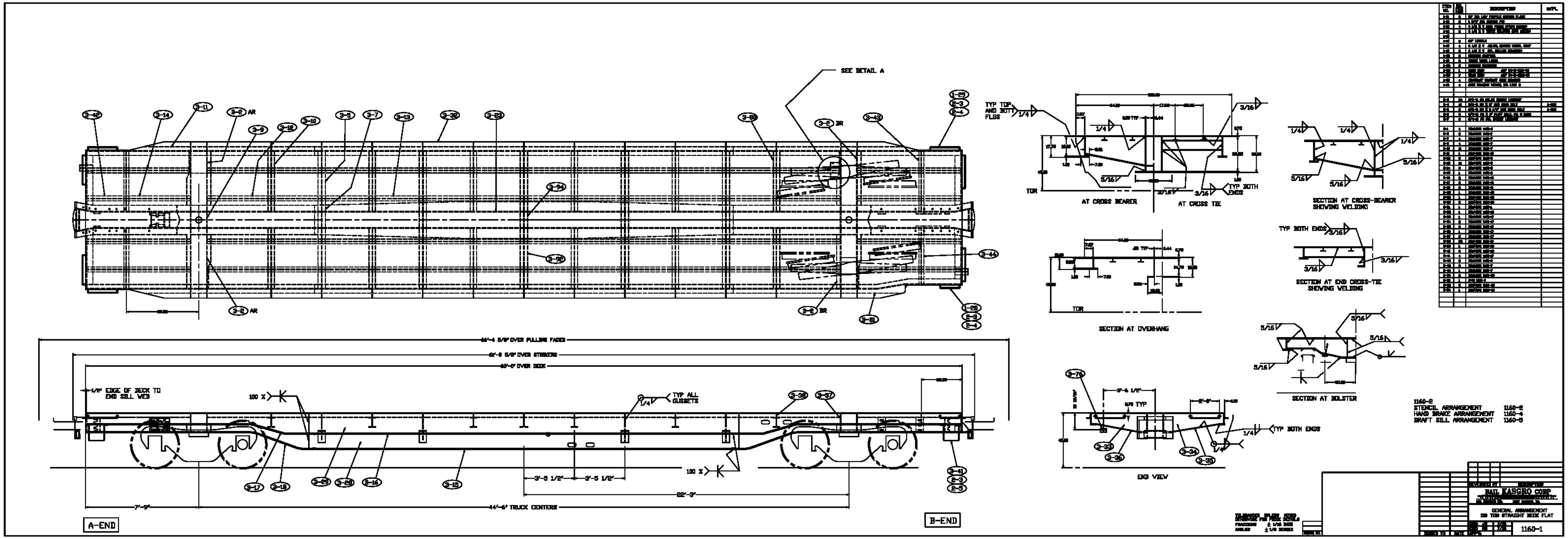
Appendix H – Preliminary Buffer Prototype Railcar Deliverables

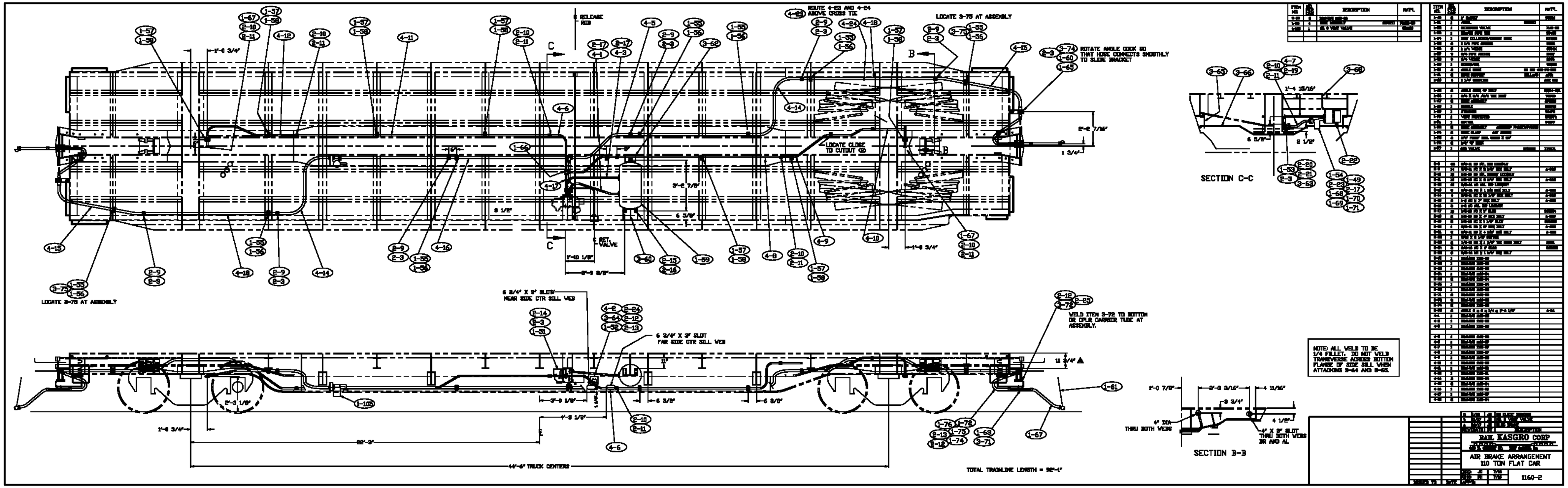
APPENDIX H-1

BUFFER RAILCAR PRELIMINARY FABRICATION DRAWINGS

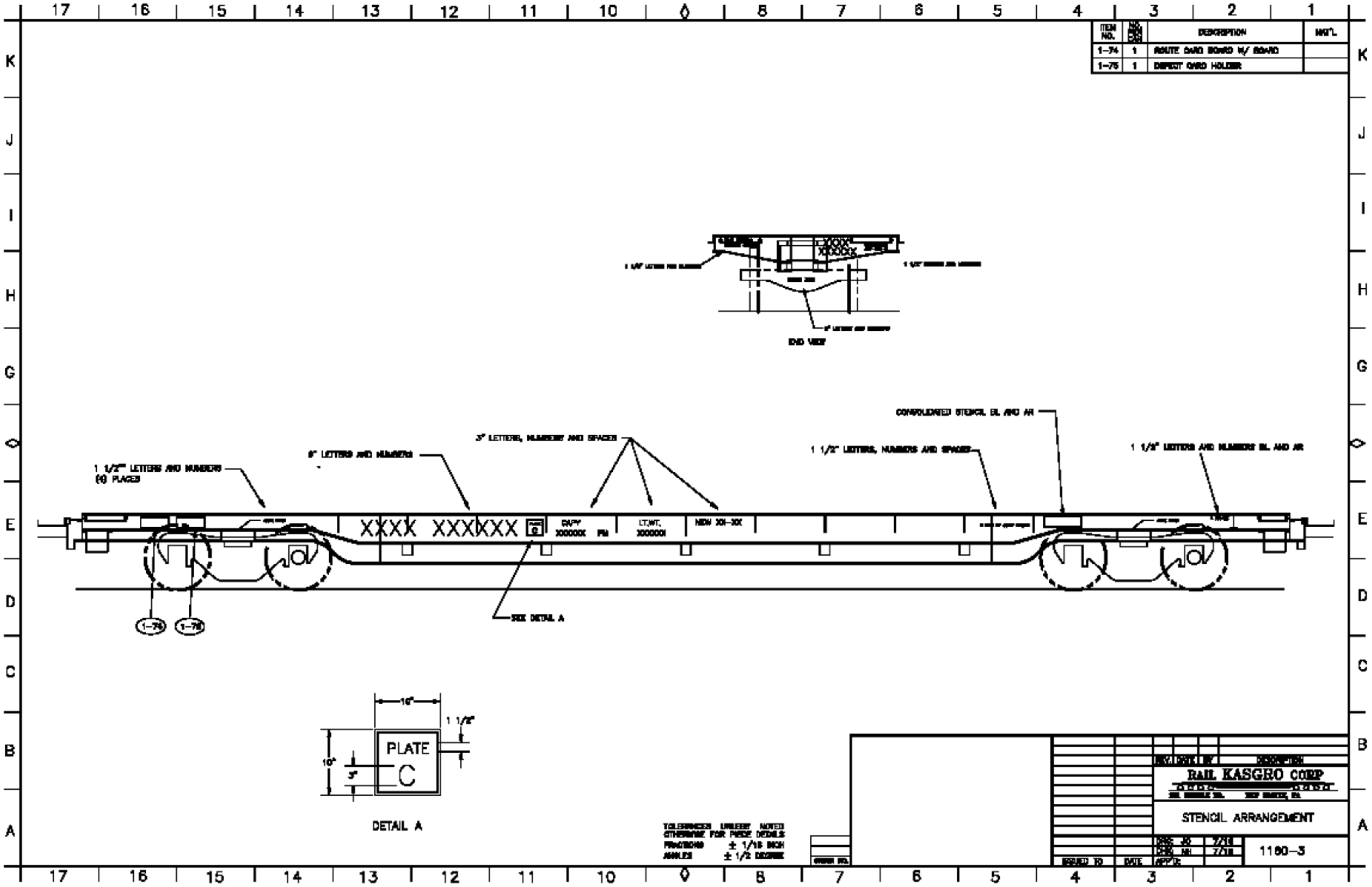
Appendix H-1.1 General Arrangement



Appendix H-1.2 Air Brake Arrangement

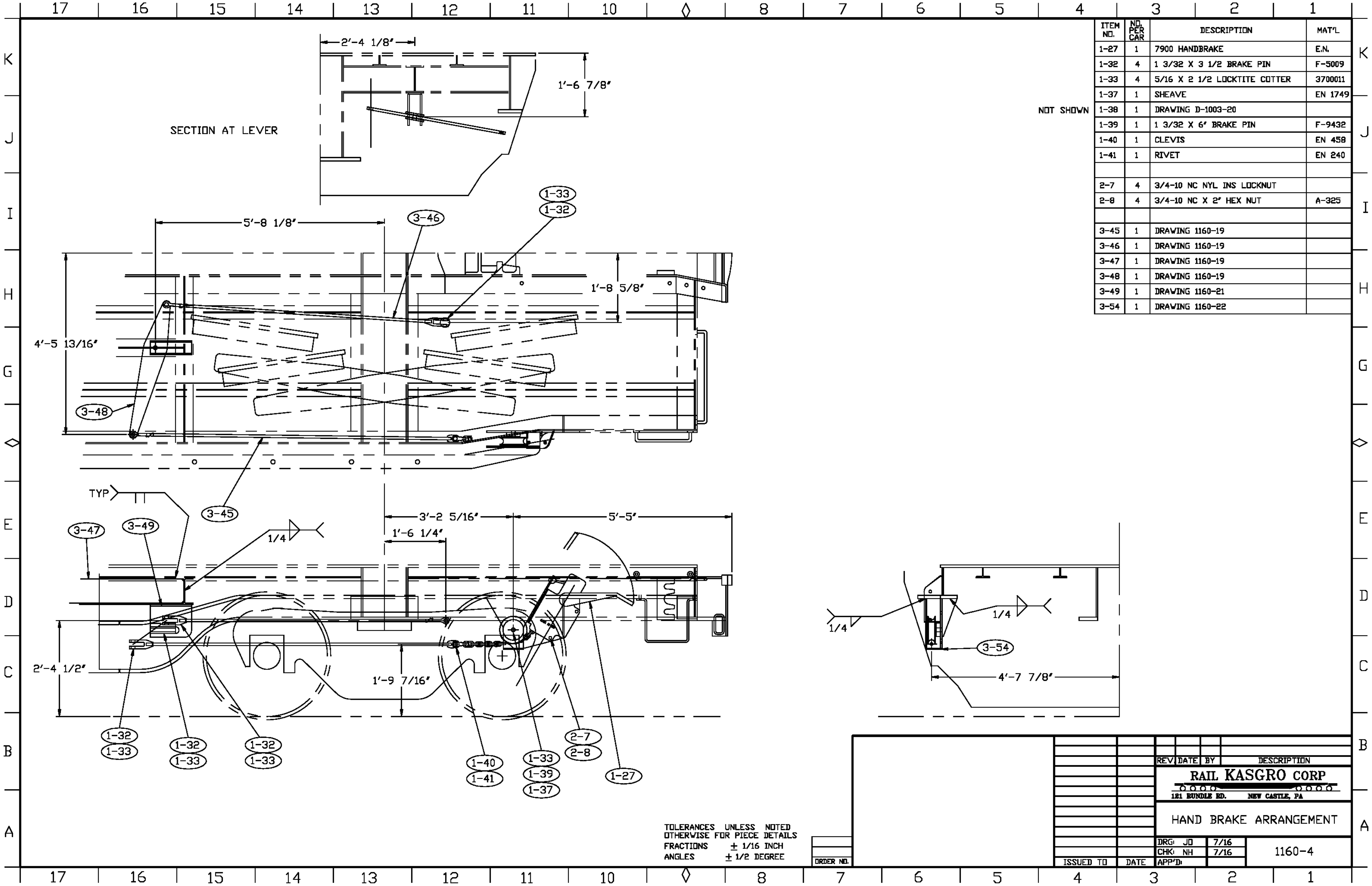


Appendix H-1.3 Stencil Arrangement



ITEM NO.	NO. REQ'D	DESCRIPTION	MAT'L
1-74	1	ROUTE CARD BOARD W/ BOARD	
1-75	1	DEFECT CARD HOLDER	

Appendix H-1.4 Hand Brake Arrangement



NOT SHOWN: 1-38

ITEM NO.	NO. PER CAR	DESCRIPTION	MAT'L
1-27	1	7900 HANDBRAKE	E.N.
1-32	4	1 3/32 X 3 1/2 BRAKE PIN	F-5009
1-33	4	5/16 X 2 1/2 LOCKTITE COTTER	3700011
1-37	1	SHEAVE	EN 1749
1-38	1	DRAWING D-1003-20	
1-39	1	1 3/32 X 6" BRAKE PIN	F-9432
1-40	1	CLEVIS	EN 458
1-41	1	RIVET	EN 240
2-7	4	3/4-10 NC NYL INS LOCKNUT	
2-8	4	3/4-10 NC X 2" HEX NUT	A-325
3-45	1	DRAWING 1160-19	
3-46	1	DRAWING 1160-19	
3-47	1	DRAWING 1160-19	
3-48	1	DRAWING 1160-19	
3-49	1	DRAWING 1160-21	
3-54	1	DRAWING 1160-22	

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

ORDER NO.

ISSUED TO | DATE

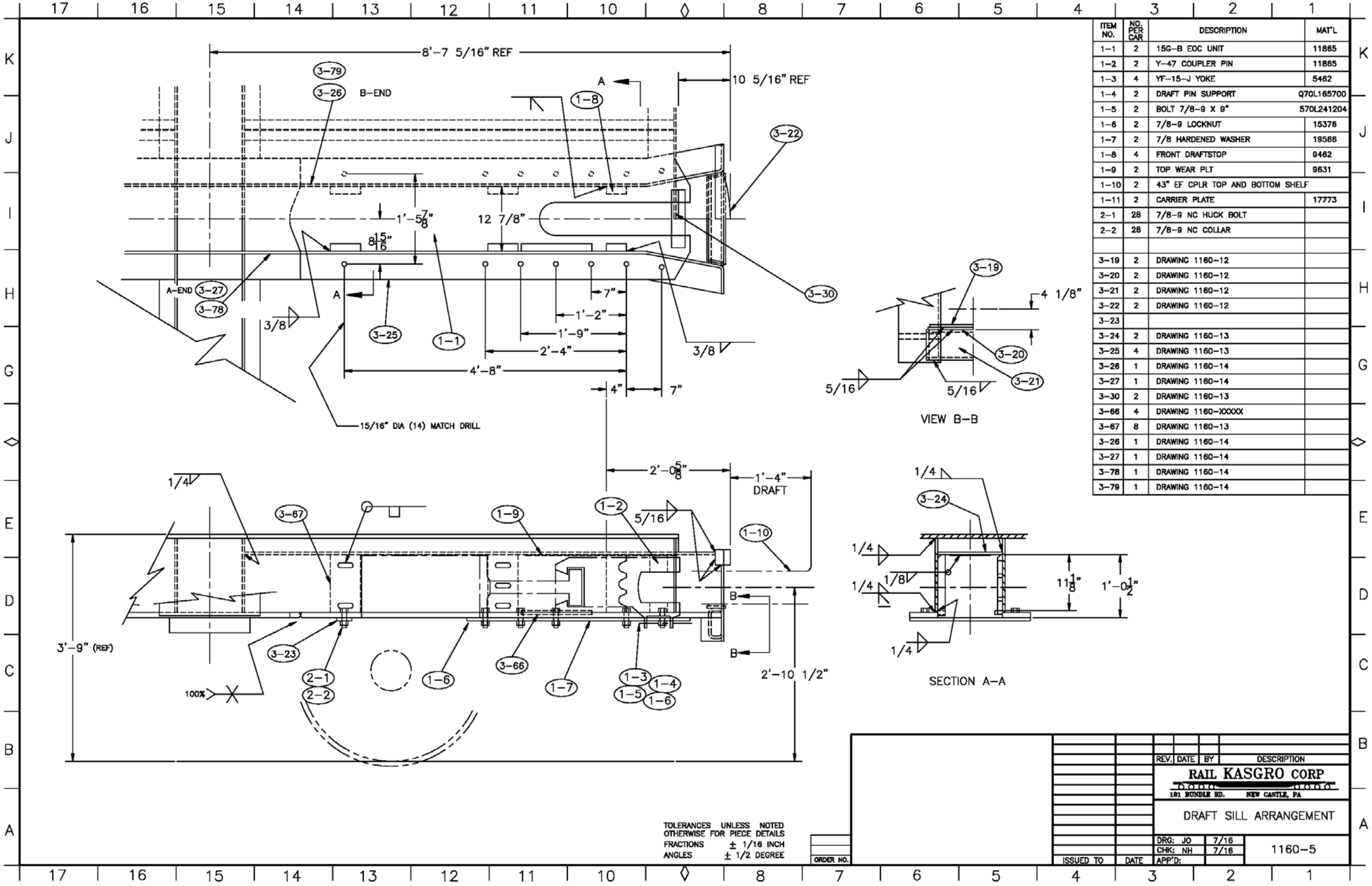
REV.	DATE	BY	DESCRIPTION

RAIL KASGRO CORP
121 BUNDLE RD. NEW CASTLE, PA

HAND BRAKE ARRANGEMENT

DRG: JD	7/16	1160-4
CHK: NH	7/16	
APP'D:		

Appendix H-1.5 Draft Sill Details



ITEM NO.	NO. PER CAR	DESCRIPTION	MAT'L
1–1	2	15G–B EOC UNIT	11865
1–2	2	Y–47 COUPLER PIN	11865
1–3	4	YF–15–J YOKE	5462
1–4	2	DRAFT PIN SUPPORT	Q70L165700
1–5	2	BOLT 7/8–9 X 9"	570L241204
1–6	2	7/8–9 LOCKNUT	15376
1–7	2	7/8 HARDENED WASHER	19566
1–8	4	FRONT DRAFTSTOP	9462
1–9	2	TOP WEAR PLT	9631
1–10	2	43" EF CPLR TOP AND BOTTOM SHELF	
1–11	2	CARRIER PLATE	17773
2–1	28	7/8–9 NC HUCK BOLT	
2–2	28	7/8–9 NC COLLAR	
3–19	2	DRAWING 1160–12	
3–20	2	DRAWING 1160–12	
3–21	2	DRAWING 1160–12	
3–22	2	DRAWING 1160–12	
3–23			
3–24	2	DRAWING 1160–13	
3–25	4	DRAWING 1160–13	
3–26	1	DRAWING 1160–14	
3–27	1	DRAWING 1160–14	
3–30	2	DRAWING 1160–13	
3–66	4	DRAWING 1160–XXXXX	
3–67	8	DRAWING 1160–13	
3–26	1	DRAWING 1160–14	
3–27	1	DRAWING 1160–14	
3–78	1	DRAWING 1160–14	
3–79	1	DRAWING 1160–14	

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

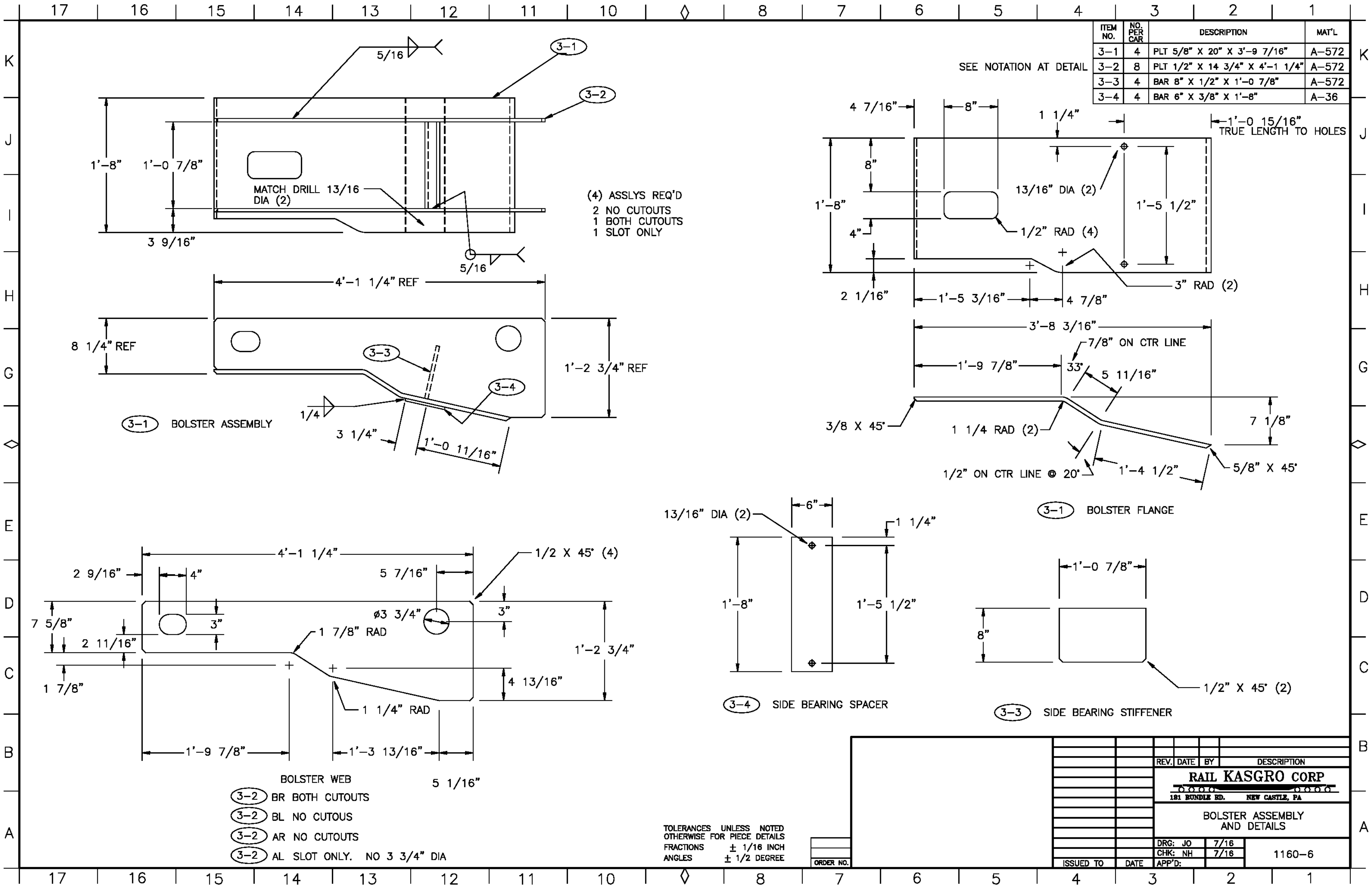
ORDER NO.
ISSUED TO | DATE
REV. | DATE | BY | DESCRIPTION

RAIL KASGRO CORP
181 RUNDLE RD. NEW CASTLE, PA

DRAFT SILL ARRANGEMENT

DRG: JO 7/16
CHK: NH 7/16
APP'D:
1160–5

Appendix H-1.6 Bolster Assembly and Details



ITEM NO.	NO. PER CAR	DESCRIPTION	MAT'L
3-1	4	PLT 5/8" X 20" X 3'-9 7/16"	A-572
3-2	8	PLT 1/2" X 14 3/4" X 4'-1 1/4"	A-572
3-3	4	BAR 8" X 1/2" X 1'-0 7/8"	A-572
3-4	4	BAR 6" X 3/8" X 1'-8"	A-36

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

ORDER NO.

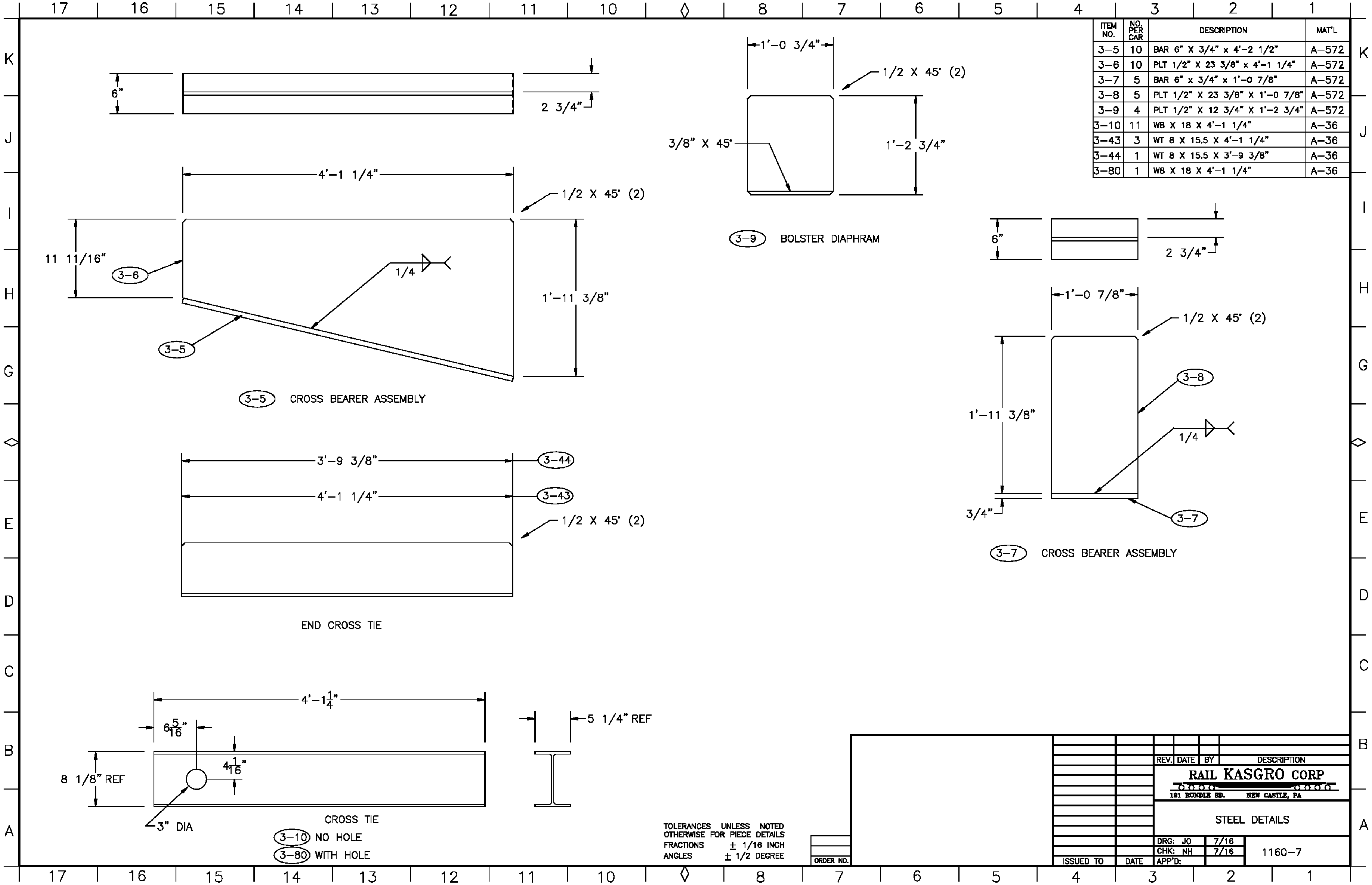
ISSUED TO	DATE	REV.	DATE	BY	DESCRIPTION

RAIL KASGRO CORP
181 BUNDLE RD. NEW CASTLE, PA

BOLSTER ASSEMBLY
AND DETAILS

DRG: JO 7/16
CHK: NH 7/16
APP'D:
1160-6

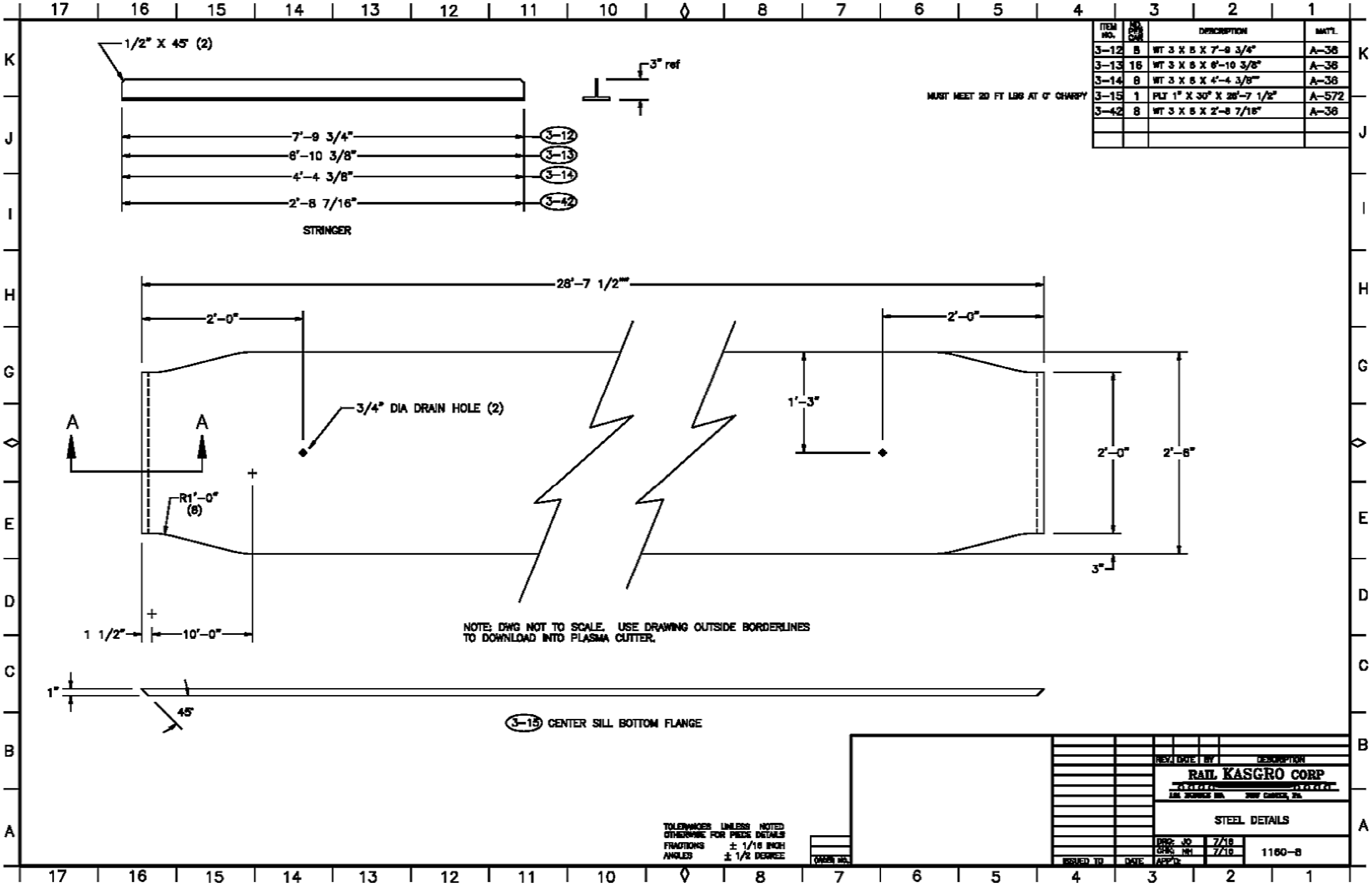
Appendix H-1.7 Steel Details



ITEM NO.	NO. PER CAR	DESCRIPTION	MAT'L
3–5	10	BAR 6" X 3/4" x 4'–2 1/2"	A–572
3–6	10	PLT 1/2" X 23 3/8" x 4'–1 1/4"	A–572
3–7	5	BAR 6" x 3/4" x 1'–0 7/8"	A–572
3–8	5	PLT 1/2" X 23 3/8" X 1'–0 7/8"	A–572
3–9	4	PLT 1/2" X 12 3/4" X 1'–2 3/4"	A–572
3–10	11	W8 X 18 X 4'–1 1/4"	A–36
3–43	3	WT 8 X 15.5 X 4'–1 1/4"	A–36
3–44	1	WT 8 X 15.5 X 3'–9 3/8"	A–36
3–80	1	W8 X 18 X 4'–1 1/4"	A–36

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

Appendix H-1.8 Steel Details

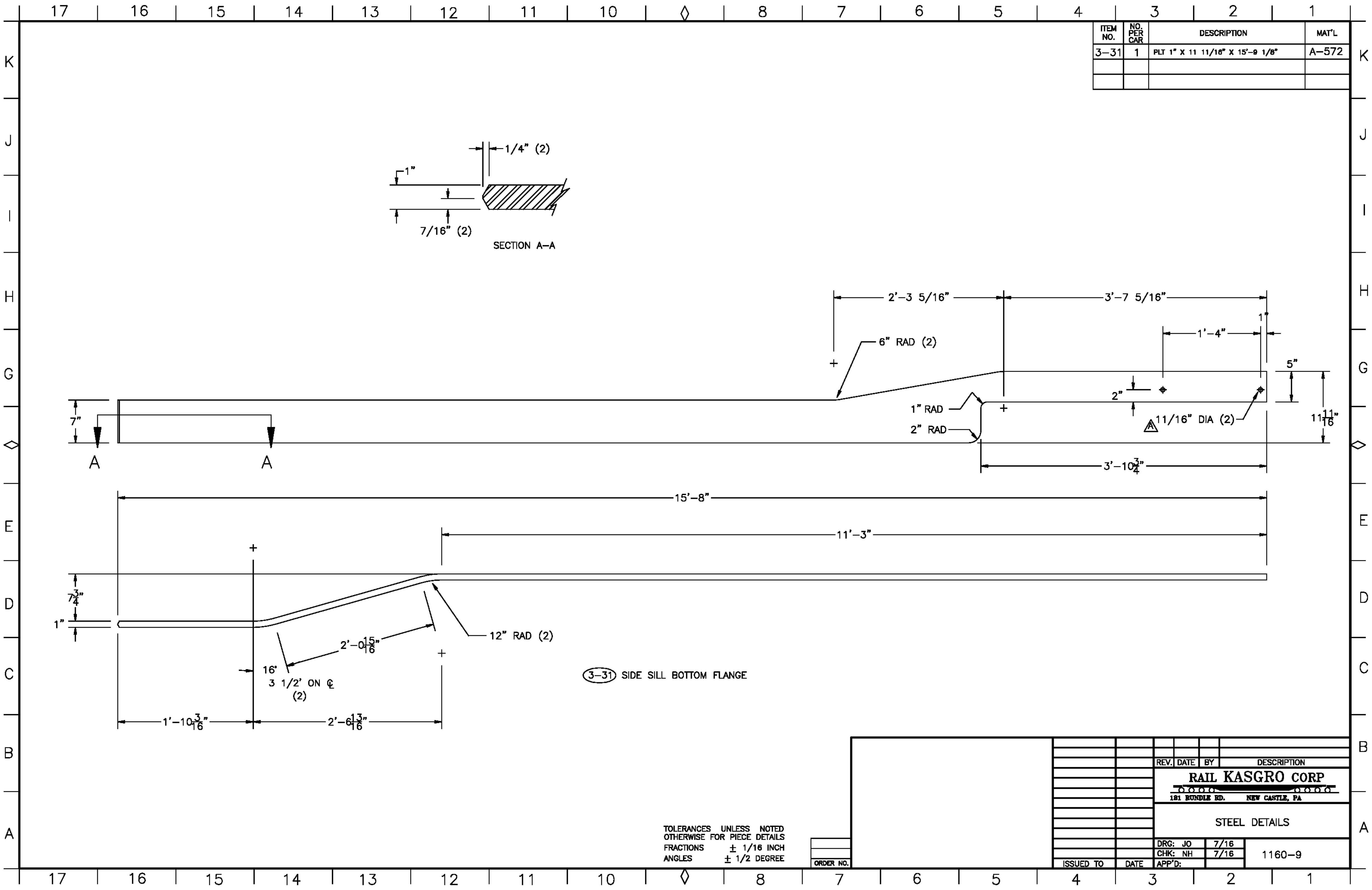


ITEM NO.	NO. PER CAR	DESCRIPTION	MAT'L
3-12	8	WT 3 X 6 X 7'-9 3/4"	A-36
3-13	16	WT 3 X 6 X 6'-10 3/8"	A-36
3-14	8	WT 3 X 6 X 4'-4 3/8"	A-36
3-15	1	PLT 1" X 30" X 28'-7 1/2"	A-572
3-42	8	WT 3 X 6 X 2'-8 7/16"	A-36

NOTE: DWG NOT TO SCALE. USE DRAWING OUTSIDE BORDERLINES TO DOWNLOAD INTO PLASMA CUTTER.

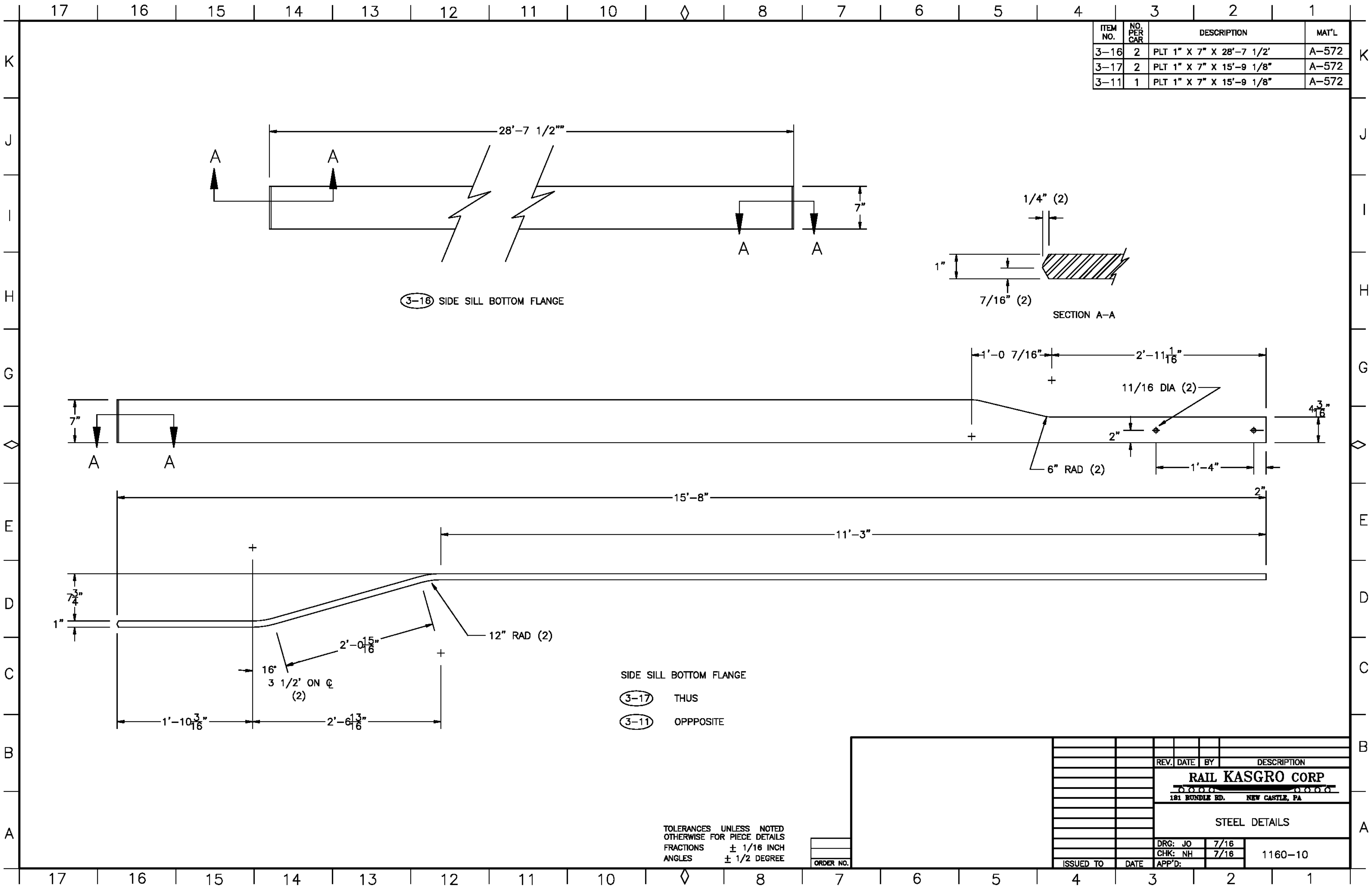
TOLERANCES UNLESS NOTED OTHERWISE FOR PIECE DETAILS
FRACTIONS ± 1/16 INCH
ANGLES ± 1/2 DEGREE

Appendix H-1.9 Steel Details



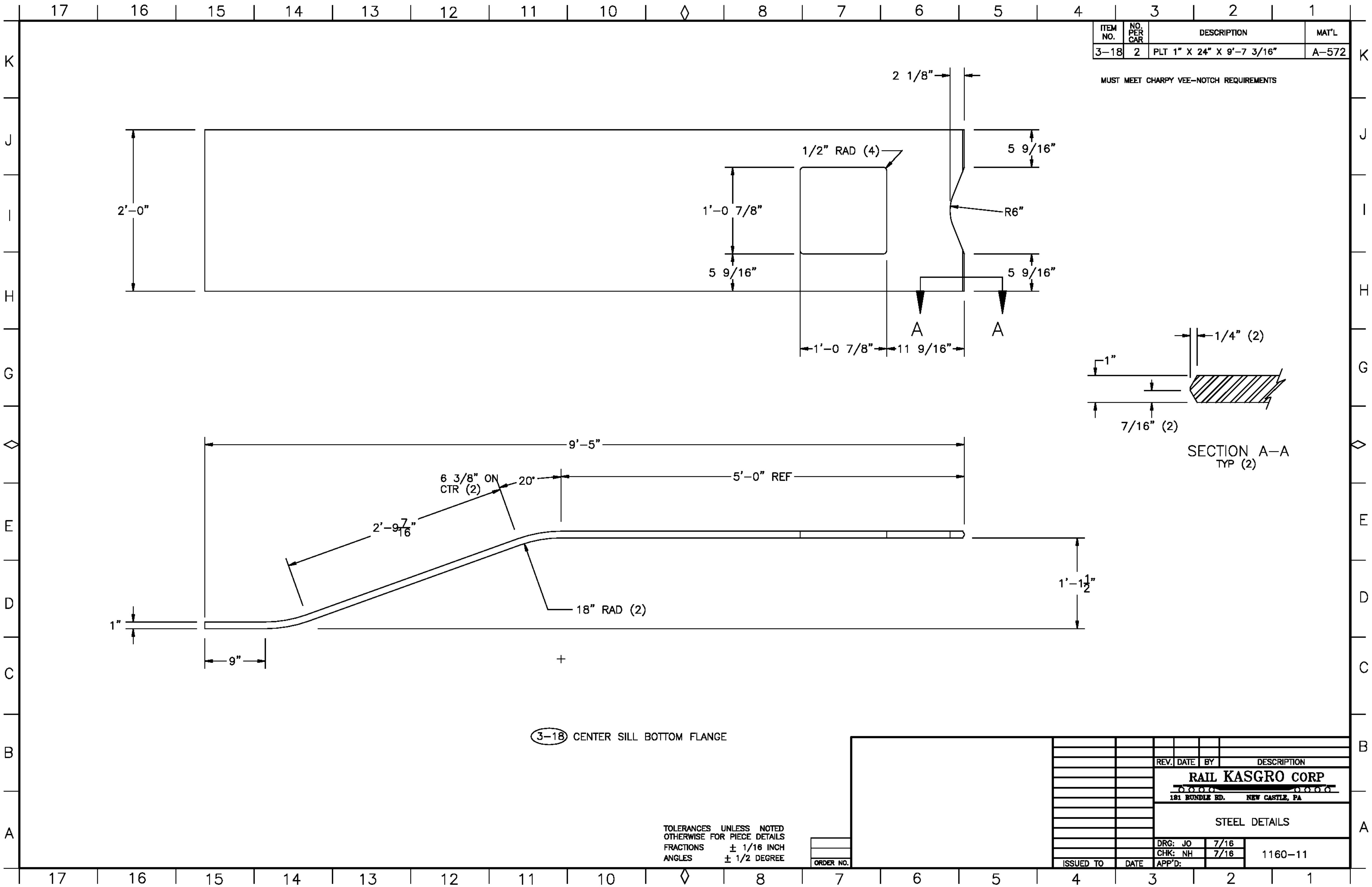
ITEM NO.	NO. PER CAR	DESCRIPTION	MAT'L
3–31	1	PLT 1" X 11 11/16" X 15'–9 1/8"	A–572

Appendix H-1.10 Steel Details

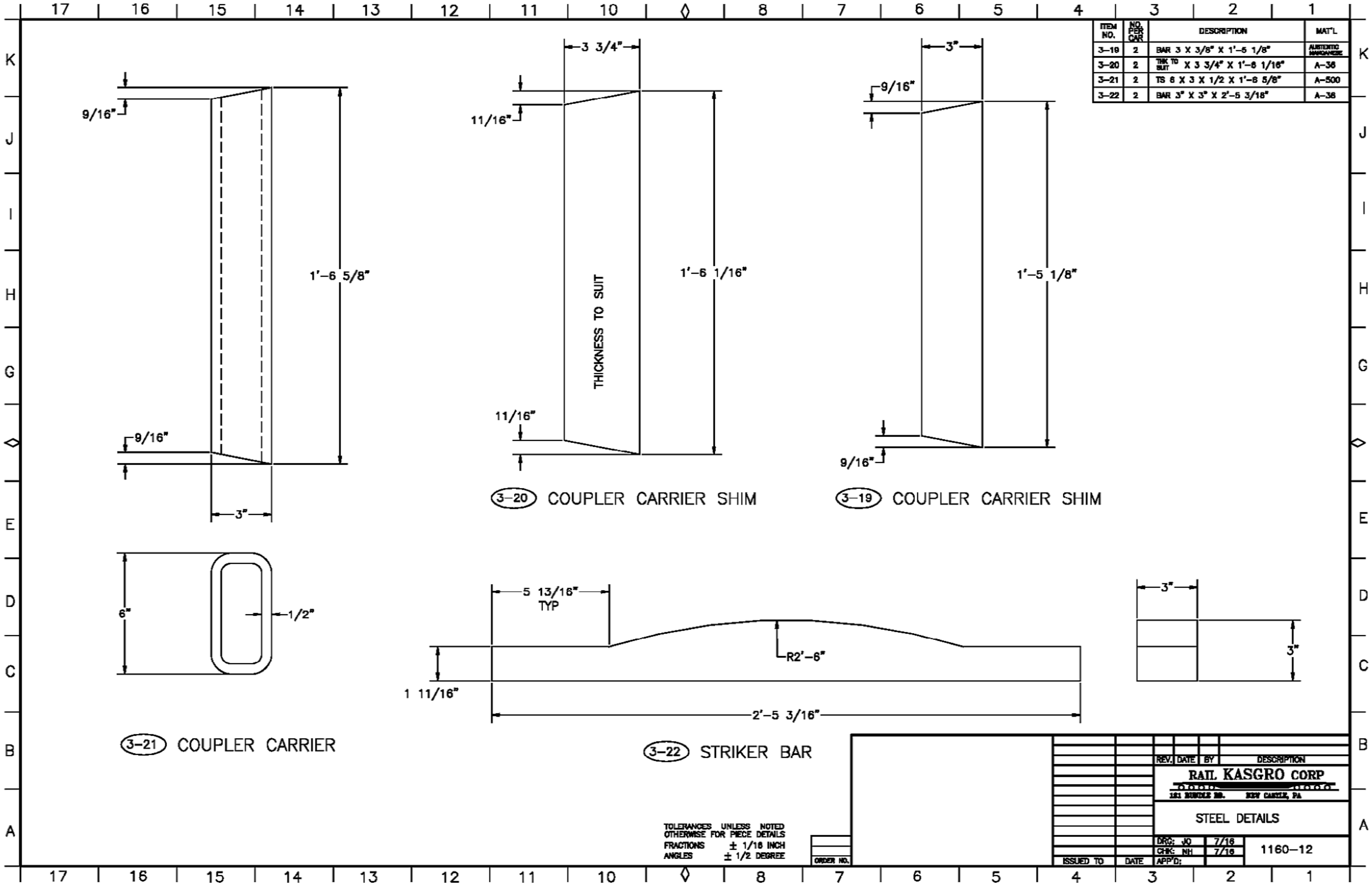


ITEM NO.	NO. PER CAR	DESCRIPTION	MAT'L
3–16	2	PLT 1" X 7" X 28'–7 1/2'	A–572
3–17	2	PLT 1" X 7" X 15'–9 1/8"	A–572
3–11	1	PLT 1" X 7" X 15'–9 1/8"	A–572

Appendix H-1.11 Steel Details

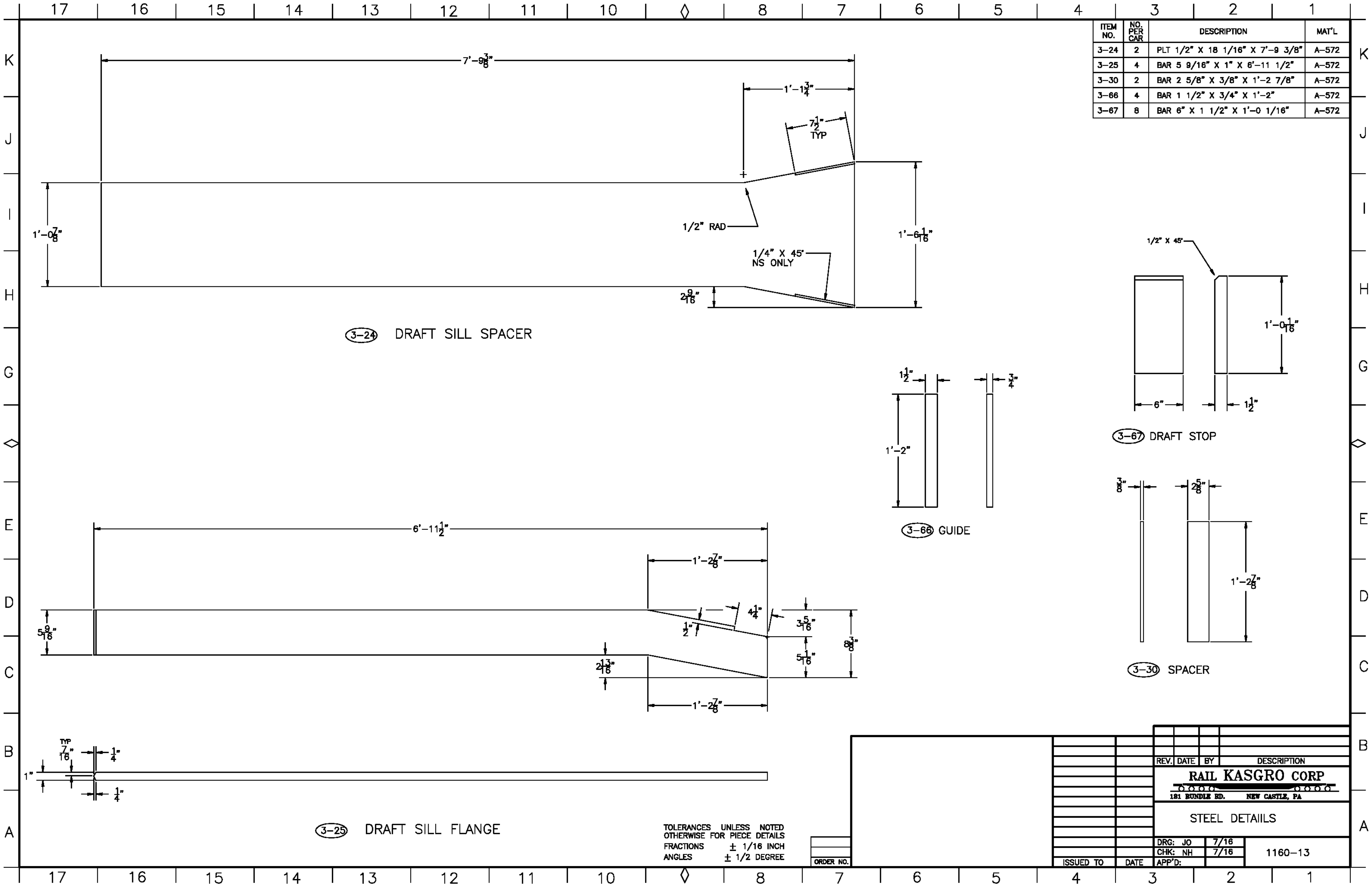


Appendix H-1.12 Steel Details



ITEM NO.	NO. PER CAR	DESCRIPTION	MAT'L
3–19	2	BAR 3 X 3/8" X 1'–5 1/8"	AUSTENITIC MANGANESE
3–20	2	THK TO SUIT X 3 3/4" X 1'–6 1/16"	A–36
3–21	2	TS 6 X 3 X 1/2 X 1'–6 5/8"	A–500
3–22	2	BAR 3" X 3" X 2'–5 3/16"	A–36

Appendix H-1.13 Steel Details



ITEM NO.	NO. PER CAR	DESCRIPTION	MAT'L
3-24	2	PLT 1/2" X 18 1/16" X 7'-9 3/8"	A-572
3-25	4	BAR 5 9/16" X 1" X 6'-11 1/2"	A-572
3-30	2	BAR 2 5/8" X 3/8" X 1'-2 7/8"	A-572
3-66	4	BAR 1 1/2" X 3/4" X 1'-2"	A-572
3-67	8	BAR 6" X 1 1/2" X 1'-0 1/16"	A-572

(3-24) DRAFT SILL SPACER

(3-67) DRAFT STOP

(3-66) GUIDE

(3-30) SPACER

(3-25) DRAFT SILL FLANGE

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

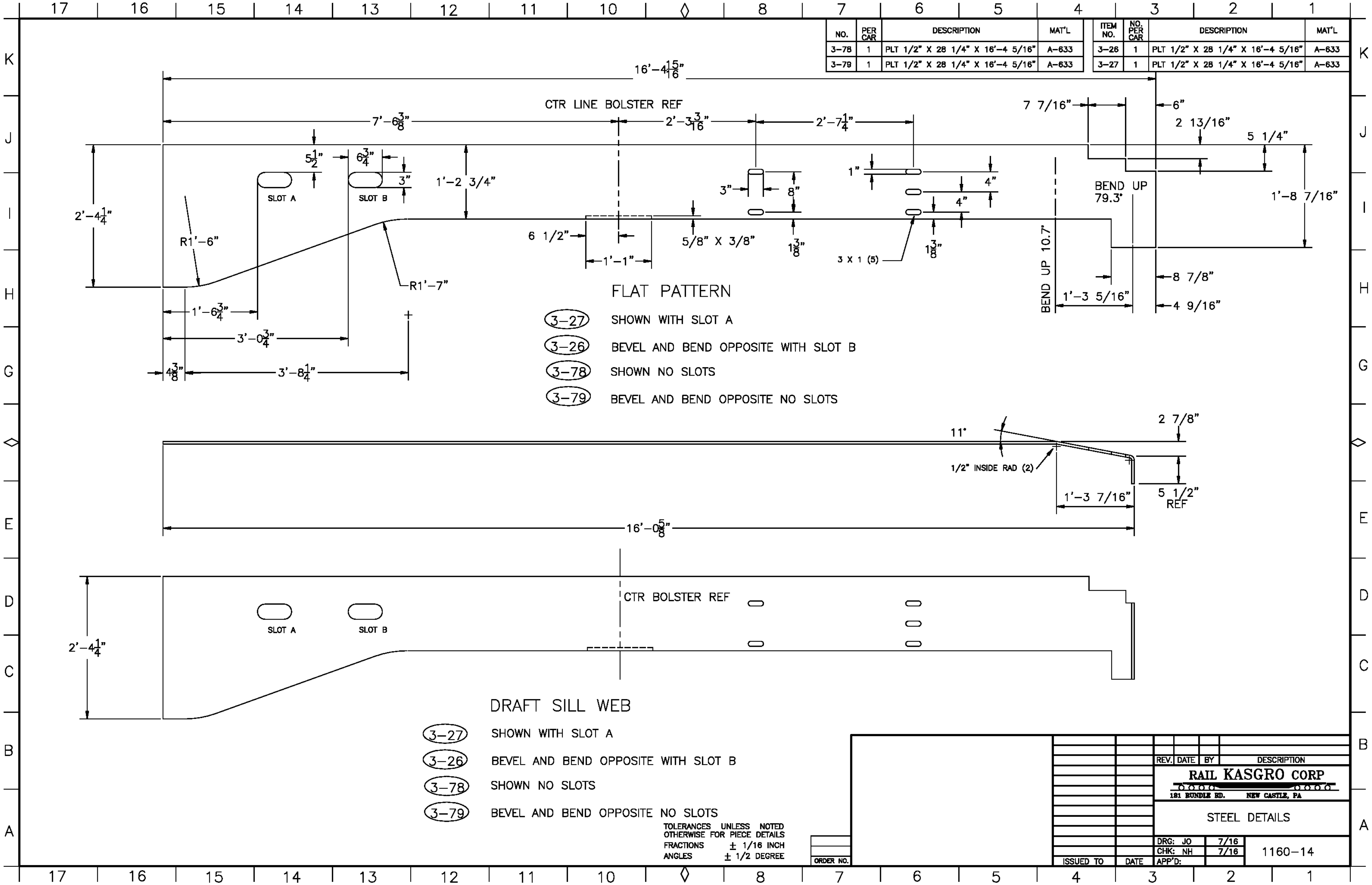
REV.	DATE	BY	DESCRIPTION

RAIL KASGRO CORP
181 RUNDLE RD. NEW CASTLE, PA

STEEL DETAIILS

DRG: JO 7/16
CHK: NH 7/16
APP'D:
1160-13

Appendix H-1.14 Steel Details



NO.	PER CAR	DESCRIPTION	MAT'L
3-78	1	PLT 1/2" X 28 1/4" X 16'-4 5/16"	A-633
3-79	1	PLT 1/2" X 28 1/4" X 16'-4 5/16"	A-633

ITEM NO.	NO. PER CAR	DESCRIPTION	MAT'L
3-26	1	PLT 1/2" X 28 1/4" X 16'-4 5/16"	A-633
3-27	1	PLT 1/2" X 28 1/4" X 16'-4 5/16"	A-633

FLAT PATTERN

(3-27)	SHOWN WITH SLOT A
(3-26)	BEVEL AND BEND OPPOSITE WITH SLOT B
(3-78)	SHOWN NO SLOTS
(3-79)	BEVEL AND BEND OPPOSITE NO SLOTS

DRAFT SILL WEB

(3-27)	SHOWN WITH SLOT A
(3-26)	BEVEL AND BEND OPPOSITE WITH SLOT B
(3-78)	SHOWN NO SLOTS
(3-79)	BEVEL AND BEND OPPOSITE NO SLOTS

TOLERANCES UNLESS NOTED OTHERWISE FOR PIECE DETAILS

FRACTIONS	± 1/16 INCH
ANGLES	± 1/2 DEGREE

ORDER NO.

