-pressure vessels, of User, 178  
 of high-pressure vessels, system of units used, 178  
 loadings, 333  
 of nuclear reactor vessels, 143, 159, 166  
 of nuclear reactor vessels, provided by User, 139  
 and reconciliation documentation, 370  
 reference in Repair/Replacement Plan, 355  
 and rerating of nuclear power plant items, 366  
 revision and updating, 365  
 Revisions, recertification of, 521  
 Section X vessels, 253–254  
 of Section X vessels, corrosion tolerances on nozzle location noted, 253



- Design stress intensity, of nuclear reactor vessels, 144
- Design temperature, of nuclear reactor vessel, 144
- Design thickness, definition, 96
- Detailed visual examination, of Class MC components and metal liners of Class CC containments, 448
- Detector probe technique, 19
- DF designation, for direct firing provision, 48
- Differential equation techniques, to solve fluid flow equations, 583
- Differential shock, 557
- Diffusion process, 483–484
- Digital image acquisition, 6
- Digital image display process, 4
- Digitizing, 10
- Dimethylaniline, 277
- Dimpled assemblies, 103–105
- DIN base metals, 213
- DIN standards, 318–319
- Dip brazing, 64
- Direct current (DC), 211
- Direct current (DC) welding, 213, 231  
change in current, 231
- Direct fired vessels, application limits, 178
- Direct firing  
brazing prohibited, 64  
cast ductile iron material prohibited, 76  
cast iron material prohibited, 76  
of pressure vessels, 50
- Direct-Integration Time-History Method, definition, 547
- Discontinuity, 423  
definition, 307, 411
- Discontinuity stress analysis, of Section X vessels, 249
- Displacement-controlled loading, 564
- Displacement transducers, 602, 607
- Dissimilar metals, in nuclear reactor vessels, 140, 143
- Dissimilar metal welds, 9  
examination requirements, 455  
pressure-retaining examination requirements, 404  
revision of examination category E-F, 454
- Distance-amplitude correction (DAC), 310
- Distance-amplitude curve (DAC), 13–14
- Disturbance time, 582–583
- Division of Engineering Design (DED), of SEC, 526–527
- Docket date, issue by NRC, 531
- DOE. *See* Department of Energy.
- Double-elastic-slope criterion, 147
- Double-elastic-slope method, 172
- Double fillet lap weld, 51, 55
- Double full-fillet lap joints, maximum allowable joint efficiencies for arc-and gas-welded joints, 51–52
- Drafting symbols, for mat-woven-roving laminates, 239
- Draft Pump and Valve Code, 339, 366
- Drag coefficient, 585
- Drilled holes  
not penetrating nuclear reactor vessel wall, 173  
not penetrating pressure vessel wall, 113
- Drop-weight testing, 83  
of nuclear reactor vessel materials, 143
- Dual certification, of stainless steel products, 35
- Ductile iron, for pressure vessels, 82–83
- Duplex stainless steels all-position electrodes, F-Number, 75
- Duplex stainless steels, for pressure vessels, 75–76
- Dwell time, of penetrant, 16
- Dye-penetrant examination, of high-pressure vessels, 182, 188
- Dynamic-earthquake analysis methods, 555
- Dynamic-impulse loadings, 545
- Dynamic loads, 545  
as consideration in operability evaluation, 565  
types, 545–546
- Dynamic-pressure transducers, 607
- EAC. *See* Environmentally-assisted cracking.
- Earthquake cyclic-type dynamic loads, 545
- Earthquake exceedance level, for safe shutdown earthquake, 548
- Earthquake loads, *See also* Seismic loading, 545  
combinations of closely spaced modes, 555  
cutoff-frequency effects, 555  
damping, 555  
direction and time-phase considerations, 555  
effect on nuclear reactor vessels, 143  
floor-response spectra, 553–555  
ground-response spectra, 551, 553  
magnitude, 555  
methods of dynamic-earthquake analysis, 555–556  
missing-mass effects, 555  
primary inertia effects combined with secondary seismic anchor motions, 555–556  
time histories, 555  
time-history duration, 555
- Earthquake occurrence exceedance level, 551
- Earthquake-response time-histories, 551
- Eastern Asia, ASME companies holding B&PV certificates (including nuclear) as of June, 1999, 537
- EBW. *See* Electron beam welding.
- ECC. *See* Emergency core-cooling system.
- Eccentricity of lug forces, 274
- ECCS (European code), 148
- ECP. *See* Electrochemical corrosion potential.
- Eddy-current examination  
calibration, 19  
of coated ferritic materials, 18  
of ERW tubes for pressure vessels, 50  
evaluation, 16  
examining steam-generator tubing, 313–314  
general requirements, 18  
glossary of terms, 18  
installed nonferromagnetic heat exchanger tubing, 18  
of light water-cooled nuclear power plants, 392–393  
nonferromagnetic heat exchanger tubing, 18  
of painted ferritic material surfaces, 327  
performance demonstration, 317  
personnel qualification, 18  
of pressurized water reactor (PWR) steam-generator tubing, 393  
procedure, 18  
reference standard, 18–19  
steam-generator tubing, 332, 393  
as surface examination, 316–317  
of tubular products, 18
- Edge effect, 41
- EDM. *See* Electrodischarge machining.
- Effective mass, definition, 547
- Effective mass ratio, definition, 547
- Effective number of temperature change cycles, of nuclear reactor vessels, 145
- Effective tube pitch, 88
- Effective uplift force from the wind moment, 265
- E-glass fibers, mechanical properties, 236
- EGW. *See* Electrogas welding.
- Eigenfrequencies, 584  
in connecting piping, 581–582, 584
- Eigen-values, 550
- Eigen vectors, 551
- EJMA. *See* Expansion Joint Manufacturer's Association.
- Elastic analysis, of nuclear reactor vessels, 147
- Elastic-foundation analysis, gasket-pressure distribution, 708
- Elastic interaction, 708
- Elastic modulus ratio correction, 651

- Elastic piping-system analyses, 627
- Elastic-plastic analysis
  - of high-pressure vessels, 181–182
  - of nuclear reactor vessels, 170
- Elastic-plastic finite element analysis, 644
  - of high-pressure vessels, 183, 190
- Elastic-plastic fracture mechanics, 651–653
  - for evaluating ferritic piping in light-water reactor plants, 433
- Elastic-plastic shakedown analysis, of high-pressure vessels, 187
- Elastic-plastic strain range fatigue analysis, 652
- Elastic-plastic stress analysis, of high-pressure vessels, 185
- Elastic-plastic theory, 627
- Elastic stress analysis, of girth butt welds, 630
- Elastomers, as gasket materials and contact facings, 687
- Elbow factors, 634
- Elbows, 637–638
  - B-stress indices, 632
- Elbow tests, 629
- Elbow theory, 629
- Electrical resistance brazing, 64
- Electric Power Research Institute (EPRI)
  - multiple structure piping system tests, 568
  - piping acceptance standards published, 313
  - referenced, 390
  - reports on stress indices, flexibility factors, 629
  - sponsored Piping and Fitting Dynamic Reliability Program, 568
- Electric Power Research Institute (EPRI) Reports
  - EPRI NP-719 SR (Flaw Evaluation Procedures), 324
  - EPRI NP-4865, 571
  - EPRI NP-6443 (Improved Criteria for Snubber Testing), 567, 571, 573
  - EPRI TR-101968, 573
- Electric resistance welding (ERW)
  - pipe and tube material, construction requirements, 32
  - of tubes for pressure vessels, 49–50
  - of tubes in pressure vessels, lethal service, 49
  - of welded joints of pressure vessels, 53
- Electrochemical corrosion potential (ECP), controlling susceptibility
  - of PWR to environmentally-assistance cracking, 498
- Electrochemical deposition, sleeving of heat-exchanger tubing, 385
- Electrodes, change in nominal size, 210
- Electrodischarge machining, 374
- Electrogas welding (EGW), 198, 200
  - of welded joints of pressure vessels, 52
- Electromagnetic (Eddy current)(ET). *See also* Eddy current examination.
  - abbreviation, 307
- Electron beam welding (EBW), 198, 202
  - of pressure vessels, 63
- Electronic simulation, 13
- Electroslag remelt method, 105, 173
- Electroslag welding (ESW), 198–199
  - of pressure vessels, 63
- Elevated-temperature properties, water fatigue in low-alloy steels, 661
- Embossed assemblies, 103–105
- Emergency core-cooling systems (ECC), 307, 329
  - Class 2 components exempt from examination, 398
- Emergency operating procedures (EOPs), 506–507
- Endurance limit, 644–645, 651
  - of nuclear reactor vessel materials, 146
  - for nuclear reactor vessels, 172
  - of piping, defined, 594
- Endurance strength, 632
- Energy, Title 10 of the CFR, 392
- Energy losses, unplanned, 505
- Enforcement Authority, 521
  - definition, 306, 442
  - involvement in Section XI activities, 523
- Engineered evaluation, definition, 442
- Engineering evaluation
  - definition, 412
- Engineering Evaluation Report, for Class CC containments, 470
- Engineering judgment, 563
  - definition, 28, 251
- ENP. *See* Example Nuclear Plant.
- Enveloped/Uniform Response Spectra analysis method, 568
- Environmental effects, 643
  - water and fatigue of pressure vessels, 663
- Environmentally-assisted cracking (EAC)
  - of ferritic steels in PWR environments, 653–657
  - of high-pressure vessels, 181–182
  - of pressure vessels, 484–485
  - stress-corrosion cracking, 30–31
- Environmental qualification (EQ), 507
- EOP. *See* Emergency operating procedure.
- “E” plies. *See* Exotherm plies.
- Epoxy resins
  - chemical resistance, 236
  - curing process, 236, 239
  - properties, 236
  - as vessel materials, 235
- EPRI. *See* The Electric Power Research Institute.
- EPS. *See* Equivalent penetrometer sensitivity.
- EQ. *See* Environmental qualification.
- Equipment
  - flexible, definition, 547
  - rigid, definition, 547
- Equivalence, definition, 310
- Equivalent-axial-force method, 704
- Equivalent penetrometer sensitivity (EPS), of image quality indicators (IQIs), 4
- Equivalent-pressure method, 704
- Equivalent static load
  - definition, 547
  - for impact load, 551
  - for impulse load, 550
- Erosion. *See also* Erosion-corrosion.
  - pipe wall-thinning in light-water reactor plants, 433
  - of piping, 322, 324, 326, 433
  - and piping steady-state vibrations, 593
  - pump casings and valve bodies, 423
- ERW. *See* Electric resistance welding.
- Essential variables, 205
  - of welding and brazing, 206, 212–214, 218, 227, 229, 232
- ESW. *See* Electroslag welding.
- ET. *See* Electromagnetic (Eddy current), Eddy-current examination.
- Ethylene, atmospheric pressure boiling temperature of, 33
- Europe, ASME companies holding B&PV certificates (including nuclear) as of June, 1999, 534, 536
- European Community’s Programme for Inspection of Steel Components (PISC) project, 317
- Evaluation, definition, 412, 442
- Evaluation standards, of light-water nuclear plant components, 411
- Evaporators, 29
- Examination, 3
  - definition, 306, 442
- Examination Categories, 403–405
  - definition, 442
- Examination Categories, specific types
  - B-A (vessel welds), 403, 421–422
  - B-B (vessel welds other than reactor vessels), 403, 421–422
  - B-D (full penetration welded nozzles in vessels), 327, 330, 403, 421–422
  - B-F, item B 5.50, 330
  - B-F (pressure-retaining dissimilar metal welds in vessel nozzles), 330, 403–404, 421–422

- B-G-1 (bolting greater than 2 in. in diameter), 330, 403, 404, 421, 422, 423
- B-G-1, Item B 6.10, 327
- B-G-2 (bolting 2 in. in diameter and less), 403–404, 421, 423
- B-H, 330–331
- B-J (pressure-retaining welds in piping), 311–312, 327, 330, 334, 403–404, 421, 422
- B-K (welded attachments for vessels, piping, pumps, and valves), 403, 421, 423
- B-K-1, 330–331
- B-L-1 (pressure-retaining welds in pump casings), 403, 421, 423
- B-L-2 (pump casings), 403–404, 421, 423
- B-M-1 (pressure-retaining welds in valve bodies), 403, 421–422
- B-M-2 (valve bodies), 403–404, 421, 423
- B-N, 324
- B-N-1 (interior of reactor vessel), 331, 403, 421, 423
- B-N-2 (welded core support structures and interior attachments to reactor vessels), 331, 403, 421, 423
- B-N-3 (removable core support structures), 403, 421, 423
- B-O (control rod drive housing welds), 403, 421, 423
- B-O, Item B 14.10 for peripheral control rod-drive housing welds, 331
- B-P (pressure-retaining components), 327, 331, 403–404, 421, 423
- B-Q (steam generator tubing), 403, 421, 423
- C-A, 329, 436–437
- C-B, 436–437
- C-C, 330, 436–437
- C-D, 436–437
- C-E-1, 330
- C-F, 312, 327, 329
- C-F-1, 311, 437
- C-F-2, 311, 437
- C-G, 437
- C-H, 327, 403, 437
- D-A, 330
- D-B, 330, 406
- D-C, 330
- E-A (containment surfaces), 446, 448, 452–454, 456, 459–460
- E-A, revisions (containment surfaces), 457
- E-B, 452–455, 459–460
- E-B, 459
- E-C, 452–456, 459–461
- E-C, revisions (containment surfaces requiring augmented examination), 449
- E-D (seals, gaskets, and moisture barriers), 449, 453–454, 456, 459–460
- E-D, revisions (seals, gaskets, and moisture barriers), 455
- E-F (pressure-retaining dissimilar metal welds), 452–454, 456–457, 459–460
- E-F, revisions (pressure retaining dissimilar metal welds), 455
- E-G (pressure-retaining bolting), 449, 453–454, 457, 459, 461
- E-G, revisions (pressure retaining bolting), 455
- E-P (all pressure-retaining components), 452–453, 456–457, 462
- E-P, revisions (all pressure-retaining components), 455
- E-P, Type B leakage test, 445
- E-Q (acceptance standard for containment examination), 331
- L-A (requirements for concrete), 465
- L-B (requirements for the unbonded post-tensioning system), 464
- Examination programs
  - interpretations affecting, 331
  - Section XI Code Cases for, 328
- Example Nuclear Plant (ENP), 524
  - support material requirements, 526–528
- Example Nuclear Plant (ENP) Preliminary Safety Analysis Report (PSAR), 527
- Exceedance probability, 551
- Exceedance trigger values, 514
- Excessive drag, as support failure mode, 562
- Exemption curves, of nuclear reactor vessels, 140–141
- Exercise test, as inservice test requirement for values, 565
- Exothermic reactions
  - and pressure vessels, 123
  - resin curing, 239
- Exotherm plies (“E” plies), 231–232
- Expansion, sleeving of heat exchanger tubing, 385
- Expansion Joint Manufacturer’s Association’s (EJMA) design method, 108–112
- Expansion joints
  - bellows, thickness equations of EJMA, 108–112
  - flanged and flued or flanged-only, 96–97
  - for pressure vessels and heat exchangers, 108–112
  - short-term operability acceptance criteria, 568–570
- Experimental stress analysis
  - of high-pressure vessels, 193
  - of nuclear reactor vessels, 144, 169, 172
- Explosive clad plate, 13
- Explosively bonded technique, to produce integral cladding on pressure vessels, 78
- Explosive welding, 315, 385
  - for plugging heat exchanger tubing, 385
  - of pressure vessels, 63
  - sleeving of heat exchanger tubing, 385
- Exposures, number of, 8
- Extensional strain, 245–246
- External corrosion allowance, construction of pressure vessels, 30
- External pressure, 91
- Fabrication
  - definition, 442
  - of nuclear reactor vessels, 159–161
  - of nuclear reactor vessels, special requirements, 164–165
- Fabricator
  - accreditation of, 276
  - definition, 240
  - responsible for Section X vessel corrosion barrier design and installation, 252
- Fabricator’s Quality Control System, 261, 275–276
- FAC. *See* Flow-assisted corrosion.
- FAD. *See* Fracture analysis diagram.
- Failure line (*ED*), 644–645
- Fasteners, tightening, 329
- Fast Flux Test Facility (FFTF), 315
- Fast fracture, of high-pressure vessels, 182
- Fast valve closure, 604
  - definition, 599–600
- Fatigue, 591
  - Classes 1, 2, or 3 piping, 631–632
  - evaluation in an operating plant, 494
  - evaluation in light-water reactor plants, 436
  - evaluation procedure, 647–648
  - as piping failure mode, 321, 562
  - of pressure vessel alloys, 649, 651
  - pressure vessels tested in air, 651
  - vibrational, 592
- Fatigue analysis
  - of bolting in pressure vessels, 678
  - computing vibratory stress, 556
  - of high-pressure vessels, 179–184, 187
  - of nuclear reactor vessels, 138–139, 145, 164–165, 169–172
  - of threaded connections of high-pressure vessels, 190
  - of welded joints of nuclear reactor vessels, 161
- Fatigue crack growth
  - behavior schematic showing regions, 474
  - in light-water reactor plant components, 427–428

- Fatigue crack growth analysis, 472–485  
 crack shape changes calculation, 475  
 elastic-plastic crack growth, 478–479  
 evaluation methods, 473–474  
 of ferritic steels in PWR environment, 498–501  
 operating plant fatigue assessment (Section XI, Appendix L), 493–497  
 reference curves: austenitic steels in air environments, 479–481, 482  
 reference curves: austenitic steels in water environment, 485  
 reference curves: ferritic steels in air environments, 478–479  
 reference curves: ferritic steels in water environment, 481–485  
 thermal aging, 479–480
- Fatigue crack growth equation, 412
- Fatigue cracking, 523  
 of half-pipe jackets, 131–132
- Fatigue curves  
 for austenitic stainless steels, 651–652  
 of carbon steels, 659  
 of nickel-iron-chromium alloys, 651
- Fatigue exemption rules, for nuclear reactor vessels, 145
- Fatigue failure, 563
- Fatigue life (S-N), 643, 651
- Fatigue strength reduction factor, 145–146  
 of expansion joints, 111  
 stress indices of nuclear reactor vessels, 157
- Fatigue testing, 172  
 of high-pressure vessels, 182, 192
- Fatigue usage factor, calculation of, 319
- FB. *See* Furnace brazing.
- FCAW. *See* Flux-cored arc welding.
- Federal Register (FR), acronym/abbreviation, 440
- Feedwater nozzles, 524–526
- Ferritic all-position electrodes, F-Number, 203
- Ferritic materials, underwater welding, 340
- Ferritic stainless steels  
 environmentally-assisted cracking in PWR environments, 498–502  
 fatigue crack growth analysis in water environment, 481–485  
 fatigue crack growth rate in air environments, 478–479  
 piping, flaw evaluation, 315, 333  
 for piping, flaw evaluation in light-water reactor plants, 333, 433  
 P-Number, 203  
 for pressure vessels, with tensile properties enhanced by heat treatment, 83–84
- Ferritic steels, Russian, specific types  
 15 Kh2MFA, 479  
 15 Kh2NMFA, 479
- Ferrography, 512
- Ferrule, 202
- f*-factor, 631
- FFTF. *See* Fast Flux Test Facility.
- Fiber bundles, 236–237
- Fiber content by weight, of laminae, 238
- Fiberglass. *See* Fiber-reinforced plastic, RTP-1.
- Fiber manufacturer, design limitations, 250
- Fiber-reinforced plastic (FRP)-composite materials, 235–239  
 curing process, 236  
 joined by adhesives, 236
- Fiber-reinforced plastic (FRP) technology, 235–239, 702
- Filament winding, 235, 240–241  
 bedding ply application, 241  
 cylinder sizes, 241  
 description, 237  
 laminate glass content by weight, 241  
 parting agents, 241  
 quality control, 241  
 schematic diagram, 241
- Filament-wound laminae  
 compressive strength, 238  
 compressive strength in fiber direction vs. cross-fiber direction, 238–239  
 density, 238  
 fiber content by weight, 238  
 fiber diameter, 237  
 fiber number, 237  
 glass content by weight, 237  
 glass-rovings, continuous, 237  
 orthotropic in stiffness and strength, 237  
 Poisson's ratio, 238  
 reinforcement weight, 238  
 shear modulus, 238  
 shear strength, 238  
 tensile strength, 238  
 tensile strength in fiber direction vs. cross-fiber direction, 238  
 thickness, 238  
 weight, 237  
 wind angles, 237  
 Young's modulus, 238
- Filler metal, take form of, 201
- Filler metal classifications, 210  
 F-Numbers, 203, 209–215
- Fillet welds, 51, 53, 54, 67  
 attaching half-pipe jackets to pressure vessel shell, 130–131  
 and dimpled or embossed assemblies, 105  
 non-pressure-retaining, qualification testing for, 221  
 of nuclear reactor vessels, 145, 153, 158–159, 162  
 pressure-retaining, qualification testing for, 221  
 of pressure vessels, 57–60  
 set-through nozzle, 213  
 and slip-on flanges, 690, 693
- Fillet weld test, 213, 225
- Film artifacts, 9
- Film density, 9
- Final Safety Analysis Report (FSAR), 505, 507, 509, 513, 527, 572
- Finished opening, definition, 41
- Finite-element analysis. *See also* Finite-element methods, Finite-element model, Finite-element analysis.  
 for analyzing openings of nuclear reactor vessels, 156–157  
 for calculating stresses of high-pressure vessels, 186–187  
 of fasteners of high-pressure vessels, 190  
 of nuclear reactor vessels, 173  
 for pipe fittings and components, 616–617  
 programs for high-pressure vessels, 182, 189  
 vibration in piping, 620
- Finite-element methods, 91, 704–705, 709. *See also* Finite-element analysis, finite-element model, Finite-element stress analysis.  
 for nuclear reactor vessel stress analysis, 170
- Finite-element models. *See also* Finite-element analysis, Finite-element method, Finite-element stress analysis.  
 for operability evaluation, 568–569
- Finite-element stress analysis. *See also* Finite-element analysis, Finite-element methods, Finite element model.  
 of FRP tanks and vessels, 246  
 for nuclear reactor vessels, 169
- Finned tubes, 32  
 design of, 106
- Fire conditions, 126  
 fire protection equipment, 509
- Fired process tubular heaters, 139  
 construction provisions, 28
- Fire-protection relief devices, 49–50
- Fitness-for-service plan, of high-pressure vessels, 182
- Fittings  
 cast ductile iron, 82  
 NPS 1 and smaller repair/replacement activity, 334



- Flange discontinuity analysis, 682
- Flange regions, bolted, factor of safety, 430
- Flange rigidity factor ( $J$ ), 707–708
- Flange ring, 128
- Flanges
  - allowable stress values, 128
  - Appendix Y, 698–700
  - blind, 695
  - bolt area and spacing, 689
  - bolted, 56, 128–130
  - bolted connections with ring-type gaskets, for pressure vessels, 93–96
  - bolted, of nuclear reactor vessels, 174
  - cast ductile iron, 82
  - of cast iron, 80, 82
  - with clamp-type connections, 681, 703, 700
  - compact-ring, 705
  - corrosion allowance, 682
  - design for external loads, 703–705
  - design for external pressure, 697
  - design for pressure vessels, 675–679
  - design methods, 680–703
  - design rules, new proposed ASME, 705–708
  - dimensions used in Section X calculations, 258
  - effective gasket width, 682, 686
  - elastic interaction, 708
  - ferritic steel, for nuclear reactor vessels, 141
  - fiber-reinforced plastic, 703
  - flat-face, 129
  - flat-face with full-face gaskets, 703
  - flat-head, 682–689
  - forces acting on, 682
  - Gray-Loc-style, 676
  - header design, 703
  - heat treatment, 700
  - integral, 681, 682–686, 687–690, 692, 694, 708
  - joint assembly, 708
  - lap-joint, 682–690
  - loose, 685–689, 691–692, 695, 707–708
  - loose-ring, 705
  - metal-to-metal contact, 129
  - with metal-to-metal contact outside of the bolt circle, 681, 698–700
  - minimum required tightness, 705
  - noncircular, 681–690, 697
  - noncircular with circular bore, 697
  - for nuclear reactor vessels, 158, 169
  - optional, 681–690, 694
  - for penetrating-nozzle-installation-laminate overlays, 243–244
  - for piping, design of, 679–680
  - raised-face, 333
  - raised-face using ring-type gaskets, 682–690, 708
  - rectangular, 703
  - reversed, 681–690, 694–695
  - ring-joint using ring-type gaskets, 681–689
  - shape factor, 699–700
  - short-term operability acceptance criteria, 564, 569–570
  - slip-on, 681–688, 690, 694
  - socket-welding, 684, 690
  - split-ring, 681–690
  - standards, 680
  - stresses, 692–694, 696–698, 700–701, 703, 705–708
  - thicknesses, practical, for Section X, 258
  - threaded, 681–692
  - tightness-based design, 705–708
  - types, 681, 684
  - Van Stone (lap joint), 678
  - weld-neck (integral), 681–688, 690, 692, 694, 708
- Flange welds, 452
  - Category C, 452
- Flashing, 604, 620
  - in piping, 596, 597
- Flat-face flanges, 698, 703
  - Category 1, 129
  - Category 2, 129
  - Category 3, 129
  - class 1, 129
  - class 2, 129
  - class 3, 129
- Flat flow, 233
- Flat-head flanges, 681–689
- Flat heads, 40–41, 51, 57, 70, 103, 173, 695
- Flat metal, as gasket materials and contact facings, 688
- Flaw acceptance criteria and evaluation
  - analytical evaluation of flaws, 423–435
  - in Class 1 components, acceptance of, 416–423
  - Class 2, 3, MC and NF components, 436–437
  - Code Cases for, 326
  - evaluation of examination results, 412–416
  - of ferritic piping, 433
  - interpretations affecting, 322–323
  - pipe wall-thinning, 433–435
  - of plant-operating events, 434
- Flaw removal, 372
- Flaws
  - acceptance standards, 417, 421–423
  - acceptance standards for Class MC and Class CC components, 445
  - aligned linear, 416
  - allowable flaw size, 421
  - analytical evaluation, 310–311, 423–435
  - area of, 416
  - area of laminar, 416
  - aspect ratio of, 413, 416, 421
  - in austenitic stainless steel piping, 431
  - axial separation requirements, 416
  - characterization, 310
  - characterization and proximity rules, 431, 424
  - circumferential, 431
  - cladding, 421–424
  - cladding depth, 412–413, 423–424
  - in Class 1 components, acceptance of, 416–423
  - correction factor for bending stress, 424
  - correction factor for membrane stress, 424
  - correction factors ( $Z$  factors), 431
  - crack growth rate, 475
  - cracklike, 310
  - critical size, 423, 428
  - critical size, emergency and faulted conditions, 428–429, 431
  - critical size, normal and upset conditions, 428, 431
  - curvilinear, 416
  - definition, 307, 342, 411, 443
  - depth, 413, 416, 421, 431
  - documentation of acceptance criteria, 318
  - elliptical, 424
  - and Engineering Evaluation for Class MC containments and metallic liners for Class CC containments, 456–458
  - end of period flaw size, 428, 430
  - evaluation methods of Section XI, 483
  - factor of safety, 429, 431
  - failure bending stress, 431
  - fatigue crack growth, 427
  - ferritic vessel acceptance criteria, 429, 431
  - flaw-shape parameter  $Q$ , 424
  - fracture toughness, 424, 428–431
  - free surface correction factors, 424
  - grouped, 416

Flaws (*Continued*)

- growth analysis considering intergranular stress-corrosion cracking and fatigue crack growth, 431
- laminar, 416, 421
- length, 412–413, 416, 421
- linear, 416–417, 420–421
- linearized stress method for characterization of, 423–424
- linear surface, 416, 420
- maximum total depth, 416, 418
- multiple aligned, 416, 420
- multiple linear surface, 332
- multiple nonaligned coplanar, 416, 418, 420
- multiple parallel, 416, 420
- nonaligned, 416, 420
- nonoverlapping, 416, 420
- nonplanar elliptical subsurfaces, 416–417
- overlapping, 416, 420
- overlapping parallel, 416, 420
- parallel planar, 416
- of piping, 321
- planar, 413–416, 421
- plastic zone correction factor, 424–425
- polynomial stress distribution method for characterization of, 423–424
- reference, dimensions, 310
- repair/replacement for removal, 417
- residual stresses, 424
- safety factor, 429, 431
- stress-corrosion cracking, 431
- stress intensity factor, 421, 423–431, 434,
- subsurface, 415–419, 421, 424, 429, 431
- subsurface, embedded, crack growth, 481
- surface, 413, 415–419, 421, 424, 429, 431
- surface, exposed to air, crack growth, 481
- surface, magnification factors, 475–478
- through-wall separation criteria, 416
- Y-factor for near-surface effects, 421
- Flaw tolerance evaluation, of operating plant, 494–496
- Flexibility factors, 625, 633, 638
  - best estimate, 633, 638
  - conservative, 638
- Floor acceleration
  - definition, 547
  - maximum, 547
- Flow-accelerated corrosion (flow-assisted corrosion-erosion)(FAC), 368
  - of piping, 312, 320–322
  - as piping failure mode, 562
  - requiring functionality assessment, 563
- Flow capacity tests, 195
- Flow coefficient, 578
- Flow-direction (check valves), operability, ASME Code requirements for, 563–564
- Flow-induced vibrations, 643
- Flow orifice, addition to eliminate vibration, 612
- Flow turbulence, 620
- Flued head circumferential weld, 451
- Fluence factor, dimensionless, 427
- Fluid acceleration, 584
- Fluid disturbances
  - bulk flow response, 575
  - waterhammer response, 575
- Fluid flow-induced vibration of structures, 545
- Fluid-flow phenomena, 575–590
- Fluid forces, 575
  - buoyant forces, 575
  - hydrostatic forces, 575
  - lift forces, 575
  - from moving fluids, 575
  - nature of, 575
  - pressure and shear forces from fluid motion, 575
  - pressure forces, 575
  - shear forces, 575
  - from stationary fluids, 575
- Fluidhammer phenomena, 546, 557–558
- Fluid jets, 558
- Fluids, 575–590
  - bulk flow in pipes, 582
  - centrifugal pumps, 575, 581
  - check valve closure, 578–580
  - condensation-induced waterhammer, 581
  - disturbance sources, 577–584
  - estimating fluid-flow forces in pipes, 584
  - forces on submerged structures, 584–585
  - gas cushion, 582
  - impact pressure, 580
  - liquid column impact at area contraction, 580
  - liquid column separation, 580
  - pipe movement, 581
  - pipe rupture, 580
  - positive displacement pumps, 582
  - propagative flow modeling in pipes, 582
  - safety/relief valves (SRV), 578–579
  - standard drag force, 585
  - vortex shedding, 582
- Fluid-structure interaction (FSI), 585–590
  - acoustic disturbances, 588
  - analysis for scale modeling, 586–588
  - cavitation, 589–590
  - incompressible, non-acoustic flows, 588–589
- Flutter loads, 546
- Flux-cored arc welding (FCAW), 199–200
- Flux-cored ferrous electrodes, F-Number, 203
- Flux-cored ferrous rods, F-Number, 203
- Flux-cored wire, as filler metal, 201
- F-Numbers, 203
  - brazing classification system, 232
  - change, in base metals for welds, 209–210, 214
  - No. 1, 203, 214
  - No. 2, 203, 214
  - No. 3, 203, 214
  - No. 4, 203, 210, 214
  - No. 5, 203, 214
  - No. 6, 203, 214
  - No. 21–25 (aluminum alloys), 203, 214
  - No. 23, 203, 214
  - No. 31–37 (copper alloys), 203, 214
  - No. 36, 203, 214
  - No. 41–45 (nickel alloys), 203, 214
  - No. 51–54 (titanium alloys), 203, 214
  - No. 61 (zirconium alloys), 203, 214
  - No. 71, 203, 214
  - No. 72, 203, 214
  - No. 101, 232
  - No. 102 (silver alloys), 233
  - No. 103 (copper-phosphorus alloys), 233
  - No. 104 (aluminum-silicon alloys), 233
  - No. 106 (copper-zinc alloys), 233
  - No. 107 (nickel-base alloys), 233
  - No. 108 (gold alloys), 233
- Footprint load, 262, 271
  - of RTP-1 vessels, 251
- Footprint stress, 270
- Forces. *See* Fluid forces.
- Force transducers, 608
- Forcing function frequency, 545, 602, 603

- Foreign material specification, for Code construction, 214
- Forgings
  - in nuclear reactor vessels, 165
  - of pressure vessels, 63
  - ultrasonic examination, 50
- Form drag, 575, 584
- Forming, of nuclear reactor vessels, 139
- Form N-2, 329
- Form N-3, 340, 351, 531
- Form N-5, 329
- Form NIS-1, 392, 315
- Form NIS-2, 315, 317, 329, 348, 353, 356, 372, 391–392, 524
  - evaluation report as part of, 528
- Form NIS-2A, 353
- Form NM-1, 529
  - Data Report form, 529
- Form NP-1, 519
- Form Q-120, Procedure specification for Section X Class II vessels, 268–269, 294–303
- Form U-2, 32
- Form U-2A, 32
- Fort St. Vrain nuclear power plant, 314
- Foundation, 545
  - definition, 547
- Fourier spectrum, definition, 547
- four-point bending tests, 627
- FR. *See* Federal Register.
- Fracture analysis diagram (FAD), 70, 72
- Fracture mechanics analysis, 179, 182, 187, 188
- Fracture mechanics evaluations, 411, 412
- Fracture safety margins, 68
- Fracture test, 221
  - of welds, 227
- Fracture toughness
  - of high-pressure vessels, 164
  - in light-water reactor plant components, 429, 430
  - of nuclear reactor vessels, and operability, 567–568
  - thermal aging effect, 479, 481
- Fragility, definition, 547
- Fragility level, definition, 547
- Fragility response spectrum, definition, 547
- Free-body diagram, for half-pipe jacket and shell, 130
- Frequency, 546
- Friction welding, of pressure vessels, 58
- FRP. *See* Fiber-reinforced plastic.
- FSAR. *See* Final Safety Analysis Report.
- FSI. *See* Fluid-structure interaction.
- Full-fusion corner joints, 161–162
- Full-penetration welds, 161
  - pressure boundary, 83, 87
- Full qualification, definition, 572
- Function, definition, 504
- Functionality
  - as-built conditions divergent from design, 563
  - assessments, 563
  - nomenclature, 571
- Furan resins, as vessel materials, 235
- Furnace, for postweld heat treatment of welded components, 62
- Furnace brazing (FB), 232
- Fusion welding, 202
  
- Gamma radiation, 23
- Gamma-ray method, for weld examination, 2
- Gap correction factor, 192
- Gas backing, 213
- Gas cushion, 582
- Gasket compressive load, 108
- Gasket factor (*m*), 93, 681
- Gasket reaction, 704
- Gaskets, 129, 385
  - of Class MC containments, 455
  - constants, 705
  - examination requirements, 452
  - flange standards for, 680
  - m*-factors, 707
  - of nuclear reactor vessels, 169
  - process piping, 680
  - replacement of, 329
  - stress, 705
  - stress distribution, 708
  - tightness, 705–708
  - tightness classes, 706–707
  - visual examination and acceptance standards, 459
  - y*-factors, 707
- Gasket stress, 682
  - minimum required cold-bolt-up, 705
  - vs. tightness parameter, 706
- Gas metal arc welding (GMAW), 198, 206, 210, 212, 431
  - composition requirements for  $2\frac{1}{4}\text{Cr-1Mo-}\frac{1}{4}\text{V}$  weld metal, 116
  - flaw acceptance standards, 315
  - of high-alloy steels for pressure vessels, 76
  - for plugging heat exchanger tubing, 383
  - sleeving of heat exchanger tubing, 383
- Gas-shielded arc welding (GSAW), 200–202
- Gas-shielding-flux-cored arc welding, 200, 201
- Gas tungsten-arc temper bead welding, 383
- Gas tungsten arc welding (GTAW), 198, 206, 210, 212, 431
  - composition requirements for  $2\frac{1}{4}\text{Cr-1Mo-}\frac{1}{4}\text{V}$  weld metal, 116
  - flaw acceptance standards, 315
  - of high-alloy steels for pressure vessels, 76
  - for plugging heat exchanger tubing, 383
  - sleeving of heat exchanger tubing, 383
- GDC. *See* General Design Criteria.
- GEN IV reactors. *See* Generation IV reactors.
- Generation IV reactors, 389
- General corrosion, definition, 443
- General Design Criteria (GDC)
  - acronym/abbreviation, 442
  - GDC 16 (Containment Design), 444
  - GDC 50 (Containment Design Basis), 444
  - GDC 51 (Fracture Prevention of Containment Pressure Boundary), 444
  - GDC 52 (Capability for Containment Leakage Rate Testing), 444
  - GDC 53 (Provisions for Containment Testing and Inspection), 444
  - GDC 54 (Systems Penetrating Containment), 444
  - GDC 55 (Reactor Coolant Pressure Boundary), 444
  - GDC 56 (Primary Containment Isolation), 444
  - GDC 57 (Closed System Isolation Values), 444
- General primary membrane stress, 35
- General Visual (GV) examination
  - acronym/abbreviation, 442
  - Class CC revisions replacing VT-1C and VT-3C examination, 460
  - of Class MC components and metal liners of Class CC components, 449
  - compare to examination of pressure-retaining welds, 454
  - of dissimilar metal welds, examination of surface areas, 455
  - examining MC containment surfaces, 449
  - as IWE examination method, 457
  - by qualified personnel, 445
  - replacing VT-3 examination, in E-A examination category, 457
  - by responsible individual, 457
  - revision, containment pressure-retaining bolting, 457
  - revision, containment pressure-retaining surface, 457
  - standards for examination containment surfaces, 457
- Generic Letter 91-18, 571
- Geometrically linear collapse analysis, 148

- Geometric unsharpness, 406  
 limitations, 2, 8  
 values ( $U_g$ ), formula for calculation, 9
- Girth butt welds, 636, 638  
 fatigue testing, 627, 629
- Glass fibers  
 content in filament-wound laminates, 241  
 diameter range, 236  
 reinforcement for ACME 105 vinyl ester resin, 252  
 for reinforcing thermosetting resin vessels, 235
- Glassing operation, 113
- Glass linings, for pressure vessels, 112
- Glass-transition temperature (TG), 248
- Globalization, 534
- Globalization, 534, 536, 538
- Global Standard for nuclear power plant construction, 518
- Glossary, 411–412
- Goodman diagram, modified, 644–645
- “Governing thickness”, 134
- Gravitational potential energy missile, definition, 558
- Gravity, as consideration in operability evaluation, 564
- Gray-Loc-style flanges, 676
- Grinding  
 of piping welds, 313  
 for removing defects from forged pressure vessels, 64  
 of welds to reduce stress-concentration effects of reinforcement, 61
- Groove-and-fillet weld, nominal thickness, 67
- Grooved metal, as gasket materials and contact facings, 688
- Groove weld qualification tests, 222
- Groove welds  
 corrosion-resistant overlay portion, 232  
 nominal thickness, 67  
 qualification testing, 221  
 set-through nozzle, 213
- Ground acceleration  
 definition, 547  
 maximum amplitude, 547
- Ground-response spectrum, 551–553
- Group Numbers, 218  
 of nuclear reactor vessels, testing, 167  
 in P-Number categories, 203  
 and postweld heat treatment of carbon and low-alloy steels, 67
- GSAW. *See* Gas shielded arc welding.
- GTAW. *See* Gas tungsten arc welding.
- Guided-bend tests, 224–225
- GV. *See* General visual examination.
- Half bead weld repair techniques, 383
- Half-pipe jackets, 130–131  
 minimum thickness, 130–131
- Halide Leak Detector Test, 449
- Halogen diode detector probe test, 19
- Hand lay-up method  
 for applying joint plies in joining process, 242  
 of contact molding, 240–241
- Hangers, spring, short-term operating acceptance criteria, 571
- Hardfacing overlay, 227–232
- Hardfacing weld metal overlay, welder performance qualification, 232
- Hardness testing, of forgings of pressure vessels, 64
- Hard-surfacing electrodes, F-Number, 203
- Hard-surfacing rods, F-Number, 203
- Harmful gradient, 163
- HAZ. *See* Heat-affected zone.
- Heads, 255  
 Code flanged and dished (Code F&D), 39  
 conical, 39, 91, 268, 271  
 dished, 268  
 ellipsoidal, 38–39, 43, 53, 91  
 ellipsoidal, of nuclear reactor vessels, 147–148, 170, 172  
 elliptical, 268  
 flanged and dished (F&D), of RTP-1 Vessel, 262  
 flat, 39–41, 51, 57, 70, 103  
 flat, design equations for, 695  
 flat, for nuclear reactor vessel, 173  
 flat, hubs for, 173  
 formed, 38–39, 43, 62, 271  
 formed, attachment details, 53–58  
 formed, of nuclear reactor vessels, 148, 152, 155, 158, 161  
 formed, thickness determination, 121  
 formed torispherical, 39  
 hemispherical, 43, 51, 54  
 hemispherical, of high-pressure vessels, 191–192  
 of high-pressure vessels, 190–192  
 hydrostatic, 123, 144  
 integral flat, 103  
 noncircular, 695  
 seamless formed, 87  
 toriconical, 39, 43  
 torispherical, 38–39, 43, 91  
 torispherical, of nuclear reactor vessels, 147–149, 170, 172  
 torispherical, of RTP-1 vessel, 273–274  
 unstayed flat, 695
- Heat-affected zone (HAZ), 221, 224–225  
 of nuclear reactor vessels, 167  
 of nuclear reactor vessel welds, examination of, 311  
 in pressure vessels, 67–68  
 of pressure vessels, impact testing of, 70–73  
 of welds of pressure vessels, 127
- Heat-affected zone (HAZ) cracking, 75
- Heat-deflection temperature, 248  
 definition, 248
- Heat-distortion temperature. *See* Heat-deflection temperature.
- Heat exchangers, 29, 47  
 air-cooled, alternative corner joint detail for box headers, 113  
 expansion joints, 108–111  
 fixed tubesheet, 56–57  
 fixed tubesheet, radiography of, 52  
 operability evaluation methods, 568–569  
 plugging, 384–385  
 shell-and-tube, 97  
 steam-generating, 29  
 tubesheet design, 87–90  
 tubing, exemption for NPS 1 and smaller size, 346  
 tubing, plugging of, 335, 384–385  
 tubing repair by sleeving, 317  
 tubing, sleeving of, 335, 384–385  
 tubing, thermal shock, 557  
 vortex shedding forces and eigenfrequencies, 584
- Heat-transfer analysis, 630
- Heat treatment  
 of chromium-molybdenum steels for pressure vessels, 114  
 effect on yield strength, 646  
 enhancing tensile properties of ferritic steel pressure vessels, 83–84  
 of high-pressure vessel weldments, 194  
 of nuclear reactor vessel materials, 140  
 of nuclear reactor vessels, 139, 143, 162–164, 167
- Heavy section welding, 201
- Heissdampf Reactor (HDR), tests, 568
- Helical-coil threaded inserts, 364–365
- Helium mass spectrometer (Detector probe technique), 19
- Helium mass spectrometer (Tracer probe and hood technique), 19
- High-alloy materials, impact-test exemption rules, Section VIII, Division 2, 141
- High-alloy steels, for pressure vessels, 74–76



