

---

***Chapter 14***  
***Element Library***

---



# ANSYS Theory Reference

## Chapter 14 – Table of Contents

14.0	Introduction .....	14-1
14.1	LINK1 — 2-D Spar (or Truss) .....	14-3
14.1.1	Assumptions and Restrictions .....	14-3
14.1.2	Other Applicable Sections .....	14-3
14.2	PLANE2 — 2-D 6-Node Triangular Structural Solid .....	14-4
14.2.1	Other Applicable Sections .....	14-5
14.3	BEAM3 — 2-D Elastic Beam .....	14-6
14.3.1	Element Matrices and Load Vectors .....	14-7
14.3.2	Stress Calculations .....	14-9
14.4	BEAM4 — 3-D Elastic Beam .....	14-11
14.4.1	Stiffness and Mass Matrices .....	14-12
14.4.2	Gyroscopic Damping Matrix .....	14-15
14.4.3	Pressure and Temperature Load Vector .....	14-16
14.4.4	Local to Global Conversion .....	14-16
14.4.5	Stress Calculations .....	14-18
14.5	SOLID5 — 3-D Coupled Field Solid .....	14-20
14.5.1	Other Applicable Sections .....	14-21
14.6	This section intentionally omitted	
14.7	COMBIN7 — Revolute Joint .....	14-22
14.7.1	Element Description .....	14-22

14.8	LINK8 — 3–D Spar (or Truss) .....	14–29
14.8.1	Assumptions and Restrictions .....	14–29
14.8.2	Element Matrices and Load Vector .....	14–30
14.8.3	Force and Stress .....	14–32
14.9	INFIN9 — 2–D Infinite Boundary .....	14–34
14.9.1	Introduction .....	14–34
14.9.2	Theory .....	14–34
14.10	LINK10 — Tension Only or Compression–only Spar .....	14–38
14.10.1	Assumptions and Restrictions .....	14–38
14.10.2	Element Matrices and Load Vector .....	14–39
14.11	LINK11 — Linear Actuator .....	14–42
14.11.1	Assumptions and Restrictions .....	14–42
14.11.2	Element Matrices and Load Vector .....	14–42
14.11.3	Force, Stroke, and Length .....	14–44
14.12	CONTAC12 — 2–D Point–to–Point Contact .....	14–46
14.12.1	Element Matrices .....	14–46
14.12.2	Orientation of the Element .....	14–49
14.12.3	Rigid Coulomb Friction .....	14–49
14.13	PLANE13 — 2–D Coupled–Field Solid .....	14–50
14.13.1	Other Applicable Sections .....	14–52
14.14	COMBIN14 — Spring–Damper .....	14–53
14.14.1	Types of Input .....	14–53
14.14.2	Stiffness Pass .....	14–54
14.14.3	Output Quantities .....	14–55
14.15	This section intentionally omitted	
14.16	PIPE16 — Elastic Straight Pipe .....	14–57
14.16.1	Other Applicable Sections .....	14–58
14.16.2	Assumptions and Restrictions .....	14–58

14.16.3	Stiffness Matrix .....	14–58
14.16.4	Mass Matrix .....	14–59
14.16.5	Gyroscopic Damping Matrix .....	14–60
14.16.6	Stress Stiffness Matrix .....	14–61
14.16.7	Load Vector .....	14–61
14.16.8	Stress Calculation .....	14–63
14.17	PIPE17 — Elastic Pipe Tee .....	14–69
14.17.1	Other Applicable Sections .....	14–70
14.18	PIPE18 — Elastic Curved Pipe (Elbow) .....	14–71
14.18.1	Other Applicable Sections .....	14–72
14.18.2	Stiffness Matrix .....	14–72
14.18.3	Mass Matrix .....	14–75
14.18.4	Load Vector .....	14–75
14.18.5	Stress Calculations .....	14–76
14.19	This section intentionally omitted	
14.20	PIPE20 — Plastic Straight Pipe .....	14–77
14.20.1	Assumptions and Restrictions .....	14–78
14.20.2	Other Applicable Sections .....	14–78
14.20.3	Stress and Strain Calculation .....	14–78
14.21	MASS21 — Structural Mass .....	14–83
14.22	This section intentionally omitted	
14.23	BEAM23 — 2–D Plastic Beam .....	14–85
14.23.1	Other Applicable Sections .....	14–86
14.23.2	Integration Points .....	14–86
14.23.3	Tangent Stiffness Matrix for Plasticity .....	14–91
14.23.4	Newton–Raphson Load Vector .....	14–94
14.23.5	Stress and Strain Calculation .....	14–97