ISSUED TO | DATE

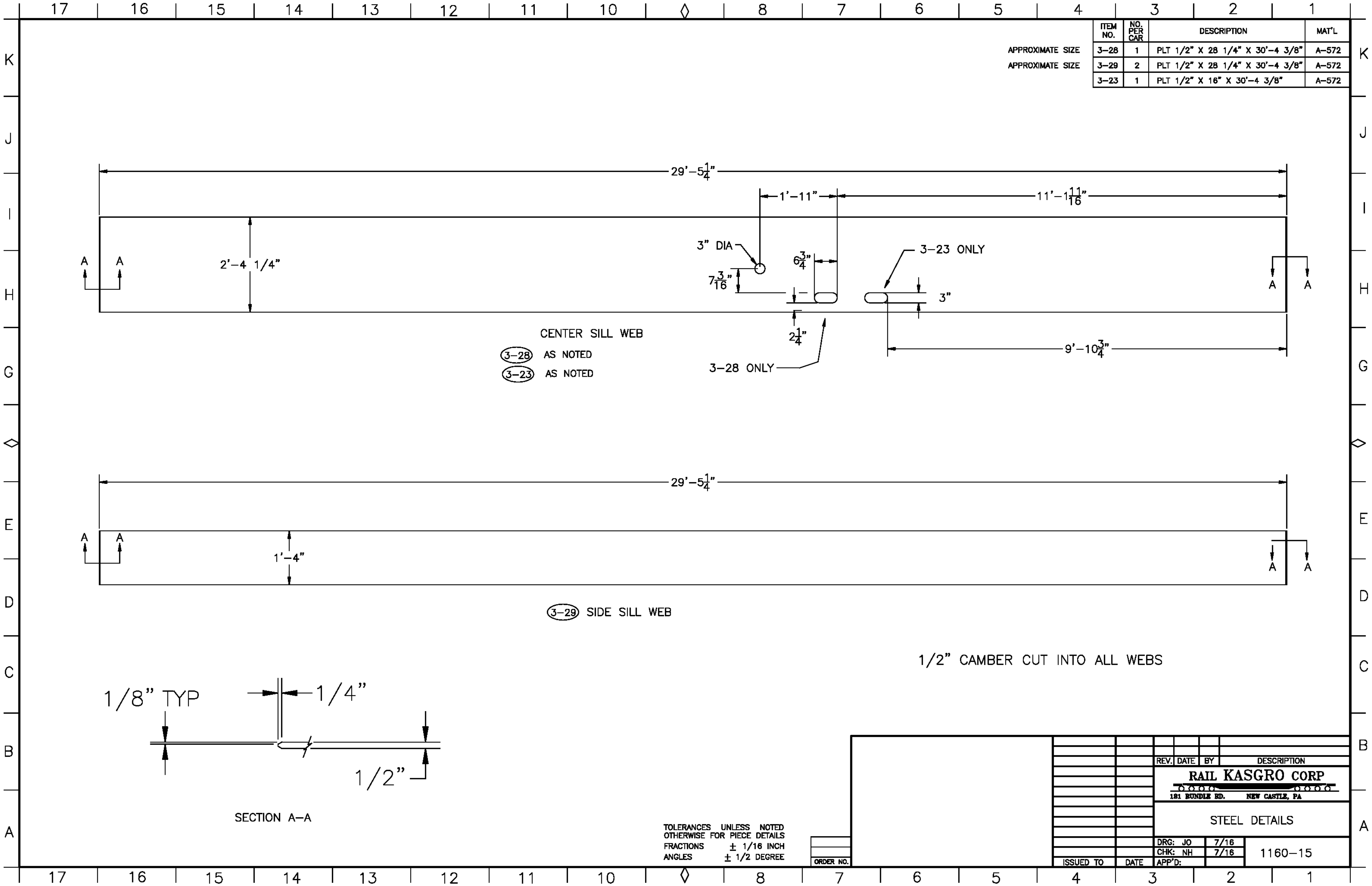
REV. | DATE | BY | DESCRIPTION

RAIL KASGRO CORP
181 BUNDLE RD. NEW CASTLE, PA

STEEL DETAILS

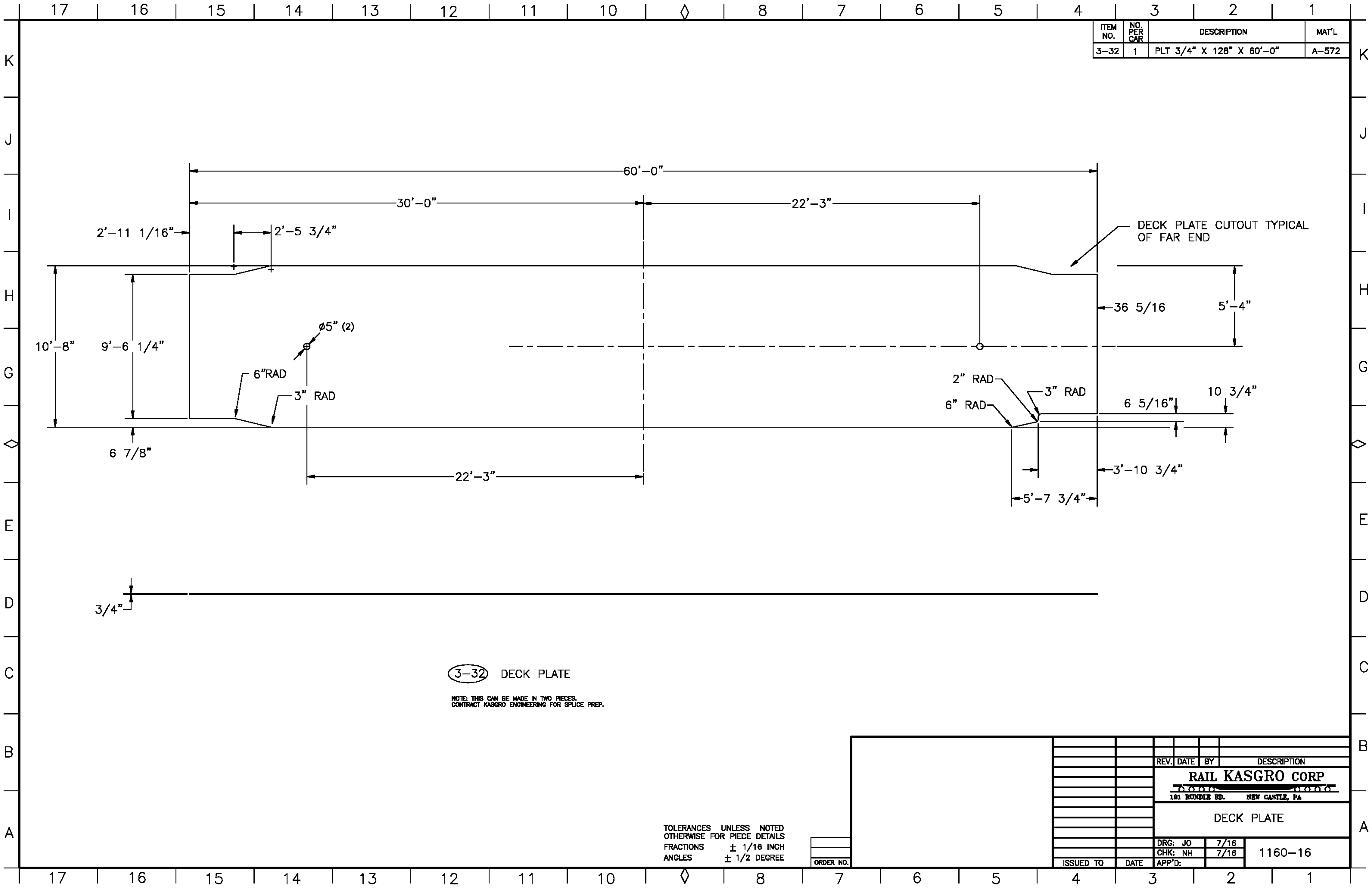
DRG: JO	7/16	1160-14
CHK: NH	7/16	
APP'D:		

Appendix H-1.15 Steel Details

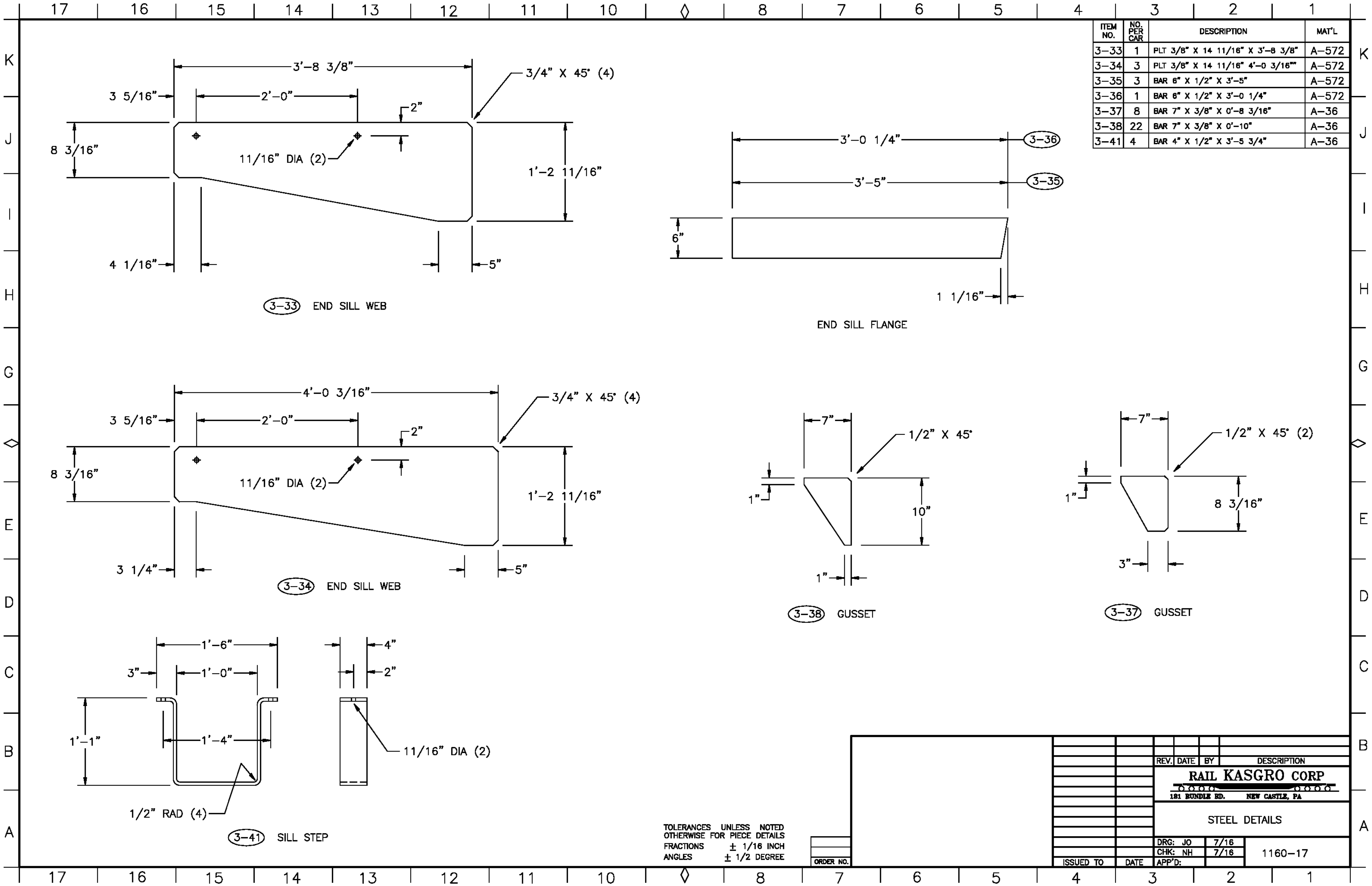


	ITEM NO.	NO. PER CAR	DESCRIPTION	MAT'L
APPROXIMATE SIZE	3–28	1	PLT 1/2" X 28 1/4" X 30'–4 3/8"	A–572
APPROXIMATE SIZE	3–29	2	PLT 1/2" X 28 1/4" X 30'–4 3/8"	A–572
	3–23	1	PLT 1/2" X 16" X 30'–4 3/8"	A–572

Appendix H-1.16 Deck Plate

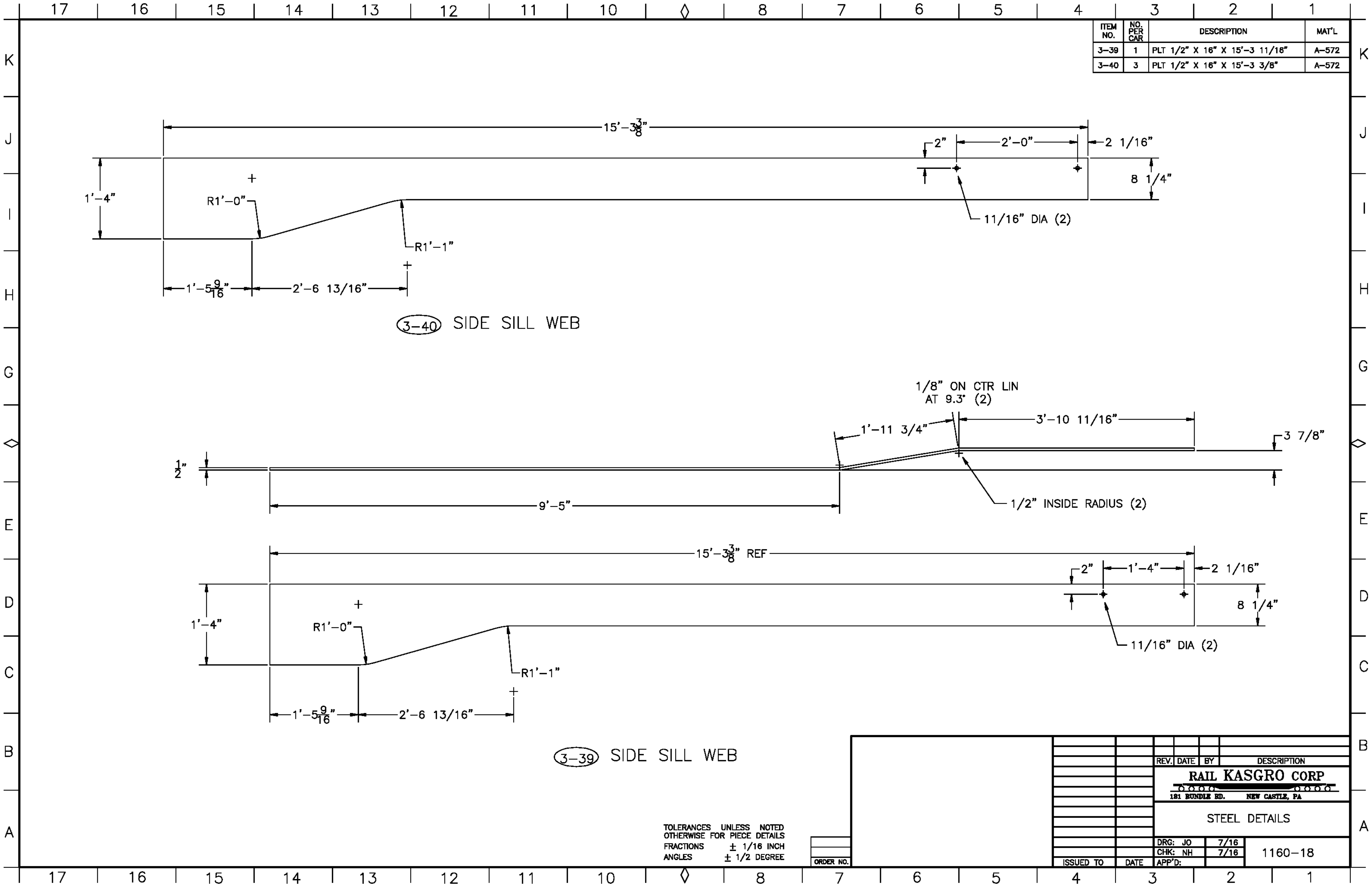


Appendix H-1.17 Steel Details



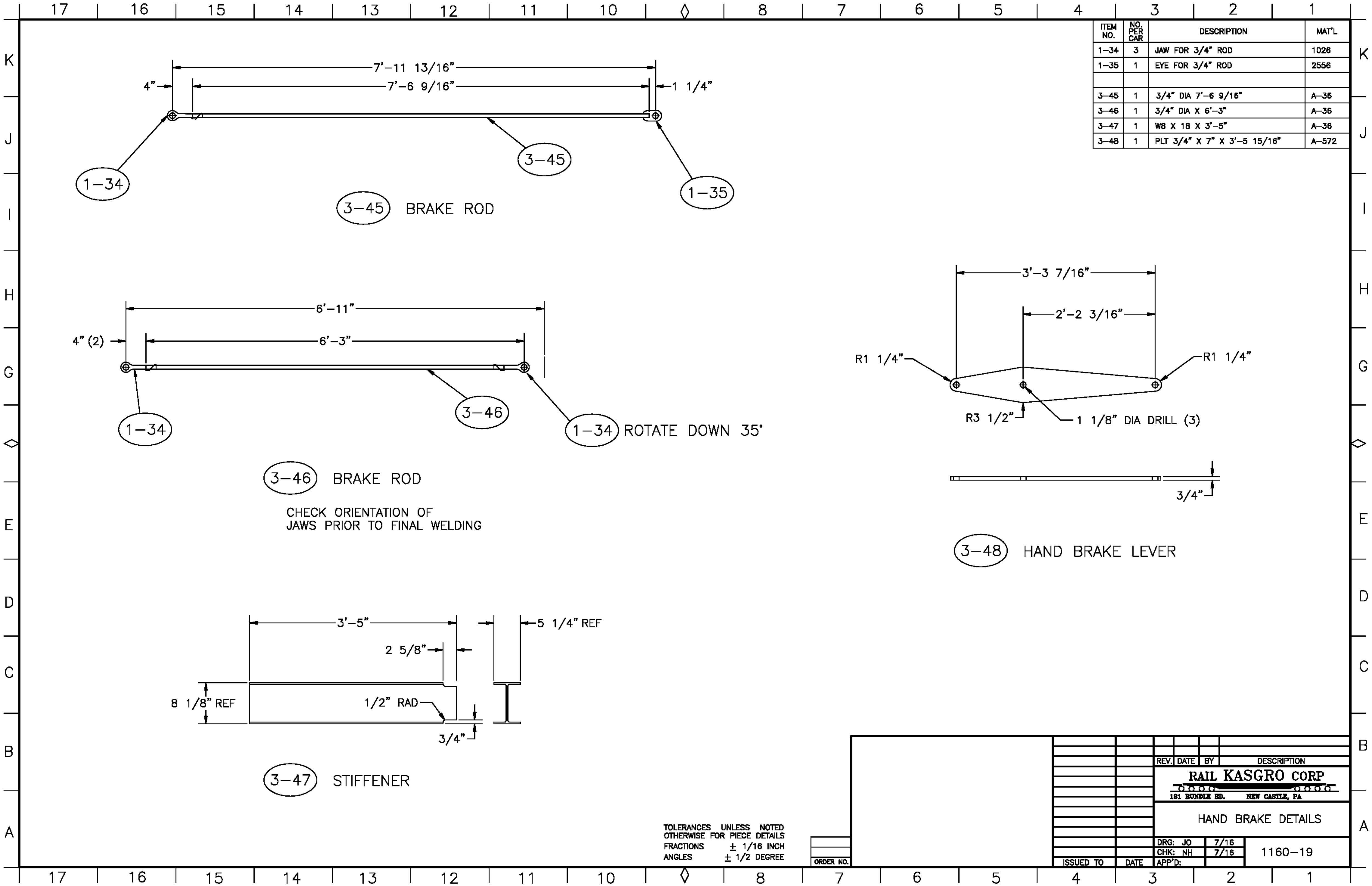
ITEM NO.	NO. PER CAR	DESCRIPTION	MAT'L
3–33	1	PLT 3/8" X 14 11/16" X 3'–8 3/8"	A–572
3–34	3	PLT 3/8" X 14 11/16" 4'–0 3/16""	A–572
3–35	3	BAR 6" X 1/2" X 3'–5"	A–572
3–36	1	BAR 6" X 1/2" X 3'–0 1/4"	A–572
3–37	8	BAR 7" X 3/8" X 0'–8 3/16"	A–36
3–38	22	BAR 7" X 3/8" X 0'–10"	A–36
3–41	4	BAR 4" X 1/2" X 3'–5 3/4"	A–36

Appendix H-1.18 Steel Details



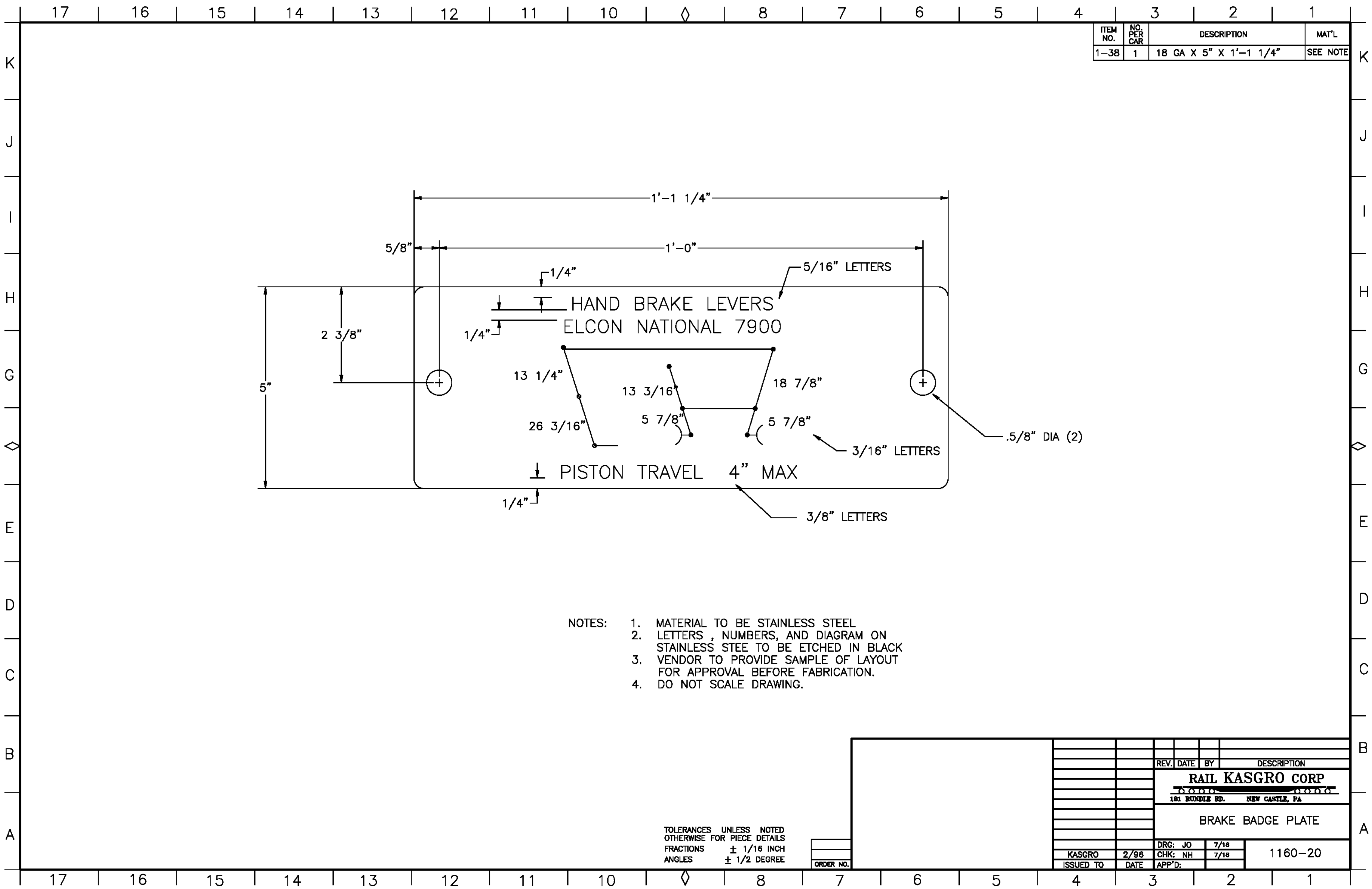
ITEM NO.	NO. PER CAR	DESCRIPTION	MAT'L
3–39	1	PLT 1/2" X 16" X 15'–3 11/16"	A–572
3–40	3	PLT 1/2" X 16" X 15'–3 3/8"	A–572

Appendix H-1.19 Hand Brake Details



ITEM NO.	NO. PER CAR	DESCRIPTION	MAT'L
1-34	3	JAW FOR 3/4" ROD	1026
1-35	1	EYE FOR 3/4" ROD	2556
3-45	1	3/4" DIA 7'-6 9/16"	A-36
3-46	1	3/4" DIA X 6'-3"	A-36
3-47	1	W8 X 18 X 3'-5"	A-36
3-48	1	PLT 3/4" X 7" X 3'-5 15/16"	A-572

Appendix H-1.20 Brake Badge Plate

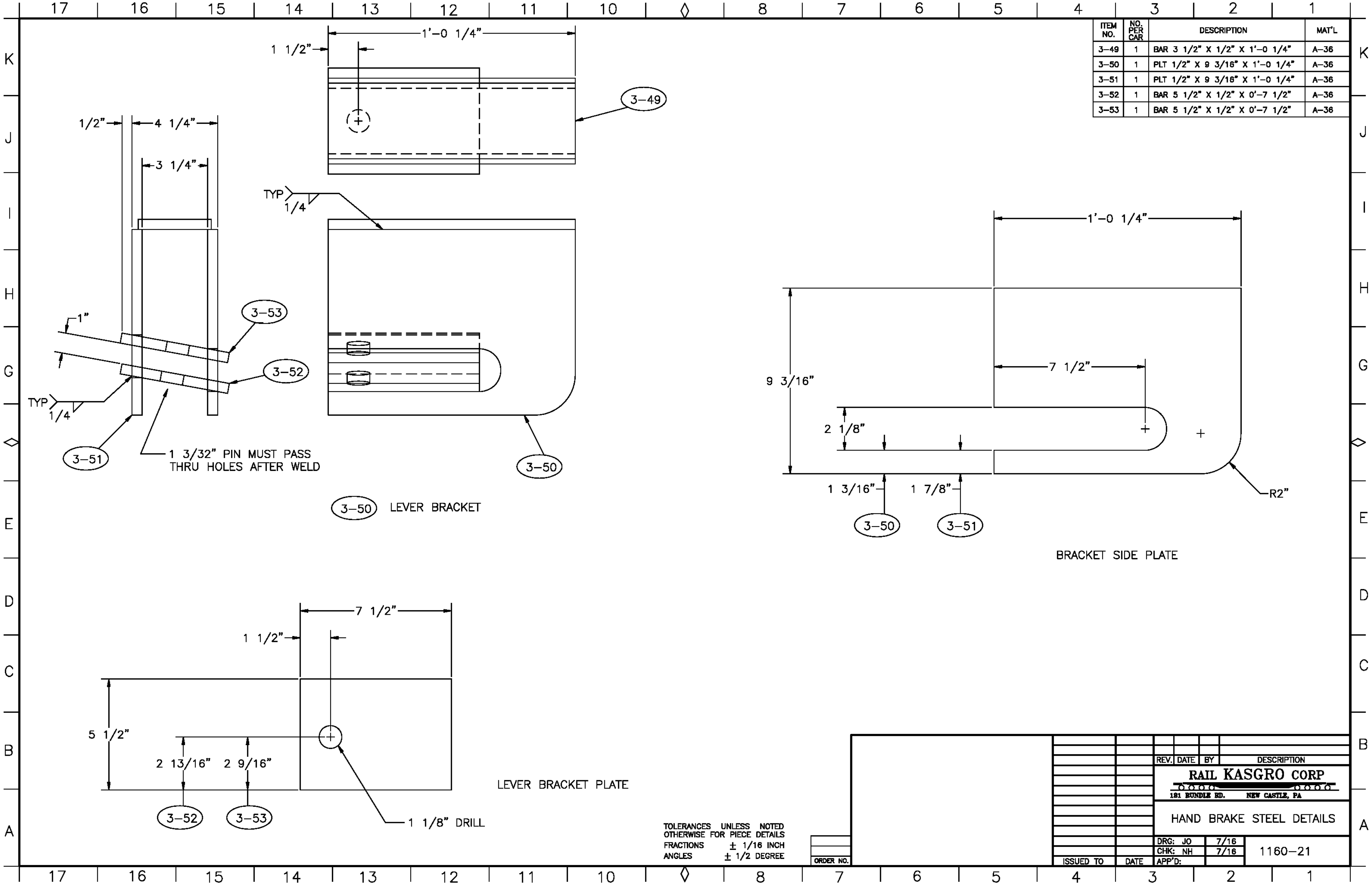


ITEM NO.	NO. PER CAR	DESCRIPTION	MAT'L
1–38	1	18 GA X 5" X 1'–1 1/4"	SEE NOTE

NOTES:
1. MATERIAL TO BE STAINLESS STEEL
2. LETTERS , NUMBERS, AND DIAGRAM ON STAINLESS STEE TO BE ETCHED IN BLACK
3. VENDOR TO PROVIDE SAMPLE OF LAYOUT FOR APPROVAL BEFORE FABRICATION.
4. DO NOT SCALE DRAWING.

]

Appendix H-1.21 Hand Brake Steel Details



ITEM NO.	NO. PER CAR	DESCRIPTION	MAT'L
3–49	1	BAR 3 1/2" X 1/2" X 1'–0 1/4"	A–36
3–50	1	PLT 1/2" X 9 3/16" X 1'–0 1/4"	A–36
3–51	1	PLT 1/2" X 9 3/16" X 1'–0 1/4"	A–36
3–52	1	BAR 5 1/2" X 1/2" X 0'–7 1/2"	A–36
3–53	1	BAR 5 1/2" X 1/2" X 0'–7 1/2"	A–36

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

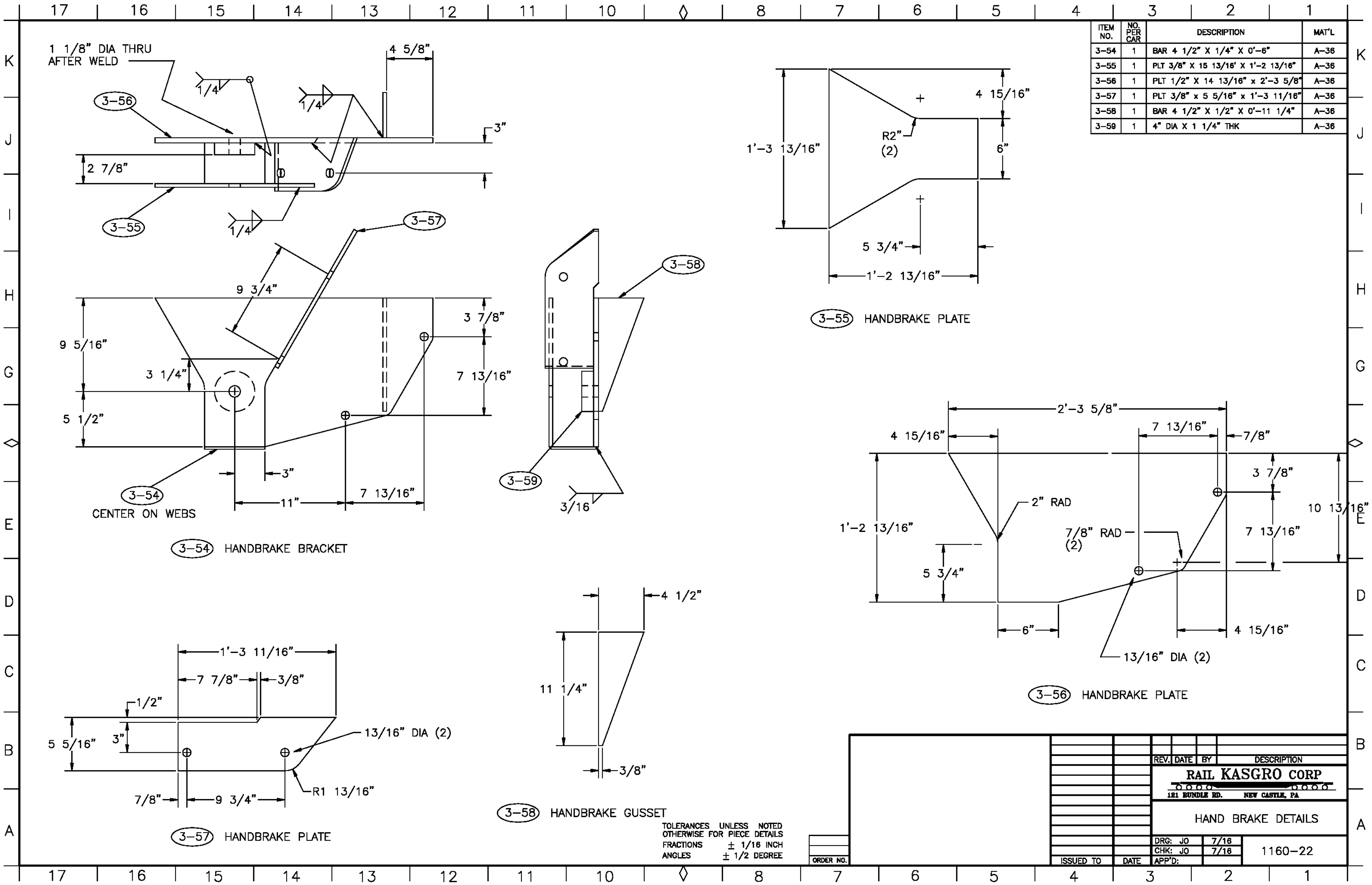
ORDER NO.
ISSUED TO
DATE
REV. DATE BY DESCRIPTION

RAIL KASGRO CORP
181 BUNDLE RD. NEW CASTLE, PA

HAND BRAKE STEEL DETAILS

DRG: JO 7/16
CHK: NH 7/16
APP'D:
1160–21

Appendix H-1.22 Hand Brake Details



ITEM NO.	NO. PER CAR	DESCRIPTION	MAT'L
3-54	1	BAR 4 1/2" X 1/4" X 0'-6"	A-36
3-55	1	PLT 3/8" X 15 13/16' X 1'-2 13/16"	A-36
3-56	1	PLT 1/2" X 14 13/16" x 2'-3 5/8"	A-36
3-57	1	PLT 3/8" x 5 5/16" x 1'-3 11/16"	A-36
3-58	1	BAR 4 1/2" X 1/2" X 0'-11 1/4"	A-36
3-59	1	4" DIA X 1 1/4" THK	A-36

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

ORDER NO.
ISSUED TO
DATE

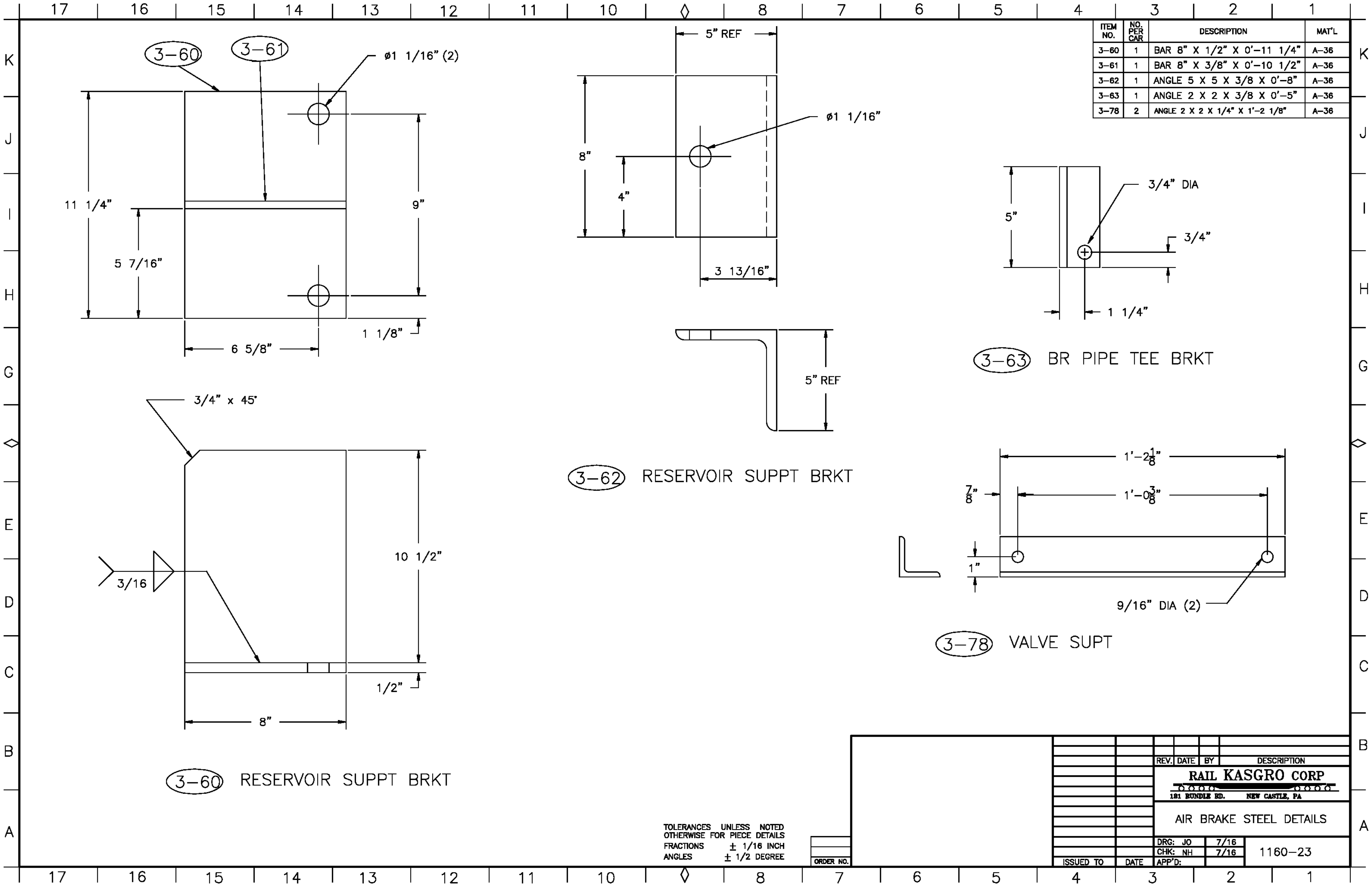
REV. DATE BY DESCRIPTION

RAIL KASGRO CORP
121 BUNDLE RD. NEW CASTLE, PA

HAND BRAKE DETAILS

DRG: JO 7/16
CHK: JO 7/16
APP'D:
1160-22

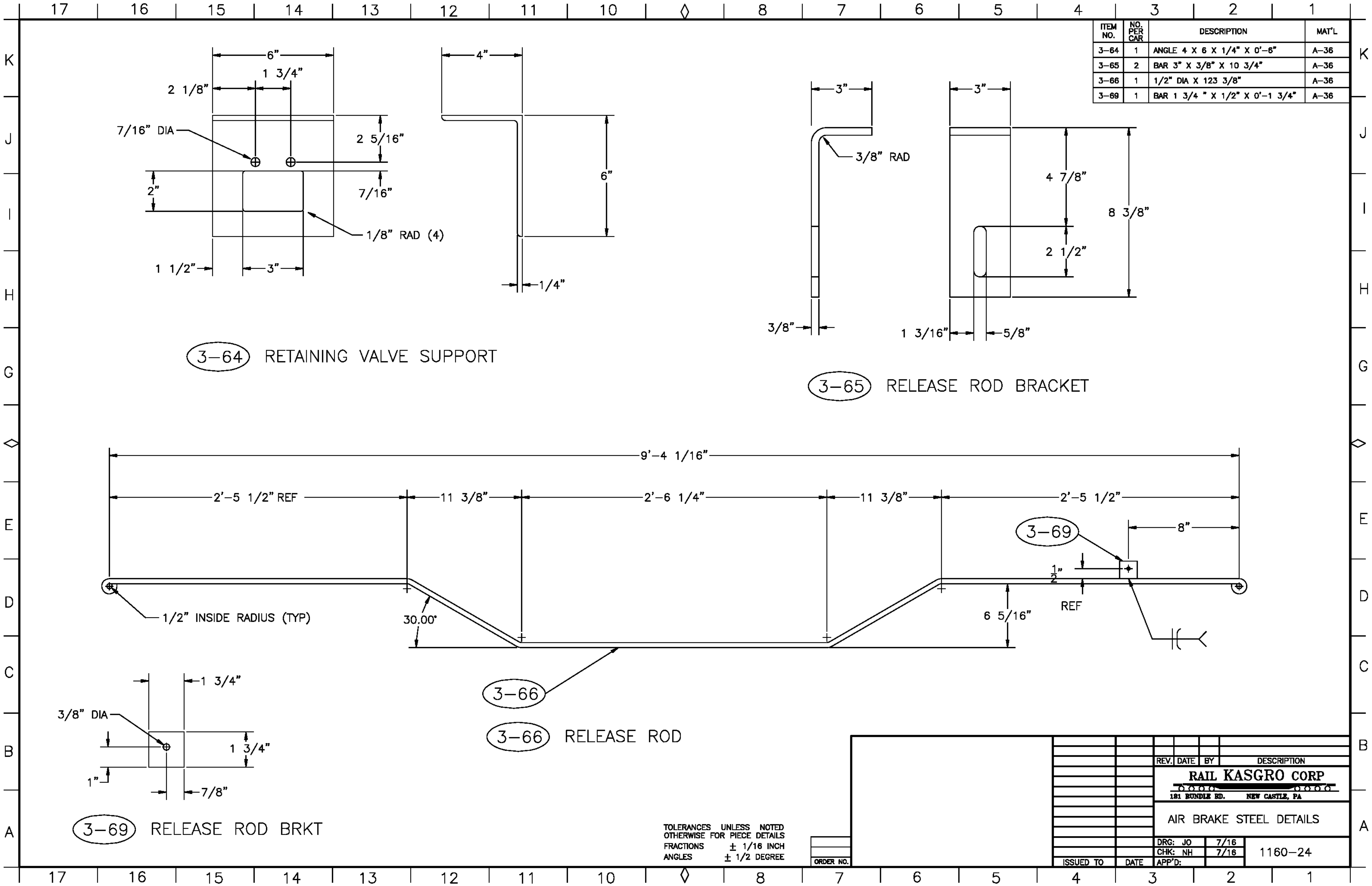
Appendix H-1.23 Air Brake Steel Details



ITEM NO.	NO. PER CAR	DESCRIPTION	MAT'L
3-60	1	BAR 8" X 1/2" X 0'-11 1/4"	A-36
3-61	1	BAR 8" X 3/8" X 0'-10 1/2"	A-36
3-62	1	ANGLE 5 X 5 X 3/8 X 0'-8"	A-36
3-63	1	ANGLE 2 X 2 X 3/8 X 0'-5"	A-36
3-78	2	ANGLE 2 X 2 X 1/4" X 1'-2 1/8"	A-36

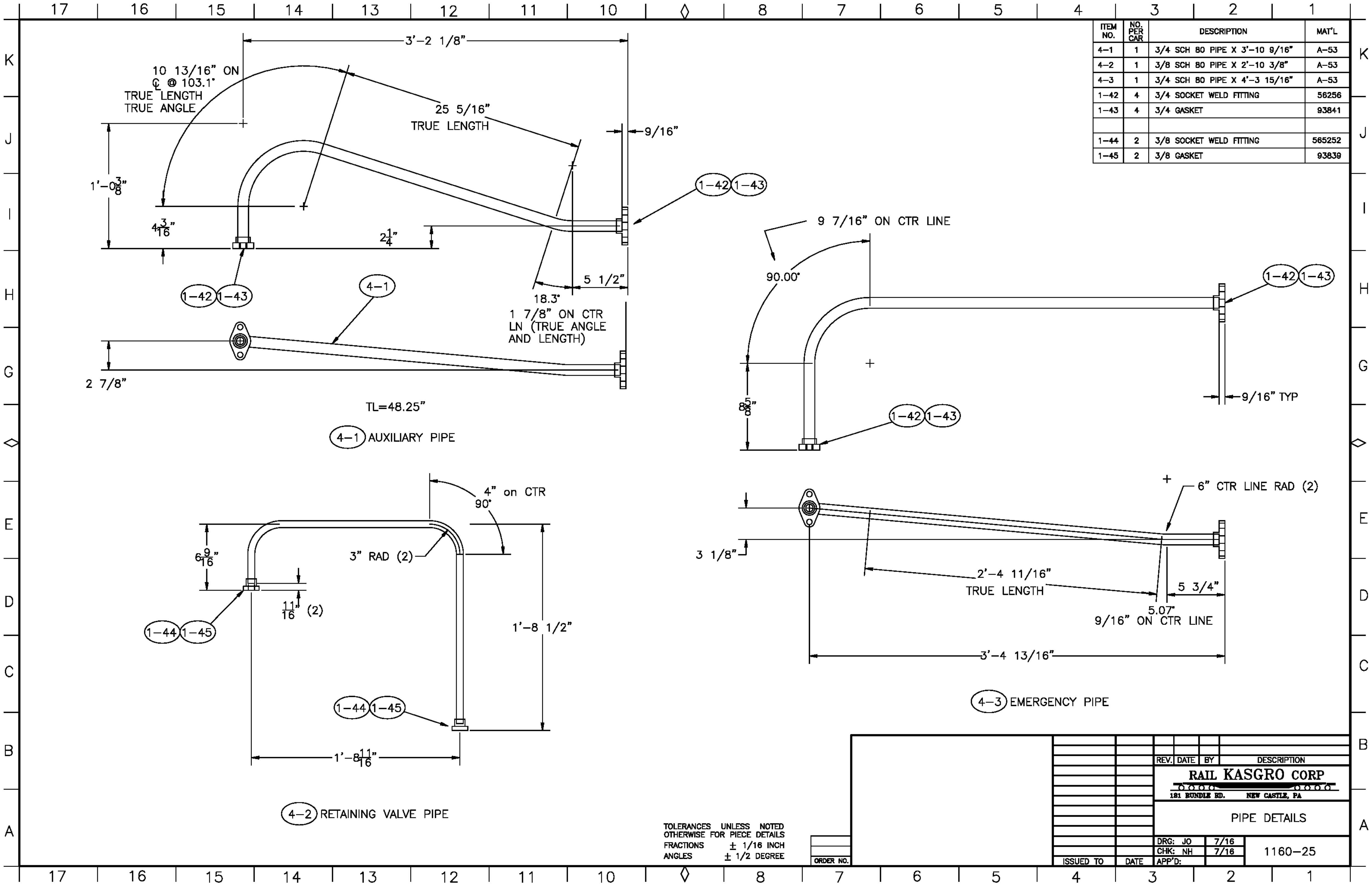
TOLERANCES UNLESS NOTED OTHERWISE FOR PIECE DETAILS
FRACTIONS ± 1/16 INCH
ANGLES ± 1/2 DEGREE

Appendix H-1.24 Air Brake Steel Details



ITEM NO.	NO. PER CAR	DESCRIPTION	MAT'L
3–64	1	ANGLE 4 X 6 X 1/4" X 0'–6"	A–36
3–65	2	BAR 3" X 3/8" X 10 3/4"	A–36
3–66	1	1/2" DIA X 123 3/8"	A–36
3–69	1	BAR 1 3/4 " X 1/2" X 0'–1 3/4"	A–36

Appendix H-1.25 Pipe Details



ITEM NO.	NO. PER CAR	DESCRIPTION	MAT'L
4-1	1	3/4 SCH 80 PIPE X 3'-10 9/16"	A-53
4-2	1	3/8 SCH 80 PIPE X 2'-10 3/8"	A-53
4-3	1	3/4 SCH 80 PIPE X 4'-3 15/16"	A-53
1-42	4	3/4 SOCKET WELD FITTING	56256
1-43	4	3/4 GASKET	93841
1-44	2	3/8 SOCKET WELD FITTING	565252
1-45	2	3/8 GASKET	93839

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

ORDER NO.

ISSUED TO | DATE

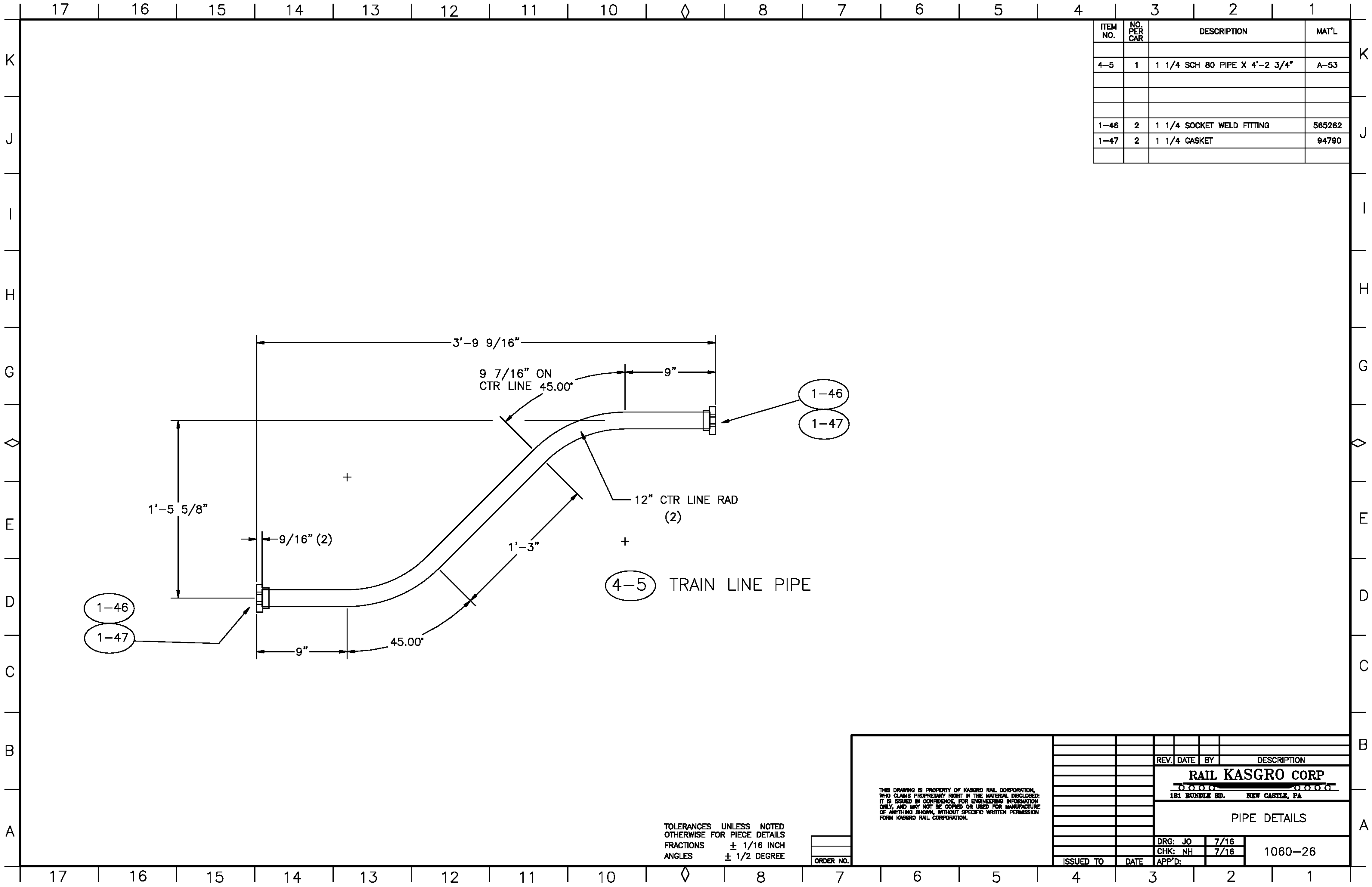
REV.	DATE	BY	DESCRIPTION

RAIL KASGRO CORP
181 BUNDLE RD. NEW CASTLE, PA

PIPE DETAILS

DRG: JO 7/16
CHK: NH 7/16
APP'D:
1160-25

Appendix H-1.26 Pipe Details



ITEM NO.	NO. PER CAR	DESCRIPTION	MAT'L
4-5	1	1 1/4 SCH 80 PIPE X 4'-2 3/4"	A-53
1-46	2	1 1/4 SOCKET WELD FITTING	565262
1-47	2	1 1/4 GASKET	94790

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

ORDER NO.

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ISSUED TO
DATE

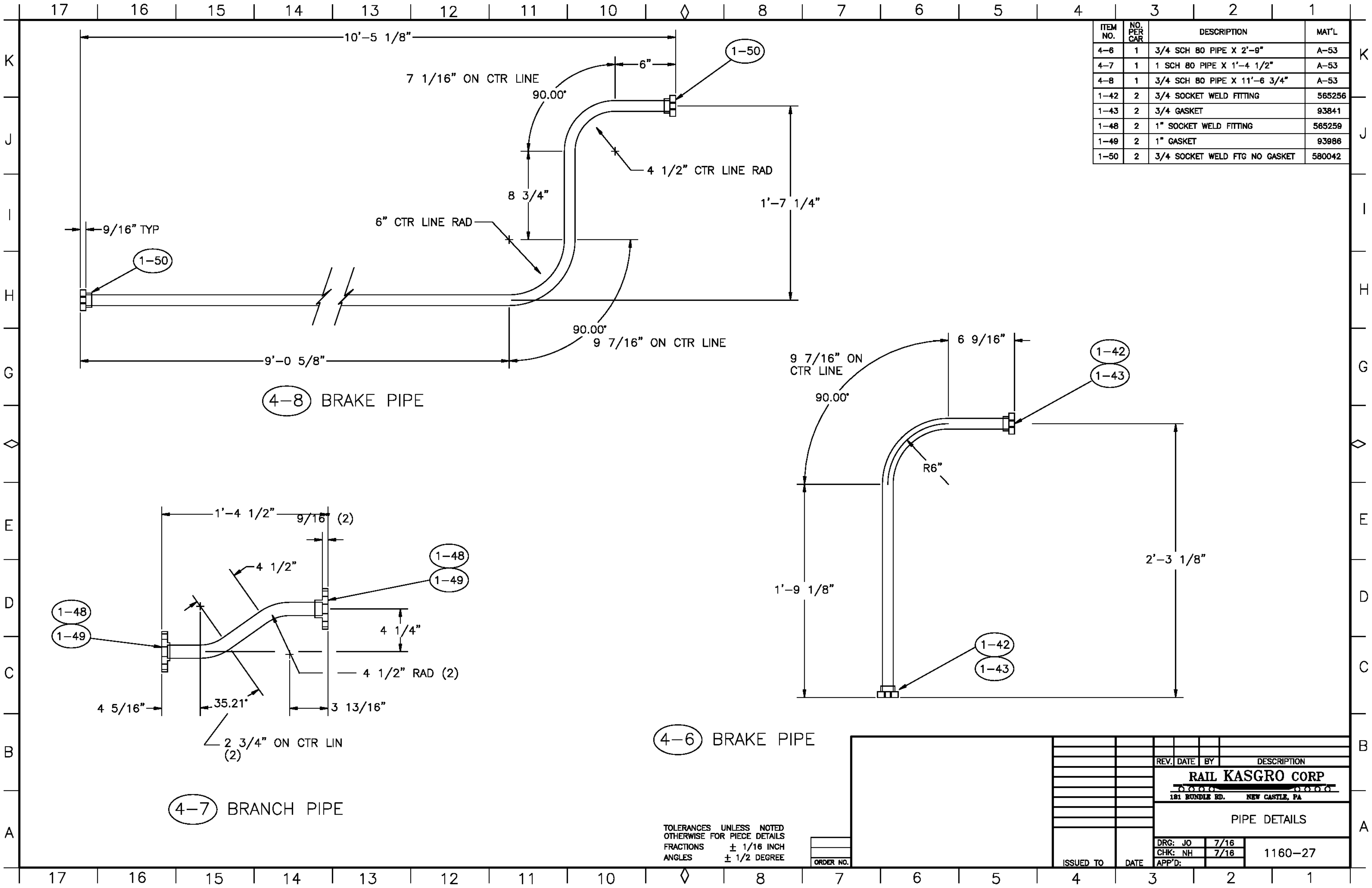
REV. DATE BY DESCRIPTION

RAIL KASGRO CORP
121 BUNDLE RD. NEW CASTLE, PA

PIPE DETAILS

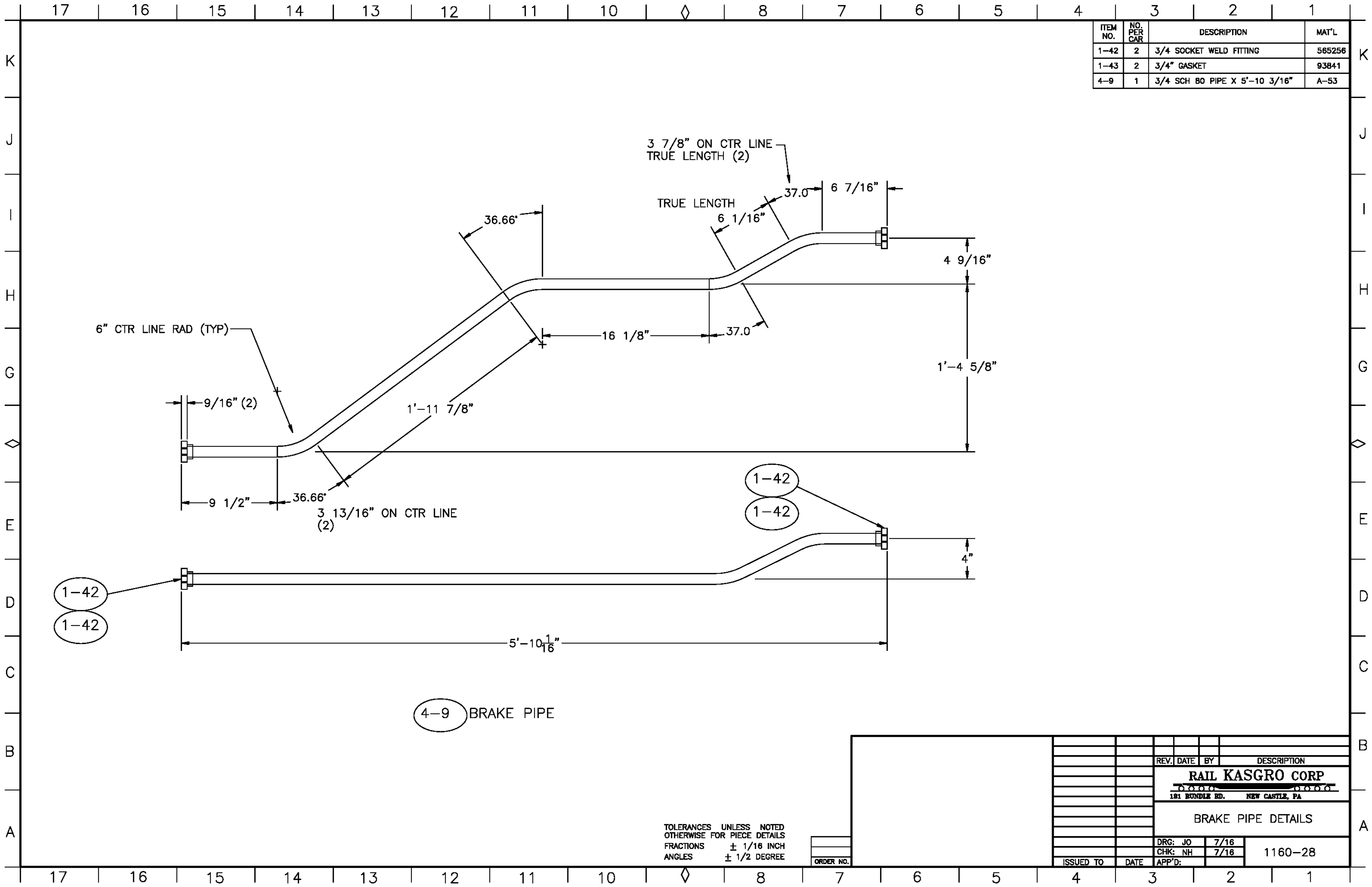
DRG: JO 7/16
CHK: NH 7/16
APP'D:
1060-26

Appendix H-1.27 Pipe Details



ITEM NO.	NO. PER CAR	DESCRIPTION	MAT'L
4–6	1	3/4 SCH 80 PIPE X 2'–9"	A–53
4–7	1	1 SCH 80 PIPE X 1'–4 1/2"	A–53
4–8	1	3/4 SCH 80 PIPE X 11'–6 3/4"	A–53
1–42	2	3/4 SOCKET WELD FITTING	565256
1–43	2	3/4 GASKET	93841
1–48	2	1" SOCKET WELD FITTING	565259
1–49	2	1" GASKET	93986
1–50	2	3/4 SOCKET WELD FTG NO GASKET	580042

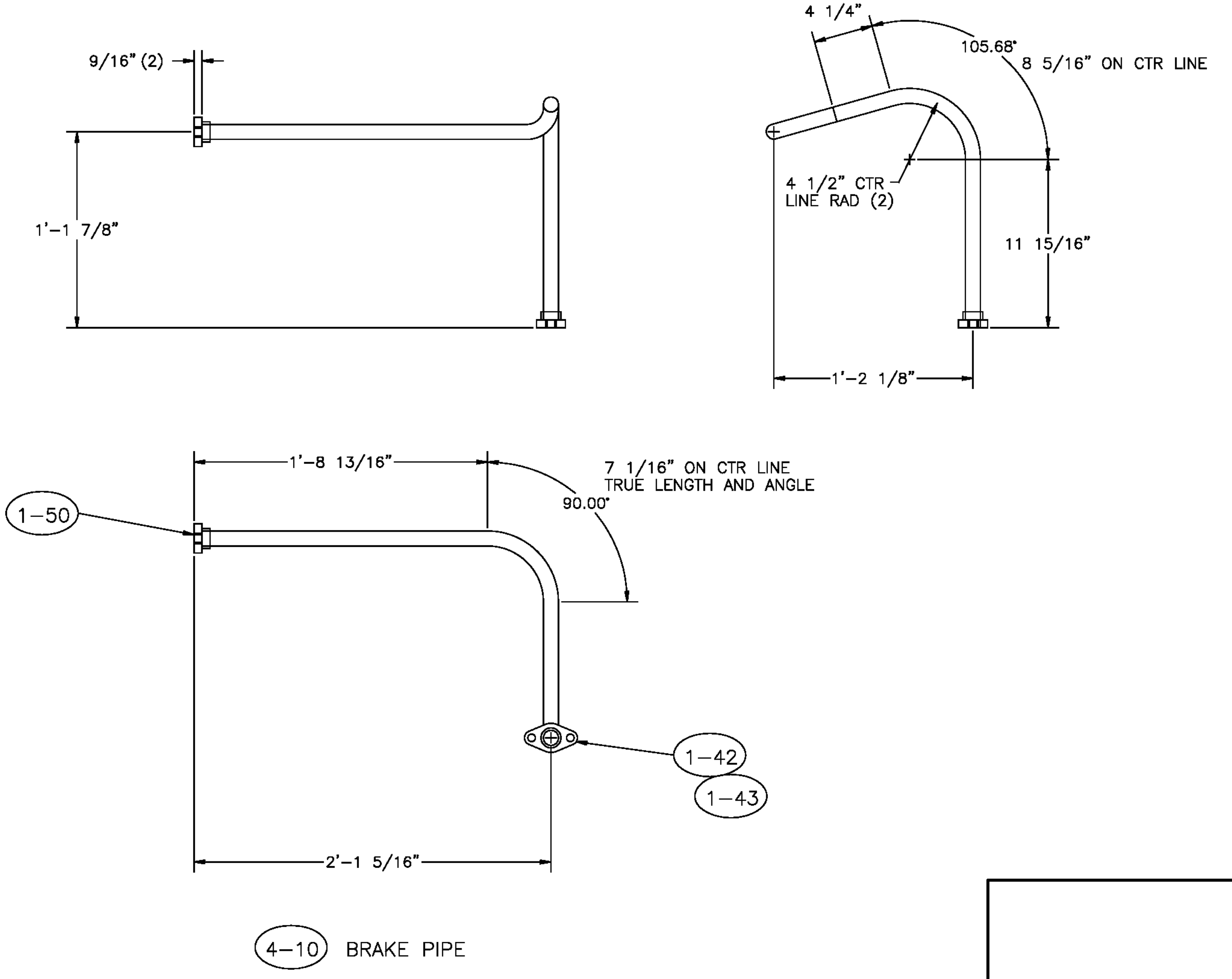
Appendix H-1.28 Brake Pipe Details



ITEM NO.	NO. PER CAR	DESCRIPTION	MAT'L
1–42	2	3/4 SOCKET WELD FITTING	565256
1–43	2	3/4" GASKET	93841
4–9	1	3/4 SCH 80 PIPE X 5'–10 3/16"	A–53

Appendix H-1.29 Air Brake Details

ITEM NO.	NO. PER CAR	DESCRIPTION	MAT'L
1–42	1	3/4 SOCKET WELD FITTING	565256
1–43	1	3/4 GASKET	93841
1–50	1	3/4 SOCKET WELD FITTING NO GASKET	580042
4–10	1	3/4 SCH 80 PIPE X 3'–11"	A–53



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

ORDER NO.