- High-cycle fatigue, and low-cycle fatigue compared, 643
- High-cycle fatigue service, of high-pressure vessel, 187–188
- High-cycle mechanical fatigue, of piping, 321
- High-cycle thermal mixing, 643
- High-energy piping system, 386  
class 3 ferritic steel piping, 328  
definition, 547
- High-pressure safety injection systems, 329
- High-pressure vessels  
analysis techniques, 183–186  
attachments, 191  
bolting, 190  
bolting requirements, 181  
buckling, 182, 185  
cladding, 181  
closures, 190  
concentrically wrapped and welded layered, 192  
corrosion fatigue, 189  
design margin, 182  
design requirements, 181–193  
distortion or leakage from local yielding, 182  
environmental cracking, 180, 182  
external pressure, 185  
fabrication requirements, 194–195  
failure modes, 182  
fast fracture, 182  
fatigue analysis, 179, 182, 187–188  
fitness-for-service plan, 182  
fracture mechanics analysis, 179, 181–183, 186–188  
heads, 190–191  
heat treatment of weldments, 194  
helically wound interlocking strip vessels, 195  
inspection rules, 179  
interlocking strip-wound vessels, 193  
jacket construction, 178  
jackets, heating and cooling, 191  
layered vessels, 191–192, 194–195  
leak-before-burst behavior, 179, 182–183, 194  
linings, 181–182, 194  
loadings, 182  
marking, stamping, reports, and records, 196  
material requirements, 179–181  
monoblock and shrink-fit layered, 179  
openings, 190–191  
organization, 178  
plastic collapse or through-thickness yielding, 182  
pressure-relief devices, 195  
residual stresses, 181–182, 186, 188–191  
responsibilities and duties of User, Manufacturer, and Inspector, 178–179  
scope and jurisdiction, 177–178  
seals, 190–191  
shrink-fit cylindrical shells, 191  
stress-corrosion cracking, 182, 189  
supports, 191  
surface finish correction (roughness) factor, 187  
thermal cutting, 194  
toughness requirements, 178–181  
welded vessels, 193–194  
welding, 194–194  
weld overlay materials, 181  
wire-wound vessels and frames, 192, 195
- High-strength, low-alloy (HSLA) steels  
environmental cracking in high-pressure vessels, 182  
for high-pressure vessels, 194
- High-temperature gas-cooled reactor (HGTR), 314, 410
- High-tuning, 602–604, 618
- Holes  
diameters, 8  
drilled partially in pressure vessel walls, 113  
drilling, in nuclear reactor vessel wall, 173
- Hole-type IQI designation thickness and hole diameters, in., 8
- Hooke's law, 184
- Hoop moment, 267
- Hoop stress, 38, 259, 417. *See also* Stresses.  
of piping in light-water reactor plants, 433–434  
in shell of pressure vessel, 131
- Horizontal flow, 233
- Hostile-environment applications, acoustic emission monitoring, 22
- Housner spectrum, 551
- HTGR. *See* High-temperature gas-cooled reactor.
- Hubs, 105  
of tubesheets and flat heads machined from plate, 173
- Hub stress correction factors, 691
- Hydraulic shock, 557
- Hydrodynamic computer codes, 545, 551
- Hydrodynamic mass, 585
- Hydrogen embrittlement  
of ferritic steel pressure vessels, 84  
of pressure vessels, 67–68, 84
- Hydrogen recombiners, 329
- Hydrogen recombine system, 505
- Hydropneumatic testing, and leak testing, 20
- Hydrostatic pressure  
equation for, 269  
of RTP-1 vessels, 262, 269, 270
- Hydrostatic pressure differential equation, 575
- Hydrostatic pressure testing (10-year), of Class 1, 2, and 3 components, 406
- Hydrostatic testing, 34  
bolted flange connections, 708  
of cast ductile iron pressure vessels, 83  
of cast iron pressure vessels, 78, 83  
of Class 1 components, 406  
of Class 2 components, 406  
Class 2 piping repair or replacement, 406  
of ERW tubes for pressure vessels, 50  
exemptions of small items for nuclear power plants, 345  
of expansion joints, 110  
of ferritic steel pressure vessels, 84  
of finned tubes, 32  
of high-pressure vessels, 194  
of layered pressure vessels, 86  
and leak testing, 20, 317, 333  
of light-water reactor plants, 406  
of lined pressure vessels, 119–120  
of nuclear power plant items, 378–383  
of nuclear reactor vessels, 167  
of pressure vessels, welded joints, 123  
of RTP-1 vessels, exemptions, 252  
of steam-generator feedwater nozzle weld, 526  
test pressurization boundaries, 407
- Hydrostatic test pressure, 47–48
- Hydrotests  
of high-pressure vessels, 119–120  
of high-pressure vessels, inservice, 186  
of high-pressure vessels, preservice, 186  
of nuclear reactor vessels, 164, 167
- IB. *See* Induction brazing.
- IBC. *See* International Building Code.
- Identification markings, 525  
of welders, stamped on nuclear reactor vessels, 161
- IE, Bulletin 79-20, 572
- i*-factors. *See* Stress intensification factors.

- IGSCC. *See* Intergranular stress-corrosion cracking.
- IHSI. *See* Induction heat stress improvement (IHSI) process.
- ILRT. *See* Integrated leakage rate test.
- Image Quality Indicators (IQI)  
 design, 7  
 placement and number, 9  
 plaque- or hole-type, and corresponding diameter of wires, 4  
 selection, 8–9
- Impact loads, 546  
 equations of motion and time-dependent loading functions, 551  
 equivalent static load, 551
- Impact pressure, 582  
 of fluids, 580
- Impact property testing, 203
- Impact-test exemption temperature, of nuclear reactor vessel materials, 141
- Impact testing, 34, 44, 221–222  
 of carbon and low-alloy steels for pressure vessels, 69  
 exemption curves, 68–69  
 exemption rules for nuclear reactor vessel materials, 142  
 of ferritic steel pressure vessels, 83  
 of ferritic steel pressure vessels enhanced by heat treatment, 83  
 of ferrous materials in Section VIII, Division 2, 140  
 of glass-lined pressure vessels, 112  
 of high-alloy steels for pressure vessels, 75  
 of high-pressure vessels, 181–182  
 of nuclear reactor vessel materials, 140–143  
 of nuclear reactor vessels, 160, 167  
 of pressure vessel materials, 50  
 of pressure vessels having higher allowable stresses at low temperature, 87  
 of pressure vessels operated below MDMT, 70
- Impact-type loadings, 545
- Imperfection, 16, 407. *See also* Defects, Flaws.  
 definition, 411, 442, 443
- Impulse loads, 546  
 equations of motion and time-dependent loading functions, 550–551  
 equivalent static load, 550
- Inadequate clearance, as support failure mode, 562
- Inadequate component settings, as support failure mode, 562
- Inconel alloys  
 as high-alloy nonferrous filler material, 74
- Independent support motion method, 568
- Indication  
 definition, 307, 411, 442  
 evaluation in ultrasonic examination, 13
- Individual plant external event evaluation (IPEEE), 507, 509
- Induction brazing (IB), 64, 232
- Induction heat stress improvement (IHSI) process, 329
- Industrywide operating experience, definition, 504
- Inertia and continuous drive friction welding, 198
- Inertia welding, of pressure vessels, 58
- Infrared surveys, 512
- In-motion radiography, 6
- INPO. *See* Institute of Nuclear Power Operations.
- Inquiries to Code Committee  
 Inquiry IN 99-10, 368  
 Inquiry IN 99-31, 360  
 submittal requirements, 173
- Inservice examination, definition, 426–427
- Inservice inspection (ISI), 522–523  
 acronym/abbreviation, 441  
 definition, 443  
 and USNRC Maintenance Rule, 509, 512  
 work plan, 523
- Inservice inspection (ISI) examination, 305, 372  
 component replacement, 311  
 documentation, 314–315, 319  
 documentation, inservice inspection records, 316  
 documentation with records and reports, 311, 316  
 ISI 97-35/MC 98-438 (B&PV Committee Action), 342  
 ISI 98-17/BC 98-382 (B&PV Committee Action), 342  
 NDE examinations, 341  
 pressure tests, 341  
 repair procedure, 311  
 report, 309  
 required, 341, 372, 407  
 risk-informed inspection, 409–410  
 Section XI-required, 341
- Inservice inspection (ISI) program, 311, 317  
 accreditation requirements and, 523  
 agreeing with Repair/Replacement Program edition and addenda, 353  
 insulation removal requirement, 331  
 meeting provisions of the Edition of the Code, 374  
 monitoring frequency, 509  
 monitoring the condition of structures, 512  
 Owner's, 406  
 repair/replacement activity rules, 334
- Inservice inspection (ISI) sampling program development, 329
- Inservice Test Criteria (ISTC)  
 ISTC-3500, 565  
 ISTC-3600, 565  
 ISTC-5000, 565
- Inservice testing (IST), and USNRC Maintenance Rule, 509
- Inspection, 4  
 definition, 306, 443  
 of nuclear reactor vessels, 166–167
- Inspection interval  
 definition, 443  
 periods of, 401
- Inspection period  
 definition, 443
- Inspection program, definition, 443
- Inspection Program A  
 Class MC containments, 452  
 of light-water reactor plants, 396, 401
- Inspection Program B  
 Class MC containments, 452  
 of light-water reactor plants, 396, 401–402
- Inspection records, 277
- Inspector  
 certifying nuclear reactor vessels by signing Data Report, 139  
 definition, 46, 306, 443  
 duties in construction of pressure vessels, 44–46  
 inspection vs. examination defined, 4  
 manufacturer's record of welder or weld operator employment, 61  
 of pressure vessels, 47  
 responsibilities for nuclear reactor vessels, 139  
 for RTP-1, 261
- Installation  
 definition, 443  
 of nuclear power plant items, 368–376
- Institute of Nuclear Power Operations (INPO), 591
- Instrument screen height linearity, ultrasonic examination, 10
- Integral attachment, definition, 443
- Integral flange factors, 690–699
- Integral support, of light-water reactor plants, 400
- Integral welded attachments, short-term operability acceptance criteria, 571
- Integrated Leakage Rate Test (ILRT), 444  
 acronym/abbreviation, 441  
 Type A, 445  
 Type A, Type B, or Type C Periodic, 445
- Intensity, definition, 547

- Intent Interpretations, 173
- Intergranular stress-corrosion cracking (IGSCC), 311, 318–319
  - detection techniques, 327
  - of piping, 319, 324
  - requiring functionality assessment, 563
- Interim Letter, 530–531
  - replaced by Certificate of Accreditation, 531
- Interlocking strips, helically wound, to produce layered pressure vessels, 113
- Internal components, of pressure vessels, 119
- Internal probabilistic evaluation (IPE), 507, 509, 510, 513–514
- International Building Code (IBC), for nuclear power plants, 551
- Interpretations, 173, 328–336
  - agreement with NRC regulations, 337–338
  - Code, purpose, 103
  - notation, 328
  - publishing of, 520
  - requests for, 1
  - revised, 328
  - rules for intent, 323
  - of Section XI, 323, 446
  - as technical inquiry subject, 1
  - use of Construction Code requirements, 360–361
- Interpretations, by specific notation
  - III-1-81-134, 381
  - III-1-83-165, 381
  - III-1-86-95, 381
  - III-1-89-24, 381
  - III-1-89-38, 381
  - VIII-80-10, 47
  - VIII-1-83-29, 49, 125
  - VIII-1-83-100, 62, 67
  - VIII-1-83-104, 29
  - VIII-1-86-201, 29
  - VIII-1-89-267, 221
  - VIII-1-89-268, 72
  - VIII-1-95-48, 30
  - VIII-1-98-57, 32
  - IX-80-67, 213
  - IX-82-02, 199
  - IX-83-03, 206
  - IX-83-159, 217
  - IX-86-03, 206
  - IX-92-78, 205
  - IX-92-79, 223
  - IX-92-92, 205
  - X-1-95-29, 367
  - XI-77-03, 332
  - XI-77-07, 333
  - XI-77-15, 332
  - XI-77-16, 332
  - XI-77-18, 333
  - XI-78-01, 333
  - XI-78-02, 332
  - XI-78-06, 330
  - XI-78-07, 330
  - XI-78-13, 334, 364
  - XI-78-15, 332
  - XI-78-18, 328
  - XI-78-20, 330
  - XI-78-21, 332
  - XI-1-79-01, 329, 360
  - XI-79-05, 330
  - XI-79-11, 330
  - XI-79-12, 330
  - XI-79-13, 332
  - XI-79-14, 328
  - XI-79-16, 330
  - XI-79-17, 334
  - XI-1-79-20, 329
  - XI-80-02, 328
  - XI-80-03, 330
  - XI-80-05, 328–329
  - XI-80-07, 352
  - XI-80-11, 330
  - XI-81-02, 330
  - XI-81-07, 364
  - XI-81-08, 354
  - XI-81-11R, 329, 351
  - XI-82-01, 330
  - XI-82-03, 329
  - XI-1-83-02, 329
  - XI-1-83-04, 330
  - XI-1-83-10, 329, 340, 351
  - XI-1-83-11, 330
  - XI-1-83-12R2, 330
  - XI-1-83-13, 329
  - XI-1-83-25, 333
  - XI-1-83-26R, 329
  - XI-1-83-28, 381, 383
  - XI-1-83-28R, 334, 383
  - XI-1-83-29, 333
  - XI-1-83-30, 329
  - XI-1-83-32, 332
  - XI-1-83-37R2, 383
  - XI-1-83-39, 330
  - XI-1-83-40R, 378
  - XI-1-83-41R, 374
  - XI-1-83-42, 353, 369
  - XI-1-83-43, 374
  - XI-1-83-50R, 361
  - XI-1-83-52, 329
  - XI-1-83-57, 334, 341
  - XI-1-83-58, 333, 383
  - XI-83-63R, 333
  - XI-1-83-66, 333, 378
  - XI-1-83-71R, 329
  - XI-1-83-72, 329
  - XI-1-83-76, 329
  - XI-1-83-78, 329
  - XI-1-83-80R, 329
  - XI-1-83-81, 374
  - XI-1-83-83, 345, 346
  - XI-1-86-05, 329
  - XI-1-86-06, 329
  - XI-1-86-07, 329
  - XI-1-86-08, 330
  - XI-1-86-13R, 379
  - XI-1-86-17, 330
  - XI-1-86-20, 330
  - XI-1-86-21R, 329
  - XI-1-86-23, 369
  - XI-1-86-30R, 330
  - XI-1-86-32, 333
  - XI-1-86-35, 333
  - XI-1-86-36, 334
  - XI-1-86-39R, 361
  - XI-1-86-41, 385
  - XI-1-86-43R, 330
  - XI-1-86-47, 334, 369
  - XI-1-86-51, 354, 364
  - XI-1-86-53, 333
  - XI-1-86-54, 397
  - XI-1-86-55R, 361
  - XI-1-86-58, 334
  - XI-1-86-59, 334

Interpretations, by specific notation (*Continued*)

- XI-1-86-62, 334
- XI-1-86-67, 330
- XI-1-86-74, 402
- XI-1-89-01, 373
- XI-1-89-02, 330
- XI-1-89-04, 334, 345
- XI-1-89-05, 332
- XI-1-89-08, 333
- XI-1-89-11, 332
- XI-1-89-12, 332
- XI-1-89-13, 332
- XI-1-89-16, 332–333
- XI-1-89-19, 334
- XI-1-89-20, 362
- XI-1-89-24, 334, 361
- XI-1-89-28, 334, 391
- XI-1-89-31, 333, 383
- XI-1-89-34, 334
- XI-1-89-35, 374
- XI-1-89-36, 385
- XI-1-89-37, 379
- XI-1-89-40, 334
- XI-1-89-41, 362
- XI-1-89-42, 378
- XI-1-89-44, 334, 378
- XI-1-89-46R, 360
- XI-1-89-51, 329
- XI-1-89-56, 334, 342
- XI-1-89-63, 330
- XI-1-89-64R, 391
- XI-1-89-66, 333
- XI-1-89-67, 390
- XI-1-89-68, 334, 336, 360
- XI-1-89-73, 336
- XI-1-92-03, 390, 411
- XI-1-92-04, 333
- XI-1-92-05, 330
- XI-1-92-07, 329, 330
- XI-1-92-08, 336, 374
- XI-1-92-09, 331
- XI-1-92-13, 331
- XI-1-92-15, 356
- XI-1-92-18, 333
- XI-1-92-19, 333, 390, 408
- XI-1-92-20, 330
- XI-1-92-22, 331
- XI-1-92-27, 329
- XI-1-92-29, 331
- XI-1-92-31, 333, 367, 408
- XI-1-92-32, 336, 346, 385
- XI-1-92-33, 331, 347
- XI-1-92-35R, 378
- XI-1-92-40, 331
- XI-1-92-42, 393
- XI-1-92-43, 331
- XI-1-92-44, 336, 385
- XI-1-92-45, 329, 398
- XI-1-92-46, 331
- XI-1-92-49, 332
- XI-1-92-52, 332
- XI-1-92-56, 336
- XI-1-92-59, 336, 371
- XI-1-92-60, 385
- XI-1-92-66, 385
- XI-1-92-68, 336, 385
- XI-1-92-70, 393
- XI-1-95-01, 333
- XI-1-95-02, 356
- XI-1-95-05, 331
- XI-1-95-09, 351
- XI-1-95-12, 381
- XI-1-95-16, 335
- XI-1-95-25, 329, 367, 371
- XI-1-95-26, 336, 408
- XI-1-95-27, 331
- XI-1-95-28, 331
- XI-1-95-29, 371
- XI-1-95-34, 333
- XI-1-95-35, 332–333
- XI-1-95-37, 381
- XI-1-95-38, 332
- XI-1-95-40, 332
- XI-1-95-41, 332
- XI-1-95-45, 381
- XI-1-95-47, 333
- XI-1-95-48R, 333–334
- XI-1-95-49, 333
- XI-1-95-52, 334, 379
- XI-1-95-54, 334
- XI-1-95-56, 329
- XI-1-95-57, 362
- XI-1-95-60, 374
- XI-1-95-61, 332
- XI-1-95-66, 379
- XI-1-98-01, 380
- XI-1-98-03, 340, 351, 391
- XI-1-98-08, 342, 371
- XI-1-98-20R, 342, 371
- XI-1-98-22, 404
- XI-1-98-42, 378
- XI-1-98-54, 373
- XI-1-98-61, 352, 381
- XI-1-98-62, 351
- XI-1-98-66, 360
- Interpretations Group, of Code Committee, 173
- Intervening element, of light-water reactor plants, 400
- IPE. *See* Internal Probabilistic Evaluation.
- IPEEE. *See* Individual Plant External Event Evaluation.
- IQI. *See* Image quality indicators.
- Iron, as gasket material and contact facings, 687–688
- Irradiated steels, fatigue crack growth analysis, 480–481
- ISI. *See* Inservice Inspection.
- Isophthalic polyester resins
  - applications, 236
  - cost, 236
  - curing process, 236
  - properties, 236
- ISO Registration Program, 533
- Isotropic material, 237
  - shear modulus relation to Young's modulus and Poisson's ratio, 238
- IST. *See* Inservice testing.
- Item, definition, 306, 342–343
- Item Number, Examination, 402–404
- Jacketed vessels, 99
- Jackets
  - construction, of high-pressure vessels, 178
  - half-pipe, 130–131
  - heating and cooling, of high-pressure vessels, 191
- Jaeger test charts, 19
- Jaeger Type No. 2 Standard Chart, 99
- Japanese Joint Research Proprietary Report "Simulation of Test #37 and Parametric Study," 607
- J*-integral, 651
  - for flaws in nuclear reactor vessels, 319



- J*-integral approach, 478
- JIS base metals, 213
- JIS standards, non-ASTM materials, 319
- Joining
  - of RTP-1 vessel parts, 242–243
  - of Section X vessel parts, 242–243
- Joint categories
  - Category A joints, 153–154, 157
  - Category B joints, 153–154, 157
  - Category C joints, 153
  - Category D joints, 153–154
- Joint efficiency, 52, 58, 63, 57, 103, 101
  - and allowable stress values, 126
  - application through flow charts and examples, 121–122
  - of brazed joints, 65
  - of tube-to-tubesheet joints, 116, 118
- Joints, 198–200. *See also* Weldments, Welds.
  - impact testing, 167
  - single-welded circumferential butt, radiograph of, 2
  - tube-to-tubesheet, in pressure vessels, 116–119
- Joint tightness, 682
- Joukowski equation, 580
- Junctions
  - cone knuckle-to-cylinder, 36–37
  - cone-to-cylinder, 36–37
  - cone-to-shell, 36, 39
- Jurisdiction
  - high-pressure vessels, 177–178
  - pressure-relief devices in nuclear reactor vessels, 165
- Jurisdictional Authority, role in accreditation process, 532
- Jurisdictional boundary, definition, 443
  
- Kalnins, Professor Arturs, 146, 148
- Key plant safety functions, applicable to plant design, 513
- Kinematic viscosity, 582–583
- Kirchoff hypothesis, 244
- Kirchoff's plate bending equations, 681
- Knockdown factors, 159
  - of nuclear reactor vessels, 151–152
- Knuckle, 149, 161
  - area of formed heads, 148
  - for flat-bottom tank, 264
  - of RTP-1 vessels, 263
  
- Ladle-analysis of the heat, 527
- Lamé effect, 35–36, 90
- Lamé equation, 703
  - for hoop stress in a thick-walled cylinder, 703
- Laminae
  - compressive strength, 238
  - definition, 236
  - density, 238
  - fiber content by weight, 238
  - Poisson's ratio, 238
  - reinforcement weight, 238
  - shear modulus, 238
  - shear strength, 238
  - tensile strength, 238
  - thickness, 238
  - types, 236–239
  - Young's modulus, 238
- Laminar flaw, definition, 395. *See also* Flaws, laminar.
- Laminar reflectors
- Laminate
  - corrosion barrier, 237, 245
  - definition, 236
  - filament-wound, 239
  - homogeneous, stresses of, 245–247
  - mat-woven-roving, 239, 268
  - mat-woven-roving 7-ply example, 240, 245, 254–256, 259–260
  - normal stress distribution in direction perpendicular to bending, 245–246
  - normal stress from bending load in bending direction, 245–246
  - normal stress in load direction for extensional strain, 245
  - normal stress perpendicular to load direction for extensional strain, 245
  - nozzle attachment, 259, 268
  - penetrating-nozzle-installation-laminate overlays, 243, 244
  - RTP-1 properties, mat woven-roving, 261
  - Section X, realizable attachment and reinforcing pad thicknesses, 260
  - sequence notation, 239–240
- Laminate sequences, 239
- Laminate stack-up, 239–240
- Lamination analysis, 243
- Laminations
  - in nuclear reactor vessels, 160
  - in plate material, 105
- Lamination theory, 239, 244
  - description, 235
- Laminators, definition, 277
- Lanyard potentiometers, 607
- Lap joint
  - brazing, 66
  - flanges, 681, 684, 686
- Laser beam welding (LBW), 198, 202
  - of pressure vessels, 63
  - sleeving of heat exchanger tubing, 383
- Layered construction, for fabricating pressure vessels, 84, 191
- Layered vessel
  - definition, 84
  - of high-pressure vessels, 190–192
  - hydrostatic testing, 194
- LBW. *See* Laser beam welding.
- LCO. *See* Limiting condition for operating.
- L designation, for lethal service provision, 48
- Leakage, 563
- Leak-before-break, of high-pressure vessels, 179
- Leak-before-burst behavior, of high-pressure vessels, 179, 182–183, 191, 194
- Leak-detection application, acoustic emission monitoring, 22
- Leak testing (LT), 19–20, 328
  - abbreviation, 307
  - calibration, 20
  - of Class MC and Class CC components of light-water reactor plants, 399
  - documentation, 20
  - equipment (gages), 20
  - evaluation, 20
  - formula symbols, 20
  - and hydrostatic pressure tests compared, 20, 317, 333
  - inservice test requirements for values, 565
  - in lieu of 10 year hydrostatic test, 317
  - of light-water reactor plants, 406–407
  - of nuclear power plant items, 394–396
  - procedure, 19–20
  - record retention, 20
  - requirements, 20
  - technique, 20
- Leak-tight integrity, definition, 547
- Leak-tightness factor, for nuclear reactor vessel flanges, 169
- LEFM. *See* Linear-elastic fracture mechanics.
- Length of the tensile perimeter, 266
- LERs. *See* Licensee Event Reports.
- Lethal service, 47, 50, 52
  - of carbon steel pressure vessels, prohibition of, 67

- Lethal service (*Continued*)
- cast ductile iron pressure vessels, prohibited, 82
  - definition, 30, 49
  - of jacketed pressure vessels, 99
  - of layered pressure vessels, 84–85
  - of low-alloy steel pressure vessels, 68
  - of nuclear reactor vessels, 139, 153–154, 162–163, 168
  - of pressure vessels, 72, 82
  - pressure vessels, brazing prohibition, 64
  - and radiographic examination of welded joints, 123
  - steel castings use for, 98
  - vessels exempted from Section X scope, 247
- Lethal substances, 50
- definition, 30, 49
- Level I NDE personnel, 394
- qualification examinations, experience, and responsibilities, 394
- Level II NDE personnel, 394
- qualification examinations, experience, and responsibilities, 394
- Level II-R certification, 394
- Level III NDE personnel, qualification examinations, experience, and responsibilities, 394
- Licensee Event Reports (LERs), 562, 591
- Life fraction approach, 187
- Lift force, oscillating, 584
- Ligament efficiency, 35, 121
- f tubesheet, 87–88
  - method, 103
- Light water-cooled nuclear power plants, 389–410
- additional examinations, 402–403
  - application and classifications, 392
  - Code Cases application, 398
  - component support examinations, 400, 405
  - Construction Code for, 390, 400, 408
  - containment vessel examination, 405
  - corrective action, 407, 408
  - examination and inspection, 392, 400
  - examination and pressure test requirements, 403–405
  - Examination Category Table, 403–404
  - examination exemptions, 398–399
  - inservice degradation and restoration through repair/replacement activities, 390–391
  - inspection line lists for each system, 396
  - inspection piping and instrument diagrams (P&IDs), 396
  - inspection plans and schedules, 395–396
  - inspection program, 395–396, 401–402
  - Inspection Program A, 396, 401
  - inspection schedule, 401–402
  - inspection summary reports, 409
  - instruments for system hydrostatic tests, 409
  - jurisdiction, 391
  - nondestructive examination personnel qualifications, 393–394
  - Owner's responsibility, 392
  - Owner's Specifications (Design Specifications), 399
  - periodic system pressure tests, 406
  - plant walkdown experience for personnel certification, 394
  - preservice examinations combined with construction code shop and field examinations, 400
  - pressure test requirements, 406–407
  - quality assurance criteria, 392
  - quality group classifications, 392
  - referenced standards and specifications, 392
  - reinforced concrete containment vessel portions and their post-tensioning systems exempt from examination, 400
  - retention of records and reports, 409
  - standard review plan, 392
  - steam-generator tubing, inspections, 402–403
  - successive inspections, 402
  - surface examination requirements, 409
  - system pressure tests, 405–406
  - system pressure tests for repair/replacement activities, 406
  - Technical Specifications, 400, 402
  - test pressurization boundaries, 407
  - test records, 409
  - Three Mile Island (TMI)-related requirements for containment integrity, 443
  - ultrasonic examination qualification of nondestructive examination personnel, 394
  - unbonded post-tensioning systems, examination of, 405
  - visual examination, 407
  - visual examination, personnel qualification, and the responsible engineer, 401
  - visual examination, personnel qualification, and the responsible individual, 400, 401
  - weld reference system, 398
- Light-water reactor piping systems, vibration experiences, 590–591
- Limit analysis, of nuclear reactor vessels, 170–171
- Limited zone monitoring, acoustic emission monitoring, 22
- Limiting Condition for Operation (LCO), 562
- Limit load, 632
- Limit load criterion, 626
- Limit pressure of a cylindrical shell, 146–147
- Linear cumulative-damage hypothesis, 632
- Linear-elastic analysis, of high-pressure analysis, 182, 184, 185
- Linear-elastic finite element analysis, of high-pressure analysis, 183
- Linear-elastic fracture mechanics (LEFM), 423, 429–430
- applied to flaw, 309
  - assessing flaws effects on nuclear components, 314
  - for evaluating ferritic piping in light-water reactor plants, 433
- Linear flaw, definition, 395. *See also* Flaws, linear.
- Linearized stress method, 424
- Linear stress-strain law, of laminae, 244
- Linear-type supports, short-term operability acceptance criteria, 570–571
- Linear-variable differential transformer (LVDT), 607, 621
- Line of support, 272
- Linings
- for high-pressure vessels, 194–195
  - for nuclear reactor vessels, 164–165
  - of pressure vessels, 108, 119
  - refractory, for pressure vessels, 129
  - rubber, for steel vessels, 252
- Liquidhammer. *See* Fluidhammer.
- Liquid metal-cooled fast-breeder nuclear power plants (LMFBR), 314
- Liquid penetrant (PT) examination, 15–16
- abbreviation, 307
  - of bellows expansion joints, 111
  - of brazed joints of pressure vessels, 65
  - of cast iron welds in pressure vessels, 76
  - contaminants, control of, 15
  - of corner joints, 46
  - after defect removal in nuclear reactor vessels, 159
  - determining surface linear flaws, 416
  - documentation and records, 16
  - equipment, 15
  - evaluation, 16
  - of forgings of pressure vessels, 64
  - of high-alloy steels for pressure vessels, 75
  - of high-pressure vessels, 196
  - of hubs of tubesheets and flat heads, 105
  - of integrally forged pressure vessel, 106
  - interpretation and light intensity, 15
  - of light-water reactor plants, 392, 406
  - of nuclear reactor vessels, 172
  - of pressure vessels having higher allowable stresses at low temperature, 87

- of pressure vessels, methods for, 98
- of pressure vessels of nonferrous materials, 74
- procedures and procedure revisions, 15
- of steel castings of pressure vessels, 98
- surface preparation, 15
- techniques, 15
- of welded joints of pressure vessels, 81
- of welds around openings and all attachment welds, 47
  - of welds of nuclear reactor vessels, 154, 162, 164
- LLRT. *See* Local Leakage Rate Tests.
- LMFBR. *See* Liquid metal-cooled fast-breeder nuclear power plants.
- Load capacity-ratings, 527
- LOCA. *See* Loss of coolant accident.
- Local area, definition, 146
- Local corrosion, of piping, 321
- Local fluence (*f*), 427
- Local Leakage Rate Tests (LLRT), 444–445
  - acronym/abbreviation, 441
- Local postweld heat treatment, task force, 163
- Local primary membrane stress, 87. *See also* Stresses.
- Local regions, 146
- Local thin areas, 165
  - of nuclear reactor vessels, 146
- Location marker requirements, 8
- Lockup,
  - as support failure mode, 562
- Longitudinal bend test, 224, 225
- Longitudinal stresses. *See also* Stresses.
  - in piping in light-water reactor plants, 433–434
- Longitudinal welds, 86, 436. *See also* Weldments, Welds.
  - examination of, 329
- Loose hub flange factors, 692
- Loss-of-coolant accident (LOCA), 563
  - as consideration in operability evaluation, 563
- Low-alloy steel electrodes, F-Number, 203
- Low-alloy steel, 621
  - Low-alloy steels, 647
    - cyclic stress-strain behavior, 649
    - fatigue curve, 646–647
    - P-Number, 203
    - postweld heat treatment of pressure vessels, 61–62
    - pressure vessel construction requirements, 66–74
- Low-cycle fatigue
  - definition, 547
  - and high-cycle fatigue compared, 643
  - service of high-pressure vessels, 187–188
- Low-damping frequency, 546
- Low-energy piping, 334
- Low-pressure containers, 21
- Low-stress stamps
  - to identify welds in light-water reactor plants, 398
- Low-temperature heavy-water reactor (LTHWR), 324
- Low-temperature overpressure protection (LTOP) systems, 327
- Low-tuning, 602–604
- LT. *See* Leak testing.
- LTHWR. *See* Low-temperature heavy-water reactor.
- LTOP. *See* Low-temperature overpressure protection systems.
- Lube oil analysis, 512
- Lugs
  - analysis input values, 266
  - failure modes, 267
  - force on, 265
  - hold-down, for RTP-1 vessel, 264–268
  - yield strength, 265
- LVDT. *See* Linear-variable differential transformer.
- Mach number, definition, 597
- Macroexamination, 221
  - of welds, 221, 225
- Magnetic-particle (MT) examination, 16–18, 98
  - abbreviation, 307
  - calibration of equipment, 17
  - of cast iron welds in pressure vessels, 79–80
  - of coated materials, 317
  - of corner joints, 46
    - after defect removal in nuclear reactor vessels, 159
  - demagnetization, 17
  - determining surface linear flaws, 416
  - equipment, 17
  - evaluation, 24
  - examination medium, 17
  - of ferritic steel pressure vessels, 84
  - of forgings of pressure vessels, 64
  - of high-pressure vessels, 182, 189
  - of hub of tubesheets and flat heads, 105
  - of integrally forged pressure vessels, 106
  - of layered pressure vessels, 84–85
  - lifting power of yokes, 17
  - of light-water reactor plants, 392, 406
  - magnetic field adequacy and direction, 17
  - of nuclear reactor vessel materials, 141–143
  - of nuclear reactor vessels, 172
  - of painted ferritic material surfaces, 327
  - of pressure vessels, methods for, 98
  - procedure/technique, 17
  - records, 17
  - rectified current, 17
  - of steel castings of pressure vessels, 98
  - surface conditioning, 17
  - techniques, 174
    - of welds around openings and all attachment welds, 48
    - of welds of nuclear reactor vessels, 154, 162, 164
- Magnetic-particle field indicator, 17–18
- Magnification factors, 475, 478–479
- Magnitude, definition, 548
- Main Committee of N626 Committee on Qualifications and Duties for Authorized Nuclear Inspection and Specialized Professional Engineers, 533
- Main Committee on Qualifications and Duties for Authorized Nuclear Inspection and Specialized Professional Engineers, 521
- Maintenance, 319
  - definition, 504
  - programmed, 507
  - programmed, definition, 504
- Maintenance-preventable functional failure (MPFF), 508–509, 511, 515
  - definition, 504, 511
  - direct, 504
  - indirect, 504
  - initial, 504, 509
  - monitoring of, 504, 511
  - repetitive, 504, 508–509, 511
- Maintenance Rule. *See* USNRC Maintenance Rule.
- Maintenance shutdowns, and inservice examination and system pressure tests, 402
- Mandatory submittal of technical inquiries (Appendix II of Section V), 1
- Manganese, requirements for 20Cr-1Mo-1/3V weld metal compound, 204
- Manganese sulfides, in pressure vessel water environment, 482–483
- Manganese-vanadium (Mn-V) steels, P-Number, 203
- Manholes, in nuclear reactor vessels, 159
- Man load, 261
- Manual for Steel Construction* (AISC), 38

- Manually-operated valves (MOV), 577–578
- Manual welding, 315
- Manufacturer
- of bellows, Partial Data Report required, 111
  - certification of welders and weld operators for pressure vessels, 63
  - definition of, 31, 240
  - developing procedures for ultrasonic examination of pumps and valves, 15
  - generating welding procedures, 161
  - maintaining records of brazers or operators, qualification tests and identification, 66
  - maintenance of nuclear reactor vessel file of material certifications, examinations, testing, heat treatments, manufacturing procedures, and drawings, 169
  - preparing Certification of Capacity of relief valves, 166
  - qualification of welder as responsibility, 204
  - quality control system, 168
  - responsibilities in construction of pressure vessels, 44
  - responsibilities in design of Division 2 vessels, 138
  - responsibilities with design of nuclear reactor vessels, 139
  - responsibility for radiograph review, interpretation, and evaluation, 9
  - responsibility for Standard Welding Procedure Specification use, signed and dated forms, 204
  - responsibility for welding of nuclear reactor vessel, 161
  - responsible for safety of nuclear reactor vessels, 166
  - serial number, 48
  - welded or weld operator employment record, 61
  - welding of test coupon, 205
  - written practice, limited certification of personnel, 4
- Manufacturer's certificate of compliance, 210
- Manufacturer's Data Form (MDF), 129
- Form U1 (Manufacturer's Data Report for Pressure Vessels), 129
  - Form U-1A (Manufacturer's Data Report for Pressure Vessels), 129
  - Form U-2 (Partial Data Report), 129
  - Form U-2A (Manufacturer's Partial Data Report), 129
  - Form U-3 (Manufacturer's Certificate of Compliance), 129
  - Form U-4 (Manufacturer's Data Report Supplementary Sheet), 129
- Manufacturer's Data Report (MDR), 316, 357
- maintained in pressure vessel quality control system, 99
  - maintenance of radiographs and records of pressure vessels, 63
  - of nuclear reactor vessels, lining material used, 165
  - of nuclear reactor vessels, preparation guidelines, 173–174
  - for pressure vessels, 49
  - of pressure vessels, Appendix 19 use noted in "Remarks" section, 105
  - of pressure vessels, Appendix 20 use noted in "Remarks" section, 105
  - of pressure vessels, Appendix 21 use noted in "Remarks" section, 105
  - of pressure vessels, Appendix 23 use noted in "Remarks" section, 106
  - of pressure vessels having higher allowable stresses at low temperature, 87
  - of pressure vessels, preparation guide, 129
  - of pressure vessels, reduced MAWP shown, 112
  - repair/replacement items, 329
  - responsibilities of Manufacturer, 169
  - and ultrasonic examination of pressure vessel welds, 99
- Manufacturer's Design Report, of nuclear reactor vessels, 139
- Manufacturer's Quality Control System, for nuclear reactor vessels, 167
- Manufacturers Standardization Society (MSS) of the Valve and Fittings Industry, Inc., standards
- SP-6, 181
  - SP-44, 181
  - SP-58, 527
  - SP-61 (Hydrostatic Testing of Steel Valves), 518
  - SP-66 (Pressure Temperature Ratings for steel Butt-Welding End Valves), 518
- Manufacturer's trade name, 210
- Manways, 268, 696
- examination of Class 1 and 2 components, 330
  - opening, of Section X vessels, 258–259
  - of RTP-1 vessel, 272
- Manway-to-vessel welds, 330
- MAPP. *See* Oxygen-methylacetylene-propadiene gas.
- MARC FE code, 147
- Marker placement, 8
- Marking
- of high-pressure vessels, 196
  - of nuclear reactor vessels, 168
- Mark I fatigue tests, 630, 632
- Mark I/George fatigue tests, 627
- Mark I-type fatigue tests, 626–627, 630, 632
- Mark I containments, repair welding for torus supports, 444
- Mark I reinforced concrete containments, 440
- Mark I steel containments, 444
- Mark II reinforced concrete containments, 444
- Mark II reinforced concrete post-tensioned wetwell containments, 444
- Mark II steel containments, 444
- Mark III reinforced concrete containments, 444
- Martensitic all-position electrodes, F-Numbers, 203
- Martensitic stainless steels, P-Number, 203
- Mass conservation principle for a flexible, nonuniform flow passage, 577
- Mass ratio effect, 554
- "Master Curve" approach, 327
- Material
- definition, 443
  - non-ASTM, use provisions, 319
  - plate, 33
- Material Certifications, 316, 334, 357
- Material fatigue, 591
- Material flow stress, 480
- Material Manufacturer (MM), 361–362
- heat treatment information of nuclear reactor vessel materials, 143
  - responsibilities for nuclear reactor vessels, 140
- Material Manufacturer (MM) certificate, 531
- Material Organization (MO), 531, 341
- Material procurement, 528
- Material-receiving reports, 277
- Materials documentation, 529
- Material Specifications, annullment in material procurement, 529
- Material Supplier (MS) certificate, 531
- Material Suppliers (MS), 361
- Material test report, 46
- Mathcad program, 255, 275
- Mathcad worksheet, 262
- Mathematical modeling, 319
- Mat lamina
- applications, 236
  - compressive strength, 238
  - density, 238
  - fiber content by weight, 238
  - fiberglass-reinforcing, 236
  - isotropic in stiffness and strength, 237
  - Poisson's ratio, 238
  - product forms, 236
  - reinforcement weight, 238
  - shear modulus, 238
  - shear strength, 238
  - tensile strength, 238
  - tensile strength same in both directions, 238



