Subject Index

A

Acicular ferrite, see Intragranular ferrite plates
AFNOR NF A 81460, 195
AISI 1215 steel, 51–66
chemical analysis, 53, 56
experimental procedure, 53
hardness, 53, 58
machinability, 54–55, 58, 60–64
MnS inclusion
aspect ratio, residual effect, 53, 59
size, residual effect, 53, 58
oxide inclusion, 53–54, 59
properties, 53–54, 56–59
residual levels investigated, 52–53
roto-bar rejection rate, 53, 56
tensile ductility and strength, residual effect, 57
Alloy steel
high strength, 266
relative cost of restricting residual levels, 32–33
Alumina inclusions, machinability, 72
Aluminum
content during ladle refining, 42–43
deoxidation constant, 41
Aluminum oxide, 76
Arc length, 243–258
back-gouging, 257
deposit nitrogen and oxygen level effects, 251–256
SMA electrodes, 257
specimen extraction and testing, 248
Ashby-Orowan equation, 225
ASTM Standards
A 20/A20M–86a, 117
A 240–85, 151, 153
A 242, 34
A 255–67, 36
A 262–85a, 150, 154, 158–162, 164
A 266–69, 115
A 266–84a, 114, 117, 123
A 266–85, 115
A 269–85, 151, 153
A 352/A 352M–85, 122
A 376, 6
A 430, 6
A 450/A 450M–86A, 151, 153
A 480/A 480M–84A, 151, 153
A 508–84a, 100–101, 107, 114, 117
A 508/A 508–86, 115
A 516/A 516M–84, 196
A 530/A 530M–85a, 151, 153
A 533/A 533M–85b, 100–101, 106
A 588, 34
A 751, 1
A 771–83, 124–125
A 788, 202, 208
A 858/A 858M–86, 122
A 860/A 860M–86, 122
E 8, 212
E 23, 212
E 45–76, 193
E 112, 125, 212
E 139–83, 126–127
E 618–81, 51, 53
G 5–82, 154
G 31–72(1985), 154
G 48–76(1980), 154
Auger spectroscopy, 100
Austenitic stainless steel
carbide contents, 160
high temperature ductility, 164
see also Titanium stabilized austenitic stainless steel
Austenitization
martensitic 12% chromium steel, 88
temperature, 113
Automatic screw machine test, 53–54
Axisymmetric specimens, 100

B

Ball bearing steels, calcium, 70
Biaxial stress rupture
tests, D9I, 127
titanium stabilized austenitic stainless steel, 132, 135
Borides, 163
Boron, 150
corrosion resistance of Type 304 stainless steel and, 152
D9 levels, 125–126
stress rupture life effect, 128–130
RESIDUAL AND UNSPECIFIED ELEMENTS IN STEEL

Boron (cont.)

tertiary creep and, 146
titanium stabilized austenitic stainless steel effect, 145-147
see also Titanium stabilized austenitic stainless steel
British Standards 4060 50E, 169
British Standards 5762:1979, 175
Butt weld
charpy toughness, 180-184
cutting scheme, 174
crack tip opening displacement, 184-185
fractographic examination, 186-188
microstructural observations, 177-179
chemical analyses, 174-177
tensile and hardness data, 179-183