ISSUED TO | DATE

REV. | DATE | BY | DESCRIPTION

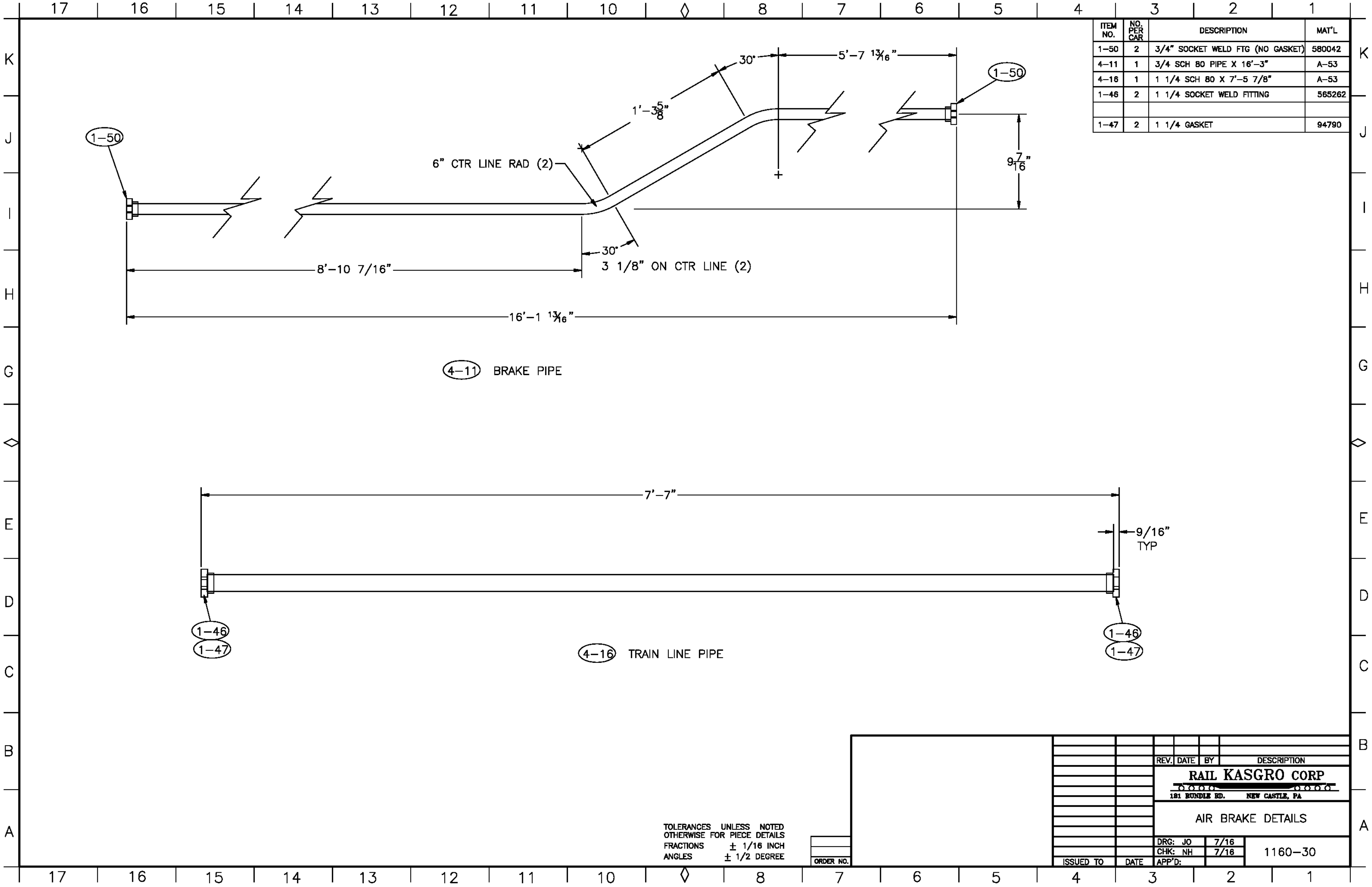
RAIL KASGRO CORP
181 BUNDLE RD. NEW CASTLE, PA

AIR BRAKE DETAILS

DRG: JO 7/16
CHK: NH 7/16
APP'D:

1160–29

Appendix H-1.30 Air Brake Details



ITEM NO.	NO. PER CAR	DESCRIPTION	MAT'L
1–50	2	3/4" SOCKET WELD FTG (NO GASKET)	580042
4–11	1	3/4 SCH 80 PIPE X 16'–3"	A–53
4–16	1	1 1/4 SCH 80 X 7'–5 7/8"	A–53
1–46	2	1 1/4 SOCKET WELD FITTING	565262
1–47	2	1 1/4 GASKET	94790

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

ORDER NO.

ISSUED TO | DATE

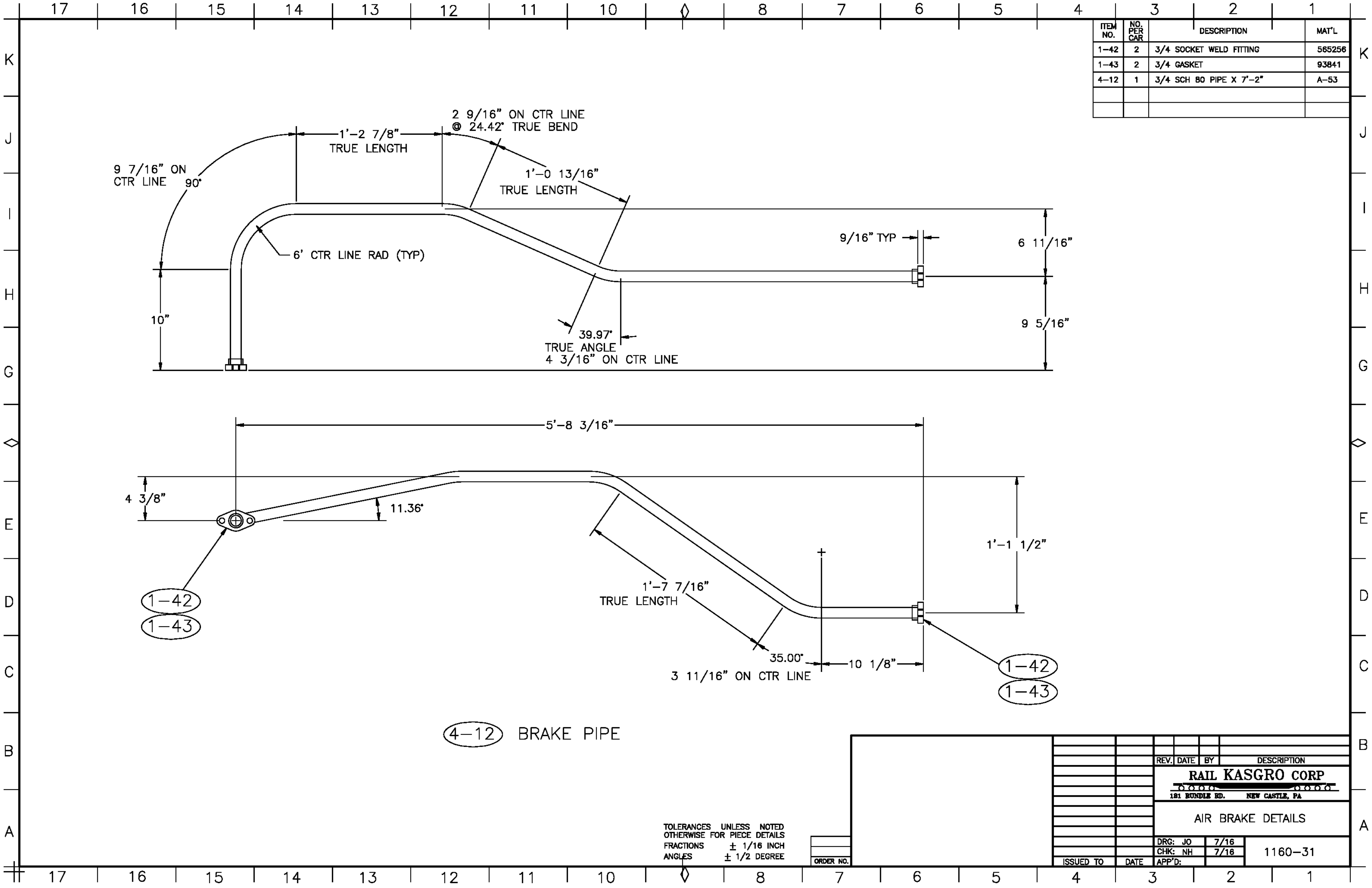
REV. | DATE | BY | DESCRIPTION

RAIL KASGRO CORP
181 BUNDLE RD. NEW CASTLE, PA

AIR BRAKE DETAILS

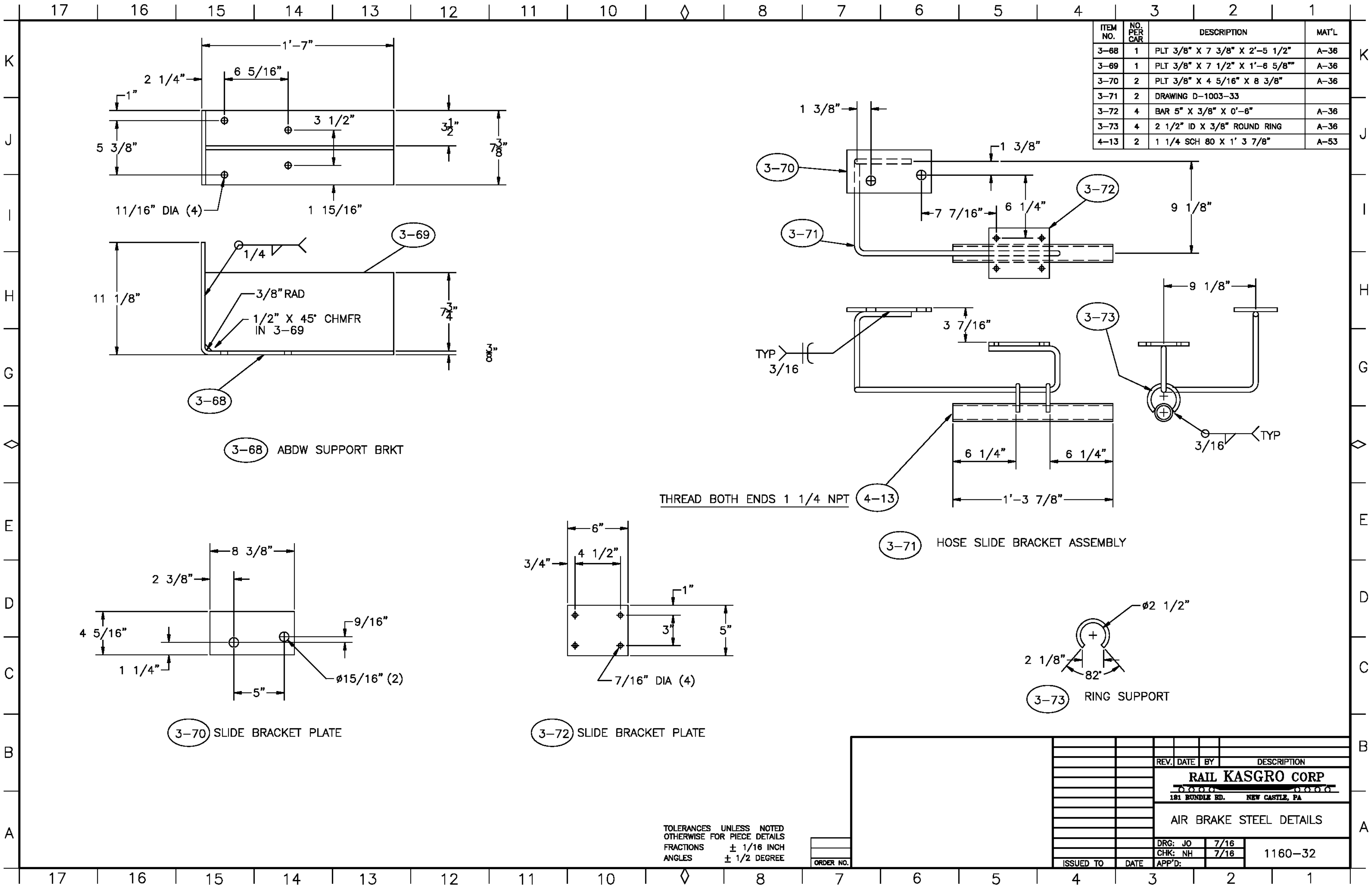
DRG: JO 7/16
CHK: NH 7/16
APP'D:
1160–30

Appendix H-1.31 Air Brake Details



ITEM NO.	NO. PER CAR	DESCRIPTION	MAT'L
1–42	2	3/4 SOCKET WELD FITTING	565256
1–43	2	3/4 GASKET	93841
4–12	1	3/4 SCH 80 PIPE X 7'–2"	A–53

Appendix H-1.32 Air Brake Steel Details



ITEM NO.	NO. PER CAR	DESCRIPTION	MAT'L
3-68	1	PLT 3/8" X 7 3/8" X 2'-5 1/2"	A-36
3-69	1	PLT 3/8" X 7 1/2" X 1'-6 5/8""	A-36
3-70	2	PLT 3/8" X 4 5/16" X 8 3/8"	A-36
3-71	2	DRAWING D-1003-33	
3-72	4	BAR 5" X 3/8" X 0'-6"	A-36
3-73	4	2 1/2" ID X 3/8" ROUND RING	A-36
4-13	2	1 1/4 SCH 80 X 1' 3 7/8"	A-53

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

ORDER NO.

ISSUED TO
DATE

REV. DATE BY DESCRIPTION

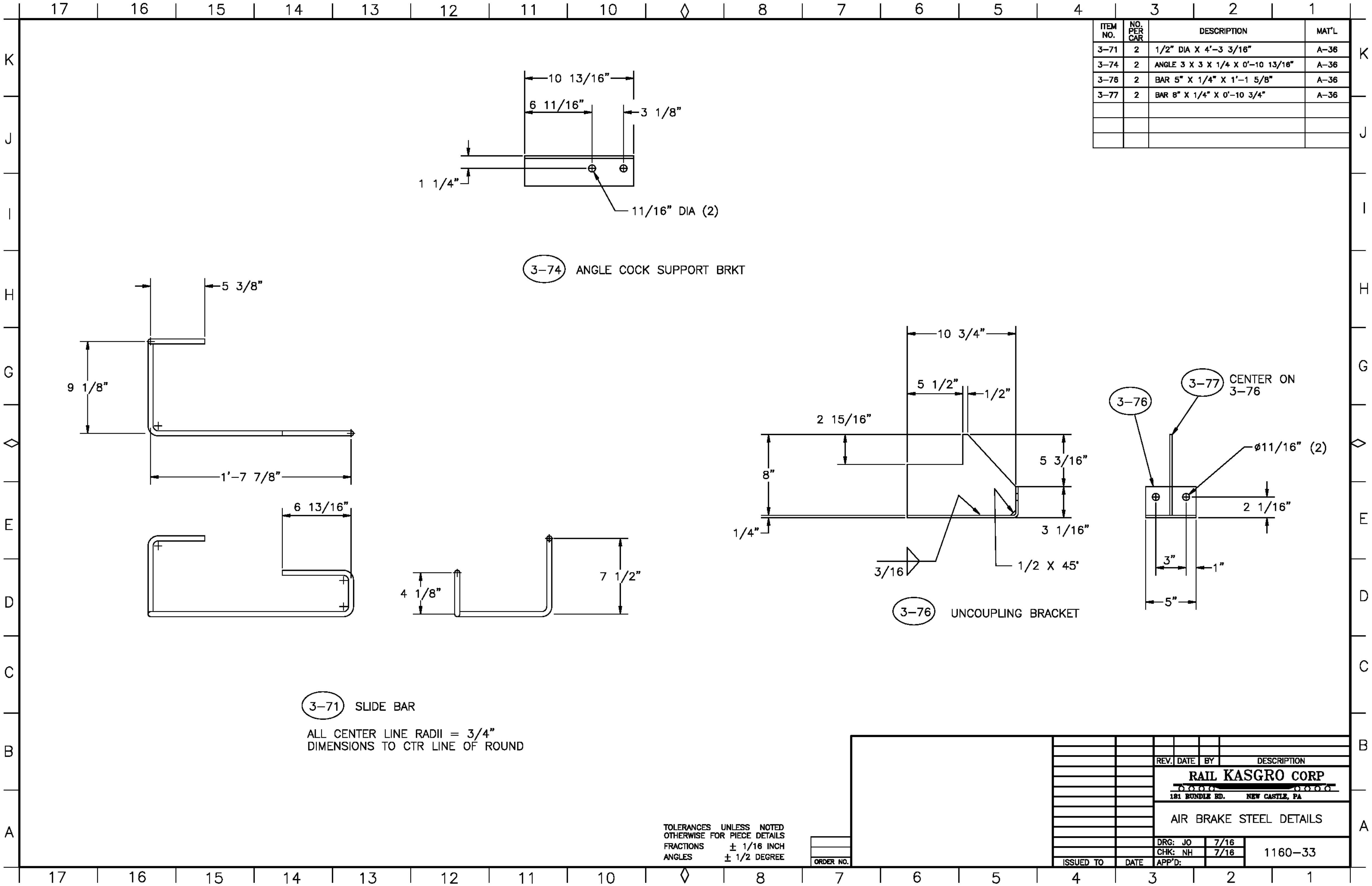
RAIL KASGRO CORP
121 RUNDLE RD. NEW CASTLE, PA

AIR BRAKE STEEL DETAILS

DRG: JO 7/16
CHK: NH 7/16
APP'D:

1160-32

Appendix H-1.33 Air Brake Steel Details



(3-74) ANGLE COCK SUPPORT BRKT

(3-71) SLIDE BAR

ALL CENTER LINE RADII = 3/4"
DIMENSIONS TO CTR LINE OF ROUND

(3-77) CENTER ON 3-76

(3-76) UNCOUPLING BRACKET

ITEM NO.	NO. PER CAR	DESCRIPTION	MAT'L
3-71	2	1/2" DIA X 4'-3 3/16"	A-36
3-74	2	ANGLE 3 X 3 X 1/4 X 0'-10 13/16"	A-36
3-76	2	BAR 5" X 1/4" X 1'-1 5/8"	A-36
3-77	2	BAR 8" X 1/4" X 0'-10 3/4"	A-36

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

ORDER NO.

ISSUED TO DATE

REV. DATE BY DESCRIPTION

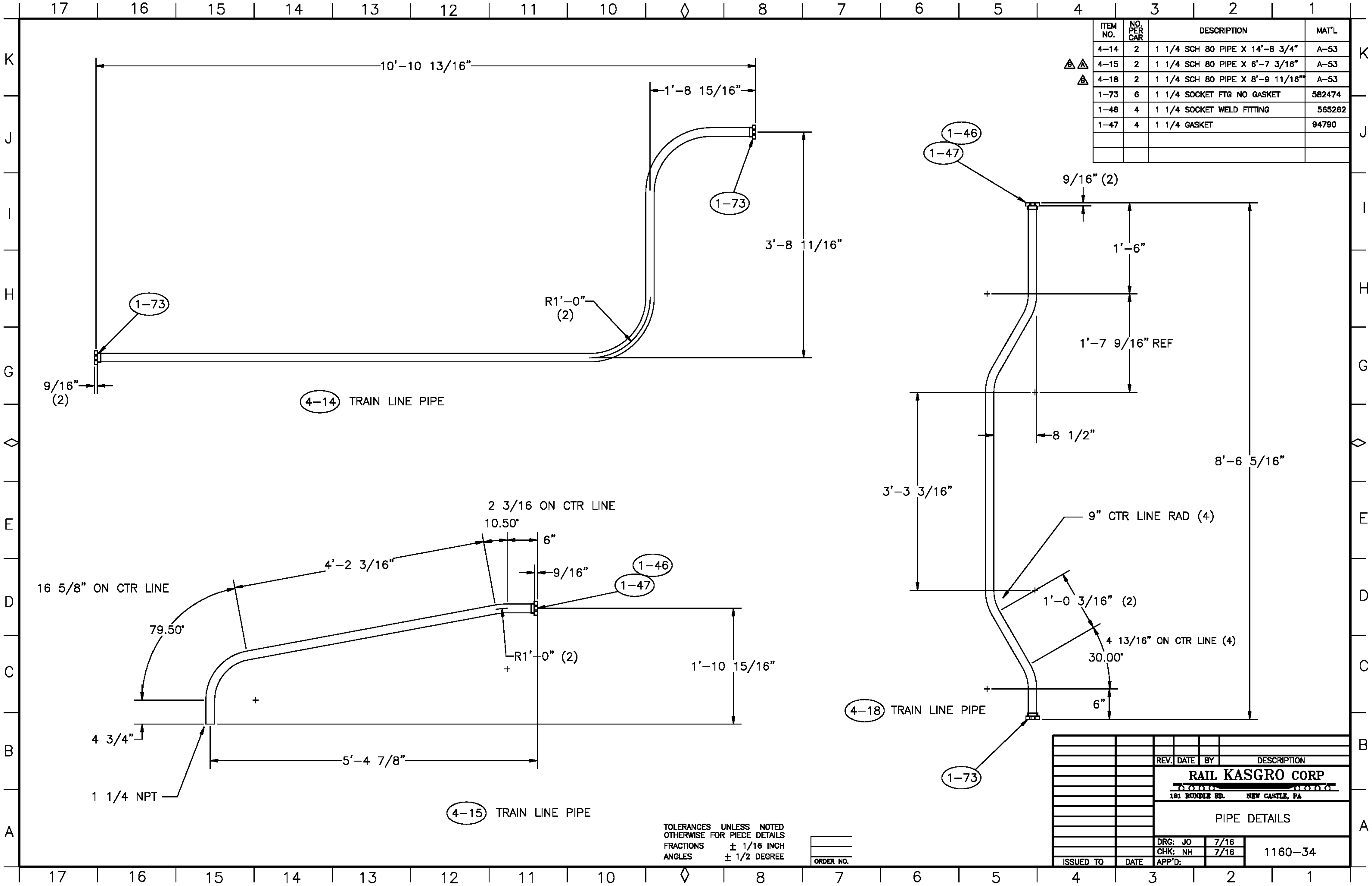
RAIL KASGRO CORP
181 BUNDLE RD. NEW CASTLE, PA

AIR BRAKE STEEL DETAILS

DRG: JO 7/16
CHK: NH 7/16
APP'D:

1160-33

Appendix H-1.34 Pipe Details



	ITEM NO.	NO. PER CAR	DESCRIPTION	MAT'L
	4–14	2	1 1/4 SCH 80 PIPE X 14'–8 3/4"	A–53
B A	4–15	2	1 1/4 SCH 80 PIPE X 6'–7 3/16"	A–53
B	4–18	2	1 1/4 SCH 80 PIPE X 8'–9 11/16""	A–53
	1–73	6	1 1/4 SOCKET FTG NO GASKET	582474
	1–46	4	1 1/4 SOCKET WELD FITTING	565262
	1–47	4	1 1/4 GASKET	94790

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

ORDER NO.

REV.	DATE	BY	DESCRIPTION

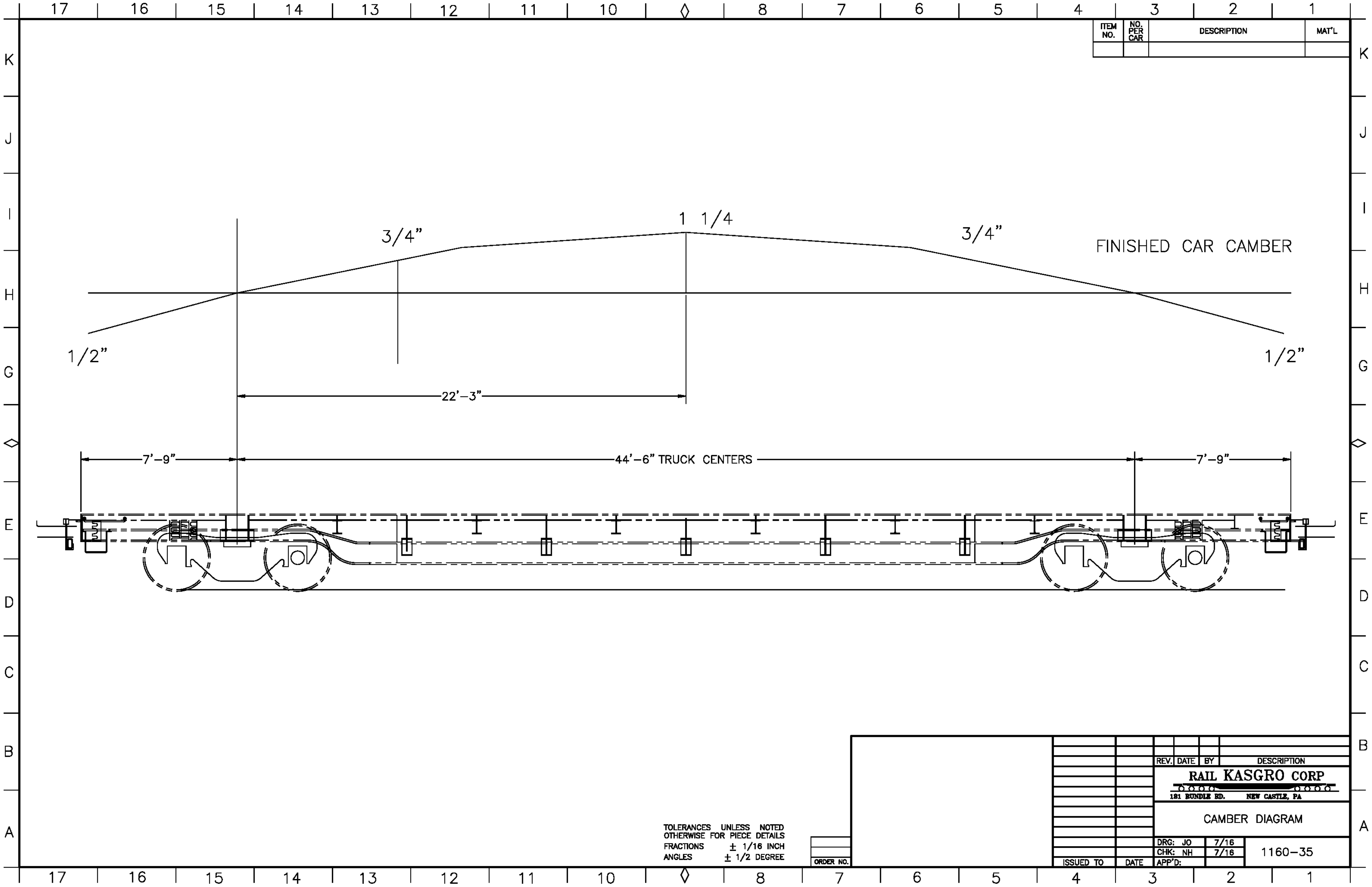
RAIL KASGRO CORP
181 BUNDLE RD. NEW CASTLE, PA

PIPE DETAILS

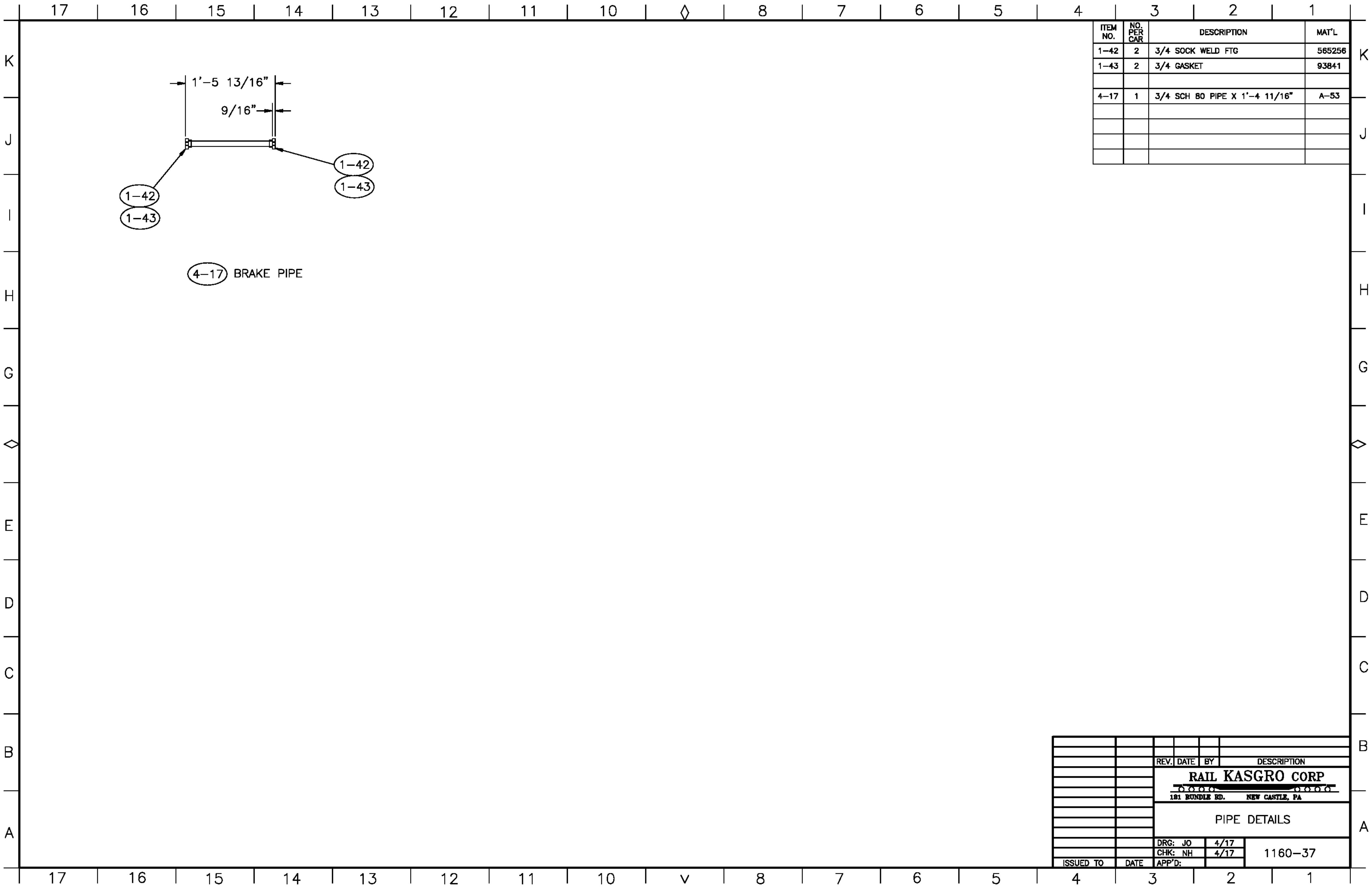
ISSUED TO	DATE	DRG: JO	7/16
		CHK: NH	7/16
		APP'D:	

1160–34

Appendix H-1.35 Camber Diagram

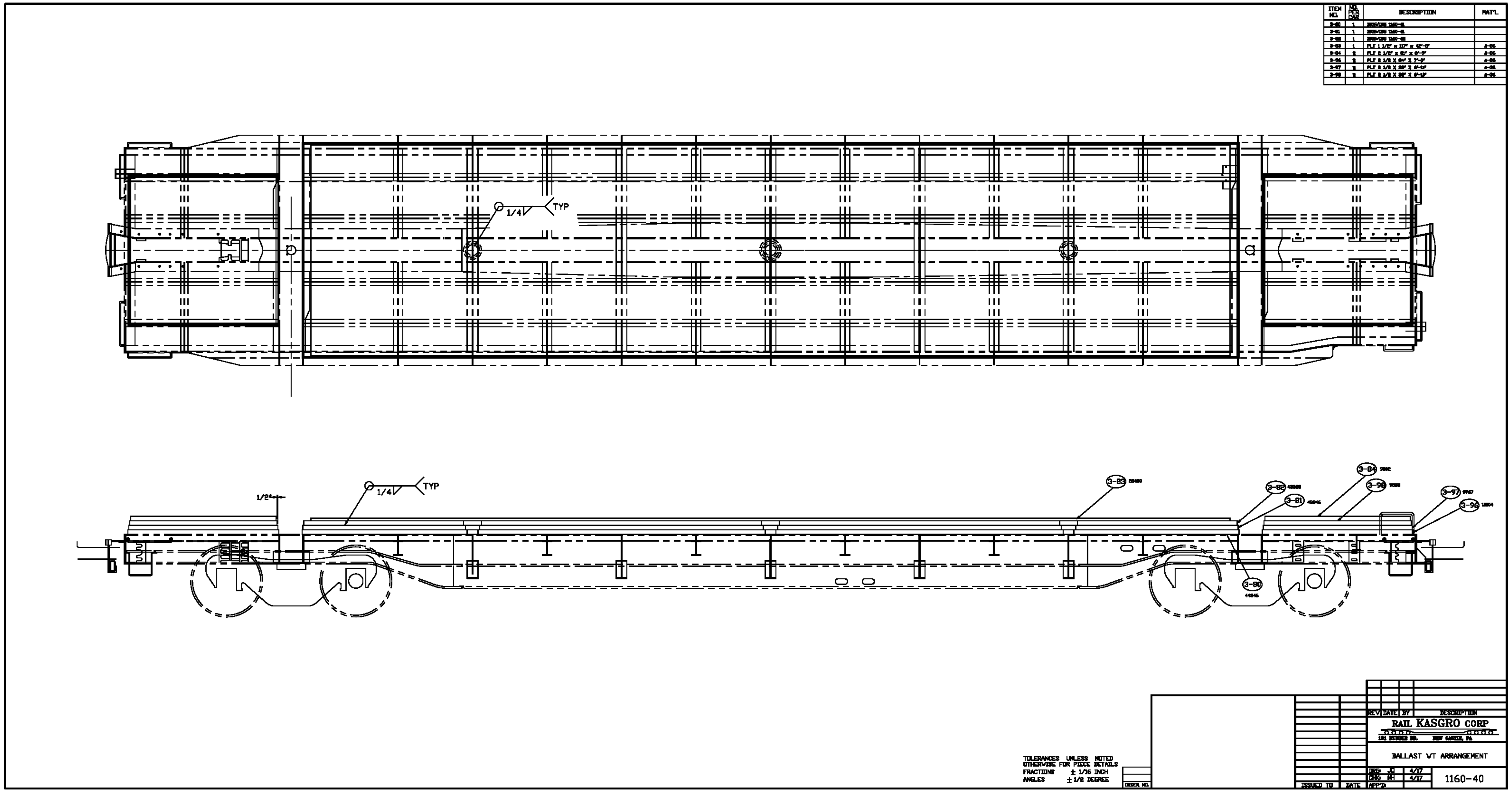


Appendix H-1.36 Pipe Details

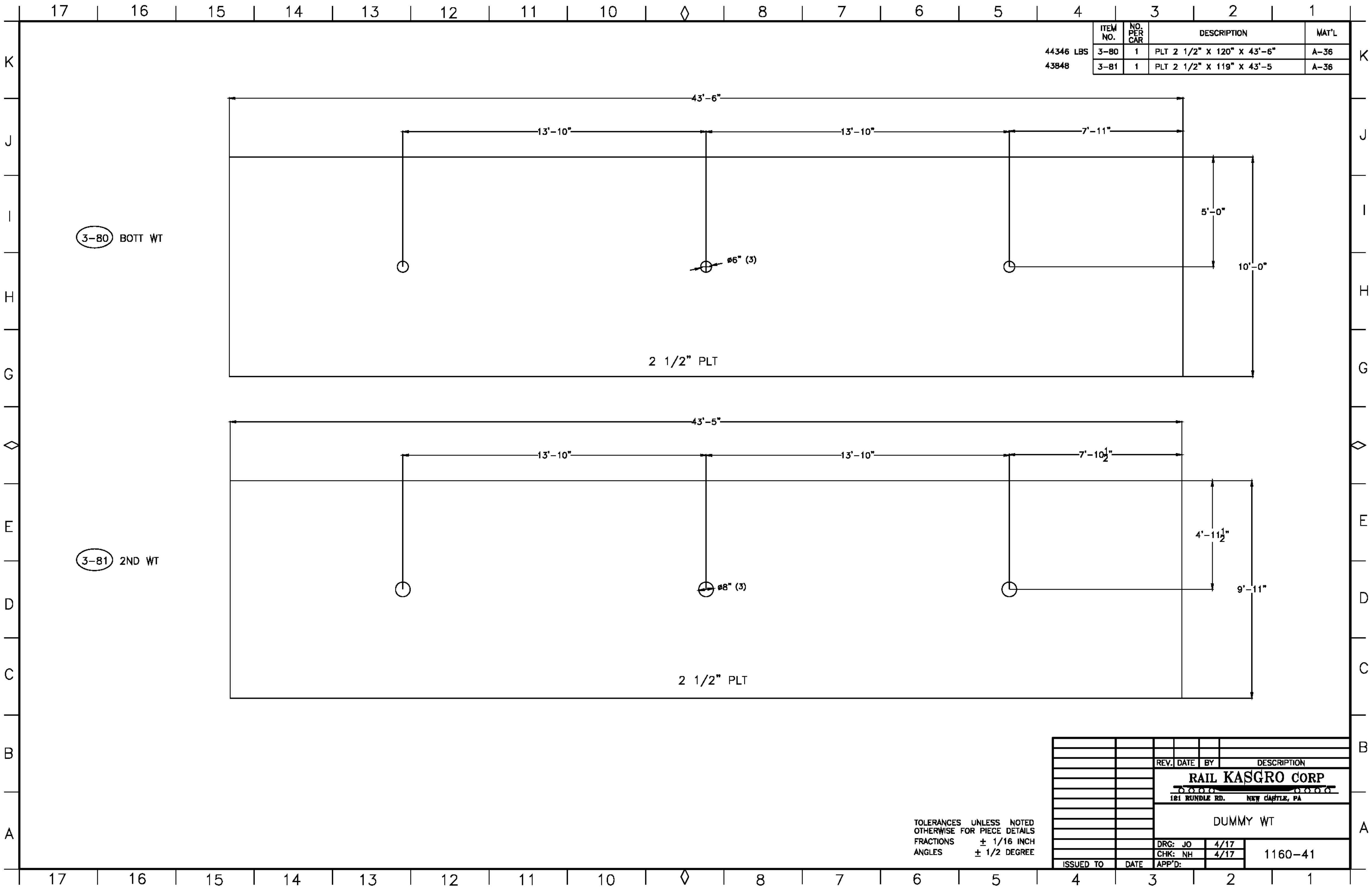


ITEM NO.	NO. PER CAR	DESCRIPTION	MAT'L
1–42	2	3/4 SOCK WELD FTG	565256
1–43	2	3/4 GASKET	93841
4–17	1	3/4 SCH 80 PIPE X 1'–4 11/16"	A–53

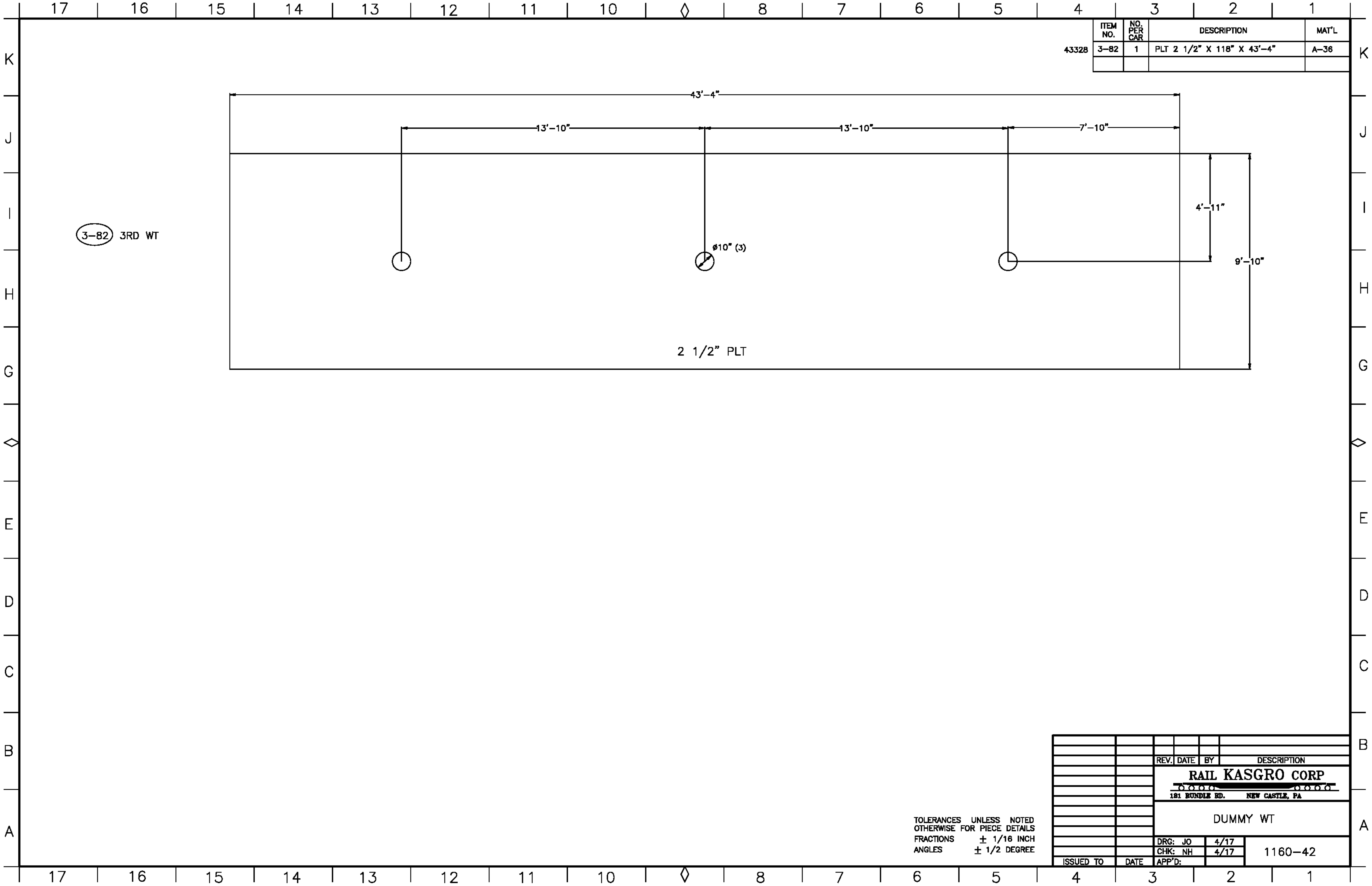
Appendix H-1.37 Ballast Weight Arrangement



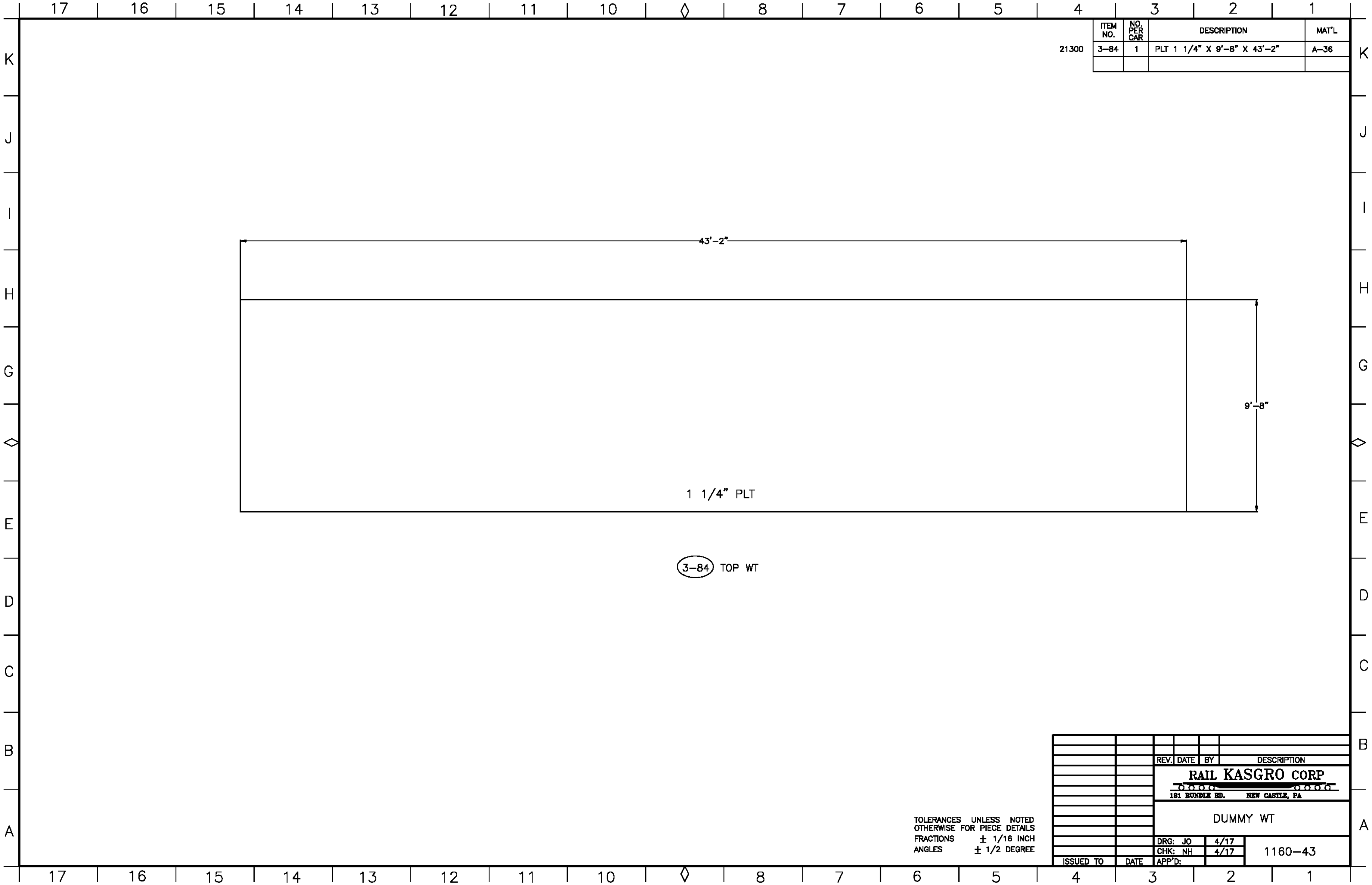
Appendix H-1.38 Dummy Weight



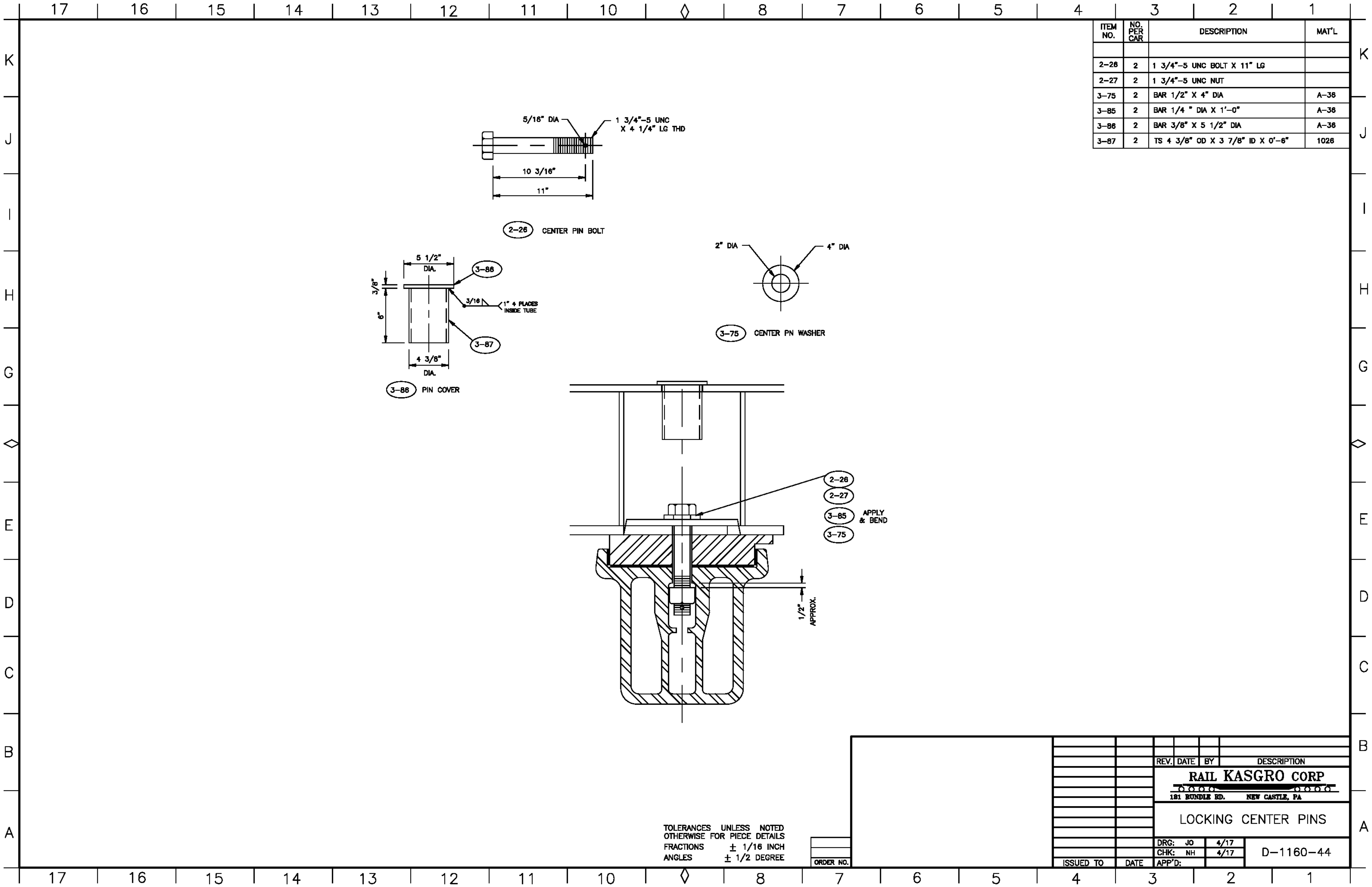
Appendix H-1.39 Dummy Weight



Appendix H-1.40 Dummy Weight



Appendix H-1.41 Locking Center Pins



ITEM NO.	NO. PER CAR	DESCRIPTION	MAT'L
2-26	2	1 3/4"-5 UNC BOLT X 11" LG	
2-27	2	1 3/4"-5 UNC NUT	
3-75	2	BAR 1/2" X 4" DIA	A-36
3-85	2	BAR 1/4 " DIA X 1'-0"	A-36
3-86	2	BAR 3/8" X 5 1/2" DIA	A-36
3-87	2	TS 4 3/8" OD X 3 7/8" ID X 0'-6"	1026

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
181 BUNDLE RD. NEW CASTLE, PA

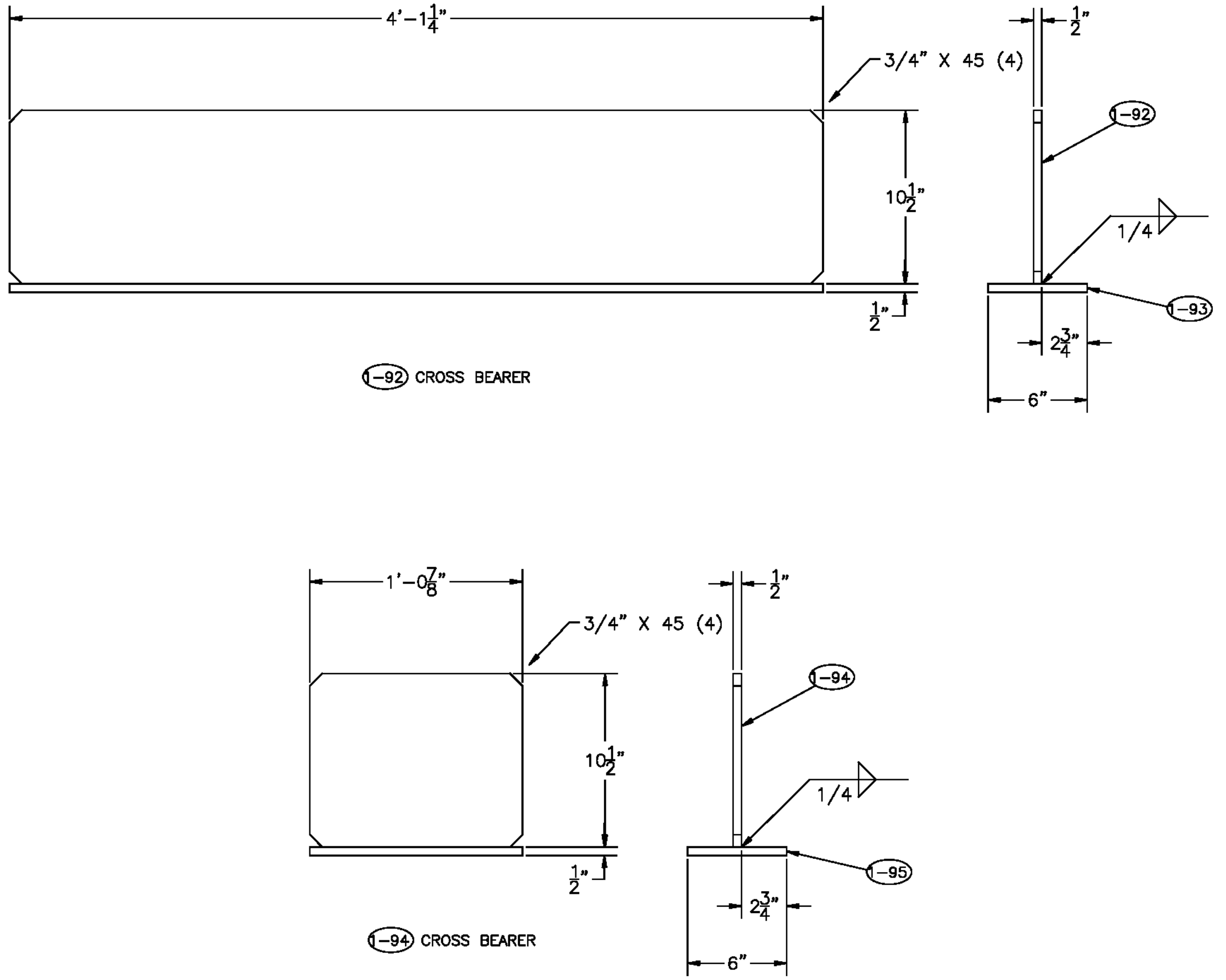
LOCKING CENTER PINS

DRG: JO 4/17
CHK: NH 4/17
APP'D:

D-1160-44

Appendix H-1.42 Steel Details

ITEM NO.	NO. PER CAR	DESCRIPTION	MAT'L
1–92	2	PLT 1/2" X 10 1/2" X 4'–1 1/4"	A–572
1–93	2	PLT 1/2" X 6" X 4'–1 1/4"	A–572
1–94	1	PLT 1/2" X 10 1/2" X 1'–0 7/8"	A–572
1–95	1	PLT 1/2" X 6" X 1'–0 7/8"	A–572



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
181 BUNDLE RD. NEW CASTLE, PA

STEEL DETAILS

DRG: JO 4/17
CHK: NH 4/17
APP'D:

1160–45

Appendix H-1.43 Atlas Buffer Railcar Structural Analysis

XASGRO RAIL

ATLAS 4 AXLE FLAT CAR

Preliminary Loading Analysis

60 FT 110-TON FLATCAR

For S-2043 Service

October 2016
October 2017
November 2017

Prepared by: Jon Odden

Checked by: Nicholas Hinsch

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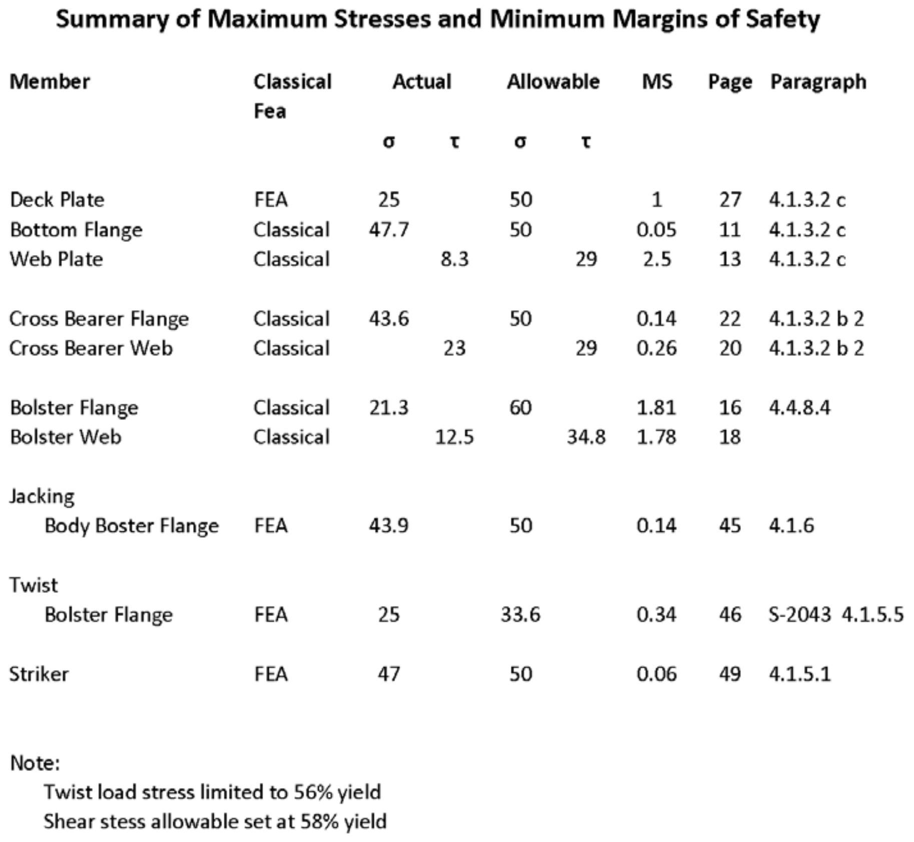


Summary of Maximum Stresses and Minimum Margins of Safety

Member	Classical Fea	Actual		Allowable		MS	Page	Paragraph
		σ	τ	σ	τ			
Deck Plate	FEA	25		50		1	27	4.1.3.2 c
Bottom Flange	Classical	47.7		50		0.05	11	4.1.3.2 c
Web Plate	Classical		8.3		29	2.5	13	4.1.3.2 c
Cross Bearer Flange	Classical	43.6		50		0.14	22	4.1.3.2 b 2
Cross Bearer Web	Classical		23		29	0.26	20	4.1.3.2 b 2
Bolster Flange	Classical	21.3		60		1.81	16	4.4.8.4
Bolster Web	Classical		12.5		34.8	1.78	18	
Jacking								
Body Boster Flange	FEA	43.9		50		0.14	45	4.1.6
Twist								
Bolster Flange	FEA	25		33.6		0.34	46	S-2043 4.1.5.5
Striker	FEA	47		50		0.06	49	4.1.5.1

Note:

Twist load stress limited to 56% yield

Shear stess allowable set at 58% yield

INTRODUCTION

The stress analysis was done both by the classical method and FEA. The classical method was used to size the members initially and to determine the shear stress and welding. The FEA was used to verify and refine the classical method.

The classical analysis was done using spreadsheets and hand calculations. Input data and output are self-explanatory. Appropriate AAR load factors are used.

The finite element analysis was done by modeling in AutoCAD inventor and launching the built-in FEA program in Inventor. One quarter of the car was used with symmetry to duplicate the full car body.

The car was designed as a general service flat car. The dynamic modeling showed the need for ballast weight over the entire car body. The design of this will lower the stresses because of the distribution of the weight and the addition to the cross-section of the underframe. Further, the capacity is now at 263k GRL whereas the calculations used 286 GRL.

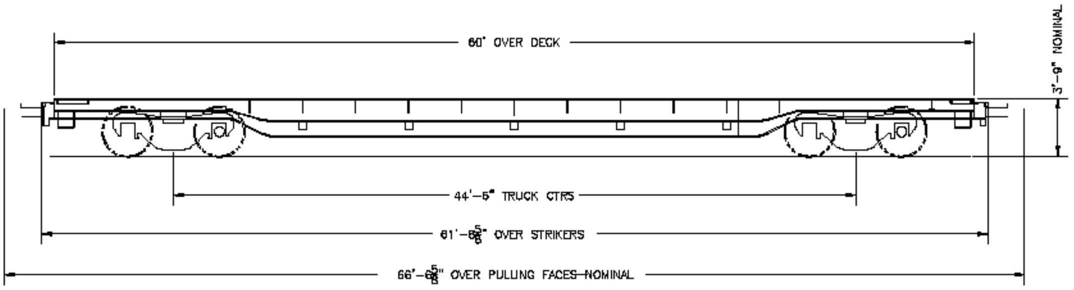
CAR BODY MATERIALS

Gussets, cross-ties, and stringers	A-36
Draft sill webs through transition, bolster	A-572 Gr. 60
Balance of car	A-572 Gr. 50

Steel meets AAR Charpy V-notch requirements where applicable.

