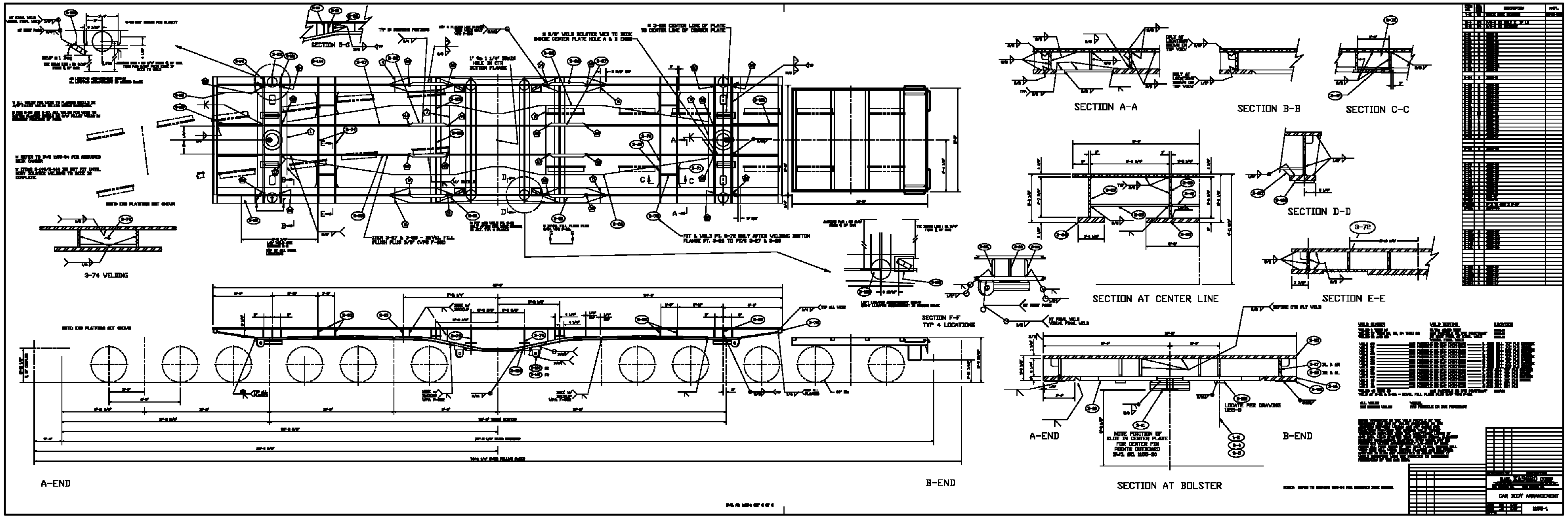
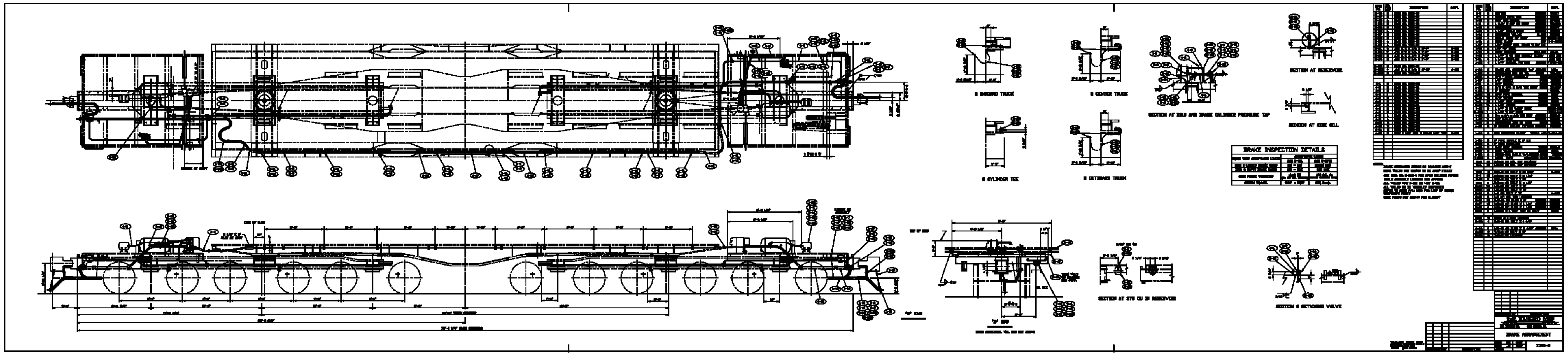
Appendix G – Preliminary Atlas Prototype Railcar Deliverables

APPENDIX G-1
ATLAS RAILCAR PRELIMINARY FABRICATION DRAWINGS

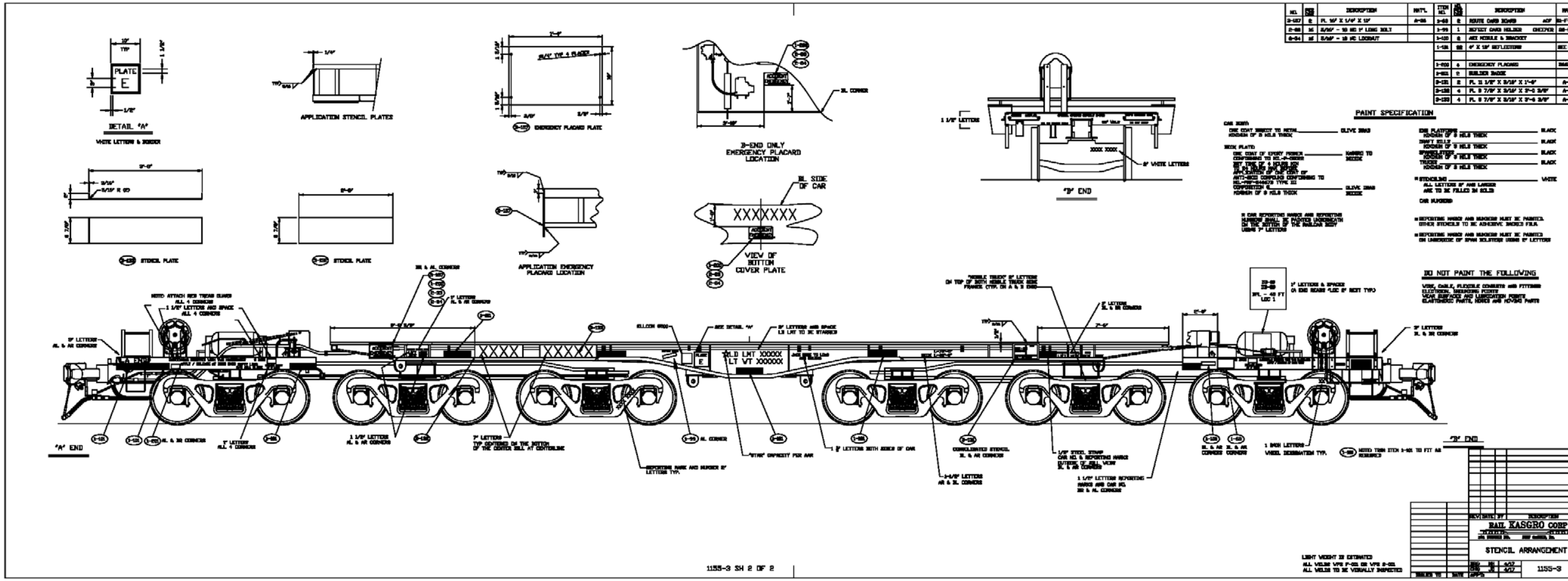
APPENDIX G-1.1 GENERAL ARRANGEMENT



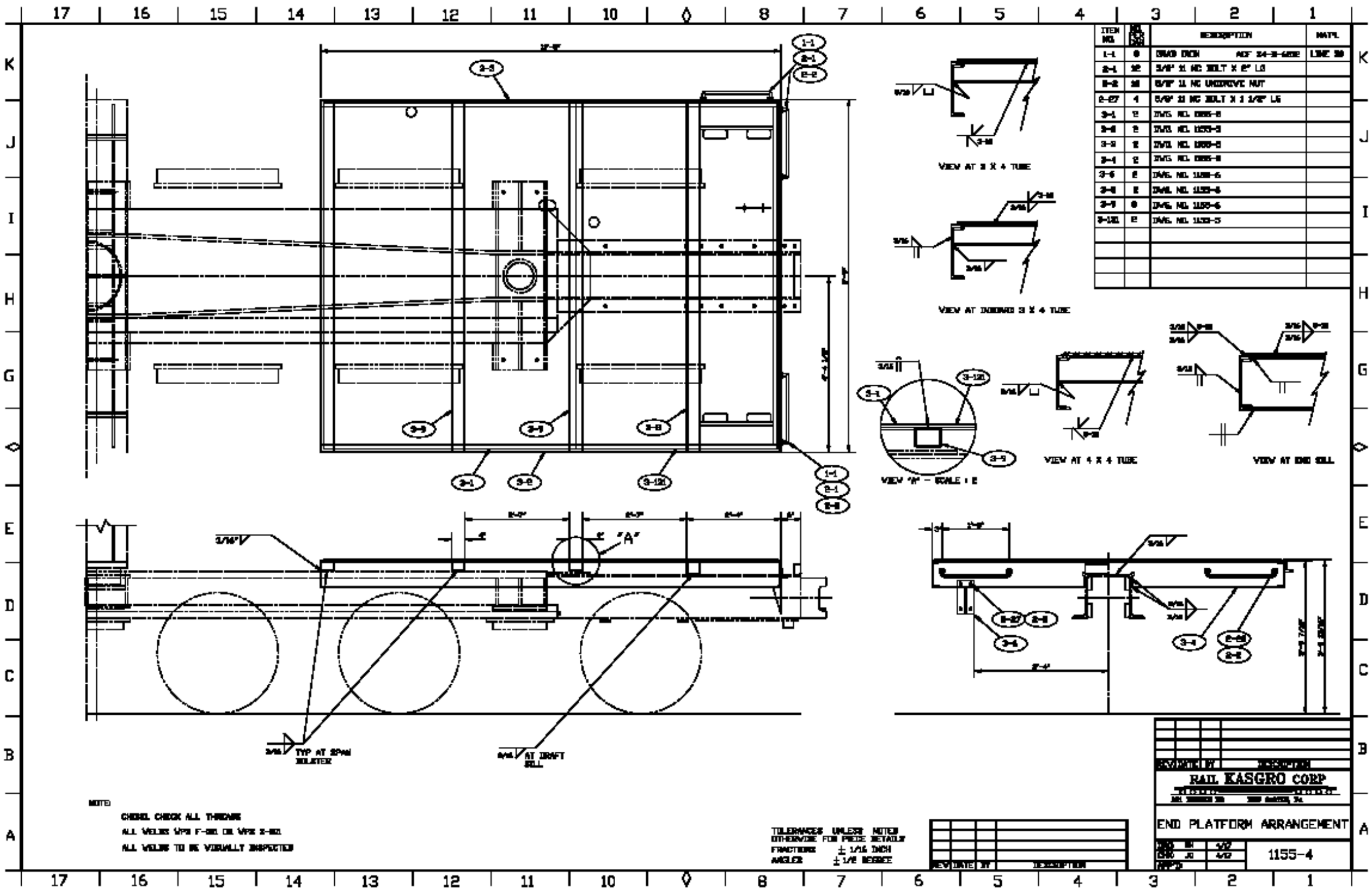
APPENDIX G-1.2 BRAKE ARRANGEMENT



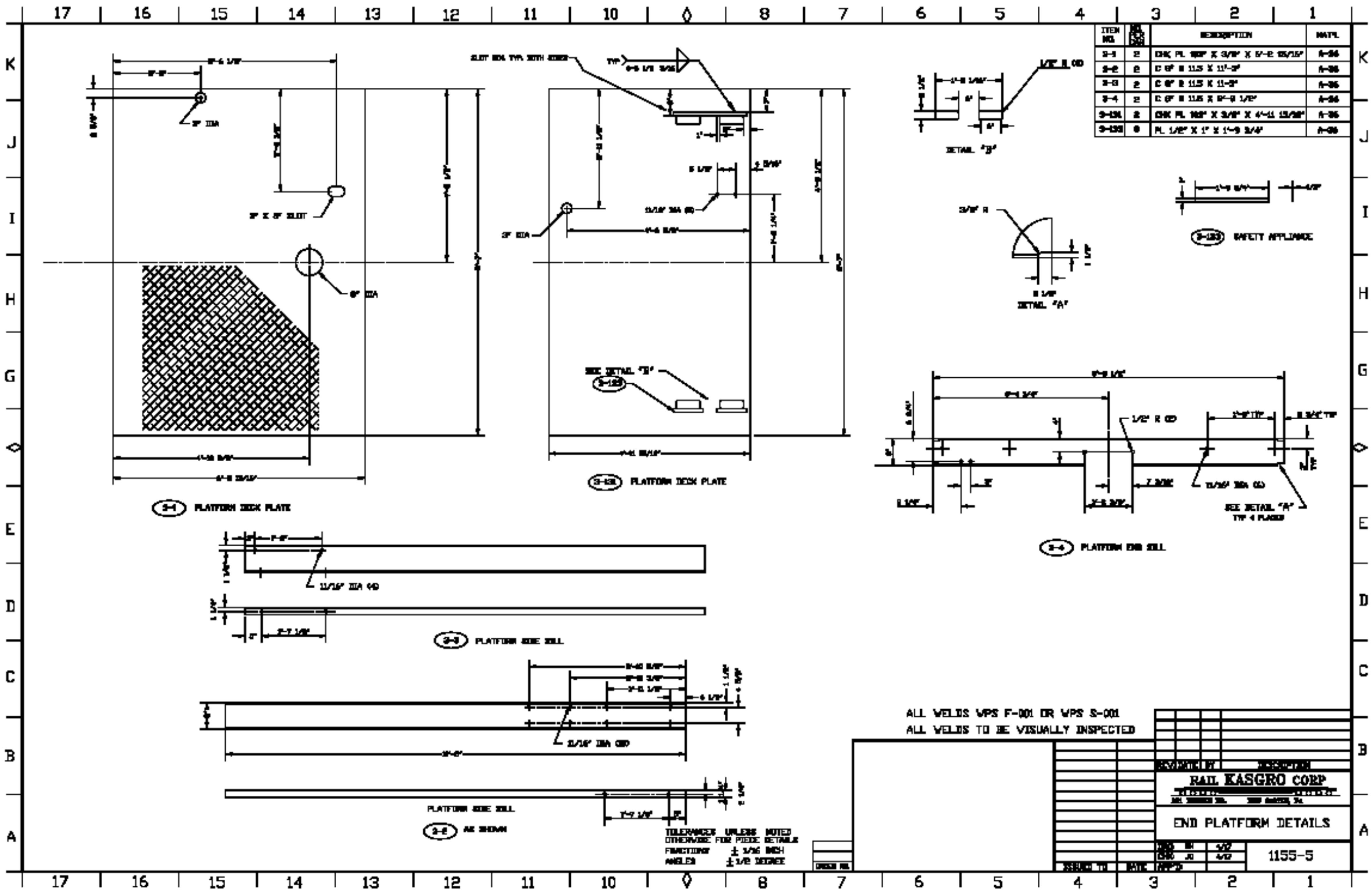
APPENDIX G-1.3 STENCIL ARRANGEMENT



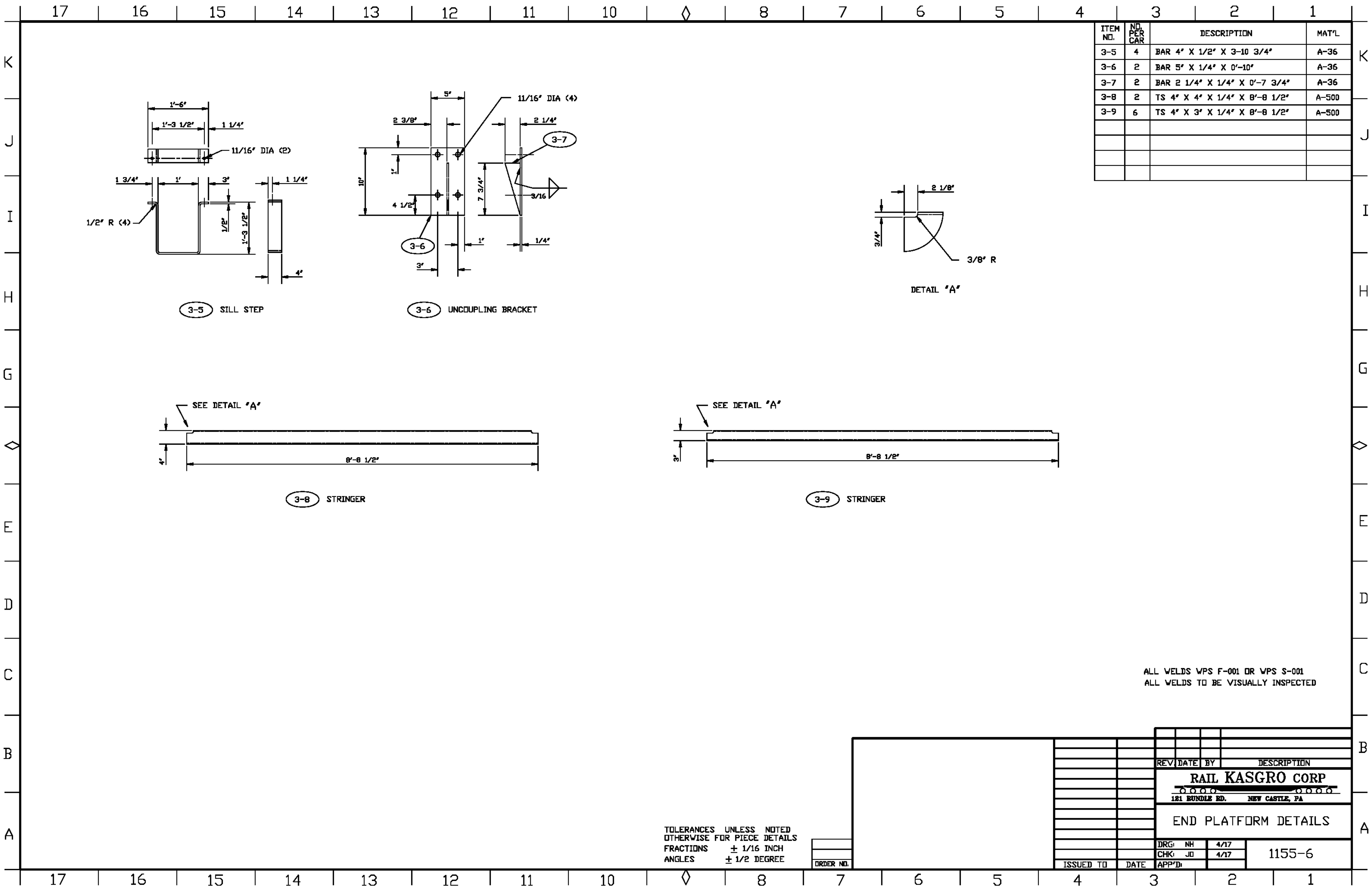
APPENDIX G-1.4 END PLATFORM ARRANGEMENT



APPENDIX G-1.5 END PLATFORM DETAILS

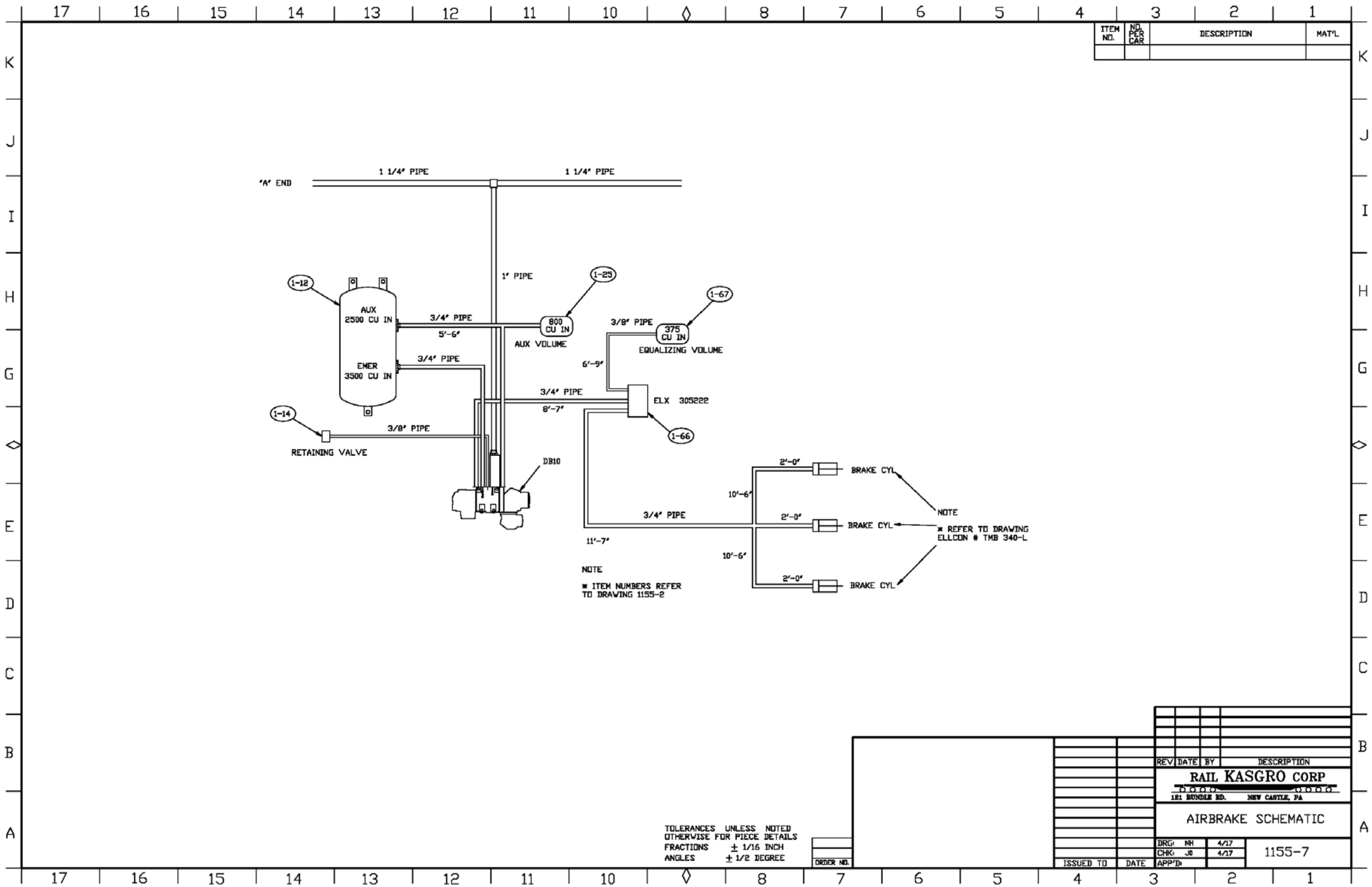


APPENDIX G-1.6 END PLATFORM DETAILS

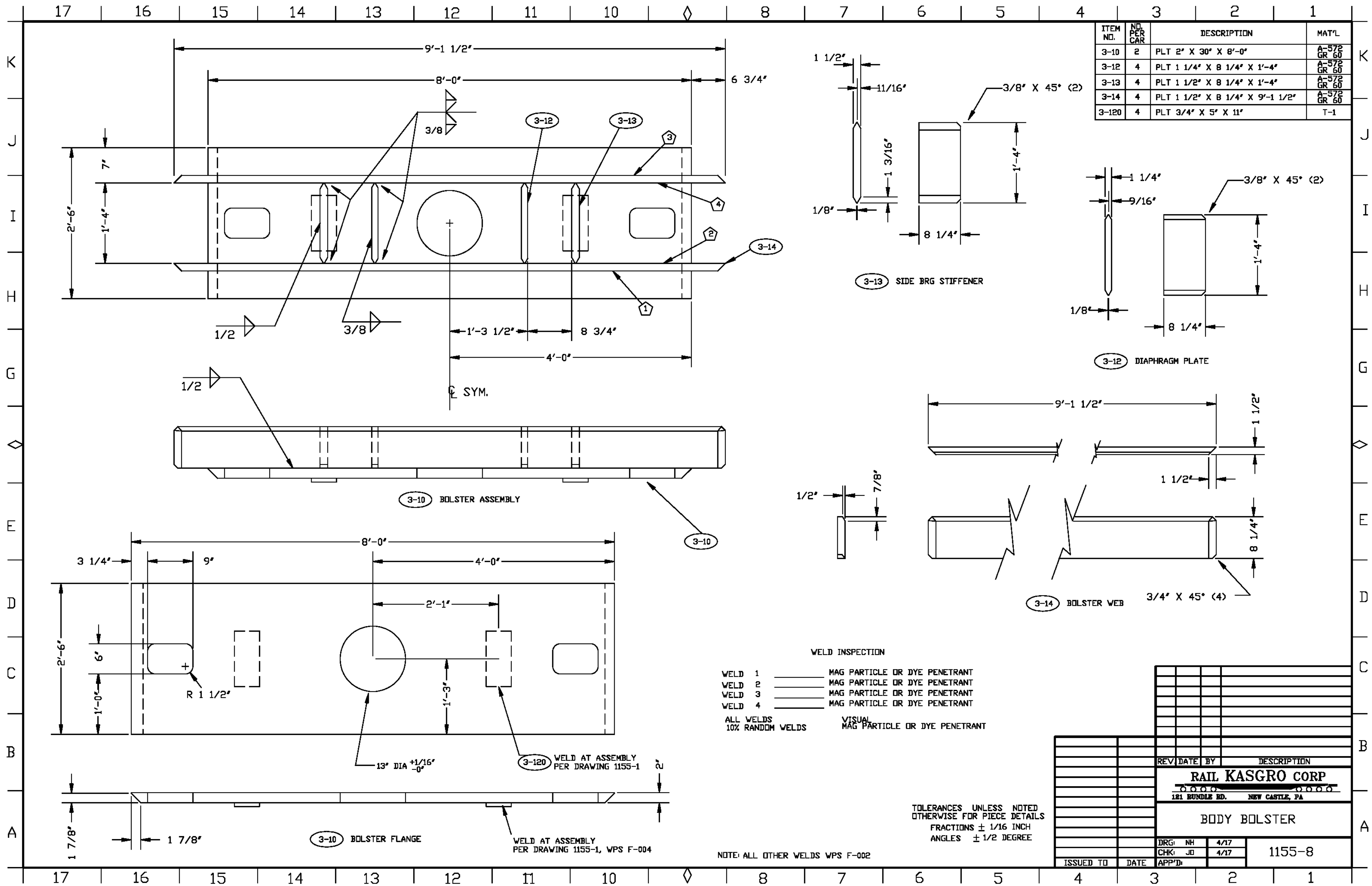


ITEM NO.	NO. PER CAR	DESCRIPTION	MAT'L
3-5	4	BAR 4" X 1/2" X 3-10 3/4"	A-36
3-6	2	BAR 5" X 1/4" X 0'-10"	A-36
3-7	2	BAR 2 1/4" X 1/4" X 0'-7 3/4"	A-36
3-8	2	TS 4" X 4" X 1/4" X 8'-8 1/2"	A-500
3-9	6	TS 4" X 3" X 1/4" X 8'-8 1/2"	A-500

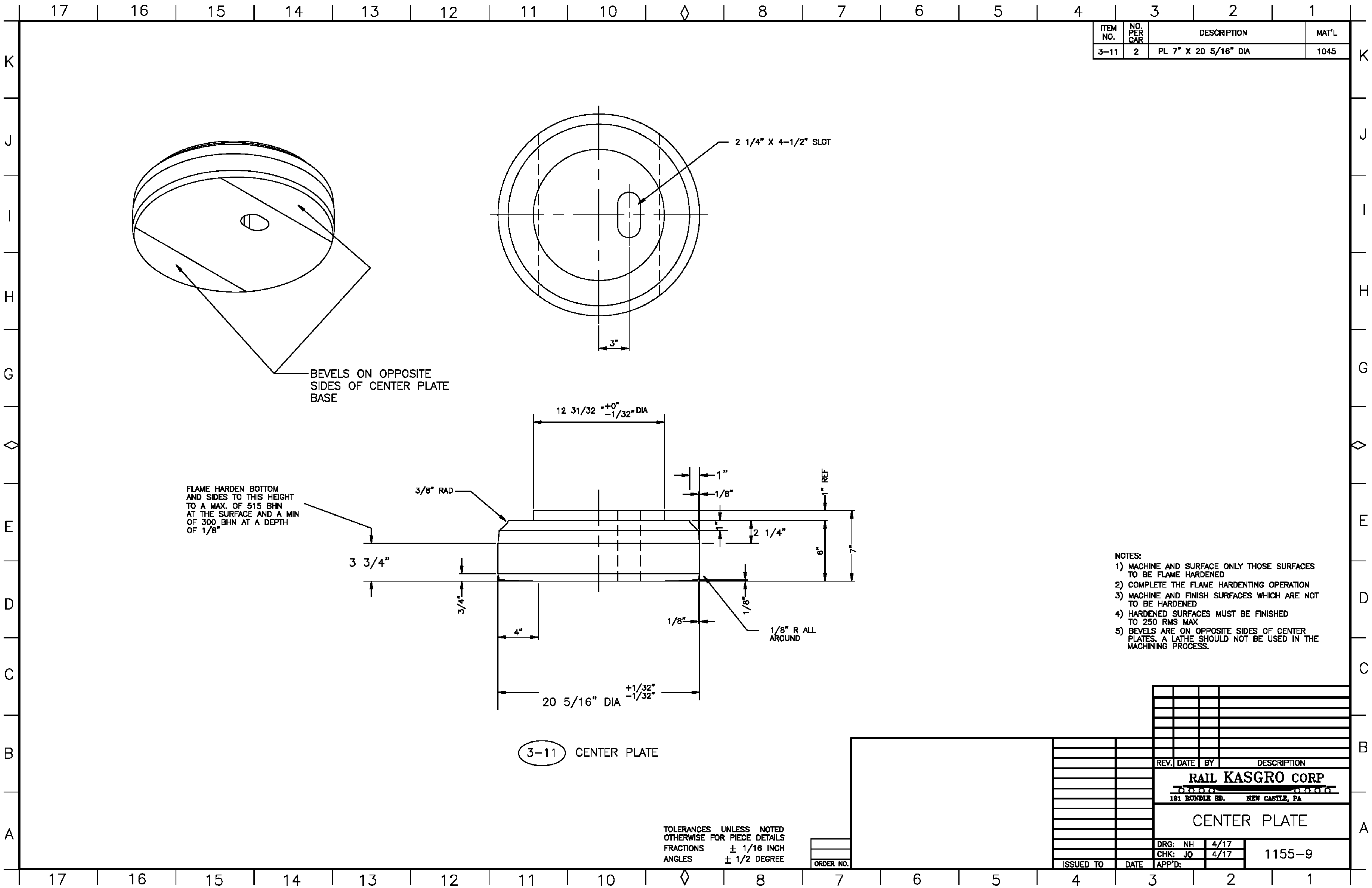
APPENDIX G-1.7 AIR BRAKE SCHEMATIC



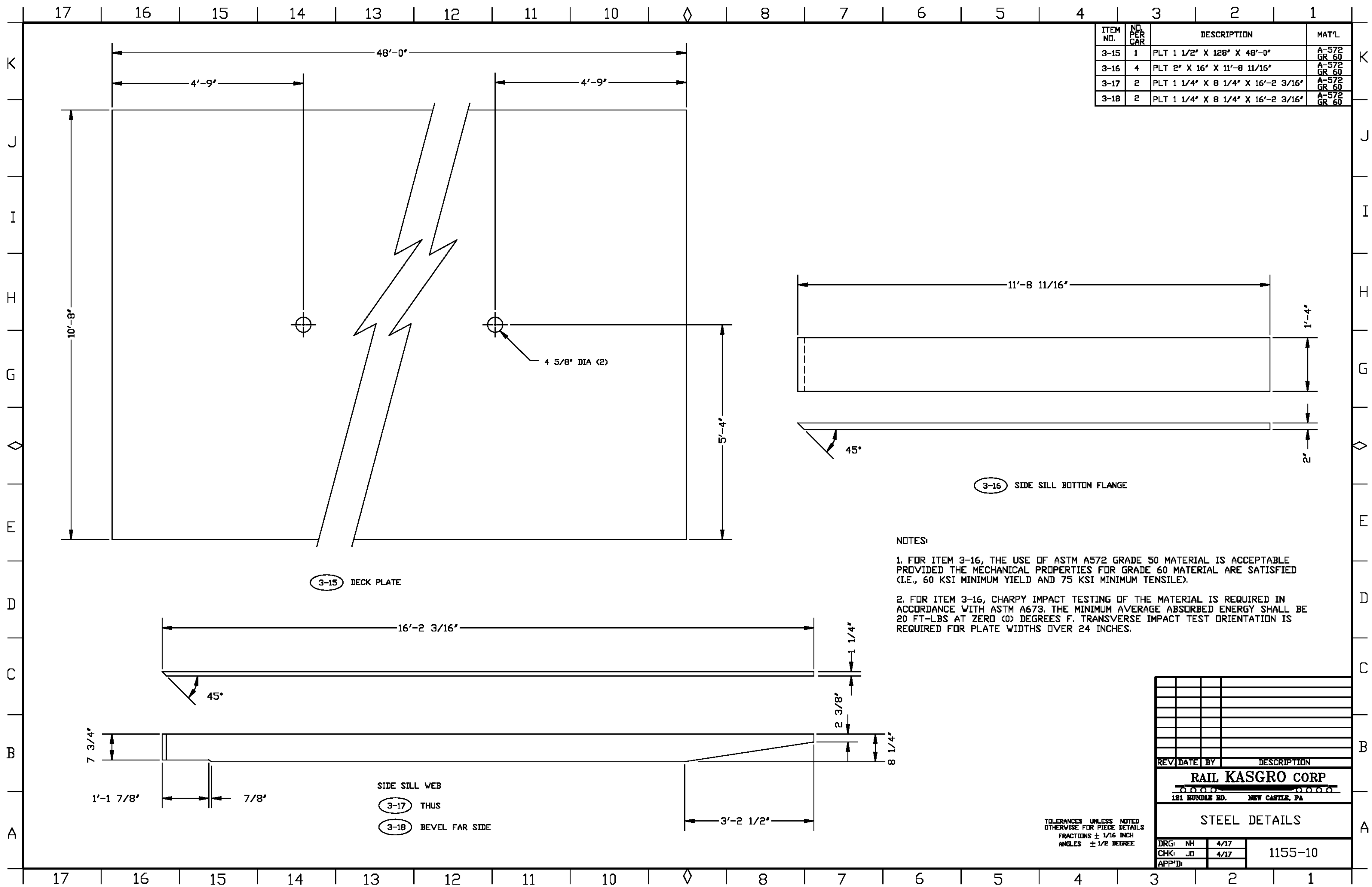
APPENDIX G-1.8 BODY BOLSTER



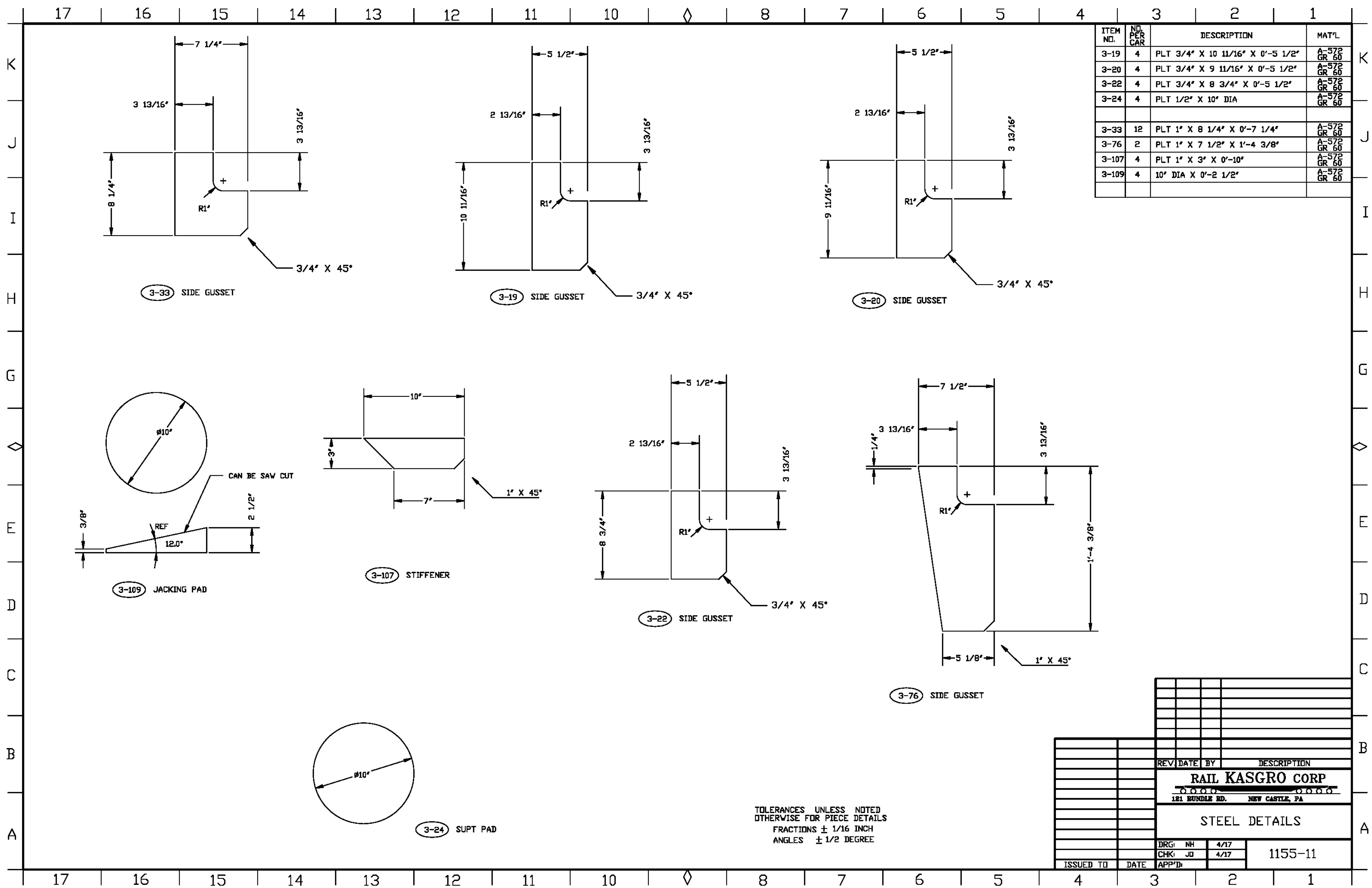
APPENDIX G-1.9 CENTER PLATE



APPENDIX G-1.10 STEEL DETAILS

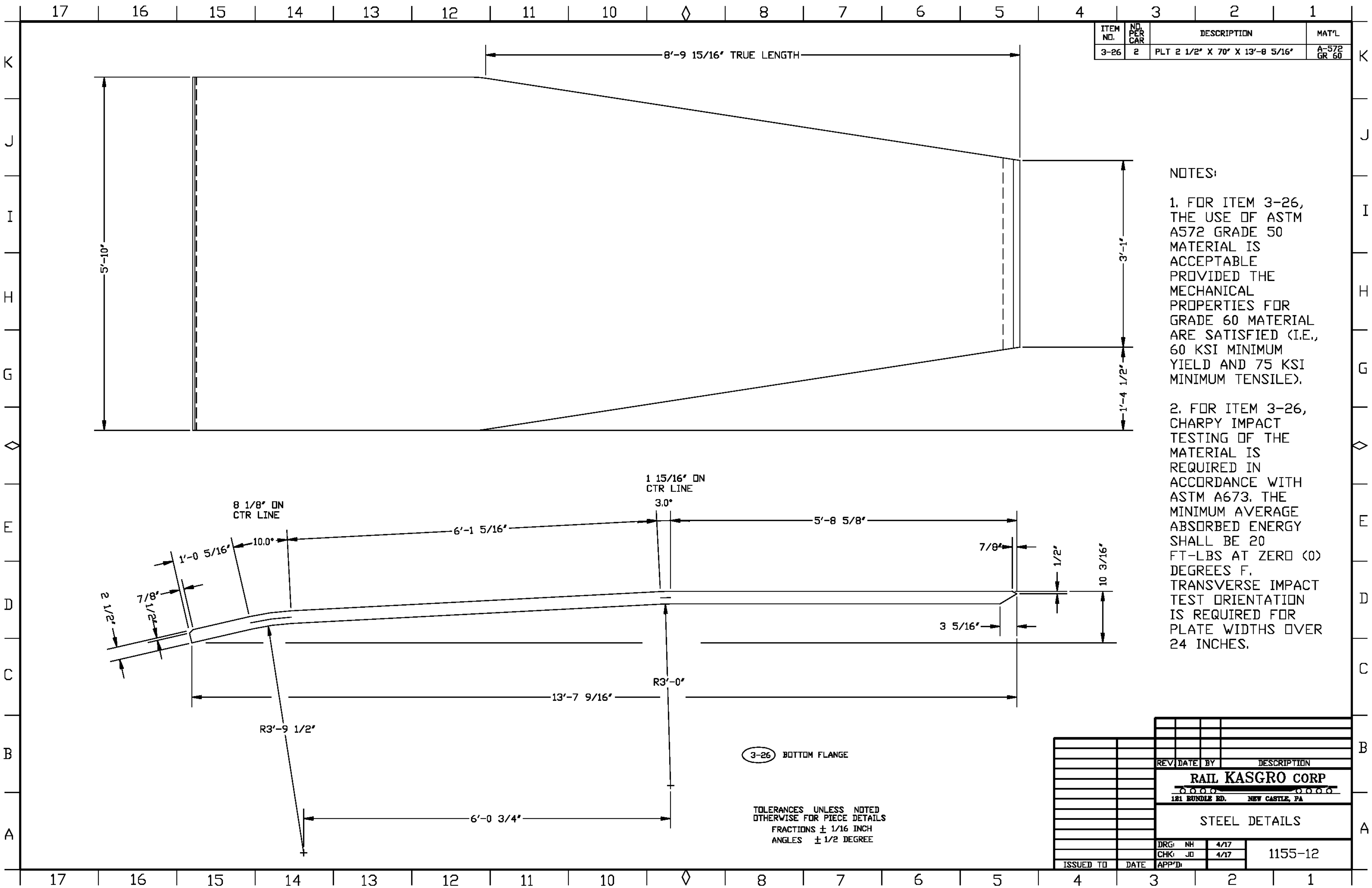


APPENDIX G-1.11 STEEL DETAILS

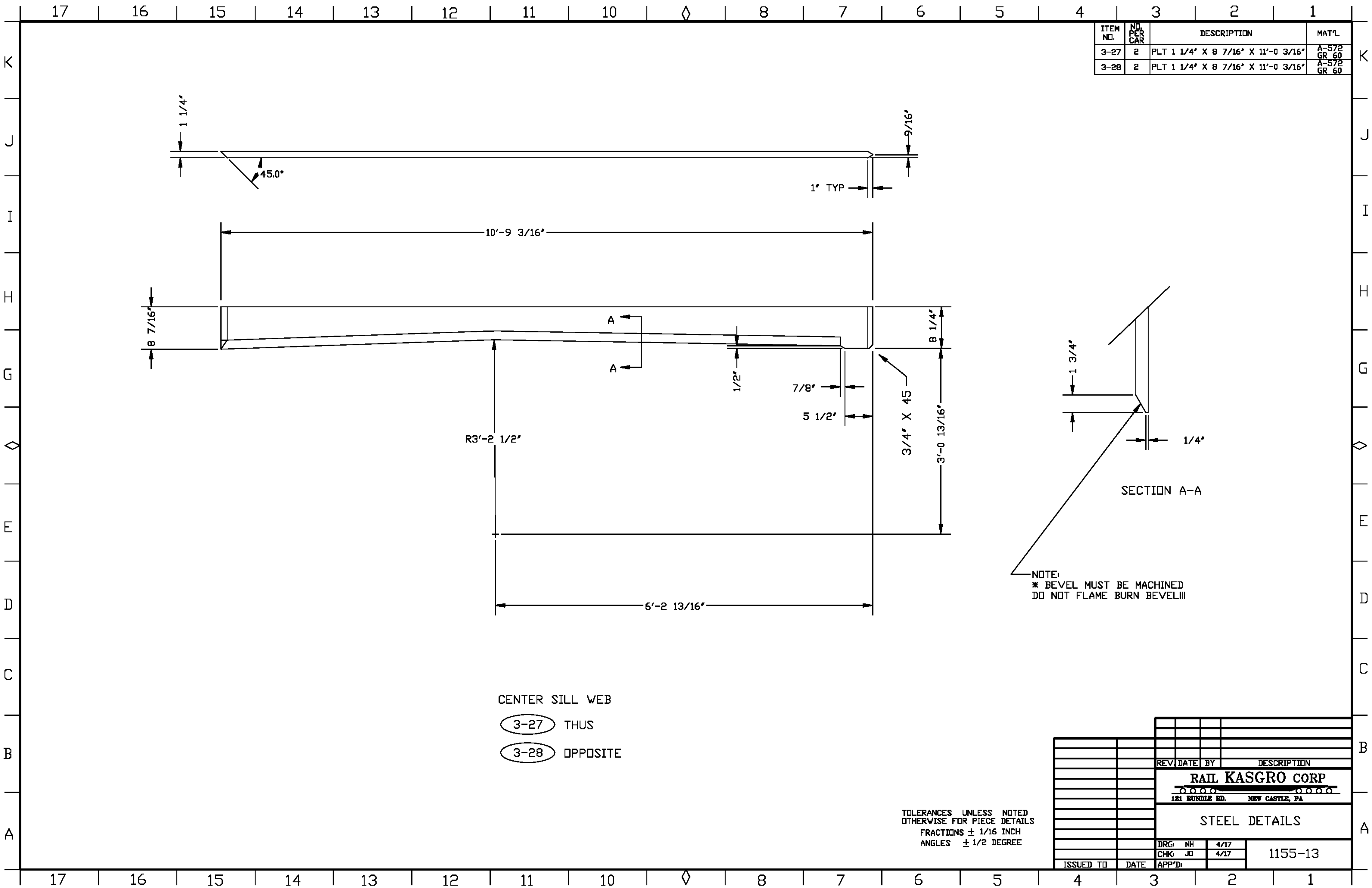


ITEM NO.	NO. PER CAR	DESCRIPTION	MAT'L
3-19	4	PLT 3/4" X 10 11/16" X 0'-5 1/2"	A-572 GR 60
3-20	4	PLT 3/4" X 9 11/16" X 0'-5 1/2"	A-572 GR 60
3-22	4	PLT 3/4" X 8 3/4" X 0'-5 1/2"	A-572 GR 60
3-24	4	PLT 1/2" X 10" DIA	A-572 GR 60
3-33	12	PLT 1" X 8 1/4" X 0'-7 1/4"	A-572 GR 60
3-76	2	PLT 1" X 7 1/2" X 1'-4 3/8"	A-572 GR 60
3-107	4	PLT 1" X 3" X 0'-10"	A-572 GR 60
3-109	4	10" DIA X 0'-2 1/2"	A-572 GR 60

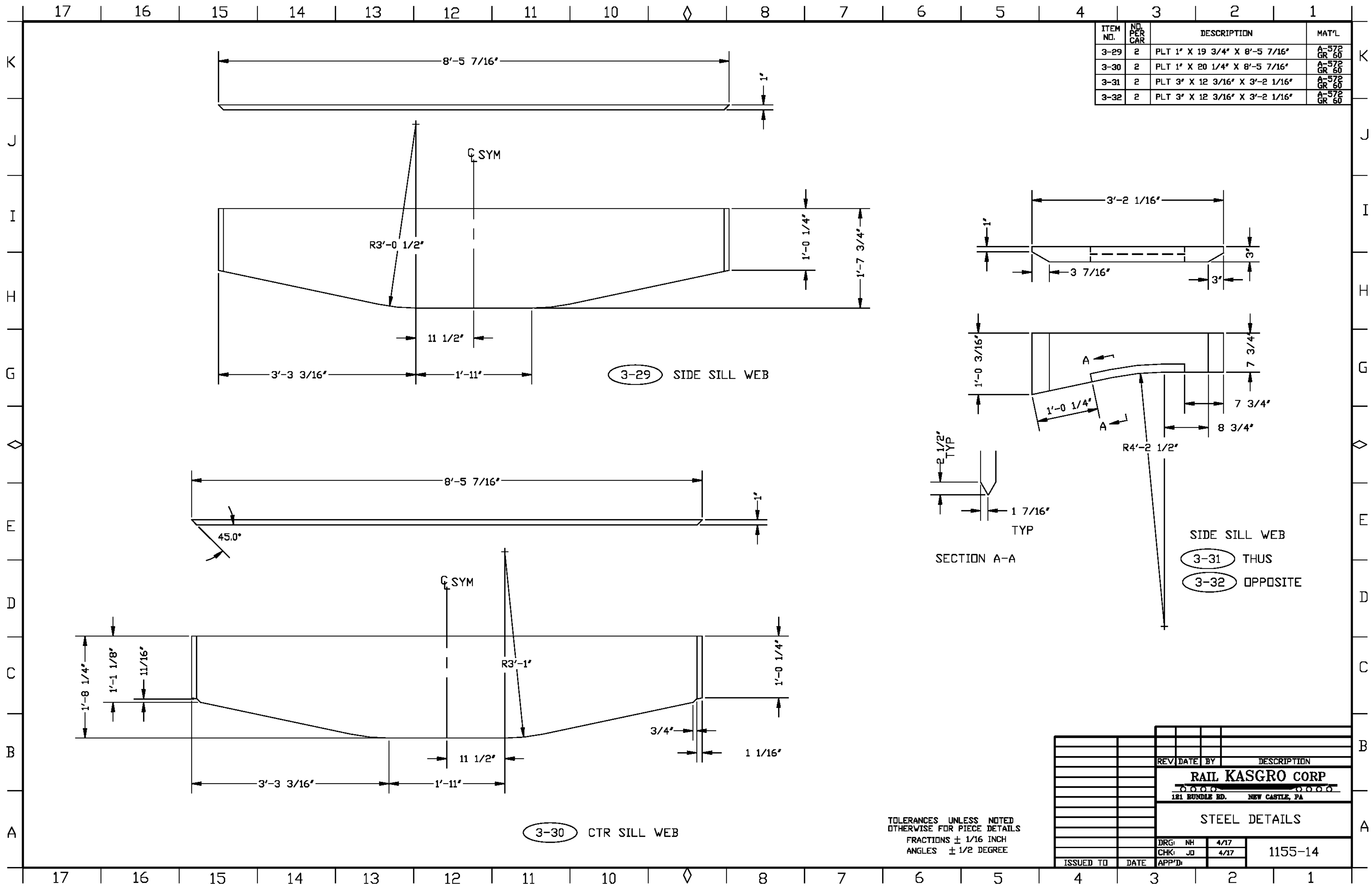
APPENDIX G-1.12 STEEL DETAILS



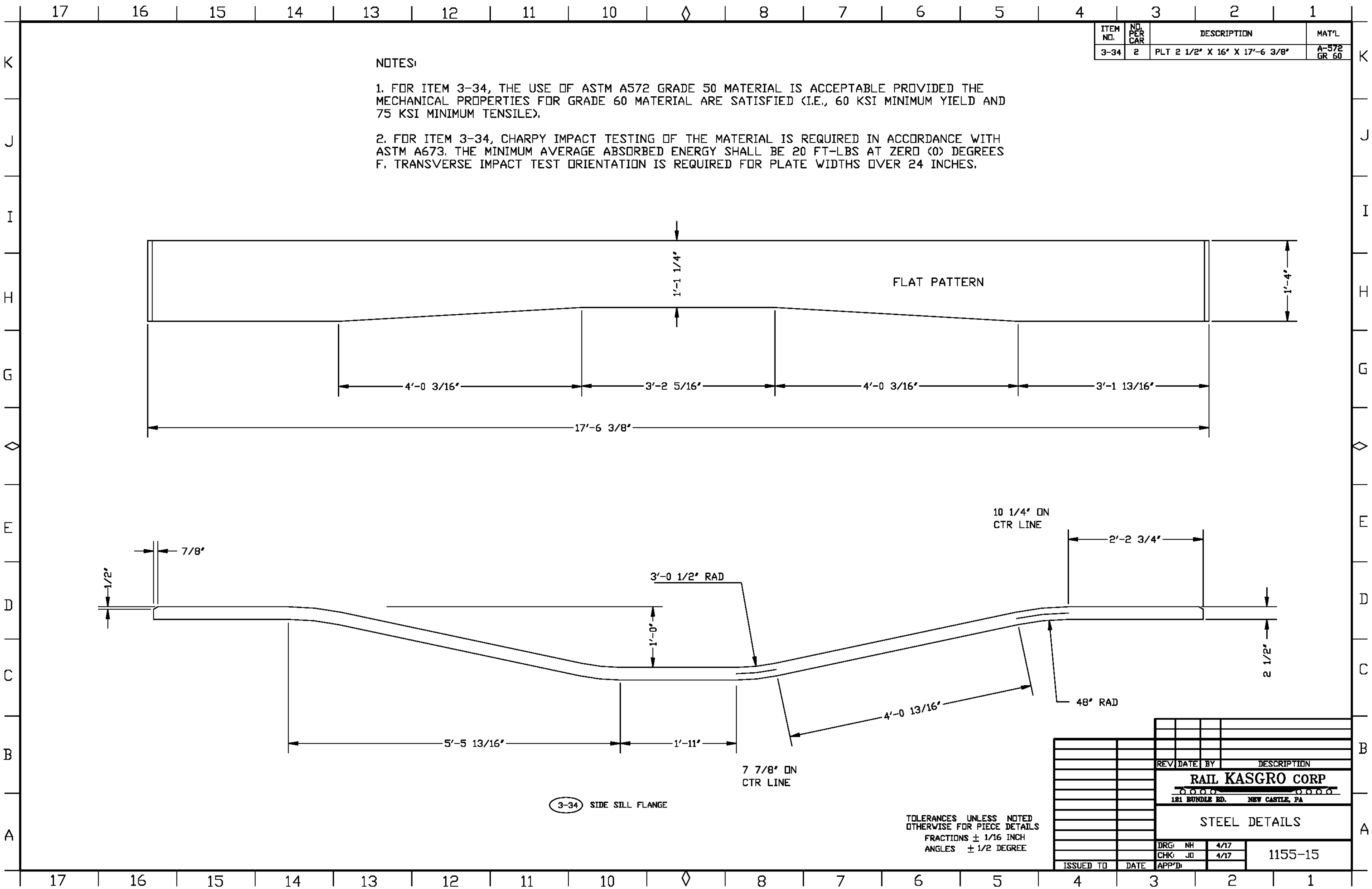
APPENDIX G-1.13 STEEL DETAILS



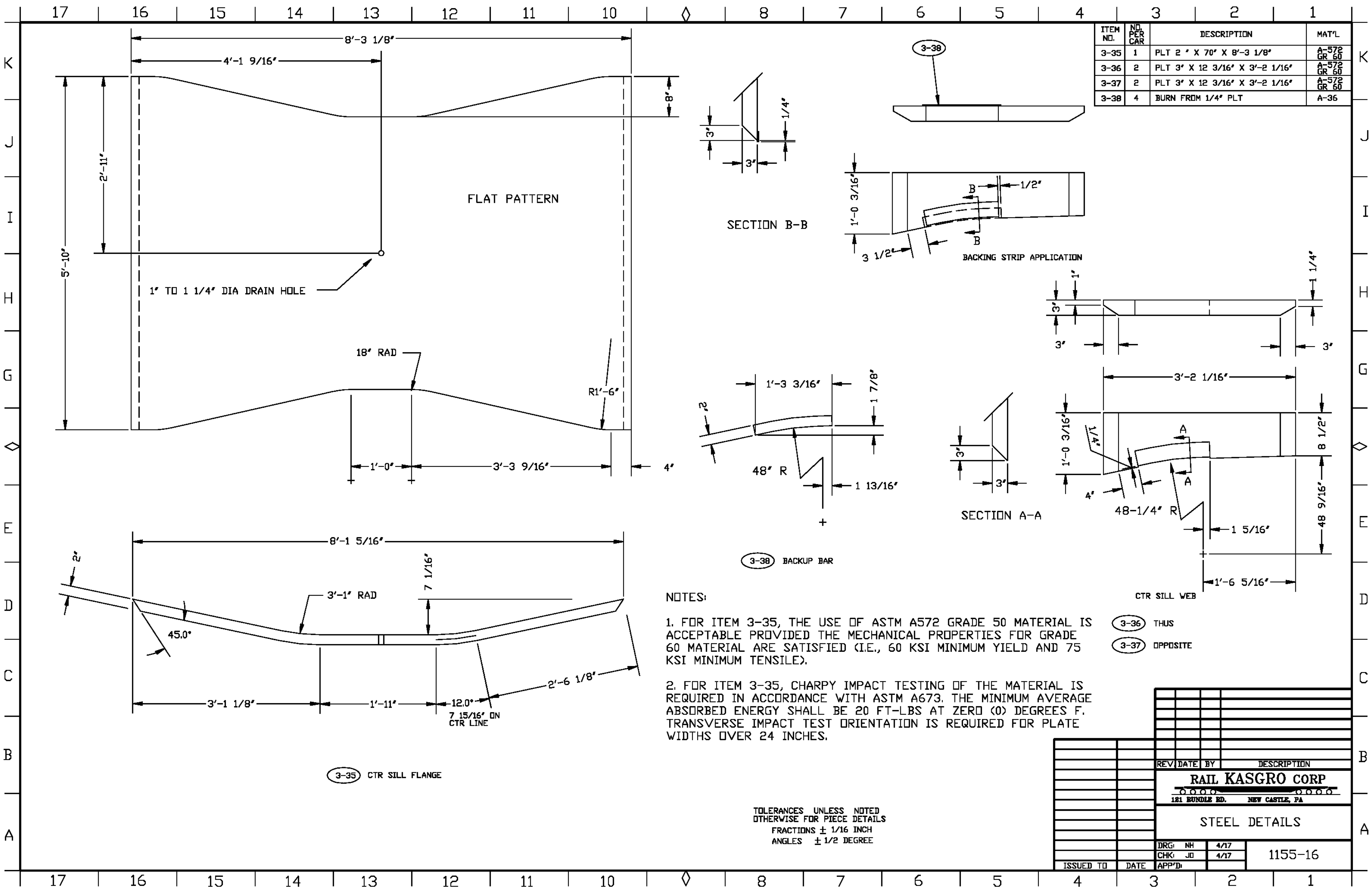
APPENDIX G-1.14 STEEL DETAILS



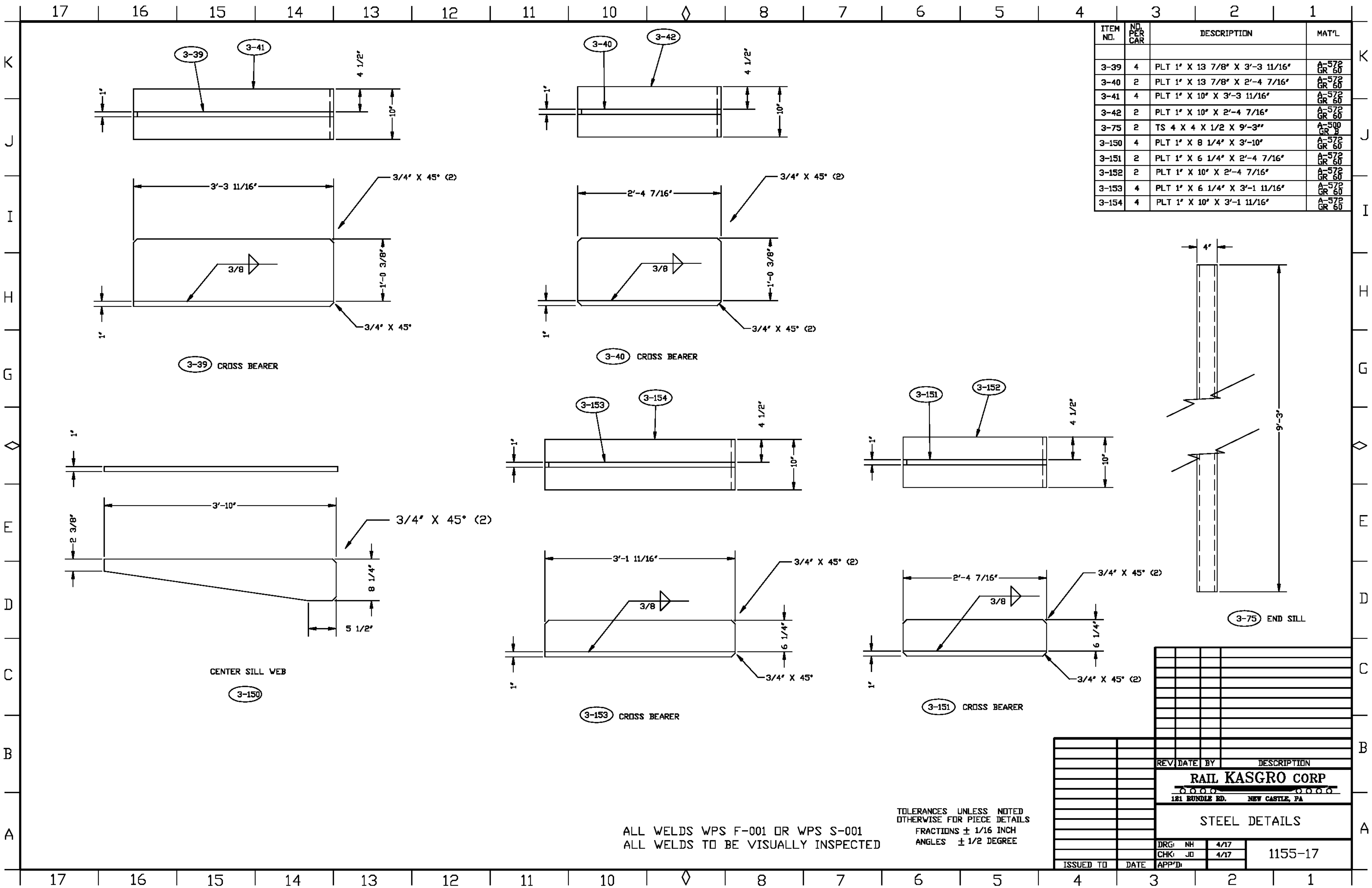
APPENDIX G-1.15 STEEL DETAILS



APPENDIX G-1.16 STEEL DETAILS

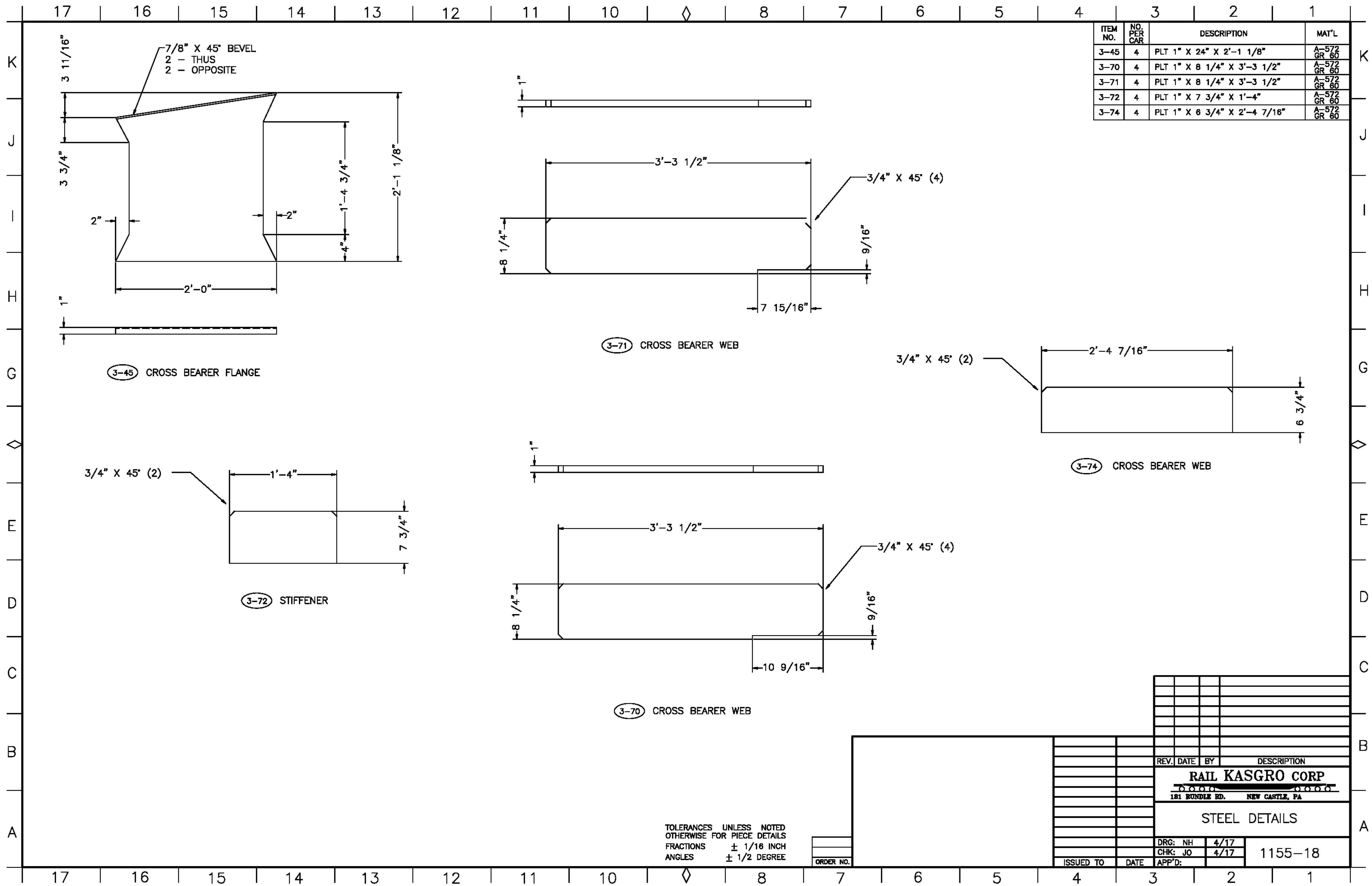


APPENDIX G-1.17 STEEL DETAILS



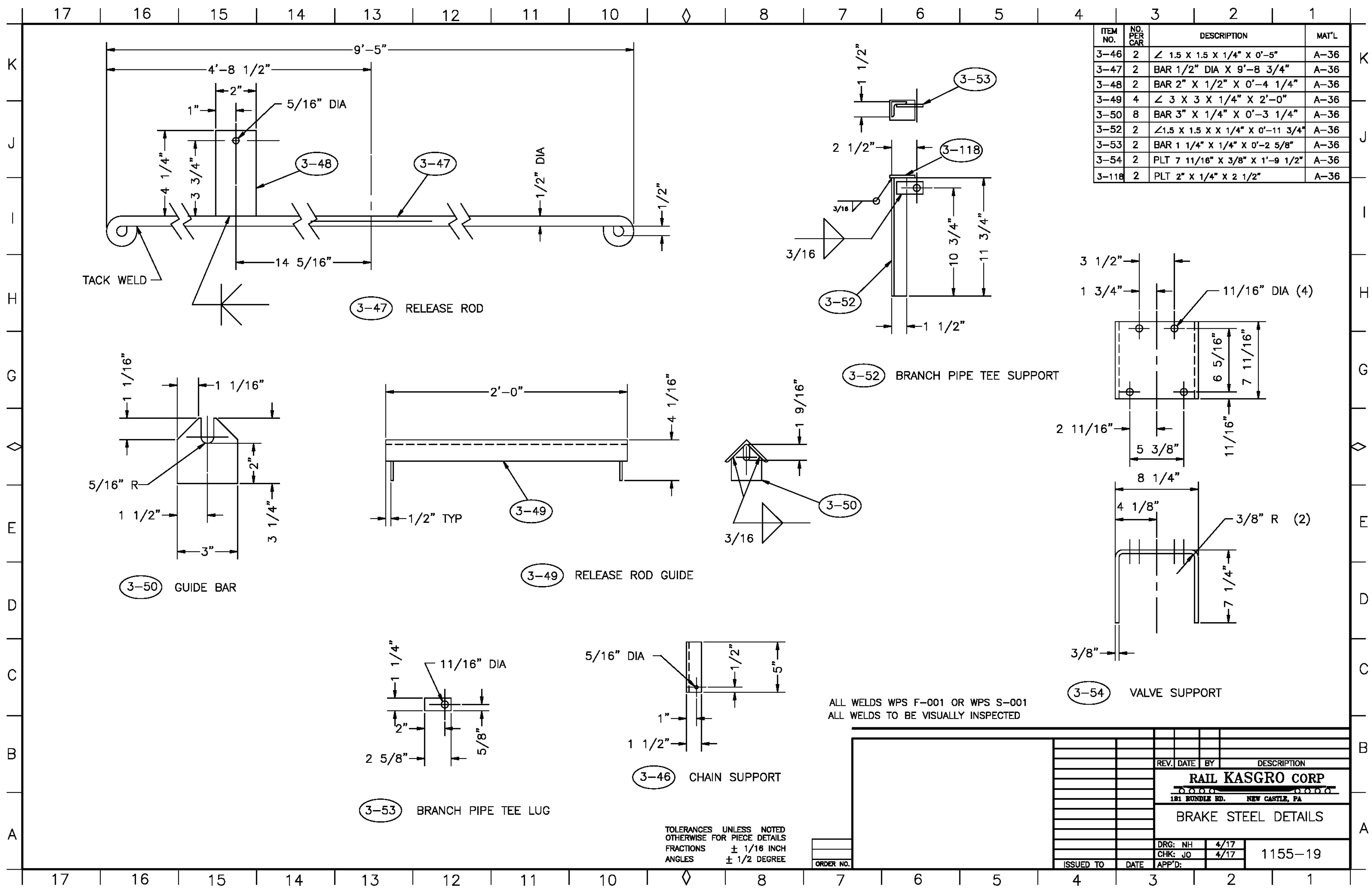
ITEM NO.	NO. PER CAR	DESCRIPTION	MAT'L
3-39	4	PLT 1" X 13 7/8" X 3'-3 11/16"	A-572 GR 60
3-40	2	PLT 1" X 13 7/8" X 2'-4 7/16"	A-572 GR 60
3-41	4	PLT 1" X 10" X 3'-3 11/16"	A-572 GR 60
3-42	2	PLT 1" X 10" X 2'-4 7/16"	A-572 GR 60
3-75	2	TS 4 X 4 X 1/2 X 9'-3""	A-500 GR B
3-150	4	PLT 1" X 8 1/4" X 3'-10"	A-572 GR 60
3-151	2	PLT 1" X 6 1/4" X 2'-4 7/16"	A-572 GR 60
3-152	2	PLT 1" X 10" X 2'-4 7/16"	A-572 GR 60
3-153	4	PLT 1" X 6 1/4" X 3'-1 11/16"	A-572 GR 60
3-154	4	PLT 1" X 10" X 3'-1 11/16"	A-572 GR 60

APPENDIX G-1.18 STEEL DETAILS



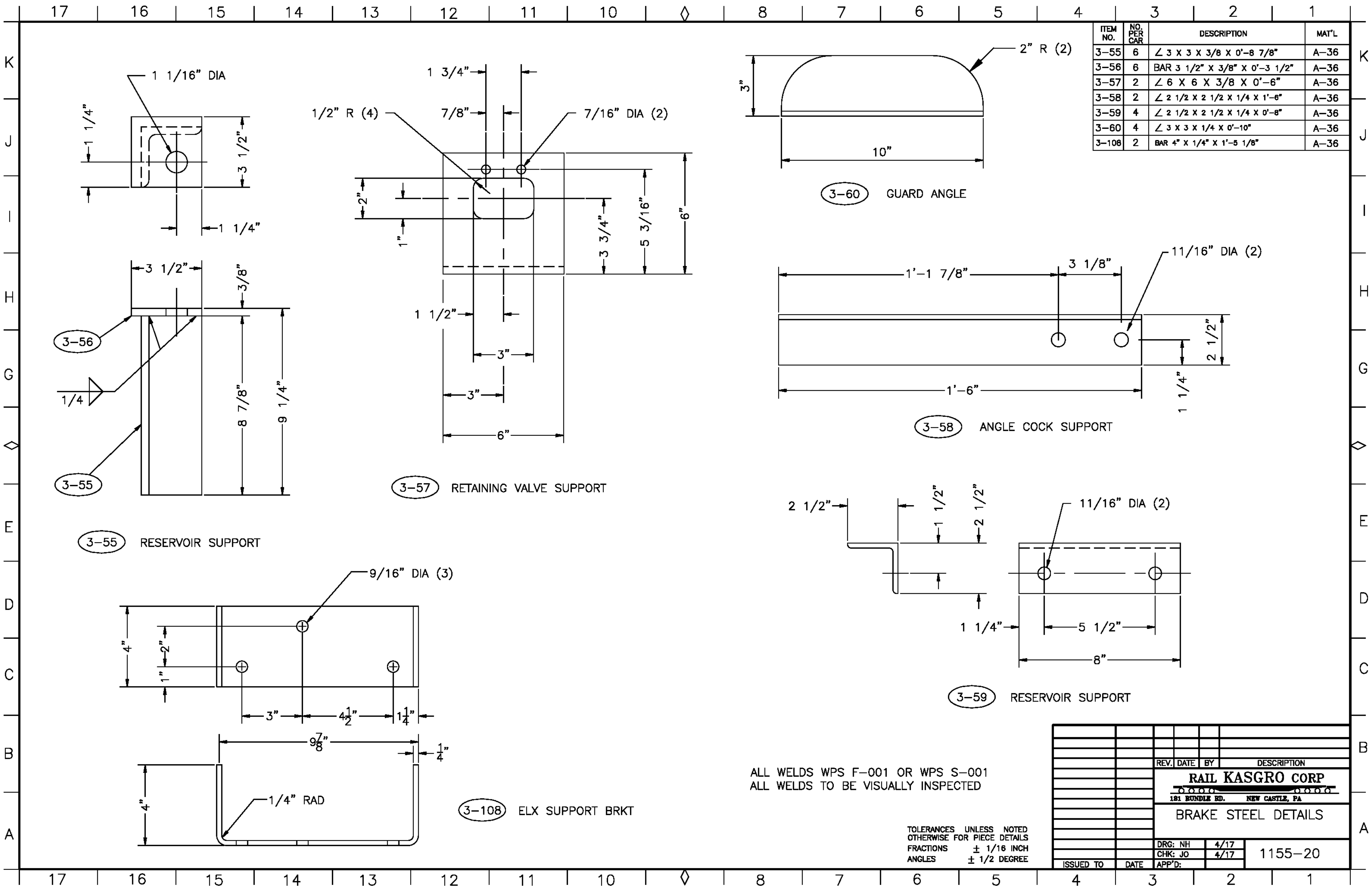
ITEM NO.	NO. PER CAR	DESCRIPTION	MAT'L
3-45	4	PLT 1" X 24" X 2'-1 1/8"	A-572 GR 60
3-70	4	PLT 1" X 8 1/4" X 3'-3 1/2"	A-572 GR 60
3-71	4	PLT 1" X 8 1/4" X 3'-3 1/2"	A-572 GR 60
3-72	4	PLT 1" X 7 3/4" X 1'-4"	A-572 GR 60
3-74	4	PLT 1" X 6 3/4" X 2'-4 7/16"	A-572 GR 60

APPENDIX G-1.19 BRAKE STEEL DETAILS



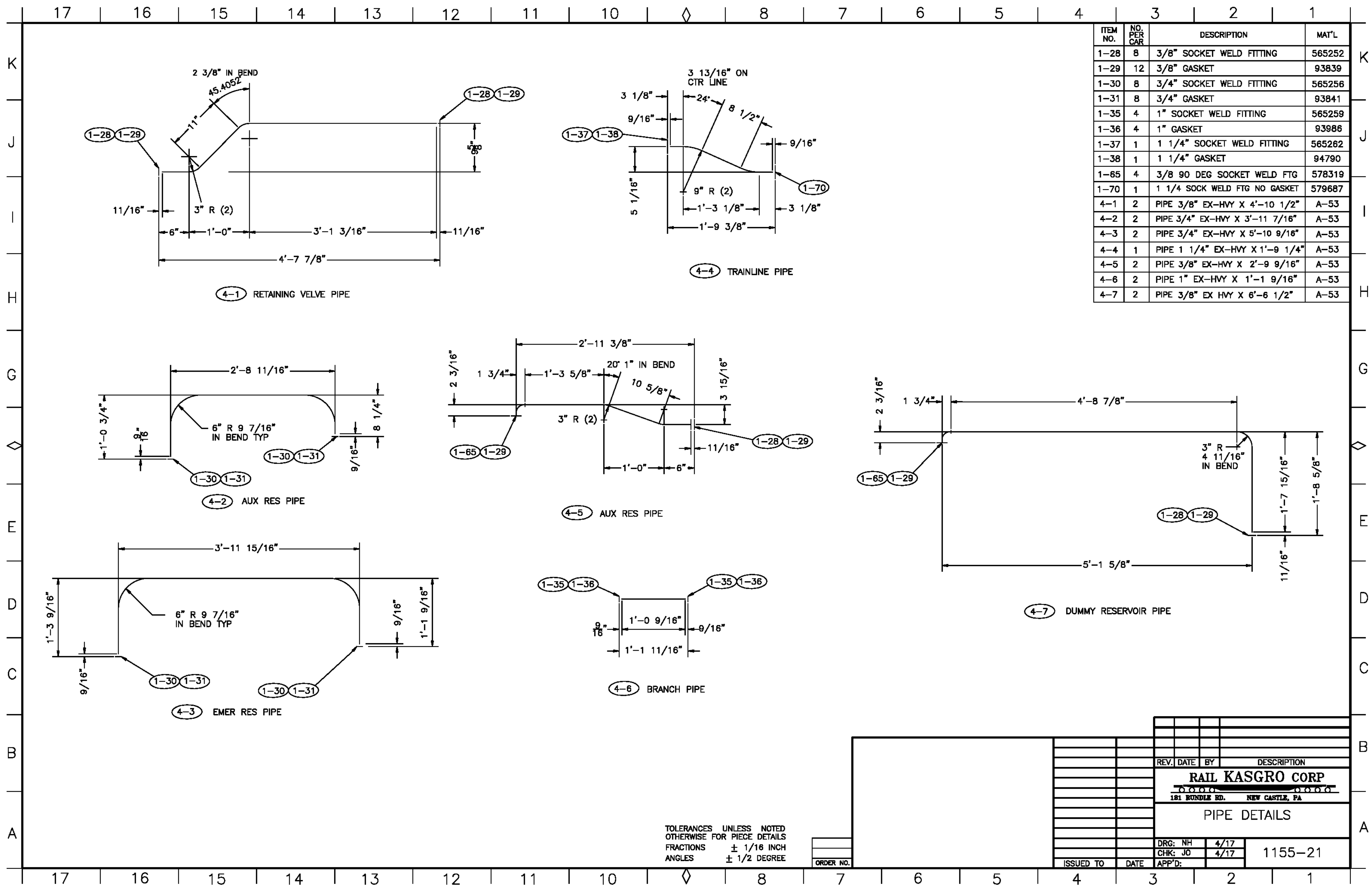
ITEM NO.	NO. PER CAR	DESCRIPTION	MAT'L
3-46	2	∠ 1.5 X 1.5 X 1/4" X 0'-5"	A-36
3-47	2	BAR 1/2" DIA X 9'-8 3/4"	A-36
3-48	2	BAR 2" X 1/2" X 0'-4 1/4"	A-36
3-49	4	∠ 3 X 3 X 1/4" X 2'-0"	A-36
3-50	8	BAR 3" X 1/4" X 0'-3 1/4"	A-36
3-52	2	∠1.5 X 1.5 X X 1/4" X 0'-11 3/4"	A-36
3-53	2	BAR 1 1/4" X 1/4" X 0'-2 5/8"	A-36
3-54	2	PLT 7 11/16" X 3/8" X 1'-9 1/2"	A-36
3-118	2	PLT 2" X 1/4" X 2 1/2"	A-36

APPENDIX G-1.20 BRAKE STEEL DETAILS



ITEM NO.	NO. PER CAR	DESCRIPTION	MAT'L
3-55	6	∠ 3 X 3 X 3/8 X 0'-8 7/8"	A-36
3-56	6	BAR 3 1/2" X 3/8" X 0'-3 1/2"	A-36
3-57	2	∠ 6 X 6 X 3/8 X 0'-6"	A-36
3-58	2	∠ 2 1/2 X 2 1/2 X 1/4 X 1'-6"	A-36
3-59	4	∠ 2 1/2 X 2 1/2 X 1/4 X 0'-8"	A-36
3-60	4	∠ 3 X 3 X 1/4 X 0'-10"	A-36
3-108	2	BAR 4" X 1/4" X 1'-5 1/8"	A-36

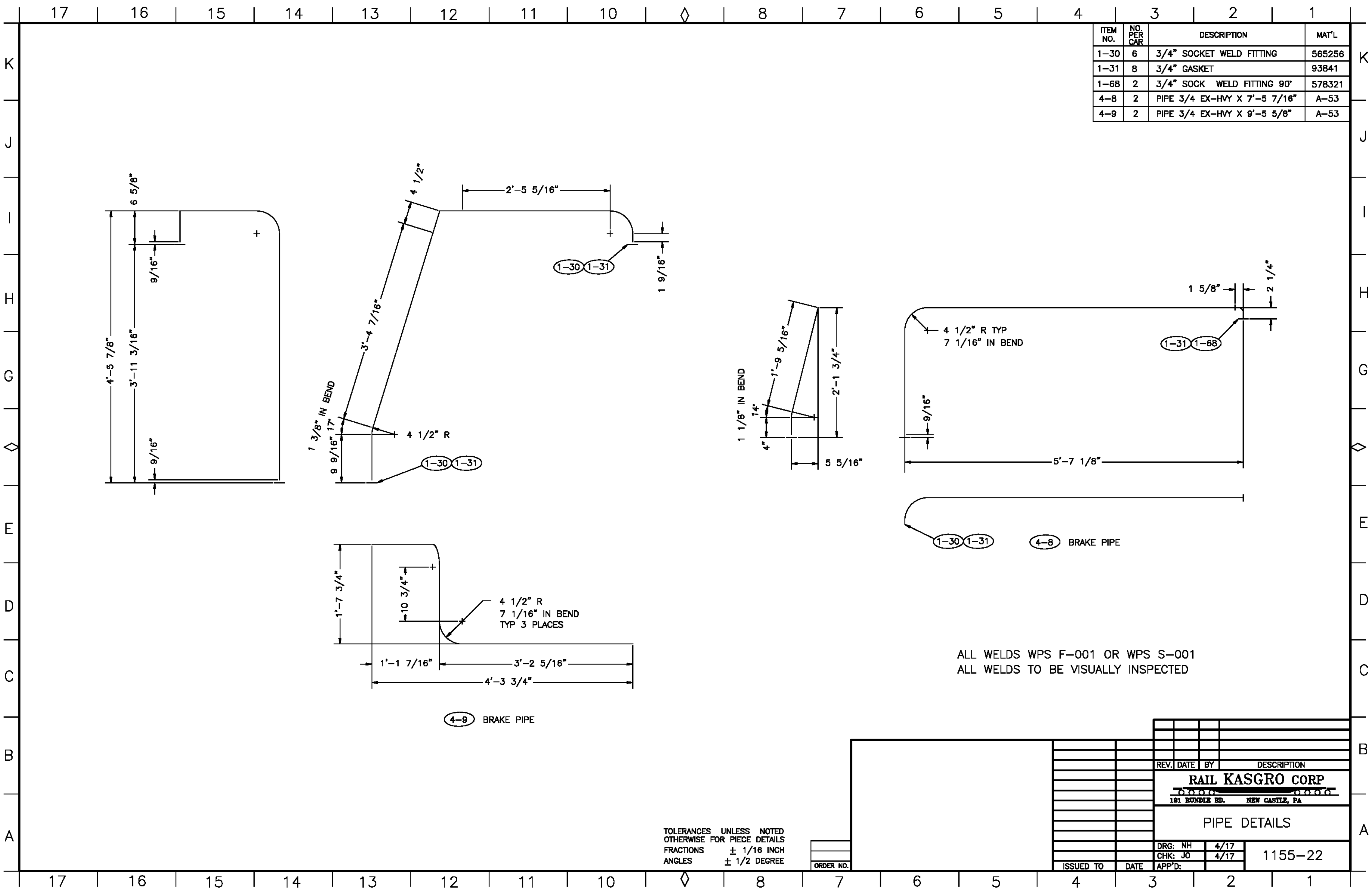
APPENDIX G-1.21 PIPE DETAILS



ITEM NO.	NO. PER CAR	DESCRIPTION	MAT'L
1-28	8	3/8" SOCKET WELD FITTING	565252
1-29	12	3/8" GASKET	93839
1-30	8	3/4" SOCKET WELD FITTING	565256
1-31	8	3/4" GASKET	93841
1-35	4	1" SOCKET WELD FITTING	565259
1-36	4	1" GASKET	93986
1-37	1	1 1/4" SOCKET WELD FITTING	565262
1-38	1	1 1/4" GASKET	94790
1-65	4	3/8 90 DEG SOCKET WELD FTG	578319
1-70	1	1 1/4 SOCK WELD FTG NO GASKET	579687
4-1	2	PIPE 3/8" EX-HVY X 4'-10 1/2"	A-53
4-2	2	PIPE 3/4" EX-HVY X 3'-11 7/16"	A-53
4-3	2	PIPE 3/4" EX-HVY X 5'-10 9/16"	A-53
4-4	1	PIPE 1 1/4" EX-HVY X 1'-9 1/4"	A-53
4-5	2	PIPE 3/8" EX-HVY X 2'-9 9/16"	A-53
4-6	2	PIPE 1" EX-HVY X 1'-1 9/16"	A-53
4-7	2	PIPE 3/8" EX HVY X 6'-6 1/2"	A-53

APPENDIX G-1.22 PIPE DETAILS

ITEM NO.	NO. PER CAR	DESCRIPTION	MAT'L
1–30	6	3/4" SOCKET WELD FITTING	565256
1–31	8	3/4" GASKET	93841
1–68	2	3/4" SOCK WELD FITTING 90°	578321
4–8	2	PIPE 3/4 EX–HVY X 7'–5 7/16"	A–53
4–9	2	PIPE 3/4 EX–HVY X 9'–5 5/8"	A–53



ALL WELDS WPS F–001 OR WPS S–001
ALL WELDS TO BE VISUALLY INSPECTED

TOLERANCES UNLESS NOTED OTHERWISE FOR PIECE DETAILS
FRACTIONS ± 1/16 INCH
ANGLES ± 1/2 DEGREE

ORDER NO. | ISSUED TO | DATE

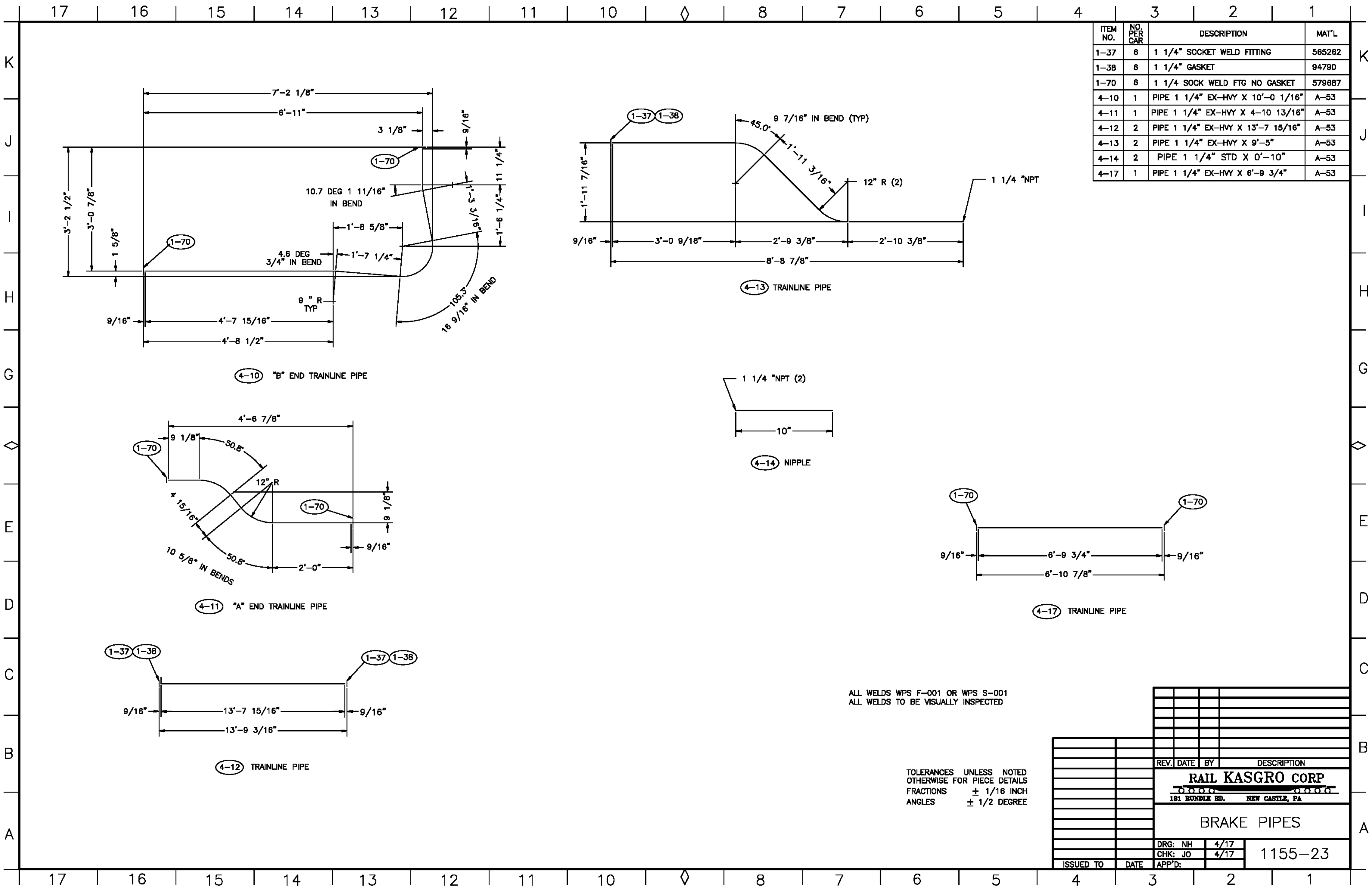
REV. | DATE | BY | DESCRIPTION

RAIL KASGRO CORP
121 RUNDLE RD. NEW CASTLE, PA

PIPE DETAILS

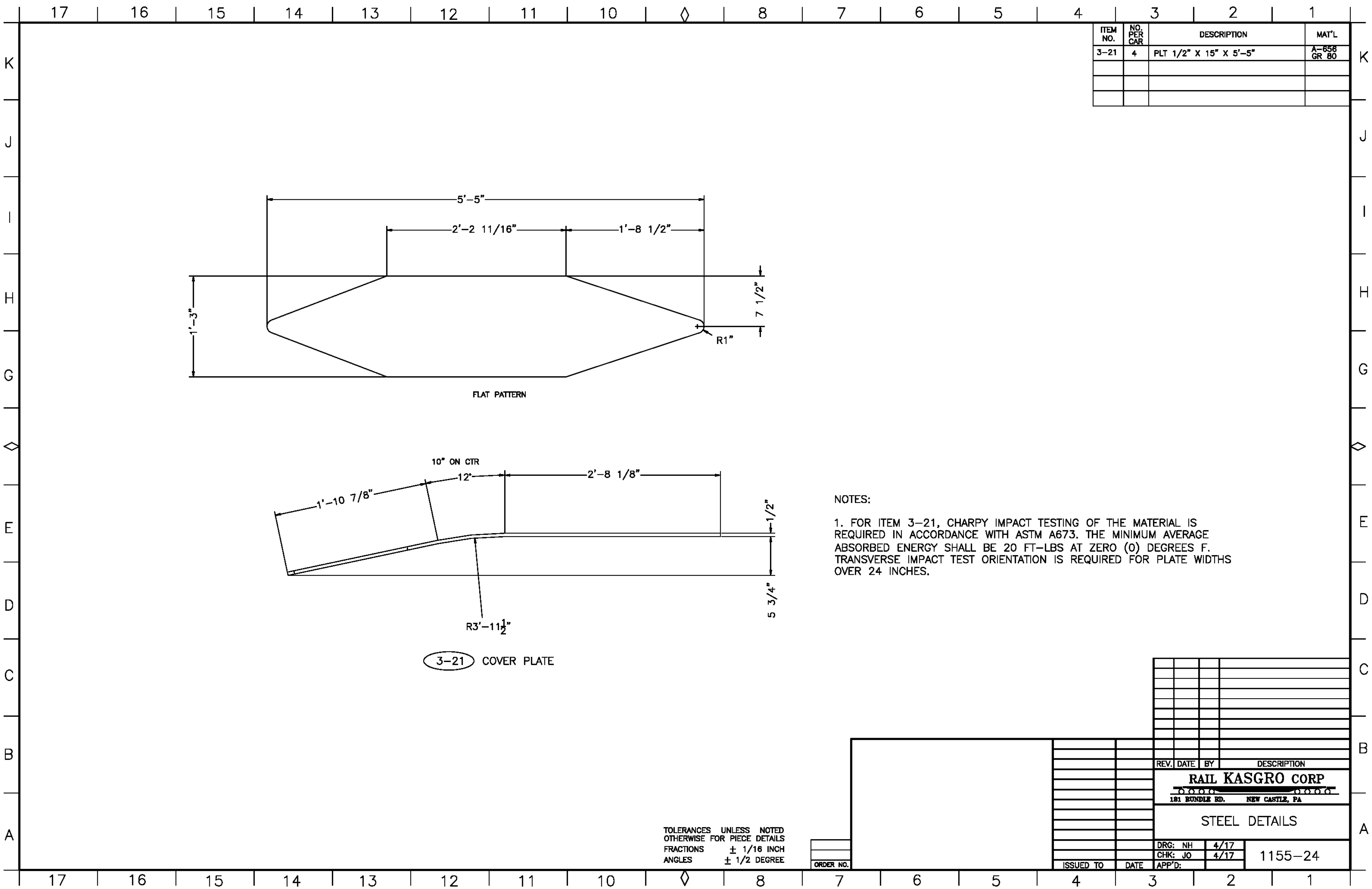
DRG: NH 4/17
CHK: JO 4/17
APP'D:
1155–22