Caustic embrittlement, 5-6
Charpy impact test
fracture appearance transition temperature, 269, 271
weld metal, 239-240
Charpy toughness, 100, 170
butt weld, 180-184
DC straight polarity deposits, 186
de-embrittling treatment, 104, 106
forged and plate steel, 106, 108
Charpy V notch
fracture energy, 104
impact test properties, X-70 line pipe steel, 291-292
specimens, 103, 288
transition curves, heat affected zone, 294
Chromium, 51
Cleanliness, calcium treatment and, 69-72
Cleavage, 100
isolated regions, welds, 186, 188
stress, critical, 108, 110
Clinch River breeder reactor, 203
C-Mn-Ni welds, 179, 182-183
Cold cracking
heat affected zone, 296
hydrogen induced, 296-297
Cold formability, residuals and, 35-36
Cold upsetting, calcium treatment, 71-72
Columbium-vanadium steel, low carbon, 286
Compact tension specimens, 103
Constituent ratios
LN steel, 275-276
Ti-oxide bearing steel, 275-276
Continuous casting, 26
growth of, 28
percent of U. S. production, 28
trends, 11, 13
Continuous cooling transformation diagram
LN steel, 273-274
Ti-oxide bearing steel, 273-275
Copper, 51, 150, 202-227
average monthly residual, scrap, 19, 21
corrosion resistance, 208
Type 304 stainless steel and, 151-152, 154-158
dilatometry, 212
factors favorably affecting hot workability, 34
hardenability, 208
iron-copper phase diagram, 207-208
laboratory-produced steels, 221-223
light microscopy, examination, 212
load-elongation curve, 224
machinability and, 51-52
materials, 204-206
particles, 215-216, 220

Calcium
alloys, see Inclusion control
ball bearing steels, 70
carbo-nitriding, 70-71
cleanliness and, 69-72
cold upsetting, 71-72
fatigue life, 70-71
machinability, 72-73
Calcium-aluminum, deoxidation constant, 41
Calcium oxide, 77
Calcium sulfide, 77
Carbides, 83, 150
martensitic 12% chromium steel, 98-99
precipitation reactions, 215
strengthening, 202, 227
Carboborides, 163
Carbon
content effect on heat affected zone toughness, 269, 271-273
equivalent, 114, 120-122
interstitial, 225
segregation, negative, 114
Carbo-nitriding, calcium treatment, 70-71
Carbon-manganese steels, 169, 243
welds, mechanical property, 179, 181
Carbon steel forgings, 114
chemical composition, 115, 122
heat analyses and product analyses, 117, 119
heat treatment, 114, 116-117
impact test results, 117-118
mechanical property test locations, 114, 116
results, 117-120

precipitation, grain boundary, 213, 218
procedure, 209–212
regression analysis, scrap, 16, 19
restriction, hot shortness and, 34–35
tensile/impact testing, 212
values of purchased scrap grades, 22
yield strength, 224
annealed, 224
PWHT/AC, 226–227
PWHT/FC, 224–226
see also Weld metal, embrittlement
Copper alloys, elimination, 7
Corrosion, 7
Corrosion resistance
copper and, 208
Type 304 stainless steel, 150–165
boron effects, 152
copper and molybdenum effects, 151–152, 154–158
corrosion rates, 158
effect of alloy boron content and sensitizing treatment, 161–162
intergranular corrosion rates, 158–159
materials, 152–154
potentiodynamic anodic polarization curves, 155–157
reference standards, 160
Counterfeit bolts, 25
Cracking
hydrogen induced, 286
solidification, 297
Crack tip opening displacement, 169, 175
butt weld, 184–185
C-Mn-Ni deposits, 188
scatter in values, 189–190
Creep, 124
Creep resistance, 83
Creep test, martensitic 12% chromium steel, 96–97
CrMo steel, HAZ tempering characteristics, 264–265
2-1/4Cr-1Mo steel, 202
chemical analysis, 205
critical temperatures, 213
laboratory-produced
residual copper, 221–223
yield and tensile strengths, 223
CrMoV steel, HAZ tempering characteristics, 264–265
Current supply, 243–258
AC, 244
DC reverse polarity, 186
deposit nitrogen and oxygen level effects, 251–256
SMA welding, 243–244
welding, 170, 174