- thickness, 238  
 weight (oz./ft.<sup>2</sup>), 236  
 Young's modulus, 238
- Mat-woven-rovings laminates, 269  
 design calculations for properties, 254–260  
 drafting symbols, 239
- Mat-woven-rovings laminate sequences, 239
- MAWP. *See* Maximum allowable working pressure.
- Maximum allowable compressive stress, 37. *See also* Stresses.
- Maximum allowable external pressure  
 of cylindrical shell of Section X, 255  
 of finned tubes, 106  
 for Section X elliptical head, 254
- Maximum allowable longitudinal compressive stress, 35
- Maximum allowable temperature, of Section X vessels intended for Section IV potable-water use, 248
- Maximum allowable tensile stress, 35
- Maximum allowable working pressure (MAWP), 33, 36, 46–47  
 of cast ductile iron pressure vessels, 83  
 of cast iron pressure vessels, 76–77  
 for cylinders, 91  
 of forged pressure vessels, 63  
 of glass-lined pressure vessels, 111  
 of lower shell segment of RTP-1, 273  
 of nuclear reactor vessels, 165  
 and pressure-relief devices, 49  
 for pressure vessels, 46, 48  
 of RTP-1 vessels, 275  
 of Section X vessels intended for Section IV potable-water use, 248  
 stamped on integrally forged pressure vessel with “Appendix 22,” 100  
 on top head of RTP-1 vessel, 270–271  
 of work-hardened nickel inner shell of jacketed vessel, 105
- Maximum anticipated operating pressure, and valve set pressure (design pressure of vessel), 126
- Maximum bending stress. *See also* Stresses.  
 in homogeneous laminate, 244
- Maximum design temperature, 33  
 of pressure vessel walls, 119
- Maximum external moment to avoid leakage, 704
- Maximum general primary membrane stress, 35
- Maximum (peak) ground acceleration, definition, 548
- Maximum shear stress theory of failure (Tresca criterion), 144, 169, 182, 518, 646
- Maximum unit radial load on the overwrap, 265
- MDF. *See* Manufacturer's Data Form.
- MDM. *See* Metal disintegration machining.
- MDMT. *See* Minimum design metal temperature.
- MDR. *See* Manufacturer's Data Report.
- Mean metal temperature, 33
- Mean stress  
 and cyclic loading, 644–646  
 of high-pressure vessels, 189–190
- Mean stress component, 646
- Mean stress intensity factor correction, for high-pressure vessels, 189
- Mechanical clamping devices, 328, 349
- Mechanical-property test reports, 277
- Mechanical shock, 34
- Mechanical tests, 46  
 of brazed joints, 65  
 of hubbed tubesheets, 57  
 of materials, 32  
 qualification test effort, 205
- Mechanical tube plugs, 347
- Membrane stress, 87, 262. *See also* Stresses.  
 correction factor for, 424  
 plus secondary bending stress, 91
- Metal-cored wire, as filler metal, 201
- Metal disintegration machining (MDM), 375
- Metallic inert gas (MIG) process, 201
- Metallic liners. *See* Class CC containments, Class MC containments.
- Metallic vessels, acoustic emission examination during pressure testing, 21
- Metal Properties Council, reference crack growth curve as task group development for Section XI, 479, 481
- Metal removal, 341–342, 345  
 and nuclear power plant items, 372  
 from piping weld crown, 335
- m*-gasket factor, 681
- Microbiologically-induced corrosion, of piping, 319
- Microvoids, in high-pressure vessels, 185
- Middle East countries, ASME companies holding B&PV certificates (including nuclear) as of June, 1999, 533
- MIG. *See* Metallic inert gas welding.
- Mill test report (MTR), 525
- Miner's Rule, of cumulative damage, 172, 187, 494
- Minimum collapse pressure (*B*), 106
- Minimum design metal temperature (MDMT), 33, 44, 47  
 of carbon and low-alloy steel pressure vessels, 70  
 determination of, 121  
 of ferritic steel pressure vessels enhanced by heat treatment, 83  
 of high-alloy steel, 76  
 of high-pressure vessels, 178, 182  
 at maximum allowable working pressure, 48  
 of nuclear reactor vessels, 144  
 of nuclear reactor vessels, and impact testing requirement, 141  
 of pressure vessel, determination of, 141  
 pressure vessel possible to operate below, 70  
 and test pressure of nuclear reactor vessel, 167
- Minimum design seating stress ( $\gamma$ ), 91. *See also* Stresses.
- Minimum test pressure, for pressure vessels, 47
- Von Mises criterion, 184  
 deciding if stress state is excessive, 247  
 of RTP-1 vessel, 275
- Von Mises stress distribution, 184–185, 192
- Von Mises theory of failure, 170
- Von Mises yield criterion, 182, 190, 632
- Missiles, 558–559  
 characteristics, 558  
 effects on targets, 558–559  
 forcing function load parameters, 559  
 forcing functions used to represent impact, 559  
 penetration, 559  
 secondary, 559  
 soft impact, 559  
 types, 558
- Missing-mass correction factor, 555
- MM. *See* Material Manufacturer.
- MO. *See* Material organization.
- Moderate-energy piping system, 327  
 definition, 548  
 ferritic steel piping, 328
- “Modern Flange Design” (Taylor Forge), 708
- Modulus of elasticity, of bellows material, 111
- Moisture barriers  
 of Class MC containments, 450  
 examination requirements, 452, 455  
 revision in examination procedures, 466  
 visual examination and acceptance standards, 459
- Molten metal bath dip brazing (DB), 232
- Molybdenum, requirements for  $2\frac{1}{2}\text{Cr}-1\text{Mo}-\frac{1}{3}\text{V}$  weld metal composition, 115–116
- Moment arm, 682, 685, 692
- Moment correction factor, 705
- Moment loading, 630

- Moment of inertia, 92
- Moments, 637–638, 640  
for example piping system, 635
- Momentum equation, 577
- Momentum principle, 584
- Monel alloy, as gasket materials and contact facings, 687–688
- Motion loading functions, 551
- Motor-operated valves (MOVs), 577–578  
improperly installed spring pack, 504
- Motor voltage checks, 512
- MOV. *See* Manually-operated valves, Motor-operated valves.
- MPFF. *See* Maintenance-preventable functional failure.
- MS. *See* Material Supplier.
- MSS. *See* Manufacturer's Standardization Society.
- MT. *See* Magnetic-particle examination.
- MTR. *See* Mill Test Report.
- Mufflers, 619, 620
- Multiple flaws, definition, 395. *See also* Flaws.
- N/A. *See* Not applicable.
- NACE. *See* National Association of Corrosion Engineers.
- NA-Certificate Holder, 531
- NA Certificate of Authorization, 329, 351
- Nameplates  
adhesive use requirements, 173  
of nuclear reactor vessels, 168  
of pressure vessels, adhesive attachment, 105  
on pressure vessels, location of, 123  
pressure vessels reduced maximum allowable working pressure shown, 111  
and rerating of items, 366  
for welded supports, 531
- Nameplate stamping, 48
- Narrow-band-response spectrum, definition, 548
- NA Symbol Stamp, 329, 334, 351, 361
- National Association of Corrosion Engineers (NACE), 118
- National Board. *See* National Board of Boiler and Pressure Vessel Inspectors.
- National Board Inspection Code (NBIC), 27  
Foreword, 27  
nameplate replacement for nuclear reactor vessels, 167
- National Board NR Certification, 351  
repair/replacement requirements, 329
- National Board of Boiler and Pressure Vessel Inspectors (National Board), 46, 519, 529  
acceptance of capacity certification testing facility, 108  
Manufacturer's Data Report copies filed with nuclear reactor vessels, 169  
member on ASME Survey Team, 531  
representative as member of Subcommittee for Section V, 1
- National Bureau of Standards, PS 15-69 document, 254
- National Fire Protection Association (NFPA), NFPA 69, 121, 131
- National Valve & Manufacturing Company (NAVCO), 524, 528  
principal piping contract, 527
- Natural frequency, definition, 548
- Natural phenomena missiles, definition, 558
- NAVCO. *See* National Valve & Manufacturing Company.
- NBIC. *See* National Board Inspection Code.
- N-Certificate holders, 326, 531
- N Certificate of Authorization, 329
- N-Class TP Certificate of Authorization, 533
- NDE. *See* Nondestructive examination.
- "ND" stamp, 533
- NDT. *See* Nil-ductility temperature.
- Near-random earthquake ground motion, 553
- Near-resonance frequency, 546
- NEI 96-03, 515
- Net uplift force, 265
- Neuron fluences, 481
- New applications, Code cases for, 328
- Newton's law, for structural dynamic response of fluids, 585
- Nexus lamina, 243  
compressive strength, 238  
density, 238  
fiber content weight, 238  
layers, 237  
Poisson's ratio, 238  
reinforcement, carbon fibers, 237  
reinforcement, polyester fibers, 237  
reinforcement weight, 238  
shear modulus, 230  
shear strength, 230  
tensile strength, 230  
thickness, 230  
veil types, 237  
Young's modulus, 230
- N45-2 Subcommittee on Nuclear Quality Assurance Standards, 522
- NFPA. *See* National Fire Protection Association.
- Nickel  
work-hardened for jacketed pressure vessels, 105  
P-Number, 203
- Nickel alloys  
as gasket materials and contact facings, 687–688  
liquid-penetrant examination, 15  
P-Number, 203
- Nickel alloys, specific types  
alloy 200, 74  
alloy 201, 74  
alloy 400, 74  
alloy 401, 74  
alloy 405, 74  
alloy 600, 74, 651  
alloy 718, 651  
alloy 800, 651–652  
N06600, 385  
N06625, 74  
N08800, 74  
N08810, 74  
N08811, 74  
N10001, 74  
N10665, 74
- Nickel alloy steels  
for inner shells and heads, 84  
P-Number, 203
- Nickel-base electrodes, F-Number, 203
- Nickel-base rods, F-Number, 203
- Nickel-chrome-iron alloys, fatigue curve, 647
- Nickel-chromium alloys, alloy, 651, 718
- Nickel electrodes, F-Number, 203
- Nickel-iron-chromium alloys  
alloy 600, 74, 651  
alloy 800, 651  
fatigue curves, 651  
F-Number, 203
- Nil-ductility transition temperature (NDT)  
computed shift of, 426  
of ferritic steel pressure vessels, 83  
95% confidence limit, reference fatigue crack growth curves for austenitic steels, 481
- Niobium (Cb)  
content limit in nuclear reactor vessels, 164  
requirements for 2 $\Omega$ Cr-1Mo-1/3V weld metal composition, 115–116
- NM notation, on RTP-1 vessel design drawings, 251
- No-break criterion, for nuclear reactor vessel materials, 143

- Nomenclature, 572
  - for Code Case N-643, 498
  - of Code equations, 625, 639
- Nominal Pipe Size (NPS)
  - acronym/abbreviation, 442
  - dimensionless designator of nominal pipe size, 398
- Nominal thickness, 67
  - definition, 96
- Noncompliance, 3
- Nonconforming condition, definition, 572
- Nondestructive examination (NDE), 505. *See also* specific types of
  - procedures named in subheadings
  - acoustic emission examination, 20, 22
  - acronym/abbreviation, 442
  - calibrations of equipment, 4
  - calibration standards, Code Cases for, 327
  - Class MC containments, 445
  - definition, 443
  - detection corrosion mechanisms in piping, 324
  - documentation, 4
  - eddy-current examination of tubular products, 18–19
  - following defect removal, nuclear power plant items, 370
  - glossary of terms, 4
  - inspection vs. examination defined, 4
  - installation weld examination requirements, 353
  - for installation welds of nuclear power plants, 376
  - of layered pressure vessels, 86
  - leak testing, 20
  - Level I personnel, 332, 394
  - Level II personnel, 394
  - Level III personnel, 393–394
  - light water-cooled nuclear power plant components, 392
  - lighting requirement, 390
  - liquid-penetrant examination, 390
  - magnetic-particle examination, 390
  - methods, 3, 307
  - for monitoring SSCs, in USNRC Maintenance Rule, 509
  - of nuclear power plant components, 389
  - of nuclear reactor vessels, 138
  - personnel qualification, 394–395
  - personnel qualification and certification, 4, 316, 327
  - qualification test effort, 205
  - radiographic examination, 4, 7, 9
  - records and documentation maintenance, 4
  - requirements, 3
  - techniques, Code Cases for, 327
  - terminology, 4
  - test method evaluation, 4
  - ultrasonic examination, 15–16
  - ultrasonic examination (UT) for piping welds, 390
  - ultrasonic examination Trainee and NDE Instructor, light-water power plants, 395
  - ultrasonic inspection, 9
  - vision examinations for personnel, 393
  - visual examination, 407–408
- Nondestructive examination personnel
  - Level I, 395
  - Level II, 395
  - Level III, 393, 395
  - qualification programs for light-water reactor plants, 393, 395
  - Standard for Qualification and Certification, 4, 316, 327
- Nonessential variables, 205
  - of welding and brazing, 205, 210, 232
- Nonferromagnetic heat exchanger tubing, eddy-current examination, 18
- Nonferrous materials, pressure vessel applications, 74
- Nonintegral attachment, definition, 443
- Nonintegral support, of light-water reactor plants, 400
- Nonmetallic components, acoustic emission monitoring, 22
- Nonnuclear metal components, acoustic emission monitoring, 22
- Nonplanar flaw, definition, 395. *See also* Flaws.
- Nonpressure parts, of nuclear reactor vessels, 163
- Non-pressure-retaining material, 527
- Nonreversing loads, 632
  - dynamic, 632
- Normal mode, definition, 548
- Normal operation, definition, 505
- North America, ASME companies holding B&PV certificates
  - (including nuclear certificates) as of June, 1999, 534–535
- Not applicable (N/A), acronym/abbreviation, 442
- Notch blunting, 68
- Notch nullification, 68
- Notch sensitivity, fatigue testing, 644
- Notch toughness, of nonferrous materials, 74
- Notch toughness testing, 218, 220
- Nozzle attachment, 83
  - nominal thickness, 67
- Nozzle elevations, measurement of, 254
- Nozzle flexibility, 634, 637
- Nozzle necks, 41
  - of layered construction pressure vessels, 85
  - of nuclear reactor vessels, 155
  - and postweld heat treatment, 67
  - thicknesses, practical, for Section X, 258
- Nozzles
  - cracking, 563
  - dimensions used in Section X calculations, 258
  - Hillside, 259
  - misplaced, 276
  - set-on, 213
  - set-through, 213
  - welding speeds, 202
- Nozzle-to-shell welds, 83, 91
  - Category D, 565
- NPRDS. *See* Nuclear Plant Reliability Data System.
- NPS. *See* Nominal Pipe Size.
- NPS 1 exemption, 385
- NPT-Certificate Holder, 531
- NPT Certificate of Authorization, 352, 531
  - Class TP, 533
- NPT-Code Symbol Stamp, 329
  - materials documentation, 529
- NRC. *See* United States Nuclear Regulatory Commission (USNRC).
- NS Certificate. *See* Nuclear Support Certificate.
- N626 Committee, 533
- NSSS. *See* Nuclear steam system supplier.
- N-symbol stamp, 329, 334
  - payment for, 531
  - valve, replacement of, 334
- N-Type Certificate Holder, 362
  - jurisdiction, QA Program, 391
  - materials documentation, 529
  - mechanical clamping devices requirements, 349
- N-Type Certificate of Authorization
  - Class TP, 533
  - scope, 531
- N-type stamped components, pressure testing, 381
- Nuclear accreditation programs, 530–531, 533
- Nuclear applications, digital image application, display, interpretations, and storage of radiographs, 6
- Nuclear certificates, 530
  - in Africa, 534, 538
  - in Australia, 534, 538
  - in Canada, 534
  - in Eastern Asia countries, 534
  - in effect in United States, 534

- Nuclear certificates (*Continued*)
  - in Europe, 534, 536
  - in Middle East countries, 534
  - in North America, 534
  - in South America, 534, 536
  - in United States, 534
  - list of, 541
- Nuclear Code, incorporation, 517
- Nuclear Code Cases, 520
- Nuclear components, acoustic emission monitoring, 22
- Nuclear energy, history, 518
- Nuclear Energy Institute, criteria for implementing the Maintenance Rule, 503
- Nuclear excursion missile, definition, 558
- Nuclear Plant Reliability Data System (NPRDS), 562
- Nuclear Power Plant Components (ASME Section III), 519
- Nuclear power plant items, repair/replacement activities, 337–388
  - alternatives to Construction Code welding, 383
  - Authorized Inspection Agency involvement, 356
  - brazing, 368–376
  - Code Cases, 385–386
  - defect removal, 341–342, 344
  - defect removal by metal removal, 341–342, 345
  - design associated with, 365–368
  - design change, 344
  - documentation, 356–358
  - examination and testing requirements, 376–383
  - gas-cooled nuclear plants, 340
  - half bead weld repair techniques, 338
  - heat exchanger tubing, plugging and sleeving, 383
  - heat exchanger tubing repair by sleeving, 340
  - helical-coil threaded inserts, 364–365
  - hydrostatic testing at elevated temperature, 340
  - installation, 341–342
  - interpretations on use of Construction Code requirements, 360–362
  - items used, requirements for, 358–365
  - maintenance activities, 319
  - mechanical clamping devices, 349
  - mechanical tube plugs, 385
  - pipng vibration requirements, 592–593
  - Plant aging, 309
  - plant construction code differences, 339
  - post-tensioning systems, 340
  - pressure relief valves, 348
  - pressure testing, 378–383
  - reconciliation requirements, 362–364
  - reinstallation of equipment, 351
  - repair/replacement program and plan, 352–355
  - rerating, 365–366
  - responsibilities, 349–351
  - responsibility of Owner and Repair/Replacement Organization 349–350
  - scope and applicability, 340–345
  - sleeving for heat exchanger tubing, 369, 385
  - snubbers, 378, 567, 571
  - stamping, 351–352
  - temper bead welding, 340
  - underwater welding, 340
  - verification of acceptability, 356
  - welding, 343, 368–378
- Nuclear reactor vessels
  - accessibility requirements for ISI examinations, 311
  - analysis methods, 169–171
  - Appendix 4 analysis, 169–171
  - AQT materials, 153
  - attachments, 158–159, 165
  - bolted flanges, adequate rigidity formula, 174
  - bolted flange connections, 169
  - cladding, corrosion-resistant, 164–165
  - Code Cases of, 385, 398
  - Code formulas and rules application, 173
  - core support structures, 324
  - cost, 138
  - design/analysis costs, 138
  - design for internal pressure, 146–152
  - design of flat heads and bolted connections, 158
  - design of shells for buckling, 151–152
  - design requirements, 143–145
  - deterioration in service, 138
  - drilled holes not penetrating wall, 173
  - fabrication requirements, 159
  - fabrication, special requirements, 164
  - fabrication tolerances, 160–161
  - fatigue analysis, 145, 165, 171–172
  - forgings, 165
  - general requirements, 138–139
  - heat treatment, 140, 143, 162–164
  - helically wound interlocking strip layered, 173
  - history, 137
  - identification markings, after fabrication, 159–160
  - inservice inspection, 9
  - inspection, 166–167
  - installation and operation practices, 173
  - knockdown factors, 151–152
  - layered, 173
  - lining material, 164–165
  - of low upper-shelf Charpy impact energy levels, assessment of, 319
  - marking, 168–169
  - material requirements, 139–140
  - materials with tensile properties enhanced by heat treatment, 143
  - maximum underthickness tolerance, 160
  - mill test marking (TG), 140
  - nonstandard pressure parts, 140
  - nozzle attachment details, 144, 157
  - obtaining of operating temperatures of vessel walls in service, 173
  - openings, access and inspection, 159
  - openings, reinforcement of, 155–157, 196
  - operability, ASME Code requirements for, 564–568
  - ownership and control, 139
  - plates, forgings and castings requirements, 140
  - postweld heat treatments, 139, 141
  - pressure-relief devices, 165–166
  - radiographic examination, 166–167
  - replacement program work package, 528
  - reports, 168–169
  - stamping, 168–169
  - stress indices, 170
  - supports, 158–159
  - temperature protection, 173
  - testing requirements, 167–168
  - toughness requirements, 140–143
  - wall thickness, 144
  - welded joints, 153–155
  - weld examination, 311–312
  - welding requirements, 161–162
- Nuclear Regulatory Commission (NRC), acronym/abbreviation, 425.
  - See* United States Nuclear Regulatory Commission (USNRC) for further information.
- Nuclear safety-related, definition, 548
- Nuclear steam supply system (NSSS) vendor, 524
  - Class 1 system makeup capability, 346
- Nuclear Support (NS) Certificate, 531
- Nuclear surveys
  - “abort” opportunity for company, 533
  - in foreign countries, 533
- Nuclear survey teams, 519



- Nuclear Utilities Procurement Issues Committee (NUPIC), 533  
 Nuclear vessel nozzle inner radius and inner corner regions, scanning requirements, 13  
 NUMARC 87-00, Appendix D, use of exceedance trigger values, 514  
 NUMARC 91-06, "Guidelines for Industry Actions to Assess Shutdown Management," 497  
 NUMARC 93-01, 511  
 NUPIC. *See* Nuclear Utilities Procurement Issues Committee.  
 NUREGS. *See* U.S. Nuclear Regulatory Commission Regulatory Guides.
- Nuts  
   vessel closure, 317  
   vessel closure-head, 330  
 NV-Certificate Holder, 531  
 NV Certificate of Authorization, 531  
 NV Code symbol stamp, 363, 391
- Oak Ridge National Laboratory  
   analysis of openings in nuclear reactor vessels, 156–157  
   ORNL-NSIC-22, 560  
   ORNL-TM-3645 (*Nuclear Piping Design*), 560  
 OBE. *See* Operating-Basis Earthquake.  
 Occasional loads, 639  
 Octave, definition, 548  
 OFW. *See* Oxyfuel welding.  
 One-dimensional flow theory, 577  
 One hundred percent critical damping, 547  
 Openings, 41–42  
   for access and inspection, in nuclear reactor vessels, 159  
   and deflagration, 121  
   of high-pressure vessels, 190  
   in nuclear reactor vessels, reinforcement of, 155–157  
   of pressure vessels, 57  
   in pressure vessels, large, single, circular, centrally located, 103  
 Openings and reinforcement, of high-pressure vessels, 196  
 Operability  
   ASME Code requirements for, 564–568  
   assessments, 563–564  
   definition, 561–562  
   evaluation methods, 568, 569  
   faulted or service level D loads to consider in evaluations, 564  
   long-term, 571  
   nomenclature, 572  
   scoping evaluation, 563  
   short-term acceptance criteria, 569–571  
 Operable, definition, 561–562  
 Operating-Basis Earthquake (OBE), definition, 548  
 Operating condition, 697  
 Operating design moment, 705  
 Operating-gasket stress, minimum required, 707  
 Operating pressure, of nuclear reactor vessels, 144  
 Operating system, definition, 505  
 Operating temperature, of pressure vessel walls, inservice, 118  
 Operations and Maintenance (O&M) Committee. *See* American Society of Mechanical Engineers (ASME) Operations and Maintenance Committee.
- Optical pyrometers, 129  
 Ordering effect, 475  
 Oscillating lift force, 584  
 OSHA 1910.119 (Process Safety Management for Hazardous Materials), 27  
 Out-of-roundness  
   determination for cylindrical shell, 121  
   of nuclear reactor vessels, 165  
   tolerance, 42  
 Ovality tolerance, for nuclear reactor vessels, 160  
 Overlay hoop stress, 258. *See also* Stresses.
- Overpressure Protection Report, 316, 357  
   and Repair/Replacement Plan, 355  
 Overpressure testing, of nuclear reactor vessels, 167–168  
 Overstrain, of piping in light-water reactor plants, 436  
 Owner  
   definition, 306, 443, 548  
   evaluation of welded attachments, light-water reactor plants, 402  
   jurisdiction, QA Program, 391  
   licensing commitments, 345  
   nuclear reactor vessels, deviation of shell radius, 161  
   Repair program, 340  
   Repair/Replacement Program interface with work control processes, 352  
   requirements for visual examination performance, personnel, qualification, and responsible engineer, 401  
   responsibilities in repair/replacement activities for nuclear power, plant items, 349–350  
   responsibility for alternate flaw acceptance standards, 420  
   responsibility for containment's leak-tight and structural integrity, 445  
 Owner's Certificate, 351, 530, 532  
 Owner's Design Specification, certified by Registered Professional Engineer, 521  
 Owner's Inservice Testing Program, 343, 348  
 Owner's Pump and Valve Test Program, 389  
 Owner's Quality Assurance Program, 329, 346, 350  
   responsibility of acceptability, materials documentation, 529  
 Owner's Repair Program, 334  
 Owner's Repair/Replacement Report  
   Form N-3, 340, 351, 531  
   Form NIS-1, 392, 409  
   Form NIS-2, 348, 356, 391, 397  
   Form NIS-2, Authorized Nuclear Inservice Inspector (ANII) requirement, 345, 442  
   Form NIS-2, documentation, 355  
   Form NIS-2, evaluation report, 528  
   Form NIS-2, 528  
   Form NIS-2, nonconformance, 524  
   Form NIS-2A, 353, 358  
   interpretations, 329  
 Owner's Requirements, 355, 359  
   and Construction Codes, 358, 360  
   definition, 443  
   and design of nuclear power plants, 365–366  
   and welding, brazing, defect removal, and installation activities, 369–370  
 Owner's Review of the Design Report, 521  
 Oxyacetylene cutting, 375  
 Oxyacetylene gas, 198  
 Oxyacetylene welding process, 198  
 Oxyfuel welding (OFW), 198–199  
   of pressure vessels, 63  
 Oxygen-methylacetylene-propadiene (MAPP) gas, 198  
 Oxygen-natural gas, 198  
 Oxygen-propane gas, 198
- Packing, replacement of, 129  
 Pad plates, 157  
 Painting  
   of nuclear reactor vessels, 168  
   of pressure vessels, 123  
   preventing atmospheric corrosion of pressure vessels, 119  
 P&IDs. *See* Piping and instrument diagrams.  
 Partial Data Report  
   from bellows manufacturer, 111–112  
   of nuclear reactor vessels, 168  
 Partially drilled holes (PDH), in pressure vessel walls, 113  
 Partial-penetration welds, of nuclear reactor vessels, 145, 154, 159

## Parts

- A. *See* Section II.
- AT. *See* Section VIII, Division 2.
- B. *See* Section II.
- C. *See* Section II.
- definition, 342, 443
- 3. *See* RTP-1.
- 4. *See* RTP-1.
- D. *See* Section II.
- PW. *See* Section I.
- QB. *See* Section IX.
- QW. *See* Section IX.
- UG. *See* Section VIII.
- UW. *See* Section VIII.
- Passive failure, definition, 548
- Passive safety injection systems, statically pressurized, 308
- PAW. *See* Plasma arc welding.
- P construction stamp, for pressure welded (except for resistance welding) construction, 48
- PDH. *See* Partially drilled holes.
- Peak stress indices, 614–615
- Peel load, 266
- Peening, 212
- Penalty factor, for nuclear reactor vessel analysis, 170
- Penetrometer, 7, 406
  - hole-type, placement sketches for welds, 6
  - numbers of (special cases), 6, 8
- Penetration assembly, definition, 443
- Penetration equation of the Ballistic Research Laboratory, 559
- Penetration formulas, for concrete, 559
- Penetrations,
  - of Class MC containments, 446–447
- PER. *See* Problem Evaluation Report.
- Performance, definition, 505
- Performance criteria, establishment of goals for improvement, 503
- Performance monitoring, definition, 504–505
- Performance trending, 512
- Periodic pressure testing, 389
- Permeation-type leak standards, 20
- Personnel qualification (PQ), 2
  - for acoustic emission continuous monitoring, 22
  - brazers or braze operators, 65
  - certification, 2
  - for eddy-current examination, 317
  - for nondestructive personnel, 3, 316, 332, 393–394
  - for ultrasonic examination, 317–318
  - for ultrasonic examination of pressure vessel welds, 99
  - for visual examination, 317
  - for visual examination of light-water reactor plants, 393–394, 401
  - for welders or weld operators, 65
- Peterson cubic equation, 646
- Phenolic resins
  - curing process, 236
  - ductility, 236
  - flammability properties, 236
  - processability, 236
  - as vessel materials, 235
- Phosphorus, requirements for 20Cr-1Mo-1/3V weld metal
  - composition, 144
- Photoelastic tests, 172
- Photosensitive eyeglass lenses, 17
- PHT designation, for pressure vessels, 48
- Pie gage, 17
- Pie indicator, 17
- Pipe. *See also* Pipe vibration testing and analysis, Piping, and Piping systems.
  - bulk flow, 582–591
  - cracking, 563
  - ferritic, and ferritic welds in, 17–18
  - fluid-flow forces, estimation of, 584
  - NPS 4 Schedule 80, 313
  - NPS Schedule 140, 313
  - propagative flow modeling, 582–584
  - rupture, 560
  - shell-mode frequencies for various sizes, 616
  - straight, *B*-stress indices, 632
  - welding, technique sketches, 4–5
- Pipe break loads, 557–558
- Pipe break restraint, 557
- Pipe clamps, 331
- Pipe factor, 395
- Pipe-groove weld test, 216
- Pipe leg, definition, 591
- Pipe snubbers. *See* Snubbers.
- Pipe vibration testing and analysis, 591–623
  - acoustical response of piping, 617–618
  - acoustic analysis, 595
  - allowable piping response for vibration, 591–593
  - ASME/ANSI O&M standard on piping vibration, 593
  - case studies in vibration, 618–622
  - causes of piping vibration, 594–601
  - cavitation, 596–597, 604
  - continuous-monitoring data-acquisition system, 607–608
  - cracks in tap lines, 591
  - damping, 602–604
  - design considerations and guidelines for piping, 601–604
  - flashing, 595–597, 604
  - flow turbulence, 593–595
  - high-tuning, 602–604
  - industry codes and standards, 591–592
  - instrumentation requirements for vibration measurements, 605
  - low-tuning, 602–604
  - nuclear power plant requirements, 592–593
  - pipe cracking resulting from pipe vibration, 591–592
  - piping shell-mode vibration, 616–617
  - piping structural response, 612–615
  - pump-induced pressure pulsation, 594–596
  - routing and support structures, 604
  - routing and support techniques, 604
  - simple-beam model for determining vibration limits, 614
  - steamhammer, 599–601
  - stiffness and mass effects, 601
  - stress allowables, 593
  - system walkdown procedures, 608–612
  - testing procedures, 604–622
  - vibration acceptance criteria, 593–594
  - vibration experience with U.S. nuclear power plants, 591–592
  - vibration-monitoring systems for vibration measurements, 606–608
  - vortex shedding, 597–599
  - waterhammer, 599–601
  - weld failure in large-bore piping, 591
- Pipe welds, 9
  - Class 1 acceptance standard, 315
  - Class 1 Category B-J, 311–312
  - Class 2 acceptance standard, 315
  - Class 2 Category C-F, 313
  - Class 2 Category C-F-1, 311
  - Class 2 Category C-F-2, 311
  - in containment penetrations, examination exemption, 317
  - flaws inservice inspection, 315–316
  - leakage testing, 317
  - pipe-groove weld test, 216
  - technique sketches, 4, 6
  - ultrasonic examination, 304

- Pipe whip, definition, 548
- Pipe-whip loadings, 603
- Pipe-whip restraint, definition, 548
- Piping
  - of austenitic stainless steels, flaw evaluation in light-water reactor plants, 430–431
  - code compliance, 637
  - condensate, 620
  - degradation mechanisms, 321, 324
  - failure modes, 562
  - faulted or Service Level D loads, operability evaluation, 564
  - feedwater-recirculation, 620
  - flange design, 680–681
  - flaw evaluation, for light-water reactor plants, 431, 433
  - high-pressure core spray minimum-flow, 615–616
  - history in 1950's, 518
  - history in 1960's, 519
  - main steam-bypass, 620
  - motor-driven feedwater pump discharge, 619
  - NPS 1 and smaller repair/replacement activity, 334–335
  - open-ended discharge, 407
  - operability, ASME Code requirements for, 567
  - penetration requirements with MC containments, 446
  - of pressure vessels, to pressure-relief device, 123
  - safety-injection, 620
  - service water, 620
  - shell-mode vibration, 616–617
  - specified safety functions, 562
- Piping and instrument diagrams (P&IDs), 515
- Piping components, exempted from Section X scope, 249
- Piping network, definition, 548
- Piping run, definition, 548
- Piping stress analysis computer programs, 555
- Piping supports material documentation, 526–528
- Piping systems. *See also* Pipe, Pipe vibration testing and analysis, and Piping.
  - analyses, 633
  - analysis computer programs, 633
  - example, Code compliance, 637
  - example, Code equations, 635
  - example, illustrating *i*-factors, stress indices, and flexibility factors, 634
  - exempted from Section X scope, 247
  - operability evaluation methods, 568–569
  - short-term operability acceptance criteria, 569–570
  - strain limit acceptance criterion, 570
  - stress acceptance criterion, 570
  - stress intensification factors, stress indices, and flexibility factors, 625–642
  - visual examination inclusions, 569
- PISC. *See* Programme for Inspection of Steel Components project, European Community's.
- Pitting, 372, 386
  - of piping, 324
- Planar flaw, definition, 411
- Planar flaw criterion, 309
- Planar reflectors
  - non-amplitude-based techniques for recording data, 11
  - amplitude-based techniques for recording data, 11
  - interfering with examination, 11
- Plant-level performance criteria, in USNRC Maintenance Rule, 508–509, 512, 515
- Plant maintenance activities, 319
- Plant walkdown experience, 394
  - procedure, of piping system, 608–612
- Plasma, in weld process, 202
- Plasma arc welding (PAW), 198, 200–202, 208, 212–213
  - of high-alloy steels for pressure vessels, 76
- Plasma cutting, 375
- Plastic analysis, of nuclear reactor vessels, 170–171
- Plastic finite-element analysis, of nuclear reactor vessels, 147
- Plasticity correction, 478
- Plasticity reduction factors, of nuclear reactor vessels, 153
- Plastic strain, and fatigue damage in plastic region, 643
- Plastic strain concentration factors, 644
- Plate-and-shell theory, 235, 244
- Plate-groove weld test, 216
- Plates
  - dimpled, 103–105
  - explosive clad, 13
  - flat, attachment details, 53–57
  - forgings and castings requirements for nuclear reactor vessels, 140
  - ultrasonic examination, 10
- Plugging
  - of heat exchanger tubing, 335, 384–385
  - as valve failure mode, 562
- PM. *See* Programmed maintenance.
- Pneumatic leakage test, 334
- Pneumatic testing
  - of ERW tubes for pressure vessels, 50
  - of finned tubes, 32
  - interpretations concerning, 333
  - of nuclear reactor vessels, 167–168
  - of pressure vessels, 48
  - of pressure vessels having higher allowable stresses at low temperature, 87
  - of pressure vessels, welded joints, 48
- P-Numbers, 218, 228
  - alternate base material for welder qualification, 214
  - brazing classification system, 232
  - change, in base metals of welds, 209, 213
  - classification of materials, 202–203
  - of dissimilar base metals for welds, 208
  - equivalent, 10
  - group numbers, 218
  - guided-bend testing, 224
  - and heat treatment for nuclear reactor vessels, 162–164
  - of high-alloy steels, 75
  - materials within same, preheating results, 126
  - not all materials assigned to, 209
  - of nuclear reactor vessel materials, and heat treatment, 167
  - postweld heat treatment conditions, 67–68, 70, and postweld heat treatment for carbon and low-alloy steels, 70–71
  - preheat requirements of welds categorized by, 126
  - as special process essential variable, 221
  - temper bead welding, 383
- P-Numbers, specific types
  - P-No. 1, 67, 162, 164, 228
    - alternate base material for welder qualification, 214
    - base metal used for procedure qualification, 209, 218
    - classification of materials, 202
    - equivalence, 10
    - Grade 1, 67, 70, 163
    - Grade 2, 67, 163
    - group 1, 163, 204, 218
    - group 2, 163, 204, 218
    - mechanical processing of thermally cut processes, 374
    - specific heat requirements, 126
    - underwater welding, 383
    - welded to P-No. 3 material, 331
    - weld procedure, 526
  - P-No. 2, 218
  - P-No. 3, 70, 162, 164
    - alternate base material for welder qualification, 214
    - base metal used for procedure qualification, 209, 218
    - classification of materials, 202

P-Numbers, specific types (*Continued*)

- equivalence, 10
- welded to P-No. 1 material, 330
- weld procedure, 525
- P-No. 4, 67, 70, 162
  - alternate base material for welder qualification, 214
  - base metal used for procedure qualification, 209, 218
  - classification of materials, 202
  - equivalence, 10
- P-No. 5, 67, 70
  - alternate base material for welder qualification, 214
  - base metal used for procedure qualification, 209, 218
  - equivalence, 10
- P-No. 5A, 202, 209, 218
- P-No. 5B, 202, 209, 218
- P-No. 5C, 202, 209, 218
- P-No. 6, 203, 218
- P-No. 7, 203, 218
- P-No. 8, 208
  - alternate base material for welder qualification, 214
  - base metal used for procedure qualification, 218
  - classification of material, 203
  - group 1, 204
  - mechanical processing of thermally cut processes, 374
  - underwater welding, 383
- P-No. 9, 209, 218
- P-No. 9A, 203
- P-No. 9B, 203
- P-No. 9C, 203
- P-No. 10, 228, 209
  - alternate base material for welder qualification, 214
  - base metal used for procedure qualification, 209, 218
- P-No. 10A, 203, 209, 218, 229
- P-No. 10B, 203, 209, 218, 229
- P-No. 10C, 203, 209, 218, 229
- P-No. 10D, 203
- P-No. 10E, 203
- P-No. 10F, 203
- P-No. 10G, 203
- P-No. 10H, 203
- P-No. 10I, 203
- P-No. 10J, 203
- P-No. 10K, 203
- P-No. 11, 203, 221, 228
  - base metal used for procedure qualification, 218
  - classification of materials, 203
- P-No. 21, 203
- P-No. 22, 203
- P-No. 23, 203
- P-No. 23, 203
- P-No. 24, 203
- P-No. 25, 203
- P-No. 31, 203
- P-No. 32, 203
- P-No. 33, 203
- P-No. 34, 203
- P-No. 35, 213
- P-No. 41, 203
- P-No. 42, 203
- P-No. 43, 203, 374
- P-No. 44, 203
- P-No. 45, 203
- P-No. 46, 203
- P-No. 47, 203
- P-No. 51, 203
- P-No. 52, 203
- P-No. 53, 203
- P-No. 61, 203
- P-No. 62, 203
- P-No. 4X, underwater welding, 383
- Point spring concept, 633
  - of branch connections, 636–637
- Poisson's ratio, of laminae, 238
- Polarity, type of, 220
  - change in, 231
- Polarity of current, 211
- Polyester fibers, veil for nexus lamina, 237
- Polyester resins, as vessel materials, 235
- Polynomial stress distribution method, 424–428
- Pop action safety relief valves, 195
- Position indicators, 530
- Post-tensioning, definition, 443
- Post-tensioning systems, 340
  - of containments, documentation, 319
  - inspection schedule, 402
- Postulated pipe break, definition, 548
- Postweld heat treatment mill test, of glass-lined pressure vessels, 112
- Postweld heat treatments (PWHT)
  - of carbon and low-alloy steels for pressure vessels, 67, 70
  - of clad, weld overlaid, and lined pressure vessels, 78
  - exemptions for service, 67, 70
  - of ferritic steel pressure vessels, 83
  - of layered construction pressure vessels, 84
  - minimizing stress-corrosion cracking, 31
  - of nuclear reactor vessels, 138, 162, 164
  - of pressure vessel jackets, 99
  - of pressure vessels, 71
  - temper bead welding, 383
  - of welded components, 67
- Power piping, stresses, 638
- Power spectral density (PSD), definition, 548
- PQ. *See* Personnel qualification.
- PQR. *See* Procedure qualification record.
- PRA. *See* Probabilistic risk assessment.
- Praxair, 148
- PRD. *See* Pressure-relief device.
- Precipitation-hardening stainless steel all-position electrodes, F-Number, 203
- Preheating
  - of nuclear reactor vessel, 162, 164
  - requirements of welds, 127
- Preliminary Safety Analysis Report (PSAR), 314, 527
- Preoperational (baseline) examination, 306
- Pressure change test, 19
- Pressure containers, exempted from Section X scope, 248
- Pressure-differential method, 32
- Pressure drop test, 408
- Pressure excursions, 563
- Pressure loads, 90
  - unbalanced, 90
  - from weight, 90
- Pressure-relief devices (PRDs), 46
  - for high-pressure vessels, 195
  - nonreclosing, 49, 165
  - of nuclear reactor vessels, 143
  - for pressure vessels, 48–49
  - of pressure vessels constructed of materials having higher allowable stresses at low temperature, 87
  - protecting the vessel from overpressurization, 34
  - in scope of Section VIII, Division 2, 139
  - for steam jacket of pressure vessel, 105
- Pressure-relief discharge loads, 556–557
- Pressure-relief valves, 348
  - ASME Code requirements for operability, 564–565
  - capacity certification, 108