APPENDIX G-1.23 BRAKE PIPES

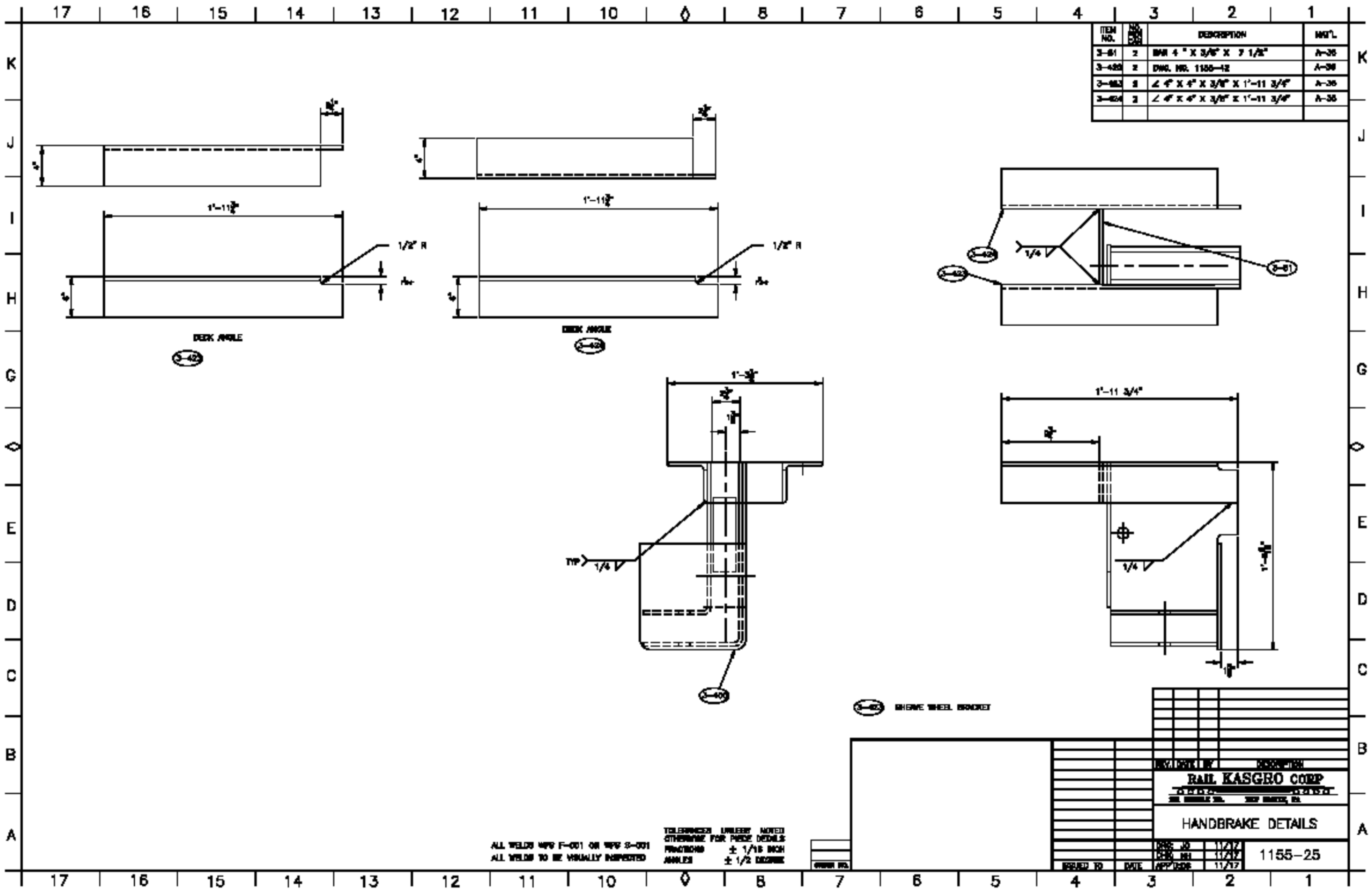


ITEM NO.	NO. PER CAR	DESCRIPTION	MAT'L
1-37	6	1 1/4" SOCKET WELD FITTING	565262
1-38	6	1 1/4" GASKET	94790
1-70	6	1 1/4 SOCK WELD FTG NO GASKET	579687
4-10	1	PIPE 1 1/4" EX-HVY X 10'-0 1/16"	A-53
4-11	1	PIPE 1 1/4" EX-HVY X 4-10 13/16"	A-53
4-12	2	PIPE 1 1/4" EX-HVY X 13'-7 15/16"	A-53
4-13	2	PIPE 1 1/4" EX-HVY X 9'-5"	A-53
4-14	2	PIPE 1 1/4" STD X 0'-10"	A-53
4-17	1	PIPE 1 1/4" EX-HVY X 6'-9 3/4"	A-53

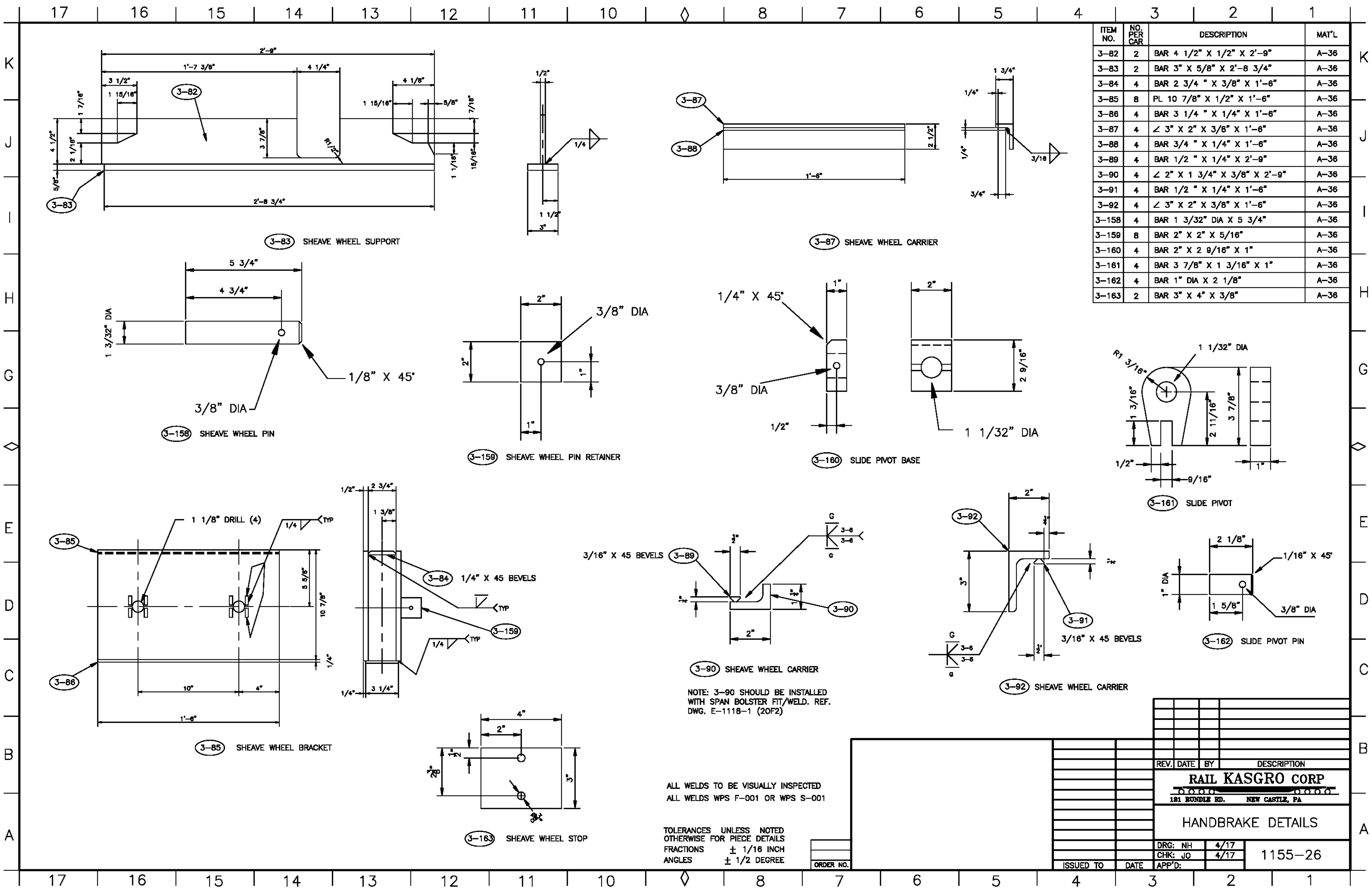
APPENDIX G-1.24 STEEL DETAILS



APPENDIX G-1.25 HAND BRAKE DETAILS

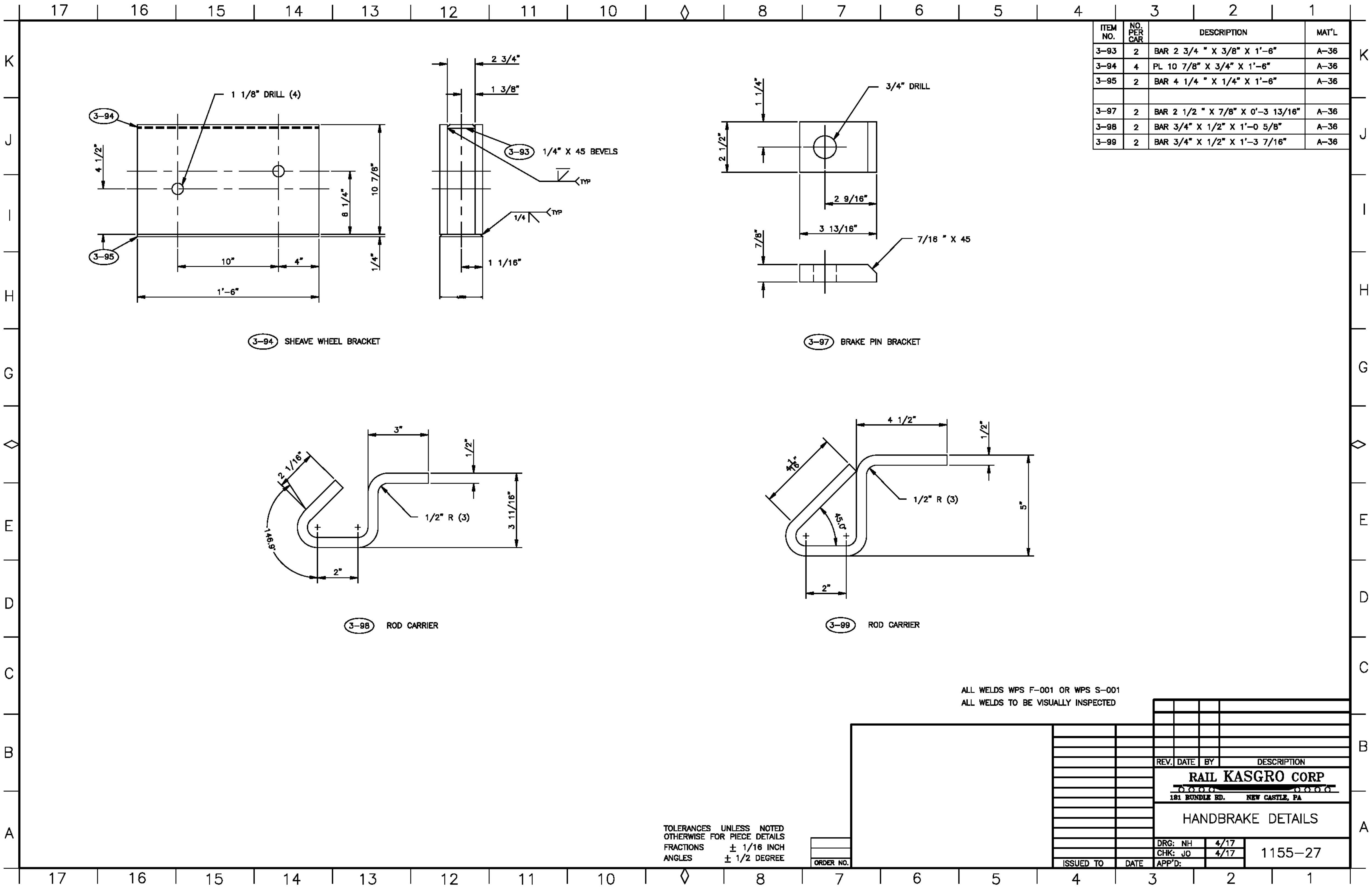


APPENDIX G-1.26 HAND BRAKE DETAILS



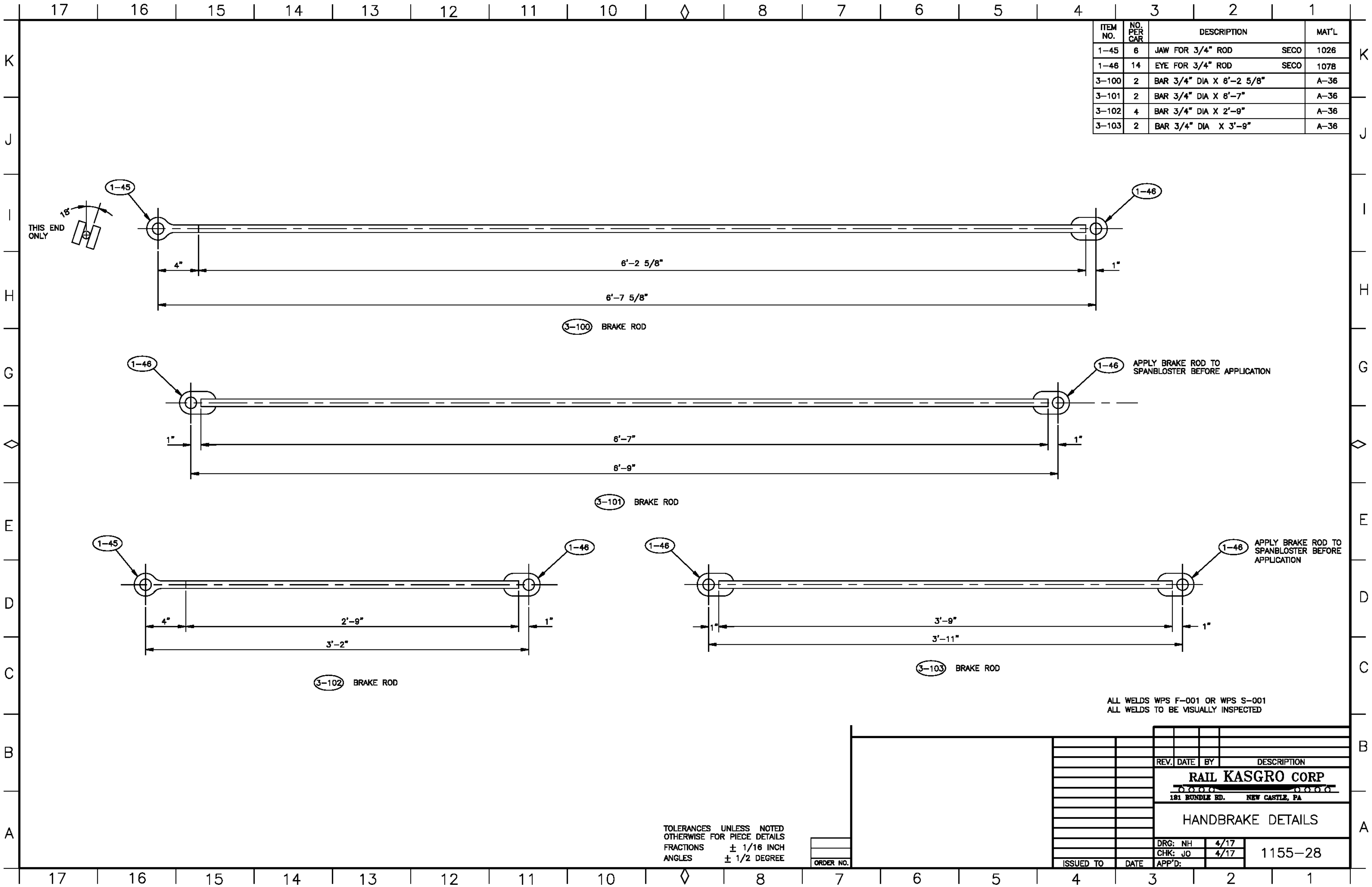
ITEM NO.	NO. PER CAR	DESCRIPTION	MAT'L
3-82	2	BAR 4 1/2" X 1/2" X 2'-9"	A-36
3-83	2	BAR 3" X 5/8" X 2'-8 3/4"	A-36
3-84	4	BAR 2 3/4 " X 3/8" X 1'-6"	A-36
3-85	8	PL 10 7/8" X 1/2" X 1'-6"	A-36
3-86	4	BAR 3 1/4 " X 1/4" X 1'-6"	A-36
3-87	4	∠ 3" X 2" X 3/8" X 1'-6"	A-36
3-88	4	BAR 3/4 " X 1/4" X 1'-6"	A-36
3-89	4	BAR 1/2 " X 1/4" X 2'-9"	A-36
3-90	4	∠ 2" X 1 3/4" X 3/8" X 2'-9"	A-36
3-91	4	BAR 1/2 " X 1/4" X 1'-6"	A-36
3-92	4	∠ 3" X 2" X 3/8" X 1'-6"	A-36
3-158	4	BAR 1 3/32" DIA X 5 3/4"	A-36
3-159	8	BAR 2" X 2" X 5/16"	A-36
3-160	4	BAR 2" X 2 9/16" X 1"	A-36
3-161	4	BAR 3 7/8" X 1 3/16" X 1"	A-36
3-162	4	BAR 1" DIA X 2 1/8"	A-36
3-163	2	BAR 3" X 4" X 3/8"	A-36

APPENDIX G-1.27 HAND BRAKE DETAILS



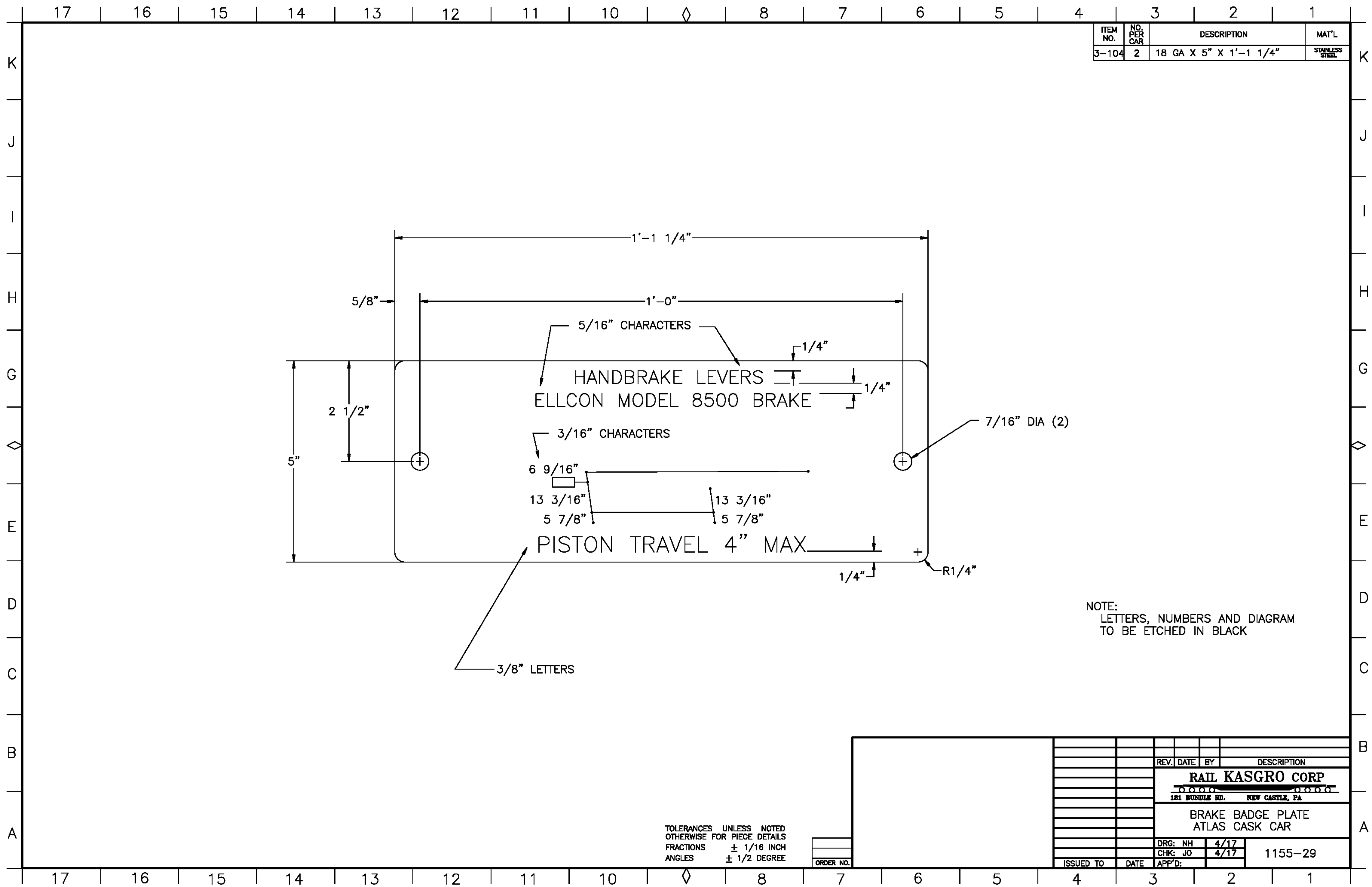
ITEM NO.	NO. PER CAR	DESCRIPTION	MAT'L
3-93	2	BAR 2 3/4 " X 3/8" X 1'-6"	A-36
3-94	4	PL 10 7/8" X 3/4" X 1'-6"	A-36
3-95	2	BAR 4 1/4 " X 1/4" X 1'-6"	A-36
3-97	2	BAR 2 1/2 " X 7/8" X 0'-3 13/16"	A-36
3-98	2	BAR 3/4" X 1/2" X 1'-0 5/8"	A-36
3-99	2	BAR 3/4" X 1/2" X 1'-3 7/16"	A-36

APPENDIX G-1.28 HAND BRAKE DETAILS

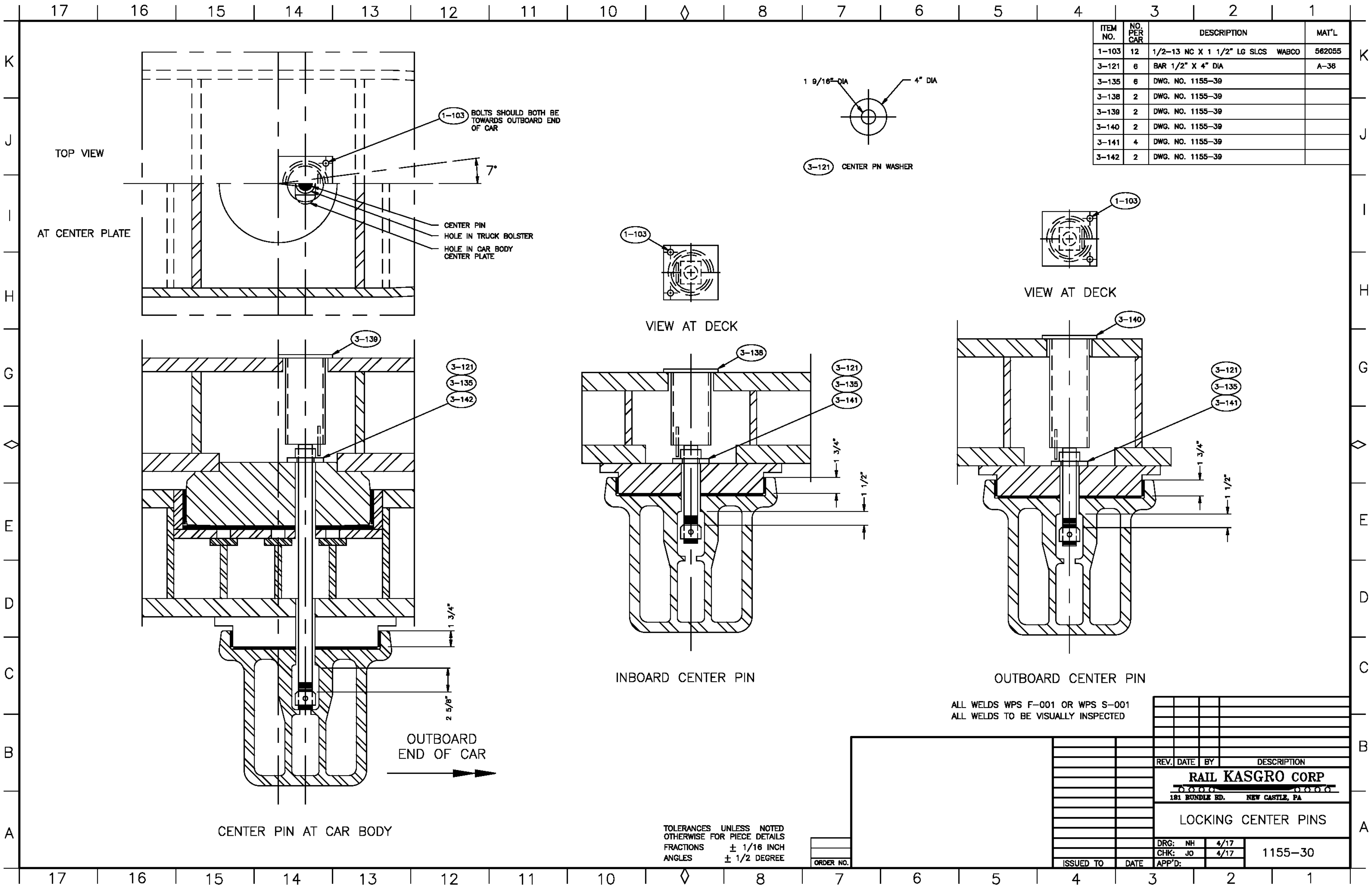


ITEM NO.	NO. PER CAR	DESCRIPTION	MAT'L
1-45	6	JAW FOR 3/4" ROD SECO	1026
1-46	14	EYE FOR 3/4" ROD SECO	1078
3-100	2	BAR 3/4" DIA X 6'-2 5/8"	A-36
3-101	2	BAR 3/4" DIA X 8'-7"	A-36
3-102	4	BAR 3/4" DIA X 2'-9"	A-36
3-103	2	BAR 3/4" DIA X 3'-9"	A-36

APPENDIX G-1.29 BRAKE BADGE PLATE

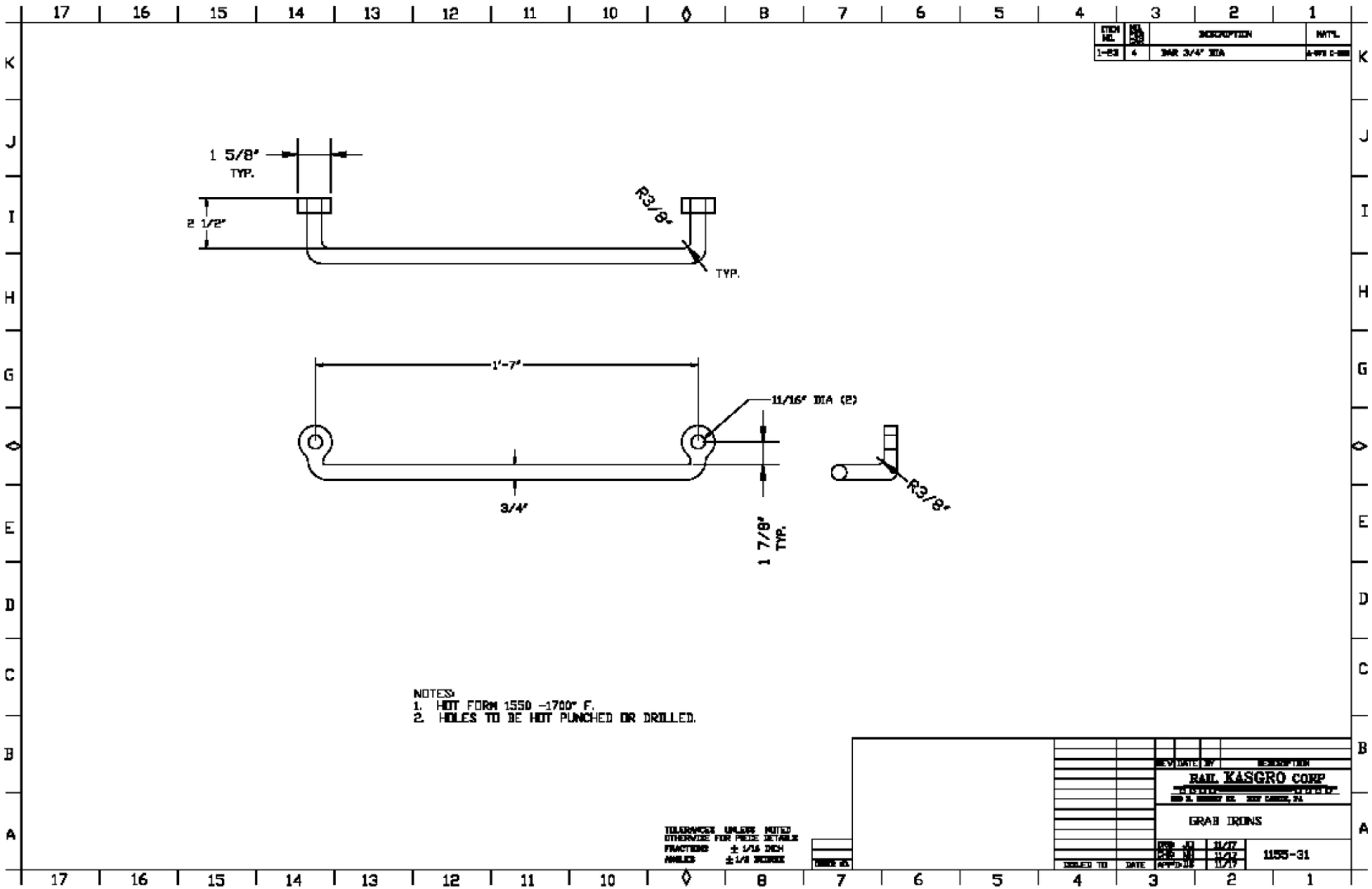


APPENDIX G-1.30 LOCKING CENTER PINS



ITEM NO.	NO. PER CAR	DESCRIPTION	MAT'L
1-103	12	1/2-13 NC X 1 1/2" LG SLCS WABCO	562055
3-121	6	BAR 1/2" X 4" DIA	A-36
3-135	6	DWG. NO. 1155-39	
3-138	2	DWG. NO. 1155-39	
3-139	2	DWG. NO. 1155-39	
3-140	2	DWG. NO. 1155-39	
3-141	4	DWG. NO. 1155-39	
3-142	2	DWG. NO. 1155-39	

APPENDIX G-1.31 HAND BRAKE DETAILS



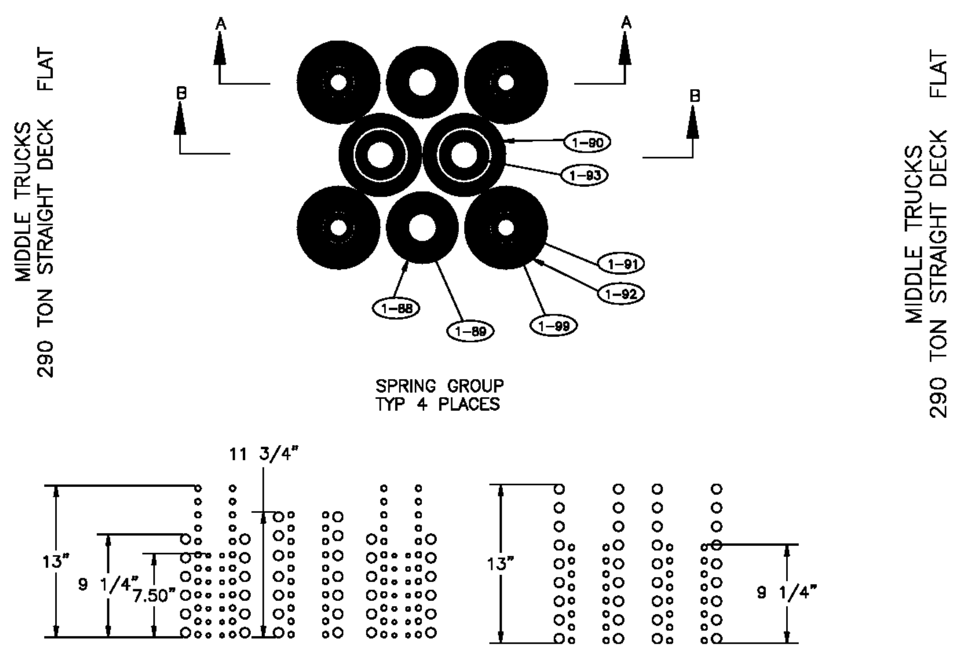
APPENDIX G-1.32 SPRING GROUPING

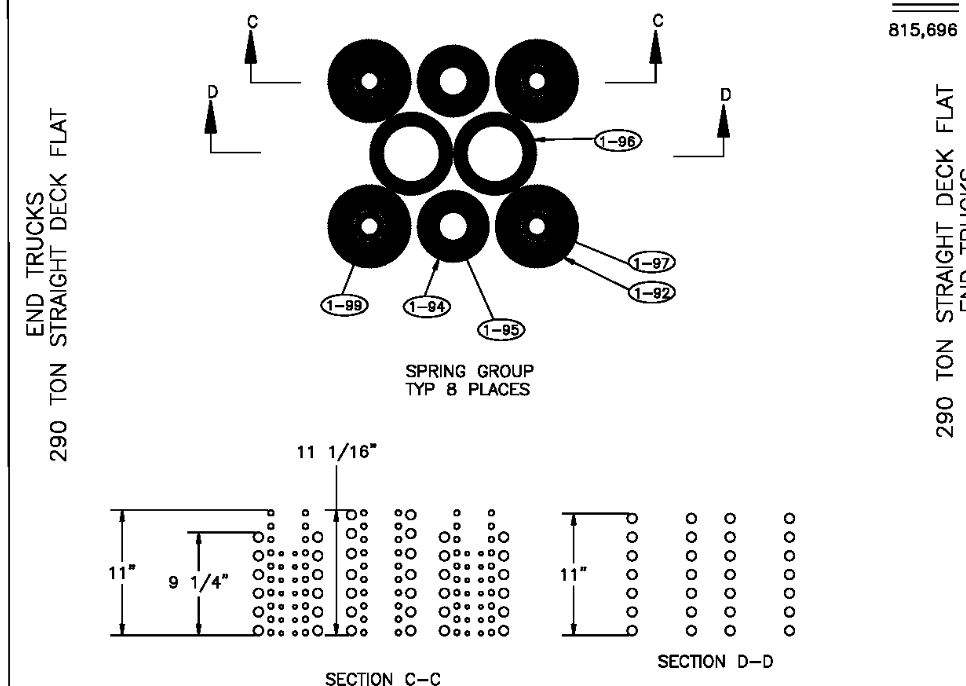
MIDDLE TRUCKS — 290 TON STRAIGHT DECK FLAT

ITEM	QTY/ CAR	SPRING	BAR DIA	INNER DIA	OUTER DIA	FREE HT	SOLID HT	SPR RATE	SOLID CAPY	CAR CAPY
1–88	8	CONTROL COIL OUTER	0.781	3.19	4.75	11.72	6.69	1161	5841	46,728
1–89	8	CONTROL COIL INNER	0.500	1.94	2.94	11.72	6.69	500	2517	20,136
1–90	8	EMPTY COIL OUTER	0.844	3.81	5.50	13.00	6.69	1074	6781	54,248
1–91	16	EMPTY COIL INNER	0.50	2.25	3.25	13.00	6.69	348	2197	35,152
1–92	16	LOADED COIL OUTER	1.063	3.38	5.50	9.25	6.69	4183	10719	171,504
1–93	8	LOADED COIL INNER	0.688	1.88	3.25	9.25	6.69	2219	5686	45,488
1–99	16	LOAD COIL INNER INNER	0.375	1.188	1.94	7.50	5.375	555	1180	18,880
										392,136

END TRUCKS — 290 TON STRAIGHT DECK FLAT

ITEM	QTY/ CAR	SPRING	BAR DIA	INNER DIA	OUTER DIA	FREE HT	SOLID HT	SPR RATE	SOLID CAPY	CAR CAPY
1–94	16	CONTROL COIL OUTER	0.813	3.25	4.88	11.09	6.69	1328	5847	93,552
1–95	16	CONTROL COIL INNER	0.531	1.94	3.00	11.09	6.69	656	2891	46,256
1–96	16	EMPTY COIL OUTER	0.969	3.56	5.50	11.00	6.69	2409	10389	166,224
1–97	32	EMPTY COIL INNER	0.594	2.06	3.25	11.00	6.69	934	4028	128,896
1–92	32	LOAD COIL	1.063	3.37	5.50	9.25	6.69	4183	10719	343,008
1–99	32	LOAD COIL INNER INNER	0.375	1.188	1.94	7.50	5.375	555	1180	37,760
										815,696





SPRING RATE CTR = 121,008 #/in
SPRING RATE OUTER = 251,792 #/in
TOTAL SPRING RATE = 372,800 #/in

GRL 789,000
SPR WT 727,050
RATIO 1,207,832/727,050 = 1.66

NOTES:
1. ALL SPRINGS NOT LABELED AS A CONTROL COIL ARE LOAD COILS
2. QUANTITIES ARE PER CAR
3. MATERIAL SHALL BE GRADE 5160H PER ASTM A304, EXCEPT ITEM 1–99 SHALL BE CHROMIUM–SILICON ALLOY PER ASTM A401. THE USE OF ALTERNATE MATERIALS SHALL BE APPROVED BY KASGRO RAIL.
4. SPRING MANUFACTURE SHALL BE IN ACCORDANCE WITH AAR SPECIFICATION M–114 AND ASTM A125
5. SPRING END CONSTRUCTION SHALL BE TAPERED SQUARED AND WET GROUND.
6. INNER SPRING (ITEMS 1–89, 1–91, 1–93, 1–95 AND 1–97) SHALL BE WOUND CLOCKWISE (RIGHT–HAND). OUTER SPRINGS AND INNER–INNER SPRINGS (ITEMS 1–88, 1–90, 1–92, 1–94, 1–96 AND 1–99) SHALL BE WOUND COUNTER–CLOCKWISE (LEFT–HAND).
7. WET FLORESCENT MAGNETIC PARTICLE TESTING SHALL BE PERFORMED ON THE FLAT END AND THE FIRST ACTIVE COIL OF EACH SPRING (BOTH ENDS) IN ACCORDANCE WITH ASTM E709. THE ACCEPTANCE CRITERIA SPECIFIED IN KASGRO PROCEDURE NO.12 SHALL APPLY.
8. SPRINGS SHALL BE DEMAGNETIZED FOLLOWING MT EXAMINATION. MAXIMUM RESIDUAL MAGNETISM SHALL NOT EXCEED 5 GAUSS.
9. THE ENTIRE SURFACE OF EACH SPRING SHALL BE SHOT PEENED. THE GROUND ENDS OF THE SPRINGS SHALL BE PEENED AFTER WET FLORESCENT MAGNETIC PARTICLE TESTING.
10. SPRING TOLERANCES AND LOAD TESTING SHALL BE AS SPECIFIED BY KASGRO PROCEDURE NO. 12. THIS TESTING SHALL BE PERFORMED AFTER ALL SURFACES HAVE BEEN SHOT PEENED.

REV. | DATE | BY | DESCRIPTION

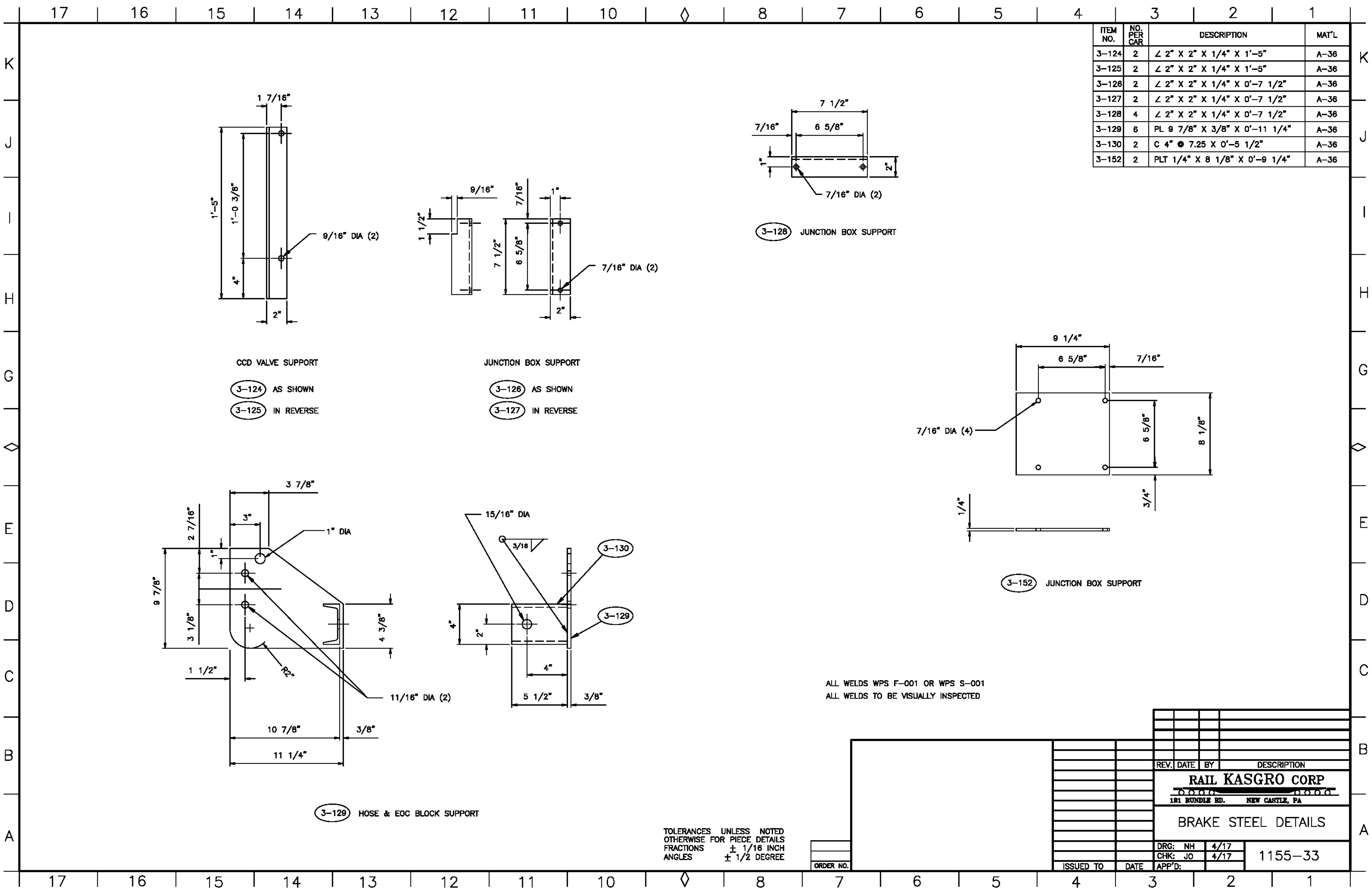
RAIL KASGRO CORP

SPRING GROUPING
290 TON STRAIGHT DECK FLAT CAR

DRG: NH 4/17
CHK: JO 4/17
APP'D:
1155–32

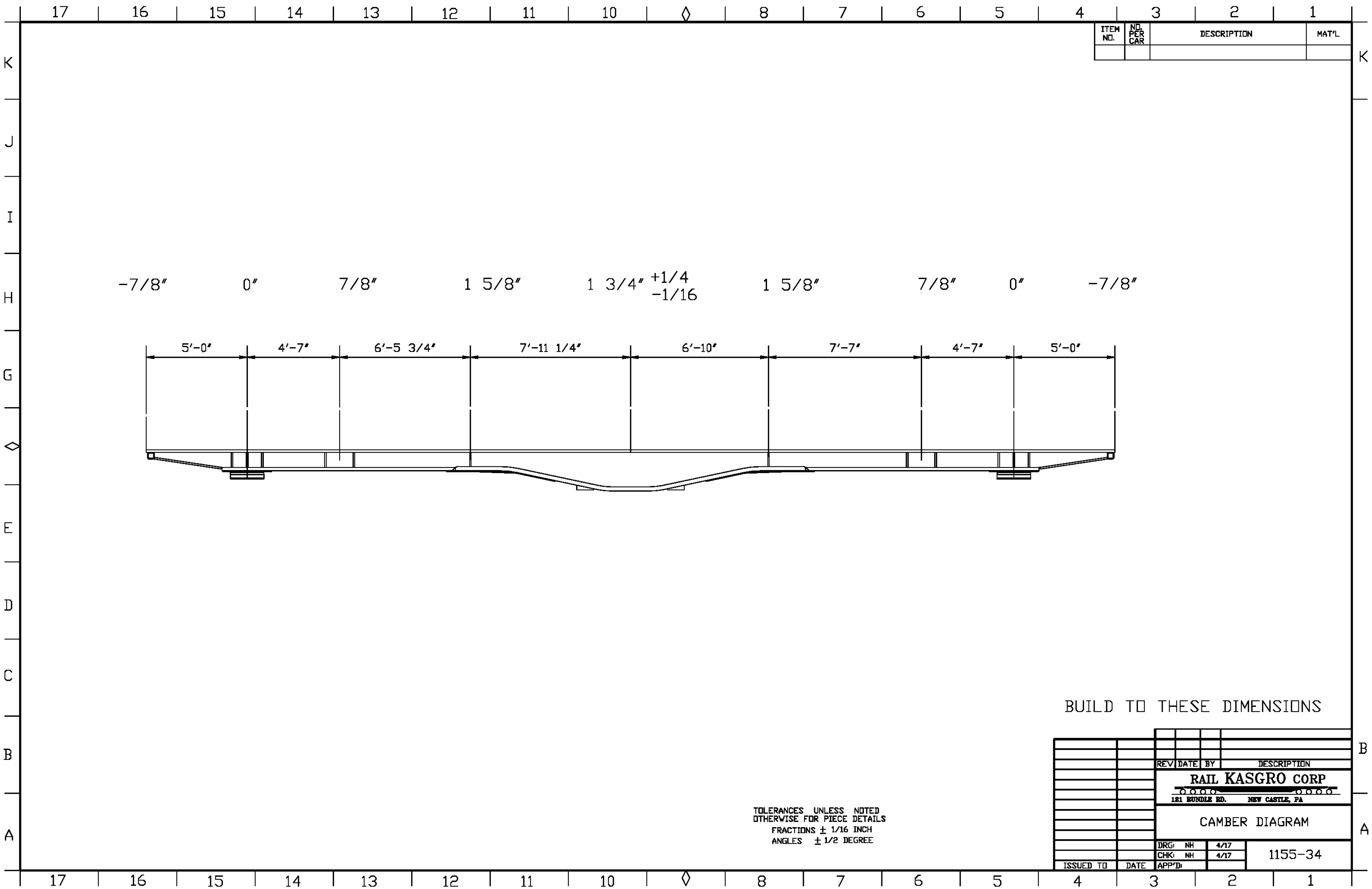
ISSUED TO | DATE

APPENDIX G-1.33 BRAKE STEEL DETAILS

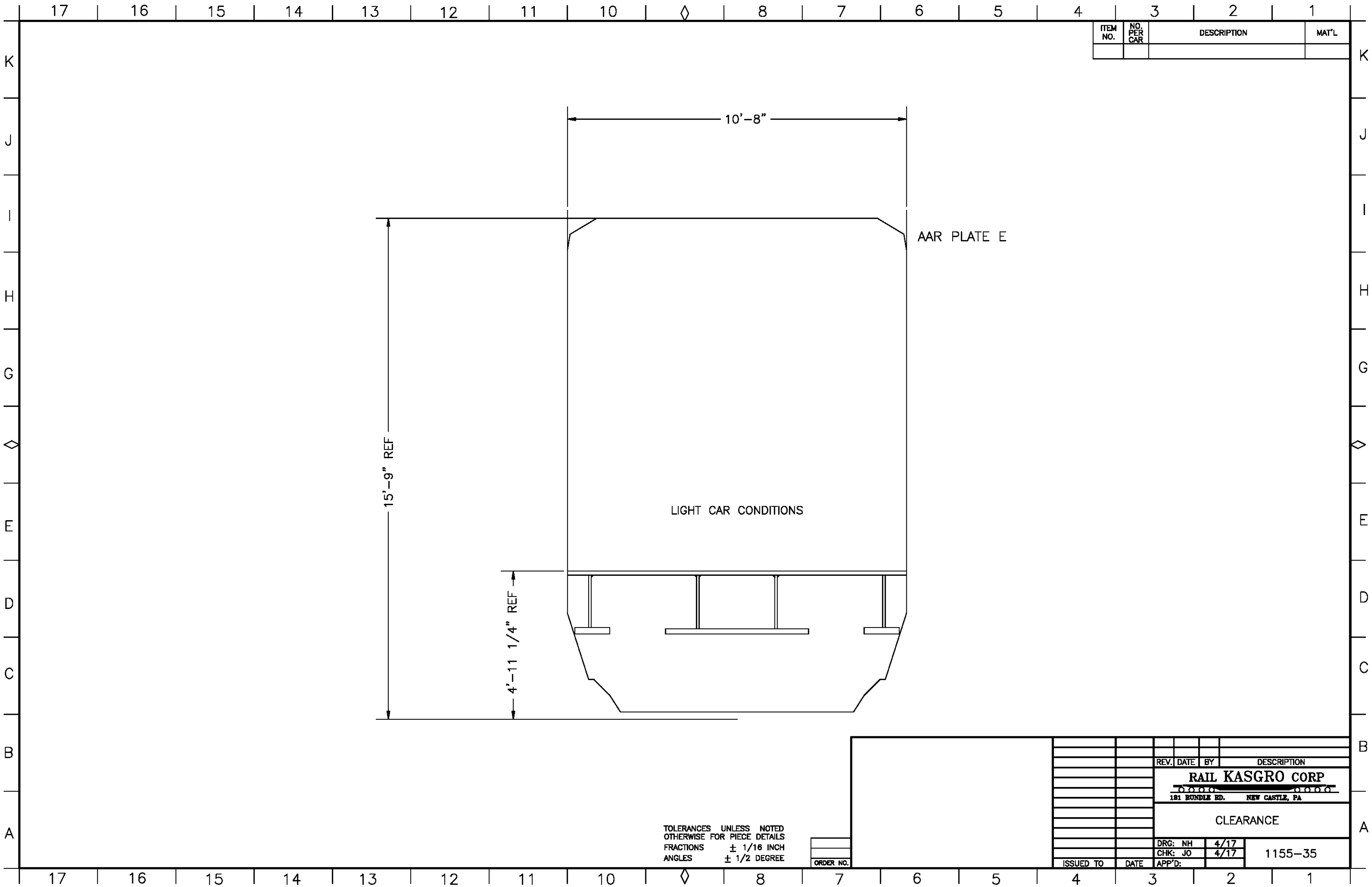


ITEM NO.	NO. PER CAR	DESCRIPTION	MAT'L
3–124	2	∠ 2" X 2" X 1/4" X 1'–5"	A–36
3–125	2	∠ 2" X 2" X 1/4" X 1'–5"	A–36
3–126	2	∠ 2" X 2" X 1/4" X 0'–7 1/2"	A–36
3–127	2	∠ 2" X 2" X 1/4" X 0'–7 1/2"	A–36
3–128	4	∠ 2" X 2" X 1/4" X 0'–7 1/2"	A–36
3–129	6	PL 9 7/8" X 3/8" X 0'–11 1/4"	A–36
3–130	2	C 4" @ 7.25 X 0'–5 1/2"	A–36
3–152	2	PLT 1/4" X 8 1/8" X 0'–9 1/4"	A–36

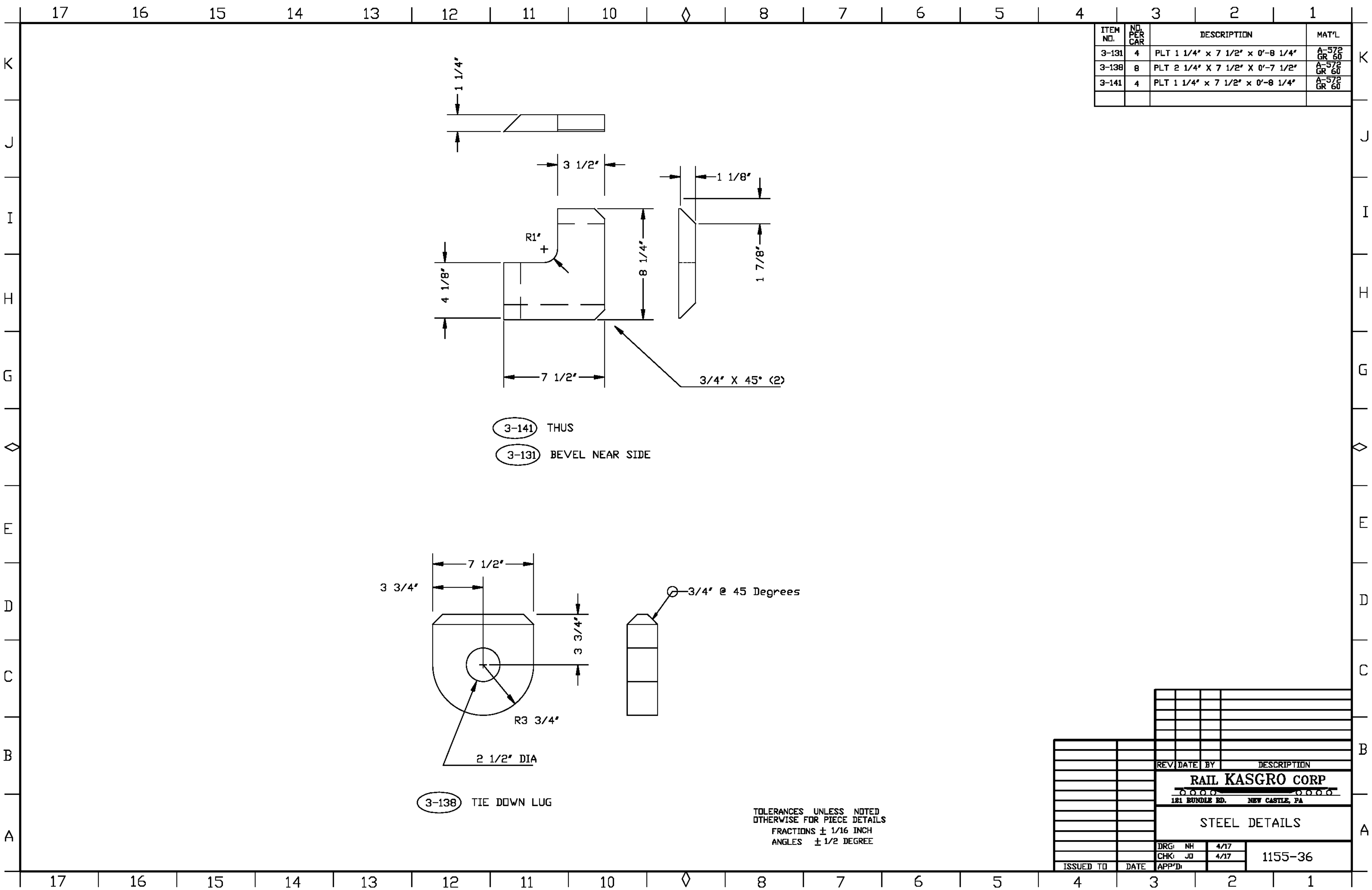
APPENDIX G-1.34 CAMBER DIAGRAM



APPENDIX G-1.35 CLEARANCE

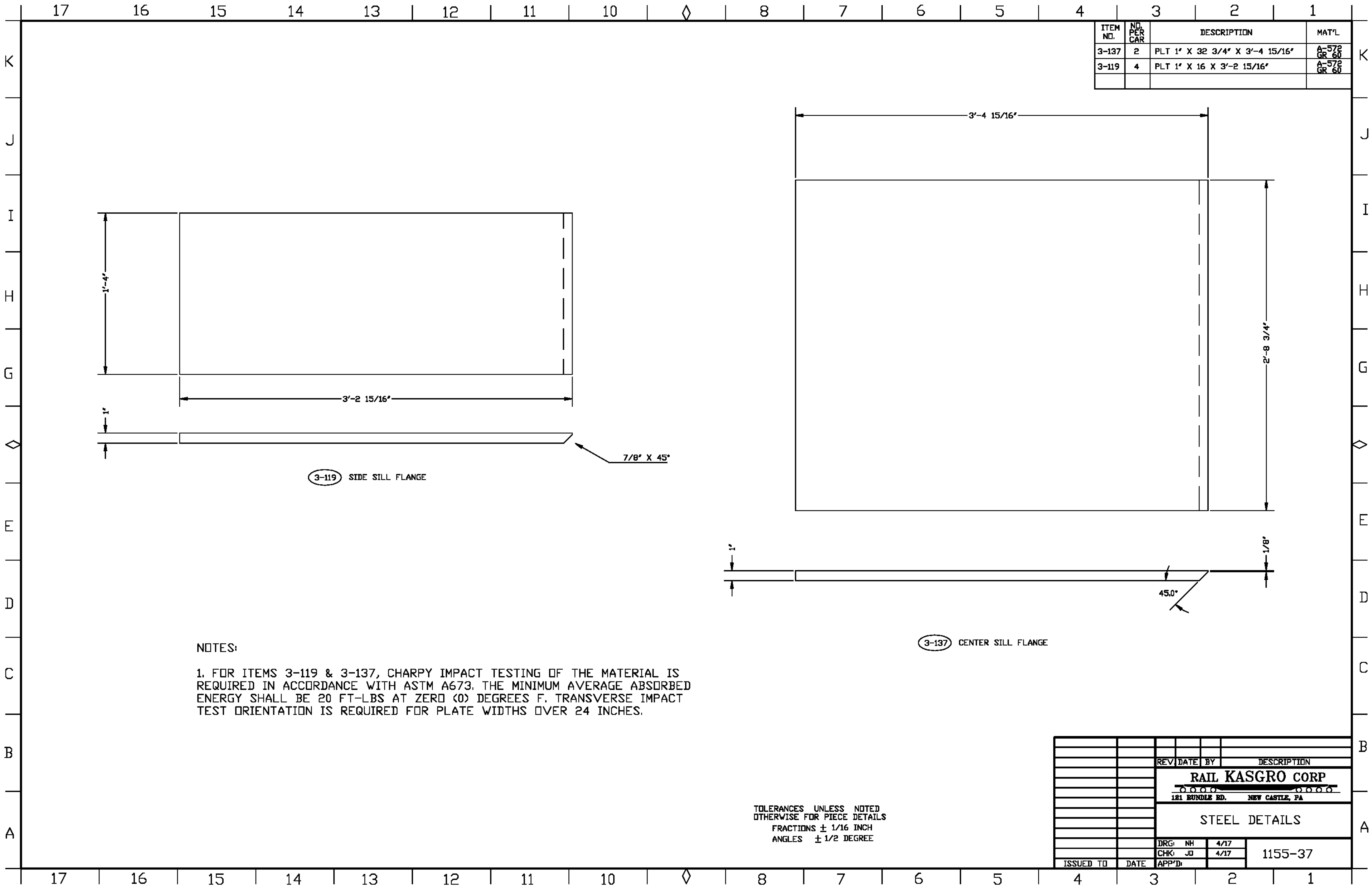


APPENDIX G-1.36 STEEL DETAILS

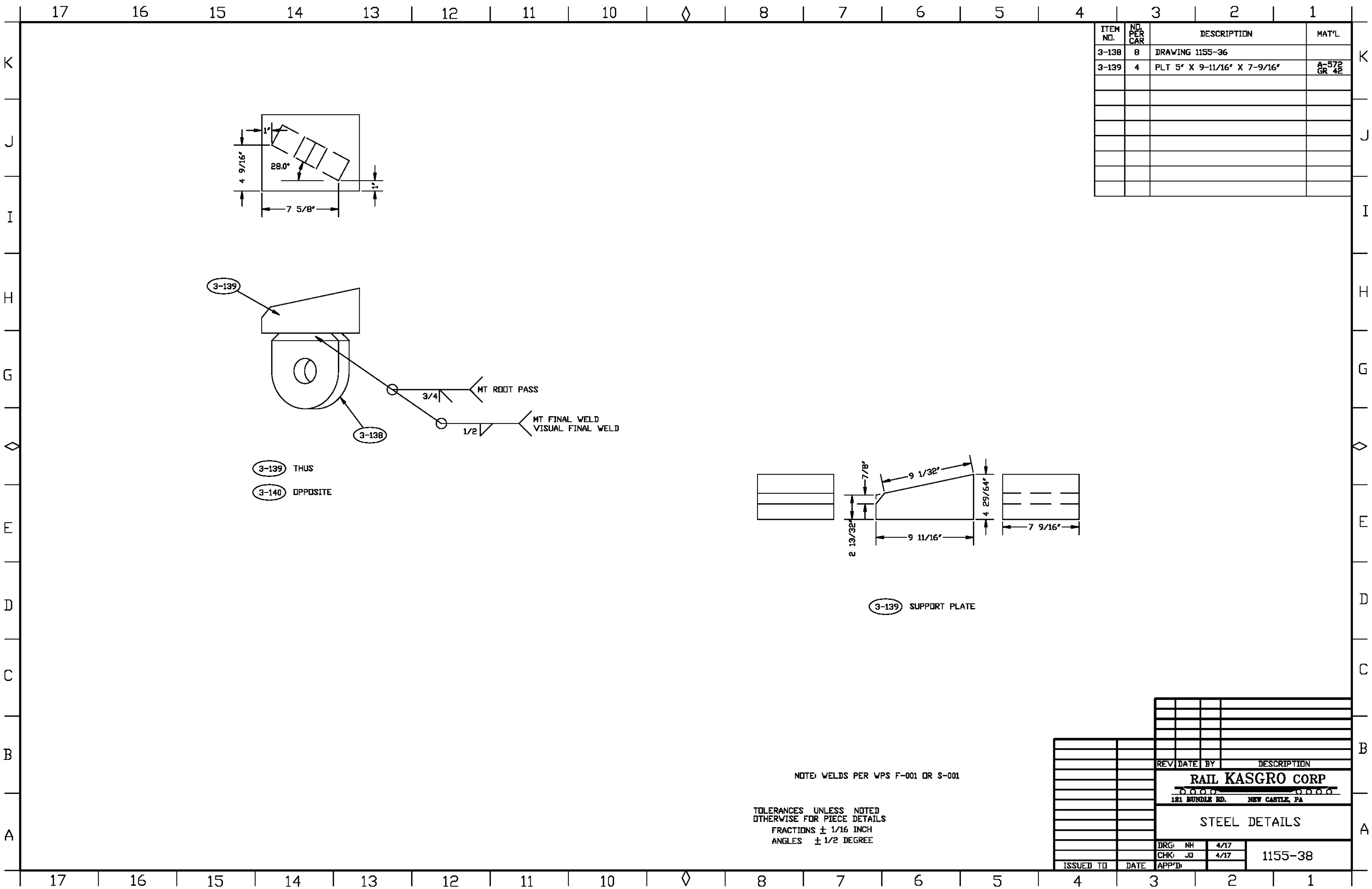


ITEM NO.	NO. PER CAR	DESCRIPTION	MAT'L
3-131	4	PLT 1 1/4" x 7 1/2" x 0'-8 1/4"	A-572 GR 60
3-138	8	PLT 2 1/4" X 7 1/2" X 0'-7 1/2"	A-572 GR 60
3-141	4	PLT 1 1/4" x 7 1/2" x 0'-8 1/4"	A-572 GR 60

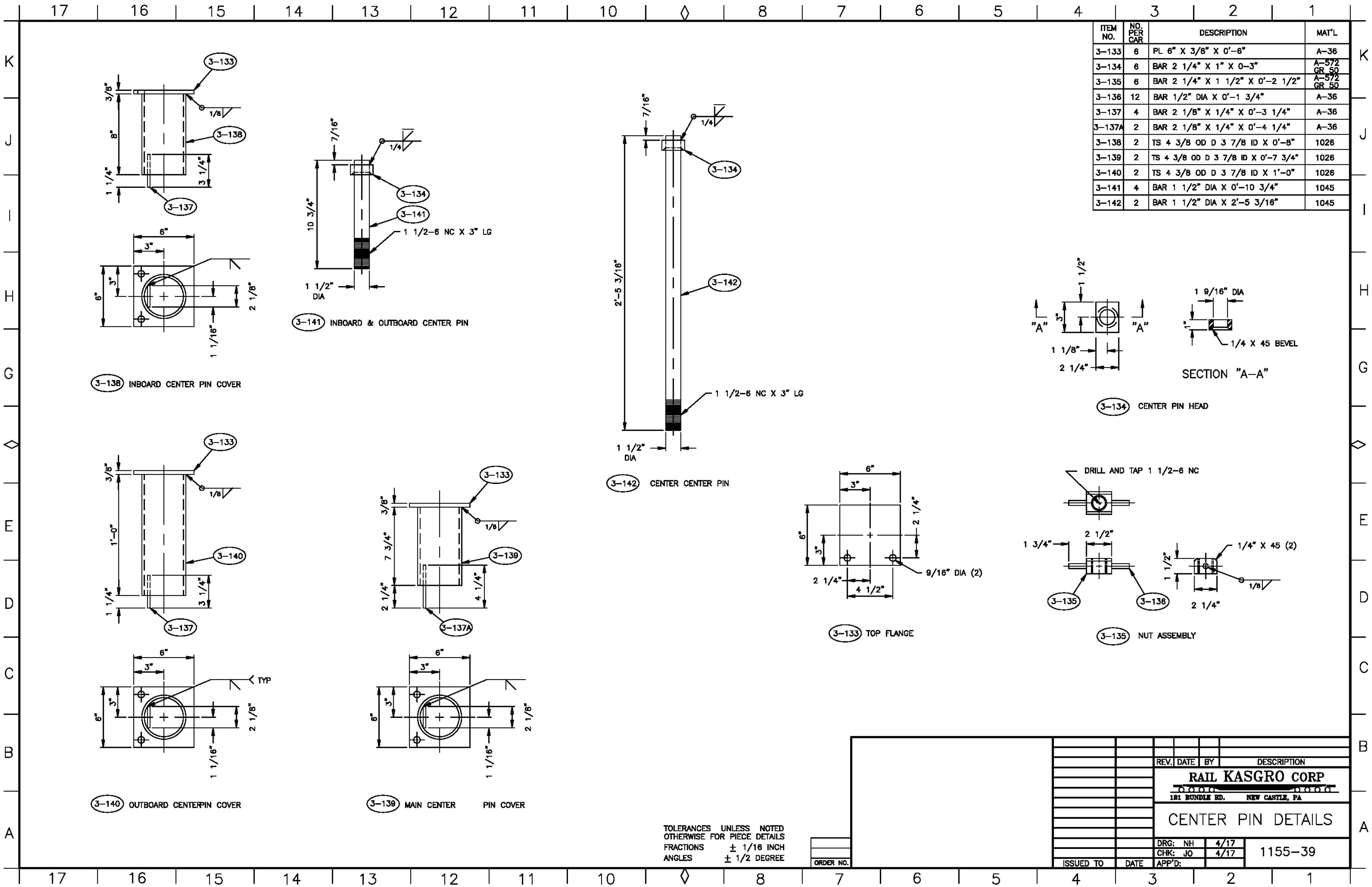
APPENDIX G-1.37 STEEL DETAILS



APPENDIX G-1.38 STEEL DETAILS

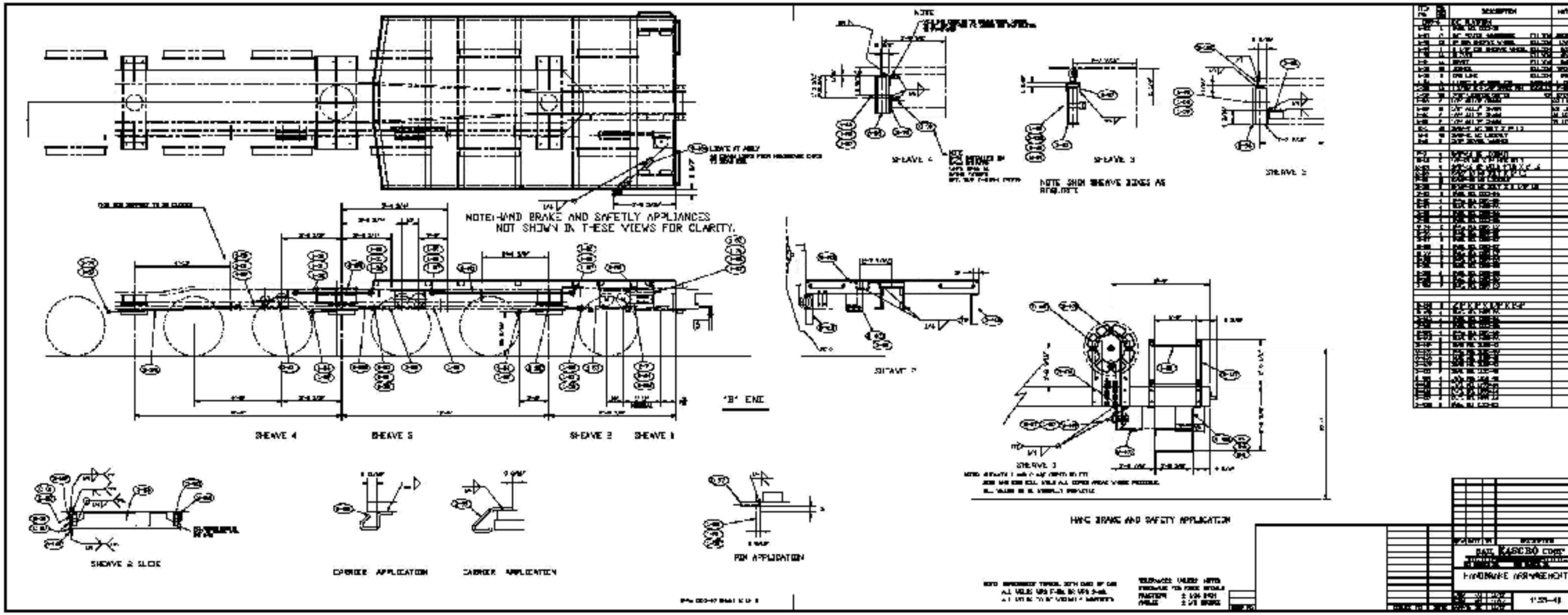


APPENDIX G-1.39 CENTER PIN DETAILS

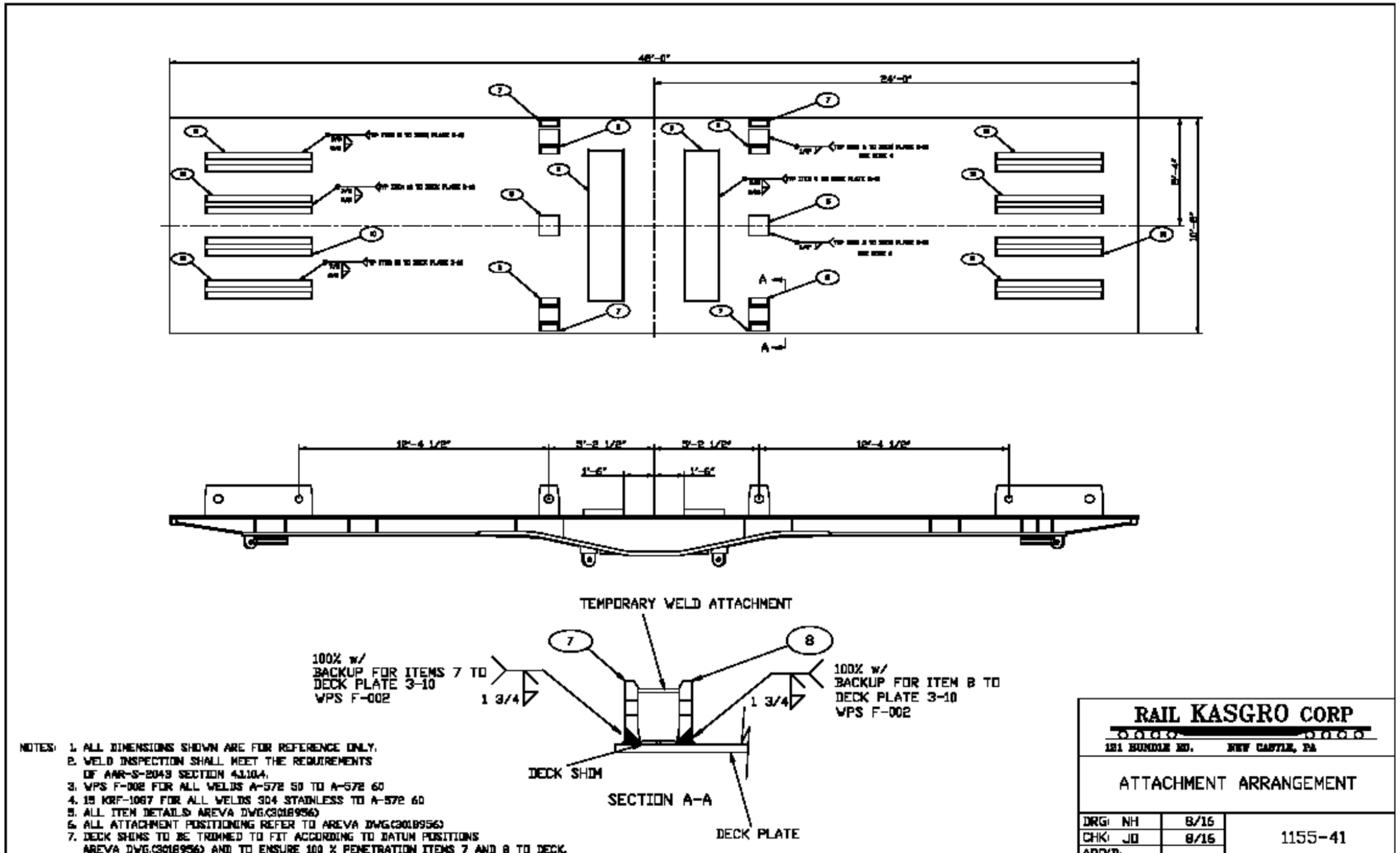


ITEM NO.	NO. PER CAR	DESCRIPTION	MAT'L
3-133	6	PL 6" X 3/8" X 0'-6"	A-36
3-134	6	BAR 2 1/4" X 1" X 0-3"	A-572 GR 50
3-135	6	BAR 2 1/4" X 1 1/2" X 0'-2 1/2"	A-572 GR 50
3-136	12	BAR 1/2" DIA X 0'-1 3/4"	A-36
3-137	4	BAR 2 1/8" X 1/4" X 0'-3 1/4"	A-36
3-137A	2	BAR 2 1/8" X 1/4" X 0'-4 1/4"	A-36
3-138	2	TS 4 3/8 OD D 3 7/8 ID X 0'-8"	1026
3-139	2	TS 4 3/8 OD D 3 7/8 ID X 0'-7 3/4"	1026
3-140	2	TS 4 3/8 OD D 3 7/8 ID X 1'-0"	1026
3-141	4	BAR 1 1/2" DIA X 0'-10 3/4"	1045
3-142	2	BAR 1 1/2" DIA X 2'-5 3/16"	1045

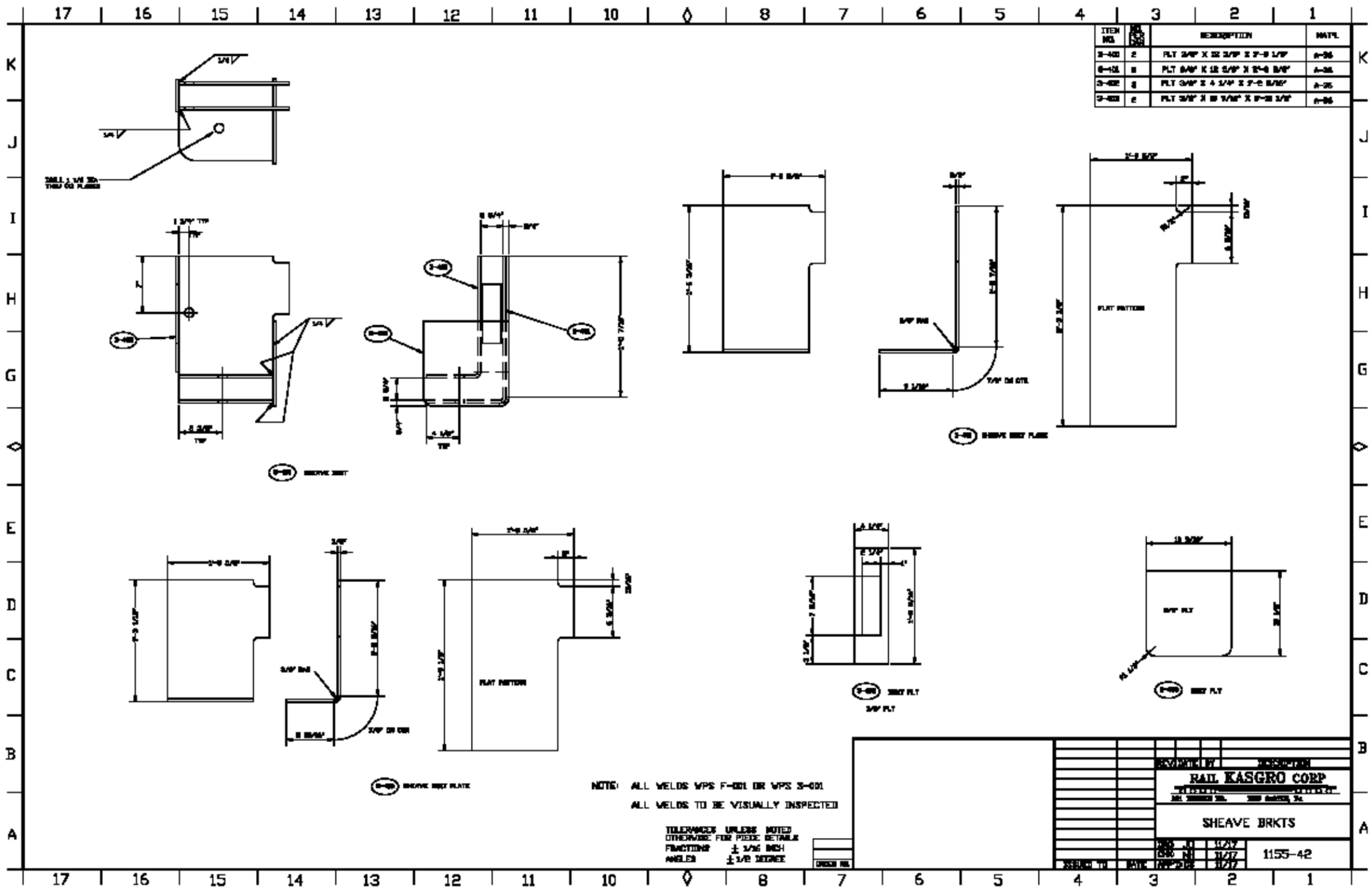
APPENDIX G-1.40 HANDBRAKE ARRANGEMENT



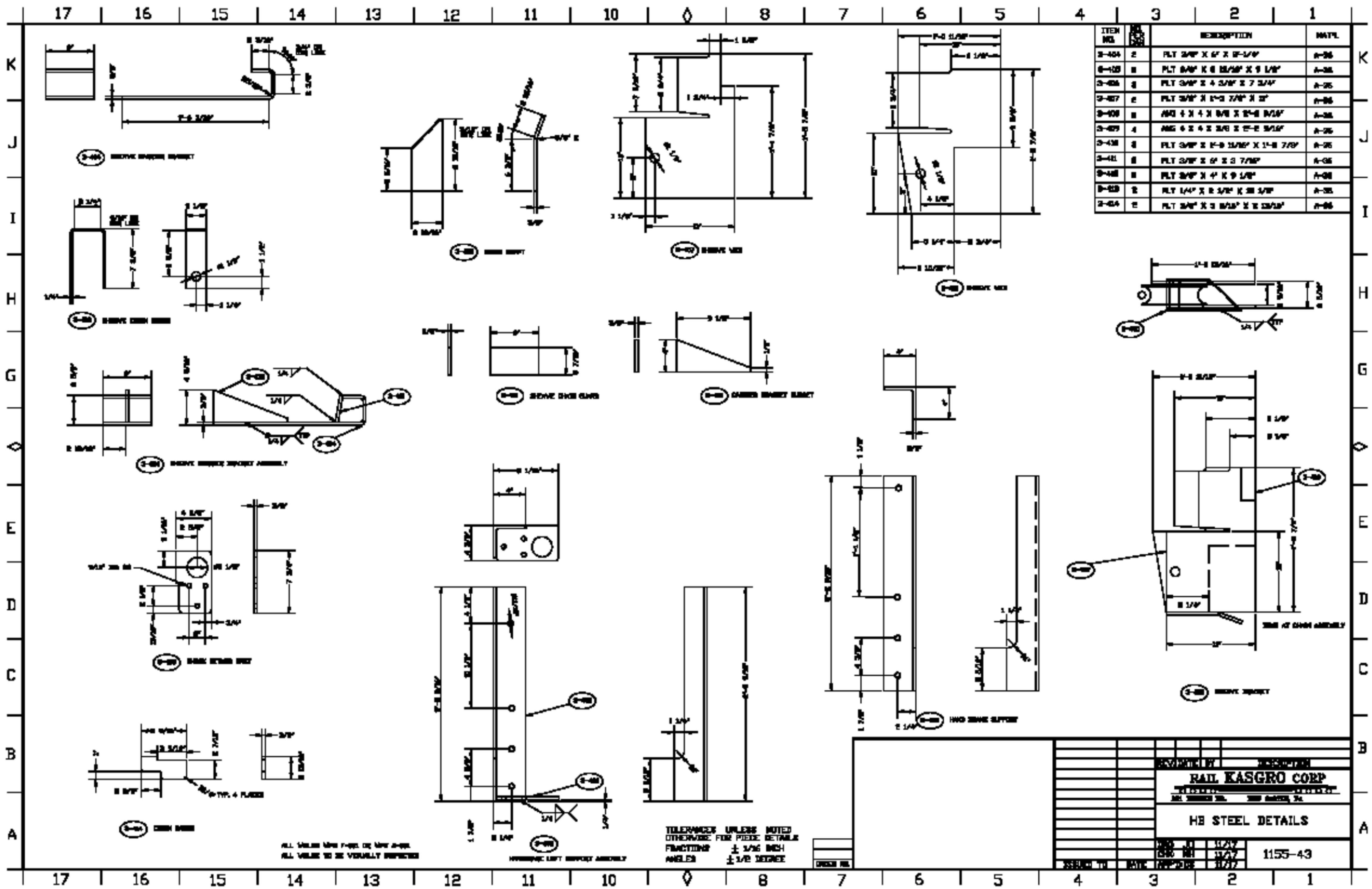
APPENDIX G-1.41 ATTACHMENT ARRANGEMENT



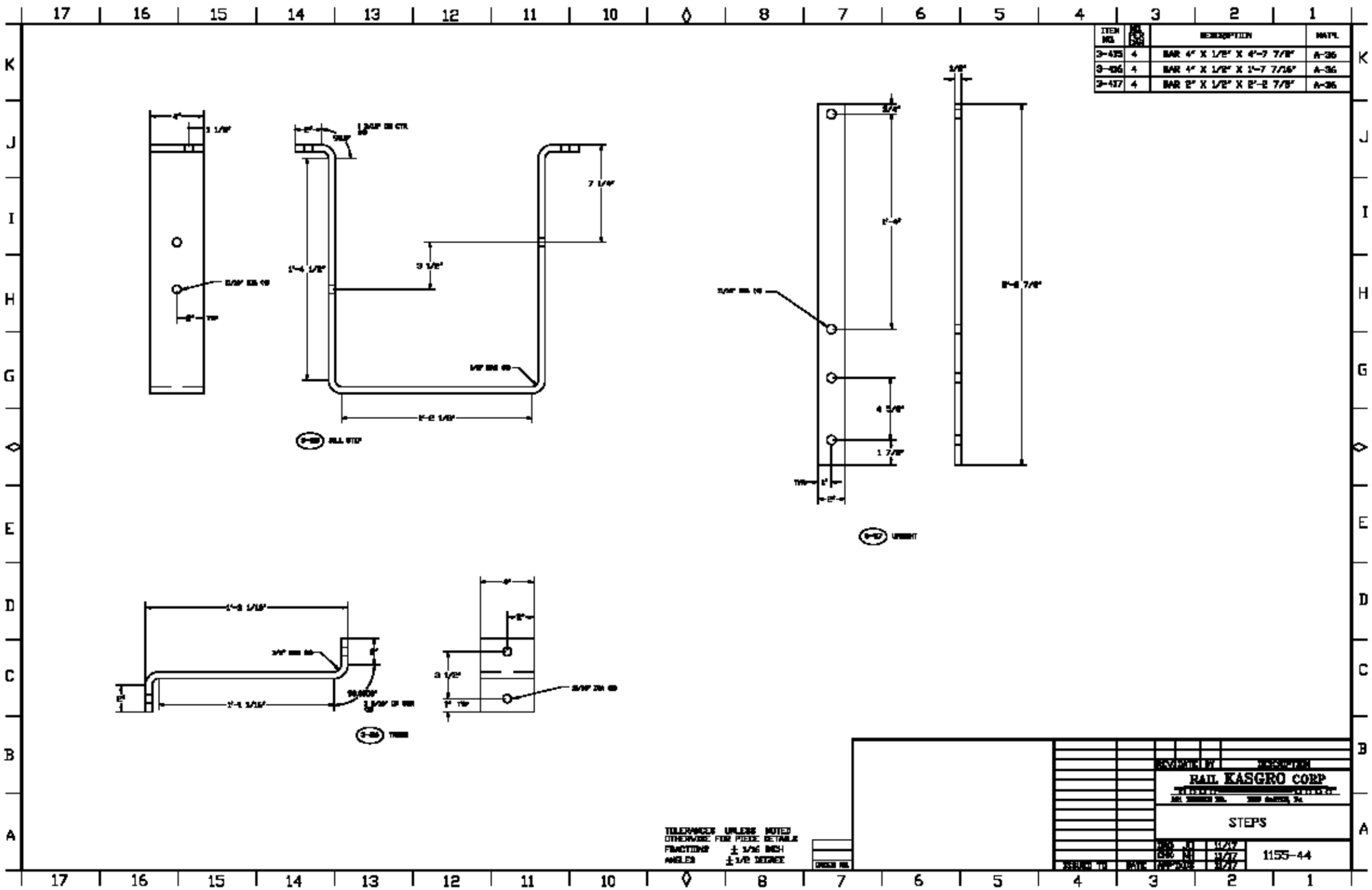
APPENDIX G-1.42 SHEAVE BRKTS



APPENDIX G-1.43 HB STEEL DETAILS



APPENDIX G-1.44 STEPS



APPENDIX G-1.45 ATLAS CASK RAILCAR STRUCTURAL ANALYSIS

KASGRO RAIL

ATLAS 12 AXLE FLAT CAR

S-2043 4.1 Structural Analysis

HLRM Service

November 2017

Prepared by:

Nicholas Hinsch

Checked by:

Jon Odden

CONTENTS

Introduction:

The 12 axle flat car is made up of a flat car body, two tri-spans and end platforms. The car body has been analyzed in FEA and classical methods. Classical methods are used to determine normal stresses. FEA was used to verify and refine the classical method.

The classical method was done using spreadsheets and hand calculations. Input data and output data are explained prior to the center line calculations. There are hand calculations shown to verify the spread sheet and show how the numbers are derived.

The finite element analysis was done first by modeling one quarter of the car body using Autodesk Inventor version 10. The model then was exported to Algor finite element analysis software 19.1. Symmetry was used to minimize model size. Models are shown prior to each input.

Component Stenciling: Refer to drawing 1155-3 for stencil details. (S-2043 4.1.7.2)

Material:

Multiple materials have been used for the car body including ASTM 1045, A-572 60 and A-656 80. Material selection has been assigned according to all stress results.

Top Flange (deck plate): A-572 60

Bolster Assembly: A-572 60

Center and side sill webs: A-572 60

Cross members: A-572 60

Center and side sill bottom flanges: A-572 60

Side Sill Cover Plate: A-656 80

Centers plates: ASTM 1045

Weld Rod Material:

All material is to be welded with E80XX weld wire. Majority of the car body and tri-span will be fabricated out of A-572 Grade 60 material.

Design Parameters:

The 12 axle analysis consists of the following for the car body: (S-2043 4.1.5) AAR Standard Load Cases

Vertical and longitudinal loads and forces are applied per AAR MSRP Section C Part II.

- Dead and Live Loads (S-2043 4.1.5.1,4.1.5.2) (M-1001, paragraph 4.1.2)
- Buff Load (350-kip compressive force applied at coupler and 517 kip vertical) (S-2043 4.1.5.1) (M-1001, paragraph 4.1.2)
- Draft Load (350-kip tension force applied at coupler and 517-kip vertical) (S-2043 4.1.5.6) (M-1001, paragraph 4.1.9)

- Squeeze Load (1,000-kip compression force applied at coupler and 517-kip vertical) (S-2043 4.1.5.7) (M-1001, paragraph 4.1.9)
- Dead and Live Load deflections (517-kip vertical) (S-2043 4.1.5.1-4.1.5.2)
- The 517-kip vertical load will be applied at inboard and outboard attachments. The total vertical load consists of the Hi-Star 190 cask and cradle, the weight of the end stops and all attachments. However, the distributed dead load is shown in the shear and moments diagrams. The attachment weight will also be included in the light weight of the car.

A load factor of 1.8 will be applied to the live, dead, buff and draft loads. The squeeze load will only have a load factor of 1.0. Deflections will not include a load factor.

All stresses were below yield to where each steel grade was applied in both FEA and classical methods.

<u>Margin of Safety:</u> (S-2043 4.1.5.9)

This is a summary of maximum stresses and minimum margins of safety. Members of the car body with max stresses are made from A-572 Grade 60 and A-656-80 material. There are higher stresses found in the transition area. The car body bolsters are made from A-572 60, however the stresses in the bolster sections are well below the yield. The max stresses for each cross section of the car body were derived from the finite element analysis of both symmetrical and unsymmetrical loading. (S-2043 4.1.5.9)

Mechanical Properties of A-572 60: Yield = 60 ksi min, Ultimate Tensile = 75 ksi min

Mechanical Properties of A-572 60: Yield = 60 ksi min, Ultimate Tensile = 75 ksi min

Mechanical Properties of A-656 80: Yield = 80 ksi min, Ultimate Tensile = 90 ksi min

(T) – Member in Tension (C) – Member in Compression

AAR Section 4.2.2.1.2 (The allowable design stress shall be the yield or 80% of ultimate, whichever is lower.)

M.S. = (Allowable stress/Actual stress) -1

Member	Max Stress	Allowable Stress	Margin of Safety	Pg.
Top Flange (C)	51.1 ksi	60 ksi	0.17	25
Cover Plate (T)	49.7 ksi	72 ksi	0.45	26
Side Sill flange (T)	54 ksi	60 ksi	0.11	26
Center Sill Flange (T)	47.9ksi	60 ksi	0.25	27
Body Bolster Webs (Shear)	12.9 ksi	29 ksi	1.24	16
Body Bolster Flange (T)	27.6 ksi	60 ksi	1.17	16
Car Body Web (Shear)	9.46 ksi	29 ksi	2.07	12
Cross Bearer (Shear)	11.16 ksi	29 ksi	1.60	19

Spreadsheet Analysis Comments:

Section properties, bending stress, axial stress, combined stress, shear flow, and shear stress are calculated using an excel spreadsheet.

Inputs:

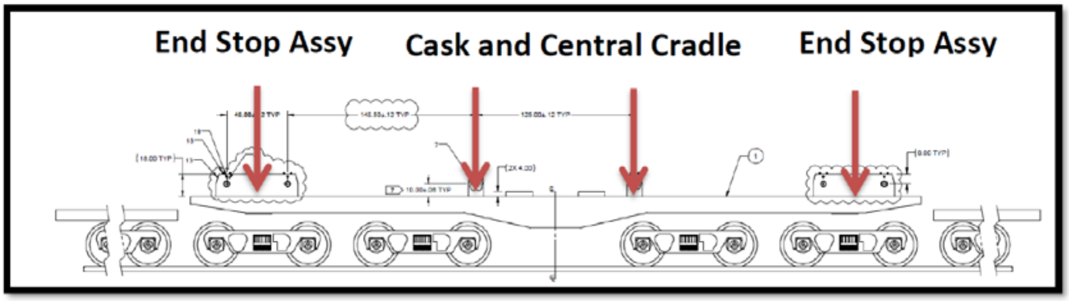
CG	Distance from element cg to top fiber
Deck Height	Section Height
Moment	Bending Moment (ft.-kips)
Shear	Vertical Shear Force (kips)
Axial	Axial Load (kips)
Load Factor	Applied Load Factor to Stresses

Outputs:

Q-Full	Static moment of section area about neutral axis using full section (in^3)
Shear Flow	Load factor (usually1.8) times shear divided by moment of inertia (k/in). Used for weld sizes
Total Area	Section Area (in^2)
Inertia	Moment of inertia (in^4)
Eccentric	Eccentricity between neutral axis and force applied at center plate
Induced moment	Eccentric distance time axial for applied at center plate
M/S	Stress due to moment (ksi)
P/A	Stress due to axial load (ksi)
M/S + P/A	Total combined stress (ksi)
VQ/IT	Shear stress at neutral axis (ksi)
T	Thickness of a member

All stresses were below yield to where each steel grade was applied in both FEA and classical methods.

Model for Analysis:



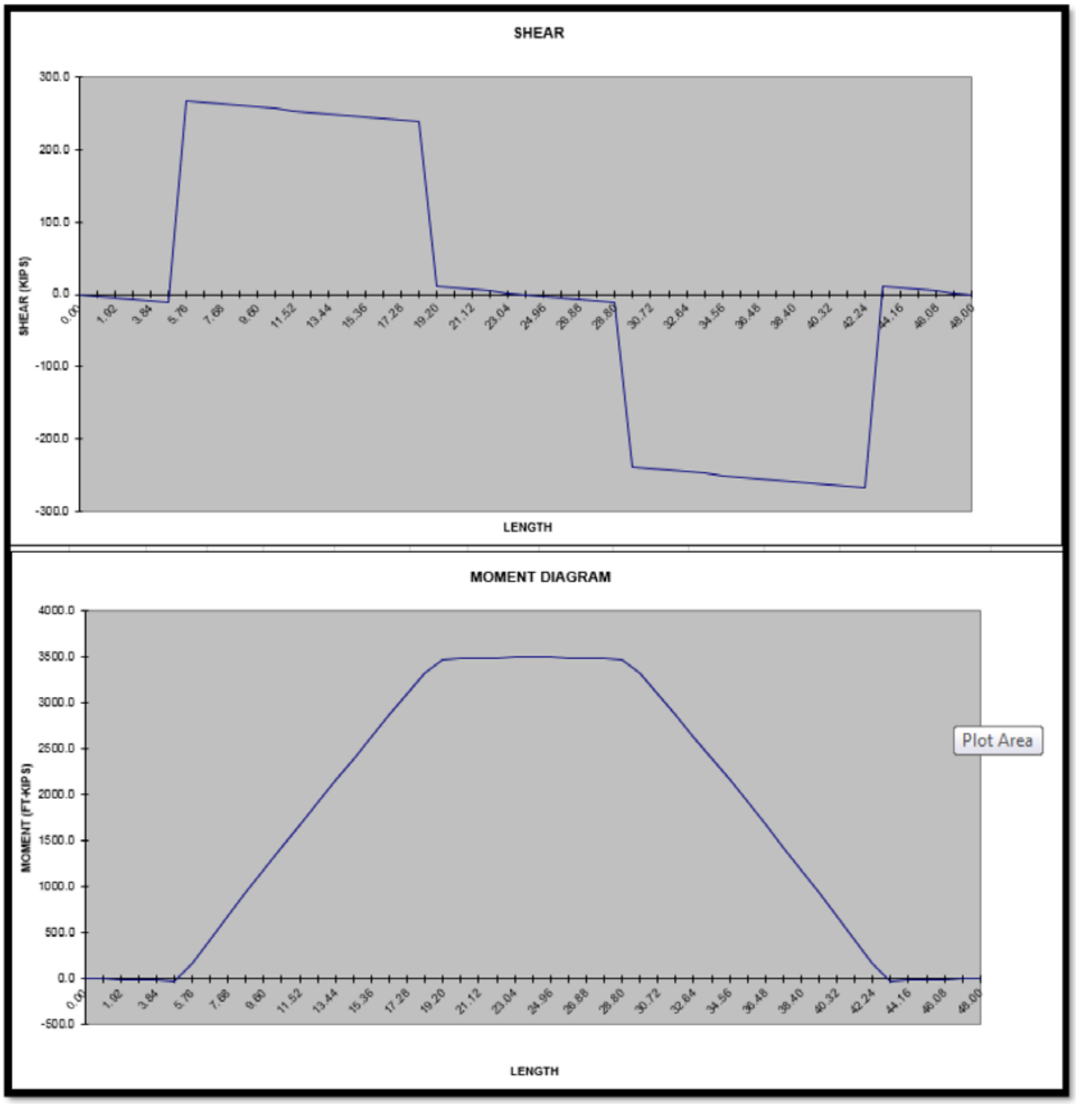
Free Body Diagram for Different Cask Families

The Atlas rail car loading is shown in the figures above and below. A shear and moment diagram was created to show the HI-Star 190 loading on the car body of the Atlas rail car. The weight of the cask and cradle was applied at the inboard attachments shown below. The car body distributed load including attachment weight is shown in the uniform load columns. The car body comes out to 48 ft. in length and estimated at 2.34 kip/ft. which was derived from the FEA model. Concentrated loading of the cask and cradle of the HI- Star 190 are shown, due to symmetry, a vertical load of 112.5 kip was applied at each inboard attachment. This is done to find the max bending moment and shear force subjected to the car body. The distance between vertical supports (truck centers) is 38 ft. which is shown on the left. That leaves an overhang of 5 ft. on each side of the railcar. The concentrated loads occur 62.5 inches each way off center, dimensions (x) shown below are distances shown from left edge of the car body for hand calculation purposes.