D
D9, 124–125
boron effect
ductility, 130–131
stress rupture life, 128–130, 132–134
creep curves, modified by additions of boron phosphorus, 130
in-reactor creep behavior, 135, 139–141
neutron-induced swelling, 141, 143
phosphorus and boron levels, 125–126
phosphorus effects
ductility, 130–131
stress rupture life, 128–129
precipitate-free zones, 146
swelling behavior, 136, 139
unirradiated, 133–139
as-received condition, 136
carbide and Laves distribution, 135, 138
creep cavitation, 134, 137
high phosphorus-high boron heat, 135, 138
MC precipitates, 135, 139
phase identification, 134–135, 137
D91, 127–128
Deoxidation, 38
Deoxidation constant, aluminum, 41
Dephosphorization, 40
Desulfurization, 38
Diffusion deoxidation, 43–44
Dilatometry
production forgings, 213
residual copper, 212
DIN 50602, 193
Dissociation, ladle lining, 42–43
Dropweight tear test, 300
Ductile to brittle transition temperature, 101, 107–108
Ductility, optimum, 261

E
Electric arc furnaces, 26
Electric furnace steelmaking, 26–27
trends, 11–12
Electron microscopy, see Production forgings
Electroslag remelting, 202, 204, 206
ferrite matrix, 216, 220
Embrittlement, effect of phosphorus segregation, 296
End quench hardenability test, 36
Engineered bar products
maximum levels of residual content, 29
nickel-copper ratio, 34
Erosion-corrosion, in feedwater and wet steam piping, 7
Fatigue life, calcium treatment, 70-71
Fatigue limit, versus tensile strength, 70-71
Fe-Al-Ca-O-S system, equilibrium diagram, 73-74
Ferritic steel, see Sulfur, weldability and Formability, 26
Fractography, temper embrittlement, 103-104
Fracture appearance transition temperature, 300
  charpy impact test, 269, 271
  sulfur content and, 278-279, 281
  X-70 line pipe steel, 291
Fracture surface
  heat affected zone, 296-296
  martensitic 12% chromium steel, 93, 96
  microstructure below, 279, 281
Fracture toughness, 7, 104-105, 169
  effect of reaustenitization and temper, 104, 107
  temper embrittlement, 104-105
Free-machining steel, 51
Fuel cladding, 125
Furnace, advanced procedures, 14

Galvanized material, in scrap, 24
Gas metal arc weld, 193
Gas-shielded welding, nitrogen, 256-257
Grain size, 266
Graphitization, 5-6

Hardenability, 26
  end quench test, 36
  residual copper, 208
  residual levels and, 36-37
Hardening
  dynamic strain, 238
  see also Precipitation hardening
Hardness, 261
  AISI 1215 steel, 53, 58
  butt welds, 179-183
  martensitic 12% chromium steel, 88, 90-93
  postweld heat treatment, 263
  X-70 line pipe steel, 293-294
  see also Underbead hardness
Heat-affected zone, 261-262, 266-267
  charpy V notch transition curves, 294
  cold cracking, 296
  fracture surfaces, 296-296
  mechanical properties, 293-296
  microstructure, 269
  niobium content, 271-272
  scanning electron fractographs, 295
  shelf energy, 295
  simulated coarse-grained microstructure, 290
  tempering characteristics of CrMo and CrMoV steels, 264-265
  toughness, 286, 296
  carbon or niobium content effect, 269, 271-273
  heating temperature effect, 269, 271
  test, 267
  underbead hardness, 192
  weld thermal cycle, 288-289
Heat analyses and product analyses, carbon steel forgings, 117, 119
Heat treatment, 101, 103
  carbon steel forgings, 114, 116-117
  inter-critical, 114, 117
  temper embrittlement, 101, 103
  Hollomon-Jaffe parameter, 261-262
Homogenization
  martensitic 12% chromium steel, 85, 87
  temper embrittlement, 113
Hot ductility test, 6
Hot shortness, 26
  copper restriction, 34-35
Huey test, 159-160, 164
Hydrogen, 192
  induced cold cracking, 296-297
  induced cracking, resistance, 286
  sensitivity and sulfur, 198
  weld deposit content, 195
  weldment effects, 196-197