- capacity certification tests, ASME acceptance of testing laboratories and Authorized Observers, 173
- and impulse loads, 546
- for nuclear reactor vessels, 165
- for pressure vessels, 124
- rotation and reinstallation, 317
- Pressure-retaining components
  - examination requirements, 448
  - revision of examination Category E-P, 455
- Pressure testing, 389
  - change test, 19
  - of Class CC containments, 445
  - Class MC containments and metal liners for Class CC containments, 445
  - Code Cases for, 326–327
  - of containment vessels, light-water reactor plants, 406
  - drop test, 408
  - of expansion joints, 111
  - of high-pressure vessels, 181
  - interpretations affecting, 335
  - leak-tightness after repair/replacement activity, light-water reactor plants, 406
  - of light-water reactor plants, 402, 404, 406, 408
  - of metallic vessels, acoustic emission examination, 21
  - of nuclear power plant items, 378–379, 383
  - periodic system of light-water reactor plants, 406
  - of pressure vessels, 46
  - of pressure vessels having higher allowable stresses at low temperature, 87
- Pressure transducers, 607, 620
- Pressure Vessel and Piping (PVP) Conference
  - Holston, W.C., paper presented, 363
- Pressure vessel engineering, knowledge of, 27
- Pressure Vessel Research Committee (PVRC), fatigue testing, crack initiation project on model/full-sized vessels, 682
- Pressure Vessel Research Council (PVRC), 137
  - cone-to-cylinder junctions research project, 147
  - design rules for openings in nuclear reactor vessels, 15
  - diameter ratio limit reduction for high-pressure vessels, 184
  - fatigue analysis rules of nuclear reactor vessels, revision project, 172
  - gasket material research, 169
  - method, 681
  - method on flange design, 705
  - postweld heat treatment of nuclear reactor vessels, 162
  - programs on NDE sensitivity and reproducibility, 309
  - research project, Lehigh University (Professor Kalnins), 145
  - strain limits as function of hydrostatic stress, project development for, 185
  - “3D Stress Classification” project, 169
- Pressure vessels. *See also* Construction of pressure vessels.
  - exempted from Section X scope, 247
  - history in 1950’s, 518
  - for human occupancy, 247
- Pressure Vessels and Piping: Design and Analysis, A Decade of Progress* (Vol.2)(ASME), 120
- Pressurized reactors, flaw evaluation, 430
- Pressurized water reactor (PWR), 484
  - acronym/abbreviation, 440
  - containment types in U.S., 139–140
  - environmentally-assisted cracking, 484
  - environmentally-assisted cracking of ferritic steels, 198–502
  - flaw effect on integrity of nuclear components, 313
  - valves, leakage rates and operability requirements, 565
  - water-slugging loads in pressurizer-relief piping, 601
- Pressurized water reactor (PWR) plants
  - piping vibration case studies, 620, 622
  - piping weld examination, 313
- Pressurizing mediums, 333
- Prestressed concrete, definition, 443
- Primary bending stress, 124, 125, 127. *See also* Stresses.
- Primary bending stress, 124–125
  - limit, 89
- Primary membrane stresses, 164. *See also* Stresses.
- Primary reference response (PRR), 12
- Probabilistic risk assessment (PRA), 312, 321, 325, 326, 387, 410, 542, 543
  - /IPE (in-process examination) methods, determining whether SSCs are risk-significant, 505
- Problem Evaluation Reports (PERs)
  - of Example Nuclear Plant, 526
  - recommended disposition of, 528
- Procedure qualification record (PQR), 203–206, 212, 218, 328, 335, 374
  - definition, 205
  - generating welding procedure specifications, 373
  - ownership, 206
  - sharing by various manufacturing centers in one organization, 206
  - source reflected in quality control system/quality assurance program, 206
  - test coupon, 210
- Procedure Specification for Class II Vessels (Form Q-120), 277, 294
- Procedure specifications, 218, 276, 277, 294, 373, 374
- Process fluid temperature, 33
- Process piping
  - cryogenic service, 33
  - external thermal insulation, 680
  - flange design, 679
  - flange pressure-temperature ratings, 680
  - stresses, 639, 640
- Production impact tests, 44
- Production weld tests, of high-pressure vessels, 181
- Programmed maintenance (PM)
  - definition, 504
  - in USNRC Maintenance Rule, 507
- Programme for Inspection of Steel Components project, European Community’s (PISC), 317
- Promoter, 276
- Proof test, definition, 548
- Proof testing, of finned tubes, 32
- Propagation time, 582
- Propagative flow, 582
- Propagative flow velocity, 584
- Prototype
  - definition, 548
  - for qualification of Section X Class I vessel design, 241
  - of Section X vessels, 249
- PRR. *See* Primary reference response.
- PSAR. *See* Preliminary Safety Analysis Report.
- PSD. *See* Power spectral density.
- PT. *See* Liquid penetrant examination.
- P-T limit curves, 327
- Pulsation dampers, 619
- Pulsation frequencies, potential, equation for, 595
- Pump blade-passing frequency, 608
- Pump casings, corrosion or erosion, 423
- Pump drivers, 530
- Pump flywheels, 324
- Pump impellers, 530
- Pumps
  - auxiliary feedwater, 620
  - case cracking, 595
  - centrifugal, 581–582
  - failure modes, 562
  - faulted or Service Level D loads, operability evaluation, 549
  - functional testing, 308



Pumps (*Continued*)

- history, 518–519
- in light-water reactor plants, 404, 405, 407
- of nuclear vessels, ultrasonic examination, 15
- operability, ASME Code requirements for, 565
- operability evaluation methods, 568
- penetration requirements with MC containments, 444
- positive displacement, 581–582
- pressure-retaining welds, 421
- triplex, 581–582
- visual examination inclusions, 569
- PRR. *See* Primary reference response.
- PVP. *See* Pressure Vessel and Piping Conference.
- PVRC. *See* Pressure Vessel Research Council.
- PWHT. *See* Postweld heat treatment.
- PWR. *See* Pressurized water reactor.
  
- QAI. *See* Qualifications for Authorized Inspection.
- QA Manual. *See* Quality Assurance Manual.
- QA Program. *See* Quality Assurance Program.
- QD forms, quality deficiencies noted by nuclear survey team, 533
- QSC. *See* Quality System Certificate, Quality System Certificate Holders.
- Quadratic interaction criterion, 246
- Qualifications for Authorized Inspection (QAI)
  - Main Committee, 522, 530
  - Subcommittee on AIA Accreditation, 533
- Qualification test effort, 205
- Quality Assurance, 522
  - interpretations, 329
  - of RTP-1 vessels, 275–277
  - of Section X vessels, 275–277
- Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants (10CFR50), 392
- Quality Assurance Manager, role in nuclear survey, 522
- Quality Assurance Manual (QA Manual), 521
  - English translation expected by survey team, 533
  - submittal for approval, 531
- Quality Assurance (QA) Program, 348, 522
  - and Design Specification revision, 358
  - documentation for implementation of Maintenance Rule, 515
  - mechanical clamping devices requirements, 349
  - nuclear power plant components, 389
  - for nuclear power plants, 349
  - nuclear survey, 531
  - for repair/replacement activities, 356
  - repairs, temporary vs. permanent, 341
  - welder qualification for nuclear power plant items, 373
- Quality Assurance Program Requirements for Nuclear Facilities (ASME NQA-1), 392
- Quality control, spot radiography of pressure vessel welds, 63
- Quality control manual, of capacity certification testing facility, 108
- Quality control system
  - of Fabricator of Section X and RTP-1 vessels, 275, 277
  - maintenance required for retaining Certificate of Authorization, 168
  - of Manufacturer, 46, 161
  - of Manufacturer, controls over contract welders, 161
  - Manufacturer's mandatory requirements, 172
  - of pressure vessels, 99
- Quality System Certificate (QSC), 529
  - application and accreditation process, 531
  - manual revisions and audits, 531
  - (Materials), 329, 361
  - NCA-3800, 334, 349, 361–362, 365, 520, 523–524, 528, 531
- Quality System Certificate (QSC) Holders, 361
  - mechanical clamping devices requirements, 349

- Quench-and-temper heat treatment
  - of ferritic steel pressure vessels, 83
  - of forgings of pressure vessels, 64
- Quenched and tempered steels, high-strength low-alloy steels for high-pressure vessels, 194
  
- Rabbit joint, brazing, 66
- Radiation beam offset, 8
- Radiation energy, 8
- Radiographic examination (RT)(Radiography), 6–10
  - calibration of equipment, 8
  - of clad or lined vessels, 82
  - of Class MC and Class CC components of light-water reactor plants, 399
  - of Class MC components, inaccessible surface areas, 445
  - Construction Code method of volumetric examination, 308
  - designation on nameplate, 48
  - determining subsurface linear flaws, 416
  - documentation, 9
  - double-wall, 8
  - equipment and materials, 7
  - evaluation, 9
  - extent of examination, 7
  - of ferritic steel pressure vessels, 83
  - film selection, 7
  - general requirements, 4
  - of high-alloy steels for pressure vessels, 74
  - of hubs of tubesheets and flat heads, 105
  - of layered pressure vessels, 85
  - of light-water reactor plants, 392
  - limitations based on crack orientation, 309
  - of nuclear power plant items, 376
  - of nuclear reactor vessels, 138
  - of nuclear reactor vessel welds, 149, 154, 165
  - of opening seams of pressure vessels, 57
  - of pressure vessels having higher allowable stresses at low temperature, 87
  - of pressure vessels of nonferrous materials, 74
  - of pressure vessel welds, 50, 63, 70, 121, 123
  - review form, 9
  - rounded indication charts' acceptance standards for welds in pressure vessels, 96
  - single-wall, 8
  - of steel castings of pressure vessels, 98
  - surface preparation, 4,
  - techniques for examination, 8
  - of "UM" vessels not required, 30
  - of welded joints of nuclear reactor vessels, 162, 164
  - of weld repairs in nuclear reactor vessels, 159
  - of welds, 225
- Radiographic sensitivity, 8
- Radiographic technique, review and Code Interpretation request, 197
- Radiographs
  - density, 9
  - on microfilm, retained as records by Owner, 409
  - quality of, 9
  - review and Code Interpretation request, 1
- Radiography (RT), 209. *See also* Radiographic examination.
  - abbreviation, 307
  - ensuring soundness of weldment, 211
  - glossary of terms, 4
  - of metallic castings, 4
  - for nuclear applications, 4
  - storage for, 4
  - test results interpretation, evaluation, and disposition, 4
  - welder qualification, 214
- Radioscopic examination, 6

- Radioscopy
  - storage for, 6
  - test results interpretation, evaluation, and disposition, 6
- RAGAGEP. *See* Recognized and generally accepted good engineering practice.
- Raju-Newman solutions, 475
- Ratchet analysis, computing vibratory stress, 556
- Ratcheting, 545
  - of nuclear reactor vessels, 172
- RB. *See* Resistance brazing.
- RE. *See* Reynolds flow number.
- Reactor Coolant Pressure Boundary, Definition of (10CFR50.2), 392
- Reactor coolant pump flywheels, 324
- Reactor coolant system
  - boric acid accumulation, 407
  - boundary, 407
- Rebrazing, of pressure vessels, 66
- Recognized and generally accepted good engineering practice (RAGAGEP), 27
- Reconciliation, 517, 524
  - definition, 362
  - documentation, 359, 366, 370
- Recorded value or range, 205
- Records, of high-pressure vessels, 196
- Records and documentation, of nondestructive examination, 4
- Red book, 682
- Reducers, 630
- Reducing-branch connections, 639
- Referencing system of nuclear vessel nozzle, 15
- Refueling shutdowns, and inservice examination and system pressure tests, 402
- Region III crack growth, 473
- Registered Professional Engineer (RPE), 517
  - certifying design and design temperature of RTP-1 vessels, 248
  - certifying design calculations of Section X, 249
  - certifying Design Report of Class 1 components and Class 2 vessels, 357
  - certifying Design Report of Division 2 vessels, 138
  - certifying Design Report of nuclear reactor vessels, 139
  - certifying Design Specifications and Design Reports, 365
  - certifying Design Specifications of Division 2 vessels, 138
  - certifying Design Specifications of nuclear reactor vessels, 138
  - certifying Section X Class II vessels design calculations, 254
  - certifying software used in Section X design, 249
  - performing or directing General Visual Examination of Class MC containment or metallic liner of Class CC containment, 450
  - responsibilities, 521
  - responsibility for assuring continued structural integrity of concrete containments, 454–455
  - responsibility for continued adequacy of nuclear containment, 446
  - for visual examination of light-water reactor plants, 401
- Regulatory authority, definition, 306
- Regulatory Guide (USNRC)(RG), acronym/abbreviation, 425. *See also* United States Nuclear Regulatory Commission (USNRC) Regulatory Guide.
- Reinforced concrete, definition, 443
- Reinforced thermoset resin (RTP-1)
  - acoustic-emission examination, 235
  - acronym, 235
  - Appendix 3, Article NM3-321 (critical buckling stress equation), 260
  - Appendix 3, Article NM3-321 (wind loading equation), 263
  - Appendix 4 (NM-4)(Hold-down Lug Design), 266
  - Appendix 5 (NM-5)(Ring Support of Vessels), 273
  - Appendix 5, Fig. NM5-8 (Maximum von Miess stress), 275
  - Appendix 5, Fig. NM5-9 (Maximum von Miess stress), 275
  - Appendix 5, Fig. NM5-10 (Maximum von Miess stress), 275
- Appendix 11, calculating stress in center of F&D head under footprint load, 262, 270
- Appendix 11, NM11-300 (temporary external pressure), 270
- Appendix 25.B, providing UBRS for the vessel, 269
- Article 1-130, 249
- Article 1-400 (Inspection: Roles of a Certified Individual, an Inspector, and an inspector), 261, 277
- Article 3A-210, contact-molded cylindrical shell thickness, 262
- Article 3A-320, elastic stability of head, external pressure, 262
- Article 3A-340, man load requirement, 261
- Article 3B-300, man load requirement, 261
- Article 6-940, 254
- Article 6-940, Table 6-1, 254
- bell-and-spigot joint, 243
- bottom head design, 273–275
- butt-joint overlay, 264
- butt joints, 233
- certification of vessel design and design temperature, 249
- design example 2, 269–275
- design of bottom and bottom knuckle, 263–264
- design of shell, 271–275
- design of vacuum rings, 271–275
- design overview, 252
- design rules determining joint overlay thickness, 256
- design rules, stress analysis, 243–247
- Example 1, design specification, 261–269
- Example 2, calculations, 270
- Example 2, Design Specifications, 269–270
- Example 2, laminate properties, 270
- fabrication methods for pressure-containing parts, 239–243
- footprint-load requirement, 251
- FRP equipment excluded from scope, 249
- geometric jurisdiction, 249
- hold-down lug design, 264–267
- Inspection Personnel, 251
- inspector, definition, 261
- joining of vessel parts, 235
- knuckle-reinforcement overlay, 264
- Mandatory Appendix M-11, 278
- materials for vessels, limitations, 250
- mat-woven-roving laminates, 261
- maximum allowable working pressure, 248
- M5-530, 246
- nozzle attachment and reinforcement dimensions, 269
- nozzle attachment to shells or heads, 256
- nozzle reinforcement and attachment design, 268–269
- Part 3 (design), subparts A and B, 249
- Part 4, Article 4-310 (Shell-to-Shell Joint), 251
- Part 4, Article 4-320 (Head-to-Shell Joint), 264–265
- Part 4, Article 4-320, Fig. 4.2, 264
- Part 4, Article 4-320, Fig. 4.5, 264
- Part 4, Table 4.1 (Table 25.26) (Shear-Bond Width), 268
- Part 4, Table 4.2 (Manway Table), 255
- Part 4, Fig. 4.8, 268
- Part 4, Fig. 4.9, 268
- penetrating-nozzle-installation-laminate overlays, 244
- pressure scope, 235
- Quality Assurance, 276
- reinforcement materials, 236
- scope, 235, 247
- seal overlay, 264
- shell design, 262–263
- strength behavior of materials, 238
- Subpart 3A, 3A-210 (Shell Internal Pressure), 251, 260
- Subpart 3A, 3A-220 (Internal Pressure, Torispherical Head), 270
- Subpart 3A, 3A-230 (Ellipsoidal Head Internal Pressure), 251
- Subpart 3A, 3A-240 (Conical Head Internal Pressure), 251
- Subpart 3A, 3A-250, 251, 272

- Reinforced thermoset resin (RTP-1) (*Continued*)
- Subpart 3A, 3A-250, Fig. 4.3, 251
  - Subpart 3A, 3A-310 (Maximum Allowable External Pressure), 272
  - Subpart 3A, 3A-320 (External Pressure, Torispherical Head), 262
  - Subpart 3A, 3A-330 (Vacuum Stiffener Ring), 251, 272
  - Subpart 3A, 3A-330, Fig. 4.4, 251
  - Subpart 3A, 3A-340, (Footprint Load), 251
  - Subpart 3A, 3A-350, 251
  - Subpart 3A, 3A-370, Fig. 4.6 (Nozzle and Attachments), 272
  - Subpart 3A, 3A-370, Fig. 4.6 (Nozzle and Attachments), 251
  - Subpart 3A, 3A-370, Fig. 4.7 (Nozzle and Attachments), 251
  - Subpart 3A, 3A-370, Fig. 4.8 (Manway Table, Nozzle and Attachments), 251
  - Subpart 3A, 3A-370, Fig. 4.9 (Manway Table, Nozzle and Attachments), 251
  - Subpart 3A, 3A-700, 268
  - Subpart 3B, (method B design), 251
  - Subpart 3B, (strength criterion), 251
  - support ring design, 273–275
  - top head design, 262
  - vessel design qualifications, 249
- Reinforced thermosetting-resin cured-in-place pipe, for nuclear power plants, 386
- Reinforcements, 41
- Reinforcement weight, of laminae, 237
- Reinforcing pad
- dimensions, Section X vessels, 258
  - minimum length, 259
  - thickness, Section X vessels, 259
- Relevant condition, definition, 412, 443
- Reliability, 509, 513
- definition, 505
- Relief Request, 446
- Relief valves, 165
- capacity conversions, 100
  - discharge loads, 556–557
- Remaining strength factor (RSF), of pressure vessel shells, 113
- Repair, 523
- acceptance-rejection level, 308
  - code cases for, 338
  - defects in pressure vessels, 42
  - definition, 443
  - of flaws, 418
  - interpretations affecting, 334
  - to steel castings, 99
- Repair Plan, 352
- Repair Program, 351–352, 354
- Repair/replacement activities for nuclear power plants. *See* Nuclear power plant items.
- Repair/replacement activity
- definition, 335
- Repair/replacement organization, 348, 351
- definition, 443
  - Quality Assurance Program responsibilities for nuclear power plants, 349
  - reports and records, 357
  - welder qualifications, 375
- Repair/Replacement Plan, 349, 353
- nondestructive examination of nuclear power plant items, 373
- Repair/Replacement Program, 349, 353, 365
- for Class CC containments, 445, 456
- Repair/Replacement Program and Plan, for Class MC containments and metallic liners of Class CC containments, 445
- Replacement, 523
- acceptance-rejection level, 308
  - component procurement for, 530
  - definition, 314
  - like-for-like, 528
- Replacement Evaluation Report, 316
- Report of Reconciliation, 359
- Reports
- of high-pressure vessels, 196
  - of nuclear reactor vessels, 168–169
- Required input motion (RIM), definition, 548
- Required response spectrum (RRS), definition, 548
- Required thickness, definition, 96
- Reradiography, 6
- Rerating
- definition, 366
  - of flanges, 676–677
  - of nuclear power plant items, 365–366
- RES construction stamp, for resistance welded construction, 48
- Residual heat removal (RHR) system, of Class 2 components exempt from examination, 398
- Residual stresses
- environmental cracking resulting from, 31
  - in ferritic piping in light-water reactor plants, 433
  - flaws in light-water nuclear plants, 424, 431
  - of high-pressure vessels, 181, 188, 190–192
  - in nuclear reactor vessels, 162
  - in pressure vessels, 47
- Resin curing, 239
- Resin Manufacturer
- consultation for elevated temperature applications, 249
  - design limitations, 251
- Resin putty, 243
- Resin test records, 277
- Resistance brazing (RB), 232
- Resistance projection welding, 198
- Resistance spot welding, 198
- Resistive temperature devices (RTDs), 607
- Resonance, 546, 603–604, 608
- acoustic, 617–618
  - pressure pulsations in piping amplified, 597–598, 601–602
- Resonance frequency, definition, 548
- Resonant condition, 546
- Response equalization line, 12
- Response spectrum, definition, 548
- Response spectrum modal analysis, 551
- Responsible Engineer
- conducting system pressure tests on Class CC containments, 459
  - for inservice examination of Class CC containments, 456, 459
  - for preservice examination of Class CC containments, 456
  - for repair or restoration evaluation of Class CC containments, 456
  - for visual examination of light-water reactor plants, 401
- Responsible Individual, conducting visual examination of light-water reactor plants, 401
- Restoration, 470
- of Class CC containments, 470
- Retainers, 208
- Retesting, of welding procedure for pressure vessels, 63
- Reverse polarity, 231
- of current, 211
- Reversing dynamic loads, 633
- Revolution analysis, of nuclear reactor vessels, 170
- Reynolds flow number (RE), 582, 585, 598
- RG. *See* Regulatory Guide (USNRC).
- RHR. *See* Residual heat removal system.
- Rigid, definition, 548
- Rigidity factor  $J$ , 93
- Rigidity index, 93
- Rigid range, definition, 548
- RIM. *See* Required input motion.
- Ring joint, as gasket material and contact facing, 676
- Risk, definition, 505

- Risk-significant SSCs. *See* Structures, systems and components, risk-significant.
- Riveting, 197
- Roberts equation, bolt spacing, 709
- Rock, definition, 548
- Rod-drive housings, control, pressure-retaining welds, 423
- Roll bond, 13
- Roll bonded technique, to produce integral cladding on pressure vessels, 78
- Root-cause analysis, 563
- Root mean square (rms) readings, of vibration signals, 605
- Root spacing, 208
- Rotational energy missile, definition, 558
- Rounded indications, 3  
definition, 96  
in nuclear reactor vessel welds, 172
- RP Code symbol stamp, 249, 276
- RPE. *See* Registered Professional Engineer.
- R ratio, 474, 480–481  
negative, 480
- RRS. *See* Required response spectrum.
- RSF. *See* Remaining strength factor.
- RT. *See* Radiographic examination, Radiography.
- RT 1 designation, for radiographed pressure vessel, 48
- RT 2 designation, for radiographed pressure vessel, 48
- RT 3 designation, for radiographed pressure vessel, 48
- RT 4 designation, for radiographed pressure vessel, 48
- RTD. *See* Resistive temperature device.
- RTP. *See* Reinforced thermoset resin. *See also* Fiber-reinforced plastic.
- RTP symbol stamp, 277
- Rubber liners, for steel vessels, 252
- Ruggedness, definition, 548
- “Rules for the Construction of Stationary Boilers and for Allowable Working Pressures, 501
- Run ends, 636–637
- Rupture-disk devices, 49
- S.I. (metric) units, 389
- Safe life evaluations
- Safe shutdown earthquake (SSE), 548  
as consideration in operability evaluation, 563  
definition, 548
- Safe shutdown earthquake-seismic anchor motions (SSE-SAM), as consideration in operability evaluation, 564
- Safety Analysis Reports (SARs), 594
- Safety factors for fatigue, 649
- Safety functions, key plant, 512
- Safety margins, of nuclear reactor vessels, 172
- Safety/relief valves (SRV), 562, 578  
blowdown characteristics, 125  
capacity conversions, 99  
capacity conversions, for nuclear reactor vessels, 172  
failure modes, 562  
openings, 598  
rapid opening, 600  
vortex shedding, 598
- Safety systems, 506
- Salt or flux bath dip brazing (DB), 232
- San Onofre station in California, 570
- SAR. *See* Safety Analysis Report.
- Savannah River site reactors, periodic inspection program, 324
- SBO. *See* Station Blackout Rule.
- Scaling resistance, 75
- Scanning requirements, of ultrasonic examination, 13
- Scarfig, of Section X parts before joining, 243
- Scarf joint, brazing, 66
- SCBPVA. *See* Subcommittee on Boiler and Pressure Vessel Accreditation.
- Schedule 80, 85
- SCNA. *See* Subcommittee on Nuclear Accreditation.
- Scram (rapid reactor shutdown), 504, 507, 601  
automatic reactor, 507
- Screen height linearity, 11  
of ultrasonic examination, 15
- SCV. *See* Subcommittee for Section V.
- SDF. *See* Single-degree-of-freedom response.
- SDOF. *See* Single-degree-of-freedom oscillators.
- Sealants, 409  
for light-water nuclear plant component leakage, 409  
as repairs for flanged joints, 335
- Seal overlay, for RTP-1 vessel, 264
- Seals  
of Class MC containments, 445  
examination requirements, 449–450  
of high-pressure vessels, 190  
replacement, 333  
visual examination and acceptance standards, 459
- Search unit, 13  
for ultrasonic examination, 13
- SEC. *See* Southeastern Electric Cooperative, Example Nuclear Plant.
- Secondary bending stress, 87. *See also* Stresses.
- Secondary missiles, definition, 558
- Sections. Subheadings of Sections are followed by parts, paragraphs, and then Appendices.
- Section I  
codes addressing flange design, 675  
Figure 3.1 (Fig. 20.1), 3  
power boilers, 678  
requirements for nondestructive examination, 3  
PG-3, 678  
PG-11, 678  
PG-31, 678  
PG-42.1, 678  
PG-42.4.4, 678  
PG-42.4.5, 678  
PG-42.4.7, 678  
PG-42.4.8, 678  
PG-59, 31  
PG-59.1.1.2, 678  
PG-60, 31  
PG-61, 31  
PW-11 (Radiographic and Ultrasonic Examination of Welds), 1  
PW-11.1, 1  
PW-29, 211  
PW-51 (Acceptance Standards for Radiography), 2  
PW-51.1, 2  
PW-51.2, 2  
PW-51.3, 2  
PW-51.3.1, 2  
PW-51.3.2, 2  
PW-51.3.3, 2  
PW-51.3.4, 2  
PW-51.4, 2  
PW-51.5, 2  
Appendix A-250, 2  
Appendix A, Table A-360, 58  
Appendix A, Table A-361, 678
- Section II  
materials for construction of pressure vessels, 32  
materials specifications, 70, 74, 181  
Part A, material specifications, 74, 390, 528  
Part B, 390, 528  
Part C, material procurement, 70, 528  
Part D, 32, 35, 36, 39, 43, 67, 76  
Part D, allowable stress, 53, 106, 108, 126, 677  
Part D, allowable stress tables, 68



Section II (*Continued*)

- Part D, Appendix 1, Table 1-100 (Table 21.11) (Criteria for Establishing Allowable Stress Values for Tables 1A and 1B), 126
- Part D, Code-allowable stress, 121
- Part D, compilation of materials data, 250
- Part D, design stress value, 108, 112, 144
- Part D, limits to maximum allowable stress, 127
- Part D, NFA-4 (external pressure chart), 106
- Part D, reference to tables of material properties, 181
- Part D, shells under external pressure, 76
- Part D, Subpart 1, 678
- Part D, Subpart 1, Table 2A, 527
- Part D, Subpart 1, Table 2B, 527
- Part D, Table 3, 74, 143, 527
- Part D, Table 4, 143, 527, 677
- Section III (Power Piping Codes), 212, 390, 591
  - adoption of NQA-1, 522
  - application of rules, 522
  - Article 3 (Materials), 525
  - ASME B 16.34, 365
  - ASME B 31.1, 338, 360
  - ASME B 31.7, 338, 360, 365
  - Certified Stress Report for Class A&B vessels, 357
  - changes in Code requirements on repair, 340
  - Class 1 systems, 319, 570, 591, 625, 677
  - Class 2 systems, 307, 319, 570, 591, 625, 677
  - Class 3 systems, 307, 319, 570, 591, 625, 677
  - Class A vessels, 518
  - Class B vessels, 518
  - Class C vessels, 518
  - Code Data Report, 343
  - Code of Record of ASME Section III (Nuclear Vessels), 1968, edition, 524
  - code requirements for operability, 564
  - codes addressing flange design, 675
  - compared to Section XI, 307
  - compliance, 532
  - Data Report, damage to light water-cooled nuclear power plant, 391
  - Design Code, 493
  - design fatigue rules, 493
  - design margins for ferritic reactor vessels, 429
  - Design Specification, 349
    - and engineering evaluation of Class MC containments, 457
  - examination records, 330
  - external pressure rules, 151
  - fabrication requirements, 381
  - factor of safety, 430
  - fatigue curves, allowable stresses and, 593
  - fatigue failure data, 646
  - fatigue usage factor calculations, 319
  - flaws or cracklike indications, 417
  - hydrostatic testing, 333
  - initial construction standards and flaw acceptance, 417
  - NA Symbol Stamp, 351
  - NDE methods and acceptance criteria, 380
  - N-Type Certificate Holder, 351–352
  - nuclear accreditation programs, 529
  - nuclear power plant items covered, 372
  - Owner's Requirements, 355
  - plastic strain concentration factors, 644
  - process piping classification requirement, 392
  - Quality Assurance, 522
  - radiography, 338
  - renaming, 519
  - repair/replacement activity, 338
  - replacement piping, 329
  - requirements and changes to Section V requirements, 2
  - requirements for containments, 444, 446
  - rules covering repair welds, 334
  - stress indices, 629
  - structural integrity provisions, 334
  - structural integrity provisions, for light-water reactor plants, 408
  - Table 4, 677
  - using material in lieu of using original Construction Code, 534
  - “Vessels in Nuclear Service”, prevention of low-cycle fatigue failure, 643
  - weld deposit testing, 526
- Section III, Division 1, 406, 572
  - Rules for Construction of Nuclear Power Plant Components, 622
  - rules for metal components of nuclear system, 520
  - Table I-724, 525
  - Appendix I, 594
    - Appendix I, Figure I-9.1, 594
    - Appendix I, Table I-9-1, 636
    - Appendix I, Figure I-9.2
    - Appendix I, Figure I-9.3, 526
    - Appendix I, I-104.4, 525
    - Appendix II, II-1430 (Criterion of Collapse Load), 632, 639
    - Appendix IX (Quality Control and NDE Methods), 522, 692
    - Appendix XI, 678–679, 682, 689
    - Appendix XX, 521
    - Appendix XXIII, 521, 532
    - Appendix E, 678
    - Appendix F, evaluation of functionality and operability criteria, 561, 569,
      - Appendix F, F-1334, 570
      - Appendix F, F-1334.4(c), 570
      - Appendix F, F-1334.5, 571
      - Appendix F, F-1335, 571
    - Appendix G, maximum postulated defects, 310, 420–421
    - Appendix G, G-2110(b), 421
    - Appendix G, G-2120, 421
    - Appendix N (Dynamic Analysis Method), 545–546, 560, 568
    - Appendix N, N-13(a), 454
    - Appendix N, N-132, 519
    - Appendix N, N-133, 519
    - Appendix N, N-141 (Design Specifications), 524
    - Appendix N, N-142 (Stress Report), 524
    - Appendix N, N-143, 524
    - Appendix N, N-144, 524
    - Appendix N, N-151, 524
    - Appendix N, N-153, 519
    - Appendix N, N-310, 525
    - Appendix N, N-312, 525
    - Appendix N, Table N-421, 525
    - Appendix N, Table N-422, 525
    - Appendix N, Table N-423, 525
    - Appendix N, N-454(b), 525
    - Appendix N, N-511, 525
    - Appendix N, N-511.3, 525
    - Appendix N, N-511.4, 525
    - Appendix N, N-511.5, 525
    - Appendix N, N-512, 525
    - Appendix N, N-523(b), 525
    - Appendix N, N-612, 519
    - Appendix N, N-811, 519
    - Appendix N, N-815, 519
    - Appendix N, N-816, 519
    - Appendix N, N-817, 519
    - Appendix N, N-818, 519
    - Appendix P, contents of a typical CMTR, 529–530
    - Subsection NA (General Requirements), 520
    - NA-3700, materials, 360, 520, 525
    - NA-3767.4(a), 526, 528



- NA-4000 (Quality Assurance Program), 522
- Subsection NB, factors leading to peak stress index, 613, 614
- NB-2331, 421
- NB-2500, 417
- NB-3000, 428
- NB-3132, 678
- NB-3132-1, 625
- Table NB-3132-1, 678
- NB-3200 (Design by Analysis), 625, 678
- NB-3222, 678
- NB-3222.4, 678
- NB-3224 (Level C Service Limits), 135
- NB-3225 (Level D Service Limits), 136
- NB-3226, testing, 678
- NB-3227.4, 678
- NB-3228.5 (Simplified Elastic-Plastic Analysis), 637, 629
- NB-3230, 678
- NB-3232.3, 679
- NB-3328.5, 625
- NB-3338.2, 629
- Figure NB-3338.2(a)-2, 629
- Table NB-3338.2(c)-1, 629
- NB-3600, 395
- NB-3622, 622
- NB-3650, 639
- NB-3653.1, 630
- NB-3653.2, 630
- NB-3658, 679
- Table NB-3681(a)-1, 629, 632
- NB-3683, 571
- NB-3683.1(d), 637
- Figure NB-3683.1(d)-1, 637
- NB-3686.5, 634
- NB-4000, 395
- NB-4250, 630
- NB-4422, 212
- NB-5000, 395
- NB-5112, 6
- NB-5300, 417
- Subsection NC
- NC-3111(g) (General Design, Loading Criteria, Loading Conditions), 631
- NC-3132-1, 625
- NC-3262.1, 679
- NC-3262.2, 679
- NC-3262.3, 679
- NC-3262.4, 679
- NC-3600, 395, 637
- NC-3611.2, 639
- Table NC-3611.2(e)-1, 625
- NC-3622, 622
- NC-3640, 627
- NC-3650, 627–628, 630
- NC-3658.1, 679
- NC-3658.2, 679
- NC-3658.3, 679
- NC-3672.6(b), 436
- NC-3673.2, 628, 630
- NC-3673.2(b)-1, 627, 629, 632–633
- Figure NC-3673.2(b)-2, 637–638
- Subsection ND
- ND-3132-1, 625
- ND-3600, 395
- ND-3622, 622
- ND-3650, 627
- Subsection NE
- NE-1120, 448
- Figure NE-1120-1 (Fig. 30.3) (Typical Containment Penetrations), 448
- NE-1132.1, 442
- NE-1132.1(a), 442
- NE-1132.1(b), 442
- NE-1132.1(c), 442
- NE-1132.1(d), 442
- NE-1132.1(e), 442
- Subsection NF (component supports), 329, 520, 526, 528,
- NF-1214, 531
- NF-2000, 528
- NF-2121, 528
- NF-2130, 528
- NF-2610, 528
- NF-3322.1(e)(1), 571
- Subsection NG (core-support structures), 324, 520
- Subsection NX
- NX-2000, 349
- NX-2600, 525
- NX-2610, 360
- NX-4000, 368
- NX-5500, 522
- NX-7000, 564
- Section III, Division 2 (Code for Concrete Reactor Vessels and Containments), 520, 444
- Class CC, inservice inspection, 315
- Class MC, inservice inspection, 315
- components, provisions for, 530
- nuclear accreditation programs, 530
- Subsection NCA (General Requirements), 520
- NCA-1110, 530
- NCA-1120, 530
- NCA-1130(a), 530
- NCA-1130(b), 530
- NCA-1140, 530
- NCA-1140(b), 395, 529
- NCA-1140(f), 529
- NCA-1220, 360
- NCA-3000, duties and responsibilities of Certificate Holder, 531
- NCA-3554, 524
- NCA-3800 (Quality System Certificate), 334, 349, 360, 364, 523, 528, 531
- NCA-3820(c), 531
- NCA-4000 (QA Program), 349, 531
- NCA-4134, 522, 530
- NCA-4134.17, 530
- NCA-5000, duties and responsibilities of Authorized Inspector, 531
- NCA-5121, 521
- NCA-5220, 521
- NCA-8000 (Other Certificate Holders), 531
- NCA-8100, 530
- NCA-8162, 531
- NCA-9000, 442–443
- Section III, Division 3 (Containment Systems for Transport Packaging), 534
- Section III Quality System Certificate (QSC) holders, materials procured from, 361
- Section III Subcommittee for Nuclear Power, 444
- Section III subgroup on nuclear packaging (NUPACK), new subsection WD, 542
- Section IV, 197
- Section V: Nondestructive Examination, 1–26, 63, 98–101, 166, 172, 307, 312, 317, 319, 331, 380, 396
- examination of welded joints, 166
- relation to other ASME Code Book sections, 2–3
- Standard Reference Radiographs for Steel Castings, 98