14.24	BEAM24 — 3-D Thin-Walled Beam .....	14-99
14.24.1	Assumptions and Restrictions .....	14-100
14.24.2	Other Applicable Sections .....	14-100
14.24.3	Temperature Distribution Across Cross-Section .....	14-101
14.24.4	Calculation of Cross-Section Section Properties .....	14-101
14.24.5	Offset Transformation .....	14-107
14.25	PLANE25 — 4-Node Axisymmetric-Harmonic Structural Solid .....	14-111
14.25.1	Other Applicable Sections .....	14-112
14.25.2	Assumptions and Restrictions .....	14-112
14.25.3	Use of Temperature .....	14-113
14.26	CONTAC26 — 2-D Point-to-Ground Contact .....	14-114
14.26.1	Operation of Element .....	14-114
14.26.2	Element Matrices .....	14-116
14.26.3	Stress Pass .....	14-117
14.27	MATRIX27 — Stiffness, Damping, or Mass Matrix .....	14-117
14.27.1	Assumptions and Restrictions .....	14-117
14.28	SHELL28 — Shear/Twist Panel .....	14-118
14.28.1	Assumptions and Restrictions .....	14-118
14.28.2	Commentary .....	14-119
14.28.3	Output Terms .....	14-119
14.29	FLUID29 — 2-D Acoustic Fluid .....	14-121
14.29.1	Other Applicable Sections .....	14-121
14.30	FLUID30 — 3-D Acoustic Fluid .....	14-122
14.30.1	Other Applicable Sections .....	14-122
14.31	LINK31 — Radiation Link .....	14-123
14.31.1	Standard Radiation (KEYOPT(3) = 0) .....	14-123
14.31.2	Empirical Radiation (KEYOPT(3) = 1) .....	14-124
14.31.3	Solution .....	14-124

14.32	LINK32 — 2–D Conduction Bar .....	14–126
14.32.1	Other Applicable Sections .....	14–126
14.32.2	Matrices and Load Vectors .....	14–126
14.33	LINK33 — 3–D Conduction Bar .....	14–127
14.33.1	Other Applicable Sections .....	14–127
14.33.2	Matrices and Load Vectors .....	14–127
14.33.3	Output .....	14–128
14.34	LINK34 — Convection Link .....	14–129
14.34.1	Conductivity Matrix .....	14–129
14.34.2	Output .....	14–130
14.35	PLANE35 — 2–D 6–Node Triangular Thermal Solid .....	14–131
14.35.1	Other Applicable Sections .....	14–131
14.36	SOURC36 — Current Source .....	14–132
14.36.1	Description .....	14–132
14.37	COMBIN37 — Control .....	14–133
14.37.1	Element Characteristics .....	14–133
14.37.2	Element Matrices .....	14–135
14.37.3	Adjustment of Real Constants .....	14–135
14.37.4	Evaluation of Control Parameter .....	14–136
14.38	FLUID38 — Dynamic Fluid Coupling .....	14–138
14.38.1	Description .....	14–139
14.38.2	Assumptions and Restrictions .....	14–139
14.38.3	Mass Matrix Formulation .....	14–139
14.38.4	Damping Matrix Formulation .....	14–140
14.39	COMBIN39 — Nonlinear Spring .....	14–142
14.39.1	Input .....	14–142
14.39.2	Element Stiffness Matrix and Load Vector .....	14–143
14.39.3	Choices for Element Behavior .....	14–144