SHEAR AND MOMENT DIAGRAMS

			CONCENTRATED LOAD		UNIFORM LOAD		
			P	X	w	X1	X2
OH1=	5		225	18.8	2.34	0	48
TC=	38.0000		225	29.2	0	0	0
OH2=	5						
RL=	281.16						
RR=	281.16						
		SUM	450				

Car Body Shear and Moment Diagram for Symmetrical Loading of HI- Star 190 on Center



Loading Summary:

Concentrated loading at pin connections

Horizontal distances from left side of car body: 18.8125ft. and 29.1825ft.

Overhang from left center plate (left vertical reaction) to left side of car: 5 ft.

Overhang from right center plate (right vertical reaction) to right side of car: 5 ft.

Vertical supports (5 ft. from each end): 38 ft.

Overall Length: 48 ft.

Dead Load: Distributed uniform over 48 ft.

Live Load: Concentrated loads applied on pin connections

Live Load: 450 kip (conservative for cask and cradle)

Dead Load: 112.32 kip (2.34 kip/ft. including weight of attachments)

Vertical Reaction Left: 281.16 lbs.

Vertical Reaction Right: 281.16 lbs.

Max Moment: 3500 kip-ft. on centerline.

Max Vertical Shear Force on car body under symmetrical loading: 267.7 kip at vertical supports. (Just inboard of body bolsters)

Note: The HI-Star 190 loading of 450 kip is the max vertical loading of the railcar combined with the AAR train action forces. The HI-Star 180 loading (referred on page 34) is the max unsymmetrical loading while the car is being unloaded. The car will not experience train action forces but the load will be rotated off of centerline of the Atlas railcar.

Section Elements and Properties on Center Line

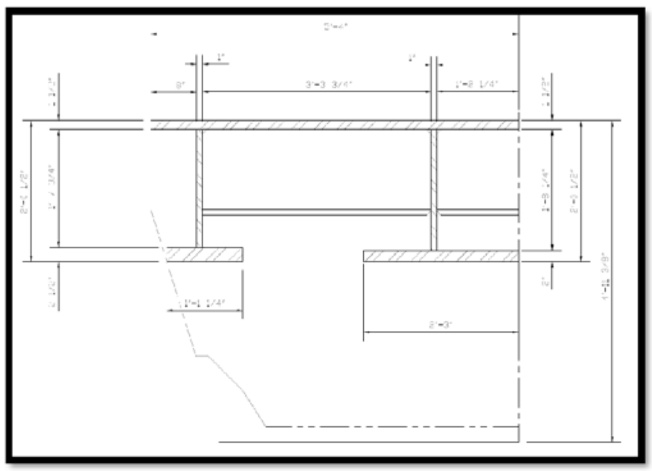
This section of the car will be analyzed with the moment of the static HI-Star 190 loading scenario (worst case) along with the AAR Buff, Draft and Squeeze loading. Below is the base, height and centroid of each member in the cross section. A general image of the cross section is shown below. Refer to drawing 1155-1 for further cross section details.

Parallel Axis Theorem:

Part	Thickness (in)	CG (in)	Height (in)
Top Flange	128.00	0.75	1.50
Center Webs	2.00	11.63	20.25
Bottom Flange	54.00	22.75	2.00
Side Sill Webs	2.00	11.38	19.75
Side Sill Bottom Flanges	26.50	22.13	2.50

Section Properties and Plate E:

N-A (from top)	11.18 (in)
Total Area	446.25 (in^2)
Deck Height	23.75 (in)
Eccentric	4.57 (in)
Moment	3500.0 (kip-ft)
Section Modulus Top	-4122.04(in^3)
Section Modulus Bottom	3663.21(in^3)
Inertia	46064.33 (in^4)



Normal Stresses:

AXIAL (kip)	MOMENT (kip-ft)	INDUCED MOMEMNT (kip-ft)	M/S (ksi)		P/A (ksi)	COMBINED LOADING	
0	3500.00	0.00	top	-18.34	0.00	-18.34	ksi
350	3500.00	133.29	bottom	20.64	0.00	20.64	ksi
-350	3500.00	-133.29	top	-19.04	1.41	-17.63	ksi
-1000	3500.00	-380.83	bottom	21.42	1.41	22.84	ksi
			top	-17.64	-1.41	-19.05	ksi
			bottom	19.85	-1.41	18.44	ksi
			top	-9.08	-2.24	-11.32	ksi
			bottom	10.22	-2.24	7.98	ksi

Shear stress on centerline cross section: (S-2043 4.1.10)

Max vertical shear force center cross section: 9.0 kip

Max vertical shear force between truck centers: 267.7 kip (Just Inboard of body bolster)

Vertical shearing stress = VQ/IT

V= 9.0 kip

I=46064.33 in^4

Q-value for cross section:

Q= A_pY

Q-Deck plate (128 in x 1.5 in) (11.18in-.75in) = 2002.56 in^3

Q-NA: 2002.56in^3 + (11.18in-1.5in) (4in) (4.84in) =2248in^3

Shear flow for deck plate:

Q-deck= (1.8(2002.56in^3) (9.0 kip))/46064.33in^4 = 0.70 k/in

Shear stress at neutral axis:

1.8(9.0 kip) (2248in^3)/((46064.33in^4) (4in)) = 0.20 ksi

Welding deck to webs:

Shear flow = (0.70 k/in)/4 =0.18 k/in per web

Use 3/8 double sided fillet per web good for 0.375 (0.707) (33.06) (2) = 17.5 k/in

Where:

0.375 = weld size (conservative)

0.707 = effective throat at 45 deg angle

33.06 = allowable weld shear stress per AAR Section C table 4.3.4.1.3

2 = double sided fillet

Check whether throat or leg of weld is stronger

Throat strength = 17.5 k/in from above

Leg to base metal strength = 60 (0.58) (0.375) (2) = 26.1 k/in

60 = base material yield stress

2 = double sided fillet

.58 = AAR conversion factor for shear stress

0.375 = weld throat size

Therefore throat calculation governs for Grade 60 Steel

Section Elements and Properties Above Inboard Wheel:

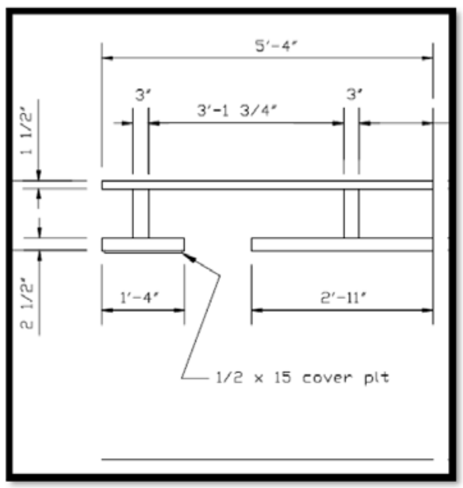
This section of the car will be analyzed with the moment of the static HI-Star 190 loading scenario (worst case) along with the AAR Buff, Draft and Squeeze loading. Below is the base, height and centroid of each member in the cross section. A general image of the cross section is shown below. Refer to drawing 1155-1 for further cross section details.

Parallel Axis Theorem:

Part	Thickness (in)	CG (in)	Height (in)
Top Flange	128.00	0.75	1.50
Center Webs	12	5.75	9.50
Bottom Flange	70.00	11.25	2.50
Side Flange	32.00	11.25	2.50
Cover Plate	30	12.50	0.50

Section Properties:

N-A (from top)	6.71 (in)
Total Area	564.00 (in^2)
Deck Height	13.00 (in)
Eccentric	8.25 (in)
Moment (HI-Star190)	3100.0 (kip-ft)
Section Modulus Top	-2004.17(in^3)
Section Modulus Bottom	2140.70(in^3)
Inertia	13456.21 (in^4)



Normal Stresses:

AXIAL (kip)	MOMENT (kip-ft)	INDUCED MOMEMNT (kip-ft)	M/S (ksi)		P/A (ksi)	COMBINED LOADING	
0	3100.00	0.00	top	-33.41	0.00	-33.41	ksi
350	3100.00	240.63	bottom	31.28	0.00	31.28	ksi
-350	3100.00	-240.63	top	-36.00	1.12	-34.89	ksi
-1000	3100.00	-687.50	bottom	33.71	1.12	34.82	ksi
			top	-30.82	-1.12	-31.93	ksi
			bottom	28.85	-1.12	27.73	ksi
			top	-14.44	-1.78	-16.22	ksi
			bottom	13.52	-1.78	11.74	ksi

Shear stress above inboard wheel cross section:

(S-2043 4.1.10)

Max vertical shear force at section (Hi Star 190): 256.40 kip

Vertical shearing stress = VQ/IT = 4.62 ksi

V= 256.40 kip

Q-NA = 1307.67

I=11088.00in^4

Q-full deck plate: 1144.48 in^3 Shear flow= 47.64 k/in

Q-full center and side sill bottom flanges: 1285.20 in^3 Shear flow = 53.49 k/in

Q-full cover plate 87.00 in^3 Shear flow = 3.62 k/in

Welding deck to webs:

Shear flow = (47.64 k/in)/4 =11.91 k/in per web

Use 3/8 double sided fillet per web good for 0.375 (0.707) (33.06) (2) = 17.5 k/in

Welding flanges to webs: = (53.49 k/in)/4 = 13.37 k/in per web

Side sills use 3/8" double sided fillet per web good for = 17.5 k/in

Center Sill use 3/4" single sided fillet per web good for 17.5 k/in (refer to drawing 1155-1)

Where:

0.375 = weld size (conservative)

0.707 = effective throat at 45 deg angle

33.06 = allowable weld shear stress per AAR Section C table 4.3.4.1.3

2 = double sided fillet

Check whether throat or leg of weld is stronger

Throat strength = 17.5 k/in from above

Leg to base metal strength = 60 (0.58) (0.375) (2) = 26.1 k/in

Where:

60 = base material yield stress

2 = double sided fillet

.58 = AAR conversion factor for shear stress

0.375 = weld throat size

Therefore throat calculation governs for Grade 60 Steel

Shear stress at 10 ft. inboard of body bolster:

(S-2043 4.1.10) Refer to drawing 1155-1 for further cross section details.

Max vertical shear force at section (Hi Star 190): 267.70 kip

Vertical shearing stress = VQ/IT = 9.46 ksi

V= 267.70 kip

Q-NA = 935.10 in^3

I=9527.00in^4

Q-full deck plate: 891.00 in^3 Shear flow= 45.07 k/in

Q-full side sill bottom flanges: 88.32in^3 Shear flow = 17.56 k/in

Q-full bottom flange: 724.5 in^3 Shear flow = 36.64 k/in

Welding deck to webs:

Shear flow = (45.07 k/in)/4 =11.26 k/in per web

Use 3/8 double sided fillet per web good for 0.375 (0.707) (33.06) (2) = 17.5 k/in

Welding side sill flanges to webs: = (17.56 k/in)/2 = 8.75 k/in per web, Center sill: (36.64 k/in)/2 =18.32 k/in

Side sills use 3/8" double sided fillet per web good for = 17.5 k/in

Center Sill use 3/8" single sided fillet plus 1" 60 deg bevel per web good for 29 k/in (refer to drawing 1155-1)

Where:

0.375 = weld size (conservative)

0.707 = effective throat at 45 deg angle

33.06 = allowable weld shear stress per AAR Section C table 4.3.4.1.3

2 = double sided fillet

Check whether throat or leg of weld is stronger

Throat strength = 17.5 k/in from above

Leg to base metal strength = 60 (0.58) (0.375) (2) = 26.1 k/in

Where:

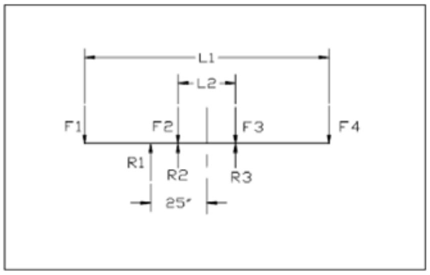
60 = base material yield stress 2 = double sided fillet

.58 = AAR conversion factor for shear stress

0.375 = weld throat size Therefore throat calculation governs for Grade 60 Steel

Bolster Analysis:

BODY BOLSTER

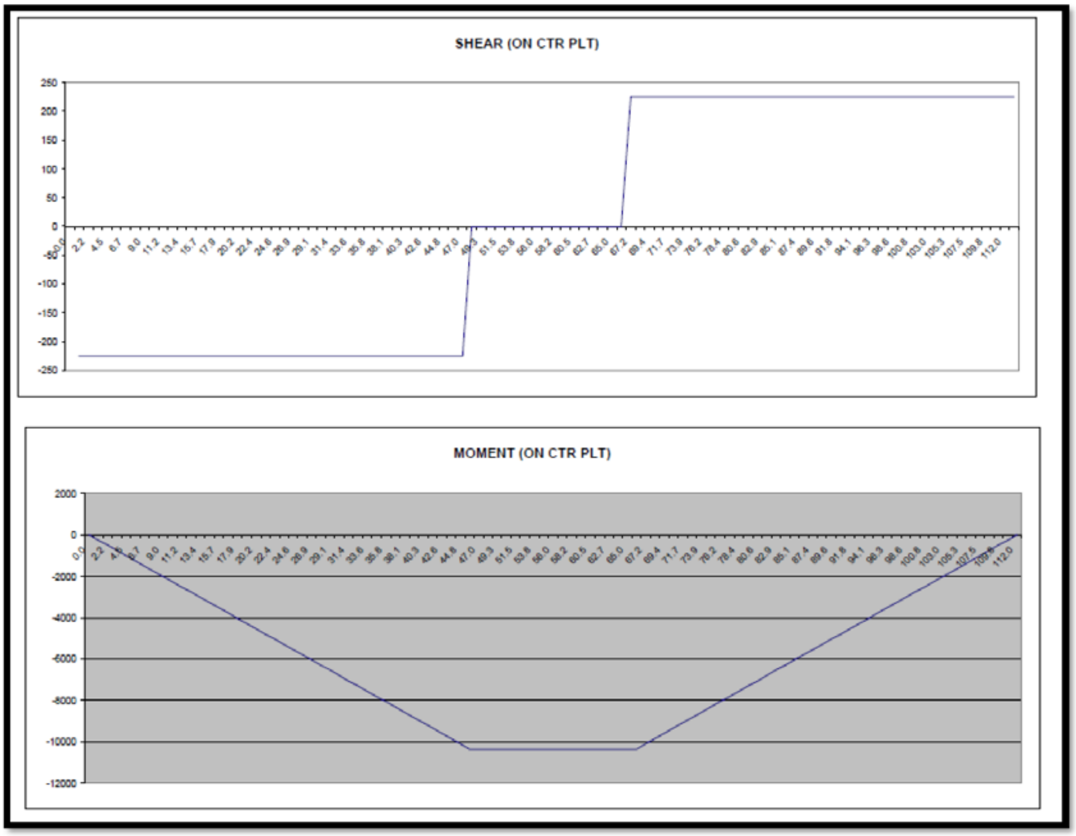


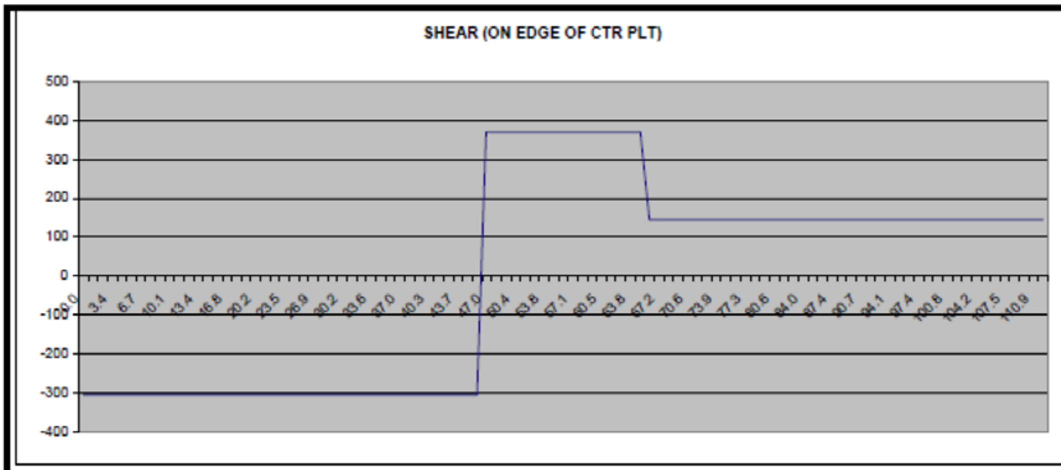
REFERENCE	CTR SILL LOAD	EDGE OF CTR SILL	SIDE BRG LOAD
70 TON TRUCKS	230	230	144
100 TON TRUCKS	300	300	188
125 TON TRUCKS	325	325	207
2-70 TON TRUCKS	460	460	288
2-100 TON TRUCKS	600	600	376
2-125 TON TRUCKS	650	650	414

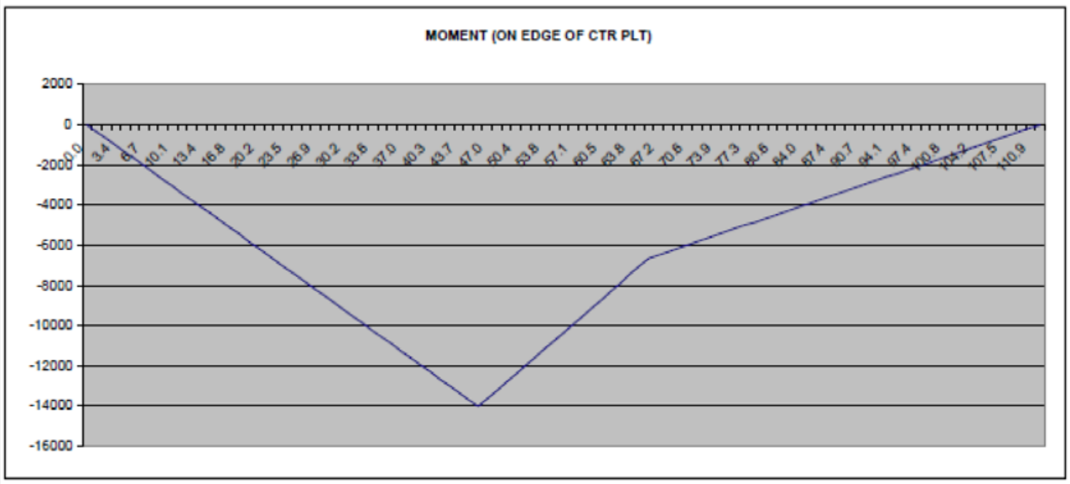
LENGTH (L2)	20	INCHES
LENGTH (L1)	112	INCHES
% CARRIED BY CENTER SILL	50	%
CTR PLT LOAD	900	KIPS
SIDE BEARING LOAD	564	KIPS

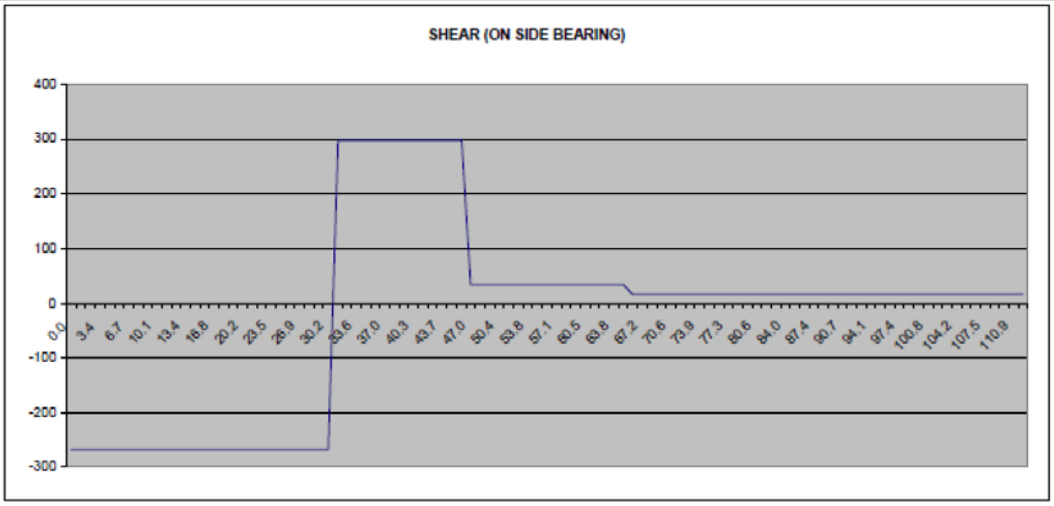
Conservative because wheels not fully loaded and lower span is quite heavy.

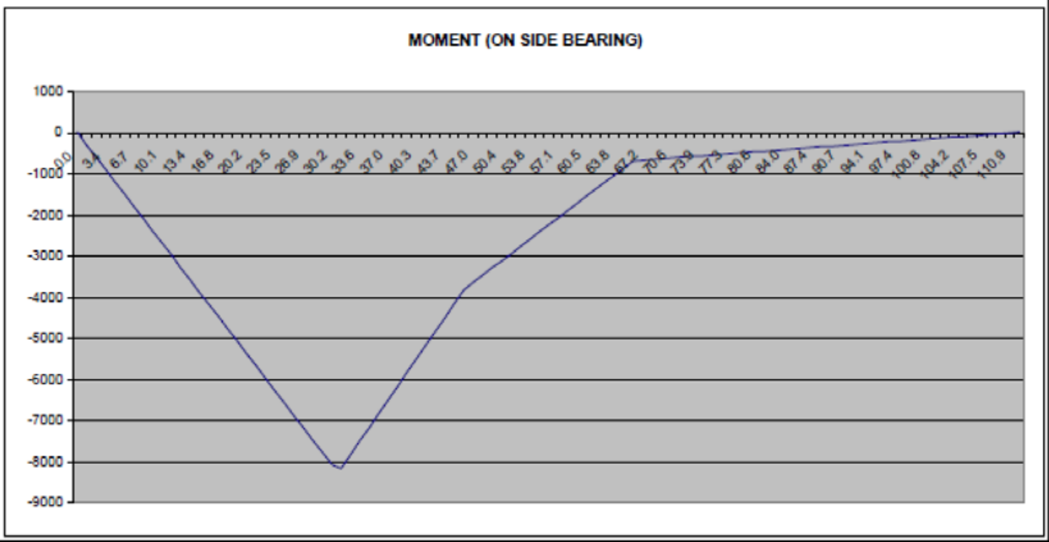
REACTIONS AND FORCES	LOAD ON CTR PLT	LOAD ON EDGE OF CTR PLT	LOAD ON SIDE BRG
F1	225.0	305.4	266.9
F2	225.0	225.0	141.0
F3	225.0	225.0	141.0
F4	225.0	144.6	15.1
R1	0.0	0.0	564.0
R2	450.0	900.0	0.0
R3	450.0	0.0	0.0


SHEAR (ON CTR PLT)
MOMENT (ON CTR PLT)


SHEAR (ON EDGE OF CTR PLT)
500
400
300
200
100
0
-100
-200
-300
-400


MOMENT (ON EDGE OF CTR PLT)
2000
0
-2000
-4000
-6000
-8000
-10000
-12000
-14000
-16000


SHEAR (ON SIDE BEARING)
400
300
200
100
0
-100
-200
-300
0.0 3.4 6.7 10.1 13.4 16.8 20.2 23.5 26.9 30.2 33.6 37.0 40.3 43.7 47.0 50.4 53.8 57.1 60.5 63.8 67.2 70.6 73.9 77.3 80.6 84.0 87.4 90.7 94.1 97.4 100.8 104.2 107.5 110.9


MOMENT (ON SIDE BEARING)
1000
0
-1000
-2000
-3000
-4000
-5000
-6000
-7000
-8000
-9000
0.0 3.4 6.7 10.1 13.4 16.8 20.2 23.5 26.9 30.2 33.6 37.0 40.3 43.7 47.0 50.4 53.8 57.1 60.5 63.8 67.2 70.6 73.9 77.3 80.6 84.0 87.4 90.7 94.1 97.4 100.8 104.2 107.5 110.9

Bolster Analysis:

This section of the car will be analyzed to AAR M-1001 (4.4.8). Below is the base, height and centroid of each member in the cross section. A general image of the cross section is shown below. A general cross section of the bolster is shown below. All data was taken from the shear and moment diagrams shown above. Refer to drawing 1155-1 for further cross section details.

The bolsters were analyzed using the loading for 100 ton trucks.

Thus,

V= 375 kip
Q-top = 249.75 in^3
Q-bottom = 267.00 in^3

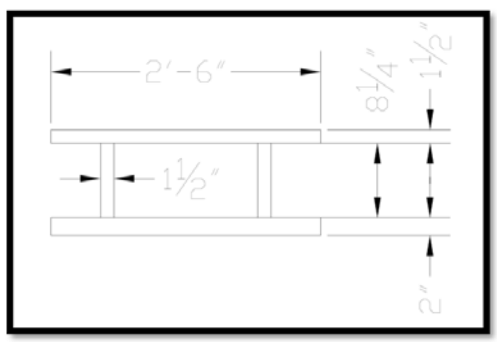
Shear flow top = (375 kip (249.75 in^3))/ 2754.35 in^4 = 34 k/in
Shear flow bottom = (375 kip (267.00in^3))/ 2754.35 in^4 =36.35 k/in

(S-2043 4.1.10)

Shear (VQ/IT) = (375 kip) (284.31 in^3) / ((2754.35 in^4) (3 in)) = 12.9 ksi @ neutral axis

M/S top = -32.03 ksi
M/S bottom= 27.66 ksi

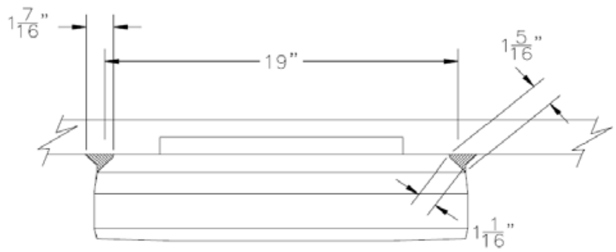
N-A (from top)	6.30 (in)
Total Area	129.75(in^2)
Deck Height	11.75 (in)
Eccentric	0 (in)
Moment	1166 (ft-kip)
Section Modulus Top	-436.91(in^3)
Section Modulus Bottom	505.77(in^3)
Inertia	2754.35 (in^4)



Refer to drawings 1155-1 and 1155-8 for welding instructions

CENTER PLATE WELD

Weld shown in cross-hatched area



Check for weakest throat (based on base material or weld material)

1 7/16" q = 1.4375 x 29 = 41.7 k/in

1.3125" q = 1.3125 x 20.88 = 27.7 k/in ← governs

1 1/16" q = 1.0625 x 33.06 = 35.1 k/in

Center plate connection good for (27.7) (pi) (19) = 1653 kips

(Does not include mechanical connection.)

Cross Bearer Analysis:

This section of the car will be analyzed to AAR M-1001. Below is the base, height and centroid of each member in the cross section. A general image of the cross section is shown below. A general cross section of the bolster is shown below. All data was taken from the shear and moment diagrams shown above. Refer to drawing 1155-1 for further cross section details.

Cross bearer must carry 37.5% of the live load (450 kip), less that carried by the side sill, back to the center sill.

Estimate that 50% of the load is carried by the center sill and each side sill carries 25%.

Thus,

450 kip (.375) (0.5) = 84.36 kip
Length of Cross Bearer= 40 in

Moment = 40in (84.36 kip) = 3374 in-k = 281.17 ft-kip

V= 84.36 kip

Max Stress on top = 1.8 (3374 in-k / 252.70 $in^{3)}$ = 24.03 ksi tension on top flange

Max Stress bottom flange = 1.8 (3374 in-k / 184.44in^3) = 32.9 ksi compression on bottom flange

Shear (VQ/IT) = 1.8 (84.36 kip) (128.34 in^3) / ((1745.91 in^4) (1 in)) = 11.16 ksi @ neutral axis

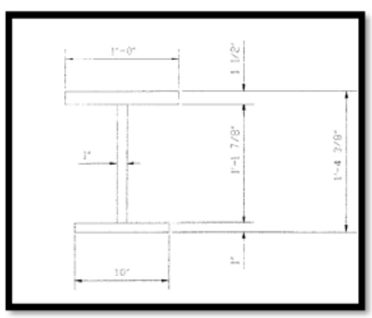
Q top flange =110.90 in^3

V= 84.36 kip

Shear Flow = q= 1.8 84.36 kip (110.9 in^3) / 1745.91 in^4 = 9.55 k/in
(S-2043 4.1.10)

Use 0.375 fillet weld both sides to both top and bottom flange (17.5 k/in)

N-A (from top)	6.91 (in)
Total Area	41.88 (in^2)
Deck Height	16.38 (in)
Eccentric	0 (in)
Moment	281.17 (ft-kip)
Section Modulus Top	-252.70(in^3)
Section Modulus Bottom	184.44(in^3)
Inertia	1745.91 (in^4)



COOPER RATING
KASGRO RAIL CORP
Atlas Cask Car (S-2043 4.7.9.2)

LOAD	AXLE SPACING
65.75	6
65.75	4.5
65.75	6
65.75	4.5
65.75	6
65.75	11.5
65.75	6
65.75	4.5
65.75	6
65.75	4.5
65.75	6
65.75	0

SPAN	BENDING		END SHEAR		FLOOR BEAM REACTION	
FT	FT-KIPS	E	KIPS	E	KIPS	E
6	99	65.7	80	68.7	82	61.6
8	136	67.9	94	68.3	111	63.2
10	197	70.2	101	67.3	128	64.0
12	260	65.1	112	64.1	156	66.9
13	297	62.5	120	65.2	169	68.8
14	346	62.9	126	65.3	180	69.2
15	395	63.3	131	65.3	191	69.8
16	445	63.5	137	64.3	199	70.1
18	543	63.9	150	64.5	219	72.2
20	654	63.4	160	63.9	237	72.2
25	1019	66.8	192	67.5	276	72.9
30	1430	69.7	217	68.8	316	73.2
35	1899	72.6	241	69.6	361	74.1
40	2389	72.9	259	68.6	409	75.6
45	2880	72.0	283	69.4	451	75.8
50	3452	73.0	308	70.4	485	75.1
60	4751	73.4	364	73.8	536	69.7
70	6347	74.3	417	75.5	572	64.4
80	8267	76.4	459	73.9	599	60.0
90	10230	76.4	497	72.4	620	56.4
100	12195	75.5	525	70.0	637	53.4
110	14162	70.8	552	68.3	651	51.0
120	16130	69.9	571	65.7	662	48.4

Kasgro Rail Corporation Page 20

130	18099	66.4	584	63.1	672	46.4
140	20067	64.5	603	61.3	681	44.0
150	22036	63.0	616	59.9	688	42.3
160	24005	60.1	622	56.8	694	40.2
170	25975	58.0	635	55.7	700	38.6
180	27946	56.5	642	53.4	705	36.8
200	31888	53.5	656	50.1	713	33.9
225	36816	50.2	670	46.4	721	30.8
250	41744	47.2	683	43.5	728	28.2
275	46673	44.5	692	40.7	734	26.0
300	51601	42.1	702	38.4	738	24.1
350	61461	37.6	713	34.2	746	21.0
400	71322	33.9	720	30.8	751	18.5

FEA INTRODUCTION:

FEA was used to verify the classical analysis of the car body. Also, to get an accurate analysis of deflections, stresses and transition areas. The car body was modeled with quarter symmetry. The model was created in Autodesk inventor and analyzed in Algor FEA software. (S-2043 4.1.3)

Car Body Weight: 83,000 lbs. (EST. 112,000 lbs. with attachments) Material: A572 60

Element Type: Brick

Meshed Model of car body with quarter symmetry:

Translational (Z), Rotational (X) and Rotational (Y) on Longitudinal Centerline

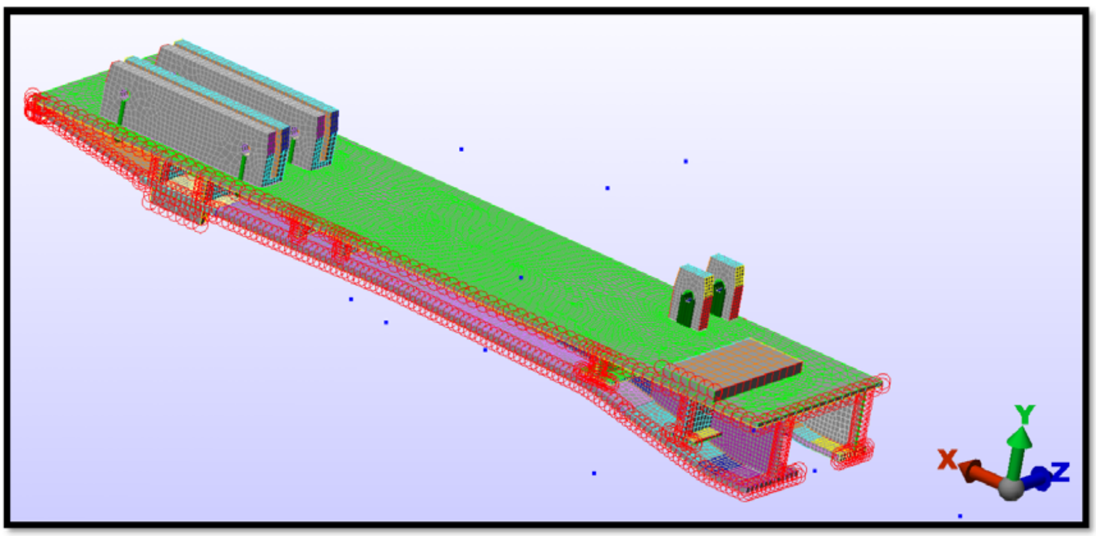
Translational (X), Rotational (Y) and Rotational (Z) on Lateral Centerline

Loads applied at inboard and outboard attachments

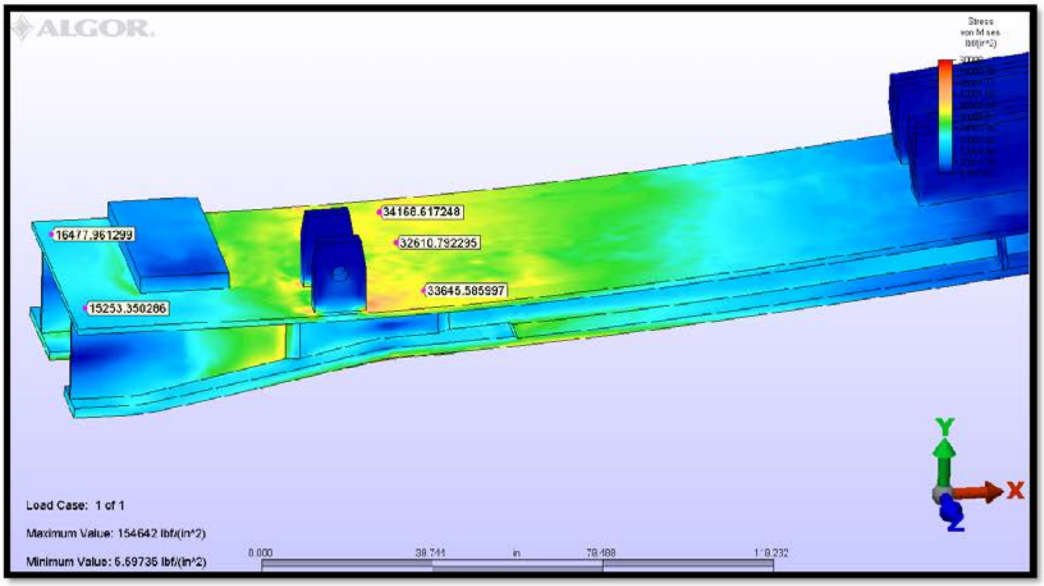
Translational (Y) constraint on center plate

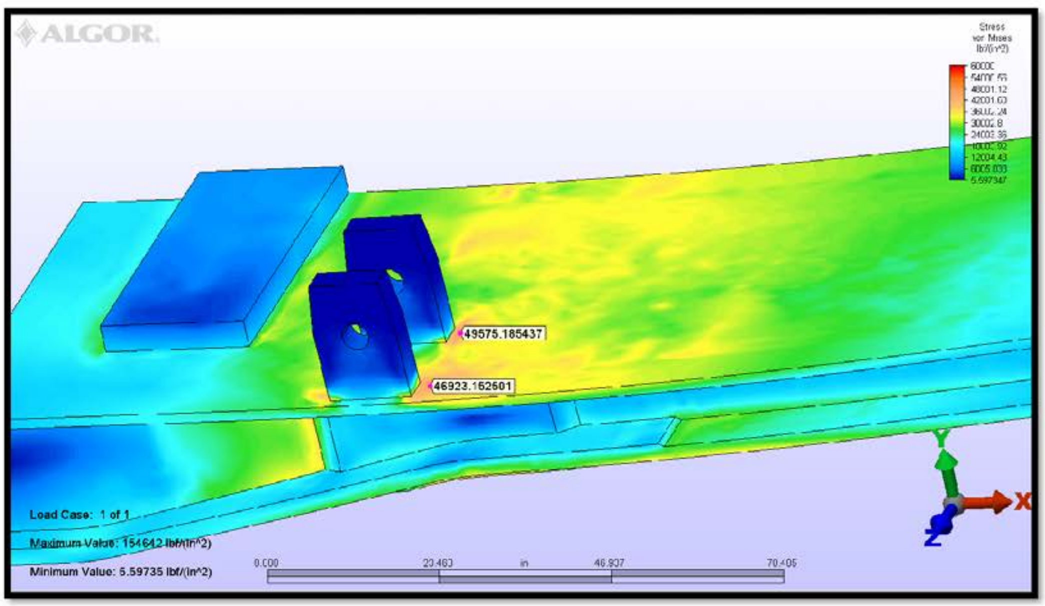
Jacking Load: Half symmetry, Translational (Z), Rotational (X) and Rotational (Y) with Translation (Y) constraints on all jacking pads.

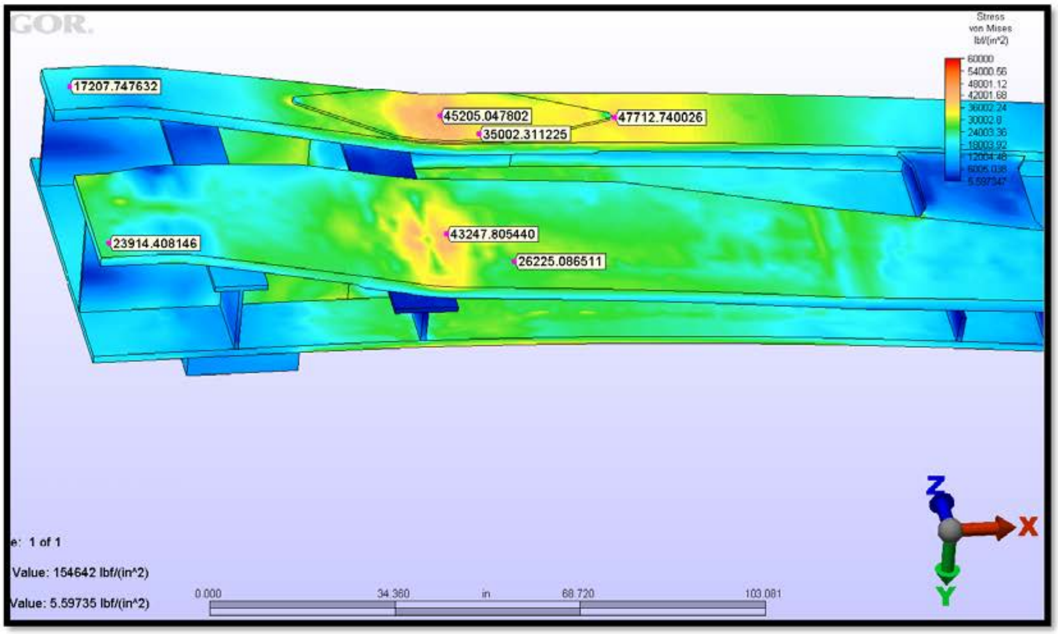
Refer to drawing 1155-1 for Jacking Pad locations.



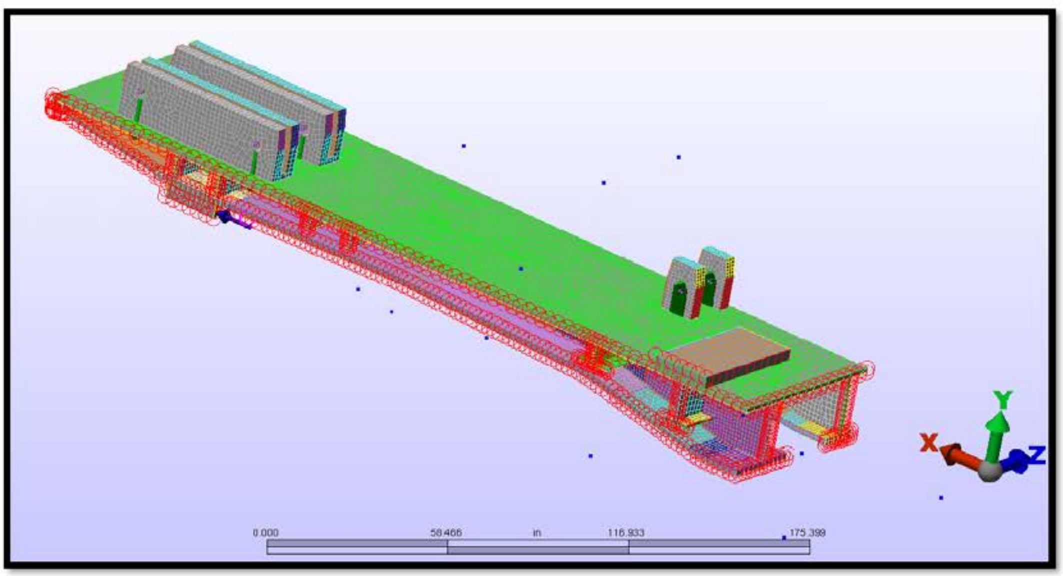
No axial load applied at coupler:

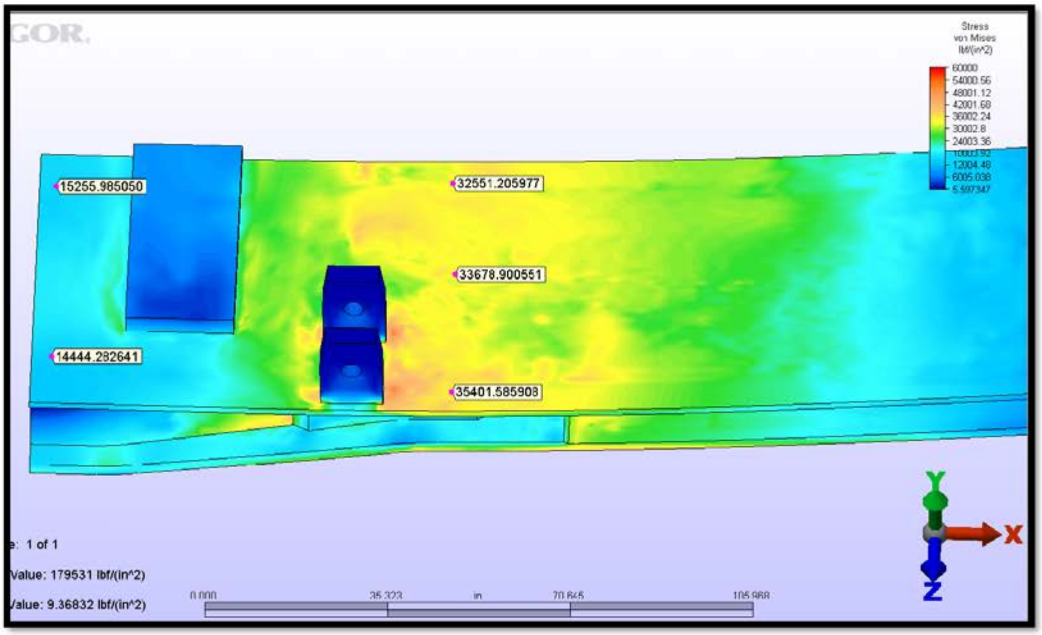


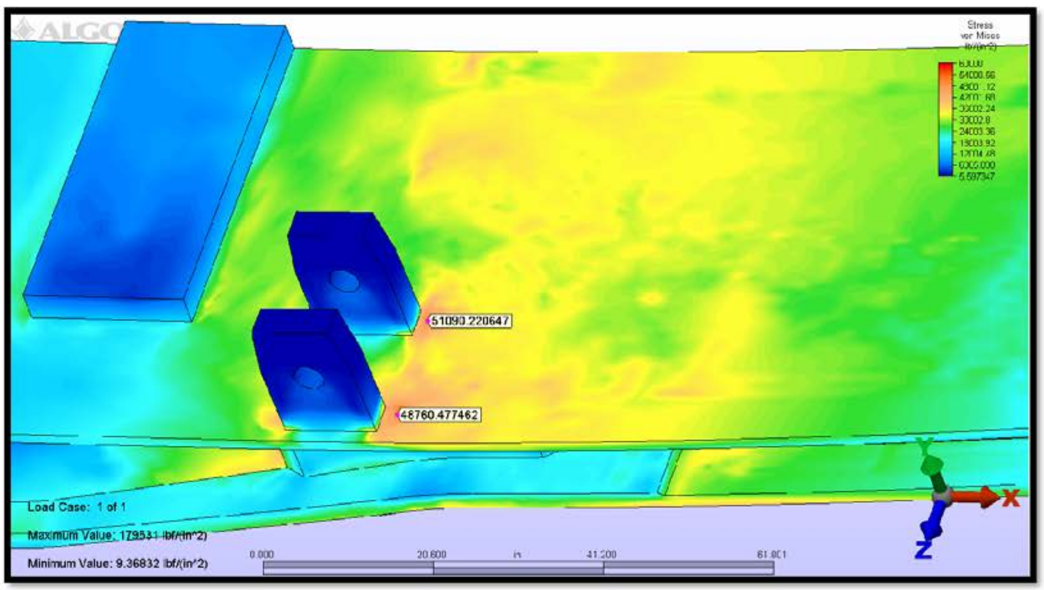


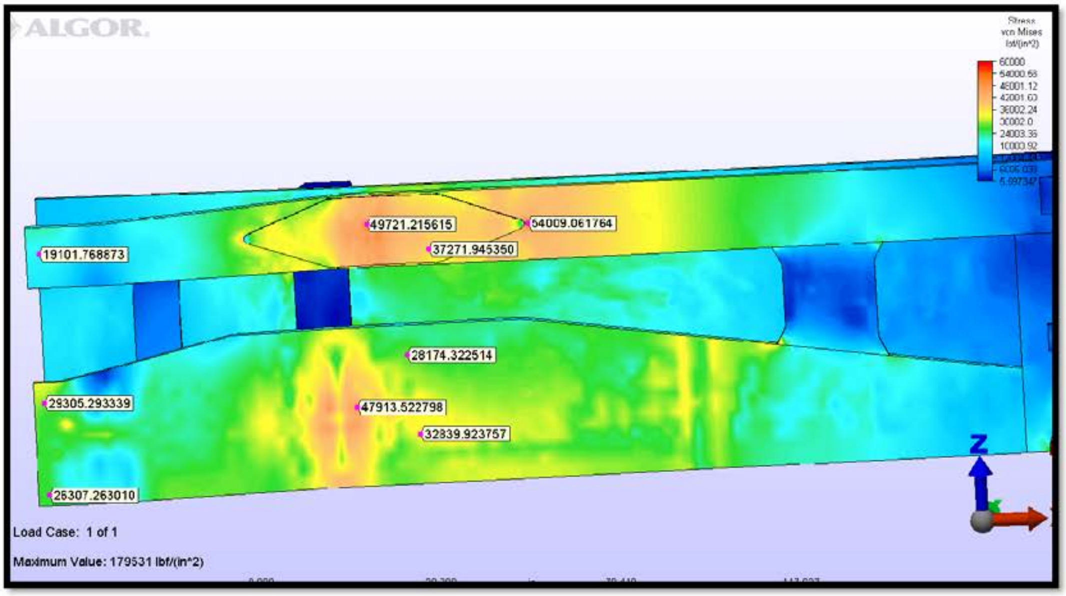

Stress
von Mises
lbf/(in^2)
60000
54000.56
48001.12
42001.68
36002.24
30002.8
24003.36
18003.92
12004.48
6005.036
5.59735
17207.747632
45205.047802
47712.740026
35002.311225
23914.408146
43247.805440
26225.086511
e: 1 of 1
Value: 154642 lbf/(in^2)
Value: 5.59735 lbf/(in^2)
0.000
34.360
in
68.720
103.081
Z
X
Y

Draft Load:

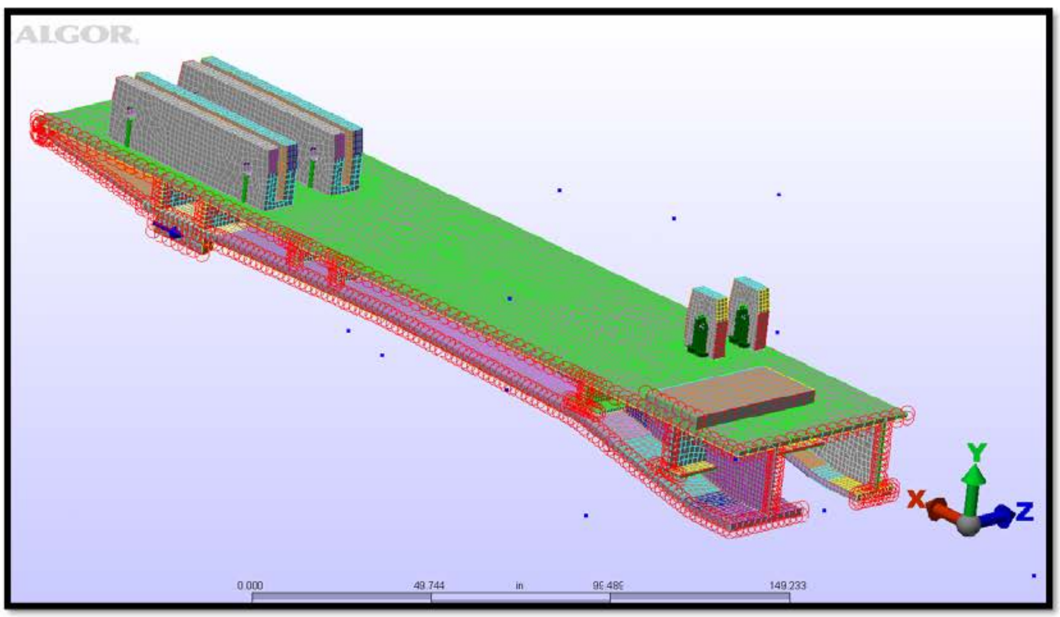

0.000
58.466
in
116.933
175.399
Y
X
Z

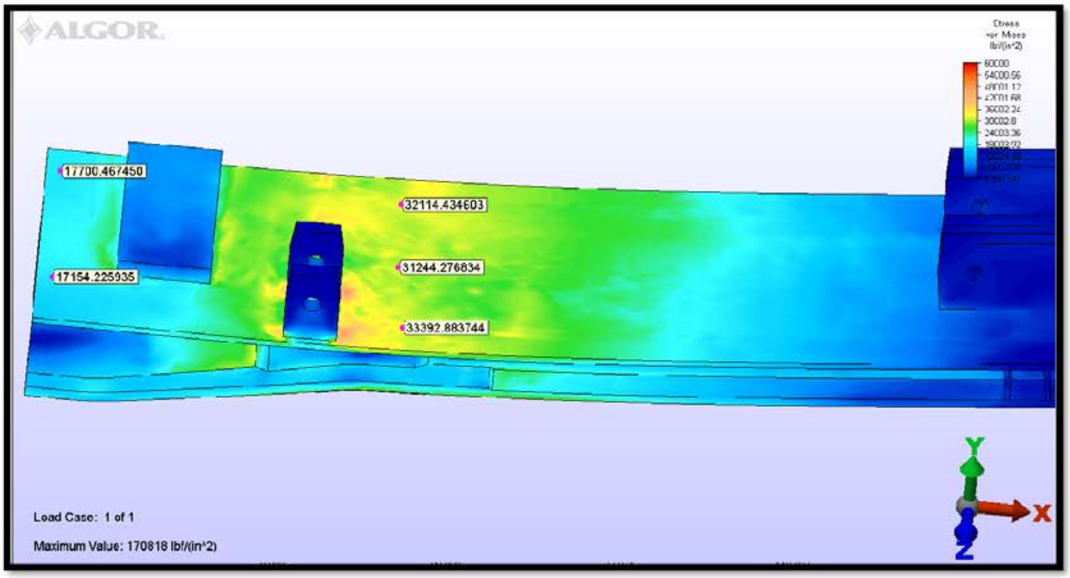

15255.985050
32551.205977
33678.900551
14444.282641
35401.585908
1 of 1
Value: 179531 lbf/(in^2)
Value: 9.36832 lbf/(in^2)

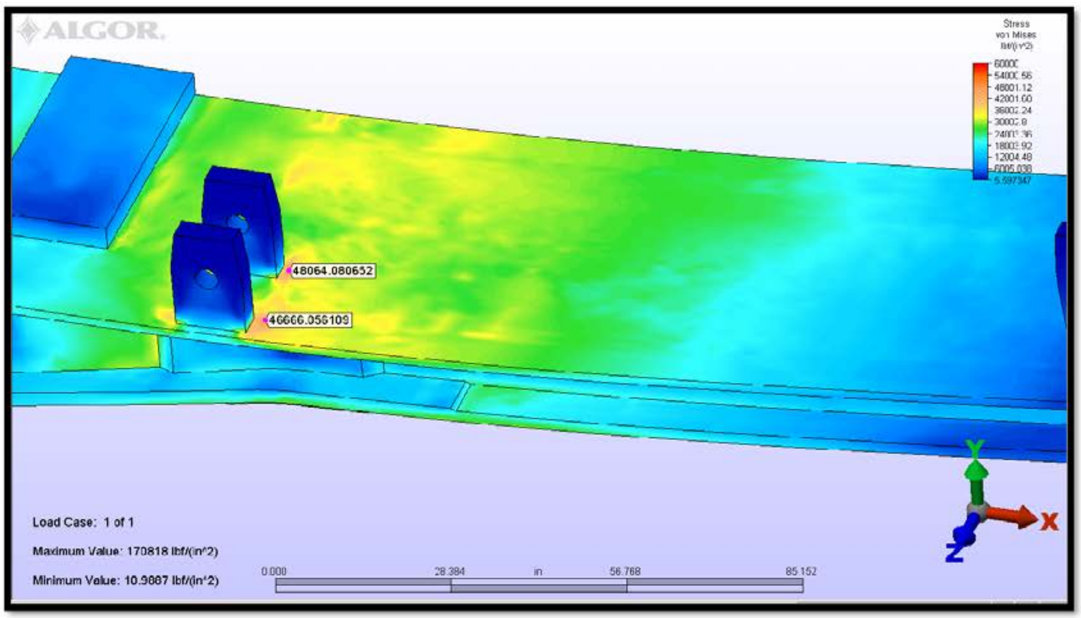

51090.220647
48760.477462
Load Case: 1 of 1
Maximum Value: 179531 lbf/(in^2)
Minimum Value: 9.36832 lbf/(in^2)

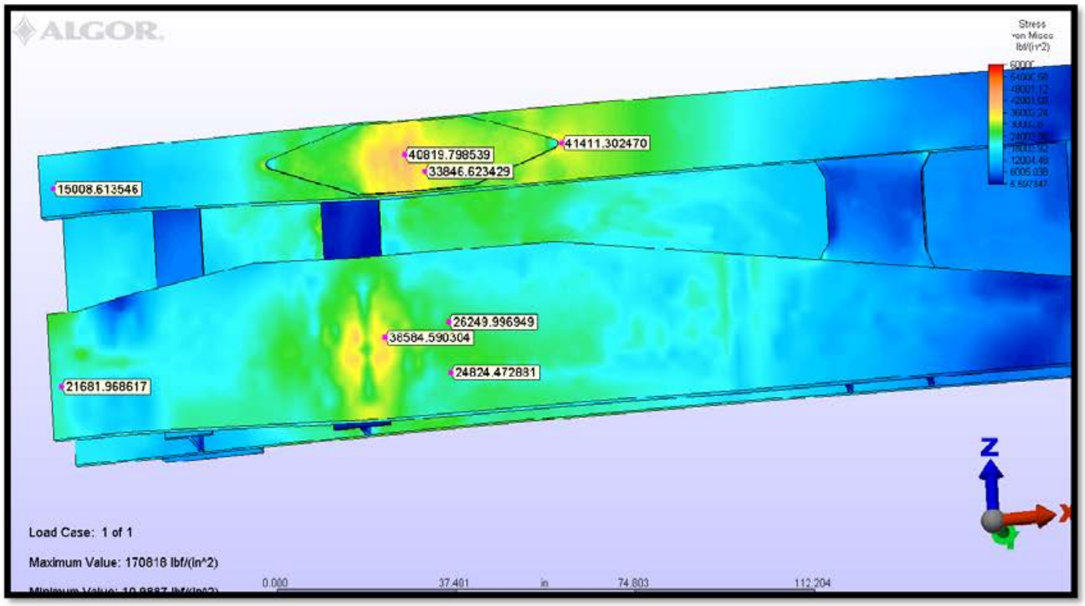

ALGOR.
Stress
von Mises
lbf/(in^2)
60000
54000.68
48001.12
42001.63
36002.24
30002.0
24003.36
18003.92
49721.215615
54009.061764
37271.945350
19101.768873
28174.322514
29305.293339
47913.522798
32839.923757
26307.263010
Load Case: 1 of 1
Maximum Value: 179531 lbf/(in^2)

Buff Load:

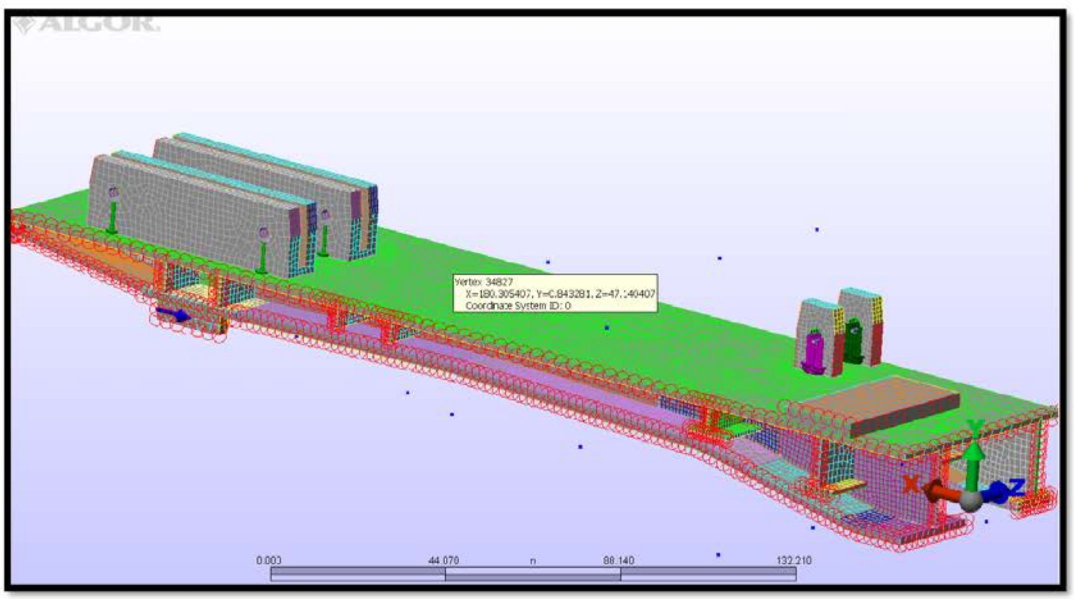

ALGOR.
0.000
49.744
in
149.233

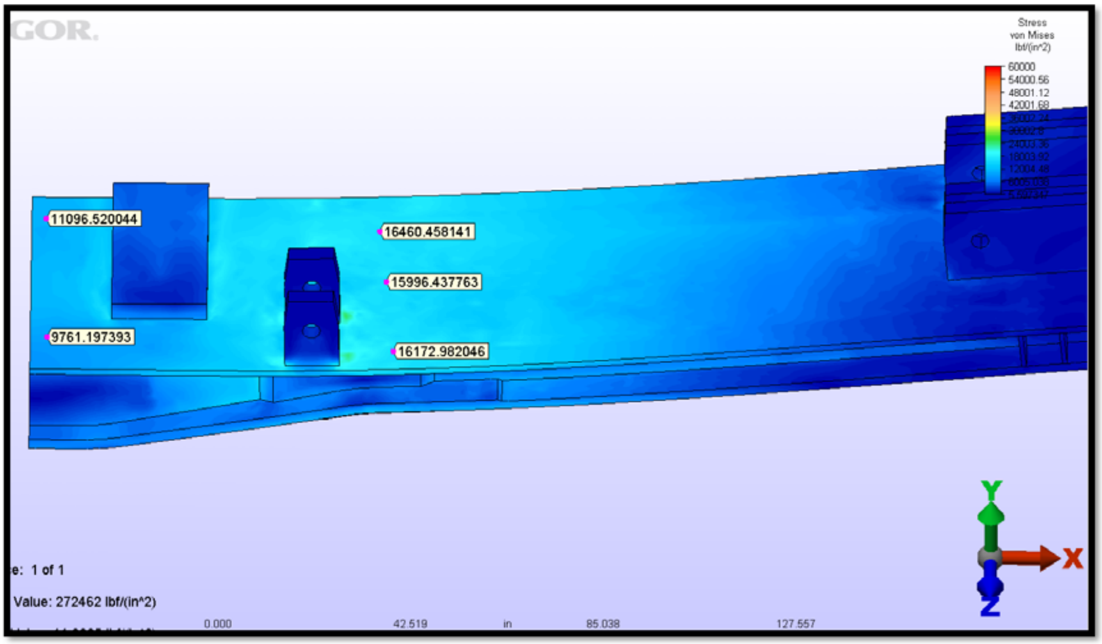

ALGOR
17700.467450
17154.225935
32114.434603
31244.276834
33392.883744
Load Case: 1 of 1
Maximum Value: 170818 lbf/(in^2)
Y
X
Z

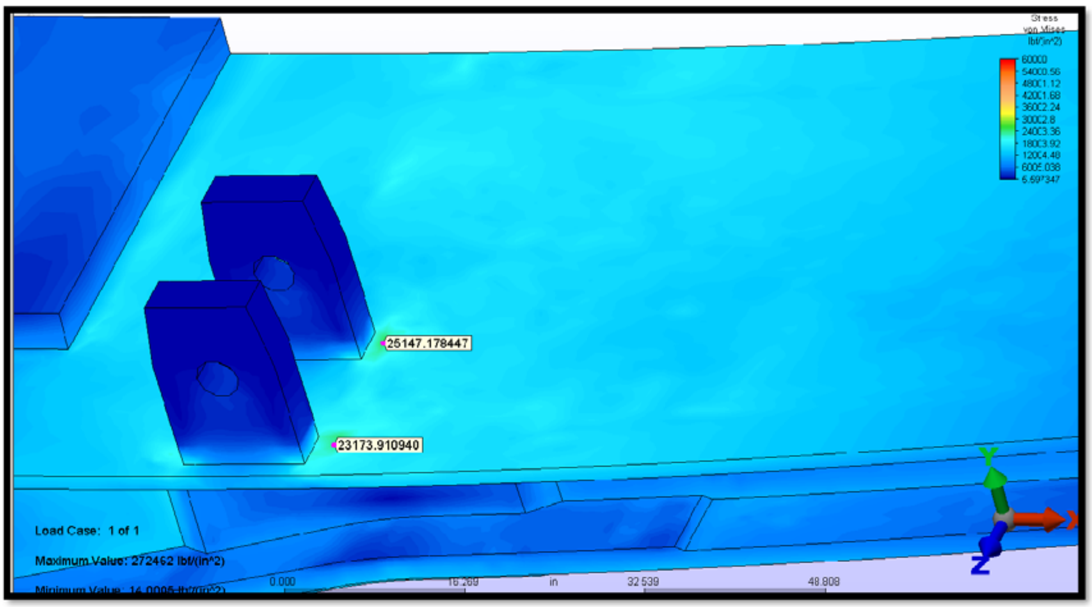

ALGOR
Stress
von Mises
lbf/(in^2)
48064.080652
46666.056109
Load Case: 1 of 1
Maximum Value: 170818 lbf/(in^2)
Minimum Value: 10.9887 lbf/(in^2)
0.000
28.384
in
56.768
85.152
Y
X
Z

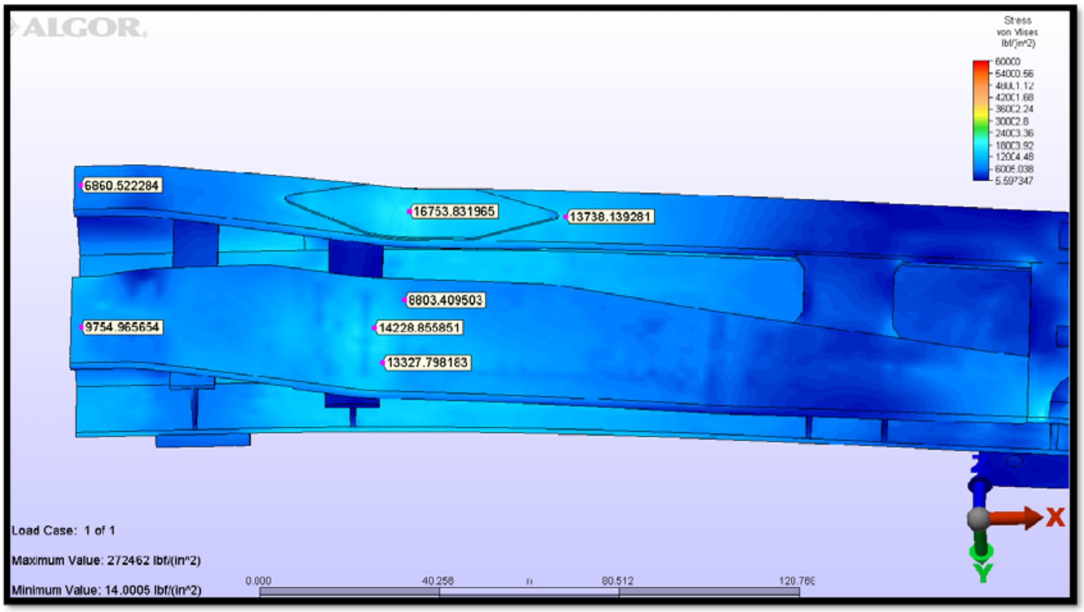


Squeeze Load:

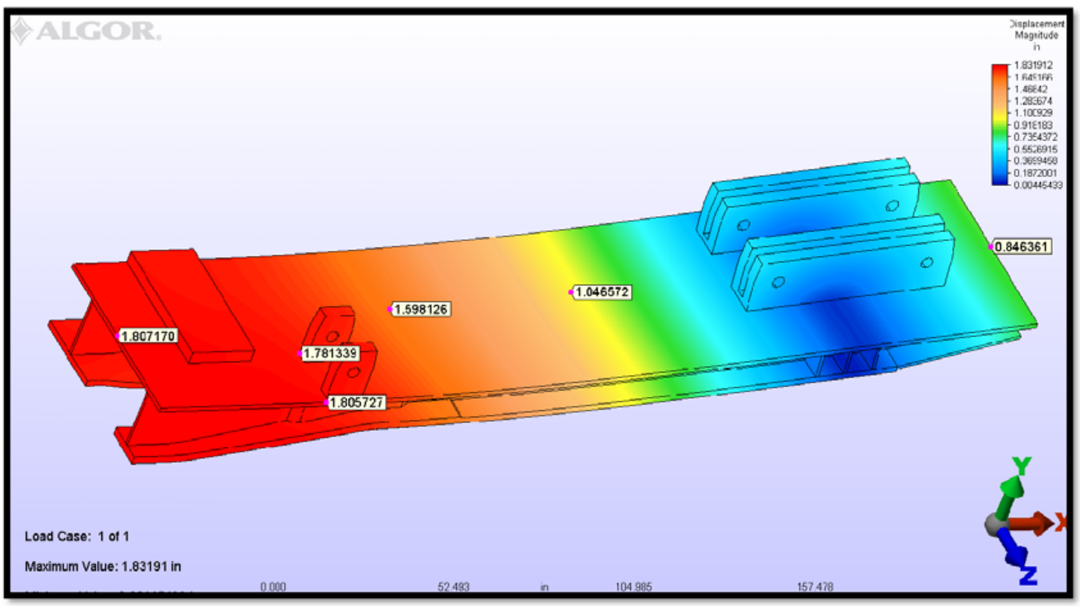



Stress
von Mises
lbf/(in^2)
60000
54000.56
48001.12
42001.68
11096.520044
16460.458141
15996.437763
9761.197393
16172.982046
e: 1 of 1
Value: 272462 lbf/(in^2)
0.000
42.519
in
85.038
127.557
Y
X
Z

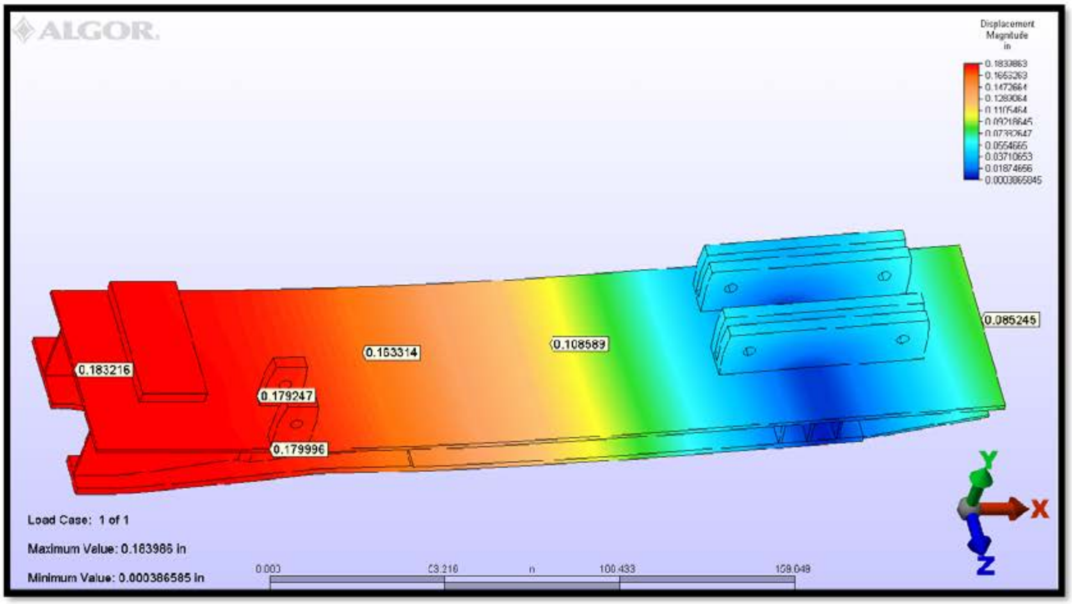

25147.178447
23173.910940
Load Case: 1 of 1
Maximum Value: 272462 lbf/(in^2)
0.000
in
32.539
48.808



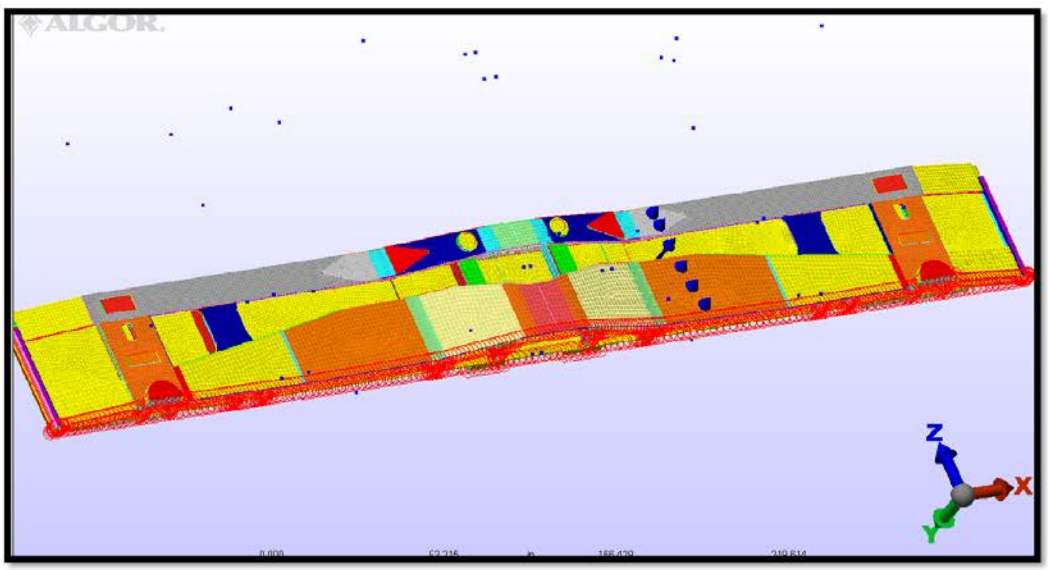
Live Load Deflection:

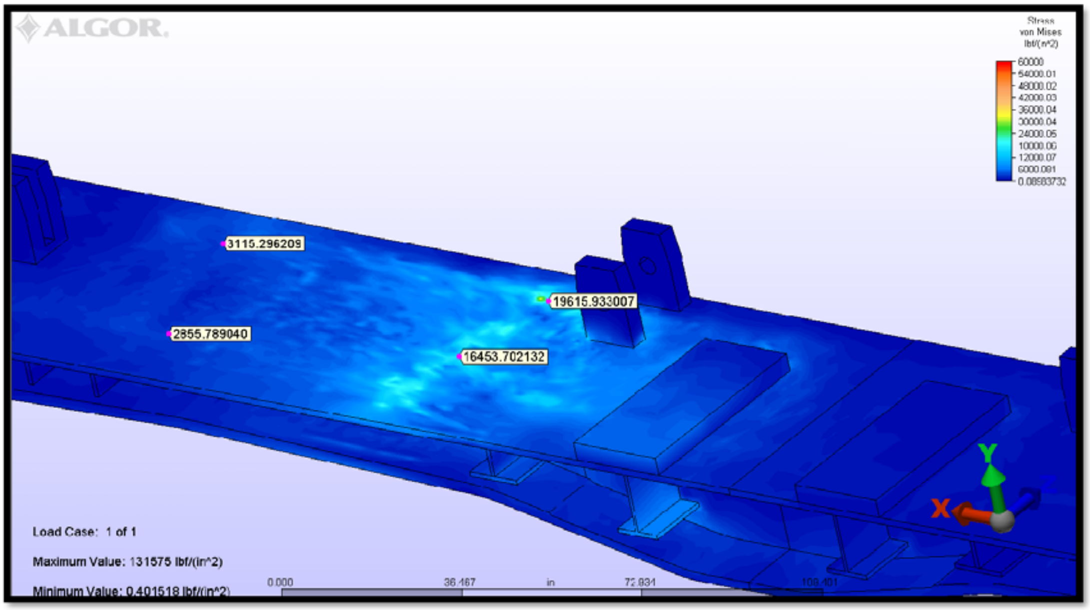


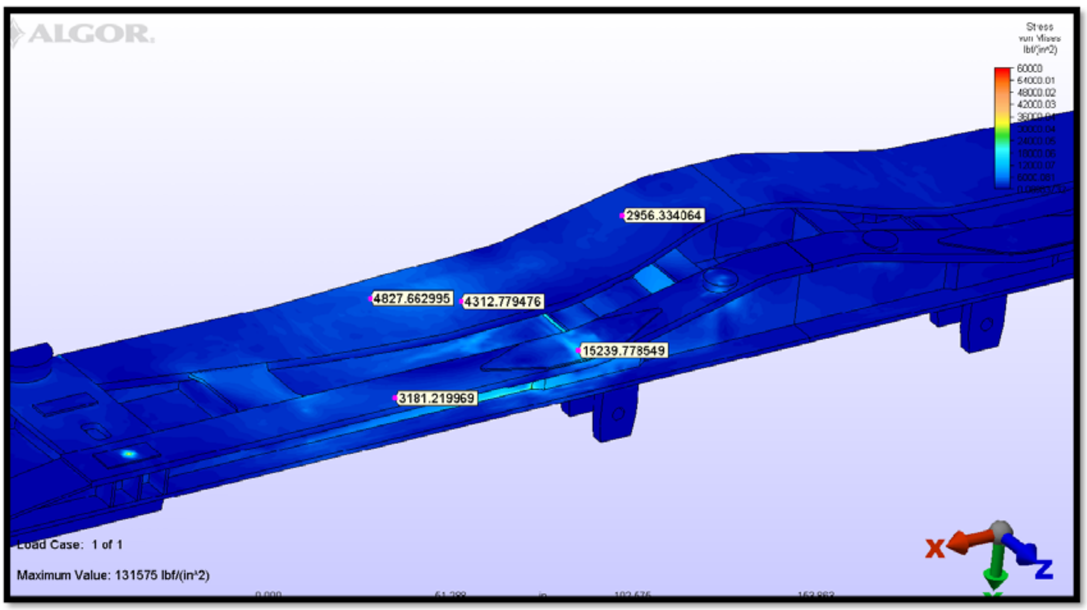
Dead Load Deflection:

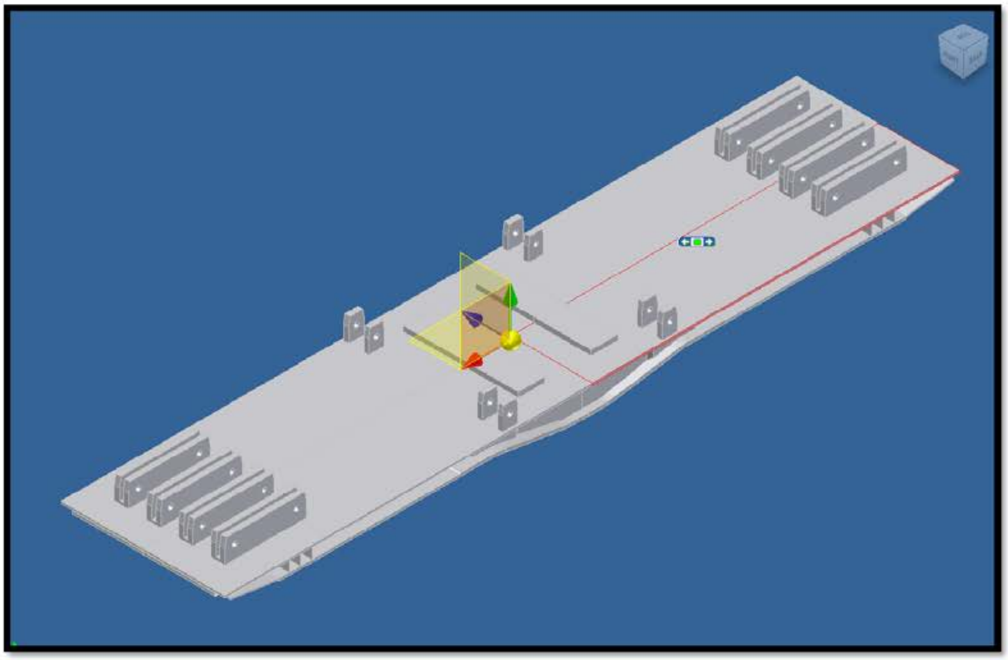


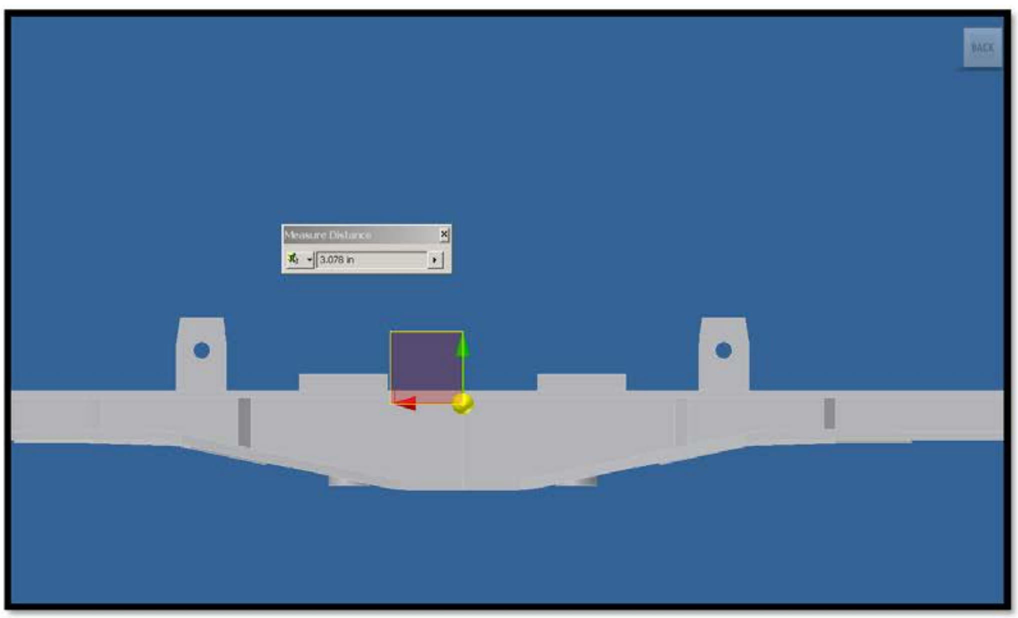
Jacking Load (HI-Star 180):




ALGOR
Stress
von Mises
lbf/(in^2)
60000
54000.01
48000.02
42000.03
36000.04
30000.04
24000.05
18000.06
12000.07
6000.081
0.08883732
3115.296209
19615.933007
2855.789040
16453.702132
Load Case: 1 of 1
Maximum Value: 131575 lbf/(in^2)
Minimum Value: 0.401518 lbf/(in^2)


ALGOR
Stress
von Mises
lbf/(in^2)
2956.334064
4827.662995
4312.779476
15239.778549
3181.219969
Load Case: 1 of 1
Maximum Value: 131575 lbf/(in^2)





Kasgro Rail Corporation Page 33

Maximum Vertical Load Location

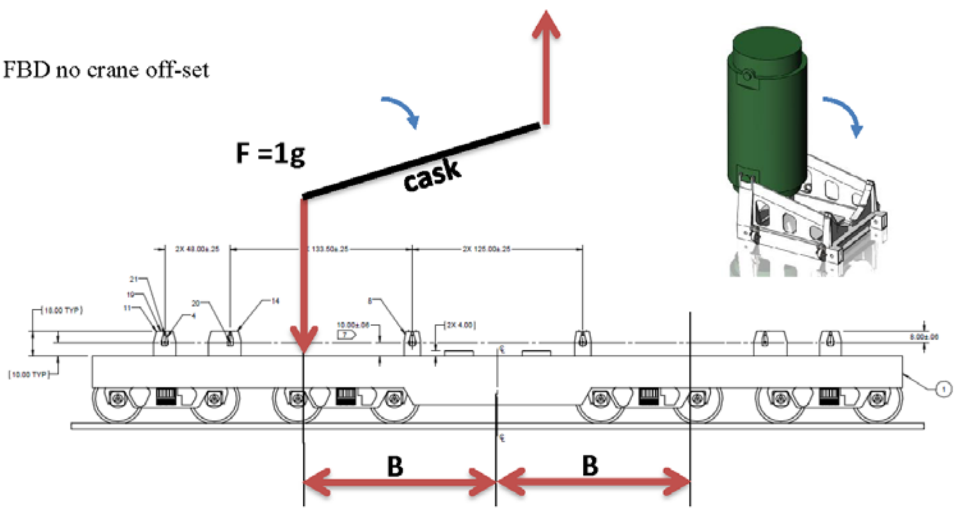
Slade Klein, Engineer, AFS

The maximum vertical loads and locations are shown in the table below:

Cask rotated on cradle	Load "F" on Railcar (lb.)	Horizontal distance "B" from load to center of railcar (in.)
TN-68	299,500	63.5
HI-STAR 60	234,400	67.56
NAC-STC	298,600	78.6
HI-STAR 180	371,347	81.75
NAC MAGNATRAN	356,000	89.3
NAC-UMS	299,000	89.3
TS-125	315,910	98

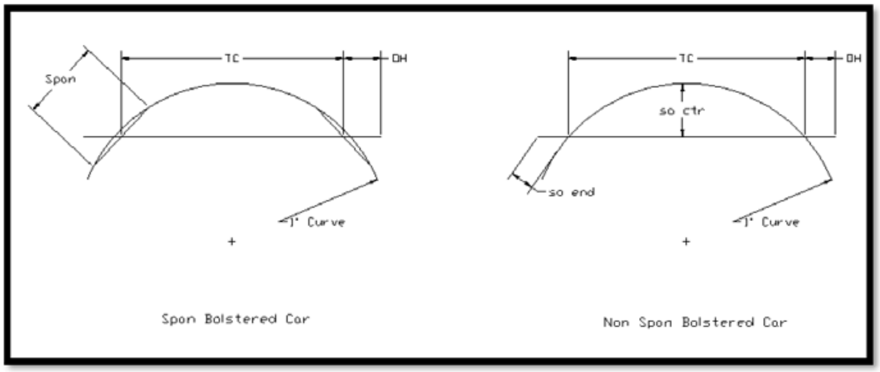
The dimensions are shown in the figure below for clarity. Note that the maximum vertical load could occur on either side of the railcar centerline at any location "B". The load "F" is applied in the vertical direction. There also can be some side load depending on the crane off-set applied.

FBD no crane off-set



The HI-Star 180 was analyzed in the unsymmetrical loading for worst case. Distances and weights are shown above. The model had all 4 jacking locations constrained in the vertical direction (8 in reality). A load factor of 1.8 was applied to the HI-Star 180 along with gravitational loads. Stress is all areas were rather low. Screen plots are shown on pages 31-32.

Swing Out:



Span = 21 ft

Truck Center = 38 ft

Over Hang = 5 ft

Swing out at center = 0.493 inches per degree of curvature

Swing out at ends = 0.110 inches per degree of curvature

Weight and Center of Gravity AREVA 12 Axle Cask Car (Loaded at 55.375 deck Height)

The CG of the Atlas Car body is separated into 5 sections listed below. Each section has its own CG and distance to the top of the rail. 34.6 inches is the CG while the car is fully loaded with the HI-Star 190. That is with spring and car body deflection.

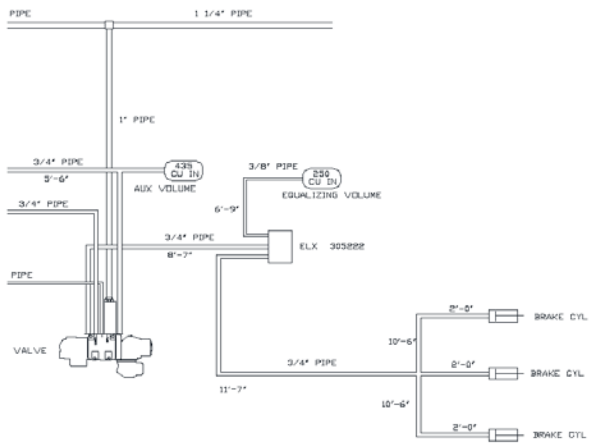
Item of Rail Car	Weight (lbs.)	Distance of CG to Rail (in.)	Weight * CG Distance
Car Body	83k	48.63	4036.29
Trucks	66k	18	1188
Spans	33k	32.8	1082.4
End Platforms	12k	40	480
Misc.	5k	18	90
Totals:	199k		6876.69
		CG Loaded:	34.6

Weight and Center of Gravity AREVA 12 Axle Cask Car (Unloaded with Car Body Fully Cambered 59.25 deck height)

Item of Rail Car	Weight (lbs.)	Distance of CG to Rail (in.)	Weight * CG Distance
Car Body	83k	51.0	4233
Trucks	66k	18	1188
Spans	33k	34.8	1148.4
End Platforms	12k	42	504
Misc.	5k	18	90
Totals:	199k		7225.65
		CG Unloaded:	35.9

These are the final estimated CG distances for the Atlas Cask Car loaded and unloaded. All distances are to the top of the rail. These final estimates will not impact the loaded, partially loaded and unloaded decks heights of the Atlas Cask Car.

Brake Schematic: (S-2043 4.7.7)



Brake equalization pressure: (S-2043 4.7.7)

KASGRO 12-AXLE FLAT
EQUALIZATION PRESSURE CALCULATOR
Aug-16

INPUT:

initial charge (psig)	reservoir volume (in3)	Aux reservoir (in3)	pipe brkt clear vol (in3)	clearance vol/cyl (in3)	cyl dia (in)	no. of cyls	piston travel (in)	3/8" pipe lenngth (ft)	1/2" brk cyl pipe lgth (ft)	3/4" brk cyl pipe lgth (ft)	1" brk cyl pipe lgth (ft)	1 1/4" brk cyl pipe lgth (ft)
90	2503	435	175	18	9	3	2.75	2	0	52.7	0	0

RESULTS:

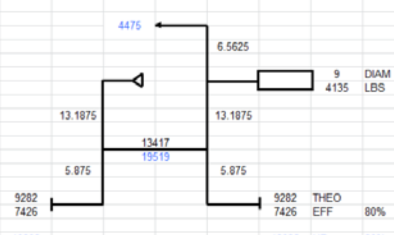
piston area (in2)	piston displ vol (in3)	bc pipe volume (in3)	equalization pressure (psi)
63.62	174.95	276.83	64.68

Note:
Clearance volume of relay valve and vent valve included n pipe bracket clearance volume above.

REQ'D EQUALIZATION 63.5 TO 66.5 PSI

BRAKE CYLINDER CLEARANCE VOLUMES

Type/size	in3	
TMX 7"	10.0	
TMX 8"	12.0	
TMX 9.25 "	14.0	
Elcon 7.5"	11.5	
Elcon 8.5"	13.0	
Elcon 9.5	18.0	est
Elcon 10"	25.5	
Thrall - # 36	?	
Thrall - # 50	44.0	
Thrall - # 60	73.0	
ABU 10x12"	18.0	
ABU 8.5x12"	215.0	



			ELLCON NAT'L TRUCK MTD BRAKE						
			340L MODIFIED FOR 9.5" DIA CYL						
			HAND BRAKE 33000						
GRL	789,000		LT WT =	199000				LIGHT WT WITH CASK =	716000 *
# OF AXLES	12								
HAND BRAKE FORCE		137,024	17.4%		>10%				
AIR BRAKE FORCE		89107	11.3%		11-13%				
EMPTY CAR RATIO			26.7%						
AT 30 PSI REDUCTION									
S-2043 REQUIREMENT		*	12.4%		<28%	S-2043 REQUIREMENT			
AT 30 PSI REDUCTION									

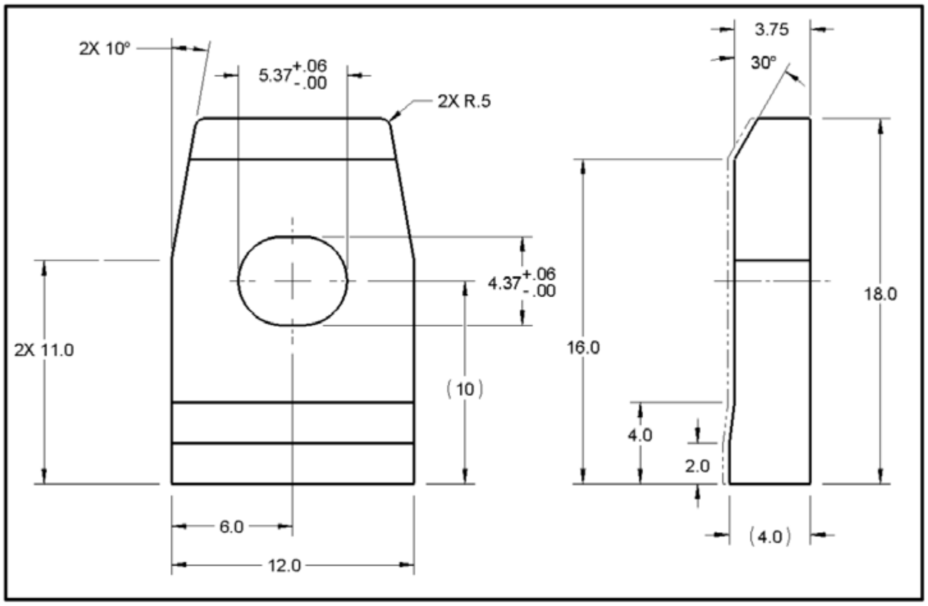


Figure 5-1: Center Pin Attachment Block

S-2043 (4.1.8.1) Loads provided from Areva.

Vertical Load Weld Calculations on Pin Attachments:

All attachments are to be welded to the deck plate.

Assuming 100 % Weld Lateral Load = 611kip Vertical Load = 312 kip
Stress from Doc./Rev.: Calc-3015276-002 (Rule 88 A.15.c)

Tensile = 3.50 ksi

Shear = 13.2 ksi

Bending = 26.3 ksi

Combined = 37.6 ksi < 50 ksi

Stress from Doc./Rev.: Calc-3015276-002 (10 CFR 71.45)

Tensile = 3.50 ksi

Shear = 13.2 (5/2) = 33 ksi

Bending = 26.3 (5/2) = 65.75 ksi

Combined = 89.8 ksi > 65 ksi

From the stress results listed above, 100% penetration weld will be required on all attachments to the railcar deck plate.

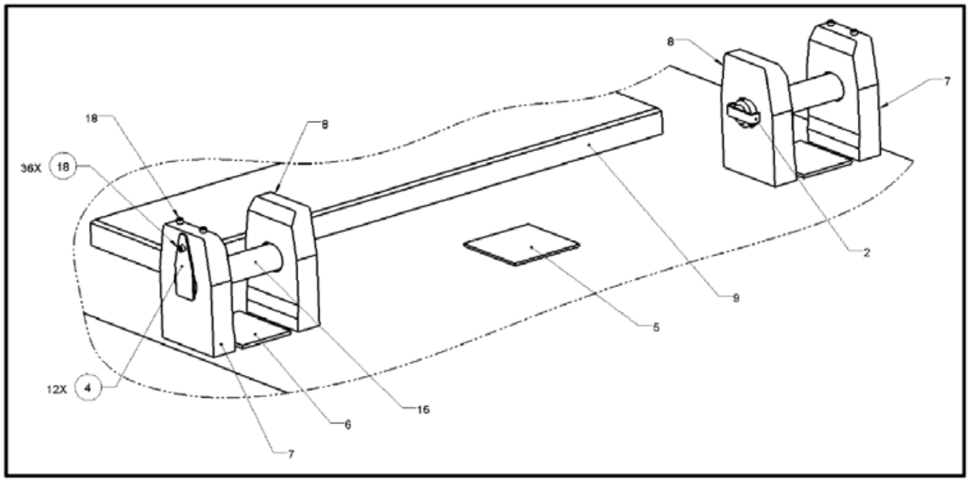


Figure 5-2: Shear Blocks

Shear Block Weld Calculations:

All attachments are to be welded to the deck plate.