## Section V, Subsection A (Articles 1 through 13, Mandatory and Nonmandatory appendices), 1

- Article 1 (General Requirements), 3, 4, 18, 21
- Article 1, Appendix I, glossary of terms, I-130, 3
- Article 1, T-140, 3
- Article 1, T-150 (Procedures), 3, 18,
- Article I, T-160 (Calibration), 3
- Article 1, T-170 (Examinations and Inspections), 3
- Article 1, T-180 (Evaluation), 4
- Article 1, T-190 (Records), 4
- Article 1, T-270 (Examination), 3
- Article 2 (Radiographic Examination), 4, 7, 9, 62
- Article 2, Figure 1 (Fig. 20.2)(IQI Design), 7
- Article 2, Appendix I, glossary of terms, 4
- Article 2, Appendix I (In-Motion Radiography), 4
- Article 2, Appendix II (Radioscopic Examination), 4
- Article 2, Appendix III (Digital Image Acquisition and Storage for Radiography and Radioscopy), 4
- Article 2, Appendix IV (Interpretation, Evaluation, and Disposition of Radiographic and Radioscopic Examination Test Results Produced by the Digital Image Acquisition and Display Process), 4
- Article 2, Appendix V (Glossary of Terms for Radiographic Examination), 4
- Article 2, Appendix VI (Digital Image Acquisition, Display, Interpretation, and Storage of radiographs for Nuclear Applications), 4
- Article 2, Appendix VII (radiographic Examination of Metallic Castings), 4
- Article 2, Appendix A (Technique Sketches for Pipe or Tube Welds), 4, 7
- Article 2, Appendix B (Equivalent IQI [Penetrameter] Sensitivity [EPS]), 4, 7
- Article 2, Appendix C (Hole-Type Penetrameter Placement Sketches for Welds), 4
- Article 2, Appendix D (Number of Penetrameters [Special Cases]), 6, 9
- Article 2, T-210 (Scope), 4
- Article 2, T-220 (General Requirements), 6
- Article 2, T-222 (Surface Preparation), 6
- Article 2, T-226 (Extent of Examination), 7
- Article 2, T-230 (Equipment and Materials), 7
- Article 2, Table T-233.1 (Table 20.2)(Hole-type IQI Designations, Thickness, and Hole Diameters, In.), 7, 8
- Article 2, Table T-233.2 (Table 20.3)(Wire IQI Designation and Wire-type Diameters, In.), 7, 9
- Article 2, T-260 (Calibration), 8
- Article 2, T-262 (Step Wedge Film and Densitometer), 6, 8
- Article 2, T-270 (Examination), 8–9
- Article 2, T-271, 6, 8
- Article 2, T-272, 8
- Article 2, T-274, 8
- Article 2, Figure T-275, 8
- Article 2, T-276, 8–9
- Article 2, 7, Table T-276 (Table 20.4)(IQI Selection), 8, 9
- Article 2, T-277, 9
- Article 2, T-280 (Evaluation), 9
- Article 2, T-281 (Radiographic Density), 9
- Article 2, T-281 (Quality of Radiographs), 9
- Article 2, T-285 (Geometric Unsharpness Limitations), 2, 9
- Article 2, T-286, 9
- Article 2, T-290 (Documentation), 8
- Article 2, T-291, 8
- Article 2, T-292 (Radiographic Review Form), 8
- Article 4 (Ultrasonic Examination Methods for Inservice Inspection), 10–14
- Article 4, Appendix III, 10
- Article 4, Appendix A, 9
- Article 4, Appendix B (B-60 Beam Spread)
- Article 4, Appendix C (General Techniques for Straight Beam Calibrations), 9
- Article 4, Appendix D, 9
- Article 4, Appendix E, 9
- Article 4, Appendix F, 9
- Article 4, Appendix G, 9
- Article 4, Appendix H, 9
- Article 4, Appendix I, 9
- Article 4, Appendix J, 9
- Article 4, Appendix J, Figure J-10 (fig. 20.3)(Basic Calibration Block) 9, 10,
- Article 4, Appendix K, 9
- Article 4, Appendix L, 9, 14, 18
- Article 4, Appendix L, Figure L-13-1 (Fig. 20.4)(calibration notch configurations for Outside surface Reflectors)
- Article 4, T-410, 9
- Article 4, T-421, 9
- Article 4, T-422, 9
- Article 4, T-424(General Examination Requirement)
- Article 4, T-435, 14
- Article 4, T-440, (Requirement for Vessel Examinations)
- Article 4, T-441.4.4, 312
- Article 4, T-441.5, 312
- Article 4, T-441.5.1, 312
- Article 4, T-441.5.2, 312
- Article 5, use with Appendix 12 (Section VIII, Division 1): Ultrasonic Examination of Welds (UT), 101
- Article 5, Appendix III, 10
- Article 5, Appendix A, 18
- Article 5, T-54010
- Article 5, Figure T-541.5.1 (Fig. 20.5)(Straight Beam Calibration Block), 18
- Article 5, Table T-541.5.2 (Table 20.5)(Calibration Block Designation per Length and Hole Location), 18
- Article 5, Figure T-542.8.1.1 (Fig. 20.7)(Angle Beam Calibration)[Pope Welds] 18
- Article 5, Figure T-543.2 (Fig. 20.8)(Calibration Block for Technique 1)18
- Article 6 (Liquid-Penetrant Examination), 15–16
- Article 6, Appendix I, 4
- Article 6, Table T-672 (Table 20.6) (Minimum Dwell Times), 16
- Article 6, used with Section VIII, Division 1, Appendix 8, 99
- Article 7 (Magnetic-Particle Examination), 16
- Article 7, Appendix I, 4
- Article 7, Appendix II, 16
- Article 7, T-741.1, 17
- Article 7, T-742.2, 17
- Article 7, Figure T-753 (Fig. 20.9) (Magnetic-Particle Field Indicators), 18
- Article 7, T-790, 18
- Article 7, used with Section VIII, Division 1, Appendix 6, 98
- Article 8 (Eddy-Current Examination of Tubular Products), 18–19
- Article 8, Appendix I (Eddy-Current Examination Method for Installed Nonferromagnetic Heat Exchanger Tubing), 18–19
- Article 8, Appendix II (Eddy-Current Examination of Nonferromagnetic Heat Exchanger Tubing), 18–19
- Article 8, Appendix III (Eddy-Current Examination on Coated Ferritic Method), 18–19
- Article 8, Appendix IV (Glossary of Terms for Eddy-Current Examination), 18–19
- Article 9 (Visual Examination), 19
- Article 9, Appendix I, 19
- Article 10 (Leak Testing), 19
- Article 10, Appendix I (Bubble Test [Direct Pressure Technique]), 19
- Article 10, Appendix II (Bubble Test [Vacuum Box Technique]), 19
- Article 10, Appendix III (Halogen Diode Detector Probe Test), 19

- Article 10, Appendix IV (Helium Mass Spectrometer [Detector Probe Technique]), 19
- Article 10, Appendix V (Helium Mass Spectrometer [Tracer Probe and Hood Technique]), 19
- Article 10, Appendix VI (Pressure Change Test), 19
- Article 10, Appendix VII (Glossary of Terms), 19
- Article 10, Appendix A (Leak Testing Formula Symbols), 20
- Article 11 (Acoustic Emission Examination of Fiber-Reinforced Plastic Vessels), 21
- Article 11, Appendix I (Instrumentation Performance Requirements), 21
- Article 11, Appendix II (Instrument Calibration), 21,
- Article 11, Appendix III (Glossary of Terms), 21
- Article 11, Appendix A (Sensor Placement Guidelines), 21
- Article 11, Appendix B (Supplemental Information for Conducting AE Examinations), 22
- Article 11, T-1121, 21
- Article 12 (Acoustic Emission Examination of Metallic Vessels during Pressure Testing), 21
- Article 12, Appendix I (Instrumentation Performance Requirements), 21
- Article 12, Appendix II (Instrumentation Calibration and Cross-Referencing), 21
- Article 12, Appendix III (Glossary of Terms), 21
- Article 12, Appendix A (Sensor Placement Guidelines), 21, 22
- Article 12, Appendix B (Supplemental Information for Conducting AE Examinations), 22
- Article 13 (Continuing AE Monitoring), 26
- Article 13, Appendix I (Nuclear Components), 26
- Article 13, Appendix II (Nonnuclear Metal Components), 26
- Article 13, Appendix III (Nonmetallic Components), 26
- Article 13, Appendix IV (Limited Zone Monitoring), 26
- Article 13, Appendix V (Hostile-Environment Applications), 26
- Article 13, Appendix VI (Leak-Detection Applications), 26
- Article 13, Appendix VII (Glossary of Terms), 26
- Section V, Subsection B (ASTM Standards: Article 22 through 30 adopted by the Code), 1
- Section V
  - Article 22, SE- 94, 7
  - Article 22, SE- 747, 7
  - Article 22, SE-999, 7
  - Article 22, SE-1025, 7
  - Article 22, SE-1079 (Calibration of Transmission Densitometers), 3, 7
  - Article 22, SE-1815(Standard Test Method for Film Systems for Industrial Radiography), 7
  - Article 23, SA, SB, and SE standards, 10, 15
  - Article 23, SA-578, 13
  - Article 24, SD standard 129, 15
  - Article 24, SD standard 516, 15
  - Article 24, SD standard 808, 15
  - Article 24, SD standard 1552, 15
  - Article 24, SE-165, 15–16
  - Article 24, SE-165, Annex 1, 16
  - Article 24, SE-1209, 2
  - Article 24, SE-1219, 2
  - Article 24, SE-1220, 2
  - Article 25, SE-709,
  - Article 26, SE-215, 2, 18
  - Article 26, SE-243, 18
  - Article 26, SE- 246, 18
  - Article 26, SE-309, 18
  - Article 26, SE-571, 2
  - Article 30, SE-1316 (Standard Terminology for Nondestructive Examination), 4, 18
- Subsections A and B, Mandatory Appendix II (Mandatory Submittal of Technical Inquiries to BPVC, guidance and directions for) and categories, 1
- Section IV, Section XI and, 522
- Section VII, Section XI and, 522
- Section VIII, 21, 197, 211, 679
  - construction of unfired pressure vessels, 444
  - design rules, 704
- Section VIII, Division 1 (Rules for Construction of Pressure Vessels), 675–709
  - codes addressing flange design, 675
  - design accordance with ASME B 31.1, 679
  - design of nonstandard flanges, 680
  - design rules compared to Section X, Class II pressure vessel scope, 708
  - fatigue analysis requirement, 148
  - Figure 21.11 (Definition of Supported Tubesheet), 57
  - Figure 21.19 (Fracture Analysis Diagram for the Engineering Selection of Fracture-safe Steels Based on NDT Temperature), 71, 72
  - Figure 21.22 (Cone-to-Cylinder Free Body Diagram), 91
  - Figure 21.23 (Free Body Diagram of Bolted Flange), 92, 94
  - Figure 21.38 (Free Body diagram for Tubesheet Shell), 87–88
  - Figure 21.41 (Free Body Diagram-Half-Pipe Jacket), 130
  - Figure 40.1 (Flange Discontinuity Analysis), 681
  - HAZ impact specimen location not specified, 220
  - jacket of Division 3 high-pressure vessel construction, 178
  - longitudinal-hub stress, 692
  - non-allowance of reinforcement rings, 148
  - nozzle attachment details, 157–158
  - openings in pressure vessels, 155–156
  - qualification of flanges not in accordance, 680
  - rules for construction of pressure vessels, 30–38, 41–43, 45–47, 49–52, 56–57, 59–63, 65–66, 69, 71–74, 81, 83, 85, 87, 91–94, 97, 99, 100–102, 106–108, 110, 112, 114–115, 118, 121–122, 124–126, 132, 134
  - rules for design of nonstandard flanges, 677
  - Table 40.2 (The Moment Arm), 683
  - Table 40.5 (Bolt Area and Spacing), 683, 688, 693, 697, 699, 709
  - terminology, 705
- Section VIII, Division 1, Subsection A (General Requirements for All Methods of Construction and All Materials), 31–38, 41–43, 45–47, 49, 63, 66, 81
  - fabrication and inspection of jacketed vessels, requirements, 101
  - general requirements, supplementing, 86
  - mandatory for high-alloy steel material, 74
  - when layered vessel is used in lethal service, 84–86
  - U-1 (Scope of Section VIII), 28–30
  - U-1(c)(1), 29–30, 123
  - U-1(c)(2)(h), 44
  - U-1(d), 29
  - U-1(e)(1)(c), 32
  - U-1(g), 29–31
  - U-1(h), 28–31, 36
  - U-1(i), 28–29
  - U-1(j), 29–30, 48, 129, 130
  - U-2, 30–31
  - U-2(a), 30, 118, 121, 125
  - U-2(a)(4), 31
  - U-2(b), 31
  - U-2(d), 31
  - U-2(g), 31, 72, 97, 103, 108, 632, 702, 703
  - U-3, 31, 41
  - Table U-3 (Table 40.1)(Year of Acceptance Edition of Referenced Standards), 31, 676
  - Part UB (Requirements for Pressure Vessels Fabricated by Brazing), 65–66
  - Table UB-2 (Table 21.4)(Maximum Design Temperatures, °F, for Brazing Filler Metal), 65
  - UB-12, 63

## Section VIII, Division 1, Subsection A (Continued)

Figure UB-14 (Fig. 21.15)(Examples of Filler Metal Application), 65

UB-14(a), 118

UB-14(b), 118

Figure UB-16 (Fig. 21.16)(Some Acceptable Types of Brazed Joints), 65–66

Table UB-17 (Table 21.5)(Recommended Joint Clearances at Brazing Temperature), 65–66

UB-31, 65

UB-32, 65

UB-43, 65

UB-44, 65

UC-98, 49, 125

Part UF (Requirements for Pressure Vessels Fabricated by Forging), 63–64, 83, 106

UF-12, 63

UF-27, 63

Table UF-27, 63

UF-32(b), 65

UF-37, 65

UF-37(b), 65

Part UG, 31–32

Part UG, design of layered vessels, 84

Part UG, forged construction requirements, supplemented, 63

Part UG, reinforcement rules for opening, 57

Part UG, rules for reinforcement, 65

UG-2(a), 46

UG-4, 32

UG-4(b), 32

UG-5, 32

UG-6, 32

UG-7, 32

UG-8, 32, 106

UG-9, 32

UG-10, 32, 66

UG-11, 32, 66

UG-11(2), 676

UG-12, 32

UG-13, 32

UG-14, 32

UG-15, 32

UG-16, 42, 32–33

UG-16(b), 42

UG-16(c), 33

UG-16(d), 33

UG-16(e), 33

UG-20, 33, 47–48, 93, 118

UG-20(b), 33, 72

UG-20(f), 33, 44, 47, 141

UG-21, 33, 34, 46, 125

UG-22, 31, 33–35, 42, 46, 51–52, 70, 72, 87, 118, 121, 143, 676

UG-22(b), 35

UG-23, 34, 35, 51, 87

UG-23(a), 32, 34

UG-23(b), 35

UG-23(c), 35, 97

UG-23(d), 35

UG-24, 82, 83

UG-25, 35

UG-27, 35, 38, 97, 87, 91

UG-27(c)(1), 124

UG-28, 36, 42, 74

Figure UG-28.1 (Fig. 21.1)(Diagrammatic Representation of Lines of Support for Design of Cylindrical Vessels Subjected to External Pressure), 36–37, 92

Figure UG-29, 36, 38

UG-29(c)(1), 37–38

UG-29(c)(2), 37–38

UG-29(c)(3), 37–38

UG-29(c)(4), 37–38

Figure UG-29.2 (Fig. 21.2)(Maximum Arc of Shell Left Unsupported Because of Gap in Stiffening Ring of Cylindrical Shell Under External Pressure), 37–38, 42, 83

UG-32, 38, 41

UG-32(d)(Ellipsoidal Heads), 91, 124

UG-32(e), 91, 124

UG-32(f) (Hemispherical heads), 124

UG-32(g)(Conical heads and sections), 124

UG-32(j), 38

UG-33, 41

UG-33(d), 41

UG-33(e), 41

UG-34 (Unstayed flat heads), 41–42, 56, 103, 676, 696

UG-34(b), 56

UG-34(c)(2)(Flat Heads), 124

UG-34(d), 41

Figure UG-34 (Fig. 21.3)(Some Acceptable Types of Unstayed Flat Heads and Covers), 40–41, 57

UG-36, 77, 82, 99

UG-36(b)(1), 92

UG-36(c)(3), 42, 57, 63

UG-36(c)(3)(c), 115

UG-36(c)(3)(d), 115

UG-37, 33, 42, 57

Figure UG-37 (Fig. 21.4)(Chart for Determining Value of F, as Required in VG-37) 42

UG-40, 33

UG-41, 57

UG-44, 31, 92, 133, 675

UG-45, 42, 41, 85, 157

UG-45(b), 42

UG-46, 77, 82, 99

UG-47, 99

UG-53, 35, 42

UG-75, 42

UG-76, 42

UG-77, 42

UG-78, 42

UG-79, 42

UG-80, 42–44, 64, 111

UG-80(b), 43

UG-80(b)(9), 43

UG-80(b)(10), 43

Figure UG-80.1 (Fig. 21.5)(Maximum Permissible Deviation from a Circular Form  $e$  for Vessels Under External Pressure), 42–43

UG-81, 42–43

UG-82, 42

UG-83, 42

UG-84, 34, 42, 72, 83

UG-84(b), 44

UG-84(c)(4)(b), 45

UG-84(c)(5)(b), 44

UG-84(g)(1), 220–221

UG-84(g)(2), 220–221

UG-84(h)(3), 220–221

UG-84(i), 71, 76

Figure UG-84 (Fig. 21.6)(Simple Beam Impact Test Specimens [Charpy Type Test]), 44

Figure UG-84.1 (Fig. 21.7)(Charpy V-Notch Impact Test Requirements for Full Specimens for Carbon and Low-Alloy Steels, min. TS < 95KSI), 45

Table UG-84.4, 44, 69

UG-85, 42

UG-90, 44

- UG-90(c)(1), 44
- UG-90(c)(2), 46
- UG-91, 46
- UG-93, 46
- UG-98, 46
- UG-99, 32, 46–47, 62, 78, 111
- UG-99(a), 47
- UG-99(b), 34, 47
- UG-99(c), 47, 96
- UG-100, 46, 87, 96
- UG-100(b), 96
- UG-101, 41, 48, 99, 103, 105, 133
- UG-103, 44
- UG-115, 48
- UG-116, 133
- UG-116(d), 29
- UG-118, 133
- UG-120, 48, 129
- UG-120(c), 111
- UG-125, 48–49, 125
- UG-125(a), 49, 125
- UG-125(b), 29, 49, 125
- UG-125(g), 49, 124
- UG-125(h), 49, 125
- UG-126, 49
- UG-127, 49
- UG-131, 108
- UG-134(a), 48
- UG-137, 48
- Section VIII, Division 1, Subsection B (Requirements Pertaining to Methods of Fabrication of Pressure Vessels), 49–52, 56–57, 59–60, 62–63, 65–66, 81, 527
- fabrication and inspection of jacketed vessels, requirements, 101
- mandatory for high-alloy steel material, 74
- when layered vessel is used in lethal service, 84, 86
- Part UW (Requirements for Pressure Vessels Fabricated by Welding), 49–52, 56–57, 59–60, 62–63
- UW-2, 30, 41, 47, 49, 51–52, 57, 62, 68, 75, 101, 121, 124
- UW-2(a), 49, 67–68, 71–72, 84–85, 105
- UW-2(b), 50, 71
- UW-2(c), 29, 50
- UW-2(d), 50
- UW-2(d)(3), 33, 50
- UW-3(b), 51–52
- Figure UW-3 (Fig. 21.8)(Illustration of Welded Joint Locations Typical of Categories A, B, C, and D), 50
- UW-5, 32, 50, 83
- UW-9, 51
- UW-9(d), 51
- UW-9(f), 55
- UW-9(g), 51–52
- UW-11, 52, 69, 74–75, 124
- UW-11(a), 63, 122
- UW-11(a)(1), 122, 124
- UW-11(a)(2), 121–122, 124
- UW-11(a)(3), 122, 124
- UW-11(a)(4), 48
- UW-11(a)(5), 48, 122, 124
- UW-11(a)(5)(b), 48, 52, 62–63, 121–122, 124
- UW-11(a)(7), 52, 87
- UW-11(b), 48, 52, 63, 122, 124
- UW-11(c), 122, 124
- UW-11(f), 51
- UW-12, 124
- UW-12(d), 122
- Table UW-12 (Table 21.1)(Maximum Allowable Joint Efficiencies for Arc- and Gas-welded Joints), 36, 50–52, 56, 73, 74, 81, 83, 121–122, 124
- UW-13, 56
- UW-13(b)(3), 56
- UW-13(b)(4), 51
- UW-13(d), 55
- UW-13(e)(3), 56–57
- UW-13(e)(4), 46, 113
- UW-13(f), 57
- Figure UW-13.1 (Fig. 21.9)(Heads Attached to Shells), 53, 87
- Figure UW-13.1 (Fig. 21.10)(Attachment of Pressure Parts to Flat Plates to Form a Corner Joint), 51, 53, 56
- Figure UW-13.2, 67
- Figure UW-13.2(e), 102
- Figure UW-13.2(f), 67, 102
- Figure UW-13.2(g), 102
- Figure UW-13.3 (Fig. 21.12)(Typical Pressure Parts with Butt-Welded Hubs), 57
- Figure UW-13.4 (Fig. 21.13)(Nozzle Necks Attached to Piping of Lesser Wall Thickness), 57
- Figure UW-13.5, 50
- UW-14, 57
- UW-15, 57
- UW-16, 57
- UW-16(c)(1), 59
- UW-16(c)(2), 59
- UW-16(f)(2), 61
- UW-16(f)(4), 61
- Figure UW-16.1 (Fig. 21.14)(Some Acceptable Types of Welded Nozzles and Other Connections to Shells, Heads, etc.), 57, 59–60
- Figure UW-16.1(a), 67
- UW-17, 51
- UW-18, 58
- UW-18(b), 52, 55
- UW-18(d), 58
- UW-19(c), 105
- UW-20, 58, 90, 116
- UW-20(a)(2), 118
- UW-27, 58
- UW-32, 212
- UW-33, 55, 58, 60
- Table UW-33 (Table 21.2)(Allowable Offset at Butt Welds), 61
- UW-35, 51, 61, 83
- UW-35(d), 61
- UW-37(f), 61
- UW-39, N212
- UW-40, 61–62, 68
- UW-40(a), 62
- UW-40(a)(3), 62
- UW-40(a)(7), 62
- UW-40(f), 62, 67, 68, 75, 96
- UW-41, 121
- UW-42, 51, 62
- UW-47, 63
- UW-48, 63
- UW-49, 63
- UW-50, 47
- UW-51, 52, 62, 121
- UW-52, 7, 52, 62, 121
- UW-53, 52
- Section III, Division 1, Subsection C (Requirements Pertaining to Classes of Materials), 63, 67, 70–72, 78, 83, 87
- Part UCD, 82–83
- UCD-3, 82
- UCD-23, 126
- Table UCD-23, 32, 82, 126, 127
- UCD-37, 82
- UCD-78(a), 83
- UCD-78(b), 83



Section III, Division 1, Subsection C (*Continued*)

- UCD-101, 83
- Part UCI, 76, 78, 82
- UCI-3, 76
- UCI-23, 32, 126
- Table UCI-23, 32, 76, 127
- UCI-37, 78
- UCI-78(a), 78
- UCI-78(b), 78
- UCI-101, 78
- Part UCL, 78, 81
- UCL-35, 52, 82, 133
- UCL-36, 52
- Part UCS (Requirements for Pressure Vessels Constructed of Carbon and Low-Alloy Steels), 50, 67, 70–72, 83
- Table UCS-23, 32, 45, 66, 70, 73
- UCS-56, 62, 67, 71, 83, 99, 126
- UCS-56(d), 68
- UCS-56(f), 68
- Table UCS-56 (Table 21.3)(Postweld Heat Treatment Requirements for Carbon and Low-Alloy Steels), 67, 70–71
- Table UCS-56.1 (Table 21.6)(Alternative Postweld Heat Treatment Requirements for Carbon and Low-Alloy Steels), 62, 67–68
- UCS-57, 52, 68, 70
- Table UCS-57 (Table 21.7)(Thickness Above Which Full Radiographic Examination of Butt-Welded Joints is Mandatory), 70
- UCS-66, 34, 44, 69, 71 123
- UCS-66(a), 70
- UCS-66(b), 70, 73
- UCS-66(d), 70
- Figure UCS-66 (Fig. 21.17)(Impact Test Exemption Curves), 34, 67, 69–72, 123
- Figure UCS-66.1 (Fig. 21.20)(Reduction in Minimum Design Metal Temperature Without Impact Testing), 72–73, 123
- Figure UCS-66.2, 73
- Figure UCS-66.3 (Fig. 21.18)(Some Typical Vessel Details Showing the Governing Thicknesses as Defined in UCS-66), 70–71
- UCS-67, 67, 70–72
- UCS-67(d), 71
- UCS-68, 67, 70–72
- UCS-68(c), 71
- UCS-79, 71
- UCS-79(d), 41, 71
- UCS-85, 41, 71, 73
- UCS-85(f), 71
- UCS-160, 72, 83
- Part UHA (Requirements for Pressure Vessels Constructed of High-alloy Steel), 50, 63, 74–76
- Table UHA-23, 32, 75
- UHA-32, 62, 75, 127
- Table UHA-32, 62, 75, 126
- UHA-33, 52, 75
- UHA-34, 75
- UHA-51, 44, 75–76
- UHA-51(a)(3), 75
- UHA-51(a)(4), 75
- UHA-51(c), 75
- UHA-51(d), 76
- UHA-51(e), 76
- UHA-51(f), 76
- Part UHT, 83–84, 87
- UHT-5(d), 87
- UHT-6, 83
- UHT-6(a)(4), 83
- Figure UHT-6.1, 83
- UHT-17(b), 83
- UHT-18, 83
- UHT-20, 83
- Table UHT-23, 32, 83
- UHT-28, 83
- UHT-56, 83, 62, 86
- Table UHT-56, 62, 83
- UHT-57, 84
- UHT-57(a), 52
- UHT-79(a), 41
- UHT-81, 84
- UHT-82, 84
- Part ULT, 86–87, 127
- ULT-16, 87
- ULT-23, 87
- Table ULT-23, 32, 87
- ULT-27, 87
- ULT-57, 87
- Figure ULT-82, 87
- ULT-99, 87
- ULT-115, 87
- Part ULW, 84–86,
- Figure ULW-2.1 (Fig. 21.21)(Some Acceptable Layered Shell Types), 85, 86
- ULW-16, 84
- Figure ULW-17.1, 84
- Figure ULW-17.2, 84
- Figure ULW-17.3, 84
- Figure ULW-17.4, 84
- Figure ULW-18.1, 84, 85
- ULW-77, 86
- ULW-78, 86
- Part UNF (Requirements for Pressure Vessels Constructed of Nonferrous Materials), 71, 74
- UNF-19, 74
- Table UNF-23, 32, 74, 133
- UNF-56, 74
- UNF-57, 52, 74
- UNF-58, 74
- UNF-65, 87
- Appendix NF, 74
- Section V, Subsection A (Articles 1-14 Mandatory and Nonmandatory Appendices), 22
- Article 1, Nonmandatory Appendix A, 4
- Article 4, Nonmandatory Appendix L, 14
- Article 5, Mandatory Appendices I, II, and IV, 15
- Article 6, Mandatory Appendices II and III, 16
- Article 7, Mandatory Appendix III, 18
- Article 10, Mandatory Appendix X, 20
- Article 10, Mandatory IX, 20
- Article 14, 22
- Section V, Subsection B (ASTM Standards: Article 22 through 30 adopted by the code), 2
- Article 22, SE-42, 2
- Article 22, SE-186, 2
- Article 22, SE-242, 2
- Article 22, SE-280, 2
- Article 22, SE-446, 2
- Article 22, SE-1079, 2
- Article 22, SE-1815, 2
- Article 22, SE-1209, 2
- Article 22, SE-1219, 2
- Article 22, SE-1220, 2
- Article 26, SE-215, 2
- Article 26, SE-309, 2
- Article 26, SE-426, 2
- Article 26, SE-571, 2
- Article 27, SE-432, 2

- Article 27, SE-479, 2  
 Article 28, SD-2563, 2  
 Section VIII, Division 1, Appendices, 4, 7, 9–10, 15, 21, 26, 30  
 Appendix 1 (Supplementary Design Formulas), 87, 90  
 Appendix 1, 1-1 87, 90–91  
 Appendix 1, 1-2, 90–91  
 Appendix 1, 1-3, 90  
 Appendix 1, 1-4, 4, 91  
 Appendix 1, 1-5, 4, 7, 91  
 Appendix 1, 1-6, 91  
 Appendix 1, 1-7, 4, 7, 91  
 Appendix 1, 1-7(a), 4, 7, 91  
 Appendix 1, 1-7(b), 91  
 Appendix 1, 1-8, 91–92  
 Appendix 2 (Rules for Bolted Flange Connections with Ring-Type Gaskets), 42, 92–94, 256, 677, 681, 682, 686, 688, 698, 700, 702–703, 707  
 Appendix 2, 4  
 Appendix 2, Figure 2-4 (Fig 21.24), (Types of flanges), 92  
 Appendix 2, Figure 2-4 (Fig 40.3) (Types of flanges), 684–686  
 Appendix 2, 2-5(e), 696  
 Appendix 2, Table 2-5.1 (Table 40.4)(Gasket Materials and Contact Facing), 687–688  
 Appendix 2, Table 2-5.2 (Table 40.3)(Effective Gasket Width), 682, 686, 696  
 Appendix 2, Table 2-6 (Table 40.2)(The Moment Arm), 692,  
 Appendix 2, Figure 2-7.1 (Fig. 40.4)(Values of  $T$ ,  $U$ ,  $Y$ , and  $Z$  [terms involving  $K$ ]), 689  
 Appendix 2, Table 2-7.1, 694  
 Appendix 2, Figure 2-7.2 (Fig. 40.5)(Values of  $F$  [Integral Flange Factors]), 689–690, 694  
 Appendix 2, Figure 2-7.3 (Fig. 40.7)(Values of  $V$  [Integral Flange Factors]), 689, 691, 694  
 Appendix 2, Figure 2-7.4 (Fig. 40.8)(Values of  $FL$  [Loose Hub Factors]), 692  
 Appendix 2, Figure 2-7.5 (Fig. 40.9)(Loose Hub Flange Factors), 692  
 Appendix 2, Figure 2-7.6 (Fig. 40.6)(Values of  $f$  [Hub Stress Correction Factor]), 689, 691, 694  
 Appendix 2, 4, 7, 9  
 Appendix 2, 2-8(a)(4), 128  
 Appendix 2, Figure 2-13.1 (Fig. 40.10)(Reverse Flange), 694, 695  
 Appendix 2, Figure 2-13.2 (Fig. 40.11)(Loose Ring-Type Reverse Flange), 694, 695  
 Appendix 3 (General Primary membrane Stress), 35, 46  
 Appendix 4 (Rounded Indication Charts, Acceptance Standards for Radiographically Determined Rounded Indications in Welds), 62, 99  
 Appendix 4, Figure 4.1, 99  
 Appendix 4, Table 4-1, 99  
 Appendix 4, Figure 4.3, 99  
 Appendix 4, Figure 4.4, 100  
 Appendix 4, Figure 4.5, 99  
 Appendix 4, Figure 4.6, 99  
 Appendix 4, Figure 4.7, 99  
 Appendix 4, Figure 4.8, 99  
 Appendix 6 (Methods for Magnetic-Particle Examination [MT]), 99  
 Appendix 7 (Examination of Steel Castings), 99  
 Appendix 7, 7-3, 99  
 Appendix 8 (Methods for Liquid-Penetrant Examination [PT]), 99, 100  
 Appendix 9 (Jacketed Vessels), 99–102  
 Appendix 9, 9-5, 99  
 Appendix 9, 9-6, 99  
 Appendix 9, 9-6(d)(6), 99  
 Appendix 9, Figure 9.2 (Fig. 21.25), 100  
 Appendix 9, 101  
 Appendix 9, Figure 9.6 (Fig. 21.27)(Some Acceptable Types of Penetration Details), 102  
 Appendix 10 (Quality Control System), 101  
 Appendix 11 (Capacity Conversions for Safety Valve), 101  
 Appendix 12 (Ultrasonic Examination of Welds [UT]), 101  
 Appendix 13 (Vessels of Noncircular Cross Section), 101  
 Appendix 13, 13-4(c), 103  
 Appendix 13, 13-6, 103  
 Appendix 13, 13-14, 103, 10  
 Appendix 13, 13-15, 103, 10  
 Appendix 13, 13-16, 103, 10  
 Appendix 13, 13-17, 103, 10  
 Appendix 13, 13-18, 103, 10  
 Appendix 14 (Integral Flat Heads with a Large, Single, Circular, Centrally Located Opening), 103  
 Appendix 16 (Submittal of Technical Inquiries to the Boiler and Pressure Vessel Committee), 103  
 Appendix 17, 103-105  
 Appendix 18 (Adhesive Attachment of Nameplates), 105  
 Appendix 19 (Electrically Heated or Gas-Fired Jacketed Steam Kettles), 105  
 Appendix 20 (Hubs of Tubesheets and Flat Heads Machined from Plate), 105  
 Appendix 20, 105  
 Appendix 21 (Jacketed Vessels Constructed of Work-Hardened Nickel), 105  
 Appendix 22 (Integrally Forged Construction), 105  
 Appendix 22, Figure 22-1 (Fig. 21.29)(Typical Section of Special Seamless Vessels), 106  
 Appendix 23 (External Pressure Design of Copper, Copper Alloy, and Titanium Alloy Seamless Condenser and Heat-Exchanger Tubes with Integral Fins), 32, 106  
 Appendix 23, 23-4, 106  
 Appendix 24 (Design Rules for Clamp Connections), 106, 107, 677, 700  
 Appendix 24, Figure 24-1 (Fig. 21.30)(Typical Hub and Clamp), 106, 107, 108  
 Appendix 24, Figure 24.1 (Fig. 40.13)(Typical Hub and Clamp), 701  
 Appendix 24, Figure 24-2 (Fig. 21.30)(Typical Hub and Clamp), 106, 107, 108  
 Appendix 24, Figure 24-2 (Fig. 40.14)(Typical Clamp-Lug Configurations), 702  
 Appendix 24, 24-6, 108  
 Appendix 24, Table 24-8, 108  
 Appendix 25 (Acceptance of Testing Laboratories and Authorized Observers for Capacity Certification of Pressure-Relief Valves), 108  
 Appendix 26 (Pressure Vessel and Heat-Exchanger Expansion Joints), 108, 110, 112,  
 Appendix 26, 108, 110  
 Appendix 26, Figure 26.2 (Fig 21.32)(Some Typical Flexible Elements to Weld End Details), 110, 112  
 Appendix 26, 26-3(a) 110, 112  
 Appendix 27 (Alternative Requirements for Glass-Lined Vessels), 65, 111  
 Appendix 27, 27-2, 111  
 Appendix 27, 27-4, 112  
 Appendix 28 (Alternative Corner Joint Detail for Box Headers for Air-Cooled Heat Exchangers), 113  
 Appendix 28, Figure 28-1 (Fig. 21.33)(Weld Fusion Line and Geometry Requirements for Using Appendix 28), 114  
 Appendix 29 (Requirements for Steel Bars of Special Section for Helically wound, Interlocking Strip-Layered Vessels), 114, 115  
 Appendix 29, Tabel 29-2-1, 114  
 Appendix 29, Tabel 29-2-2, 114  
 Appendix 29, Tabel 29-6-1, 114

Section VIII, Division 1, Appendices, (*Continued*)

- Appendix 30 (Rules for Drilled Holes, not Penetrated through the Vessel Wall), 115
- Appendix 30, Figure 30-1 (Fig. 21.34)(Thickness Ratio versus Diameter Ratio) 115
- Appendix 31 (Rules for Cr-Mo Steels with Additional Requirements for Welding and Heat Treatment), 115
- Appendix 31, Table 31-1 (Table 21.8)(Material Specifications), 115
- Appendix 31, Table 31-2 (Table 21.9)(Composition Requirements for  $2\frac{1}{2}$  Cr-1Mo- $\frac{1}{2}$  V Weld Metal), 115
- Appendix A (Basis for Establishing Allowable Loads for Tube-to-Tubesheet Joints), 115, 118
- Appendix A, A-2, 118
- Appendix A, Figure A-2 (Fig. 21.35)(Some Acceptable Types of Tube-to-Tubesheet Welds), 118
- Appendix A, Table A-2 (Table 21.10)(Efficiencies  $f_r$ ), 118
- Appendix A, A-3, 118
- Appendix A, A-3(a), 118
- Appendix A, A-3(k), 118
- Appendix A, A-4, 118
- Appendix C (Suggested Methods for Obtaining the Operating Temperature of Vessel Walls in Service), 118
- Appendix D (Suggested Good Practice Regarding Internal Structures), 118
- Appendix E (Suggested Good Practice Regarding Corrosion Allowance), 118–119
- Appendix F (Suggested Good Practice Regarding Linings), 119
- Appendix G (Suggested Good Practice Regarding Piping Reactions and Design of Supports and Attachments), 120
- Appendix H (Guidance to Accommodate Loadings Produced by Deflagration), 34, 121
- Appendix K (Sectioning of Welded Joints), 121
- Appendix L (Examples Illustrating the Application of Code Formulas and Rules), 36, 38, 69, 121–122, 124
- Appendix L, L-1, 121
- Appendix L, Figure L-1.4-1 (Fig. 21.36)(Joint Efficiency and Weld Joint-Type Cylinders and Cones), 121–122
- Appendix L, Figure L-1.4-3 (Fig. 21.37)(Joint Efficiencies for Categories A and D Welded Joints in Shells, Heads, or Cones), 124
- Appendix L, example L-1.5.2, 124
- Appendix L, example L-2.1, 123
- Appendix L, L-2, 121
- Appendix L, L-3, 121
- Appendix L, L-4, 43, 121
- Appendix L, L-5, 121
- Appendix L, L-6, 121
- Appendix L, L-7, 42, 121
- Appendix L, example L-7.2, 57
- Appendix L, example L-7.3, 57
- Appendix L, example L-7.4, 57
- Appendix L, example L-7.5, 57
- Appendix L, example L-7.6, 57
- Appendix L, L-8, 121
- Appendix L, L-9, 121
- Appendix M (Installation and Operation), 49, 123, 125–126
- Appendix M, M-2, 123
- Appendix M, M-3, 123
- Appendix M, M-5, 123
- Appendix M, M-5(a), 123
- Appendix M, M-5(b), 123
- Appendix M, M-6, 125
- Appendix M, M-7, 125
- Appendix M, M-8, 125
- Appendix M, M11, 125
- Appendix M, M-14, 126
- Appendix P (Basis for Determining Allowable Stress Values), 126
- Appendix P, Table P-1, 126
- Appendix R (Preheating), 126
- Appendix S (Design Considerations for Bolted Flange Connections), 92–93, 126, 677, 682, 707, 709
- Appendix S, S-2, 93
- Appendix T (Temperature Protection), 93
- Appendix W (Guide for Preparing Manufacturer's Data Reports 129
- Appendix Y (Flat-Face Flanges with Metal-to-Metal Contact Outside the Bolt Circle), 129,
- Appendix Y, Figure Y-3.2 (Fig. 40.12)(Flange Dimensions and Forces), 698–699
- Appendix Y, Table Y-6.1, 699
- Appendix Y, Y-10, 130
- Appendix AA (Rules for the Design of Tubesheets), 89
- Appendix CC (Flanged and Flued or Flanged-Only Expansion Joints), 97
- Appendix CC, CC-3(a)(1), 97
- Appendix CC, CC-3(a)(2) 97
- Appendix CC, CC-6, 97
- Appendix DD (Guide to Information Appearing on the Certificate of Authorization), 97
- Appendix EE (Half-Pipe Jackets), 132, 134
- Appendix EE, Figure EE-1 (Figure 21.42)(NPS 2 Pipe Jacket), 132
- Appendix EE, EE-2, 130
- Section VIII, Division 2 (Alternate Rules for Pressure Vessels), 644, 688
  - allowable stress for stainless steel, 97
  - alternative rules for pressure vessel design, 677
  - Codes addressing flange design, 675
  - compared with Section VIII, Division 1, 138
  - cost of pressure vessels, 138
  - covers gas-cooled nuclear plants,
  - detailed stress analysis in accordance,
  - exemptions, 139
  - Figure 22.1 (Charpy V-Notch Impact Test Requirements for TS <95 KSI as listed in Table ACS-1), 142
  - Figure 22.2 (Charpy V-Notch Impact Test Requirements for TS >95 KSI for Table AQT-1 materials), 143
  - Figure 22.3 (Comparison of Cylindrical Shell Formulas), 147
  - Figure 22.4, 149
  - Figure 22.5, 152
  - Figure 22.6, 151
  - Figure 22.7, 152
  - Figure 22.8, 153–154
  - Figure 22.9, 153
  - Figure 22.10 (Spheres under External Pressure), 153, 157
  - geometric scope, 139
  - longitudinal-hub stress, 692
  - scope and jurisdiction, 139, 389
  - Table ACS-1, 142
- Part AD (Special Design and Fabrication Requirements), 137
- Article D-1, 143
- AD-100, 146, 157
- AD-100(b), 145
- AD-110, 143
- AD-121, 143
- Table AD-150.1, 143
- AD-151, 145
- AD-160, 169, 171
- AD-160.2, 145
- AD-160.3, 145
- Article D-2, 143, 145
- AD-200, 145, 171
- AD-200(c), 171
- AD-201, 145
- AD-202, 145
- AD-203, 145
- AD-204, 145
- Figure AD-204.1, 169

- AD-205, 145  
 AD-206, 145  
 AD-207, 145  
 AD-208, 145  
 AD-209, 145  
 AD-210, 145  
 AD-211, 145  
 Figure AD-211.1, 147  
 Figure AD-211.2, 147  
 AD-212, 145  
 Figure AD-212.1, 147  
 Figure AD-212.2, 147  
 Article D-3, 143  
 Article D-4, 143, 153  
 Figure AD-420.2, 155  
 Figure AD-420.3, 155  
 Article D-5, 155–157  
 AD-560, 169  
 Table AD 560.7, 157  
 Article D-6, 157  
 AD-602, 157  
 Article D-7, 158, 677  
 AD-710, 158  
 AD-711, 677  
 AD-711.1, 153, 677  
 AD-711.1(f), 158  
 AD-712, 677  
 AD-720, 158  
 Article D-9, 154, 158  
     AD-901.1, 145  
 AD-910, 158–159  
 AD-911, 145  
 AD-911(a), 145  
 AD-911(e), 145  
 AD-912, 145  
 AD-912(a), 145  
 AD-912(e), 145  
 AD-920, 159  
 AD-925, 125  
 Article D-10, 159  
 Part AF, 159  
 Article F-1, 159  
 Figure AF-130.2, 160  
 Figure AF-130.3, 161  
 Table AF-142.1, 161  
 Article F-2 (Permissible Welding Processes), 161  
 Table AF-214.1, 159  
 AF-220, 153, 161  
 AF-240, 162  
 Table AF-241.1, 159, 162  
 Article F-4, 162  
 AF-402, 162  
 Table AF-402.1, 162–163  
 Table AF-402.2, 162–163  
 AF-402.3, 163  
 AF-410, 163  
 AF-415, 163  
 AF-420.1, 164  
 Article F-5, 164  
 AF-570, 164  
 AF-590, 165  
 Article F-6, 165  
 AF-612, 165, 175  
 AF-616, 165  
 AF-620, 158  
 AF-620.1, 164  
 Table AF-630.1, 165  
 Article F-7, 165  
 Part AG (General Requirements), 137–139  
 Article G-1, 139  
 AG-100, 139  
 AG-120, 139  
 Article G-3, 139  
 AG-301, 139  
 AG-302, 139  
 AG-303, 139  
 Part AM (General Material Requirements), 137, 139–143, 159  
 Article M-2, 140  
 AM-200, 167  
 AM-210, 140  
 AM-211.2, 142  
 Figure AM-211.2 (Fig. 22.2), 141  
 AM-218, 141  
 Figure AM-218 (Fig. 22.1), 141  
 Figure AM-218.1, 140–141  
 AM-218.2, 141, 167  
 Figure AM-218.2, 141  
 Figure AM-218.3, 141, 143  
 Article M-3 (Special Requirements for Materials of Certain Categories), 143  
 Article M-4, 143  
 Article M-5, 143  
 AM-510, 143  
 AM-520, 143  
 Part AT (Detailed Requirements on Testing), 143  
 Article T-2, 167  
 Table AQT, 143, 153, 158  
 Table AQT-1, 143  
 Section VIII, Divisions 2, mandatory appendices, 172  
     Appendix 3, 141, 158, 169, 677, 680, 682  
     Appendix 3, 35, 46–47, 84, 95  
     Appendix 3, Article 3-5, 169,  
     Appendix 4 (Design by Analysis), 34–35, 91, 97, 112, 143, 145,  
     158, 169, 171, 677, 702–703  
     Appendix 4, Article 4-1, 169–170  
     Appendix 4, Article 4-2, 169  
     Appendix 4, Article 4-3, 169  
     Appendix 4, Article 4-4, 169  
     Appendix 4, Article 4-5, 169  
     Appendix 4, Article 4-6, 169  
     Appendix 4, Article 4-7, 169  
     Appendix 4, Article 4-8, 169  
     Appendix 4, 4-14, 4, 7, 9–10, 677  
     Appendix 4, 4-100(b), 169  
     Appendix 4, 4-130, 145  
     Appendix 4, 4-132, 145  
     Appendix 4, 4-136, 145  
     Appendix 4, 4-136.3, 171  
     Appendix 4, 4-136.4, 145  
     Appendix 4, 4-136.5, 169  
     Appendix 4, 4-136.7, 677  
     Appendix 5 (Design by Analysis), 34, 97, 143, 158, 171, 677  
     Appendix 5, Figure 5-110.1 (Fig. 22.11)(Design Fatigue Curves),  
     171, 172  
     Appendix 6, 143, 158, 171–172, 677  
     Appendix 18, 172  
 Section VIII, Division 2, nonmandatory appendices, 174  
     Appendix A, 173  
     Appendix B, 173  
     Appendix C, 173  
     Appendix D, 162  
     Appendix G, 173  
     Appendix I, 173  
     Appendix L, 174  
     Appendix L, L-2.1, 35  
     Appendix M, 174, 677