14.40	COMBIN40 — Combination .....	14–148
14.40.1	Characteristics of the Element .....	14–148
14.40.2	Element Matrices for Structural Applications .....	14–149
14.40.3	Determination of F1 and F2 for Structural Applications .....	14–150
14.40.4	Thermal Analysis .....	14–151
14.41	SHELL41 — Membrane Shell .....	14–153
14.41.1	Assumptions and Restrictions .....	14–154
14.41.2	Wrinkle Option .....	14–155
14.42	PLANE42 — 2–D Structural Solid .....	14–156
14.42.1	Other Applicable Sections .....	14–157
14.43	SHELL43 — Plastic Shell .....	14–158
14.43.1	Other Applicable Sections .....	14–159
14.43.2	Assumptions and Restrictions .....	14–159
14.43.3	Assumed Displacement Shape Functions .....	14–160
14.43.4	Stress–Strain Relationships .....	14–160
14.43.5	In–Plane Rotational DOF .....	14–161
14.43.6	Spurious Mode Control with Allman Rotation .....	14–162
14.43.7	Natural Space Extra Shape Functions with Allman Rotation .	14–164
14.43.8	Warping .....	14–164
14.43.9	Stress Output .....	14–164
14.44	BEAM44 — 3–D Elastic Tapered Unsymmetrical Beam .....	14–165
14.44.1	Other Applicable Sections .....	14–166
14.44.2	Assumptions and Restrictions .....	14–166
14.44.3	Tapered Geometry .....	14–166
14.44.4	Shear Center Effects .....	14–167
14.44.5	Offset at the Ends of the Member .....	14–169
14.44.6	End Moment Release .....	14–171
14.44.7	Local to Global Conversion .....	14–172
14.44.8	Stress Calculations .....	14–172

14.45	SOLID45 — 3–D Structural Solid .....	14–174
14.45.1	Other Applicable Sections .....	14–175
14.46	SOLID46 — 3–D Layered Structural Solid .....	14–176
14.46.1	Other Applicable Sections .....	14–177
14.46.2	Assumptions and Restrictions .....	14–177
14.46.3	Stress–Strain Relationships .....	14–178
14.46.4	General Strain and Stress Calculations .....	14–181
14.46.5	Interlaminar Shear Stress Calculation .....	14–182
14.47	INFIN47 — 3–D Infinite Boundary .....	14–184
14.47.1	Introduction .....	14–185
14.47.2	Theory .....	14–185
14.48	CONTAC48 — 2–D Point–to–Surface Contact .....	14–191
14.48.1	Introduction .....	14–191
14.48.2	Contact Kinematics .....	14–191
14.48.3	Contact Forces .....	14–195
14.48.4	Stiffness Matrix and Load Vector .....	14–198
14.48.5	Thermal/Structural Contact .....	14–199
14.48.6	Description of Element Output Quantities .....	14–200
14.49	CONTAC49 — 3–D Point–to–Surface Contact .....	14–201
14.49.1	Introduction .....	14–201
14.49.2	Contact Kinematics .....	14–202
14.49.3	Contact Forces .....	14–204
14.49.4	Stiffness Matrix And Load Vector .....	14–208
14.49.5	Thermal/Structural Contact .....	14–209
14.49.6	Description Of Element Output Quantities .....	14–210
14.50	MATRIX50 — Superelement (or Substructure) .....	14–212
14.50.1	Other Applicable Sections .....	14–213
14.51	SHELL51 — Axisymmetric Structural Shell .....	14–214
14.51.1	Other Applicable Sections .....	14–215