Longitudinal Load 2,921 kips

Length of shear block = (21in + 90 in) 2 = 222 inches

q = P/L = 2921 kip / 222 inches = 13.2 k/in (Rule 88 A.15.c)

q = P (10/7.5)/L = 2921 kip (10/7.5) / 222 inches = 17.5 k/in (10 CFR 71.45)

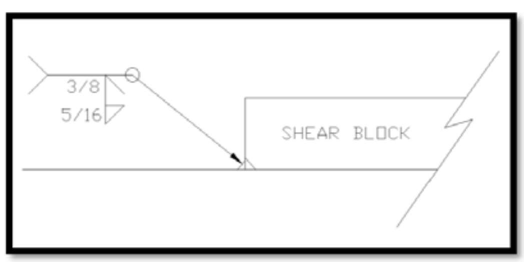
Throat size for bevel and fillet weld shown below:

Throat = $((5/16)^2 + (3/8)^2)^{1/2} = 0.49$

(0.49) (33.06) =16.2 k/in

16.2 k/in > 13.2 k/in (Rule 88 A.15.c)

16.2 k/in < 17.5 k/in (10 CFR 71.45)



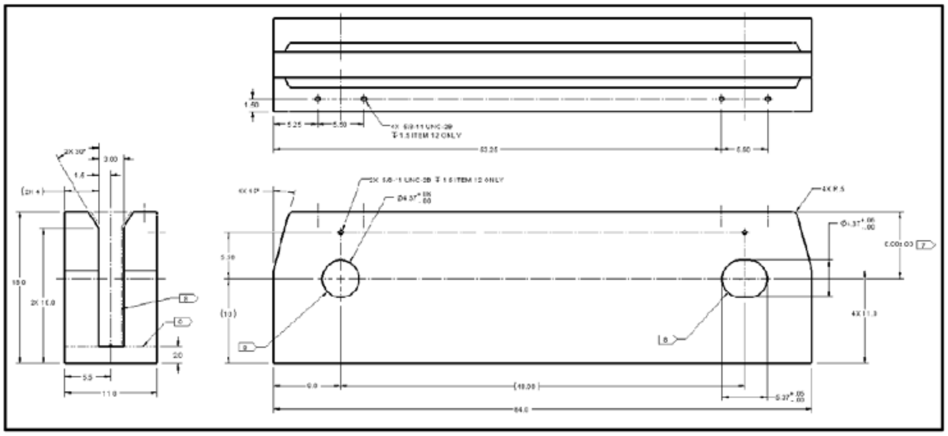


Figure 5-9: Outer Pin Attachment Block

Outer Pin Block Attachment Weld Calculations: (10 CFR 71.45)

All attachments are to be welded to the deck plate.

Longitudinal Load 944 (10/7.5) =1258.7 kip

Vertical Loads 1077 kip

The moment was taken about the CG of the weld.

t = thickness of weld

Moment = 1258.7 kip (10 in) + 2 1077 kip (24 in) = 64,283 in-k

A= (128 + 22) t = 150 t

$I_{yy} = 1/12\ (2)\ (64\text{in})^3\ t + 2\ (11\ \text{in})\ t\ (32\ \text{in})^2$

I = 43690t + 22528t = 66218t

S = (t)66218/ 32 = 2069.3t

F' = 1258.7/150t = 8.4/t

F'' = M/S = 64,283/2069.3=31.07/t

$F = ((8.4/t)^2 + (31.07/t)^2\ )^{1/2} = 32.2/t$

32.2/33.06 = t = 0.97 which is required

7/8" bevel with 3/8" fillet = $t = ((7/8)^2 + (3/8)^2\ )^{1/2} = 0.95$ in < 0.97 required to fail. (10 CFR 71.45)

Outer Pin Block Attachment Weld Calculations: (Rule 88 A.15.c)

All attachments are to be welded to the deck plate.

Longitudinal Load 944 kip

Vertical Loads 1077 kip

The moment was taken about the CG of the weld.

t = thickness of weld

Moment = 944 kip (10 in) + 2 (1077 kip) (24 in) = 61,136 in-k

A= (128 + 22) t = 150 t

I_{yy} =1/12 (2) $(64in)^3$ t + 2 (11 in) t $(32 \text{ in})^2$

I = 43690t + 22528t = 66218t

S = (t)66218/ 32 = 2069.3t

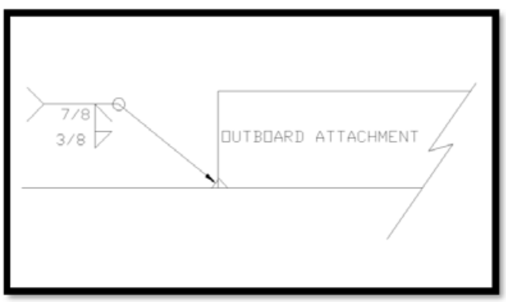
F' = 944/150t = 6.3/t

F'' = M/S = 61,136/2069.3t = 29.54/t

F = $((6.3/t)^2 + (29.54/t)^2)^{1/2}$ = 30.2/t

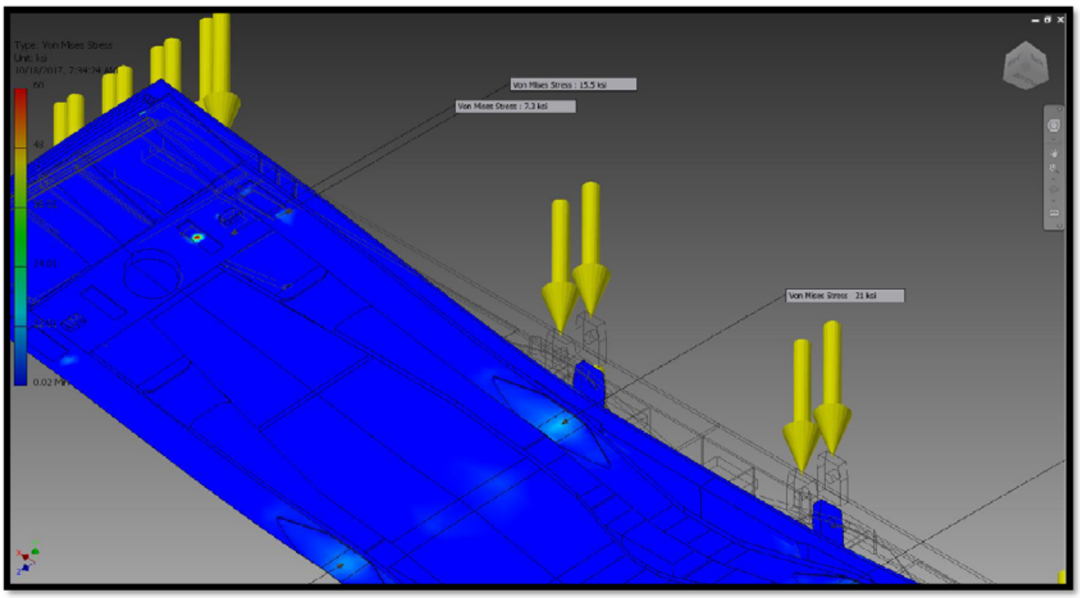
30.2/33.06 = t = 0.91 which is required

7/8" bevel with 3/8" fillet = t = $((7/8)^2 + (3/8)^2)^{1/2}$ = 0.95 in > 0.91 which is required (Rule 88 A.15.c)



Twist Load:

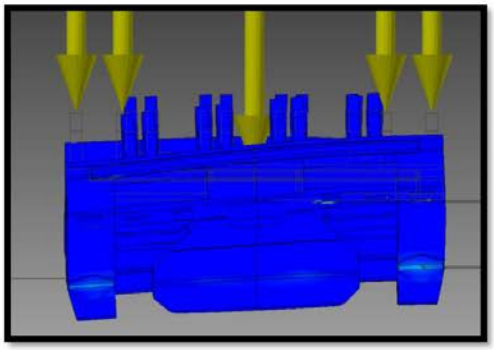
(AAR M-1001 11.3.3.5) (S-2043 4.1.5.5)



The twist load was analyzed by applying a fixed vertical constraint on one side bearing pad of the car body A-End while constraining the B-End of the car body's center plate. This is to simulate a vertical jacking load applied to a truck at one end of the car. The force flow will go through the Tri-Span body side bearing to the car body side bearing causing the car structure to twist. The HI-Star 190 load was applied to the inboard load attachments considering that it is the max vertical load on the car. The end stop load was applied to the outboard attachments just like the other FEA models.

The twist load FEA was performed in Autodesk Inventor Professional 2014.

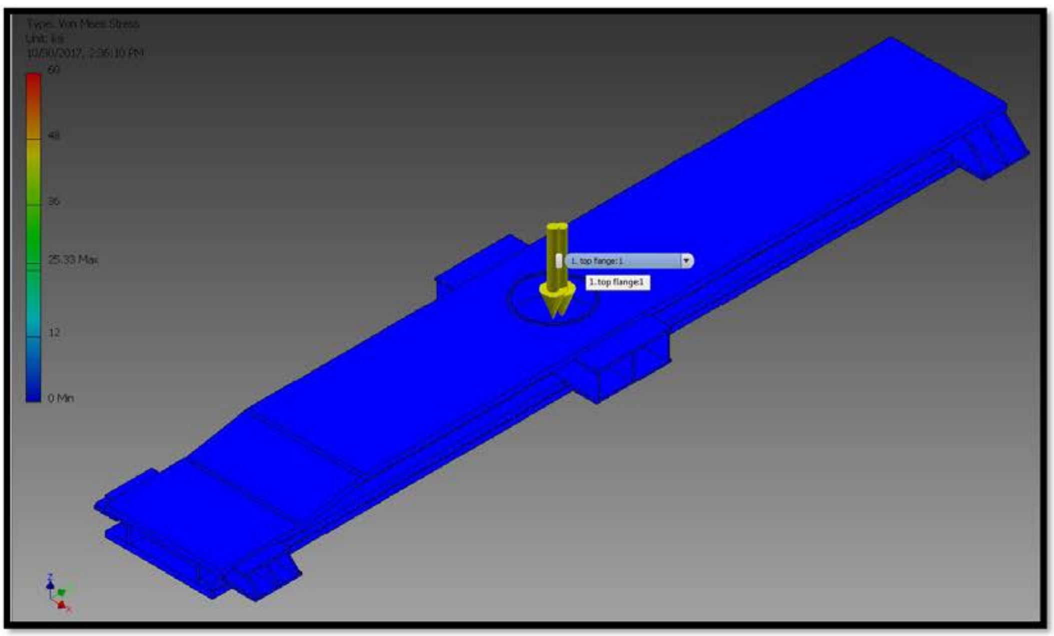
Car Body Twist View:

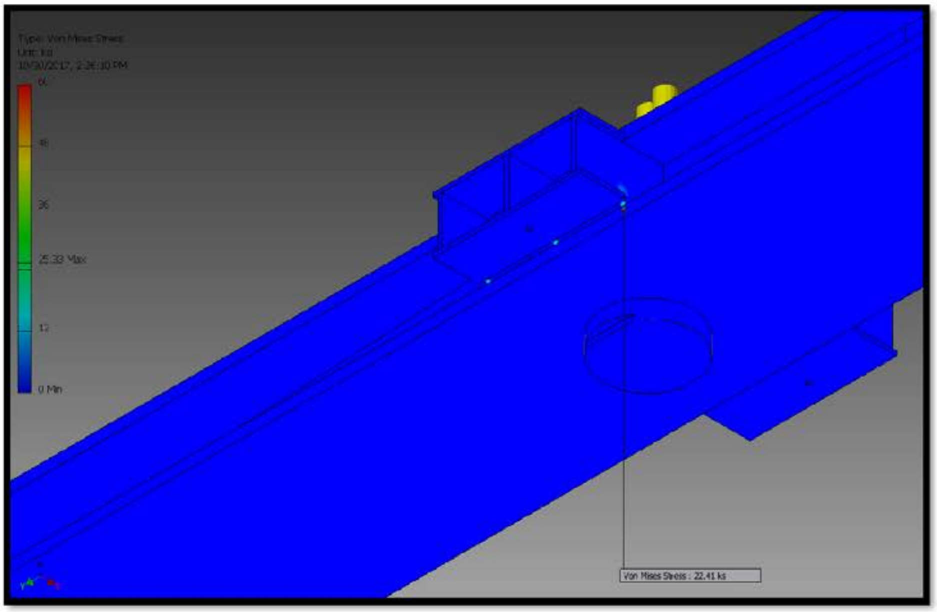


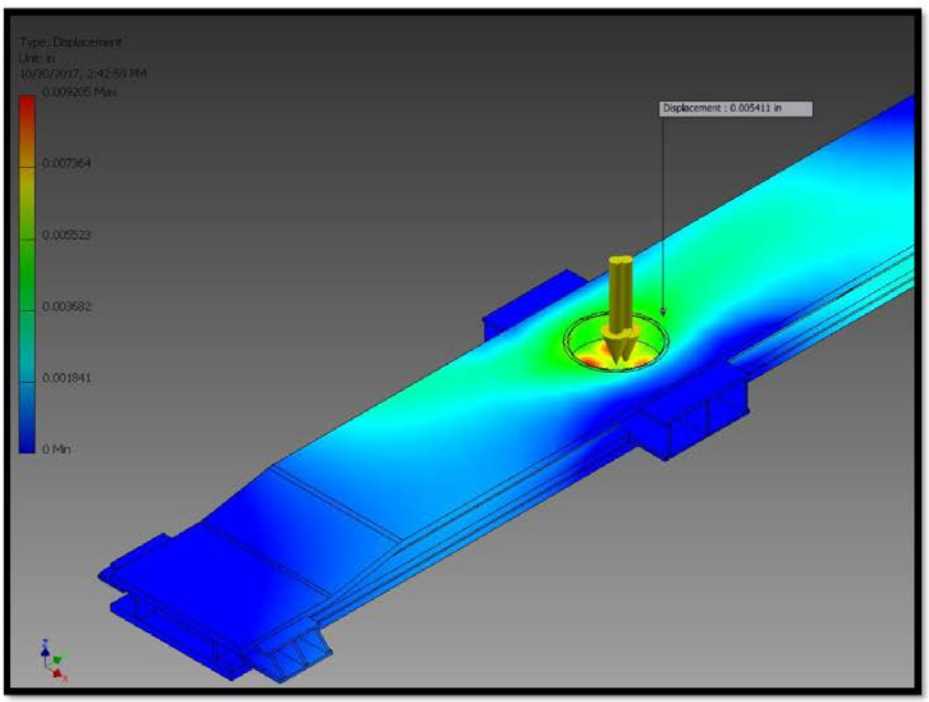
Twist Load: Tri-Span

(AAR M-1001 11.3.3.5) (S-2043 4.1.5.5)

The Tri-Span twist load was analyzed by applying a vertical constraint on one side bearing pad on the left side of the span. The right side of the span had all three side bearing plates constrained vertically. A Live Load of 300,000 lbs. was applied at the center plate bowl. The Tri-Span is made of A-572 Grade 60 material. The max stress was roughly 25 ksi.

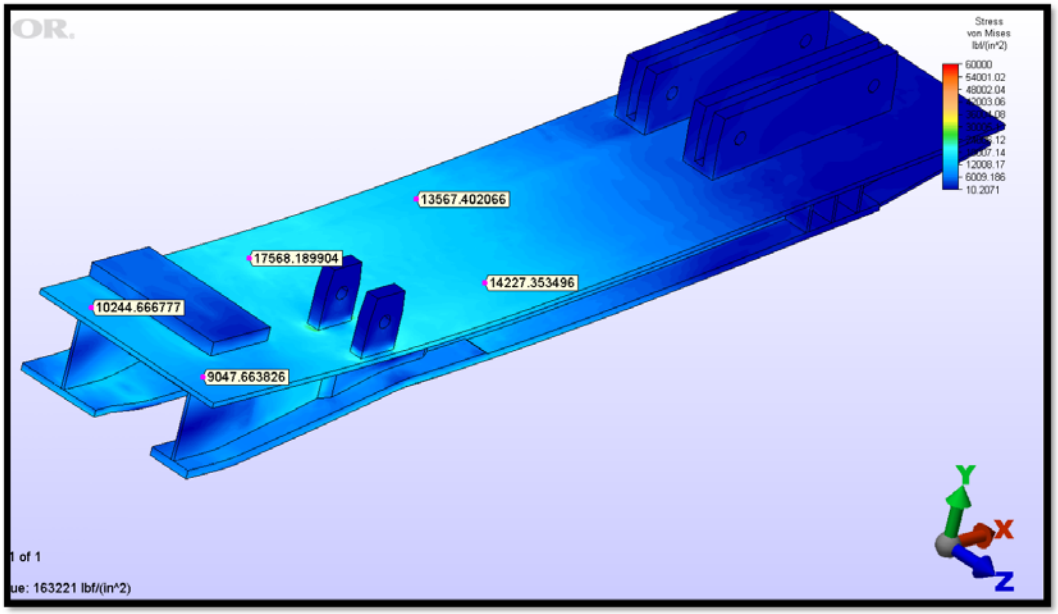


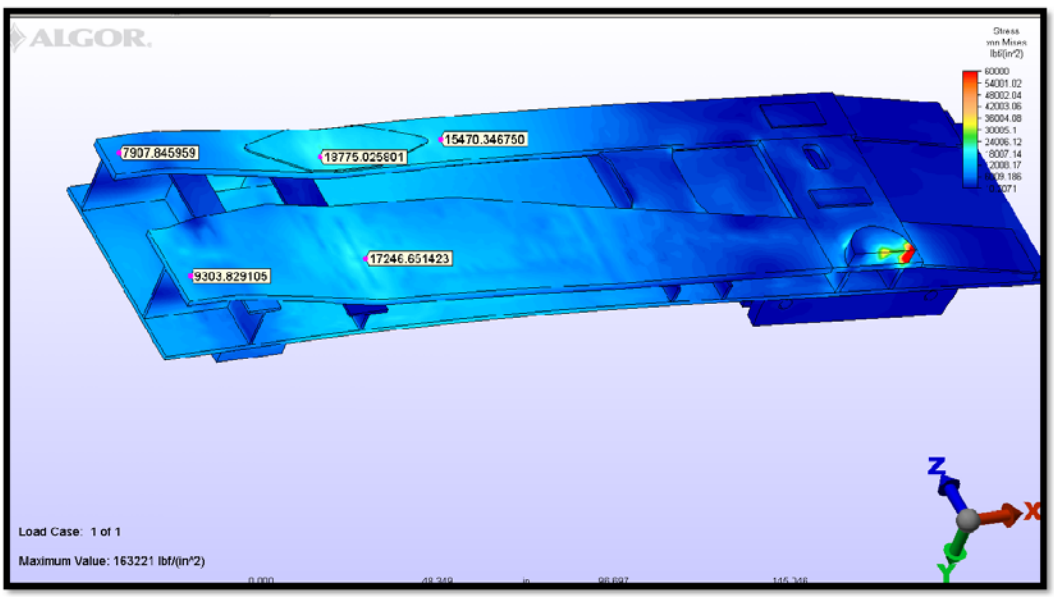

Type: Von Mises Stress
36
25.33 Max
12
0 Min
Von Mises Stress : 22.41 ksi


Type: Displacement
Unit: in
10/30/2017, 2:42:59 PM
0.009205 Max
0.007364
0.005523
0.003682
0.001841
0 Min
Displacement : 0.005411 in

Impact Load: (M-1001 4.1.10) (S-2043 4.1.5.8)

The Atlas railcar is equipped with an EOC cushioning unit with 15 inches of travel. Table 4.3 structural requirements for EOC-equipped cars states length of travel greater than 14 inches requires a coupler force of 600,000 lbs. to be applied.

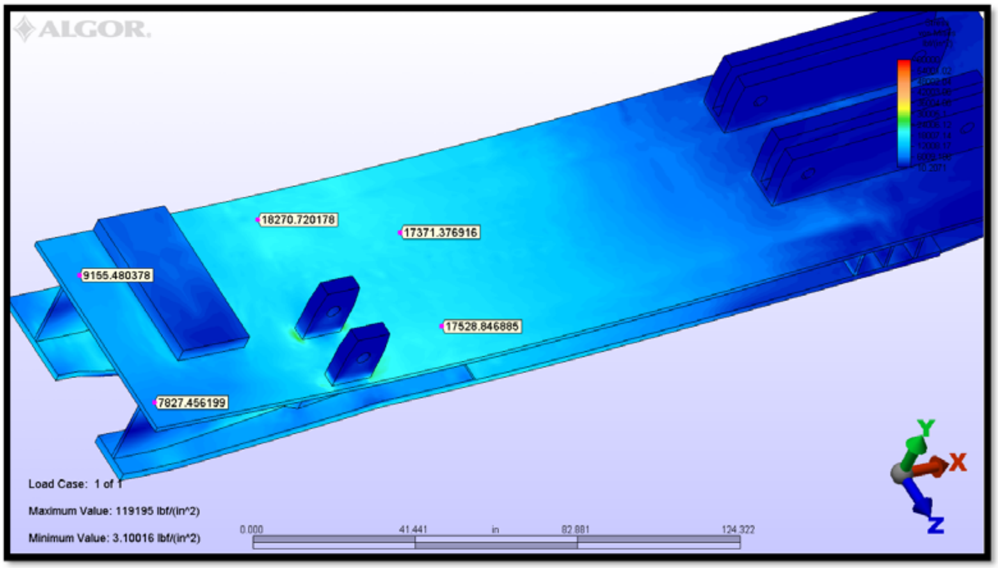


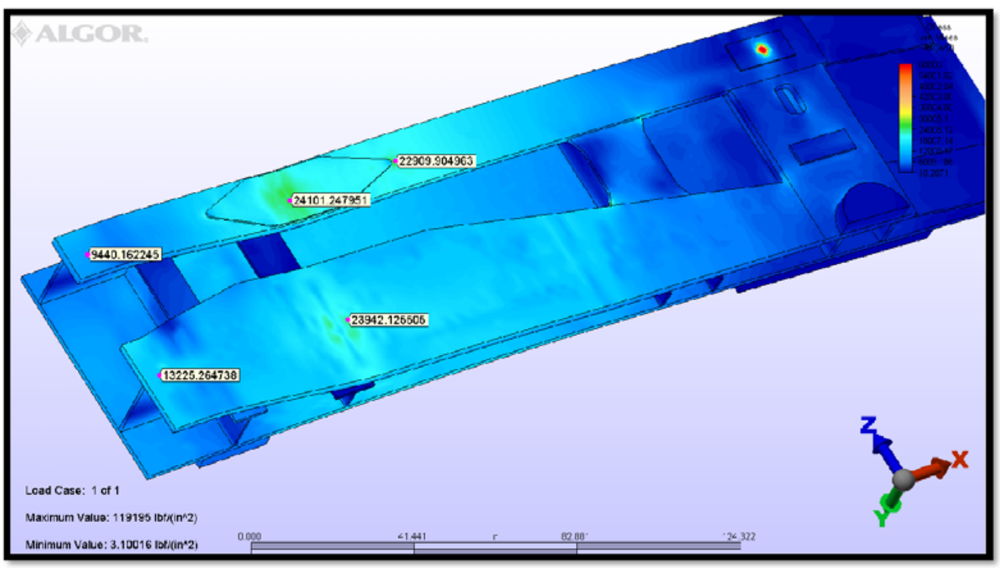


Jacking Load:

(M-1001 4.1.6) (S-2043 4.1.5.4)

A vertical constraint was applied at the car body jacking pad. This is to simulate jacks placed under the portion of the car extending outside of the rails. The car was fully loaded with the HI Star 190 applied to the inboard attachments with the end stops applied at the outboard attachments.





Vertical Loads on Coupler:

(M-1001 4.1.5) (S-2043 4.1.5.3)

The Vertical loads on coupler have been tested and proven on the M-290 by TTCI. No further analysis has been done.

S-234 Lifting Freight Cars

M-1001 4.1.6 & Office Manual Rule 88.C.3.c (10) (B)

Lifting loading analysis is the same as Jacking. Provisions are detailed into the car body to allow the AAR standard hook to be attached to the underside of the car body bolster. Local deformation will occur if the car is lifted no gross yielding of the overall structure will happen.

Fatigue Introduction:

Fatigue Analysis is based on the AAR METHOD AS DOCUMENTED IN THE MSRP Section C, Part II.

The spreadsheet is based on the AAR method as shown in Table 7.1 and Table 7.2 of the above referenced specification. No data is published for a general service flat car with a steel deck. In lieu of this the data for a high-sided gondola is used.

The only area examined was the center sill bottom flange splice. This will give a more conservative result than the side sill spice because of the nominal stress. The bolster has relatively low nominal stresses and is similar in design as other general service flat cars in use.

Stresses used are from the FEA. The car is fully loaded with the HI-Star 190 and end stops.

FATIGUE DATA FOR CENTER SILL AT SPLICE

(Coupler Load 110 Ton High-sided Gon)

Max	Min	No.	α Pct	Static Stress	Dynamic Stress Max	Dynamic Stress Min	Max Adjusted	R Min/Max	Endurance Limit	Cycles to Failure N	α/N
430	-250	1	0.00007	18.3	23.1	15.5	23.1	0.672	52.1	NO DAMAGE	
410	390	1	0.00007	18.3	22.9	22.6	22.9	0.990	1754.7	NO DAMAGE	
410	310	1	0.00007	18.3	22.9	21.8	22.9	0.951	350.9	NO DAMAGE	
395	365	2	0.00015	18.3	22.7	22.4	22.7	0.985	1161.3	NO DAMAGE	
385	365	1	0.00007	18.3	22.6	22.4	22.6	0.990	1733.3	NO DAMAGE	
380	250	1	0.00007	18.3	22.5	21.1	22.5	0.936	266.0	NO DAMAGE	
360	300	1	0.00007	18.3	22.3	21.6	22.3	0.970	570.7	NO DAMAGE	
360	290	1	0.00007	18.3	22.3	21.5	22.3	0.965	489.1	NO DAMAGE	
360	-130	1	0.00007	18.3	22.3	16.9	22.3	0.755	69.9	NO DAMAGE	
360	-230	1	0.00007	18.3	22.3	15.7	22.3	0.705	58.0	NO DAMAGE	
350	220	1	0.00007	18.3	22.2	20.8	22.2	0.935	262.1	NO DAMAGE	
350	-230	1	0.00007	18.3	22.2	15.7	22.2	0.709	58.7	NO DAMAGE	
340	320	3	0.00022	18.3	22.1	21.9	22.1	0.990	1694.9	NO DAMAGE	
340	-120	1	0.00007	18.3	22.1	17.0	22.1	0.768	73.7	NO DAMAGE	
340	-150	1	0.00007	18.3	22.1	16.6	22.1	0.753	69.2	NO DAMAGE	
330	-120	1	0.00007	18.3	22.0	17.0	22.0	0.772	74.9	NO DAMAGE	
320	310	2	0.00015	18.3	21.9	21.8	21.9	0.995	3355.5	NO DAMAGE	
320	250	1	0.00007	18.3	21.9	21.1	21.9	0.964	479.4	NO DAMAGE	
310	290	2	0.00015	18.3	21.8	21.5	21.8	0.990	1669.2	NO DAMAGE	
310	-210	1	0.00007	18.3	21.8	16.0	21.8	0.734	64.2	NO DAMAGE	
310	-290	1	0.00007	18.3	21.8	15.1	21.8	0.693	55.6	NO DAMAGE	
280	-210	1	0.00007	18.3	21.4	16.0	21.4	0.745	67.1	NO DAMAGE	
270	200	1	0.00007	18.3	21.3	20.5	21.3	0.963	467.1	NO DAMAGE	
270	110	1	0.00007	18.3	21.3	19.5	21.3	0.916	204.4	NO DAMAGE	
270	100	1	0.00007	18.3	21.3	19.4	21.3	0.911	192.4	NO DAMAGE	
270	-10	1	0.00007	18.3	21.3	18.2	21.3	0.854	116.8	NO DAMAGE	
270	-80	1	0.00007	18.3	21.3	17.4	21.3	0.817	93.4	NO DAMAGE	
265	-255	1	0.00007	18.3	21.3	15.5	21.3	0.727	62.7	NO DAMAGE	
260	220	2	0.00015	18.3	21.2	20.8	21.2	0.979	813.2	NO DAMAGE	
260	20	1	0.00007	18.3	21.2	18.5	21.2	0.874	135.5	NO DAMAGE	
260	-150	1	0.00007	18.3	21.2	16.6	21.2	0.784	79.3	NO DAMAGE	
260	-220	1	0.00007	18.3	21.2	15.8	21.2	0.748	67.8	NO DAMAGE	
260	-240	1	0.00007	18.3	21.2	15.6	21.2	0.737	65.1	NO DAMAGE	
260	-260	1	0.00007	18.3	21.2	15.4	21.2	0.727	62.6	NO DAMAGE	
250	240	1	0.00007	18.3	21.1	21.0	21.1	0.995	3235.8	NO DAMAGE	
250	230	9	0.00067	18.3	21.1	20.9	21.1	0.989	1617.9	NO DAMAGE	
250	220	2	0.00015	18.3	21.1	20.8	21.1	0.984	1078.6	NO DAMAGE	
250	190	1	0.00007	18.3	21.1	20.4	21.1	0.968	539.3	NO DAMAGE	
250	90	1	0.00007	18.3	21.1	19.3	21.1	0.915	202.2	NO DAMAGE	
250	-50	1	0.00007	18.3	21.1	17.7	21.1	0.841	107.9	NO DAMAGE	
250	-100	1	0.00007	18.3	21.1	17.2	21.1	0.815	92.5	NO DAMAGE	
250	-160	1	0.00007	18.3	21.1	16.5	21.1	0.783	78.9	NO DAMAGE	
250	-180	1	0.00007	18.3	21.1	16.3	21.1	0.773	75.3	NO DAMAGE	
250	-220	1	0.00007	18.3	21.1	15.8	21.1	0.752	68.8	NO DAMAGE	
250	-410	1	0.00007	18.3	21.1	13.7	21.1	0.651	49.0	36700336	2.72E-10
245	225	1	0.00007	18.3	21.0	20.8	21.0	0.989	1613.6	NO DAMAGE	
245	155	1	0.00007	18.3	21.0	20.0	21.0	0.952	358.6	NO DAMAGE	
245	-315	1	0.00007	18.3	21.0	14.8	21.0	0.703	57.6	NO DAMAGE	
240	230	5	0.00037	18.3	21.0	20.9	21.0	0.995	3218.7	NO DAMAGE	
240	220	2	0.00015	18.3	21.0	20.8	21.0	0.989	1609.4	NO DAMAGE	
240	210	2	0.00015	18.3	21.0	20.6	21.0	0.984	1072.9	NO DAMAGE	
240	180	1	0.00007	18.3	21.0	20.3	21.0	0.968	536.5	NO DAMAGE	
240	140	1	0.00007	18.3	21.0	19.9	21.0	0.947	321.9	NO DAMAGE	
240	110	1	0.00007	18.3	21.0	19.5	21.0	0.931	247.6	NO DAMAGE	
240	70	1	0.00007	18.3	21.0	19.1	21.0	0.910	189.3	NO DAMAGE	
240	-70	1	0.00007	18.3	21.0	17.5	21.0	0.835	103.8	NO DAMAGE	
240	-110	1	0.00007	18.3	21.0	17.1	21.0	0.814	92.0	NO DAMAGE	
240	-120	1	0.00007	18.3	21.0	17.0	21.0	0.809	89.4	NO DAMAGE	
240	-160	1	0.00007	18.3	21.0	16.5	21.0	0.787	80.5	NO DAMAGE	
240	-170	1	0.00007	18.3	21.0	16.4	21.0	0.782	78.5	NO DAMAGE	
240	-210	1	0.00007	18.3	21.0	16.0	21.0	0.761	71.5	NO DAMAGE	
240	-240	1	0.00007	18.3	21.0	15.6	21.0	0.745	67.1	NO DAMAGE	
235	225	13	0.00097	18.3	20.9	20.8	20.9	0.995	3210.2	NO DAMAGE	
235	215	9	0.00067	18.3	20.9	20.7	20.9	0.989	1605.1	NO DAMAGE	
230	220	2	0.00015	18.3	20.9	20.8	20.9	0.995	3201.6	NO DAMAGE	
230	200	2	0.00015	18.3	20.9	20.5	20.9	0.984	1067.2	NO DAMAGE	
230	190	2	0.00015	18.3	20.9	20.4	20.9	0.979	800.4	NO DAMAGE	
230	170	1	0.00007	18.3	20.9	20.2	20.9	0.968	533.6	NO DAMAGE	
230	-10	1	0.00007	18.3	20.9	18.2	20.9	0.872	133.4	NO DAMAGE	
230	-90	1	0.00007	18.3	20.9	17.3	20.9	0.829	100.1	NO DAMAGE	
230	-110	1	0.00007	18.3	20.9	17.1	20.9	0.818	94.2	NO DAMAGE	
230	-160	1	0.00007	18.3	20.9	16.5	20.9	0.792	82.1	NO DAMAGE	
230	-180	1	0.00007	18.3	20.9	16.3	20.9	0.781	78.1	NO DAMAGE	
230	-200	1	0.00007	18.3	20.9	16.1	20.9	0.770	74.5	NO DAMAGE	
230	-205	1	0.00007	18.3	20.9	16.0	20.9	0.768	73.6	NO DAMAGE	
230	-260	1	0.00007	18.3	20.9	15.4	20.9	0.738	65.3	NO DAMAGE	
230	-270	1	0.00007	18.3	20.9	15.3	20.9	0.733	64.0	NO DAMAGE	
225	215	22	0.00164	18.3	20.8	20.7	20.8	0.995	3193.1	NO DAMAGE	
225	205	8	0.00060	18.3	20.8	20.6	20.8	0.989	1596.5	NO DAMAGE	
225	-385	1	0.00007	18.3	20.8	14.0	20.8	0.673	52.3	NO DAMAGE	
220	210	10	0.00075	18.3	20.8	20.6	20.8	0.995	3184.5	NO DAMAGE	
220	200	6	0.00045	18.3	20.8	20.5	20.8	0.989	1592.3	NO DAMAGE	
220	190	4	0.00030	18.3	20.8	20.4	20.8	0.984	1061.5	NO DAMAGE	
220	180	2	0.00015	18.3	20.8	20.3	20.8	0.979	796.1	NO DAMAGE	
220	170	3	0.00022	18.3	20.8	20.2	20.8	0.973	636.9	NO DAMAGE	
220	150	1	0.00007	18.3	20.8	20.0	20.8	0.962	454.9	NO DAMAGE	

cycles per mile	153.8
Yield stress	60 ksi
Y-int (b)	17.1
slope	1
k	0.29

cycles per mile	153.8	
Yield stress	60	ksi

			α	Static	Dynamic Stress		Max	R	Endurance	to Failure	
Max	Min	No.	Pct	Stress	Max	Min	Adjusted	Min/Max	Limit	N	α/N
220	140	1	0.00007	18.3	20.8	19.9	20.8	0.957	398.1	NO DAMAGE	
220	130	1	0.00007	18.3	20.8	19.7	20.8	0.952	353.8	NO DAMAGE	
220	70	1	0.00007	18.3	20.8	19.1	20.8	0.919	212.3	NO DAMAGE	
220	30	1	0.00007	18.3	20.8	18.6	20.8	0.898	167.6	NO DAMAGE	
220	-70	1	0.00007	18.3	20.8	17.5	20.8	0.844	109.8	NO DAMAGE	
220	-90	1	0.00007	18.3	20.8	17.3	20.8	0.834	102.7	NO DAMAGE	
220	-110	1	0.00007	18.3	20.8	17.1	20.8	0.823	96.5	NO DAMAGE	
220	-130	1	0.00007	18.3	20.8	16.9	20.8	0.812	91.0	NO DAMAGE	
220	-135	1	0.00007	18.3	20.8	16.8	20.8	0.809	89.7	NO DAMAGE	
220	-180	3	0.00022	18.3	20.8	16.3	20.8	0.785	79.6	NO DAMAGE	
220	-190	1	0.00007	18.3	20.8	16.2	20.8	0.780	77.7	NO DAMAGE	
220	-220	2	0.00015	18.3	20.8	15.8	20.8	0.764	72.4	NO DAMAGE	
220	-230	1	0.00007	18.3	20.8	15.7	20.8	0.758	70.8	NO DAMAGE	
215	205	14	0.00104	18.3	20.7	20.6	20.7	0.995	3176.0	NO DAMAGE	
215	195	32	0.00239	18.3	20.7	20.5	20.7	0.989	1588.0	NO DAMAGE	
215	185	1	0.00007	18.3	20.7	20.4	20.7	0.984	1058.7	NO DAMAGE	
215	165	2	0.00015	18.3	20.7	20.1	20.7	0.973	635.2	NO DAMAGE	
215	-175	1	0.00007	18.3	20.7	16.4	20.7	0.790	81.4	NO DAMAGE	
215	-225	2	0.00015	18.3	20.7	15.8	20.7	0.763	72.2	NO DAMAGE	
215	-325	1	0.00007	18.3	20.7	14.7	20.7	0.709	58.8	NO DAMAGE	
210	200	12	0.00089	18.3	20.6	20.5	20.6	0.995	3167.4	NO DAMAGE	
210	190	17	0.00127	18.3	20.6	20.4	20.6	0.989	1583.7	NO DAMAGE	
210	180	13	0.00097	18.3	20.6	20.3	20.6	0.984	1055.8	NO DAMAGE	
210	170	2	0.00015	18.3	20.6	20.2	20.6	0.978	791.9	NO DAMAGE	
210	160	1	0.00007	18.3	20.6	20.1	20.6	0.973	633.5	NO DAMAGE	
210	130	1	0.00007	18.3	20.6	19.7	20.6	0.957	395.9	NO DAMAGE	
210	70	1	0.00007	18.3	20.6	19.1	20.6	0.924	226.2	NO DAMAGE	
210	60	1	0.00007	18.3	20.6	19.0	20.6	0.919	211.2	NO DAMAGE	
210	30	1	0.00007	18.3	20.6	18.6	20.6	0.903	176.0	NO DAMAGE	
210	20	1	0.00007	18.3	20.6	18.5	20.6	0.897	166.7	NO DAMAGE	
210	10	1	0.00007	18.3	20.6	18.4	20.6	0.892	158.4	NO DAMAGE	
210	-10	2	0.00015	18.3	20.6	18.2	20.6	0.881	144.0	NO DAMAGE	
210	-30	1	0.00007	18.3	20.6	18.0	20.6	0.870	132.0	NO DAMAGE	
210	-90	1	0.00007	18.3	20.6	17.3	20.6	0.838	105.6	NO DAMAGE	
210	-130	2	0.00015	18.3	20.6	16.9	20.6	0.816	93.2	NO DAMAGE	
210	-150	5	0.00037	18.3	20.6	16.6	20.6	0.806	88.0	NO DAMAGE	
210	-160	1	0.00007	18.3	20.6	16.5	20.6	0.800	85.6	NO DAMAGE	
210	-190	1	0.00007	18.3	20.6	16.2	20.6	0.784	79.2	NO DAMAGE	
210	-200	2	0.00015	18.3	20.6	16.1	20.6	0.779	77.3	NO DAMAGE	
210	-210	1	0.00007	18.3	20.6	16.0	20.6	0.773	75.4	NO DAMAGE	
210	-220	2	0.00015	18.3	20.6	15.8	20.6	0.768	73.7	NO DAMAGE	
210	-230	1	0.00007	18.3	20.6	15.7	20.6	0.762	72.0	NO DAMAGE	
205	195	56	0.00417	18.3	20.6	20.5	20.6	0.995	3158.9	NO DAMAGE	
205	185	48	0.00358	18.3	20.6	20.4	20.6	0.989	1579.4	NO DAMAGE	
205	180	2	0.00015	18.3	20.6	20.3	20.6	0.986	1263.6	NO DAMAGE	
205	175	11	0.00082	18.3	20.6	20.3	20.6	0.984	1053.0	NO DAMAGE	
205	165	2	0.00015	18.3	20.6	20.1	20.6	0.978	789.7	NO DAMAGE	
205	155	1	0.00007	18.3	20.6	20.0	20.6	0.973	631.8	NO DAMAGE	
205	150	1	0.00007	18.3	20.6	20.0	20.6	0.970	574.3	NO DAMAGE	
205	140	1	0.00007	18.3	20.6	19.9	20.6	0.965	486.0	NO DAMAGE	
205	135	1	0.00007	18.3	20.6	19.8	20.6	0.962	451.3	NO DAMAGE	
205	-85	1	0.00007	18.3	20.6	17.4	20.6	0.843	108.9	NO DAMAGE	
205	-115	1	0.00007	18.3	20.6	17.0	20.6	0.827	98.7	NO DAMAGE	
205	-165	1	0.00007	18.3	20.6	16.5	20.6	0.800	85.4	NO DAMAGE	
205	-180	1	0.00007	18.3	20.6	16.3	20.6	0.792	82.0	NO DAMAGE	
205	-195	1	0.00007	18.3	20.6	16.1	20.6	0.783	79.0	NO DAMAGE	
205	-210	1	0.00007	18.3	20.6	16.0	20.6	0.775	76.1	NO DAMAGE	
205	-220	1	0.00007	18.3	20.6	15.8	20.6	0.770	74.3	NO DAMAGE	
205	-235	1	0.00007	18.3	20.6	15.7	20.6	0.762	71.8	NO DAMAGE	
205	-245	1	0.00007	18.3	20.6	15.6	20.6	0.756	70.2	NO DAMAGE	
205	-285	2	0.00015	18.3	20.6	15.1	20.6	0.735	64.5	NO DAMAGE	
200	190	37	0.00276	18.3	20.5	20.4	20.5	0.995	3150.3	NO DAMAGE	
200	185	11	0.00082	18.3	20.5	20.4	20.5	0.992	2100.2	NO DAMAGE	
200	180	48	0.00358	18.3	20.5	20.3	20.5	0.989	1575.2	NO DAMAGE	
200	175	2	0.00015	18.3	20.5	20.3	20.5	0.986	1260.1	NO DAMAGE	
200	170	22	0.00164	18.3	20.5	20.2	20.5	0.984	1050.1	NO DAMAGE	
200	165	3	0.00022	18.3	20.5	20.1	20.5	0.981	900.1	NO DAMAGE	
200	160	10	0.00075	18.3	20.5	20.1	20.5	0.978	787.6	NO DAMAGE	
200	155	2	0.00015	18.3	20.5	20.0	20.5	0.976	700.1	NO DAMAGE	
200	150	3	0.00022	18.3	20.5	20.0	20.5	0.973	630.1	NO DAMAGE	
200	140	4	0.00030	18.3	20.5	19.9	20.5	0.967	525.1	NO DAMAGE	
200	135	2	0.00015	18.3	20.5	19.8	20.5	0.965	484.7	NO DAMAGE	
200	110	1	0.00007	18.3	20.5	19.5	20.5	0.951	350.0	NO DAMAGE	
200	100	2	0.00015	18.3	20.5	19.4	20.5	0.946	315.0	NO DAMAGE	
200	60	1	0.00007	18.3	20.5	19.0	20.5	0.924	225.0	NO DAMAGE	
200	30	1	0.00007	18.3	20.5	18.6	20.5	0.908	185.3	NO DAMAGE	
200	20	2	0.00015	18.3	20.5	18.5	20.5	0.902	175.0	NO DAMAGE	
200	0	1	0.00007	18.3	20.5	18.3	20.5	0.891	157.5	NO DAMAGE	
200	-80	2	0.00015	18.3	20.5	17.4	20.5	0.848	112.5	NO DAMAGE	
200	-100	1	0.00007	18.3	20.5	17.2	20.5	0.837	105.0	NO DAMAGE	
200	-110	1	0.00007	18.3	20.5	17.1	20.5	0.832	101.6	NO DAMAGE	
200	-130	2	0.00015	18.3	20.5	16.9	20.5	0.821	95.5	NO DAMAGE	
200	-135	1	0.00007	18.3	20.5	16.8	20.5	0.818	94.0	NO DAMAGE	
200	-150	1	0.00007	18.3	20.5	16.6	20.5	0.810	90.0	NO DAMAGE	
200	-170	1	0.00007	18.3	20.5	16.4	20.5	0.799	85.1	NO DAMAGE	
200	-180	1	0.00007	18.3	20.5	16.3	20.5	0.794	82.9	NO DAMAGE	
200	-220	2	0.00015	18.3	20.5	15.8	20.5	0.772	75.0	NO DAMAGE	
200	-240	1	0.00007	18.3	20.5	15.6	20.5	0.761	71.6	NO DAMAGE	
200	-260	2	0.00015	18.3	20.5	15.4	20.5	0.750	68.5	NO DAMAGE	
200	-265	1	0.00007	18.3	20.5	15.3	20.5	0.748	67.7	NO DAMAGE	
195	185	174	0.01297	18.3	20.5	20.4	20.5	0.995	3141.8	NO DAMAGE	

cycles per mile	153.8
Yield stress	60 ksi

Max	Min	No.	α Pct	Static Stress	Dynamic Stress Max	Dynamic Stress Min	Max Adjusted	R Min/Max	Endurance Limit	to Failure N	α/N
195	180	10	0.00075	18.3	20.5	20.3	20.5	0.992	2094.5	NO DAMAGE	
195	175	103	0.00768	18.3	20.5	20.3	20.5	0.989	1570.9	NO DAMAGE	
195	170	6	0.00045	18.3	20.5	20.2	20.5	0.986	1256.7	NO DAMAGE	
195	165	30	0.00224	18.3	20.5	20.1	20.5	0.984	1047.3	NO DAMAGE	
195	160	5	0.00037	18.3	20.5	20.1	20.5	0.981	897.7	NO DAMAGE	
195	155	21	0.00157	18.3	20.5	20.0	20.5	0.978	785.4	NO DAMAGE	
195	150	2	0.00015	18.3	20.5	20.0	20.5	0.976	698.2	NO DAMAGE	
195	145	4	0.00030	18.3	20.5	19.9	20.5	0.973	628.4	NO DAMAGE	
195	140	3	0.00022	18.3	20.5	19.9	20.5	0.970	571.2	NO DAMAGE	
195	135	3	0.00022	18.3	20.5	19.8	20.5	0.967	523.6	NO DAMAGE	
195	125	1	0.00007	18.3	20.5	19.7	20.5	0.962	448.8	NO DAMAGE	
195	115	2	0.00015	18.3	20.5	19.6	20.5	0.956	392.7	NO DAMAGE	
195	95	1	0.00007	18.3	20.5	19.4	20.5	0.946	314.2	NO DAMAGE	
195	85	2	0.00015	18.3	20.5	19.2	20.5	0.940	285.6	NO DAMAGE	
195	75	1	0.00007	18.3	20.5	19.1	20.5	0.935	261.8	NO DAMAGE	
195	55	1	0.00007	18.3	20.5	18.9	20.5	0.924	224.4	NO DAMAGE	
195	45	2	0.00015	18.3	20.5	18.8	20.5	0.918	209.5	NO DAMAGE	
195	35	1	0.00007	18.3	20.5	18.7	20.5	0.913	196.4	NO DAMAGE	
195	5	1	0.00007	18.3	20.5	18.4	20.5	0.897	165.4	NO DAMAGE	
195	-75	1	0.00007	18.3	20.5	17.5	20.5	0.853	116.4	NO DAMAGE	
195	-105	1	0.00007	18.3	20.5	17.1	20.5	0.837	104.7	NO DAMAGE	
195	-125	1	0.00007	18.3	20.5	16.9	20.5	0.826	98.2	NO DAMAGE	
195	-135	1	0.00007	18.3	20.5	16.8	20.5	0.820	95.2	NO DAMAGE	
195	-145	1	0.00007	18.3	20.5	16.7	20.5	0.815	92.4	NO DAMAGE	
195	-155	2	0.00015	18.3	20.5	16.6	20.5	0.810	89.8	NO DAMAGE	
195	-165	1	0.00007	18.3	20.5	16.5	20.5	0.804	87.3	NO DAMAGE	
195	-195	1	0.00007	18.3	20.5	16.1	20.5	0.788	80.6	NO DAMAGE	
195	-235	1	0.00007	18.3	20.5	15.7	20.5	0.766	73.1	NO DAMAGE	
195	-245	2	0.00015	18.3	20.5	15.6	20.5	0.761	71.4	NO DAMAGE	
195	-255	2	0.00015	18.3	20.5	15.5	20.5	0.755	69.8	NO DAMAGE	
195	-265	1	0.00007	18.3	20.5	15.3	20.5	0.750	68.3	NO DAMAGE	
195	-275	1	0.00007	18.3	20.5	15.2	20.5	0.744	66.8	NO DAMAGE	
195	-595	1	0.00007	18.3	20.5	11.7	20.5	0.570	39.8	19743211	5.07E-10
190	180	141	0.01051	18.3	20.4	20.3	20.4	0.995	3133.2	NO DAMAGE	
190	175	31	0.00231	18.3	20.4	20.3	20.4	0.992	2088.8	NO DAMAGE	
190	170	117	0.00872	18.3	20.4	20.2	20.4	0.989	1566.6	NO DAMAGE	
190	165	17	0.00127	18.3	20.4	20.1	20.4	0.986	1253.3	NO DAMAGE	
190	160	45	0.00335	18.3	20.4	20.1	20.4	0.984	1044.4	NO DAMAGE	
190	155	4	0.00030	18.3	20.4	20.0	20.4	0.981	895.2	NO DAMAGE	
190	150	8	0.00060	18.3	20.4	20.0	20.4	0.978	783.3	NO DAMAGE	
190	145	1	0.00007	18.3	20.4	19.9	20.4	0.975	696.3	NO DAMAGE	
190	140	5	0.00037	18.3	20.4	19.9	20.4	0.973	626.6	NO DAMAGE	
190	120	2	0.00015	18.3	20.4	19.6	20.4	0.962	447.6	NO DAMAGE	
190	115	1	0.00007	18.3	20.4	19.6	20.4	0.959	417.8	NO DAMAGE	
190	110	3	0.00022	18.3	20.4	19.5	20.4	0.956	391.7	NO DAMAGE	
190	100	2	0.00015	18.3	20.4	19.4	20.4	0.951	348.1	NO DAMAGE	
190	80	1	0.00007	18.3	20.4	19.2	20.4	0.940	284.8	NO DAMAGE	
190	75	1	0.00007	18.3	20.4	19.1	20.4	0.937	272.5	NO DAMAGE	
190	70	1	0.00007	18.3	20.4	19.1	20.4	0.935	261.1	NO DAMAGE	
190	50	2	0.00015	18.3	20.4	18.9	20.4	0.924	223.8	NO DAMAGE	
190	40	1	0.00007	18.3	20.4	18.7	20.4	0.918	208.9	NO DAMAGE	
190	30	2	0.00015	18.3	20.4	18.6	20.4	0.913	195.8	NO DAMAGE	
190	25	1	0.00007	18.3	20.4	18.6	20.4	0.910	189.9	NO DAMAGE	
190	10	1	0.00007	18.3	20.4	18.4	20.4	0.902	174.1	NO DAMAGE	
190	-10	1	0.00007	18.3	20.4	18.2	20.4	0.891	156.7	NO DAMAGE	
190	-20	1	0.00007	18.3	20.4	18.1	20.4	0.885	149.2	NO DAMAGE	
190	-45	1	0.00007	18.3	20.4	17.8	20.4	0.872	133.3	NO DAMAGE	
190	-50	1	0.00007	18.3	20.4	17.7	20.4	0.869	130.6	NO DAMAGE	
190	-90	1	0.00007	18.3	20.4	17.3	20.4	0.847	111.9	NO DAMAGE	
190	-100	3	0.00022	18.3	20.4	17.2	20.4	0.842	108.0	NO DAMAGE	
190	-130	2	0.00015	18.3	20.4	16.9	20.4	0.825	97.9	NO DAMAGE	
190	-165	1	0.00007	18.3	20.4	16.5	20.4	0.806	88.3	NO DAMAGE	
190	-190	3	0.00022	18.3	20.4	16.2	20.4	0.793	82.5	NO DAMAGE	
190	-195	1	0.00007	18.3	20.4	16.1	20.4	0.790	81.4	NO DAMAGE	
185	175	578	0.04309	18.3	20.4	20.3	20.4	0.995	3124.7	NO DAMAGE	
185	170	102	0.00760	18.3	20.4	20.2	20.4	0.992	2083.1	NO DAMAGE	
185	165	566	0.04220	18.3	20.4	20.1	20.4	0.989	1562.3	NO DAMAGE	
185	160	5	0.00037	18.3	20.4	20.1	20.4	0.986	1249.9	NO DAMAGE	
185	155	142	0.01059	18.3	20.4	20.0	20.4	0.984	1041.6	NO DAMAGE	
185	150	4	0.00030	18.3	20.4	20.0	20.4	0.981	892.8	NO DAMAGE	
185	145	38	0.00283	18.3	20.4	19.9	20.4	0.978	781.2	NO DAMAGE	
185	140	1	0.00007	18.3	20.4	19.9	20.4	0.975	694.4	NO DAMAGE	
185	135	9	0.00067	18.3	20.4	19.8	20.4	0.973	624.9	NO DAMAGE	
185	130	1	0.00007	18.3	20.4	19.7	20.4	0.970	568.1	NO DAMAGE	
185	125	1	0.00007	18.3	20.4	19.7	20.4	0.967	520.8	NO DAMAGE	
185	120	1	0.00007	18.3	20.4	19.6	20.4	0.964	480.7	NO DAMAGE	
185	115	4	0.00030	18.3	20.4	19.6	20.4	0.962	446.4	NO DAMAGE	
185	105	5	0.00037	18.3	20.4	19.5	20.4	0.956	390.6	NO DAMAGE	
185	95	1	0.00007	18.3	20.4	19.4	20.4	0.951	347.2	NO DAMAGE	
185	85	1	0.00007	18.3	20.4	19.2	20.4	0.945	312.5	NO DAMAGE	
185	80	1	0.00007	18.3	20.4	19.2	20.4	0.943	297.6	NO DAMAGE	
185	75	1	0.00007	18.3	20.4	19.1	20.4	0.940	284.1	NO DAMAGE	
185	65	1	0.00007	18.3	20.4	19.0	20.4	0.934	260.4	NO DAMAGE	
185	60	1	0.00007	18.3	20.4	19.0	20.4	0.932	250.0	NO DAMAGE	
185	55	2	0.00015	18.3	20.4	18.9	20.4	0.929	240.4	NO DAMAGE	
185	35	2	0.00015	18.3	20.4	18.7	20.4	0.918	208.3	NO DAMAGE	
185	25	3	0.00022	18.3	20.4	18.6	20.4	0.912	195.3	NO DAMAGE	
185	20	1	0.00007	18.3	20.4	18.5	20.4	0.910	189.4	NO DAMAGE	
185	15	2	0.00015	18.3	20.4	18.5	20.4	0.907	183.8	NO DAMAGE	
185	5	3	0.00022	18.3	20.4	18.4	20.4	0.901	173.6	NO DAMAGE	
185	-5	1	0.00007	18.3	20.4	18.2	20.4	0.896	164.5	NO DAMAGE	

cycles per mile 153.8
Yield stress 60 ksi

Max	Min	No.	α Pct	Static Stress	Dynamic Stress Max	Dynamic Stress Min	Max Adjusted	R Min/Max	Endurance Limit	to Failure N	α/N
185	-15	1	0.00007	18.3	20.4	18.1	20.4	0.891	156.2	NO DAMAGE	
185	-65	1	0.00007	18.3	20.4	17.6	20.4	0.863	125.0	NO DAMAGE	
185	-95	1	0.00007	18.3	20.4	17.2	20.4	0.847	111.6	NO DAMAGE	
185	-100	1	0.00007	18.3	20.4	17.2	20.4	0.844	109.6	NO DAMAGE	
185	-105	1	0.00007	18.3	20.4	17.1	20.4	0.841	107.7	NO DAMAGE	
185	-115	1	0.00007	18.3	20.4	17.0	20.4	0.836	104.2	NO DAMAGE	
185	-120	1	0.00007	18.3	20.4	17.0	20.4	0.833	102.4	NO DAMAGE	
185	-125	3	0.00022	18.3	20.4	16.9	20.4	0.830	100.8	NO DAMAGE	
185	-145	1	0.00007	18.3	20.4	16.7	20.4	0.819	94.7	NO DAMAGE	
185	-155	2	0.00015	18.3	20.4	16.6	20.4	0.814	91.9	NO DAMAGE	
185	-160	1	0.00007	18.3	20.4	16.5	20.4	0.811	90.6	NO DAMAGE	
185	-165	5	0.00037	18.3	20.4	16.5	20.4	0.808	89.3	NO DAMAGE	
185	-170	1	0.00007	18.3	20.4	16.4	20.4	0.806	88.0	NO DAMAGE	
185	-175	2	0.00015	18.3	20.4	16.4	20.4	0.803	86.8	NO DAMAGE	
185	-180	1	0.00007	18.3	20.4	16.3	20.4	0.800	85.6	NO DAMAGE	
185	-190	1	0.00007	18.3	20.4	16.2	20.4	0.795	83.3	NO DAMAGE	
185	-195	2	0.00015	18.3	20.4	16.1	20.4	0.792	82.2	NO DAMAGE	
185	-200	2	0.00015	18.3	20.4	16.1	20.4	0.789	81.2	NO DAMAGE	
185	-205	1	0.00007	18.3	20.4	16.0	20.4	0.787	80.1	NO DAMAGE	
185	-215	2	0.00015	18.3	20.4	15.9	20.4	0.781	78.1	NO DAMAGE	
185	-235	2	0.00015	18.3	20.4	15.7	20.4	0.770	74.4	NO DAMAGE	
185	-245	3	0.00022	18.3	20.4	15.6	20.4	0.765	72.7	NO DAMAGE	
185	-275	1	0.00007	18.3	20.4	15.2	20.4	0.748	67.9	NO DAMAGE	
185	-355	1	0.00007	18.3	20.4	14.3	20.4	0.704	57.9	NO DAMAGE	
180	170	389	0.02900	18.3	20.3	20.2	20.3	0.995	3116.1	NO DAMAGE	
180	165	84	0.00626	18.3	20.3	20.1	20.3	0.992	2077.4	NO DAMAGE	
180	160	216	0.01610	18.3	20.3	20.1	20.3	0.989	1558.1	NO DAMAGE	
180	155	23	0.00171	18.3	20.3	20.0	20.3	0.986	1246.5	NO DAMAGE	
180	150	53	0.00395	18.3	20.3	20.0	20.3	0.984	1038.7	NO DAMAGE	
180	145	4	0.00030	18.3	20.3	19.9	20.3	0.981	890.3	NO DAMAGE	
180	140	42	0.00313	18.3	20.3	19.9	20.3	0.978	779.0	NO DAMAGE	
180	135	7	0.00052	18.3	20.3	19.8	20.3	0.975	692.5	NO DAMAGE	
180	130	8	0.00060	18.3	20.3	19.7	20.3	0.973	623.2	NO DAMAGE	
180	125	2	0.00015	18.3	20.3	19.7	20.3	0.970	566.6	NO DAMAGE	
180	120	1	0.00007	18.3	20.3	19.6	20.3	0.967	519.4	NO DAMAGE	
180	110	3	0.00022	18.3	20.3	19.5	20.3	0.962	445.2	NO DAMAGE	
180	105	2	0.00015	18.3	20.3	19.5	20.3	0.959	415.5	NO DAMAGE	
180	95	1	0.00007	18.3	20.3	19.4	20.3	0.953	366.6	NO DAMAGE	
180	90	2	0.00015	18.3	20.3	19.3	20.3	0.951	346.2	NO DAMAGE	
180	80	5	0.00037	18.3	20.3	19.2	20.3	0.945	311.6	NO DAMAGE	
180	75	1	0.00007	18.3	20.3	19.1	20.3	0.942	296.8	NO DAMAGE	
180	60	2	0.00015	18.3	20.3	19.0	20.3	0.934	259.7	NO DAMAGE	
180	45	1	0.00007	18.3	20.3	18.8	20.3	0.926	230.8	NO DAMAGE	
180	40	1	0.00007	18.3	20.3	18.7	20.3	0.923	222.6	NO DAMAGE	
180	30	2	0.00015	18.3	20.3	18.6	20.3	0.918	207.7	NO DAMAGE	
180	20	1	0.00007	18.3	20.3	18.5	20.3	0.912	194.8	NO DAMAGE	
180	0	2	0.00015	18.3	20.3	18.3	20.3	0.901	173.1	NO DAMAGE	
180	-5	1	0.00007	18.3	20.3	18.2	20.3	0.898	168.4	NO DAMAGE	
180	-10	3	0.00022	18.3	20.3	18.2	20.3	0.896	164.0	NO DAMAGE	
180	-45	1	0.00007	18.3	20.3	17.8	20.3	0.877	138.5	NO DAMAGE	
180	-60	3	0.00022	18.3	20.3	17.6	20.3	0.868	129.8	NO DAMAGE	
180	-70	2	0.00015	18.3	20.3	17.5	20.3	0.863	124.6	NO DAMAGE	
180	-80	2	0.00015	18.3	20.3	17.4	20.3	0.857	119.9	NO DAMAGE	
180	-90	2	0.00015	18.3	20.3	17.3	20.3	0.852	115.4	NO DAMAGE	
180	-100	2	0.00015	18.3	20.3	17.2	20.3	0.846	111.3	NO DAMAGE	
180	-110	4	0.00030	18.3	20.3	17.1	20.3	0.841	107.5	NO DAMAGE	
180	-120	1	0.00007	18.3	20.3	17.0	20.3	0.835	103.9	NO DAMAGE	
180	-130	2	0.00015	18.3	20.3	16.9	20.3	0.830	100.5	NO DAMAGE	
180	-140	1	0.00007	18.3	20.3	16.7	20.3	0.824	97.4	NO DAMAGE	
180	-145	1	0.00007	18.3	20.3	16.7	20.3	0.822	95.9	NO DAMAGE	
180	-150	3	0.00022	18.3	20.3	16.6	20.3	0.819	94.4	NO DAMAGE	
180	-160	1	0.00007	18.3	20.3	16.5	20.3	0.813	91.7	NO DAMAGE	
180	-170	2	0.00015	18.3	20.3	16.4	20.3	0.808	89.0	NO DAMAGE	
180	-185	1	0.00007	18.3	20.3	16.2	20.3	0.800	85.4	NO DAMAGE	
180	-190	1	0.00007	18.3	20.3	16.2	20.3	0.797	84.2	NO DAMAGE	
180	-200	2	0.00015	18.3	20.3	16.1	20.3	0.791	82.0	NO DAMAGE	
180	-210	1	0.00007	18.3	20.3	16.0	20.3	0.786	79.9	NO DAMAGE	
180	-215	1	0.00007	18.3	20.3	15.9	20.3	0.783	78.9	NO DAMAGE	
180	-230	1	0.00007	18.3	20.3	15.7	20.3	0.775	76.0	NO DAMAGE	
180	-240	1	0.00007	18.3	20.3	15.6	20.3	0.770	74.2	NO DAMAGE	
175	165	835	0.06225	18.3	20.3	20.1	20.3	0.994	3107.6	NO DAMAGE	
175	160	85	0.00634	18.3	20.3	20.1	20.3	0.992	2071.7	NO DAMAGE	
175	155	529	0.03944	18.3	20.3	20.0	20.3	0.989	1553.8	NO DAMAGE	
175	150	20	0.00149	18.3	20.3	20.0	20.3	0.986	1243.0	NO DAMAGE	
175	145	231	0.01722	18.3	20.3	19.9	20.3	0.983	1035.9	NO DAMAGE	
175	140	21	0.00157	18.3	20.3	19.9	20.3	0.981	887.9	NO DAMAGE	
175	135	40	0.00298	18.3	20.3	19.8	20.3	0.978	776.9	NO DAMAGE	
175	130	6	0.00045	18.3	20.3	19.7	20.3	0.975	690.6	NO DAMAGE	
175	125	8	0.00060	18.3	20.3	19.7	20.3	0.972	621.5	NO DAMAGE	
175	120	2	0.00015	18.3	20.3	19.6	20.3	0.970	565.0	NO DAMAGE	
175	115	6	0.00045	18.3	20.3	19.6	20.3	0.967	517.9	NO DAMAGE	
175	105	3	0.00022	18.3	20.3	19.5	20.3	0.961	443.9	NO DAMAGE	
175	65	1	0.00007	18.3	20.3	19.0	20.3	0.939	282.5	NO DAMAGE	
175	45	1	0.00007	18.3	20.3	18.8	20.3	0.928	239.0	NO DAMAGE	
175	35	1	0.00007	18.3	20.3	18.7	20.3	0.923	222.0	NO DAMAGE	
175	25	1	0.00007	18.3	20.3	18.6	20.3	0.917	207.2	NO DAMAGE	
175	20	1	0.00007	18.3	20.3	18.5	20.3	0.915	200.5	NO DAMAGE	
175	15	2	0.00015	18.3	20.3	18.5	20.3	0.912	194.2	NO DAMAGE	
175	5	2	0.00015	18.3	20.3	18.4	20.3	0.906	182.8	NO DAMAGE	
175	0	2	0.00015	18.3	20.3	18.3	20.3	0.904	177.6	NO DAMAGE	
175	-15	1	0.00007	18.3	20.3	18.1	20.3	0.895	163.6	NO DAMAGE	

cycles per mile	153.8
Yield stress	60 ksi

Max	Min	No.	α Pct	Static Stress	Dynamic Stress Max	Dynamic Stress Min	Max Adjusted	R Min/Max	Endurance Limit	to Failure N	α/N
175	-35	1	0.00007	18.3	20.3	17.9	20.3	0.884	148.0	NO DAMAGE	
175	-55	1	0.00007	18.3	20.3	17.7	20.3	0.873	135.1	NO DAMAGE	
175	-65	1	0.00007	18.3	20.3	17.6	20.3	0.868	129.5	NO DAMAGE	
175	-75	1	0.00007	18.3	20.3	17.5	20.3	0.862	124.3	NO DAMAGE	
175	-80	1	0.00007	18.3	20.3	17.4	20.3	0.860	121.9	NO DAMAGE	
175	-85	1	0.00007	18.3	20.3	17.4	20.3	0.857	119.5	NO DAMAGE	
175	-95	3	0.00022	18.3	20.3	17.2	20.3	0.851	115.1	NO DAMAGE	
175	-105	1	0.00007	18.3	20.3	17.1	20.3	0.846	111.0	NO DAMAGE	
175	-115	1	0.00007	18.3	20.3	17.0	20.3	0.840	107.2	NO DAMAGE	
175	-125	1	0.00007	18.3	20.3	16.9	20.3	0.835	103.6	NO DAMAGE	
175	-135	1	0.00007	18.3	20.3	16.8	20.3	0.829	100.2	NO DAMAGE	
175	-145	3	0.00022	18.3	20.3	16.7	20.3	0.824	97.1	NO DAMAGE	
175	-155	1	0.00007	18.3	20.3	16.6	20.3	0.818	94.2	NO DAMAGE	
175	-165	3	0.00022	18.3	20.3	16.5	20.3	0.813	91.4	NO DAMAGE	
175	-185	1	0.00007	18.3	20.3	16.2	20.3	0.802	86.3	NO DAMAGE	
175	-195	3	0.00022	18.3	20.3	16.1	20.3	0.796	84.0	NO DAMAGE	
175	-215	2	0.00015	18.3	20.3	15.9	20.3	0.785	79.7	NO DAMAGE	
175	-225	1	0.00007	18.3	20.3	15.8	20.3	0.780	77.7	NO DAMAGE	
175	-235	1	0.00007	18.3	20.3	15.7	20.3	0.774	75.8	NO DAMAGE	
175	-245	1	0.00007	18.3	20.3	15.6	20.3	0.769	74.0	NO DAMAGE	
175	-255	1	0.00007	18.3	20.3	15.5	20.3	0.763	72.3	NO DAMAGE	
170	160	397	0.02960	18.3	20.2	20.1	20.2	0.994	3099.0	NO DAMAGE	
170	155	85	0.00634	18.3	20.2	20.0	20.2	0.992	2066.0	NO DAMAGE	
170	150	301	0.02244	18.3	20.2	20.0	20.2	0.989	1549.5	NO DAMAGE	
170	145	34	0.00253	18.3	20.2	19.9	20.2	0.986	1239.6	NO DAMAGE	
170	140	140	0.01044	18.3	20.2	19.9	20.2	0.983	1033.0	NO DAMAGE	
170	135	10	0.00075	18.3	20.2	19.8	20.2	0.981	885.4	NO DAMAGE	
170	130	30	0.00224	18.3	20.2	19.7	20.2	0.978	774.8	NO DAMAGE	
170	125	4	0.00030	18.3	20.2	19.7	20.2	0.975	688.7	NO DAMAGE	
170	120	11	0.00082	18.3	20.2	19.6	20.2	0.972	619.8	NO DAMAGE	
170	115	2	0.00015	18.3	20.2	19.6	20.2	0.970	563.5	NO DAMAGE	
170	110	8	0.00060	18.3	20.2	19.5	20.2	0.967	516.5	NO DAMAGE	
170	100	7	0.00052	18.3	20.2	19.4	20.2	0.961	442.7	NO DAMAGE	
170	90	9	0.00067	18.3	20.2	19.3	20.2	0.956	387.4	NO DAMAGE	
170	80	7	0.00052	18.3	20.2	19.2	20.2	0.950	344.3	NO DAMAGE	
170	70	3	0.00022	18.3	20.2	19.1	20.2	0.945	309.9	NO DAMAGE	
170	65	1	0.00007	18.3	20.2	19.0	20.2	0.942	295.1	NO DAMAGE	
170	40	1	0.00007	18.3	20.2	18.7	20.2	0.928	238.4	NO DAMAGE	
170	30	3	0.00022	18.3	20.2	18.6	20.2	0.923	221.4	NO DAMAGE	
170	25	1	0.00007	18.3	20.2	18.6	20.2	0.920	213.7	NO DAMAGE	
170	20	3	0.00022	18.3	20.2	18.5	20.2	0.917	206.6	NO DAMAGE	
170	0	2	0.00015	18.3	20.2	18.3	20.2	0.906	182.3	NO DAMAGE	
170	-10	1	0.00007	18.3	20.2	18.2	20.2	0.901	172.2	NO DAMAGE	
170	-40	1	0.00007	18.3	20.2	17.9	20.2	0.884	147.6	NO DAMAGE	
170	-50	1	0.00007	18.3	20.2	17.7	20.2	0.879	140.9	NO DAMAGE	
170	-70	1	0.00007	18.3	20.2	17.5	20.2	0.868	129.1	NO DAMAGE	
170	-90	1	0.00007	18.3	20.2	17.3	20.2	0.857	119.2	NO DAMAGE	
170	-100	2	0.00015	18.3	20.2	17.2	20.2	0.851	114.8	NO DAMAGE	
170	-105	1	0.00007	18.3	20.2	17.1	20.2	0.848	112.7	NO DAMAGE	
170	-110	3	0.00022	18.3	20.2	17.1	20.2	0.846	110.7	NO DAMAGE	
170	-115	1	0.00007	18.3	20.2	17.0	20.2	0.843	108.7	NO DAMAGE	
170	-120	1	0.00007	18.3	20.2	17.0	20.2	0.840	106.9	NO DAMAGE	
170	-130	2	0.00015	18.3	20.2	16.9	20.2	0.834	103.3	NO DAMAGE	
170	-140	2	0.00015	18.3	20.2	16.7	20.2	0.829	100.0	NO DAMAGE	
170	-150	1	0.00007	18.3	20.2	16.6	20.2	0.823	96.8	NO DAMAGE	
170	-160	2	0.00015	18.3	20.2	16.5	20.2	0.818	93.9	NO DAMAGE	
170	-180	1	0.00007	18.3	20.2	16.3	20.2	0.807	88.5	NO DAMAGE	
170	-210	3	0.00022	18.3	20.2	16.0	20.2	0.790	81.6	NO DAMAGE	
170	-230	1	0.00007	18.3	20.2	15.7	20.2	0.779	77.5	NO DAMAGE	
165	155	845	0.06300	18.3	20.1	20.0	20.1	0.994	3090.5	NO DAMAGE	
165	150	95	0.00708	18.3	20.1	20.0	20.1	0.992	2060.3	NO DAMAGE	
165	145	957	0.07135	18.3	20.1	19.9	20.1	0.989	1545.2	NO DAMAGE	
165	140	52	0.00388	18.3	20.1	19.9	20.1	0.986	1236.2	NO DAMAGE	
165	135	293	0.02184	18.3	20.1	19.8	20.1	0.983	1030.2	NO DAMAGE	
165	130	13	0.00097	18.3	20.1	19.7	20.1	0.981	883.0	NO DAMAGE	
165	125	39	0.00291	18.3	20.1	19.7	20.1	0.978	772.6	NO DAMAGE	
165	120	6	0.00045	18.3	20.1	19.6	20.1	0.975	686.8	NO DAMAGE	
165	115	12	0.00089	18.3	20.1	19.6	20.1	0.972	618.1	NO DAMAGE	
165	105	4	0.00030	18.3	20.1	19.5	20.1	0.967	515.1	NO DAMAGE	
165	95	1	0.00007	18.3	20.1	19.4	20.1	0.961	441.5	NO DAMAGE	
165	85	3	0.00022	18.3	20.1	19.2	20.1	0.956	386.3	NO DAMAGE	
165	70	1	0.00007	18.3	20.1	19.1	20.1	0.947	325.3	NO DAMAGE	
165	60	1	0.00007	18.3	20.1	19.0	20.1	0.942	294.3	NO DAMAGE	
165	55	1	0.00007	18.3	20.1	18.9	20.1	0.939	281.0	NO DAMAGE	
165	40	1	0.00007	18.3	20.1	18.7	20.1	0.931	247.2	NO DAMAGE	
165	35	2	0.00015	18.3	20.1	18.7	20.1	0.928	237.7	NO DAMAGE	
165	25	3	0.00022	18.3	20.1	18.6	20.1	0.923	220.7	NO DAMAGE	
165	15	2	0.00015	18.3	20.1	18.5	20.1	0.917	206.0	NO DAMAGE	
165	-5	2	0.00015	18.3	20.1	18.2	20.1	0.906	181.8	NO DAMAGE	
165	-30	1	0.00007	18.3	20.1	18.0	20.1	0.892	158.5	NO DAMAGE	
165	-55	1	0.00007	18.3	20.1	17.7	20.1	0.878	140.5	NO DAMAGE	
165	-105	1	0.00007	18.3	20.1	17.1	20.1	0.851	114.5	NO DAMAGE	
165	-125	1	0.00007	18.3	20.1	16.9	20.1	0.840	106.6	NO DAMAGE	
165	-135	1	0.00007	18.3	20.1	16.8	20.1	0.834	103.0	NO DAMAGE	
165	-140	1	0.00007	18.3	20.1	16.7	20.1	0.831	101.3	NO DAMAGE	
165	-145	1	0.00007	18.3	20.1	16.7	20.1	0.828	99.7	NO DAMAGE	
165	-165	2	0.00015	18.3	20.1	16.5	20.1	0.817	93.7	NO DAMAGE	
165	-185	1	0.00007	18.3	20.1	16.2	20.1	0.806	88.3	NO DAMAGE	
165	-190	1	0.00007	18.3	20.1	16.2	20.1	0.804	87.1	NO DAMAGE	
165	-205	1	0.00007	18.3	20.1	16.0	20.1	0.795	83.5	NO DAMAGE	
165	-215	1	0.00007	18.3	20.1	15.9	20.1	0.790	81.3	NO DAMAGE	

cycles per mile 153.8
Yield stress 60 ksi

			α	Static	Dynamic Stress		Max	R	Endurance	to Failure	
Max	Min	No.	Pct	Stress	Max	Min	Adjusted	Min/Max	Limit	N	α/N
165	-225	2	0.00015	18.3	20.1	15.8	20.1	0.784	79.2	NO DAMAGE	
165	-255	1	0.00007	18.3	20.1	15.5	20.1	0.768	73.6	NO DAMAGE	
165	-275	1	0.00007	18.3	20.1	15.2	20.1	0.757	70.2	NO DAMAGE	
160	150	611	0.04555	18.3	20.1	20.0	20.1	0.994	3081.9	NO DAMAGE	
160	145	158	0.01178	18.3	20.1	19.9	20.1	0.992	2054.6	NO DAMAGE	
160	140	378	0.02818	18.3	20.1	19.9	20.1	0.989	1541.0	NO DAMAGE	
160	135	41	0.00306	18.3	20.1	19.8	20.1	0.986	1232.8	NO DAMAGE	
160	130	113	0.00842	18.3	20.1	19.7	20.1	0.983	1027.3	NO DAMAGE	
160	125	20	0.00149	18.3	20.1	19.7	20.1	0.981	880.6	NO DAMAGE	
160	120	53	0.00395	18.3	20.1	19.6	20.1	0.978	770.5	NO DAMAGE	
160	115	2	0.00015	18.3	20.1	19.6	20.1	0.975	684.9	NO DAMAGE	
160	110	24	0.00179	18.3	20.1	19.5	20.1	0.972	616.4	NO DAMAGE	
160	105	4	0.00030	18.3	20.1	19.5	20.1	0.969	560.4	NO DAMAGE	
160	100	12	0.00089	18.3	20.1	19.4	20.1	0.967	513.7	NO DAMAGE	
160	95	3	0.00022	18.3	20.1	19.4	20.1	0.964	474.1	NO DAMAGE	
160	90	10	0.00075	18.3	20.1	19.3	20.1	0.961	440.3	NO DAMAGE	
160	80	4	0.00030	18.3	20.1	19.2	20.1	0.956	385.2	NO DAMAGE	
160	75	1	0.00007	18.3	20.1	19.1	20.1	0.953	362.6	NO DAMAGE	
160	70	3	0.00022	18.3	20.1	19.1	20.1	0.950	342.4	NO DAMAGE	
160	60	4	0.00030	18.3	20.1	19.0	20.1	0.945	308.2	NO DAMAGE	
160	50	2	0.00015	18.3	20.1	18.9	20.1	0.939	280.2	NO DAMAGE	
160	45	1	0.00007	18.3	20.1	18.8	20.1	0.936	268.0	NO DAMAGE	
160	40	3	0.00022	18.3	20.1	18.7	20.1	0.933	256.8	NO DAMAGE	
160	30	5	0.00037	18.3	20.1	18.6	20.1	0.928	237.1	NO DAMAGE	
160	20	2	0.00015	18.3	20.1	18.5	20.1	0.922	220.1	NO DAMAGE	
160	10	2	0.00015	18.3	20.1	18.4	20.1	0.917	205.5	NO DAMAGE	
160	0	5	0.00037	18.3	20.1	18.3	20.1	0.911	192.6	NO DAMAGE	
160	-10	2	0.00015	18.3	20.1	18.2	20.1	0.906	181.3	NO DAMAGE	
160	-15	1	0.00007	18.3	20.1	18.1	20.1	0.903	176.1	NO DAMAGE	
160	-30	1	0.00007	18.3	20.1	18.0	20.1	0.895	162.2	NO DAMAGE	
160	-40	1	0.00007	18.3	20.1	17.9	20.1	0.889	154.1	NO DAMAGE	
160	-70	3	0.00022	18.3	20.1	17.5	20.1	0.872	134.0	NO DAMAGE	
160	-80	2	0.00015	18.3	20.1	17.4	20.1	0.867	128.4	NO DAMAGE	
160	-90	5	0.00037	18.3	20.1	17.3	20.1	0.861	123.3	NO DAMAGE	
160	-100	4	0.00030	18.3	20.1	17.2	20.1	0.856	118.5	NO DAMAGE	
160	-110	6	0.00045	18.3	20.1	17.1	20.1	0.850	114.1	NO DAMAGE	
160	-115	1	0.00007	18.3	20.1	17.0	20.1	0.847	112.1	NO DAMAGE	
160	-120	1	0.00007	18.3	20.1	17.0	20.1	0.845	110.1	NO DAMAGE	
160	-130	3	0.00022	18.3	20.1	16.9	20.1	0.839	106.3	NO DAMAGE	
160	-135	1	0.00007	18.3	20.1	16.8	20.1	0.836	104.5	NO DAMAGE	
160	-140	4	0.00030	18.3	20.1	16.7	20.1	0.834	102.7	NO DAMAGE	
160	-150	1	0.00007	18.3	20.1	16.6	20.1	0.828	99.4	NO DAMAGE	
160	-160	3	0.00022	18.3	20.1	16.5	20.1	0.822	96.3	NO DAMAGE	
160	-170	2	0.00015	18.3	20.1	16.4	20.1	0.817	93.4	NO DAMAGE	
160	-175	1	0.00007	18.3	20.1	16.4	20.1	0.814	92.0	NO DAMAGE	
160	-180	2	0.00015	18.3	20.1	16.3	20.1	0.811	90.6	NO DAMAGE	
160	-185	1	0.00007	18.3	20.1	16.2	20.1	0.809	89.3	NO DAMAGE	
160	-190	1	0.00007	18.3	20.1	16.2	20.1	0.806	88.1	NO DAMAGE	
155	145	1673	0.12473	18.3	20.0	19.9	20.0	0.994	3073.4	NO DAMAGE	
155	140	205	0.01528	18.3	20.0	19.9	20.0	0.992	2048.9	NO DAMAGE	
155	135	1264	0.09423	18.3	20.0	19.8	20.0	0.989	1536.7	NO DAMAGE	
155	130	69	0.00514	18.3	20.0	19.7	20.0	0.986	1229.4	NO DAMAGE	
155	125	323	0.02408	18.3	20.0	19.7	20.0	0.983	1024.5	NO DAMAGE	
155	120	17	0.00127	18.3	20.0	19.6	20.0	0.981	878.1	NO DAMAGE	
155	115	108	0.00805	18.3	20.0	19.6	20.0	0.978	768.3	NO DAMAGE	
155	110	5	0.00037	18.3	20.0	19.5	20.0	0.975	683.0	NO DAMAGE	
155	105	15	0.00112	18.3	20.0	19.5	20.0	0.972	614.7	NO DAMAGE	
155	100	1	0.00007	18.3	20.0	19.4	20.0	0.969	558.8	NO DAMAGE	
155	95	15	0.00112	18.3	20.0	19.4	20.0	0.967	512.2	NO DAMAGE	
155	85	2	0.00015	18.3	20.0	19.2	20.0	0.961	439.1	NO DAMAGE	
155	80	1	0.00007	18.3	20.0	19.2	20.0	0.958	409.8	NO DAMAGE	
155	75	6	0.00045	18.3	20.0	19.1	20.0	0.955	384.2	NO DAMAGE	
155	65	3	0.00022	18.3	20.0	19.0	20.0	0.950	341.5	NO DAMAGE	
155	55	1	0.00007	18.3	20.0	18.9	20.0	0.944	307.3	NO DAMAGE	
155	50	2	0.00015	18.3	20.0	18.9	20.0	0.942	292.7	NO DAMAGE	
155	45	2	0.00015	18.3	20.0	18.8	20.0	0.939	279.4	NO DAMAGE	
155	35	2	0.00015	18.3	20.0	18.7	20.0	0.933	256.1	NO DAMAGE	
155	25	3	0.00022	18.3	20.0	18.6	20.0	0.928	236.4	NO DAMAGE	
155	15	2	0.00015	18.3	20.0	18.5	20.0	0.922	219.5	NO DAMAGE	
155	5	3	0.00022	18.3	20.0	18.4	20.0	0.917	204.9	NO DAMAGE	
155	0	3	0.00022	18.3	20.0	18.3	20.0	0.914	198.3	NO DAMAGE	
155	-5	1	0.00007	18.3	20.0	18.2	20.0	0.911	192.1	NO DAMAGE	
155	-15	1	0.00007	18.3	20.0	18.1	20.0	0.905	180.8	NO DAMAGE	
155	-25	2	0.00015	18.3	20.0	18.0	20.0	0.900	170.7	NO DAMAGE	
155	-55	1	0.00007	18.3	20.0	17.7	20.0	0.883	146.4	NO DAMAGE	
155	-80	1	0.00007	18.3	20.0	17.4	20.0	0.869	130.8	NO DAMAGE	
155	-95	1	0.00007	18.3	20.0	17.2	20.0	0.861	122.9	NO DAMAGE	
155	-105	1	0.00007	18.3	20.0	17.1	20.0	0.855	118.2	NO DAMAGE	
155	-115	1	0.00007	18.3	20.0	17.0	20.0	0.850	113.8	NO DAMAGE	
155	-120	1	0.00007	18.3	20.0	17.0	20.0	0.847	111.8	NO DAMAGE	
155	-125	2	0.00015	18.3	20.0	16.9	20.0	0.844	109.8	NO DAMAGE	
155	-130	1	0.00007	18.3	20.0	16.9	20.0	0.841	107.8	NO DAMAGE	
155	-135	5	0.00037	18.3	20.0	16.8	20.0	0.839	106.0	NO DAMAGE	
155	-145	4	0.00030	18.3	20.0	16.7	20.0	0.833	102.4	NO DAMAGE	
155	-150	2	0.00015	18.3	20.0	16.6	20.0	0.830	100.8	NO DAMAGE	
155	-165	1	0.00007	18.3	20.0	16.5	20.0	0.822	96.0	NO DAMAGE	
155	-175	1	0.00007	18.3	20.0	16.4	20.0	0.816	93.1	NO DAMAGE	
155	-185	2	0.00015	18.3	20.0	16.2	20.0	0.811	90.4	NO DAMAGE	
155	-195	1	0.00007	18.3	20.0	16.1	20.0	0.805	87.8	NO DAMAGE	
155	-220	1	0.00007	18.3	20.0	15.8	20.0	0.791	82.0	NO DAMAGE	
155	-235	1	0.00007	18.3	20.0	15.7	20.0	0.783	78.8	NO DAMAGE	

cycles per mile 153.8
Yield stress 60 ksi

Max	Min	No.	α Pct	Static Stress	Dynamic Stress Max	Dynamic Stress Min	Max Adjusted	R Min/Max	Endurance Limit	to Failure N	α/N
150	140	773	0.05763	18.3	20.0	19.9	20.0	0.994	3064.8	NO DAMAGE	
150	135	220	0.01640	18.3	20.0	19.8	20.0	0.992	2043.2	NO DAMAGE	
150	130	550	0.04100	18.3	20.0	19.7	20.0	0.989	1532.4	NO DAMAGE	
150	125	117	0.00872	18.3	20.0	19.7	20.0	0.986	1225.9	NO DAMAGE	
150	120	210	0.01566	18.3	20.0	19.6	20.0	0.983	1021.6	NO DAMAGE	
150	115	22	0.00164	18.3	20.0	19.6	20.0	0.980	875.7	NO DAMAGE	
150	110	108	0.00805	18.3	20.0	19.5	20.0	0.978	766.2	NO DAMAGE	
150	105	4	0.00030	18.3	20.0	19.5	20.0	0.975	681.1	NO DAMAGE	
150	100	48	0.00358	18.3	20.0	19.4	20.0	0.972	613.0	NO DAMAGE	
150	95	3	0.00022	18.3	20.0	19.4	20.0	0.969	557.2	NO DAMAGE	
150	90	21	0.00157	18.3	20.0	19.3	20.0	0.967	510.8	NO DAMAGE	
150	85	2	0.00015	18.3	20.0	19.2	20.0	0.964	471.5	NO DAMAGE	
150	80	7	0.00052	18.3	20.0	19.2	20.0	0.961	437.8	NO DAMAGE	
150	70	12	0.00089	18.3	20.0	19.1	20.0	0.955	383.1	NO DAMAGE	
150	65	1	0.00007	18.3	20.0	19.0	20.0	0.953	360.6	NO DAMAGE	
150	60	6	0.00045	18.3	20.0	19.0	20.0	0.950	340.5	NO DAMAGE	
150	50	6	0.00045	18.3	20.0	18.9	20.0	0.944	306.5	NO DAMAGE	
150	45	1	0.00007	18.3	20.0	18.8	20.0	0.941	291.9	NO DAMAGE	
150	40	2	0.00015	18.3	20.0	18.7	20.0	0.939	278.6	NO DAMAGE	
150	30	3	0.00022	18.3	20.0	18.6	20.0	0.933	255.4	NO DAMAGE	
150	20	6	0.00045	18.3	20.0	18.5	20.0	0.927	235.8	NO DAMAGE	
150	10	7	0.00052	18.3	20.0	18.4	20.0	0.922	218.9	NO DAMAGE	
150	5	1	0.00007	18.3	20.0	18.4	20.0	0.919	211.4	NO DAMAGE	
150	0	6	0.00045	18.3	20.0	18.3	20.0	0.916	204.3	NO DAMAGE	
150	-10	8	0.00060	18.3	20.0	18.2	20.0	0.911	191.6	NO DAMAGE	
150	-20	1	0.00007	18.3	20.0	18.1	20.0	0.905	180.3	NO DAMAGE	
150	-25	1	0.00007	18.3	20.0	18.0	20.0	0.902	175.1	NO DAMAGE	
150	-30	1	0.00007	18.3	20.0	18.0	20.0	0.900	170.3	NO DAMAGE	
150	-40	2	0.00015	18.3	20.0	17.9	20.0	0.894	161.3	NO DAMAGE	
150	-50	1	0.00007	18.3	20.0	17.7	20.0	0.888	153.2	NO DAMAGE	
150	-60	3	0.00022	18.3	20.0	17.6	20.0	0.883	145.9	NO DAMAGE	
150	-70	2	0.00015	18.3	20.0	17.5	20.0	0.877	139.3	NO DAMAGE	
150	-80	4	0.00030	18.3	20.0	17.4	20.0	0.872	133.3	NO DAMAGE	
150	-100	3	0.00022	18.3	20.0	17.2	20.0	0.861	122.6	NO DAMAGE	
150	-105	1	0.00007	18.3	20.0	17.1	20.0	0.858	120.2	NO DAMAGE	
150	-110	5	0.00037	18.3	20.0	17.1	20.0	0.855	117.9	NO DAMAGE	
150	-115	1	0.00007	18.3	20.0	17.0	20.0	0.852	115.7	NO DAMAGE	
150	-120	4	0.00030	18.3	20.0	17.0	20.0	0.849	113.5	NO DAMAGE	
150	-125	2	0.00015	18.3	20.0	16.9	20.0	0.847	111.4	NO DAMAGE	
150	-130	3	0.00022	18.3	20.0	16.9	20.0	0.844	109.5	NO DAMAGE	
150	-135	1	0.00007	18.3	20.0	16.8	20.0	0.841	107.5	NO DAMAGE	
150	-140	3	0.00022	18.3	20.0	16.7	20.0	0.838	105.7	NO DAMAGE	
150	-150	2	0.00015	18.3	20.0	16.6	20.0	0.833	102.2	NO DAMAGE	
150	-160	1	0.00007	18.3	20.0	16.5	20.0	0.827	98.9	NO DAMAGE	
150	-165	1	0.00007	18.3	20.0	16.5	20.0	0.824	97.3	NO DAMAGE	
150	-170	1	0.00007	18.3	20.0	16.4	20.0	0.821	95.8	NO DAMAGE	
150	-180	1	0.00007	18.3	20.0	16.3	20.0	0.816	92.9	NO DAMAGE	
150	-220	1	0.00007	18.3	20.0	15.8	20.0	0.794	82.8	NO DAMAGE	
150	-230	1	0.00007	18.3	20.0	15.7	20.0	0.788	80.7	NO DAMAGE	
145	135	2125	0.15842	18.3	19.9	19.8	19.9	0.994	3056.3	NO DAMAGE	
145	130	317	0.02363	18.3	19.9	19.7	19.9	0.992	2037.5	NO DAMAGE	
145	125	1702	0.12689	18.3	19.9	19.7	19.9	0.989	1528.1	NO DAMAGE	
145	120	76	0.00567	18.3	19.9	19.6	19.9	0.986	1222.5	NO DAMAGE	
145	115	343	0.02557	18.3	19.9	19.6	19.9	0.983	1018.8	NO DAMAGE	
145	110	20	0.00149	18.3	19.9	19.5	19.9	0.980	873.2	NO DAMAGE	
145	105	62	0.00462	18.3	19.9	19.5	19.9	0.978	764.1	NO DAMAGE	
145	100	9	0.00067	18.3	19.9	19.4	19.9	0.975	679.2	NO DAMAGE	
145	95	17	0.00127	18.3	19.9	19.4	19.9	0.972	611.3	NO DAMAGE	
145	90	2	0.00015	18.3	19.9	19.3	19.9	0.969	555.7	NO DAMAGE	
145	85	10	0.00075	18.3	19.9	19.2	19.9	0.966	509.4	NO DAMAGE	
145	75	4	0.00030	18.3	19.9	19.1	19.9	0.961	436.6	NO DAMAGE	
145	70	1	0.00007	18.3	19.9	19.1	19.9	0.958	407.5	NO DAMAGE	
145	65	2	0.00015	18.3	19.9	19.0	19.9	0.955	382.0	NO DAMAGE	
145	55	6	0.00045	18.3	19.9	18.9	19.9	0.950	339.6	NO DAMAGE	
145	45	6	0.00045	18.3	19.9	18.8	19.9	0.944	305.6	NO DAMAGE	
145	35	3	0.00022	18.3	19.9	18.7	19.9	0.938	277.8	NO DAMAGE	
145	30	1	0.00007	18.3	19.9	18.6	19.9	0.936	265.8	NO DAMAGE	
145	25	3	0.00022	18.3	19.9	18.6	19.9	0.933	254.7	NO DAMAGE	
145	20	2	0.00015	18.3	19.9	18.5	19.9	0.930	244.5	NO DAMAGE	
145	15	4	0.00030	18.3	19.9	18.5	19.9	0.927	235.1	NO DAMAGE	
145	10	1	0.00007	18.3	19.9	18.4	19.9	0.924	226.4	NO DAMAGE	
145	5	4	0.00030	18.3	19.9	18.4	19.9	0.922	218.3	NO DAMAGE	
145	0	1	0.00007	18.3	19.9	18.3	19.9	0.919	210.8	NO DAMAGE	
145	-5	3	0.00022	18.3	19.9	18.2	19.9	0.916	203.8	NO DAMAGE	
145	-35	2	0.00015	18.3	19.9	17.9	19.9	0.899	169.8	NO DAMAGE	
145	-75	1	0.00007	18.3	19.9	17.5	19.9	0.877	138.9	NO DAMAGE	
145	-85	1	0.00007	18.3	19.9	17.4	19.9	0.871	132.9	NO DAMAGE	
145	-95	3	0.00022	18.3	19.9	17.2	19.9	0.866	127.3	NO DAMAGE	
145	-100	1	0.00007	18.3	19.9	17.2	19.9	0.863	124.7	NO DAMAGE	
145	-105	1	0.00007	18.3	19.9	17.1	19.9	0.860	122.3	NO DAMAGE	
145	-115	3	0.00022	18.3	19.9	17.0	19.9	0.855	117.5	NO DAMAGE	
145	-135	3	0.00022	18.3	19.9	16.8	19.9	0.843	109.2	NO DAMAGE	
145	-145	3	0.00022	18.3	19.9	16.7	19.9	0.838	105.4	NO DAMAGE	
145	-155	1	0.00007	18.3	19.9	16.6	19.9	0.832	101.9	NO DAMAGE	
145	-165	3	0.00022	18.3	19.9	16.5	19.9	0.827	98.6	NO DAMAGE	
145	-185	1	0.00007	18.3	19.9	16.2	19.9	0.815	92.6	NO DAMAGE	
145	-195	2	0.00015	18.3	19.9	16.1	19.9	0.810	89.9	NO DAMAGE	
145	-215	2	0.00015	18.3	19.9	15.9	19.9	0.799	84.9	NO DAMAGE	
145	-265	1	0.00007	18.3	19.9	15.3	19.9	0.771	74.5	NO DAMAGE	
140	130	1518	0.11317	18.3	19.9	19.7	19.9	0.994	3047.7	NO DAMAGE	
140	125	298	0.02222	18.3	19.9	19.7	19.9	0.992	2031.8	NO DAMAGE	