Impact test
  carbon steel forgings, 117-118
  martensitic 12% chromium steel, 93, 95
  residual copper, 212
Impact toughness, 169, 285
  laboratory-produced steels, 222-223
Inclusion, 192, 266
  composition, predictive model, 73-76, 78
  control
    aluminum oxide, 76
    calcium oxide, 77
    calcium sulfide, 77
    calcium treated steels, 73-79
    shape control, 297
    harmfulness, 70
    oxide, AISI 1215 steel, 53-54, 59
    phase analysis, 76-79
    precipitation path, 74, 76
In-reactor creep, titanium stabilized austenitic stainless steel, 145
In-reactor stress rupture, titanium stabilized austenitic stainless steel, 135-136, 139-141
Intragranular ferrite plate, 267
area ratio and length of ferrite side plate, 280, 282
cooling time effects, 275-277
fine-grained structure, 296
formation, 266, 272-273
toughness effect, 279-282
nucleus, 269
formation, 278-281
nucleation
cooling time effect, 276-277
by TiO$_2$ particle, 281-283
transformation
effect of MnS, 278-279, 281
effect of thermal history in austenite region, 278, 280
Intergranular rupture, 100
Iron-copper phase diagram, 202, 207-208, 225
ferritic region, 207, 209
Iron-oxide, slag content, 44-45
Irradiation-induced swelling, titanium stabilized austenitic stainless steel, 136, 139, 141-143
Isothermal transformation diagram, 88-93

J
Jominy test, 36

L
Ladle
phosphorus removal, 47
lining, 38
dissociation, 42-43
influence on deoxidation effect, 43-44
refining, 38
effect of slag type, 41-42
procedure, 40
Larson Miller parameter, representation of in-reactor creep rupture, 141, 143-144
Lateral expansion transition temperature, X-70 line pipe steel, 291
Light microscopy
laboratory-produced steels, 221-222
production forgings, 213, 216
residual copper, examination, 212
LN steel
constituent ratios, 275-276
continuous cooling transformation diagram, 273-274
microstructure, 273, 275
quenching on cooling stage, 275-276
Local rupture criterion approach, 110

M
Machinability, 51, 69
AISI 1215 steel, 54-55, 58, 60-64
finish formed surface roughness, 54, 61-62
rake face, 54-55, 62
surface roughness, 55, 63-64
test conditions, 55
tool life, residual effect, 54, 60-61
calcium treatment, 72-73
copper and, 51-52
effect of aluminum and calcium to oxygen ratio, 72
evaluation, 53, 55
steel Grade 4140, 73
Martensite island, high carbon, formation, 277-278
Martensitic 12% chromium steel, 83-99
austenitization, 88
carbides, 98-99
chemical composition, 85-86
comparison between standard and super-clean heat dilatometry, 87-88
creep test, 96-97
dilatometric results after austenitization, 88-89
fracture surfaces, 93, 96
hardness, 88, 90-93
homogenization treatment, 85, 87
influence of cooling rate on structure, 88, 91-92
mechanical properties after quenching and tempering, 93-97
mechanical tests, 87
pure heat procedure, 85-86
quenching, 87
research objectives, 84
structural examination of impact test pieces, 96
super clean heat, 83, 85
tempering temperature, 87
tension test, 88, 90, 93-94
transformation temperatures, 88-93
MC precipitates, uniaxial stress rupture, 135, 139
M$_{23}$C$_6$ type carbides, production forgings, 215, 217
Melting yield, scrap, 14
Microalloyed steels, 285
Microbial corrosion, 7
Microsegregation, Ti-oxide bearing steel, 269
Microstructure
LN steel, quenching on cooling stage, 275-276
Ti-oxide bearing steel, quenching on cooling stage, 275-276
Mixed sulfur, formation, 78
MnS
IFP transformation effect, 278-279, 281
inclusion aspect ratio, AISI 1215 steel, residual effect, 53, 59
inclusion size, AISI 1215 steel, residual effect, 53, 58
Molybdenum, 150
corrosion resistance of Type 304 stainless steel and, 151-152, 154-158
M2X carbides
molybdenum/chromium ratios, 213, 315, 226-227
production forgings, 213, 218-219, 226-227
M2X carbonitrides, 219, 221