14.51.2	Integration Point Locations for Nonlinear Material Effects . . .	14–215
14.51.3	Large Deflections . . . . .	14–215
14.52	CONTAC52 — 3–D Point–to–Point Contact . . . . .	14–216
14.52.1	Other Applicable Sections . . . . .	14–216
14.52.2	Element Matrices . . . . .	14–216
14.52.3	Orientation of Element . . . . .	14–217
14.53	PLANE53 — 2–D 8–Node Magnetic Solid . . . . .	14–218
14.53.1	Other Applicable Sections . . . . .	14–219
14.53.2	Assumptions and Restrictions . . . . .	14–219
14.53.3	The VOLT DOF in 2D and Axisymmetric Skin Effect Analysis	14–219
14.54	BEAM54 — 2–D Elastic Tapered Unsymmetric Beam . . . . .	14–221
14.54.1	Derivation of Matrices . . . . .	14–222
14.55	PLANE55 — 2–D Thermal Solid . . . . .	14–223
14.55.1	Other Applicable Sections . . . . .	14–223
14.55.2	Mass Transport Option . . . . .	14–224
14.56	HYPHER56 — 2–D 4–Node Mixed U–P Hyperelastic Solid . . . . .	14–226
14.56.1	Other Applicable Sections . . . . .	14–227
14.57	SHELL57 — Thermal Shell . . . . .	14–228
14.57.1	Other Applicable Sections . . . . .	14–228
14.58	HYPHER58 — 3–D 8–Node Mixed U–P Hyperelastic Solid . . . . .	14–229
14.58.1	Other Applicable Sections . . . . .	14–230
14.58.2	Mixed Hyperelastic Element Derivation . . . . .	14–230
14.58.3	Modified Strain Energy Density . . . . .	14–230
14.58.4	Finite Element Matrices . . . . .	14–230
14.58.5	Incompressibility . . . . .	14–232
14.58.6	Instabilities in the Material Constitutive Law . . . . .	14–232
14.58.7	Existence of Multiple Solutions . . . . .	14–233

14.59	PIPE59 — Immersed Pipe or Cable	14–234
14.59.1	Overview of the Element	14–235
14.59.2	Location of the Element	14–236
14.59.3	Stiffness Matrix	14–237
14.59.4	Mass Matrix	14–237
14.59.5	Load Vector	14–238
14.59.6	Stress Output	14–247
14.60	PIPE60 — Plastic Curved Pipe (Elbow)	14–249
14.60.1	Assumptions and Restrictions	14–250
14.60.2	Other Applicable Sections	14–250
14.60.3	Load Vector	14–250
14.60.4	Stress Calculations	14–253
14.61	SHELL61 — Axisymmetric–Harmonic Structural Shell	14–257
14.61.1	Other Applicable Sections	14–258
14.61.2	Assumptions and Restrictions	14–258
14.61.3	Stress, Force, and Moment Calculations	14–258
14.62	SOLID62 — 3–D Coupled Magnetic–Structural Solid	14–263
14.62.1	Other Applicable Sections	14–264
14.63	SHELL63 — Elastic Shell	14–265
14.63.1	Other Applicable Sections	14–267
14.63.2	Foundation Stiffness	14–267
14.63.3	In–Plane Rotational Stiffness	14–267
14.63.4	Warping	14–268
14.63.5	Options for Non–Uniform Material	14–269
14.63.6	Usage of ERESX Command	14–270
14.64	SOLID64 — 3–D Anisotropic Structural Solid	14–271
14.64.1	Other Applicable Sections	14–272
14.64.2	Stress–Strain Matrix	14–272

14.65	SOLID65 — 3-D Reinforced Concrete Solid .....	14-273
14.65.1	Assumptions and Restrictions .....	14-274
14.65.2	Description .....	14-274
14.65.3	Linear Behavior – General .....	14-274
14.65.4	Linear Behavior – Concrete .....	14-275
14.65.5	Linear Behavior – Reinforcement .....	14-275
14.65.6	Nonlinear Behavior – Concrete .....	14-278
14.65.7	Modeling of a Crack .....	14-278
14.65.8	Modeling of Crushing .....	14-282
14.65.9	Nonlinear Behavior – Reinforcement .....	14-283
14.66	This section intentionally omitted	
14.67	PLANE67 — 2-D Coupled Thermal–Electric Solid .....	14-284
14.67.1	Other Applicable Sections .....	14-284
14.68	LINK68 — Coupled Thermal–Electric Line .....	14-285
14.68.1	Other Applicable Sections .....	14-285
14.69	SOLID69 — 3-D Coupled Thermal–Electric Solid .....	14-286
14.69.1	Other Applicable Sections .....	14-286
14.70	SOLID70 — 3-D Thermal Solid .....	14-287
14.70.1	Other Applicable Sections .....	14-287
14.70.2	Fluid Flow in a Porous Medium .....	14-288
14.71	MASS71 — Thermal Mass .....	14-290
14.71.1	Specific Heat Matrix .....	14-290
14.71.2	Heat Generation Load Vector .....	14-290
14.72	SOLID72 — 4-Node Tetrahedral Structural Solid with Rotations .....	14-292
14.72.1	Other Applicable Sections .....	14-293
14.73	SOLID73 — 3-D 8-Node Structural Solid with Rotations .....	14-294
14.73.1	Other Applicable Sections .....	14-295