cycles per mile 153.8
Yield stress 60 ksi

Max	Min	No.	α Pct	Static Stress	Dynamic Stress Max	Dynamic Stress Min	Max Adjusted	R Min/Max	Endurance Limit	to Failure N	α/N
140	120	667	0.04973	18.3	19.9	19.6	19.9	0.989	1523.9	NO DAMAGE	
140	115	88	0.00656	18.3	19.9	19.6	19.9	0.986	1219.1	NO DAMAGE	
140	110	316	0.02356	18.3	19.9	19.5	19.9	0.983	1015.9	NO DAMAGE	
140	105	35	0.00261	18.3	19.9	19.5	19.9	0.980	870.8	NO DAMAGE	
140	100	185	0.01379	18.3	19.9	19.4	19.9	0.978	761.9	NO DAMAGE	
140	95	18	0.00134	18.3	19.9	19.4	19.9	0.975	677.3	NO DAMAGE	
140	90	67	0.00500	18.3	19.9	19.3	19.9	0.972	609.5	NO DAMAGE	
140	85	3	0.00022	18.3	19.9	19.2	19.9	0.969	554.1	NO DAMAGE	
140	80	41	0.00306	18.3	19.9	19.2	19.9	0.966	508.0	NO DAMAGE	
140	75	5	0.00037	18.3	19.9	19.1	19.9	0.964	468.9	NO DAMAGE	
140	70	30	0.00224	18.3	19.9	19.1	19.9	0.961	435.4	NO DAMAGE	
140	65	2	0.00015	18.3	19.9	19.0	19.9	0.958	406.4	NO DAMAGE	
140	60	13	0.00097	18.3	19.9	19.0	19.9	0.955	381.0	NO DAMAGE	
140	55	1	0.00007	18.3	19.9	18.9	19.9	0.952	358.6	NO DAMAGE	
140	50	5	0.00037	18.3	19.9	18.9	19.9	0.950	338.6	NO DAMAGE	
140	45	3	0.00022	18.3	19.9	18.8	19.9	0.947	320.8	NO DAMAGE	
140	40	12	0.00089	18.3	19.9	18.7	19.9	0.944	304.8	NO DAMAGE	
140	35	1	0.00007	18.3	19.9	18.7	19.9	0.941	290.3	NO DAMAGE	
140	30	7	0.00052	18.3	19.9	18.6	19.9	0.938	277.1	NO DAMAGE	
140	20	8	0.00060	18.3	19.9	18.5	19.9	0.933	254.0	NO DAMAGE	
140	10	7	0.00052	18.3	19.9	18.4	19.9	0.927	234.4	NO DAMAGE	
140	5	1	0.00007	18.3	19.9	18.4	19.9	0.924	225.8	NO DAMAGE	
140	0	10	0.00075	18.3	19.9	18.3	19.9	0.921	217.7	NO DAMAGE	
140	-5	1	0.00007	18.3	19.9	18.2	19.9	0.919	210.2	NO DAMAGE	
140	-10	9	0.00067	18.3	19.9	18.2	19.9	0.916	203.2	NO DAMAGE	
140	-20	3	0.00022	18.3	19.9	18.1	19.9	0.910	190.5	NO DAMAGE	
140	-25	1	0.00007	18.3	19.9	18.0	19.9	0.907	184.7	NO DAMAGE	
140	-30	2	0.00015	18.3	19.9	18.0	19.9	0.905	179.3	NO DAMAGE	
140	-40	3	0.00022	18.3	19.9	17.9	19.9	0.899	169.3	NO DAMAGE	
140	-50	3	0.00022	18.3	19.9	17.7	19.9	0.893	160.4	NO DAMAGE	
140	-60	2	0.00015	18.3	19.9	17.6	19.9	0.888	152.4	NO DAMAGE	
140	-70	3	0.00022	18.3	19.9	17.5	19.9	0.882	145.1	NO DAMAGE	
140	-80	5	0.00037	18.3	19.9	17.4	19.9	0.877	138.5	NO DAMAGE	
140	-90	5	0.00037	18.3	19.9	17.3	19.9	0.871	132.5	NO DAMAGE	
140	-95	1	0.00007	18.3	19.9	17.2	19.9	0.868	129.7	NO DAMAGE	
140	-100	9	0.00067	18.3	19.9	17.2	19.9	0.865	127.0	NO DAMAGE	
140	-110	4	0.00030	18.3	19.9	17.1	19.9	0.860	121.9	NO DAMAGE	
140	-115	1	0.00007	18.3	19.9	17.0	19.9	0.857	119.5	NO DAMAGE	
140	-120	7	0.00052	18.3	19.9	17.0	19.9	0.854	117.2	NO DAMAGE	
140	-130	2	0.00015	18.3	19.9	16.9	19.9	0.849	112.9	NO DAMAGE	
140	-140	5	0.00037	18.3	19.9	16.7	19.9	0.843	108.8	NO DAMAGE	
140	-145	2	0.00015	18.3	19.9	16.7	19.9	0.840	106.9	NO DAMAGE	
140	-150	2	0.00015	18.3	19.9	16.6	19.9	0.837	105.1	NO DAMAGE	
140	-155	1	0.00007	18.3	19.9	16.6	19.9	0.834	103.3	NO DAMAGE	
140	-160	1	0.00007	18.3	19.9	16.5	19.9	0.832	101.6	NO DAMAGE	
140	-170	2	0.00015	18.3	19.9	16.4	19.9	0.826	98.3	NO DAMAGE	
140	-190	1	0.00007	18.3	19.9	16.2	19.9	0.815	92.4	NO DAMAGE	
140	-200	1	0.00007	18.3	19.9	16.1	19.9	0.809	89.6	NO DAMAGE	
140	-210	1	0.00007	18.3	19.9	16.0	19.9	0.804	87.1	NO DAMAGE	
140	-260	1	0.00007	18.3	19.9	15.4	19.9	0.776	76.2	NO DAMAGE	
135	125	2305	0.17184	18.3	19.8	19.7	19.8	0.994	3039.2	NO DAMAGE	
135	120	236	0.01759	18.3	19.8	19.6	19.8	0.992	2026.1	NO DAMAGE	
135	115	1901	0.14172	18.3	19.8	19.6	19.8	0.989	1519.6	NO DAMAGE	
135	110	117	0.00872	18.3	19.8	19.5	19.8	0.986	1215.7	NO DAMAGE	
135	105	472	0.03519	18.3	19.8	19.5	19.8	0.983	1013.1	NO DAMAGE	
135	100	55	0.00410	18.3	19.8	19.4	19.8	0.980	868.3	NO DAMAGE	
135	95	122	0.00910	18.3	19.8	19.4	19.8	0.977	759.8	NO DAMAGE	
135	90	11	0.00082	18.3	19.8	19.3	19.8	0.975	675.4	NO DAMAGE	
135	85	59	0.00440	18.3	19.8	19.2	19.8	0.972	607.8	NO DAMAGE	
135	80	6	0.00045	18.3	19.8	19.2	19.8	0.969	552.6	NO DAMAGE	
135	75	28	0.00209	18.3	19.8	19.1	19.8	0.966	506.5	NO DAMAGE	
135	70	2	0.00015	18.3	19.8	19.1	19.8	0.963	467.6	NO DAMAGE	
135	65	11	0.00082	18.3	19.8	19.0	19.8	0.961	434.2	NO DAMAGE	
135	60	1	0.00007	18.3	19.8	19.0	19.8	0.958	405.2	NO DAMAGE	
135	55	11	0.00082	18.3	19.8	18.9	19.8	0.955	379.9	NO DAMAGE	
135	50	2	0.00015	18.3	19.8	18.9	19.8	0.952	357.6	NO DAMAGE	
135	45	6	0.00045	18.3	19.8	18.8	19.8	0.949	337.7	NO DAMAGE	
135	35	3	0.00022	18.3	19.8	18.7	19.8	0.944	303.9	NO DAMAGE	
135	30	1	0.00007	18.3	19.8	18.6	19.8	0.941	289.4	NO DAMAGE	
135	25	6	0.00045	18.3	19.8	18.6	19.8	0.938	276.3	NO DAMAGE	
135	20	1	0.00007	18.3	19.8	18.5	19.8	0.935	264.3	NO DAMAGE	
135	15	5	0.00037	18.3	19.8	18.5	19.8	0.932	253.3	NO DAMAGE	
135	5	11	0.00082	18.3	19.8	18.4	19.8	0.927	233.8	NO DAMAGE	
135	0	4	0.00030	18.3	19.8	18.3	19.8	0.924	225.1	NO DAMAGE	
135	-5	1	0.00007	18.3	19.8	18.2	19.8	0.921	217.1	NO DAMAGE	
135	-15	1	0.00007	18.3	19.8	18.1	19.8	0.916	202.6	NO DAMAGE	
135	-35	1	0.00007	18.3	19.8	17.9	19.8	0.904	178.8	NO DAMAGE	
135	-40	1	0.00007	18.3	19.8	17.9	19.8	0.902	173.7	NO DAMAGE	
135	-45	3	0.00022	18.3	19.8	17.8	19.8	0.899	168.8	NO DAMAGE	
135	-65	1	0.00007	18.3	19.8	17.6	19.8	0.887	152.0	NO DAMAGE	
135	-85	2	0.00015	18.3	19.8	17.4	19.8	0.876	138.1	NO DAMAGE	
135	-95	1	0.00007	18.3	19.8	17.2	19.8	0.871	132.1	NO DAMAGE	
135	-100	1	0.00007	18.3	19.8	17.2	19.8	0.868	129.3	NO DAMAGE	
135	-105	4	0.00030	18.3	19.8	17.1	19.8	0.865	126.6	NO DAMAGE	
135	-115	3	0.00022	18.3	19.8	17.0	19.8	0.859	121.6	NO DAMAGE	
135	-125	6	0.00045	18.3	19.8	16.9	19.8	0.854	116.9	NO DAMAGE	
135	-135	4	0.00030	18.3	19.8	16.8	19.8	0.848	112.6	NO DAMAGE	
135	-145	3	0.00022	18.3	19.8	16.7	19.8	0.842	108.5	NO DAMAGE	
135	-155	3	0.00022	18.3	19.8	16.6	19.8	0.837	104.8	NO DAMAGE	
135	-160	2	0.00015	18.3	19.8	16.5	19.8	0.834	103.0	NO DAMAGE	
135	-165	2	0.00015	18.3	19.8	16.5	19.8	0.831	101.3	NO DAMAGE	

cycles per mile 153.8
Yield stress 60 ksi

Max	Min	No.	α Pct	Static Stress	Dynamic Stress Max	Dynamic Stress Min	Max Adjusted	R Min/Max	Endurance Limit	to Failure N	α/N
135	-175	2	0.00015	18.3	19.8	16.4	19.8	0.826	98.0	NO DAMAGE	
135	-185	2	0.00015	18.3	19.8	16.2	19.8	0.820	95.0	NO DAMAGE	
135	-195	2	0.00015	18.3	19.8	16.1	19.8	0.814	92.1	NO DAMAGE	
135	-205	1	0.00007	18.3	19.8	16.0	19.8	0.809	89.4	NO DAMAGE	
135	-235	1	0.00007	18.3	19.8	15.7	19.8	0.792	82.1	NO DAMAGE	
130	120	1350	0.10065	18.3	19.7	19.6	19.7	0.994	3030.6	NO DAMAGE	
130	115	357	0.02662	18.3	19.7	19.6	19.7	0.992	2020.4	NO DAMAGE	
130	110	1062	0.07918	18.3	19.7	19.5	19.7	0.989	1515.3	NO DAMAGE	
130	105	197	0.01469	18.3	19.7	19.5	19.7	0.986	1212.3	NO DAMAGE	
130	100	540	0.04026	18.3	19.7	19.4	19.7	0.983	1010.2	NO DAMAGE	
130	95	69	0.00514	18.3	19.7	19.4	19.7	0.980	865.9	NO DAMAGE	
130	90	301	0.02244	18.3	19.7	19.3	19.7	0.977	757.7	NO DAMAGE	
130	85	20	0.00149	18.3	19.7	19.2	19.7	0.975	673.5	NO DAMAGE	
130	80	166	0.01238	18.3	19.7	19.2	19.7	0.972	606.1	NO DAMAGE	
130	75	15	0.00112	18.3	19.7	19.1	19.7	0.969	551.0	NO DAMAGE	
130	70	66	0.00492	18.3	19.7	19.1	19.7	0.966	505.1	NO DAMAGE	
130	65	7	0.00052	18.3	19.7	19.0	19.7	0.963	466.3	NO DAMAGE	
130	60	35	0.00261	18.3	19.7	19.0	19.7	0.961	432.9	NO DAMAGE	
130	55	6	0.00045	18.3	19.7	18.9	19.7	0.958	404.1	NO DAMAGE	
130	50	34	0.00253	18.3	19.7	18.9	19.7	0.955	378.8	NO DAMAGE	
130	45	2	0.00015	18.3	19.7	18.8	19.7	0.952	356.5	NO DAMAGE	
130	40	12	0.00089	18.3	19.7	18.7	19.7	0.949	336.7	NO DAMAGE	
130	35	1	0.00007	18.3	19.7	18.7	19.7	0.946	319.0	NO DAMAGE	
130	30	6	0.00045	18.3	19.7	18.6	19.7	0.944	303.1	NO DAMAGE	
130	25	1	0.00007	18.3	19.7	18.6	19.7	0.941	288.6	NO DAMAGE	
130	20	10	0.00075	18.3	19.7	18.5	19.7	0.938	275.5	NO DAMAGE	
130	10	11	0.00082	18.3	19.7	18.4	19.7	0.932	252.6	NO DAMAGE	
130	0	11	0.00082	18.3	19.7	18.3	19.7	0.927	233.1	NO DAMAGE	
130	-5	2	0.00015	18.3	19.7	18.2	19.7	0.924	224.5	NO DAMAGE	
130	-10	8	0.00060	18.3	19.7	18.2	19.7	0.921	216.5	NO DAMAGE	
130	-20	1	0.00007	18.3	19.7	18.1	19.7	0.915	202.0	NO DAMAGE	
130	-30	5	0.00037	18.3	19.7	18.0	19.7	0.910	189.4	NO DAMAGE	
130	-35	1	0.00007	18.3	19.7	17.9	19.7	0.907	183.7	NO DAMAGE	
130	-40	2	0.00015	18.3	19.7	17.9	19.7	0.904	178.3	NO DAMAGE	
130	-50	2	0.00015	18.3	19.7	17.7	19.7	0.898	168.4	NO DAMAGE	
130	-60	8	0.00060	18.3	19.7	17.6	19.7	0.893	159.5	NO DAMAGE	
130	-70	5	0.00037	18.3	19.7	17.5	19.7	0.887	151.5	NO DAMAGE	
130	-80	4	0.00030	18.3	19.7	17.4	19.7	0.882	144.3	NO DAMAGE	
130	-90	6	0.00045	18.3	19.7	17.3	19.7	0.876	137.8	NO DAMAGE	
130	-100	4	0.00030	18.3	19.7	17.2	19.7	0.870	131.8	NO DAMAGE	
130	-110	5	0.00037	18.3	19.7	17.1	19.7	0.865	126.3	NO DAMAGE	
130	-120	2	0.00015	18.3	19.7	17.0	19.7	0.859	121.2	NO DAMAGE	
130	-130	2	0.00015	18.3	19.7	16.9	19.7	0.853	116.6	NO DAMAGE	
130	-140	1	0.00007	18.3	19.7	16.7	19.7	0.848	112.2	NO DAMAGE	
130	-150	1	0.00007	18.3	19.7	16.6	19.7	0.842	108.2	NO DAMAGE	
130	-160	3	0.00022	18.3	19.7	16.5	19.7	0.836	104.5	NO DAMAGE	
130	-170	1	0.00007	18.3	19.7	16.4	19.7	0.831	101.0	NO DAMAGE	
130	-205	1	0.00007	18.3	19.7	16.0	19.7	0.811	90.5	NO DAMAGE	
130	-215	1	0.00007	18.3	19.7	15.9	19.7	0.805	87.8	NO DAMAGE	
130	-220	1	0.00007	18.3	19.7	15.8	19.7	0.803	86.6	NO DAMAGE	
125	115	3294	0.24558	18.3	19.7	19.6	19.7	0.994	3022.1	NO DAMAGE	
125	110	660	0.04920	18.3	19.7	19.5	19.7	0.992	2014.7	NO DAMAGE	
125	105	2822	0.21039	18.3	19.7	19.5	19.7	0.989	1511.0	NO DAMAGE	
125	100	259	0.01931	18.3	19.7	19.4	19.7	0.986	1208.8	NO DAMAGE	
125	95	752	0.05606	18.3	19.7	19.4	19.7	0.983	1007.4	NO DAMAGE	
125	90	87	0.00649	18.3	19.7	19.3	19.7	0.980	863.5	NO DAMAGE	
125	85	266	0.01983	18.3	19.7	19.2	19.7	0.977	755.5	NO DAMAGE	
125	80	34	0.00253	18.3	19.7	19.2	19.7	0.975	671.6	NO DAMAGE	
125	75	137	0.01021	18.3	19.7	19.1	19.7	0.972	604.4	NO DAMAGE	
125	70	14	0.00104	18.3	19.7	19.1	19.7	0.969	549.5	NO DAMAGE	
125	65	87	0.00649	18.3	19.7	19.0	19.7	0.966	503.7	NO DAMAGE	
125	60	9	0.00067	18.3	19.7	19.0	19.7	0.963	464.9	NO DAMAGE	
125	55	39	0.00291	18.3	19.7	18.9	19.7	0.960	431.7	NO DAMAGE	
125	50	2	0.00015	18.3	19.7	18.9	19.7	0.958	402.9	NO DAMAGE	
125	45	22	0.00164	18.3	19.7	18.8	19.7	0.955	377.8	NO DAMAGE	
125	40	4	0.00030	18.3	19.7	18.7	19.7	0.952	355.5	NO DAMAGE	
125	35	8	0.00060	18.3	19.7	18.7	19.7	0.949	335.8	NO DAMAGE	
125	25	6	0.00045	18.3	19.7	18.6	19.7	0.943	302.2	NO DAMAGE	
125	15	8	0.00060	18.3	19.7	18.5	19.7	0.938	274.7	NO DAMAGE	
125	5	14	0.00104	18.3	19.7	18.4	19.7	0.932	251.8	NO DAMAGE	
125	0	4	0.00030	18.3	19.7	18.3	19.7	0.929	241.8	NO DAMAGE	
125	-5	5	0.00037	18.3	19.7	18.2	19.7	0.926	232.5	NO DAMAGE	
125	-15	1	0.00007	18.3	19.7	18.1	19.7	0.921	215.9	NO DAMAGE	
125	-20	1	0.00007	18.3	19.7	18.1	19.7	0.918	208.4	NO DAMAGE	
125	-25	1	0.00007	18.3	19.7	18.0	19.7	0.915	201.5	NO DAMAGE	
125	-35	1	0.00007	18.3	19.7	17.9	19.7	0.909	188.9	NO DAMAGE	
125	-55	3	0.00022	18.3	19.7	17.7	19.7	0.898	167.9	NO DAMAGE	
125	-65	1	0.00007	18.3	19.7	17.6	19.7	0.892	159.1	NO DAMAGE	
125	-75	2	0.00015	18.3	19.7	17.5	19.7	0.887	151.1	NO DAMAGE	
125	-85	3	0.00022	18.3	19.7	17.4	19.7	0.881	143.9	NO DAMAGE	
125	-95	7	0.00052	18.3	19.7	17.2	19.7	0.876	137.4	NO DAMAGE	
125	-100	3	0.00022	18.3	19.7	17.2	19.7	0.873	134.3	NO DAMAGE	
125	-105	3	0.00022	18.3	19.7	17.1	19.7	0.870	131.4	NO DAMAGE	
125	-115	3	0.00022	18.3	19.7	17.0	19.7	0.864	125.9	NO DAMAGE	
125	-120	2	0.00015	18.3	19.7	17.0	19.7	0.861	123.4	NO DAMAGE	
125	-125	3	0.00022	18.3	19.7	16.9	19.7	0.859	120.9	NO DAMAGE	
125	-135	1	0.00007	18.3	19.7	16.8	19.7	0.853	116.2	NO DAMAGE	
125	-145	1	0.00007	18.3	19.7	16.7	19.7	0.847	111.9	NO DAMAGE	
125	-155	1	0.00007	18.3	19.7	16.6	19.7	0.842	107.9	NO DAMAGE	
125	-165	2	0.00015	18.3	19.7	16.5	19.7	0.836	104.2	NO DAMAGE	
125	-190	1	0.00007	18.3	19.7	16.2	19.7	0.822	95.9	NO DAMAGE	

cycles per mile	153.8
Yield stress	60 ksi

Max	Min	No.	α Pct	Static Stress	Dynamic Stress Max	Dynamic Stress Min	Max Adjusted	R Min/Max	Endurance Limit	to Failure N	α/N
125	-205	3	0.00022	18.3	19.7	16.0	19.7	0.813	91.6	NO DAMAGE	
125	-225	2	0.00015	18.3	19.7	15.8	19.7	0.802	86.3	NO DAMAGE	
120	110	2455	0.18303	18.3	19.6	19.5	19.6	0.994	3013.5	NO DAMAGE	
120	105	678	0.05055	18.3	19.6	19.5	19.6	0.991	2009.0	NO DAMAGE	
120	100	1649	0.12294	18.3	19.6	19.4	19.6	0.989	1506.8	NO DAMAGE	
120	95	334	0.02490	18.3	19.6	19.4	19.6	0.986	1205.4	NO DAMAGE	
120	90	851	0.06344	18.3	19.6	19.3	19.6	0.983	1004.5	NO DAMAGE	
120	85	101	0.00753	18.3	19.6	19.2	19.6	0.980	861.0	NO DAMAGE	
120	80	398	0.02967	18.3	19.6	19.2	19.6	0.977	753.4	NO DAMAGE	
120	75	38	0.00283	18.3	19.6	19.1	19.6	0.974	669.7	NO DAMAGE	
120	70	202	0.01506	18.3	19.6	19.1	19.6	0.972	602.7	NO DAMAGE	
120	65	15	0.00112	18.3	19.6	19.0	19.6	0.969	547.9	NO DAMAGE	
120	60	115	0.00857	18.3	19.6	19.0	19.6	0.966	502.3	NO DAMAGE	
120	55	12	0.00089	18.3	19.6	18.9	19.6	0.963	463.6	NO DAMAGE	
120	50	63	0.00470	18.3	19.6	18.9	19.6	0.960	430.5	NO DAMAGE	
120	45	2	0.00015	18.3	19.6	18.8	19.6	0.957	401.8	NO DAMAGE	
120	40	37	0.00276	18.3	19.6	18.7	19.6	0.955	376.7	NO DAMAGE	
120	35	3	0.00022	18.3	19.6	18.7	19.6	0.952	354.5	NO DAMAGE	
120	30	27	0.00201	18.3	19.6	18.6	19.6	0.949	334.8	NO DAMAGE	
120	25	3	0.00022	18.3	19.6	18.6	19.6	0.946	317.2	NO DAMAGE	
120	20	15	0.00112	18.3	19.6	18.5	19.6	0.943	301.4	NO DAMAGE	
120	15	1	0.00007	18.3	19.6	18.5	19.6	0.940	287.0	NO DAMAGE	
120	10	13	0.00097	18.3	19.6	18.4	19.6	0.938	274.0	NO DAMAGE	
120	5	5	0.00037	18.3	19.6	18.4	19.6	0.935	262.0	NO DAMAGE	
120	0	23	0.00171	18.3	19.6	18.3	19.6	0.932	251.1	NO DAMAGE	
120	-5	4	0.00030	18.3	19.6	18.2	19.6	0.929	241.1	NO DAMAGE	
120	-10	19	0.00142	18.3	19.6	18.2	19.6	0.926	231.8	NO DAMAGE	
120	-20	3	0.00022	18.3	19.6	18.1	19.6	0.921	215.3	NO DAMAGE	
120	-30	7	0.00052	18.3	19.6	18.0	19.6	0.915	200.9	NO DAMAGE	
120	-40	1	0.00007	18.3	19.6	17.9	19.6	0.909	188.3	NO DAMAGE	
120	-45	1	0.00007	18.3	19.6	17.8	19.6	0.906	182.6	NO DAMAGE	
120	-50	6	0.00045	18.3	19.6	17.7	19.6	0.904	177.3	NO DAMAGE	
120	-55	1	0.00007	18.3	19.6	17.7	19.6	0.901	172.2	NO DAMAGE	
120	-60	3	0.00022	18.3	19.6	17.6	19.6	0.898	167.4	NO DAMAGE	
120	-70	9	0.00067	18.3	19.6	17.5	19.6	0.892	158.6	NO DAMAGE	
120	-80	5	0.00037	18.3	19.6	17.4	19.6	0.887	150.7	NO DAMAGE	
120	-85	1	0.00007	18.3	19.6	17.4	19.6	0.884	147.0	NO DAMAGE	
120	-90	8	0.00060	18.3	19.6	17.3	19.6	0.881	143.5	NO DAMAGE	
120	-100	6	0.00045	18.3	19.6	17.2	19.6	0.875	137.0	NO DAMAGE	
120	-110	7	0.00052	18.3	19.6	17.1	19.6	0.869	131.0	NO DAMAGE	
120	-115	1	0.00007	18.3	19.6	17.0	19.6	0.867	128.2	NO DAMAGE	
120	-120	3	0.00022	18.3	19.6	17.0	19.6	0.864	125.6	NO DAMAGE	
120	-130	2	0.00015	18.3	19.6	16.9	19.6	0.858	120.5	NO DAMAGE	
120	-135	1	0.00007	18.3	19.6	16.8	19.6	0.855	118.2	NO DAMAGE	
120	-140	5	0.00037	18.3	19.6	16.7	19.6	0.852	115.9	NO DAMAGE	
120	-145	1	0.00007	18.3	19.6	16.7	19.6	0.850	113.7	NO DAMAGE	
120	-150	2	0.00015	18.3	19.6	16.6	19.6	0.847	111.6	NO DAMAGE	
120	-155	1	0.00007	18.3	19.6	16.6	19.6	0.844	109.6	NO DAMAGE	
120	-160	2	0.00015	18.3	19.6	16.5	19.6	0.841	107.6	NO DAMAGE	
120	-180	2	0.00015	18.3	19.6	16.3	19.6	0.830	100.5	NO DAMAGE	
120	-235	1	0.00007	18.3	19.6	15.7	19.6	0.799	84.9	NO DAMAGE	
115	105	4703	0.35062	18.3	19.6	19.5	19.6	0.994	3005.0	NO DAMAGE	
115	100	908	0.06769	18.3	19.6	19.4	19.6	0.991	2003.3	NO DAMAGE	
115	95	3914	0.29180	18.3	19.6	19.4	19.6	0.989	1502.5	NO DAMAGE	
115	90	307	0.02289	18.3	19.6	19.3	19.6	0.986	1202.0	NO DAMAGE	
115	85	2643	0.19704	18.3	19.6	19.2	19.6	0.983	1001.7	NO DAMAGE	
115	80	181	0.01349	18.3	19.6	19.2	19.6	0.980	858.6	NO DAMAGE	
115	75	676	0.05040	18.3	19.6	19.1	19.6	0.977	751.2	NO DAMAGE	
115	70	90	0.00671	18.3	19.6	19.1	19.6	0.974	667.8	NO DAMAGE	
115	65	334	0.02490	18.3	19.6	19.0	19.6	0.972	601.0	NO DAMAGE	
115	60	32	0.00239	18.3	19.6	19.0	19.6	0.969	546.4	NO DAMAGE	
115	55	129	0.00962	18.3	19.6	18.9	19.6	0.966	500.8	NO DAMAGE	
115	50	13	0.00097	18.3	19.6	18.9	19.6	0.963	462.3	NO DAMAGE	
115	45	39	0.00291	18.3	19.6	18.8	19.6	0.960	429.3	NO DAMAGE	
115	40	5	0.00037	18.3	19.6	18.7	19.6	0.957	400.7	NO DAMAGE	
115	35	21	0.00157	18.3	19.6	18.7	19.6	0.954	375.6	NO DAMAGE	
115	30	1	0.00007	18.3	19.6	18.6	19.6	0.952	353.5	NO DAMAGE	
115	25	10	0.00075	18.3	19.6	18.6	19.6	0.949	333.9	NO DAMAGE	
115	20	2	0.00015	18.3	19.6	18.5	19.6	0.946	316.3	NO DAMAGE	
115	15	11	0.00082	18.3	19.6	18.5	19.6	0.943	300.5	NO DAMAGE	
115	5	18	0.00134	18.3	19.6	18.4	19.6	0.937	273.2	NO DAMAGE	
115	0	4	0.00030	18.3	19.6	18.3	19.6	0.935	261.3	NO DAMAGE	
115	-5	5	0.00037	18.3	19.6	18.2	19.6	0.932	250.4	NO DAMAGE	
115	-15	2	0.00015	18.3	19.6	18.1	19.6	0.926	231.2	NO DAMAGE	
115	-20	3	0.00022	18.3	19.6	18.1	19.6	0.923	222.6	NO DAMAGE	
115	-25	2	0.00015	18.3	19.6	18.0	19.6	0.920	214.6	NO DAMAGE	
115	-35	2	0.00015	18.3	19.6	17.9	19.6	0.915	200.3	NO DAMAGE	
115	-40	2	0.00015	18.3	19.6	17.9	19.6	0.912	193.9	NO DAMAGE	
115	-45	2	0.00015	18.3	19.6	17.8	19.6	0.909	187.8	NO DAMAGE	
115	-50	1	0.00007	18.3	19.6	17.7	19.6	0.906	182.1	NO DAMAGE	
115	-55	1	0.00007	18.3	19.6	17.7	19.6	0.903	176.8	NO DAMAGE	
115	-65	2	0.00015	18.3	19.6	17.6	19.6	0.898	166.9	NO DAMAGE	
115	-75	2	0.00015	18.3	19.6	17.5	19.6	0.892	158.2	NO DAMAGE	
115	-85	2	0.00015	18.3	19.6	17.4	19.6	0.886	150.2	NO DAMAGE	
115	-95	3	0.00022	18.3	19.6	17.2	19.6	0.880	143.1	NO DAMAGE	
115	-105	4	0.00030	18.3	19.6	17.1	19.6	0.875	136.6	NO DAMAGE	
115	-115	2	0.00015	18.3	19.6	17.0	19.6	0.869	130.7	NO DAMAGE	
115	-125	3	0.00022	18.3	19.6	16.9	19.6	0.863	125.2	NO DAMAGE	
115	-135	1	0.00007	18.3	19.6	16.8	19.6	0.858	120.2	NO DAMAGE	
115	-155	1	0.00007	18.3	19.6	16.6	19.6	0.846	111.3	NO DAMAGE	
115	-170	1	0.00007	18.3	19.6	16.4	19.6	0.838	105.4	NO DAMAGE	

cycles per mile	153.8
Yield stress	60 ksi

			α	Static	Dynamic Stress			R	Endurance	to Failure	
Max	Min	No.	Pct	Stress	Max	Min	Max Adjusted	Min/Max	Limit	N	α/N
115	-190	1	0.00007	18.3	19.6	16.2	19.6	0.826	98.5	NO DAMAGE	
115	-195	1	0.00007	18.3	19.6	16.1	19.6	0.824	96.9	NO DAMAGE	
115	-215	1	0.00007	18.3	19.6	15.9	19.6	0.812	91.1	NO DAMAGE	
110	100	3541	0.26399	18.3	19.5	19.4	19.5	0.994	2996.4	NO DAMAGE	
110	95	922	0.06874	18.3	19.5	19.4	19.5	0.991	1997.6	NO DAMAGE	
110	90	2060	0.15358	18.3	19.5	19.3	19.5	0.989	1498.2	NO DAMAGE	
110	85	527	0.03929	18.3	19.5	19.2	19.5	0.986	1198.6	NO DAMAGE	
110	80	1233	0.09192	18.3	19.5	19.2	19.5	0.983	998.8	NO DAMAGE	
110	75	313	0.02334	18.3	19.5	19.1	19.5	0.980	856.1	NO DAMAGE	
110	70	677	0.05047	18.3	19.5	19.1	19.5	0.977	749.1	NO DAMAGE	
110	65	107	0.00798	18.3	19.5	19.0	19.5	0.974	665.9	NO DAMAGE	
110	60	289	0.02155	18.3	19.5	19.0	19.5	0.971	599.3	NO DAMAGE	
110	55	26	0.00194	18.3	19.5	18.9	19.5	0.969	544.8	NO DAMAGE	
110	50	126	0.00939	18.3	19.5	18.9	19.5	0.966	499.4	NO DAMAGE	
110	45	5	0.00037	18.3	19.5	18.8	19.5	0.963	461.0	NO DAMAGE	
110	40	74	0.00552	18.3	19.5	18.7	19.5	0.960	428.1	NO DAMAGE	
110	35	6	0.00045	18.3	19.5	18.7	19.5	0.957	399.5	NO DAMAGE	
110	30	32	0.00239	18.3	19.5	18.6	19.5	0.954	374.6	NO DAMAGE	
110	25	2	0.00015	18.3	19.5	18.6	19.5	0.951	352.5	NO DAMAGE	
110	20	28	0.00209	18.3	19.5	18.5	19.5	0.949	332.9	NO DAMAGE	
110	15	1	0.00007	18.3	19.5	18.5	19.5	0.946	315.4	NO DAMAGE	
110	10	26	0.00194	18.3	19.5	18.4	19.5	0.943	299.6	NO DAMAGE	
110	5	1	0.00007	18.3	19.5	18.4	19.5	0.940	285.4	NO DAMAGE	
110	0	47	0.00350	18.3	19.5	18.3	19.5	0.937	272.4	NO DAMAGE	
110	-5	2	0.00015	18.3	19.5	18.2	19.5	0.934	260.6	NO DAMAGE	
110	-10	22	0.00164	18.3	19.5	18.2	19.5	0.932	249.7	NO DAMAGE	
110	-20	4	0.00030	18.3	19.5	18.1	19.5	0.926	230.5	NO DAMAGE	
110	-30	5	0.00037	18.3	19.5	18.0	19.5	0.920	214.0	NO DAMAGE	
110	-35	1	0.00007	18.3	19.5	17.9	19.5	0.917	206.7	NO DAMAGE	
110	-40	2	0.00015	18.3	19.5	17.9	19.5	0.914	199.8	NO DAMAGE	
110	-50	5	0.00037	18.3	19.5	17.7	19.5	0.909	187.3	NO DAMAGE	
110	-60	6	0.00045	18.3	19.5	17.6	19.5	0.903	176.3	NO DAMAGE	
110	-70	6	0.00045	18.3	19.5	17.5	19.5	0.897	166.5	NO DAMAGE	
110	-80	6	0.00045	18.3	19.5	17.4	19.5	0.892	157.7	NO DAMAGE	
110	-90	8	0.00060	18.3	19.5	17.3	19.5	0.886	149.8	NO DAMAGE	
110	-100	9	0.00067	18.3	19.5	17.2	19.5	0.880	142.7	NO DAMAGE	
110	-110	6	0.00045	18.3	19.5	17.1	19.5	0.874	136.2	NO DAMAGE	
110	-120	5	0.00037	18.3	19.5	17.0	19.5	0.869	130.3	NO DAMAGE	
110	-130	1	0.00007	18.3	19.5	16.9	19.5	0.863	124.9	NO DAMAGE	
110	-135	1	0.00007	18.3	19.5	16.8	19.5	0.860	122.3	NO DAMAGE	
110	-140	2	0.00015	18.3	19.5	16.7	19.5	0.857	119.9	NO DAMAGE	
110	-150	2	0.00015	18.3	19.5	16.6	19.5	0.852	115.2	NO DAMAGE	
110	-160	1	0.00007	18.3	19.5	16.5	19.5	0.846	111.0	NO DAMAGE	
110	-170	1	0.00007	18.3	19.5	16.4	19.5	0.840	107.0	NO DAMAGE	
110	-180	1	0.00007	18.3	19.5	16.3	19.5	0.835	103.3	NO DAMAGE	
110	-210	1	0.00007	18.3	19.5	16.0	19.5	0.817	93.6	NO DAMAGE	
105	95	10845	0.80852	18.3	19.5	19.4	19.5	0.994	2987.9	NO DAMAGE	
105	90	1293	0.09640	18.3	19.5	19.3	19.5	0.991	1991.9	NO DAMAGE	
105	85	5514	0.41108	18.3	19.5	19.2	19.5	0.989	1493.9	NO DAMAGE	
105	80	765	0.05703	18.3	19.5	19.2	19.5	0.986	1195.2	NO DAMAGE	
105	75	2419	0.18034	18.3	19.5	19.1	19.5	0.983	996.0	NO DAMAGE	
105	70	358	0.02669	18.3	19.5	19.1	19.5	0.980	853.7	NO DAMAGE	
105	65	920	0.06859	18.3	19.5	19.0	19.5	0.977	747.0	NO DAMAGE	
105	60	78	0.00582	18.3	19.5	19.0	19.5	0.974	664.0	NO DAMAGE	
105	55	262	0.01953	18.3	19.5	18.9	19.5	0.971	597.6	NO DAMAGE	
105	50	22	0.00164	18.3	19.5	18.9	19.5	0.969	543.3	NO DAMAGE	
105	45	100	0.00746	18.3	19.5	18.8	19.5	0.966	498.0	NO DAMAGE	
105	40	4	0.00030	18.3	19.5	18.7	19.5	0.963	459.7	NO DAMAGE	
105	35	54	0.00403	18.3	19.5	18.7	19.5	0.960	426.8	NO DAMAGE	
105	30	1	0.00007	18.3	19.5	18.6	19.5	0.957	398.4	NO DAMAGE	
105	25	20	0.00149	18.3	19.5	18.6	19.5	0.954	373.5	NO DAMAGE	
105	20	4	0.00030	18.3	19.5	18.5	19.5	0.951	351.5	NO DAMAGE	
105	15	18	0.00134	18.3	19.5	18.5	19.5	0.948	332.0	NO DAMAGE	
105	10	1	0.00007	18.3	19.5	18.4	19.5	0.946	314.5	NO DAMAGE	
105	5	22	0.00164	18.3	19.5	18.4	19.5	0.943	298.8	NO DAMAGE	
105	0	2	0.00015	18.3	19.5	18.3	19.5	0.940	284.6	NO DAMAGE	
105	-5	4	0.00030	18.3	19.5	18.2	19.5	0.937	271.6	NO DAMAGE	
105	-10	1	0.00007	18.3	19.5	18.2	19.5	0.934	259.8	NO DAMAGE	
105	-15	3	0.00022	18.3	19.5	18.1	19.5	0.931	249.0	NO DAMAGE	
105	-20	1	0.00007	18.3	19.5	18.1	19.5	0.928	239.0	NO DAMAGE	
105	-25	2	0.00015	18.3	19.5	18.0	19.5	0.926	229.8	NO DAMAGE	
105	-35	4	0.00030	18.3	19.5	17.9	19.5	0.920	213.4	NO DAMAGE	
105	-45	3	0.00022	18.3	19.5	17.8	19.5	0.914	199.2	NO DAMAGE	
105	-55	1	0.00007	18.3	19.5	17.7	19.5	0.908	186.7	NO DAMAGE	
105	-65	1	0.00007	18.3	19.5	17.6	19.5	0.903	175.8	NO DAMAGE	
105	-75	2	0.00015	18.3	19.5	17.5	19.5	0.897	166.0	NO DAMAGE	
105	-85	6	0.00045	18.3	19.5	17.4	19.5	0.891	157.3	NO DAMAGE	
105	-95	6	0.00045	18.3	19.5	17.2	19.5	0.886	149.4	NO DAMAGE	
105	-105	3	0.00022	18.3	19.5	17.1	19.5	0.880	142.3	NO DAMAGE	
105	-110	2	0.00015	18.3	19.5	17.1	19.5	0.877	139.0	NO DAMAGE	
105	-120	2	0.00015	18.3	19.5	17.0	19.5	0.871	132.8	NO DAMAGE	
105	-125	1	0.00007	18.3	19.5	16.9	19.5	0.868	129.9	NO DAMAGE	
105	-145	3	0.00022	18.3	19.5	16.7	19.5	0.857	119.5	NO DAMAGE	
105	-165	1	0.00007	18.3	19.5	16.5	19.5	0.845	110.7	NO DAMAGE	
105	-185	1	0.00007	18.3	19.5	16.2	19.5	0.834	103.0	NO DAMAGE	
105	-195	1	0.00007	18.3	19.5	16.1	19.5	0.828	99.6	NO DAMAGE	
105	-225	1	0.00007	18.3	19.5	15.8	19.5	0.811	90.5	NO DAMAGE	
105	-255	1	0.00007	18.3	19.5	15.5	19.5	0.794	83.0	NO DAMAGE	
100	90	4690	0.34965	18.3	19.4	19.3	19.4	0.994	2979.3	NO DAMAGE	
100	85	1557	0.11608	18.3	19.4	19.2	19.4	0.991	1986.2	NO DAMAGE	
100	80	3257	0.24282	18.3	19.4	19.2	19.4	0.989	1489.7	NO DAMAGE	

cycles per mile 153.8
Yield stress 60 ksi

Max	Min	No.	α Pct	Static Stress	Dynamic Stress Max	Dynamic Stress Min	Max Adjusted	R Min/Max	Endurance Limit	to Failure N	α/N
100	75	901	0.06717	18.3	19.4	19.1	19.4	0.986	1191.7	NO DAMAGE	
100	70	1551	0.11563	18.3	19.4	19.1	19.4	0.983	993.1	NO DAMAGE	
100	65	248	0.01849	18.3	19.4	19.0	19.4	0.980	851.2	NO DAMAGE	
100	60	739	0.05509	18.3	19.4	19.0	19.4	0.977	744.8	NO DAMAGE	
100	55	63	0.00470	18.3	19.4	18.9	19.4	0.974	662.1	NO DAMAGE	
100	50	318	0.02371	18.3	19.4	18.9	19.4	0.971	595.9	NO DAMAGE	
100	45	22	0.00164	18.3	19.4	18.8	19.4	0.968	541.7	NO DAMAGE	
100	40	168	0.01252	18.3	19.4	18.7	19.4	0.966	496.6	NO DAMAGE	
100	35	5	0.00037	18.3	19.4	18.7	19.4	0.963	458.4	NO DAMAGE	
100	30	90	0.00671	18.3	19.4	18.6	19.4	0.960	425.6	NO DAMAGE	
100	25	11	0.00082	18.3	19.4	18.6	19.4	0.957	397.2	NO DAMAGE	
100	20	55	0.00410	18.3	19.4	18.5	19.4	0.954	372.4	NO DAMAGE	
100	15	1	0.00007	18.3	19.4	18.5	19.4	0.951	350.5	NO DAMAGE	
100	10	42	0.00313	18.3	19.4	18.4	19.4	0.948	331.0	NO DAMAGE	
100	5	2	0.00015	18.3	19.4	18.4	19.4	0.945	313.6	NO DAMAGE	
100	0	58	0.00432	18.3	19.4	18.3	19.4	0.943	297.9	NO DAMAGE	
100	-5	1	0.00007	18.3	19.4	18.2	19.4	0.940	283.7	NO DAMAGE	
100	-10	32	0.00239	18.3	19.4	18.2	19.4	0.937	270.8	NO DAMAGE	
100	-15	1	0.00007	18.3	19.4	18.1	19.4	0.934	259.1	NO DAMAGE	
100	-20	5	0.00037	18.3	19.4	18.1	19.4	0.931	248.3	NO DAMAGE	
100	-30	7	0.00052	18.3	19.4	18.0	19.4	0.925	229.2	NO DAMAGE	
100	-40	2	0.00015	18.3	19.4	17.9	19.4	0.920	212.8	NO DAMAGE	
100	-45	1	0.00007	18.3	19.4	17.8	19.4	0.917	205.5	NO DAMAGE	
100	-50	7	0.00052	18.3	19.4	17.7	19.4	0.914	198.6	NO DAMAGE	
100	-60	8	0.00060	18.3	19.4	17.6	19.4	0.908	186.2	NO DAMAGE	
100	-70	3	0.00022	18.3	19.4	17.5	19.4	0.902	175.3	NO DAMAGE	
100	-80	2	0.00015	18.3	19.4	17.4	19.4	0.897	165.5	NO DAMAGE	
100	-90	9	0.00067	18.3	19.4	17.3	19.4	0.891	156.8	NO DAMAGE	
100	-100	4	0.00030	18.3	19.4	17.2	19.4	0.885	149.0	NO DAMAGE	
100	-110	3	0.00022	18.3	19.4	17.1	19.4	0.879	141.9	NO DAMAGE	
100	-120	1	0.00007	18.3	19.4	17.0	19.4	0.874	135.4	NO DAMAGE	
100	-125	1	0.00007	18.3	19.4	16.9	19.4	0.871	132.4	NO DAMAGE	
100	-130	3	0.00022	18.3	19.4	16.9	19.4	0.868	129.5	NO DAMAGE	
100	-140	2	0.00015	18.3	19.4	16.7	19.4	0.862	124.1	NO DAMAGE	
100	-150	2	0.00015	18.3	19.4	16.6	19.4	0.857	119.2	NO DAMAGE	
100	-160	1	0.00007	18.3	19.4	16.5	19.4	0.851	114.6	NO DAMAGE	
100	-180	2	0.00015	18.3	19.4	16.3	19.4	0.839	106.4	NO DAMAGE	
100	-190	2	0.00015	18.3	19.4	16.2	19.4	0.834	102.7	NO DAMAGE	
100	-200	3	0.00022	18.3	19.4	16.1	19.4	0.828	99.3	NO DAMAGE	
100	-205	1	0.00007	18.3	19.4	16.0	19.4	0.825	97.7	NO DAMAGE	
100	-210	1	0.00007	18.3	19.4	16.0	19.4	0.822	96.1	NO DAMAGE	
95	85	7900	0.58897	18.3	19.4	19.2	19.4	0.994	2970.8	NO DAMAGE	
95	80	1725	0.12860	18.3	19.4	19.2	19.4	0.991	1980.5	NO DAMAGE	
95	75	6072	0.45268	18.3	19.4	19.1	19.4	0.988	1485.4	NO DAMAGE	
95	70	643	0.04794	18.3	19.4	19.1	19.4	0.986	1188.3	NO DAMAGE	
95	65	2494	0.18593	18.3	19.4	19.0	19.4	0.983	990.3	NO DAMAGE	
95	60	216	0.01610	18.3	19.4	19.0	19.4	0.980	848.8	NO DAMAGE	
95	55	984	0.07336	18.3	19.4	18.9	19.4	0.977	742.7	NO DAMAGE	
95	50	63	0.00470	18.3	19.4	18.9	19.4	0.974	660.2	NO DAMAGE	
95	45	319	0.02378	18.3	19.4	18.8	19.4	0.971	594.2	NO DAMAGE	
95	40	22	0.00164	18.3	19.4	18.7	19.4	0.968	540.1	NO DAMAGE	
95	35	103	0.00768	18.3	19.4	18.7	19.4	0.965	495.1	NO DAMAGE	
95	30	19	0.00142	18.3	19.4	18.6	19.4	0.963	457.0	NO DAMAGE	
95	25	38	0.00283	18.3	19.4	18.6	19.4	0.960	424.4	NO DAMAGE	
95	20	2	0.00015	18.3	19.4	18.5	19.4	0.957	396.1	NO DAMAGE	
95	15	11	0.00082	18.3	19.4	18.5	19.4	0.954	371.3	NO DAMAGE	
95	5	28	0.00209	18.3	19.4	18.4	19.4	0.948	330.1	NO DAMAGE	
95	0	7	0.00052	18.3	19.4	18.3	19.4	0.945	312.7	NO DAMAGE	
95	-5	5	0.00037	18.3	19.4	18.2	19.4	0.942	297.1	NO DAMAGE	
95	-15	1	0.00007	18.3	19.4	18.1	19.4	0.937	270.1	NO DAMAGE	
95	-25	2	0.00015	18.3	19.4	18.0	19.4	0.931	247.6	NO DAMAGE	
95	-35	3	0.00022	18.3	19.4	17.9	19.4	0.925	228.5	NO DAMAGE	
95	-45	1	0.00007	18.3	19.4	17.8	19.4	0.919	212.2	NO DAMAGE	
95	-55	1	0.00007	18.3	19.4	17.7	19.4	0.914	198.1	NO DAMAGE	
95	-70	1	0.00007	18.3	19.4	17.5	19.4	0.905	180.0	NO DAMAGE	
95	-75	6	0.00045	18.3	19.4	17.5	19.4	0.902	174.8	NO DAMAGE	
95	-85	5	0.00037	18.3	19.4	17.4	19.4	0.896	165.0	NO DAMAGE	
95	-95	4	0.00030	18.3	19.4	17.2	19.4	0.891	156.4	NO DAMAGE	
95	-100	1	0.00007	18.3	19.4	17.2	19.4	0.888	152.3	NO DAMAGE	
95	-105	5	0.00037	18.3	19.4	17.1	19.4	0.885	148.5	NO DAMAGE	
95	-110	3	0.00022	18.3	19.4	17.1	19.4	0.882	144.9	NO DAMAGE	
95	-115	3	0.00022	18.3	19.4	17.0	19.4	0.879	141.5	NO DAMAGE	
95	-125	1	0.00007	18.3	19.4	16.9	19.4	0.873	135.0	NO DAMAGE	
95	-135	2	0.00015	18.3	19.4	16.8	19.4	0.868	129.2	NO DAMAGE	
95	-140	1	0.00007	18.3	19.4	16.7	19.4	0.865	126.4	NO DAMAGE	
95	-145	1	0.00007	18.3	19.4	16.7	19.4	0.862	123.8	NO DAMAGE	
95	-165	3	0.00022	18.3	19.4	16.5	19.4	0.850	114.3	NO DAMAGE	
95	-225	1	0.00007	18.3	19.4	15.8	19.4	0.816	92.8	NO DAMAGE	
95	-280	1	0.00007	18.3	19.4	15.2	19.4	0.784	79.2	NO DAMAGE	
90	80	6066	0.45224	18.3	19.3	19.2	19.3	0.994	2962.2	NO DAMAGE	
90	75	1408	0.10497	18.3	19.3	19.1	19.3	0.991	1974.8	NO DAMAGE	
90	70	3591	0.26772	18.3	19.3	19.1	19.3	0.988	1481.1	NO DAMAGE	
90	65	591	0.04406	18.3	19.3	19.0	19.3	0.986	1184.9	NO DAMAGE	
90	60	1593	0.11876	18.3	19.3	19.0	19.3	0.983	987.4	NO DAMAGE	
90	55	275	0.02050	18.3	19.3	18.9	19.3	0.980	846.4	NO DAMAGE	
90	50	789	0.05882	18.3	19.3	18.9	19.3	0.977	740.6	NO DAMAGE	
90	45	83	0.00619	18.3	19.3	18.8	19.3	0.974	658.3	NO DAMAGE	
90	40	470	0.03504	18.3	19.3	18.7	19.3	0.971	592.4	NO DAMAGE	
90	35	20	0.00149	18.3	19.3	18.7	19.3	0.968	538.6	NO DAMAGE	
90	30	188	0.01402	18.3	19.3	18.6	19.3	0.965	493.7	NO DAMAGE	
90	25	8	0.00060	18.3	19.3	18.6	19.3	0.962	455.7	NO DAMAGE	

cycles per mile 153.8
Yield stress 60 ksi

Max	Min	No.	α Pct	Static Stress	Dynamic Stress Max	Dynamic Stress Min	Max Adjusted	R Min/Max	Endurance Limit	to Failure N	α/N
90	20	113	0.00842	18.3	19.3	18.5	19.3	0.960	423.2	NO DAMAGE	
90	15	4	0.00030	18.3	19.3	18.5	19.3	0.957	395.0	NO DAMAGE	
90	10	68	0.00507	18.3	19.3	18.4	19.3	0.954	370.3	NO DAMAGE	
90	5	2	0.00015	18.3	19.3	18.4	19.3	0.951	348.5	NO DAMAGE	
90	0	78	0.00582	18.3	19.3	18.3	19.3	0.948	329.1	NO DAMAGE	
90	-5	2	0.00015	18.3	19.3	18.2	19.3	0.945	311.8	NO DAMAGE	
90	-10	32	0.00239	18.3	19.3	18.2	19.3	0.942	296.2	NO DAMAGE	
90	-15	1	0.00007	18.3	19.3	18.1	19.3	0.939	282.1	NO DAMAGE	
90	-20	4	0.00030	18.3	19.3	18.1	19.3	0.937	269.3	NO DAMAGE	
90	-30	4	0.00030	18.3	19.3	18.0	19.3	0.931	246.9	NO DAMAGE	
90	-40	6	0.00045	18.3	19.3	17.9	19.3	0.925	227.9	NO DAMAGE	
90	-45	1	0.00007	18.3	19.3	17.8	19.3	0.922	219.4	NO DAMAGE	
90	-50	7	0.00052	18.3	19.3	17.7	19.3	0.919	211.6	NO DAMAGE	
90	-60	14	0.00104	18.3	19.3	17.6	19.3	0.913	197.5	NO DAMAGE	
90	-70	8	0.00060	18.3	19.3	17.5	19.3	0.908	185.1	NO DAMAGE	
90	-80	13	0.00097	18.3	19.3	17.4	19.3	0.902	174.2	NO DAMAGE	
90	-90	6	0.00045	18.3	19.3	17.3	19.3	0.896	164.6	NO DAMAGE	
90	-95	1	0.00007	18.3	19.3	17.2	19.3	0.893	160.1	NO DAMAGE	
90	-100	7	0.00052	18.3	19.3	17.2	19.3	0.890	155.9	NO DAMAGE	
90	-110	2	0.00015	18.3	19.3	17.1	19.3	0.885	148.1	NO DAMAGE	
90	-115	2	0.00015	18.3	19.3	17.0	19.3	0.882	144.5	NO DAMAGE	
90	-120	3	0.00022	18.3	19.3	17.0	19.3	0.879	141.1	NO DAMAGE	
90	-140	2	0.00015	18.3	19.3	16.7	19.3	0.867	128.8	NO DAMAGE	
90	-145	1	0.00007	18.3	19.3	16.7	19.3	0.864	126.1	NO DAMAGE	
90	-150	2	0.00015	18.3	19.3	16.6	19.3	0.861	123.4	NO DAMAGE	
90	-160	3	0.00022	18.3	19.3	16.5	19.3	0.856	118.5	NO DAMAGE	
90	-170	1	0.00007	18.3	19.3	16.4	19.3	0.850	113.9	NO DAMAGE	
90	-180	1	0.00007	18.3	19.3	16.3	19.3	0.844	109.7	NO DAMAGE	
90	-190	1	0.00007	18.3	19.3	16.2	19.3	0.838	105.8	NO DAMAGE	
85	75	8202	0.61148	18.3	19.2	19.1	19.2	0.994	2953.7	NO DAMAGE	
85	70	1902	0.14180	18.3	19.2	19.1	19.2	0.991	1969.1	NO DAMAGE	
85	65	6590	0.49130	18.3	19.2	19.0	19.2	0.988	1476.8	NO DAMAGE	
85	60	711	0.05301	18.3	19.2	19.0	19.2	0.986	1181.5	NO DAMAGE	
85	55	3052	0.22754	18.3	19.2	18.9	19.2	0.983	984.6	NO DAMAGE	
85	50	292	0.02177	18.3	19.2	18.9	19.2	0.980	843.9	NO DAMAGE	
85	45	792	0.05905	18.3	19.2	18.8	19.2	0.977	738.4	NO DAMAGE	
85	40	65	0.00485	18.3	19.2	18.7	19.2	0.974	656.4	NO DAMAGE	
85	35	260	0.01938	18.3	19.2	18.7	19.2	0.971	590.7	NO DAMAGE	
85	30	14	0.00104	18.3	19.2	18.6	19.2	0.968	537.0	NO DAMAGE	
85	25	111	0.00828	18.3	19.2	18.6	19.2	0.965	492.3	NO DAMAGE	
85	20	1	0.00007	18.3	19.2	18.5	19.2	0.962	454.4	NO DAMAGE	
85	15	71	0.00529	18.3	19.2	18.5	19.2	0.959	422.0	NO DAMAGE	
85	5	72	0.00537	18.3	19.2	18.4	19.2	0.954	369.2	NO DAMAGE	
85	0	6	0.00045	18.3	19.2	18.3	19.2	0.951	347.5	NO DAMAGE	
85	-5	6	0.00045	18.3	19.2	18.2	19.2	0.948	328.2	NO DAMAGE	
85	-15	5	0.00037	18.3	19.2	18.1	19.2	0.942	295.4	NO DAMAGE	
85	-20	1	0.00007	18.3	19.2	18.1	19.2	0.939	281.3	NO DAMAGE	
85	-25	2	0.00015	18.3	19.2	18.0	19.2	0.936	268.5	NO DAMAGE	
85	-35	2	0.00015	18.3	19.2	17.9	19.2	0.931	246.1	NO DAMAGE	
85	-45	6	0.00045	18.3	19.2	17.8	19.2	0.925	227.2	NO DAMAGE	
85	-50	2	0.00015	18.3	19.2	17.7	19.2	0.922	218.8	NO DAMAGE	
85	-55	2	0.00015	18.3	19.2	17.7	19.2	0.919	211.0	NO DAMAGE	
85	-65	4	0.00030	18.3	19.2	17.6	19.2	0.913	196.9	NO DAMAGE	
85	-70	1	0.00007	18.3	19.2	17.5	19.2	0.910	190.6	NO DAMAGE	
85	-75	5	0.00037	18.3	19.2	17.5	19.2	0.907	184.6	NO DAMAGE	
85	-85	4	0.00030	18.3	19.2	17.4	19.2	0.902	173.7	NO DAMAGE	
85	-90	1	0.00007	18.3	19.2	17.3	19.2	0.899	168.8	NO DAMAGE	
85	-95	5	0.00037	18.3	19.2	17.2	19.2	0.896	164.1	NO DAMAGE	
85	-100	1	0.00007	18.3	19.2	17.2	19.2	0.893	159.7	NO DAMAGE	
85	-105	3	0.00022	18.3	19.2	17.1	19.2	0.890	155.5	NO DAMAGE	
85	-110	3	0.00022	18.3	19.2	17.1	19.2	0.887	151.5	NO DAMAGE	
85	-115	1	0.00007	18.3	19.2	17.0	19.2	0.884	147.7	NO DAMAGE	
85	-135	1	0.00007	18.3	19.2	16.8	19.2	0.873	134.3	NO DAMAGE	
85	-145	1	0.00007	18.3	19.2	16.7	19.2	0.867	128.4	NO DAMAGE	
85	-165	1	0.00007	18.3	19.2	16.5	19.2	0.855	118.1	NO DAMAGE	
85	-215	1	0.00007	18.3	19.2	15.9	19.2	0.826	98.5	NO DAMAGE	
80	70	7655	0.57070	18.3	19.2	19.1	19.2	0.994	2945.1	NO DAMAGE	
80	65	1558	0.11615	18.3	19.2	19.0	19.2	0.991	1963.4	NO DAMAGE	
80	60	4677	0.34868	18.3	19.2	19.0	19.2	0.988	1472.6	NO DAMAGE	
80	55	681	0.05077	18.3	19.2	18.9	19.2	0.985	1178.1	NO DAMAGE	
80	50	2097	0.15634	18.3	19.2	18.9	19.2	0.983	981.7	NO DAMAGE	
80	45	222	0.01655	18.3	19.2	18.8	19.2	0.980	841.5	NO DAMAGE	
80	40	927	0.06911	18.3	19.2	18.7	19.2	0.977	736.3	NO DAMAGE	
80	35	49	0.00365	18.3	19.2	18.7	19.2	0.974	654.5	NO DAMAGE	
80	30	460	0.03429	18.3	19.2	18.6	19.2	0.971	589.0	NO DAMAGE	
80	25	16	0.00119	18.3	19.2	18.6	19.2	0.968	535.5	NO DAMAGE	
80	20	239	0.01782	18.3	19.2	18.5	19.2	0.965	490.9	NO DAMAGE	
80	15	7	0.00052	18.3	19.2	18.5	19.2	0.962	453.1	NO DAMAGE	
80	10	110	0.00820	18.3	19.2	18.4	19.2	0.959	420.7	NO DAMAGE	
80	5	4	0.00030	18.3	19.2	18.4	19.2	0.956	392.7	NO DAMAGE	
80	0	129	0.00962	18.3	19.2	18.3	19.2	0.954	368.1	NO DAMAGE	
80	-5	2	0.00015	18.3	19.2	18.2	19.2	0.951	346.5	NO DAMAGE	
80	-10	63	0.00470	18.3	19.2	18.2	19.2	0.948	327.2	NO DAMAGE	
80	-15	1	0.00007	18.3	19.2	18.1	19.2	0.945	310.0	NO DAMAGE	
80	-20	4	0.00030	18.3	19.2	18.1	19.2	0.942	294.5	NO DAMAGE	
80	-25	1	0.00007	18.3	19.2	18.0	19.2	0.939	280.5	NO DAMAGE	
80	-30	5	0.00037	18.3	19.2	18.0	19.2	0.936	267.7	NO DAMAGE	
80	-35	1	0.00007	18.3	19.2	17.9	19.2	0.933	256.1	NO DAMAGE	
80	-40	7	0.00052	18.3	19.2	17.9	19.2	0.930	245.4	NO DAMAGE	
80	-50	15	0.00112	18.3	19.2	17.7	19.2	0.925	226.5	NO DAMAGE	
80	-55	1	0.00007	18.3	19.2	17.7	19.2	0.922	218.2	NO DAMAGE	

cycles per mile 153.8
Yield stress 60 ksi

Max	Min	No.	α Pct	Static Stress	Dynamic Stress Max	Dynamic Stress Min	Max Adjusted	R Min/Max	Endurance Limit	to Failure N	α/N
80	-60	12	0.00089	18.3	19.2	17.6	19.2	0.919	210.4	NO DAMAGE	
80	-70	10	0.00075	18.3	19.2	17.5	19.2	0.913	196.3	NO DAMAGE	
80	-75	1	0.00007	18.3	19.2	17.5	19.2	0.910	190.0	NO DAMAGE	
80	-80	13	0.00097	18.3	19.2	17.4	19.2	0.907	184.1	NO DAMAGE	
80	-85	1	0.00007	18.3	19.2	17.4	19.2	0.904	178.5	NO DAMAGE	
80	-90	8	0.00060	18.3	19.2	17.3	19.2	0.901	173.2	NO DAMAGE	
80	-95	1	0.00007	18.3	19.2	17.2	19.2	0.898	168.3	NO DAMAGE	
80	-100	4	0.00030	18.3	19.2	17.2	19.2	0.895	163.6	NO DAMAGE	
80	-110	2	0.00015	18.3	19.2	17.1	19.2	0.890	155.0	NO DAMAGE	
80	-120	4	0.00030	18.3	19.2	17.0	19.2	0.884	147.3	NO DAMAGE	
80	-130	1	0.00007	18.3	19.2	16.9	19.2	0.878	140.2	NO DAMAGE	
80	-140	1	0.00007	18.3	19.2	16.7	19.2	0.872	133.9	NO DAMAGE	
80	-150	3	0.00022	18.3	19.2	16.6	19.2	0.866	128.0	NO DAMAGE	
80	-170	1	0.00007	18.3	19.2	16.4	19.2	0.855	117.8	NO DAMAGE	
80	-220	1	0.00007	18.3	19.2	15.8	19.2	0.826	98.2	NO DAMAGE	
75	65	8167	0.60887	18.3	19.1	19.0	19.1	0.994	2936.6	NO DAMAGE	
75	60	1797	0.13397	18.3	19.1	19.0	19.1	0.991	1957.7	NO DAMAGE	
75	55	5826	0.43434	18.3	19.1	18.9	19.1	0.988	1468.3	NO DAMAGE	
75	50	731	0.05450	18.3	19.1	18.9	19.1	0.985	1174.6	NO DAMAGE	
75	45	2118	0.15790	18.3	19.1	18.8	19.1	0.983	978.9	NO DAMAGE	
75	40	220	0.01640	18.3	19.1	18.7	19.1	0.980	839.0	NO DAMAGE	
75	35	882	0.06576	18.3	19.1	18.7	19.1	0.977	734.1	NO DAMAGE	
75	30	70	0.00522	18.3	19.1	18.6	19.1	0.974	652.6	NO DAMAGE	
75	25	369	0.02751	18.3	19.1	18.6	19.1	0.971	587.3	NO DAMAGE	
75	20	19	0.00142	18.3	19.1	18.5	19.1	0.968	533.9	NO DAMAGE	
75	15	149	0.01111	18.3	19.1	18.5	19.1	0.965	489.4	NO DAMAGE	
75	10	6	0.00045	18.3	19.1	18.4	19.1	0.962	451.8	NO DAMAGE	
75	5	111	0.00828	18.3	19.1	18.4	19.1	0.959	419.5	NO DAMAGE	
75	0	15	0.00112	18.3	19.1	18.3	19.1	0.956	391.5	NO DAMAGE	
75	-5	10	0.00075	18.3	19.1	18.2	19.1	0.953	367.1	NO DAMAGE	
75	-15	4	0.00030	18.3	19.1	18.1	19.1	0.948	326.3	NO DAMAGE	
75	-25	4	0.00030	18.3	19.1	18.0	19.1	0.942	293.7	NO DAMAGE	
75	-35	1	0.00007	18.3	19.1	17.9	19.1	0.936	267.0	NO DAMAGE	
75	-45	1	0.00007	18.3	19.1	17.8	19.1	0.930	244.7	NO DAMAGE	
75	-55	3	0.00022	18.3	19.1	17.7	19.1	0.924	225.9	NO DAMAGE	
75	-65	3	0.00022	18.3	19.1	17.6	19.1	0.918	209.8	NO DAMAGE	
75	-75	3	0.00022	18.3	19.1	17.5	19.1	0.913	195.8	NO DAMAGE	
75	-85	2	0.00015	18.3	19.1	17.4	19.1	0.907	183.5	NO DAMAGE	
75	-90	1	0.00007	18.3	19.1	17.3	19.1	0.904	178.0	NO DAMAGE	
75	-95	2	0.00015	18.3	19.1	17.2	19.1	0.901	172.7	NO DAMAGE	
75	-105	2	0.00015	18.3	19.1	17.1	19.1	0.895	163.1	NO DAMAGE	
75	-110	1	0.00007	18.3	19.1	17.1	19.1	0.892	158.7	NO DAMAGE	
75	-115	3	0.00022	18.3	19.1	17.0	19.1	0.889	154.6	NO DAMAGE	
75	-135	1	0.00007	18.3	19.1	16.8	19.1	0.878	139.8	NO DAMAGE	
75	-145	1	0.00007	18.3	19.1	16.7	19.1	0.872	133.5	NO DAMAGE	
75	-160	1	0.00007	18.3	19.1	16.5	19.1	0.863	125.0	NO DAMAGE	
75	-215	2	0.00015	18.3	19.1	15.9	19.1	0.831	101.3	NO DAMAGE	
75	-235	1	0.00007	18.3	19.1	15.7	19.1	0.819	94.7	NO DAMAGE	
70	60	8507	0.63422	18.3	19.1	19.0	19.1	0.994	2928.0	NO DAMAGE	
70	55	1533	0.11429	18.3	19.1	18.9	19.1	0.991	1952.0	NO DAMAGE	
70	50	5273	0.39312	18.3	19.1	18.9	19.1	0.988	1464.0	NO DAMAGE	
70	45	696	0.05189	18.3	19.1	18.8	19.1	0.985	1171.2	NO DAMAGE	
70	40	2334	0.17401	18.3	19.1	18.7	19.1	0.982	976.0	NO DAMAGE	
70	35	258	0.01923	18.3	19.1	18.7	19.1	0.980	836.6	NO DAMAGE	
70	30	1115	0.08313	18.3	19.1	18.6	19.1	0.977	732.0	NO DAMAGE	
70	25	49	0.00365	18.3	19.1	18.6	19.1	0.974	650.7	NO DAMAGE	
70	20	562	0.04190	18.3	19.1	18.5	19.1	0.971	585.6	NO DAMAGE	
70	15	11	0.00082	18.3	19.1	18.5	19.1	0.968	532.4	NO DAMAGE	
70	10	276	0.02058	18.3	19.1	18.4	19.1	0.965	488.0	NO DAMAGE	
70	5	7	0.00052	18.3	19.1	18.4	19.1	0.962	450.5	NO DAMAGE	
70	0	205	0.01528	18.3	19.1	18.3	19.1	0.959	418.3	NO DAMAGE	
70	-5	3	0.00022	18.3	19.1	18.2	19.1	0.956	390.4	NO DAMAGE	
70	-10	102	0.00760	18.3	19.1	18.2	19.1	0.953	366.0	NO DAMAGE	
70	-20	8	0.00060	18.3	19.1	18.1	19.1	0.947	325.3	NO DAMAGE	
70	-30	7	0.00052	18.3	19.1	18.0	19.1	0.942	292.8	NO DAMAGE	
70	-40	11	0.00082	18.3	19.1	17.9	19.1	0.936	266.2	NO DAMAGE	
70	-45	2	0.00015	18.3	19.1	17.8	19.1	0.933	254.6	NO DAMAGE	
70	-50	13	0.00097	18.3	19.1	17.7	19.1	0.930	244.0	NO DAMAGE	
70	-55	1	0.00007	18.3	19.1	17.7	19.1	0.927	234.2	NO DAMAGE	
70	-60	15	0.00112	18.3	19.1	17.6	19.1	0.924	225.2	NO DAMAGE	
70	-70	13	0.00097	18.3	19.1	17.5	19.1	0.918	209.1	NO DAMAGE	
70	-75	1	0.00007	18.3	19.1	17.5	19.1	0.915	201.9	NO DAMAGE	
70	-80	7	0.00052	18.3	19.1	17.4	19.1	0.912	195.2	NO DAMAGE	
70	-90	7	0.00052	18.3	19.1	17.3	19.1	0.907	183.0	NO DAMAGE	
70	-95	3	0.00022	18.3	19.1	17.2	19.1	0.904	177.5	NO DAMAGE	
70	-100	7	0.00052	18.3	19.1	17.2	19.1	0.901	172.2	NO DAMAGE	
70	-105	1	0.00007	18.3	19.1	17.1	19.1	0.898	167.3	NO DAMAGE	
70	-110	3	0.00022	18.3	19.1	17.1	19.1	0.895	162.7	NO DAMAGE	
70	-120	1	0.00007	18.3	19.1	17.0	19.1	0.889	154.1	NO DAMAGE	
70	-125	1	0.00007	18.3	19.1	16.9	19.1	0.886	150.2	NO DAMAGE	
70	-130	2	0.00015	18.3	19.1	16.9	19.1	0.883	146.4	NO DAMAGE	
70	-135	1	0.00007	18.3	19.1	16.8	19.1	0.880	142.8	NO DAMAGE	
70	-140	4	0.00030	18.3	19.1	16.7	19.1	0.877	139.4	NO DAMAGE	
65	55	7279	0.54267	18.3	19.0	18.9	19.0	0.994	2919.5	NO DAMAGE	
65	50	1741	0.12980	18.3	19.0	18.9	19.0	0.991	1946.3	NO DAMAGE	
65	45	6262	0.46685	18.3	19.0	18.8	19.0	0.988	1459.7	NO DAMAGE	
65	40	731	0.05450	18.3	19.0	18.7	19.0	0.985	1167.8	NO DAMAGE	
65	35	2747	0.20480	18.3	19.0	18.7	19.0	0.982	973.2	NO DAMAGE	
65	30	194	0.01446	18.3	19.0	18.6	19.0	0.979	834.1	NO DAMAGE	
65	25	998	0.07440	18.3	19.0	18.6	19.0	0.977	729.9	NO DAMAGE	
65	20	64	0.00477	18.3	19.0	18.5	19.0	0.974	648.8	NO DAMAGE	

cycles per mile	153.8
Yield stress	60 ksi

Max	Min	No.	α Pct	Static Stress	Dynamic Stress Max	Dynamic Stress Min	Max Adjusted	R Min/Max	Endurance Limit	to Failure N	α/N
65	15	357	0.02662	18.3	19.0	18.5	19.0	0.971	583.9	NO DAMAGE	
65	10	15	0.00112	18.3	19.0	18.4	19.0	0.968	530.8	NO DAMAGE	
65	5	243	0.01812	18.3	19.0	18.4	19.0	0.965	486.6	NO DAMAGE	
65	0	10	0.00075	18.3	19.0	18.3	19.0	0.962	449.2	NO DAMAGE	
65	-5	12	0.00089	18.3	19.0	18.2	19.0	0.959	417.1	NO DAMAGE	
65	-15	5	0.00037	18.3	19.0	18.1	19.0	0.953	364.9	NO DAMAGE	
65	-25	2	0.00015	18.3	19.0	18.0	19.0	0.947	324.4	NO DAMAGE	
65	-35	4	0.00030	18.3	19.0	17.9	19.0	0.941	291.9	NO DAMAGE	
65	-45	4	0.00030	18.3	19.0	17.8	19.0	0.936	265.4	NO DAMAGE	
65	-50	1	0.00007	18.3	19.0	17.7	19.0	0.933	253.9	NO DAMAGE	
65	-55	1	0.00007	18.3	19.0	17.7	19.0	0.930	243.3	NO DAMAGE	
65	-65	3	0.00022	18.3	19.0	17.6	19.0	0.924	224.6	NO DAMAGE	
65	-75	2	0.00015	18.3	19.0	17.5	19.0	0.918	208.5	NO DAMAGE	
65	-80	3	0.00022	18.3	19.0	17.4	19.0	0.915	201.3	NO DAMAGE	
65	-85	4	0.00030	18.3	19.0	17.4	19.0	0.912	194.6	NO DAMAGE	
65	-95	3	0.00022	18.3	19.0	17.2	19.0	0.906	182.5	NO DAMAGE	
65	-125	2	0.00015	18.3	19.0	16.9	19.0	0.889	153.7	NO DAMAGE	
65	-135	1	0.00007	18.3	19.0	16.8	19.0	0.883	146.0	NO DAMAGE	
65	-145	1	0.00007	18.3	19.0	16.7	19.0	0.877	139.0	NO DAMAGE	
65	-155	2	0.00015	18.3	19.0	16.6	19.0	0.871	132.7	NO DAMAGE	
65	-195	1	0.00007	18.3	19.0	16.1	19.0	0.848	112.3	NO DAMAGE	
65	-205	1	0.00007	18.3	19.0	16.0	19.0	0.842	108.1	NO DAMAGE	
60	50	9784	0.72942	18.3	19.0	18.9	19.0	0.994	2910.9	NO DAMAGE	
60	45	1627	0.12130	18.3	19.0	18.8	19.0	0.991	1940.6	NO DAMAGE	
60	40	7071	0.52716	18.3	19.0	18.7	19.0	0.988	1455.5	NO DAMAGE	
60	35	637	0.04749	18.3	19.0	18.7	19.0	0.985	1164.4	NO DAMAGE	
60	30	2949	0.21986	18.3	19.0	18.6	19.0	0.982	970.3	NO DAMAGE	
60	25	225	0.01677	18.3	19.0	18.6	19.0	0.979	831.7	NO DAMAGE	
60	20	1559	0.11623	18.3	19.0	18.5	19.0	0.977	727.7	NO DAMAGE	
60	15	59	0.00440	18.3	19.0	18.5	19.0	0.974	646.9	NO DAMAGE	
60	10	740	0.05517	18.3	19.0	18.4	19.0	0.971	582.2	NO DAMAGE	
60	5	16	0.00119	18.3	19.0	18.4	19.0	0.968	529.3	NO DAMAGE	
60	0	419	0.03124	18.3	19.0	18.3	19.0	0.965	485.2	NO DAMAGE	
60	-5	3	0.00022	18.3	19.0	18.2	19.0	0.962	447.8	NO DAMAGE	
60	-10	132	0.00984	18.3	19.0	18.2	19.0	0.959	415.8	NO DAMAGE	
60	-15	1	0.00007	18.3	19.0	18.1	19.0	0.956	388.1	NO DAMAGE	
60	-20	7	0.00052	18.3	19.0	18.1	19.0	0.953	363.9	NO DAMAGE	
60	-25	1	0.00007	18.3	19.0	18.0	19.0	0.950	342.5	NO DAMAGE	
60	-30	11	0.00082	18.3	19.0	18.0	19.0	0.947	323.4	NO DAMAGE	
60	-40	7	0.00052	18.3	19.0	17.9	19.0	0.941	291.1	NO DAMAGE	
60	-50	10	0.00075	18.3	19.0	17.7	19.0	0.935	264.6	NO DAMAGE	
60	-55	1	0.00007	18.3	19.0	17.7	19.0	0.932	253.1	NO DAMAGE	
60	-60	10	0.00075	18.3	19.0	17.6	19.0	0.930	242.6	NO DAMAGE	
60	-70	14	0.00104	18.3	19.0	17.5	19.0	0.924	223.9	NO DAMAGE	
60	-80	9	0.00067	18.3	19.0	17.4	19.0	0.918	207.9	NO DAMAGE	
60	-90	7	0.00052	18.3	19.0	17.3	19.0	0.912	194.1	NO DAMAGE	
60	-100	6	0.00045	18.3	19.0	17.2	19.0	0.906	181.9	NO DAMAGE	
60	-110	3	0.00022	18.3	19.0	17.1	19.0	0.900	171.2	NO DAMAGE	
60	-120	4	0.00030	18.3	19.0	17.0	19.0	0.894	161.7	NO DAMAGE	
60	-130	3	0.00022	18.3	19.0	16.9	19.0	0.888	153.2	NO DAMAGE	
60	-140	2	0.00015	18.3	19.0	16.7	19.0	0.883	145.5	NO DAMAGE	
60	-220	1	0.00007	18.3	19.0	15.8	19.0	0.836	104.0	NO DAMAGE	
55	45	8119	0.60529	18.3	18.9	18.8	18.9	0.994	2902.4	NO DAMAGE	
55	40	1589	0.11846	18.3	18.9	18.7	18.9	0.991	1934.9	NO DAMAGE	
55	35	6838	0.50979	18.3	18.9	18.7	18.9	0.988	1451.2	NO DAMAGE	
55	30	654	0.04876	18.3	18.9	18.6	18.9	0.985	1161.0	NO DAMAGE	
55	25	2920	0.21769	18.3	18.9	18.6	18.9	0.982	967.5	NO DAMAGE	
55	20	269	0.02005	18.3	18.9	18.5	18.9	0.979	829.3	NO DAMAGE	
55	15	1189	0.08864	18.3	18.9	18.5	18.9	0.976	725.6	NO DAMAGE	
55	10	61	0.00455	18.3	18.9	18.4	18.9	0.973	645.0	NO DAMAGE	
55	5	597	0.04451	18.3	18.9	18.4	18.9	0.971	580.5	NO DAMAGE	
55	0	26	0.00194	18.3	18.9	18.3	18.9	0.968	527.7	NO DAMAGE	
55	-5	38	0.00283	18.3	18.9	18.2	18.9	0.965	483.7	NO DAMAGE	
55	-10	1	0.00007	18.3	18.9	18.2	18.9	0.962	446.5	NO DAMAGE	
55	-15	6	0.00045	18.3	18.9	18.1	18.9	0.959	414.6	NO DAMAGE	
55	-25	7	0.00052	18.3	18.9	18.0	18.9	0.953	362.8	NO DAMAGE	
55	-35	2	0.00015	18.3	18.9	17.9	18.9	0.947	322.5	NO DAMAGE	
55	-45	4	0.00030	18.3	18.9	17.8	18.9	0.941	290.2	NO DAMAGE	
55	-55	1	0.00007	18.3	18.9	17.7	18.9	0.935	263.9	NO DAMAGE	
55	-65	3	0.00022	18.3	18.9	17.6	18.9	0.929	241.9	NO DAMAGE	
55	-70	1	0.00007	18.3	18.9	17.5	18.9	0.926	232.2	NO DAMAGE	
55	-75	1	0.00007	18.3	18.9	17.5	18.9	0.923	223.3	NO DAMAGE	
55	-85	1	0.00007	18.3	18.9	17.4	18.9	0.918	207.3	NO DAMAGE	
55	-95	3	0.00022	18.3	18.9	17.2	18.9	0.912	193.5	NO DAMAGE	
55	-105	3	0.00022	18.3	18.9	17.1	18.9	0.906	181.4	NO DAMAGE	
55	-110	1	0.00007	18.3	18.9	17.1	18.9	0.903	175.9	NO DAMAGE	
55	-115	1	0.00007	18.3	18.9	17.0	18.9	0.900	170.7	NO DAMAGE	
55	-135	2	0.00015	18.3	18.9	16.8	18.9	0.888	152.8	NO DAMAGE	
55	-150	1	0.00007	18.3	18.9	16.6	18.9	0.879	141.6	NO DAMAGE	
55	-165	1	0.00007	18.3	18.9	16.5	18.9	0.870	131.9	NO DAMAGE	
50	40	12549	0.93556	18.3	18.9	18.7	18.9	0.994	2893.8	NO DAMAGE	
50	35	1846	0.13762	18.3	18.9	18.7	18.9	0.991	1929.2	NO DAMAGE	
50	30	10880	0.81113	18.3	18.9	18.6	18.9	0.988	1446.9	NO DAMAGE	
50	25	787	0.05867	18.3	18.9	18.6	18.9	0.985	1157.5	NO DAMAGE	
50	20	5251	0.39148	18.3	18.9	18.5	18.9	0.982	964.6	NO DAMAGE	
50	15	264	0.01968	18.3	18.9	18.5	18.9	0.979	826.8	NO DAMAGE	
50	10	2229	0.16618	18.3	18.9	18.4	18.9	0.976	723.5	NO DAMAGE	
50	5	56	0.00417	18.3	18.9	18.4	18.9	0.973	643.1	NO DAMAGE	
50	0	885	0.06598	18.3	18.9	18.3	18.9	0.970	578.8	NO DAMAGE	
50	-5	9	0.00067	18.3	18.9	18.2	18.9	0.968	526.2	NO DAMAGE	
50	-10	181	0.01349	18.3	18.9	18.2	18.9	0.965	482.3	NO DAMAGE	

cycles per mile 153.8
Yield stress 60 ksi

			α	Static	Dynamic Stress		Max	R	Endurance	to Failure	
Max	Min	No.	Pct	Stress	Max	Min	Adjusted	Min/Max	Limit	N	α/N
50	-20	15	0.00112	18.3	18.9	18.1	18.9	0.959	413.4	NO DAMAGE	
50	-25	1	0.00007	18.3	18.9	18.0	18.9	0.956	385.8	NO DAMAGE	
50	-30	12	0.00089	18.3	18.9	18.0	18.9	0.953	361.7	NO DAMAGE	
50	-40	17	0.00127	18.3	18.9	17.9	18.9	0.947	321.5	NO DAMAGE	
50	-45	1	0.00007	18.3	18.9	17.8	18.9	0.944	304.6	NO DAMAGE	
50	-50	20	0.00149	18.3	18.9	17.7	18.9	0.941	289.4	NO DAMAGE	
50	-60	19	0.00142	18.3	18.9	17.6	18.9	0.935	263.1	NO DAMAGE	
50	-65	1	0.00007	18.3	18.9	17.6	18.9	0.932	251.6	NO DAMAGE	
50	-70	9	0.00067	18.3	18.9	17.5	18.9	0.929	241.2	NO DAMAGE	
50	-75	2	0.00015	18.3	18.9	17.5	18.9	0.926	231.5	NO DAMAGE	
50	-80	8	0.00060	18.3	18.9	17.4	18.9	0.923	222.6	NO DAMAGE	
50	-90	6	0.00045	18.3	18.9	17.3	18.9	0.917	206.7	NO DAMAGE	
50	-100	4	0.00030	18.3	18.9	17.2	18.9	0.911	192.9	NO DAMAGE	
50	-105	1	0.00007	18.3	18.9	17.1	18.9	0.908	186.7	NO DAMAGE	
50	-110	2	0.00015	18.3	18.9	17.1	18.9	0.905	180.9	NO DAMAGE	
50	-120	2	0.00015	18.3	18.9	17.0	18.9	0.900	170.2	NO DAMAGE	
50	-130	2	0.00015	18.3	18.9	16.9	18.9	0.894	160.8	NO DAMAGE	
50	-140	1	0.00007	18.3	18.9	16.7	18.9	0.888	152.3	NO DAMAGE	
50	-210	1	0.00007	18.3	18.9	16.0	18.9	0.846	111.3	NO DAMAGE	
45	35	8451	0.63005	18.3	18.8	18.7	18.8	0.994	2885.3	NO DAMAGE	
45	30	1938	0.14448	18.3	18.8	18.6	18.8	0.991	1923.5	NO DAMAGE	
45	25	7167	0.53432	18.3	18.8	18.6	18.8	0.988	1442.6	NO DAMAGE	
45	20	859	0.06404	18.3	18.8	18.5	18.8	0.985	1154.1	NO DAMAGE	
45	15	3380	0.25199	18.3	18.8	18.5	18.8	0.982	961.8	NO DAMAGE	
45	10	291	0.02169	18.3	18.8	18.4	18.8	0.979	824.4	NO DAMAGE	
45	5	1312	0.09781	18.3	18.8	18.4	18.8	0.976	721.3	NO DAMAGE	
45	0	52	0.00388	18.3	18.8	18.3	18.8	0.973	641.2	NO DAMAGE	
45	-5	25	0.00186	18.3	18.8	18.2	18.8	0.970	577.1	NO DAMAGE	
45	-15	13	0.00097	18.3	18.8	18.1	18.8	0.964	480.9	NO DAMAGE	
45	-25	5	0.00037	18.3	18.8	18.0	18.8	0.959	412.2	NO DAMAGE	
45	-30	1	0.00007	18.3	18.8	18.0	18.8	0.956	384.7	NO DAMAGE	
45	-35	2	0.00015	18.3	18.8	17.9	18.8	0.953	360.7	NO DAMAGE	
45	-45	5	0.00037	18.3	18.8	17.8	18.8	0.947	320.6	NO DAMAGE	
45	-55	1	0.00007	18.3	18.8	17.7	18.8	0.941	288.5	NO DAMAGE	
45	-60	1	0.00007	18.3	18.8	17.6	18.8	0.938	274.8	NO DAMAGE	
45	-65	1	0.00007	18.3	18.8	17.6	18.8	0.935	262.3	NO DAMAGE	
45	-75	2	0.00015	18.3	18.8	17.5	18.8	0.929	240.4	NO DAMAGE	
45	-85	2	0.00015	18.3	18.8	17.4	18.8	0.923	221.9	NO DAMAGE	
45	-90	1	0.00007	18.3	18.8	17.3	18.8	0.920	213.7	NO DAMAGE	
45	-95	1	0.00007	18.3	18.8	17.2	18.8	0.917	206.1	NO DAMAGE	
45	-105	1	0.00007	18.3	18.8	17.1	18.8	0.911	192.4	NO DAMAGE	
45	-115	1	0.00007	18.3	18.8	17.0	18.8	0.905	180.3	NO DAMAGE	
45	-135	1	0.00007	18.3	18.8	16.8	18.8	0.893	160.3	NO DAMAGE	
45	-145	2	0.00015	18.3	18.8	16.7	18.8	0.887	151.9	NO DAMAGE	
45	-165	1	0.00007	18.3	18.8	16.5	18.8	0.876	137.4	NO DAMAGE	
40	30	17965	1.33934	18.3	18.7	18.6	18.7	0.994	2876.7	NO DAMAGE	
40	25	2047	0.15261	18.3	18.7	18.6	18.7	0.991	1917.8	NO DAMAGE	
40	20	18409	1.37244	18.3	18.7	18.5	18.7	0.988	1438.4	NO DAMAGE	
40	15	1038	0.07739	18.3	18.7	18.5	18.7	0.985	1150.7	NO DAMAGE	
40	10	6033	0.44978	18.3	18.7	18.4	18.7	0.982	958.9	NO DAMAGE	
40	5	221	0.01648	18.3	18.7	18.4	18.7	0.979	821.9	NO DAMAGE	
40	0	1756	0.13091	18.3	18.7	18.3	18.7	0.976	719.2	NO DAMAGE	
40	-5	10	0.00075	18.3	18.7	18.2	18.7	0.973	639.3	NO DAMAGE	
40	-10	261	0.01946	18.3	18.7	18.2	18.7	0.970	575.3	NO DAMAGE	
40	-20	31	0.00231	18.3	18.7	18.1	18.7	0.964	479.5	NO DAMAGE	
40	-25	2	0.00015	18.3	18.7	18.0	18.7	0.961	442.6	NO DAMAGE	
40	-30	18	0.00134	18.3	18.7	18.0	18.7	0.958	411.0	NO DAMAGE	
40	-40	15	0.00112	18.3	18.7	17.9	18.7	0.952	359.6	NO DAMAGE	
40	-50	21	0.00157	18.3	18.7	17.7	18.7	0.947	319.6	NO DAMAGE	
40	-60	11	0.00082	18.3	18.7	17.6	18.7	0.941	287.7	NO DAMAGE	
40	-65	1	0.00007	18.3	18.7	17.6	18.7	0.938	274.0	NO DAMAGE	
40	-70	10	0.00075	18.3	18.7	17.5	18.7	0.935	261.5	NO DAMAGE	
40	-80	8	0.00060	18.3	18.7	17.4	18.7	0.929	239.7	NO DAMAGE	
40	-90	4	0.00030	18.3	18.7	17.3	18.7	0.923	221.3	NO DAMAGE	
40	-100	3	0.00022	18.3	18.7	17.2	18.7	0.917	205.5	NO DAMAGE	
40	-110	1	0.00007	18.3	18.7	17.1	18.7	0.911	191.8	NO DAMAGE	
40	-120	3	0.00022	18.3	18.7	17.0	18.7	0.905	179.8	NO DAMAGE	
40	-130	3	0.00022	18.3	18.7	16.9	18.7	0.899	169.2	NO DAMAGE	
40	-140	1	0.00007	18.3	18.7	16.7	18.7	0.893	159.8	NO DAMAGE	
35	25	8887	0.66255	18.3	18.7	18.6	18.7	0.994	2868.2	NO DAMAGE	
35	20	2334	0.17401	18.3	18.7	18.5	18.7	0.991	1912.1	NO DAMAGE	
35	15	8440	0.62923	18.3	18.7	18.5	18.7	0.988	1434.1	NO DAMAGE	
35	10	748	0.05577	18.3	18.7	18.4	18.7	0.985	1147.3	NO DAMAGE	
35	5	2726	0.20323	18.3	18.7	18.4	18.7	0.982	956.1	NO DAMAGE	
35	0	130	0.00969	18.3	18.7	18.3	18.7	0.979	819.5	NO DAMAGE	
35	-5	46	0.00343	18.3	18.7	18.2	18.7	0.976	717.0	NO DAMAGE	
35	-10	1	0.00007	18.3	18.7	18.2	18.7	0.973	637.4	NO DAMAGE	
35	-15	10	0.00075	18.3	18.7	18.1	18.7	0.970	573.6	NO DAMAGE	
35	-20	1	0.00007	18.3	18.7	18.1	18.7	0.967	521.5	NO DAMAGE	
35	-25	15	0.00112	18.3	18.7	18.0	18.7	0.964	478.0	NO DAMAGE	
35	-35	25	0.00186	18.3	18.7	17.9	18.7	0.958	409.7	NO DAMAGE	
35	-40	1	0.00007	18.3	18.7	17.9	18.7	0.955	382.4	NO DAMAGE	
35	-45	10	0.00075	18.3	18.7	17.8	18.7	0.952	358.5	NO DAMAGE	
35	-55	2	0.00015	18.3	18.7	17.7	18.7	0.946	318.7	NO DAMAGE	
35	-65	3	0.00022	18.3	18.7	17.6	18.7	0.940	286.8	NO DAMAGE	
35	-75	1	0.00007	18.3	18.7	17.5	18.7	0.934	260.7	NO DAMAGE	
35	-85	2	0.00015	18.3	18.7	17.4	18.7	0.928	239.0	NO DAMAGE	
35	-95	3	0.00022	18.3	18.7	17.2	18.7	0.922	220.6	NO DAMAGE	
35	-100	1	0.00007	18.3	18.7	17.2	18.7	0.920	212.5	NO DAMAGE	
35	-105	4	0.00030	18.3	18.7	17.1	18.7	0.917	204.9	NO DAMAGE	
35	-115	1	0.00007	18.3	18.7	17.0	18.7	0.911	191.2	NO DAMAGE	

cycles per mile 153.8
Yield stress 60 ksi

			α	Static	Dynamic Stress		Max	R	Endurance	to Failure	
Max	Min	No.	Pct	Stress	Max	Min	Adjusted	Min/Max	Limit	N	α/N
35	-120	1	0.00007	18.3	18.7	17.0	18.7	0.908	185.0	NO DAMAGE	
35	-170	1	0.00007	18.3	18.7	16.4	18.7	0.878	139.9	NO DAMAGE	
30	20	22074	1.64568	18.3	18.6	18.5	18.6	0.994	2859.6	NO DAMAGE	
30	15	2052	0.15298	18.3	18.6	18.5	18.6	0.991	1906.4	NO DAMAGE	
30	10	16038	1.19568	18.3	18.6	18.4	18.6	0.988	1429.8	NO DAMAGE	
30	5	628	0.04682	18.3	18.6	18.4	18.6	0.985	1143.9	NO DAMAGE	
30	0	5070	0.37798	18.3	18.6	18.3	18.6	0.982	953.2	NO DAMAGE	
30	-5	24	0.00179	18.3	18.6	18.2	18.6	0.979	817.0	NO DAMAGE	
30	-10	474	0.03534	18.3	18.6	18.2	18.6	0.976	714.9	NO DAMAGE	
30	-15	1	0.00007	18.3	18.6	18.1	18.6	0.973	635.5	NO DAMAGE	
30	-20	25	0.00186	18.3	18.6	18.1	18.6	0.970	571.9	NO DAMAGE	
30	-25	1	0.00007	18.3	18.6	18.0	18.6	0.967	519.9	NO DAMAGE	
30	-30	35	0.00261	18.3	18.6	18.0	18.6	0.964	476.6	NO DAMAGE	
30	-40	27	0.00201	18.3	18.6	17.9	18.6	0.958	408.5	NO DAMAGE	
30	-50	23	0.00171	18.3	18.6	17.7	18.6	0.952	357.5	NO DAMAGE	
30	-60	20	0.00149	18.3	18.6	17.6	18.6	0.946	317.7	NO DAMAGE	
30	-65	1	0.00007	18.3	18.6	17.6	18.6	0.943	301.0	NO DAMAGE	
30	-70	9	0.00067	18.3	18.6	17.5	18.6	0.940	286.0	NO DAMAGE	
30	-80	5	0.00037	18.3	18.6	17.4	18.6	0.934	260.0	NO DAMAGE	
30	-90	6	0.00045	18.3	18.6	17.3	18.6	0.928	238.3	NO DAMAGE	
30	-95	2	0.00015	18.3	18.6	17.2	18.6	0.925	228.8	NO DAMAGE	
30	-100	2	0.00015	18.3	18.6	17.2	18.6	0.922	220.0	NO DAMAGE	
30	-110	2	0.00015	18.3	18.6	17.1	18.6	0.916	204.3	NO DAMAGE	
30	-120	1	0.00007	18.3	18.6	17.0	18.6	0.910	190.6	NO DAMAGE	
30	-125	1	0.00007	18.3	18.6	16.9	18.6	0.907	184.5	NO DAMAGE	
30	-135	1	0.00007	18.3	18.6	16.8	18.6	0.901	173.3	NO DAMAGE	
30	-140	1	0.00007	18.3	18.6	16.7	18.6	0.898	168.2	NO DAMAGE	
30	-145	1	0.00007	18.3	18.6	16.7	18.6	0.895	163.4	NO DAMAGE	
30	-200	1	0.00007	18.3	18.6	16.1	18.6	0.862	124.3	NO DAMAGE	
30	-210	1	0.00007	18.3	18.6	16.0	18.6	0.856	119.2	NO DAMAGE	
30	-270	1	0.00007	18.3	18.6	15.3	18.6	0.821	95.3	NO DAMAGE	
25	15	9876	0.73628	18.3	18.6	18.5	18.6	0.994	2851.1	NO DAMAGE	
25	10	1825	0.13606	18.3	18.6	18.4	18.6	0.991	1900.7	NO DAMAGE	
25	5	7958	0.59329	18.3	18.6	18.4	18.6	0.988	1425.5	NO DAMAGE	
25	0	410	0.03057	18.3	18.6	18.3	18.6	0.985	1140.4	NO DAMAGE	
25	-5	105	0.00783	18.3	18.6	18.2	18.6	0.982	950.4	NO DAMAGE	
25	-10	1	0.00007	18.3	18.6	18.2	18.6	0.979	814.6	NO DAMAGE	
25	-15	33	0.00246	18.3	18.6	18.1	18.6	0.976	712.8	NO DAMAGE	
25	-20	3	0.00022	18.3	18.6	18.1	18.6	0.973	633.6	NO DAMAGE	
25	-25	317	0.02363	18.3	18.6	18.0	18.6	0.970	570.2	NO DAMAGE	
25	-30	1	0.00007	18.3	18.6	18.0	18.6	0.967	518.4	NO DAMAGE	
25	-35	89	0.00664	18.3	18.6	17.9	18.6	0.964	475.2	NO DAMAGE	
25	-40	2	0.00015	18.3	18.6	17.9	18.6	0.961	438.6	NO DAMAGE	
25	-45	11	0.00082	18.3	18.6	17.8	18.6	0.958	407.3	NO DAMAGE	
25	-65	3	0.00022	18.3	18.6	17.6	18.6	0.946	316.8	NO DAMAGE	
25	-70	1	0.00007	18.3	18.6	17.5	18.6	0.943	300.1	NO DAMAGE	
25	-75	3	0.00022	18.3	18.6	17.5	18.6	0.940	285.1	NO DAMAGE	
25	-85	1	0.00007	18.3	18.6	17.4	18.6	0.934	259.2	NO DAMAGE	
25	-95	3	0.00022	18.3	18.6	17.2	18.6	0.928	237.6	NO DAMAGE	
25	-105	6	0.00045	18.3	18.6	17.1	18.6	0.922	219.3	NO DAMAGE	
25	-125	3	0.00022	18.3	18.6	16.9	18.6	0.910	190.1	NO DAMAGE	
25	-135	1	0.00007	18.3	18.6	16.8	18.6	0.904	178.2	NO DAMAGE	
25	-145	1	0.00007	18.3	18.6	16.7	18.6	0.898	167.7	NO DAMAGE	
25	-155	1	0.00007	18.3	18.6	16.6	18.6	0.892	158.4	NO DAMAGE	
20	10	22202	1.65522	18.3	18.5	18.4	18.5	0.994	2842.5	NO DAMAGE	
20	5	1921	0.14322	18.3	18.5	18.4	18.5	0.991	1895.0	NO DAMAGE	
20	0	21178	1.57888	18.3	18.5	18.3	18.5	0.988	1421.3	NO DAMAGE	
20	-5	101	0.00753	18.3	18.5	18.2	18.5	0.985	1137.0	NO DAMAGE	
20	-10	1141	0.08506	18.3	18.5	18.2	18.5	0.982	947.5	NO DAMAGE	
20	-15	4	0.00030	18.3	18.5	18.1	18.5	0.979	812.2	NO DAMAGE	
20	-20	49	0.00365	18.3	18.5	18.1	18.5	0.976	710.6	NO DAMAGE	
20	-25	1	0.00007	18.3	18.5	18.0	18.5	0.973	631.7	NO DAMAGE	
20	-30	47	0.00350	18.3	18.5	18.0	18.5	0.970	568.5	NO DAMAGE	
20	-40	39	0.00291	18.3	18.5	17.9	18.5	0.964	473.8	NO DAMAGE	
20	-45	1	0.00007	18.3	18.5	17.8	18.5	0.961	437.3	NO DAMAGE	
20	-50	22	0.00164	18.3	18.5	17.7	18.5	0.958	406.1	NO DAMAGE	
20	-55	1	0.00007	18.3	18.5	17.7	18.5	0.955	379.0	NO DAMAGE	
20	-60	12	0.00089	18.3	18.5	17.6	18.5	0.952	355.3	NO DAMAGE	
20	-65	1	0.00007	18.3	18.5	17.6	18.5	0.949	334.4	NO DAMAGE	
20	-70	10	0.00075	18.3	18.5	17.5	18.5	0.946	315.8	NO DAMAGE	
20	-80	10	0.00075	18.3	18.5	17.4	18.5	0.940	284.3	NO DAMAGE	
20	-85	1	0.00007	18.3	18.5	17.4	18.5	0.937	270.7	NO DAMAGE	
20	-90	6	0.00045	18.3	18.5	17.3	18.5	0.934	258.4	NO DAMAGE	
20	-100	2	0.00015	18.3	18.5	17.2	18.5	0.928	236.9	NO DAMAGE	
20	-110	2	0.00015	18.3	18.5	17.1	18.5	0.922	218.7	NO DAMAGE	
20	-130	1	0.00007	18.3	18.5	16.9	18.5	0.910	189.5	NO DAMAGE	
20	-185	1	0.00007	18.3	18.5	16.2	18.5	0.877	138.7	NO DAMAGE	
15	5	10885	0.81151	18.3	18.5	18.4	18.5	0.994	2834.0	NO DAMAGE	
15	0	1626	0.12122	18.3	18.5	18.3	18.5	0.991	1889.3	NO DAMAGE	
15	-5	1500	0.11183	18.3	18.5	18.2	18.5	0.988	1417.0	NO DAMAGE	
15	-10	1	0.00007	18.3	18.5	18.2	18.5	0.985	1133.6	NO DAMAGE	
15	-15	1448	0.10795	18.3	18.5	18.1	18.5	0.982	944.7	NO DAMAGE	
15	-20	7	0.00052	18.3	18.5	18.1	18.5	0.979	809.7	NO DAMAGE	
15	-25	657	0.04898	18.3	18.5	18.0	18.5	0.976	708.5	NO DAMAGE	
15	-30	1	0.00007	18.3	18.5	18.0	18.5	0.973	629.8	NO DAMAGE	
15	-35	14	0.00104	18.3	18.5	17.9	18.5	0.970	566.8	NO DAMAGE	
15	-40	2	0.00015	18.3	18.5	17.9	18.5	0.967	515.3	NO DAMAGE	
15	-45	5	0.00037	18.3	18.5	17.8	18.5	0.964	472.3	NO DAMAGE	
15	-55	3	0.00022	18.3	18.5	17.7	18.5	0.958	404.9	NO DAMAGE	
15	-65	3	0.00022	18.3	18.5	17.6	18.5	0.952	354.2	NO DAMAGE	
15	-70	1	0.00007	18.3	18.5	17.5	18.5	0.949	333.4	NO DAMAGE	