N
Neutron-induced swelling, 141-143
Nickel, 51
Nickel-copper ratio, engineered bar products, 34
3.5% NiCrMoV steel, 38-39
Niobium, content effect on heat affected zone toughness, 269, 271-273
Nitrogen, 169, 243
deposit contents, 255-257
arc length and current supply effects, 251-256
gas-shielded welding, 256-257
welds, 186
interstitial, 226
pick-up during welding, 243-244
requirement, 7
Notch toughness, 232

O
Obsolete scrap, 29
Oxide inclusion, AISI 1215 steel, 53-54, 59
Oxygen, 169, 243
deposit contents, 176-177, 254-255
arc length and current supply effects, 251-256
pick-up during welding, 243-244
transportation mechanism in slag, 46

P
Phosphorus, 285-300
D9 levels, 125-126
increase in transition temperature, 297
microsegregation, 101
removal, ladle, 47
segregation, embrittlement effect, 296
stress rupture life effect, 128-129
titanium stabilized austenitic stainless steel effect, 145-147
see also Titanium stabilized austenitic stainless steel
Polarity, 169-170, 177, 243
deposit nitrogen and oxygen level effects, 251-256
Postweld heat treatment, 202-203, 232, 261-265
AC condition, production forgings, 216-217, 221
FC condition, production forgings, 213, 215-216, 219-220
hardness, 263
heat affected zone tempering response, 262-263
procedure, 262-263
temperature-time relationships, 262
Postweld stress relief heat treatment, 237
Precipitation hardening, 232, 236, 238
strengthening, 202
Pressure vessel, 100
Pressurized water reactor, 100
Probability of cleavage fracture, 110, 111
Production forgings, 213-221
dilatometry, 213
electron microscopy, 213, 215-221
annealed, 213, 217-218
PWHT/AC, 216-217, 221
PWHT/FC, 213, 215-216, 219-220
eutectoid phase, 213, 217
iron-copper phase diagram, 225
light microscopy, 213, 216
load-elongation curves, 213, 215
M23C6 type carbides, 215, 217
M2X carbides, 213, 218-219, 226-227
Purchased scrap, 11, 29