WELD ROD MATERIAL

All weld rod used is E70XX.



Gross Rail Load	286 k
Est Light Wt.	67
Estimated Capacity	224 k

Note: Car body designed to full capacity of trucks. It is very likely that the gross rail load and capacity will be starred and registered to keep limit the axle loading to 65.75 k/axle.

GENERAL LOADING

GROSS RAIL LOAD	286,000 LBS
EST LIGHT WT	62,000 LBS
EST LOAD LIMIT	224,000 LBS

		Paragraph
CAR BODY DEAD LOAD 42/60 =	0.7 K/FT	
LL ON CTR 18′ 224/18 =	12.44 K/FT	4.1.3.2 (c)
LL ON DECK 224/60 =	3.73 K/FT	4.1.3.2 (a)
75% LL ON CTR .75(224) =	168 K	4.1.3.2 (b)
15% ON OVERHANG 33.6/7.75 =	4.3 K/FT	4.1.3.2 (d)

COUPLER AND MISC LOADS AND LOAD FACTORS

DRAFT LOAD	350 K	LF = 1.8
BUFF LOAD	-350 K	LF =1.8
SQUEEZE	-1000 K	LF = 1.0
IMPACT	-600 K	LF = 1.0 (NOT APP. SQUEEZE LOAD MORE SEVERE)
VERT COUPLER LOAD	+/-50 K	LF =1.0 (CUSHIONED UNDERFRAME)
	125% load	LF = 1.0

NOTE: VERTICAL COUPLER LOADS, TWIST LOAD, AND JACKING LOAD COVERED IN FEA. LIFTING LOAD SAME AS THE JACKING LOAD FOR OVERALL STRUCTURE OF THE CAR ALTHOUGH LOCAL DEFORMATION WILL OCCUR.

Paragraph 4.1.3.2 c

SHEAR AND MOMENT DIAGRAMS

live load on ctr 18 ft

OH1= 7.75
TC= 44.5
OH2= 7.75

RL= 133
RR= 133

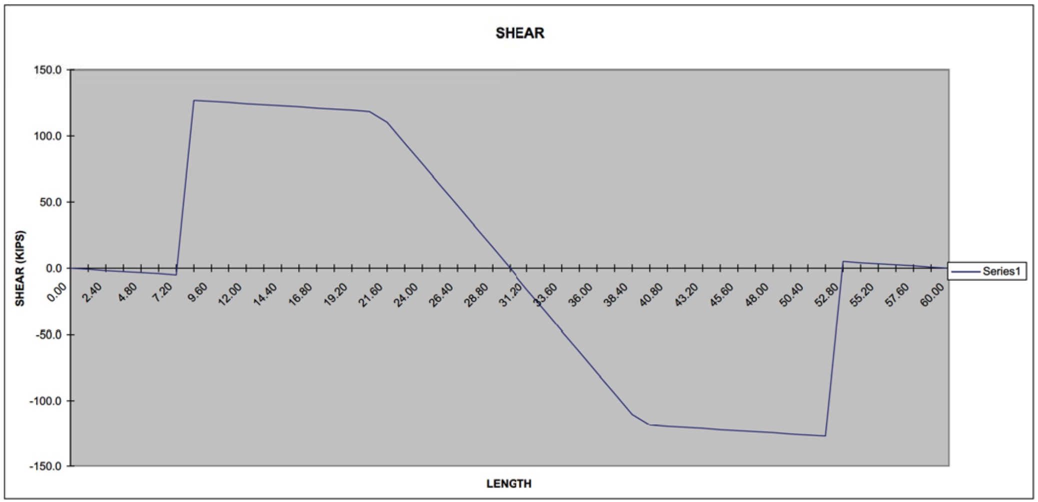
CONCENTRATED LOAD

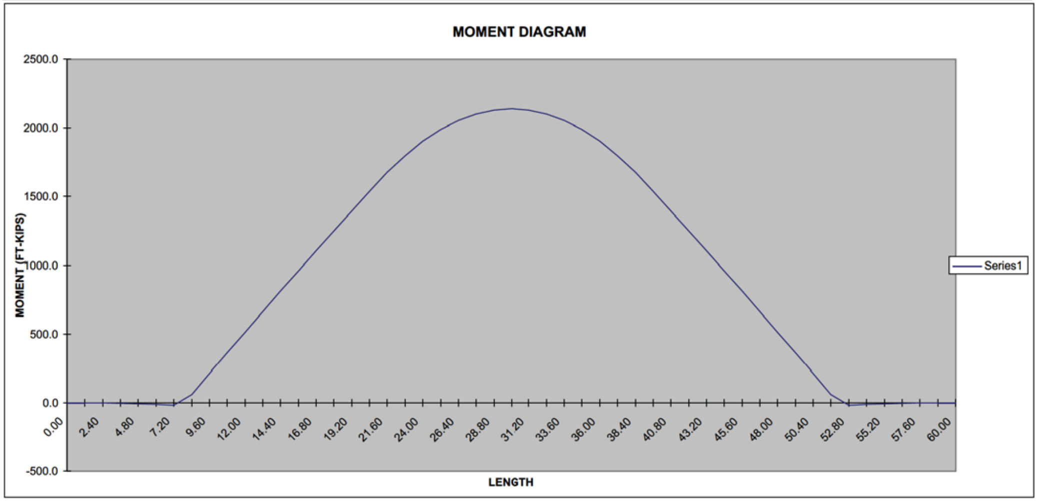
P	X

SUM 0

UNIFORM LOAD

w	X1	X2
0.7	0	60
12.44	21	39





Paragraph 4.1.3.2 a

SHEAR AND MOMENT DIAGRAMS

over full deck

OH1= 7.75
TC= 44.5
OH2= 7.75

RL= 134
RR= 134

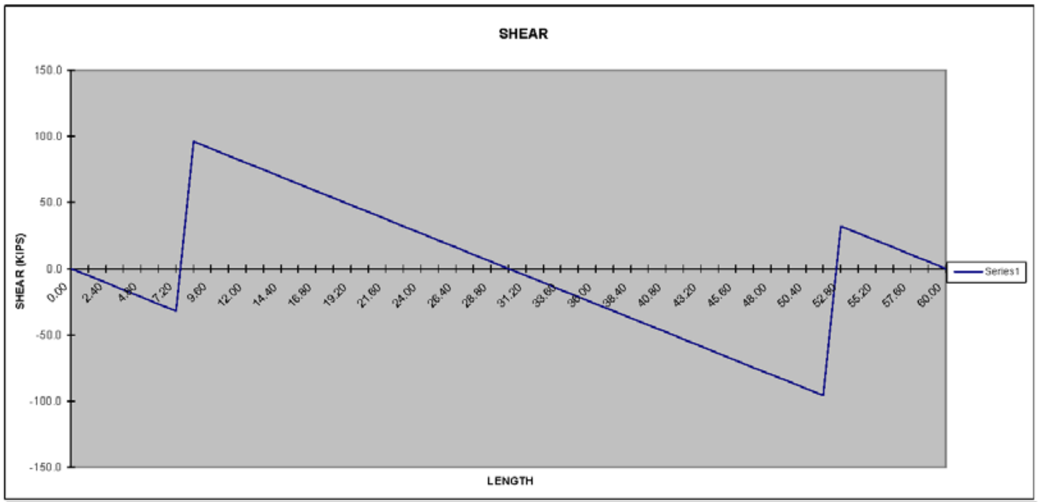
CONCENTRATED LOAD

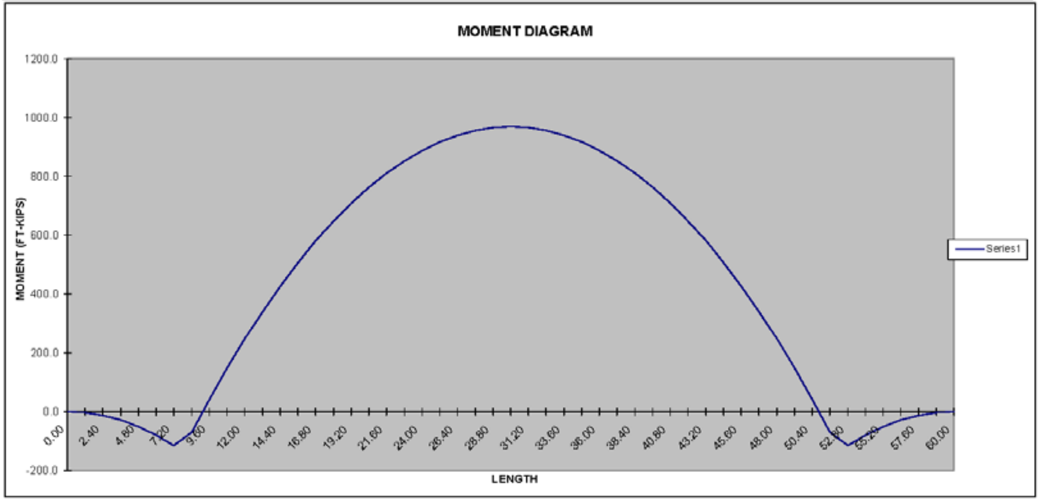
P	X

SUM 0

UNIFORM LOAD

w	X1	X2
0.7	0	60
3.75	0	60





Paragraph 4.1.3.2 b

SHEAR AND MOMENT DIAGRAMS

75% at ctr

OH1= 7.75
TC= 44.5
OH2= 7.75

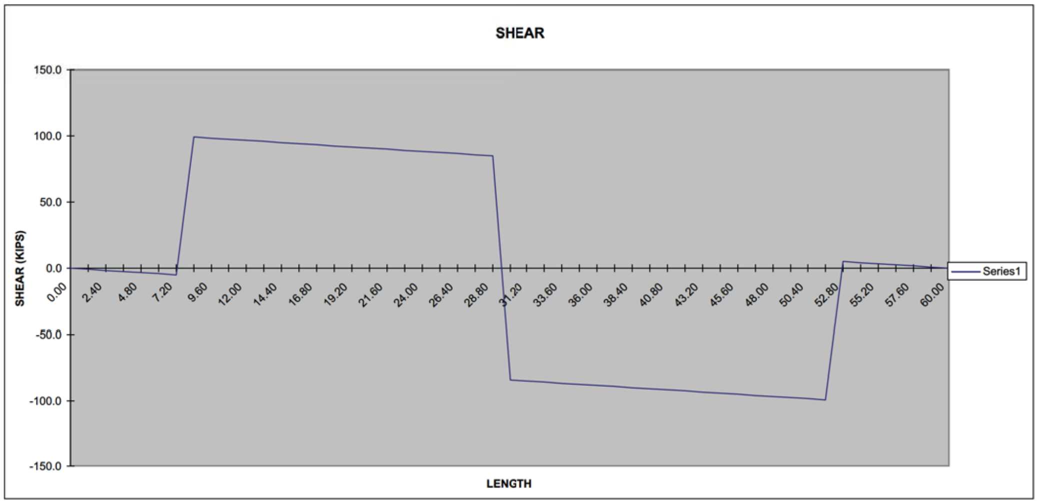
RL= 105
RR= 105

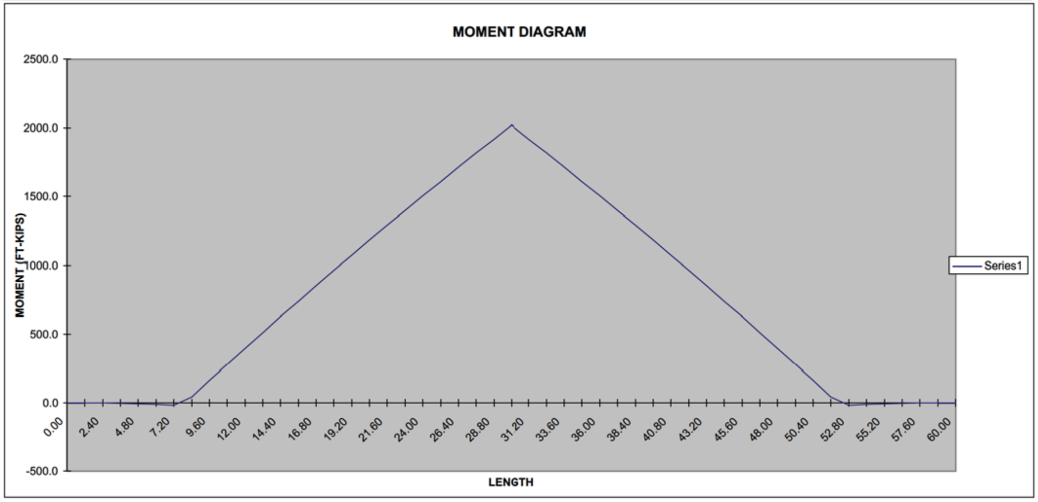
CONCENTRATED LOAD

	P	X
	168	30
SUM	168	

UNIFORM LOAD

w	X1	X2
0.7	0	60





Paragraph 4.1.3.2d

SHEAR AND MOMENT DIAGRAMS

15% on oh

OH1= 7.75
TC= 44.5
OH2= 7.75

RL= 54.3
RR= 54.3

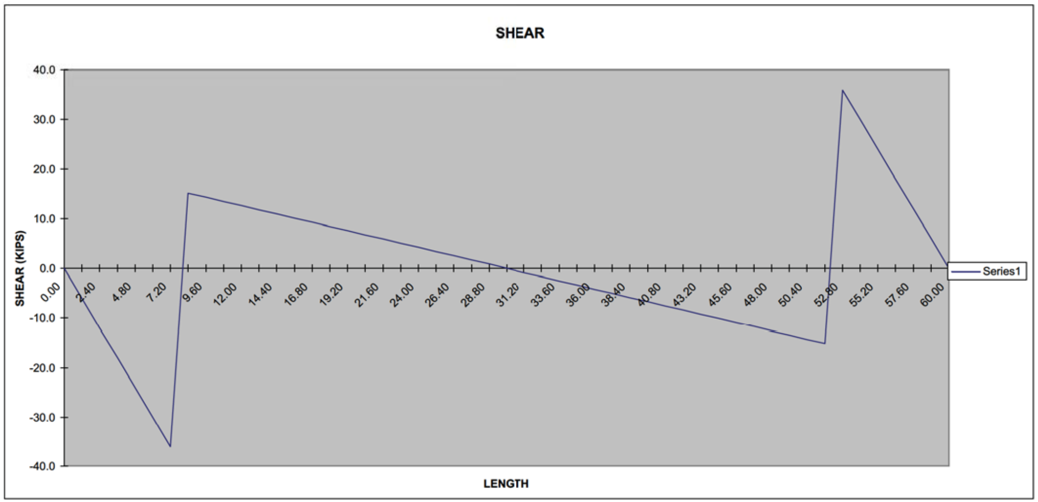
CONCENTRATED LOAD

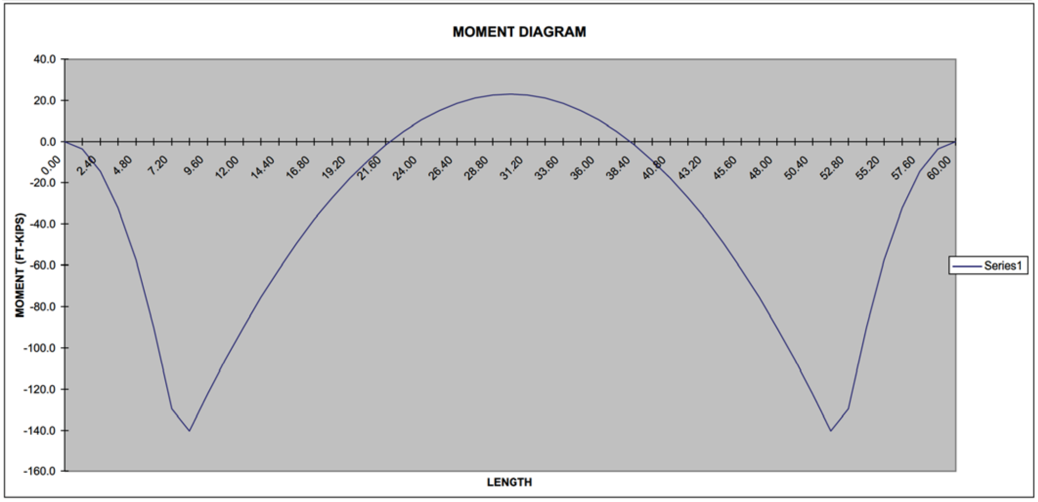
P	X

SUM 0

UNIFORM LOAD

w	X1	X2
0.7	0	60
4.3	0	7.75
4.3	52.25	60





10

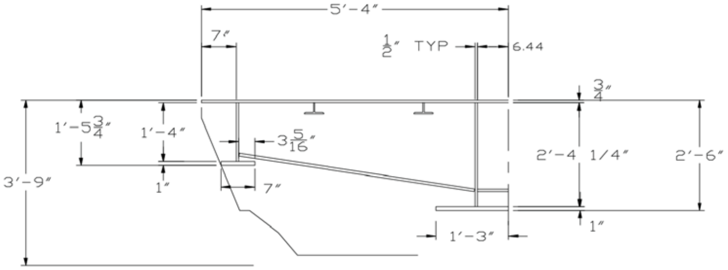
SECTION ELEMENTS AND PROPERTIES

at centerline

B	T	CG			Q-full	SHEAR FLOW
64.00	0.75	0.37	DEPTH	30.00	799.6	8.0
0.50	16.00	8.75	DECK	45.00	NA	
0.50	28.25	14.88	MOMENT	2140.00	NA	
15.00	1.00	29.50	CPLR	34.50	-624.2	-6.2
			SHEAR	127.00		
			FULL/HALF	2		

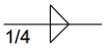
AREA= 170.25
NA= 8.69
I= 22952.86
S-top= -2639.89
S-bott= 1077.33
ECCENT= 1.81
Q-na= 862.76

AXIAL LOAD	MOM	IND MOM		M/S	P/A	M/S+P/A	VQ/It
0	2140	0.0	f-top	-17.5	0.0	**-17.5**	**4.30**
			f-bot	42.9	0.0	**42.9**	
350	2140	52.7	f-top	-17.9	3.7	**-14.2**	
			f-bot	44.0	3.7	**47.7**	
-350	2140	-52.7	f-top	-17.1	-3.7	**-20.8**	
			f-bot	41.9	-3.7	**38.1**	
-1000	2140	-150.4	f-top	-9.7	-5.9	**-15.6**	
			f-bot	23.8	-5.9	**18.0**	

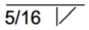


Welding

Deck to webs
good for 46 k/in



Flange to webs
good for 44.5 k/in



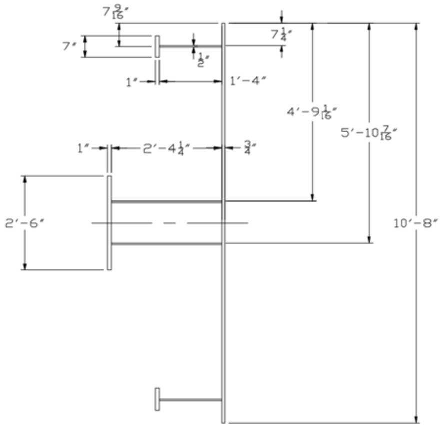
SECTION ELEMENTS AND PROPERTIES

at centerline weak axis

B	T	CG			Q-full	SHEAR FLOW
0.75	128.00	64.00	DEPTH	128.00	NA	
1.00	7.00	7.56	DECK	45.00	395.1	0.4
1.00	7.00	120.44	MOMENT	642.00	-395.1	-0.4
16.00	0.50	7.50	CPLR	34.50	452.0	0.4
16.00	0.50	120.50	SHEAR	127.00	-452.0	-0.4
1.00	30.00	64.00			NA	
28.50	0.50	57.31	FULL/HALF	1	95.3	0.1
28.50	0.50	70.69			-95.3	-0.1

AREA= 184.50
NA= 64.00
I= 230322.38
S-top= -3598.79
S-bott= 3598.78
ECCENT= -53.50
Q-na= 2590.86

AXIAL LOAD	MOM	IND MOM		M/S	P/A	M/S+P/A	VQ/It
0	642	0.0	f-top	-3.2	0.0	**-3.2**	**1.47**
			f-bot	3.2	0.0	**3.2**	



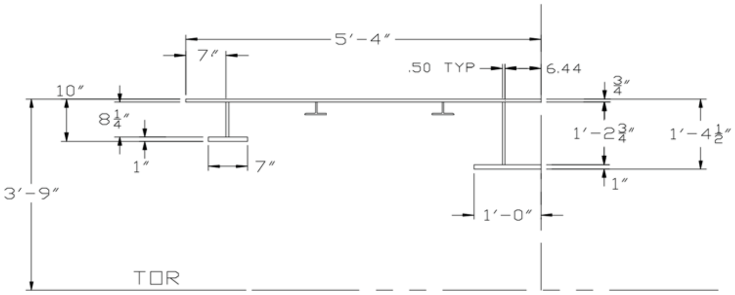
SECTION ELEMENTS AND PROPERTIES

at transition

B	T	CG			Q-full	SHEAR FLOW
64.00	0.75	0.37	DEPTH	16.50	400.4	16.1
0.50	8.25	4.88	DECK	45.00	NA	
0.50	14.75	8.13	MOMENT	500.00	NA	
7.00	1.00	9.50	CPLR	34.50	-69.5	-2.8
12.00	1.00	16.00	SHEAR	127.00	-275.1	-11.1
			FULL/HALF	2		

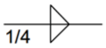
AREA= 157.00
NA= 4.54
I= 5682.09
S-top= -1252.75
S-bott= 474.92
ECCENT= 5.96
Q-na= 414.72

AXIAL LOAD	MOM	IND MOM		M/S	P/A	M/S+P/A	VQ/It
0	500	0.0	f-top	-8.6	0.0	**-8.6**	**8.34**
			f-bot	22.7	0.0	**22.7**	
350	500	174.0	f-top	-11.6	4.0	**-7.6**	
			f-bot	30.7	4.0	**34.7**	
-350	500	-174.0	f-top	-5.6	-4.0	**-9.6**	
			f-bot	14.8	-4.0	**10.8**	
-1000	500	-497.0	f-top	-4.8	-6.4	**-11.2**	
			f-bot	12.6	-6.4	**6.3**	

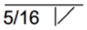


Welding

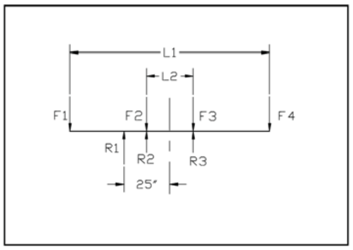
Deck to webs
good for 46 k/in



Flange to webs
good for 44.5 k/in



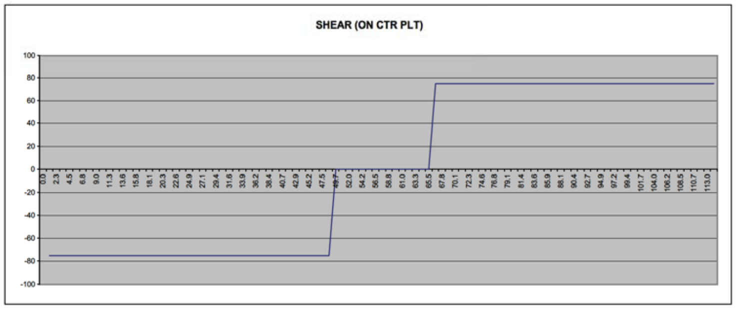
Body Bolster
Paragraph 4.4.8.4

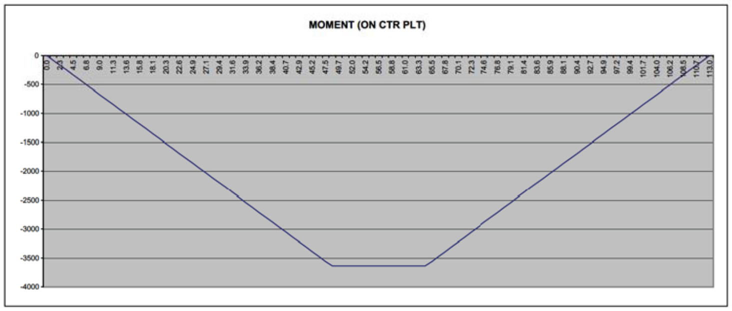


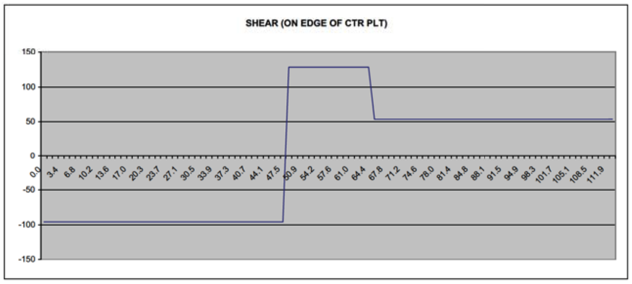
REFERENCE	CTR SILL LOAD	EDGE OF CTR SILL	SIDE BRG LOAD
70 TON TRUCKS	230	230	144
100 TON TRUCKS	300	300	188
125 TON TRUCKS	325	325	207
2-70 TON TRUCKS	460	460	288
2-100 TON TRUCKS	600	600	376
2-125 TON TRUCKS	650	650	414

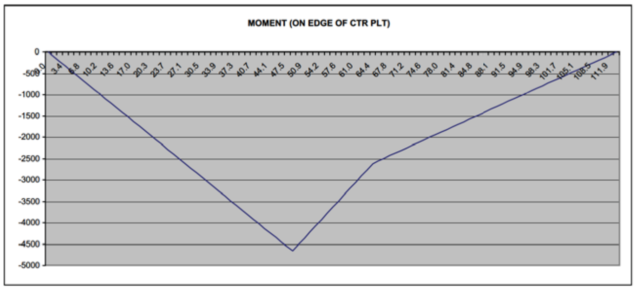
LENGTH (L2)	16	INCHES
LENGTH (L1)	113	INCHES
% CARRIED BY CENTER SILL	50	%
CTR PLT LOAD	300	KIPS
SIDE BEARING LOAD	188	KIPS

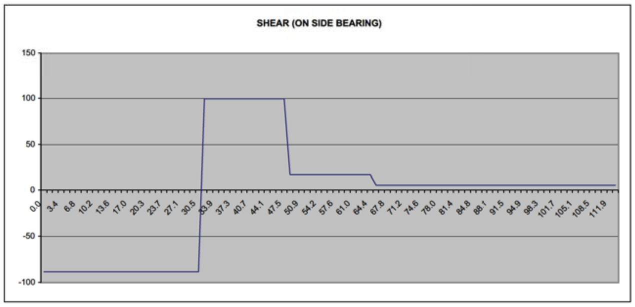
REACTIONS AND FORCES	LOAD ON CTR PLT	LOAD ON EDGE OF CTR PLT	LOAD ON SIDE BRG
F1	75.0	96.2	88.6
F2	75.0	75.0	47.0
F3	75.0	75.0	47.0
F4	75.0	53.8	5.4
R1	0.0	0.0	188.0
R2	150.0	300.0	0.0
R3	150.0	0.0	0.0

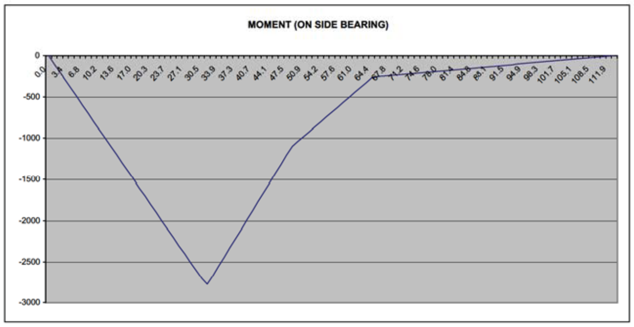





SHEAR (ON EDGE OF CTR PLT)
150
100
50
0
-50
-100
-150
0.0 3.4 6.8 10.2 13.6 17.0 20.3 23.7 27.1 30.5 33.9 37.3 40.7 44.1 47.5 50.9 54.2 57.6 61.0 64.4 67.8 71.2 74.6 78.0 81.4 84.8 88.1 91.5 94.9 98.3 101.7 105.1 108.5 111.9


MOMENT (ON EDGE OF CTR PLT)
0
-500
-1000
-1500
-2000
-2500
-3000
-3500
-4000
-4500
-5000
0.0 3.4 6.8 10.2 13.6 17.0 20.3 23.7 27.1 30.5 33.9 37.3 40.7 44.1 47.5 50.9 54.2 57.6 61.0 64.4 67.8 71.2 74.6 78.0 81.4 84.8 88.1 91.5 94.9 98.3 101.7 105.1 108.5 111.9


SHEAR (ON SIDE BEARING)
150
100
50
0
-50
-100
0.0 3.4 6.8 10.2 13.6 17.0 20.3 23.7 27.1 30.5 33.9 37.3 40.7 44.1 47.5 50.9 54.2 57.6 61.0 64.4 67.8 71.2 74.6 78.0 81.4 84.8 88.1 91.5 94.9 98.3 101.7 105.1 108.5 111.9


MOMENT (ON SIDE BEARING)
0
-500
-1000
-1500
-2000
-2500
-3000
0.0 3.4 6.8 10.2 13.6 17.0 20.3 23.7 27.1 30.5 33.9 37.3 40.7 44.1 47.5 50.9 54.2 57.6 61.0 64.4 67.8 71.2 74.6 78.0 81.4 84.8 88.1 91.5 94.9 98.3 101.7 105.1 108.5 111.9

SECTION ELEMENTS AND PROPERTIES

BOLSTER AT CTR SILL

B	T	CG			Q-full	SHEAR FLOW
12.00	0.75	0.38	DEPTH	16.13	120.7	7.8
0.50	14.75	8.13	DECK	51.00	NA	
10.00	0.63	15.50	MOMENT	388.00	-105.3	-6.8
			CPLR	34.00		
			SHEAR	128.00		
			FULL/HALF	2		

AREA= 45.25
NA= 7.08
I= 1980.21
S-top= -279.71
S-bott= 218.91
ECCENT= 9.92
Q-na= 140.71

AXIAL LOAD	MOM	IND MOM		M/S	P/A	M/S+P/A	VQ/It
0	388	0.0	f-top	-16.6	0.0	**-16.6**	**9.10**
			f-bot	21.3	0.0	**21.3**	

See following page for sketch

SECTION ELEMENTS AND PROPERTIES

BOLSTER AT SIDE BEARING

B	T	CG			Q-full	SHEAR FLOW
12.00	0.75	0.38	DEPTH	13.38	99.6	7.4
0.50	12.00	6.75	DECK	51.00	NA	
10.00	0.63	13.06	MOMENT	245.00	-89.4	-6.7
			CPLR	34.00		
			SHEAR	100.00		
			FULL/HALF	2		

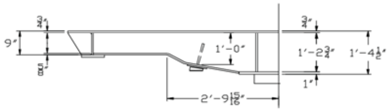
AREA= 42.50
NA= 5.91
I= 1344.65
S-top= -227.65
S-bott= 180.05
ECCENT= 11.09
Q-na= 112.86

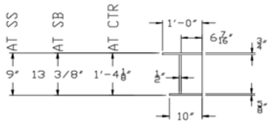
AXIAL LOAD	MOM	IND MOM		M/S	P/A	M/S+P/A	VQ/It
0	245	0.0	f-top	-12.9	0.0	**-12.9**	**8.39**
			f-bot	16.3	0.0	**16.3**	

Welding

Deck to webs 5/16
good for 29 k/in

Flange to webs 5/16
good for 14.5 k/in





SECTION ELEMENTS AND PROPERTIES

BOLSTER AT SIDE SILL

B	T	CG			Q-full	SHEAR FLOW
12.00	0.75	0.38	DEPTH	9.00	63.8	11.9
0.50	6.63	4.56	DECK	51.00	NA	
10.00	0.63	8.69	MOMENT	181.00	-59.6	-11.1
			CPLR	34.00		
			SHEAR	100.00		
			FULL/HALF	2		

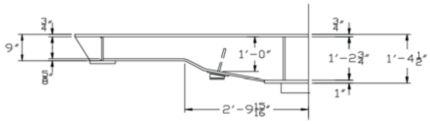
AREA= 37.13
NA= 3.92
I= 538.54
S-top= -137.34
S-bott= 106.03
ECCENT= 13.08
Q-na= 67.40

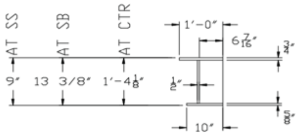
AXIAL LOAD	MOM	IND MOM		M/S	P/A	M/S+P/A	VQ/It
0	181	0.0	f-top	-15.8	0.0	**-15.8**	**12.51**
			f-bot	20.5	0.0	**20.5**	

Welding

Deck to webs 5/16
good for 29 k/in

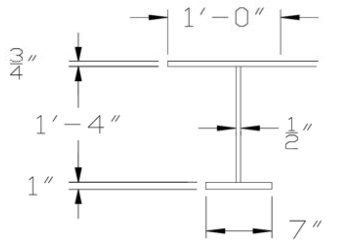
Flange to webs 5/16
good for 14.5 k/in

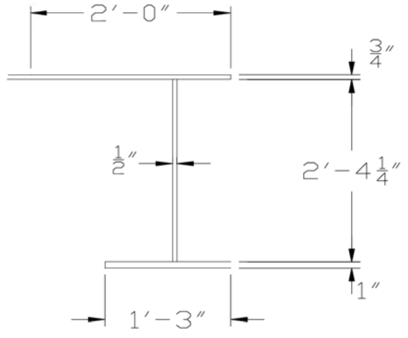




Cross Bearer
37.5% on side sill

RELATIVE STIFFENESS OF SIDE SILL AND CENTER SILL





SIDE SILL

12	0.75	0.375
0.5	16	8.75
7	1	17.25

I = 1300

REL STIFF SS = 1300/9202 = 14%

CENTER SILL

24	0.75	0.375
0.5	16	8.75
15	1	17.25

I=7902

REL STIFF = 86%

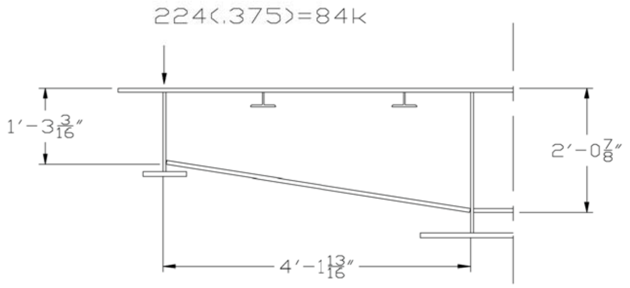
SECTION ELEMENTS AND PROPERTIES

x bearer

B	T	CG			Q-full	SHEAR FLOW
6.00	0.75	0.37	DEPTH	15.31	32.8	8.4
0.50	13.81	7.66	DECK	45.00	NA	
6.00	0.75	14.94	MOMENT	0.00	-32.8	-8.4
			CPLR	0.00		
			SHEAR	84.00		
			FULL/HALF	1		

AREA= 15.91
NA= 7.65
I= 588.03
S-top= -76.83
S-bott= 76.78
ECCENT= 37.35
Q-na= 44.71

AXIAL LOAD	MOM	IND MOM		M/S	P/A	M/S+P/A	VQ/It
0	0	0.0	f-top	0.0	0.0	**0.0**	**22.99**
			f-bot	0.0	0.0	**0.0**	

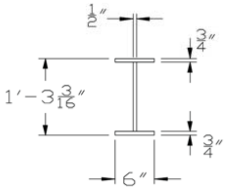


SECTION ELEMENTS AND PROPERTIES

x bearer

B	T	CG			Q-full
6.00	0.75	0.37	DEPTH	15.19	32.5
0.50	6.66	7.59	DECK	45.00	NA
6.00	0.75	14.81	MOMENT	0.00	-32.5
			CPLR	0.00	
			SHEAR	84.00	

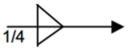
FULL/HALF 1



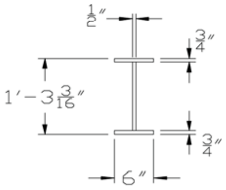
AREA=	12.33
NA=	7.59
I=	482.35
S-top=	-63.55
S-bott=	63.49
ECCENT=	37.41
Q-na=	35.28

AXIAL LOAD	MOM	IND MOM		M/S	P/A	M/S+P/A	VQ/It
0	0	0.0	f-top	0.0	0.0	**0.0**	**22.12**
			f-bot	0.0	0.0	**0.0**	

WELD



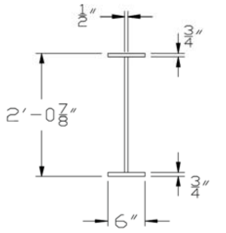
11.7 K/IN



SECTION ELEMENTS AND PROPERTIES

x bearer at ctr sill

B	T	CG			Q-full	SHEAR FLOW
6.00	0.75	0.37	DEPTH	24.88	54.3	3.8
0.50	23.38	12.44	DECK	45.00	NA	
6.00	0.75	24.50	MOMENT	299.00	-54.3	-3.8
			CPLR	0.00		
			SHEAR	72.00		

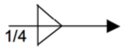


FULL/HALF 1

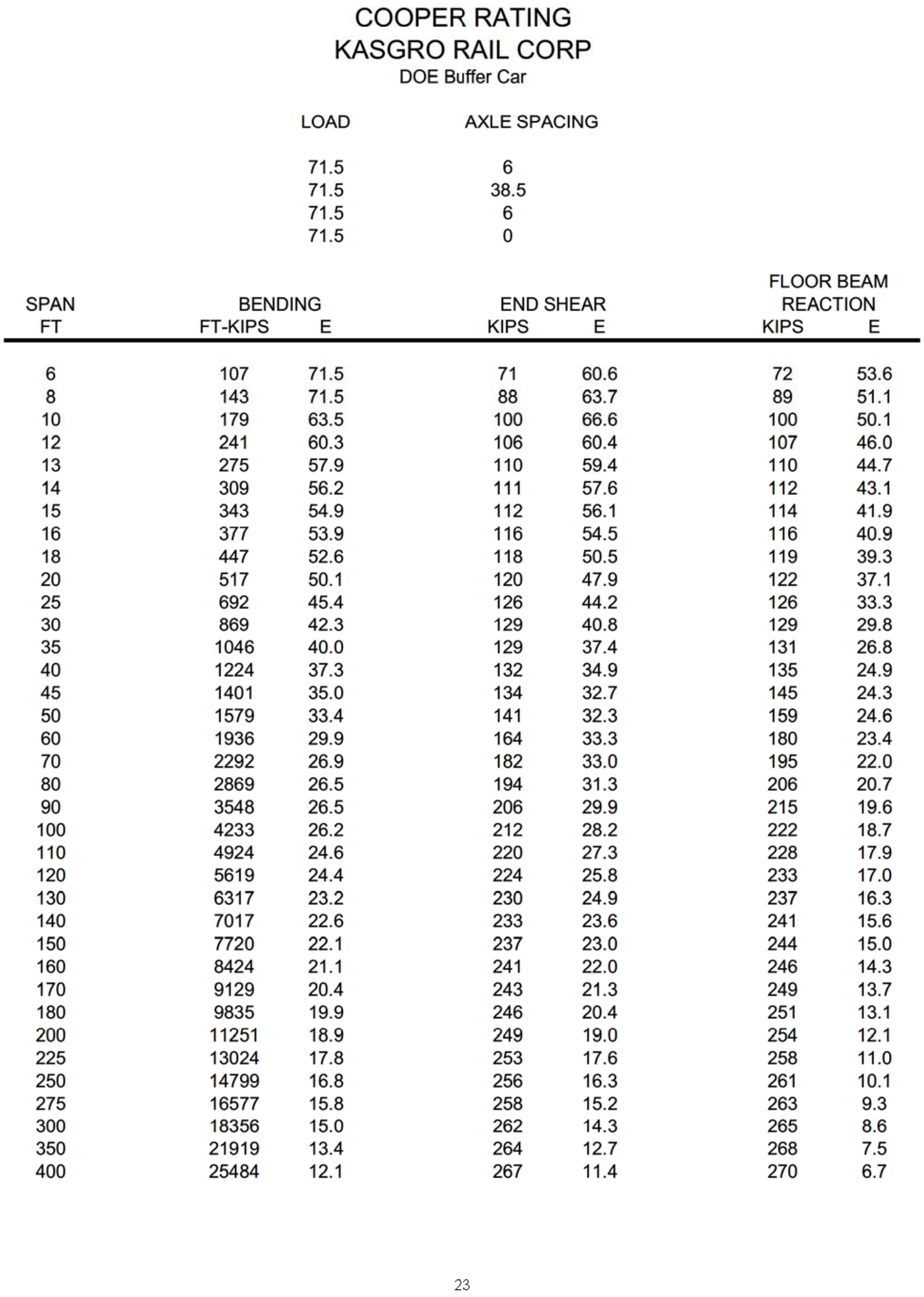
AREA= 20.69
NA= 12.44
I= 1843.20
S-top= -148.22
S-bott= 148.17
ECCENT= 32.56
Q-na= 88.45

AXIAL LOAD	MOM	IND MOM		M/S	P/A	M/S+P/A	VQ/It
0	299	0.0	f-top	-43.6	0.0	**-43.6**	**12.44**
			f-bot	43.6	0.0	**43.6**	

WELD



11.7 K/IN



COOPER RATING
KASGRO RAIL CORP
DOE Buffer Car

LOAD	AXLE SPACING
71.5	6
71.5	38.5
71.5	6
71.5	0

SPAN	BENDING		END SHEAR		FLOOR BEAM REACTION	
FT	FT-KIPS	E	KIPS	E	KIPS	E
6	107	71.5	71	60.6	72	53.6
8	143	71.5	88	63.7	89	51.1
10	179	63.5	100	66.6	100	50.1
12	241	60.3	106	60.4	107	46.0
13	275	57.9	110	59.4	110	44.7
14	309	56.2	111	57.6	112	43.1
15	343	54.9	112	56.1	114	41.9
16	377	53.9	116	54.5	116	40.9
18	447	52.6	118	50.5	119	39.3
20	517	50.1	120	47.9	122	37.1
25	692	45.4	126	44.2	126	33.3
30	869	42.3	129	40.8	129	29.8
35	1046	40.0	129	37.4	131	26.8
40	1224	37.3	132	34.9	135	24.9
45	1401	35.0	134	32.7	145	24.3
50	1579	33.4	141	32.3	159	24.6
60	1936	29.9	164	33.3	180	23.4
70	2292	26.9	182	33.0	195	22.0
80	2869	26.5	194	31.3	206	20.7
90	3548	26.5	206	29.9	215	19.6
100	4233	26.2	212	28.2	222	18.7
110	4924	24.6	220	27.3	228	17.9
120	5619	24.4	224	25.8	233	17.0
130	6317	23.2	230	24.9	237	16.3
140	7017	22.6	233	23.6	241	15.6
150	7720	22.1	237	23.0	244	15.0
160	8424	21.1	241	22.0	246	14.3
170	9129	20.4	243	21.3	249	13.7
180	9835	19.9	246	20.4	251	13.1
200	11251	18.9	249	19.0	254	12.1
225	13024	17.8	253	17.6	258	11.0
250	14799	16.8	256	16.3	261	10.1
275	16577	15.8	258	15.2	263	9.3
300	18356	15.0	262	14.3	265	8.6
350	21919	13.4	264	12.7	268	7.5
400	25484	12.1	267	11.4	270	6.7

FINITE ELEMENT ANALYSIS

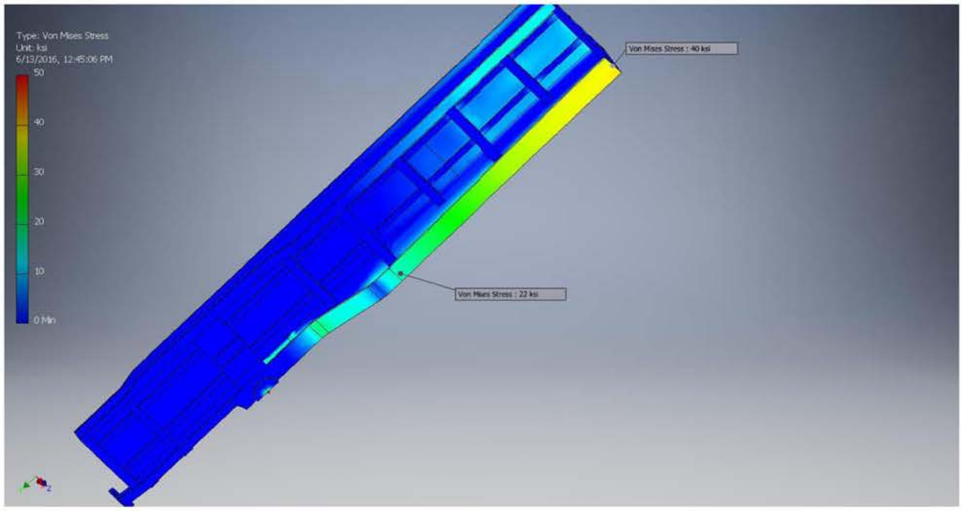
The car body was modeled in Inventor 2017. The built-in FEA was used in analysis. One quarter of the car was with symmetry was used for all of the loadings except the twist load where a full car model was used.

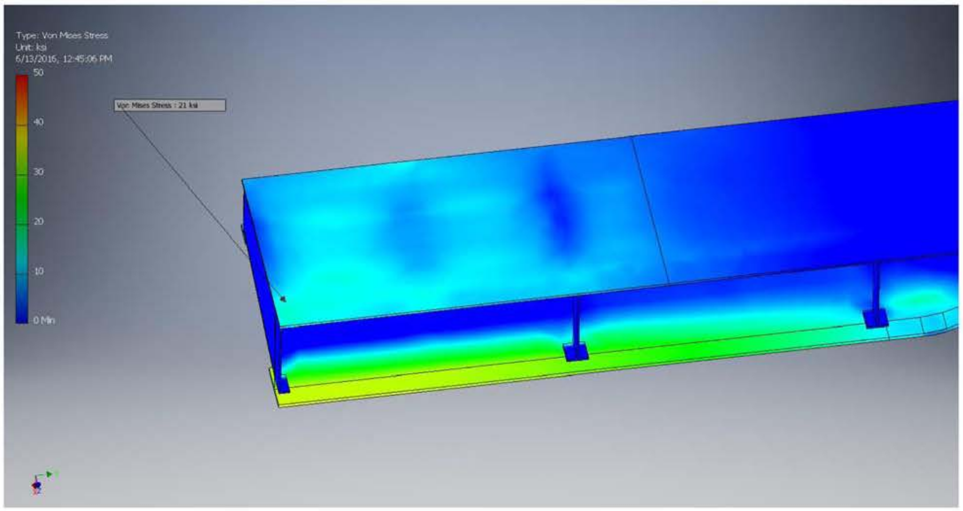
Results of the live load distributed over the center 18 feet was the governing criteria. All load cases are shown for reference.

LOADING	PARA.	PAGE
LL CTR 18 FT	4.1.3.2 c	
STATIC		25
DRAFT		26
BUFF		27
SQUEEZE		28
LL FULL CAR	4.1.3.2 a	
STATIC		29
DRAFT		30
BUFF		31
SQUEEZE		32
LL 15% ON OVERHANG	4.1.3.2 d	
STATIC		33
DRAFT		34
BUFF		35
SQUEEZE		36
LL 75% ON CTR SILL	4.1.3.2 b 1	
STATIC		37
DRAFT		38
BUFF		39
SQUEEZE		40
LL 37.5 % ON SIDE SILL	4.1.3.2 b 2	
STATIC		41
DRAFT		42
BUFF		43
SQUEEZE		44
JACKING LOAD	4.1.6	45
TWIST LOAD S-2043	4.1.5.5	46-47
VERTICAL COUPLER	4.1.5	48-49
DEFLECTION		50

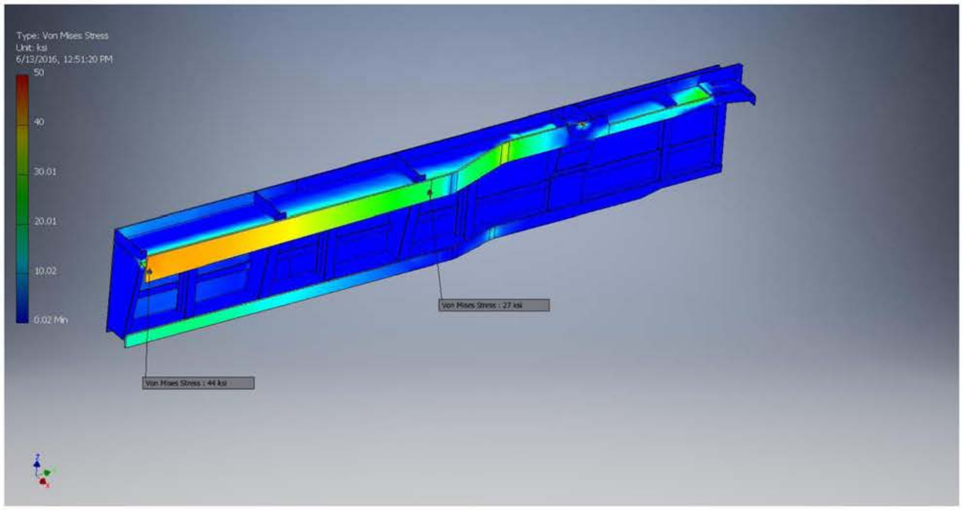
Some loads and supports were entered into the model as point loads. This causes a resulting high stress at the point of application. The point loads were necessary to maintain integrity in the model. High point stresses were ignored in the overall stress summary.

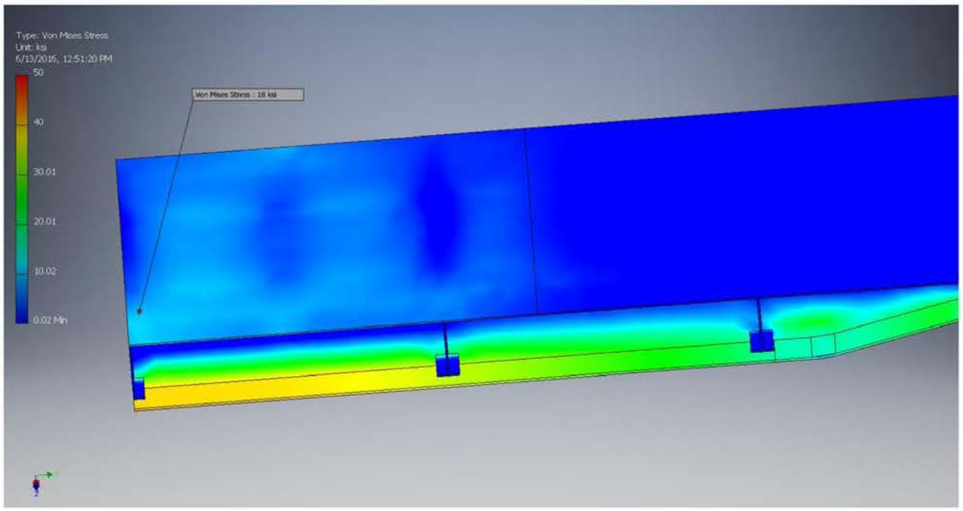
Load over 18 feet static
Paragraph 4.1.3.2 c