14.74	HYPER74 — 2-D 8-Node Mixed U-P Hyperelastic Solid .....	14-296
14.74.1	Other Applicable Sections .....	14-297
14.74.2	Assumptions and Restrictions .....	14-297
14.75	PLANE75 — Axisymmetric-Harmonic Thermal Solid .....	14-298
14.75.1	Other Applicable Sections .....	14-298
14.76	This section intentionally omitted	
14.77	PLANE77 — 2-D 8-Node Thermal Solid .....	14-299
14.77.1	Other Applicable Sections .....	14-299
14.77.2	Assumptions and Restrictions .....	14-300
14.78	PLANE78 — Axisymmetric-Harmonic 8-Node Thermal Solid .....	14-301
14.78.1	Other Applicable Sections .....	14-301
14.78.2	Assumptions and Restrictions .....	14-302
14.79	FLUID79 — 2-D Contained Fluid .....	14-303
14.79.1	Other Applicable Sections .....	14-304
14.80	FLUID80 — 3-D Contained Fluid .....	14-305
14.80.1	Other Applicable Sections .....	14-306
14.80.2	Assumptions and Restrictions .....	14-306
14.80.3	Material Properties .....	14-306
14.80.4	Free Surface Effects .....	14-307
14.80.5	Other Assumptions and Limitations .....	14-309
14.81	FLUID81 — Axisymmetric-Harmonic Contained Fluid .....	14-311
14.81.1	Other Applicable Sections .....	14-312
14.81.2	Assumptions and Restrictions .....	14-312
14.81.3	Load Vector Correction .....	14-312
14.82	PLANE82 — 2-D 8-Node Structural Solid .....	14-313
14.82.1	Other Applicable Sections .....	14-314
14.82.2	Assumptions and Restrictions .....	14-314

14.83	PLANE83 — 8–Node Axisymmetric–Harmonic Structural Solid . . . . .	14–315
14.83.1	Other Applicable Sections . . . . .	14–316
14.83.2	Assumptions and Restrictions . . . . .	14–316
14.84	HYPHER84 — 2–D 8–Node Hyperelastic Solid . . . . .	14–317
14.84.1	Assumptions and Restrictions . . . . .	14–318
14.84.2	Other Applicable Sections . . . . .	14–318
14.85	This section intentionally omitted	
14.86	HYPHER86 — 3–D 8–Node Hyperelastic Solid . . . . .	14–319
14.86.1	Other Applicable Sections . . . . .	14–320
14.86.2	Virtual Work Statement . . . . .	14–320
14.86.3	Element Matrix Derivation . . . . .	14–321
14.86.4	Reduced Integration on Volumetric Term in Stiffness Matrix .	14–322
14.86.5	Description of Additional Output Strain Measures . . . . .	14–324
14.87	SOLID87 — 3–D 10–Node Tetrahedral Thermal Solid . . . . .	14–326
14.87.1	Other Applicable Sections . . . . .	14–326
14.88	VISCO88 — 2–D 8–Node Viscoelastic Solid . . . . .	14–327
14.88.1	Other Applicable Sections . . . . .	14–328
14.89	VISCO89 — 20–Node Viscoelastic Solid . . . . .	14–329
14.89.1	Other Applicable Sections . . . . .	14–330
14.90	SOLID90 — 20–Node Thermal Solid . . . . .	14–331
14.90.1	Other Applicable Sections . . . . .	14–332
14.91	SHELL91 — Nonlinear Layered Structural Shell . . . . .	14–333
14.91.1	Other Applicable Sections . . . . .	14–334
14.91.2	Assumptions and Restrictions . . . . .	14–334
14.91.3	Stress–Strain Relationship . . . . .	14–335
14.91.4	Stress, Force and Moment Calculations . . . . .	14–335
14.91.5	Sandwich Option . . . . .	14–339