					Dynamic					to	
			α	Static	Stress		Max	R	Endurance	Failure	
Max	Min	No.	Pct	Stress	Max	Min	Adjusted	Min/Max	Limit	N	α/N
15	-75	1	0.00007	18.3	18.5	17.5	18.5	0.946	314.9	NO DAMAGE	
15	-80	1	0.00007	18.3	18.5	17.4	18.5	0.943	298.3	NO DAMAGE	
15	-85	3	0.00022	18.3	18.5	17.4	18.5	0.940	283.4	NO DAMAGE	
15	-95	5	0.00037	18.3	18.5	17.2	18.5	0.934	257.6	NO DAMAGE	
15	-100	1	0.00007	18.3	18.5	17.2	18.5	0.931	246.4	NO DAMAGE	
15	-105	8	0.00060	18.3	18.5	17.1	18.5	0.928	236.2	NO DAMAGE	
15	-125	2	0.00015	18.3	18.5	16.9	18.5	0.916	202.4	NO DAMAGE	
15	-155	2	0.00015	18.3	18.5	16.6	18.5	0.897	166.7	NO DAMAGE	
15	-195	1	0.00007	18.3	18.5	16.1	18.5	0.873	135.0	NO DAMAGE	
15	-235	1	0.00007	18.3	18.5	15.7	18.5	0.849	113.4	NO DAMAGE	
10	0	37244	2.77664	18.3	18.4	18.3	18.4	0.994	2825.4	NO DAMAGE	
10	-5	1213	0.09043	18.3	18.4	18.2	18.4	0.991	1883.6	NO DAMAGE	
10	-10	11887	0.88621	18.3	18.4	18.2	18.4	0.988	1412.7	NO DAMAGE	
10	-15	26	0.00194	18.3	18.4	18.1	18.4	0.985	1130.2	NO DAMAGE	
10	-20	95	0.00708	18.3	18.4	18.1	18.4	0.982	941.8	NO DAMAGE	
10	-25	2	0.00015	18.3	18.4	18.0	18.4	0.979	807.3	NO DAMAGE	
10	-30	77	0.00574	18.3	18.4	18.0	18.4	0.976	706.4	NO DAMAGE	
10	-35	3	0.00022	18.3	18.4	17.9	18.4	0.973	627.9	NO DAMAGE	
10	-40	38	0.00283	18.3	18.4	17.9	18.4	0.970	565.1	NO DAMAGE	
10	-50	25	0.00186	18.3	18.4	17.7	18.4	0.964	470.9	NO DAMAGE	
10	-55	1	0.00007	18.3	18.4	17.7	18.4	0.961	434.7	NO DAMAGE	
10	-60	7	0.00052	18.3	18.4	17.6	18.4	0.958	403.6	NO DAMAGE	
10	-70	11	0.00082	18.3	18.4	17.5	18.4	0.952	353.2	NO DAMAGE	
10	-75	2	0.00015	18.3	18.4	17.5	18.4	0.949	332.4	NO DAMAGE	
10	-80	9	0.00067	18.3	18.4	17.4	18.4	0.946	313.9	NO DAMAGE	
10	-90	7	0.00052	18.3	18.4	17.3	18.4	0.939	282.5	NO DAMAGE	
10	-95	1	0.00007	18.3	18.4	17.2	18.4	0.936	269.1	NO DAMAGE	
10	-100	6	0.00045	18.3	18.4	17.2	18.4	0.933	256.9	NO DAMAGE	
10	-110	1	0.00007	18.3	18.4	17.1	18.4	0.927	235.5	NO DAMAGE	
10	-160	1	0.00007	18.3	18.4	16.5	18.4	0.897	166.2	NO DAMAGE	
10	-175	1	0.00007	18.3	18.4	16.4	18.4	0.888	152.7	NO DAMAGE	
10	-190	2	0.00015	18.3	18.4	16.2	18.4	0.879	141.3	NO DAMAGE	
10	-255	1	0.00007	18.3	18.4	15.5	18.4	0.840	106.6	NO DAMAGE	
5	-5	8727	0.65062	18.3	18.4	18.2	18.4	0.994	2816.9	NO DAMAGE	
5	-10	15	0.00112	18.3	18.4	18.2	18.4	0.991	1877.9	NO DAMAGE	
5	-15	4923	0.36702	18.3	18.4	18.1	18.4	0.988	1408.4	NO DAMAGE	
5	-20	5	0.00037	18.3	18.4	18.1	18.4	0.985	1126.8	NO DAMAGE	
5	-25	386	0.02878	18.3	18.4	18.0	18.4	0.982	939.0	NO DAMAGE	
5	-30	4	0.00030	18.3	18.4	18.0	18.4	0.979	804.8	NO DAMAGE	
5	-35	51	0.00380	18.3	18.4	17.9	18.4	0.976	704.2	NO DAMAGE	
5	-40	1	0.00007	18.3	18.4	17.9	18.4	0.973	626.0	NO DAMAGE	
5	-45	17	0.00127	18.3	18.4	17.8	18.4	0.970	563.4	NO DAMAGE	
5	-50	3	0.00022	18.3	18.4	17.7	18.4	0.967	512.2	NO DAMAGE	
5	-55	17	0.00127	18.3	18.4	17.7	18.4	0.964	469.5	NO DAMAGE	
5	-60	1	0.00007	18.3	18.4	17.6	18.4	0.961	433.4	NO DAMAGE	
5	-65	4	0.00030	18.3	18.4	17.6	18.4	0.958	402.4	NO DAMAGE	
5	-75	7	0.00052	18.3	18.4	17.5	18.4	0.951	352.1	NO DAMAGE	
5	-85	4	0.00030	18.3	18.4	17.4	18.4	0.945	313.0	NO DAMAGE	
5	-90	1	0.00007	18.3	18.4	17.3	18.4	0.942	296.5	NO DAMAGE	
5	-95	4	0.00030	18.3	18.4	17.2	18.4	0.939	281.7	NO DAMAGE	
5	-110	1	0.00007	18.3	18.4	17.1	18.4	0.930	244.9	NO DAMAGE	
5	-115	2	0.00015	18.3	18.4	17.0	18.4	0.927	234.7	NO DAMAGE	
5	-125	1	0.00007	18.3	18.4	16.9	18.4	0.921	216.7	NO DAMAGE	
5	-145	1	0.00007	18.3	18.4	16.7	18.4	0.909	187.8	NO DAMAGE	
5	-155	1	0.00007	18.3	18.4	16.6	18.4	0.903	176.1	NO DAMAGE	
5	-165	1	0.00007	18.3	18.4	16.5	18.4	0.897	165.7	NO DAMAGE	
5	-175	1	0.00007	18.3	18.4	16.4	18.4	0.891	156.5	NO DAMAGE	
5	-255	1	0.00007	18.3	18.4	15.5	18.4	0.842	108.3	NO DAMAGE	
5	-285	1	0.00007	18.3	18.4	15.1	18.4	0.824	97.1	NO DAMAGE	
0	-10	9883	0.73680	18.3	18.3	18.2	18.3	0.994	2808.3	NO DAMAGE	
0	-15	1482	0.11049	18.3	18.3	18.1	18.3	0.991	1872.2	NO DAMAGE	
0	-20	595	0.04436	18.3	18.3	18.1	18.3	0.988	1404.2	NO DAMAGE	
0	-25	59	0.00440	18.3	18.3	18.0	18.3	0.985	1123.3	NO DAMAGE	
0	-30	122	0.00910	18.3	18.3	18.0	18.3	0.982	936.1	NO DAMAGE	
0	-35	15	0.00112	18.3	18.3	17.9	18.3	0.979	802.4	NO DAMAGE	
0	-40	36	0.00268	18.3	18.3	17.9	18.3	0.976	702.1	NO DAMAGE	
0	-45	5	0.00037	18.3	18.3	17.8	18.3	0.973	624.1	NO DAMAGE	
0	-50	35	0.00261	18.3	18.3	17.7	18.3	0.970	561.7	NO DAMAGE	
0	-55	4	0.00030	18.3	18.3	17.7	18.3	0.967	510.6	NO DAMAGE	
0	-60	13	0.00097	18.3	18.3	17.6	18.3	0.963	468.1	NO DAMAGE	
0	-65	2	0.00015	18.3	18.3	17.6	18.3	0.960	432.1	NO DAMAGE	
0	-70	12	0.00089	18.3	18.3	17.5	18.3	0.957	401.2	NO DAMAGE	
0	-75	2	0.00015	18.3	18.3	17.5	18.3	0.954	374.4	NO DAMAGE	
0	-80	7	0.00052	18.3	18.3	17.4	18.3	0.951	351.0	NO DAMAGE	
0	-85	3	0.00022	18.3	18.3	17.4	18.3	0.948	330.4	NO DAMAGE	
0	-90	5	0.00037	18.3	18.3	17.3	18.3	0.945	312.0	NO DAMAGE	
0	-95	2	0.00015	18.3	18.3	17.2	18.3	0.942	295.6	NO DAMAGE	
0	-100	9	0.00067	18.3	18.3	17.2	18.3	0.939	280.8	NO DAMAGE	
0	-105	2	0.00015	18.3	18.3	17.1	18.3	0.936	267.5	NO DAMAGE	
0	-110	4	0.00030	18.3	18.3	17.1	18.3	0.933	255.3	NO DAMAGE	
0	-120	3	0.00022	18.3	18.3	17.0	18.3	0.927	234.0	NO DAMAGE	
0	-125	3	0.00022	18.3	18.3	16.9	18.3	0.924	224.7	NO DAMAGE	
0	-140	1	0.00007	18.3	18.3	16.7	18.3	0.915	200.6	NO DAMAGE	
0	-155	1	0.00007	18.3	18.3	16.6	18.3	0.906	181.2	NO DAMAGE	
0	-180	1	0.00007	18.3	18.3	16.3	18.3	0.890	156.0	NO DAMAGE	
-5	-15	19509	1.45445	18.3	18.2	18.1	18.2	0.994	2799.8	NO DAMAGE	
-5	-20	1685	0.12562	18.3	18.2	18.1	18.2	0.991	1866.5	NO DAMAGE	
-5	-25	7756	0.57823	18.3	18.2	18.0	18.2	0.988	1399.9	NO DAMAGE	
-5	-30	412	0.03072	18.3	18.2	18.0	18.2	0.985	1119.9	NO DAMAGE	
-5	-35	2199	0.16394	18.3	18.2	17.9	18.2	0.982	933.3	NO DAMAGE	
-5	-40	111	0.00828	18.3	18.2	17.9	18.2	0.979	799.9	NO DAMAGE	

cycles per mile	153.8
Yield stress	60 ksi

cycles per mile	153.8
Yield stress	60 ksi

Max	Min	No.	α Pct	Static Stress	Dynamic Stress Max	Dynamic Stress Min	Max Adjusted	R Min/Max	Endurance Limit	to Failure N	α/N
-5	-45	789	0.05882	18.3	18.2	17.8	18.2	0.976	699.9	NO DAMAGE	
-5	-50	49	0.00365	18.3	18.2	17.7	18.2	0.973	622.2	NO DAMAGE	
-5	-55	349	0.02602	18.3	18.2	17.7	18.2	0.969	560.0	NO DAMAGE	
-5	-60	12	0.00089	18.3	18.2	17.6	18.2	0.966	509.1	NO DAMAGE	
-5	-65	127	0.00947	18.3	18.2	17.6	18.2	0.963	466.6	NO DAMAGE	
-5	-70	11	0.00082	18.3	18.2	17.5	18.2	0.960	430.7	NO DAMAGE	
-5	-75	45	0.00335	18.3	18.2	17.5	18.2	0.957	400.0	NO DAMAGE	
-5	-80	6	0.00045	18.3	18.2	17.4	18.2	0.954	373.3	NO DAMAGE	
-5	-85	41	0.00306	18.3	18.2	17.4	18.2	0.951	350.0	NO DAMAGE	
-5	-90	5	0.00037	18.3	18.2	17.3	18.2	0.948	329.4	NO DAMAGE	
-5	-95	47	0.00350	18.3	18.2	17.2	18.2	0.945	311.1	NO DAMAGE	
-5	-100	7	0.00052	18.3	18.2	17.2	18.2	0.942	294.7	NO DAMAGE	
-5	-105	13	0.00097	18.3	18.2	17.1	18.2	0.939	280.0	NO DAMAGE	
-5	-110	1	0.00007	18.3	18.2	17.1	18.2	0.936	266.6	NO DAMAGE	
-5	-115	14	0.00104	18.3	18.2	17.0	18.2	0.933	254.5	NO DAMAGE	
-5	-125	4	0.00030	18.3	18.2	16.9	18.2	0.927	233.3	NO DAMAGE	
-5	-135	3	0.00022	18.3	18.2	16.8	18.2	0.921	215.4	NO DAMAGE	
-5	-145	3	0.00022	18.3	18.2	16.7	18.2	0.914	200.0	NO DAMAGE	
-5	-155	1	0.00007	18.3	18.2	16.6	18.2	0.908	186.7	NO DAMAGE	
-5	-165	1	0.00007	18.3	18.2	16.5	18.2	0.902	175.0	NO DAMAGE	
-5	-175	1	0.00007	18.3	18.2	16.4	18.2	0.896	164.7	NO DAMAGE	
-5	-185	1	0.00007	18.3	18.2	16.2	18.2	0.890	155.5	NO DAMAGE	
-5	-205	2	0.00015	18.3	18.2	16.0	18.2	0.878	140.0	NO DAMAGE	
-5	-215	1	0.00007	18.3	18.2	15.9	18.2	0.872	133.3	NO DAMAGE	
-5	-235	1	0.00007	18.3	18.2	15.7	18.2	0.860	121.7	NO DAMAGE	
-10	-20	31560	2.35289	18.3	18.2	18.1	18.2	0.994	2791.2	NO DAMAGE	
-10	-25	5740	0.42793	18.3	18.2	18.0	18.2	0.991	1860.8	NO DAMAGE	
-10	-30	19970	1.48882	18.3	18.2	18.0	18.2	0.988	1395.6	NO DAMAGE	
-10	-35	956	0.07127	18.3	18.2	17.9	18.2	0.985	1116.5	NO DAMAGE	
-10	-40	5567	0.41504	18.3	18.2	17.9	18.2	0.982	930.4	NO DAMAGE	
-10	-45	300	0.02237	18.3	18.2	17.8	18.2	0.979	797.5	NO DAMAGE	
-10	-50	1639	0.12219	18.3	18.2	17.7	18.2	0.975	697.8	NO DAMAGE	
-10	-55	37	0.00276	18.3	18.2	17.7	18.2	0.972	620.3	NO DAMAGE	
-10	-60	645	0.04809	18.3	18.2	17.6	18.2	0.969	558.2	NO DAMAGE	
-10	-65	11	0.00082	18.3	18.2	17.6	18.2	0.966	507.5	NO DAMAGE	
-10	-70	300	0.02237	18.3	18.2	17.5	18.2	0.963	465.2	NO DAMAGE	
-10	-75	2	0.00015	18.3	18.2	17.5	18.2	0.960	429.4	NO DAMAGE	
-10	-80	215	0.01603	18.3	18.2	17.4	18.2	0.957	398.7	NO DAMAGE	
-10	-85	7	0.00052	18.3	18.2	17.4	18.2	0.954	372.2	NO DAMAGE	
-10	-90	114	0.00850	18.3	18.2	17.3	18.2	0.951	348.9	NO DAMAGE	
-10	-95	1	0.00007	18.3	18.2	17.2	18.2	0.948	328.4	NO DAMAGE	
-10	-100	63	0.00470	18.3	18.2	17.2	18.2	0.945	310.1	NO DAMAGE	
-10	-105	2	0.00015	18.3	18.2	17.1	18.2	0.942	293.8	NO DAMAGE	
-10	-110	46	0.00343	18.3	18.2	17.1	18.2	0.939	279.1	NO DAMAGE	
-10	-115	3	0.00022	18.3	18.2	17.0	18.2	0.936	265.8	NO DAMAGE	
-10	-120	21	0.00157	18.3	18.2	17.0	18.2	0.933	253.7	NO DAMAGE	
-10	-125	1	0.00007	18.3	18.2	16.9	18.2	0.930	242.7	NO DAMAGE	
-10	-130	12	0.00089	18.3	18.2	16.9	18.2	0.926	232.6	NO DAMAGE	
-10	-140	6	0.00045	18.3	18.2	16.7	18.2	0.920	214.7	NO DAMAGE	
-10	-150	6	0.00045	18.3	18.2	16.6	18.2	0.914	199.4	NO DAMAGE	
-10	-155	2	0.00015	18.3	18.2	16.6	18.2	0.911	192.5	NO DAMAGE	
-10	-160	2	0.00015	18.3	18.2	16.5	18.2	0.908	186.1	NO DAMAGE	
-10	-170	5	0.00037	18.3	18.2	16.4	18.2	0.902	174.5	NO DAMAGE	
-10	-180	1	0.00007	18.3	18.2	16.3	18.2	0.896	164.2	NO DAMAGE	
-10	-190	1	0.00007	18.3	18.2	16.2	18.2	0.890	155.1	NO DAMAGE	
-10	-195	1	0.00007	18.3	18.2	16.1	18.2	0.887	150.9	NO DAMAGE	
-10	-200	1	0.00007	18.3	18.2	16.1	18.2	0.884	146.9	NO DAMAGE	
-10	-210	1	0.00007	18.3	18.2	16.0	18.2	0.877	139.6	NO DAMAGE	
-10	-220	1	0.00007	18.3	18.2	15.8	18.2	0.871	132.9	NO DAMAGE	
-15	-25	15612	1.16392	18.3	18.1	18.0	18.1	0.994	2782.7	NO DAMAGE	
-15	-30	4802	0.35800	18.3	18.1	18.0	18.1	0.991	1855.1	NO DAMAGE	
-15	-35	11214	0.83603	18.3	18.1	17.9	18.1	0.988	1391.3	NO DAMAGE	
-15	-40	1636	0.12197	18.3	18.1	17.9	18.1	0.985	1113.1	NO DAMAGE	
-15	-45	2753	0.20524	18.3	18.1	17.8	18.1	0.982	927.6	NO DAMAGE	
-15	-50	106	0.00790	18.3	18.1	17.7	18.1	0.978	795.1	NO DAMAGE	
-15	-55	686	0.05114	18.3	18.1	17.7	18.1	0.975	695.7	NO DAMAGE	
-15	-60	20	0.00149	18.3	18.1	17.6	18.1	0.972	618.4	NO DAMAGE	
-15	-65	218	0.01625	18.3	18.1	17.6	18.1	0.969	556.5	NO DAMAGE	
-15	-70	12	0.00089	18.3	18.1	17.5	18.1	0.966	505.9	NO DAMAGE	
-15	-75	106	0.00790	18.3	18.1	17.5	18.1	0.963	463.8	NO DAMAGE	
-15	-80	3	0.00022	18.3	18.1	17.4	18.1	0.960	428.1	NO DAMAGE	
-15	-85	68	0.00507	18.3	18.1	17.4	18.1	0.957	397.5	NO DAMAGE	
-15	-90	1	0.00007	18.3	18.1	17.3	18.1	0.954	371.0	NO DAMAGE	
-15	-95	28	0.00209	18.3	18.1	17.2	18.1	0.951	347.8	NO DAMAGE	
-15	-100	3	0.00022	18.3	18.1	17.2	18.1	0.948	327.4	NO DAMAGE	
-15	-105	13	0.00097	18.3	18.1	17.1	18.1	0.945	309.2	NO DAMAGE	
-15	-110	1	0.00007	18.3	18.1	17.1	18.1	0.942	292.9	NO DAMAGE	
-15	-115	5	0.00037	18.3	18.1	17.0	18.1	0.939	278.3	NO DAMAGE	
-15	-120	1	0.00007	18.3	18.1	17.0	18.1	0.935	265.0	NO DAMAGE	
-15	-125	3	0.00022	18.3	18.1	16.9	18.1	0.932	253.0	NO DAMAGE	
-15	-135	2	0.00015	18.3	18.1	16.8	18.1	0.926	231.9	NO DAMAGE	
-15	-145	4	0.00030	18.3	18.1	16.7	18.1	0.920	214.1	NO DAMAGE	
-15	-155	1	0.00007	18.3	18.1	16.6	18.1	0.914	198.8	NO DAMAGE	
-15	-160	1	0.00007	18.3	18.1	16.5	18.1	0.911	191.9	NO DAMAGE	
-15	-165	3	0.00022	18.3	18.1	16.5	18.1	0.908	185.5	NO DAMAGE	
-15	-170	2	0.00015	18.3	18.1	16.4	18.1	0.905	179.5	NO DAMAGE	
-15	-185	1	0.00007	18.3	18.1	16.2	18.1	0.896	163.7	NO DAMAGE	
-15	-205	1	0.00007	18.3	18.1	16.0	18.1	0.883	146.5	NO DAMAGE	
-15	-240	1	0.00007	18.3	18.1	15.6	18.1	0.862	123.7	NO DAMAGE	
-15	-245	1	0.00007	18.3	18.1	15.6	18.1	0.859	121.0	NO DAMAGE	
-20	-30	30520	2.27535	18.3	18.1	18.0	18.1	0.994	2774.1	NO DAMAGE	

cycles per mile 153.8
Yield stress 60 ksi

Max	Min	No.	α Pct	Static Stress	Dynamic Stress Max	Dynamic Stress Min	Max Adjusted	R Min/Max	Endurance Limit	to Failure N	α/N
-20	-35	6326	0.47162	18.3	18.1	17.9	18.1	0.991	1849.4	NO DAMAGE	
-20	-40	18311	1.36514	18.3	18.1	17.9	18.1	0.988	1387.1	NO DAMAGE	
-20	-45	518	0.03862	18.3	18.1	17.8	18.1	0.985	1109.7	NO DAMAGE	
-20	-50	5081	0.37880	18.3	18.1	17.7	18.1	0.982	924.7	NO DAMAGE	
-20	-55	59	0.00440	18.3	18.1	17.7	18.1	0.978	792.6	NO DAMAGE	
-20	-60	1465	0.10922	18.3	18.1	17.6	18.1	0.975	693.5	NO DAMAGE	
-20	-65	29	0.00216	18.3	18.1	17.6	18.1	0.972	616.5	NO DAMAGE	
-20	-70	431	0.03213	18.3	18.1	17.5	18.1	0.969	554.8	NO DAMAGE	
-20	-75	8	0.00060	18.3	18.1	17.5	18.1	0.966	504.4	NO DAMAGE	
-20	-80	196	0.01461	18.3	18.1	17.4	18.1	0.963	462.4	NO DAMAGE	
-20	-85	3	0.00022	18.3	18.1	17.4	18.1	0.960	426.8	NO DAMAGE	
-20	-90	52	0.00388	18.3	18.1	17.3	18.1	0.957	396.3	NO DAMAGE	
-20	-95	2	0.00015	18.3	18.1	17.2	18.1	0.954	369.9	NO DAMAGE	
-20	-100	34	0.00253	18.3	18.1	17.2	18.1	0.951	346.8	NO DAMAGE	
-20	-110	11	0.00082	18.3	18.1	17.1	18.1	0.945	308.2	NO DAMAGE	
-20	-120	13	0.00097	18.3	18.1	17.0	18.1	0.938	277.4	NO DAMAGE	
-20	-130	4	0.00030	18.3	18.1	16.9	18.1	0.932	252.2	NO DAMAGE	
-20	-150	1	0.00007	18.3	18.1	16.6	18.1	0.920	213.4	NO DAMAGE	
-20	-155	1	0.00007	18.3	18.1	16.6	18.1	0.917	205.5	NO DAMAGE	
-20	-160	3	0.00022	18.3	18.1	16.5	18.1	0.914	198.2	NO DAMAGE	
-20	-170	1	0.00007	18.3	18.1	16.4	18.1	0.908	184.9	NO DAMAGE	
-25	-35	14163	1.05589	18.3	18.0	17.9	18.0	0.994	2765.6	NO DAMAGE	
-25	-40	2509	0.18705	18.3	18.0	17.9	18.0	0.991	1843.7	NO DAMAGE	
-25	-45	7096	0.52903	18.3	18.0	17.8	18.0	0.988	1382.8	NO DAMAGE	
-25	-50	460	0.03429	18.3	18.0	17.7	18.0	0.985	1106.2	NO DAMAGE	
-25	-55	2477	0.18467	18.3	18.0	17.7	18.0	0.981	921.9	NO DAMAGE	
-25	-60	92	0.00686	18.3	18.0	17.6	18.0	0.978	790.2	NO DAMAGE	
-25	-65	885	0.06598	18.3	18.0	17.6	18.0	0.975	691.4	NO DAMAGE	
-25	-70	46	0.00343	18.3	18.0	17.5	18.0	0.972	614.6	NO DAMAGE	
-25	-75	446	0.03325	18.3	18.0	17.5	18.0	0.969	553.1	NO DAMAGE	
-25	-80	10	0.00075	18.3	18.0	17.4	18.0	0.966	502.8	NO DAMAGE	
-25	-85	155	0.01156	18.3	18.0	17.4	18.0	0.963	460.9	NO DAMAGE	
-25	-90	4	0.00030	18.3	18.0	17.3	18.0	0.960	425.5	NO DAMAGE	
-25	-95	55	0.00410	18.3	18.0	17.2	18.0	0.957	395.1	NO DAMAGE	
-25	-100	1	0.00007	18.3	18.0	17.2	18.0	0.954	368.7	NO DAMAGE	
-25	-105	13	0.00097	18.3	18.0	17.1	18.0	0.951	345.7	NO DAMAGE	
-25	-115	10	0.00075	18.3	18.0	17.0	18.0	0.944	307.3	NO DAMAGE	
-25	-120	2	0.00015	18.3	18.0	17.0	18.0	0.941	291.1	NO DAMAGE	
-25	-125	9	0.00067	18.3	18.0	16.9	18.0	0.938	276.6	NO DAMAGE	
-25	-135	2	0.00015	18.3	18.0	16.8	18.0	0.932	251.4	NO DAMAGE	
-25	-145	2	0.00015	18.3	18.0	16.7	18.0	0.926	230.5	NO DAMAGE	
-25	-155	3	0.00022	18.3	18.0	16.6	18.0	0.920	212.7	NO DAMAGE	
-25	-165	1	0.00007	18.3	18.0	16.5	18.0	0.913	197.5	NO DAMAGE	
-25	-180	1	0.00007	18.3	18.0	16.3	18.0	0.904	178.4	NO DAMAGE	
-25	-205	1	0.00007	18.3	18.0	16.0	18.0	0.889	153.6	NO DAMAGE	
-25	-225	1	0.00007	18.3	18.0	15.8	18.0	0.876	138.3	NO DAMAGE	
-25	-235	1	0.00007	18.3	18.0	15.7	18.0	0.870	131.7	NO DAMAGE	
-30	-40	19532	1.45616	18.3	18.0	17.9	18.0	0.994	2757.0	NO DAMAGE	
-30	-45	2909	0.21687	18.3	18.0	17.8	18.0	0.991	1838.0	NO DAMAGE	
-30	-50	13716	1.02257	18.3	18.0	17.7	18.0	0.988	1378.5	NO DAMAGE	
-30	-55	553	0.04123	18.3	18.0	17.7	18.0	0.984	1102.8	NO DAMAGE	
-30	-60	3849	0.28695	18.3	18.0	17.6	18.0	0.981	919.0	NO DAMAGE	
-30	-65	168	0.01252	18.3	18.0	17.6	18.0	0.978	787.7	NO DAMAGE	
-30	-70	1165	0.08685	18.3	18.0	17.5	18.0	0.975	689.3	NO DAMAGE	
-30	-75	39	0.00291	18.3	18.0	17.5	18.0	0.972	612.7	NO DAMAGE	
-30	-80	266	0.01983	18.3	18.0	17.4	18.0	0.969	551.4	NO DAMAGE	
-30	-85	5	0.00037	18.3	18.0	17.4	18.0	0.966	501.3	NO DAMAGE	
-30	-90	68	0.00507	18.3	18.0	17.3	18.0	0.963	459.5	NO DAMAGE	
-30	-95	2	0.00015	18.3	18.0	17.2	18.0	0.960	424.2	NO DAMAGE	
-30	-100	35	0.00261	18.3	18.0	17.2	18.0	0.957	393.9	NO DAMAGE	
-30	-110	12	0.00089	18.3	18.0	17.1	18.0	0.950	344.6	NO DAMAGE	
-30	-120	3	0.00022	18.3	18.0	17.0	18.0	0.944	306.3	NO DAMAGE	
-30	-125	1	0.00007	18.3	18.0	16.9	18.0	0.941	290.2	NO DAMAGE	
-30	-130	5	0.00037	18.3	18.0	16.9	18.0	0.938	275.7	NO DAMAGE	
-30	-140	5	0.00037	18.3	18.0	16.7	18.0	0.932	250.6	NO DAMAGE	
-30	-145	2	0.00015	18.3	18.0	16.7	18.0	0.929	239.7	NO DAMAGE	
-30	-150	1	0.00007	18.3	18.0	16.6	18.0	0.926	229.8	NO DAMAGE	
-30	-160	1	0.00007	18.3	18.0	16.5	18.0	0.919	212.1	NO DAMAGE	
-30	-170	1	0.00007	18.3	18.0	16.4	18.0	0.913	196.9	NO DAMAGE	
-30	-180	1	0.00007	18.3	18.0	16.3	18.0	0.907	183.8	NO DAMAGE	
-30	-190	1	0.00007	18.3	18.0	16.2	18.0	0.901	172.3	NO DAMAGE	
-30	-195	1	0.00007	18.3	18.0	16.1	18.0	0.898	167.1	NO DAMAGE	
-30	-200	1	0.00007	18.3	18.0	16.1	18.0	0.895	162.2	NO DAMAGE	
-30	-215	1	0.00007	18.3	18.0	15.9	18.0	0.885	149.0	NO DAMAGE	
-30	-255	1	0.00007	18.3	18.0	15.5	18.0	0.860	122.5	NO DAMAGE	
-35	-45	12272	0.91491	18.3	17.9	17.8	17.9	0.994	2748.5	NO DAMAGE	
-35	-50	2344	0.17475	18.3	17.9	17.7	17.9	0.991	1832.3	NO DAMAGE	
-35	-55	8732	0.65099	18.3	17.9	17.7	17.9	0.988	1374.2	NO DAMAGE	
-35	-60	676	0.05040	18.3	17.9	17.6	17.9	0.984	1099.4	NO DAMAGE	
-35	-65	3860	0.28777	18.3	17.9	17.6	17.9	0.981	916.2	NO DAMAGE	
-35	-70	154	0.01148	18.3	17.9	17.5	17.9	0.978	785.3	NO DAMAGE	
-35	-75	1443	0.10758	18.3	17.9	17.5	17.9	0.975	687.1	NO DAMAGE	
-35	-80	32	0.00239	18.3	17.9	17.4	17.9	0.972	610.8	NO DAMAGE	
-35	-85	453	0.03377	18.3	17.9	17.4	17.9	0.969	549.7	NO DAMAGE	
-35	-90	6	0.00045	18.3	17.9	17.3	17.9	0.966	499.7	NO DAMAGE	
-35	-95	105	0.00783	18.3	17.9	17.2	17.9	0.963	458.1	NO DAMAGE	
-35	-100	4	0.00030	18.3	17.9	17.2	17.9	0.960	422.8	NO DAMAGE	
-35	-105	28	0.00209	18.3	17.9	17.1	17.9	0.956	392.6	NO DAMAGE	
-35	-115	14	0.00104	18.3	17.9	17.0	17.9	0.950	343.6	NO DAMAGE	
-35	-120	1	0.00007	18.3	17.9	17.0	17.9	0.947	323.4	NO DAMAGE	
-35	-125	4	0.00030	18.3	17.9	16.9	17.9	0.944	305.4	NO DAMAGE	

cycles per mile	153.8	
Yield stress	60	ksi

Max	Min	No.	α Pct	Static Stress	Dynamic Stress Max	Dynamic Stress Min	Max Adjusted	R Min/Max	Endurance Limit	to Failure N	α/N
-35	-130	1	0.00007	18.3	17.9	16.9	17.9	0.941	289.3	NO DAMAGE	
-35	-135	5	0.00037	18.3	17.9	16.8	17.9	0.938	274.8	NO DAMAGE	
-35	-150	1	0.00007	18.3	17.9	16.6	17.9	0.928	239.0	NO DAMAGE	
-35	-165	2	0.00015	18.3	17.9	16.5	17.9	0.919	211.4	NO DAMAGE	
-35	-175	1	0.00007	18.3	17.9	16.4	17.9	0.913	196.3	NO DAMAGE	
-35	-180	1	0.00007	18.3	17.9	16.3	17.9	0.910	189.6	NO DAMAGE	
-35	-215	1	0.00007	18.3	17.9	15.9	17.9	0.888	152.7	NO DAMAGE	
-40	-50	14077	1.04948	18.3	17.9	17.7	17.9	0.994	2739.9	NO DAMAGE	
-40	-55	2298	0.17132	18.3	17.9	17.7	17.9	0.991	1826.6	NO DAMAGE	
-40	-60	10806	0.80562	18.3	17.9	17.6	17.9	0.988	1370.0	NO DAMAGE	
-40	-65	770	0.05741	18.3	17.9	17.6	17.9	0.984	1096.0	NO DAMAGE	
-40	-70	2852	0.21262	18.3	17.9	17.5	17.9	0.981	913.3	NO DAMAGE	
-40	-75	135	0.01006	18.3	17.9	17.5	17.9	0.978	782.8	NO DAMAGE	
-40	-80	567	0.04227	18.3	17.9	17.4	17.9	0.975	685.0	NO DAMAGE	
-40	-85	32	0.00239	18.3	17.9	17.4	17.9	0.972	608.9	NO DAMAGE	
-40	-90	154	0.01148	18.3	17.9	17.3	17.9	0.969	548.0	NO DAMAGE	
-40	-95	8	0.00060	18.3	17.9	17.2	17.9	0.966	498.2	NO DAMAGE	
-40	-100	43	0.00321	18.3	17.9	17.2	17.9	0.963	456.7	NO DAMAGE	
-40	-105	5	0.00037	18.3	17.9	17.1	17.9	0.959	421.5	NO DAMAGE	
-40	-110	13	0.00097	18.3	17.9	17.1	17.9	0.956	391.4	NO DAMAGE	
-40	-115	2	0.00015	18.3	17.9	17.0	17.9	0.953	365.3	NO DAMAGE	
-40	-120	7	0.00052	18.3	17.9	17.0	17.9	0.950	342.5	NO DAMAGE	
-40	-125	1	0.00007	18.3	17.9	16.9	17.9	0.947	322.3	NO DAMAGE	
-40	-130	7	0.00052	18.3	17.9	16.9	17.9	0.944	304.4	NO DAMAGE	
-40	-140	2	0.00015	18.3	17.9	16.7	17.9	0.938	274.0	NO DAMAGE	
-40	-160	2	0.00015	18.3	17.9	16.5	17.9	0.925	228.3	NO DAMAGE	
-40	-165	1	0.00007	18.3	17.9	16.5	17.9	0.922	219.2	NO DAMAGE	
-40	-180	1	0.00007	18.3	17.9	16.3	17.9	0.913	195.7	NO DAMAGE	
-45	-55	13228	0.98618	18.3	17.8	17.7	17.8	0.994	2731.4	NO DAMAGE	
-45	-60	2591	0.19317	18.3	17.8	17.6	17.8	0.991	1820.9	NO DAMAGE	
-45	-65	13577	1.01220	18.3	17.8	17.6	17.8	0.987	1365.7	NO DAMAGE	
-45	-70	751	0.05599	18.3	17.8	17.5	17.8	0.984	1092.6	NO DAMAGE	
-45	-75	4721	0.35196	18.3	17.8	17.5	17.8	0.981	910.5	NO DAMAGE	
-45	-80	159	0.01185	18.3	17.8	17.4	17.8	0.978	780.4	NO DAMAGE	
-45	-85	1270	0.09468	18.3	17.8	17.4	17.8	0.975	682.8	NO DAMAGE	
-45	-90	32	0.00239	18.3	17.8	17.3	17.8	0.972	607.0	NO DAMAGE	
-45	-95	224	0.01670	18.3	17.8	17.2	17.8	0.969	546.3	NO DAMAGE	
-45	-100	7	0.00052	18.3	17.8	17.2	17.8	0.966	496.6	NO DAMAGE	
-45	-105	59	0.00440	18.3	17.8	17.1	17.8	0.962	455.2	NO DAMAGE	
-45	-110	6	0.00045	18.3	17.8	17.1	17.8	0.959	420.2	NO DAMAGE	
-45	-115	31	0.00231	18.3	17.8	17.0	17.8	0.956	390.2	NO DAMAGE	
-45	-120	5	0.00037	18.3	17.8	17.0	17.8	0.953	364.2	NO DAMAGE	
-45	-125	12	0.00089	18.3	17.8	16.9	17.8	0.950	341.4	NO DAMAGE	
-45	-135	7	0.00052	18.3	17.8	16.8	17.8	0.944	303.5	NO DAMAGE	
-45	-145	3	0.00022	18.3	17.8	16.7	17.8	0.937	273.1	NO DAMAGE	
-45	-175	1	0.00007	18.3	17.8	16.4	17.8	0.919	210.1	NO DAMAGE	
-45	-215	1	0.00007	18.3	17.8	15.9	17.8	0.894	160.7	NO DAMAGE	
-45	-230	1	0.00007	18.3	17.8	15.7	17.8	0.884	147.6	NO DAMAGE	
-50	-60	13667	1.01891	18.3	17.7	17.6	17.7	0.994	2722.8	NO DAMAGE	
-50	-65	2746	0.20472	18.3	17.7	17.6	17.7	0.991	1815.2	NO DAMAGE	
-50	-70	9048	0.67455	18.3	17.7	17.5	17.7	0.987	1361.4	NO DAMAGE	
-50	-75	799	0.05957	18.3	17.7	17.5	17.7	0.984	1089.1	NO DAMAGE	
-50	-80	1862	0.13882	18.3	17.7	17.4	17.7	0.981	907.6	NO DAMAGE	
-50	-85	159	0.01185	18.3	17.7	17.4	17.7	0.978	778.0	NO DAMAGE	
-50	-90	403	0.03004	18.3	17.7	17.3	17.7	0.975	680.7	NO DAMAGE	
-50	-95	32	0.00239	18.3	17.7	17.2	17.7	0.972	605.1	NO DAMAGE	
-50	-100	122	0.00910	18.3	17.7	17.2	17.7	0.969	544.6	NO DAMAGE	
-50	-105	12	0.00089	18.3	17.7	17.1	17.7	0.965	495.1	NO DAMAGE	
-50	-110	33	0.00246	18.3	17.7	17.1	17.7	0.962	453.8	NO DAMAGE	
-50	-115	2	0.00015	18.3	17.7	17.0	17.7	0.959	418.9	NO DAMAGE	
-50	-120	11	0.00082	18.3	17.7	17.0	17.7	0.956	389.0	NO DAMAGE	
-50	-125	2	0.00015	18.3	17.7	16.9	17.7	0.953	363.0	NO DAMAGE	
-50	-130	5	0.00037	18.3	17.7	16.9	17.7	0.950	340.4	NO DAMAGE	
-50	-135	1	0.00007	18.3	17.7	16.8	17.7	0.947	320.3	NO DAMAGE	
-50	-140	2	0.00015	18.3	17.7	16.7	17.7	0.943	302.5	NO DAMAGE	
-50	-150	1	0.00007	18.3	17.7	16.6	17.7	0.937	272.3	NO DAMAGE	
-50	-160	3	0.00022	18.3	17.7	16.5	17.7	0.931	247.5	NO DAMAGE	
-50	-170	1	0.00007	18.3	17.7	16.4	17.7	0.925	226.9	NO DAMAGE	
-50	-180	2	0.00015	18.3	17.7	16.3	17.7	0.918	209.4	NO DAMAGE	
-50	-215	1	0.00007	18.3	17.7	15.9	17.7	0.896	165.0	NO DAMAGE	
-55	-65	16459	1.22706	18.3	17.7	17.6	17.7	0.994	2714.3	NO DAMAGE	
-55	-70	2658	0.19816	18.3	17.7	17.5	17.7	0.991	1809.5	NO DAMAGE	
-55	-75	14709	1.09660	18.3	17.7	17.5	17.7	0.987	1357.1	NO DAMAGE	
-55	-80	1037	0.07731	18.3	17.7	17.4	17.7	0.984	1085.7	NO DAMAGE	
-55	-85	3097	0.23089	18.3	17.7	17.4	17.7	0.981	904.8	NO DAMAGE	
-55	-90	215	0.01603	18.3	17.7	17.3	17.7	0.978	775.5	NO DAMAGE	
-55	-95	683	0.05092	18.3	17.7	17.2	17.7	0.975	678.6	NO DAMAGE	
-55	-100	56	0.00417	18.3	17.7	17.2	17.7	0.972	603.2	NO DAMAGE	
-55	-105	306	0.02281	18.3	17.7	17.1	17.7	0.969	542.9	NO DAMAGE	
-55	-110	6	0.00045	18.3	17.7	17.1	17.7	0.965	493.5	NO DAMAGE	
-55	-115	132	0.00984	18.3	17.7	17.0	17.7	0.962	452.4	NO DAMAGE	
-55	-120	3	0.00022	18.3	17.7	17.0	17.7	0.959	417.6	NO DAMAGE	
-55	-125	30	0.00224	18.3	17.7	16.9	17.7	0.956	387.8	NO DAMAGE	
-55	-135	4	0.00030	18.3	17.7	16.8	17.7	0.950	339.3	NO DAMAGE	
-55	-145	3	0.00022	18.3	17.7	16.7	17.7	0.943	301.6	NO DAMAGE	
-55	-155	1	0.00007	18.3	17.7	16.6	17.7	0.937	271.4	NO DAMAGE	
-55	-160	1	0.00007	18.3	17.7	16.5	17.7	0.934	258.5	NO DAMAGE	
-55	-165	1	0.00007	18.3	17.7	16.5	17.7	0.931	246.8	NO DAMAGE	
-55	-195	1	0.00007	18.3	17.7	16.1	17.7	0.912	193.9	NO DAMAGE	
-55	-205	1	0.00007	18.3	17.7	16.0	17.7	0.906	181.0	NO DAMAGE	
-55	-225	1	0.00007	18.3	17.7	15.8	17.7	0.893	159.7	NO DAMAGE	

cycles per mile 153.8
Yield stress 60 ksi

Max	Min	No.	α Pct	Static Stress	Dynamic Stress Max	Dynamic Stress Min	Max Adjusted	R Min/Max	Endurance Limit	to Failure N	α/N
-55	-235	1	0.00007	18.3	17.7	15.7	17.7	0.887	150.8	NO DAMAGE	
-55	-270	1	0.00007	18.3	17.7	15.3	17.7	0.865	126.2	NO DAMAGE	
-60	-70	12251	0.91335	18.3	17.6	17.5	17.6	0.994	2705.7	NO DAMAGE	
-60	-75	2961	0.22075	18.3	17.6	17.5	17.6	0.991	1803.8	NO DAMAGE	
-60	-80	7155	0.53342	18.3	17.6	17.4	17.6	0.987	1352.9	NO DAMAGE	
-60	-85	1139	0.08492	18.3	17.6	17.4	17.6	0.984	1082.3	NO DAMAGE	
-60	-90	1533	0.11429	18.3	17.6	17.3	17.6	0.981	901.9	NO DAMAGE	
-60	-95	213	0.01588	18.3	17.6	17.2	17.6	0.978	773.1	NO DAMAGE	
-60	-100	311	0.02319	18.3	17.6	17.2	17.6	0.975	676.4	NO DAMAGE	
-60	-105	44	0.00328	18.3	17.6	17.1	17.6	0.972	601.3	NO DAMAGE	
-60	-110	70	0.00522	18.3	17.6	17.1	17.6	0.968	541.1	NO DAMAGE	
-60	-115	11	0.00082	18.3	17.6	17.0	17.6	0.965	492.0	NO DAMAGE	
-60	-120	23	0.00171	18.3	17.6	17.0	17.6	0.962	451.0	NO DAMAGE	
-60	-125	1	0.00007	18.3	17.6	16.9	17.6	0.959	416.3	NO DAMAGE	
-60	-130	3	0.00022	18.3	17.6	16.9	17.6	0.956	386.5	NO DAMAGE	
-60	-140	3	0.00022	18.3	17.6	16.7	17.6	0.949	338.2	NO DAMAGE	
-60	-150	1	0.00007	18.3	17.6	16.6	17.6	0.943	300.6	NO DAMAGE	
-60	-160	3	0.00022	18.3	17.6	16.5	17.6	0.937	270.6	NO DAMAGE	
-60	-170	2	0.00015	18.3	17.6	16.4	17.6	0.930	246.0	NO DAMAGE	
-60	-190	1	0.00007	18.3	17.6	16.2	17.6	0.918	208.1	NO DAMAGE	
-60	-195	1	0.00007	18.3	17.6	16.1	17.6	0.915	200.4	NO DAMAGE	
-65	-75	16359	1.21961	18.3	17.6	17.5	17.6	0.994	2697.2	NO DAMAGE	
-65	-80	3270	0.24379	18.3	17.6	17.4	17.6	0.990	1798.1	NO DAMAGE	
-65	-85	10064	0.75030	18.3	17.6	17.4	17.6	0.987	1348.6	NO DAMAGE	
-65	-90	1010	0.07530	18.3	17.6	17.3	17.6	0.984	1078.9	NO DAMAGE	
-65	-95	2428	0.18101	18.3	17.6	17.2	17.6	0.981	899.1	NO DAMAGE	
-65	-100	173	0.01290	18.3	17.6	17.2	17.6	0.978	770.6	NO DAMAGE	
-65	-105	939	0.07001	18.3	17.6	17.1	17.6	0.975	674.3	NO DAMAGE	
-65	-110	22	0.00164	18.3	17.6	17.1	17.6	0.971	599.4	NO DAMAGE	
-65	-115	235	0.01752	18.3	17.6	17.0	17.6	0.968	539.4	NO DAMAGE	
-65	-125	34	0.00253	18.3	17.6	16.9	17.6	0.962	449.5	NO DAMAGE	
-65	-130	1	0.00007	18.3	17.6	16.9	17.6	0.959	415.0	NO DAMAGE	
-65	-135	4	0.00030	18.3	17.6	16.8	17.6	0.956	385.3	NO DAMAGE	
-65	-140	1	0.00007	18.3	17.6	16.7	17.6	0.952	359.6	NO DAMAGE	
-65	-145	4	0.00030	18.3	17.6	16.7	17.6	0.949	337.1	NO DAMAGE	
-65	-155	1	0.00007	18.3	17.6	16.6	17.6	0.943	299.7	NO DAMAGE	
-65	-160	2	0.00015	18.3	17.6	16.5	17.6	0.940	283.9	NO DAMAGE	
-65	-165	2	0.00015	18.3	17.6	16.5	17.6	0.937	269.7	NO DAMAGE	
-65	-175	2	0.00015	18.3	17.6	16.4	17.6	0.930	245.2	NO DAMAGE	
-65	-195	1	0.00007	18.3	17.6	16.1	17.6	0.918	207.5	NO DAMAGE	
-65	-205	1	0.00007	18.3	17.6	16.0	17.6	0.911	192.7	NO DAMAGE	
-65	-215	1	0.00007	18.3	17.6	15.9	17.6	0.905	179.8	NO DAMAGE	
-70	-80	10471	0.78064	18.3	17.5	17.4	17.5	0.994	2688.6	NO DAMAGE	
-70	-85	3301	0.24610	18.3	17.5	17.4	17.5	0.990	1792.4	NO DAMAGE	
-70	-90	5651	0.42130	18.3	17.5	17.3	17.5	0.987	1344.3	NO DAMAGE	
-70	-95	952	0.07097	18.3	17.5	17.2	17.5	0.984	1075.5	NO DAMAGE	
-70	-100	1144	0.08529	18.3	17.5	17.2	17.5	0.981	896.2	NO DAMAGE	
-70	-105	124	0.00924	18.3	17.5	17.1	17.5	0.978	768.2	NO DAMAGE	
-70	-110	229	0.01707	18.3	17.5	17.1	17.5	0.975	672.2	NO DAMAGE	
-70	-115	16	0.00119	18.3	17.5	17.0	17.5	0.971	597.5	NO DAMAGE	
-70	-120	40	0.00298	18.3	17.5	17.0	17.5	0.968	537.7	NO DAMAGE	
-70	-125	2	0.00015	18.3	17.5	16.9	17.5	0.965	488.8	NO DAMAGE	
-70	-130	9	0.00067	18.3	17.5	16.9	17.5	0.962	448.1	NO DAMAGE	
-70	-140	3	0.00022	18.3	17.5	16.7	17.5	0.955	384.1	NO DAMAGE	
-70	-150	2	0.00015	18.3	17.5	16.6	17.5	0.949	336.1	NO DAMAGE	
-70	-160	1	0.00007	18.3	17.5	16.5	17.5	0.943	298.7	NO DAMAGE	
-70	-165	1	0.00007	18.3	17.5	16.5	17.5	0.940	283.0	NO DAMAGE	
-70	-170	1	0.00007	18.3	17.5	16.4	17.5	0.936	268.9	NO DAMAGE	
-70	-180	2	0.00015	18.3	17.5	16.3	17.5	0.930	244.4	NO DAMAGE	
-70	-190	1	0.00007	18.3	17.5	16.2	17.5	0.924	224.1	NO DAMAGE	
-70	-200	3	0.00022	18.3	17.5	16.1	17.5	0.917	206.8	NO DAMAGE	
-75	-85	14182	1.05731	18.3	17.5	17.4	17.5	0.994	2680.1	NO DAMAGE	
-75	-90	2967	0.22120	18.3	17.5	17.3	17.5	0.990	1786.7	NO DAMAGE	
-75	-95	9334	0.69588	18.3	17.5	17.2	17.5	0.987	1340.0	NO DAMAGE	
-75	-100	735	0.05480	18.3	17.5	17.2	17.5	0.984	1072.0	NO DAMAGE	
-75	-105	2065	0.15395	18.3	17.5	17.1	17.5	0.981	893.4	NO DAMAGE	
-75	-110	86	0.00641	18.3	17.5	17.1	17.5	0.978	765.7	NO DAMAGE	
-75	-115	338	0.02520	18.3	17.5	17.0	17.5	0.974	670.0	NO DAMAGE	
-75	-120	14	0.00104	18.3	17.5	17.0	17.5	0.971	595.6	NO DAMAGE	
-75	-125	45	0.00335	18.3	17.5	16.9	17.5	0.968	536.0	NO DAMAGE	
-75	-130	3	0.00022	18.3	17.5	16.9	17.5	0.965	487.3	NO DAMAGE	
-75	-135	5	0.00037	18.3	17.5	16.8	17.5	0.962	446.7	NO DAMAGE	
-75	-140	1	0.00007	18.3	17.5	16.7	17.5	0.959	412.3	NO DAMAGE	
-75	-145	2	0.00015	18.3	17.5	16.7	17.5	0.955	382.9	NO DAMAGE	
-75	-150	1	0.00007	18.3	17.5	16.6	17.5	0.952	357.3	NO DAMAGE	
-75	-155	1	0.00007	18.3	17.5	16.6	17.5	0.949	335.0	NO DAMAGE	
-75	-160	3	0.00022	18.3	17.5	16.5	17.5	0.946	315.3	NO DAMAGE	
-75	-165	2	0.00015	18.3	17.5	16.5	17.5	0.943	297.8	NO DAMAGE	
-75	-195	2	0.00015	18.3	17.5	16.1	17.5	0.923	223.3	NO DAMAGE	
-75	-205	1	0.00007	18.3	17.5	16.0	17.5	0.917	206.2	NO DAMAGE	
-75	-215	1	0.00007	18.3	17.5	15.9	17.5	0.911	191.4	NO DAMAGE	
-80	-90	8101	0.60395	18.3	17.4	17.3	17.4	0.994	2671.5	NO DAMAGE	
-80	-95	2409	0.17960	18.3	17.4	17.2	17.4	0.990	1781.0	NO DAMAGE	
-80	-100	3830	0.28554	18.3	17.4	17.2	17.4	0.987	1335.8	NO DAMAGE	
-80	-105	649	0.04838	18.3	17.4	17.1	17.4	0.984	1068.6	NO DAMAGE	
-80	-110	766	0.05711	18.3	17.4	17.1	17.4	0.981	890.5	NO DAMAGE	
-80	-115	61	0.00455	18.3	17.4	17.0	17.4	0.978	763.3	NO DAMAGE	
-80	-120	135	0.01006	18.3	17.4	17.0	17.4	0.974	667.9	NO DAMAGE	
-80	-125	1	0.00007	18.3	17.4	16.9	17.4	0.971	593.7	NO DAMAGE	
-80	-130	33	0.00246	18.3	17.4	16.9	17.4	0.968	534.3	NO DAMAGE	
-80	-135	2	0.00015	18.3	17.4	16.8	17.4	0.965	485.7	NO DAMAGE	

cycles per mile 153.8
Yield stress 60 ksi

					Dynamic Stress					to Failure	
Max	Min	No.	α Pct	Static Stress	Max	Min	Max Adjusted	R Min/Max	Endurance Limit	N	α/N
-80	-140	10	0.00075	18.3	17.4	16.7	17.4	0.962	445.3	NO DAMAGE	
-80	-145	2	0.00015	18.3	17.4	16.7	17.4	0.958	411.0	NO DAMAGE	
-80	-150	2	0.00015	18.3	17.4	16.6	17.4	0.955	381.6	NO DAMAGE	
-80	-170	1	0.00007	18.3	17.4	16.4	17.4	0.942	296.8	NO DAMAGE	
-80	-180	1	0.00007	18.3	17.4	16.3	17.4	0.936	267.2	NO DAMAGE	
-80	-200	1	0.00007	18.3	17.4	16.1	17.4	0.923	222.6	NO DAMAGE	
-85	-95	13290	0.99081	18.3	17.4	17.2	17.4	0.994	2663.0	NO DAMAGE	
-85	-100	2275	0.16961	18.3	17.4	17.2	17.4	0.990	1775.3	NO DAMAGE	
-85	-105	6479	0.48303	18.3	17.4	17.1	17.4	0.987	1331.5	NO DAMAGE	
-85	-110	483	0.03601	18.3	17.4	17.1	17.4	0.984	1065.2	NO DAMAGE	
-85	-115	766	0.05711	18.3	17.4	17.0	17.4	0.981	887.7	NO DAMAGE	
-85	-120	50	0.00373	18.3	17.4	17.0	17.4	0.978	760.9	NO DAMAGE	
-85	-125	69	0.00514	18.3	17.4	16.9	17.4	0.974	665.7	NO DAMAGE	
-85	-130	7	0.00052	18.3	17.4	16.9	17.4	0.971	591.8	NO DAMAGE	
-85	-135	8	0.00060	18.3	17.4	16.8	17.4	0.968	532.6	NO DAMAGE	
-85	-140	2	0.00015	18.3	17.4	16.7	17.4	0.965	484.2	NO DAMAGE	
-85	-145	2	0.00015	18.3	17.4	16.7	17.4	0.961	443.8	NO DAMAGE	
-85	-150	1	0.00007	18.3	17.4	16.6	17.4	0.958	409.7	NO DAMAGE	
-85	-155	8	0.00060	18.3	17.4	16.6	17.4	0.955	380.4	NO DAMAGE	
-85	-160	1	0.00007	18.3	17.4	16.5	17.4	0.952	355.1	NO DAMAGE	
-85	-165	2	0.00015	18.3	17.4	16.5	17.4	0.949	332.9	NO DAMAGE	
-85	-175	1	0.00007	18.3	17.4	16.4	17.4	0.942	295.9	NO DAMAGE	
-85	-205	2	0.00015	18.3	17.4	16.0	17.4	0.923	221.9	NO DAMAGE	
-90	-100	5702	0.42510	18.3	17.3	17.2	17.3	0.994	2654.4	NO DAMAGE	
-90	-105	1616	0.12048	18.3	17.3	17.1	17.3	0.990	1769.6	NO DAMAGE	
-90	-110	2362	0.17609	18.3	17.3	17.1	17.3	0.987	1327.2	NO DAMAGE	
-90	-115	348	0.02594	18.3	17.3	17.0	17.3	0.984	1061.8	NO DAMAGE	
-90	-120	508	0.03787	18.3	17.3	17.0	17.3	0.981	884.8	NO DAMAGE	
-90	-125	42	0.00313	18.3	17.3	16.9	17.3	0.977	758.4	NO DAMAGE	
-90	-130	85	0.00634	18.3	17.3	16.9	17.3	0.974	663.6	NO DAMAGE	
-90	-135	5	0.00037	18.3	17.3	16.8	17.3	0.971	589.9	NO DAMAGE	
-90	-140	17	0.00127	18.3	17.3	16.7	17.3	0.968	530.9	NO DAMAGE	
-90	-145	3	0.00022	18.3	17.3	16.7	17.3	0.965	482.6	NO DAMAGE	
-90	-150	5	0.00037	18.3	17.3	16.6	17.3	0.961	442.4	NO DAMAGE	
-90	-155	2	0.00015	18.3	17.3	16.6	17.3	0.958	408.4	NO DAMAGE	
-90	-160	6	0.00045	18.3	17.3	16.5	17.3	0.955	379.2	NO DAMAGE	
-90	-170	2	0.00015	18.3	17.3	16.4	17.3	0.948	331.8	NO DAMAGE	
-90	-180	1	0.00007	18.3	17.3	16.3	17.3	0.942	294.9	NO DAMAGE	
-90	-190	2	0.00015	18.3	17.3	16.2	17.3	0.936	265.4	NO DAMAGE	
-90	-200	1	0.00007	18.3	17.3	16.1	17.3	0.929	241.3	NO DAMAGE	
-90	-250	1	0.00007	18.3	17.3	15.5	17.3	0.897	165.9	NO DAMAGE	
-95	-105	8428	0.62833	18.3	17.2	17.1	17.2	0.994	2645.9	NO DAMAGE	
-95	-110	1303	0.09714	18.3	17.2	17.1	17.2	0.990	1763.9	NO DAMAGE	
-95	-115	3709	0.27652	18.3	17.2	17.0	17.2	0.987	1322.9	NO DAMAGE	
-95	-120	265	0.01976	18.3	17.2	17.0	17.2	0.984	1058.4	NO DAMAGE	
-95	-125	319	0.02378	18.3	17.2	16.9	17.2	0.981	882.0	NO DAMAGE	
-95	-130	31	0.00231	18.3	17.2	16.9	17.2	0.977	756.0	NO DAMAGE	
-95	-135	43	0.00321	18.3	17.2	16.8	17.2	0.974	661.5	NO DAMAGE	
-95	-140	3	0.00022	18.3	17.2	16.7	17.2	0.971	588.0	NO DAMAGE	
-95	-145	6	0.00045	18.3	17.2	16.7	17.2	0.968	529.2	NO DAMAGE	
-95	-150	4	0.00030	18.3	17.2	16.6	17.2	0.964	481.1	NO DAMAGE	
-95	-155	5	0.00037	18.3	17.2	16.6	17.2	0.961	441.0	NO DAMAGE	
-95	-160	3	0.00022	18.3	17.2	16.5	17.2	0.958	407.1	NO DAMAGE	
-95	-165	3	0.00022	18.3	17.2	16.5	17.2	0.955	378.0	NO DAMAGE	
-95	-175	1	0.00007	18.3	17.2	16.4	17.2	0.948	330.7	NO DAMAGE	
-95	-195	1	0.00007	18.3	17.2	16.1	17.2	0.935	264.6	NO DAMAGE	
-95	-225	1	0.00007	18.3	17.2	15.8	17.2	0.916	203.5	NO DAMAGE	
-100	-110	4039	0.30112	18.3	17.2	17.1	17.2	0.994	2637.3	NO DAMAGE	
-100	-115	1147	0.08551	18.3	17.2	17.0	17.2	0.990	1758.2	NO DAMAGE	
-100	-120	1845	0.13755	18.3	17.2	17.0	17.2	0.987	1318.7	NO DAMAGE	
-100	-125	199	0.01484	18.3	17.2	16.9	17.2	0.984	1054.9	NO DAMAGE	
-100	-130	436	0.03251	18.3	17.2	16.9	17.2	0.981	879.1	NO DAMAGE	
-100	-135	20	0.00149	18.3	17.2	16.8	17.2	0.977	753.5	NO DAMAGE	
-100	-140	67	0.00500	18.3	17.2	16.7	17.2	0.974	659.3	NO DAMAGE	
-100	-145	2	0.00015	18.3	17.2	16.7	17.2	0.971	586.1	NO DAMAGE	
-100	-150	14	0.00104	18.3	17.2	16.6	17.2	0.968	527.5	NO DAMAGE	
-100	-160	7	0.00052	18.3	17.2	16.5	17.2	0.961	439.6	NO DAMAGE	
-100	-170	1	0.00007	18.3	17.2	16.4	17.2	0.955	376.8	NO DAMAGE	
-100	-175	1	0.00007	18.3	17.2	16.4	17.2	0.951	351.6	NO DAMAGE	
-100	-180	2	0.00015	18.3	17.2	16.3	17.2	0.948	329.7	NO DAMAGE	
-100	-185	1	0.00007	18.3	17.2	16.2	17.2	0.945	310.3	NO DAMAGE	
-100	-190	1	0.00007	18.3	17.2	16.2	17.2	0.942	293.0	NO DAMAGE	
-105	-115	6351	0.47348	18.3	17.1	17.0	17.1	0.993	2628.8	NO DAMAGE	
-105	-120	994	0.07411	18.3	17.1	17.0	17.1	0.990	1752.5	NO DAMAGE	
-105	-125	2749	0.20495	18.3	17.1	16.9	17.1	0.987	1314.4	NO DAMAGE	
-105	-130	177	0.01320	18.3	17.1	16.9	17.1	0.984	1051.5	NO DAMAGE	
-105	-135	305	0.02274	18.3	17.1	16.8	17.1	0.980	876.3	NO DAMAGE	
-105	-140	16	0.00119	18.3	17.1	16.7	17.1	0.977	751.1	NO DAMAGE	
-105	-145	18	0.00134	18.3	17.1	16.7	17.1	0.974	657.2	NO DAMAGE	
-105	-150	4	0.00030	18.3	17.1	16.6	17.1	0.971	584.2	NO DAMAGE	
-105	-155	4	0.00030	18.3	17.1	16.6	17.1	0.967	525.8	NO DAMAGE	
-105	-160	2	0.00015	18.3	17.1	16.5	17.1	0.964	478.0	NO DAMAGE	
-105	-165	5	0.00037	18.3	17.1	16.5	17.1	0.961	438.1	NO DAMAGE	
-105	-175	3	0.00022	18.3	17.1	16.4	17.1	0.954	375.5	NO DAMAGE	
-105	-185	2	0.00015	18.3	17.1	16.2	17.1	0.948	328.6	NO DAMAGE	
-105	-190	2	0.00015	18.3	17.1	16.2	17.1	0.945	309.3	NO DAMAGE	
-105	-195	1	0.00007	18.3	17.1	16.1	17.1	0.941	292.1	NO DAMAGE	
-105	-210	1	0.00007	18.3	17.1	16.0	17.1	0.932	250.4	NO DAMAGE	
-110	-120	3584	0.26720	18.3	17.1	17.0	17.1	0.993	2620.2	NO DAMAGE	
-110	-125	852	0.06352	18.3	17.1	16.9	17.1	0.990	1746.8	NO DAMAGE	
-110	-130	1577	0.11757	18.3	17.1	16.9	17.1	0.987	1310.1	NO DAMAGE	

cycles per mile 153.8
Yield stress 60 ksi

Max	Min	No.	α Pct	Static Stress	Dynamic Stress Max	Dynamic Stress Min	Max Adjusted	R Min/Max	Endurance Limit	to Failure N	α/N
-110	-135	127	0.00947	18.3	17.1	16.8	17.1	0.984	1048.1	NO DAMAGE	
-110	-140	260	0.01938	18.3	17.1	16.7	17.1	0.980	873.4	NO DAMAGE	
-110	-145	13	0.00097	18.3	17.1	16.7	17.1	0.977	748.6	NO DAMAGE	
-110	-150	38	0.00283	18.3	17.1	16.6	17.1	0.974	655.1	NO DAMAGE	
-110	-155	5	0.00037	18.3	17.1	16.6	17.1	0.971	582.3	NO DAMAGE	
-110	-160	10	0.00075	18.3	17.1	16.5	17.1	0.967	524.0	NO DAMAGE	
-110	-165	1	0.00007	18.3	17.1	16.5	17.1	0.964	476.4	NO DAMAGE	
-110	-170	2	0.00015	18.3	17.1	16.4	17.1	0.961	436.7	NO DAMAGE	
-110	-175	2	0.00015	18.3	17.1	16.4	17.1	0.958	403.1	NO DAMAGE	
-110	-180	2	0.00015	18.3	17.1	16.3	17.1	0.954	374.3	NO DAMAGE	
-110	-205	2	0.00015	18.3	17.1	16.0	17.1	0.938	275.8	NO DAMAGE	
-115	-125	5236	0.39036	18.3	17.0	16.9	17.0	0.993	2611.7	NO DAMAGE	
-115	-130	840	0.06262	18.3	17.0	16.9	17.0	0.990	1741.1	NO DAMAGE	
-115	-135	1968	0.14672	18.3	17.0	16.8	17.0	0.987	1305.8	NO DAMAGE	
-115	-140	141	0.01051	18.3	17.0	16.7	17.0	0.984	1044.7	NO DAMAGE	
-115	-145	138	0.01029	18.3	17.0	16.7	17.0	0.980	870.6	NO DAMAGE	
-115	-150	9	0.00067	18.3	17.0	16.6	17.0	0.977	746.2	NO DAMAGE	
-115	-155	21	0.00157	18.3	17.0	16.6	17.0	0.974	652.9	NO DAMAGE	
-115	-160	2	0.00015	18.3	17.0	16.5	17.0	0.971	580.4	NO DAMAGE	
-115	-165	8	0.00060	18.3	17.0	16.5	17.0	0.967	522.3	NO DAMAGE	
-115	-170	1	0.00007	18.3	17.0	16.4	17.0	0.964	474.9	NO DAMAGE	
-115	-175	5	0.00037	18.3	17.0	16.4	17.0	0.961	435.3	NO DAMAGE	
-115	-185	1	0.00007	18.3	17.0	16.2	17.0	0.954	373.1	NO DAMAGE	
-115	-245	1	0.00007	18.3	17.0	15.6	17.0	0.915	200.9	NO DAMAGE	
-120	-130	2973	0.22165	18.3	17.0	16.9	17.0	0.993	2603.1	NO DAMAGE	
-120	-135	831	0.06195	18.3	17.0	16.8	17.0	0.990	1735.4	NO DAMAGE	
-120	-140	1120	0.08350	18.3	17.0	16.7	17.0	0.987	1301.6	NO DAMAGE	
-120	-145	100	0.00746	18.3	17.0	16.7	17.0	0.984	1041.3	NO DAMAGE	
-120	-150	164	0.01223	18.3	17.0	16.6	17.0	0.980	867.7	NO DAMAGE	
-120	-155	8	0.00060	18.3	17.0	16.6	17.0	0.977	743.8	NO DAMAGE	
-120	-160	25	0.00186	18.3	17.0	16.5	17.0	0.974	650.8	NO DAMAGE	
-120	-170	2	0.00015	18.3	17.0	16.4	17.0	0.967	520.6	NO DAMAGE	
-120	-180	3	0.00022	18.3	17.0	16.3	17.0	0.961	433.9	NO DAMAGE	
-120	-190	1	0.00007	18.3	17.0	16.2	17.0	0.954	371.9	NO DAMAGE	
-120	-200	1	0.00007	18.3	17.0	16.1	17.0	0.947	325.4	NO DAMAGE	
-120	-205	1	0.00007	18.3	17.0	16.0	17.0	0.944	306.3	NO DAMAGE	
-120	-215	1	0.00007	18.3	17.0	15.9	17.0	0.938	274.0	NO DAMAGE	
-125	-135	4276	0.31879	18.3	16.9	16.8	16.9	0.993	2594.6	NO DAMAGE	
-125	-140	683	0.05092	18.3	16.9	16.7	16.9	0.990	1729.7	NO DAMAGE	
-125	-145	1552	0.11571	18.3	16.9	16.7	16.9	0.987	1297.3	NO DAMAGE	
-125	-150	97	0.00723	18.3	16.9	16.6	16.9	0.984	1037.8	NO DAMAGE	
-125	-155	88	0.00656	18.3	16.9	16.6	16.9	0.980	864.9	NO DAMAGE	
-125	-160	17	0.00127	18.3	16.9	16.5	16.9	0.977	741.3	NO DAMAGE	
-125	-165	13	0.00097	18.3	16.9	16.5	16.9	0.974	648.6	NO DAMAGE	
-125	-170	4	0.00030	18.3	16.9	16.4	16.9	0.970	576.6	NO DAMAGE	
-125	-175	3	0.00022	18.3	16.9	16.4	16.9	0.967	518.9	NO DAMAGE	
-125	-180	1	0.00007	18.3	16.9	16.3	16.9	0.964	471.7	NO DAMAGE	
-125	-185	3	0.00022	18.3	16.9	16.2	16.9	0.960	432.4	NO DAMAGE	
-125	-190	1	0.00007	18.3	16.9	16.2	16.9	0.957	399.2	NO DAMAGE	
-125	-195	1	0.00007	18.3	16.9	16.1	16.9	0.954	370.7	NO DAMAGE	
-130	-140	2817	0.21002	18.3	16.9	16.7	16.9	0.993	2586.0	NO DAMAGE	
-130	-145	656	0.04891	18.3	16.9	16.7	16.9	0.990	1724.0	NO DAMAGE	
-130	-150	896	0.06680	18.3	16.9	16.6	16.9	0.987	1293.0	NO DAMAGE	
-130	-155	95	0.00708	18.3	16.9	16.6	16.9	0.983	1034.4	NO DAMAGE	
-130	-160	94	0.00701	18.3	16.9	16.5	16.9	0.980	862.0	NO DAMAGE	
-130	-165	10	0.00075	18.3	16.9	16.5	16.9	0.977	738.9	NO DAMAGE	
-130	-170	15	0.00112	18.3	16.9	16.4	16.9	0.974	646.5	NO DAMAGE	
-130	-175	4	0.00030	18.3	16.9	16.4	16.9	0.970	574.7	NO DAMAGE	
-130	-180	2	0.00015	18.3	16.9	16.3	16.9	0.967	517.2	NO DAMAGE	
-130	-185	1	0.00007	18.3	16.9	16.2	16.9	0.964	470.2	NO DAMAGE	
-130	-190	2	0.00015	18.3	16.9	16.2	16.9	0.960	431.0	NO DAMAGE	
-130	-195	1	0.00007	18.3	16.9	16.1	16.9	0.957	397.9	NO DAMAGE	
-130	-220	1	0.00007	18.3	16.9	15.8	16.9	0.940	287.3	NO DAMAGE	
-130	-230	1	0.00007	18.3	16.9	15.7	16.9	0.934	258.6	NO DAMAGE	
-135	-145	3311	0.24684	18.3	16.8	16.7	16.8	0.993	2577.5	NO DAMAGE	
-135	-150	514	0.03832	18.3	16.8	16.6	16.8	0.990	1718.3	NO DAMAGE	
-135	-155	1106	0.08246	18.3	16.8	16.6	16.8	0.987	1288.7	NO DAMAGE	
-135	-160	58	0.00432	18.3	16.8	16.5	16.8	0.983	1031.0	NO DAMAGE	
-135	-165	81	0.00604	18.3	16.8	16.5	16.8	0.980	859.2	NO DAMAGE	
-135	-170	10	0.00075	18.3	16.8	16.4	16.8	0.977	736.4	NO DAMAGE	
-135	-175	14	0.00104	18.3	16.8	16.4	16.8	0.973	644.4	NO DAMAGE	
-135	-180	3	0.00022	18.3	16.8	16.3	16.8	0.970	572.8	NO DAMAGE	
-135	-185	4	0.00030	18.3	16.8	16.2	16.8	0.967	515.5	NO DAMAGE	
-135	-190	1	0.00007	18.3	16.8	16.2	16.8	0.964	468.6	NO DAMAGE	
-135	-195	1	0.00007	18.3	16.8	16.1	16.8	0.960	429.6	NO DAMAGE	
-140	-150	1992	0.14851	18.3	16.7	16.6	16.7	0.993	2568.9	NO DAMAGE	
-140	-155	454	0.03385	18.3	16.7	16.6	16.7	0.990	1712.6	NO DAMAGE	
-140	-160	517	0.03854	18.3	16.7	16.5	16.7	0.987	1284.5	NO DAMAGE	
-140	-165	61	0.00455	18.3	16.7	16.5	16.7	0.983	1027.6	NO DAMAGE	
-140	-170	54	0.00403	18.3	16.7	16.4	16.7	0.980	856.3	NO DAMAGE	
-140	-175	20	0.00149	18.3	16.7	16.4	16.7	0.977	734.0	NO DAMAGE	
-140	-180	20	0.00149	18.3	16.7	16.3	16.7	0.973	642.2	NO DAMAGE	
-140	-185	1	0.00007	18.3	16.7	16.2	16.7	0.970	570.9	NO DAMAGE	
-140	-190	1	0.00007	18.3	16.7	16.2	16.7	0.967	513.8	NO DAMAGE	
-140	-195	1	0.00007	18.3	16.7	16.1	16.7	0.963	467.1	NO DAMAGE	
-140	-200	1	0.00007	18.3	16.7	16.1	16.7	0.960	428.2	NO DAMAGE	
-140	-210	1	0.00007	18.3	16.7	16.0	16.7	0.953	367.0	NO DAMAGE	
-145	-155	2955	0.22030	18.3	16.7	16.6	16.7	0.993	2560.4	NO DAMAGE	
-145	-160	431	0.03213	18.3	16.7	16.5	16.7	0.990	1706.9	NO DAMAGE	
-145	-165	765	0.05703	18.3	16.7	16.5	16.7	0.987	1280.2	NO DAMAGE	
-145	-170	78	0.00582	18.3	16.7	16.4	16.7	0.983	1024.2	NO DAMAGE	

Max	Min	No.	α Pct	Static Stress	Dynamic Stress Max	Dynamic Stress Min	Max Adjusted	R Min/Max	Endurance Limit	to Failure N	α/N
-145	-175	50	0.00373	18.3	16.7	16.4	16.7	0.980	853.5	NO DAMAGE	
-145	-180	16	0.00119	18.3	16.7	16.3	16.7	0.977	731.5	NO DAMAGE	
-145	-185	6	0.00045	18.3	16.7	16.2	16.7	0.973	640.1	NO DAMAGE	
-145	-190	4	0.00030	18.3	16.7	16.2	16.7	0.970	569.0	NO DAMAGE	
-145	-195	8	0.00060	18.3	16.7	16.1	16.7	0.967	512.1	NO DAMAGE	
-145	-205	2	0.00015	18.3	16.7	16.0	16.7	0.960	426.7	NO DAMAGE	
-145	-225	1	0.00007	18.3	16.7	15.8	16.7	0.947	320.0	NO DAMAGE	
-150	-160	1535	0.11444	18.3	16.6	16.5	16.6	0.993	2551.8	NO DAMAGE	
-150	-165	428	0.03191	18.3	16.6	16.5	16.6	0.990	1701.2	NO DAMAGE	
-150	-170	353	0.02632	18.3	16.6	16.4	16.6	0.987	1275.9	NO DAMAGE	
-150	-175	44	0.00328	18.3	16.6	16.4	16.6	0.983	1020.7	NO DAMAGE	
-150	-180	54	0.00403	18.3	16.6	16.3	16.6	0.980	850.6	NO DAMAGE	
-150	-185	5	0.00037	18.3	16.6	16.2	16.6	0.977	729.1	NO DAMAGE	
-150	-190	10	0.00075	18.3	16.6	16.2	16.6	0.973	638.0	NO DAMAGE	
-150	-195	1	0.00007	18.3	16.6	16.1	16.6	0.970	567.1	NO DAMAGE	
-150	-200	4	0.00030	18.3	16.6	16.1	16.6	0.966	510.4	NO DAMAGE	
-150	-210	2	0.00015	18.3	16.6	16.0	16.6	0.960	425.3	NO DAMAGE	
-155	-165	2322	0.17311	18.3	16.6	16.5	16.6	0.993	2543.3	NO DAMAGE	
-155	-170	392	0.02922	18.3	16.6	16.4	16.6	0.990	1695.5	NO DAMAGE	
-155	-175	511	0.03810	18.3	16.6	16.4	16.6	0.987	1271.6	NO DAMAGE	
-155	-180	47	0.00350	18.3	16.6	16.3	16.6	0.983	1017.3	NO DAMAGE	
-155	-185	35	0.00261	18.3	16.6	16.2	16.6	0.980	847.8	NO DAMAGE	
-155	-190	2	0.00015	18.3	16.6	16.2	16.6	0.976	726.7	NO DAMAGE	
-155	-195	6	0.00045	18.3	16.6	16.1	16.6	0.973	635.8	NO DAMAGE	
-155	-200	1	0.00007	18.3	16.6	16.1	16.6	0.970	565.2	NO DAMAGE	
-155	-205	4	0.00030	18.3	16.6	16.0	16.6	0.966	508.7	NO DAMAGE	
-155	-210	1	0.00007	18.3	16.6	16.0	16.6	0.963	462.4	NO DAMAGE	
-155	-215	2	0.00015	18.3	16.6	15.9	16.6	0.960	423.9	NO DAMAGE	
-155	-225	1	0.00007	18.3	16.6	15.8	16.6	0.953	363.3	NO DAMAGE	
-160	-170	1521	0.11339	18.3	16.5	16.4	16.5	0.993	2534.7	NO DAMAGE	
-160	-175	311	0.02319	18.3	16.5	16.4	16.5	0.990	1689.8	NO DAMAGE	
-160	-180	371	0.02766	18.3	16.5	16.3	16.5	0.987	1267.4	NO DAMAGE	
-160	-185	35	0.00261	18.3	16.5	16.2	16.5	0.983	1013.9	NO DAMAGE	
-160	-190	29	0.00216	18.3	16.5	16.2	16.5	0.980	844.9	NO DAMAGE	
-160	-200	8	0.00060	18.3	16.5	16.1	16.5	0.973	633.7	NO DAMAGE	
-160	-205	1	0.00007	18.3	16.5	16.0	16.5	0.970	563.3	NO DAMAGE	
-160	-210	4	0.00030	18.3	16.5	16.0	16.5	0.966	506.9	NO DAMAGE	
-160	-215	1	0.00007	18.3	16.5	15.9	16.5	0.963	460.9	NO DAMAGE	
-160	-220	1	0.00007	18.3	16.5	15.8	16.5	0.960	422.5	NO DAMAGE	
-160	-240	1	0.00007	18.3	16.5	15.6	16.5	0.946	316.8	NO DAMAGE	
-160	-300	1	0.00007	18.3	16.5	15.0	16.5	0.906	181.1	NO DAMAGE	
-165	-175	1805	0.13457	18.3	16.5	16.4	16.5	0.993	2526.2	NO DAMAGE	
-165	-180	295	0.02199	18.3	16.5	16.3	16.5	0.990	1684.1	NO DAMAGE	
-165	-185	382	0.02848	18.3	16.5	16.2	16.5	0.986	1263.1	NO DAMAGE	
-165	-190	19	0.00142	18.3	16.5	16.2	16.5	0.983	1010.5	NO DAMAGE	
-165	-195	11	0.00082	18.3	16.5	16.1	16.5	0.980	842.1	NO DAMAGE	
-165	-200	4	0.00030	18.3	16.5	16.1	16.5	0.976	721.8	NO DAMAGE	
-165	-205	10	0.00075	18.3	16.5	16.0	16.5	0.973	631.5	NO DAMAGE	
-165	-210	1	0.00007	18.3	16.5	16.0	16.5	0.970	561.4	NO DAMAGE	
-165	-215	1	0.00007	18.3	16.5	15.9	16.5	0.966	505.2	NO DAMAGE	
-165	-225	4	0.00030	18.3	16.5	15.8	16.5	0.959	421.0	NO DAMAGE	
-165	-235	2	0.00015	18.3	16.5	15.7	16.5	0.953	360.9	NO DAMAGE	
-165	-245	1	0.00007	18.3	16.5	15.6	16.5	0.946	315.8	NO DAMAGE	
-165	-255	1	0.00007	18.3	16.5	15.5	16.5	0.939	280.7	NO DAMAGE	
-170	-180	1099	0.08193	18.3	16.4	16.3	16.4	0.993	2517.6	NO DAMAGE	
-170	-185	240	0.01789	18.3	16.4	16.2	16.4	0.990	1678.4	NO DAMAGE	
-170	-190	237	0.01767	18.3	16.4	16.2	16.4	0.986	1258.8	NO DAMAGE	
-170	-195	21	0.00157	18.3	16.4	16.1	16.4	0.983	1007.1	NO DAMAGE	
-170	-200	32	0.00239	18.3	16.4	16.1	16.4	0.980	839.2	NO DAMAGE	
-170	-205	6	0.00045	18.3	16.4	16.0	16.4	0.976	719.3	NO DAMAGE	
-170	-210	3	0.00022	18.3	16.4	16.0	16.4	0.973	629.4	NO DAMAGE	
-170	-215	3	0.00022	18.3	16.4	15.9	16.4	0.969	559.5	NO DAMAGE	
-170	-220	1	0.00007	18.3	16.4	15.8	16.4	0.966	503.5	NO DAMAGE	
-175	-185	1609	0.11996	18.3	16.4	16.2	16.4	0.993	2509.1	NO DAMAGE	
-175	-190	240	0.01789	18.3	16.4	16.2	16.4	0.990	1672.7	NO DAMAGE	
-175	-195	304	0.02266	18.3	16.4	16.1	16.4	0.986	1254.5	NO DAMAGE	
-175	-200	10	0.00075	18.3	16.4	16.1	16.4	0.983	1003.6	NO DAMAGE	
-175	-205	16	0.00119	18.3	16.4	16.0	16.4	0.980	836.4	NO DAMAGE	
-175	-210	5	0.00037	18.3	16.4	16.0	16.4	0.976	716.9	NO DAMAGE	
-175	-215	6	0.00045	18.3	16.4	15.9	16.4	0.973	627.3	NO DAMAGE	
-175	-225	2	0.00015	18.3	16.4	15.8	16.4	0.966	501.8	NO DAMAGE	
-175	-235	3	0.00022	18.3	16.4	15.7	16.4	0.959	418.2	NO DAMAGE	
-175	-255	1	0.00007	18.3	16.4	15.5	16.4	0.945	313.6	NO DAMAGE	
-180	-190	1003	0.07478	18.3	16.3	16.2	16.3	0.993	2500.5	NO DAMAGE	
-180	-195	213	0.01588	18.3	16.3	16.1	16.3	0.990	1667.0	NO DAMAGE	
-180	-200	183	0.01364	18.3	16.3	16.1	16.3	0.986	1250.3	NO DAMAGE	
-180	-205	19	0.00142	18.3	16.3	16.0	16.3	0.983	1000.2	NO DAMAGE	
-180	-210	18	0.00134	18.3	16.3	16.0	16.3	0.979	833.5	NO DAMAGE	
-180	-215	1	0.00007	18.3	16.3	15.9	16.3	0.976	714.4	NO DAMAGE	
-180	-220	1	0.00007	18.3	16.3	15.8	16.3	0.973	625.1	NO DAMAGE	
-180	-240	1	0.00007	18.3	16.3	15.6	16.3	0.959	416.8	NO DAMAGE	
-185	-195	1474	0.10989	18.3	16.2	16.1	16.2	0.993	2492.0	NO DAMAGE	
-185	-200	295	0.02199	18.3	16.2	16.1	16.2	0.990	1661.3	NO DAMAGE	
-185	-205	300	0.02237	18.3	16.2	16.0	16.2	0.986	1246.0	NO DAMAGE	
-185	-210	14	0.00104	18.3	16.2	16.0	16.2	0.983	996.8	NO DAMAGE	
-185	-215	15	0.00112	18.3	16.2	15.9	16.2	0.979	830.7	NO DAMAGE	
-185	-220	2	0.00015	18.3	16.2	15.8	16.2	0.976	712.0	NO DAMAGE	
-185	-225	10	0.00075	18.3	16.2	15.8	16.2	0.973	623.0	NO DAMAGE	
-185	-235	11	0.00082	18.3	16.2	15.7	16.2	0.966	498.4	NO DAMAGE	
-185	-245	2	0.00015	18.3	16.2	15.6	16.2	0.959	415.3	NO DAMAGE	
-190	-200	1217	0.09073	18.3	16.2	16.1	16.2	0.993	2483.4	NO DAMAGE	

cycles per mile	153.8
Yield stress	60 ksi

cycles per mile	153.8
Yield stress	60 ksi

Max	Min	No.	α Pct	Static Stress	Dynamic Stress Max	Dynamic Stress Min	Max Adjusted	R Min/Max	Endurance Limit	to Failure N	α/N
-190	-205	282	0.02102	18.3	16.2	16.0	16.2	0.990	1655.6	NO DAMAGE	
-190	-210	125	0.00932	18.3	16.2	16.0	16.2	0.986	1241.7	NO DAMAGE	
-190	-215	10	0.00075	18.3	16.2	15.9	16.2	0.983	993.4	NO DAMAGE	
-190	-220	6	0.00045	18.3	16.2	15.8	16.2	0.979	827.8	NO DAMAGE	
-190	-230	2	0.00015	18.3	16.2	15.7	16.2	0.972	620.9	NO DAMAGE	
-190	-400	1	0.00007	18.3	16.2	13.8	16.2	0.855	118.3	NO DAMAGE	
-195	-205	1915	0.14277	18.3	16.1	16.0	16.1	0.993	2474.9	NO DAMAGE	
-195	-210	306	0.02281	18.3	16.1	16.0	16.1	0.990	1649.9	NO DAMAGE	
-195	-215	280	0.02087	18.3	16.1	15.9	16.1	0.986	1237.4	NO DAMAGE	
-195	-220	2	0.00015	18.3	16.1	15.8	16.1	0.983	990.0	NO DAMAGE	
-195	-225	15	0.00112	18.3	16.1	15.8	16.1	0.979	825.0	NO DAMAGE	
-195	-235	5	0.00037	18.3	16.1	15.7	16.1	0.972	618.7	NO DAMAGE	
-195	-240	1	0.00007	18.3	16.1	15.6	16.1	0.969	550.0	NO DAMAGE	
-195	-245	5	0.00037	18.3	16.1	15.6	16.1	0.965	495.0	NO DAMAGE	
-195	-255	1	0.00007	18.3	16.1	15.5	16.1	0.959	412.5	NO DAMAGE	
-200	-210	1092	0.08141	18.3	16.1	16.0	16.1	0.993	2466.3	NO DAMAGE	
-200	-215	185	0.01379	18.3	16.1	15.9	16.1	0.990	1644.2	NO DAMAGE	
-200	-220	66	0.00492	18.3	16.1	15.8	16.1	0.986	1233.2	NO DAMAGE	
-200	-225	2	0.00015	18.3	16.1	15.8	16.1	0.983	986.5	NO DAMAGE	
-200	-230	1	0.00007	18.3	16.1	15.7	16.1	0.979	822.1	NO DAMAGE	
-205	-215	1078	0.08037	18.3	16.0	15.9	16.0	0.993	2457.8	NO DAMAGE	
-205	-220	63	0.00470	18.3	16.0	15.8	16.0	0.990	1638.5	NO DAMAGE	
-205	-225	152	0.01133	18.3	16.0	15.8	16.0	0.986	1228.9	NO DAMAGE	
-205	-230	4	0.00030	18.3	16.0	15.7	16.0	0.983	983.1	NO DAMAGE	
-205	-235	15	0.00112	18.3	16.0	15.7	16.0	0.979	819.3	NO DAMAGE	
-205	-245	15	0.00112	18.3	16.0	15.6	16.0	0.972	614.4	NO DAMAGE	
-205	-255	6	0.00045	18.3	16.0	15.5	16.0	0.965	491.6	NO DAMAGE	
-210	-220	338	0.02520	18.3	16.0	15.8	16.0	0.993	2449.2	NO DAMAGE	
-210	-225	56	0.00417	18.3	16.0	15.8	16.0	0.990	1632.8	NO DAMAGE	
-210	-230	23	0.00171	18.3	16.0	15.7	16.0	0.986	1224.6	NO DAMAGE	
-210	-240	4	0.00030	18.3	16.0	15.6	16.0	0.979	816.4	NO DAMAGE	
-210	-360	1	0.00007	18.3	16.0	14.3	16.0	0.895	163.3	NO DAMAGE	
-215	-225	503	0.03750	18.3	15.9	15.8	15.9	0.993	2440.7	NO DAMAGE	
-215	-230	11	0.00082	18.3	15.9	15.7	15.9	0.989	1627.1	NO DAMAGE	
-215	-235	172	0.01282	18.3	15.9	15.7	15.9	0.986	1220.3	NO DAMAGE	
-215	-245	29	0.00216	18.3	15.9	15.6	15.9	0.979	813.6	NO DAMAGE	
-215	-250	1	0.00007	18.3	15.9	15.5	15.9	0.975	697.3	NO DAMAGE	
-215	-255	4	0.00030	18.3	15.9	15.5	15.9	0.972	610.2	NO DAMAGE	
-220	-230	89	0.00664	18.3	15.8	15.7	15.8	0.993	2432.1	NO DAMAGE	
-220	-235	12	0.00089	18.3	15.8	15.7	15.8	0.989	1621.4	NO DAMAGE	
-220	-240	33	0.00246	18.3	15.8	15.6	15.8	0.986	1216.1	NO DAMAGE	
-220	-250	9	0.00067	18.3	15.8	15.5	15.8	0.979	810.7	NO DAMAGE	
-220	-260	1	0.00007	18.3	15.8	15.4	15.8	0.972	608.0	NO DAMAGE	
-225	-235	732	0.05457	18.3	15.8	15.7	15.8	0.993	2423.6	NO DAMAGE	
-225	-240	11	0.00082	18.3	15.8	15.6	15.8	0.989	1615.7	NO DAMAGE	
-225	-245	260	0.01938	18.3	15.8	15.6	15.8	0.986	1211.8	NO DAMAGE	
-225	-255	3	0.00022	18.3	15.8	15.5	15.8	0.979	807.9	NO DAMAGE	
-225	-260	1	0.00007	18.3	15.8	15.4	15.8	0.975	692.5	NO DAMAGE	
-225	-270	1	0.00007	18.3	15.8	15.3	15.8	0.968	538.6	NO DAMAGE	
-230	-240	86	0.00641	18.3	15.7	15.6	15.7	0.993	2415.0	NO DAMAGE	
-230	-245	12	0.00089	18.3	15.7	15.6	15.7	0.989	1610.0	NO DAMAGE	
-230	-250	14	0.00104	18.3	15.7	15.5	15.7	0.986	1207.5	NO DAMAGE	
-230	-265	1	0.00007	18.3	15.7	15.3	15.7	0.975	690.0	NO DAMAGE	
-230	-320	1	0.00007	18.3	15.7	14.7	15.7	0.936	268.3	NO DAMAGE	
-235	-245	440	0.03280	18.3	15.7	15.6	15.7	0.993	2406.5	NO DAMAGE	
-235	-250	5	0.00037	18.3	15.7	15.5	15.7	0.989	1604.3	NO DAMAGE	
-235	-255	45	0.00335	18.3	15.7	15.5	15.7	0.986	1203.2	NO DAMAGE	
-235	-260	1	0.00007	18.3	15.7	15.4	15.7	0.982	962.6	NO DAMAGE	
-235	-265	1	0.00007	18.3	15.7	15.3	15.7	0.979	802.2	NO DAMAGE	
-240	-250	42	0.00313	18.3	15.6	15.5	15.6	0.993	2397.9	NO DAMAGE	
-240	-255	2	0.00015	18.3	15.6	15.5	15.6	0.989	1598.6	NO DAMAGE	
-240	-260	8	0.00060	18.3	15.6	15.4	15.6	0.986	1199.0	NO DAMAGE	
-240	-270	2	0.00015	18.3	15.6	15.3	15.6	0.979	799.3	NO DAMAGE	
-240	-280	1	0.00007	18.3	15.6	15.2	15.6	0.971	599.5	NO DAMAGE	
-245	-255	86	0.00641	18.3	15.6	15.5	15.6	0.993	2389.4	NO DAMAGE	
-245	-260	6	0.00045	18.3	15.6	15.4	15.6	0.989	1592.9	NO DAMAGE	
-245	-265	12	0.00089	18.3	15.6	15.3	15.6	0.986	1194.7	NO DAMAGE	
-245	-270	1	0.00007	18.3	15.6	15.3	15.6	0.982	955.8	NO DAMAGE	
-250	-260	25	0.00186	18.3	15.5	15.4	15.5	0.993	2380.8	NO DAMAGE	
-250	-265	5	0.00037	18.3	15.5	15.3	15.5	0.989	1587.2	NO DAMAGE	
-250	-270	2	0.00015	18.3	15.5	15.3	15.5	0.986	1190.4	NO DAMAGE	
-250	-280	1	0.00007	18.3	15.5	15.2	15.5	0.978	793.6	NO DAMAGE	
-255	-265	49	0.00365	18.3	15.5	15.3	15.5	0.993	2372.3	NO DAMAGE	
-255	-270	8	0.00060	18.3	15.5	15.3	15.5	0.989	1581.5	NO DAMAGE	
-255	-275	6	0.00045	18.3	15.5	15.2	15.5	0.986	1186.1	NO DAMAGE	
-255	-285	1	0.00007	18.3	15.5	15.1	15.5	0.978	790.8	NO DAMAGE	
-255	-315	1	0.00007	18.3	15.5	14.8	15.5	0.957	395.4	NO DAMAGE	
-255	-535	2	0.00015	18.3	15.5	12.3	15.5	0.798	84.7	NO DAMAGE	
-260	-270	13	0.00097	18.3	15.4	15.3	15.4	0.993	2363.7	NO DAMAGE	
-260	-275	3	0.00022	18.3	15.4	15.2	15.4	0.989	1575.8	NO DAMAGE	
-260	-310	2	0.00015	18.3	15.4	14.8	15.4	0.964	472.7	NO DAMAGE	
-265	-275	22	0.00164	18.3	15.3	15.2	15.3	0.993	2355.2	NO DAMAGE	
-265	-280	3	0.00022	18.3	15.3	15.2	15.3	0.989	1570.1	NO DAMAGE	
-265	-285	1	0.00007	18.3	15.3	15.1	15.3	0.985	1177.6	NO DAMAGE	
-265	-295	1	0.00007	18.3	15.3	15.0	15.3	0.978	785.1	NO DAMAGE	
-265	-300	1	0.00007	18.3	15.3	15.0	15.3	0.975	672.9	NO DAMAGE	
-270	-280	6	0.00045	18.3	15.3	15.2	15.3	0.993	2346.6	NO DAMAGE	
-270	-285	2	0.00015	18.3	15.3	15.1	15.3	0.989	1564.4	NO DAMAGE	
-270	-290	1	0.00007	18.3	15.3	15.1	15.3	0.985	1173.3	NO DAMAGE	
-270	-295	1	0.00007	18.3	15.3	15.0	15.3	0.982	938.7	NO DAMAGE	
-275	-285	12	0.00089	18.3	15.2	15.1	15.2	0.993	2338.1	NO DAMAGE	

Max	Min	No.	α Pct	Static Stress	Dynamic Stress Max	Dynamic Stress Min	Max Adjusted	R Min/Max	Endurance Limit	to Failure N	α/N
-275	-290	11	0.00082	18.3	15.2	15.1	15.2	0.989	1558.7	NO DAMAGE	
-275	-295	3	0.00022	18.3	15.2	15.0	15.2	0.985	1169.0	NO DAMAGE	
-275	-300	1	0.00007	18.3	15.2	15.0	15.2	0.982	935.2	NO DAMAGE	
-275	-305	1	0.00007	18.3	15.2	14.9	15.2	0.978	779.4	NO DAMAGE	
-275	-345	1	0.00007	18.3	15.2	14.5	15.2	0.949	334.0	NO DAMAGE	
-280	-290	19	0.00142	18.3	15.2	15.1	15.2	0.993	2329.5	NO DAMAGE	
-280	-295	4	0.00030	18.3	15.2	15.0	15.2	0.989	1553.0	NO DAMAGE	
-285	-295	8	0.00060	18.3	15.1	15.0	15.1	0.993	2321.0	NO DAMAGE	
-285	-300	1	0.00007	18.3	15.1	15.0	15.1	0.989	1547.3	NO DAMAGE	
-285	-315	2	0.00015	18.3	15.1	14.8	15.1	0.978	773.7	NO DAMAGE	
-285	-325	1	0.00007	18.3	15.1	14.7	15.1	0.971	580.2	NO DAMAGE	
-285	-335	4	0.00030	18.3	15.1	14.6	15.1	0.963	464.2	NO DAMAGE	
-290	-300	3	0.00022	18.3	15.1	15.0	15.1	0.993	2312.4	NO DAMAGE	
-295	-305	6	0.00045	18.3	15.0	14.9	15.0	0.993	2303.9	NO DAMAGE	
-295	-315	11	0.00082	18.3	15.0	14.8	15.0	0.985	1151.9	NO DAMAGE	
-295	-325	16	0.00119	18.3	15.0	14.7	15.0	0.978	768.0	NO DAMAGE	
-295	-335	14	0.00104	18.3	15.0	14.6	15.0	0.970	576.0	NO DAMAGE	
-300	-315	1	0.00007	18.3	15.0	14.8	15.0	0.989	1530.2	NO DAMAGE	
-305	-315	63	0.00470	18.3	14.9	14.8	14.9	0.993	2286.8	NO DAMAGE	
-305	-325	124	0.00924	18.3	14.9	14.7	14.9	0.985	1143.4	NO DAMAGE	
-305	-335	25	0.00186	18.3	14.9	14.6	14.9	0.978	762.3	NO DAMAGE	
-305	-345	8	0.00060	18.3	14.9	14.5	14.9	0.970	571.7	NO DAMAGE	
-315	-325	133	0.00992	18.3	14.8	14.7	14.8	0.992	2269.7	NO DAMAGE	
-315	-335	114	0.00850	18.3	14.8	14.6	14.8	0.985	1134.8	NO DAMAGE	
-315	-345	13	0.00097	18.3	14.8	14.5	14.8	0.977	756.6	NO DAMAGE	
-325	-335	32	0.00239	18.3	14.7	14.6	14.7	0.992	2252.6	NO DAMAGE	
-325	-345	2	0.00015	18.3	14.7	14.5	14.7	0.985	1126.3	NO DAMAGE	
-345	-385	1	0.00007	18.3	14.5	14.0	14.5	0.969	554.6	NO DAMAGE	
-355	-375	1	0.00007	18.3	14.3	14.1	14.3	0.984	1100.6	NO DAMAGE	
-365	-385	2	0.00015	18.3	14.2	14.0	14.2	0.984	1092.1	NO DAMAGE	
-375	-385	1	0.00007	18.3	14.1	14.0	14.1	0.992	2167.1	NO DAMAGE	
		1341324.00000	99.99940							Sum	7.79E-10
										N	1.28E+09
										Miles	8.35E+06

cycles per mile	153.8
Yield stress	60 ksi

APPENDIX G-2
ATLAS RAILCAR SPECIAL PURPOSE SPECIFICATIONS

APPENDIX G-2.1

ATLAS RAILCAR WELDING PROCEDURE QUALIFICATIONS AND SPECIFICATIONS

Appendix G-2.1.1 Procedure Qualification Record Example

AWS D15.1/D15.1M:2012 ANNEX D

PROCEDURE QUALIFICATION RECORD (PQR)

PROCEDURE SPECIFICATION

Material specification A572 Grade 50
Welding process FCAW
Manual or machine Both (Semi-Automatic)
Position of welding Vertical
Filler metal specification AWS A5.20
Filler metal classification E71T-1
Weld metal grade*
Shielding gas CO2 Flow rate 35 cfh
Single or multiple pass Multiple
Single or multiple arc Single
Welding current DCEP
Welding progression Uphill
Preheat temperature 70 deg.
Postheat treatment N/A
Welder's name Triston Mills - Clock #821
*Applicable when filler metal has no AWS classification.