Q-R
Quenching, martensitic 12% chromium steel, 87
Reactor pressure vessel steels, 7
Refinement, 146
Revert scrap, 29
Rupture, fractographic aspects, 104-105
Scrap, 28-31
  charges, 32-33
 chemistry, 15-16, 19
 continuous casting, 28
 copper levels, hot shortness and, 34-35
 electric arc furnace steelmaking, 26
 "free of alloys", 29
 grade, 16, 18
 home, residual levels and, 65
 homogeneity, 16
 inclusion of galvanized material, 24
 inspection, 15-17
 management for residual control, 32-33
 material segregation, 19-21
 melting yield, 14
 number 1 bundle price trend, 32
 obsolete, 29
 versus other raw materials, 15
 production as percent of consumption, 13
 purchased, 11, 29
 ratio of purchases to steel produced, 11-12
 regression analysis, 16, 18
 relative cost to control residual levels, 32-33
 residual levels
  cold formability and, 35-36
  control, 24
  hardenability and, 36-37
 revert, 29
 shredded
  copper content, 23
  density, 23
 size and density, 14-15
 sources, 14
 specifications, 15
 suppliers, 22-23
 trends in steel industry, 11-14
 types, 30-31
 Segregation, 100
 Sensitization, 150
 Shield metal arc welding, 169-170, 193, 243
  electrodes, arc length, 257
  current supply, 243-244
 Slag, 38
  chemical composition, 41-42
  iron-oxide content, 44-45
  oxygen transportation mechanism, 46
 Solidification cracking, weld, 297
 Solid-solution strengthening, 202, 207-208
 Steam generator, 202-203
 Steam turbines, super critical, 83
 Steel
  chemical analyses, 171, 194, 211, 245, 268
  Grade 4140, machinability, 73
  industry trends, 11-14
  low carbon, 266
  low temperature service, 266
  making, 192
  percent of U. S. production by furnace type, 27
  producers, 11
  U. S. raw steel capability, 27
 Strain aging, welds, 188-189
 Stress corrosion, 5
 Stress rupture, 124-126
 Stress-strain behavior, serrated, 242
 Submerged arc weld, 285
 Sulfur
  constant and fracture appearance transition temperature, 278-279, 281
  content, X-70 line pipe steel, 286
  weldability and, 192-201
  critical preheat temperature, 196-200
  hydrogen sensitivity, 198
  materials, 192-194
  stress direction, 196-197, 199-200
  sulfide shape, 199-200
  underbead hardness, 195-196, 198
  welding conditions, 196-198
  welding tests, 193, 195
 Super-clean heat, 83, 85
  dilatometry, 87-88
  influence of cooling rate on structure, 88, 92
 Super clean steels, production, 38-46
  equipment and sequence, 40
  experiments, 39-40
 Surface roughness, AISI 1215 steel, residual effects, 55, 63-64
 Swelling, 124-125
  D9, 136, 139
  neutron-induced, 141-143
  resistance, D9I, 128
  titanium stabilized austenitic stainless steel, 145
 Tempering response, 261
 Tempering temperature, martensitic 12% chromium steel, 87
 Tensile ductility, AISI 1215 steel, residual effect, 57

T
 Temper embrittlement, 38, 100-113
  auger electron spectroscopy, 106-107, 109
  fractography, 103-104
  heat treatment, 101, 103
  homogenization, 113
  materials, 101-102
  onset susceptibility, 113
  reversible, 101
  specimens and mechanical tests, 103
 Tempering response, 261
 Tempering temperature, martensitic 12% chromium steel, 87
 Tensile ductility, AISI 1215 steel, residual effect, 57
Tensile/impact testing, residual copper, 212
Tensile strength, 114–123, 232
against product analysis carbon content, 120–121
AISI 1215 steel, residual effect, 57
butt welds, 179–183
fatigue limits versus, 70–71
laboratory-produced steels, 221–223
production forgings, 213–215
residual copper, 212
step cooled and de-embrittled smooth specimens, 104, 107
test
martensitic 12% chromium steel, 93–94
weld metal, 234–237
X-70 line pipe steel, 288
X-70 line pipe steel, as-rolled plates, 290–291
Ti$_2$O$_3$ particles, stability, 266
Ti-oxide bearing steel, 266–283
CMA patterns, 273
constituent ratios, 275–276
continuous cooling transformation diagram, 273–275
effective grain size, 279, 282
high carbon martensite island formation, 277–278
IFP nucleus, analysis, 269–270
microsegregation, 269
microstructure, 273, 275
analysis, 269
quenching on cooling stage, 275–276
shelf energy, 295
size and distribution of martensite-austenite constituent, 278–279
specimen preparation, 267–268
transformation characteristics from $\gamma$ to $\alpha$, 269
see also Heat affected zone
Titanium stabilized austenitic stainless steel, 124–147
biaxial stress rupture, 132, 135
effect of phosphorus and boron, 145–147
experimental procedures, 125–128
in-reactor creep, 145
in-reactor stress rupture, 135–136, 139–141
irradiation-induced swelling, 136, 139, 141–143
neutron-induced swelling, 141–143
swelling, 145
uniaxial stress rupture, 128–134, 143–145
Tool life, residual effects, AISI 1215 steel, 54, 60–61
Toughness, 100, 266
influence of composition, 186, 188
welds, 186, 188–190
Transformation temperatures, martensitic 12% chromium steel, 88–93
Tubesheet forgings, 202–204
comparison of ESR and VAR, 210
copper level, 208
cross section, 204
heat treatment cycles, 204, 206, 210
yield strength, 204, 207
Turbine rotors, 38, 83
martensitic 12% chromium steel, 97
Type 304 stainless steel, 6–7
ASTM compositional specifications, 151
modified
chemical composition, 153
corrosion test results, 156
potentiodynamic anodic polarization curves, 156–157
weldability, 164
see also Corrosion resistance, Type 304 stainless steel
Type 316 stainless steel, 6, 125
Type 316 LN stainless steel, weldability, 163–164