14.92	SOLID92 — 3-D 10-Node Tetrahedral Structural Solid .....	14-340
14.92.1	Other Applicable Sections .....	14-341
14.93	SHELL93 — 8-Node Structural Shell .....	14-342
14.93.1	Other Applicable Sections .....	14-343
14.93.2	Assumptions and Restrictions .....	14-343
14.93.3	Stress-Strain Relationships .....	14-344
14.93.4	Stress Output .....	14-344
14.94	This section intentionally omitted	
14.95	SOLID95 — 20-Node Structural Solid .....	14-345
14.95.1	Other Applicable Sections .....	14-346
14.96	SOLID96 — 3-D Magnetic Scalar Solid .....	14-347
14.96.1	Other Applicable Sections .....	14-347
14.97	SOLID97 — 3-D Magnetic Solid .....	14-348
14.97.1	Other Applicable Sections .....	14-349
14.98	SOLID98 — Tetrahedral Coupled-Field Solid .....	14-350
14.98.1	Other Applicable Sections .....	14-351
14.99	SHELL99 — Linear Layered Structural Shell .....	14-352
14.99.1	Other Applicable Sections .....	14-353
14.99.2	Assumptions and Restrictions .....	14-353
14.99.3	Direct Matrix Input .....	14-354
14.99.4	Stress Calculations .....	14-356
14.99.5	Force and Moment Summations .....	14-356
14.99.6	Shear Strain Adjustment .....	14-358
14.99.7	Interlaminar Shear Stress Calculations .....	14-358
14.99.8	Failure Criteria .....	14-361

14.100	This section intentionally omitted	
14.101	This section intentionally omitted	
14.102	This section intentionally omitted	
14.103	This section intentionally omitted	
14.104	This section intentionally omitted	
14.105	This section intentionally omitted	
14.106	VISCO106 — 2–D Viscoplastic Solid .....	14–365
	14.106.1 Other Applicable Sections .....	14–366
14.107	VISCO107 — 3–D Viscoplastic Solid .....	14–367
	14.107.1 Basic Assumptions .....	14–368
	14.107.2 Element Tangent Matrices and Newton–Raphson Restoring Force .....	14–368
	14.107.3 Plastic Energy Output .....	14–370
14.108	VISCO108 — 2–D 8–Node Viscoplastic Solid .....	14–371
	14.108.1 Other Applicable Sections .....	14–372
	14.108.2 Assumptions and Restrictions .....	14–372
14.109	This section intentionally omitted	
14.110	INFIN110 — 2–D Infinite Solid .....	14–373
	14.110.1 Mapping Functions .....	14–373
	14.110.2 Matrices .....	14–375
14.111	INFIN111 — 3–D Infinite Solid .....	14–378
	14.111.1 Other Applicable Sections .....	14–378

14.112	This section intentionally omitted	
14.113	This section intentionally omitted	
14.114	This section intentionally omitted	
14.115	INTER115 — 3-D Magnetic Interface .....	14-379
	14.115.1 Element Matrix Derivation .....	14-379
	14.115.2 The A, V-A-f Formulation .....	14-380
14.116	FLUID116 — Coupled Thermal-Fluid Pipe .....	14-386
	14.116.1 Assumptions and Restrictions .....	14-387
	14.116.2 Combined Equations .....	14-387
	14.116.3 Thermal Matrix Definitions .....	14-388
	14.116.4 Fluid Equations .....	14-391
14.117	SOLID117 — 3-D Magnetic Edge .....	14-394
	14.117.1 Other Applicable Sections .....	14-395
	14.117.2 Matrix formulation of low frequency edge element and tree gauging .....	14-395
14.118	This section intentionally omitted	
14.119	HF119 — 3-D High-Frequency Tetrahedral Solid .....	14-397
	14.119.1 Other Applicable Sections .....	14-397
	14.119.2 Solution Shape Functions – H (curl) Conforming Elements .	14-398
14.120	HF120 — High-Frequency Brick Solid .....	14-400
	14.120.1 Other Applicable Sections .....	14-401
	14.120.2 Solution Shape Functions – H(curl) Conforming Element ...	14-401
14.121	PLANE121 — 2-D 8-Node Electrostatic Solid .....	14-405
	14.121.1 Other Applicable Sections .....	14-405
	14.121.2 Assumptions and Restrictions .....	14-405
14.122	SOLID122 — 20-Node Electrostatic Solid .....	14-406
	14.122.1 Other Applicable Sections .....	14-406