## Section VIII, Division 3, 177

Codes addressing flange design, 675  
 covers liquid metal-cooled fast-breeder reactor nuclear plants, 389  
 Figure 23.1 (Vessel Weight per Meter of Length), 180  
 Table 23.1 (Cylindrical Vessel Weight as a Function of Material Yield Strength), 179  
 Figure 23.3 (Component Stress Distribution in a Thick-Wall Cylinder), 184,  
 Figure 23.4 (Combined Stress Distribution in a Thick-Wall Cylinder), 184–185  
 high-pressure vessels, 677  
 scope, 389  
 Part KD (Design Requirements), 182, 184–185, 187, 191  
 Article KD-1 (General Design Requirements), 182  
 KD-100, 181  
 KD-103, 181  
 KD-110, 181  
 KD-112, 182  
 KD-113, 182, 194  
 KD-114, 182  
 KD-131, 182  
 KD-132, 181  
 KD-140, 182  
 KD-141, 181  
 Article KD-2 (Basic Design Requirements), 184–185  
 KD-241, 185  
 KD-250, 182, 184–185  
 KD-251.1, 191  
 KD-252, 185  
 Article KD-3 (Fatigue Evaluation), 182, 187  
 KD-301, 186  
 KD-302, 186  
 KD-311.2, 187  
 KD-312.2, 187  
 KD-312.4, 187  
 KD-313, 187  
 KD-320, 187  
 KD-330, 187  
 Article KD-4 (Fracture Mechanics Evaluation), 183, 186–187, 189,  
 191, 193, 196  
 KD-401, 188  
 KD-401(c), 188  
 KD-411, 188  
 KD-411(b), 188  
 KD-420, 189  
 KD-430, 189  
 Article KD-5 (Design Using Autofrettage), 186, 189–190  
 KD-501, 190  
 KD-520, 190  
 KD-521, 190  
 KD-522, 190  
 KD-522.2, 190  
 KD-523, 190  
 KD-524, 190  
 KD-525, 190  
 KD-526, 190  
 KD-527, 190  
 KD-528, 190  
 KD-529, 190  
 KD-530, 190  
 Article KD-6 (Design Requirements for Openings, Closures,  
 Heads, Bolting, and Seals), 190,  
 KD-600, 188  
 KD-610, 190  
 KD-611, 677  
 KD-612, 190, 677  
 KD-613, 190, 677  
 KD-614, 190, 677

KD-615, 190, 677  
 KD-616, 190  
 KD-617, 190  
 KD-618, 190  
 KD-619, 190  
 KD-620, 190, 677  
 KD-621, 190  
 KD-630, 190  
 KD-631.4, 191  
 KD-650, 190  
 KD-651, 191  
 KD-652, 191  
 KD-652.1, 191  
 KD-653, 191  
 Article KD-7 (Design Requirements for Attachments, Supports,  
 and Heating and Cooling Jackets), 190, 191  
 KD-710, 191  
 KD-711, 191  
 KD-712, 191  
 KD-713, 191  
 KD-714, 191  
 KD-715, 191  
 KD-716, 191  
 KD-717, 191  
 KD-718, 191  
 KD-719, 191  
 KD-720, 191  
 KD-721, 191  
 KD-722, 191  
 KD-723, 191  
 KD-724, 191  
 KD-725, 191  
 KD-726, 191  
 KD-727, 191  
 KD-728, 191  
 KD-729, 191  
 KD-730, 191  
 KD-740, 191  
 KD-750, 191  
 Article KD-8 (Special Design Requirements for Layered Vessels),  
 191–192  
 KD-811, 191  
 KD-811.3, 192  
 KD-812, 191  
 KD-820, 192  
 KD-821(a), 192  
 KD-824, 192  
 KD-825, 192  
 KD-840, 192  
 Figure KD-850, 190  
 Article KD-9 (Special Design Requirements for Wire-Wound  
 Vessels and Frames), 192  
 KD-911, 192  
 KD-932, 192  
 Article KD-10 (Special Design Requirements for Interlocking  
 Strip-Wound Vessels), 193  
 Article KD-11 (Design Requirements for Welded Vessels),  
 193  
 KD-1110, 193  
 Figure KD-1131, 194  
 Article KD-12 (Experimental Design Verification), 193  
 KD-1260, 186, 188, 190  
 Section VIII, Division 3, mandatory appendices, 196  
 Section VIII, Division 3  
 Appendix 1 (Nomenclature), 178  
 Appendix 2 (Quality Control System), 178  
 Appendix 3 (Submittal of Technical Inquiries to the Boiler and  
 Pressure Vessel Committee), 178



- Appendix 4 (Acceptance of Testing Laboratories and Authorized Observers for Capacity Certification of Pressure Relief Devices), 178
- Appendix 5 (Adhesive Attachment of Nameplate), 178
- Appendix 6 (Rounded Indications Charts Acceptance Standard for Radiographically Determined Rounded Indications in Welds), 178
- Appendix 6, Figure 6-153, 193
- Section VIII, Division 3, nonmandatory appendices, 196
- Section VIII, Division 3
  - Appendix A (Guide for Preparing Manufacturer's Data Reports), 178
  - Appendix B (Requalification), 178
  - Appendix C (Guide to Information Appearing on Certification of Authorization), 178
  - Appendix D (Fracture Mechanics Calculations), 178, 181, 196, Appendix D, D-600, 196
  - Appendix E (Construction Details), 178, 198
  - Appendix F (Approval of New Materials Under the ASME Boiler and Pressure Vessel Code), 178
  - Appendix G (Design Rules for Clamp Connections), 178, 196, 677, 700
  - Appendix H (Openings and Their Reinforcement), 178, 196
  - Part KE (Examination Requirements), 188, 193, 196
    - KE-211, 195
    - KE-232.2, 188
    - KE-4KE-4, 196
  - Part KF (Fabrication Requirements), 193
    - Article KF-1 (General Fabrication Requirements), 193, 195
      - KF-121.1, 193
      - KF-121.2, 193
    - Article KF-2 (Supplemental Welding Fabrication Requirements), 193
      - KF-204, 194
      - KF-220, 194
      - KF-221, 193
      - KF-222.1, 194
    - Article KF-3 (Fabrication Requirements for Materials with Protective Linings), 194
    - Article KF-4 (Heat Treatment of Weldments), 194
    - Article KF-5 (Additional Fabrication Requirements for Autofrettaged Vessels), 194
      - KF-520, 194
    - Article KF-6 (Additional Fabrication Requirements for Quenched and Tempered Steels), 194
      - KF-630, 194
    - Article KF-7 (Supplementary Requirements for Materials with Welding Restrictions), 194
    - Article KF-8 (Specific Fabrication Requirements for Layered Vessels), 194
      - KF-810, 194–195
      - KF-820, 195
      - KF-824, 195
      - KF-825, 195
      - KF-826, 195
    - Article KF-9 (Specific Fabrication Requirements for Wire-Wound Vessels and Frames), 195
    - Article KF-10 (Specific Fabrication Requirements for Helically Wound Interlocking Strip Vessels), 195
  - Part KG (General Requirements), 177
    - Article KG-1 (Scope and Jurisdiction), 177
      - KG-101, 177
      - KG-102, 178
      - KG-110, 178
      - KG-111, 178
      - KG-112, 178
      - KG-113, 178
      - KG-114, 178
      - KG-115, 178
      - KG-116, 178
      - KG-117, 178
      - KG-142, 178
      - KG-150, 178
    - Article KG-2 (Organization of Division 3), 178
    - Article KG-3 (Responsibilities and Duties), 178
      - KG-310, 178
      - KG-311, 178–179
        - KG-311.11, 179
    - Article KG-4 (General Rules for Inspection), 179
      - KG-421, 179
    - Part KM (Material Requirements), 171, 189
      - Article KM-1 (General Requirements for Materials), 181
      - Article KM-2 (Mechanical Property Test Requirements), 181
      - Article KM-3 (Supplementary Requirements for Bolting), 181
      - Article KM-4 (Material Design Data), 181
    - Part KR (Pressure-Relief Devices), 179, 195
      - KR-125, 195
      - KR-150, 195
        - Article KR-5, 195
    - Part KS (Marking, Stamping, Reports, and Records), 179, 196
    - Part KT (Testing Requirements), 196
  - Section IX, 197–233, 526
    - Appendix I, 225
      - Figure 24.1 (Oxyacetylene Welding Process), 198
      - Figure 24.2 (Shielded Metal Arc Welding Process), 199
      - Figure 24.3 (Submerged Arc Welding Process), 199–200
      - Figure 24.4 (Gas Tungsten Arc Welding Operation), 200–201
      - Figure 24.5 (Gas Metal Arc Welding Process), 201
      - Figure 24.6 (Plasma Arc Welding Torch), 202
      - Figure 24.7 (Set-on versus Set-Through Nozzle), 213
      - Figure 24.14 (Removal of Full-Thickness Tension Test Specimen), 223
      - Figure 24.15 (Removal of Multiple Tension Test Specimens), 223
      - Figure 24.16 (Face-, Root-, and Side-Bend Specimens), 225
      - Figure 24.20 (Basic Lap and Butt Joints for Brazing), 232
        - history, 197
        - organization, 197
        - qualification tests required for maximum design temperature for filler metals, 64, 66
        - scope of weld processes, 197
    - Table 24.11 (Comparison of Minimum Base Metal Thickness Qualified for Notch Toughness and Pre-Notch Toughness Procedure Qualification), 218
    - Table 24.12 (Summary of Section VIII, Division 1 Impact Testing Rules), 221
    - Table 24.15 (Procedure Qualification Position Limitations), 230
  - weld deposit testing, 526
  - welders/weld operators qualified for pressure vessels, 63
  - welding procedures for pressure vessel qualified, 63
  - welding requirements, 373
  - weld procedure qualification requirements, 162
  - weld repair example, 524
  - Part QB (Brazing), 197, 232
    - Article XI (General Requirements), 197
    - Article XII (Brazing Procedure Qualifications), 197
    - Article XIII (Brazer Performance Qualifications), 197
    - Article XIV (Variables), 197
      - QB-402.1, 232
      - QB-403.1, 232
      - QB-403.2, 232
      - QB-406.1, 232
      - QB-407.1, 232
      - QB-408.2, 232
      - QB-408.4, 232
      - QB-409.1, 232
      - QB-409.2, 232

Section IX (*Continued*)

- QB-422, 203, 209, 213, 218, 224, 228  
 Table QB-422, 203, 209, 213, 218, 224, 229  
 Table QB-432, 203  
 Part QW (Welding), 197, 232  
 Article I (General Requirements for Welding Procedure and  
 Welder Performance Qualifications), 197  
 QW-120, 215  
 QW-130, 215  
 QW-151, 223  
 QW-153.1, 223  
 QW-161, 224  
 QW-163, 226  
 QW-170, 220  
 QW-183 (Procedure), 226  
 QW-184 (Performance), 226  
 QW-191.2, 225  
 QW-194, 225  
 Article II (Welding Procedure Qualification), 197  
 QW-201, 373  
 QW-201.1, 206  
 QW-202, 221  
 QW-202.2, 209  
 QW-202.3, 209  
 QW-202.4, 209  
 QW-202.4(b), 209  
 QW-214 (Corrosion-Resistant Overlay), 227  
 QW-216 (Hardfacing Overlay), 227  
 QW-250, 206  
 QW-251, 206  
 QW-252, 206  
 Table QW-252, 206, 218, 227  
 Table QW-252.1, 227  
 QW-253, 206  
 Table QW-253 (Table 24.3) (Welding Variables Procedure  
 Specification (WPS) Shielded Metal Arc Welding  
 [SMAW]), 206–207, 218, 227  
 Table QW-253.1 (Table 24.13) (Welding Variables Procedure  
 Specification [WPS] and Shielded Metal Arc Welding  
 [SMAW]), 227  
 QW-254, 206  
 Table QW-254, 206, 218, 227  
 Table QW-254.1, 227  
 QW-255, 206  
 Table QW-255, 206, 218, 227  
 Table QW-255.1, 227  
 QW-256, 206  
 Table QW-256, 206, 218, 227  
 Table QW-256.1, 227  
 QW-257, 206  
 Table QW-257, 206, 218, 227  
 Table QW-257.1, 227  
 QW-258, 206  
 Table QW-258, 206, 218, 227  
 Table QW-258.1, 227  
 QW-259, 206  
 Table QW-259, 206, 218, 227  
 Table QW-259.1, 227  
 QW-260, 206  
 Table QW-260, 206, 218, 227  
 Table QW-260.1, 227  
 QW-261, 206  
 Table QW-261, 206, 218, 227  
 Table QW-261.1, 227  
 QW-262, 206  
 Table QW-262, 206, 218, 227  
 Table QW-262.1, 227  
 QW-263, 206  
 Table QW-263, 206, 218, 227  
 Table QW-263.1, 227  
 QW-264, 206  
 Table QW-264, 206, 218, 227  
 Table QW-264.1, 227  
 QW-265, 205, 218  
 QW-266, 206  
 QW-267, 206  
 QW-268, 206  
 QW-269, 206  
 QW-270, 206  
 QW-271, 206  
 QW-272, 206  
 QW-273, 206  
 QW-274, 206  
 QW-275, 206  
 QW-276, 206  
 QW-277, 206  
 QW-278, 206  
 QW-279, 206  
 QW-280, 206  
 QW-281, 206  
 QW-282, 206  
 Article III (Welder Performance Qualification), 197  
 QW-302, 221  
 QW-303, 213–215  
 QW-303.1, 213–214,  
 QW-303.2, 213–215  
 QW-306, 314  
 QW-322, 216  
 QW-322.1(b), 216  
 QW-322.2(b), 216  
 QW-350, 221  
 QW-352, 212  
 QW-353, 212, 213  
 Table QW-353 (Table 24.5) (Shielded Metal Arc Welding [SMAW]  
 Essential Variables), 212–213  
 QW-357, 212  
 QW-360, 221  
 QW-361, 212  
 QW-363, 212  
 Article IV (Welding Data), 197, 206, 218  
 QW-401.3, 220  
 QW-402 (Joints), 206–207  
 QW-402.1 (Groove Design), 206–207  
 QW-402.4, 207–209, 212–213  
 QW-402.10, 209  
 QW-402.11, 209  
 QW-402.16, 227–228  
 QW-402.41 (Backing), 212  
 QW-403 (Base Metals), 207, 209  
 QW-403.2, 209  
 QW-403.3, 209  
 QW-403.5 (Group Number), 218  
 QW-403.6, 209, 218  
 QW-403.7, 209, 218  
 QW-403.8, 209, 218  
 QW-403.9, 207, 209  
 QW-403.10, 209  
 QW-403.11, 209  
 QW-403.13, 209  
 QW-403.16, 213, 216  
 QW-403.18, 213  
 QW-403.20, 229  
 QW-403.23, 229  
 QW-404 (Filler Metals), 207  
 QW-404.12, 219, 229  
 QW-404.32, 209

- QW-404.4, 210, 219
- QW-404.5, 209, 230
- QW-404.6, 210
- QW-404.7, 218
- QW-404.12, 219, 229
- QW-404.15, 214
- QW-404.30, 210, 214
- QW-404.33, 210
- QW-404.37, 230
- QW-404.38, 230
- QW-405 (Positions), 207
- QW-405.1, 210, 216
- QW-405.2, 219
- QW-405.3, 210, 216, 219
- QW-405.4, 230
- QW-406 (Preheat), 207, 210
- QW-406.1, 210–211, 219, 230, 233
- QW-406.2, 211
- QW-406.3, 219, 230
- QW-406.4, 231
- QW-407 (Postweld Heat Treatment), 207
- QW-407.1, 206, 211, 231
- QW-407.1(a), 211
- QW-407.1(a)(2), 211
- QW-407.1(a)(3), 211
- QW-407.1(a)(4), 211
- QW-407.1(b), 211
- QW-407.2, 219
- QW-407.4, 209, 211
- QW-407.6, 231
- QW-408 (Gas), 209
- QW-408.8, 213
- QW-409 (Electrical Characteristics), 207
- QW-409.1, 220
- QW-409.22, 231
- QW-409.4, 211, 231
- QW-409.8, 211
- QW-410 (Technique), 207, 211
- QW-410.1, 211
- QW-410.25, 210, 212
- QW-410.26, 211–212
- QW-410.38, 231
- QW-410.5, 211–212
- QW-410.6, 211–212
- QW-420, 213, 375, 384
- QW-420.2, 213
- QW-422, 209, 226, 228
- QW-423, 213–214
- Table QW-423 (Table 24.7) (Alternate Base Materials for Welder Qualification), 214
- QW-424, 209
- Table QW-424 (Table 24.4) (Base Metals Used for Procedure Qualifications), 209
- QW-432, 203, 210, 226
- Table QW-432, 203, 210
- QW-432.2, 214
- QW-433, 214–215
- Table QW-433 (Table 24.8) (Alternate F-Numbers for Welder Performance Qualification), 215
- QW-442, 209, 215, 230
- Table QW-442 (Table 24.1) (A-numbers), 215
- QW-451, 208, 210, 214
- QW-451.1, 209, 221
- Table QW-451.1 (Table 24.3) (Procedure Qualification Thickness Limits), 209, 211
- Table QW-451.3, 221
- QW-452, 213–214
- QW-452.1, 214–215, 221, 224
- Table QW-452.1 (Table 24.9) (Performance Qualification Thickness Limits Transverse-bend Tests), 215
- QW-452.3, 213, 216
- Table QW-452.3 (Table 24.6) (Groove Weld Diameter Limits), 213
- QW-452.4, 216
- Table QW-452.5, 221
- QW-452.6, 216
- QW-453, 228, 231
- Table QW-453 (Table 24.14) (Procedure/Performance Qualification Thickness Limits), 230
- QW-453.3, 213
- QW-453.4, 213
- QW-461.1, 216, 230
- QW-461.2, 216, 230
- Figure QW-461.3 (Fig. 24.8) (Groove Welds in Plate-Test Positions), 215–216
- Figure QW-461.4 (Fig. 24.9) (Groove Welds in Pipe-Test Positions), 216
- Table QW-461.9 (Table 24.10) (Performance Qualification-Position and Diameter Limitations), 216
- Figure QW-462.4(a) (Fig. 24.18) (Plate and Pipe Fillet Weld Procedure Qualification Test), 227
- Figure QW-462.4(b) (Fig. 24.19) (Plate and Pipe Fillet Weld Performance Qualification Test), 228
- Figure QW-462.4(c) (Fig. 24.19) (Plate and Pipe Fillet Weld Performance Qualification Test), 228
- Figure QW-462.4(d) (Fig. 24.18) (Plate and Pipe Fillet Weld Procedure Qualification Test), 227
- QW-462.5(a), 227–228
- QW-462.5(b), 227–228
- QW-462.5(c), 227–228
- QW-462.5(d), 227–228
- QW-462.5(e), 227–228
- Figure QW-463.1(a) (Fig. 24.10) (Test Specimen Removal from Plate Procedure Qualification), 221
- Figure QW-463.1(b) (Fig. 24.10) (Test Specimen Removal from Plate Procedure Qualification), 221
- Figure QW-463.1(d) (Fig. 24.12) (Test Specimen Removal from Pipe Procedure Qualification), 222
- Figure QW-463.1(e) (Fig. 24.12) (Test Specimen Removal from Pipe Procedure Qualification), 222
- QW-463.1(f), 216
- Figure QW-463.2(a) (Fig. 24.11) (Test Specimen Removal from Plate, Performance Qualification), 221–222
- Figure QW-463.2(b) (Fig. 24.11) (Test Specimen Removal from Plate, Performance Qualification), 221–222
- Figure QW-463.2(d) (Fig. 24.13) (Test Specimen Removal from Pipe Performance Qualification), 222–223
- Figure QW-463.2(e) (Fig. 24.13) (Test Specimen Removal from Pipe Performance Qualification), 222–223
- QW-466.1, 226
- Figure QW-466.1 (Fig. 24.17) (Guided-Bend Test Jig Dimensions), 226
- QW-466.2, 226
- QW-466.3, 226
- QW-466.4, 226
- Form QW-482, 206
- QW-483 (Suggested Format for Procedure Qualification Record), 406
- Section X (Fiber-Reinforced Plastic Pressure Vessels), 20, 21, 277, 702
  - acoustic-emission examination, 235
  - Appendix 25.A (User's Basic Requirements Specification, Example 1), 260, 279–287
  - Appendix 25.B, 288–293
  - Appendix 25.C, 294–303
  - Appendix AA (Suggested Methods of Preliminary Design for Class I Vessels), 249

Section X (Fiber-Reinforced Plastic Pressure Vessels) (*Continued*)

Appendix AC (Discontinuity Stresses for Class II Method B Vessels), 249

Applied stress, 260

butt joint, 242

Class I vessels, 239

- bag molding, 241
- design qualifications, 249–251
- fabrication methods for pressure-containing parts, 239–241
- jurisdiction, 247, 249
- for mass production, 241
- Procedure Specifications, 277
- qualification testing, 250, 275
- scope of, 247–248
- temperature scope, 247

Class II vessels, 239

- butt joints, 242–243
- corrosion barrier thickness and structural strength, 254
- design of FRP vessels, 259–260
- design qualifications, 249–251
- jurisdiction, 247, 249
- method B components, 249
- for one-of-a-kind/limited production, 241
- Procedure Specifications, 276
- procedure specification, for Class II vessels (Form Q-120), 294–303
- qualified by design calculations backed by measured laminate properties, 275
- quality assurance as compared to RTP-1, 278
- scope of, 247–249
- simple vessels, design rules, 243–247
- temperature scope, 247
- vessels certified by Registered Professional Engineer, 275–276

component pressures, 254

Design Specification, corrosion tolerances on nozzle located noted, 252

Fabricator's quality control manual, 275

finite-element methods for stress analysis, 239

Form Q-120 Procedure Specification, 277, 295–303

geometric jurisdiction, 249

head-to-shell joint, 254

internal pressure scope of vessels, 247

joining of vessel parts, 242–243

jurisdiction, 247, 249

materials for vessels, limitations, 249

method A design calculation, 249–250, 252

method B design calculation, 249–250, 252

nozzle attachment design calculations, 256–259

nozzle design calculations, 256–259

quality assurance, 275–277

penetrating-nozzle-installation-laminate overlays, 243–244

pressure scope, 235, 247

reinforcing pad design calculations, 256–259

reinforcement materials, 236

RP Symbol Stamp, 276–277

scope, 235, 247–248

scope exemptions, 247

secondary overlay thickness, 256

shell-design computations, 255

shell-to-head joints, computations, 256

strength behavior of materials, 238

support skirt design, 260

Table 1173.2, 255

Vessel Design Specification, 252–253

Article RD-12, 249, 254

RD-188.5, 246

Table RD-620.1 (Table 25.14) (Flange and Nozzle Dimensions for Hand Lay-up and Pressure-Molded Flanges), 256–257

Article RD-1150, 249

Article RD-1171.1 (Cylindrical Shell Internal Pressure), 249, 255

Article RD-1172.1 (Cylindrical Shell External Pressure), 249, 255

Article RD-1173.1, 254

Article RD-1173.1(a) (Ellipsoidal Head Internal Pressure), 249

Article RD-1173.1(b) (Hemispherical Head Internal Pressure), 249

Article RD-1173.2 (Elliptical Head External Pressure), 254

Article RD-1173.2(a) (Hemispherical Head External Pressure), 249

Article RD-1173.2(b) (Ellipsoidal Head External Pressure), 249

Article RD-1174.1 (Opening Reinforcement and Nozzle Attachment), 249

Article RD-1174.2 (Opening Reinforcement and Nozzle Attachment), 249

Figure RD-1174.3, 258

Article RD-1175 (Head-to-Head and Shell-to-Shell), 243, 249

RD-1175.2 (Shell-to-Head), 256

Article RD-1176 (Flange), 249, 256

Article RD-1186 (Attachments), 251

Article RD-1188, 249

Article RG-113, 278

Article RG-121, 278

Article RG-310 (Requirements for a Design Specification), 252–253

Article RQ-141 (Visual Inspection), 253

Section XI (Inservice Inspection of Nuclear Reactor Cooling Systems), 9, 10, 522, 573

- addenda to, 338–385
- Applicability Index for Section XI Cases, 397
- application of rules, 522
- Article 3000, 196
- Class 1 piping, 305, 317–318, 329
- Class 1 vessel standards for volumetric examination, 315
- Class 2 construction, 315
- Class 2 piping, 317–318, 329
- Class 2 systems, 305, 329
- Class 3 high-energy ferritic steel piping, 328
- Class 3 low- and moderate-energy piping, 327
- Class 3 moderate-energy ferritic steel piping, 328
- Class 3 piping, 305, 331
- Class 3 systems, 305, 329
- Code Cases, 326–328, 446–447
- Code requirements for operability, 564
- as compared to section III, 307–308
- Construction Code for repairs, steam generator weld filler metal, 526
- design margins, 430, 433
- Design Specification, 428
- Design Specifications, Class MC containments, 446
- Figure 30.1 (BWR Containments in the United States), 439–440
- Figure 30.2 (PWR Containments in the United States), 439
- Figure 3220-1 (Fig. 29.16) (Code Case N-597) (Acceptance Flow Chart), 433, 435
- Figure 3621-1 (Fig. 29.14) (Code Case N-480) (Illustration of Erosion-Corrosion Wall-Thinning), 433
- Figure 3622-1 (Fig. 29.15) (Code Case N-480) (Allowable Depth and Length of Locally Thinned Area), 434
- Figure RWS 1 (Figure 28.1) (Quality or Level of Compliance with Construction, Code Technical Requirements), 390
- flaw acceptance criteria, 390–391
- flaw inspection and evaluation, 411
- glossary, 442–443
- history of development, 522
- inservice inspection (ISI) of nuclear power plant components, 372, 342, 411
- interfaces, 523
- Interpretations, 446
- for light-water-cooled reactor system, 306
- organization, 389–390



- origin and first publishing, 305
- Owner's Specifications (Design Specifications), 399
- piping evaluation, 430–436
- planar flaw criterion, 309
- preface, 389
- reference law for cracks in carbon and low-alloy steels in a water environment, 476
- repair/replacement activity, 340, 350, 523
- repair/replacement requirements, 372
- replacement program work package, 528
- required action ranges for safety functions, 562
- required ISI examinations, 341
- requirements and changes to Section V requirements, 3
- requirements for evaluation of degraded piping components, 567
- requirements for evaluation of flaws and radiation embrittlement, 567
- requirements, replacement or installation of supports, 528
- restructuring of Code paragraphs and terminology, 339
- Rules for Inservice Inspection of Nuclear Power Plant Components*, 444
- scope of Division 1, 389
- surveillance testing and inspection performance, 509
- Table 26.1 (Fundamental Differences Between Section III and Section XI), 307–308
- Table 29.5 (Overview of IWB-3600 Evaluation Procedures), 423
- Technical Specifications, 400, 402
- White Paper, 311–312, 326
- Section XI, Division 1, Subsection IWA (General Requirements), 306, 389, 439, 446
  - IWA-1000 (Scope and Responsibility), 446, 390–392
  - IWA-1100 (Scope), 390–391
  - IWA-1200 (Jurisdiction), 340, 391
  - IWA-1300 (Application and Classification), 391–392
  - IWA-1300(e), 330
  - IWA-1320(e), 343
  - IWA-1400 (Owner's Responsibility), 389, 392
  - IWA-1400(a), 342, 380
  - IWA-1400(b), 446
  - IWA-1400(c), 396
  - IWA-1400(i), 391
  - IWA-1400(m), 332
  - IWA-1400(n), 350
  - IWA-1500, 446
  - IWA-1600 (Referenced Standards and Specifications), 392
  - Table IWA-1600-1, 392
  - IWA-2000 (Examination and Inspection), 381, 392–393, 400, 446
  - IWA-2100 (Authorized Inspection), 356, 392
  - IWA-2100(j), 356
  - IWA-2100(k), 356
  - IWA-2110, 389, 392
  - IWA-2110(a), 396
  - IWA-2120, 356
  - IWA-2200 (Examination Methods), 335, 390, 392, 449
  - IWA-2200(b), 334
  - IWA-2210 (Visual Examination), 335, 390, 392, 446, 449, 462
  - Table IWA-2210-1, 334
  - IWA-2211, 390, 412, 423
  - IWA-2212, 390, 412, 423
  - IWA-2213, 331, 390, 412, 423
  - IWA-2220 (Surface Examination), 390, 392
  - IWA-2230 (Volumetric Examination), 390, 392–393
  - IWA-2240 (Alternative Examinations), 328, 376, 390, 393, 403
  - IWA-2300 (Qualifications of Nondestructive Examination Personnel), 316, 332, 376, 390, 393–394, 446
  - IWA-2300(f), 332
  - IWA-2310 (General), 393
  - IWA-2314, 393
  - IWA-2315, 317
  - IWA-2320 to IWA-2380, 393
  - IWA-2320 (Qualification Examinations, Experience, and Responsibilities), 393
  - IWA-2325, 393
  - IWA-2350 (Limited Certification), 393–394
  - IWA-2380, 393
  - IWA-2400 (Inspection Program), 394, 396
  - IWA-2410 (Application of Code Edition and Addenda), 374, 394
  - IWA-2420 (Inspection Plans and Schedules), 392, 395–396
  - IWA-2430 (Inspection Intervals), 396
  - IWA-2432 (Inspection Intervals), 397
  - IWA-2440 (Application of Code Cases), 397
  - IWA-2500 (Extent of Examination), 397–398, 446
  - IWA-2600 (Weld Reference System), 398, 446
  - IWA-2610 (General), 398
  - IWA-3000 (Standards for Examination Evaluation), 412–415, 423, 430, 446
  - IWA-3200, 496
  - Figure IWA-3300-1 (Fig. 29.1) (Flaw Length and Depth), 412
  - IWA-3310, 398, 499
  - Figure IWA-3310-1 (Fig. 29.2) (Flaw Characterization for Surface Planar Flaws), 412–413, 499
  - IWA-3320, 421
  - Figure IWA-3320-1 (Fig. 29.3) (Flaw Characterization for Subsurface Planar Flaws), 413–414
  - Figure IWA-3330-1 (Fig. 29.4) (Characterization and Grouping of Multiple Planar Flaws), 413–416
  - Figure IWA-3340-1 (Fig. 29.5) (Characterization of Nonplanar Elliptical Subsurface Flaws), 416–417
  - Figure IWA-3350-1, 416
  - IWA-3360, 416, 422
  - IWA-3380(e), 416
  - Figure IWA-3380-1 (Fig. 29.6) (Characterization and Grouping Multiple Unaligned Coplanar Flaws), 416, 418
  - IWA-3390, 416
  - Figure IWA-3390-1 (Fig. 29.7) (Characterization and Grouping of Multiple Aligned Planar Flaws), 419
  - IWA-3400, 416
  - Figure IWA-3400-1 (Fig. 29.8) (Examples of Linear Surface Flaws), 420
  - IWA-4000 (Repair and Replacement), 329, 334–335, 338–339, 341–342, 347, 366–367, 397, 408, 446
    - alternatives, 345–346, 382
    - consolidation with IWA-7000, 356, 523
    - defect removal requirements, 359, 371
    - design/configuration change, 365–366
    - Design Specifications for plants, 357
    - examination, 364, 376
    - hydrostatic pressure testing, 380
    - items covered, 342
    - items not covered, 343
    - metal removal requirements, 374
    - organizations performing repair/replacement, 350
    - Owner's Requirements, 340, 353
    - preservice inspection, 378
    - pressure testing exemptions, 378, 382
    - QA Program, 350, 531
    - repair rules, 334
    - repair/replacement activity requirements by functional areas, 367
    - repair/replacement on nuclear power plant items, 337
    - Repair/Replacement Program, 352, 363
    - repair/replacement performance, 353
    - repair/replacement pressure test, exemptions, 379
    - repairs by brazing, 367, 369
    - Reports/Records for Repair/Replacement activities, 357
    - revision of scope, 358–359
    - and Section III Construction Code, 361



Section XI, Division 1, Subsection IWA (*Continued*)

- weld repairs, 524
- when it applies, 340–342
- IWA-4100, 342, 355, 371
- IWA-4110, 340
- IWA-4110(a), 340
- IWA-4110(b), 341–342, 378
- IWA-4120, 335, 341, 347, 353, 359, 371, 376
- IWA-4120(a), 343, 347
- IWA-4120(b), 343, 344
- IWA-4120(b)(5), 343
- IWA-4120(b)(6), 343
- IWA-4120(c), 343
- IWA-4120(d), 343
- IWA-4120(e), 343
- IWA-4120(f), 343
- IWA-4120(g), 343
- IWA-4121, 523
- IWA-4122, 523
- IWA-4130, 332, 341, 345, 356, 446
- IWA-4130(a)(Repair Program), 367
- IWA-4131, 347, 352, 382–383
- IWA-4131.1, 349
- IWA-4131.2, 349
- IWA-4131.2(a), 349
- IWA-4131.2(b), 349
- IWA-4131.2(c), 349
- IWA-4131.2(d), 349
- IWA-4131.2(e), 349, 352
- IWA-4132, 318, 349
- IWA-4132(d), 349
- IWA-4133, 349, 366
- IWA-4140, 350, 446, 530
- IWA-4141, 350
- IWA-4142, 350, 363
- IWA-4142(b), 350
- IWA-4143, 350, 363
- IWA-4143(a), 363, 367
- IWA-4150 (Repair/Replacement Program and Plan), 332, 352, 356, 397
- IWA-4150(b), 353
- IWA-4150(c), 352–353, 355, 366
- IWA-4150(c)(5), 355
- IWA-4150(c)(7), 355
- IWA-4160, 342, 356–357
- IWA-4170, 356, 359, 524
- IWA-4170(b), 371
- IWA-4180, 321, 356, 359, 365–366
- IWA-4180(b), 357–358
- IWA-4180(b)(2), 357
- IWA-4180(c), 357–358, 366, 369
- IWA-4180(d), 357
- IWA-4200, 341, 349, 359
- IWA-4210 (General Requirements), 358
- IWA-4220, 349, 350, 353, 359, 366, 369
- IWA-4221, 353, 359, 363, 366
- IWA-4221(a), 359
- IWA-4221(b), 359–360, 363, 369
- IWA-4221(c), 359–360, 369
- IWA-4222, 359, 363, 366, 369
- IWA-4223, 359, 363, 366
- IWA-4224, 363, 366, 369
- IWA-4224.1(b), 363, 365
- IWA-4224.2(b), 363, 365
- IWA-4225, 359, 363, 366
- IWA-4226, 359, 363, 366
- IWA-4226.2(a), 365
- IWA-4300, 335, 339, 355, 359, 365–366, 369, 371–372, 374
- IWA-4300(c)(1), 374
- IWA-4310, 345
- IWA-4311, 357, 363, 365–366, 372
- IWA-4311(a), 366
- IWA-4311(b), 366
- IWA-4311(d), 366
- IWA-4312, 366
- IWA-4312 to IWA-4330, 366
- IWA-4320, 366
- IWA-4330, 366
- IWA-4331, 366
- IWA-4331(c), 366
- IWA-4332, 366
- IWA-4333, 366
- IWA-4334, 366
- IWA-4340 (Mitigation of Defects by Modification), 366–367
- IWA-4340(c), 366–367
- IWA-4400, 335, 349, 359, 367, 369, 371, 382
- IWA-4400(a)(3), 382
- IWA-4400(b), 332, 382–383
- IWA-4400(b)(5), 382
- IWA-4410, 360, 369
- IWA-4410(a), 369
- IWA-4410(b), 369
- IWA-4410(c), 352, 369
- IWA-4420, 347, 359, 369, 385
- IWA-4421, 353, 359, 369, 371–372
- IWA-4421(a), 359, 369
- IWA-4421(b), 369
- IWA-4421(c), 369
- IWA-4422, 359, 371–372
- IWA-4422.1, 371–372
- IWA-4422.1(b), 372
- IWA-4422.2, 372
- IWA-4422.2.1, 372
- IWA-4422.2.1(c), 372
- IWA-4422.2.2, 372
- IWA-4422.2.2(a), 372
- IWA-4422.2.2(a)(3), 372
- IWA-4422.2.2(b), 372
- IWA-4430, 369
- IWA-4440, 367, 369, 372, 374–375
- IWA-4440(a), 372
- IWA-4440(b), 374
- IWA-4440(c), 372
- IWA-4440(d), 374
- IWA-4451, 364
- IWA-4451.1(a), 364
- IWA-4451.1(b), 364
- IWA-4451.1(c), 364
- IWA-4451.1(d), 364
- IWA-4460, 369, 371–372, 374
- IWA-4461, 374
- IWA-4461.1, 374
- Table IWA-4461.1-1, 374
- IWA-4461.2, 374
- IWA-4461.3, 374
- IWA-4461.4, 374
- IWA-4462, 374
- IWA-4500 (General Requirements), 339, 353, 364, 371, 382
- IWA-4510, 364, 376
- IWA-4520, 349, 372
- IWA-4520(a), 364, 376
- IWA-4520(b), 364
- IWA-4520(c), 376
- IWA-4530, 343, 364
- IWA-4530(a), 366, 376–378
- IWA-4530(b), 378