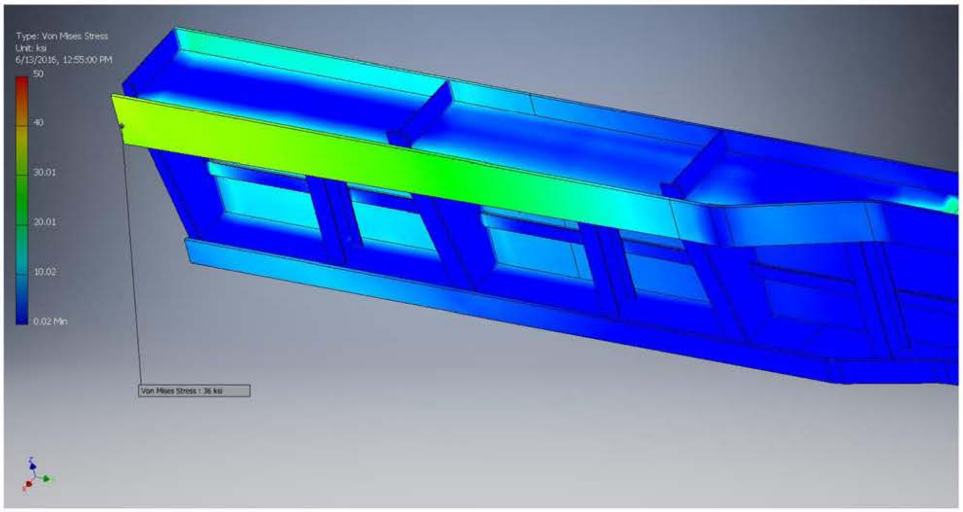


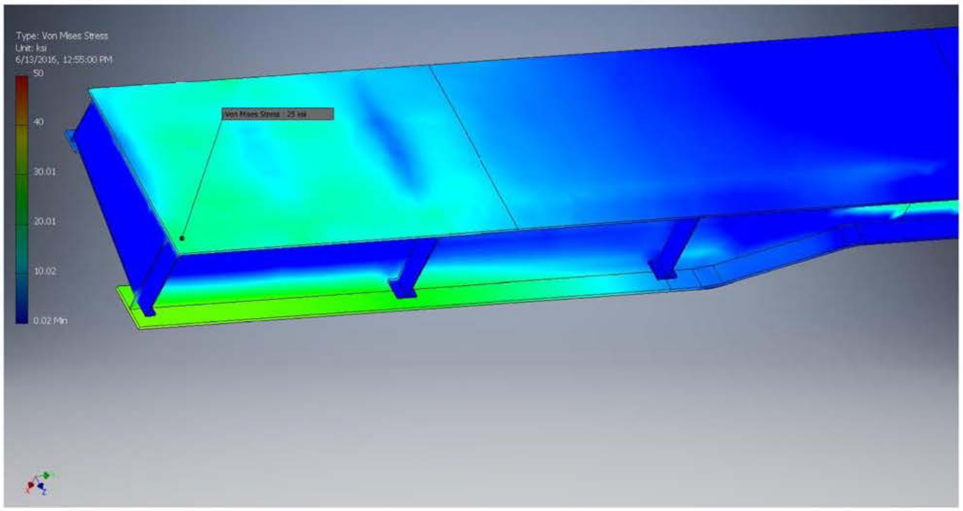
18 feet with draft
Paragraph 4.1.3.2 c





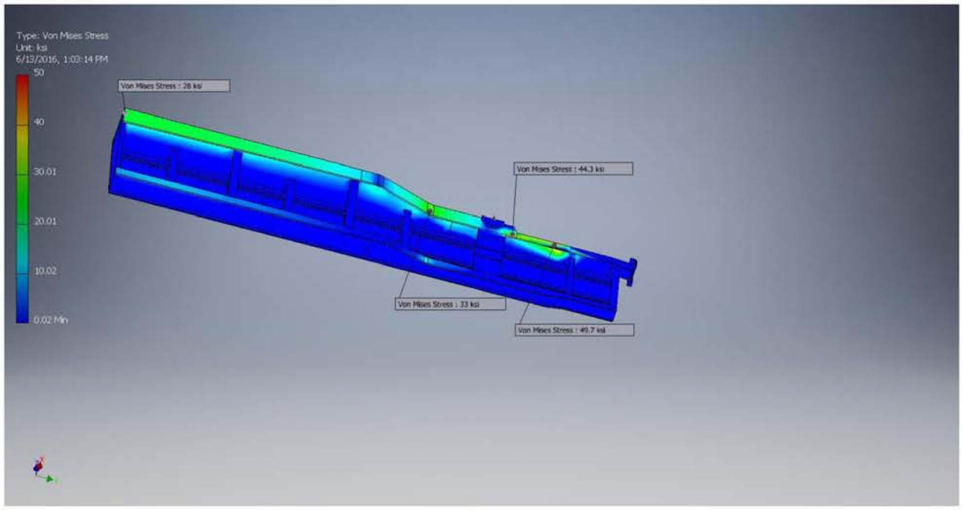
Paragraph 4.1.3.2 c
18 feet with buff

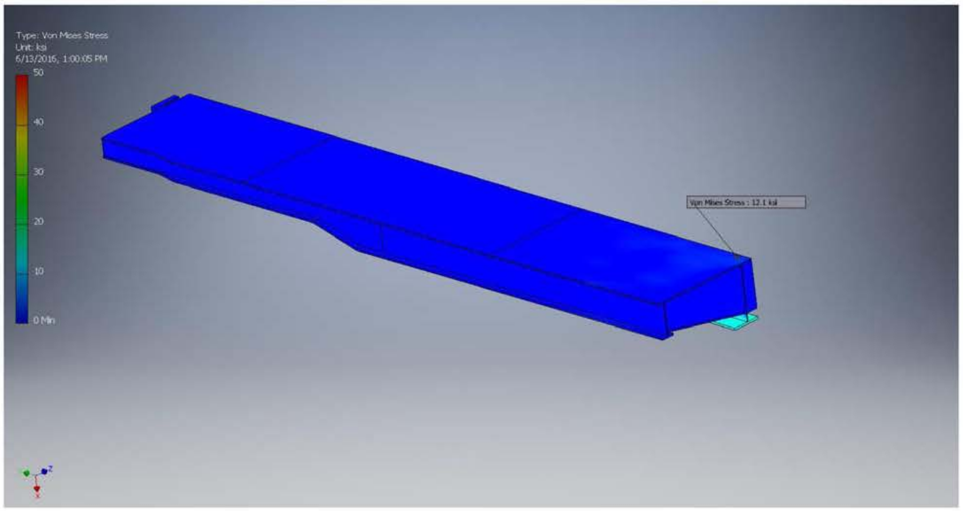




18 feet squeeze

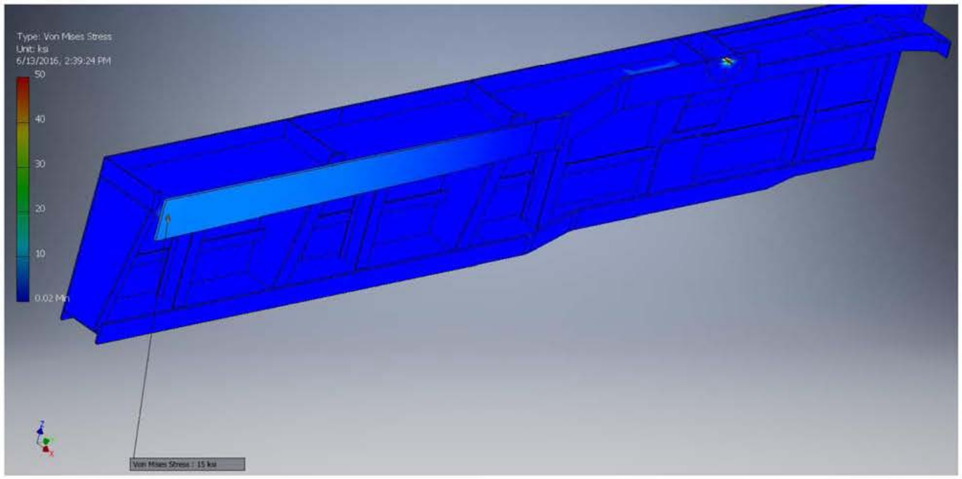
Paragraph 4.1.3.2 c

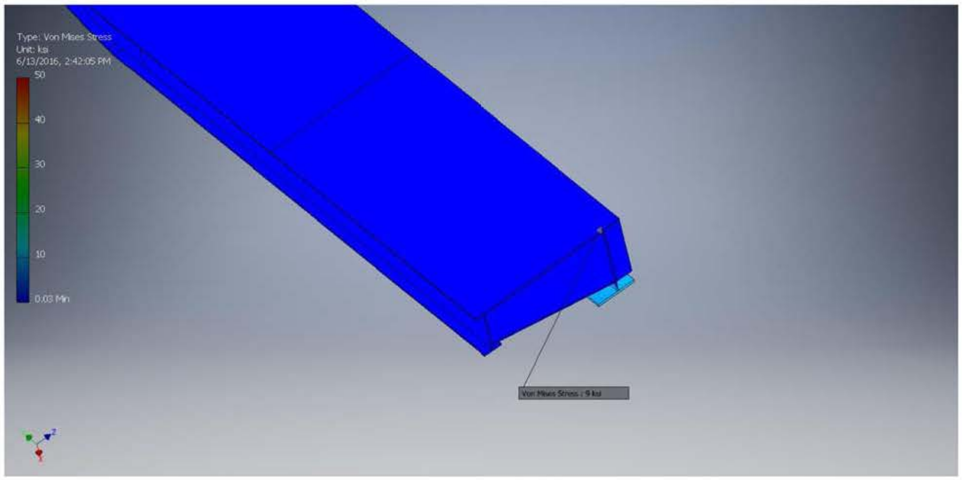




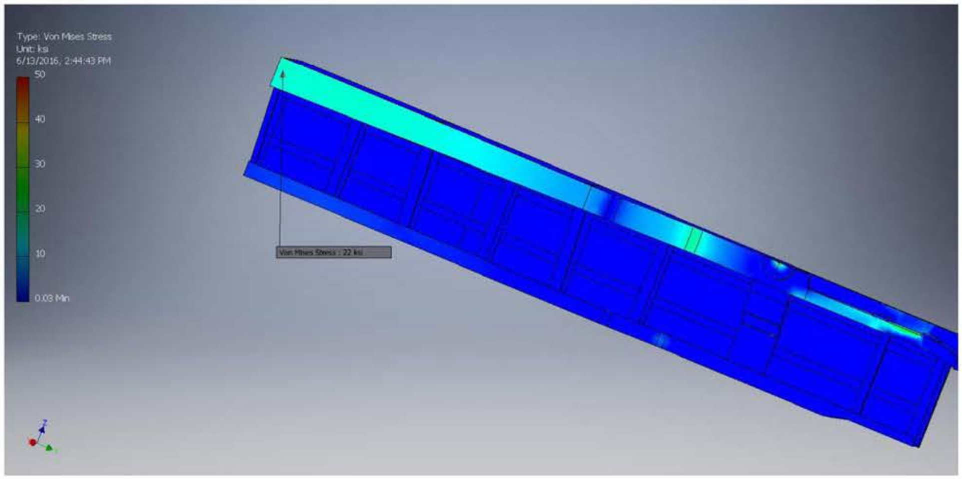
Load over full car static

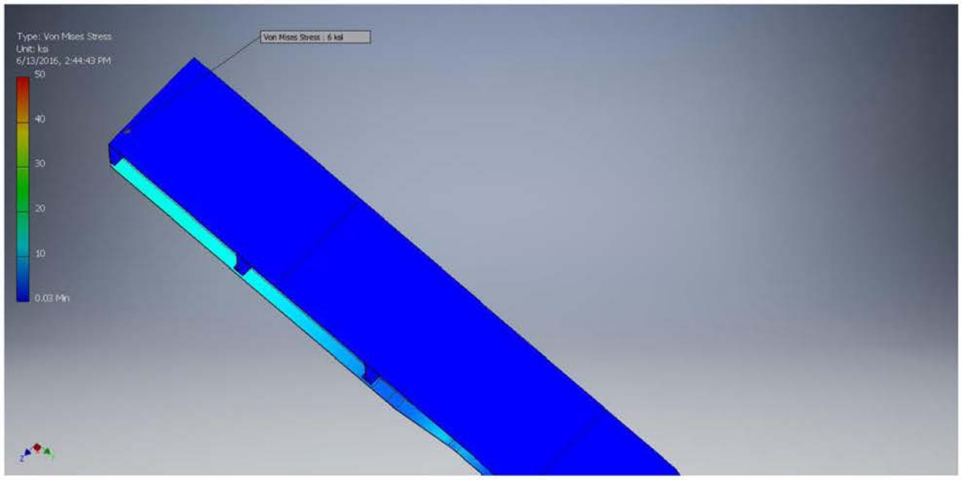
Paragraph 4.1.3.2 a



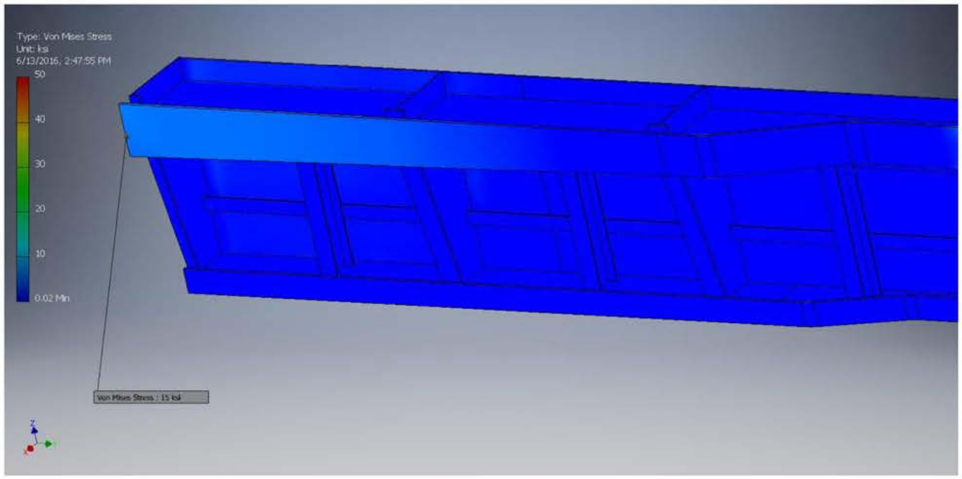


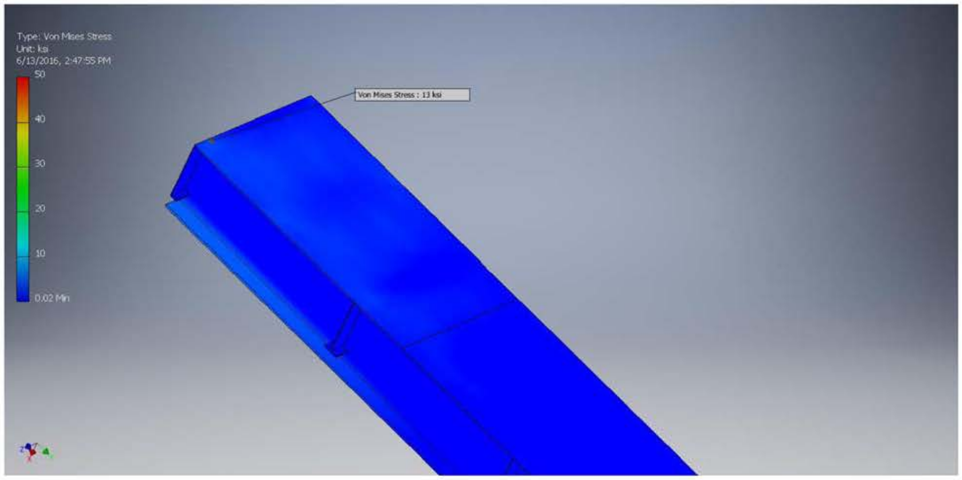
Over deck draft
Paragraph 4.1.3.2 a





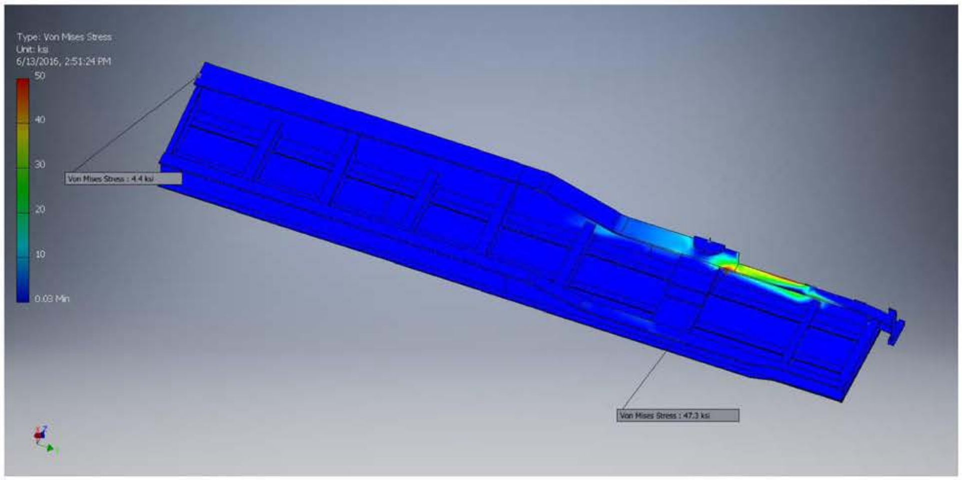
Over deck with buff
Paragraph 4.1.3.2 a

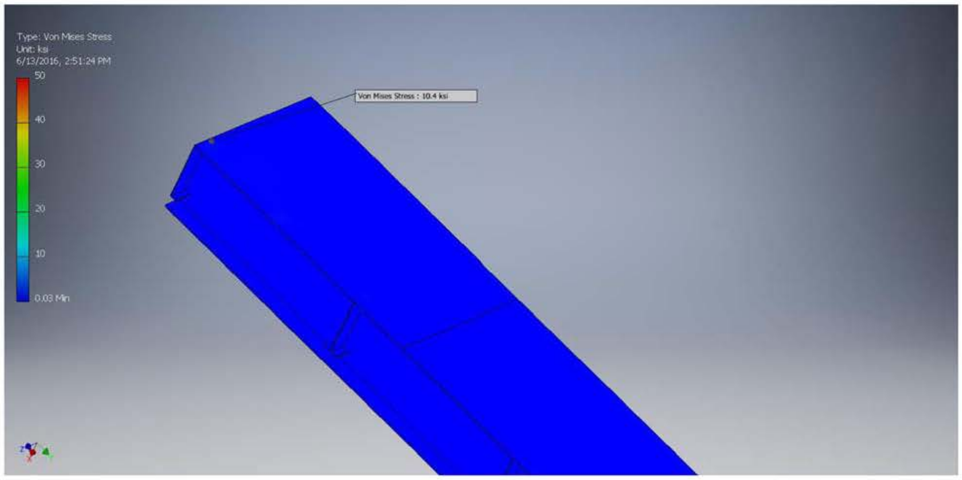




Paragraph 4.1.3.2 a

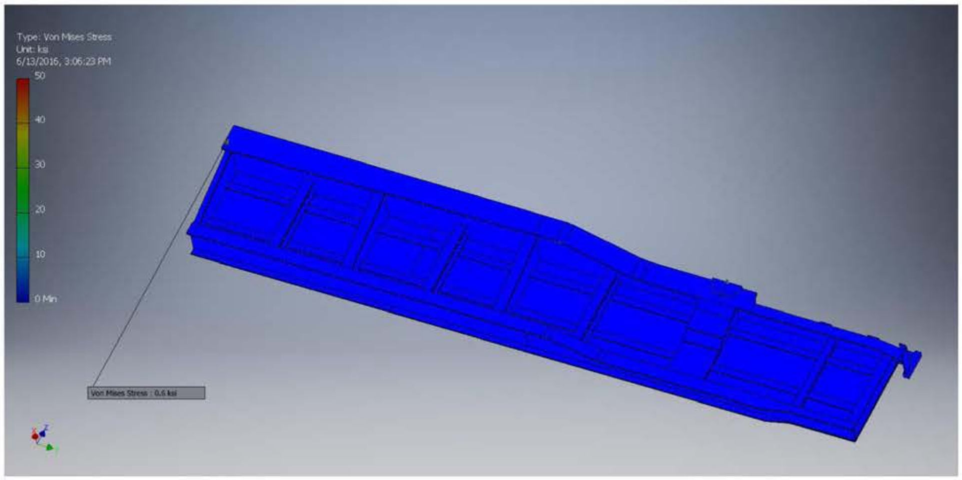
Over deck squeeze

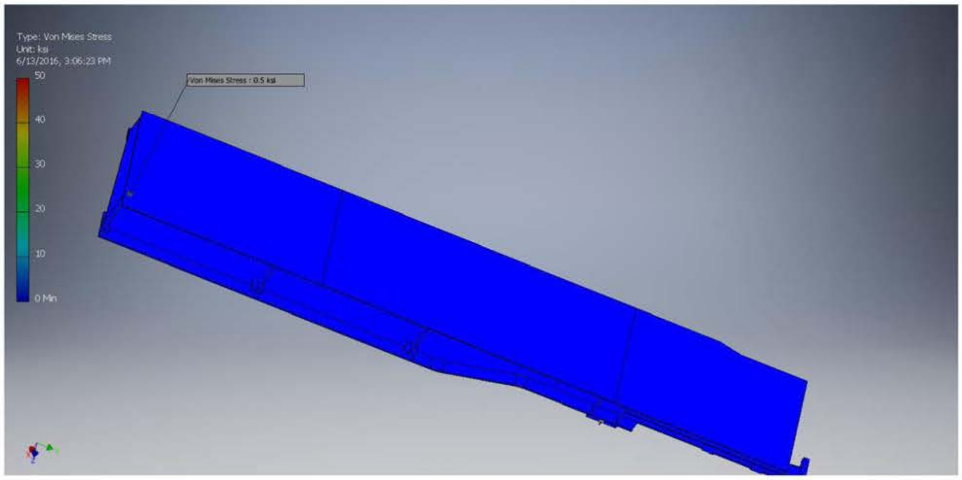




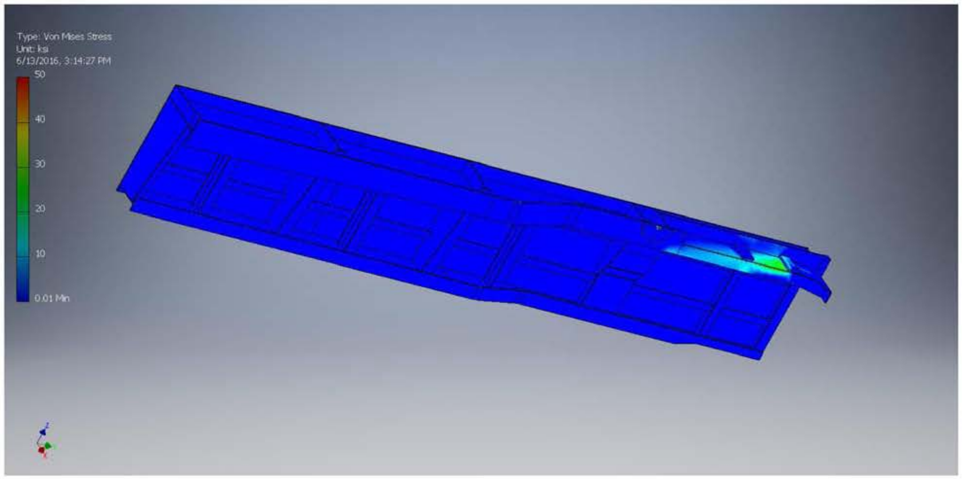
Paragraph 4.1.3.2 d

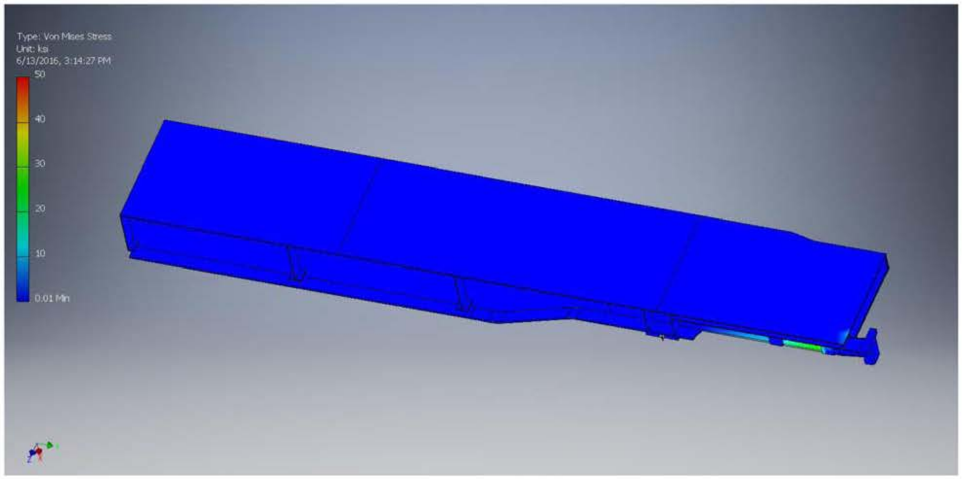
15 percent on overhang static





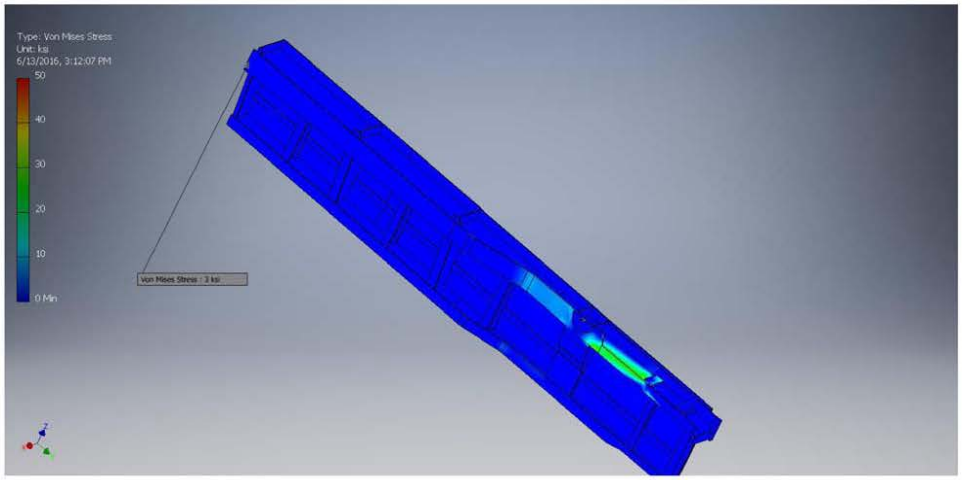
Overhang with draft
Paragraph 4.1.3.2 d

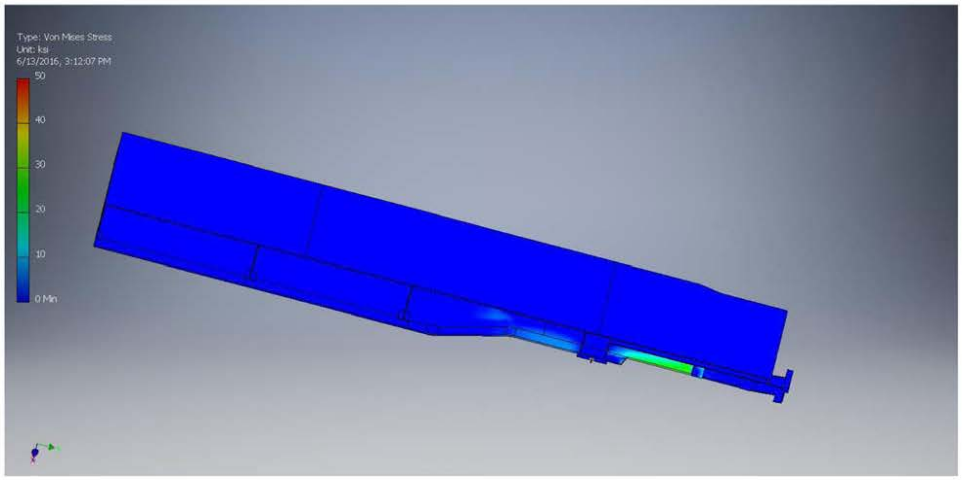




Paragraph 4.1.3.2 d

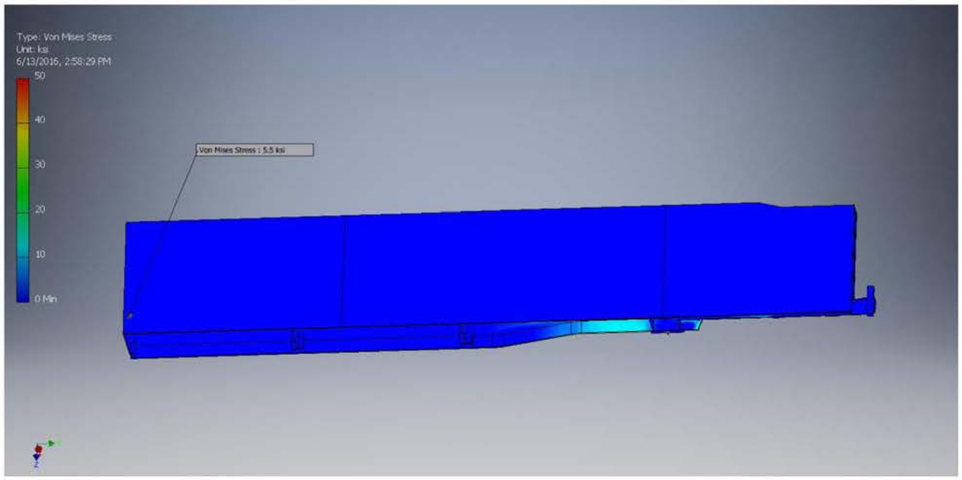
Overhang buff

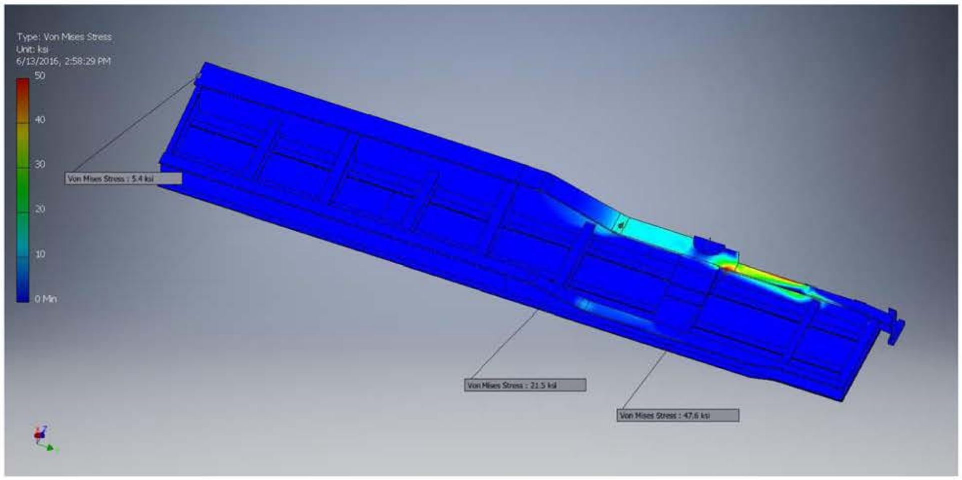




Paragraph 4.1.3.2 d

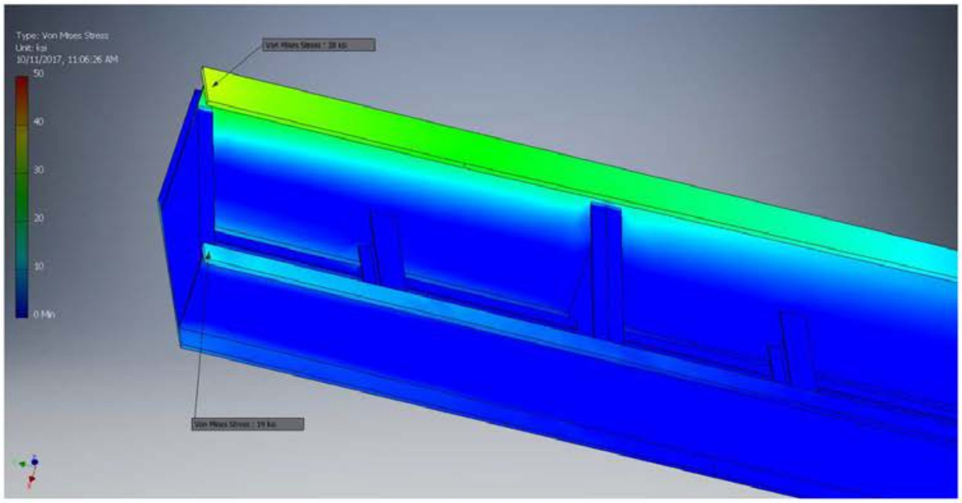
Overhang squeeze

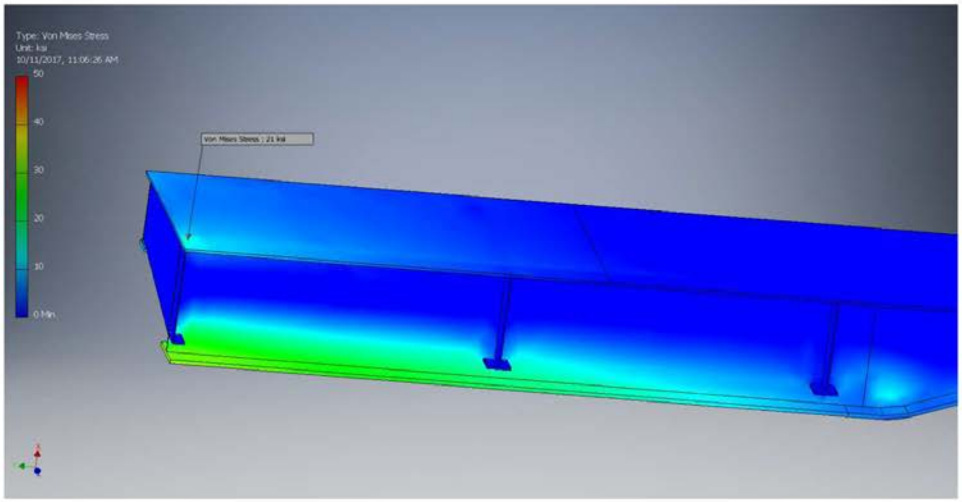




75 % on center sill static

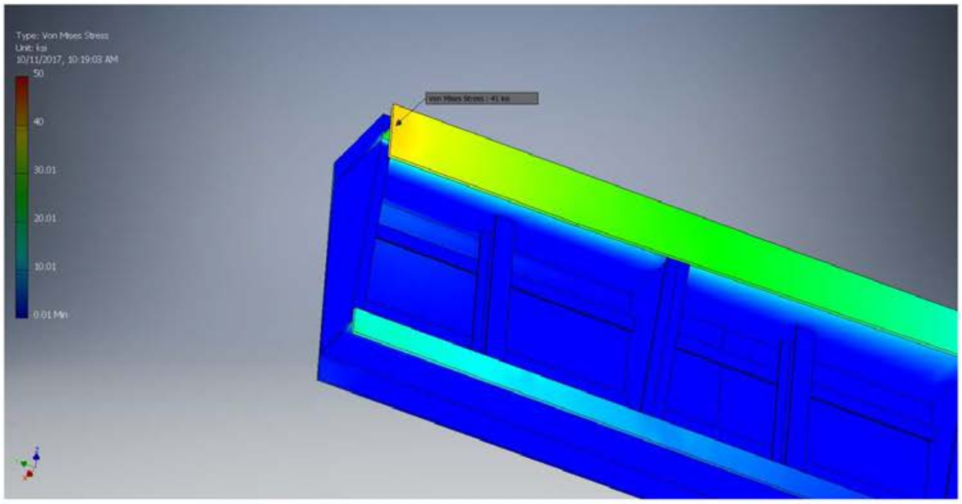
Paragraph 4.1.3.2 b 1

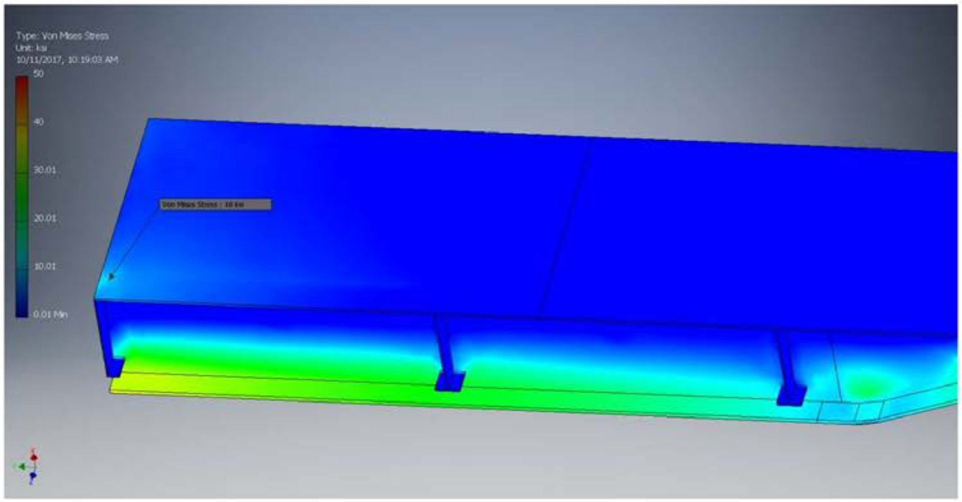




75% on center at center sill with draft

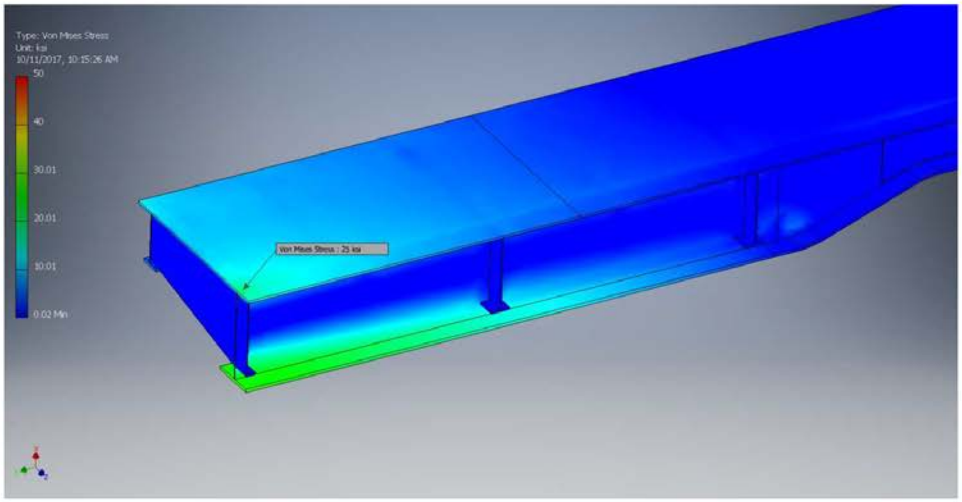
Paragraph 4.1.3.2 b 1

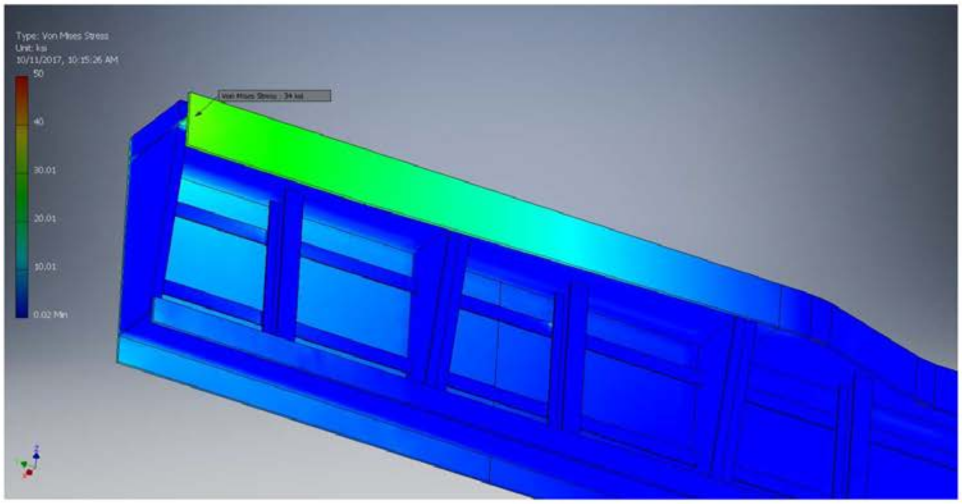




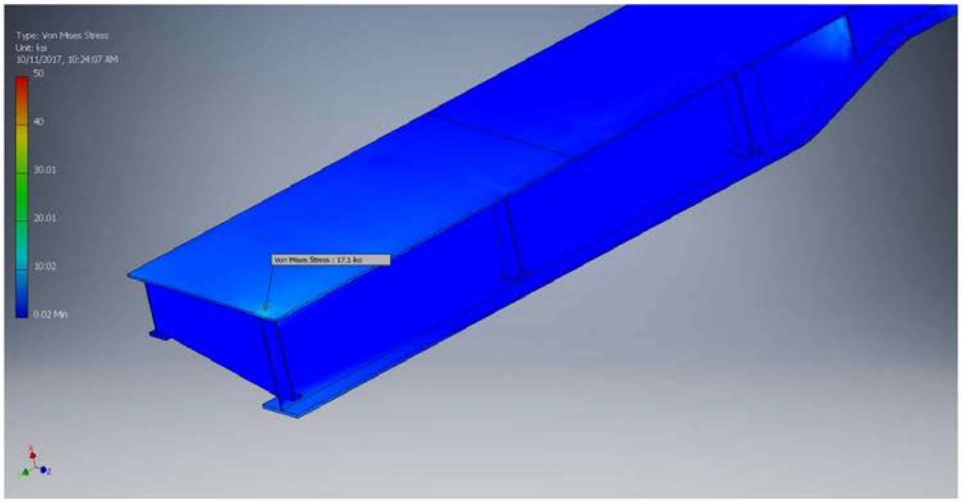
75% on center at center sill with buff

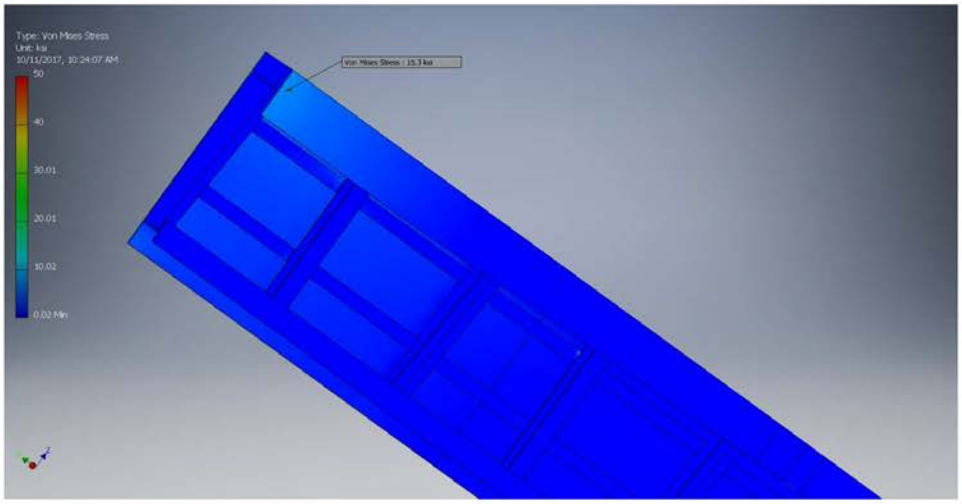
Paragraph 4.1.3.2 b 1



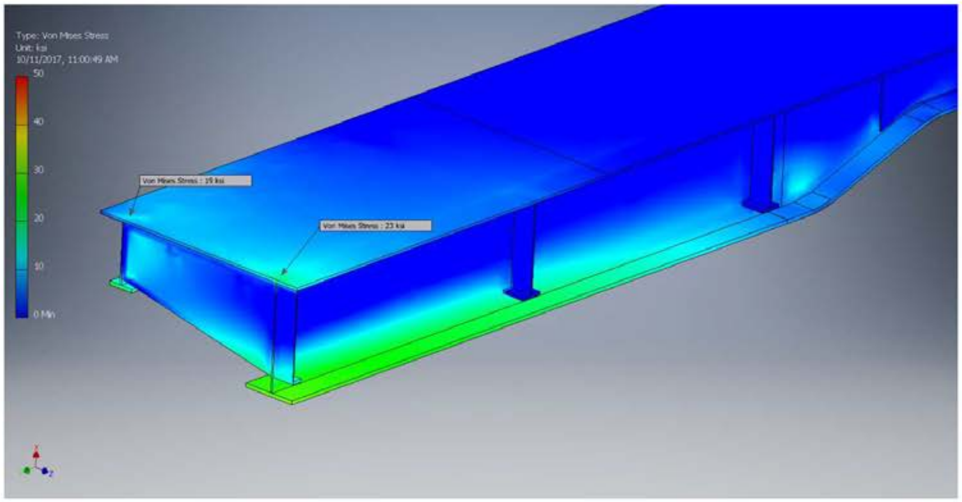


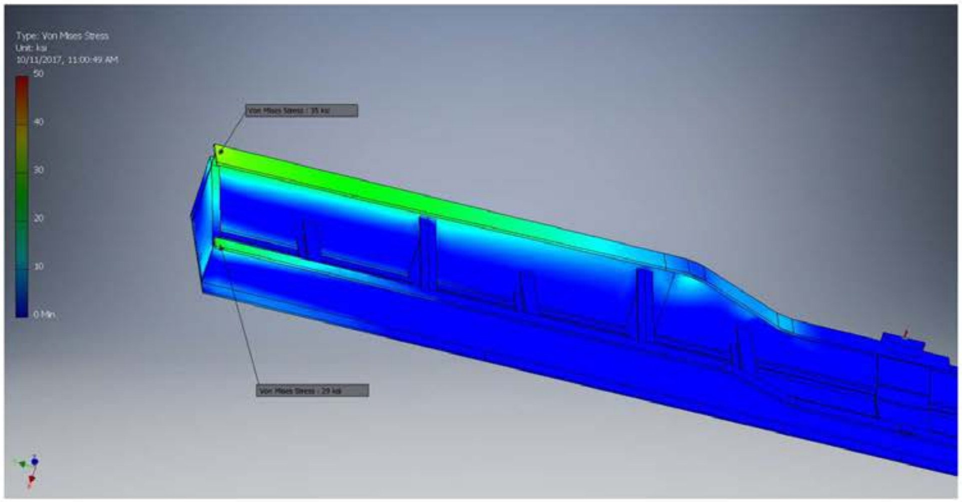
75% on center at center sill with squeeze
Paragraph 4.1.3.2 b 1





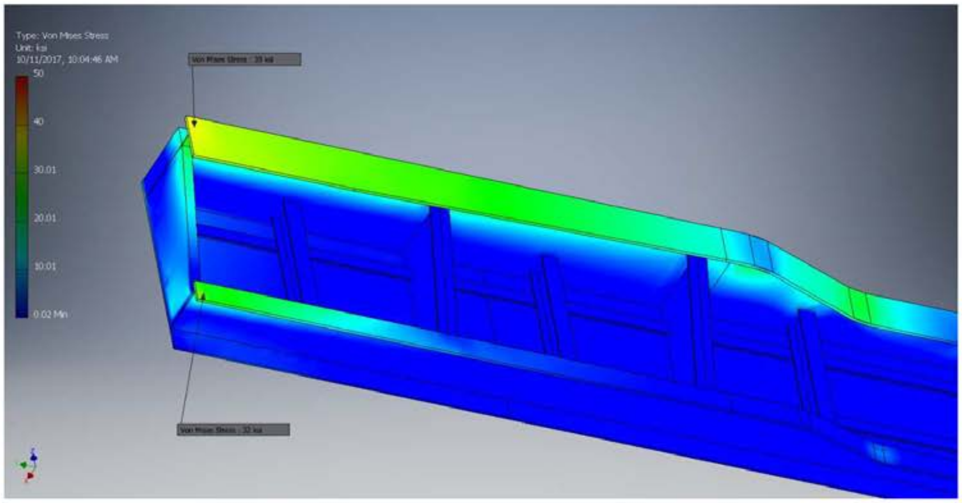
37.5% at side sill static
Paragraph 4.1.3.2 b 2

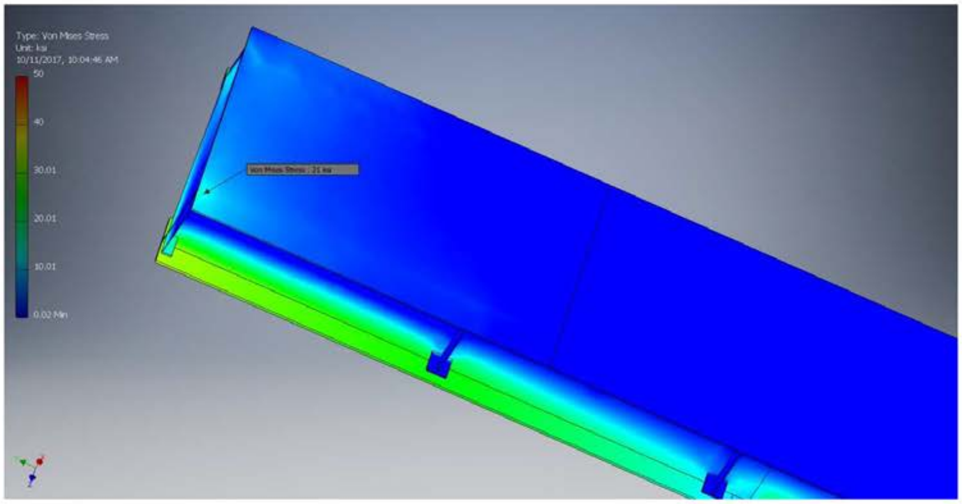




37.5% at side sill with draft

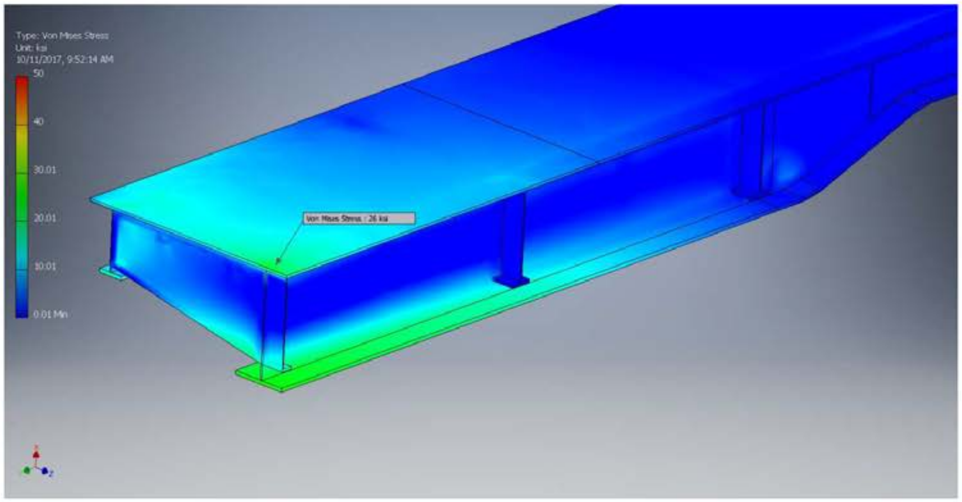
Paragraph 4.1.3.2 b 2

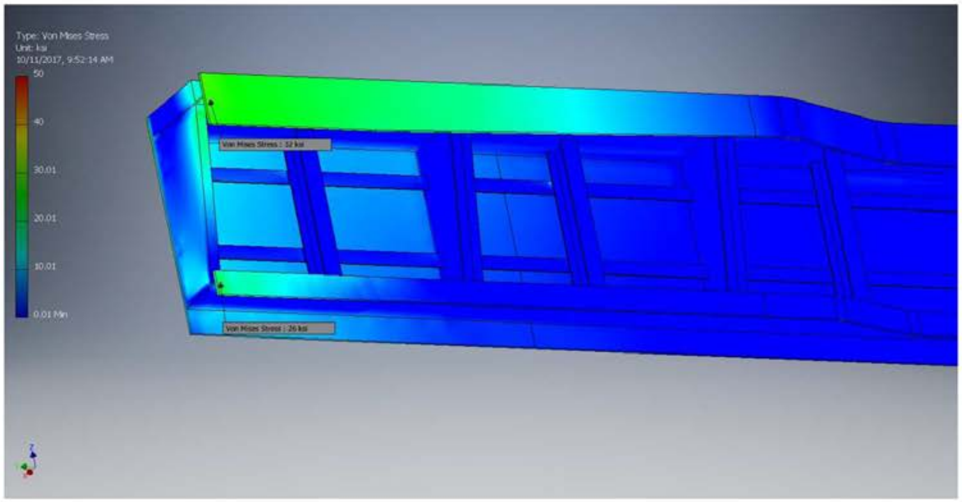




37.5% at side sill with buff

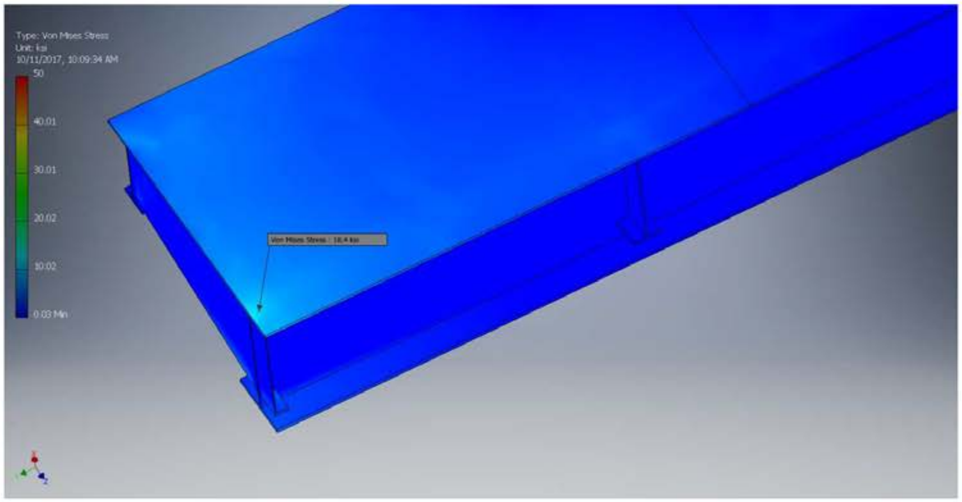
Paragraph 4.1.3.2 b 2

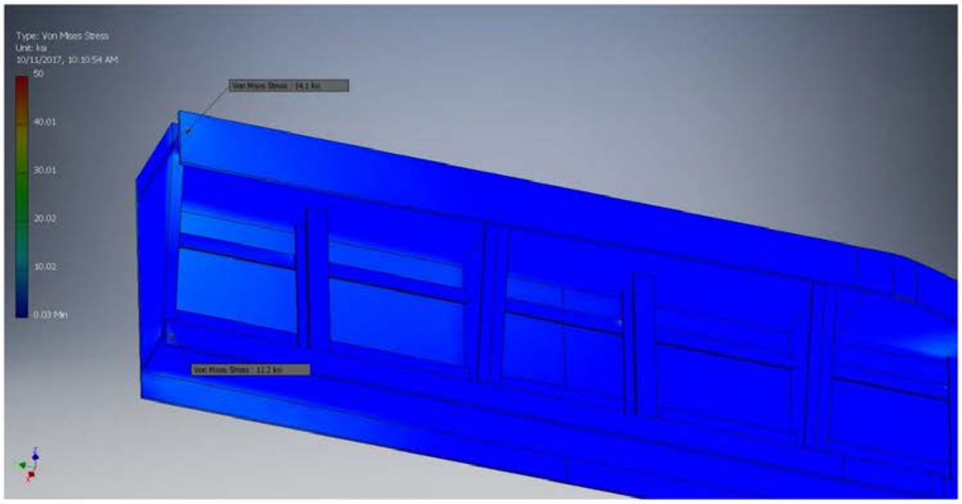




37.5% at side sill with squeeze

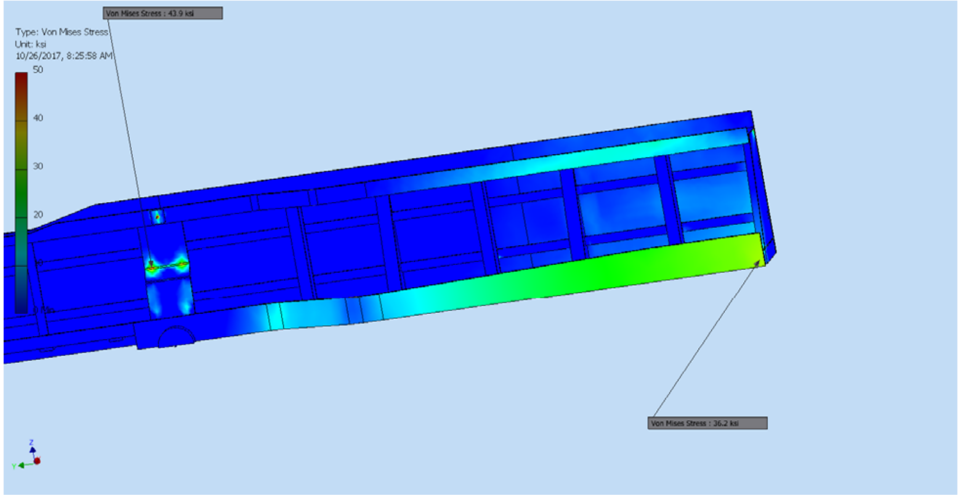
Paragraph 4.1.3.2 b 2

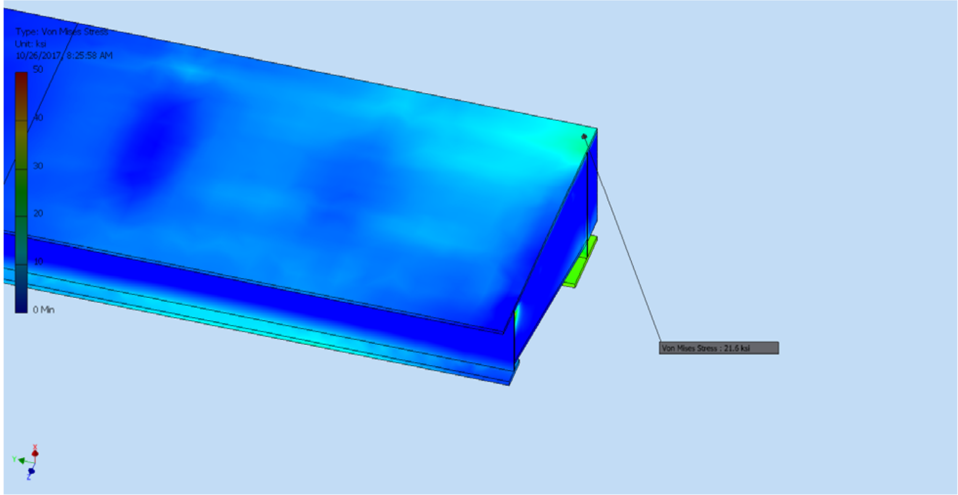




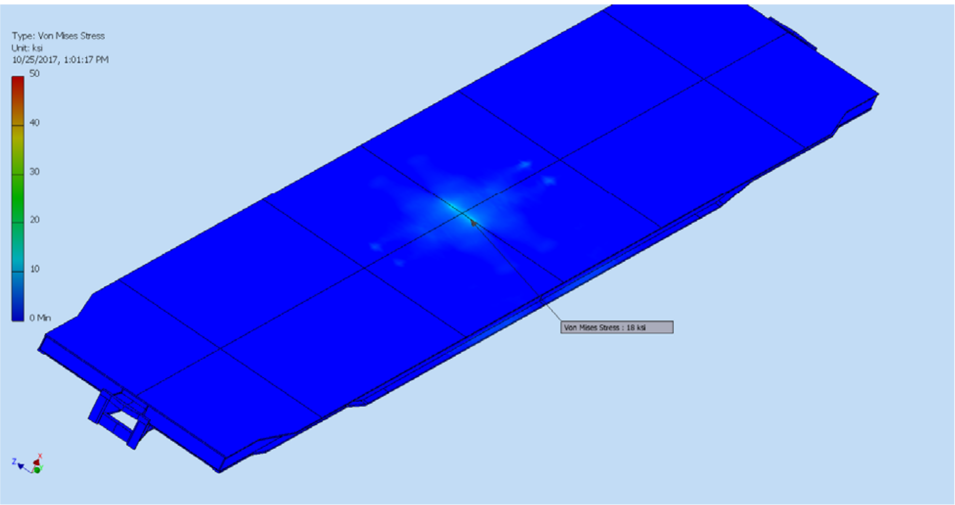
Jacking 40% at jacking pad

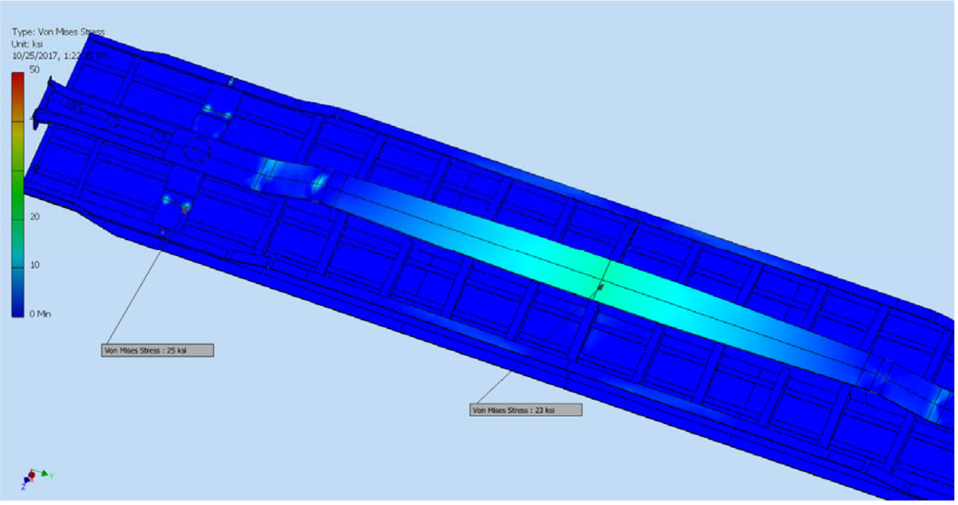
Paragraph 4.1.6

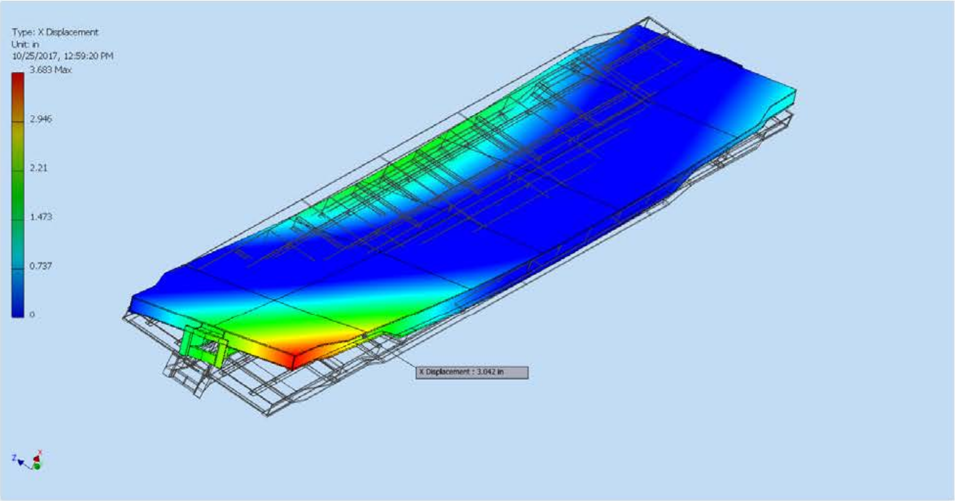




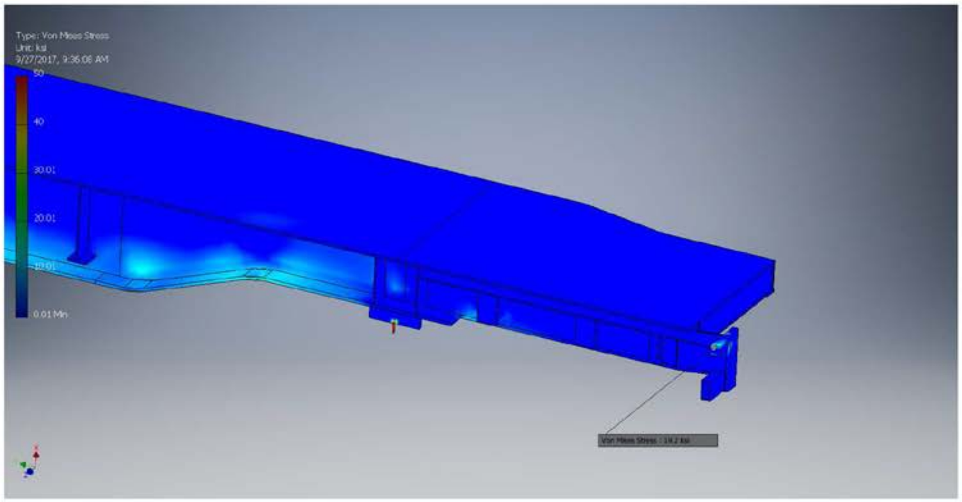
Twist load 3” deflection at wheel
Paragraph 4.1.5.5 from S-2043
Simple supports at longitudinal opposite jacking pad and opposite end center plate.

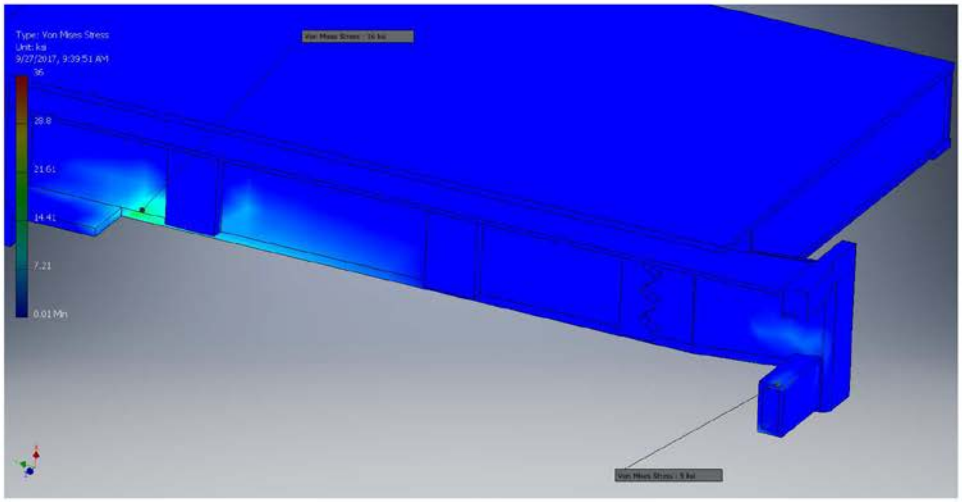





Type: X Displacement
Unit: in
10/25/2017, 12:59:20 PM
3.683 Max
2.946
2.21
1.473
0.737
0
X Displacement : 3.042 in
Z
X

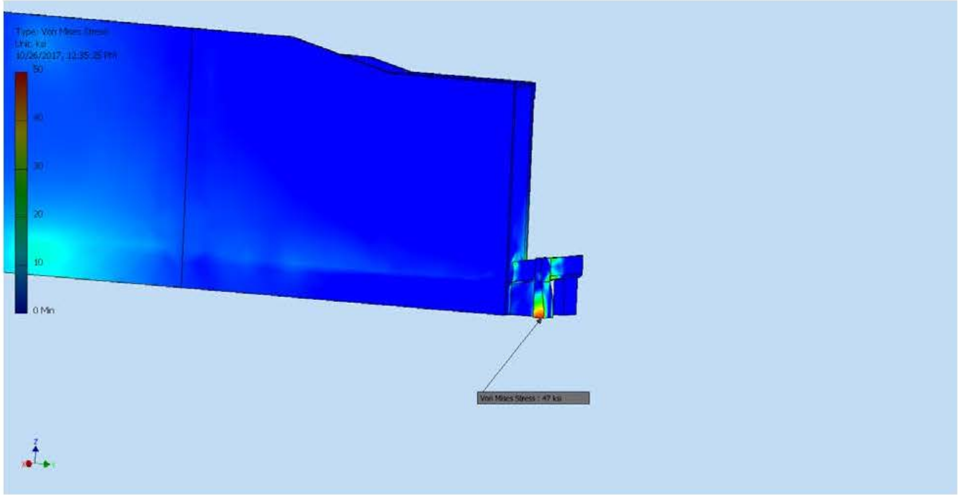
Vertical up and down load on coupler 50,000 lbs
Paragraph 4.1.5

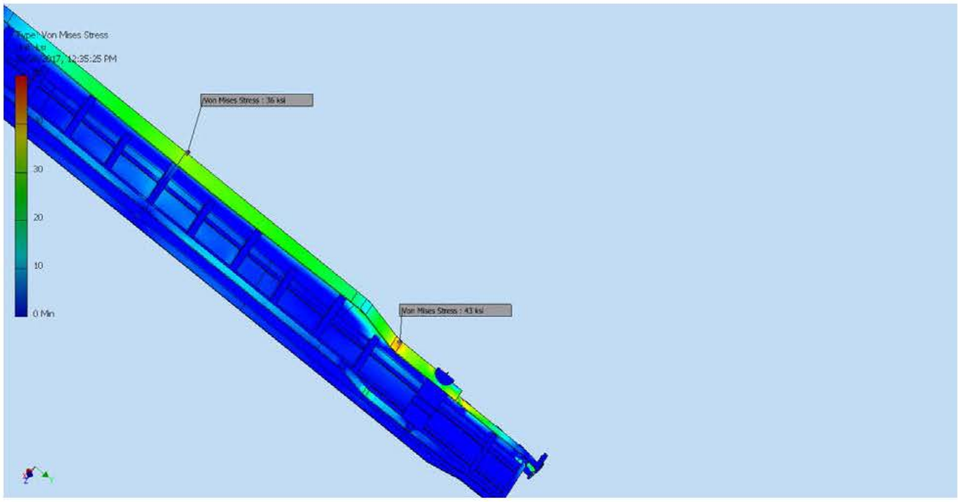




125% Load at striker

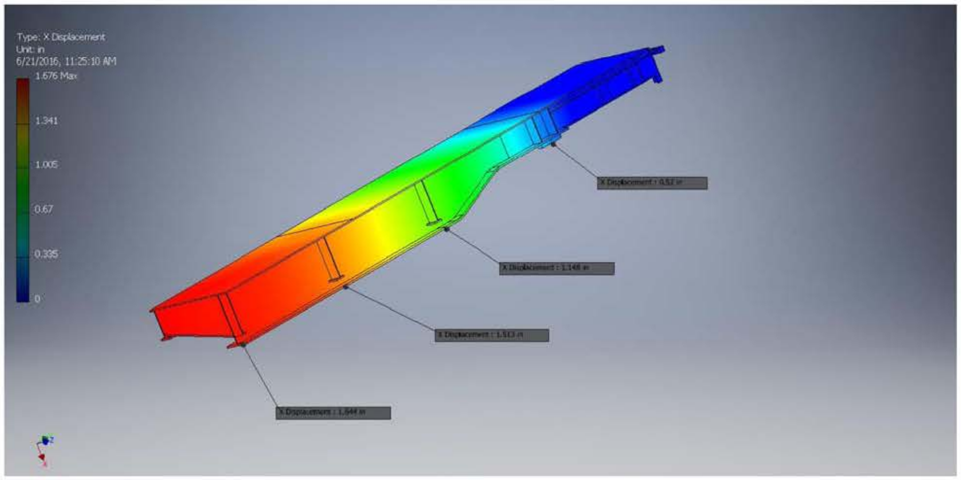
Paragraph 4.1.5.1





Deflection with load on center 18 feet

Deflection



FATIGUE ANALYSIS

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 splice because of nominal stress. The draft sill was not analyzed as its design is of the manufacturers recommendation. The bolster has relatively low nominal stresses and is of the same type design as other general service flat cars in use.