14.123	SOLID123 — 3–D 10–Node Tetrahedral Electrostatic Solid .....	14–407
14.123.1	Other Applicable Sections .....	14–407
14.124	CIRCU124 — General Electric Circuit Element .....	14–408
14.124.1	Electric Circuit Elements .....	14–408
14.124.2	Electric Circuit Element Matrices .....	14–409
14.125	This section intentionally omitted	
14.126	TRANS126 — Electromechanical Transducer for MEMS .....	14–411
14.127	SOLID127 — Tet Electrostatic p–Element .....	14–415
14.127.1	Other Applicable Sections .....	14–415
14.128	SOLID128 — Brick Electrostatic p–Element .....	14–416
14.128.1	Other Applicable Sections .....	14–417
14.129	FLUID129 — 2–D Infinite Acoustic .....	14–418
14.129.1	Other Applicable Sections .....	14–418
14.130	FLUID130 — 3–D Infinite Acoustic .....	14–419
14.130–1	Mathematical Formulation and F.E. Discretization .....	14–419
14.130–2	Finite Element Discretization .....	14–421

14.131	This section intentionally omitted	
14.132	This section intentionally omitted	
14.133	This section intentionally omitted	
14.134	This section intentionally omitted	
14.135	This section intentionally omitted	
14.136	This section intentionally omitted	
14.137	This section intentionally omitted	
14.138	This section intentionally omitted	
14.139	This section intentionally omitted	
14.140	This section intentionally omitted	
14.141	FLUID141 — 2-D Fluid .....	14-425
	14.141.1 Other Applicable Sections .....	14-427
14.142	FLUID142 — 3-D Fluid .....	14-428
	14.142.1 Other Applicable Sections .....	14-430
	14.142.2 Distributed Resistance Main Diagonal Modification .....	14-430
	14.142.3 Turbulent Kinetic Energy Source Term Linearization .....	14-431
	14.142.4 Turbulent Kinetic Energy Dissipation Rate Source Term Linearization .....	14-432
14.143	SHELL143 — Plastic Shell .....	14-434
	14.143.1 Other Applicable Sections .....	14-435
	14.143.2 Assumptions and Restrictions .....	14-435
	14.143.3 Assumed Displacement Shape Functions .....	14-436
	14.143.4 Stress-Strain Relationships .....	14-436
	14.143.5 In-Plane Rotational DOF .....	14-436
	14.143.6 Spurious Mode Control with Allman Rotation .....	14-436

14.143.7	Natural Space Extra Shape Functions with Allman Rotation .	14-436
14.143.8	Warping .....	14-437
14.143.9	Consistent Tangent .....	14-437
14.143.10	Stress Output .....	14-437
14.144	This section intentionally omitted	
14.145	PLANE145 — 2-D Quadrilateral Structural Solid p-Element .....	14-438
14.145.1	Other Applicable Sections .....	14-439
14.146	PLANE146 — 2-D Triangular Structural Solid p-Element .....	14-440
14.146.1	Other Applicable Sections .....	14-441
14.147	SOLID147 — 3-D Brick Structural Solid p-Element .....	14-442
14.147.1	Other Applicable Sections .....	14-443
14.148	SOLID148 — 3-D Tetrahedral Structural Solid p-Element .....	14-444
14.148.1	Other Applicable Sections .....	14-445
14.149	This section intentionally omitted	
14.150	SHELL150 — 8-Node Structural Shell p-Element .....	14-446
14.150.1	Other Applicable Sections .....	14-447
14.150.2	Assumptions and Restrictions .....	14-447
14.150.3	Stress-Strain Relationships .....	14-448
14.151	SURF151 — 2-D Thermal Surface Effect .....	14-449
14.152	SURF152 — 3-D Thermal Surface Effect .....	14-450
14.152.1	Matrices and Load Vectors .....	14-451
14.152.2	Adiabatic Wall Temperature as Bulk Temperature .....	14-452
14.152.3	Radiation Form Factor Calculation .....	14-453