VISUAL INSPECTION

Appearance Acceptable
Undercut NONE
Piping porosity NONE

Test date July 10, 2014
Witnessed by Daniel S. Gjurich

GROOVE WELD TEST RESULTS

Tensile strength, psi
1. (A) 78026
2. (B) 77322

Guided-bend tests (2 root-, 2 face-, or 4 side-bend)

Root	Face
1. Side- Pass	1. Side- Pass
2. Side- Pass	2. Side- Pass

Radiographic-ultrasonic examination

RT report no. N/A
UT report no. #256

FILLET WELD TEST RESULTS

Minimum size multiple pass Macroetch	Maximum size single pass Macroetch
1. N/A 2. N/A	1. N/A 3. N/A
3. N/A	2. N/A

All-weld-metal tension test

Tensile strength, psi N/A
Yield point/strength, psi N/A
Elongation in 2 in, % N/A
Laboratory test no. N/A

WELDING PROCEDURE

Pass No.	Electrode Size	Electrical Characteristics Amperes	Electrical Characteristics Volts	Travel Speed	Joint Detail
All	1/16"	255	26	4 ipm	See Attached: Thickness of weld layers not to exceed 1/4"

We, the undersigned, certify that the statements in this record are correct and that the test welds were prepared, welded, and tested in accordance with the requirements of AWS D15.1: (2012 (year)) *Railroad Welding Specification for Cars and Locomotives.*

Procedure no. F-001
Revision no. 3
Form D-2

Manufacturer or Contractor Kasgro Rail Corp.
Authorized by [signature]
Date 7-16-14

181

Appendix G-2.1.2 Prequalified Welding Procedure Specifications

ANNEX D AWS D15.1/D15.1M:2012

TEST QUALIFIED WELDING PROCEDURE SPECIFICATION (WPS)

Qualified by procedure qualification no. F-001
Material specification Class 1 & 2 (A36, A572/gr42&50, A500 gr B, A216/gr WCC, etc.)
Welding process FCAW
Manual or machine Both
Position of welding Flat, Horizontal, Vertical, Overhead
Filler metal specification A5.20
Filler metal classification E71T-1
Flux N/A
Weld metal grade* N/A
Shielding gas CO2 Flow rate 35-50 cfh
Single or multiple pass Both
Single or multiple arc
Welding current Direct
Polarity DCEP
Welding progression Vertical (3G) - Uphill
Root treatment Clean to sound metal
Preheat and interpass temperature See attached report
Postweld Heat Treatment None
*Applicable only when filler metal has no AWS classification.

WELDING PROCEDURE

Pass No.	Electrode Size	Electrical Characteristics Amperes	Volts	Travel Speed	Joint Detail
As	Required				See attached details
F-1G	.045"	180-280	27-32	8-13 ipm	
	1/16"	200-400	25-31	8-13 ipm	
	3/32"	250-400	17-32	6-13 ipm	
H-2G	1/16"	200-400	25-31	8-13 ipm	
	3/32"	250-400	17-32	6-13 ipm	
V-3G	.045"	160-210	24-39	4-9 ipm	
	1/16"	180-250	25-30	6-11 ipm	
O-4G	.045"	180-240	24-29	8-13 ipm	
	1/16"	200-270	26-30	8-13 ipm	
					Thickness of weld layers not to exceed 1/4"

This procedure may vary due to fabrication sequence, fit-up, pass size, etc., within the limitation of variables given in AWS D15.1: (2012) *Railroad Welding Specification for Cars and Locomotives.*
(year)

Procedure no. F-001
Revision no. 3
Form D-3

Manufacturer or Contractor KASGRO RAIL CORP.
Authorized by [signature]
Date 11/25/13

182

ANNEX D

PREQUALIFIED WELDING PROCEDURE SPECIFICATION (WPS)

Material specification A 572 Grade 50 and A52 Grade 60
Welding process F.C.A.W.
Manual or machine Manual
Position of welding Flat, Horizontal, Vertical, Overhead
Filler metal specification A5.29
Filler metal classification E81T-1 – Ni-ICU H8
Flux N/A
Weld metal grade* N/A
Shielding gas C02 Flow rate 35 – 50 CFH
Single or multiple pass Single/Multiple
Single or multiple arc Single
Welding current Direct
Polarity Reverse
Welding progression Vertical (3G) – Uphill
Root treatment Clean to sound metal
Preheat and interpass temperature See attached report
Postweld Heat Treatment None None X
*Applicable only when filler metal has no AWS classification.

WELDING PROCEDURE

Pass No.	Electrode Size	Welding Current Amperes	Welding Current Volts	Travel Speed	Joint Detail
As Required					* See Attached Report
F-1G	1/16"	200–400	25–31	8–13 ipm	
H-2G	1/16"	180–250	24–39	8–13 ipm	
V-3G	1/16"	180–250	24–39	6–11 ipm	
O-4G	1/16"	200–270	26–30	8–13 ipm	
					Thickness of weld layers not to exceed 1/4"

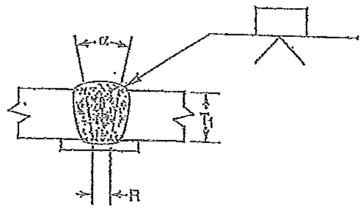
This procedure may vary due to fabrication sequence, fit-up, pass size, etc., within the limitation of variables given in AWS D15.1, (2012) Railroad Welding Specification—Cars and Locomotives.
(year)

Procedure no. F-002
Revision no. 3
Form D-1

Manufacturer or Contractor KASGRO RAIL CORP.
Authorized by [signature]
Date 6-10-14

17

Single-V-groove weld (2)
Butt joint (B)



Tolerances	
As Detailed (see 7.5.2)	As Fit-Up (see 6.3)
R = +1/16, −0 [+2, −0]	+1/4, −1/16 [+6, −2]
α = +10°, −0°	+10°, −5°

All dimensions are in [mm]

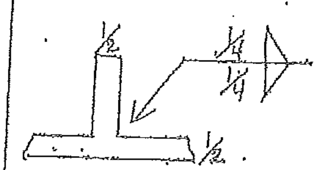
Welding Process	Joint Designation	Base Metal Thickness (U = Unlimited)		Groove Preparation		Permitted Welding Positions	Gas Shielding for FCAW	Notes
		T_1	T_2	Root Opening	Groove Angle			
SMAW	B-U2a	U	—	R = 1/4 [6]	α = 45°	All	—	g
				R = 3/8 [10]	α = 30°	F, OH, V	—	g
				R = 1/2 [13]	α = 20°	F, OH, V	—	g
GMAW FCAW	B-U2a-GF	U	—	R = 3/16 [5]	α = 30°	F, OH, V	Required	a, g
				R = 3/8 [10]	α = 30°	F, OH, V	Not Required	a, g
				R = 1/4 [6]	α = 45°	F, OH, V	Not Required	a, g
SAW	B-L2a-S	2 [51] max.	—	R = 1/4 [6]	α = 30°	F	—	g
SAW	B-U2-S	U	—	R = 5/8 [16]	α = 20°	F	—	g

Figure 7.1B—Prequalified Complete Joint Penetration (CJP) Groove Welded Joint Details

TEST QUALIFIED WELDING PROCEDURE SPECIFICATION (WPS)

Material specification A572 grade 60 to A656 grade 80
Welding process F.C.A.W.
Manual or machine Manual
Position of welding Flat, Horizontal, Vertical, Overhead
Filler metal specification A5.29
Filler metal classification E81T1-Ni1CJ H8
Flux N/A
Weld metal grade* N/A
Shielding gas CO2 Flow rate 35 to 50 CFH
Single or multiple pass Single/Multiple
Single or multiple arc Single
Welding current Direct
Polarity Reverse
Welding progression Vertical - Uphill
Root treatment Clean to sound metal
Preheat and interpass temperature 250° F
Postweld Heat Treatment None None X
*Applicable only when filler metal has no AWS classification.

WELDING PROCEDURE

Pass no.	Electrode size	Welding current: Amperes	Welding current: Volts	Travel speed	Joint detail
All	1/16"	See attached report		8-11 ipm	

This procedure may vary due to fabrication sequence, fit-up, pass size, etc., within the limitation of variables given in AWS D15.1, (2012), year

Procedure no. F-003
Revision no.
Form D-1

Manufacturer or contractor Kasgro Rail Corp
Authorized by [signature]
Date 11/25/13

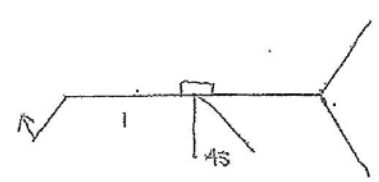
47

TEST QUALIFIED WELDING PROCEDURE SPECIFICATION (WPS)

Qualified by procedure qualification # 09KRC-1092
Material specification A514T1 to A572 Grade 60
Welding process F.C.A.W.
Manual or machine Manual
Position of welding Vertical
Filler metal specification A5.29
Filler metal classification E111T1-K3
Flux
Weld metal grade*
Shielding gas 75% Argon 25% C02 Flow rate 40 CFH
Single or multiple pass Multiple
Single or multiple arc Single
Welding current Direct
Polarity Reverse
Welding progression Uphill
Root treatment Clean to sound metal
Preheat and interpass temperature See attached report
Postweld Heat Treatment None

*Applicable only when filler metal has no AWS classification.

WELDING PROCEDURE

Pass no.	Electrode size	Welding current		Travel speed	Joint detail
		Amperes	Volts		
All	.062"	190–300	27–30	8–11 ipm	

This procedure may vary due to fabrication sequence, fit-up, pass size, etc., within the limitation of variables given in AWS D15.1, (2012 year).

Procedure no. F-004
Revision no. 1
Form D-3

Manufacturer or contractor KASGRO RAIL CORP.
Authorized by [signature]
Date 11/25/13

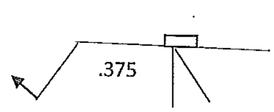
ANNEX D

AWS D15.1/D15.1M:2012

TEST QUALIFIED WELDING PROCEDURE SPECIFICATIONS (WPS)

Qualified by procedure qualification no. 08KRF-1087-6/30/08/ AND 15KR-F1087-1/14/15.
ˋlaterial specification A572 GRADE 60 TO A240 GRADE 304 .
elding process F.C.A.W. .
anual or machine Manual .
sition of welding 1G Flat .
iller metal specification 5.22 .
Filler metal classification DW-309L .
Flux ______ .
Weld metal grade* ______ .
Shielding gas CO2 . Flow rate 40 – 50 CFH .
Single or multiple pass Multiple .
Single or multiple arc Single .
Welding current DCEP .
Polarity Reverse .
Welding progression Forehand .
Root treatment Clean to sound metal .
Preheat and interpass temperature 50°F .
Post weld Heat Treatment None . None x .
*Applicable only when filler metal has no aws classification.

WELDING PROCEDURE

'ass no.	Electrode Size	Welding Current		Travel Speed	Joint Detail
		Amperes	Volts		
ALL	.062"	240-280	29-33	15-18 imp	

This procedure may vary due to fabrication sequence, fit-up, pass size, etc., within the limitation of variables given in AWS D15.1, (2012) Railroad Welding Specification for Cars and Locomotives.
(Year)

Procedure no. 08KR-F1087 .

ˋvision no. 2 .

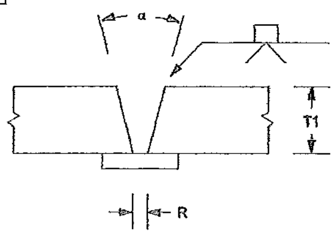
Manufacturer or Contractor KASGRO RAIL CORP.

Authorized by [signature] .

Date 07/27/15 .

)-1

Single-V-groove weld (2)
Butt joint (B)



Welding Process	Joint Designation	Base Metal Thickness (U=unlimited)		Groove Preparation			
						Tolerances	
		T1	T2	Root Opening	Groove Angle	As Detailed (see 3.13.1)	As Fit Up (see 3.13.1)
GMAW FCAW	B-U2a-GF	U	-	R = 3/16	α = 30°	R = +1/16, -0	+1/4, -1/16
				R = 3/8	α = 30°	α = +10°, -0°	+10°, -5°
				R = 1/4	α = 45°		

b-u2a-gf.gif

Preheat

Less than or = to 3/4"	50 deg.
Over 3/4" thru 1-12"	150 deg.
Over 1-1/2" thru 2-1/2"	225 deg.
Over 2-1/2"	300 deg.

ANNEX D

AWS D15.1/D15.1M:2012

TEST QUALIFIED WELDING PROCEDURE SPECIFICATION (WPS)

Qualified by procedure qualification no. 15KR-F1087
Material specification A572 Gr. 65 to A240 Gr. 304
Welding process FCAW
Manual or machine Both (Semi-Automatic)
Position of welding Flat, Horizontal,
Filler metal specification AWS A5.22
Filler metal classification DW-309L
Flux N/A
Weld metal grade* N/A
Shielding gas CO2 - Welding Grade Flow rate 30 to 50
Single or multiple pass Multiple
Single or multiple arc DCEP
Welding current DCEP
Polarity DCEP
Welding progression N/A
Root treatment Grind, chip and wire brush
Preheat and interpass temperature See Attached
Postweld Heat Treatment N/A
*Applicable only when filler metal has no AWS classification.

WELDING PROCEDURE

Pass No.	Electrode Size	Electrical Characteristics		Travel Speed	Joint Detail
		Amperes	Volts		
All	1/16"	229-281	26-30	Various	See Attached: Thickness of weld layers not to exceed 1/4"

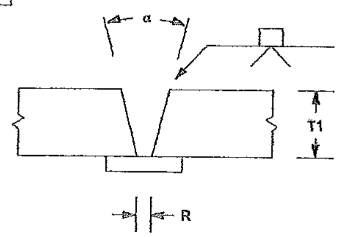
This procedure may vary due to fabrication sequence, fit-up, pass size, etc., within the limitation of variables given in AWS D15.1: (2012) *Railroad Welding Specification for Cars and Locomotives.*
(year)

Procedure no. 15KR-F1087
Revision no. 2
Form D-3

Manufacturer or Contractor Kasgro Rail Car
Authorized by [signature]
Date 1-14-15

182

Single-V-groove weld (2)
Butt joint (B)



Welding Process	Joint Designation	Base Metal Thickness (U=unlimited)		Groove Preparation			
						Tolerances	
		T1	T2	Root Opening	Groove Angle	As Detailed (see 3.13.1)	As Fit Up (see 3.13.1)
GMAW FCAW	B-U2a-GF	U	-	R = 3/16	α = 30°	R = +1/16, -0	+1/4, -1/16
				R = 3/8	α = 30°	α = +10°, -0°	+10°, -5°
				R = 1/4	α = 45°		

b-u2a-gf.gfl

Preheat

Less than or = to 3/4"	50 deg.
Over 3/4" thru 1-12"	150 deg.
Over 1-1/2" thru 2-1/2"	225 deg.
Over 2-1/2"	300 deg.

APPENDIX G-2.2

ATLAS RAILCAR SECUREMENT AND JACKING LUGS PROOF TESTING

Appendix G-2.2.1 Procedure #11 Lug Proof Test Procedure, Rev 5

1

Kasgro Rail Corp
Procedure # 11
Lug Proof Test Procedure

Revision: 5 JULY 28, 2017

Scope: Procedure Proof Test Tie Down Lugs
Component: S-2043 Shipping Container Railcar
Drawing: Car Body Arrangement Drawing No.:
Standard Identifier:
For Proof Test Apparatus and Component Assembly Refer to
Drawings D-1128-1, 3, 4 and 5

Lug Proof Test Procedure

Position the Car Body on Lay Out Table in the Inverted Position Against Stops on Lay Out Table
A-End Lugs – Orient the Fixture Such That the Applied Load is in-line with the Plane of the Lugs and is $39^{0} \pm 1^{0}$ From Horizontal
Center Lugs – Orient the Fixture Such That the Applied Load is in-line With the Plane of the Lugs and is $29^{0} \pm 1^{0}$ From Horizontal.
Bolt Lug Test Fixtures to the Layout Table as Required by Drawing D-1128-1
Pin Hydraulic Cylinder to Fixtures at Both Ends

Test Procedure – End Lugs

Pressurize Rod End of Cylinder to 3000 P.S.I. + 45 P.S.I. – 140 P.S.I.
To Obtain a Test Load of 66800 LBS + 4452 - 0
Maintain Pressure for 10 minutes
Release
Repeat At Other Lug. As an Option, Both Lugs May be Tested Simultaneously.
Record Information on the Proof Test Certification Form

Test Procedure – Center Lugs
Pressurize Rod End of Cylinder to 3000 P.S.I. + 45 P.S.I. – 140 P.S.I.
To Obtain a Test Load of 66800 LBS + 4452 - 0
Maintain Pressure for 10 minutes
Release
Repeat At Other Lug. As an Option, Both Lugs May be Tested Simultaneously.
Record Information on the Proof Test Certification Form

NDT Requirements
Acceptance Criteria Per AWS D 15.1
Magnetic Particle Test – Final Weld
Visual Inspect – Final Weld
Visual Inspect Weld After Proof Testing
Magnetic Particle Test Final Weld After Proof of Testing
Visually Inspect the Attachment Lug and Lug Eye for Damage and Deformation

Equipment to be Used

1) Penincular Hydraulic Cylinder, Model 1-P3600A, or equivalent, With a 6" Bore and 2.5" Rod and a Working Pressure of 5000 P.S.I.
2) Calibrated Pressure Gage

Test Records:
The results of each load test are to be recorded and certified on the "Component/Equipment Proof Test Certification" sheet.

Seller's Authorized Representative: ______________________ Signature

______________________ Typed Name

______________________ Date

Appendix G-2.2.2 Securing and Jacking Lug Proof Test Certification Form, Form 45, Rev 1

3

SECURING AND JACKING LUG PROOF TEST CERTIFICATION FORM

Form 45 Rev 1 7-15-2015

Component – Tie Down Lugs
Drawing Number – D – 1114-37
Part Number – 3-138
Standard Identifier –
Car # ______________
Use Lug Proof Test Procedure # 11

Lug Location	Test Pressure	Test Load in Pounds	Minutes Tested	Post Test Inspection	Date
CL					
CR					
AL					
AR					

Securing and Jacking Lug Proof Test to be performed using Kasgro Rail Corp Lug Test Fixture Drawing D-1128-1

The securing and jacking lugs have been proof tested in strict accordance with all applicable specifications, drawings, procedures and contract requirements, including amendments / change notices.

Proof Test Certification covering compliance to this specification, Proof Test Procedure and results of pre-and post-proof test NDT inspection results are on file at Kasgro Rail Corp.

Seller's Authorized Representative: ______________________________

Date:

Sellers Name: KASGRO RAIL CORP

Note: The recording of false, fictitious, or fraudulent statements on this document may be punishable as a felony under federal statues

APPENDIX G-2.3

ATLAS RAILCAR SPRING PROPERTIES REQUIREMENT

SPRING TEST REQUIREMENTS AND TOLERANCES PROCEDURE #12, REV 3

Kasgro Rail Corporation Spring Testing

290-ton flatcar springs shall be manufactured in accordance with the Association of American Railroads Specification M-114, ASTM A125, Kasgro Rail Corporation (Kasgro) Drawing D-1114-33, and the requirements specified herein. Kasgro reserves the right to reject springs not meeting the below stated requirements. All criteria herein shall be met unless otherwise approved or authorized by Kasgro.

Subsequent to end grinding, wet florescent magnetic particle testing of each spring shall be performed as specified on Drawing D-1114-33. Test and acceptance criteria shall be as follows:

- Examination shall be by the continuous method.
- Indications less than 1/64 inch shall be disregarded.
- There shall be no linear indications 1/32 inch or greater. A linear indication is any indication where the length of the major axis is at least three times the length of the minor axis.
- Rounded indications larger than 1/16 are cause for rejection.
- Linearly disposed rounded indications shall be cause for rejection. Linearly disposed indications are three or more indications where adjacent indications are separated by less than 1/8 inch and a straight line can be drawn touching all three indications.
- Surface indications that are not crack-like in appearance and are due to surface roughness may be accepted provided that at least 10 percent of each type of indication is removed and the indications do not reappear upon re-examination.
- Local material removal (reworked surfaces) to determine the relevancy of an indication or to evaluate surface roughness shall be limited to a depth of 1/64 inch. Material may be removed by polishing or hand grinding (e.g., 100 grit stone).
- Reworked surfaces shall be blended. Blended contours shall have no discontinuities or lapped-over surfaces. The bottom radius of a blended cavity shall be at least three times

the depth of the cavity, and the edges of the cavity shall be blended into the surrounding surfaces. All reworked and blended areas shall be re-wet florescent magnetic particle tested to confirm defect removal.

> All indications revealed by magnetic particle inspection do not necessarily represent defects since non-relevant indications are sometimes encountered. Indications caused by approved marking methods may be considered non-relevant. Examples of other such indications are as follows:

(a) Magnetic Writing. These indications are caused by contact with other steel or magnets while magnetized. They may be fuzzy and will be destroyed by demagnetization. They shall be verified as non-relevant by demagnetizing and re-examination.

(b) Change in Section. Indications which are broad and fuzzy may be caused by a concentration of the magnetic field coincident with a change in section. Non-relevancy shall be verified by a visual examination of the section and re-examination at a lower magnetizing current.

(c) Flow Lines. These are large groups of parallel indications which may occur in wrought material under excessive currents. Non-relevancy shall be determined by demagnetization and re-examination at a lower current.

Spring measurement and load test requirements and tolerances are defined as follows:

1. **All** springs are to be tested with the following values to be recorded.

1.1. Free Height – Spring height in inches under zero load. If heights are measured in fractions of an inch, minimum data resolution is to be 0.03125 inches (1/32). If heights are measured digitally, minimum data resolution is to be 0.02 inches.

1.2. Solid Height – Spring height in inches under a load which forces all or most coils into contact. If heights are measured in fractions of an inch, minimum data resolution is to

The recording of false, fictitious, or fraudulent statements or entries on this document may be punishable as a felony under federal law statutes.

be 0.03125 inches (1/32). If heights are measured digitally, minimum data resolution is to be 0.02 inches.

1.3. Load at Test Height 1 – Spring load in pounds at a defined test height (Test Height 1). Actual test height is to be within ±0.0625 inches (1/16) of the defined test height. Minimum data resolution is to be to 1 pound.

1.4. Load at Test Height 2 – Spring load in pounds at a defined test height (Test Height 2). Actual test height is to be within ±0.0625 inches (1/16) of the defined test height. Minimum data resolution is to be 1 pound.

2. Springs are to be compressed to solid height three (3) times before start of the above tests.

3. Testing is to be performed using industry-accepted methods. All gages, test machines, load cells, or other test equipment are to be properly maintained and have current calibration certificates. Evidence of such calibration is to be provided on request.

4. Results are to be provided in the form of a Microsoft Excel spreadsheet. The spreadsheet is to include header lines clearly identifying the spring tested and the test equipment used. Test results are to then follow in tabular form. Data are to include: Spring Serial Number, Free Height, Solid Height, Load at Test Height 1, Load at Test Height 2, Test Date, and Test Operator. Average and standard deviation values for each of the numeric data are to be calculated (using the Microsoft Excel AVERAGE and STDEVP functions). These values are to be followed by lines providing the minimum and maximum accepted value for each measurement as per the tables given in Paragraphs 5 and 6 below. A sample spreadsheet meeting the above requirements will be provided. A signed and dated paper copy of the spreadsheet is to be provided attesting that the measurements are accurate and have been performed according to the stated requirements.

5. Test heights and acceptance tolerances for individual springs are as shown in Table 1. Minimum and maximum accepted values are given in the shaded columns. Solid Height max-

imum tolerances must be maintained per values listed in Table 1. * Solid height minimum dimensions are shown as desired values only and it is not required to have all springs meet the minimum value.

Table 1. Spring Test Heights and Acceptance Tolerances

	Free Height (inches)			Solid Height (inches)			Test Heights		Load (lbs) at Height 1			Load (lbs) at Height 2		
Spring		Min	Max		Min*	Max	1	2		Min	Max		Min	Max
1-88	11.720	11.501	11.939	6.690	6.250	6.750	10.250	8.000	1707	1415	1999	4320	4028	4612
1-89	11.720	11.501	11.939	6.690	6.250	6.750	10.250	8.000	736	610	861	1861	1736	1987
1-90	13.000	12.750	13.250	6.690	6.250	6.750	10.250	8.000	2955	2616	3294	5373	5034	5712
1-91	13.000	12.750	13.250	6.690	6.250	6.750	10.250	8.000	957	848	1067	1741	1631	1851
1-92	9.250	9.125	9.375	6.690	6.250	6.750	9.000	8.000	1047	511	1583	5234	4698	5770
1-93	9.250	9.125	9.375	6.690	6.250	6.750	9.000	8.000	555	271	840	2776	2492	3061
1-94	11.090	10.903	11.278	6.690	6.250	6.750	10.250	8.000	1116	824	1409	4106	3814	4399
1-95	11.090	10.903	11.278	6.690	6.250	6.750	10.250	8.000	552	407	696	2030	1886	2175
1-96	11.000	10.813	11.188	6.690	6.250	6.750	10.250	8.000	1808	1288	2327	7231	6712	7751
1-97	11.000	10.813	11.188	6.690	6.250	6.750	10.250	8.000	701	500	902	2804	2602	3005
1-99	7.500	7.375	7.625	5.375	4.935	5.435	7.250	6.250	139	80	198	694	635	753

6. Table 2 provides acceptance tolerance per spring population (i.e., all springs of one type). The given tolerance ranges apply to the average value for a population. This requirement is intended to ensure that springs within a population do not cluster to one side or other of the tolerance range for individual springs. Minimum and maximum accepted values are again given in the shaded columns.

Table 2. Spring Population Acceptance Tolerances

	Free Height (inches)			Load (lbs) at Height 1			Load (lbs) at Height 2		
Spring		Min	Max		Min	Max		Min	Max
1-88	11.720	11.647	11.793	1707	1610	1804	4320	4222	4417
1-89	11.720	11.647	11.793	736	694	778	1861	1820	1903
1-90	13.000	12.917	13.083	2955	2842	3068	5373	5260	5486
1-91	13.000	12.917	13.083	957	921	994	1741	1704	1778
1-92	9.250	9.208	9.292	1047	868	1225	5234	5055	5413
1-93	9.250	9.208	9.292	555	461	650	2776	2682	2871
1-94	11.090	11.028	11.153	1116	1019	1214	4106	4009	4204
1-95	11.090	11.028	11.153	552	504	600	2030	1982	2078
1-96	11.000	10.938	11.063	1808	1635	1981	7231	7058	7404
1-97	11.000	10.938	11.063	701	634	768	2804	2737	2871
1-99	7.500	7.458	7.542	139	119	158	694	674	714

APPENDIX G-2.4

ATLAS RAILCAR WEIGHTING

Appendix G-2.4.1 Procedure #13, Car Weighting Procedure, Rev 5

Kasgro Rail Corp
Procedure # 13
Car Weighing Procedure

Revision: 5 7-28-2017
Scope: Procedure for Weighing a Loaded Car
Component: S-2043 Shipping Container Railcar
Drawing: General Arrangement

Test Procedure:

1) Determine the weight of the empty car by centering each truck on the scale and recording the weight at each location (trucks A through F).
2) Load the car with weights to simulate the weight of a shipping container and securement cradle (approximately 480,000 lbs). This may be accomplished by using test weight components as illustrated in Exhibit F, or equivalent.
   All weights shall be positioned on the car body so that the combined center-of-gravity is located over the center of the rail car (i.e. approximately equal weight on each span bolster.)
3) Determine the weight distribution of the loaded car by centering each truck on the scale and recording the weight at each location (trucks A through F).

Equipment to be used:

1) Calibrated 2000 series Fairbanks Rail Scale

Test Records:

The results of each load test are to be recorded and certified on the Railcar Weighing Form.

Seller's Authorized Representative: ____________________Signature

____________________Typed Name

____________________Date

EXHIBIT F

Actual amount of weight to be applied to Cask Car Deck and applicable shop test weights to be used, to be decided later.

Component	Unit	Quantity	Total Wt.
		Total	

Appendix G-2.4.2 Railcar Weighting Form, Form 46, Rev 3

RAILCAR WEIGHING FORM
Form 46 Rev 3

7-7-2015

Drawing Number – D-1114-40
Standard Identifier –
Car #
Use Car Weighing Procedure # 13

Truck	Weight of Empty Car Pounds	Weight of Loaded Car Pounds	Percentage of Total weight	Shims Applied
A				
F				
E				
D				
C				
B				
TOTAL				

Acceptance Criteria:

1) The percentage of the weight on individual trucks shall range from 15.75% to 18% of the total weight.
2) The greater weight must be on the outboard trucks (trucks A & B)
3) Shims shall be installed beneath the span bolster center plates to obtain the required load distribution; refer to Drawing D-1118-SHIM-2.

Seller's Authorized Representative: ______________________

Sellers Name: KASGRO RAIL CORP

Note: The recording of false, fictitious, or fraudulent statements on this document may be punishable as a felony under federal tues

Appendix G-2.4.3 Kasgro Track Scale Calibration Form, Form 14, Rev 2

KASGRO RAIL CORP
FORM 14
MEASURING AND TEST EQUIPMENT CALIBRATION RECORD

Revision "2" 6/5/03

Equipment Type	Track Scale	**Serial No. 100470050013**		
Calibration Frequency	**Annually**	**Acceptance Criteria NIST**		
Check Method	Test Car# WC210500			
Action to take when results are unsatisfactory per 2.8 of Quality Manual				
Location	**Date Cal.**	**Date Next Cal.**	**As Found Condition**	**Calibrated By**
Kas 1	5/25/2016	5/25/2017	OK	Rail Scale Inc

Appendix G-2.4.4 Railscale, Inc. Track Scale – Test and Inspection Report 10/14/2015

RAIL SCALE, INC.

TRACK SCALE - TEST AND INSPECTION REPORT

As per NIST Handbook 44 Testing Standards

DATE OF TEST

05/25/2016

Railroad ID #: None

Location Information
Railroad
CSX
City/State
New Castle, PA
Owner/Industry Name
Kasgro Rail Corp. (Pit 1)

Location Information	
House Condition	Good
Pit Condition	Good
Pit Foundation Type	Concrete
Pit Drainage Type	Drain

Location Information				
Manufacturer		Length of Weight Rail		Date of Last RSI Test
Fairbanks Scale		10ft		06/17/2015
Instrument Serial Number	# of Sections	Total Capacity	Sectional Capacity	
100470050013	2	125	85	
Type/Condition of Scale				
Operation Type	Static	Display Type	Digital	
Control Type	Digital	Dead Rail	No	
Girder Type	Continuous	Girder Condition	Good	
Deck Type	Live	Deck Condition	Good	
Condition of Pivots and Bearings or Load Cells			Good	
Condition of Approach Rail Right End			Good	
Condition of Approach Rail Left End			Good	

Test Vehicle Information				
Test Car #	Nominal Weight	Wheel Base	Jacks	Calibration Date
WC210500	80,000 lbs.	5'3"	N/A	10/14/2015

Balance as Found		S.R. Test (Beam Scale Only)			
Indicator Reading (lbs.)	0	SR at Zero Load		SR at M Load	
		SR Meets Requirements?		N/A	
Master Scale Location		State of Minnesota W & M			

Strain/Buildup Test	
Sub. Weight	
Cal. Weight	80000
Total Weight	
Disp. Weight	
Error	
Complies?	See Remarks

TEST RESULTS

First 2 Runs As Found

Run Info	Test Load	Zero	1	2	Zero									
————>	80,000 lbs.	0	0	0	0									
<————	80,000 lbs.	0	0	0	0									

Weather Conditions: Clear Wind Factor: None Temperature: Warm

REMARKS

No Adjustments needed. No power available for a strain test.

Test is billable by RSI to: Industry Industry PO #: K16-0139 This test is: Annual

UNDER CONDITIONS STATED ABOVE THIS TEST HAS BEEN LEFT Weighing Within Tolerance

Owner/Industry Representative
Bill Baker

State Representative
Not Available

Scale Company Representative
Frank Spencer

RSI Representative
Michael Hamrick

APPENDIX G-2.5

ATLAS RAILCAR BRAKE TESTING

Appendix G-2.5.1 Static Force Brake Test Data, Form 36-A, Rev 1

FORM 36-A — **KASGRO RAIL CORP** — **STATIC FORCE BRAKE TEST DATA** — **Rev 1 10/27/2008**

Brake System:	DB-60 / EP-60	Date:	November 20, 2008
Brake Rigging:	Ellcon National 8500	Product Order:	[redacted]
Slack Adjuster:	Ellcon National 7100-33	Car Type:	290 Ton FM
Handbrake:	Ellcon National 33000-2	For:	[redacted]
Bell Crank:	N/A	Car Series:	39470-39488
Sheave Wheel:	8"	Test Car No:	[redacted]
Brake Shoe:	2" true Guard	Date Built:	Jul-08

Air Brake Force (Gross):	N/A #		Light Weight:	195,600 #
Brake Lever Ratio:	N/A :1		Gross Rail Load:	789,000 #
Handbrake Force (Gross):	4475 Vert. #		Brake Force Schem.:	TMB 341-L
EMPTY LOAD %:	40 %		Brake Arrangement:	E1114-2

MEASURED BRAKE SHOE FORCE (IN NET POUNDS)

Brake Cylinder Pressure (psig):

			Min red 6-7	Light Car:	27.25	Loaded Car:	64.5	FORCE	3350 lbs. on Vert. Chain
	WHEEL	CHANNEL	UNTAPPED	UNTAPPED	TAPPED	UNTAPPED	TAPPED	H	
P	L-1	1	405	1335	1708	3656	4107	A	4328
N	R-1	2	428	1508	1913	4175	4488	N	4804
E	L-2	3	472	1524	1853	4118	4510	D	5308
U	R-2	4	432	1552	1816	4241	4534	B	5442
M	L-3	1	372	1382	1751	3934	4203	R	3250
A	R-3	2	443	1559	1916	4537	4634	A	3691
T	L-4	3	468	1456	1783	3926	4283	K	3738
I	R-4	4	489	1564	1825	4336	4479	E	3956
C	L-5	1	460	1350	1760	3730	4130		2430
	R-5	2	490	1440	1810	3820	4340		2900
	L-6	3	480	1430	1800	3910	4210		2590
	R-6	4	580	1600	1950	4130	4670		3110
	L-7	1	630	1470	1660	4350	4700		3610
	R-7	2	520	1380	1570	3970	4470		3390
	L-8	3	360	1500	1730	4670	4740		3340
	R-8	4	510	1270	1440	3990	4120		2820
	L-9	1	520	1500	1680	3920	4400		3900
	R-9	2	530	1470	1710	3800	4380		3850
	L-10	3	470	1520	1770	3970	4210		3520
	R-10	4	440	1320	1683	3621	4161		3165
	L-11	1	470	1540	1790	4174	4753		5327
	R-11	2	392	1423	1756	3927	4674		5179
	L-12	3	392	1361	1690	3996	4583		4358
	R-12	4	443	1269	1572	3653	4202		3963
	TOTALS:		11196		41936		105981		91969
	BCP @ Min. Red.	"A" End	(AVERAGE) 468.50	"B" End		(MINIMUM) 3863.9	(AVERAGE) 4415.9	(MAXIMUM) 4967.9	

PISTON Loaded	B23/4"C23/4"D27/8"E23/4"F27/8"A23/4"	Brake Cylinder Pressure, Min. 30psig Reduction:	64.50
TRAVEL: Empty	B21/4"C23/8"D25/16"E21/4"F25/16"A21/4"	Emergency Application:	75

	Pneumatic Loaded %	*Handbrake Loaded %*	*Pneumatic Light %*
NET SHOE FORCE x100 = / LIGHT WEIGHT			41936 x 100 / 195600 = 21.44
NET SHOE FORCE x100 = / GROSS RAIL LOAD	105981 / 789000 13.43	91969 x 100 / 789000 = 11.66	
NET SHOE FORCE x100 = / GROSS SHOE FORCE	105981 / N/A #VALUE!	91969 x 100 / 4475 Vert. = #VALUE!	41936 x 100 / #VALUE! = #VALUE!

BRAKE PIPE CHARGE OF 90 psig — ATTESTED: [redacted]

Appendix G-2.5.2 Air Brake Test Report, Form 6-A, Rev 1

Rev.1

Kasgro Rail Corp

FORM 6-A 2/25/2016

Air Brake Test Report
(X=Tested)

CAR NUMBER [redacted]

Single Car Test, 1Set		Single Car Test, 2 Sets	
Single Car Test (includes B.C. Pressrure Test)		Single Car Test (includes B.C. Pressure Test), 2 Sets	X
Slack Adjuster Test	X	Retainer Valve Test	X
Empty / Load Valve Test	X	Brake Pipe Leakage Test	X
System Leakage Test	X	Equailization Pressure	X
Piston Travel (Unit Brakes)		If Equipped With Load Sensor	X
Piston Travel (Trk MTD Brakes)	X	Equailization Pressure Load Sensor	X
WABCOPAC / NYPOAC Piston Travel Adjustment		Equailization Pressure Loaded	X
(Truck Mounted Brakees with Slack Adjuster	X	Equailization Pressure Empty	X
#1 #2 #3 #4		Slack Adjuster Rack Measurement	
Lube Handbrake	X		
		EMERGENCY PRESSURE	X

SYSTEM REPAIRS- List repairs, parts replaced, Location, and why made.

Piston Travels

B-END: (1) 2¾ (2) 2⅞ (3) 2¾ B-END: SERVICE LOADED – 64 PSI
DB-10 — DB-20 EMERGENCY – 75 PSI
40% LOAD SENSOR EMPTY – 25 PSI

A-END: (4) 2¾ (5) 2¾ (6) 3 A-END: SERVICE LOADED – 63 PSI
DB-10 — DB-20 EMERGENCY – 74 PSI
40% LOAD SENSOR EMPTY – 24 PSI

Signature of Tester [redacted] Date 1-4-17

Note: The recording of false, fictitious, or fraudulent statements on this document may be punishable as a felony under federal statues.

Appendix G-2.5.3 EP-60 Single Car Test Results

[redacted] B 20170105 13.48

EP-60 Single Car Test Results: Passed

EPSCTD Version 2.20
EPSCTD Support Files Version 2.25
EPSCTD Language Files Version 1.6

Tester ID: 0164

Road Number: [redacted]
Car Type: Kasgro
12 Axle Spent Fuel Car

CCD Type: Overlay

Test Date and time: 1/5/2017 1:35:04 PM to 1/5/2017 1:47:31 PM

No.	Test	Step	Expected	Actual	P/F
2.2	AAR Standard S-486	Single Car Test	Yes	Yes	P
2.5	Charging Brake Pipe	Verify User entered BCP	0.0 to 3.0 psi	0.0 psi	P
2.6	Empty/Load Valve	Set E/L Valve(s) to Loaded	Yes	Yes	-
2.8	Release Test	Verify CCD Rel BCP	0.0 to 3.0 psi	0.4 psi	P
2.9	Loaded Full Service Test	Verify Reservoir pressure	88.0 psi min	91.5 psi	-
2.11	Loaded Full Service Test	Verify CCD Loaded FS BCP	62.0 to 68.0 psi	65.6 psi	P
2.13	Loaded Full Service Test	Verify User entered BCP	62.0 to 68.0 psi	65.0 psi	P
2.17	Min Service Test	Verify CCD Min BCP	7.0 to 13.0 psi	10.4 psi	P
2.19	Min Service Test	Verify User entered BCP	7.0 to 13.0 psi	10.0 psi	P
2.22	Loaded Emergency Test	Verify Reservoir pressure	88.0 psi min	90.4 psi	-
2.24	Loaded Emergency Test	Verify CCD Loaded Emer BCP	75.0 to 81.0 psi	77.5 psi	P
2.26	Loaded Emergency Test	Verify User entered BCP	75.0 to 81.0 psi	77.0 psi	P
2.28	Release from EP Emergency	Verify CCD Rel BCP	0.0 to 3.0 psi	0.4 psi	P
2.30	Release from EP Emergency	Verify User entered BCP	0.0 to 3.0 psi	0.0 psi	P
2.31	Empty/Load Valve	Set E/L Valve(s) to Empty	Yes	Yes	-
2.34	Empty/Load Valve	Verify CCD Empty FS BCP	62.0 to 68.0 psi	63.7 psi	P
2.37	Empty/Load Valve	Verify User entered BCP	-	24.0 psi	-
2.37	Empty/Load Valve	Empty FS BCP Acceptable	Yes	Yes	P
2.40	Empty Emergency Test	Verify CCD Empty Emer BCP	75.0 to 81.0 psi	78.0 psi	P
2.42	Empty Emergency Test	Verify User entered BCP	-	30.0 psi	-
2.43	Battery Test	Verifying battery voltage	11 vdc min	12.6 vdc	P

Page 1

Appendix G-2.5.4 Example of AAR Air Brake Test Witness Letter TTCI Letter #CC-209.221 datd January 17, 2017

Transportation Technology Center, Inc.

Kenneth Pfahler
Field Inspector - MID/QA Auditor
427 North 3rd Street, Ext.
Bellwood, PA 16617
Cell: 814-515-3803
Email: ken_pfahler@ttci.aar.com

January 17, 2017

File: CC-209.221

Subject: Single Car Air Brake Test Observations Results / Kasgro Rail Corporation, New Castle, PA / Specifications S-2043 & S-486 -- H/D Flat Car ([redacted]) used to carry High-Level Radioactive Material

Mr. David L. Cackovic
Chief – Technical Standards & Inspections
Transportation Technology Center, Inc.
P.O. Box 11130
Pueblo, CO 81001
E-mail: David_Cackovic@aar.com

Dear Mr. Cackovic,

Specification testing of [redacted] Heavy Duty Flat Car, specifically the Single Car Air Brake Test has been completed. Testing was done at the Kasgro Rail Corporation facility in New Castle, Pennsylvania on January 17, 2017 to comply with Specification S-2043 and S-486.

I was present (test witness) for the required Single Car Air Brake Test and can conclude that applicable requirements of AAR Specification S-486 have been satisfactorily addressed. I also witnessed the Brake Pipe Restriction Test and can conclude that the AAR Specification S-471 appeared to have been satisfactorily addressed. Additionally, per an email from Mr. Belport dated July 27, 2010 a Brake Shoe Force Measurement Test was to be performed on two (2) cars, this has been satisfactory completed on KRL 39470 and [redacted].

Attached information was supplied by the Kasgro Rail Corporation in support of the approval process. Should you need any additional information, please do not hesitate to call.

Sincerely,

Kenneth Pfahler
Kenneth Pfahler

cc: [redacted], TTCI
[redacted], Kasgro

Appendix G-2.5.5 Wabtec Corporation Practice Test and Practical Exam per AAR Standard S-486-13

Written Exam on Freight Air Brake Single Car Tests per AAR S-486 - 13

Wabtec CORPORATION

NAME: [redacted] DATE: 1-5-16
COMPANY: Kasgro Rail Corp MARK: ______

Circle the letter next to the **most** correct answer for each question or will make the statement correct per AAR S-486-13. There is only one answer that is the most correct for each question or will make the statement correct in each case. READ THE QUESTIONS CAREFULLY BEFORE ANSWERING.

1. What is the minimum brake cylinder pressure that must be obtained for a full service brake application on a loaded car? ______________
   a. 65 psi
   b. 60 psi
   c. 70 psi
   d. 50 psi
   e. None of the above.

2. To secure reliable and uniform results with the Manual Single Car Test Device, it must be kept free from leakage and must be disassembled, cleaned and tested not less frequently than ______ after being placed into service or more often if necessary (AAR 2.2)?
   a. 365 days.
   b. 60 days
   c. 30 days
   d. 92 days
   e. None of the above.

3. The hose/combination hose and pipe between the test device and the outlet hose coupling must be ¾" I.D. with ½" connections nipples and not exceed _____ in length (AAR 2.2.2).
   a. 4 feet.
   b. 6 feet.
   c. 8 feet
   d. 2 feet
   e. None of the above.

4. When applying the brake cylinder gauge it must be applied to the correct tap on the freight car. Which location is correct?
   a. Any tap on the car will work
   b. The tap downstream from the empty/load equipment
   c. The tap upstream from the empty/load equipment
   d. None of the above.

5. The Daily Test 2.3 allows for how much leakage from the test device rotary valve exhaust?
   a. no leakage
   b. 1 psi in one minute
   c. 3 psi
   d. a 1" bubble in 5 seconds

(1 of 6)

Written Exam - AAR S-486-13

6. Why is it necessary to blow out the supply line before any connection is made to the Single Car Test Device?
   a. To remove moisture from the air line.
   b. To remove dirt from the air line.
   c. To remove any foreign object from the air line.
   d. All of the above.
   e. None of the above.

7. When performing a daily test, what variance between the brake cylinder pressure gauge and the test device is allowed per the Daily Test (2.3.4)?
   a. +/- 3psi.
   b. +/- 5psi.
   c. +/- 6psi.
   d. All of the above.
   e. None of the above.

8. In the Brake Pipe Leakage Test (3.3) with the cut-out cock closed, the brake pipe is charged to 90 psi and the brake pipe is checked for leakage. The reservoirs are completely drained of air for this test, why?
   a. To check for leakage from the reservoirs.
   b. To check for leakage in the brake cylinder.
   c. To check for leakage in the brake pipe.
   d. To check for leakage at the angle cock
   e. To check for leakage past the dirt collector/cutout cock.

9. When checking brake cylinder piston travel in accordance with Piston Travel & Rigging Test 3.9, a car equipped with empty/load brake equipment must have the equipment in the ____ position.
   a. Empty
   b. Loaded
   c. Empty or loaded does not matter
   d. Whatever the car is – empty or loaded
   e. None of the above

10. Cars with an A-1 Reduction Relay Valve and less than ____ feet of brake pipe must have the B-1 Quick Service valve nullified when performing the Separate Vent Valve Test 3.4.
   a. 100
   b. 90
   c. 85
   d. Any length of feet
   e. Not required to plug

Written Exam - AAR S-486-13

11. During the Service Stability Test 3.8, if the car goes into emergency, the most probable cause of failure would be the ___________________ .
    a. Emergency portion.
    b. Service portion
    c. # 8 vent valve.
    d. Empty/load valve.
    e. None of the above.

12. Before performing the Service Stability Test 3.8 on a car equipped with a #8 Vent Valve, the vent valve must be nullified by ________________ .
    a. Removing the valve
    b. Closing the cut-out cock
    c. Removing the vent on the valve and inserting the plug portion of the vent into the body of the vent valve
    d. Hitting it with a hammer
    e. None of the above

13. When checking piston travel during the Piston Travel & Rigging Test 3.9, the piston travel must be in accordance with what standards?
    a. The badge plate
    b. The decal on the car
    c. 7 – 9 inches
    d. AAR Rule 3
    e. The standard for that car, which may be a, b, c or d or any combination thereof.

14. The Hand Brake Inspection (AAR 3.6) includes the following requirements.
    a. An air brake application to check the piston travel
    b. Oil the handbrake with 30W oil, apply the handbrake, check the bell crank, check the shoes with a bar, release the handbrake
    c. Checking the brake shoes for wear
    d. Checking the operation of the empty/load equipment
    e. All of the above

15. In the Emergency Test 3.10, once the 3/8" cock has been opened, the brake cylinder pressure must be ____________________ compared to the pressure noted in the Service Stability Test?
    a. The same
    b. A minimum of 5 psi higher than full service pressure
    c. A minimum of 5 psi lower than full service pressure
    d. Zero psi
    e. None of the above.

Written Exam - AAR S-486-13

16. For the Service Stability Test 3.8, brake pipe pressure is reduced to ___________?
    a. 30 psi
    b. 40 psi
    c. 50 psi.
    d. Reduce pressure to zero
    e. None of the above.

17. During the Release After Emergency Test 3.11, brake pipe is charged to 28 psi, the rotary valve is placed in position 3. Brake pipe must rise. This verifies the _________ is functioning correctly?
    a. Service Accelerated Release Feature
    b. Brake cylinder
    c. Reservoir
    d. Single Car Test Device
    e. Emergency Accelerated Release Feature

18. How long must the brake cylinder remain extended during the Retaining Valve Test 3.12?
    a. Five minutes
    b. Ten minutes
    c. Four minutes
    d. Four hours
    e. Does not have to remain applied

19. Brake cylinder pressure at the end of the waiting period described in question 18 for the Retaining Valve Test 3.12 must be _____________?
    a. 25 psi
    b. 12 psi
    c. 15 psi
    d. Between 60 - 70 psi
    e. Higher than full service

20. The flowrator is used to verify the car is charged when performing the Minimum application and Quick Service Limiting Valve Test 3.13. What is the minimum point that the car must be charged to perform this test?
    a. The ball floats below the top of the tube
    b. The ball is below the red line.
    c. The ball is at the bottom of the tube.
    d. The ball is two lines below the red line.
    e. None of the above.

Written Exam - AAR S-486-13

21. Brake Cylinder Leakage Test 3.14, after the brake pipe pressure has stabilized wait __________?
    a. One minute.
    b. Two minutes.
    c. Three minutes
    d. 90 seconds.
    e. None of the above.

22. Test 3.14.2 allows no more than 1 psi increase or decrease in pressure variation from the noted in 3.14.1. If the brake cylinder pressure drops more than one psi the problem is________________?
    a. You did not wait long enough
    b. You waited too long
    c. There is a leak in the brake cylinder or associated piping
    d. The vent valve has failed
    e. None of the above.

23. Which air brake valves (emergency portions) do not have an AAV valve?
    a. ABDW, ABDWS, ABDW-2.
    b. ABDX, ABDXR, ABDX-L, ABDXR-L.
    c. AB, ABD, ABDS
    d. DB-20, DB-20-L
    e. All of the above.

24. In the Slow Release Test 3.15, what is the maximum release time for a car with 108 ft of brake pipe?
    a. 45 seconds
    b. 55 seconds
    c. 60 seconds
    d. 75 seconds
    e. 100 seconds

25. Test 3.18 Recheck of Piston Travel, piston travel must be within ______ of length measured in Test 3.9.1?
    a. +/- 1 inch
    b. +/- 1/2 inch
    c. +/- 3/4 inch
    d. exactly the same
    e. whatever you get for a measurement is fine

Written Exam - AAR S-486-13

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26. When completing the Empty/Load Test 3.20, the brake cylinder pressure noted in 3.20.2 must be at least _________ lower than pressure noted in Test 3.9.4.
    a. 5 psi
    b. 10 psi.
    c. 17 psi.
    d. 20 psi.
    e. None of the above.

27. After removing the brake cylinder measurement gauge from the brake cylinder pressure tap, in Test 3.21.1, the tap must be checked for leakage. How much leakage is allowed on the brake cylinder pressure tap?
    a. 3 psi.
    b. 2 psi.
    c. 1 psi.
    d. No leakage is allowed
    e. None of the above.

28. When performing the Slack Adjuster & Piston Travel Adjustment Test 4.1, you reduce brake pipe pressure to ___________ on the test device gauge to make the brake applications.
    a. 50 psi
    b. 60 psi
    c. 80 psi
    d. zero psi
    e. 20 psi

29. When performing the Brake Cylinder Leakage Test 4.5 in the Special Tests, an empty car with empty/load brake equipment must have the empty/load sensor in the _______________ .
    a. Empty position
    b. Loaded position
    c. Empty or loaded does not matter
    d. Removed
    e. None of the above

30. During the Single Car Test when reducing the brake pipe pressure, if the brake pipe continues to reduce after the test device handle is placed in Position 3, the person performing the test is instructed to do what?
    a. Change the emergency portion
    b. Change the service portion
    c. Move the test device handle to position 2 to stop the reduction in pressure, then move the handle back to position 3. Perform this procedure once.
    d. Get a new test device, that one has failed
    e. Let the brake pipe pressure drop as far as it wants, it does not matter

Practical Exam of Single Car Test Procedures per S-486-13

Wabtec CORPORATION

Name: [redacted] **Company:** KASGRO RAILCORP
Date: 1-5-16 **Mark:** PASS

The instructor must observe the person taking the test. Depending upon the type of car under test, indicate in the space provided if the person taking the test passed each section of the test. If any part of an individual test is not performed in accordance with applicable standards or the instructor/tester is not satisfied with the procedure, indicate in the fail column. At the end of the test, the instructor/tester may add any notes that will qualify a pass or fail situation. Note test 3.12.3.1 is not applicable for cars tested to AAR Specifications.

TEST	PASS	FAIL
2.0 - SINGLE CAR TEST DEVICE		
1. Is test device within date allowed by AAR standard.		
2. Air supply to minimum 90 psi, recommended 100 psi for testing.		
3. Test device within 15 degrees of vertical.		
4. Hose on test device no longer than 8 feet.		
2.3 - DAILY TEST		
1. Blow out air supply before coupling to test device.		
2. Device in high pressure.		
3. Close 3/8" cock.		
4. Handle to Position 2.		
5. Close & open flowrator, ball rises and falls, does not stick.		
6. Handle to Position 3.		
7. Attach dummy coupling and brake cylinder gauge.		
8. Handle to Position 1, pressure at 90 psi.		
9. Set to Low Pressure, gauge reads 80 psi.		
10. Brake cylinder measurement gauge within +/-3 psi of test device gauge.		
11. Reset to High Pressure.		
12. Charge to 90 psi, Position 3.		
13. Time 1 minute, Leakage <1 psi or check with soap suds < 1" bubble in 5 seconds.		
14. Open 3/8" cock, remove dummy coupling.		
15. Apply coupling with .28 mm opening.		
16. Close 3/8" cock, handle to Position 1.		
17. Check flowrator. Ball floats between condemning line and top of tube.		
18. Position 3, open flowrator and 3/8" cock.		
19. Remove coupling, close 3/8" cock.		
20. Leakage at BP end and rotary valve exhaust less than 1" bubble in 5 seconds.		
3.0 - TESTS - STANDARD FREIGHT BRAKE		
3.1 - Preliminary Procedures & Inspections		
1. Wheels chocked, car protected from movement.		
2. Handbrake released, brake cylinder push rod returned into brake cylinder.		
3. Check shoes, brake levers, pins, rods, rigging for wear and does not bind or foul.		
4. Check dates on air hoses, if not changed, replace hose gaskets.		
5. Both angle cocks open.		
6. Apply brake cylinder measurement tap, if not installed.		
7. Apply brake cylinder measurement gauge to tap.		
8. Retainer valve in Direct Exhaust (EX).		
9. Loosen vent protector & elbow on vent valve if equipped.		
10. Completely drain reservoirs.		
11. Close branch pipe cut out cock.		
12. Set empty/load equipment to loaded position as required.		

(1 of 5)

Practical Exam per S-486-13

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TEST	PASS	FAIL
3.2 - Connecting Device to Car		
1. Confirm Daily Test completed. 2. Supply line blown out. 3. Test device reads 90 in HP, 80 in LP. 4. 3/8" cock closed. 5. Flowrator open. 6. Close branch pipe cut out cock. 7. Reservoirs drained. 8. Couple test device to car air hose - prefer B end. 9. Angle cocks open, handle in Position 1. 10. Continuous blow at angle cock open end. 11. Close angle cock, attach dummy, reopen.	(initials)	
3.3 - Brake Pipe Leakage Test		
1. Position 1, charge brake pipe to 90 psi. 2. Close flowrator, top of flowrator ball below condemning line. 3. Open flowrator.	(initials)	
3.4 - Separate Brake Pipe Venting Devices - OPTIONAL-		
3.4.1 - Continuous Quick Service Test - OPTIONAL-		
1. Control valve cut out, charged to 90 psi, handle to Position 4. 2. Pressure reduces on gauge, must not produce emergency. 3. Intermittent exhaust at quick service vent. No exhaust = failure. 3. Handle to Position 1, recharge to 90 psi.	(initials)	
3.4.2, 3.4.3 - Separate Vent Valve Test - OPTIONAL -		
1. A-1 Reduction Relay and < 85' of BP - plug B-1 Quick Service. 2. Position 5, reduce BP to 50 psi then lap 3. BP pressure does not reduce to zero. 3. Separate emergency vent valve, BP < 75' use Position 5, >75' use Position 6. 4. BP no lower than 40 psi, open 3/8" cock. BP pressure must reduce to zero. 5. Close 3/8" cock.	(initials)	
3.5 - System Leakage Test		
1. Handle in Position 1. 2. Cut in control valve, charge to 90 psi. 3. During charge, no venting at retainer, brake cylinder remains in release. 4. Close flowrator, ball below condemning line. 5. Soap reservoir pipes fittings and gaskets for leaks. No leakage allowed. 6. Open flowrator.	(initials)	
3.6 - Hand Brake Inspection		
1. Lubricate handbrake - if required. 2. HB released, piston pushrod into hollow rod. 3. Apply handbrake, check bell crank position. 4. Use bar, all shoes all locations HB applies are tight. No binding or fouling. 5. Wabcopac/Nycopac trucks one shoe per beam tight. 6. Release handbrake, chain fully unwound. 7. Chain unwound, bellcrank drops to lower limit, horizontal chain has slack.	(initials)	✓

(2 of 5)

Practical Exam per S-486-13

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TEST	PASS	FAIL
3.7 - Slack Adjuster Conditioning		
1. Install block(s) between shoe(s) and wheel(s). 2. Charge to 90 psi, make 15 psi reduction, immediately return to Position 1. 3. Wait for cylinder to release. 4. Make 30 psi reduction, Position 5, immediately return to Position 1. 5. Wait for cylinder to release. 6. Charge to 90 psi, Flowrator ball below top of tube. Open Flowrator.		
3.8 - Service Stability Test		
1. Vent valve plugged as applicable. VX bleed stem pulled, air blow noticed as applicable. 2. Cars up to 75', 40 psi reduction in Position 5, @ 55 psi use Position 4, lap @ 50 psi. No Emergency. Use Position 2 to stop reduction as applicable. 3. Cars > 75', 40 psi reduction in Position 6, @ 55 psi use Position 4, lap @ 50 psi. No Emergency. Use Position 2 to stop reduction as applicable. 4. Bleed stem of VX valve reset as applicable.		
3.9 - Piston Travel (W/Blocks), Rigging & BC Pressure		
1. Measure & note piston travel per AAR Standards. 2. Check brake levers for angularity. 3. Determine all shoes firmly set against wheels, verify no fouling in linkage. 4. Brake cylinder pressure must be higher than 50 psi, (except cars with Mod valves). 5. Modulating valves and empty/load valves unable to set to loaded must develop minimum 25 psi BC pressure. 6. Note brake cylinder pressure.		
3.10 - Emergency Test		
1. Cars with <100ft of BP, BP no lower than 40 psi, quickly open 3/8" cock. 2. Cars with > 100 ft of BP, BP no lower than 40 psi, Position 4 open 3/8" cock. 4. Must produce emergency application, BP to zero. 5. BC pressure must be at least 5 psi higher than full service 3.9.5.		
3.11 - Release Test after Emergency		
1. Retainer handle to high pressure (HP) position. 2. Close 3/8" cock, handle to Position 3, watch BP for 2 minutes. 3. Open 3/8' cock, no air exhaust, close 3/8" cock. 4. Handle to Position 1, charge BP to 28 psi, immediately return handle to Position 3. 5. Bake pipe pressure must continue to rise.		
3.12 - Retaining Valve Test		
1. Handle to Position 1, charge for four minutes. 2. Brakes remain applied, BC pressure must be equal to or greater than 12 psi. 3. Retainer to direct exhaust (EX), blow of air noted at retainer valve exhaust.		
3.13 - Min. Application & Quick Service Limiting Valve		
1. Position 1, charge to 90 psi, flowrator ball is below top of tube. 2. Handle to Position 4, reduce to 87 psi, Position 3. 3. Brakes must apply. 4. BP drops below to 86 psi, use Position 2 then lap to stop as required - only once. 5. Reducing valve to low pressure, device handle to Position 1.		

Practical Exam per S-486-13

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TEST	PASS	FAIL
3.14 - Brake Cylinder Leakage Test		
1. Pressure stabilized @ 80 psi, wait 3 minutes. 2. Note BC pressure. Brake cylinder pressure must be greater than 12 psi. 3. Wait another minute, check BC pressure. 4. No more than 1 psi increase or decrease is allowed. 5. Close flowrator, observe ball stabilizes. 6. Top of flowrator ball must stay below condemning line. 7. Open flowrator by-pass cock.	[illegible]	
3.15 - Slow Release Test		
1. BP pressure @ 80 psi, brakes applied, handle in Position 3. 2. Reducing valve handle to high pressure, check BP length. 3. Position 2, brakes must release within time specified by BP length, note exhaust @ retainer. 4. Position 1, charge to 90 psi. 5. Remove block(s) between shoe(s) and wheel(s).	[illegible]	
3.16 - Slack Adjuster Conditioning (without blocks)		
1. Make 15 psi reduction, immediately return to Position 1. 2. Wait for cylinder to release. 3. Make 30 psi reduction, Position 5, immediately return to Position 1. 4. Wait for cylinder to release. 5. Charge to 90 psi, Flowrator ball below top of tube. Open flowrator.	[illegible]	
3.17- Accelerated Application Valve (AAV) Test		
1. Handle to Position 4, BP pressure reducing, note exhaust at emergency portion. 2. No emergency application. 3. Reduce BP to 60 psi, Position 3. No exhaust - failed emergency portion. 4. BP continues to drop, use Position 2 then lap to stop as required - only once. 5. BP reduction must stop.	[illegible]	
3.18 - Recheck of Piston Travel (W/O blocks, cars with auto slack adjusters)		
1. If BP not at 60 psi, reduce to 60 psi in Position 5. 2. Use Position 5, 4 and lap to reach 60 psi. 3. Recheck piston travel. 4. Piston travel must be within +/- 1/2" of travel noted in 3.9.1. 5. May require to cycle slack adjuster with several applications. Last time BP to 90 psi flowrator ball below top of tube. 6. Slack adjuster defective, finish test before replacing.	[illegible]	
3.19 - Manual Release Valve Test		
1. Handle to Position 5, BP drops to zero. (remove strap on ELX-S as applicable) 2. Pull release rod for 3 seconds, brakes release. (check lockout button on ELX-S) 3. Verify release rod does not bind or foul 4. Brake cylinder piston must return to release. 5. Position 1, High Pressure position. 6. Brake cylinder piston must remain in release. 7. Car is empty and has empty/load go to 3.20 8. Position 1, charge to 80 psi. 9. Position 5, reduce BP to zero. 10. Brake must apply. Go to 3.21	[illegible]	

Practical Exam per S-486-13

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TEST	PASS	FAIL
3.20 - Empty/Load Test		
1. Handle to Position 1. 2. Regulator valve in High Pressure. 3. Set empty/load valve to empty configuration. 4. Charge BP until flowrator ball is below top of tube. 5. Handle to Position 5, reduce BP to zero, brakes must apply. 6. Brake cylinder pressure must be 17 psi below full service in 3.9.5. 7. Soap empty/load device, reservoir and piping for leaks - no leakage allowed.	(initials)	
3.21 - Disconnecting the Single Car Test Device		
1. Remove brake cylinder gauge, soap pressure tap - No leakage allowed. 2. Any valve plugged, remove plug reapply vent protector. Separate emergency portion cut-in. 3. Secure car from movement. 4. Shut off air supply or Position 3 on test device. 5. Drain car reservoirs. Empty/load reset to empty. 6. Remove dummy coupling.	(initials)	

4.0 - SPECIAL TESTS - OPTIONAL
4.1 - Slack Adjuster Test and Piston Travel Adjustment
4.2 - Retaining Valve Test
4.3 - Auxiliary Devices
4.4 - Brake Cylinder Pressure Tap - Leakage Test
4.5 - Brake Cylinder Leakage Test Using Gauge
4.6 - Empty/Load Test

(initials written across section 4.0)

Exceptions: GOOD TEST, KEEP UP THE GOOD WORK

Tested By: [redacted]
Signature

Title: MECH ENG / AB INSTR

Company: WABTEC

(5 of 5)

APPENDIX G-2.6

ATLAS RAILCAR NDE EXAMINATIONS AND TESTING

Appendix G-2.6.1 TUV Rheinland Industrial Solutions, Non-Destructive Testing Group Work Instruction No. PA-WI-08-005, Rev No. 1 Ultrasonic Testing to AWS D15.1 Railroad Welding Specification

NDT Non•Destructive Testing Group Quality by Integrity and Knowledge	WORK INSTRUCTION	NUMBER PA-WI-08-005
	Title: Ultrasonic Testing to AWS D15.1 Railroad Welding Specification	Rev. No. 1 Effective Date: March 17, 2008

REVISION RECORD

Revision 1 / March 17, 2008	Corrected 5.7.6.1 to refer to 7.3 / Added resolution calibration requirement to 7.5
Revision 0 February 19, 2008	New Issue

Originator: Robert D. Nichol (signature) Date: March 17, 2008

Robert D. Nichol

1.0 SCOPE

1.1 This written practice describes the techniques, calibration for use, acceptance standards, and documentation requirements for the ultrasonic testing of groove welds and the heat affected zone between the thicknesses of 5/16" and 8 inches.

2.0 REFERENCE DOCUMENTS

2.1	AWS D 15.2-2007	Railroad Welding Specification for Cars and Locomotives
2.2	AWS D 1.1-2006	Structural Welding Code-Steel
2.3	NDTG-UT-2	NDTG Procedure: Ultrasonic Shear Wave Testing of Welds
2.4	NDTG-UTQC-1	NDTG Procedure: Evaluating Performance, UT Test Equipment
2.5	NDTG-CTP-1	Corporate Training Policy
2.6	ASNT SNT-TC-1A	Recommended Practice (Certification of NDT Personnel)

3.0 PERSONNEL

3.1 All ultrasonic testing personnel shall meet the minimum education and training requirements of the Non-Destructive Testing Group's Corporate Training Policy, NDTG-CTP-1. Personnel interpreting test results for acceptance or rejection shall be certified to Level II or III in the ultrasonic method. Level I personnel may perform testing, under direct supervision of a Level II or III technician.

4.0 GENERAL

4.1 The procedures and standards set forth shall govern the UT of groove welds and HAZs between the thicknesses of 5/16 inch and 8 inch [8 mm and 200 mm] inclusive.

4.2 The ultrasonic testing procedure and technique shall be in accordance with AWS D1.1

5.0 UT EQUIPMENT

5.1 Equipment Requirements

5.1.1 The UT instrument shall be the pulse echo type suitable for use with transducers oscillating at frequencies between 1 and 6 megahertz. The display shall be an "A" scan rectified video trace.

5.2 Horizontal Linearity

5.2.1 The horizontal linearity of the test instrument shall be qualified over the full sound path distance to be used in testing.

5.3 Requirements for Test Instruments

5.3.1 Test instruments shall include internal stabilization so that after warm-up, no variation in response greater than ± 1dB occurs with a supply voltage change of 15% nominal or, in the case of a battery, throughout the charge operation life. There shall be an alarm or meter to signal a drop in battery voltage prior to instrument shutoff due to battery exhaustion.

5.4 Calibration of Test Instruments

5.4.1 The test instrument shall have a calibrated gain control (attenuator) adjustable in discrete 1 or 2 dB steps over a range of at least 60dB. The accuracy of the attenuator settings shall be within plus or minus 1 dB.

5.4.2 Equipment Qualification Procedures

5.4.2.1 Equipment will be certified per the requirements of NDTG-UTQC-1.

5.5 Display Range

5.5.1 The dynamic range of the instrument's display shall be such that a difference of 1 dB of amplitude can be easily detected in the display.

5.6 Straight-Beam (Longitudinal Wave) Search Units

5.6.1 Straight-beam (longitudinal wave) search unit transducers shall have an active area of not less than ½ square inches [323 square millimeters] or more than 1 square inch [645 square millimeters]. The transducer shall be round or square. Transducers hall be capable of resolving the three reflections as described when transducer is set in position "F" on the IIW block.

5.6.2 The transducer frequency shall be 2.25 Mhz.

5.7 Angle-Beam Search Units

5.7.1 Angle-beam search units shall consist of a transducer and an angle wedge.

5.7.2 Frequency

5.7.2.1 The transducer frequency shall be between 2 and 2.5 MHz, inclusive.

5.7.3 Transducer dimensions.

5.7.3.1.1 The transducer crystal shall be square or rectangular in shape and may vary form 5/8 inches to 1 inch [15 to 25 mm] width and from 5/8 to 13/16 inches [15 to 20 mm] in height. The maximum width to height ratio shall be 1.2 to 1.0, and the minimum width-to-height ratio shall be 1.0 to 1.0.

5.7.4 Angles

5.7.4.1 The search unit shall produce a sound beam in the material being tested within plus or minus 2° of one of the following proper angles: 70°, 60° or 45° as described in 7.4.2.2

5.7.5 Marking

5.7.5.1 Each search unit shall be marked to clearly indicate the frequency of the transducer, nominal angle of refraction and index point. (See 7.4.2.1)

5.7.6 Internal Reflections

5.7.6.1 Maximum allowable internal reflections from the search unit shall be as described in 7.3.

5.7.7 Edge Distance

5.7.7.1 The dimensions of the search unit shall be such that the distance from the leading edge of the search unit to the index point shall not exceed 1 inch [25 mm].

5.7.8 IIW Block

5.7.8.1 The qualification procedure using the IIW reference block shall be in conformance with NDTG-UTQC-1.

6.0 Reference Standards

6.1 IIW Standards

6.1.1 The international Institute of Welding (IIW) UT reference block, shall be the standard used for both distance and sensitivity calibration. Other portable blocks may be used, provided the reference level sensitivity for instrument/ search unit combination shall be adjusted to be the equivalent of that achieved with the IIW Block (see AWS D1.1 Figure X-1 for examples).

6.2 Prohibited Reflectors

6.2.1 The use of a "corner" reflector for calibration purpose shall be prohibited.

6.3 Resolution Requirements

6.3.1 The combination of search unit and instrument shall resolve three holes in the RC resolution reference test block shown in Figure 6.3. The search unit position is described in 7.4.2.5. The resolution shall be evaluated with the instrument controls set at normal test settings and with indications from the holes brought to midscreen height. Resolution shall be sufficient to distinguish at least the peaks of indications from the three holes. Use of the RC resolution reference block for calibration shall be prohibited. Each combination of instrument search unit (shoe and transducer) shall be checked prior to this initial use. This equipment verification shall be done initially with each search unit and UT unit combination. The verification need not be done again provided documentation is maintained that records the following items:

(1) UT machine's, make, model and serial number
(2) Search unit's manufacturer, type, size, angle, and serial number
(3) Date of verification and technician's name

7.0 Equipment Qualification

7.1 Horizontal Linearity

7.1.1 The horizontal linearity of the test instrument shall be requalified after each 40 hours of instrument use in each of the distance ranges that the instrument will be used. The qualification procedure shall be in conformance with NDTG-UTQC-1 and AWS D1.1. (see NDTG-UTQC-1 see Annex X in AWS D1.1 for alternative methods).

7.2 Gain Control

7.2.1 The instrument's gain control (attenuator) shall meet the requirements of 5.4 shall be checked for correct calibration at two month intervals in conformance with NDTG-UTQC-1. Alternative methods may be used for calibrated gain control (attenuator) qualification if proven at least equivalent with NDTG-UTQC-1.

7.3 Internal Reflections

7.3.1 Maximum internal reflections from each search unit shall be verified at a maximum time interval of 40 hours of instrument use in conformance with 6.30.3 of AWS D.1.1

7.4 Calibration of Angle-Bean Search Units

7.4.1 With the use of an approved calibration block, each angle-beam of an approved calibration block, each angle-beam search unit shall be checked after each eight hours of use to determine that the contact face is flat, that the sound entry point is correct, and that the beam angle is within the allowed plus or minus 2° tolerance in conformance with 7.4.2.1.1 and 7.4.2.2.1. Search units, which do not meet these requirements, shall be corrected or replaced.

7.4.2 Shear Wave Mode (Transverse)

7.4.2.1 Index Point

7.4.2.1.1 The transducer sound entry point (index point) shall be located or checked by the following procedure:

(1) The transducer shall be set in position D on the IIW bock.

(2) The transducer shall be moved until the signal form the
radius is maximized. The point on the transducer, which aligns with the radius line on the calibration block, is the point of sound entry. (see Annex X in AWS D1.1 for alternative methods).

7.4.2.2 Angle

7.4.2.2.1 The transducer sound-path angle shall be checked or determined by one of the following procedures:

(1) The transducer shall be set in position B on IIW block for angles 40° through 60°, or in position C on IIW block for angles 60° through 70° (see Figure 7.4.1).

(2) For the selected angle, the transducer shall be moved back and forth over the line indicative of the transducer angle until the signal form the radius is maximized. The sound entry point on the transducer shall be compared with the angle mark on the calibration block (tolerance ± 2°) (see Annex X in AWS D1.1 for alternative methods).

7.4.2.3 Distance Calibration Procedure

7.4.2.3.1 The transducer shall be set in position D on the IIW block (any angle). The instrument shall then be adjusted to attain indications at 4 inch [100 mm on a metric block] and 8 inch [200 mm on a metric block] or 9 inches [225 mm on a metric block] on the display, 4 inches [100 mm] and 9 inches [230 mm] on Type 1 block; or 4 inches [100 mm] and 8 inches [200 mm] on a Type 2 block (see Annex X in AWS D1.1 for alternative method).

7.4.2.4 Amplitude or Sensitivity Calibration Procedure

7.4.2.4.1 The transducer shall be set in position A on the IIW block (any angle). The maximized signal shall then be adjusted form the 0.060 inch [1.59 mm] hole to attain a horizontal reference-line height indication (see Annex X, of AWS D1.1 for alternative method).

7.4.2.5 Resolution:

7.4.2.5.1 (1) The transducer shall be set on resolution block RC position
Q for 70° angle, position R for 60° angle, or position S for 45° angle.
(3) Transducer and instrument shall resolve the three test holes, at least to the extent of distinguishing the peaks of the indications from the three holes.

7.4.2.6 Approach Distance of Search Unit

7.4.2.6.1 The minimum allowable distance between the toe of the search unit and the edge of IIW block shall be as follows:

For 70° transducer,
X = 2 inches [50 mm]

For 60° transducer
X = 1-7/16 inches [37 mm]

For 45° transducer
X = 1inch [25 mm]

7.5 Calibration of Straight Beam Search Units:

7.5.1 Recognized standards, such as the IIW or DSC blocks may be utilized to verify the horizontal and vertical linearity and to establish distance calibration. For thinner materials, a step wedge may be used to establish distance reflectors over a known range. For test pieces of greater length, special reference standards of a known length may be used to achieve a back reflection on the CRT that will be representative of the length of the part to be tested. In all instances, a minimum of the initial pulse and one back reflection shall be present on the CRT screen. Calibration standards shall have parallel surfaces to assure proper sound transmission and reception.

7.5.2 Sensitivity shall be established by maximizing a reflector on the CRT at 50 to 80% of the full screen height (FSH), at a distance which is the same or greater than the thickness or length of the item to be examined. This may be adjusted from the actual back reflection of the test piece once distance calibration has been completed, to compensate for differences in the surface conditions or acoustical differences in the test material.

7.5.3 Resolution Requirement. The combination of search unit and instrument shall resolve three holes or notches. The resolution shall be sufficient to distinguish at least the peaks of indications from the three holes or notches. This will be completed prior to calibration.

7.5.4 Calibration standards shall be of the same material type as the items to be examined and with smooth parallel surfaces.

7.5.5 Calibration should be checked periodically and shall be checked any time there is a change to the equipment, a change of operators, a shutdown of the power source, or any time there is reason to suspect an equipment malfunction.

8.0 Calibration for Testing

8.1 Position of Reject Control

8.1.1 All calibrations and tests shall be made with the reject (clipping or suppression) control turned off. Use of the reject (clipping or suppression) control may alter the amplitude linearity of the instrument and invalidate test results.

8.2 Technique

8.2.1 Calibration for sensitivity and horizontal sweep (distance) shall be made by the UT operator just prior to and at the location of testing of each weld.

8.3 Recalibration

8.3.1 Recalibration shall be made after a change of operators, each 30 minute maximum time interval, or when the electrical circuitry is disturbed in any way which includes the following:

(1) Transducer change
(2) Battery change
(3) Electrical outlet change
(4) Coaxial cable change
(5) Power outage (failure)

8.3.2 Recalibration verification shall be performed after completing the inspection to verify valid calibration.

8.3.2.1 Should the end of test calibration prove to be invalid, all tested area since the last valid calibration verification shall be re-tested.

8.4 Straight-Beam Testing of Base Metal

8.4.1 Sweep

8.4.1.1 The horizontal sweep shall be adjusted for distance calibration to present the equivalent of at least two plate thicknesses on the display.

8.4.2 Sensitivity

8.4.2.1 The sensitivity shall be adjusted at a location free of indications so that the first back reflection from the far side of the plate will be 50% to 75% of full screen height.

8.5 Calibration for Angle-Beam Testing

8.5.1 Calibration for angle-beam testing shall be performed as follows (see Annex X of 1 in AWS D1.1 for alterative methods).

8.5.2 Horizontal Sweep

8.5.2.1 The horizontal sweep shall be adjusted to represent the actual sound-path distance by using the IIW block or alternative blocks as described in 6.1. The distance calibration shall be made using either, the 5 inches [122 mm] scale, or 10 inches [250 mm] scale on display, whichever is appropriate. If, however the joint configuration or thickness prevents full examination of the weld at either of these settings, the distance calibration shall be made using 15 inches or 20 inches [400 mm or 500 mm] scale is required. The search unit position is described in 7.4.2.3.

8.5.2.2 Zero Reference Level

8.5.2.2.1 The zero reference level sensitivity used for discontinuity evaluation ("b" on the ultrasonic test report, NDTG form AWS shall be attained by adjusting the calibrated gain control (attenuator) of the discontinuity detector, meeting the requirements of 5.0, so that a maximized horizontal trace deflection (adjusted to horizontal reference line height with calibrated gain control [attenuator]) results on the display, in conformance with 7.4.2.4.

9.0 Testing Procedures

9.1 "X" Line

9.1.1 An "X" line for discontinuity location shall be marked on the test face of the weldment in a direction parallel to the weld axis. The location distance perpendicular to the weld axis shall be based on the dimensional figures on the detail drawing and usually falls on the centerline of the butt joint welds, and always falls on the near face of the connecting member of T and corner joint welds (the face opposite Face C).

9.2 "Y" Line

9.2.1 A "Y" accompanied with a weld identification number shall be clearly marked on the base metal adjacent to the weld that is subject to UT. This marking is used for the following purpose:

(1) Weld identification
(2) Identification of Face A
(3) Distance measurements and direction (+ or -) from the "X" line.
(4) Location measurements from weld ends or edges.

9.3 Cleanliness

9.3.1 All surfaces to which a search unit is applied shall be free of weld spatter, dirt, grease, oil (other than that used as a couplant), paint, and loose scale and shall have a contour allowing intimate coupling.

9.4 Couplants

9.4.1 A couplant material shall be used between the search unit and the test material. The couplant shall be either glycerin or cellulose gum and water mixture of a suitable consistency. A wetting agent may be added if needed. Light machine oil may be used for couplant on calibration blocks.

9.5 Extent of Testing

9.5.1 The entire base metal through which ultrasound must travel to test the weld shall be tested for laminar reflectors using a straight-beam search unit conforming to the requirements of 5.6 and calibrated in conformance with 8.4. If any area of base metal exhibits total loss of back reflection or an indication equal to or greater than the original back reflection height is located in a position that will interfere with the normal weld scanning procedure, its size location, and depth from the A face shall be determined and reported on the UT report, and an alternate weld scanning procedure shall be used.

9.5.2 Reflector Size

9.5.2.1 If part of a weld is inaccessible to testing in conformance with the requirements of Table 6.7, due to laminar content recorded in conformance with 9.5.1 the testing shall be conducted using one or more of the following alternative procedures as necessary to attain full weld coverage:

(1) Weld surface(s) shall be ground flush.
(2) Testing form Faces A and B shall be performed.
(3) Other search unit angles shall be used.

9.6 Testing of Welds

9.6.1 Welds shall be tested using and angle beam search unit conforming to the requirements of 5.7 with the instrument calibrated in conformance with 8.5 using the angle as shown in Table 6.7. Following calibration and during testing, the only instrument adjustment allowed is the sensitivity level adjustment with the calibrated gain control (attenuator). The reject (clipping or suppression) control shall be turned off. Sensitivity shall be increased from the reference level for weld scanning in conformance with Table 6.2 of this procedure or AWS D15.2-2007, Table 17.2.

9.6.2 Scanning

9.6.2.1 The testing angle and scanning procedure shall be in conformance with those show in Table 6.7.

9.6.3 Butt Joint

9.6.3.1 All butt joint welds shall be tested from each side of the weld axis. Corner and T-joint welds shall be primarily tested form one side of the weld axis only. All welds shall be tested using the applicable scanning pattern or pattern shown in Figure 9.6 as necessary to detect both longitudinal and transverse discontinuities. It is intended that, as a minimum, all welds be tested by passing sound through the entire volume of the weld and the HAZ in two crossing directions, wherever practical.

9.6.4 Maximum Indication

9.6.4.1 When a discontinuity indication appears on the screen, the maximum attainable indication from the discontinuity shall be adjusted to produce a horizontal reference level trace deflection on the display. This adjustment shall be made with the calibrated gain control (attenuator), and the instrument reading in decibels shall be used as the "Indication Level, a," for calculating the "Indication Rating, d," as shown on the test report (NDTG form AWS form No.0004 or equivalent).

9.6.5 Attenuation Factor

9.6.5.1 The "Attenuation Factor, c," on the test report shall be attained by subtracting 1 inch [25 mm] from the sound-path distance and multiplying the remainder by 2. This factor shall be rounded out to the nearest dB value. Fractional values less than ½ dB shall be reduced to the lower dB level and those of 1/2 dB or greater increased to the higher level.

9.6.6 Indication Rating

9.6.6.1 The "Indication Rating, d," in the UT report, (NDTG form AWS form No.0004 or equivalent), represents the algebraic difference in decibels between the indication level and the reference level with correction for attenuation as indicated in the following expressions:

Instruments with gain in dB:
a-b-c = d
Instruments with attenuation in dB
b-a-c = d

9.7 Length of Discontinuities

9.7.1 The length of discontinuities shall be determined in conformance with procedure described in 10.2.

9.8 Basis for Acceptance or Rejection

9.8.1 Each weld discontinuity shall be accepted or rejected on the basis of its indication rating and its length, in conformance with Table 6.2 for statically loaded structures or AWS D15.1-2007, Table 17.2. Only those discontinuities, which are rejectable, need be recorded on the test report.

9.9 Identification of Reject Area

9.9.1 Each rejectable discontinuity shall be indicated on the weld by a mark directly over the discontinuity for its entire length. The depth from the surface and indication rating shall be noted on nearby base metal.

9.10 Repairs

9.10.1 Welds found unacceptable by UT shall be repaired by methods allowed by AWS D1.1 (see 5.26)

9.11 Retest Reports

9.11.1 Evaluation of retested repaired weld areas shall be tabulated on a new line on the report form. If the original report form is used, and R1, R2, … Rn shall prefix the weld number. If additional reports are used the Rn will suffix the weld no. shall prefix the report number.

9.12 Steel Backing

9.12.1 UT of CJP groove welds with steel backing shall be performed with a UT technique that recognizes potential reflectors created by the base metal-backing interface. (see Commentary C6.26.12 of AWS D1.1 for additional guidance scanning groove welds containing steel backing).

10.0 Discontinuity Size Evaluation Procedures

10.1 Each discontinuity shall be accepted or rejected on a basis of it's indication rating and it's length in accordance with this written practice and AWS D15.1-2007, Table 17.2

10.2 Straight-Beam (Longitudinal) Testing

10.1.1 The size of lamellar discontinuities is not always easily determined, especially those that are smaller than the transducer size. When the discontinuity is larger than the transducer, a full loss of back reflection will occur and a 6dB loss of amplitude and measurement to the centerline of the transducer s usually reliable for determining discontinuity edges. However, the approximate size evaluation of those reflectors, which are smaller than the transducer, shall be made by beginning outside of the discontinuity with equipment calibrated in conformance with 8.4 and moving the transducer toward the area of discontinuity until an indication on the display begins to form. The leading edge of the search unit at this point is indicative of the edge of the discontinuity.

10.2 Angle-Beam (Shear) Testing

10.2.1 The following procedure shall be used to determined lengths of indications, which have dB ratings more serious than for a Class D indication. The length of such indication shall be determined by measuring the distance between the transducer centerline locations where the indication rating amplitude drops 50% (6 dB) below the rating for the applicable "discontinuity length" on the test report. Where warranted by discontinuity amplitude, thus procedure shall be repeated to determine the length of Class A. B, and C discontinuities.

11.0 Scanning Patterns

11.1 Longitudinal Discontinuities

11.1.1 Scanning Movement A.

11.1.1.1 Rotation angle a = 10°

11.1.2 Scanning Movement B.

11.1.2.1 Scanning distance b shall be such that the section of weld being tested is covered.

11.1.3 Scanning Movement C.

11.1.3.1 Progression distance c shall be approximately one-half the transducer width.

**Note: movement A, B, and C may be combined into one scanning pattern.*

11.2 Transverse Discontinuities

11.2.1 Ground Welds

11.2.1.1 Scanning pattern D shall be used when welds are ground flush.

11.2.2 Unground Welds

11.2.2.1 Scanning pattern E shall be used when the welds reinforcement is not ground flush. Scanning angle e = 15° maximum.

**Note: The scanning pattern shall cover the full weld section.*

11.3 ESW or EGW Welds (Additional Scanning Pattern)

11.3.1 Scanning Pattern E Search unit rotation angle e between 45° and 60°.

**Note: The scanning pattern shall cover the full weld section.*

12.0 Preparation and Disposition of Reports

12.1 Content of Reports.

12.1.1 A report form, which clearly identifies the work and the area of inspection, shall be completed by the UT operator at the time of inspection. The report form for welds that are acceptable need only contain sufficient information to identify the weld, the operator (signature), and the acceptability of the weld. An example of such a form is NDTG AWS Form NDTG-0004 or equivalent.

12.2 Prior Inspection Reports

12.2.1 Before a weld subject to UT by the Contractor for the Owner is accepted, all report forms pertaining to the weld, including any that show unacceptable quality prior to repair, shall be submitted to the Inspector.