Stresses used are from the FEA. The car is basically loaded to full capacity at all times with the dummy weights (as designed) permanently attached and adding substantially to the cross-sectional properties. This was not considered in the analysis thus giving conservative results. However, this does allow a slightly different design of the dummy weights should the necessity arise.

Looking at the twist load a high stress existed in the center sill bottom flange. For this reason the ARR fatigue design was investigated for the torque load. The maximum torsional load was applied to an empty car and a loaded car. This resulted in stress well below the endurance limit of the steel. This was not analyzed further. Results of this loading follow the spreadsheets of the fatigue calculations.

Based on this calculation the calculated lifetime miles is 16 million.

FATIGUE DATA FOR CENTER SILL AT SPLICE

(Coupler Load 110 Ton High-sided Gon)

			α	Static	Dynamic Stress		Max	R	Endurance	Cycles to Failure	
Max	Min	No.	Pct	Stress	Max	Min	Adjusted	Min/Max	Limit	N	α/N
430	-250	1	0.00007	12.2	15.6	10.2	15.6	0.655	49.5	106396682	9.40E-11
410	390	1	0.00007	12.2	15.5	15.3	15.5	0.990	1666.0	NO DAMAGE	
410	310	1	0.00007	12.2	15.5	14.7	15.5	0.949	333.2	NO DAMAGE	
395	365	2	0.00015	12.2	15.4	15.1	15.4	0.984	1102.1	NO DAMAGE	
385	365	1	0.00007	12.2	15.3	15.1	15.3	0.990	1644.6	NO DAMAGE	
380	250	1	0.00007	12.2	15.2	14.2	15.2	0.932	252.4	NO DAMAGE	
360	300	1	0.00007	12.2	15.1	14.6	15.1	0.968	541.1	NO DAMAGE	
360	290	1	0.00007	12.2	15.1	14.5	15.1	0.963	463.8	NO DAMAGE	
360	-130	1	0.00007	12.2	15.1	11.2	15.1	0.742	66.3	NO DAMAGE	
360	-230	1	0.00007	12.2	15.1	10.4	15.1	0.689	55.0	NO DAMAGE	
350	220	1	0.00007	12.2	15.0	14.0	15.0	0.931	248.4	NO DAMAGE	
350	-230	1	0.00007	12.2	15.0	10.4	15.0	0.693	55.7	NO DAMAGE	
340	320	3	0.00022	12.2	14.9	14.8	14.9	0.989	1606.1	NO DAMAGE	
340	-120	1	0.00007	12.2	14.9	11.3	14.9	0.755	69.8	NO DAMAGE	
340	-150	1	0.00007	12.2	14.9	11.0	14.9	0.739	65.6	NO DAMAGE	
330	-120	1	0.00007	12.2	14.8	11.3	14.8	0.759	71.0	NO DAMAGE	
320	310	2	0.00015	12.2	14.8	14.7	14.8	0.995	3178.0	NO DAMAGE	
320	250	1	0.00007	12.2	14.8	14.2	14.8	0.962	454.0	NO DAMAGE	
310	290	2	0.00015	12.2	14.7	14.5	14.7	0.989	1580.5	NO DAMAGE	
310	-210	1	0.00007	12.2	14.7	10.6	14.7	0.719	60.8	NO DAMAGE	
310	-290	1	0.00007	12.2	14.7	9.9	14.7	0.675	52.7	NO DAMAGE	
280	-210	1	0.00007	12.2	14.4	10.6	14.4	0.731	63.5	NO DAMAGE	
270	200	1	0.00007	12.2	14.4	13.8	14.4	0.961	441.8	NO DAMAGE	
270	110	1	0.00007	12.2	14.4	13.1	14.4	0.912	193.3	NO DAMAGE	
270	100	1	0.00007	12.2	14.4	13.0	14.4	0.906	181.9	NO DAMAGE	
270	-10	1	0.00007	12.2	14.4	12.1	14.4	0.845	110.4	NO DAMAGE	
270	-80	1	0.00007	12.2	14.4	11.6	14.4	0.806	88.4	NO DAMAGE	
265	-255	1	0.00007	12.2	14.3	10.2	14.3	0.712	59.3	NO DAMAGE	
260	220	2	0.00015	12.2	14.3	14.0	14.3	0.978	768.9	NO DAMAGE	
260	20	1	0.00007	12.2	14.3	12.4	14.3	0.867	128.1	NO DAMAGE	
260	-150	1	0.00007	12.2	14.3	11.0	14.3	0.772	75.0	NO DAMAGE	
260	-220	1	0.00007	12.2	14.3	10.5	14.3	0.733	64.1	NO DAMAGE	
260	-240	1	0.00007	12.2	14.3	10.3	14.3	0.722	61.5	NO DAMAGE	
260	-260	1	0.00007	12.2	14.3	10.2	14.3	0.711	59.1	NO DAMAGE	
250	240	1	0.00007	12.2	14.2	14.1	14.2	0.994	3058.3	NO DAMAGE	
250	230	9	0.00067	12.2	14.2	14.0	14.2	0.989	1529.2	NO DAMAGE	
250	220	2	0.00015	12.2	14.2	14.0	14.2	0.983	1019.4	NO DAMAGE	
250	190	1	0.00007	12.2	14.2	13.7	14.2	0.966	509.7	NO DAMAGE	
250	90	1	0.00007	12.2	14.2	12.9	14.2	0.911	191.1	NO DAMAGE	
250	-50	1	0.00007	12.2	14.2	11.8	14.2	0.832	101.9	NO DAMAGE	
250	-100	1	0.00007	12.2	14.2	11.4	14.2	0.804	87.4	NO DAMAGE	
250	-160	1	0.00007	12.2	14.2	10.9	14.2	0.771	74.6	NO DAMAGE	
250	-180	1	0.00007	12.2	14.2	10.8	14.2	0.760	71.1	NO DAMAGE	
250	-220	1	0.00007	12.2	14.2	10.5	14.2	0.737	65.1	NO DAMAGE	
250	-410	1	0.00007	12.2	14.2	9.0	14.2	0.631	46.3	117932880	8.48E-11
245	225	1	0.00007	12.2	14.2	14.0	14.2	0.989	1524.9	NO DAMAGE	
245	155	1	0.00007	12.2	14.2	13.5	14.2	0.950	338.9	NO DAMAGE	
245	-315	1	0.00007	12.2	14.2	9.7	14.2	0.686	54.5	NO DAMAGE	
240	230	5	0.00037	12.2	14.1	14.0	14.1	0.994	3041.2	NO DAMAGE	
240	220	2	0.00015	12.2	14.1	14.0	14.1	0.989	1520.6	NO DAMAGE	
240	210	2	0.00015	12.2	14.1	13.9	14.1	0.983	1013.7	NO DAMAGE	
240	180	1	0.00007	12.2	14.1	13.6	14.1	0.966	506.9	NO DAMAGE	
240	140	1	0.00007	12.2	14.1	13.3	14.1	0.944	304.1	NO DAMAGE	
240	110	1	0.00007	12.2	14.1	13.1	14.1	0.927	233.9	NO DAMAGE	
240	70	1	0.00007	12.2	14.1	12.8	14.1	0.904	178.9	NO DAMAGE	
240	-70	1	0.00007	12.2	14.1	11.7	14.1	0.826	98.1	NO DAMAGE	
240	-110	1	0.00007	12.2	14.1	11.3	14.1	0.803	86.9	NO DAMAGE	
240	-120	1	0.00007	12.2	14.1	11.3	14.1	0.798	84.5	NO DAMAGE	
240	-160	1	0.00007	12.2	14.1	10.9	14.1	0.775	76.0	NO DAMAGE	
240	-170	1	0.00007	12.2	14.1	10.9	14.1	0.769	74.2	NO DAMAGE	
240	-210	1	0.00007	12.2	14.1	10.6	14.1	0.747	67.6	NO DAMAGE	
240	-240	1	0.00007	12.2	14.1	10.3	14.1	0.730	63.4	NO DAMAGE	
235	225	13	0.00097	12.2	14.1	14.0	14.1	0.994	3032.7	NO DAMAGE	
235	215	9	0.00067	12.2	14.1	13.9	14.1	0.989	1516.3	NO DAMAGE	
230	220	2	0.00015	12.2	14.0	14.0	14.0	0.994	3024.1	NO DAMAGE	
230	200	2	0.00015	12.2	14.0	13.8	14.0	0.983	1008.0	NO DAMAGE	
230	190	2	0.00015	12.2	14.0	13.7	14.0	0.977	756.0	NO DAMAGE	
230	170	1	0.00007	12.2	14.0	13.6	14.0	0.966	504.0	NO DAMAGE	
230	-10	1	0.00007	12.2	14.0	12.1	14.0	0.864	126.0	NO DAMAGE	
230	-90	1	0.00007	12.2	14.0	11.5	14.0	0.819	94.5	NO DAMAGE	
230	-110	1	0.00007	12.2	14.0	11.3	14.0	0.808	88.9	NO DAMAGE	
230	-160	1	0.00007	12.2	14.0	10.9	14.0	0.779	77.5	NO DAMAGE	
230	-180	1	0.00007	12.2	14.0	10.8	14.0	0.768	73.8	NO DAMAGE	
230	-200	1	0.00007	12.2	14.0	10.6	14.0	0.757	70.3	NO DAMAGE	
230	-205	1	0.00007	12.2	14.0	10.6	14.0	0.754	69.5	NO DAMAGE	
230	-260	1	0.00007	12.2	14.0	10.2	14.0	0.723	61.7	NO DAMAGE	
230	-270	1	0.00007	12.2	14.0	10.1	14.0	0.717	60.5	NO DAMAGE	
225	215	22	0.00164	12.2	14.0	13.9	14.0	0.994	3015.6	NO DAMAGE	
225	205	8	0.00060	12.2	14.0	13.8	14.0	0.989	1507.8	NO DAMAGE	
225	-385	1	0.00007	12.2	14.0	9.2	14.0	0.654	49.4	154744264	6.46E-11
220	210	10	0.00075	12.2	14.0	13.9	14.0	0.994	3007.0	NO DAMAGE	
220	200	6	0.00045	12.2	14.0	13.8	14.0	0.989	1503.5	NO DAMAGE	
220	190	4	0.00030	12.2	14.0	13.7	14.0	0.983	1002.3	NO DAMAGE	

cycles per mile	153.8
Yield stress	50 ksi
Y-int (b)	17.1
slope	1
k	0.29

cycles per mile 153.8
Yield stress 50 ksi

					Dynamic					to	
			α	Static	Stress		Max	R	Endurance	Failure	
Max	Min	No.	Pct	Stress	Max	Min	Adjusted	Min/Max	Limit	N	α/N
220	180	2	0.00015	12.2	14.0	13.6	14.0	0.977	751.8	NO DAMAGE	
220	170	3	0.00022	12.2	14.0	13.6	14.0	0.972	601.4	NO DAMAGE	
220	150	1	0.00007	12.2	14.0	13.4	14.0	0.960	429.6	NO DAMAGE	
220	140	1	0.00007	12.2	14.0	13.3	14.0	0.955	375.9	NO DAMAGE	
220	130	1	0.00007	12.2	14.0	13.3	14.0	0.949	334.1	NO DAMAGE	
220	70	1	0.00007	12.2	14.0	12.8	14.0	0.915	200.5	NO DAMAGE	
220	30	1	0.00007	12.2	14.0	12.5	14.0	0.892	158.3	NO DAMAGE	
220	-70	1	0.00007	12.2	14.0	11.7	14.0	0.835	103.7	NO DAMAGE	
220	-90	1	0.00007	12.2	14.0	11.5	14.0	0.824	97.0	NO DAMAGE	
220	-110	1	0.00007	12.2	14.0	11.3	14.0	0.812	91.1	NO DAMAGE	
220	-130	1	0.00007	12.2	14.0	11.2	14.0	0.801	85.9	NO DAMAGE	
220	-135	1	0.00007	12.2	14.0	11.1	14.0	0.798	84.7	NO DAMAGE	
220	-180	3	0.00022	12.2	14.0	10.8	14.0	0.773	75.2	NO DAMAGE	
220	-190	1	0.00007	12.2	14.0	10.7	14.0	0.767	73.3	NO DAMAGE	
220	-220	2	0.00015	12.2	14.0	10.5	14.0	0.750	68.3	NO DAMAGE	
220	-230	1	0.00007	12.2	14.0	10.4	14.0	0.744	66.8	NO DAMAGE	
215	205	14	0.00104	12.2	13.9	13.8	13.9	0.994	2998.5	NO DAMAGE	
215	195	32	0.00239	12.2	13.9	13.8	13.9	0.989	1499.2	NO DAMAGE	
215	185	1	0.00007	12.2	13.9	13.7	13.9	0.983	999.5	NO DAMAGE	
215	165	2	0.00015	12.2	13.9	13.5	13.9	0.971	599.7	NO DAMAGE	
215	-175	1	0.00007	12.2	13.9	10.8	13.9	0.778	76.9	NO DAMAGE	
215	-225	2	0.00015	12.2	13.9	10.4	13.9	0.749	68.1	NO DAMAGE	
215	-325	1	0.00007	12.2	13.9	9.6	13.9	0.692	55.5	NO DAMAGE	
210	200	12	0.00089	12.2	13.9	13.8	13.9	0.994	2989.9	NO DAMAGE	
210	190	17	0.00127	12.2	13.9	13.7	13.9	0.989	1495.0	NO DAMAGE	
210	180	13	0.00097	12.2	13.9	13.6	13.9	0.983	996.6	NO DAMAGE	
210	170	2	0.00015	12.2	13.9	13.6	13.9	0.977	747.5	NO DAMAGE	
210	160	1	0.00007	12.2	13.9	13.5	13.9	0.971	598.0	NO DAMAGE	
210	130	1	0.00007	12.2	13.9	13.3	13.9	0.954	373.7	NO DAMAGE	
210	70	1	0.00007	12.2	13.9	12.8	13.9	0.920	213.6	NO DAMAGE	
210	60	1	0.00007	12.2	13.9	12.7	13.9	0.914	199.3	NO DAMAGE	
210	30	1	0.00007	12.2	13.9	12.5	13.9	0.897	166.1	NO DAMAGE	
210	20	1	0.00007	12.2	13.9	12.4	13.9	0.891	157.4	NO DAMAGE	
210	10	1	0.00007	12.2	13.9	12.3	13.9	0.886	149.5	NO DAMAGE	
210	-10	2	0.00015	12.2	13.9	12.1	13.9	0.874	135.9	NO DAMAGE	
210	-30	1	0.00007	12.2	13.9	12.0	13.9	0.863	124.6	NO DAMAGE	
210	-90	1	0.00007	12.2	13.9	11.5	13.9	0.828	99.7	NO DAMAGE	
210	-130	2	0.00015	12.2	13.9	11.2	13.9	0.806	87.9	NO DAMAGE	
210	-150	5	0.00037	12.2	13.9	11.0	13.9	0.794	83.1	NO DAMAGE	
210	-160	1	0.00007	12.2	13.9	10.9	13.9	0.788	80.8	NO DAMAGE	
210	-190	1	0.00007	12.2	13.9	10.7	13.9	0.771	74.7	NO DAMAGE	
210	-200	2	0.00015	12.2	13.9	10.6	13.9	0.766	72.9	NO DAMAGE	
210	-210	1	0.00007	12.2	13.9	10.6	13.9	0.760	71.2	NO DAMAGE	
210	-220	2	0.00015	12.2	13.9	10.5	13.9	0.754	69.5	NO DAMAGE	
210	-230	1	0.00007	12.2	13.9	10.4	13.9	0.748	68.0	NO DAMAGE	
205	195	56	0.00417	12.2	13.8	13.8	13.8	0.994	2981.4	NO DAMAGE	
205	185	48	0.00358	12.2	13.8	13.7	13.8	0.989	1490.7	NO DAMAGE	
205	180	2	0.00015	12.2	13.8	13.6	13.8	0.986	1192.5	NO DAMAGE	
205	175	11	0.00082	12.2	13.8	13.6	13.8	0.983	993.8	NO DAMAGE	
205	165	2	0.00015	12.2	13.8	13.5	13.8	0.977	745.3	NO DAMAGE	
205	155	1	0.00007	12.2	13.8	13.5	13.8	0.971	596.3	NO DAMAGE	
205	150	1	0.00007	12.2	13.8	13.4	13.8	0.968	542.1	NO DAMAGE	
205	140	1	0.00007	12.2	13.8	13.3	13.8	0.963	458.7	NO DAMAGE	
205	135	1	0.00007	12.2	13.8	13.3	13.8	0.960	425.9	NO DAMAGE	
205	-85	1	0.00007	12.2	13.8	11.5	13.8	0.834	102.8	NO DAMAGE	
205	-115	1	0.00007	12.2	13.8	11.3	13.8	0.816	93.2	NO DAMAGE	
205	-165	1	0.00007	12.2	13.8	10.9	13.8	0.788	80.6	NO DAMAGE	
205	-180	1	0.00007	12.2	13.8	10.8	13.8	0.779	77.4	NO DAMAGE	
205	-195	1	0.00007	12.2	13.8	10.7	13.8	0.771	74.5	NO DAMAGE	
205	-210	1	0.00007	12.2	13.8	10.6	13.8	0.762	71.8	NO DAMAGE	
205	-220	1	0.00007	12.2	13.8	10.5	13.8	0.756	70.1	NO DAMAGE	
205	-235	1	0.00007	12.2	13.8	10.4	13.8	0.748	67.8	NO DAMAGE	
205	-245	1	0.00007	12.2	13.8	10.3	13.8	0.742	66.3	NO DAMAGE	
205	-285	2	0.00015	12.2	13.8	10.0	13.8	0.719	60.8	NO DAMAGE	
200	190	37	0.00276	12.2	13.8	13.7	13.8	0.994	2972.8	NO DAMAGE	
200	185	11	0.00082	12.2	13.8	13.7	13.8	0.991	1981.9	NO DAMAGE	
200	180	48	0.00358	12.2	13.8	13.6	13.8	0.988	1486.4	NO DAMAGE	
200	175	2	0.00015	12.2	13.8	13.6	13.8	0.986	1189.1	NO DAMAGE	
200	170	22	0.00164	12.2	13.8	13.6	13.8	0.983	990.9	NO DAMAGE	
200	165	3	0.00022	12.2	13.8	13.5	13.8	0.980	849.4	NO DAMAGE	
200	160	10	0.00075	12.2	13.8	13.5	13.8	0.977	743.2	NO DAMAGE	
200	155	2	0.00015	12.2	13.8	13.5	13.8	0.974	660.6	NO DAMAGE	
200	150	3	0.00022	12.2	13.8	13.4	13.8	0.971	594.6	NO DAMAGE	
200	140	4	0.00030	12.2	13.8	13.3	13.8	0.965	495.5	NO DAMAGE	
200	135	2	0.00015	12.2	13.8	13.3	13.8	0.963	457.4	NO DAMAGE	
200	110	1	0.00007	12.2	13.8	13.1	13.8	0.948	330.3	NO DAMAGE	
200	100	2	0.00015	12.2	13.8	13.0	13.8	0.942	297.3	NO DAMAGE	
200	60	1	0.00007	12.2	13.8	12.7	13.8	0.919	212.3	NO DAMAGE	
200	30	1	0.00007	12.2	13.8	12.5	13.8	0.902	174.9	NO DAMAGE	
200	20	2	0.00015	12.2	13.8	12.4	13.8	0.896	165.2	NO DAMAGE	
200	0	1	0.00007	12.2	13.8	12.2	13.8	0.885	148.6	NO DAMAGE	
200	-80	2	0.00015	12.2	13.8	11.6	13.8	0.839	106.2	NO DAMAGE	
200	-100	1	0.00007	12.2	13.8	11.4	13.8	0.827	99.1	NO DAMAGE	
200	-110	1	0.00007	12.2	13.8	11.3	13.8	0.822	95.9	NO DAMAGE	
200	-130	2	0.00015	12.2	13.8	11.2	13.8	0.810	90.1	NO DAMAGE	
200	-135	1	0.00007	12.2	13.8	11.1	13.8	0.807	88.7	NO DAMAGE	
200	-150	1	0.00007	12.2	13.8	11.0	13.8	0.799	84.9	NO DAMAGE	
200	-170	1	0.00007	12.2	13.8	10.9	13.8	0.787	80.3	NO DAMAGE	

cycles per mile 153.8
Yield stress 50 ksi

Max	Min	No.	α Pct	Static Stress	Dynamic Stress Max	Min	Max Adjusted	R Min/Max	Endurance Limit	to Failure N	α/N
200	-180	1	0.00007	12.2	13.8	10.8	13.8	0.781	78.2	NO DAMAGE	
200	-220	2	0.00015	12.2	13.8	10.5	13.8	0.758	70.8	NO DAMAGE	
200	-240	1	0.00007	12.2	13.8	10.3	13.8	0.747	67.6	NO DAMAGE	
200	-260	2	0.00015	12.2	13.8	10.2	13.8	0.735	64.6	NO DAMAGE	
200	-265	1	0.00007	12.2	13.8	10.1	13.8	0.733	63.9	NO DAMAGE	
195	185	174	0.01297	12.2	13.8	13.7	13.8	0.994	2964.3	NO DAMAGE	
195	180	10	0.00075	12.2	13.8	13.6	13.8	0.991	1976.2	NO DAMAGE	
195	175	103	0.00768	12.2	13.8	13.6	13.8	0.988	1482.1	NO DAMAGE	
195	170	6	0.00045	12.2	13.8	13.6	13.8	0.986	1185.7	NO DAMAGE	
195	165	30	0.00224	12.2	13.8	13.5	13.8	0.983	988.1	NO DAMAGE	
195	160	5	0.00037	12.2	13.8	13.5	13.8	0.980	846.9	NO DAMAGE	
195	155	21	0.00157	12.2	13.8	13.5	13.8	0.977	741.1	NO DAMAGE	
195	150	2	0.00015	12.2	13.8	13.4	13.8	0.974	658.7	NO DAMAGE	
195	145	4	0.00030	12.2	13.8	13.4	13.8	0.971	592.9	NO DAMAGE	
195	140	3	0.00022	12.2	13.8	13.3	13.8	0.968	539.0	NO DAMAGE	
195	135	3	0.00022	12.2	13.8	13.3	13.8	0.965	494.0	NO DAMAGE	
195	125	1	0.00007	12.2	13.8	13.2	13.8	0.960	423.5	NO DAMAGE	
195	115	2	0.00015	12.2	13.8	13.1	13.8	0.954	370.5	NO DAMAGE	
195	95	1	0.00007	12.2	13.8	13.0	13.8	0.942	296.4	NO DAMAGE	
195	85	2	0.00015	12.2	13.8	12.9	13.8	0.937	269.5	NO DAMAGE	
195	75	1	0.00007	12.2	13.8	12.8	13.8	0.931	247.0	NO DAMAGE	
195	55	1	0.00007	12.2	13.8	12.7	13.8	0.919	211.7	NO DAMAGE	
195	45	2	0.00015	12.2	13.8	12.6	13.8	0.913	197.6	NO DAMAGE	
195	35	1	0.00007	12.2	13.8	12.5	13.8	0.908	185.3	NO DAMAGE	
195	5	1	0.00007	12.2	13.8	12.3	13.8	0.890	156.0	NO DAMAGE	
195	-75	1	0.00007	12.2	13.8	11.6	13.8	0.844	109.8	NO DAMAGE	
195	-105	1	0.00007	12.2	13.8	11.4	13.8	0.827	98.8	NO DAMAGE	
195	-125	1	0.00007	12.2	13.8	11.2	13.8	0.815	92.6	NO DAMAGE	
195	-135	1	0.00007	12.2	13.8	11.1	13.8	0.810	89.8	NO DAMAGE	
195	-145	1	0.00007	12.2	13.8	11.1	13.8	0.804	87.2	NO DAMAGE	
195	-155	2	0.00015	12.2	13.8	11.0	13.8	0.798	84.7	NO DAMAGE	
195	-165	1	0.00007	12.2	13.8	10.9	13.8	0.792	82.3	NO DAMAGE	
195	-195	1	0.00007	12.2	13.8	10.7	13.8	0.775	76.0	NO DAMAGE	
195	-235	1	0.00007	12.2	13.8	10.4	13.8	0.752	68.9	NO DAMAGE	
195	-245	2	0.00015	12.2	13.8	10.3	13.8	0.746	67.4	NO DAMAGE	
195	-255	2	0.00015	12.2	13.8	10.2	13.8	0.740	65.9	NO DAMAGE	
195	-265	1	0.00007	12.2	13.8	10.1	13.8	0.735	64.4	NO DAMAGE	
195	-275	1	0.00007	12.2	13.8	10.0	13.8	0.729	63.1	NO DAMAGE	
195	-595	1	0.00007	12.2	13.8	7.5	13.8	0.544	37.5	63442844	1.58E-10
190	180	141	0.01051	12.2	13.7	13.6	13.7	0.994	2955.7	NO DAMAGE	
190	175	31	0.00231	12.2	13.7	13.6	13.7	0.991	1970.5	NO DAMAGE	
190	170	117	0.00872	12.2	13.7	13.6	13.7	0.988	1477.9	NO DAMAGE	
190	165	17	0.00127	12.2	13.7	13.5	13.7	0.986	1182.3	NO DAMAGE	
190	160	45	0.00335	12.2	13.7	13.5	13.7	0.983	985.2	NO DAMAGE	
190	155	4	0.00030	12.2	13.7	13.5	13.7	0.980	844.5	NO DAMAGE	
190	150	8	0.00060	12.2	13.7	13.4	13.7	0.977	738.9	NO DAMAGE	
190	145	1	0.00007	12.2	13.7	13.4	13.7	0.974	656.8	NO DAMAGE	
190	140	5	0.00037	12.2	13.7	13.3	13.7	0.971	591.1	NO DAMAGE	
190	120	2	0.00015	12.2	13.7	13.2	13.7	0.960	422.2	NO DAMAGE	
190	115	1	0.00007	12.2	13.7	13.1	13.7	0.957	394.1	NO DAMAGE	
190	110	3	0.00022	12.2	13.7	13.1	13.7	0.954	369.5	NO DAMAGE	
190	100	2	0.00015	12.2	13.7	13.0	13.7	0.948	328.4	NO DAMAGE	
190	80	1	0.00007	12.2	13.7	12.9	13.7	0.936	268.7	NO DAMAGE	
190	75	1	0.00007	12.2	13.7	12.8	13.7	0.933	257.0	NO DAMAGE	
190	70	1	0.00007	12.2	13.7	12.8	13.7	0.931	246.3	NO DAMAGE	
190	50	2	0.00015	12.2	13.7	12.6	13.7	0.919	211.1	NO DAMAGE	
190	40	1	0.00007	12.2	13.7	12.5	13.7	0.913	197.0	NO DAMAGE	
190	30	2	0.00015	12.2	13.7	12.5	13.7	0.907	184.7	NO DAMAGE	
190	25	1	0.00007	12.2	13.7	12.4	13.7	0.905	179.1	NO DAMAGE	
190	10	1	0.00007	12.2	13.7	12.3	13.7	0.896	164.2	NO DAMAGE	
190	-10	1	0.00007	12.2	13.7	12.1	13.7	0.884	147.8	NO DAMAGE	
190	-20	1	0.00007	12.2	13.7	12.1	13.7	0.879	140.7	NO DAMAGE	
190	-45	1	0.00007	12.2	13.7	11.9	13.7	0.864	125.8	NO DAMAGE	
190	-50	1	0.00007	12.2	13.7	11.8	13.7	0.861	123.2	NO DAMAGE	
190	-90	1	0.00007	12.2	13.7	11.5	13.7	0.838	105.6	NO DAMAGE	
190	-100	3	0.00022	12.2	13.7	11.4	13.7	0.832	101.9	NO DAMAGE	
190	-130	2	0.00015	12.2	13.7	11.2	13.7	0.815	92.4	NO DAMAGE	
190	-165	1	0.00007	12.2	13.7	10.9	13.7	0.795	83.3	NO DAMAGE	
190	-190	3	0.00022	12.2	13.7	10.7	13.7	0.780	77.8	NO DAMAGE	
190	-195	1	0.00007	12.2	13.7	10.7	13.7	0.777	76.8	NO DAMAGE	
185	175	578	0.04309	12.2	13.7	13.6	13.7	0.994	2947.2	NO DAMAGE	
185	170	102	0.00760	12.2	13.7	13.6	13.7	0.991	1964.8	NO DAMAGE	
185	165	566	0.04220	12.2	13.7	13.5	13.7	0.988	1473.6	NO DAMAGE	
185	160	5	0.00037	12.2	13.7	13.5	13.7	0.985	1178.9	NO DAMAGE	
185	155	142	0.01059	12.2	13.7	13.5	13.7	0.983	982.4	NO DAMAGE	
185	150	4	0.00030	12.2	13.7	13.4	13.7	0.980	842.0	NO DAMAGE	
185	145	38	0.00283	12.2	13.7	13.4	13.7	0.977	736.8	NO DAMAGE	
185	140	1	0.00007	12.2	13.7	13.3	13.7	0.974	654.9	NO DAMAGE	
185	135	9	0.00067	12.2	13.7	13.3	13.7	0.971	589.4	NO DAMAGE	
185	130	1	0.00007	12.2	13.7	13.3	13.7	0.968	535.8	NO DAMAGE	
185	125	1	0.00007	12.2	13.7	13.2	13.7	0.965	491.2	NO DAMAGE	
185	120	1	0.00007	12.2	13.7	13.2	13.7	0.962	453.4	NO DAMAGE	
185	115	4	0.00030	12.2	13.7	13.1	13.7	0.959	421.0	NO DAMAGE	
185	105	5	0.00037	12.2	13.7	13.1	13.7	0.954	368.4	NO DAMAGE	
185	95	1	0.00007	12.2	13.7	13.0	13.7	0.948	327.5	NO DAMAGE	
185	85	1	0.00007	12.2	13.7	12.9	13.7	0.942	294.7	NO DAMAGE	
185	80	1	0.00007	12.2	13.7	12.9	13.7	0.939	280.7	NO DAMAGE	
185	75	1	0.00007	12.2	13.7	12.8	13.7	0.936	267.9	NO DAMAGE	

cycles per mile 153.8
Yield stress 50 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	65	1	0.00007	12.2	13.7	12.7	13.7	0.930	245.6	NO DAMAGE	
185	60	1	0.00007	12.2	13.7	12.7	13.7	0.927	235.8	NO DAMAGE	
185	55	2	0.00015	12.2	13.7	12.7	13.7	0.925	226.7	NO DAMAGE	
185	35	2	0.00015	12.2	13.7	12.5	13.7	0.913	196.5	NO DAMAGE	
185	25	3	0.00022	12.2	13.7	12.4	13.7	0.907	184.2	NO DAMAGE	
185	20	1	0.00007	12.2	13.7	12.4	13.7	0.904	178.6	NO DAMAGE	
185	15	2	0.00015	12.2	13.7	12.3	13.7	0.901	173.4	NO DAMAGE	
185	5	3	0.00022	12.2	13.7	12.3	13.7	0.896	163.7	NO DAMAGE	
185	-5	1	0.00007	12.2	13.7	12.2	13.7	0.890	155.1	NO DAMAGE	
185	-15	1	0.00007	12.2	13.7	12.1	13.7	0.884	147.4	NO DAMAGE	
185	-65	1	0.00007	12.2	13.7	11.7	13.7	0.855	117.9	NO DAMAGE	
185	-95	1	0.00007	12.2	13.7	11.5	13.7	0.838	105.3	NO DAMAGE	
185	-100	1	0.00007	12.2	13.7	11.4	13.7	0.835	103.4	NO DAMAGE	
185	-105	1	0.00007	12.2	13.7	11.4	13.7	0.832	101.6	NO DAMAGE	
185	-115	1	0.00007	12.2	13.7	11.3	13.7	0.826	98.2	NO DAMAGE	
185	-120	1	0.00007	12.2	13.7	11.3	13.7	0.823	96.6	NO DAMAGE	
185	-125	3	0.00022	12.2	13.7	11.2	13.7	0.820	95.1	NO DAMAGE	
185	-145	1	0.00007	12.2	13.7	11.1	13.7	0.809	89.3	NO DAMAGE	
185	-155	2	0.00015	12.2	13.7	11.0	13.7	0.803	86.7	NO DAMAGE	
185	-160	1	0.00007	12.2	13.7	10.9	13.7	0.800	85.4	NO DAMAGE	
185	-165	5	0.00037	12.2	13.7	10.9	13.7	0.797	84.2	NO DAMAGE	
185	-170	1	0.00007	12.2	13.7	10.9	13.7	0.794	83.0	NO DAMAGE	
185	-175	2	0.00015	12.2	13.7	10.8	13.7	0.791	81.9	NO DAMAGE	
185	-180	1	0.00007	12.2	13.7	10.8	13.7	0.788	80.7	NO DAMAGE	
185	-190	1	0.00007	12.2	13.7	10.7	13.7	0.782	78.6	NO DAMAGE	
185	-195	2	0.00015	12.2	13.7	10.7	13.7	0.780	77.6	NO DAMAGE	
185	-200	2	0.00015	12.2	13.7	10.6	13.7	0.777	76.5	NO DAMAGE	
185	-205	1	0.00007	12.2	13.7	10.6	13.7	0.774	75.6	NO DAMAGE	
185	-215	2	0.00015	12.2	13.7	10.5	13.7	0.768	73.7	NO DAMAGE	
185	-235	2	0.00015	12.2	13.7	10.4	13.7	0.756	70.2	NO DAMAGE	
185	-245	3	0.00022	12.2	13.7	10.3	13.7	0.751	68.5	NO DAMAGE	
185	-275	1	0.00007	12.2	13.7	10.0	13.7	0.733	64.1	NO DAMAGE	
185	-355	1	0.00007	12.2	13.7	9.4	13.7	0.687	54.6	NO DAMAGE	
180	170	389	0.02900	12.2	13.6	13.6	13.6	0.994	2938.6	NO DAMAGE	
180	165	84	0.00626	12.2	13.6	13.5	13.6	0.991	1959.1	NO DAMAGE	
180	160	216	0.01610	12.2	13.6	13.5	13.6	0.988	1469.3	NO DAMAGE	
180	155	23	0.00171	12.2	13.6	13.5	13.6	0.985	1175.4	NO DAMAGE	
180	150	53	0.00395	12.2	13.6	13.4	13.6	0.983	979.5	NO DAMAGE	
180	145	4	0.00030	12.2	13.6	13.4	13.6	0.980	839.6	NO DAMAGE	
180	140	42	0.00313	12.2	13.6	13.3	13.6	0.977	734.7	NO DAMAGE	
180	135	7	0.00052	12.2	13.6	13.3	13.6	0.974	653.0	NO DAMAGE	
180	130	8	0.00060	12.2	13.6	13.3	13.6	0.971	587.7	NO DAMAGE	
180	125	2	0.00015	12.2	13.6	13.2	13.6	0.968	534.3	NO DAMAGE	
180	120	1	0.00007	12.2	13.6	13.2	13.6	0.965	489.8	NO DAMAGE	
180	110	3	0.00022	12.2	13.6	13.1	13.6	0.959	419.8	NO DAMAGE	
180	105	2	0.00015	12.2	13.6	13.1	13.6	0.956	391.8	NO DAMAGE	
180	95	1	0.00007	12.2	13.6	13.0	13.6	0.951	345.7	NO DAMAGE	
180	90	2	0.00015	12.2	13.6	12.9	13.6	0.948	326.5	NO DAMAGE	
180	80	5	0.00037	12.2	13.6	12.9	13.6	0.942	293.9	NO DAMAGE	
180	75	1	0.00007	12.2	13.6	12.8	13.6	0.939	279.9	NO DAMAGE	
180	60	2	0.00015	12.2	13.6	12.7	13.6	0.930	244.9	NO DAMAGE	
180	45	1	0.00007	12.2	13.6	12.6	13.6	0.921	217.7	NO DAMAGE	
180	40	1	0.00007	12.2	13.6	12.5	13.6	0.919	209.9	NO DAMAGE	
180	30	2	0.00015	12.2	13.6	12.5	13.6	0.913	195.9	NO DAMAGE	
180	20	1	0.00007	12.2	13.6	12.4	13.6	0.907	183.7	NO DAMAGE	
180	0	2	0.00015	12.2	13.6	12.2	13.6	0.895	163.3	NO DAMAGE	
180	-5	1	0.00007	12.2	13.6	12.2	13.6	0.892	158.8	NO DAMAGE	
180	-10	3	0.00022	12.2	13.6	12.1	13.6	0.889	154.7	NO DAMAGE	
180	-45	1	0.00007	12.2	13.6	11.9	13.6	0.869	130.6	NO DAMAGE	
180	-60	3	0.00022	12.2	13.6	11.7	13.6	0.860	122.4	NO DAMAGE	
180	-70	2	0.00015	12.2	13.6	11.7	13.6	0.855	117.5	NO DAMAGE	
180	-80	2	0.00015	12.2	13.6	11.6	13.6	0.849	113.0	NO DAMAGE	
180	-90	2	0.00015	12.2	13.6	11.5	13.6	0.843	108.8	NO DAMAGE	
180	-100	2	0.00015	12.2	13.6	11.4	13.6	0.837	105.0	NO DAMAGE	
180	-110	4	0.00030	12.2	13.6	11.3	13.6	0.831	101.3	NO DAMAGE	
180	-120	1	0.00007	12.2	13.6	11.3	13.6	0.825	98.0	NO DAMAGE	
180	-130	2	0.00015	12.2	13.6	11.2	13.6	0.820	94.8	NO DAMAGE	
180	-140	1	0.00007	12.2	13.6	11.1	13.6	0.814	91.8	NO DAMAGE	
180	-145	1	0.00007	12.2	13.6	11.1	13.6	0.811	90.4	NO DAMAGE	
180	-150	3	0.00022	12.2	13.6	11.0	13.6	0.808	89.0	NO DAMAGE	
180	-160	1	0.00007	12.2	13.6	10.9	13.6	0.802	86.4	NO DAMAGE	
180	-170	2	0.00015	12.2	13.6	10.9	13.6	0.796	84.0	NO DAMAGE	
180	-185	1	0.00007	12.2	13.6	10.8	13.6	0.788	80.5	NO DAMAGE	
180	-190	1	0.00007	12.2	13.6	10.7	13.6	0.785	79.4	NO DAMAGE	
180	-200	2	0.00015	12.2	13.6	10.6	13.6	0.779	77.3	NO DAMAGE	
180	-210	1	0.00007	12.2	13.6	10.6	13.6	0.773	75.3	NO DAMAGE	
180	-215	1	0.00007	12.2	13.6	10.5	13.6	0.770	74.4	NO DAMAGE	
180	-230	1	0.00007	12.2	13.6	10.4	13.6	0.761	71.7	NO DAMAGE	
180	-240	1	0.00007	12.2	13.6	10.3	13.6	0.756	70.0	NO DAMAGE	
175	165	835	0.06225	12.2	13.6	13.5	13.6	0.994	2930.1	NO DAMAGE	
175	160	85	0.00634	12.2	13.6	13.5	13.6	0.991	1953.4	NO DAMAGE	
175	155	529	0.03944	12.2	13.6	13.5	13.6	0.988	1465.0	NO DAMAGE	
175	150	20	0.00149	12.2	13.6	13.4	13.6	0.985	1172.0	NO DAMAGE	
175	145	231	0.01722	12.2	13.6	13.4	13.6	0.982	976.7	NO DAMAGE	
175	140	21	0.00157	12.2	13.6	13.3	13.6	0.980	837.2	NO DAMAGE	
175	135	40	0.00298	12.2	13.6	13.3	13.6	0.977	732.5	NO DAMAGE	
175	130	6	0.00045	12.2	13.6	13.3	13.6	0.974	651.1	NO DAMAGE	
175	125	8	0.00060	12.2	13.6	13.2	13.6	0.971	586.0	NO DAMAGE	

cycles per mile 153.8
Yield stress 50 ksi

					Dynamic					to	
			α	Static	Stress		Max	R	Endurance	Failure	
Max	Min	No.	Pct	Stress	Max	Min	Adjusted	Min/Max	Limit	N	α/N
175	120	2	0.00015	12.2	13.6	13.2	13.6	0.968	532.7	NO DAMAGE	
175	115	6	0.00045	12.2	13.6	13.1	13.6	0.965	488.3	NO DAMAGE	
175	105	3	0.00022	12.2	13.6	13.1	13.6	0.959	418.6	NO DAMAGE	
175	65	1	0.00007	12.2	13.6	12.7	13.6	0.936	266.4	NO DAMAGE	
175	45	1	0.00007	12.2	13.6	12.6	13.6	0.924	225.4	NO DAMAGE	
175	35	1	0.00007	12.2	13.6	12.5	13.6	0.918	209.3	NO DAMAGE	
175	25	1	0.00007	12.2	13.6	12.4	13.6	0.912	195.3	NO DAMAGE	
175	20	1	0.00007	12.2	13.6	12.4	13.6	0.910	189.0	NO DAMAGE	
175	15	2	0.00015	12.2	13.6	12.3	13.6	0.907	183.1	NO DAMAGE	
175	5	2	0.00015	12.2	13.6	12.3	13.6	0.901	172.4	NO DAMAGE	
175	0	2	0.00015	12.2	13.6	12.2	13.6	0.898	167.4	NO DAMAGE	
175	-15	1	0.00007	12.2	13.6	12.1	13.6	0.889	154.2	NO DAMAGE	
175	-35	1	0.00007	12.2	13.6	11.9	13.6	0.877	139.5	NO DAMAGE	
175	-55	1	0.00007	12.2	13.6	11.8	13.6	0.866	127.4	NO DAMAGE	
175	-65	1	0.00007	12.2	13.6	11.7	13.6	0.860	122.1	NO DAMAGE	
175	-75	1	0.00007	12.2	13.6	11.6	13.6	0.854	117.2	NO DAMAGE	
175	-80	1	0.00007	12.2	13.6	11.6	13.6	0.851	114.9	NO DAMAGE	
175	-85	1	0.00007	12.2	13.6	11.5	13.6	0.848	112.7	NO DAMAGE	
175	-95	3	0.00022	12.2	13.6	11.5	13.6	0.842	108.5	NO DAMAGE	
175	-105	1	0.00007	12.2	13.6	11.4	13.6	0.837	104.6	NO DAMAGE	
175	-115	1	0.00007	12.2	13.6	11.3	13.6	0.831	101.0	NO DAMAGE	
175	-125	1	0.00007	12.2	13.6	11.2	13.6	0.825	97.7	NO DAMAGE	
175	-135	1	0.00007	12.2	13.6	11.1	13.6	0.819	94.5	NO DAMAGE	
175	-145	3	0.00022	12.2	13.6	11.1	13.6	0.813	91.6	NO DAMAGE	
175	-155	1	0.00007	12.2	13.6	11.0	13.6	0.807	88.8	NO DAMAGE	
175	-165	3	0.00022	12.2	13.6	10.9	13.6	0.802	86.2	NO DAMAGE	
175	-185	1	0.00007	12.2	13.6	10.8	13.6	0.790	81.4	NO DAMAGE	
175	-195	3	0.00022	12.2	13.6	10.7	13.6	0.784	79.2	NO DAMAGE	
175	-215	2	0.00015	12.2	13.6	10.5	13.6	0.772	75.1	NO DAMAGE	
175	-225	1	0.00007	12.2	13.6	10.4	13.6	0.767	73.3	NO DAMAGE	
175	-235	1	0.00007	12.2	13.6	10.4	13.6	0.761	71.5	NO DAMAGE	
175	-245	1	0.00007	12.2	13.6	10.3	13.6	0.755	69.8	NO DAMAGE	
175	-255	1	0.00007	12.2	13.6	10.2	13.6	0.749	68.1	NO DAMAGE	
170	160	397	0.02960	12.2	13.6	13.5	13.6	0.994	2921.5	NO DAMAGE	
170	155	85	0.00634	12.2	13.6	13.5	13.6	0.991	1947.7	NO DAMAGE	
170	150	301	0.02244	12.2	13.6	13.4	13.6	0.988	1460.8	NO DAMAGE	
170	145	34	0.00253	12.2	13.6	13.4	13.6	0.985	1168.6	NO DAMAGE	
170	140	140	0.01044	12.2	13.6	13.3	13.6	0.982	973.8	NO DAMAGE	
170	135	10	0.00075	12.2	13.6	13.3	13.6	0.980	834.7	NO DAMAGE	
170	130	30	0.00224	12.2	13.6	13.3	13.6	0.977	730.4	NO DAMAGE	
170	125	4	0.00030	12.2	13.6	13.2	13.6	0.974	649.2	NO DAMAGE	
170	120	11	0.00082	12.2	13.6	13.2	13.6	0.971	584.3	NO DAMAGE	
170	115	2	0.00015	12.2	13.6	13.1	13.6	0.968	531.2	NO DAMAGE	
170	110	8	0.00060	12.2	13.6	13.1	13.6	0.965	486.9	NO DAMAGE	
170	100	7	0.00052	12.2	13.6	13.0	13.6	0.959	417.4	NO DAMAGE	
170	90	9	0.00067	12.2	13.6	12.9	13.6	0.953	365.2	NO DAMAGE	
170	80	7	0.00052	12.2	13.6	12.9	13.6	0.947	324.6	NO DAMAGE	
170	70	3	0.00022	12.2	13.6	12.8	13.6	0.941	292.2	NO DAMAGE	
170	65	1	0.00007	12.2	13.6	12.7	13.6	0.939	278.2	NO DAMAGE	
170	40	1	0.00007	12.2	13.6	12.5	13.6	0.924	224.7	NO DAMAGE	
170	30	3	0.00022	12.2	13.6	12.5	13.6	0.918	208.7	NO DAMAGE	
170	25	1	0.00007	12.2	13.6	12.4	13.6	0.915	201.5	NO DAMAGE	
170	20	3	0.00022	12.2	13.6	12.4	13.6	0.912	194.8	NO DAMAGE	
170	0	2	0.00015	12.2	13.6	12.2	13.6	0.900	171.9	NO DAMAGE	
170	-10	1	0.00007	12.2	13.6	12.1	13.6	0.895	162.3	NO DAMAGE	
170	-40	1	0.00007	12.2	13.6	11.9	13.6	0.877	139.1	NO DAMAGE	
170	-50	1	0.00007	12.2	13.6	11.8	13.6	0.871	132.8	NO DAMAGE	
170	-70	1	0.00007	12.2	13.6	11.7	13.6	0.860	121.7	NO DAMAGE	
170	-90	1	0.00007	12.2	13.6	11.5	13.6	0.848	112.4	NO DAMAGE	
170	-100	2	0.00015	12.2	13.6	11.4	13.6	0.842	108.2	NO DAMAGE	
170	-105	1	0.00007	12.2	13.6	11.4	13.6	0.839	106.2	NO DAMAGE	
170	-110	3	0.00022	12.2	13.6	11.3	13.6	0.836	104.3	NO DAMAGE	
170	-115	1	0.00007	12.2	13.6	11.3	13.6	0.833	102.5	NO DAMAGE	
170	-120	1	0.00007	12.2	13.6	11.3	13.6	0.830	100.7	NO DAMAGE	
170	-130	2	0.00015	12.2	13.6	11.2	13.6	0.824	97.4	NO DAMAGE	
170	-140	2	0.00015	12.2	13.6	11.1	13.6	0.819	94.2	NO DAMAGE	
170	-150	1	0.00007	12.2	13.6	11.0	13.6	0.813	91.3	NO DAMAGE	
170	-160	2	0.00015	12.2	13.6	10.9	13.6	0.807	88.5	NO DAMAGE	
170	-180	1	0.00007	12.2	13.6	10.8	13.6	0.795	83.5	NO DAMAGE	
170	-210	3	0.00022	12.2	13.6	10.6	13.6	0.778	76.9	NO DAMAGE	
170	-230	1	0.00007	12.2	13.6	10.4	13.6	0.766	73.0	NO DAMAGE	
165	155	845	0.06300	12.2	13.5	13.5	13.5	0.994	2913.0	NO DAMAGE	
165	150	95	0.00708	12.2	13.5	13.4	13.5	0.991	1942.0	NO DAMAGE	
165	145	957	0.07135	12.2	13.5	13.4	13.5	0.988	1456.5	NO DAMAGE	
165	140	52	0.00388	12.2	13.5	13.3	13.5	0.985	1165.2	NO DAMAGE	
165	135	293	0.02184	12.2	13.5	13.3	13.5	0.982	971.0	NO DAMAGE	
165	130	13	0.00097	12.2	13.5	13.3	13.5	0.979	832.3	NO DAMAGE	
165	125	39	0.00291	12.2	13.5	13.2	13.5	0.977	728.2	NO DAMAGE	
165	120	6	0.00045	12.2	13.5	13.2	13.5	0.974	647.3	NO DAMAGE	
165	115	12	0.00089	12.2	13.5	13.1	13.5	0.971	582.6	NO DAMAGE	
165	105	4	0.00030	12.2	13.5	13.1	13.5	0.965	485.5	NO DAMAGE	
165	95	1	0.00007	12.2	13.5	13.0	13.5	0.959	416.1	NO DAMAGE	
165	85	3	0.00022	12.2	13.5	12.9	13.5	0.953	364.1	NO DAMAGE	
165	70	1	0.00007	12.2	13.5	12.8	13.5	0.944	306.6	NO DAMAGE	
165	60	1	0.00007	12.2	13.5	12.7	13.5	0.938	277.4	NO DAMAGE	
165	55	1	0.00007	12.2	13.5	12.7	13.5	0.935	264.8	NO DAMAGE	
165	40	1	0.00007	12.2	13.5	12.5	13.5	0.927	233.0	NO DAMAGE	
165	35	2	0.00015	12.2	13.5	12.5	13.5	0.924	224.1	NO DAMAGE	

cycles per mile	153.8
Yield stress	50 ksi

					Dynamic					to	
			α	Static	Stress		Max	R	Endurance	Failure	
Max	Min	No.	Pct	Stress	Max	Min	Adjusted	Min/Max	Limit	N	α/N
165	25	3	0.00022	12.2	13.5	12.4	13.5	0.918	208.1	NO DAMAGE	
165	15	2	0.00015	12.2	13.5	12.3	13.5	0.912	194.2	NO DAMAGE	
165	-5	2	0.00015	12.2	13.5	12.2	13.5	0.900	171.4	NO DAMAGE	
165	-30	1	0.00007	12.2	13.5	12.0	13.5	0.886	149.4	NO DAMAGE	
165	-55	1	0.00007	12.2	13.5	11.8	13.5	0.871	132.4	NO DAMAGE	
165	-105	1	0.00007	12.2	13.5	11.4	13.5	0.842	107.9	NO DAMAGE	
165	-125	1	0.00007	12.2	13.5	11.2	13.5	0.830	100.4	NO DAMAGE	
165	-135	1	0.00007	12.2	13.5	11.1	13.5	0.824	97.1	NO DAMAGE	
165	-140	1	0.00007	12.2	13.5	11.1	13.5	0.821	95.5	NO DAMAGE	
165	-145	1	0.00007	12.2	13.5	11.1	13.5	0.818	94.0	NO DAMAGE	
165	-165	2	0.00015	12.2	13.5	10.9	13.5	0.806	88.3	NO DAMAGE	
165	-185	1	0.00007	12.2	13.5	10.8	13.5	0.795	83.2	NO DAMAGE	
165	-190	1	0.00007	12.2	13.5	10.7	13.5	0.792	82.1	NO DAMAGE	
165	-205	1	0.00007	12.2	13.5	10.6	13.5	0.783	78.7	NO DAMAGE	
165	-215	1	0.00007	12.2	13.5	10.5	13.5	0.777	76.7	NO DAMAGE	
165	-225	2	0.00015	12.2	13.5	10.4	13.5	0.771	74.7	NO DAMAGE	
165	-255	1	0.00007	12.2	13.5	10.2	13.5	0.753	69.4	NO DAMAGE	
165	-275	1	0.00007	12.2	13.5	10.0	13.5	0.742	66.2	NO DAMAGE	
160	150	611	0.04555	12.2	13.5	13.4	13.5	0.994	2904.4	NO DAMAGE	
160	145	158	0.01178	12.2	13.5	13.4	13.5	0.991	1936.3	NO DAMAGE	
160	140	378	0.02818	12.2	13.5	13.3	13.5	0.988	1452.2	NO DAMAGE	
160	135	41	0.00306	12.2	13.5	13.3	13.5	0.985	1161.8	NO DAMAGE	
160	130	113	0.00842	12.2	13.5	13.3	13.5	0.982	968.1	NO DAMAGE	
160	125	20	0.00149	12.2	13.5	13.2	13.5	0.979	829.8	NO DAMAGE	
160	120	53	0.00395	12.2	13.5	13.2	13.5	0.976	726.1	NO DAMAGE	
160	115	2	0.00015	12.2	13.5	13.1	13.5	0.974	645.4	NO DAMAGE	
160	110	24	0.00179	12.2	13.5	13.1	13.5	0.971	580.9	NO DAMAGE	
160	105	4	0.00030	12.2	13.5	13.1	13.5	0.968	528.1	NO DAMAGE	
160	100	12	0.00089	12.2	13.5	13.0	13.5	0.965	484.1	NO DAMAGE	
160	95	3	0.00022	12.2	13.5	13.0	13.5	0.962	446.8	NO DAMAGE	
160	90	10	0.00075	12.2	13.5	12.9	13.5	0.959	414.9	NO DAMAGE	
160	80	4	0.00030	12.2	13.5	12.9	13.5	0.953	363.1	NO DAMAGE	
160	75	1	0.00007	12.2	13.5	12.8	13.5	0.950	341.7	NO DAMAGE	
160	70	3	0.00022	12.2	13.5	12.8	13.5	0.947	322.7	NO DAMAGE	
160	60	4	0.00030	12.2	13.5	12.7	13.5	0.941	290.4	NO DAMAGE	
160	50	2	0.00015	12.2	13.5	12.6	13.5	0.935	264.0	NO DAMAGE	
160	45	1	0.00007	12.2	13.5	12.6	13.5	0.932	252.6	NO DAMAGE	
160	40	3	0.00022	12.2	13.5	12.5	13.5	0.929	242.0	NO DAMAGE	
160	30	5	0.00037	12.2	13.5	12.5	13.5	0.923	223.4	NO DAMAGE	
160	20	2	0.00015	12.2	13.5	12.4	13.5	0.918	207.5	NO DAMAGE	
160	10	2	0.00015	12.2	13.5	12.3	13.5	0.912	193.6	NO DAMAGE	
160	0	5	0.00037	12.2	13.5	12.2	13.5	0.906	181.5	NO DAMAGE	
160	-10	2	0.00015	12.2	13.5	12.1	13.5	0.900	170.8	NO DAMAGE	
160	-15	1	0.00007	12.2	13.5	12.1	13.5	0.897	166.0	NO DAMAGE	
160	-30	1	0.00007	12.2	13.5	12.0	13.5	0.888	152.9	NO DAMAGE	
160	-40	1	0.00007	12.2	13.5	11.9	13.5	0.882	145.2	NO DAMAGE	
160	-70	3	0.00022	12.2	13.5	11.7	13.5	0.865	126.3	NO DAMAGE	
160	-80	2	0.00015	12.2	13.5	11.6	13.5	0.859	121.0	NO DAMAGE	
160	-90	5	0.00037	12.2	13.5	11.5	13.5	0.853	116.2	NO DAMAGE	
160	-100	4	0.00030	12.2	13.5	11.4	13.5	0.847	111.7	NO DAMAGE	
160	-110	6	0.00045	12.2	13.5	11.3	13.5	0.841	107.6	NO DAMAGE	
160	-115	1	0.00007	12.2	13.5	11.3	13.5	0.838	105.6	NO DAMAGE	
160	-120	1	0.00007	12.2	13.5	11.3	13.5	0.835	103.7	NO DAMAGE	
160	-130	3	0.00022	12.2	13.5	11.2	13.5	0.829	100.2	NO DAMAGE	
160	-135	1	0.00007	12.2	13.5	11.1	13.5	0.826	98.5	NO DAMAGE	
160	-140	4	0.00030	12.2	13.5	11.1	13.5	0.823	96.8	NO DAMAGE	
160	-150	1	0.00007	12.2	13.5	11.0	13.5	0.817	93.7	NO DAMAGE	
160	-160	3	0.00022	12.2	13.5	10.9	13.5	0.812	90.8	NO DAMAGE	
160	-170	2	0.00015	12.2	13.5	10.9	13.5	0.806	88.0	NO DAMAGE	
160	-175	1	0.00007	12.2	13.5	10.8	13.5	0.803	86.7	NO DAMAGE	
160	-180	2	0.00015	12.2	13.5	10.8	13.5	0.800	85.4	NO DAMAGE	
160	-185	1	0.00007	12.2	13.5	10.8	13.5	0.797	84.2	NO DAMAGE	
160	-190	1	0.00007	12.2	13.5	10.7	13.5	0.794	83.0	NO DAMAGE	
155	145	1673	0.12473	12.2	13.5	13.4	13.5	0.994	2895.9	NO DAMAGE	
155	140	205	0.01528	12.2	13.5	13.3	13.5	0.991	1930.6	NO DAMAGE	
155	135	1264	0.09423	12.2	13.5	13.3	13.5	0.988	1447.9	NO DAMAGE	
155	130	69	0.00514	12.2	13.5	13.3	13.5	0.985	1158.3	NO DAMAGE	
155	125	323	0.02408	12.2	13.5	13.2	13.5	0.982	965.3	NO DAMAGE	
155	120	17	0.00127	12.2	13.5	13.2	13.5	0.979	827.4	NO DAMAGE	
155	115	108	0.00805	12.2	13.5	13.1	13.5	0.976	724.0	NO DAMAGE	
155	110	5	0.00037	12.2	13.5	13.1	13.5	0.973	643.5	NO DAMAGE	
155	105	15	0.00112	12.2	13.5	13.1	13.5	0.970	579.2	NO DAMAGE	
155	100	1	0.00007	12.2	13.5	13.0	13.5	0.968	526.5	NO DAMAGE	
155	95	15	0.00112	12.2	13.5	13.0	13.5	0.965	482.6	NO DAMAGE	
155	85	2	0.00015	12.2	13.5	12.9	13.5	0.959	413.7	NO DAMAGE	
155	80	1	0.00007	12.2	13.5	12.9	13.5	0.956	386.1	NO DAMAGE	
155	75	6	0.00045	12.2	13.5	12.8	13.5	0.953	362.0	NO DAMAGE	
155	65	3	0.00022	12.2	13.5	12.7	13.5	0.947	321.8	NO DAMAGE	
155	55	1	0.00007	12.2	13.5	12.7	13.5	0.941	289.6	NO DAMAGE	
155	50	2	0.00015	12.2	13.5	12.6	13.5	0.938	275.8	NO DAMAGE	
155	45	2	0.00015	12.2	13.5	12.6	13.5	0.935	263.3	NO DAMAGE	
155	35	2	0.00015	12.2	13.5	12.5	13.5	0.929	241.3	NO DAMAGE	
155	25	3	0.00022	12.2	13.5	12.4	13.5	0.923	222.8	NO DAMAGE	
155	15	2	0.00015	12.2	13.5	12.3	13.5	0.917	206.8	NO DAMAGE	
155	5	3	0.00022	12.2	13.5	12.3	13.5	0.911	193.1	NO DAMAGE	
155	0	3	0.00022	12.2	13.5	12.2	13.5	0.908	186.8	NO DAMAGE	
155	-5	1	0.00007	12.2	13.5	12.2	13.5	0.906	181.0	NO DAMAGE	
155	-15	1	0.00007	12.2	13.5	12.1	13.5	0.900	170.3	NO DAMAGE	