14.153	SURF153 — 2-D Structural Surface Effect .....	14-455
14.154	SURF154 — 3-D Structural Surface Effect .....	14-456
14.155	This section intentionally omitted	
14.156	This section intentionally omitted	
14.157	SHELL157 — Coupled Thermal-Electric Shell .....	14-460
	14.157.1 Other Applicable Sections .....	14-460
14.158	HYPER158 — 3-D 10-Node Tetrahedral Mixed U-P Hyperelastic Solid	14-461
	14.158.1 Other Applicable Sections .....	14-462
14.159	This section intentionally omitted	
14.160	LINK160 — Explicit 3-D Spar .....	14-463
14.161	BEAM161 — Explicit 3-D Beam .....	14-465
14.162	This section intentionally omitted	
14.163	SHELL163 — Explicit Thin Structural Shell .....	14-466
14.164	SOLID164 — Explicit 3-D Structural Solid .....	14-467
14.165	COMBI165 — Explicit Spring-Damper .....	14-468
14.166	MASS166 — Explicit 3-D Structural Mass .....	14-469
14.167	LINK167 — Explicit Tension-Only Spar .....	14-470
14.168	This section intentionally omitted	
14.169	TARGE169 — 2-D Target Segment .....	14-471
	14.169.1 Other Applicable Sections .....	14-471
	14.169.2 Segment Types .....	14-471

14.170	TARGE170 — 3-D Target Segment .....	14-472
14.170.1	Introduction .....	14-472
14.170.2	Segment Types .....	14-472
14.170.3	Reaction Forces .....	14-473
14.171	CONTA171 — 2-D Surface-to-Surface Contact .....	14-474
14.171.1	Other Applicable Sections .....	14-474
14.172	CONTA172 — 2-D 3-Node Surface-to-Surface Contact .....	14-475
14.172.1	Other Applicable Sections .....	14-475
14.173	CONTA173 — 3-D Surface-to-Surface Contact .....	14-476
14.173.1	Other Applicable Sections .....	14-476
14.174	CONTA174 — 3-D 8-Node Surface-to-Surface Contact .....	14-477
14.174.1	Introduction .....	14-477
14.174.2	Contact Kinematics .....	14-478
14.174.3	Frictional Model .....	14-480
14.174.4	Contact Algorithm .....	14-481
14.175	This section intentionally omitted	
14.176	This section intentionally omitted	
14.177	This section intentionally omitted	
14.178	This section intentionally omitted	
14.179	PRETS179 — Pre-tension .....	14-483
14.179.1	Introduction .....	14-483
14.179.2	Assumptions and Restrictions .....	14-483
14.180	LINK180 — 3-D Finite Strain Spar (or Truss) .....	14-484
14.180.1	Assumptions and Restrictions .....	14-485
14.180.2	Element Mass Matrix .....	14-485

14.181	SHELL181 — Large Strain Shell .....	14-487
14.181.1	Other Applicable Sections .....	14-488
14.181.2	Assumptions and Restrictions .....	14-488
14.181.3	Assumed Displacement Shape Functions .....	14-488
14.181.4	Warping .....	14-488
14.182	PLANE182 — 2-D Structural Solid .....	14-490
14.182.1	Other Applicable Sections .....	14-491
14.182.2	Theory .....	14-491
14.183	PLANE183 — 2-D 8-Node Structural Solid .....	14-492
14.183.1	Other Applicable Sections .....	14-493
14.183.2	Assumptions and Restrictions .....	14-493
14.184	This section intentionally omitted	
14.185	SOLID185 — 3-D Structural Solid .....	14-494
14.185.1	Other Applicable Sections .....	14-495
14.185.2	Theory .....	14-495
14.186	SOLID186 — 20-Node Structural Solid .....	14-496
14.186.1	Other Applicable Sections .....	14-497
14.187	SOLID187 — 3-D 10-Node Tetrahedral Structural Solid .....	14-498
14.187.1	Other Applicable Sections .....	14-499
14.188	BEAM188 — 3-D Finite Strain Linear Beam .....	14-500
14.189	BEAM189 — 3-D Finite Strain Quadratic Beam .....	14-502
14.189.1	Assumptions and Restrictions .....	14-503
14.189.2	Stress Evaluation .....	14-504