12.3 Completed Reports

12.3.1 A full set of completed report forms of welds subject to UT by the Contractor for the Owner, including any that show unacceptable quality prior to repair, shall be delivered to the Owner upon completion of the work. The Contractor's obligation to retain UT reports shall cease (1) upon delivery of this full set to the

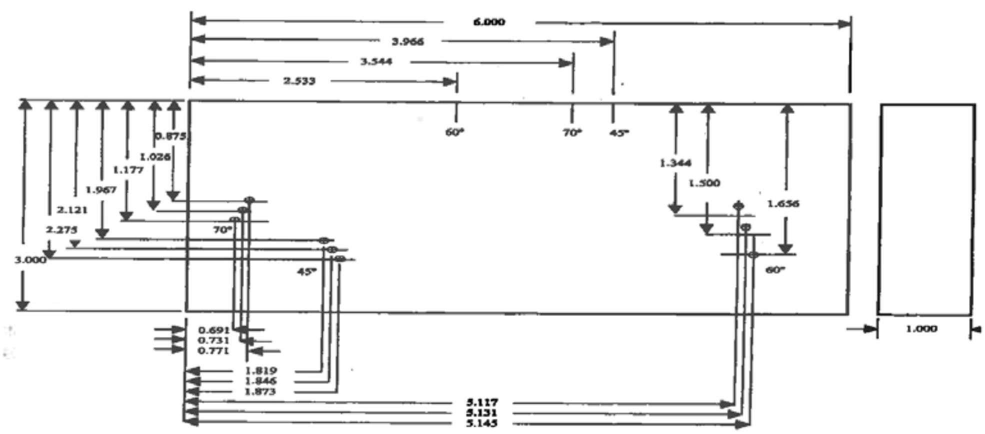
Owner, or (5) years after completion of the Contractor's work, provided that the Owner is given prior written notice.

13.0 Marking

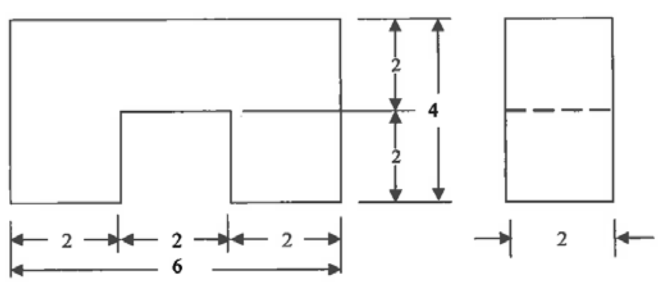
13.1 Each rejectable discontinuity shall be indicated on the weld by a mark directly over the discontinuity for it's entire length. The depth from the surface and the type of the discontinuity shall be noted nearby on base metal.

13.2 Upon completion and acceptance of each weld tested the level II technician shall mark each weld with a white paint stick. The marking shall be as close to the weld as possible. The acceptance marking shall be as follows:

UT Accepted
NDTG – (inspector's initials)
(Date)

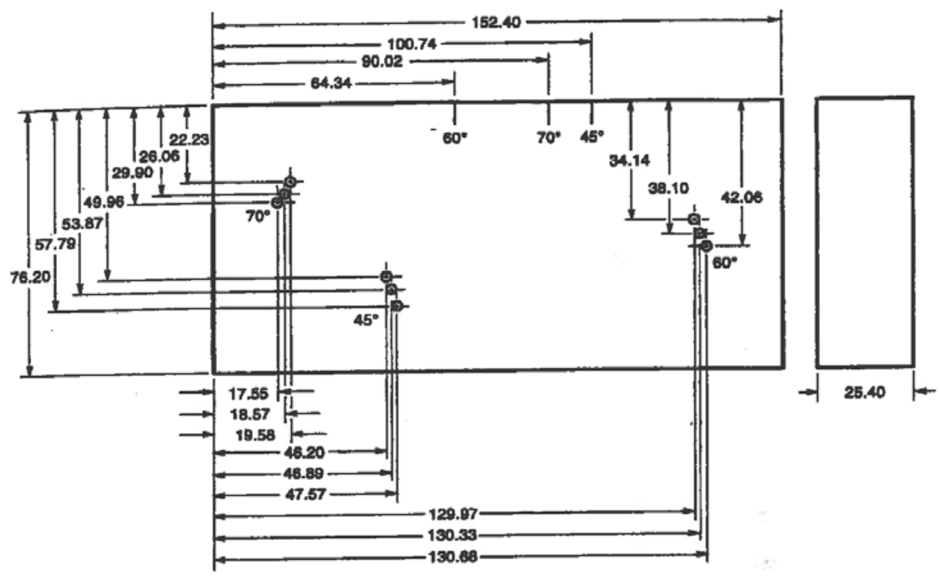


RC – RESOLUTION REFERENCE BLOCK

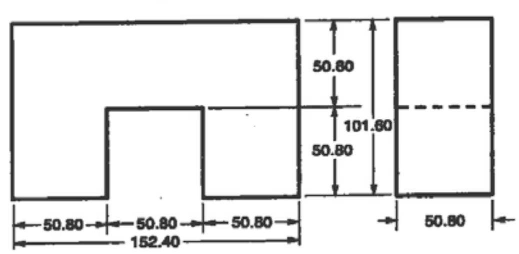


TYPE – DISTANCE AND SENSITIVITY REFERENCE BLOCK

Figure 6.3 – Qualification Blocks (see 6.3)

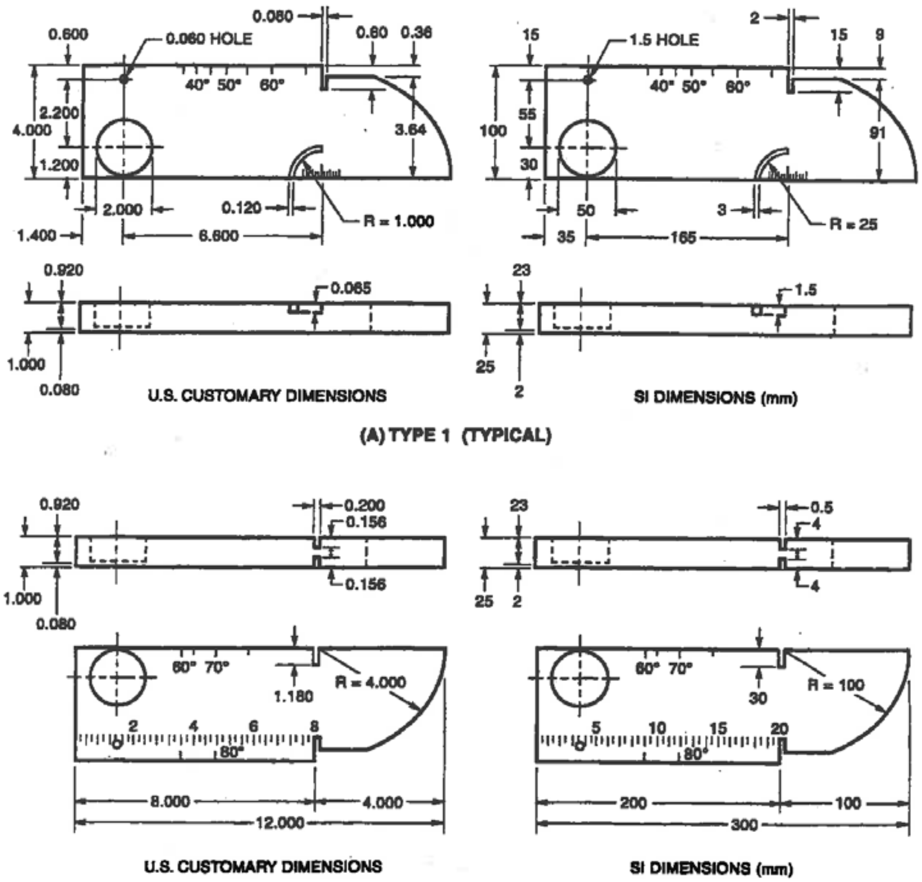


RC – RESOLUTION REFERENCE BLOCK



TYPE – DISTANCE AND SENSITIVITY REFERENCE BLOCK

WI-PA-08-001
Revision 1
March 17, 2008
Page 17 of 24



General Notes:

- The dimensional tolerance between all surfaces involved in referencing or calibrating shall be within ± .005 in. [0.13 mm] of detailed dimension.
- The surface finish of all surfaces to which sound is applied or reflected form shall have a maximum of 125 μin. [3 μm] r.m.s.
- All materials shall be ASTM A 36 or acoustically equivalent.
- All holes shall have a smooth internal finish and shall be drilled 90° to the material surface.
- Degree lines and identification markings shall be indented into the material surface so that permanent orientation can be maintained.
- Other approved reference blocks with slightly different dimensions or distance calibration slots are permissible (see Annex X).
- These notes shall apply to all sketches in Figures 6.22 and 6.23.

Figure 7.4 – International Institute of Welding (IIW) UT Reference Blocks

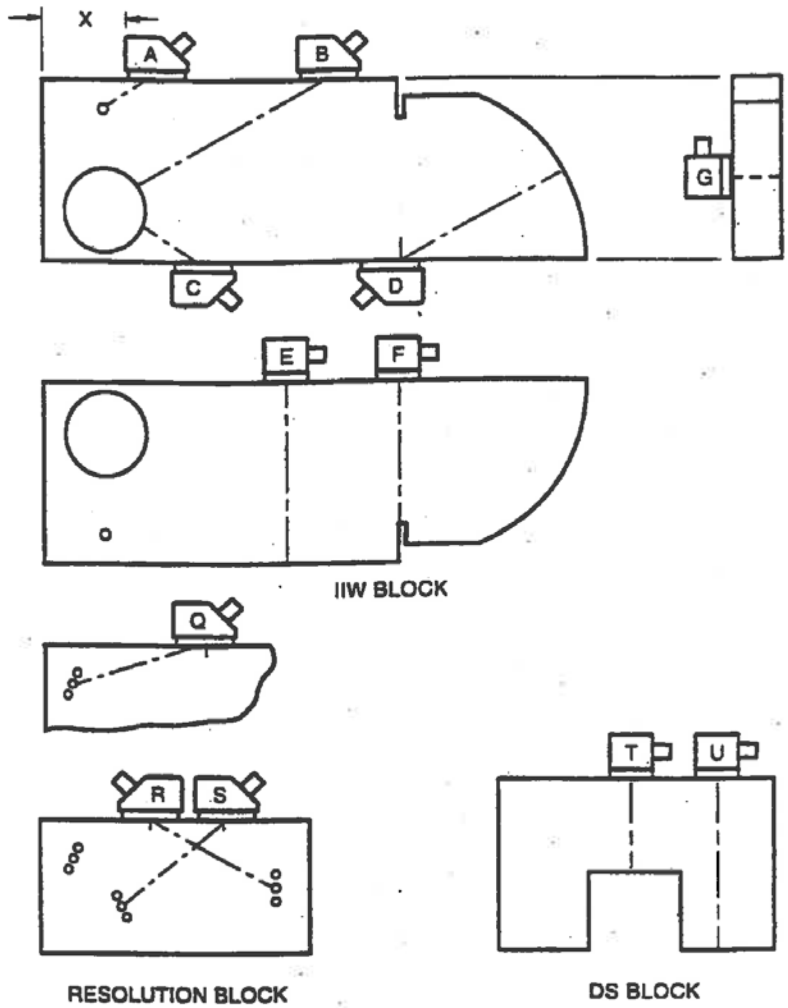


Figure 7.4.1- Transducer Positions (Typical)

Table 6.2

UT Acceptance-Rejection Criteria (Statically Loaded Nontubular Connections) (see 6.13.1 of AWS D1.1)

Weld Thickness[1] in in. [mm] and Search Unit Angle

Discontinuity Severity Class	5/16 through 3/4 [8-20]	>3/4 through 1-1/2 [20-38]	> 1-1/2 through 2-1/2 [38-65]			> 2-1/2 through 4 [65-100]			> 4 through 8 [100-200]		
	70°	70°	70°	60°	45°	70°	60°	45°	70°	60°	45°
Class A	+5 &	+2 &	-2 &	+1 &	+3 &	-5 &	-2 &	0 &	-7 &	-4 &	-1 &
	lower	lower	lower	lower	lower	lower	lower	lower	lower	lower	lower
Class B	+6	+3	-1	+2	+4	-4	-1	+1	-6	-3	0
			0	+3	+5	-3	0	+2	-5	-2	+1
Class C	+7	+4	+1	+4	+6	-2 to	+1	+3	-4 to	-1 to	+2
			+2	+5	+7	+2	+2	+4	+2	+2	+3
Class D	+8	+5	+3	+6	+8	+3	+3	+5	+3	+3	+4
	& up	& up	& up	& up	& up	& up	& up	& up	& up	& up	& up

General Notes:

- Class B and C discontinuities shall be separated by a least 2L, L being the length of the longer discontinuity, except that when two or more such discontinuities are not separated by a least 2L, but the combined length of discontinuities and their separation distance is equal to or less than the maximum allowable length under the provisions of Class B or C, the discontinuity shall be considered a single acceptable discontinuity.
- Class B and C discontinuities shall not begin at a distance less than 2L from weld ends carrying primary tensile stress, L being the discontinuity length.
- Discontinuities detected at "scanning level" in the root face area of CJP double groove weld joints shall be evaluated using an indicating rating 4 dB more sensitive than described in 6.26.6.5 when such welds are designated as "tension welds" on the drawing (subtract 4 dB from the indication rating "d"). <u>This shall not apply if the weld joint is backgouged to sound metal to remove the root face and MT used to verify that the root face has been removed.</u>
- ESW or EGWs: discontinuities detected at "scanning level" which exceed 2 in [50 mm] in length shall be suspected as being piping porosity and shall be further evaluated with radiography.
- For indications that remain on the display as the search unit is moved, refer 6.13.1.

Note:
1. Weld thickness shall be defined as the nominal thickness of the thinner of the two parts being joined.

Class A (large discontinuities)

Any indication in this category shall be rejected (regardless of length).

Class B (medium discontinuities)

Any indication in this category having a length greater than ¾ in. [20 mm] shall be rejected.

Class C (small discontinuities)

Any indication in this category having a length greater than 2 in. [50 mm] shall be rejected.

Class D (minor discontinuities)

Any indication in this category shall be accepted regardless of length or location in the weld.

Scanning Levels	
Sound path[2] in in. [mm]	Above Zero Reference, dB
through 2-1/2 [65 mm]	14
>2-1/2 through 5 [65-125 mm]	19
>5 through 15 [125-250 mm]	29
>10 through 15 [250-380 mm]	39

Note:
2. This column refers to sound path distances; NOT material thickness.

Class A (large discontinuities)
Any indication in this category shall be rejected (regardless of length).

Class B (medium discontinuities)
Any indication in this category having a length greater than ¾ in. [20 mm] shall be rejected.

Class C (small discontinuities)
Any indication in this category having a length greater than 2 in. [50 mm] in the middle half or ¾ in [20 mm] length in the top or bottom quarter of weld thickness shall be rejected.

Class D (minor discontinuities)
Any indication in this category shall be accepted regardless of length or location in the weld.

Scanning Levels	
Sound path[2] in in. [mm]	Above Zero Reference, dB
through 2-1/2 [65 mm]	20
>2-1/2 through 5 [65-125 mm]	25
>5 through 15 [125-250 mm]	35
>10 through 15 [250-380 mm]	45

Note:
2. This column refers to sound path distances; NOT material thickness.

Table 6.7
Testing Angle
Procedure Chart
Material Thickness in. [mm]

Weld Type	5/16 [8] to 1-1/2 [38]		>1-1/2 [38] to 1-3/4 [45]		>1-3/42 [45] to 2-1/2 [60]		>2-1/2 [60] to 3-1/2 [90]		>3-1/2 [90] to 4-1/2 [110]		>4-1/2 [110] to 5 [130]		>5 [130] to 6-1/2 [160]		>6-1/2 [160] to 7 [180]		>7 [180] to 8 [200]	
	*		*		*		*		*		*		*		*		*	
Butt	1	0	1	F	1G or 4	F	1G or 5	F	6 or 7	F	8 or 10	F	9 or 11	F	12 or 13	F	12	F
T-	1	0	1	F or XF	4	F or XF	5	F or XF	7	F or XF	10	F or XF	11	F or XF	13	F or XF	---	---
Corner	1	0	1	F or XF	1G or 4	F or XF	1G or 5	F or XF	6 or 7	F or XF	8 or 10	F or XF	9 or 11	F or XF	13 or 14	F or XF	---	---

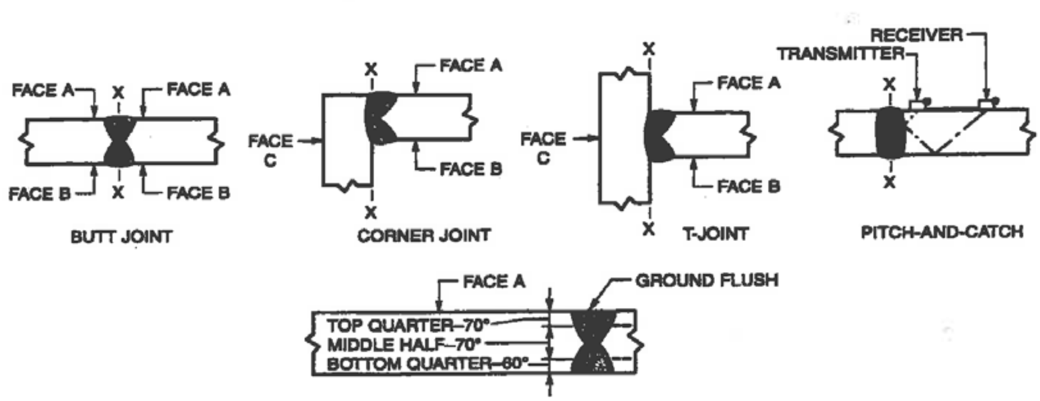


Table 6.7 (Continued)		
Legend:		
X	–	Check from Face "C".
G	–	Grind weld face flush.
O	–	Not required.
A Face	–	The face of the material from which the initial scanning is done (on T – and corner joints, follow above sketches).
B Face	–	Opposite the "A" face (same plate).
C Face	–	The face opposite the weld on the connection member or a T – or corner joint
*	–	Required only where display reference height indication of discontinuity is noted at the weld metal-base metal interface while searching at scanning level with primary procedures selected from first column.
**	–	Use 15 in. [400 mm] or 20 in. [500 mm] screen distance calibration.
P	–	Pitch and catch shall be conducted for further discontinuity evaluation in only the middle half of the material thickness with only 45° or 70° transducers of equal specification. Both facing the weld. (Transducers must be held in a fixture to control positioning – see sketch.) Amplitude calibration for pitch and catch is normally made by calibration a single search unit. When switching to dual search units for pitch and catch inspection, there should be assurance that this calibration does not change as a result of instrument variables.
F	–	Weld metal – base metal interface indications shall be further evaluated with either 70°, 60°, or 45° transducer- whichever sound path is nearest to being perpendicular to the suspected fusion surface.

General Notes:

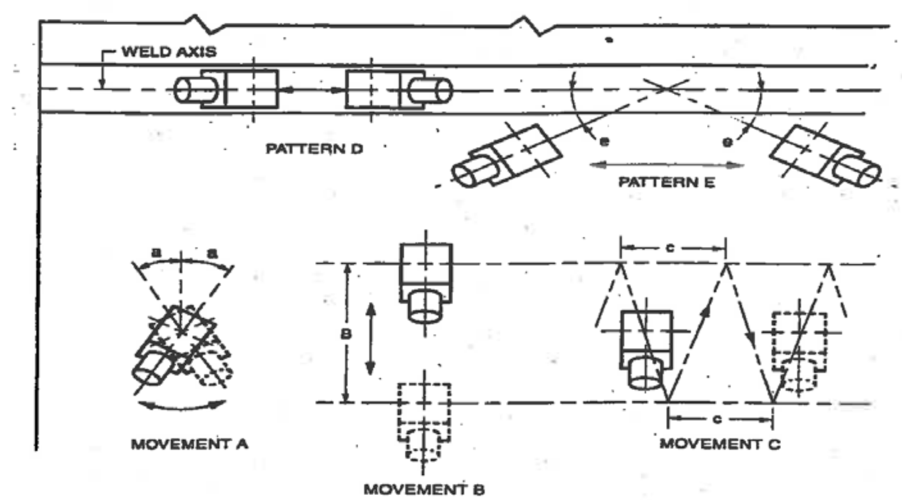
- Where possible, all examinations shall be made from Face A and n Leg 1, unless otherwise specified in this table.
- Root areas of single groove weld joints which have backing not requiring removal by contract, shall be tested in Leg 1, where possible, with Face A being that opposite the backing. (Grinding of the weld face or testing from additional weld faces may be necessary to permit complete scanning of the weld root.)
- Examination in Leg II or III shall be made only to satisfy provisions of this table or when necessary to test weld areas made inaccessible by an unground weld surface, or interference with other portions of the weldment, or to meet the requirements of 6.26.6.2.
- A maximum of Leg III shall be used only where thickness or geometry prevents scanning of complete weld areas and HAZs in Leg I or Leg II.
- On tension welds in cyclically loaded structures, the top quarter of thickness shall be tested with the final leg of sound progressing from Face B toward Face A, the bottom quarter of thickness shall be tested with the final leg of sound progressing Face A toward Face B; i.e., the top quarter of thickness shall be tested either from Face A in Leg II or from Face B in Leg I at the contractor's option, unless otherwise specified in the contract documents.
- The weld face indicated shall be ground flush before using procedure 1G, 6, 8, 9, 12, 14 or 15. Face A for both connected member shall be in the same plane.

(See Legend on next page)

Procedure Legend

No.	Area of Weld Thickness: Top Quarter	Middle Half	Bottom Quarter
1	70°	70°	70°
2	60°	60°	60°
3	45°	45°	45°
4	60°	70°	70°
5	45°	70°	70°
6	70°G A	70°	60°
7	60°B	70°	60°
8	70°G A	60°	60°
9	70°G A	60°	45°
10	60° B	60°	60°
11	45° B	70°**	45°
12	70°G A	45°	70° G B
13	45° B	45°	45°
14	70°G A	45°	45°
15	70°G A	70°A B	70° G B

Figure 9.6 Plan View of UT Scanning Patterns



WI-PA-08-001
Revision 1
March 17, 2008
Page 23 of 24

General Notes:

- Testing patterns are all symmetrical around the weld axis with the exception of pattern D, which shall be conducted directly over the weld axis.
- Testing from both sides of the weld axis shall be made wherever mechanically possible.

REPORT OF ULTRASONIC INSPECTION

TESTED FOR:	**PROJECT:**
	P.O. NO.:
DATE:	**REPORT NO.:**

Client Order No.	Length:	Ultrasonic Unit: Serial No.:
Test Method Standard:	Thickness:	Location:
Acceptance Standard:		

Weld Identification	Meets Code	Fails Code	Procedure Legend No.	Indication Number	Transducer Angle	From Face	Leg *	Decibels** Indication a	Reference b	Attenuation c	Indication d	Discontinuity Length	Angular Distance h)	Depth From "A"	Distance From	From

Couplant:		Frequency:	
Calibration Blocks:		Surface Condition:	
Technician:	Level: II	Interpreter:	Level:

**Gain in DB a – b – c = d	**Attenuation in DB b – a – c = d

WI-PA-08-001
Revision 1
March 17, 2008
Page 24 of 24

This report shall not be reproduced except in full without the written approval of the laboratory.

Reviewed by: ____________________________
Date:____________________________________
Is this test within the scope of the A2LA certification? _X_ YES ___ NO

Revised Form NDTG-0004
August 20, 2003
mic

Appendix G-2.6.2 TUV Rheinland Industrial Solutions Procedure TRIS NDE-VT-4, Rev No. 0
Visual Inspection Technical Publications T9074-AS-GIB 010/271

PROCEDURE	TRIS NDE-VT-4	TÜVRheinland® Industrial Solutions
VISUAL INSPECTION [redacted] TECHNICAL PUBLICATION T9074-AS-GIB 010/271		
Revision Number: 0	Issue Date: March 11, 2013	Page: 1 of 21

Prepared by: Randy Riegler
Corporate Level III

Reviewed and Approved by: Claude D. Davis
Technical Director
NDE Level III

Revision	Date	Description
0	March 11, 2013	Initial Issue

[redacted]

Printed: March 11, 2013 **Approved Documents Valid 2 Days**
Verify as current revision when invalid

[redacted]

TABLE OF CONTENTS

VISUAL INSPECTIONS
NDE-VT-4

1.0 SCOPE

The general intent of the procedure is to meet or exceed the requirements established in T9074-AS-GIB-010/271. The visual inspection process is to determine that all welds and adjacent base materials be inspected as required to comply with applicable procedures, drawings, and fabrication documents. The visual inspection process shall include visual inspection for discontinuities, fit –up, and dimensional requirements in welds, and base metals. Visual inspection shall be performed prior to other nondestructive methods.

2.0 GENERAL

2.1 Type of Welds to be inspected

a. Full penetration welds
b. Attachment welds
c. Consumable insert welds
d. Seal welds
e. Hardfacing welds
f. Non-structural welds
g. Partial penetration welds, fillet welds and backing ring welds

2.2 Measuring devices

a. Scales
b. Fillet weld gauges
c. Feeler gauges
d. Calipers
e. Micrometers
f. Templates
g. Other calibrated measuring devices, as necessary to disposition welds

2.3 Inspection methods

a. Visual – no magnification
b. Visual 5 to 10 times magnification (see 5.2)
c. Lighting should be sufficient to perform proper evaluation – roughly 50 foot-candles (see 5.3)

2.4 Weld attributes to be inspected:

a. Weld preps – fit-up and dimensional
b. Each Layer - dimensional
c. Base material – 1/2 inch each side of welded joint
d. Discontinuities – as listed in section 4.0 as applicable

[redacted]

2.5 Record requirements - Visual inspection results will be reported to the customer on the appropriate inspection report. This report shall as a minimum contain the following:

a. Description and unique identification of item inspected
b. Approved procedure identification
c. Acceptance standard used
d. Date of inspection
e. Signature of inspectors
f. Disposition (accept/reject) of the item inspected

3.0 PERSONNEL

3.1 All visual inspections shall be conducted by personnel certified in accordance with TRIS NDE-PQ-1, as modified by [redacted] Technical Publication T904-AS-GIB-010/271.

3.2 Visual examination personnel shall have an annual visual examination to assure natural or corrected near distance acuity such that they are capable of reading standard J-1 letters on standard Jaeger test type charts for near vision or equivalent methods.

3.3 The final visual inspection procedure and/or any subsequent revisions must be approved by a cognizant Level III prior to implementation of the procedure.

4.0 WELD ATTRIBUTES

4.1 **Arc Strike:** Any localized heat affected zone or change in the contour of the surface of the finished weld or adjacent base metal resulting from an arc or heat generated by the passage of electrical energy between the surface of the finished weld or base metal and a current surface, such as welding electrodes, magnetic particle inspections prods, etc.

4.2 **Burn –Through:** A void or open hole extending into a backing ring or strip, fused root, or adjacent metal. The adjacent metal may be either base metal.

4.3 **Crack or Tear:** A linear rupture or metal under stress.

4.4 **Crater Pit:** An approximately circular surface condition extending into the weld in an irregular manner such as from the inside diameter surface of a fused root insert.

4.5 **Incomplete Fusion:** Lack of complete fusion of some portion of the metal in a weld joint with adjacent metal. The adjacent metal may be either base metal or previously deposited weld metal, or consumable insert.

4.6 **Melt Through:** A convex or concave irregularity on the surface of a backing ring or strip, fused root, or adjacent base metal resulting from fusion completely through a localized region but without development of a void or open hole.

4.7 **Oxidation:** A condition resulting from partial or complete lack of inert gas shielding of a surface which is heated during welding resulting in formation of oxide on the surface. This condition may range from slight oxidation through the formation of a tightly adhering black film to the extreme of a very rough surface having a crystalline appearance.

4.8 **Porosity:** Gas pockets or voids in a weld or casting.

4.9 **Root Surface Concavity:** A depression on the root surface of a weld, which may be due to gravity, internal purge or shrinkage.

4.10 **Root Surface Convexity:** Reinforcement on the root surface of a weld.

4.11 **Root Surface Center Line Crease or Shrinkage:** An intermittent or continuous peripheral centerline concavity formed on the root surface.

4.12 **Slag:** Non-metallic solid material entrapped between beads of weld metal or between weld metal and base metal in casting.

4.13 **Undercut:** A groove melted into the base metal at the toe of the weld and left unfilled by weld metal.

4.14 **Root Undercut:** A groove in the internal surface of a base metal or backing ring or strip along the edge of the roof of the weld.

4.15 **Weld Spatter:** Material particles which deposit on the surface of the weld or adjacent base metal during welding and which do not form a part of the weld.

4.16 **Linear Indication:** Indication greater than 1/16" long, revealed NDT inspections whose length is equal to or greater than three times it's width.

4.17 **Non-Linear or Rounded Indications:** Indication revealed by NDT inspections whose length is less than three times its width.

4.18 **Build Up:** Buildup is a surfacing variation which surfacing metal is deposited to restore base material or weld surface dimensions.

4.19 **Buttering:** Buttering is a surface variation that deposits surfacing metal on one or more surfaces to provide compatible weld metal for the subsequent completion of the weld.

4.20 **Cladding:** Cladding is a surfacing variation that deposits or applies surfacing materials, usually to improve corrosion or heat resistance.

4.21 **Wormhole Porosity:** Wormhole porosity refers to gas inclusions having an elongated form known as "wormholes" or "pipes" usually oriented almost perpendicular to the weld surface.

4.22 **Re-Entrant Angle:** A re-entrant angle is one, which the angle formed between the base plate and weld, at the weld edge, is less than 90 degrees.

4.23 **Back Gouge:** A back gouge consists of the preparation of the backside of the root layer or full penetration welds to the extent necessary to permit proper deposition of weld metal from the second side.

4.24 **Completed Weld:** Welding is completed when preheat is removed and the material has cooled to ambient temperature and the weld has been visually accepted and is ready for other NDT inspections.

4.25 **Weld Contour:** Weld contour is the surface profile of a weld in the as-deposited condition or after preparation to meet workmanship or NDT requirements.

Note: See Figures 1, 2, 3 and 4 for typical dimensional fit-up attributes.

5.0 GENERAL INSPECTION REQUIREMENTS

5.1 The inspector's eyes must be within 24 inches and not more than 30 degrees to the surface area to be examined.

5.2 Visual inspection need not be performed employing magnification, unless otherwise specified in the applicable fabrication document. When a reference standard is required and magnification, such as a borescope or magnifying glass is employed, evaluation and acceptance shall be based upon comparison with a reference standard where both magnified and unmagnified appearance can be determined.

5.3 The weld under examination shall be illuminated if necessary with a flashlight or other auxiliary lighting for proper evaluation.

5.4 To prove the examination procedure a fine line 1/32" or less in width or some other artificial flaw located on the surface or similar surface to that to be examined shall be discernible. The line or artificial flaw should be in the least discernible location on the area examined to prove the procedure.

6.0 EVALUATION AND REPORTING

Visual inspection results will be reported to the customer on the appropriate visual inspection form. Evaluation of items inspected in accordance with this procedure is performed in accordance with customer requirements and referenced specification.

7.0 ACCEPTANCE CRITERIA MIL-STD-2035A (SH)

Visual inspection shall be performed prior to other required nondestructive tests. Welds, castings, and wrought materials shall meet the requirements of the applicable fabrication document or material specifications, and, unless otherwise specified, the following standards shall apply:

7.1 Welds: And grinding or other mechanical operation performed on welds shall be performed so that the thickness of the weld and its adjacent base metal are not reduced below the minimum design thickness or the minimum drawing thickness, whichever is greater.

7.2 Shape of the weld face: Welds shall be free of sharp irregularities between weld beads and shall blend smoothly and gradually into the base metal at the weld edges without exceeding the undercut or re-entrant angle limits of this procedure. Irregularities in contour from localized burring, grinding, and similar mechanical operations are acceptable provided that they comply with the other requirements of this procedure.

7.3 Fillet: Fillet and fillet reinforced welds with an essentially flat contour are considered as meeting the minimum throat thickness, provided the minimum specified leg sizes have been met.

7.4 Root Contour: Full penetration welds made from one side, consumable insert, or nonpermanent backing ring pipe welds shall meet the root contour requirements of Table I.

[redacted]

TABLE I – Root Contour limits. [1]

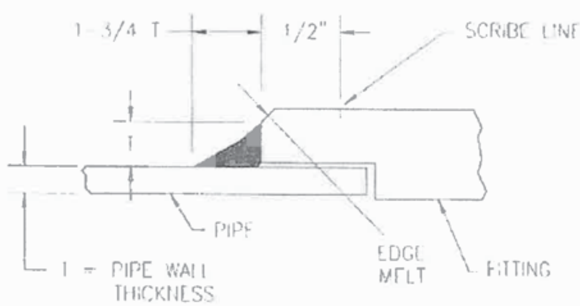
Condition	Material size (nominal)	Maximum (inch)
Convexity	Pipe less than 2 inches in diameter and other shapes less than 5/32 thick.	1/16 [2]
Convexity	Pipe 2 inches and over in diameter and other shapes 5/32 inch and over in thickness	3/32 [3]
Convexity	Pipe less than 2 inches in diameter and other shapes less than 5/32 thick	1/32
Convexity	Pipe 2 inches and over in diameter and other shapes 5/32 inch and over in thickness	1/16

[1]Except for centerline shrinkage or wrinkling, the contour of the root shall have a uniform radius and shall blend smoothly into the base metal. No concavity of contour is permitted unless the resulting thickness of weld metal is not less than the minimum thickness of the adjacent base metal.

[2]For copper-nickel and nickel-copper materials, the root convexity of consumable insert fabricated welds may exceed this amount, provided that: for pipe nominal sizes less than 2 inches, the maximum height of convexity shall not exceed 3/32 inch and the total length of all such areas shall not exceed 1 inch; for pipe nominal sizes 2 inches and greater, the maximum height of convexity shall not exceed 1/8 inch and the total length of all such areas shall not exceed 25 percent of the inside circumference of the pipe.

[3] In the event of joint offset, root surface concavity or convexity shall be measured from a line connecting the two points at which the weld meets the base material.

7.5 **Fillet weld size, piping only:** Fillet weld size, excluding seal welds, shall not be less t T x 1-3/4T unless otherwise specified by drawing. See drawing below.



7.6 **Fillet weld size, other than piping:** Fillet and fillet reinforced welds shall not be less than the drawing specified size. Weld sizes greater than required by the drawing are acceptable provided that they comply with the other requirements of this procedure.

7.7 **Butt welds:** Butt weld surfaces shall not be below the adjacent base material surfaces, except for the localized weld surface areas and weld toes (un-ground or corrected by grinding) that do not exceed the limitations for undercut of paragraph 7.21. Unless otherwise specified in the fabrication document, the final thickness of weld reinforcement on either weld face shall be as shown in table II.

TABLE II - Weld Reinforcements

Class	Base Metal Thickness (inch)	Maximum Reinforcement (inch)
1	Up to 1/4 , inclusive	1/16
	Over ¼ to 1	3/32
	Over 1 to 2	1/8
	Over 2	5/32
2 and 3	Up to ½, inclusive	3/32
	Over 1/2	5/32

7.8 **Joint Offset:** Unless otherwise specified in the fabrication document or by the applicable specification, the maximum permissible offset for all welded joints shall be as shown in table III.

TABLE III - Maximum Permissible Offset

Base Metal Thickness	Maximum Offset
¼ inch and less	25 percent of joint thickness
Over ¼ inch to ¾ inch	25 percent of joint thickness but not to exceed 1/8 inch
Over ¾ inch to 1 ½ inch	3/16 inch
Over 1 ½ inch	12 ½ percent of joint thickness, but not to exceed ¼ inch.

7.9 **Cracks:** Weld joints and base material shall be free of cracks.

7.10 **Burn-through:** Weld joints and base material shall be free of burn-through.

7.11 **Incomplete fusion:** Weld joints and base material shall be free of incomplete fusion.

[redacted]

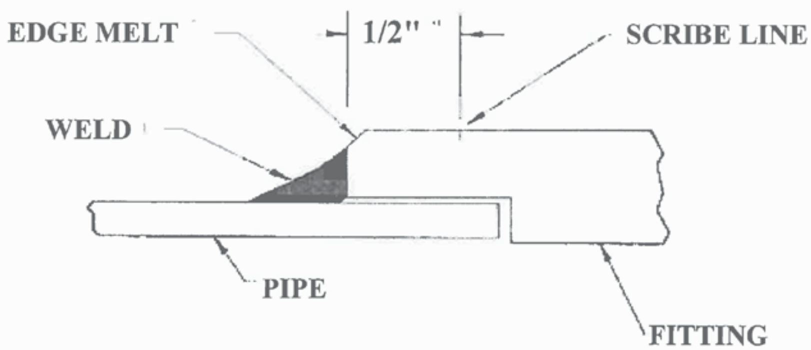
7.12 **Melt through:** Melt-through and repaired burn-through areas are acceptable provided the areas do not contain cracks, crevices, excessive oxidation, or globules, and provided the root convexity and concavity limits are not exceeded.

7.13 **Crater Pits:** Crater pits are considered acceptable provided the area contains no cracks, the root concavity and convexity limits are not exceeded, and the minimum weld thickness requirement is met.

7.14 **Oxidation:** Welds and adjacent base metal shall be free of oxide scale accompanied by a wrinkled or crystalline surface appearance. Tightly adhering, iridescent temper films shall be considered acceptable.

7.15 **Porosity:** Individual pores cannot exceed 3/32 inch diameter or length. Pores the sum of whose diameters exceed 1/8 inch in any 2 inch length of weld are unacceptable. (Do not count pores 1/32 inch or less diameter.)

7.16 **Edge melt:** Pipe fitting edge-melt is acceptable provided the scribe line established as a reference for verifying fillet size is evident as show below:



7.17 **Arc strikes:** For applications covered by a fabrication document, in which treatment of arc strikes is detailed, arc strikes shall be removed and re-inspected as required therein. For other applications, arc strike removal sites within the allowances specified below are acceptable provided minimum thickness requirements (see paragraph 7.1) are met and all heat affected zones are removed.

Class 1. Welds and adjacent base metal must be free of arc strikes. Where arc strikes are removed, the resulting cavities shall not exceed 1/64 inch in depth or 10 percent of the adjacent base metal thickness, whichever is less, and shall blend smoothly into the base metal.

Class 2 and 3. Welds and adjacent material must be free of arc strikes. Where arc strikes are removed, the resulting cavities shall not exceed 1/32 inch in depth or 10 percent of the adjacent base metal thickness, whichever is less, and shall blend smoothly into the base metal.

7.18 **Gouges, grind marks and surface roughness:** Localized discontinuities within the specified below are acceptable provided that minimum thickness requirements (see paragraph 7.1) are met, and the bottom of the depression is visible and rounded or free of notches. The length of the discontinuity shall be limited to 12 inches maximum except for piping and pressure vessels where the maximum length shall be 12 inches or ¼ of the circumference, whichever is less.

Class 1. Welds and adjacent base metal shall be free of localized discontinuities which exceed a depth of 1/64 inch or 10 percent of the adjacent base metal thickness, which-ever is less.

Class 2 and 3. Welds and adjacent base metal shall be free of localized discontinuities, which exceed a depth of 1/32 inch on materials less than ½ inch in thickness and 1/16 inch on materials ½ inch and thicker.

7.19 Weld Spatter

Class 1. Welds and adjacent base material shall be free of weld spatter.

Class 2 and 3. Weld spatter which can be removed with a hand wire brush is rejectable. Tightly adhering spatter 1/8 inch or less in diameter or length is acceptable except for the following circumstances, wherein the inspection area shall be free of spatter: if PT, UT, or RT is required; on internal surfaces on closed systems; and on surfaces which are to be wetted.

7.20 Slag

Class 1. Welds and adjacent base material shall be free of slag.

Class 2 and 3. Tightly adhering slag, that which cannot be removed by a slag pick or hand wire brush, is permissible unless the weld requires MT, PT, RT, or UT. If MT, UT, or RT is required, slag or scale 1/8 inch or less is allowed provided it does not interfere with test interpretation. If PT is required, the weld shall be free of slag. NOTE: Slag shall not interfere with the evaluation of other visible attributes. Additionally, background surfaces shall be free of slag prior to depositing subsequent passes.

7.21 Undercut

Class 1. The maximum depth of undercut measured from the unground adjacent base metal surface shall not exceed 1/64 inch or 10 percent of the minimum thickness (see paragraph 7.1), whichever is less.

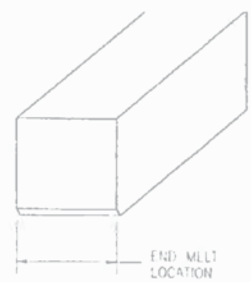
Class 2 and 3. The maximum undercut shall be 1/32 inch or 10 percent of the minimum thickness (see paragraph 7.1), whichever is less. For base metal thickness ½ inch or greater, undercut up to 1/16 inch is allowed if the accumulated length of undercut exceeding 1/32 inch does not exceed 15 percent of the joint length or 12 inches in any 36 inch length of weld, whichever is less.

[redacted]

7.22 End-melt: When undercut exists at the ends of attachment welds (see below), the following undercut requirements apply. Note that the plan requirement for weld size shall be maintained after grinding or machining.

Class 1. Maximum depth, measured from the un-ground adjacent base metal surface, shall not exceed 1/64 inch or 10 percent of the adjacent base metal's nominal thickness, whichever is less.

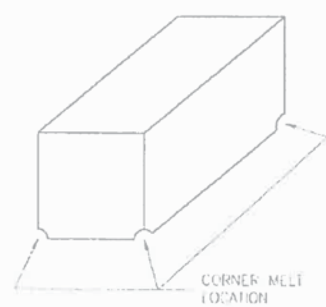
Class 2 and 3. For welds across the end of a ¼ inch thick or less member, the maximum as-welded end-melt is 1/16 inch. If end –melt is greater than 1/16 inch and less than or equal to 3/32 inch, it may be repaired by mechanical means to a maximum depth of 3/32 inch.



7.23 Corner-melt: When undercut exists at the corner of attachment welds (see below), the following undercut requirements apply. Note that the plan requirement for weld size shall be maintained after grinding or machining.

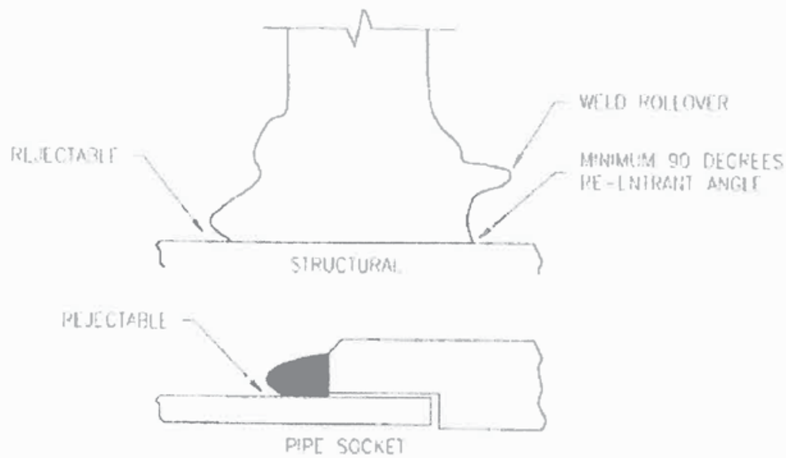
Class 1. Maximum depth, measured from the un-ground adjacent base metal surface, shall not exceed 1/64 inch or 10 percent of the adjacent base material's nominal thickness, whichever is less.

Class 2 and 3. For welds at the corner of attachment welds, the maximum as-welded corner-melt is 1/16 inch. If the corner-melt is greater than 1/16 inch and less than or equal to 3/32 inch, it may be repaired b mechanical means to a maximum depth of 3/32 inch.



[redacted]

7.24 **Re-entrant angle:** The angle formed between the base plate and the toe of the weld and the angle formed between adjacent beads of weld must be 90 degrees or greater. Weld rollover near the base material is acceptable provided the weld is completely fused and the final re-entrant angle to the base material is a minimum of 90 degrees as shown below.



7.25 **Paint:** Welds shall be essentially free of paint, except that indications of paint 1/8 inch and smaller are acceptable after normal removal operations. If PT is required, the inspection area shall be free of paint.

7.26 **Castings:** Casting surfaces shall meet the requirements of the applicable material specification.

7.27 **Wrought materials (pipes, bars, plates, forgings, and extrusions):** Wrought material shall be visually inspected in accordance with the applicable material specification.

7.28 **Bronze propellers:** Visual inspection acceptance standards for bronze propeller shall be in accordance with Table IV.

TABLE IV – Acceptance standards for inspection of bronze propellers [9]

Location of discontinuities	Type of discontinuities[2]	Maximum acceptable discontinuity size (inches)[1, 3]	Discontinuity Acceptance Standards: 6 x 6 Area of concentration[6, 7] Maximum No. [8, 9]	Discontinuity Acceptance Standards: Maximum spacing between aligned discontinuities[4, 5]	Allowable areas of concentration
CASTINGS					
A band located around the periphery of each blade on both the pressure and suction faces with a width equal to 10 percent of the width of the blade measured at the 0.6 radius, but not to exceed 6 inches; and an area measured from (and including) the hub fillet to 0.4 radius on the pressure face only.	Non-linear	1/8	20	D	5 percent of propeller surface area with distribution limited by a maximum of 5 percent for each blade surface.
	Linear	1/8	6	4D	
The remaining surfaces of the blades	Non-linear	1/8	20	D	
	Linear	¼	8	4D	
Hub outside diameter (OD)	Non-linear	¼	15	D	
	Linear	3/8	6	4D or 1 inch, whichever is less	
WELDMENTS					
All surfaces	Non-linear	1/16	12	4D	5 percent of total weld area
	Linear	0	0	-	

[1]Liquid penetrant inspection shall be performed as an aid to visual inspection in locating discontinuities. Only discontinuity size shall be used as a basis for rejection.

[2] A linear discontinuities one in which the length is greater than or equal to three times the width.

[3] Any linear discontinuity over 1/16 inch in length located within a peripheral band 1 inch wide; and whose major dimension is oriented normal to the blade edge, shall be repaired.

[4] Maximum spacing is the distance separating two adjacent discontinuities in terms of the major dimensions of the larger discontinuity (D). Aligned non-linear discontinuities shall consist of four or more discontinuities in a line. Aligned linear discontinuities shall consist of two or more discontinuities whose major dimensions are oriented in a line. However, when the total length of the aligned discontinuities does not exceed the maximum length permitted for a single discontinuity, these aligned discontinuities shall be considered one discontinuity, and shall not be cause for rejection.

[redacted]

[5] When the major dimension of clustered discontinuities does not exceed the maximum size permitted for a single discontinuity, these clustered discontinuities shall be considered as one discontinuity and shall not be cause for rejection. Scattered discontinuities, separated from the cluster by 1/8 inch or more, shall not be considered part of the cluster.

[6]Randomly dispersed casting discontinuities whose major dimensions are 1/16 inch or less shall not be counted in determining total number of discontinuities within an area of concentration.

[7]More than six discontinuities whose major dimensions are greater than 3/32 inch, in any 6 by 6 inch area of the propeller surface constitute an area of concentration. Each area of concentration shall be separated from an adjacent area of concentration by a minimum of 18 inches.

[8]The total number of non-linear discontinuities may be increased to the combined total, or part thereof, represented by the absence of linear discontinuities.

[9]For used propellers not originally inspected to the requirements of this standard, the allowable number of discontinuities in each area of concentration may be increased by 15 percent for each blade surface, and the minimum spacing between adjacent aligned linear discontinuities may be reduced to 2D provided that: (a) the discontinuities do not exceed the limits of any other requirements of this procedure, and (b) the discontinuities have shown no deleterious effects in service.

8.0 EVALUATION OF WELDS AND BASE METAL PER MIL-STD-1698A

8.1 **Welds:** VT inspection of welds shall be done after slag removal and with the weld in the final surface condition. Surfaces which have been cleaned and painted with one coat of primer are considered suitable for inspection.

8.2 **Base Material:** The surfaces to be inspected shall be in a clean condition (free of scale). Surfaces which have been cleaned and painted with one coat of primer of primer considered suitable for inspection.

9.0 ACCEPTANCE CRITERIA MIL-STD-1689A

9.1 Discontinuities that exceed the limits specified herein shall be rejected. Unless otherwise specified, the inspection zone shall include the weld face and ½ inch of adjacent base material.

9.2 **Cleanliness:** Welds inspected for final acceptance shall be free of slag, paint and weld metal spatter in excess of 1/8 inch length or diameter.

9.3 **Weld Surface Uniformity:** The weld surface shall be free of sharp irregularities deeper than 1/16 inch between beads and shall fair into the base material at the weld edges without undercut or overlap (rollover) in excess of the requirements of this standard. Surface roughness, burn through, melt through, oxidation and crater pits shall not exceed the acceptance criteria of MIL-STD-2035A (SH).

9.4 Shape of Fillet Weld Face: Fillet and fillet reinforced welds shall be essentially flat (minus 1/16 inch to plus 3/16 inch of a line drawn toe to toe). Weld concavity is acceptable provided the minimum throat thickness is at least equal to the minimum specified leg multiplied by 0.7 (see figure 4). Excessive roughness at weld edges and re-entrant angles less than 90 degrees, as shown in Figure 4, shall be corrected.

9.5 Arc Strikes: Arc strikes up to and including 1/32 inch depth are acceptable without repair. Arc strikes in excess of 1/32 inch in depth shall be rejected.

9.6 Cracks: Cracks shall be removed.

9.7 Porosity: Only pores greater than 1/32 inch in diameter shall be evaluated. No single pore shall be greater than 3/32 inch in length or diameter. The sum of pore diameters in any 2 inch weld length shall not exceed 3/16 inch. Porosity requirements for fillet welds on primer-coated surfaces shall in accordance with 9.7.1.

9.7.1 Fillet Welds on Primer Coated Surfaces: Fillet welds deposited on primer coated surfaces shall not exhibit porosity or wormholes in excess of the following:

(a) Single-pass fillet welds: One indication 1/32 inch or greater in any 6 inch length exclusive of weld crater porosity.

(b) Multi-pass fillet welds: [redacted] Class 1, Figure 4 medium, shall apply for gouged surfaces. If VT inspection of the first pass deposited is performed in lieu of gouging, the acceptance standard for the first pass shall be as defined in (a) above.

9.8 Undercut, End Melt, and Corner Melt: Undercut, end melt, and corner melt shall not exceed the limitations detailed in Table V. The depth of undercut or grinding shall be measured from the un-ground base material adjacent to the weld.

Table V – Undercut, End Melt and Corner Melt

Submarine pressure hull structure and surface ship primary hull structure				
Condition	Base metal thickness Inch	Maximum depth as-welded condition Inch	Maximum depth/length after grinding, Inch	
			Depth	Length Restriction
Undercut	Under ½	1/32	1/32	None
	½ and over	1/32	1/32	None
	½ and over	1/32	1/16	[1]
End Melt[2]	¼ and under	1/16	3/32	Only at ends of a member
Corner Melt	All	1/16	3/32	Only at corners of a member
Other Structures				
Undercut	Under ½	1/16	1/16	None
	½ and over	1/16	1/16	None
	½ and over	1/16	3/32	[1]
End melt[2]	¼ and under	3/32	1/8	Only at ends of a member
Corner melt	All	3/32	1/8	Only at corners of a member

[1] The accumulated length does not exceed either 15 percent of the joint length or 12 inches in any 36 inch length of welding, whichever is less.

[2] For base metal thicknesses greater than ¼ inch, undercut requirements apply.

9.9 Weld Size:

9.9.1 Groove Tee and Fillet Welds: Groove tee fillet reinforced welds shall be at least equal to the size specified on the drawing (except as allowed by 9.11). When fillet size must be increased as a result of excessive gap between members at the time of fit-up, the fillet size shall be increased as required by MIL-STD-1689, Paragraph 14.3. Weld size in excess of that required is acceptable provided the contour requirements of 9.4 are satisfied.

9.9.2 **Butt-Welds:** Butt weld surfaces shall not be below the adjacent plate surfaces, except localized weld surface indication areas and weld toes, un-ground or corrected by grinding, that do not exceed the depth limitations for undercut of 9.8. The as-deposited surfaces at the weld edge shall be satisfactory, provided they do not form a re-entrant angle less than 90 degrees with the base plate due to excessive convexity or roll-over. Butt welds ground for hydrodynamic purposes shall not extend more than 1/16 inch above the adjacent plate surfaces. Otherwise, butt weld reinforcement shall not require a maximum height limitation provided the surface condition is uniform. In the case of butt welds joining plates of unequal thickness, the weld shall taper gradually, approximately four to one, from the beveled edge of the thicker plate surface to the thinner plate. No point of the finished tapered butt weld surface shall be below a line from the edges of the weld joint preparation except for allowable undercut. Otherwise, butt weld reinforcement shall not require a maximum height limitation provided all other requirements of this section are met.

9.10 **Seal-Off and Wrap-Around Welding:** Fillet and fillet reinforced partial penetration welds shall be sealed off with weld at end(s) of members (flat bars, angles, channels, and tees) to form a closed loop where surfaces are to be wetted. Members which will not be wetted shall be sealed off when practical. When specified by a weld all-around symbol, the minimum weld reinforcement size shall be maintained (wrap around) at the end(s) of attached members. When the member is located per tolerances and the full size fillet weld (wrap around) is not obtainable, the maximum size obtainable shall be considered acceptable provided the above seal-off requirement in wetted areas is maintained.

9.11 **Contour Grinding:** When required, contour ground welds shall comply with the requirements of MIL-STD-1689, Paragraph 14.2. Contour grinding of fillet or partial penetration welds shall not be performed unless required by the ship specifications or drawings, or MIL-STD-1689, Paragraph 14.4; in which cases the fillet size requirements shall be maintained after contouring.

9.12 **Nicks, Gouges, and Other Fabrication Scars:** Nicks, gouges, and other fabrication scars in the weld inspection zone shall not exceed 1/32 inches in depth and 12 inches in length of materials less than ½ inch thick; and 1/16 inch in depth and 12 inches in length for materials equal to or greater than ½ inch thick.

9.13 **VT Inspection for Edge Laminations**

9.13.1 **Surface Ships:** Continuous laminations 8 inches or less in any 24 inch length, or discontinuous laminations in a straight line whose total length is 12 inches or less in any 24 inch length and with no single continuous laminations greater than 6 inches are acceptable. Edge laminations which exceed these limitations shall be repaired or the affected plate area replaced. Any laminations disclosed on exposed plate edges will not be covered by welding.

9.13.2 **Submarines:** Edge laminations visually detected in submarine plating shall be MT inspected.

9.14 **Circularity and Frame Dimensional Tolerances:** Submarine hill circularity and frame dimensions shall meet the requirements specified in MIL-STD-1688.

[redacted]

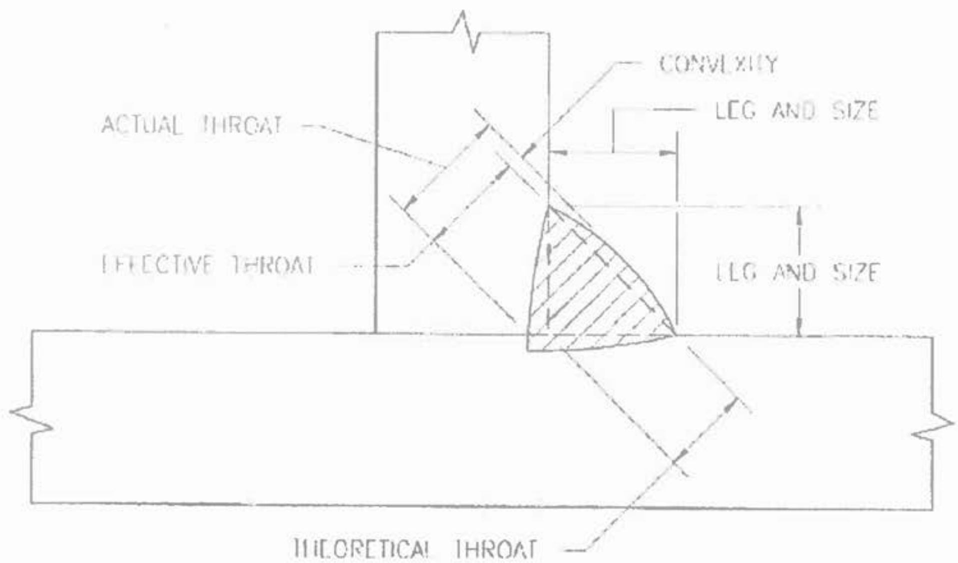


Figure 1. Convex Fillet Weld

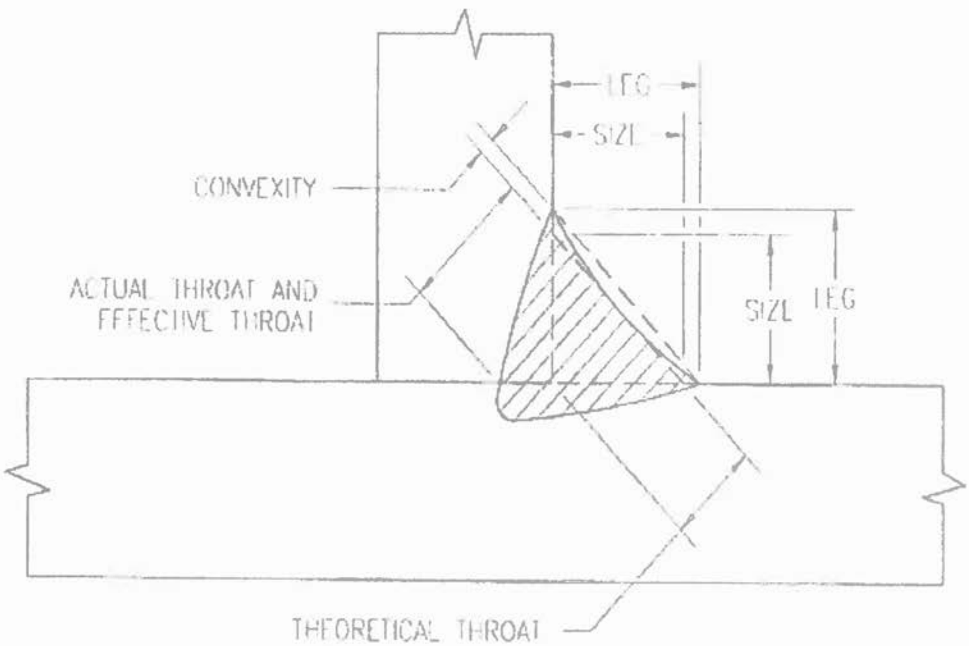
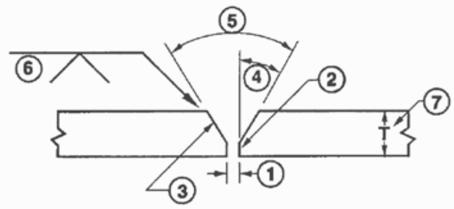
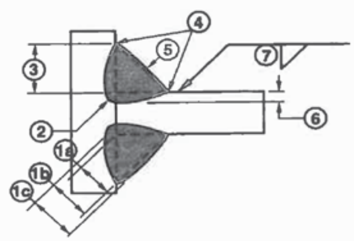


Figure 2. Concave Fillet Weld



1. ROOT OPENING: A separation at the joint root between the workpieces.
2. ROOT FACE: That portion of the groove face adjacent to the joint root.
3. GROOVE FACE: The surface of a joint member included in the groove.
4. BEVEL ANGLE: The angle formed between the prepared edge of a member and a plane perpendicular to the surface of the member.
5. GROOVE ANGLE: The total included angle of the groove between workpieces.
6. GROOVE WELD SIZE: The joint penetration of a groove weld.
7. PLATE THICKNESS (T): Thickness of the base metals to be welded.



1. FILLET WELD THROAT
   a. THEORETICAL THROAT: The distance from the beginning of the joint root perpendicular to the hypotenuse of the Largest right triangle that can be inscribed within the cross section of a fillet weld. This dimension is based on the assumption that the root opening is equal to zero.
   b. EFFECTIVE THROAT: The minimum distance minus any convexity between the weld root and the face of a fillet weld.
   c. ACTUAL THROAT: The shortest distance between the weld root and the face of the fillet weld.
2. WELD ROOT: The points, shown in a cross section, at which the root surface intersects the base metal surfaces.
3. FILLET WELD LEG: The distance from the joint root to the toe of the fillet weld.
4. WELD TOE: The junction of the weld face and the base metal.
5. WELD FACE: The exposed surface of a weld on the side from which welding was done.
6. DEPTH OF FUSION: The distance that fusion extends into the base metal or previous bead from the surface melted during welding.
7. FILLET WELD SIZE: For equal leg fillet welds, the lengths of the largest isosceles right triangle that can be inscribed within the fillet weld cross section. For unequal leg fillet welds, the leg lengths of the largest right triangle that can be inscribed with the fillet weld cross section.

Figure 3 Details of a Groove and Fillet Weld

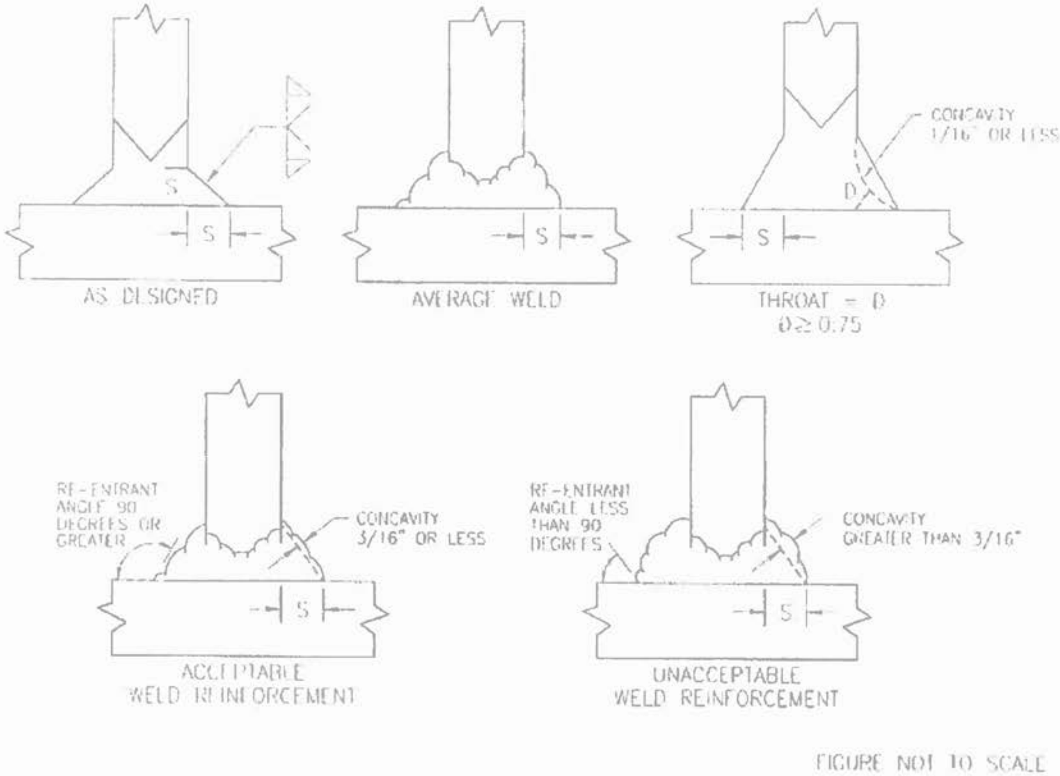


Figure 4. Typical Contour for Fillet Groove Tee Welds and Fillet Welds.

[redacted]

Appendix G-2.6.3 TUV Rheinland Industrial Solutions, Non-Destructive Testing Group, Work Instruction No. WI-08-001, Rev No. 1 Liquid Penetrant Examination

NDT Non•Destructive Testing Group Quality by Integrity and Knowledge	WORK INSTRUCTION	Number: WI-08-001
	Title: Liquid Penetrant Examination [redacted]	Rev. No. 1 Effective Date: **March 17, 2008**

REVISION RECORD

Revision 1 / March 17, 2008	Revised 16.0 (Acceptance Standards)
January 21, 2008	New Issue

[redacted]

Approved By: Robert D. Nichol, Level III   Date: 3/17/2008

SCOPE

1.1 This procedure specifies the methods, equipment, materials, personnel qualifications and acceptance standards for liquid penetrant examination of ferrous and nonferrous, nonporous materials, castings, forgings, weldments and other approved materials using portable penetrant inspection methods.

2.0 PERSONNEL

2.1 Personnel performing liquid Penetrant examinations shall be qualified and certified in accordance with NDTG-CTP-1 for the Qualification and Certification of Personnel.

2.2 Only those personnel Certified as a Liquid Penetrant Level II or Level III shall interpret indications for acceptance or rejection.

3.0 REFERENCES

3.1 WI-08-001 CONFORMS TO THE FOLLOWING REFERENCES

NDTG-PT-01	Liquid Penetrant Examination, Portable Applications
ASTM-E-1208	Fluorescent Liquid Penetrant Examination using the Lipophilic Post Emulsification Process.
ASTM-E-1209	Standard Test Method for Fluorescent Liquid Penetrant Examination using the Water-Washable Process.
ASTM-E-1316	Terminology for Non-Destructive Testing.
ASTM-E-1210	Standard Test Method for Fluorescent Liquid Penetrant Examination using the Hydrophilic Post-Emulsification Process.
ASTM-E-1417	Standard Practice for Liquid Penetrant Examination.
ASTM-E-165	Standard Test Method for Liquid Penetrant Examination.
ASME Section V	Liquid Penetrant Examination.
AWS D1.1	Structural Welding Code Steel.
AWS D1.2	Structural Welding Code Aluminum
AWS D1.5	Bridge Welding Code.

AWS D1.6	Structural Welding Code Stainless Steel
NDTG-PTQC-1	Quality Control of Penetrant Materials

3.2 All references will be of the latest revision.

4.0 GENERAL REQUIREMENTS

4.1 In order to perform liquid penetrant examination to this instruction, it will be necessary for the client to provide the following information:

4.1.1 Identity of the pieces to be inspected. This information should include project or contract designation, the component or piece mark, the weld joint, with respect to location on the component or piece, and the site.

4.1.2 Designate the extent of the examination; this should include the state of welding during which the examination is to be performed, as cast, finished, etc. This will include whether complete or spot examination is to be performed. Complete examination shall mean 100% coverage of all areas to be examined.

4.1.3 When inspecting welds, the examination shall include ½" of base metal, adjacent to the edges of the weld, for the entire length of the weld.

4.1.4 When spot welding is designated, the number, location and size of spots will be clearly specified by the client.

4.1.5 The Acceptance Standard to be used.

4.1.6 When applicable, the marking system required.

4.1.7 The client is to be responsible for any required surface conditioning unless otherwise specified by the contracts.

4.2 All components are to be processed in accordance with customer's requirements and specifications.

5.0 PENETRANT MATERIAL

5.1 Methods used for liquid penetrant examination may be Type I, flourescent or Type II, color contrast (visible) Penetrants.

5.1.1 Fluorescent penetrant examination shall not follow a color contrast penetrant examination.

5.1.2 Type II penetrants (Visible Dye) shall not be used for final acceptance examination of aerospace products.

5.2 Classification: Penetrant examination processes and materials are classified in accordance with the material classification contained in QPL-AMS-2644. Penetrant systems covered by this practice shall be of the following types, methods, and sensitivity levels:

5.2.1 Type:

5.2.1.1 Type I – Fluorescent Dye.

5.2.1.2 Type II – Visible Dye.

5.2.2 Method:

5.2.2.1 Method A – Water Washable.

5.2.2.2 Method C – Solvent-Removable.

5.2.3 Sensitivity – These levels apply to Type I penetrant systems only. Type II penetrant systems have only a single sensitivity and it is not represented by levels listed below:

5.2.3.1 Sensitivity Level ½ - Very Low.

5.2.3.2 Sensitivity Level 1 – Low.

5.2.3.3 Sensitivity Level 2 – Medium.

5.2.3.4 Sensitivity Level 3 – High.

5.2.3.5 Sensitivity Level 4 – Ultrahigh.

5.2.4 Developers shall be of the following forms:

5.2.4.1 Form d - Nonaqueous for Type I Fluorescent Penetrant.

5.2.4.2 Form e – Nonaqueous for Type II visible dye.

5.2.4.3 Form f – Specific Application.

5.2.5 Solvent Removers shall be of the following classes:

5.2.5.1 Class 1 – Halogenated.

5.2.5.2 Class 2 – Nonhalogenated.

5.2.5.3 Class 3 – Specific Application.

5.3 Penetrant materials shall be used only in the conditions recommended by the penetrant manufacturer.

5.3.1 Penetrant materials include all penetrants, solvent, or cleaning agents, cleaner / removers and developers used with this examination procedure.

5.4 Penetrant material utilized in this procedure shall meet the requirements of MIL-I-25135 or QPl-AMS-2644. Purchased penetrant materials must be certified from the manufacturer to meet the above reference documents.

5.4.1 Examination of Nickel base alloys: All materials shall be certified by the manufacturer for sulfur content to be less than l% of the residue by weight.

5.4.2 Examination of Austenitic stainless steel and titanium: All materials shall be certified by the manufacturer to contain less than l% chlorine or fluorine by weight.

6.0 QUALITY CONTROL OF MATERIALS

6.1 Penetrant System Materials that are dispensed from aerosol cans have no material Quality Control checks.

6.2 The shelf life expiration will be verified prior to issue and use of penetrant materials dispensed from aerosol cans.

6.3 Materials that are dispensed from bulk storage containers (example: 1 gallon cans, 5 or 55 gallon drums) will be discarded at the end of each day. These materials will be subject to all quality control checks as specified in NDTG-PTQC-1 if they are not discarded.

7.0 SURFACE PREPERATION AND PRE-CLEANING

7.1 Surface Preparation - Surfaces may be liquid penetrant examined in the as welded, as cast, as rolled or as forged condition provided that the surface condition will not interfere with the interpretation of the examination. All weld contours shall blend into the base metals. All weld beads shall be ground free of excessive bumps, valleys, crevices, and undercut. Hand wire brushing of austenitic steels or nickel base alloys shall be done with a stainless steel wire brush not presently used on any carbon or low alloy steel. Surfaces to be examined shall not be subjected to any operation which may tend to peen the surface and mask defects, such as blasting with shot, dull sand, needle gunning, etc.

7.2 Precleaning – Prior to penetrant examination, the surface to be examined, and all adjacent areas within at least one-inch shall be dry and free of any dirt, grease, lint, scale, welding flux, weld spatter, oil, or other extraneous matter that could obscure surface openings or otherwise interfere with the examination. Typical cleaning agents, which may be used are detergents, organic solvents, descaling solutions, paint removers, and cleaners. Vapor degreasing and ultrasonic cleaning methods may also be used. After cleaning, drying of the surface to be examined shall be accomplished by normal evaporation or within a circulating hot air oven. The air temperature shall not exceed 125°F. A minimum of five (5) minutes drying time, after all visible traces of the cleaning solvent or agent has been removed adequate time shall be allowed to assure that all traces have evaporated from the test surface.

7.3 Parts processed in the Laboratory in accordance with this procedure are to be visually inspected to determine the cleanliness of the part. This inspection will be notated on the Lab Routing Card. Parts that are not acceptable for pre-inspection cleaning will not be processed. The customer should be notified and arrangements made for proper pre-cleaning of the parts.

7.4 As a standard practice, the temperature of the penetrant and the surface of the part to be processed shall not be below 50°F. nor above 120°F. throughout the examination period. Other temperatures may be used, provided that the procedure is qualified as described in paragraph 7.0.

8.0 PENETRANT APPLICATION

8.1 Penetrant Application – After the part has been cleaned, dried, and is within the specified temperature range, the penetrant shall be applied to the surface to be examined, so that the entire part, or area under examination is completely covered with penetrant.

8.2 Modes of Application – Penetrant may be applied by spraying, dipping, brushing or other method to provide coverage as required. Typically when processing parts in accordance with this procedure, penetrant will be applied by brushing, swabbing, or spraying.

8.3 Penetrant Dwell Times – After application, allow excess penetrant to drain from the part (care should be taken to prevent pools of penetrant from forming on the part), while allowing for proper dwell time (see Table 1). The length of time the penetrant must remain on the part to allow proper penetration should be as recommended by the penetrant manufacturer. Recommended dwell times are specified in Table 1.

Table 1 Minimum Dwell Times

Material	Form	Type of Discontinuity	Dwell Times (Minutes) Penetrant	Dwell Times (Minutes) Developer
Aluminum, Magnesium, Steel, Brass, and Bronze, Titanium and High Temperature Alloys	Castings & Welds	Cold Shuts, Porosity Lack of Fusion, Cracks (all forms)	5*	10
	Wrought Materials Extrusions, Forgings Plate	Laps & Cracks (all forms)	10	10
Carbide-tipped Tools		Lack of Fusion Porosity, Cracks	5*	10
Plastics	All forms	Cracks	5*	10
Glass	All forms	Cracks	5*	10
Ceramic	All forms	Cracks, Porosity	5*	10

***Any inspections done to ASTM-E-1417 will have a minimum dwell time of 10 minutes**
*** The maximum dwell time for all test methods is 1 hour.**

9.0 EXCESS PENETRANT REMOVAL

9.1 Excess Penetrant Removal – After the penetrant time has elapsed, excess penetrant is removed from the test surface. Inadequate removal will leave a background, which can interfere with subsequent interpretations of discontinuities. Care is to be exercised to limit removal of penetrant from any discontinuity to as little as possible.

9.2 Water Washable Penetrant – With water washable penetrant the excess shall be removed by spraying with water. Standard water line pressure shall not exceed 40 PSI and water temperature shall be between 50°F. - 100°F. After rinsing, drain water from the component and utilize repositioning, suction, blotting with a clean absorbent material..

9.3 Solvent Removable Penetrants – Excess penetrant is removed by first wiping the surface thoroughly with a clean, dry cloth or absorbent paper. The remaining excess penetrant is removed by wiping the surface with a clean cloth or absorbent paper, slightly moistened with the approved solvent cleaner. To minimize removal of penetrant from discontinuities, care shall be taken to avoid the use of excess solvent. In no case shall the examination surface be flushed with solvent following application of the penetrant and prior to developing.

10.0 DRYING

10.1 Water Washable Method shall be dried by normal evaporation, or with circulating hot air. Air temperature shall not exceed 125°F. A minimum of five (5) minutes drying time, after all visible traces of surface moisture have been removed, shall be allowed to ensure that all traces of surface moisture have evaporated from the examination surface.

10.2 Solvent Removal Method – Following the solvent removal method, drying shall be accomplished by allowing a minimum of five (5) minutes for normal evaporation and a maximum of ten (10) minutes.

11.0 DEVELOPER

11.1 The developer shall be applied as soon as possible after the surface penetrant has been removed and drying time elapsed. The interval shall not exceed ten (10) minutes.

11.2 Non-aqueous Wet Developers are applied as suspensions of developer particles in a non-aqueous solvent carrier and are ready for use as supplied in an aerosol can. They are applied to the test surface by spraying after the excess penetrant has been removed. This developer provides a blotting action as well as a contrasting background.

11.2.1 The test surface must be thoroughly dried prior to application of the developer.

11.2.2 Application of this developer is by spraying only.

11.2.3 A light, even coat of developer shall be applied to the test surface. Caution should be taken to not apply an excessive amount of developer. If excessive developer is applied the test surface shall be cleaned and the test re-processed.

12.0 EXAMINATION

12.1 Visible light intensity – Visible light shall be used when examining with visible dye penetrants. The intensity of the visible light at the work surface area undergoing examination using visible dye penetrants should be a minimum of 100 ft. Candles (1000 lux). For field inspection, using visible dye penetrants, light intensities may be as low as 50 ft. Candles, when agreed by the contracting agency.

12.2 Visible Ambient Light for Fluorescent Systems – The intensity of ambient visible light in a darkened room should not exceed 2 ft. Candles (20 lux) at the work surface area.

12.3 Black (Ultraviolet) Light – Allow the black light to warm-up for a minimum of 10 minutes prior to its use or measurement of intensity. The black light intensity shall be measured at least once at the beginning of each shift. And after bulb replacement for output. Black light reflectors and filter shall be checked for cleanliness and integrity. The minimum acceptable intensity is 1000 microwatts per cm^2 at the work surface area when using a black light meter.

12..4 Dark Area Eye Adaptation – It is recommended the inspector be in the darkened area for at least one (1) minute prior to examining parts using black light. If the examiner wears glasses they shall not be photosensitive.

13.0 EVALUATION

13.1 Evaluation of Results – Examination surfaces inspected, using liquid penetrant examination techniques shall be evaluated and accepted or rejected in accordance with applicable acceptance standards.

13.1.1 With visible dye penetrants the developer forms an even white coating. Discontinuities are indicated by a bleeding out of the penetrant, which is normally of a deep red color staining the developer. Indications with a light pink color staining the developer indicate excessive cleaning. Inadequate cleaning may leave an excessive background, making interpretation difficult. Adequate light intensity, either natural or artificial is required to ensure no loss of sensitivity in the examination.

13.1.2 Mechanical discontinuities at the surface will be indicated by bleeding out of the penetrant; however, localized surface imperfections such as machining marks or surface conditions may produce similar indications, which are non-relevant to the detection of unacceptable discontinuities.

13.1.3 Any indication which is believed to be non-relevant shall be re-examined to verify whether or not actual defects are present. Surface conditions may preclude the re-examination. Non-relevant indications and broad areas of pigmentation which would mask indications of defects are unacceptable.

13.2 Bleed Back Evaluation – Bleed back evaluation is not permitted when performing examinations in accordance with this work instruction.

13.3 Relevant indications are those, which result from mechanical discontinuities.

a. Linear indications are those indications in which the length is more than three (3) times the width.

b. Rounded indications are indications, which are circular or elliptical with the length less than three (3) times the width.

13.4 After a defect is thought to have been removed and prior to making repairs, the area shall be re-examined to ensure that the defect has been eliminated.

13.5 After the repairs have been made, the repaired area shall be re-examined by the liquid penetrant method and by all other methods of examination that were originally required for the affected area.

13.6 Final Cleaning – When the examination is concluded, the penetrant materials shall be removed as soon as possible using an approved solvent or cleaner, which may be sprayed directly onto the examination surface. The surface shall be wiped with a paper towel or a clean rag.

13.7 Marking – If the contract specifies its own marking requirement, the contract specification will take precedence. If ASTM-E-1417 is specified, marking will be in accordance with appendix "A".

14.0 QUALIFICATION OF PROCEDURES FOR NON-STANDARD TEMPERATURES

14.1 When it is impractical to conduct a liquid penetrant examination within the temperature range of 50°F. to 120°F., the examination procedure at the proposed temperature must be qualified. This is accomplished by using liquid penetrant comparator blocks, examining on block at the proposed temperature, and the other block at a temperature in a normal range of 50°F. to 120°F. The blocks will be of a construction as outlined in ASME Section V, Article 6.

14.1.1 The blocks shall be marked "A" and "B".

14.1.2 If it is desired to qualify a liquid penetrant examination procedure at a temperature less than 50°F., the proposed procedures shall be applied to block "B" after the block and all materials have been cooled to the proposed examination temperature. The block "A" shall then be processed at a temperature of 50°F. to 120°F., and examined in a manner which has been demonstrated to be suitable for use in this temperature range. The indications of cracks shall be compared for blocks "A" and "B". If the indications obtained under the proposed conditions are essentially as those obtained under the examination at 50°F. to 120°F. the proposed procedure may be considered qualified for use.

14.1.3 If the proposed temperature for the examination is above 120°F. the blocks shall be examined and compared as described in Paragraph 7.1.1.3, but at the higher temperature sought for qualification.

14.1.4 As an alternate to paragraphs 7.1.1.1 and 7.1.1.2, when using visible dye penetrants, it is permissible to use a single comparator block for the standard nonstandard temperatures and to make the comparison by photography. Identical photographic techniques shall be used to make the comparison photographs. The block shall be thoroughly cleaned between the two processing steps.

15.0 REPORTING RESULTS

15.1 Examination Records – Each penetrant examination shall be documented using the attached form. (Attachment A). The penetrant examination report form must be completed in it's entirety and detail the specific test parameters.

15.2 Recording of Indications – The requirement and method of recording indications will be determined by the client. When the client specifies marking requirements, the location of all rejectable indications may be marked on the part and permanent records of the locations, direction, and frequency of indications may be made by one of the following method:

15.2.1 Written Description – By recording the location, length, direction, and number of indications by a detailed sketch.

16.0 ACCEPTANCE STANDARDS

16.1 Acceptance standards shall be in accordance with AWS D15.1, section 17.2

16.1.1 The client shall have final authority and responsibility for interpretation and acceptance of all liquid penetrant examination results.

Appendix A

A 1.0 MARKING

A1.1 Unless otherwise specified, each component that has been penetrant inspected and accepted in accordance to contractual agreement shall be marked as specified by the customer and be detailed on the work order. Marking shall be applied in a manner and location that is harmless to the component or its intended function.

Attachment A

Liquid Penetrant Examination Worksheet

Non•Destructive Testing Group

LIQUID PENETRANT INSPECTION WORKSHEET

Tested For: ______________________ Report #: ________ Page ____ of

Attention: ______________________ P.O. #: ______________

Address: ______________________ Work Order #: ______________

______________________ Project: ______________

Date: ______________________

Description: ______________________

NDTG Procedure: ______________

Test Method Standard: ______________

Acceptance Standard: ______________

Product Form: ______________

Type of Material: ______________

Surface Condition: ______________

Percent of Inspection:
____ 100%
____ %

Production Stage:
____ In Progress
____ Final
____ Other

For Welds:
____ Root Pass
____ Intermediate
____ Final

PT Material Identification:
Mfg. ______________
Penetrant ______________
Developer ______________
Cleaner ______________
Emulsifier ______________

(Indicate type number and batch number for each item used)

Product / Weld Identification	Accept	Reject	Linear	Rounded	Cracks	Undercut	Other	Defect Location or Remarks

Technique: ______
Fluorescent ______
Visible Dye ______
Water Washable ______
Post Emulsified ______
Solvent Removed ______
UV Meter No. ______
WL Meter No. ______
Meter Calibration ______
Due Date ______
Black Light Intensity ______
White Light Intensity ______

Technician: ______________ Level: ______________

Reviewed By: ______________ Date: ______________

Quality by Integrity and Knowledge

NDTG-0002-W
September 17, 2003
ddk

Appendix G-2.6.4 TUV Rheinland Industrial Solutions, Non-Destructive Testing Group, Work Instruction No. WI-08-002, Rev No. 1 Magnetic Particle Examination of Ferromagnetic Materials

NDT Non•Destructive Testing Group *Quality by Integrity and Knowledge*	WORK INSTRUCTION	Number: WI-08-002
	Title: **Magnetic Particle Examination of Ferromagnetic Materials** [redacted]	Rev. No. 1 Effective Date: **March 17, 2008**

REVISION RECORD

Revision 1 / March 17, 2008	Corrected paragraph numbering / revised 16.0 (Acceptance Criteria)
Revision 0 / January 22, 2008	New Issue

[redacted]

Approved By: Robert D. Nichol (signature)
Robert D. Nichol, Level III

Date: 3/17, 2008

1.0 SCOPE

1.1 This work instruction covers the general requirements for magnetic particle examination of ferromagnetic materials using portable yoke or prod equipment. The magnetic particle examination method is used to detect cracks, laps, seams, inclusions, and other discontinuities on or near the surface of ferromagnetic materials. Magnetic particle examination may be applied to raw material, billets, finished and semi-finished materials, welds, and in-service parts. Magnetic particle examination is not applicable to non-ferromagnetic metals and alloys such as austenitic or Ferritic stainless steels (200-300-400 grade).

1.2 Materials suitable for Magnetic Particle Inspection in accordance with ASTM E-1444 are found in Appendix B of this procedure.

2.0 GENERAL REQUIREMENTS

2.1 In order to perform a magnetic particle examination of ferromagnetic materials to this procedure, the client should provide the following information.

2.1.1 Identify the material to be examined. This information should include project or contract designation, P.O. number, drawing number, the component serial number, and part number.

2.1.2 Designate the extent of examination.

2.1.2.1 Complete examination shall mean 100% coverage of accessible areas.

2.1.2.2 When partial examination is designated, the number, location, and size of area will be clearly specified by the client.

2.1.2.3 When the sample examination is designated, the client shall identify the number of items to be magnetic particle examined.

2.1.3 The acceptance standards/criteria to be used.

2.1.4 When applicable, the marking system required.

2.1.5 When magnetic particle testing is performed for a manufacturer or contractor, prior to being presented to the inspector for acceptance, the part shall be examined and interpreted by the manufacturer or contractor as complying with the referencing code section. The interpretation and disposition of the material examined shall be recorded on an appropriate report form.

2.1.6 The client is to be responsible for any required surface preparation unless otherwise specified by the contract.

3.0 REFERENCE DOCUMENTS

3.1 WI-08-002 CONFORMS TO THE FOLLOWING REFERENCES

NDTG-MT-2	Magnetic Particle Examination, Field Applications
MIL-STD-2175	Castings, classification, and inspection of.
AMS-30410-	Magnetic particles wet method, oil vehicle.
DOD-F-87935-	Fluid, magnetic particle inspection, suspension medium.
NAS-410	NDT, personnel qualification and certifications.
MIL-STD-1949-A	Inspection, Magnetic Particle Inspection.
MIL-STD-1907	Inspection, Liquid Penetrant, and Magnetic Particle soundness requirements for materials, parts, and weldments.
NDTG-CTP-1	Corporate Training Policy.
NDTG-MTQC-3	Q.C. Magnetic Particle material and equipment.
ASTM-E-1444	Standard practice for Magnetic Particle Examination.
ASME Section V	American Society of Mechanical Engineers 2004 through 2005 with Addenda Boiler and Pressure Vessel Code – Non-Destructive Examination.
NAVSEA –T9074-AS-GIB-010/271	Requirements for Non-Destructive Testing Methods.
AWS-D1.1	Structural Welding Code
AWS-D1.5	Structural Welding Code Bridges

3.2 All references will be of the latest revision

4.0 DEFINITIONS

4.1 *Prods:* Hand held electrodes through which a magnetizing current is applied resulting in a distorted circular field.

4.2 *Yoke:* A "U" shaped magnet that induces a magnetic field in the area of a part that lies between its poles. Yokes may be permanent magnets or either alternating current or direct current electro magnets.

5.0 MATERIAL

5.1 *Magnetic Particle Methods:* The particle used shall be finely divided ferromagnetic material, which have been treated to import visibility against the background of the surfaces under inspection.

5.2 *Dry Particles:* Dry particles shall meet the requirements of AMS 3040 or AMS 3044.

5.3 *Wet Particles:* Wet particles shall meet the requirements of AMS 3041 or AMS 3045.

6.0 PERSONNEL

6.1 Personnel performing magnetic particle examination to this procedure shall be qualified and certified in accordance with Non-Destructive Testing Group, Inc.'s "Corporate Training Policy"(NDTG-CTP-1).

6.6.1 Personnel performing inspectors shall be prohibited from wearing photo chromatic lenses.

6.6.2 Only those personnel Certified as a Magnetic Particle Level II or Level III shall interpret indications for acceptance or rejection.

7.0 QUALITY CONTROL

7.1 Quality Control of materials and equipment not referenced in this procedure are located in NDTG-MTQC-1 "Quality Control of Material and Equipment – Magnetic Particle Method"

7.2 QUALITY CONTROL TESTS AND FREQUENCY

TABLE 1					
EQUIPMENT	**MTQC-1**	**Type of Check**	**Property checked**	**Frequency**	**E-1444**
Prods Ammeter Accuracy	17.0	Operational Check	Ammeter Gauge	6 months	N/A
Equipment - Yoke Dead Weight	18.0	Operational Check	Weight Lift test	6 months	7.3.4

7.3 PROD AMMETER CHECK

7.3.1 The Ammeter of the equipment shall be checked by a calibrated ammeter traceable to NIST in series with the output circuit at three (3) output levels. In comparing the three (3) readings, a deviation shall not exceed plus (+) or minus (-) ten (10) percent of full current when half wave rectified alternating current is used. If half wave direct current is used, ammeter reading shall be doubled. Attach cables to either side of the calibrated shunt meter and record results in the appropriate department log.

7.4 YOKE DEAD WEIGHT TEST

7.4.1 The magnetizing force of the yoke can be determined by its lifting power on steel plates.

7.4.2 Alternating Current (AC) yokes shall have the lifting force of at least ten (10) pounds with a 2 inch – 6 inch spacing between legs.

7.4.3 Direct Current (DC) shall have the lifting force of at least fifty (50) pounds with a 4 inch – 6 inch spacing between legs.

8.0 PRE-INSPECTION CLEANLINESS

8.1 *Pre-inspection Demagnetization:* The part(s) shall be demagnetized before inspection if prior operations have produced a residual magnetic field, which will interfere with the inspection.

8.2 *Surface Preparation:* The surface of the part to be inspected shall be essentially smooth, clean, dry, and free of oil, scale, machining marks, or other contaminants, which might interfere with the efficiency of the inspection.

8.3 *Coatings:* Magnetic particle inspection shall not be performed with coatings in place that could prevent the detection of surface defects. Such coatings include metallic paint or chrome plate greater than .003 inch in thickness or ferromagnetic coatings such as electroplated nickel greater than .001 inch in thickness. If coatings are thicker than these limits, it must be demonstrated that minimum allowable defects can be detected through the maximum coating thickness applied. When coatings are non-conductive, they must be removed where electrical contact is to be made.

9.0 LIGHTING AND EXAMINATION AREA

9.1 *Light Intensity for Examination:* Visible light shall be used when examining with non-fluorescent particles. Fluorescent particles must be used in a darkened room under a black (ultraviolet) light.

9.1.1 *Visible Light Intensity:* The intensity of the visible light at the work surface area undergoing examination using non-fluorescent particles should be a minimum of 100 ft. candies (1000 lux.) For field inspection, using non-fluorescent particles, visible light intensities as low as 50 fc (500 lux.) may be used when agreed on by the contracting agency. The intensity of ambient visible light in a darkened room, using fluorescent particles, should not exceed 2 fc (20 lux) at the work surface area.

9.1.2 *Special Visible Internal Light source*: When examinations of internal surfaces must be performed using special visible light sources, the image produced must have sufficient resolution to effectively evaluate the required discontinuities.

9.2 *Black Ultraviolet Light*

9.2.1 *Black Light Warm Up* - Allow the black light to warm for a minimum of 5 minutes prior to its use or measurement of the intensity.

9.2.2 *Black Light Intensity* - Black light intensity shall be checked at least once a day and after bulb replacement, for output. Black light reflectors and filter shall be checked daily for cleanliness and integrity. The minimum acceptable intensity is 1000 $\mu w/cm^2$ at 15 inches or the work surface area; whichever is greater, when using a suitable black light meter.

9.2.3 *Dark Area Eye Adaptation* - The inspector be in the darkened area for at least 3 minutes prior to examining parts using black light.

10.0 MAGNETIZATION METHODS

10.1 *Longitudinal Magnetization Using Yokes:* Longitudinal magnetization is often accomplished by passing current through a coil encircling the part, or section of the part. This produces a magnetic field parallel to the axis of the coil.

11.0 PARTICLE APPLICATION

11.1 *Continuous Method:* In the dry continuous method, magnetic particles are applied to the part while the magnetizing force is present. In the wet continuous method the magnetizing current shall be applied immediately after diverting suspension from the part.

11.2 *Residual Magnetization Method:* Residual magnetization method is not permitted in accordance with this written instruction.

11.3 *Dry Magnetic Particle Application:* When using dry particle the flow of magnetizing current shall be initiated prior to the application of the magnetic particles to the test surface under test and terminated after powder application has been completed and any access blown off. The duration of the magnetizing current shall be at least ½ second and short enough to prevent any damage to the part due to overheating. Dry powder shall be applied in a manner such that a light, uniform dust-like coating settles on the surface of the test part while the part is being magnetized. Specially designed powder blowers shall introduce the particle into the air in such a manner that they reach the part surface in a uniform cloud with a minimum force. After the powder is applied and before the magnetizing force is removed, excess powder shall be removed by means of a dry air current with sufficient force to remove the excess particles, but not to disturb particle held by a leakage field that is indicative of a discontinuity. Dry particle method shall not be used to inspect aerospace components without specific approval of the contracting agency.

12.0 MAGNETIC FIELD ADEQUANCY AND DIRECTION

12.1 The applied magnetic field shall have sufficient strength to produce satisfactory indications, but not so strong that it causes the masking of relevant indications. The field strength will be verified by using one or more of the following methods. Results will be recorded on the appropriate record.

12.2 Pie shaped magnetic field strength indicator shall be positioned on the surface to be examined with the copper-plated side away from the inspected surface. If a clearly defined line of particles is not formed, the magnetizing technique shall be changed as needed. The field will be proven to be adequate in two directions at 90° to each other. The pie type indicators are best used with dry particle process.

13.0 REPORTING RESULTS

13.1 *Examination Records:* Each magnetic particle examination shall be documented on Magnetic Particle Inspection Test Report. (Attachment A)

13.2 *Recording of indications:* The location of all rejectable indications shall be marked on the part and permanent records of the locations, direction, and frequency of indications may be made by one or more of the following methods:

13.2.1 *Written Description:* By recording the location, length, direction, and number of indications by a detailed sketch.

13.2.2 *Transparent Tape:* For dry particle indications, by applying transparent adhesive backed tape to which the indications will adhere and place it on an approved form along with information giving it's location on the part.

13.2.3 *Photography:* Photographing the indication themselves and including the pictures with the report.

14.0 POST INSPECTION

14.1 *Demagnetization and Cleaning:* Demagnetization will be performed if specified by the client.

14.3 *Post Inspection Cleaning:* Unless otherwise specified by the contracting agency, cleaning shall be by use of suitable solvent, air blower, or other means. Parts shall be inspected to ensure that the cleaning procedure has removed magnetic particle residues, since such residue could have an adverse effect on the intended use of the part.

15.0 MARKING SYSTEM

15.1 *Marking of Inspected Parts:* After the examination is completed the parts will be marked accepted or rejected per the customer's requirements

16.0 ACCEPTANCE

16.1 Acceptance standards shall be in accordance with AWS D15.1, section 17.2

16.2 The client shall have final authority and responsibility for interpretation and acceptance of all liquid penetrant examination results.

Attachment A

Magnetic Particle Inspection Worksheet

Non•Destructive Testing Group

MAGNETIC PARTICLE INSPECTION WORKSHEET

Tested For: ______ Report #: ______ Page ____ of ____
Attention: ______ P.O. #: ______
Address: ______ Work Order #: ______
Project: ______

Date: ______
Description: ______

NDTG Procedure: ______
Surface Condition: ______
Test Method Standard: ______
Acceptance Standard: ______
Type of Material: ______

Production Stage:
___ In Progress
___ Final
___ Other

For Welds:
___ Root Pass
___ Intermediate
___ Final

Equipment Identification:
Model #: ______
Serial #: ______
Cal. Due Date: ______

Product / Weld Identification	Accept	Reject	Linear	Rounded	Cracks	Undercut	Other	Defect Location or Remarks

Technique:
Wet Method: ______
Dry Method: ______
Fluorescent: ______
Visible: ______
Consumable Batch #: ______
Coil / Cabins: ______
Head Shot: ______
Prod Method: ______
Yoke Method: ______
Current AC: ☐ DC: ☐
Amperage: ______
UV Meter #: ______
Quantity Tested 100%: ______
Random: ______ %

Set Up / Location Sketch:

The UV intensity was verified at the prescribed intervals: ☐ Yes ☐ No ☐ NA

Technician: ______ Level: ______

Reviewed By: ______ Date: ______

Testing was performed in accordance with accepted industry practice as well as the test methods referenced. This test report applies only to those items tested. This report shall not be reproduced except in full without the written consent of Non-Destructive Testing Group, Inc.

Quality by Integrity and Knowledge
DOMESTIC & INTERNATIONAL LOCATIONS

NDTG-0007-W
September 26, 2003
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