cycles per mile 153.8
Yield stress 50 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
155	-25	2	0.00015	12.2	13.5	12.0	13.5	0.894	160.9	NO DAMAGE	
155	-55	1	0.00007	12.2	13.5	11.8	13.5	0.876	137.9	NO DAMAGE	
155	-80	1	0.00007	12.2	13.5	11.6	13.5	0.861	123.2	NO DAMAGE	
155	-95	1	0.00007	12.2	13.5	11.5	13.5	0.852	115.8	NO DAMAGE	
155	-105	1	0.00007	12.2	13.5	11.4	13.5	0.846	111.4	NO DAMAGE	
155	-115	1	0.00007	12.2	13.5	11.3	13.5	0.841	107.3	NO DAMAGE	
155	-120	1	0.00007	12.2	13.5	11.3	13.5	0.838	105.3	NO DAMAGE	
155	-125	2	0.00015	12.2	13.5	11.2	13.5	0.835	103.4	NO DAMAGE	
155	-130	1	0.00007	12.2	13.5	11.2	13.5	0.832	101.6	NO DAMAGE	
155	-135	5	0.00037	12.2	13.5	11.1	13.5	0.829	99.9	NO DAMAGE	
155	-145	4	0.00030	12.2	13.5	11.1	13.5	0.823	96.5	NO DAMAGE	
155	-150	2	0.00015	12.2	13.5	11.0	13.5	0.820	94.9	NO DAMAGE	
155	-165	1	0.00007	12.2	13.5	10.9	13.5	0.811	90.5	NO DAMAGE	
155	-175	1	0.00007	12.2	13.5	10.8	13.5	0.805	87.8	NO DAMAGE	
155	-185	2	0.00015	12.2	13.5	10.8	13.5	0.799	85.2	NO DAMAGE	
155	-195	1	0.00007	12.2	13.5	10.7	13.5	0.793	82.7	NO DAMAGE	
155	-220	1	0.00007	12.2	13.5	10.5	13.5	0.779	77.2	NO DAMAGE	
155	-235	1	0.00007	12.2	13.5	10.4	13.5	0.770	74.3	NO DAMAGE	
150	140	773	0.05763	12.2	13.4	13.3	13.4	0.994	2887.3	NO DAMAGE	
150	135	220	0.01640	12.2	13.4	13.3	13.4	0.991	1924.9	NO DAMAGE	
150	130	550	0.04100	12.2	13.4	13.3	13.4	0.988	1443.7	NO DAMAGE	
150	125	117	0.00872	12.2	13.4	13.2	13.4	0.985	1154.9	NO DAMAGE	
150	120	210	0.01566	12.2	13.4	13.2	13.4	0.982	962.4	NO DAMAGE	
150	115	22	0.00164	12.2	13.4	13.1	13.4	0.979	824.9	NO DAMAGE	
150	110	108	0.00805	12.2	13.4	13.1	13.4	0.976	721.8	NO DAMAGE	
150	105	4	0.00030	12.2	13.4	13.1	13.4	0.973	641.6	NO DAMAGE	
150	100	48	0.00358	12.2	13.4	13.0	13.4	0.970	577.5	NO DAMAGE	
150	95	3	0.00022	12.2	13.4	13.0	13.4	0.967	525.0	NO DAMAGE	
150	90	21	0.00157	12.2	13.4	12.9	13.4	0.964	481.2	NO DAMAGE	
150	85	2	0.00015	12.2	13.4	12.9	13.4	0.962	444.2	NO DAMAGE	
150	80	7	0.00052	12.2	13.4	12.9	13.4	0.959	412.5	NO DAMAGE	
150	70	12	0.00089	12.2	13.4	12.8	13.4	0.953	360.9	NO DAMAGE	
150	65	1	0.00007	12.2	13.4	12.7	13.4	0.950	339.7	NO DAMAGE	
150	60	6	0.00045	12.2	13.4	12.7	13.4	0.947	320.8	NO DAMAGE	
150	50	6	0.00045	12.2	13.4	12.6	13.4	0.941	288.7	NO DAMAGE	
150	45	1	0.00007	12.2	13.4	12.6	13.4	0.938	275.0	NO DAMAGE	
150	40	2	0.00015	12.2	13.4	12.5	13.4	0.935	262.5	NO DAMAGE	
150	30	3	0.00022	12.2	13.4	12.5	13.4	0.929	240.6	NO DAMAGE	
150	20	6	0.00045	12.2	13.4	12.4	13.4	0.923	222.1	NO DAMAGE	
150	10	7	0.00052	12.2	13.4	12.3	13.4	0.917	206.2	NO DAMAGE	
150	5	1	0.00007	12.2	13.4	12.3	13.4	0.914	199.1	NO DAMAGE	
150	0	6	0.00045	12.2	13.4	12.2	13.4	0.911	192.5	NO DAMAGE	
150	-10	8	0.00060	12.2	13.4	12.1	13.4	0.905	180.5	NO DAMAGE	
150	-20	1	0.00007	12.2	13.4	12.1	13.4	0.899	169.8	NO DAMAGE	
150	-25	1	0.00007	12.2	13.4	12.0	13.4	0.896	165.0	NO DAMAGE	
150	-30	1	0.00007	12.2	13.4	12.0	13.4	0.893	160.4	NO DAMAGE	
150	-40	2	0.00015	12.2	13.4	11.9	13.4	0.887	152.0	NO DAMAGE	
150	-50	1	0.00007	12.2	13.4	11.8	13.4	0.882	144.4	NO DAMAGE	
150	-60	3	0.00022	12.2	13.4	11.7	13.4	0.876	137.5	NO DAMAGE	
150	-70	2	0.00015	12.2	13.4	11.7	13.4	0.870	131.2	NO DAMAGE	
150	-80	4	0.00030	12.2	13.4	11.6	13.4	0.864	125.5	NO DAMAGE	
150	-100	3	0.00022	12.2	13.4	11.4	13.4	0.852	115.5	NO DAMAGE	
150	-105	1	0.00007	12.2	13.4	11.4	13.4	0.849	113.2	NO DAMAGE	
150	-110	5	0.00037	12.2	13.4	11.3	13.4	0.846	111.1	NO DAMAGE	
150	-115	1	0.00007	12.2	13.4	11.3	13.4	0.843	109.0	NO DAMAGE	
150	-120	4	0.00030	12.2	13.4	11.3	13.4	0.840	106.9	NO DAMAGE	
150	-125	2	0.00015	12.2	13.4	11.2	13.4	0.837	105.0	NO DAMAGE	
150	-130	3	0.00022	12.2	13.4	11.2	13.4	0.834	103.1	NO DAMAGE	
150	-135	1	0.00007	12.2	13.4	11.1	13.4	0.831	101.3	NO DAMAGE	
150	-140	3	0.00022	12.2	13.4	11.1	13.4	0.828	99.6	NO DAMAGE	
150	-150	2	0.00015	12.2	13.4	11.0	13.4	0.822	96.2	NO DAMAGE	
150	-160	1	0.00007	12.2	13.4	10.9	13.4	0.816	93.1	NO DAMAGE	
150	-165	1	0.00007	12.2	13.4	10.9	13.4	0.813	91.7	NO DAMAGE	
150	-170	1	0.00007	12.2	13.4	10.9	13.4	0.810	90.2	NO DAMAGE	
150	-180	1	0.00007	12.2	13.4	10.8	13.4	0.805	87.5	NO DAMAGE	
150	-220	1	0.00007	12.2	13.4	10.5	13.4	0.781	78.0	NO DAMAGE	
150	-230	1	0.00007	12.2	13.4	10.4	13.4	0.775	76.0	NO DAMAGE	
145	135	2125	0.15842	12.2	13.4	13.3	13.4	0.994	2878.8	NO DAMAGE	
145	130	317	0.02363	12.2	13.4	13.3	13.4	0.991	1919.2	NO DAMAGE	
145	125	1702	0.12689	12.2	13.4	13.2	13.4	0.988	1439.4	NO DAMAGE	
145	120	76	0.00567	12.2	13.4	13.2	13.4	0.985	1151.5	NO DAMAGE	
145	115	343	0.02557	12.2	13.4	13.1	13.4	0.982	959.6	NO DAMAGE	
145	110	20	0.00149	12.2	13.4	13.1	13.4	0.979	822.5	NO DAMAGE	
145	105	62	0.00462	12.2	13.4	13.1	13.4	0.976	719.7	NO DAMAGE	
145	100	9	0.00067	12.2	13.4	13.0	13.4	0.973	639.7	NO DAMAGE	
145	95	17	0.00127	12.2	13.4	13.0	13.4	0.970	575.8	NO DAMAGE	
145	90	2	0.00015	12.2	13.4	12.9	13.4	0.967	523.4	NO DAMAGE	
145	85	10	0.00075	12.2	13.4	12.9	13.4	0.964	479.8	NO DAMAGE	
145	75	4	0.00030	12.2	13.4	12.8	13.4	0.958	411.3	NO DAMAGE	
145	70	1	0.00007	12.2	13.4	12.8	13.4	0.955	383.8	NO DAMAGE	
145	65	2	0.00015	12.2	13.4	12.7	13.4	0.952	359.8	NO DAMAGE	
145	55	6	0.00045	12.2	13.4	12.7	13.4	0.947	319.9	NO DAMAGE	
145	45	6	0.00045	12.2	13.4	12.6	13.4	0.941	287.9	NO DAMAGE	
145	35	3	0.00022	12.2	13.4	12.5	13.4	0.935	261.7	NO DAMAGE	
145	30	1	0.00007	12.2	13.4	12.5	13.4	0.932	250.3	NO DAMAGE	
145	25	3	0.00022	12.2	13.4	12.4	13.4	0.929	239.9	NO DAMAGE	
145	20	2	0.00015	12.2	13.4	12.4	13.4	0.926	230.3	NO DAMAGE	
145	15	4	0.00030	12.2	13.4	12.3	13.4	0.923	221.4	NO DAMAGE	

cycles per mile 153.8
Yield stress 50 ksi

			α	Static	Dynamic Stress		Max	R	Endurance	to Failure	
Max	Min	No.	Pct	Stress	Max	Min	Adjusted	Min/Max	Limit	N	α/N
145	10	1	0.00007	12.2	13.4	12.3	13.4	0.920	213.2	NO DAMAGE	
145	5	4	0.00030	12.2	13.4	12.3	13.4	0.917	205.6	NO DAMAGE	
145	0	1	0.00007	12.2	13.4	12.2	13.4	0.914	198.5	NO DAMAGE	
145	-5	3	0.00022	12.2	13.4	12.2	13.4	0.911	191.9	NO DAMAGE	
145	-35	2	0.00015	12.2	13.4	11.9	13.4	0.893	159.9	NO DAMAGE	
145	-75	1	0.00007	12.2	13.4	11.6	13.4	0.869	130.9	NO DAMAGE	
145	-85	1	0.00007	12.2	13.4	11.5	13.4	0.863	125.2	NO DAMAGE	
145	-95	3	0.00022	12.2	13.4	11.5	13.4	0.857	119.9	NO DAMAGE	
145	-100	1	0.00007	12.2	13.4	11.4	13.4	0.854	117.5	NO DAMAGE	
145	-105	1	0.00007	12.2	13.4	11.4	13.4	0.851	115.2	NO DAMAGE	
145	-115	3	0.00022	12.2	13.4	11.3	13.4	0.846	110.7	NO DAMAGE	
145	-135	3	0.00022	12.2	13.4	11.1	13.4	0.834	102.8	NO DAMAGE	
145	-145	3	0.00022	12.2	13.4	11.1	13.4	0.828	99.3	NO DAMAGE	
145	-155	1	0.00007	12.2	13.4	11.0	13.4	0.822	96.0	NO DAMAGE	
145	-165	3	0.00022	12.2	13.4	10.9	13.4	0.816	92.9	NO DAMAGE	
145	-185	1	0.00007	12.2	13.4	10.8	13.4	0.804	87.2	NO DAMAGE	
145	-195	2	0.00015	12.2	13.4	10.7	13.4	0.798	84.7	NO DAMAGE	
145	-215	2	0.00015	12.2	13.4	10.5	13.4	0.786	80.0	NO DAMAGE	
145	-265	1	0.00007	12.2	13.4	10.1	13.4	0.756	70.2	NO DAMAGE	
140	130	1518	0.11317	12.2	13.3	13.3	13.3	0.994	2870.2	NO DAMAGE	
140	125	298	0.02222	12.2	13.3	13.2	13.3	0.991	1913.5	NO DAMAGE	
140	120	667	0.04973	12.2	13.3	13.2	13.3	0.988	1435.1	NO DAMAGE	
140	115	88	0.00656	12.2	13.3	13.1	13.3	0.985	1148.1	NO DAMAGE	
140	110	316	0.02356	12.2	13.3	13.1	13.3	0.982	956.7	NO DAMAGE	
140	105	35	0.00261	12.2	13.3	13.1	13.3	0.979	820.1	NO DAMAGE	
140	100	185	0.01379	12.2	13.3	13.0	13.3	0.976	717.6	NO DAMAGE	
140	95	18	0.00134	12.2	13.3	13.0	13.3	0.973	637.8	NO DAMAGE	
140	90	67	0.00500	12.2	13.3	12.9	13.3	0.970	574.0	NO DAMAGE	
140	85	3	0.00022	12.2	13.3	12.9	13.3	0.967	521.9	NO DAMAGE	
140	80	41	0.00306	12.2	13.3	12.9	13.3	0.964	478.4	NO DAMAGE	
140	75	5	0.00037	12.2	13.3	12.8	13.3	0.961	441.6	NO DAMAGE	
140	70	30	0.00224	12.2	13.3	12.8	13.3	0.958	410.0	NO DAMAGE	
140	65	2	0.00015	12.2	13.3	12.7	13.3	0.955	382.7	NO DAMAGE	
140	60	13	0.00097	12.2	13.3	12.7	13.3	0.952	358.8	NO DAMAGE	
140	55	1	0.00007	12.2	13.3	12.7	13.3	0.949	337.7	NO DAMAGE	
140	50	5	0.00037	12.2	13.3	12.6	13.3	0.946	318.9	NO DAMAGE	
140	45	3	0.00022	12.2	13.3	12.6	13.3	0.943	302.1	NO DAMAGE	
140	40	12	0.00089	12.2	13.3	12.5	13.3	0.940	287.0	NO DAMAGE	
140	35	1	0.00007	12.2	13.3	12.5	13.3	0.937	273.4	NO DAMAGE	
140	30	7	0.00052	12.2	13.3	12.5	13.3	0.934	260.9	NO DAMAGE	
140	20	8	0.00060	12.2	13.3	12.4	13.3	0.929	239.2	NO DAMAGE	
140	10	7	0.00052	12.2	13.3	12.3	13.3	0.923	220.8	NO DAMAGE	
140	5	1	0.00007	12.2	13.3	12.3	13.3	0.920	212.6	NO DAMAGE	
140	0	10	0.00075	12.2	13.3	12.2	13.3	0.917	205.0	NO DAMAGE	
140	-5	1	0.00007	12.2	13.3	12.2	13.3	0.914	197.9	NO DAMAGE	
140	-10	9	0.00067	12.2	13.3	12.1	13.3	0.911	191.3	NO DAMAGE	
140	-20	3	0.00022	12.2	13.3	12.1	13.3	0.905	179.4	NO DAMAGE	
140	-25	1	0.00007	12.2	13.3	12.0	13.3	0.902	174.0	NO DAMAGE	
140	-30	2	0.00015	12.2	13.3	12.0	13.3	0.899	168.8	NO DAMAGE	
140	-40	3	0.00022	12.2	13.3	11.9	13.3	0.893	159.5	NO DAMAGE	
140	-50	3	0.00022	12.2	13.3	11.8	13.3	0.887	151.1	NO DAMAGE	
140	-60	2	0.00015	12.2	13.3	11.7	13.3	0.881	143.5	NO DAMAGE	
140	-70	3	0.00022	12.2	13.3	11.7	13.3	0.875	136.7	NO DAMAGE	
140	-80	5	0.00037	12.2	13.3	11.6	13.3	0.869	130.5	NO DAMAGE	
140	-90	5	0.00037	12.2	13.3	11.5	13.3	0.863	124.8	NO DAMAGE	
140	-95	1	0.00007	12.2	13.3	11.5	13.3	0.860	122.1	NO DAMAGE	
140	-100	9	0.00067	12.2	13.3	11.4	13.3	0.857	119.6	NO DAMAGE	
140	-110	4	0.00030	12.2	13.3	11.3	13.3	0.851	114.8	NO DAMAGE	
140	-115	1	0.00007	12.2	13.3	11.3	13.3	0.848	112.6	NO DAMAGE	
140	-120	7	0.00052	12.2	13.3	11.3	13.3	0.845	110.4	NO DAMAGE	
140	-130	2	0.00015	12.2	13.3	11.2	13.3	0.839	106.3	NO DAMAGE	
140	-140	5	0.00037	12.2	13.3	11.1	13.3	0.833	102.5	NO DAMAGE	
140	-145	2	0.00015	12.2	13.3	11.1	13.3	0.830	100.7	NO DAMAGE	
140	-150	2	0.00015	12.2	13.3	11.0	13.3	0.827	99.0	NO DAMAGE	
140	-155	1	0.00007	12.2	13.3	11.0	13.3	0.824	97.3	NO DAMAGE	
140	-160	1	0.00007	12.2	13.3	10.9	13.3	0.821	95.7	NO DAMAGE	
140	-170	2	0.00015	12.2	13.3	10.9	13.3	0.815	92.6	NO DAMAGE	
140	-190	1	0.00007	12.2	13.3	10.7	13.3	0.803	87.0	NO DAMAGE	
140	-200	1	0.00007	12.2	13.3	10.6	13.3	0.797	84.4	NO DAMAGE	
140	-210	1	0.00007	12.2	13.3	10.6	13.3	0.791	82.0	NO DAMAGE	
140	-260	1	0.00007	12.2	13.3	10.2	13.3	0.762	71.8	NO DAMAGE	
135	125	2305	0.17184	12.2	13.3	13.2	13.3	0.994	2861.7	NO DAMAGE	
135	120	236	0.01759	12.2	13.3	13.2	13.3	0.991	1907.8	NO DAMAGE	
135	115	1901	0.14172	12.2	13.3	13.1	13.3	0.988	1430.8	NO DAMAGE	
135	110	117	0.00872	12.2	13.3	13.1	13.3	0.985	1144.7	NO DAMAGE	
135	105	472	0.03519	12.2	13.3	13.1	13.3	0.982	953.9	NO DAMAGE	
135	100	55	0.00410	12.2	13.3	13.0	13.3	0.979	817.6	NO DAMAGE	
135	95	122	0.00910	12.2	13.3	13.0	13.3	0.976	715.4	NO DAMAGE	
135	90	11	0.00082	12.2	13.3	12.9	13.3	0.973	635.9	NO DAMAGE	
135	85	59	0.00440	12.2	13.3	12.9	13.3	0.970	572.3	NO DAMAGE	
135	80	6	0.00045	12.2	13.3	12.9	13.3	0.967	520.3	NO DAMAGE	
135	75	28	0.00209	12.2	13.3	12.8	13.3	0.964	476.9	NO DAMAGE	
135	70	2	0.00015	12.2	13.3	12.8	13.3	0.961	440.3	NO DAMAGE	
135	65	11	0.00082	12.2	13.3	12.7	13.3	0.958	408.8	NO DAMAGE	
135	60	1	0.00007	12.2	13.3	12.7	13.3	0.955	381.6	NO DAMAGE	
135	55	11	0.00082	12.2	13.3	12.7	13.3	0.952	357.7	NO DAMAGE	
135	50	2	0.00015	12.2	13.3	12.6	13.3	0.949	336.7	NO DAMAGE	
135	45	6	0.00045	12.2	13.3	12.6	13.3	0.946	318.0	NO DAMAGE	

cycles per mile 153.8
Yield stress 50 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	35	3	0.00022	12.2	13.3	12.5	13.3	0.940	286.2	NO DAMAGE	
135	30	1	0.00007	12.2	13.3	12.5	13.3	0.937	272.5	NO DAMAGE	
135	25	6	0.00045	12.2	13.3	12.4	13.3	0.934	260.2	NO DAMAGE	
135	20	1	0.00007	12.2	13.3	12.4	13.3	0.931	248.8	NO DAMAGE	
135	15	5	0.00037	12.2	13.3	12.3	13.3	0.928	238.5	NO DAMAGE	
135	5	11	0.00082	12.2	13.3	12.3	13.3	0.922	220.1	NO DAMAGE	
135	0	4	0.00030	12.2	13.3	12.2	13.3	0.919	212.0	NO DAMAGE	
135	-5	1	0.00007	12.2	13.3	12.2	13.3	0.916	204.4	NO DAMAGE	
135	-15	1	0.00007	12.2	13.3	12.1	13.3	0.910	190.8	NO DAMAGE	
135	-35	1	0.00007	12.2	13.3	11.9	13.3	0.898	168.3	NO DAMAGE	
135	-40	1	0.00007	12.2	13.3	11.9	13.3	0.895	163.5	NO DAMAGE	
135	-45	3	0.00022	12.2	13.3	11.9	13.3	0.892	159.0	NO DAMAGE	
135	-65	1	0.00007	12.2	13.3	11.7	13.3	0.880	143.1	NO DAMAGE	
135	-85	2	0.00015	12.2	13.3	11.5	13.3	0.869	130.1	NO DAMAGE	
135	-95	1	0.00007	12.2	13.3	11.5	13.3	0.863	124.4	NO DAMAGE	
135	-100	1	0.00007	12.2	13.3	11.4	13.3	0.860	121.8	NO DAMAGE	
135	-105	4	0.00030	12.2	13.3	11.4	13.3	0.857	119.2	NO DAMAGE	
135	-115	3	0.00022	12.2	13.3	11.3	13.3	0.851	114.5	NO DAMAGE	
135	-125	6	0.00045	12.2	13.3	11.2	13.3	0.845	110.1	NO DAMAGE	
135	-135	4	0.00030	12.2	13.3	11.1	13.3	0.839	106.0	NO DAMAGE	
135	-145	3	0.00022	12.2	13.3	11.1	13.3	0.833	102.2	NO DAMAGE	
135	-155	3	0.00022	12.2	13.3	11.0	13.3	0.827	98.7	NO DAMAGE	
135	-160	2	0.00015	12.2	13.3	10.9	13.3	0.824	97.0	NO DAMAGE	
135	-165	2	0.00015	12.2	13.3	10.9	13.3	0.821	95.4	NO DAMAGE	
135	-175	2	0.00015	12.2	13.3	10.8	13.3	0.815	92.3	NO DAMAGE	
135	-185	2	0.00015	12.2	13.3	10.8	13.3	0.809	89.4	NO DAMAGE	
135	-195	2	0.00015	12.2	13.3	10.7	13.3	0.803	86.7	NO DAMAGE	
135	-205	1	0.00007	12.2	13.3	10.6	13.3	0.797	84.2	NO DAMAGE	
135	-235	1	0.00007	12.2	13.3	10.4	13.3	0.779	77.3	NO DAMAGE	
130	120	1350	0.10065	12.2	13.3	13.2	13.3	0.994	2853.1	NO DAMAGE	
130	115	357	0.02662	12.2	13.3	13.1	13.3	0.991	1902.1	NO DAMAGE	
130	110	1062	0.07918	12.2	13.3	13.1	13.3	0.988	1426.6	NO DAMAGE	
130	105	197	0.01469	12.2	13.3	13.1	13.3	0.985	1141.2	NO DAMAGE	
130	100	540	0.04026	12.2	13.3	13.0	13.3	0.982	951.0	NO DAMAGE	
130	95	69	0.00514	12.2	13.3	13.0	13.3	0.979	815.2	NO DAMAGE	
130	90	301	0.02244	12.2	13.3	12.9	13.3	0.976	713.3	NO DAMAGE	
130	85	20	0.00149	12.2	13.3	12.9	13.3	0.973	634.0	NO DAMAGE	
130	80	166	0.01238	12.2	13.3	12.9	13.3	0.970	570.6	NO DAMAGE	
130	75	15	0.00112	12.2	13.3	12.8	13.3	0.967	518.7	NO DAMAGE	
130	70	66	0.00492	12.2	13.3	12.8	13.3	0.964	475.5	NO DAMAGE	
130	65	7	0.00052	12.2	13.3	12.7	13.3	0.961	438.9	NO DAMAGE	
130	60	35	0.00261	12.2	13.3	12.7	13.3	0.958	407.6	NO DAMAGE	
130	55	6	0.00045	12.2	13.3	12.7	13.3	0.955	380.4	NO DAMAGE	
130	50	34	0.00253	12.2	13.3	12.6	13.3	0.952	356.6	NO DAMAGE	
130	45	2	0.00015	12.2	13.3	12.6	13.3	0.949	335.7	NO DAMAGE	
130	40	12	0.00089	12.2	13.3	12.5	13.3	0.946	317.0	NO DAMAGE	
130	35	1	0.00007	12.2	13.3	12.5	13.3	0.943	300.3	NO DAMAGE	
130	30	6	0.00045	12.2	13.3	12.5	13.3	0.940	285.3	NO DAMAGE	
130	25	1	0.00007	12.2	13.3	12.4	13.3	0.937	271.7	NO DAMAGE	
130	20	10	0.00075	12.2	13.3	12.4	13.3	0.934	259.4	NO DAMAGE	
130	10	11	0.00082	12.2	13.3	12.3	13.3	0.928	237.8	NO DAMAGE	
130	0	11	0.00082	12.2	13.3	12.2	13.3	0.922	219.5	NO DAMAGE	
130	-5	2	0.00015	12.2	13.3	12.2	13.3	0.919	211.3	NO DAMAGE	
130	-10	8	0.00060	12.2	13.3	12.1	13.3	0.916	203.8	NO DAMAGE	
130	-20	1	0.00007	12.2	13.3	12.1	13.3	0.910	190.2	NO DAMAGE	
130	-30	5	0.00037	12.2	13.3	12.0	13.3	0.904	178.3	NO DAMAGE	
130	-35	1	0.00007	12.2	13.3	11.9	13.3	0.901	172.9	NO DAMAGE	
130	-40	2	0.00015	12.2	13.3	11.9	13.3	0.898	167.8	NO DAMAGE	
130	-50	2	0.00015	12.2	13.3	11.8	13.3	0.892	158.5	NO DAMAGE	
130	-60	8	0.00060	12.2	13.3	11.7	13.3	0.886	150.2	NO DAMAGE	
130	-70	5	0.00037	12.2	13.3	11.7	13.3	0.880	142.7	NO DAMAGE	
130	-80	4	0.00030	12.2	13.3	11.6	13.3	0.874	135.9	NO DAMAGE	
130	-90	6	0.00045	12.2	13.3	11.5	13.3	0.868	129.7	NO DAMAGE	
130	-100	4	0.00030	12.2	13.3	11.4	13.3	0.862	124.0	NO DAMAGE	
130	-110	5	0.00037	12.2	13.3	11.3	13.3	0.856	118.9	NO DAMAGE	
130	-120	2	0.00015	12.2	13.3	11.3	13.3	0.850	114.1	NO DAMAGE	
130	-130	2	0.00015	12.2	13.3	11.2	13.3	0.844	109.7	NO DAMAGE	
130	-140	1	0.00007	12.2	13.3	11.1	13.3	0.838	105.7	NO DAMAGE	
130	-150	1	0.00007	12.2	13.3	11.0	13.3	0.832	101.9	NO DAMAGE	
130	-160	3	0.00022	12.2	13.3	10.9	13.3	0.826	98.4	NO DAMAGE	
130	-170	1	0.00007	12.2	13.3	10.9	13.3	0.820	95.1	NO DAMAGE	
130	-205	1	0.00007	12.2	13.3	10.6	13.3	0.799	85.2	NO DAMAGE	
130	-215	1	0.00007	12.2	13.3	10.5	13.3	0.793	82.7	NO DAMAGE	
130	-220	1	0.00007	12.2	13.3	10.5	13.3	0.790	81.5	NO DAMAGE	
125	115	3294	0.24558	12.2	13.2	13.1	13.2	0.994	2844.6	NO DAMAGE	
125	110	660	0.04920	12.2	13.2	13.1	13.2	0.991	1896.4	NO DAMAGE	
125	105	2822	0.21039	12.2	13.2	13.1	13.2	0.988	1422.3	NO DAMAGE	
125	100	259	0.01931	12.2	13.2	13.0	13.2	0.985	1137.8	NO DAMAGE	
125	95	752	0.05606	12.2	13.2	13.0	13.2	0.982	948.2	NO DAMAGE	
125	90	87	0.00649	12.2	13.2	12.9	13.2	0.979	812.7	NO DAMAGE	
125	85	266	0.01983	12.2	13.2	12.9	13.2	0.976	711.1	NO DAMAGE	
125	80	34	0.00253	12.2	13.2	12.9	13.2	0.973	632.1	NO DAMAGE	
125	75	137	0.01021	12.2	13.2	12.8	13.2	0.970	568.9	NO DAMAGE	
125	70	14	0.00104	12.2	13.2	12.8	13.2	0.967	517.2	NO DAMAGE	
125	65	87	0.00649	12.2	13.2	12.7	13.2	0.964	474.1	NO DAMAGE	
125	60	9	0.00067	12.2	13.2	12.7	13.2	0.961	437.6	NO DAMAGE	
125	55	39	0.00291	12.2	13.2	12.7	13.2	0.958	406.4	NO DAMAGE	
125	50	2	0.00015	12.2	13.2	12.6	13.2	0.955	379.3	NO DAMAGE	

cycles per mile 153.8
Yield stress 50 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	45	22	0.00164	12.2	13.2	12.6	13.2	0.952	355.6	NO DAMAGE	
125	40	4	0.00030	12.2	13.2	12.5	13.2	0.949	334.7	NO DAMAGE	
125	35	8	0.00060	12.2	13.2	12.5	13.2	0.946	316.1	NO DAMAGE	
125	25	6	0.00045	12.2	13.2	12.4	13.2	0.940	284.5	NO DAMAGE	
125	15	8	0.00060	12.2	13.2	12.3	13.2	0.934	258.6	NO DAMAGE	
125	5	14	0.00104	12.2	13.2	12.3	13.2	0.928	237.0	NO DAMAGE	
125	0	4	0.00030	12.2	13.2	12.2	13.2	0.925	227.6	NO DAMAGE	
125	-5	5	0.00037	12.2	13.2	12.2	13.2	0.922	218.8	NO DAMAGE	
125	-15	1	0.00007	12.2	13.2	12.1	13.2	0.916	203.2	NO DAMAGE	
125	-20	1	0.00007	12.2	13.2	12.1	13.2	0.913	196.2	NO DAMAGE	
125	-25	1	0.00007	12.2	13.2	12.0	13.2	0.910	189.6	NO DAMAGE	
125	-35	1	0.00007	12.2	13.2	11.9	13.2	0.904	177.8	NO DAMAGE	
125	-55	3	0.00022	12.2	13.2	11.8	13.2	0.892	158.0	NO DAMAGE	
125	-65	1	0.00007	12.2	13.2	11.7	13.2	0.886	149.7	NO DAMAGE	
125	-75	2	0.00015	12.2	13.2	11.6	13.2	0.880	142.2	NO DAMAGE	
125	-85	3	0.00022	12.2	13.2	11.5	13.2	0.874	135.5	NO DAMAGE	
125	-95	7	0.00052	12.2	13.2	11.5	13.2	0.868	129.3	NO DAMAGE	
125	-100	3	0.00022	12.2	13.2	11.4	13.2	0.865	126.4	NO DAMAGE	
125	-105	3	0.00022	12.2	13.2	11.4	13.2	0.862	123.7	NO DAMAGE	
125	-115	3	0.00022	12.2	13.2	11.3	13.2	0.856	118.5	NO DAMAGE	
125	-120	2	0.00015	12.2	13.2	11.3	13.2	0.853	116.1	NO DAMAGE	
125	-125	3	0.00022	12.2	13.2	11.2	13.2	0.850	113.8	NO DAMAGE	
125	-135	1	0.00007	12.2	13.2	11.1	13.2	0.844	109.4	NO DAMAGE	
125	-145	1	0.00007	12.2	13.2	11.1	13.2	0.838	105.4	NO DAMAGE	
125	-155	1	0.00007	12.2	13.2	11.0	13.2	0.832	101.6	NO DAMAGE	
125	-165	2	0.00015	12.2	13.2	10.9	13.2	0.826	98.1	NO DAMAGE	
125	-190	1	0.00007	12.2	13.2	10.7	13.2	0.811	90.3	NO DAMAGE	
125	-205	3	0.00022	12.2	13.2	10.6	13.2	0.802	86.2	NO DAMAGE	
125	-225	2	0.00015	12.2	13.2	10.4	13.2	0.790	81.3	NO DAMAGE	
120	110	2455	0.18303	12.2	13.2	13.1	13.2	0.994	2836.0	NO DAMAGE	
120	105	678	0.05055	12.2	13.2	13.1	13.2	0.991	1890.7	NO DAMAGE	
120	100	1649	0.12294	12.2	13.2	13.0	13.2	0.988	1418.0	NO DAMAGE	
120	95	334	0.02490	12.2	13.2	13.0	13.2	0.985	1134.4	NO DAMAGE	
120	90	851	0.06344	12.2	13.2	12.9	13.2	0.982	945.3	NO DAMAGE	
120	85	101	0.00753	12.2	13.2	12.9	13.2	0.979	810.3	NO DAMAGE	
120	80	398	0.02967	12.2	13.2	12.9	13.2	0.976	709.0	NO DAMAGE	
120	75	38	0.00283	12.2	13.2	12.8	13.2	0.973	630.2	NO DAMAGE	
120	70	202	0.01506	12.2	13.2	12.8	13.2	0.970	567.2	NO DAMAGE	
120	65	15	0.00112	12.2	13.2	12.7	13.2	0.967	515.6	NO DAMAGE	
120	60	115	0.00857	12.2	13.2	12.7	13.2	0.964	472.7	NO DAMAGE	
120	55	12	0.00089	12.2	13.2	12.7	13.2	0.961	436.3	NO DAMAGE	
120	50	63	0.00470	12.2	13.2	12.6	13.2	0.958	405.1	NO DAMAGE	
120	45	2	0.00015	12.2	13.2	12.6	13.2	0.955	378.1	NO DAMAGE	
120	40	37	0.00276	12.2	13.2	12.5	13.2	0.952	354.5	NO DAMAGE	
120	35	3	0.00022	12.2	13.2	12.5	13.2	0.949	333.6	NO DAMAGE	
120	30	27	0.00201	12.2	13.2	12.5	13.2	0.946	315.1	NO DAMAGE	
120	25	3	0.00022	12.2	13.2	12.4	13.2	0.943	298.5	NO DAMAGE	
120	20	15	0.00112	12.2	13.2	12.4	13.2	0.940	283.6	NO DAMAGE	
120	15	1	0.00007	12.2	13.2	12.3	13.2	0.937	270.1	NO DAMAGE	
120	10	13	0.00097	12.2	13.2	12.3	13.2	0.934	257.8	NO DAMAGE	
120	5	5	0.00037	12.2	13.2	12.3	13.2	0.931	246.6	NO DAMAGE	
120	0	23	0.00171	12.2	13.2	12.2	13.2	0.928	236.3	NO DAMAGE	
120	-5	4	0.00030	12.2	13.2	12.2	13.2	0.925	226.9	NO DAMAGE	
120	-10	19	0.00142	12.2	13.2	12.1	13.2	0.922	218.2	NO DAMAGE	
120	-20	3	0.00022	12.2	13.2	12.1	13.2	0.916	202.6	NO DAMAGE	
120	-30	7	0.00052	12.2	13.2	12.0	13.2	0.910	189.1	NO DAMAGE	
120	-40	1	0.00007	12.2	13.2	11.9	13.2	0.904	177.3	NO DAMAGE	
120	-45	1	0.00007	12.2	13.2	11.9	13.2	0.901	171.9	NO DAMAGE	
120	-50	6	0.00045	12.2	13.2	11.8	13.2	0.897	166.8	NO DAMAGE	
120	-55	1	0.00007	12.2	13.2	11.8	13.2	0.894	162.1	NO DAMAGE	
120	-60	3	0.00022	12.2	13.2	11.7	13.2	0.891	157.6	NO DAMAGE	
120	-70	9	0.00067	12.2	13.2	11.7	13.2	0.885	149.3	NO DAMAGE	
120	-80	5	0.00037	12.2	13.2	11.6	13.2	0.879	141.8	NO DAMAGE	
120	-85	1	0.00007	12.2	13.2	11.5	13.2	0.876	138.3	NO DAMAGE	
120	-90	8	0.00060	12.2	13.2	11.5	13.2	0.873	135.0	NO DAMAGE	
120	-100	6	0.00045	12.2	13.2	11.4	13.2	0.867	128.9	NO DAMAGE	
120	-110	7	0.00052	12.2	13.2	11.3	13.2	0.861	123.3	NO DAMAGE	
120	-115	1	0.00007	12.2	13.2	11.3	13.2	0.858	120.7	NO DAMAGE	
120	-120	3	0.00022	12.2	13.2	11.3	13.2	0.855	118.2	NO DAMAGE	
120	-130	2	0.00015	12.2	13.2	11.2	13.2	0.849	113.4	NO DAMAGE	
120	-135	1	0.00007	12.2	13.2	11.1	13.2	0.846	111.2	NO DAMAGE	
120	-140	5	0.00037	12.2	13.2	11.1	13.2	0.843	109.1	NO DAMAGE	
120	-145	1	0.00007	12.2	13.2	11.1	13.2	0.840	107.0	NO DAMAGE	
120	-150	2	0.00015	12.2	13.2	11.0	13.2	0.837	105.0	NO DAMAGE	
120	-155	1	0.00007	12.2	13.2	11.0	13.2	0.834	103.1	NO DAMAGE	
120	-160	2	0.00015	12.2	13.2	10.9	13.2	0.831	101.3	NO DAMAGE	
120	-180	2	0.00015	12.2	13.2	10.8	13.2	0.819	94.5	NO DAMAGE	
120	-235	1	0.00007	12.2	13.2	10.4	13.2	0.786	79.9	NO DAMAGE	
115	105	4703	0.35062	12.2	13.1	13.1	13.1	0.994	2827.5	NO DAMAGE	
115	100	908	0.06769	12.2	13.1	13.0	13.1	0.991	1885.0	NO DAMAGE	
115	95	3914	0.29180	12.2	13.1	13.0	13.1	0.988	1413.7	NO DAMAGE	
115	90	307	0.02289	12.2	13.1	12.9	13.1	0.985	1131.0	NO DAMAGE	
115	85	2643	0.19704	12.2	13.1	12.9	13.1	0.982	942.5	NO DAMAGE	
115	80	181	0.01349	12.2	13.1	12.9	13.1	0.979	807.8	NO DAMAGE	
115	75	676	0.05040	12.2	13.1	12.8	13.1	0.976	706.9	NO DAMAGE	
115	70	90	0.00671	12.2	13.1	12.8	13.1	0.973	628.3	NO DAMAGE	
115	65	334	0.02490	12.2	13.1	12.7	13.1	0.970	565.5	NO DAMAGE	
115	60	32	0.00239	12.2	13.1	12.7	13.1	0.967	514.1	NO DAMAGE	

cycles per mile	153.8
Yield stress	50 ksi

			α	Static	Dynamic Stress		Max	R	Endurance	to Failure	
Max	Min	No.	Pct	Stress	Max	Min	Adjusted	Min/Max	Limit	N	α/N
115	55	129	0.00962	12.2	13.1	12.7	13.1	0.964	471.2	NO DAMAGE	
115	50	13	0.00097	12.2	13.1	12.6	13.1	0.961	435.0	NO DAMAGE	
115	45	39	0.00291	12.2	13.1	12.6	13.1	0.958	403.9	NO DAMAGE	
115	40	5	0.00037	12.2	13.1	12.5	13.1	0.955	377.0	NO DAMAGE	
115	35	21	0.00157	12.2	13.1	12.5	13.1	0.952	353.4	NO DAMAGE	
115	30	1	0.00007	12.2	13.1	12.5	13.1	0.949	332.6	NO DAMAGE	
115	25	10	0.00075	12.2	13.1	12.4	13.1	0.946	314.2	NO DAMAGE	
115	20	2	0.00015	12.2	13.1	12.4	13.1	0.943	297.6	NO DAMAGE	
115	15	11	0.00082	12.2	13.1	12.3	13.1	0.940	282.7	NO DAMAGE	
115	5	18	0.00134	12.2	13.1	12.3	13.1	0.933	257.0	NO DAMAGE	
115	0	4	0.00030	12.2	13.1	12.2	13.1	0.930	245.9	NO DAMAGE	
115	-5	5	0.00037	12.2	13.1	12.2	13.1	0.927	235.6	NO DAMAGE	
115	-15	2	0.00015	12.2	13.1	12.1	13.1	0.921	217.5	NO DAMAGE	
115	-20	3	0.00022	12.2	13.1	12.1	13.1	0.918	209.4	NO DAMAGE	
115	-25	2	0.00015	12.2	13.1	12.0	13.1	0.915	202.0	NO DAMAGE	
115	-35	2	0.00015	12.2	13.1	11.9	13.1	0.909	188.5	NO DAMAGE	
115	-40	2	0.00015	12.2	13.1	11.9	13.1	0.906	182.4	NO DAMAGE	
115	-45	2	0.00015	12.2	13.1	11.9	13.1	0.903	176.7	NO DAMAGE	
115	-50	1	0.00007	12.2	13.1	11.8	13.1	0.900	171.4	NO DAMAGE	
115	-55	1	0.00007	12.2	13.1	11.8	13.1	0.897	166.3	NO DAMAGE	
115	-65	2	0.00015	12.2	13.1	11.7	13.1	0.891	157.1	NO DAMAGE	
115	-75	2	0.00015	12.2	13.1	11.6	13.1	0.885	148.8	NO DAMAGE	
115	-85	2	0.00015	12.2	13.1	11.5	13.1	0.879	141.4	NO DAMAGE	
115	-95	3	0.00022	12.2	13.1	11.5	13.1	0.873	134.6	NO DAMAGE	
115	-105	4	0.00030	12.2	13.1	11.4	13.1	0.867	128.5	NO DAMAGE	
115	-115	2	0.00015	12.2	13.1	11.3	13.1	0.861	122.9	NO DAMAGE	
115	-125	3	0.00022	12.2	13.1	11.2	13.1	0.855	117.8	NO DAMAGE	
115	-135	1	0.00007	12.2	13.1	11.1	13.1	0.849	113.1	NO DAMAGE	
115	-155	1	0.00007	12.2	13.1	11.0	13.1	0.837	104.7	NO DAMAGE	
115	-170	1	0.00007	12.2	13.1	10.9	13.1	0.828	99.2	NO DAMAGE	
115	-190	1	0.00007	12.2	13.1	10.7	13.1	0.816	92.7	NO DAMAGE	
115	-195	1	0.00007	12.2	13.1	10.7	13.1	0.813	91.2	NO DAMAGE	
115	-215	1	0.00007	12.2	13.1	10.5	13.1	0.800	85.7	NO DAMAGE	
110	100	3541	0.26399	12.2	13.1	13.0	13.1	0.994	2818.9	NO DAMAGE	
110	95	922	0.06874	12.2	13.1	13.0	13.1	0.991	1879.3	NO DAMAGE	
110	90	2060	0.15358	12.2	13.1	12.9	13.1	0.988	1409.5	NO DAMAGE	
110	85	527	0.03929	12.2	13.1	12.9	13.1	0.985	1127.6	NO DAMAGE	
110	80	1233	0.09192	12.2	13.1	12.9	13.1	0.982	939.6	NO DAMAGE	
110	75	313	0.02334	12.2	13.1	12.8	13.1	0.979	805.4	NO DAMAGE	
110	70	677	0.05047	12.2	13.1	12.8	13.1	0.976	704.7	NO DAMAGE	
110	65	107	0.00798	12.2	13.1	12.7	13.1	0.973	626.4	NO DAMAGE	
110	60	289	0.02155	12.2	13.1	12.7	13.1	0.970	563.8	NO DAMAGE	
110	55	26	0.00194	12.2	13.1	12.7	13.1	0.967	512.5	NO DAMAGE	
110	50	126	0.00939	12.2	13.1	12.6	13.1	0.964	469.8	NO DAMAGE	
110	45	5	0.00037	12.2	13.1	12.6	13.1	0.961	433.7	NO DAMAGE	
110	40	74	0.00552	12.2	13.1	12.5	13.1	0.958	402.7	NO DAMAGE	
110	35	6	0.00045	12.2	13.1	12.5	13.1	0.955	375.9	NO DAMAGE	
110	30	32	0.00239	12.2	13.1	12.5	13.1	0.951	352.4	NO DAMAGE	
110	25	2	0.00015	12.2	13.1	12.4	13.1	0.948	331.6	NO DAMAGE	
110	20	28	0.00209	12.2	13.1	12.4	13.1	0.945	313.2	NO DAMAGE	
110	15	1	0.00007	12.2	13.1	12.3	13.1	0.942	296.7	NO DAMAGE	
110	10	26	0.00194	12.2	13.1	12.3	13.1	0.939	281.9	NO DAMAGE	
110	5	1	0.00007	12.2	13.1	12.3	13.1	0.936	268.5	NO DAMAGE	
110	0	47	0.00350	12.2	13.1	12.2	13.1	0.933	256.3	NO DAMAGE	
110	-5	2	0.00015	12.2	13.1	12.2	13.1	0.930	245.1	NO DAMAGE	
110	-10	22	0.00164	12.2	13.1	12.1	13.1	0.927	234.9	NO DAMAGE	
110	-20	4	0.00030	12.2	13.1	12.1	13.1	0.921	216.8	NO DAMAGE	
110	-30	5	0.00037	12.2	13.1	12.0	13.1	0.915	201.4	NO DAMAGE	
110	-35	1	0.00007	12.2	13.1	11.9	13.1	0.912	194.4	NO DAMAGE	
110	-40	2	0.00015	12.2	13.1	11.9	13.1	0.909	187.9	NO DAMAGE	
110	-50	5	0.00037	12.2	13.1	11.8	13.1	0.903	176.2	NO DAMAGE	
110	-60	6	0.00045	12.2	13.1	11.7	13.1	0.897	165.8	NO DAMAGE	
110	-70	6	0.00045	12.2	13.1	11.7	13.1	0.891	156.6	NO DAMAGE	
110	-80	6	0.00045	12.2	13.1	11.6	13.1	0.885	148.4	NO DAMAGE	
110	-90	8	0.00060	12.2	13.1	11.5	13.1	0.879	140.9	NO DAMAGE	
110	-100	9	0.00067	12.2	13.1	11.4	13.1	0.873	134.2	NO DAMAGE	
110	-110	6	0.00045	12.2	13.1	11.3	13.1	0.867	128.1	NO DAMAGE	
110	-120	5	0.00037	12.2	13.1	11.3	13.1	0.860	122.6	NO DAMAGE	
110	-130	1	0.00007	12.2	13.1	11.2	13.1	0.854	117.5	NO DAMAGE	
110	-135	1	0.00007	12.2	13.1	11.1	13.1	0.851	115.1	NO DAMAGE	
110	-140	2	0.00015	12.2	13.1	11.1	13.1	0.848	112.8	NO DAMAGE	
110	-150	2	0.00015	12.2	13.1	11.0	13.1	0.842	108.4	NO DAMAGE	
110	-160	1	0.00007	12.2	13.1	10.9	13.1	0.836	104.4	NO DAMAGE	
110	-170	1	0.00007	12.2	13.1	10.9	13.1	0.830	100.7	NO DAMAGE	
110	-180	1	0.00007	12.2	13.1	10.8	13.1	0.824	97.2	NO DAMAGE	
110	-210	1	0.00007	12.2	13.1	10.6	13.1	0.806	88.1	NO DAMAGE	
105	95	10845	0.80852	12.2	13.1	13.0	13.1	0.994	2810.4	NO DAMAGE	
105	90	1293	0.09640	12.2	13.1	12.9	13.1	0.991	1873.6	NO DAMAGE	
105	85	5514	0.41108	12.2	13.1	12.9	13.1	0.988	1405.2	NO DAMAGE	
105	80	765	0.05703	12.2	13.1	12.9	13.1	0.985	1124.1	NO DAMAGE	
105	75	2419	0.18034	12.2	13.1	12.8	13.1	0.982	936.8	NO DAMAGE	
105	70	358	0.02669	12.2	13.1	12.8	13.1	0.979	803.0	NO DAMAGE	
105	65	920	0.06859	12.2	13.1	12.7	13.1	0.976	702.6	NO DAMAGE	
105	60	78	0.00582	12.2	13.1	12.7	13.1	0.973	624.5	NO DAMAGE	
105	55	262	0.01953	12.2	13.1	12.7	13.1	0.970	562.1	NO DAMAGE	
105	50	22	0.00164	12.2	13.1	12.6	13.1	0.967	511.0	NO DAMAGE	
105	45	100	0.00746	12.2	13.1	12.6	13.1	0.963	468.4	NO DAMAGE	
105	40	4	0.00030	12.2	13.1	12.5	13.1	0.960	432.4	NO DAMAGE	

cycles per mile 153.8
Yield stress 50 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
105	35	54	0.00403	12.2	13.1	12.5	13.1	0.957	401.5	NO DAMAGE	
105	30	1	0.00007	12.2	13.1	12.5	13.1	0.954	374.7	NO DAMAGE	
105	25	20	0.00149	12.2	13.1	12.4	13.1	0.951	351.3	NO DAMAGE	
105	20	4	0.00030	12.2	13.1	12.4	13.1	0.948	330.6	NO DAMAGE	
105	15	18	0.00134	12.2	13.1	12.3	13.1	0.945	312.3	NO DAMAGE	
105	10	1	0.00007	12.2	13.1	12.3	13.1	0.942	295.8	NO DAMAGE	
105	5	22	0.00164	12.2	13.1	12.3	13.1	0.939	281.0	NO DAMAGE	
105	0	2	0.00015	12.2	13.1	12.2	13.1	0.936	267.7	NO DAMAGE	
105	-5	4	0.00030	12.2	13.1	12.2	13.1	0.933	255.5	NO DAMAGE	
105	-10	1	0.00007	12.2	13.1	12.1	13.1	0.930	244.4	NO DAMAGE	
105	-15	3	0.00022	12.2	13.1	12.1	13.1	0.927	234.2	NO DAMAGE	
105	-20	1	0.00007	12.2	13.1	12.1	13.1	0.924	224.8	NO DAMAGE	
105	-25	2	0.00015	12.2	13.1	12.0	13.1	0.921	216.2	NO DAMAGE	
105	-35	4	0.00030	12.2	13.1	11.9	13.1	0.915	200.7	NO DAMAGE	
105	-45	3	0.00022	12.2	13.1	11.9	13.1	0.909	187.4	NO DAMAGE	
105	-55	1	0.00007	12.2	13.1	11.8	13.1	0.903	175.6	NO DAMAGE	
105	-65	1	0.00007	12.2	13.1	11.7	13.1	0.897	165.3	NO DAMAGE	
105	-75	2	0.00015	12.2	13.1	11.6	13.1	0.890	156.1	NO DAMAGE	
105	-85	6	0.00045	12.2	13.1	11.5	13.1	0.884	147.9	NO DAMAGE	
105	-95	6	0.00045	12.2	13.1	11.5	13.1	0.878	140.5	NO DAMAGE	
105	-105	3	0.00022	12.2	13.1	11.4	13.1	0.872	133.8	NO DAMAGE	
105	-110	2	0.00015	12.2	13.1	11.3	13.1	0.869	130.7	NO DAMAGE	
105	-120	2	0.00015	12.2	13.1	11.3	13.1	0.863	124.9	NO DAMAGE	
105	-125	1	0.00007	12.2	13.1	11.2	13.1	0.860	122.2	NO DAMAGE	
105	-145	3	0.00022	12.2	13.1	11.1	13.1	0.848	112.4	NO DAMAGE	
105	-165	1	0.00007	12.2	13.1	10.9	13.1	0.836	104.1	NO DAMAGE	
105	-185	1	0.00007	12.2	13.1	10.8	13.1	0.824	96.9	NO DAMAGE	
105	-195	1	0.00007	12.2	13.1	10.7	13.1	0.817	93.7	NO DAMAGE	
105	-225	1	0.00007	12.2	13.1	10.4	13.1	0.799	85.2	NO DAMAGE	
105	-255	1	0.00007	12.2	13.1	10.2	13.1	0.781	78.1	NO DAMAGE	
100	90	4690	0.34965	12.2	13.0	12.9	13.0	0.994	2801.8	NO DAMAGE	
100	85	1557	0.11608	12.2	13.0	12.9	13.0	0.991	1867.9	NO DAMAGE	
100	80	3257	0.24282	12.2	13.0	12.9	13.0	0.988	1400.9	NO DAMAGE	
100	75	901	0.06717	12.2	13.0	12.8	13.0	0.985	1120.7	NO DAMAGE	
100	70	1551	0.11563	12.2	13.0	12.8	13.0	0.982	933.9	NO DAMAGE	
100	65	248	0.01849	12.2	13.0	12.7	13.0	0.979	800.5	NO DAMAGE	
100	60	739	0.05509	12.2	13.0	12.7	13.0	0.976	700.5	NO DAMAGE	
100	55	63	0.00470	12.2	13.0	12.7	13.0	0.973	622.6	NO DAMAGE	
100	50	318	0.02371	12.2	13.0	12.6	13.0	0.969	560.4	NO DAMAGE	
100	45	22	0.00164	12.2	13.0	12.6	13.0	0.966	509.4	NO DAMAGE	
100	40	168	0.01252	12.2	13.0	12.5	13.0	0.963	467.0	NO DAMAGE	
100	35	5	0.00037	12.2	13.0	12.5	13.0	0.960	431.0	NO DAMAGE	
100	30	90	0.00671	12.2	13.0	12.5	13.0	0.957	400.3	NO DAMAGE	
100	25	11	0.00082	12.2	13.0	12.4	13.0	0.954	373.6	NO DAMAGE	
100	20	55	0.00410	12.2	13.0	12.4	13.0	0.951	350.2	NO DAMAGE	
100	15	1	0.00007	12.2	13.0	12.3	13.0	0.948	329.6	NO DAMAGE	
100	10	42	0.00313	12.2	13.0	12.3	13.0	0.945	311.3	NO DAMAGE	
100	5	2	0.00015	12.2	13.0	12.3	13.0	0.942	294.9	NO DAMAGE	
100	0	58	0.00432	12.2	13.0	12.2	13.0	0.939	280.2	NO DAMAGE	
100	-5	1	0.00007	12.2	13.0	12.2	13.0	0.936	266.8	NO DAMAGE	
100	-10	32	0.00239	12.2	13.0	12.1	13.0	0.933	254.7	NO DAMAGE	
100	-15	1	0.00007	12.2	13.0	12.1	13.0	0.930	243.6	NO DAMAGE	
100	-20	5	0.00037	12.2	13.0	12.1	13.0	0.927	233.5	NO DAMAGE	
100	-30	7	0.00052	12.2	13.0	12.0	13.0	0.921	215.5	NO DAMAGE	
100	-40	2	0.00015	12.2	13.0	11.9	13.0	0.915	200.1	NO DAMAGE	
100	-45	1	0.00007	12.2	13.0	11.9	13.0	0.912	193.2	NO DAMAGE	
100	-50	7	0.00052	12.2	13.0	11.8	13.0	0.908	186.8	NO DAMAGE	
100	-60	8	0.00060	12.2	13.0	11.7	13.0	0.902	175.1	NO DAMAGE	
100	-70	3	0.00022	12.2	13.0	11.7	13.0	0.896	164.8	NO DAMAGE	
100	-80	2	0.00015	12.2	13.0	11.6	13.0	0.890	155.7	NO DAMAGE	
100	-90	9	0.00067	12.2	13.0	11.5	13.0	0.884	147.5	NO DAMAGE	
100	-100	4	0.00030	12.2	13.0	11.4	13.0	0.878	140.1	NO DAMAGE	
100	-110	3	0.00022	12.2	13.0	11.3	13.0	0.872	133.4	NO DAMAGE	
100	-120	1	0.00007	12.2	13.0	11.3	13.0	0.866	127.4	NO DAMAGE	
100	-125	1	0.00007	12.2	13.0	11.2	13.0	0.863	124.5	NO DAMAGE	
100	-130	3	0.00022	12.2	13.0	11.2	13.0	0.860	121.8	NO DAMAGE	
100	-140	2	0.00015	12.2	13.0	11.1	13.0	0.854	116.7	NO DAMAGE	
100	-150	2	0.00015	12.2	13.0	11.0	13.0	0.847	112.1	NO DAMAGE	
100	-160	1	0.00007	12.2	13.0	10.9	13.0	0.841	107.8	NO DAMAGE	
100	-180	2	0.00015	12.2	13.0	10.8	13.0	0.829	100.1	NO DAMAGE	
100	-190	2	0.00015	12.2	13.0	10.7	13.0	0.823	96.6	NO DAMAGE	
100	-200	3	0.00022	12.2	13.0	10.6	13.0	0.817	93.4	NO DAMAGE	
100	-205	1	0.00007	12.2	13.0	10.6	13.0	0.814	91.9	NO DAMAGE	
100	-210	1	0.00007	12.2	13.0	10.6	13.0	0.811	90.4	NO DAMAGE	
95	85	7900	0.58897	12.2	13.0	12.9	13.0	0.994	2793.3	NO DAMAGE	
95	80	1725	0.12860	12.2	13.0	12.9	13.0	0.991	1862.2	NO DAMAGE	
95	75	6072	0.45268	12.2	13.0	12.8	13.0	0.988	1396.6	NO DAMAGE	
95	70	643	0.04794	12.2	13.0	12.8	13.0	0.985	1117.3	NO DAMAGE	
95	65	2494	0.18593	12.2	13.0	12.7	13.0	0.982	931.1	NO DAMAGE	
95	60	216	0.01610	12.2	13.0	12.7	13.0	0.979	798.1	NO DAMAGE	
95	55	984	0.07336	12.2	13.0	12.7	13.0	0.976	698.3	NO DAMAGE	
95	50	63	0.00470	12.2	13.0	12.6	13.0	0.972	620.7	NO DAMAGE	
95	45	319	0.02378	12.2	13.0	12.6	13.0	0.969	558.7	NO DAMAGE	
95	40	22	0.00164	12.2	13.0	12.5	13.0	0.966	507.9	NO DAMAGE	
95	35	103	0.00768	12.2	13.0	12.5	13.0	0.963	465.5	NO DAMAGE	
95	30	19	0.00142	12.2	13.0	12.5	13.0	0.960	429.7	NO DAMAGE	
95	25	38	0.00283	12.2	13.0	12.4	13.0	0.957	399.0	NO DAMAGE	
95	20	2	0.00015	12.2	13.0	12.4	13.0	0.954	372.4	NO DAMAGE	

cycles per mile	153.8
Yield stress	50 ksi

Max	Min	No.	α Pct	Static Stress	Dynamic Stress		Max Adjusted	R Min/Max	Endurance Limit	to Failure N	α/N
					Max	Min					
95	15	11	0.00082	12.2	13.0	12.3	13.0	0.951	349.2	NO DAMAGE	
95	5	28	0.00209	12.2	13.0	12.3	13.0	0.945	310.4	NO DAMAGE	
95	0	7	0.00052	12.2	13.0	12.2	13.0	0.942	294.0	NO DAMAGE	
95	-5	5	0.00037	12.2	13.0	12.2	13.0	0.939	279.3	NO DAMAGE	
95	-15	1	0.00007	12.2	13.0	12.1	13.0	0.933	253.9	NO DAMAGE	
95	-25	2	0.00015	12.2	13.0	12.0	13.0	0.927	232.8	NO DAMAGE	
95	-35	3	0.00022	12.2	13.0	11.9	13.0	0.920	214.9	NO DAMAGE	
95	-45	1	0.00007	12.2	13.0	11.9	13.0	0.914	199.5	NO DAMAGE	
95	-55	1	0.00007	12.2	13.0	11.8	13.0	0.908	186.2	NO DAMAGE	
95	-70	1	0.00007	12.2	13.0	11.7	13.0	0.899	169.3	NO DAMAGE	
95	-75	6	0.00045	12.2	13.0	11.6	13.0	0.896	164.3	NO DAMAGE	
95	-85	5	0.00037	12.2	13.0	11.5	13.0	0.890	155.2	NO DAMAGE	
95	-95	4	0.00030	12.2	13.0	11.5	13.0	0.884	147.0	NO DAMAGE	
95	-100	1	0.00007	12.2	13.0	11.4	13.0	0.881	143.2	NO DAMAGE	
95	-105	5	0.00037	12.2	13.0	11.4	13.0	0.878	139.7	NO DAMAGE	
95	-110	3	0.00022	12.2	13.0	11.3	13.0	0.875	136.3	NO DAMAGE	
95	-115	3	0.00022	12.2	13.0	11.3	13.0	0.871	133.0	NO DAMAGE	
95	-125	1	0.00007	12.2	13.0	11.2	13.0	0.865	127.0	NO DAMAGE	
95	-135	2	0.00015	12.2	13.0	11.1	13.0	0.859	121.4	NO DAMAGE	
95	-140	1	0.00007	12.2	13.0	11.1	13.0	0.856	118.9	NO DAMAGE	
95	-145	1	0.00007	12.2	13.0	11.1	13.0	0.853	116.4	NO DAMAGE	
95	-165	3	0.00022	12.2	13.0	10.9	13.0	0.841	107.4	NO DAMAGE	
95	-225	1	0.00007	12.2	13.0	10.4	13.0	0.804	87.3	NO DAMAGE	
95	-280	1	0.00007	12.2	13.0	10.0	13.0	0.770	74.5	NO DAMAGE	
90	80	6066	0.45224	12.2	12.9	12.9	12.9	0.994	2784.7	NO DAMAGE	
90	75	1408	0.10497	12.2	12.9	12.8	12.9	0.991	1856.5	NO DAMAGE	
90	70	3591	0.26772	12.2	12.9	12.8	12.9	0.988	1392.4	NO DAMAGE	
90	65	591	0.04406	12.2	12.9	12.7	12.9	0.985	1113.9	NO DAMAGE	
90	60	1593	0.11876	12.2	12.9	12.7	12.9	0.982	928.2	NO DAMAGE	
90	55	275	0.02050	12.2	12.9	12.7	12.9	0.979	795.6	NO DAMAGE	
90	50	789	0.05882	12.2	12.9	12.6	12.9	0.975	696.2	NO DAMAGE	
90	45	83	0.00619	12.2	12.9	12.6	12.9	0.972	618.8	NO DAMAGE	
90	40	470	0.03504	12.2	12.9	12.5	12.9	0.969	556.9	NO DAMAGE	
90	35	20	0.00149	12.2	12.9	12.5	12.9	0.966	506.3	NO DAMAGE	
90	30	188	0.01402	12.2	12.9	12.5	12.9	0.963	464.1	NO DAMAGE	
90	25	8	0.00060	12.2	12.9	12.4	12.9	0.960	428.4	NO DAMAGE	
90	20	113	0.00842	12.2	12.9	12.4	12.9	0.957	397.8	NO DAMAGE	
90	15	4	0.00030	12.2	12.9	12.3	12.9	0.954	371.3	NO DAMAGE	
90	10	68	0.00507	12.2	12.9	12.3	12.9	0.951	348.1	NO DAMAGE	
90	5	2	0.00015	12.2	12.9	12.3	12.9	0.948	327.6	NO DAMAGE	
90	0	78	0.00582	12.2	12.9	12.2	12.9	0.945	309.4	NO DAMAGE	
90	-5	2	0.00015	12.2	12.9	12.2	12.9	0.942	293.1	NO DAMAGE	
90	-10	32	0.00239	12.2	12.9	12.1	12.9	0.939	278.5	NO DAMAGE	
90	-15	1	0.00007	12.2	12.9	12.1	12.9	0.936	265.2	NO DAMAGE	
90	-20	4	0.00030	12.2	12.9	12.1	12.9	0.932	253.2	NO DAMAGE	
90	-30	4	0.00030	12.2	12.9	12.0	12.9	0.926	232.1	NO DAMAGE	
90	-40	6	0.00045	12.2	12.9	11.9	12.9	0.920	214.2	NO DAMAGE	
90	-45	1	0.00007	12.2	12.9	11.9	12.9	0.917	206.3	NO DAMAGE	
90	-50	7	0.00052	12.2	12.9	11.8	12.9	0.914	198.9	NO DAMAGE	
90	-60	14	0.00104	12.2	12.9	11.7	12.9	0.908	185.6	NO DAMAGE	
90	-70	8	0.00060	12.2	12.9	11.7	12.9	0.902	174.0	NO DAMAGE	
90	-80	13	0.00097	12.2	12.9	11.6	12.9	0.896	163.8	NO DAMAGE	
90	-90	6	0.00045	12.2	12.9	11.5	12.9	0.889	154.7	NO DAMAGE	
90	-95	1	0.00007	12.2	12.9	11.5	12.9	0.886	150.5	NO DAMAGE	
90	-100	7	0.00052	12.2	12.9	11.4	12.9	0.883	146.6	NO DAMAGE	
90	-110	2	0.00015	12.2	12.9	11.3	12.9	0.877	139.2	NO DAMAGE	
90	-115	2	0.00015	12.2	12.9	11.3	12.9	0.874	135.8	NO DAMAGE	
90	-120	3	0.00022	12.2	12.9	11.3	12.9	0.871	132.6	NO DAMAGE	
90	-140	2	0.00015	12.2	12.9	11.1	12.9	0.859	121.1	NO DAMAGE	
90	-145	1	0.00007	12.2	12.9	11.1	12.9	0.856	118.5	NO DAMAGE	
90	-150	2	0.00015	12.2	12.9	11.0	12.9	0.853	116.0	NO DAMAGE	
90	-160	3	0.00022	12.2	12.9	10.9	12.9	0.846	111.4	NO DAMAGE	
90	-170	1	0.00007	12.2	12.9	10.9	12.9	0.840	107.1	NO DAMAGE	
90	-180	1	0.00007	12.2	12.9	10.8	12.9	0.834	103.1	NO DAMAGE	
90	-190	1	0.00007	12.2	12.9	10.7	12.9	0.828	99.5	NO DAMAGE	
85	75	8202	0.61148	12.2	12.9	12.8	12.9	0.994	2776.2	NO DAMAGE	
85	70	1902	0.14180	12.2	12.9	12.8	12.9	0.991	1850.8	NO DAMAGE	
85	65	6590	0.49130	12.2	12.9	12.7	12.9	0.988	1388.1	NO DAMAGE	
85	60	711	0.05301	12.2	12.9	12.7	12.9	0.985	1110.5	NO DAMAGE	
85	55	3052	0.22754	12.2	12.9	12.7	12.9	0.982	925.4	NO DAMAGE	
85	50	292	0.02177	12.2	12.9	12.6	12.9	0.978	793.2	NO DAMAGE	
85	45	792	0.05905	12.2	12.9	12.6	12.9	0.975	694.0	NO DAMAGE	
85	40	65	0.00485	12.2	12.9	12.5	12.9	0.972	616.9	NO DAMAGE	
85	35	260	0.01938	12.2	12.9	12.5	12.9	0.969	555.2	NO DAMAGE	
85	30	14	0.00104	12.2	12.9	12.5	12.9	0.966	504.8	NO DAMAGE	
85	25	111	0.00828	12.2	12.9	12.4	12.9	0.963	462.7	NO DAMAGE	
85	20	1	0.00007	12.2	12.9	12.4	12.9	0.960	427.1	NO DAMAGE	
85	15	71	0.00529	12.2	12.9	12.3	12.9	0.957	396.6	NO DAMAGE	
85	5	72	0.00537	12.2	12.9	12.3	12.9	0.951	347.0	NO DAMAGE	
85	0	6	0.00045	12.2	12.9	12.2	12.9	0.948	326.6	NO DAMAGE	
85	-5	6	0.00045	12.2	12.9	12.2	12.9	0.945	308.5	NO DAMAGE	
85	-15	5	0.00037	12.2	12.9	12.1	12.9	0.938	277.6	NO DAMAGE	
85	-20	1	0.00007	12.2	12.9	12.1	12.9	0.935	264.4	NO DAMAGE	
85	-25	2	0.00015	12.2	12.9	12.0	12.9	0.932	252.4	NO DAMAGE	
85	-35	2	0.00015	12.2	12.9	11.9	12.9	0.926	231.3	NO DAMAGE	
85	-45	6	0.00045	12.2	12.9	11.9	12.9	0.920	213.6	NO DAMAGE	
85	-50	2	0.00015	12.2	12.9	11.8	12.9	0.917	205.6	NO DAMAGE	
85	-55	2	0.00015	12.2	12.9	11.8	12.9	0.914	198.3	NO DAMAGE	