- IWA-4540 (Butter Bead-Temper Bead Repair for Class MC and Metallic Liners of Class CC Pressure-Retaining Components and Integral Attachments), 378, 380–382, 406
- IWA-4540(a), 380, 382
- IWA-4540(b), 382, 383
- IWA-4540(b)(4), 382
- IWA-4540(b)(5), 382
- IWA-4540(b)(6), 382
- IWA-4540(b)(9), 382
- IWA-4600, 353, 359, 364, 367, 369, 371, 374, 376, 382–383
- IWA-4600(a), 378
- IWA-4610, 384
- IWA-4611, 359, 371
- IWA-4620, 384
- IWA-4621, 384
- IWA-4630, 384
- IWA-4631, 384
- IWA-4640, 384
- IWA-4660, 384
- IWA-4700, 329, 369, 384–385
- IWA-4700(a), 379
- IWA-4710, 379
- IWA-4710(c), 334, 379
- IWA-4711, 385
- IWA-4712, 385
- IWA-4720, 385
- IWA-4800 (Repair and Installation of Items), 364, 378
- IWA-4810, 364
- IWA-4820, 364
- IWA-4820(a), 390
- IWA-4820(a) to IWB-2200, 390
- IWA-4910, 357
- IWA-4920, 350
- IWA-5000 (System Pressure Tests), 378–383, 405–406, 446
- IWA-5110 (Periodic System Pressure Tests), 406
- IWA-5111(a), 381
- IWA-5120 (System Pressure Tests for Repair/Replacement Activities), 406–407
- Table IWA-5210-1, 390, 408
- IWA-5211, 332
- IWA-5211(e), 332
- IWA-5212, 381
- IWA-5213 (Test Condition Holding Time), 407
- IWA-5214 (Preservice Test), 332, 379, 407
- IWA-5214(a), 379
- IWA-5214(e), 332, 334, 379
- IWA-5240 (Visual Examination), 407, 460
- IWA-5241, 334
- IWA-5242, 334
- IWA-5243, 332
- IWA-5244 (Buried Components), 332, 408
- IWA-5250 (Corrective Action), 332, 366, 408–409
- IWA-5250(a), 332, 390–391, 408
- IWA-5250(a)(2), 408
- IWA-5260 (Instruments for System Hydrostatic Tests), 409
- IWA-5265, 332
- IWA-5300 (Test Records), 409
- IWA-6000 (Documentation: Records and Reports, Additions and Revisions to), 311, 314–315, 318–319, 330, 355–357, 391, 409, 446, 470
- IWA-6200 (Requirements), 409
- IWA-6300 (Retention), 409
- IWA-6340, 318, 409
- IWA-7000 (Replacements), 334, 338–342, 345, 347, 350, 352, 355–356, 360–361, 366–367, 369, 378, 382, 391, 397–398, 446, 523
- IWA-7110, 360
- IWA-7120, 376
- IWA-7210, 359–361, 363, 376
- IWA-7210(a), 360
- IWA-7210(a)(1), 360
- IWA-7210(b)(2), 334
- IWA-7210(c), 359, 361, 524
- IWA-7210(c)(1), 361, 363
- IWA-7210(c)(2), 361, 363
- IWA-7210(c)(3), 361, 363
- IWA-7210(c)(4), 363
- IWA-7220, 356, 528
- IWA-7310, 346, 361
- IWA-7320, 372, 374
- IWA-7330, 361
- IWA-7400, 329, 345–346, 348–349, 382
- IWA-7400(a), 345
- IWA-7400(a)(1), 348
- IWA-7400(a)(4), 348
- IWA-7400(d), 335, 345–347, 385
- IWA-7520, 357–358
- IWA-7530, 332, 353, 364
- IWA-7530(b), 348
- IWA-8000 (Other Certificate Holders), 531
- IWA-9000 (Glossary), 306, 342, 350, 353, 366, 408, 442, 446, 528
- Section XI, Division 1, Subsection IWB (Requirements for Class 1, 2, 3, MC, and CC Components and Supports), 391, 398, 446
  - construction/in-service inspection, 392
  - requirements for Class 1 components, 306, 390
- IWB-1000, 398
- IWB-1220, 329, 400
- IWB-1220(a), 329, 331, 398
- IWB-2000 (Examination and Inspection), 398, 400
- IWB-2200, 330, 376, 390
- IWB-2400 (Inspection Schedule), 396, 401–403
- IWB-2411 (Inspection Program A), 401
- IWB-2412 (Inspection Program B), 401–402
- Table IWB-2412-1, 401
- IWB-2420 (Successive Inspections), 402, 417–418, 420
- IWB-2430 (Additional Examinations), 402–403
- IWB-2500 to IWL-2500, 397
- IWB-2500 (Examination and Pressure Test Requirements), 403–404, 494
- Table IWB-2500-1 (Table 28.1) (Examination Category B-J: Pressure-Retaining Welds in Piping), 312, 323, 330, 334, 376, 398, 402–404
- Figure IWB-2500-7, 398
- Figure IWB-2500-8, 403
- IWB-3000 (Analytic Evaluation of In-service Flaws), 366, 371–372, 376, 390, 402–403, 408, 416, 421
- IWB-3110 (Preservice Volumetric and Surface Examination), 417
- IWB-3120 (Preservice Visual Examination), 417
- IWB-3122.4, 408
- IWB-3130 (In-service Volumetric Surface Examinations), 417
- IWB-3132.3, 402
- IWB-3140 (In-service Visual Examinations), 417, 420
- IWB-3142, 408
- IWB-3142.4, 402, 408
- IWB-3144, 408
- IWB-3400, 421
- IWB-3410 (Size Criteria for Crack-Like Flaws), 310
- Table IWB-3410-1 (Table 29.1) (Acceptance Standards), 402–403, 417, 420–421
- IWB-3500 (Acceptance Standard Tables for Flaws), 310, 312, 314, 332, 420–421, 423, 430, 494
- IWB-3510, 316, 422
- IWB-3510.1, 422

Section XI, Division 1, Subsection IWB (*Continued*)

Table IWB-3510-1 (Table 29.2) (Typical Acceptance Standards for Allowable Planar Flaws), 421

Table IWB-3510-2 (Table 29.3) (Allowable Laminar Flaws), 422

Table IWB-3510-3 (Table 29.4) (Allowable Linear Flaws), 314, 422

IWB-3511, 316

IWB-3512, 421–422

Table IWB-3512-2, 422

IWB-3514, 332, 421–422

Table IWB-3514-1, 332

IWB-3514.2, 318, 332

IWB-3514.3, 316, 432

Table IWB-3514-4 (Acceptance Standard for Class 1, 2 Welds in Piping), 314

IWB-3515, 421–423

Table IWB-3515-1, 422

IWB-3516, 316, 421–422

IWB-3517, 421

IWB-3518, 421, 423

Table IWB-3518-1, 423

Table IWB-3518-2, 423

IWB-3519, 421, 423

IWB-3520, 421, 423

IWB-3521, 421, 423

IWB-3522, 421, 423

IWB-3522.1, 408

IWB-3523, 421, 423

IWB-3600 (Conditionally Acceptable Flaws), 310–311, 314, 316, 332, 366, 417, 423, 430, 496

IWB-3610, 423, 498

Figure IWB-3610-1 (Fig. 29.9) (Characterization and Proximity Rules for the Evaluation of Clad Components), 423, 425, 499

IWB-3611, 428–430

IWB-3612, 314, 423, 428, 430

IWB-3613, 429–430

IWB-3620, 423

IWB-3630, 423

IWB-3640, 423, 430

IWB-3641, 430–432

IWB-3641(c), 432

Table IWB-3641-1 (Table 29.6) (Allowable End-of-Evaluation Period Flaw Depth-to-Thickness Ratio for Circumferential Flaws), 314, 432

Table IWB-3641-2, 314

Table IWB-3641-3, 314

Table IWB-3641-4, 314

Table IWB-3641-5, 314

Table IWB-3641-6, 314

IWB-3650, 423, 432–433

IWB-3700 (Analytical Evaluation of Plant Operating Events), 314, 316, 366, 436, 494

IWB-3730(b), 318

IWB-3740, 436

IWB-4000 (Special Repair Provisions), 316, 329, 338, 346–347, 359, 366, 374, 391

IWB-4120, 339

IWB-4121, 339

IWB-4122, 339

IWB-4123, 339

IWB-4124, 339

IWB-4125, 339

IWB-4126, 339

IWB-4127, 339

IWB-4128, 339

IWB-4129, 339

IWB-4130, 339

IWB-4300 (Reduction of Flaws to Acceptable Size), 311, 339, 347

IWB-4300 to IWB-4344, 339

IWB-4400, 374

IWB-4420, 311

IWB-4430, 311

IWB-5000, 330, 339

IWB-5210, 332

IWB-5220 (Test Pressurization Boundaries), 339, 423

IWB-5240, 381

IWB-7000, 338, 340, 346–347

IWB-7400(d), 334

## Section XI, Division 1, Subsection IWC (Requirements for Class 1, 2, 3, MC, and CC Components and Supports), 398, 446

component classification, 391

construction/in-service inspection, 392

exemptions of piping, 406

pressure testing requirements, 369, 378, 381, 406

requirements for Class 2 components, 306, 436

IWC-1000, 398

IWC-1220, 328–329

IWC-1221(a), 330

IWC-2000 (Preservice Examination Requirements), 398

IWC-2200 (Preservice Inspection/Testing), 376, 378

IWC-2400 (Inspection Schedule), 396, 401–403

IWC-2412, 401–402

IWC-2420 (Successive Inspections), 402

IWC-2430 (Additional Examinations), 330, 402–403

IWC-2500 (Examination and Pressure Test Requirements), 397, 402–403, 406

Table IWC-2500-1, 312, 376, 378, 402–403,

IWC-3000 (Analytic Evaluation of Inservice Flaws), 366, 371–372, 376, 390, 403, 408, 436

IWC-3122.3, 402

IWC-3132.3, 402, 408

Table IWC-3410-1, 402–403, 436

IWC-3510, 436

Table IWC-3510-1, 314

IWC-3510-3 (Acceptance Standards for Vessel Welds), 314

IWC-3511, 336

Table IWC-3511-1, 314

Table IWC-3511-2, 314

IWC-3512, 336

IWC-3513, 336

IWC-3514, 336

IWC-3515, 336

IWC-3516, 336

IWC-4000 (Special Repair Provisions), 338–339, 359, 371, 391

IWC-4120, 339

IWC-4200, 339

IWC-4300 to IWC-4344, 339

IWC-5000, 330

IWC-5210(b), 332

IWC-5220 (Test Pressurization Boundaries), 407

IWC-5222, 332

IWC-5240, 381

IWC-7000, 338–340

## Section XI, Division 1, Subsection IWD (Requirements for Class 1, 2, 3, MC, and CC Components and Supports), 306, 391, 398

IWD-1000, 398

IWD-2000 (Preservice Examination Requirements), 398

IWD-2200 (Preservice Inspection/Testing), 376

IWD-2400 (Inspection Schedule), 401–403

IWD-2420 (Successive Inspections), 402

IWD-2430 (Additional Examinations), 402–403

IWD-2500 (Examination and Pressure Test Requirements), 397, 403

Table IWD-2500-1, 330, 376, 402–403

- IWD-3000, 371, 377, 390, 402–403, 408, 436
- IWD-4000 (Special Repair Provisions), 338–339, 359, 371, 391
- IWD-4120, 339
- IWD-4200, 339
- IWD-4300 to IWD-4344, 339
- IWD-5000, 406
- IWD-5210(b), 332
- IWD-5220 (Test Pressurization Boundaries), 407
- IWD-5223, 332
- IWD-5230, 381
- IWD-7000, 338–340
- Section XI, Division 1, subsection IWE (requirements for class MC  
ans metallic liners of class CC components of light-water  
Cooled Plants), 306, 314, 325, 351, 361, 363, 388, 398,  
439, 446
- additions and revisions, 314
- containment inspection philosophy, 445–446
- containment vessel examination, 400
- pressure testing, 378
- requirements for Class MC vessels and containment penetrations  
not backed by concrete, 389
- revisions, 446–461
- rule development, 444–445
- rules for inservice inspection of Class MC components of nuclear  
power plants, 444–445
- visual examination, 392
- IWE-1000, 398
- IWE-1100 (Scope), 446
- IWE-1200 (Components Subject to Examination), 446
- IWE-1220 (Components Exempted from Examination), 446
- IWE-1230 (Accessibility for Examination), 446
- IWE-1231, 399, 446
- IWE-1231(a)(4), 449
- IWE-1232 (Inaccessible Surface Areas), 399, 446
- IWE-1240, 399, 446
- IWE-1241, 400, 401
- IWE-1242, 405, 449, 453
- IWE-2000 (Preservice Examination Requirements), 398–399
- IWE-2100 (General), 446
- IWE-2200 (Preservice Examinations), 376, 446
- IWE-2200(g)(deleted), 446
- IWE-2300 (Visual Examination, Personnel Qualification, and the  
Responsible Individual), 400–401, 446
- IWE-2310 (Visual Examination), 400–401, 446
- IWE-2320 (The Responsible Individual), 401
- IWE-2330 (Personnel Qualification), 401, 446
- IWE-2400 (Inspection Schedule), 396, 401–402
- IWE-2411, 452
- Table IWE-2411-1 (Table 30.1) (Inspection Program A), 452
- IWE-2412 (Inspection Program B), 446
- Table IWE-2412-1 (Inspection Program B), 446
- IWE-2420 (Successive Inspections), 402, 446
- IWE-2420(b), 452, 457–458
- IWE-2420(c), 452, 457–458
- IWE-2430 (Additional Examinations), 403
- IWE-2500 (Examination and Pressure Test Requirements), 397,  
403, 405
- IWE-2500(a)(Examination and Pressure Test Requirements), 452
- IWE-2500(b), 453
- IWE-2500(c), 453
- IWE-2500(c)(3), 453
- IWE-2500(c)(4), 453
- Table IWE-2500-1 (Examination Categories), 403, 446, 449–454,  
458–459
- Table IWE-2500-2 (Ultrasonic Thickness Measurements for  
Augmented Examinations), 456
- IWE-2600 (Examination Requirements for Painted or Coated  
Surfaces, Condition of Surface), 405, 454
- IWE-2600(b), 454
- IWE-3000 (Analytic Evaluation of Inservice Flaws), 367, 371,  
402–403
- IWE-3100 (Evaluation of Nondestructive Examination Results), 456
- IWE-3110 (Preservice Examination), 456
- IWE-3115 (Review by Authorities), 456
- IWE-3120 (Inservice Nondestructive Examination), 456
- IWE-3122, 456
- IWE-3122.4, 457
- IWE-3124, 457
- IWE-3200 (Supplemental Examinations), 457–458
- IWE-3500 (Acceptance Standards), 457
- IWE-3510 (Standards for Examination Category E-A,  
Containment Surfaces), 457
- IWE-3510.1 (Responsible Individual), 457–458
- IWE-3510.2, 457–458
- IWE-3510.3, 457–458
- IWE-3511 (Standards for Examination Category E-B Pressure-  
Retaining Welds), 457–458
- IWE-3511.1, 457–458
- IWE-3511.2, 457–458
- IWE-3512 (Standards for Examination Category E-C,  
Containment
- IWE-3512.1, 457
- IWE-3512.2, 457
- IWE-3512.3 (Ultrasonic Examination), 457
- IWE-3513 (Standards for Examination Category E-D, Seals,  
Gaskets, and Moisture Barriers), 458–459
- IWE-3514 (Standards for Examination Category E-F, Pressure-  
Retaining Dissimilar Metal Welds), 458–459
- IWE-3515 (Standards for Examination Category E-G, Pressure  
Bolting), 458–459
- IWE-3519.3, 331
- IWE-4000, 339–340, 359, 371, 391
- IWE-4120, 339
- IWE-4121, 339
- IWE-4122, 339
- IWE-4123, 339
- IWE-4124, 339
- IWE-4125, 339
- IWE-4126, 339
- IWE-4127, 339
- IWE-4128, 339
- IWE-4129, 339
- IWE-4130, 339
- IWE-5000 (System Pressure Tests), 459
- IWE-5200, 459
- IWE-5220, 399, 449–451
- IWE-5221, 332, 459, 461
- IWE-5222, 460
- IWE-5240 (Visual Examination), 460–461
- IWE-7000 (Penetration Liners for Class CC Containments),  
339–340
- Section XI, Division 1, Subsection IWF (Requirements for Class 1, 2,  
3, MC, and CC Components and Supports), 306, 328–329,  
398
- IWF-1000, 398
- IWF-1300 (Component Support Examination), 400
- IWF-1300(e), 331
- IWF-2000, 378, 398
- IWF-2200 (Preservice Inspection/Testing), 334, 376, 378
- IWF-2200(a), 378
- IWF-2200(b), 378
- IWF-2400 (Inspection Schedule), 396, 401–403
- IWF-2420 (Successive Inspections), 402
- IWF-2430 (Additional Examinations), 330, 402
- IWF-2500 (Examination and Pressure Test Requirements), 397,  
403, 405

Section XI, Division 1, Subsection IWF (*Continued*)

- Table IWF-2500-1, 403
- IWF-3000, 371, 376, 390, 403, 436
- IWF-3112.2, 402
- IWF-3122.2, 402
- IWF-3410, 436
- IWF-3410(a), 330
- IWF-4000, 334, 339, 391
- IWF-5200, 343
- IWF-7000, 339
- Section XI, Division 1, Subsection IWG, 306, 323, 390, 398
  - IWG-2500, 397
- Section XI, Division 1, Subsection IWL (Requirements for Class CC Concrete Components of Light-Water Cooled Plants), 306, 314, 316, 390, 398, 439
  - containment inspection philosophy, 445–446
  - containment vessel examination, 400
  - no provisions for successive inspections, 402
  - pressure testing, 378
  - Responsible Engineer as Registered Professional Engineer, 445
  - rule development, 445
  - visual examination, 392
  - IWL-1100 (Scope), 462
  - IWL-1210 (Components Subject to Examination), 462
  - IWL-1220 (Components Exempted from Examination), 462
  - IWL-2000 (Preservice Examination Requirements), 362, 398, 400
  - IWL-2100 (Inspection), 462
  - IWL-2200 (Preservice Inspection/Testing), 376
  - IWL-2220, 463
    - IWL-2220.1 (Concrete), 463
    - IWL-2220.2 (Unbonded Post-Tensioning System), 463
  - IWL-2230 (Unbonded Post-Tensioning System), 463
  - IWL-2300 (Visual Examination, Personnel Qualification, and the Responsible Engineer), 401, 463
  - IWL-2310 (Visual Examination and Personnel Qualification), 401, 463–464
    - IWL-2320 (The Responsible Engineer), 401, 463–464
  - IWL-2400 (Inservice Inspection Schedule), 402, 465
  - IWL-2410 (Concrete Inservice Inspection), 465
  - IWL-2420 (Unbonded Post-Tensioning System), 465
  - IWL-2421 (Sites with Multiple Plants), 465
  - IWL-2500 (Examination Requirements), 397, 405
  - Table IWL-2500-1 (Examination Categories), 467
  - IWL-2510 (Surface Examination), 405
  - IWL-2520 (Examination of Unbonded Post-Tensioning Systems), 405, 466
    - IWL-2521 (Tendon Selection), 466
  - Table IWL-2521-1 (Table 30.14)(Number of Tendons for Examination), 467
    - IWL-2521.1, 399
  - IWL-2522 (Tendon Force and Elongation Measurements), 467
  - IWL-2523 (Tendon Wire and Strand Sample Examination and Testing), 467
    - IWL-2523.1, 468
    - IWL-2523.2 (Sample Examination and Testing), 468
    - IWL-2523.3 (Retensioning), 468
  - IWL-2524 (Examination of Tendon Anchorage Areas), 468
    - IWL-2524.1 (Visual Examination), 468
    - IWL-2524.2 (Free Water Documentation), 468
  - IWL-2525 (Examination of Corrosion Protection Medium and Free Water), 468
    - Table IWL-2525-1 (Table 30.15)(Corrosion Protection Medium Analysis), 468–469
      - IWL-2525.1 (Samples), 468
        - IWL-2525.1(a), 468
        - IWL-2525.1(b), 468
      - IWL-2525.2 (Sample Analysis), 468
        - IWL-2525.2(a), 468

- IWL-2525.2(b), 468
- IWL-2526, 468
- IWL-3000 (Acceptance Standards), 469
- IWL-3100 (Preservice Examination), 469
- IWL-3110 (Concrete), 469
- IWL-3120 (Unbonded Post-Tensioning System), 469
- IWL-3200 (Inservice Examination), 469
- IWL-3210 (Surface Condition), 469
- IWL-3220 (Unbonded Post-Tensioning Systems), 469
  - IWL-3221.1 (Tendon Force and Elongation), 469
    - IWL-3221.1(a), 469
    - IWL-3221.1(b), 469
      - IWL-3221.1(b)(1), 469
      - IWL-3221.1(b)(2), 469
  - IWL-3221.2 (Tendon Wire or Strand Samples), 469
  - IWL-3221.3 (Tendon Anchorage Areas), 469
  - IWL-3221.4 (Corrosion Protection Medium), 469
- IWL-3300 (Acceptance and Evaluation), 469
- IWL-3310 (Engineering Evaluation Report), 469
- IWL-4000 (Repairs), 340, 391
  - IWL-4200, 470
  - IWL-4210, 470
  - IWL-4220, 470
  - IWL-4230, 470
  - IWL-4240 (Post-Tensioning System), 470
- IWL-5000 (System Pressure Tests), 459
- IWL-5200, 470
- IWL-5210, 470
- IWL-5250 (Test Procedure and Examination), 471
- IWL-5260 (Corrective Measures), 471
- IWL-5300 (Report), 446
- IWL-7000, 340, 446, 471
- IWL-7100, 471
- IWL-7120, 446
- Section XI, Division 1, Subsection IWP (Pumps), 306
  - interpretations addressing, 323
  - O&M Code for pump and valve testing, Part 6, 390
  - required system leakage test at nominal operating pressure, 329
- Section XI, Division 1, Subsection IWV (Valves), 306
  - interpretations addressing, 323
  - O&M Code for pump and valve testing, Part 10, 390
  - required system leakage test at nominal operating pressure, 329
  - testing requirements, 348
  - IWX-1000, 348
  - IWX-3100, 371
  - IWX-4300, 371
- Section XI, Division 1, Mandatory Appendices
  - Appendix I (Ultrasonic Testing for Vessels), 316, 318
    - additions/revisions, 314
    - cladding the ultrasonic calibration block, 332
    - scope, 312
    - valve category C pressure-relief devices, 565
    - I-5120 (Extent of Scanning), 312
    - I-5121 (General), 312
    - I-5122 (Scanning for Reflectors Oriented Parallel to the Weld), 312
    - I-5200 (Straight Beam Scanning), 312
    - I-5213 (Extent of Scanning), 312
    - I-6310(a), 332
  - Appendix II (Form NIS-2 “Owner’s Report for Repair/Replacement Activity”), 358
    - repair/replacement intent, 329–330
  - Appendix III (Ultrasonic Testing for Piping), 309, 317
    - for piping UT, search unit scan overlap and techniques, 332
    - scope, 311
    - III-3230(d), 332
    - III-3310, 332
    - III-3400, 332



- III-4430, 311, 332
- III-4450, 311
- III-4512, 313
- III-4520(e), 311
- III-4520(g)(3), 311
- Appendix IV, additions and revisions, 317
- Appendix V, interpretations, 323
- Appendix VI (Qualification of Personnel for Visual Examination), 317
- Appendix VII (Qualification of UT Personnel), 315–316
  - adoption of, 309
  - VII-4240, 332
- Appendix VIII (Performance Demonstration for Ultrasonic Examination Systems), 317
  - qualifying of inspectors, 494
  - VIII-3100, 332
- Appendix IX (Mechanical Clamping Devices for Class 2 and 3 Piping Pressure Boundary), 317
- Section XI, Division 1, Nonmandatory Appendices
  - Appendix A (Analysis of Flaws), 310–311, 323, 325, 328, 412, 423, 430, 482
    - comparison of Dowling's elastic-plastic tests with ferritic steels curve in an air environment, 479
    - development of analysis examples, 313
    - ferritic vessels, 494
    - fracture toughness-based reference temperature, 326
    - reference fatigue crack growth law for ferritic steels in an air environment, 479
    - stress intensity factor option, 475
    - A-2000, 423
    - A-3000, 424, 428
    - A-3200, 424
    - A-3200(a), 424
    - Figure A-3200-1 (Fig. 29.10)(Linearized Representation of Stresses), 424
    - A-3300, 424
    - Figure A-3310-1, 424
    - Figure A-3310-2, 424
    - Table A-3320-1, 425
    - Table A-3320-2, 425
    - A-4000, 424, 426
    - Figure A-4200-1 (Fig. 29.11)(Lowerbound  $KIa$  and  $KIc$  Test Data for SA-533 [Grade B, Class 1]; SA-508 [Class 2]; and SA-508 [Class 3] Steels), 412, 427–428
    - Figure A-4200-1 (Fig. 35.2), 567
    - A-4300, 427, 498
    - Figure A-4300-1, 480
    - Figure A-4300-2, 484
    - A-4400, 426
    - A-5000, 427
    - A-5200, 498
    - A-5300, 428
    - Figure A-5300-1 (Fig. 29.12)(Determination of Critical Flaw Sizes for Postulated Conditions), 429
    - A-5400, 428
  - Appendix B (Interpretations), 323, 328
  - Appendix C (Evaluation of Flaws in Austenitic Piping), 314, 316, 332, 423, 430–432, 494
    - crack growth final reference curve for ferritic steel, 480
    - C-2000, 430
    - C-3200, 431
    - Figure C-3210-1 (Fig. 31.10), 482
    - C-3220, 431
    - Figure C-3320-1 (Fig. 29.13)(Assumed Cross Section of Flawed Pipe), 432
    - C-3230, 431
  - Appendix D (Conditioning of Class 1 and 2 Piping Welds that Require Examination), 314, 316
  - Appendix E (Evaluation of Unanticipated Operating Events), 314, 316, 436
  - Appendix F (Preparation of Inspection Plans), 313, 316, 395, 436
  - Appendix G
    - fracture-toughness-based reference temperature, 327
    - $K_{I,r}$  curve switched from  $K_{I,a}$  curve, 432
    - reactor vessel material fracture toughness limits, 400
    - reference flaw shape used for demonstration of design adequacy, 494
    - revision to, 320
  - Appendix H (Evaluation of Flaws in Ferritic Piping), 318, 332, 423, 432, 494
    - as Code Case N-463-1, 345
    - Figure H-4000-1, 433
    - H-5000, 433
    - H-6000, 433
    - H-7000, 433
  - Appendix J (Guide to Plant Maintenance Activities and Section XI Repairs/Replacements), 318, 345
    - Figure J-1000-1, 345, 346
    - Article J-2000, 345
    - Article J-3000, 345
    - Article J-4000, 345
  - Appendix K (Assessment of Reactor Vessels with Low Upper-Shelf Charpy Impact Energy Levels), 318, 436
  - Appendix L (Operating Plant Fatigue Assessment), 318, 436, 484, 494, 496
    - Table L-3210-1, 494
  - Appendix M (Applying Mathematical Modeling to Ultrasonic Examination of Pressure-Retaining Components), 318, 355
  - Section XI, Division 2
    - additions and revisions, 314
    - for gas-cooled reactor systems, 305–306
    - issues considered, 323
    - revision to gas-cooled nuclear power plant rules, 314
  - Section XI, Division 3
    - additions and revisions, 314
    - issues considered, 323
    - liquid metal-cooled reactors rules, revisions and additions to, 314
    - for liquid metal-cooled reactor systems, 305–306
  - Section XI Subcommittee on Nuclear Inservice Inspection, 447
  - Section XI Subgroup on Containment, objectives for revisions to the Inservice Inspection requirements for Class MC containments and steel liners for Class CC containments, 445
  - Section XI Subgroup on Repairs, Replacements, and Modifications, 358, 375
  - Section XI Working Group on Flaw Evaluation, 475
  - Segregates, of plate material,
  - Seismic analyses,  $B$ -stress indices, 633
  - Seismic anchor motion, of supports, 570
  - Seismic Category 1, 593
    - definition, 548
  - Seismic conditions, of pressure vessels, 91
  - Seismic load, 563
  - Seismic loadings
    - and flexibility factors, 625
    - and piping vibration, 591, 602
  - Seismic reactions, 34
  - Seismic waves, apparent wave-propagation speed, 546
  - Seismic Zone 0, 260
  - Service Level A, 319, 545
    - and  $B$ -stress indices, 632
    - Code equations as fatigue check, 633
    - definition, 548
    - manufacturer's allowable loads, 570
    - normal loads, piping, designed to criteria, 570
    - standard flanges for, 680
    - stress limits, 677

- Service Level B, 547–549  
 and *B*-stress indices, 632  
 definition, 549  
 equation, sustained loads, 639  
 stress limits, 677
- Service Level C, 424, 547, 549  
 definition, 549  
 stress limits, 677
- Service Level D, 424, 545, 547  
 all dynamic loads, amplitude of the moment, 571  
 definition, 549  
 equation, occasional loads, 639  
 and faulted loads, amplitude of the moment, 571  
 and faulted loads, piping, condition limits and short-term operability, 570  
 local stress analysis, 569  
 manufacturer's allowable loads, 570  
 operability, failure mechanisms and loads, 561  
 seismic analysis, 632  
 snubbers, allowable test load, 571
- Service Life, of piping, 546
- Set-on nozzle, 194
- Set-through nozzle, 213
- Shear load test, for tube-to-tubesheet joints, 117
- Shear modulus, of laminae, 238
- Shear strength, of laminae, 238
- Shear stress. *See also* Stresses.  
 of lug assembly, 266
- Shell-and-plate theory, 705
- Shells, 53  
 attachments and stresses, 120  
 bending stresses, 64  
 connections to, 57  
 cylindrical, 35, 53, 146–147  
 of glass-lined pressure vessels, 111  
 inner, of layered pressure vessels, 84  
 joining methods of RTP-1 materials, 243  
 of nuclear reactor vessels, 146–147  
 of nuclear reactor vessels, design for buckling, 151–153  
 for RTP-1 vessel, 249–251  
 spherical, 35, 36, 147  
 thickness calculations, 121  
 of work-hardened nickel, 105
- Shell theory, 632
- Shell-to-flat-head weld, nominal thickness, 67
- Shell-to-tubesheet weld, nominal thickness, 67
- Shielded metal-arc temper bead welding, 383
- Shielded metal arc welding (SMAW), 198, 207, 213, 229, 386  
 flaw acceptance standards, 315  
 for plugging heat exchanger tubing, 383
- Shielding gases, 200
- Shippingsport (nuclear power plant), 518
- Shock loads, 34
- Shot peening, as part of repair process, 335
- Shrink fitting, 190, 195  
 of high-pressure vessels, 181–182, 189
- Shutdown. *See also* Safe shutdown earthquake (SSE), Scram (rapid reactor shutdown).
- Shutdown. *See also* Safe shutdown earthquake (SSE)  
 systems, 307–308  
 systems for maintenance, 402
- Significant pressure cycles, 649
- Silicon, requirements for 2 $\Omega$ Cr-1Mo-1/3V weld metal composition,
- Simple-beam model, for determining vibration limits, 614
- Simulator, for weld calibration check, 12
- Sine beat, definition, 549
- Single-degree-of-freedom (SDOF) oscillator, 547  
 -damped oscillators, 548
- Single-degree-of-freedom response (SDF) system, for piping, 602
- SIT. *See* Structural Integrity Test
- 6 dB drop technique, 309
- Slag, in nuclear reactor vessel, 167
- Slag-shielded arc welding, 199–200
- Sleeving  
 definition, 317  
 of heat exchanger tubing, 335, 384–385  
 repair of heat exchanger tubing, 317
- Small-tap lines, failures in, 592
- SMYS. *See* Specified minimum yield strength.
- Snow load, 34, 262–263, 268
- Snubbers, 343, 348, 604  
 designed to limit vibration, 610, 612  
 failures, 563  
 and flow turbulence, 596  
 functional testing, 308–309  
 hydraulic, 571  
 hydraulic, limiting vibration, 571, 612  
 load-bearing parts of, 528  
 “lock-up” during all levels of vibration, 610, 612  
 mechanical, limiting vibration, 610, 612  
 mechanical, supplying of, 531  
 operability, ASME Code requirements for, 567  
 operability evaluation, 563  
 and piping vibration, 592  
 rotation and reinstallation, 317  
 short-term operability acceptance criteria, 570  
 steady-state vibration effects, 593  
 visual examination inclusions, 569
- S-Numbers, 203
- Soak band, 163
- Socket welds, examination requirements, 404
- Sodium coolant, 315
- Soft missile impact, 559
- Solid ferrous electrodes, F-Number, 203
- Solid ferrous rods, F-Number, 203
- Solidification cracking, reduction of, 204
- Solution annealing, of high-alloy steels, 75
- South America, ASME companies holding B&PV certificates  
 (including nuclear) as of June, 1999, 533, 536
- Southeastern Electric Cooperative (SEC) Example Nuclear Plant  
 Certificate of Compliance, 528  
 Specification 9923 (principal piping systems and appurtenances),  
 527
- Southeastern Electric Cooperative (SEC) Section XI program, 524
- Spalling, from missiles, 559
- Splattering, 201
- Special Committee to Review Code Stress Basis, 518
- Special Working Group Toughness (SWGTT), impact test exemption  
 curves development, 68
- Specific gravity  
 of aramid fibers, 236  
 of carbon fibers, 236  
 of E-glass fibers, 236  
 of fibers, 236  
 of S-glass fibers, 236
- Specified functions, definition, 561–562
- Specified minimum yield strength (SMYS), of finned tubes, 106
- Spectral analysis, 512
- Spectrum-consistent time history, definition, 549
- Spool pieces, 334
- Spray-up method, of contact molding, 240–241
- Spring-loaded nonreclosing devices, 49
- Square root-sum-of-the-squares (SRSS) method, 568
- SRSS. *See* Square root-sum-of-the-squares method
- SRV. *See* Safety/relief valve.
- SSC. *See* System, structure, or component supports.

- SSE. *See* Safe shutdown earthquake.
- SSE-SAM. *See* Safe shutdown earthquake-seismic anchor motions.
- Stack-up, 239–240
- Stainless steels
- allowable stress for, 103
  - electrodes, F-Number, 203
  - fatigue curve, 646
  - as gasket materials and contact facings, 687–689
  - impact-tested, for pressure vessels, 50
  - pipings endurance limit, 593
  - stress allowables for piping, 593
  - weld cycle, 202
- Stainless steels, specific types, 188, 647
- type 304, 75–76, 87, 149, 496–497, 650
  - type 304L, 75
  - type 310, 651–652
  - type 316, 75, 496
  - type 316L, 75
  - type 347, 75, 665
  - type 348
  - type 405, 75, 78
  - type 410, 75
  - type 410S (ferritic), 75, 78
  - type 429, 75
  - type 430, 75
- Stamping
- of high-pressure vessels, 196
  - of nuclear power plant items, 351–352
  - of nuclear reactor vessels, 168–169
- Standard drag, 584
- Standard drag force, 585
- Standard for Qualification and Certification of NDE Personnel (ASNT CP-189-1995), 393
- Standard Reference Radiographs for Steel Castings, 98
- Standard Welding Procedure Specification (SWPS), ANSI/AWS, 189
- Standby liquid-control system, of light-water reactor plants, 408
- Station Blackout Rule (SBO), 514
- Staybolt construction, of pressure vessel jackets, 99
- Stays, 108
- Steady-state operation, 545–546
- Steady-state vibrations, definition, 549
- Steam-generator feedwater-nozzle cracks at nuclear plant in 1970s, repair of, 524
- Steam-generator tubing, eddy-current examination, 310, 317
- Steamhammer, 591, 599–600
- Steam kettles, of pressure vessels, electrically heated or gas-fired, 105
- Steam/vapor bubble collapse, 563
- Steel
- ABS alloy, 479
  - 8% nickel alloy, 87
  - 5% nickel alloy, 87
  - as gasket material and contact facings, 687–688
  - 9% nickel alloy, 87
- Steel bars, of special section for helically wound, interlocking striplayered vessels, 113–114
- Steel castings, for pressure vessels, examination methods required, 98
- Step wedge film, calibrated, 8
- Stiffening effect, 140, 148, 152
- Stiffening rings, 36–38, 67, 92, 119, 158, 165, 271, 275, 441
- for nuclear reactor vessels, 158, 165
- Stiffness
- cylinder, 88–89
  - pipings, 601
- Stop valves
- between vessel and pressure-relief valve, 123, 125
  - of nuclear reactor vessels, 173
  - on pressure vessels, installation, 123
- Storage
- for radiography, 6
  - for radioscopy, 6
- Stored strain energy missile, definition, 558
- Straight beam calibration, 12
- of welds, 11
- Straight beam scanning, 13
- Straight polarity, 220, 231
- of current, 231
- Strain acceptance criterion, 570
- Strain concentration factors, of high-pressure vessels, 187
- Strain energy of distortion theory, 648
- Strain gaging, 172, 177, 181
- Strain gauges, 172, 608, 612, 617, 620
- Strain hardening, of pressure vessel materials, 126
- Strain limit acceptance criterion, for piping systems, 570
- Strain limit in elastic-plastic analysis, of high-pressure vessels, 185
- Strain rate, 68
- Strapped butt joint, brazing, 66
- Strapping, 243
- Strength ratio ( $R$ ), 66
- Stress acceptance criterion, for piping systems, 570
- Stress analysis
- fiber-reinforced plastic vessels, 243–247
  - of high-pressure vessels, 183–184
  - of nuclear reactor vessels, 169–174
  - of RTP-1 vessels, 243–247
  - of Section X, Class II vessels, 243–247
- Stress Analysis Report, 362
- Stress classification lines, 169
- Stress classification planes, 169
- Stress concentration factors, 643–646, 648
- of high-pressure vessels, 187
  - for nuclear reactor vessel welded joints, 153
  - theoretical, 644
- Stress-corrosion cracking
- of high-pressure vessels, 182, 189
  - of piping, 319
  - as piping failure mode, 562
- Stresses
- from attachments to pressure vessel shell, 120
  - bolt, 707
  - bolt-stress limits, 704
  - for branch connections, 631
  - cyclic loading, 643–654
  - design-gasket, 707
  - in expansion joints of pressure vessels and heat exchangers, 108–112
  - flange, 692, 694–695, 697–698, 700, 707
  - footprint loading in RTP-1 vessels, 262
  - in piping, allowables, 594
  - power piping, 638–639
  - process piping, 639–640
  - rotation effect, 641
  - in 7-ply mat-woven-roving laminate, 244–246
  - surface thermal, 642
  - thermal, 642
- Stress indices, 625, 629–631
- $B$ -stress indices, 632
  - $B1$  and  $B2$ , 632
  - for branch connections, 637
  - for butt-welding tees, 630
  - $C$  and  $K$  for internal pressure loading, 629–630
  - $C_2$  and  $K_2$  for moment loading, 630
  - $C_3$  and  $C_3$  branch connections, 631
  - definition, 629
  - for elbows, 630
  - for moment loads, 629

- Stress indices (*Continued*)  
 for pressure loads, 629  
 for thermal gradient loadings, 629–631  
 in B31.1 and B31.3 piping codes, 638–640
- Stress intensification factor (*i*-factors), 364, 572, 625, 627, 638–641  
 for branch connections, 637  
 Code guidance, 627–629  
 design margins, 627–628
- Stress intensity, 598, 602  
 alternating, 598  
 definition, 144  
 equivalent alternating, of high-pressure vessels, 187  
 of nuclear vessels, 144, 145, 170
- Stress intensity factors, 473, 475  
 high-pressure vessels, 189  
 range, 473–475, 478–481, 486  
 range, applied, 500
- Stress raisers, 643
- Stress Report, loadings, 333
- Stress risers  
 in integrally forged pressure vessel prohibited, 106  
 material fatigue in piping, 591  
 of pressure vessels, 64
- Stress states, of fiber-reinforced plastic materials, 246
- Striping, of piping, 321
- Strip or wire winding, of high-pressure vessels, 181
- Strouhal number, 582, 597–598
- Structural bolts, short-term operability acceptance criteria, 571
- Structural dynamics, 545
- Structural integrity, definition, 549
- Structural Integrity Test (SIT), 459  
 for Class CC containments, 445–446  
 definition, 442  
 of light-water reactor plants, 402
- Structural proof testing, of nuclear reactor vessels, 167
- Structural steels, 265–266, 274
- Structure barrier, 551
- Structures, 545  
 definition, 549  
 monitoring condition of, 512
- Stud gun, 202
- Stud material attachment, 202
- Stud welding, 198, 202
- Subcommittee VIII, 68
- Subcommittee for Nuclear Inservice Inspection, 444
- Subcommittee for Section V (SCV), 1  
 charter and scope, 1  
 members, 1  
 review and approval functions, 1
- Subcommittee IX, 197, 206
- Subcommittee on Boiler and Pressure Vessel Accreditation (SCBPVA), 529, 533
- Subcommittee on Code Symbol Stamps, 519, 529  
 renamed Boiler and Pressure Vessel Accreditation (SCBPVA), 529
- Subcommittee on Nuclear Accreditation (SCNA), 530  
 member participation in ASME surveys, 531  
 SCNA ballot process, 531  
 Survey Team Reports review and acceptance, 533
- Subcommittee on Nuclear Certification, 530  
 renamed Subcommittee on Nuclear Accreditation, 530
- Subcommittee on Nuclear Inservice Inspection, Section XI, 447
- Subcommittee on Nuclear Power (SCIII), 315, 531  
 Subgroup on Inservice Inspection, 357, 389
- Subcontractor, with/without company representative, 205
- Submerged arc welding (SAW), 198–200  
 composition requirements for 21/4Cr-1Mo-1/4V weld metal, 116  
 flaw acceptance standards, 315  
 of high-alloy steels for pressure vessels, 74  
 modes, 199
- Submerged structures, fluid forces on, 584
- Subsurface planar flaws. *See also* Flaws.  
 definition, 411
- Successive inspections, definition, 443
- Suction stabilizers, 619
- Sulfides, in pressure vessel water environments, 482, 484
- Sulfur, requirements for 2 1/2Cr-1Mo-1/3V weld metal composition, 116
- Supplementary essential variables, of welding and brazing, 205–206, 218–220, 233
- Supports  
 D1.1 Code, 339  
 failure modes, 562  
 faulted or Service Level D loads, operability evaluation, 564  
 of high-pressure vessels, 191  
 for nuclear reactor vessels, 158, 159  
 operability evaluation methods, 568  
 short-term operability acceptance criteria, 569–570, 573  
 specified safety functions, 562  
 visual examination inclusions, 569
- Surface examination  
 of pressure-retaining dissimilar metal welds, 455
- Surface finish correction (roughness) factor, 187
- Surface planar flaw. *See also* Flaws.  
 definition, 411
- Surface thermal stresses, 623. *See also* Stresses.
- Surry Nuclear Generating Station, 562
- Survey Team Reports, SCNA review and acceptance, 533
- Sustained loads, 637, 639
- Sweep-range calibration, 13
- SWG. *See* Special Working Group Toughness.
- SWPS. *See* ANSI/AWS Standard Welding Specification.
- Synopsis of Boiler and Pressure Vessel Laws*, 27, 30
- Synthesized time histories, 555
- Synthetic time history, definition, 549
- System, 545  
 definition, 505, 549  
 evaluation of, and removal from service, 512–513  
 standby, 513  
 standby, definition, 505
- System hydrostatic tests, of light-water nuclear plants, 406–407
- System leakage test, 329, 334, 406  
 following reactor refueling outage, 333  
 of light-water nuclear plants, 406  
 of nuclear power plant items, 380
- System pneumatic tests, of light-water nuclear plants, 406–407
- System pressure tests, for Class CC containments, 460
- System, structure, or component supports (SSCs), 545, 548  
 operability evaluations, 564  
 dispositioning by discontinuing monitoring, 511  
 evaluation of functionality or operability, 561  
 Maintenance Rule-Scoped, removal from service, 512–513  
 mechanical system component failure modes, 562–563  
 nomenclature, 572  
 non-risk-significant, 508–509, 513  
 non-safety-related, 506, 509  
 non-safety-related, failure causing scram or actuating safety systems, 507  
 non-safety-related, procedure preventing safety-related SSCs from fulfilling their safety-related functions, 507  
 non-safety-related, that mitigate accidents or transients, 507  
 non-safety-related, used in emergency procedures, 507  
 outside scope of Maintenance Rule, 507  
 performance criteria for evaluation, 508–509  
 periodic assessment of maintenance effectiveness, 512–513