U
Underbead hardness, 195–196, 198
heat affected zone, 192
Uniaxial stress rupture
boron effect, 128–130, 132–133, 143–144
creep curves, 130
distribution of carbides and Laves, 135, 136
ductility, 130–131
MC precipitates, 135, 139
phase identification, 134–135, 137
phosphorus effect, 128–129, 132–133, 143–144
titanium stabilized austenitic stainless steel, 128–134, 143–145
creep cavitation, 134, 137
Unspecified elements, service experience related to, 5–8

V
Vacuum arc remelting, 202, 204, 206
Void swelling, 124–125

W
Weathering steel, 232
Weld, 169–191
charpy toughness, root and subsurface regions, 180, 184
CTOD scatter in values, 189–190
deposit hydrogen content, 195
deposit nitrogen contents, 186, 188
isolated regions of cleavage, 186-188
local initiation at large inclusion, 186-187
mechanical property, 179, 181-183
mechanical testing, 174-175
metallographic and fractographic examination, 175, 177-179
oxygen contents, 176-177
solidification cracking, 297
straight and reverse polarity, 177
strain aging, 188-189
toughness, 186, 188-190
transverse sections, 177-178
vertical-up, 179-180, 183
strain aging, 189
see also Butt weld
Weldability, 5, 266
Type 304 stainless steel, 164
Type 316 LN stainless steel, 163-164
see also Sulfur, weldability and
Welding
current supply, 170, 174, 244
equipment, 169
parameters, 195
procedure, 246, 248
vertical-up, 169
Welding electrodes, 170, 172-173, 244, 246
chemical analyses, 246-247
coating, 246, 249
handling characteristics, 248
oxygen levels, 252, 260
Weld metal, 169, 243
as-deposited, 177-178
charpy impact test, 239-240
embrittlement, 232-242
chemical composition of materials, 234
fracture appearance transition temperature, 234, 240
location of mechanical test specimens, 234
postweld stress relief heat treatment, 237
procedure, 233-234
serrated stress-strain behavior, 242
upper shelf energy test, 241
yield strength, 236, 238-239
reheated, main initiation point, 186-187
tensile test, 234-237
Weld pad, chemical analyses, 248, 250-251

X
X-70 line pipe steel, 285-300
as-rolled plates, mechanical properties, 290-292
Charpy V notch impact properties, as-rolled plates, 291-292
chemical composition, 286-287
economics, 286
fracture appearance transition temperature, 291
hardness, 293-294
lateral expansion transition temperature, 291
materials, 286-288
mechanical property tests, 288-289
metallographic and fractographic studies, 289
microstructure, 289-290
pass temperatures during rolling, 286, 288
phosphorus content, 297
segregation tendency of phosphorus, 296
shelf energy, 285
solidification cracking, 297
splitting tendency, CVN specimens, 292-293
sulfur content, 286
tensile properties, as-rolled plates, 290-291
tension tests, 288

Y
Yield strength
residual copper, 224
annealed, 224
PWHT/AC, 226-227
PWHT/FC, 224-226
tubesheet forgings, 204, 207
weld metal, embrittlement, 236, 238-239