- periodic maintenance effectiveness assessments, 513
- removal from service, evaluation, 512–513
- requiring operability assessment, 561
- risk-significant, 505, 508–509, 511, 513
- risk-significant, definition, 505
- safety-related, 506, 509, 512–513
- scope, 561
- selection for plant, 506
- standby systems of, 508–509
- subject to ASME O&M Code testing, documentation of, 515
- subject to effective program maintenance programs, 511
- supporting key plant safety functions, identifying of, 512
- surveillance activities, 509
- systems of, 509, 513
- System, structure or component (SSC) unavailability for the purpose
  - of availability or reliability calculation, 509
  - definition, 505
- Section XII, 540
- TAM. *See* Thermal anchor motions.
- Tanks, operability evaluation methods, 568–569
- Taylor Forge, 682
- Taylor Forge method, 682, 703
- TB. *See* Torch brazing.
- TBN. *See* Total base number.
- Technical inquiries: guidance and directions for mandatory submittal
  - (Appendix II of Section V), 1. *See also* Inquiries to Code Committee.
- Technical inquiries: guidance and directions for mandatory submittal
  - (Appendix II of Section V)
  - submittal of, 103
- Technical Specifications (TS), 349, 356
  - for goal setting, 509
  - included in current licensing basis, 571
  - of nuclear power plants, 388
  - of plant facilities, SSCs subject to, 561
  - safety limit, 562
- Tee joint, brazing, 66
- TEMA. *See* Tubular Exchanger Manufacturer's Association.
- Temperature
  - allowable stress for, 87
  - cold, design requirements for, 73
  - impact-test exemption of nuclear reactor vessel materials, 141
  - of pressure vessel walls, inservice operation, 118
  - protection in nuclear reactor vessels, 173
  - protection of pressure vessels, 129
- Temperature excursions, 563
- Temper bead welding, 70, 383
- Temper embrittlement, 182
- Tempering
  - of pressure vessels, 67
  - welds, 10
- Tendon
  - definition, 443
  - examination of, 465–466
- Tensile strength
  - of aramid fibers, 236
  - of carbon fibers, 236
  - of E-glass fibers, 236
  - enhanced by heat treatment, 143
  - of fibers, 236
  - of laminae, 238
  - of S-glass fibers, 236
  - testing, 84, 204
- Tension test (tensile test), 204, 222–224
  - Class MC examination requirements, pressure-retaining bolting, 452
  - of ferritic steel pressure vessels, 84
  - as IWE examination method, 454
  - for pressure-retaining bolting, 455
  - of pressure vessels having higher allowable stresses at low temperature, 87
  - of tendon wires and strand samples, 467–468
- Terminal end, definition, 549
- Testing. *See also* specific testing methods.
  - definition, 306, 443
  - methods, evaluation of, 4
  - of nuclear reactor vessels, 167
- Test positions, 216, 222, 230
- Test pressure, of nuclear reactor vessels, 144, 167
- Test response spectrum (TRS), 547
  - definition, 549
- TG. *See* Glass-transition temperature, Mill test marking.
- Theory and Design of Modern Pressure Vessels*, 91
- Thermal aging, effect on crack growth, 481
- Thermal anchor motions (TAM), as consideration in operability
  - evaluation, 564
- Thermal and discontinuity analysis, of nuclear reactor vessels, 138
- Thermal cutting
  - of ferritic steel pressure vessels, 84
  - of high-pressure vessels, 193
  - of nuclear reactor vessels, 160
- Thermal expansion, and operability evaluation, 564
- Thermal fatigue, of piping, 321
- Thermal removal processes, for nuclear power plant items, 375
- Thermal shock, 34, 557
  - of piping, 321
- Thermal stratification, 563
- Thermal stresses, 604, 623. *See also* Stresses.
- Thermal striations, 643
- Thermal striping, 632
- Thermocouples, 607
- Thermography, 512
- Thermosetting resin vessels
  - aramid fiber reinforcement, 235
  - carbon fiber reinforcement, 235
  - glass fiber reinforcement, 235
- Thermowells, failure mode, 182
- Thickness, of laminae, 238
- Thick-shell theory, 177–178, 681
- Thin-wall theory, 36
- Three Mile Island accident, 523
- Three Mile Island (TMI)-related requirements for containment
  - integrity, 443
- Through-wall pressure boundary leakage, 408
- Through-wall thermal stress. *See also* Stresses.
  - flaws in light-water nuclear plants, 431
- Thrusts, from relief and safety valve loads, 592
- TIG. *See* Tungsten inert gas process.
- Tightness, 705–707
- Tightness-based design methods, 705–708
- Tightness parameter, 705
- Time-history analysis, 568
  - artificial time-history, 554–555
- Time-history duration, 555
- Time-history excitations, 554–555
- Titanium
  - liquid-penetrant examination, 15
  - P-number, 203
- Titanium-base alloys, 203
- Titanium-base electrodes, 203
- Titanium-base rods, 203
- Titanium electrodes, 203
- Titanium rods, F- Number, 203
- TMI. *See* Three Mile Island.
- Torch brazing (TB), 64, 232



- Torsional flexibility, 634
- Total base number (TBN), calculation of, 469
- Total equivalent pressure, 679
- Total radial load, 266
- Toughness. *See also* Fracture toughness.  
of high-pressure vessels, 178–179  
of nuclear reactor vessels, 138, 140, 142  
of nuclear reactor vessels, and operability, 567
- Toughness tests, 180
- Toughness-transition temperature, 33
- Traceability,  
materials documentation, 530  
with Material Specifications, 527
- Trains, 504–505, 507, 510, 513  
definition, 505  
operating, 505  
redundant, 505  
standby, 505
- Transducers, 617, 619–621  
to monitor vibration in piping systems, 606–608
- Transfer function, definition, 549
- Transient flow, 550–551
- Transient-load effect, 546
- Transient operation, 545–546
- Transient vibrations, definition, 549
- Transition current, 201
- Transition “dutchman”, 525
- Transmissibility function, 549
- Transport missiles, definition, 558
- Transport packaging, containment systems for, 534
- Transverse-bend tests, 214
- Tresca criterion, 145, 169, 182, 518, 646  
to decide if stress state is excessive, 246
- Tresca plastic collapse formulation, 184
- Tresca stress distribution, 175–176, 183. *See also* Stresses.
- Tresca yield criterion, 146
- Trojan reactor, flaw detected by ultrasonic examination, 493
- TRS. *See* Test response spectrum.
- TS. *See* Technical Specifications.
- Tsai-Wu quadratic interaction (tensor) criterion, 246, 249
- Tube and tubing (tubular products)  
eddy-current examination, 18  
expansion of, 118  
finned, 32  
heat exchanger, plugging of, 335  
heat exchanger, sleeving of, 335  
heat exchanger, sleeving repair, 316  
installed nonferromagnetic heat exchanger, eddy-current examination, 18  
steam-generator, 309  
ultrasonic examination, 10  
welding, technique sketches, 4
- Tubesheets  
design of, 89–90  
hubbed, 57, 173  
hubs, requirements for nuclear reactor vessels, 173  
loading cases, 89  
supported, 57
- Tube-to-tubesheet joints, 116, 118
- Tubular Exchanger Manufacturer’s Association (TEMA), 90, 135
- Tungsten inert gas (TIG) process, 200
- Turbulent buffeting, 584
- Turn-around-zone, 241
- Twisting moment, 273
- IIW block, 13
- U-bolts, 570
- UBRS. *See* User’s Basic Requirements Specification.
- U Certificate, subcontractor, for welding high-pressure vessels, 179
- U2 Certificate, subcontractor, for welding high-pressure vessels, 179
- U3 Certificate, for Manufacturer of high-pressure vessels, 179
- UFSAR. *See* Updated Final Safety Analysis Report.
- UFT. *See* Unreinforced fabricated tee branch connection.
- Ultimate strength, 644  
design factor on, 137–138
- Ultrasonic cleaning methods, 16
- Ultrasonic examination. *See also* Ultrasonic inspection, Ultrasonics,  
Ultrasonic testing.
- Ultrasonic examination. *See also* Ultrasonic inspection, Ultrasonics  
accuracy and reproducibility, 309
- Ultrasonic examination. *See also* Ultrasonic inspection  
additional requirements for training, qualification, 393–394  
amplitude control linearity, 9–10  
of bars, 10, 15  
basic calibration block, 11  
of bolting material, 15  
of bolts and studs in nuclear vessels, 15  
calibration block, 11  
calibration of equipment, 10, 12–13  
calibration reflector(s), 11–12  
of castings, 10, 15  
certification levels of operators, 317–318  
of clad pressure vessels, 82  
contact wedges, 10  
of containment surfaces requiring augmented examination (E-C),  
458  
containment vessel, 405  
coverage, 9–10  
for detection of fatigue cracks in operating plants, 309–310  
for determining subsurface flaws, 413–415  
equipment, 10, 12  
equivalence of manual and mechanical techniques, 309  
of ERW tubes for pressure vessels, 50  
flaw detection of surge line of Trojan reactor, 493  
of forgings, 10, 15  
frequencies generated, 10  
glossary, 9  
of high-pressure vessels, 195  
instrument calibration, 10, 12–13  
instrument, screen height linearity, 9  
as IWE examination method, 448  
of layered pressure vessels, 86  
of light-water reactor plants, 392, 400  
methods for materials and fabrication, 15  
of nuclear power plant items, 338, 376  
of nuclear reactor vessels, 140, 159, 172  
performance demonstration for procedures, equipment, and  
personnel, 317  
performance demonstration for qualification of personnel and  
procedures, 332  
of piping welds, 311–312  
of plate, 10, 15  
of plate for hubs of tubesheets and flat heads, 105  
practical method for inservice examination, 307  
of pressure-retaining components, mathematical modeling, 315  
of pressure vessels having higher allowable stresses at low  
temperature, 87  
of pressure vessels, piping, bolts, and studs, 327  
of pressure vessel welds, procedures, 99  
procedure requirements, 19  
pulse-echo type instruments, 10  
pulse repetition rate, 9  
qualification of personnel, 9, 309, 315, 317–318  
rate of search unit movement, 9  
records, 14  
reflector evaluation, 10

- report, 14
- requirements, 9
- scanning for interference with angle beam examination, 10
- scanning for reflectors oriented parallel to weld, 10
- scanning for reflectors oriented transverse to weld, 10
- scanning functions, 10
- scanning requirements, 10, 311
- scanning sensitivity level, 9
- screen height linearity, 10
- search unit movement rate, 10
- search units, 10
- sensitivity level recording, 10
- 70 degree angle-beam examination of flaws, 315
- of steel castings of pressure vessels, 98
- studs, 15
- supplies, 10
- thickness measurement of Class MC components and metal liners of Class CC components, 449, 446
- thickness measurement requirements, 445
- of tubular products, 10, 15
- vessel examination requirements, 10
- of welded joints of pressure vessels, 52
- of welds, 10–14
- of welds in nuclear reactor vessels, 162
- written procedure requirements, 10
- Ultrasonic Examination Methods for Materials, 15
- Ultrasonic extensimeters, 129
- Ultrasonic inspection, 8–13. *See also* Ultrasonic examination, Ultrasonics, Ultrasonic testing.
- Ultrasonics (UT). *See also* Ultrasonic examination, Ultrasonic inspection, Ultrasonic testing.
- Ultrasonics (UT). *See also* Ultrasonic examination, Ultrasonic inspection
  - abbreviation, 307
- Ultrasonic testing (examination) (UT). *See also* Ultrasonic examination,
- Ultrasonic inspection, Ultrasonics.
- Ultrasonic inspection
  - acronym/abbreviation, 440–442
  - operator, UT level 2 certification, 317
  - operator, UT level 3 certification, 317
- Ultraviolet radiation, 252
- UM symbol, 30
- “UM” Vessels, 30
- Uncoupled, definition, 549
- Underwater welding, 340, 384
- Unfired steam boilers, 139
  - brazing prohibition, 64
  - carbon steel materials prohibited, 66
  - cast ductile iron material prohibited, 82
  - cast iron material prohibited, 82
  - and radiographic examination of welded joints, 123
  - in scope of Section VIII, 29
- The Uniform Building Code*, 34
- United States, ASME companies holding B&PV certificates (including nuclear) as of June, 1999, 534
- U.S. Atomic Energy Commission (AEC) (later USNRC or NRC), 444
- U.S. Nuclear Regulatory Commission (USNRC), 392
  - acronym/abbreviation, 440–442
  - Advisory Committee on Reactor Safeguards (ACRS), 440, 444
  - Class 3 weld examination by liquid penetrant method, 406
  - Code interpretations agreement with NRC regulations determined individually, 337–338
  - Committee to Review Generic Requirements (CRGR), 445
  - Construction Codes used to construct a nuclear power plant, 339
  - construction permits for light-water reactor plants, 395
  - endorsement of ASME code, 524
  - inspection plans submitted to, 396
  - Inspection Program B mandate, 398
  - licensee event reports, 591
  - missile forcing functions for tornado missiles, 559
  - review of Code Cases published by ASME, 397
  - sponsored Piping and Fitting Dynamic Reliability Program, 568
  - through-wall pressure boundary leakage corrective action, 408
  - weld exemption from examination in light-water nuclear plants, 399
- U.S. Nuclear Regulatory Commission (USNRC) Bulletins, 509
  - 79-02 (Inspection and Enforcement Bulletin), 571
  - 88-08, 493
  - 88-11, 484
- U.S. Nuclear Regulatory Commission (USNRC) Code of Federal Regulations (CFR)
  - referenced, 390
  - Title 10 (Energy), 440, 392
  - 10CFR2, current licensing basis, 571
  - 10CFR19, current licensing basis, 571
  - 10CFR20, current licensing basis, 571
  - 10CFR21, current licensing basis, 571
  - 10CFR30, current licensing basis, 571
  - 10CFR40, current licensing basis, 571
  - 10CFR50 (*Domestic Licensing of Production and Utilization Facilities*), 571, 573
    - acronym, 440
    - additional examinations, 446
    - amendment 10FR49495, 444
    - Appendix A (General Design Criteria for Nuclear Power Plants), 444, 561, 709
    - Appendix B (Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants), 349, 392, 522, 561
    - Appendix G, reactor vessel pressure-temperature limits, 567
    - Appendix H, reactor pressure vessel material surveillance tests, 509
    - Appendix J (Primary Reactor Containment Leakage Testing for Water-Cooled Power Reactors), 334, 444, 509
    - Appendix J, Type A Leakage Test, 444
    - Appendix J, Type B Leakage Test, 444
    - Appendix R, 507, 509
    - Final Rule, 709
  - 10CFR50.2 (Definition of Reactor Coolant Pressure Boundary), 392, 571
  - 10CFR50.21(b), 504, 507
  - 10CFR50.22, 504, 507
  - 10CFR50.34, 443
  - 10CFR50.34(f)(3), 444
  - 10CFR50.44(c)(3), 444
  - 10CFR50.48, 561
  - 10CFR50.49, 561, 571
  - 10CFR50.49(b)(1)(ii), 571
  - 10CFR50.55(g)(6)(i) 397, 399
  - 10CFR50.55a, 307, 319, 337–338, 353–354, 392, 395, 397, 440, 446–447, 511, 519, 528–529, 709
  - 10CFR50.55a(a)(3), 397
  - 10CFR50.55a(b)(2)(viii), 446
  - 10CFR50.55a(b)(2)(ix)(C), 446
  - 10CFR50.55a(b)(2)(x), 349
  - 10CFR50.65 (Maintenance Rule), 506
  - 10CFR50.65(a)(1), 513
  - 10CFR50.65(a)(2), 513
  - 10CFR50.65(a)(3), 513
  - 10CFR50.65(b), scope of Maintenance Rule, 506
  - 10CFR50.71, 571
  - 10CFR51, current licensing basis, 571
  - 10CFR55, current licensing basis, 571
  - 10CFR65(a)(2), Maintenance Rule scoping
  - 10CFR72, current licensing basis, 571

- U.S. Nuclear Regulatory Commission (USNRC) (*Continued*)  
 10CFR73, current licensing basis, 571  
 10CFR100, guidelines, 506, 571  
 29CFR1910.119, 131
- U.S. Nuclear Regulatory Commission (USNRC) Federal Register (FR), 560  
 10FR49495, amendment to 10CFR50, 444  
 56FR31324. *See* 10CFR50.65.  
 61FR41303, amendment to 10CFR50.55a, 339  
 64FR51370, amendment to 10CFR50.55a, 339, 446
- U.S. Nuclear Regulatory Commission (USNRC) Generic Letters, 389–390, 509  
 GL 88-01, conditions requiring functionality evaluations, 563  
 GL 91-18, evaluation of functionality and operability criteria, 561
- U.S. Nuclear Regulatory Commission (USNRC) Information Notices, 389–390  
 Information Notice No. 88–95, 528
- U.S. Nuclear Regulatory Commission (USNRC) Inspection Manual, Part 9900 (Technical Guidance), 338, 573
- U.S. Nuclear Regulatory Commission (USNRC) Maintenance Rule (*Requirements for Monitoring the Effectiveness of Maintenance at Nuclear Power Plants*), 503–515  
 applicability, 504  
 corrective actions, effectiveness reviewed, 513–514  
 documentation, 515  
 documentation of functions of SSCs, 506, 515  
 existing standards and programs use, 506  
 goal setting, 504, 506–507, 509, 513  
 methodology of selecting plant structures, systems, and components, 506–507  
 monitoring (goal setting), 509, 510  
 monitoring using nondestructive examination (NDE) analysis, 509  
 paragraph (a)(1), goal creation and monitoring, 504, 506–507, 513  
 paragraph (a)(2), preventative maintenance and performance monitoring activities, 504, 507, 509, 513  
 paragraph (b), requirements, 506–507  
 performance criteria for evaluating SSCs, 507–508  
 periodic maintenance effectiveness assessments, 513–514  
 probabilistic safety assessments, 513  
 programmed maintenance (PM) of SSCs, 507  
 providing standards of maintaining nuclear power plant structures excluding pumps, valves, and piping, 503  
 purpose, 503–504  
 requirements, 506  
 responsibility, 504  
 risk and performance criteria, establishing of (goal setting), 506–510  
 scope of, 506–507  
 scope of performance criteria, 503–504  
 Section 9.3.1, 509  
 Section 9.4.4, 513  
 Section 10.5.10, 507  
 SSCs outside the scope of, 507  
 SSCs subject to effective program maintenance program, 511–512  
 terms and definitions, 504–506  
 work order tracking, 509
- U.S. Nuclear Regulatory Commission (USNRC) Office of Nuclear Reactor Regulation
- U.S. Nuclear Regulatory Commission (USNRC) Regulatory Guides (NUREGs)  
 NUREG-0582, 622  
 NUREG-0800 (Standard Review Plan), 392, 593  
 NUREG-484-1, 573  
 NUREG-1522 (Assessment of Safety-Related Structures in Nuclear Power Plants), 512  
 NUREG/CR-0098, 554, 556, 560  
 RG 1.35 (Inservice Inspection of UngROUTed Tendons in Prestressed Concrete Containments), 709  
 RG 1.35.1 (Determining Prestressing Forces for Inspection of Prestressed Concrete Containments), 709  
 RG 1.61 (Damping), 560  
 RG 1.68 (Initial Test Programs for Water-Cooled Nuclear Power Plants), 622  
 RG 1.70 (Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants), 622  
 RG 1.91, 560  
 RG 1.147 (Inservice Inspection Code Case Acceptability), 338, 709
- U.S. Nuclear Regulatory Commission Staff Letter, utilities to audit their suppliers, 533
- United States of America Standards (USAS). *See also* American National Standards Institute, American Standards Association.  
 B 31 Code Cases, 524  
 B 31.1.0-1967, 524, 528  
 B 31.1.0, paragraph 100.2 (pipe-supporting elements), 526  
 B 31.1.0, paragraph 120.1, 526  
 B 31.1.0, paragraph 121 (design rules for pipe-supporting elements), 526  
 B 31.7 (Code for Nuclear Piping), 524, 528  
 B 31.7, paragraph 100.1.1 (piping), 526  
 B 31.7-1969, paragraph 700, 525  
 B 31.7-1969, paragraph 700(d), 525  
 B 31.7-1969, paragraph 700(e), 525  
 B 31.7-1969, paragraph 700.1.4, 525  
 B 31.7-1969, paragraph 700.2, 526  
 B 31.7-1969, paragraph 1-723 addenda (c), 527  
 B 31.7-1969, paragraph 1-723.1.1, 525  
 B 31.7-1969, paragraph 1-723.1.2, 525  
 B 31.7-1969, paragraph 1-723.1.3, 527  
 B 31.7-1969, paragraph 1-723.1.3(a), 525  
 B 31.7-1969, paragraph 1-723.1.3(b), 525  
 B 31.7-1969, paragraph 1-723.1.3(c), 525  
 B 31.7-1969, paragraph 1-723.2.3, 525  
 B 31.7-1969, Table 1-724, 525  
 B 31.7-1969, paragraph 1-725.5, 525  
 B 31.7-1969, paragraph 1-727.2, 525  
 B 31.7-1969, paragraph 1-737.1(b), 526  
 B 31.7-1969, paragraph 1-737.1.3, 526  
 B 31.7-1969, paragraph 1-737.3(g), 525  
 B 31.7-1969, paragraph 1-737.4, 526
- Unplanned automatic scrams per 7,000 critical hours, 505  
 Unplanned capability loss factor, 505, 509  
 Unplanned safety system actuations, 509  
 definition, 506
- Unreinforced fabricated tee (UFT) branch connection, 639  
 Updated Final Safety Analysis Report (UFSAR), 353, 561  
 small nuclear power plant items as exemptions, 345
- USAS. *See* United States of America Standards. *See also* American National Standards Institute, American Standards Association.
- User's Basic Requirements Specification (UBRS), 260  
 for Design Example 1, 279  
 for Design Example 2, 288
- USNRC. *See* United States Nuclear Regulatory Commission.
- UT. *See* Ultrasonic examination, Ultrasonic inspection, Ultrasonics, Ultrasonic testing.
- U-tube design methods, 89  
 U-tube steam-generator tubes, flaw acceptance criteria, 423  
 U-tube tubesheet, 89
- Vacuum arc remelt, 173  
 Vacuum rings, for RTP-1 vessel, 271–273  
 Vacuum-stiffening rings, for RTP-1 vessel, 271  
 Valve bodies, corrosion or erosion, 423  
 Valve disks, replacement, 329

- Valve operators, 530
- Valve pressure loss coefficient, 578
- Valves
  - automatic closure capability, 407
  - check, 578
  - disclaimer statement, 564
  - failure modes, 562–563
  - faulted or Service Level D loads, operability evaluation, 564
  - functional testing, 308–309
  - history, 518–519
  - leak testing, 569
  - in light-water reactor plants, 405, 407
  - NPS 1 and smaller, repair/replacement activity, 334
  - operability, ASME Code requirements for, 564
  - operability evaluation methods, 568
  - pop action safety relief, 195
  - pressure-retaining parts replaced, 333
  - pressure-retaining welds, 423
  - of pressure vessels, capacity conversions, 100
  - safety/relief, 407, 562
  - small spring-loaded, 195
  - specified safety functions, 562
  - swing-check, 578–579
  - turbine-stop, 591
- Valve Category A, 565
  - definition, 629
  - inservice test requirements, 565
  - leakage criteria, 565
  - stroke-time acceptance criteria, 565
- Valve Category B, 565
  - definition, 565
  - inservice test requirements, 565
  - stroke-time acceptance criteria, 565
- Valve Category, 565
  - definition, 565
  - inservice test requirements, 565
- Valve Category D
  - definition, 565
  - inservice test requirements, 565
- Valve set pressure, 126
- Vanadium, requirements for  $2\frac{1}{2}\text{Cr}-1\text{Mo}-\frac{1}{3}\text{V}$  weld metal composition, 116
- Van Stone (lap joint) flanges, 678
- Variables
  - essential, of welding and brazing, 197, 205–206, 212–213, 229, 232
  - nonessential, of welding and brazing, 205–206, 210–211, 219–220, 232
  - supplementary essential, of welding and brazing, 205–206, 219–220, 232
- Vegetable fiber, as gasket materials and contact facings, 687
- Veil, definition, 240, 237
- Velocity potential, 584
- Velocity transducers, 602
- Vendor Equipment Qualification Report, 568
- Vendor lists, approved, 528
- Verify, definition, 509, 529
- Vertical flow, 233
- Vessel burst strength, 121
- Vessel closure-head nuts, 320
  - visual examination of, 317
- Vessel Code, 521
- Vessel Manufacturer
  - definition, 442
  - heat treatment information of nuclear reactor vessel materials, 143
  - responsibilities for nuclear reactor vessels, 140
- Vessel marking, of pressure vessels having higher allowable stresses at low temperature, 87
- Vessel (production) test plates, impact testing of production welding, 71
- Vibration, 545, 632
  - dynamic transient, 591–592, 603, 608, 599–600
  - of pumps, 11, 563, 571
  - shell-mode, piping, 616, 617
  - steady-state, 33, 591–592, 612–613
  - as support failure mode, 562
  - vortex-induced, 597
- Vibration analysis, 512
- Vibration frequency, 602
- Vibration isolators, 603
- Vibration monitoring groups (VMGs), 594
  - Group 1 (VMG-1), rigorous qualification method, 594
  - Group 2 (VMG-2), simplified qualification method, 594
  - Group 3 (VMG-3), visual inspection, 594
- Vibratory fatigue, of piping, 321, 324
- Vibratory loads, 546, 556
  - conditions for, 556
- Vibratory motion, 546
  - as piping failure mode, 562
- Vibratory stress, 556
  - to identify welds in light-water reactor plants, 398
- Vinyl ester resins
  - cost, 268
  - curing process, 236
  - properties, 236
  - as vessel materials, 235
- Virtual mass, 585
- Vision examinations, of NDE personnel, 394
- Visual (VT) examination, 19
  - abbreviation, 307
  - of bellows expansion joints, 111
  - Class MC examination requirements, containment surfaces, 452
  - Class MC examination requirements, pressure-retaining bolting, 452
  - Class MC examination requirements, pressure-retaining welds, 452
  - Class MC examination requirements, seals, gaskets, and moisture barriers, 452
  - of Class 3 systems, 307
  - containment surfaces, 452
  - of containment surfaces requiring augmented examination, 453–454
  - containment vessel light-water reactor plants, 405
  - detailed, of light-water reactor plants, 401
  - of flaws, acceptance standards, 423
  - of light-water-cooled nuclear power plants, 392
  - of light-water reactor plants, 400
  - of nuclear reactor vessel materials, 143
  - physical requirements, 19
  - of pressure-retaining boundary, light-water reactor plants, 404
  - of pressure-retaining welds, 449
  - procedure/technique, 19
  - qualification of personnel, 317
  - of seals, gaskets, and moisture barriers, 455
  - of Section X, Class II vessel laminates, 252
  - Section XI Subgroup on Containment requirements, 445
  - of steel castings of pressure vessels, 98
  - of welds, 225
  - written procedure requirements, 19
- Visual Testing (Examination Levels: VT-1, VT-2, VT-3). *See also* VT-1 examination, VT-2 examination, and VT-3 examination.
  - acronym/abbreviation, 442
- VMG. *See* Vibration monitoring group.
- Voiding, of discharge lines, 601
- Voids, brazing and, 233
- Volume flow rate of fluid, 578



- Volumetric examination, of light-water reactor plants, 406
- Vortex shedding, 591–592, 617, 620  
 periodic flow instabilities associated with, 584  
 in piping, 597–599
- Vortex-shedding frequency, 582
- Vortex-shedding loads, 546
- VT. *See* Visual testing (Examination Levels: VT-1, VT-2, VT-3),  
 VT-1 examination, VT-2 examination, and VT-3 examination.
- VT-1 examination, 392  
 of bolted connections, 443  
 of bushings, threads, and ligaments in base material of flanges, 443  
 of Class CC containments, 463  
 of Class CC containments, of reinforcing steel, 463  
 of containment surfaces requiring augmented examination,  
 definition, 412  
 of light-water reactor plants, 398  
 personnel qualification, 318  
 for reactor vessel closure-head nuts, 327  
 of vessel closure nuts, 317
- VT-1C examination
- VT-2 examination, 392, 408  
 definition, 412  
 interior surface and internal components of reactor vessels, 423  
 for leakage detection from buried pipes during pressure tests, 332  
 Level II personnel, 332  
 of light-water reactor plants, 408  
 meaningless replacement examinations on internal items, 379  
 of mechanical joints made in installation of pressure-retaining  
 replacement items, 380  
 metal containments and metal liners of concrete containments, 449  
 qualification of personnel, 317, 332
- VT-3 examination, 392  
 of Class NF components, 436  
 on coated areas, 459  
 on coated areas of Class MC containments and metallic liners of  
 Class CC containments, 458  
 containment surfaces, 446  
 definition, 412  
 of dissimilar metal welds, examination of surface areas, 446  
 interior surfaces and internal components of reactor vessels,  
 423  
 as IWE examination methods, 446  
 of light-water reactor plants, 398, 404, 408  
 metal containments and metal liners of concrete containments,  
 446  
 personnel certification requirements, 393–394  
 personnel qualification, 317, 331  
 preservice examination of internal surfaces, 330  
 revision, containment surface standards for, 446  
 revision, replaced with General Visual Examination in E-A  
 examination category, 446  
 of seals, gaskets, and moisture barriers, 446  
 for spaces below the reactor core imposed by Categories B-N-1  
 and B-N-2, 331  
 for spaces within the reactor vessel imposed by Category B-N-1,  
 331
- VT-3C examination  
 Class CC containments, concrete, 446  
 Class CC containments, requirements for visual examination and  
 personal qualification, 446  
 Class CC containments, surface examination, 446
- Wake, 575
- Walkdown procedures, 608
- Water environment  
 austenitic steels fatigue crack growth rate, 484  
 elevated-temperature effects on low-alloy steels  
 ferritic steels fatigue crack growth rate, 481, 484
- Waterhammer, 557, 563, 600–601, 604  
 condensation-induced, 581  
 and flexibility factors, 633  
 monitoring systems for, 608  
 monitoring systems for vibration, 606
- Water slugging, 601  
 definition, 592
- Water soluble ion tests, for Class CC containments, 446
- Waters-Taylor method, 681
- Wax, use in joining vessel parts, 242
- Wear, as support failure mode, 562
- Wear-resistant hardfacing overlays, 227
- Weight density, of Section X vessels, 254
- Weld defects, visual examination, 225
- Weld deposit thickness, 214
- Welded joints  
 categories, 83, 87  
 of nuclear reactor vessels, 153–155  
 preheating, 126  
 in pressure vessels, categories, 50  
 in pressure vessels, design of, 52  
 spot examination, 7
- Welder or welding operator  
 expiration/renewal of performance qualifications, 216  
 identification marks, 61, 161  
 qualification, 212–217  
 qualification of nuclear power plant items, 372–374  
 corrosion-resistant (and hardfacing) overlay, 217  
 for nuclear power plant items, repair/replacement activities, 350  
 of pressure vessels having higher allowable stresses at low  
 temperature, 87  
 of pressure vessels with cryogenic operation, 72
- Welder Performance Qualification (WPQ) Test, 212, 216
- Weld factor, 395
- Weld identification plan, 10
- Welding  
 back gouging, 211  
 backing and deletion of, 207–208  
 base metals, 207–208, 212, 229  
 base metal thickness, 208  
 calculating heat input, 219–220  
 of chromium-molybdenum steels for pressure vessels, 114  
 classification of materials, 203–204  
 cleaning, initial and interpass, 211  
 connections of pressure vessels, 57  
 copper alloys, 224  
 corrosion-resistant weld metal overlay, 226–231  
 deposit thickness of weld metal, 210  
 dilution on the overlay, 210  
 electrical characteristics, 207, 210–211, 219–220, 229  
 filler metals, 207–208, 210, 212, 214, 219, 229  
 of forged pressure vessels, 65  
 groove designs, 206–207  
 hardfacing overlay, 210, 228–231  
 heat-affected zone (HAZ), 220, 224–225  
 heat input equation, 219  
 of high-pressure vessels, 180, 193–194  
 history of applications, 196  
 impact tested weld procedures, 216–220  
 joints, 206–208, 212, 229  
 minimum preheat temperature, 210  
 mode of process, 212  
 notch toughness testing, 219, 220  
 of nuclear power plant items, 369–374, 376  
 of nuclear reactor vessel, 139, 161  
 performance/procedure qualification, 226  
 pipe or tube, technique sketches, 4  
 positions, 207, 210, 212, 214, 216, 219, 229



- postweld heat treatment, 207, 210–211, 219, 229
- preheating, 207, 210–211, 219, 229
- pressure boundary applications, 196
- pressure vessel requirements, 49–63
- of pressure vessels, fabrication requirements, 62
- of pressure vessels, inspection and tests after, 62–63
- processes, 197–202
- qualification of procedures, 204–212
  - as repair/replacement activity, 343
  - retainers, 208
  - root spacing, 208
  - stringer bead technique, 211
  - subcontracting, 205
  - surface preparation methods, 212
  - technique, 207, 210–212, 229
  - testing and examination requirements, 221–226
  - variables covered in Section IX, 197
  - weave bead technique, 211
  - welder performance qualification, 210, 220
- Welding procedure specification (WPS), 206, 210, 212, 218, 228
  - groove design, 206–207
  - joints, 206–207
  - of nuclear reactor vessels, 162
  - ownership, 206
  - purposes of document, 206
- Welding Research Council (WRC), 141
  - Bulletin 77, 640
  - Bulletin 95, 121
  - Bulletin 107, 120, 569, 573
  - Bulletin 153, 641
  - Bulletin 198, Part 1, 120
  - Bulletin 198, Part 2, 120
  - Bulletin 252, 324
  - Bulletin 257, 324
  - Bulletin 271, 708
  - Bulletin 285, 641
  - Bulletin 297, 120, 569, 573
  - Bulletin 343, 324
  - Bulletin 352, 568, 572
  - Bulletin 370, 326
  - Bulletin 376, 326, 497, 673
  - Bulletin 382, 319, 325, 326
  - Bulletin 386, 326
  - Bulletin 387, 326
  - Bulletin 406, 151
  - Bulletin 408, 709
  - Bulletin 413, 319, 325
  - Bulletin 420, 326
  - Bulletin 429 (3D Stress Classification), 170
  - Bulletin 433, 640
  - Bulletin 435, 137
  - Bulletin 444, 148
- Weld joint efficiency, 38, 39, 63, 103–104
  - of layered pressure vessels, 84
- Weld metal
  - tensile strength, 222–223
  - welding, change in current, 230
  - welding polarity, 230
- Weld overlay, 328
  - of Class 1 components, 334
  - for high-pressure vessels, 181
  - of pressure vessels, 81–82
- Weld prep, 178
- Weld repair, 524–526
  - of cast iron pressure vessels, 76
  - of nuclear reactor vessel materials, 160, 164
  - of nuclear reactor vessels, 160, 164
  - after postweld heat treatment of pressure vessels, 68
  - of pressure vessels, 62–63
  - of pressure vessels and liquid-penetrant examination, 99
  - of pressure vessel, 99
  - of steam generator feedwater-nozzle cracks at a nuclear plant in the 1970s, 524–526
- Weld ripples, 6
- Weld spatter, 13
- Welds
  - attachments, 423
  - attachments evaluated by Owner of light-water reactor plants, 402
  - austenitic, 10
  - in cast ferritic product forms excluding pipe, 13
  - cooling rate, 67
  - dissimilar metal, 9
  - dissimilar pressure-retaining in vessel nozzles, 422
  - ferritic, in ferritic pipe, 10
  - fillet, 57–60, 67, 208
  - fillet, and dimpled or embossed assemblies, 105
  - full-penetration, of nozzles in vessels, 422
  - girth butt, 37, 627–630, 636, 638
  - high-nickel alloy, 10
  - IQI selection, 8
  - of nuclear reactor vessels, 158
  - in nuclear reactor vessels, examination of, 311–312
  - of nuclear vessels, ultrasonic examination, 312
  - partial penetration groove, 208
  - postweld heat treatment requirements, 63
  - pressure-retaining examination requirements, 454
  - pressure-retaining in Class MC containments, examination requirements, 451
  - pressure-retaining, in piping, 422
  - pressure testing, in nuclear power plant items, 381
  - in pump and valve bodies, 423
  - radiographic examination, 6
  - without reinforcement, 8
  - with reinforcements, 9
  - sectioning of, 121
  - surface weld metal buildup in pressure vessels, 62
  - tube-to-tubesheet, in pressure vessels, 116, 119
  - ultrasonic examination, 10–11
- Westinghouse steam generators, 524
- Wet fluorescent magnetic-particle examination, of high-pressure vessels, 182
- Wet magnetic-particle examination, of high-pressure vessels, 196
- White-noise earthquake ground motion, 551
- Wind, 34–36, 526
  - effect on nuclear reactor vessels, 144
  - and welded joints of pressure vessels, 123
- Wind angle, 241
  - definition, 237
- Wind conditions, of pressure vessels, 91
- Wind-driven missiles, 558
- Wind loadings, 267
  - effect on piping, exposed, 591
  - and piping vibration, 592
  - process piping, 591
  - on RTP-1 vessel, 263
- Wind moment, 263
- Wind uplift force on top head, 265
- Wire winding, of high-pressure vessels, 192
- Wire wrapping, 190
- Working Group for Concrete Pressure Components, 445
- Working Group on Design Reconciliation, 360
- Working Group on Welding and Special Repair Processes, 375
- Work plans, careful preparation of, 523

- Woven-roving lamina  
 compressive strength, 238  
 density, 238  
 fiber content by weight, 238  
 orthotropic in stiffness and strength, 237  
 Poisson's ratio, 238  
 reinforcement weight, 238  
 reinforcing glass, 237  
 shear modulus, 238  
 shear strength, 238  
 tensile strength, 238  
 thickness, 238  
 weight (oz./yd.<sup>2</sup>), 236  
 Young's modulus, 238
- WPQ. *See* Welder (or welding operator) performance qualification.
- WPS. *See* Welding procedure specification.
- Written practice, guidelines for nondestructive examination for employers, 2–3
- X-ray energy, 8
- X-ray examination, of welds, 2–3
- $\gamma$ -gasket factor, 682–683
- Yield strength  
 design factor on, 137–138  
 heat treatment effect, 646  
 of high-pressure vessels, 179–180  
 of nuclear reactor vessels, 171
- 0.2% offset, of austenitic steel pressure vessel alloys, 650
- 0.2% offset, for fatigue calculation for high-pressure vessels, 187
- Yoke method of magnetic-particle examination, 317
- Young's modulus, 238  
 of aramid fibers, 236  
 of carbon fibers, 236  
 of E-glass fibers, 236  
 of fibers, 236  
 of laminae, 238  
 of S-glass fibers, 236
- Zero period, 548
- Zero period acceleration (ZPA), 547, 554, 555  
 definition, 549
- Zero period acceleration (ZPA) frequency, 548  
 definition, 549
- Z factors, 431, 703
- Zipper effect, 87
- Zirconium  
 Grade R60705, 74  
 P-Number, 203
- Zirconium-base alloy, P-Number, 203
- Zirconium-base electrodes, F-Number, 203
- Zirconium-base rods, F-Number, 203
- Zirconium electrodes, F-Number, 203
- Zirconium rods, F-Number, 203
- ZPA. *See* Zero period acceleration.