cycles per mile 153.8
Yield stress 50 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
85	-65	4	0.00030	12.2	12.9	11.7	12.9	0.908	185.1	NO DAMAGE	
85	-70	1	0.00007	12.2	12.9	11.7	12.9	0.905	179.1	NO DAMAGE	
85	-75	5	0.00037	12.2	12.9	11.6	12.9	0.901	173.5	NO DAMAGE	
85	-85	4	0.00030	12.2	12.9	11.5	12.9	0.895	163.3	NO DAMAGE	
85	-90	1	0.00007	12.2	12.9	11.5	12.9	0.892	158.6	NO DAMAGE	
85	-95	5	0.00037	12.2	12.9	11.5	12.9	0.889	154.2	NO DAMAGE	
85	-100	1	0.00007	12.2	12.9	11.4	12.9	0.886	150.1	NO DAMAGE	
85	-105	3	0.00022	12.2	12.9	11.4	12.9	0.883	146.1	NO DAMAGE	
85	-110	3	0.00022	12.2	12.9	11.3	12.9	0.880	142.4	NO DAMAGE	
85	-115	1	0.00007	12.2	12.9	11.3	12.9	0.877	138.8	NO DAMAGE	
85	-135	1	0.00007	12.2	12.9	11.1	12.9	0.864	126.2	NO DAMAGE	
85	-145	1	0.00007	12.2	12.9	11.1	12.9	0.858	120.7	NO DAMAGE	
85	-165	1	0.00007	12.2	12.9	10.9	12.9	0.846	111.0	NO DAMAGE	
85	-215	1	0.00007	12.2	12.9	10.5	12.9	0.815	92.5	NO DAMAGE	
80	70	7655	0.57070	12.2	12.9	12.8	12.9	0.994	2767.6	NO DAMAGE	
80	65	1558	0.11615	12.2	12.9	12.7	12.9	0.991	1845.1	NO DAMAGE	
80	60	4677	0.34868	12.2	12.9	12.7	12.9	0.988	1383.8	NO DAMAGE	
80	55	681	0.05077	12.2	12.9	12.7	12.9	0.985	1107.0	NO DAMAGE	
80	50	2097	0.15634	12.2	12.9	12.6	12.9	0.981	922.5	NO DAMAGE	
80	45	222	0.01655	12.2	12.9	12.6	12.9	0.978	790.7	NO DAMAGE	
80	40	927	0.06911	12.2	12.9	12.5	12.9	0.975	691.9	NO DAMAGE	
80	35	49	0.00365	12.2	12.9	12.5	12.9	0.972	615.0	NO DAMAGE	
80	30	460	0.03429	12.2	12.9	12.5	12.9	0.969	553.5	NO DAMAGE	
80	25	16	0.00119	12.2	12.9	12.4	12.9	0.966	503.2	NO DAMAGE	
80	20	239	0.01782	12.2	12.9	12.4	12.9	0.963	461.3	NO DAMAGE	
80	15	7	0.00052	12.2	12.9	12.3	12.9	0.960	425.8	NO DAMAGE	
80	10	110	0.00820	12.2	12.9	12.3	12.9	0.957	395.4	NO DAMAGE	
80	5	4	0.00030	12.2	12.9	12.3	12.9	0.954	369.0	NO DAMAGE	
80	0	129	0.00962	12.2	12.9	12.2	12.9	0.951	346.0	NO DAMAGE	
80	-5	2	0.00015	12.2	12.9	12.2	12.9	0.947	325.6	NO DAMAGE	
80	-10	63	0.00470	12.2	12.9	12.1	12.9	0.944	307.5	NO DAMAGE	
80	-15	1	0.00007	12.2	12.9	12.1	12.9	0.941	291.3	NO DAMAGE	
80	-20	4	0.00030	12.2	12.9	12.1	12.9	0.938	276.8	NO DAMAGE	
80	-25	1	0.00007	12.2	12.9	12.0	12.9	0.935	263.6	NO DAMAGE	
80	-30	5	0.00037	12.2	12.9	12.0	12.9	0.932	251.6	NO DAMAGE	
80	-35	1	0.00007	12.2	12.9	11.9	12.9	0.929	240.7	NO DAMAGE	
80	-40	7	0.00052	12.2	12.9	11.9	12.9	0.926	230.6	NO DAMAGE	
80	-50	15	0.00112	12.2	12.9	11.8	12.9	0.920	212.9	NO DAMAGE	
80	-55	1	0.00007	12.2	12.9	11.8	12.9	0.917	205.0	NO DAMAGE	
80	-60	12	0.00089	12.2	12.9	11.7	12.9	0.913	197.7	NO DAMAGE	
80	-70	10	0.00075	12.2	12.9	11.7	12.9	0.907	184.5	NO DAMAGE	
80	-75	1	0.00007	12.2	12.9	11.6	12.9	0.904	178.6	NO DAMAGE	
80	-80	13	0.00097	12.2	12.9	11.6	12.9	0.901	173.0	NO DAMAGE	
80	-85	1	0.00007	12.2	12.9	11.5	12.9	0.898	167.7	NO DAMAGE	
80	-90	8	0.00060	12.2	12.9	11.5	12.9	0.895	162.8	NO DAMAGE	
80	-95	1	0.00007	12.2	12.9	11.5	12.9	0.892	158.1	NO DAMAGE	
80	-100	4	0.00030	12.2	12.9	11.4	12.9	0.889	153.8	NO DAMAGE	
80	-110	2	0.00015	12.2	12.9	11.3	12.9	0.883	145.7	NO DAMAGE	
80	-120	4	0.00030	12.2	12.9	11.3	12.9	0.876	138.4	NO DAMAGE	
80	-130	1	0.00007	12.2	12.9	11.2	12.9	0.870	131.8	NO DAMAGE	
80	-140	1	0.00007	12.2	12.9	11.1	12.9	0.864	125.8	NO DAMAGE	
80	-150	3	0.00022	12.2	12.9	11.0	12.9	0.858	120.3	NO DAMAGE	
80	-170	1	0.00007	12.2	12.9	10.9	12.9	0.846	110.7	NO DAMAGE	
80	-220	1	0.00007	12.2	12.9	10.5	12.9	0.815	92.3	NO DAMAGE	
75	65	8167	0.60887	12.2	12.8	12.7	12.8	0.994	2759.1	NO DAMAGE	
75	60	1797	0.13397	12.2	12.8	12.7	12.8	0.991	1839.4	NO DAMAGE	
75	55	5826	0.43434	12.2	12.8	12.7	12.8	0.988	1379.5	NO DAMAGE	
75	50	731	0.05450	12.2	12.8	12.6	12.8	0.985	1103.6	NO DAMAGE	
75	45	2118	0.15790	12.2	12.8	12.6	12.8	0.981	919.7	NO DAMAGE	
75	40	220	0.01640	12.2	12.8	12.5	12.8	0.978	788.3	NO DAMAGE	
75	35	882	0.06576	12.2	12.8	12.5	12.8	0.975	689.8	NO DAMAGE	
75	30	70	0.00522	12.2	12.8	12.5	12.8	0.972	613.1	NO DAMAGE	
75	25	369	0.02751	12.2	12.8	12.4	12.8	0.969	551.8	NO DAMAGE	
75	20	19	0.00142	12.2	12.8	12.4	12.8	0.966	501.6	NO DAMAGE	
75	15	149	0.01111	12.2	12.8	12.3	12.8	0.963	459.8	NO DAMAGE	
75	10	6	0.00045	12.2	12.8	12.3	12.8	0.960	424.5	NO DAMAGE	
75	5	111	0.00828	12.2	12.8	12.3	12.8	0.957	394.2	NO DAMAGE	
75	0	15	0.00112	12.2	12.8	12.2	12.8	0.954	367.9	NO DAMAGE	
75	-5	10	0.00075	12.2	12.8	12.2	12.8	0.950	344.9	NO DAMAGE	
75	-15	4	0.00030	12.2	12.8	12.1	12.8	0.944	306.6	NO DAMAGE	
75	-25	4	0.00030	12.2	12.8	12.0	12.8	0.938	275.9	NO DAMAGE	
75	-35	1	0.00007	12.2	12.8	11.9	12.8	0.932	250.8	NO DAMAGE	
75	-45	1	0.00007	12.2	12.8	11.9	12.8	0.926	229.9	NO DAMAGE	
75	-55	3	0.00022	12.2	12.8	11.8	12.8	0.919	212.2	NO DAMAGE	
75	-65	3	0.00022	12.2	12.8	11.7	12.8	0.913	197.1	NO DAMAGE	
75	-75	3	0.00022	12.2	12.8	11.6	12.8	0.907	183.9	NO DAMAGE	
75	-85	2	0.00015	12.2	12.8	11.5	12.8	0.901	172.4	NO DAMAGE	
75	-90	1	0.00007	12.2	12.8	11.5	12.8	0.898	167.2	NO DAMAGE	
75	-95	2	0.00015	12.2	12.8	11.5	12.8	0.895	162.3	NO DAMAGE	
75	-105	2	0.00015	12.2	12.8	11.4	12.8	0.888	153.3	NO DAMAGE	
75	-110	1	0.00007	12.2	12.8	11.3	12.8	0.885	149.1	NO DAMAGE	
75	-115	3	0.00022	12.2	12.8	11.3	12.8	0.882	145.2	NO DAMAGE	
75	-135	1	0.00007	12.2	12.8	11.1	12.8	0.870	131.4	NO DAMAGE	
75	-145	1	0.00007	12.2	12.8	11.1	12.8	0.864	125.4	NO DAMAGE	
75	-160	1	0.00007	12.2	12.8	10.9	12.8	0.854	117.4	NO DAMAGE	
75	-215	2	0.00015	12.2	12.8	10.5	12.8	0.820	95.1	NO DAMAGE	
75	-235	1	0.00007	12.2	12.8	10.4	12.8	0.808	89.0	NO DAMAGE	
70	60	8507	0.63422	12.2	12.8	12.7	12.8	0.994	2750.5	NO DAMAGE	

cycles per mile 153.8
Yield stress 50 ksi

			α	Static	Dynamic Stress		Max	R	Endurance	to Failure	
Max	Min	No.	Pct	Stress	Max	Min	Adjusted	Min/Max	Limit	N	α/N
70	55	1533	0.11429	12.2	12.8	12.7	12.8	0.991	1833.7	NO DAMAGE	
70	50	5273	0.39312	12.2	12.8	12.6	12.8	0.988	1375.3	NO DAMAGE	
70	45	696	0.05189	12.2	12.8	12.6	12.8	0.984	1100.2	NO DAMAGE	
70	40	2334	0.17401	12.2	12.8	12.5	12.8	0.981	916.8	NO DAMAGE	
70	35	258	0.01923	12.2	12.8	12.5	12.8	0.978	785.9	NO DAMAGE	
70	30	1115	0.08313	12.2	12.8	12.5	12.8	0.975	687.6	NO DAMAGE	
70	25	49	0.00365	12.2	12.8	12.4	12.8	0.972	611.2	NO DAMAGE	
70	20	562	0.04190	12.2	12.8	12.4	12.8	0.969	550.1	NO DAMAGE	
70	15	11	0.00082	12.2	12.8	12.3	12.8	0.966	500.1	NO DAMAGE	
70	10	276	0.02058	12.2	12.8	12.3	12.8	0.963	458.4	NO DAMAGE	
70	5	7	0.00052	12.2	12.8	12.3	12.8	0.960	423.2	NO DAMAGE	
70	0	205	0.01528	12.2	12.8	12.2	12.8	0.956	392.9	NO DAMAGE	
70	-5	3	0.00022	12.2	12.8	12.2	12.8	0.953	366.7	NO DAMAGE	
70	-10	102	0.00760	12.2	12.8	12.1	12.8	0.950	343.8	NO DAMAGE	
70	-20	8	0.00060	12.2	12.8	12.1	12.8	0.944	305.6	NO DAMAGE	
70	-30	7	0.00052	12.2	12.8	12.0	12.8	0.938	275.1	NO DAMAGE	
70	-40	11	0.00082	12.2	12.8	11.9	12.8	0.932	250.0	NO DAMAGE	
70	-45	2	0.00015	12.2	12.8	11.9	12.8	0.929	239.2	NO DAMAGE	
70	-50	13	0.00097	12.2	12.8	11.8	12.8	0.925	229.2	NO DAMAGE	
70	-55	1	0.00007	12.2	12.8	11.8	12.8	0.922	220.0	NO DAMAGE	
70	-60	15	0.00112	12.2	12.8	11.7	12.8	0.919	211.6	NO DAMAGE	
70	-70	13	0.00097	12.2	12.8	11.7	12.8	0.913	196.5	NO DAMAGE	
70	-75	1	0.00007	12.2	12.8	11.6	12.8	0.910	189.7	NO DAMAGE	
70	-80	7	0.00052	12.2	12.8	11.6	12.8	0.907	183.4	NO DAMAGE	
70	-90	7	0.00052	12.2	12.8	11.5	12.8	0.901	171.9	NO DAMAGE	
70	-95	3	0.00022	12.2	12.8	11.5	12.8	0.897	166.7	NO DAMAGE	
70	-100	7	0.00052	12.2	12.8	11.4	12.8	0.894	161.8	NO DAMAGE	
70	-105	1	0.00007	12.2	12.8	11.4	12.8	0.891	157.2	NO DAMAGE	
70	-110	3	0.00022	12.2	12.8	11.3	12.8	0.888	152.8	NO DAMAGE	
70	-120	1	0.00007	12.2	12.8	11.3	12.8	0.882	144.8	NO DAMAGE	
70	-125	1	0.00007	12.2	12.8	11.2	12.8	0.879	141.1	NO DAMAGE	
70	-130	2	0.00015	12.2	12.8	11.2	12.8	0.876	137.5	NO DAMAGE	
70	-135	1	0.00007	12.2	12.8	11.1	12.8	0.873	134.2	NO DAMAGE	
70	-140	4	0.00030	12.2	12.8	11.1	12.8	0.869	131.0	NO DAMAGE	
65	55	7279	0.54267	12.2	12.7	12.7	12.7	0.994	2742.0	NO DAMAGE	
65	50	1741	0.12980	12.2	12.7	12.6	12.7	0.991	1828.0	NO DAMAGE	
65	45	6262	0.46685	12.2	12.7	12.6	12.7	0.988	1371.0	NO DAMAGE	
65	40	731	0.05450	12.2	12.7	12.5	12.7	0.984	1096.8	NO DAMAGE	
65	35	2747	0.20480	12.2	12.7	12.5	12.7	0.981	914.0	NO DAMAGE	
65	30	194	0.01446	12.2	12.7	12.5	12.7	0.978	783.4	NO DAMAGE	
65	25	998	0.07440	12.2	12.7	12.4	12.7	0.975	685.5	NO DAMAGE	
65	20	64	0.00477	12.2	12.7	12.4	12.7	0.972	609.3	NO DAMAGE	
65	15	357	0.02662	12.2	12.7	12.3	12.7	0.969	548.4	NO DAMAGE	
65	10	15	0.00112	12.2	12.7	12.3	12.7	0.966	498.5	NO DAMAGE	
65	5	243	0.01812	12.2	12.7	12.3	12.7	0.963	457.0	NO DAMAGE	
65	0	10	0.00075	12.2	12.7	12.2	12.7	0.959	421.8	NO DAMAGE	
65	-5	12	0.00089	12.2	12.7	12.2	12.7	0.956	391.7	NO DAMAGE	
65	-15	5	0.00037	12.2	12.7	12.1	12.7	0.950	342.7	NO DAMAGE	
65	-25	2	0.00015	12.2	12.7	12.0	12.7	0.944	304.7	NO DAMAGE	
65	-35	4	0.00030	12.2	12.7	11.9	12.7	0.938	274.2	NO DAMAGE	
65	-45	4	0.00030	12.2	12.7	11.9	12.7	0.931	249.3	NO DAMAGE	
65	-50	1	0.00007	12.2	12.7	11.8	12.7	0.928	238.4	NO DAMAGE	
65	-55	1	0.00007	12.2	12.7	11.8	12.7	0.925	228.5	NO DAMAGE	
65	-65	3	0.00022	12.2	12.7	11.7	12.7	0.919	210.9	NO DAMAGE	
65	-75	2	0.00015	12.2	12.7	11.6	12.7	0.913	195.9	NO DAMAGE	
65	-80	3	0.00022	12.2	12.7	11.6	12.7	0.910	189.1	NO DAMAGE	
65	-85	4	0.00030	12.2	12.7	11.5	12.7	0.906	182.8	NO DAMAGE	
65	-95	3	0.00022	12.2	12.7	11.5	12.7	0.900	171.4	NO DAMAGE	
65	-125	2	0.00015	12.2	12.7	11.2	12.7	0.882	144.3	NO DAMAGE	
65	-135	1	0.00007	12.2	12.7	11.1	12.7	0.875	137.1	NO DAMAGE	
65	-145	1	0.00007	12.2	12.7	11.1	12.7	0.869	130.6	NO DAMAGE	
65	-155	2	0.00015	12.2	12.7	11.0	12.7	0.863	124.6	NO DAMAGE	
65	-195	1	0.00007	12.2	12.7	10.7	12.7	0.838	105.5	NO DAMAGE	
65	-205	1	0.00007	12.2	12.7	10.6	12.7	0.832	101.6	NO DAMAGE	
60	50	9784	0.72942	12.2	12.7	12.6	12.7	0.994	2733.4	NO DAMAGE	
60	45	1627	0.12130	12.2	12.7	12.6	12.7	0.991	1822.3	NO DAMAGE	
60	40	7071	0.52716	12.2	12.7	12.5	12.7	0.987	1366.7	NO DAMAGE	
60	35	637	0.04749	12.2	12.7	12.5	12.7	0.984	1093.4	NO DAMAGE	
60	30	2949	0.21986	12.2	12.7	12.5	12.7	0.981	911.1	NO DAMAGE	
60	25	225	0.01677	12.2	12.7	12.4	12.7	0.978	781.0	NO DAMAGE	
60	20	1559	0.11623	12.2	12.7	12.4	12.7	0.975	683.4	NO DAMAGE	
60	15	59	0.00440	12.2	12.7	12.3	12.7	0.972	607.4	NO DAMAGE	
60	10	740	0.05517	12.2	12.7	12.3	12.7	0.969	546.7	NO DAMAGE	
60	5	16	0.00119	12.2	12.7	12.3	12.7	0.966	497.0	NO DAMAGE	
60	0	419	0.03124	12.2	12.7	12.2	12.7	0.962	455.6	NO DAMAGE	
60	-5	3	0.00022	12.2	12.7	12.2	12.7	0.959	420.5	NO DAMAGE	
60	-10	132	0.00984	12.2	12.7	12.1	12.7	0.956	390.5	NO DAMAGE	
60	-15	1	0.00007	12.2	12.7	12.1	12.7	0.953	364.5	NO DAMAGE	
60	-20	7	0.00052	12.2	12.7	12.1	12.7	0.950	341.7	NO DAMAGE	
60	-25	1	0.00007	12.2	12.7	12.0	12.7	0.947	321.6	NO DAMAGE	
60	-30	11	0.00082	12.2	12.7	12.0	12.7	0.944	303.7	NO DAMAGE	
60	-40	7	0.00052	12.2	12.7	11.9	12.7	0.937	273.3	NO DAMAGE	
60	-50	10	0.00075	12.2	12.7	11.8	12.7	0.931	248.5	NO DAMAGE	
60	-55	1	0.00007	12.2	12.7	11.8	12.7	0.928	237.7	NO DAMAGE	
60	-60	10	0.00075	12.2	12.7	11.7	12.7	0.925	227.8	NO DAMAGE	
60	-70	14	0.00104	12.2	12.7	11.7	12.7	0.919	210.3	NO DAMAGE	
60	-80	9	0.00067	12.2	12.7	11.6	12.7	0.912	195.2	NO DAMAGE	
60	-90	7	0.00052	12.2	12.7	11.5	12.7	0.906	182.2	NO DAMAGE	

cycles per mile 153.8
Yield stress 50 ksi

			α	Static	Dynamic Stress		Max	R	Endurance	to Failure	
Max	Min	No.	Pct	Stress	Max	Min	Adjusted	Min/Max	Limit	N	α/N
60	-100	6	0.00045	12.2	12.7	11.4	12.7	0.900	170.8	NO DAMAGE	
60	-110	3	0.00022	12.2	12.7	11.3	12.7	0.894	160.8	NO DAMAGE	
60	-120	4	0.00030	12.2	12.7	11.3	12.7	0.887	151.9	NO DAMAGE	
60	-130	3	0.00022	12.2	12.7	11.2	12.7	0.881	143.9	NO DAMAGE	
60	-140	2	0.00015	12.2	12.7	11.1	12.7	0.875	136.7	NO DAMAGE	
60	-220	1	0.00007	12.2	12.7	10.5	12.7	0.825	97.6	NO DAMAGE	
55	45	8119	0.60529	12.2	12.7	12.6	12.7	0.994	2724.9	NO DAMAGE	
55	40	1589	0.11846	12.2	12.7	12.5	12.7	0.991	1816.6	NO DAMAGE	
55	35	6838	0.50979	12.2	12.7	12.5	12.7	0.987	1362.4	NO DAMAGE	
55	30	654	0.04876	12.2	12.7	12.5	12.7	0.984	1089.9	NO DAMAGE	
55	25	2920	0.21769	12.2	12.7	12.4	12.7	0.981	908.3	NO DAMAGE	
55	20	269	0.02005	12.2	12.7	12.4	12.7	0.978	778.5	NO DAMAGE	
55	15	1189	0.08864	12.2	12.7	12.3	12.7	0.975	681.2	NO DAMAGE	
55	10	61	0.00455	12.2	12.7	12.3	12.7	0.972	605.5	NO DAMAGE	
55	5	597	0.04451	12.2	12.7	12.3	12.7	0.969	545.0	NO DAMAGE	
55	0	26	0.00194	12.2	12.7	12.2	12.7	0.965	495.4	NO DAMAGE	
55	-5	38	0.00283	12.2	12.7	12.2	12.7	0.962	454.1	NO DAMAGE	
55	-10	1	0.00007	12.2	12.7	12.1	12.7	0.959	419.2	NO DAMAGE	
55	-15	6	0.00045	12.2	12.7	12.1	12.7	0.956	389.3	NO DAMAGE	
55	-25	7	0.00052	12.2	12.7	12.0	12.7	0.950	340.6	NO DAMAGE	
55	-35	2	0.00015	12.2	12.7	11.9	12.7	0.944	302.8	NO DAMAGE	
55	-45	4	0.00030	12.2	12.7	11.9	12.7	0.937	272.5	NO DAMAGE	
55	-55	1	0.00007	12.2	12.7	11.8	12.7	0.931	247.7	NO DAMAGE	
55	-65	3	0.00022	12.2	12.7	11.7	12.7	0.925	227.1	NO DAMAGE	
55	-70	1	0.00007	12.2	12.7	11.7	12.7	0.922	218.0	NO DAMAGE	
55	-75	1	0.00007	12.2	12.7	11.6	12.7	0.918	209.6	NO DAMAGE	
55	-85	1	0.00007	12.2	12.7	11.5	12.7	0.912	194.6	NO DAMAGE	
55	-95	3	0.00022	12.2	12.7	11.5	12.7	0.906	181.7	NO DAMAGE	
55	-105	3	0.00022	12.2	12.7	11.4	12.7	0.900	170.3	NO DAMAGE	
55	-110	1	0.00007	12.2	12.7	11.3	12.7	0.896	165.1	NO DAMAGE	
55	-115	1	0.00007	12.2	12.7	11.3	12.7	0.893	160.3	NO DAMAGE	
55	-135	2	0.00015	12.2	12.7	11.1	12.7	0.881	143.4	NO DAMAGE	
55	-150	1	0.00007	12.2	12.7	11.0	12.7	0.871	132.9	NO DAMAGE	
55	-165	1	0.00007	12.2	12.7	10.9	12.7	0.862	123.9	NO DAMAGE	
50	40	12549	0.93556	12.2	12.6	12.5	12.6	0.994	2716.3	NO DAMAGE	
50	35	1846	0.13762	12.2	12.6	12.5	12.6	0.991	1810.9	NO DAMAGE	
50	30	10880	0.81113	12.2	12.6	12.5	12.6	0.987	1358.2	NO DAMAGE	
50	25	787	0.05867	12.2	12.6	12.4	12.6	0.984	1086.5	NO DAMAGE	
50	20	5251	0.39148	12.2	12.6	12.4	12.6	0.981	905.4	NO DAMAGE	
50	15	264	0.01968	12.2	12.6	12.3	12.6	0.978	776.1	NO DAMAGE	
50	10	2229	0.16618	12.2	12.6	12.3	12.6	0.975	679.1	NO DAMAGE	
50	5	56	0.00417	12.2	12.6	12.3	12.6	0.972	603.6	NO DAMAGE	
50	0	885	0.06598	12.2	12.6	12.2	12.6	0.969	543.3	NO DAMAGE	
50	-5	9	0.00067	12.2	12.6	12.2	12.6	0.965	493.9	NO DAMAGE	
50	-10	181	0.01349	12.2	12.6	12.1	12.6	0.962	452.7	NO DAMAGE	
50	-20	15	0.00112	12.2	12.6	12.1	12.6	0.956	388.0	NO DAMAGE	
50	-25	1	0.00007	12.2	12.6	12.0	12.6	0.953	362.2	NO DAMAGE	
50	-30	12	0.00089	12.2	12.6	12.0	12.6	0.950	339.5	NO DAMAGE	
50	-40	17	0.00127	12.2	12.6	11.9	12.6	0.943	301.8	NO DAMAGE	
50	-45	1	0.00007	12.2	12.6	11.9	12.6	0.940	285.9	NO DAMAGE	
50	-50	20	0.00149	12.2	12.6	11.8	12.6	0.937	271.6	NO DAMAGE	
50	-60	19	0.00142	12.2	12.6	11.7	12.6	0.931	246.9	NO DAMAGE	
50	-65	1	0.00007	12.2	12.6	11.7	12.6	0.928	236.2	NO DAMAGE	
50	-70	9	0.00067	12.2	12.6	11.7	12.6	0.924	226.4	NO DAMAGE	
50	-75	2	0.00015	12.2	12.6	11.6	12.6	0.921	217.3	NO DAMAGE	
50	-80	8	0.00060	12.2	12.6	11.6	12.6	0.918	208.9	NO DAMAGE	
50	-90	6	0.00045	12.2	12.6	11.5	12.6	0.912	194.0	NO DAMAGE	
50	-100	4	0.00030	12.2	12.6	11.4	12.6	0.906	181.1	NO DAMAGE	
50	-105	1	0.00007	12.2	12.6	11.4	12.6	0.902	175.2	NO DAMAGE	
50	-110	2	0.00015	12.2	12.6	11.3	12.6	0.899	169.8	NO DAMAGE	
50	-120	2	0.00015	12.2	12.6	11.3	12.6	0.893	159.8	NO DAMAGE	
50	-130	2	0.00015	12.2	12.6	11.2	12.6	0.887	150.9	NO DAMAGE	
50	-140	1	0.00007	12.2	12.6	11.1	12.6	0.880	143.0	NO DAMAGE	
50	-210	1	0.00007	12.2	12.6	10.6	12.6	0.836	104.5	NO DAMAGE	
45	35	8451	0.63005	12.2	12.6	12.5	12.6	0.994	2707.8	NO DAMAGE	
45	30	1938	0.14448	12.2	12.6	12.5	12.6	0.991	1805.2	NO DAMAGE	
45	25	7167	0.53432	12.2	12.6	12.4	12.6	0.987	1353.9	NO DAMAGE	
45	20	859	0.06404	12.2	12.6	12.4	12.6	0.984	1083.1	NO DAMAGE	
45	15	3380	0.25199	12.2	12.6	12.3	12.6	0.981	902.6	NO DAMAGE	
45	10	291	0.02169	12.2	12.6	12.3	12.6	0.978	773.6	NO DAMAGE	
45	5	1312	0.09781	12.2	12.6	12.3	12.6	0.975	676.9	NO DAMAGE	
45	0	52	0.00388	12.2	12.6	12.2	12.6	0.972	601.7	NO DAMAGE	
45	-5	25	0.00186	12.2	12.6	12.2	12.6	0.968	541.6	NO DAMAGE	
45	-15	13	0.00097	12.2	12.6	12.1	12.6	0.962	451.3	NO DAMAGE	
45	-25	5	0.00037	12.2	12.6	12.0	12.6	0.956	386.8	NO DAMAGE	
45	-30	1	0.00007	12.2	12.6	12.0	12.6	0.953	361.0	NO DAMAGE	
45	-35	2	0.00015	12.2	12.6	11.9	12.6	0.949	338.5	NO DAMAGE	
45	-45	5	0.00037	12.2	12.6	11.9	12.6	0.943	300.9	NO DAMAGE	
45	-55	1	0.00007	12.2	12.6	11.8	12.6	0.937	270.8	NO DAMAGE	
45	-60	1	0.00007	12.2	12.6	11.7	12.6	0.934	257.9	NO DAMAGE	
45	-65	1	0.00007	12.2	12.6	11.7	12.6	0.931	246.2	NO DAMAGE	
45	-75	2	0.00015	12.2	12.6	11.6	12.6	0.924	225.6	NO DAMAGE	
45	-85	2	0.00015	12.2	12.6	11.5	12.6	0.918	208.3	NO DAMAGE	
45	-90	1	0.00007	12.2	12.6	11.5	12.6	0.915	200.6	NO DAMAGE	
45	-95	1	0.00007	12.2	12.6	11.5	12.6	0.912	193.4	NO DAMAGE	
45	-105	1	0.00007	12.2	12.6	11.4	12.6	0.905	180.5	NO DAMAGE	
45	-115	1	0.00007	12.2	12.6	11.3	12.6	0.899	169.2	NO DAMAGE	
45	-135	1	0.00007	12.2	12.6	11.1	12.6	0.886	150.4	NO DAMAGE	

cycles per mile 153.8
Yield stress 50 ksi

			α	Static	Dynamic Stress		Max	R	Endurance	to Failure	
Max	Min	No.	Pct	Stress	Max	Min	Adjusted	Min/Max	Limit	N	α/N
45	-145	2	0.00015	12.2	12.6	11.1	12.6	0.880	142.5	NO DAMAGE	
45	-165	1	0.00007	12.2	12.6	10.9	12.6	0.867	128.9	NO DAMAGE	
40	30	17965	1.33934	12.2	12.5	12.5	12.5	0.994	2699.2	NO DAMAGE	
40	25	2047	0.15261	12.2	12.5	12.4	12.5	0.990	1799.5	NO DAMAGE	
40	20	18409	1.37244	12.2	12.5	12.4	12.5	0.987	1349.6	NO DAMAGE	
40	15	1038	0.07739	12.2	12.5	12.3	12.5	0.984	1079.7	NO DAMAGE	
40	10	6033	0.44978	12.2	12.5	12.3	12.5	0.981	899.7	NO DAMAGE	
40	5	221	0.01648	12.2	12.5	12.3	12.5	0.978	771.2	NO DAMAGE	
40	0	1756	0.13091	12.2	12.5	12.2	12.5	0.975	674.8	NO DAMAGE	
40	-5	10	0.00075	12.2	12.5	12.2	12.5	0.971	599.8	NO DAMAGE	
40	-10	261	0.01946	12.2	12.5	12.1	12.5	0.968	539.8	NO DAMAGE	
40	-20	31	0.00231	12.2	12.5	12.1	12.5	0.962	449.9	NO DAMAGE	
40	-25	2	0.00015	12.2	12.5	12.0	12.5	0.959	415.3	NO DAMAGE	
40	-30	18	0.00134	12.2	12.5	12.0	12.5	0.956	385.6	NO DAMAGE	
40	-40	15	0.00112	12.2	12.5	11.9	12.5	0.949	337.4	NO DAMAGE	
40	-50	21	0.00157	12.2	12.5	11.8	12.5	0.943	299.9	NO DAMAGE	
40	-60	11	0.00082	12.2	12.5	11.7	12.5	0.937	269.9	NO DAMAGE	
40	-65	1	0.00007	12.2	12.5	11.7	12.5	0.933	257.1	NO DAMAGE	
40	-70	10	0.00075	12.2	12.5	11.7	12.5	0.930	245.4	NO DAMAGE	
40	-80	8	0.00060	12.2	12.5	11.6	12.5	0.924	224.9	NO DAMAGE	
40	-90	4	0.00030	12.2	12.5	11.5	12.5	0.918	207.6	NO DAMAGE	
40	-100	3	0.00022	12.2	12.5	11.4	12.5	0.911	192.8	NO DAMAGE	
40	-110	1	0.00007	12.2	12.5	11.3	12.5	0.905	179.9	NO DAMAGE	
40	-120	3	0.00022	12.2	12.5	11.3	12.5	0.899	168.7	NO DAMAGE	
40	-130	3	0.00022	12.2	12.5	11.2	12.5	0.892	158.8	NO DAMAGE	
40	-140	1	0.00007	12.2	12.5	11.1	12.5	0.886	150.0	NO DAMAGE	
35	25	8887	0.66255	12.2	12.5	12.4	12.5	0.994	2690.7	NO DAMAGE	
35	20	2334	0.17401	12.2	12.5	12.4	12.5	0.990	1793.8	NO DAMAGE	
35	15	8440	0.62923	12.2	12.5	12.3	12.5	0.987	1345.3	NO DAMAGE	
35	10	748	0.05577	12.2	12.5	12.3	12.5	0.984	1076.3	NO DAMAGE	
35	5	2726	0.20323	12.2	12.5	12.3	12.5	0.981	896.9	NO DAMAGE	
35	0	130	0.00969	12.2	12.5	12.2	12.5	0.978	768.8	NO DAMAGE	
35	-5	46	0.00343	12.2	12.5	12.2	12.5	0.975	672.7	NO DAMAGE	
35	-10	1	0.00007	12.2	12.5	12.1	12.5	0.971	597.9	NO DAMAGE	
35	-15	10	0.00075	12.2	12.5	12.1	12.5	0.968	538.1	NO DAMAGE	
35	-20	1	0.00007	12.2	12.5	12.1	12.5	0.965	489.2	NO DAMAGE	
35	-25	15	0.00112	12.2	12.5	12.0	12.5	0.962	448.4	NO DAMAGE	
35	-35	25	0.00186	12.2	12.5	11.9	12.5	0.956	384.4	NO DAMAGE	
35	-40	1	0.00007	12.2	12.5	11.9	12.5	0.952	358.8	NO DAMAGE	
35	-45	10	0.00075	12.2	12.5	11.9	12.5	0.949	336.3	NO DAMAGE	
35	-55	2	0.00015	12.2	12.5	11.8	12.5	0.943	299.0	NO DAMAGE	
35	-65	3	0.00022	12.2	12.5	11.7	12.5	0.936	269.1	NO DAMAGE	
35	-75	1	0.00007	12.2	12.5	11.6	12.5	0.930	244.6	NO DAMAGE	
35	-85	2	0.00015	12.2	12.5	11.5	12.5	0.924	224.2	NO DAMAGE	
35	-95	3	0.00022	12.2	12.5	11.5	12.5	0.917	207.0	NO DAMAGE	
35	-100	1	0.00007	12.2	12.5	11.4	12.5	0.914	199.3	NO DAMAGE	
35	-105	4	0.00030	12.2	12.5	11.4	12.5	0.911	192.2	NO DAMAGE	
35	-115	1	0.00007	12.2	12.5	11.3	12.5	0.905	179.4	NO DAMAGE	
35	-120	1	0.00007	12.2	12.5	11.3	12.5	0.901	173.6	NO DAMAGE	
35	-170	1	0.00007	12.2	12.5	10.9	12.5	0.870	131.3	NO DAMAGE	
30	20	22074	1.64568	12.2	12.5	12.4	12.5	0.994	2682.1	NO DAMAGE	
30	15	2052	0.15298	12.2	12.5	12.3	12.5	0.990	1788.1	NO DAMAGE	
30	10	16038	1.19568	12.2	12.5	12.3	12.5	0.987	1341.1	NO DAMAGE	
30	5	628	0.04682	12.2	12.5	12.3	12.5	0.984	1072.8	NO DAMAGE	
30	0	5070	0.37798	12.2	12.5	12.2	12.5	0.981	894.0	NO DAMAGE	
30	-5	24	0.00179	12.2	12.5	12.2	12.5	0.978	766.3	NO DAMAGE	
30	-10	474	0.03534	12.2	12.5	12.1	12.5	0.974	670.5	NO DAMAGE	
30	-15	1	0.00007	12.2	12.5	12.1	12.5	0.971	596.0	NO DAMAGE	
30	-20	25	0.00186	12.2	12.5	12.1	12.5	0.968	536.4	NO DAMAGE	
30	-25	1	0.00007	12.2	12.5	12.0	12.5	0.965	487.7	NO DAMAGE	
30	-30	35	0.00261	12.2	12.5	12.0	12.5	0.962	447.0	NO DAMAGE	
30	-40	27	0.00201	12.2	12.5	11.9	12.5	0.955	383.2	NO DAMAGE	
30	-50	23	0.00171	12.2	12.5	11.8	12.5	0.949	335.3	NO DAMAGE	
30	-60	20	0.00149	12.2	12.5	11.7	12.5	0.943	298.0	NO DAMAGE	
30	-65	1	0.00007	12.2	12.5	11.7	12.5	0.939	282.3	NO DAMAGE	
30	-70	9	0.00067	12.2	12.5	11.7	12.5	0.936	268.2	NO DAMAGE	
30	-80	5	0.00037	12.2	12.5	11.6	12.5	0.930	243.8	NO DAMAGE	
30	-90	6	0.00045	12.2	12.5	11.5	12.5	0.923	223.5	NO DAMAGE	
30	-95	2	0.00015	12.2	12.5	11.5	12.5	0.920	214.6	NO DAMAGE	
30	-100	2	0.00015	12.2	12.5	11.4	12.5	0.917	206.3	NO DAMAGE	
30	-110	2	0.00015	12.2	12.5	11.3	12.5	0.911	191.6	NO DAMAGE	
30	-120	1	0.00007	12.2	12.5	11.3	12.5	0.904	178.8	NO DAMAGE	
30	-125	1	0.00007	12.2	12.5	11.2	12.5	0.901	173.0	NO DAMAGE	
30	-135	1	0.00007	12.2	12.5	11.1	12.5	0.895	162.6	NO DAMAGE	
30	-140	1	0.00007	12.2	12.5	11.1	12.5	0.892	157.8	NO DAMAGE	
30	-145	1	0.00007	12.2	12.5	11.1	12.5	0.888	153.3	NO DAMAGE	
30	-200	1	0.00007	12.2	12.5	10.6	12.5	0.853	116.6	NO DAMAGE	
30	-210	1	0.00007	12.2	12.5	10.6	12.5	0.847	111.8	NO DAMAGE	
30	-270	1	0.00007	12.2	12.5	10.1	12.5	0.809	89.4	NO DAMAGE	
25	15	9876	0.73628	12.2	12.4	12.3	12.4	0.994	2673.6	NO DAMAGE	
25	10	1825	0.13606	12.2	12.4	12.3	12.4	0.990	1782.4	NO DAMAGE	
25	5	7958	0.59329	12.2	12.4	12.3	12.4	0.987	1336.8	NO DAMAGE	
25	0	410	0.03057	12.2	12.4	12.2	12.4	0.984	1069.4	NO DAMAGE	
25	-5	105	0.00783	12.2	12.4	12.2	12.4	0.981	891.2	NO DAMAGE	
25	-10	1	0.00007	12.2	12.4	12.1	12.4	0.978	763.9	NO DAMAGE	
25	-15	33	0.00246	12.2	12.4	12.1	12.4	0.974	668.4	NO DAMAGE	
25	-20	3	0.00022	12.2	12.4	12.1	12.4	0.971	594.1	NO DAMAGE	
25	-25	317	0.02363	12.2	12.4	12.0	12.4	0.968	534.7	NO DAMAGE	

cycles per mile 153.8
Yield stress 50 ksi

			α	Static	Dynamic Stress		Max	R	Endurance	to Failure	
Max	Min	No.	Pct	Stress	Max	Min	Adjusted	Min/Max	Limit	N	α/N
25	-30	1	0.00007	12.2	12.4	12.0	12.4	0.965	486.1	NO DAMAGE	
25	-35	89	0.00664	12.2	12.4	11.9	12.4	0.962	445.6	NO DAMAGE	
25	-40	2	0.00015	12.2	12.4	11.9	12.4	0.958	411.3	NO DAMAGE	
25	-45	11	0.00082	12.2	12.4	11.9	12.4	0.955	381.9	NO DAMAGE	
25	-65	3	0.00022	12.2	12.4	11.7	12.4	0.942	297.1	NO DAMAGE	
25	-70	1	0.00007	12.2	12.4	11.7	12.4	0.939	281.4	NO DAMAGE	
25	-75	3	0.00022	12.2	12.4	11.6	12.4	0.936	267.4	NO DAMAGE	
25	-85	1	0.00007	12.2	12.4	11.5	12.4	0.930	243.1	NO DAMAGE	
25	-95	3	0.00022	12.2	12.4	11.5	12.4	0.923	222.8	NO DAMAGE	
25	-105	6	0.00045	12.2	12.4	11.4	12.4	0.917	205.7	NO DAMAGE	
25	-125	3	0.00022	12.2	12.4	11.2	12.4	0.904	178.2	NO DAMAGE	
25	-135	1	0.00007	12.2	12.4	11.1	12.4	0.898	167.1	NO DAMAGE	
25	-145	1	0.00007	12.2	12.4	11.1	12.4	0.891	157.3	NO DAMAGE	
25	-155	1	0.00007	12.2	12.4	11.0	12.4	0.885	148.5	NO DAMAGE	
20	10	22202	1.65522	12.2	12.4	12.3	12.4	0.994	2665.0	NO DAMAGE	
20	5	1921	0.14322	12.2	12.4	12.3	12.4	0.990	1776.7	NO DAMAGE	
20	0	21178	1.57888	12.2	12.4	12.2	12.4	0.987	1332.5	NO DAMAGE	
20	-5	101	0.00753	12.2	12.4	12.2	12.4	0.984	1066.0	NO DAMAGE	
20	-10	1141	0.08506	12.2	12.4	12.1	12.4	0.981	888.3	NO DAMAGE	
20	-15	4	0.00030	12.2	12.4	12.1	12.4	0.978	761.4	NO DAMAGE	
20	-20	49	0.00365	12.2	12.4	12.1	12.4	0.974	666.3	NO DAMAGE	
20	-25	1	0.00007	12.2	12.4	12.0	12.4	0.971	592.2	NO DAMAGE	
20	-30	47	0.00350	12.2	12.4	12.0	12.4	0.968	533.0	NO DAMAGE	
20	-40	39	0.00291	12.2	12.4	11.9	12.4	0.962	444.2	NO DAMAGE	
20	-45	1	0.00007	12.2	12.4	11.9	12.4	0.958	410.0	NO DAMAGE	
20	-50	22	0.00164	12.2	12.4	11.8	12.4	0.955	380.7	NO DAMAGE	
20	-55	1	0.00007	12.2	12.4	11.8	12.4	0.952	355.3	NO DAMAGE	
20	-60	12	0.00089	12.2	12.4	11.7	12.4	0.949	333.1	NO DAMAGE	
20	-65	1	0.00007	12.2	12.4	11.7	12.4	0.945	313.5	NO DAMAGE	
20	-70	10	0.00075	12.2	12.4	11.7	12.4	0.942	296.1	NO DAMAGE	
20	-80	10	0.00075	12.2	12.4	11.6	12.4	0.936	266.5	NO DAMAGE	
20	-85	1	0.00007	12.2	12.4	11.5	12.4	0.933	253.8	NO DAMAGE	
20	-90	6	0.00045	12.2	12.4	11.5	12.4	0.929	242.3	NO DAMAGE	
20	-100	2	0.00015	12.2	12.4	11.4	12.4	0.923	222.1	NO DAMAGE	
20	-110	2	0.00015	12.2	12.4	11.3	12.4	0.917	205.0	NO DAMAGE	
20	-130	1	0.00007	12.2	12.4	11.2	12.4	0.904	177.7	NO DAMAGE	
20	-185	1	0.00007	12.2	12.4	10.8	12.4	0.868	130.0	NO DAMAGE	
15	5	10885	0.81151	12.2	12.3	12.3	12.3	0.994	2656.5	NO DAMAGE	
15	0	1626	0.12122	12.2	12.3	12.2	12.3	0.990	1771.0	NO DAMAGE	
15	-5	1500	0.11183	12.2	12.3	12.2	12.3	0.987	1328.2	NO DAMAGE	
15	-10	1	0.00007	12.2	12.3	12.1	12.3	0.984	1062.6	NO DAMAGE	
15	-15	1448	0.10795	12.2	12.3	12.1	12.3	0.981	885.5	NO DAMAGE	
15	-20	7	0.00052	12.2	12.3	12.1	12.3	0.977	759.0	NO DAMAGE	
15	-25	657	0.04898	12.2	12.3	12.0	12.3	0.974	664.1	NO DAMAGE	
15	-30	1	0.00007	12.2	12.3	12.0	12.3	0.971	590.3	NO DAMAGE	
15	-35	14	0.00104	12.2	12.3	11.9	12.3	0.968	531.3	NO DAMAGE	
15	-40	2	0.00015	12.2	12.3	11.9	12.3	0.965	483.0	NO DAMAGE	
15	-45	5	0.00037	12.2	12.3	11.9	12.3	0.961	442.7	NO DAMAGE	
15	-55	3	0.00022	12.2	12.3	11.8	12.3	0.955	379.5	NO DAMAGE	
15	-65	3	0.00022	12.2	12.3	11.7	12.3	0.949	332.1	NO DAMAGE	
15	-70	1	0.00007	12.2	12.3	11.7	12.3	0.945	312.5	NO DAMAGE	
15	-75	1	0.00007	12.2	12.3	11.6	12.3	0.942	295.2	NO DAMAGE	
15	-80	1	0.00007	12.2	12.3	11.6	12.3	0.939	279.6	NO DAMAGE	
15	-85	3	0.00022	12.2	12.3	11.5	12.3	0.936	265.6	NO DAMAGE	
15	-95	5	0.00037	12.2	12.3	11.5	12.3	0.929	241.5	NO DAMAGE	
15	-100	1	0.00007	12.2	12.3	11.4	12.3	0.926	231.0	NO DAMAGE	
15	-105	8	0.00060	12.2	12.3	11.4	12.3	0.923	221.4	NO DAMAGE	
15	-125	2	0.00015	12.2	12.3	11.2	12.3	0.910	189.7	NO DAMAGE	
15	-155	2	0.00015	12.2	12.3	11.0	12.3	0.891	156.3	NO DAMAGE	
15	-195	1	0.00007	12.2	12.3	10.7	12.3	0.865	126.5	NO DAMAGE	
15	-235	1	0.00007	12.2	12.3	10.4	12.3	0.839	106.3	NO DAMAGE	
10	0	37244	2.77664	12.2	12.3	12.2	12.3	0.994	2647.9	NO DAMAGE	
10	-5	1213	0.09043	12.2	12.3	12.2	12.3	0.990	1765.3	NO DAMAGE	
10	-10	11887	0.88621	12.2	12.3	12.1	12.3	0.987	1324.0	NO DAMAGE	
10	-15	26	0.00194	12.2	12.3	12.1	12.3	0.984	1059.2	NO DAMAGE	
10	-20	95	0.00708	12.2	12.3	12.1	12.3	0.981	882.6	NO DAMAGE	
10	-25	2	0.00015	12.2	12.3	12.0	12.3	0.977	756.5	NO DAMAGE	
10	-30	77	0.00574	12.2	12.3	12.0	12.3	0.974	662.0	NO DAMAGE	
10	-35	3	0.00022	12.2	12.3	11.9	12.3	0.971	588.4	NO DAMAGE	
10	-40	38	0.00283	12.2	12.3	11.9	12.3	0.968	529.6	NO DAMAGE	
10	-50	25	0.00186	12.2	12.3	11.8	12.3	0.961	441.3	NO DAMAGE	
10	-55	1	0.00007	12.2	12.3	11.8	12.3	0.958	407.4	NO DAMAGE	
10	-60	7	0.00052	12.2	12.3	11.7	12.3	0.955	378.3	NO DAMAGE	
10	-70	11	0.00082	12.2	12.3	11.7	12.3	0.948	331.0	NO DAMAGE	
10	-75	2	0.00015	12.2	12.3	11.6	12.3	0.945	311.5	NO DAMAGE	
10	-80	9	0.00067	12.2	12.3	11.6	12.3	0.942	294.2	NO DAMAGE	
10	-90	7	0.00052	12.2	12.3	11.5	12.3	0.935	264.8	NO DAMAGE	
10	-95	1	0.00007	12.2	12.3	11.5	12.3	0.932	252.2	NO DAMAGE	
10	-100	6	0.00045	12.2	12.3	11.4	12.3	0.929	240.7	NO DAMAGE	
10	-110	1	0.00007	12.2	12.3	11.3	12.3	0.923	220.7	NO DAMAGE	
10	-160	1	0.00007	12.2	12.3	10.9	12.3	0.890	155.8	NO DAMAGE	
10	-175	1	0.00007	12.2	12.3	10.8	12.3	0.881	143.1	NO DAMAGE	
10	-190	2	0.00015	12.2	12.3	10.7	12.3	0.871	132.4	NO DAMAGE	
10	-255	1	0.00007	12.2	12.3	10.2	12.3	0.829	99.9	NO DAMAGE	
5	-5	8727	0.65062	12.2	12.3	12.2	12.3	0.994	2639.4	NO DAMAGE	
5	-10	15	0.00112	12.2	12.3	12.1	12.3	0.990	1759.6	NO DAMAGE	
5	-15	4923	0.36702	12.2	12.3	12.1	12.3	0.987	1319.7	NO DAMAGE	
5	-20	5	0.00037	12.2	12.3	12.1	12.3	0.984	1055.7	NO DAMAGE	

cycles per mile 153.8
Yield stress 50 ksi

			α	Static	Dynamic Stress		Max	R	Endurance	to Failure	
Max	Min	No.	Pct	Stress	Max	Min	Adjusted	Min/Max	Limit	N	α/N
5	-25	386	0.02878	12.2	12.3	12.0	12.3	0.981	879.8	NO DAMAGE	
5	-30	4	0.00030	12.2	12.3	12.0	12.3	0.977	754.1	NO DAMAGE	
5	-35	51	0.00380	12.2	12.3	11.9	12.3	0.974	659.8	NO DAMAGE	
5	-40	1	0.00007	12.2	12.3	11.9	12.3	0.971	586.5	NO DAMAGE	
5	-45	17	0.00127	12.2	12.3	11.9	12.3	0.968	527.9	NO DAMAGE	
5	-50	3	0.00022	12.2	12.3	11.8	12.3	0.964	479.9	NO DAMAGE	
5	-55	17	0.00127	12.2	12.3	11.8	12.3	0.961	439.9	NO DAMAGE	
5	-60	1	0.00007	12.2	12.3	11.7	12.3	0.958	406.1	NO DAMAGE	
5	-65	4	0.00030	12.2	12.3	11.7	12.3	0.955	377.1	NO DAMAGE	
5	-75	7	0.00052	12.2	12.3	11.6	12.3	0.948	329.9	NO DAMAGE	
5	-85	4	0.00030	12.2	12.3	11.5	12.3	0.942	293.3	NO DAMAGE	
5	-90	1	0.00007	12.2	12.3	11.5	12.3	0.938	277.8	NO DAMAGE	
5	-95	4	0.00030	12.2	12.3	11.5	12.3	0.935	263.9	NO DAMAGE	
5	-110	1	0.00007	12.2	12.3	11.3	12.3	0.925	229.5	NO DAMAGE	
5	-115	2	0.00015	12.2	12.3	11.3	12.3	0.922	219.9	NO DAMAGE	
5	-125	1	0.00007	12.2	12.3	11.2	12.3	0.916	203.0	NO DAMAGE	
5	-145	1	0.00007	12.2	12.3	11.1	12.3	0.903	176.0	NO DAMAGE	
5	-155	1	0.00007	12.2	12.3	11.0	12.3	0.896	165.0	NO DAMAGE	
5	-165	1	0.00007	12.2	12.3	10.9	12.3	0.890	155.3	NO DAMAGE	
5	-175	1	0.00007	12.2	12.3	10.8	12.3	0.883	146.6	NO DAMAGE	
5	-255	1	0.00007	12.2	12.3	10.2	12.3	0.832	101.5	NO DAMAGE	
5	-285	1	0.00007	12.2	12.3	10.0	12.3	0.812	91.0	NO DAMAGE	
0	-10	9883	0.73680	12.2	12.2	12.1	12.2	0.994	2630.8	NO DAMAGE	
0	-15	1482	0.11049	12.2	12.2	12.1	12.2	0.990	1753.9	NO DAMAGE	
0	-20	595	0.04436	12.2	12.2	12.1	12.2	0.987	1315.4	NO DAMAGE	
0	-25	59	0.00440	12.2	12.2	12.0	12.2	0.984	1052.3	NO DAMAGE	
0	-30	122	0.00910	12.2	12.2	12.0	12.2	0.981	876.9	NO DAMAGE	
0	-35	15	0.00112	12.2	12.2	11.9	12.2	0.977	751.7	NO DAMAGE	
0	-40	36	0.00268	12.2	12.2	11.9	12.2	0.974	657.7	NO DAMAGE	
0	-45	5	0.00037	12.2	12.2	11.9	12.2	0.971	584.6	NO DAMAGE	
0	-50	35	0.00261	12.2	12.2	11.8	12.2	0.968	526.2	NO DAMAGE	
0	-55	4	0.00030	12.2	12.2	11.8	12.2	0.964	478.3	NO DAMAGE	
0	-60	13	0.00097	12.2	12.2	11.7	12.2	0.961	438.5	NO DAMAGE	
0	-65	2	0.00015	12.2	12.2	11.7	12.2	0.958	404.7	NO DAMAGE	
0	-70	12	0.00089	12.2	12.2	11.7	12.2	0.955	375.8	NO DAMAGE	
0	-75	2	0.00015	12.2	12.2	11.6	12.2	0.951	350.8	NO DAMAGE	
0	-80	7	0.00052	12.2	12.2	11.6	12.2	0.948	328.9	NO DAMAGE	
0	-85	3	0.00022	12.2	12.2	11.5	12.2	0.945	309.5	NO DAMAGE	
0	-90	5	0.00037	12.2	12.2	11.5	12.2	0.942	292.3	NO DAMAGE	
0	-95	2	0.00015	12.2	12.2	11.5	12.2	0.938	276.9	NO DAMAGE	
0	-100	9	0.00067	12.2	12.2	11.4	12.2	0.935	263.1	NO DAMAGE	
0	-105	2	0.00015	12.2	12.2	11.4	12.2	0.932	250.6	NO DAMAGE	
0	-110	4	0.00030	12.2	12.2	11.3	12.2	0.929	239.2	NO DAMAGE	
0	-120	3	0.00022	12.2	12.2	11.3	12.2	0.922	219.2	NO DAMAGE	
0	-125	3	0.00022	12.2	12.2	11.2	12.2	0.919	210.5	NO DAMAGE	
0	-140	1	0.00007	12.2	12.2	11.1	12.2	0.909	187.9	NO DAMAGE	
0	-155	1	0.00007	12.2	12.2	11.0	12.2	0.899	169.7	NO DAMAGE	
0	-180	1	0.00007	12.2	12.2	10.8	12.2	0.883	146.2	NO DAMAGE	
-5	-15	19509	1.45445	12.2	12.2	12.1	12.2	0.993	2622.3	NO DAMAGE	
-5	-20	1685	0.12562	12.2	12.2	12.1	12.2	0.990	1748.2	NO DAMAGE	
-5	-25	7756	0.57823	12.2	12.2	12.0	12.2	0.987	1311.1	NO DAMAGE	
-5	-30	412	0.03072	12.2	12.2	12.0	12.2	0.984	1048.9	NO DAMAGE	
-5	-35	2199	0.16394	12.2	12.2	11.9	12.2	0.980	874.1	NO DAMAGE	
-5	-40	111	0.00828	12.2	12.2	11.9	12.2	0.977	749.2	NO DAMAGE	
-5	-45	789	0.05882	12.2	12.2	11.9	12.2	0.974	655.6	NO DAMAGE	
-5	-50	49	0.00365	12.2	12.2	11.8	12.2	0.971	582.7	NO DAMAGE	
-5	-55	349	0.02602	12.2	12.2	11.8	12.2	0.967	524.5	NO DAMAGE	
-5	-60	12	0.00089	12.2	12.2	11.7	12.2	0.964	476.8	NO DAMAGE	
-5	-65	127	0.00947	12.2	12.2	11.7	12.2	0.961	437.0	NO DAMAGE	
-5	-70	11	0.00082	12.2	12.2	11.7	12.2	0.958	403.4	NO DAMAGE	
-5	-75	45	0.00335	12.2	12.2	11.6	12.2	0.954	374.6	NO DAMAGE	
-5	-80	6	0.00045	12.2	12.2	11.6	12.2	0.951	349.6	NO DAMAGE	
-5	-85	41	0.00306	12.2	12.2	11.5	12.2	0.948	327.8	NO DAMAGE	
-5	-90	5	0.00037	12.2	12.2	11.5	12.2	0.945	308.5	NO DAMAGE	
-5	-95	47	0.00350	12.2	12.2	11.5	12.2	0.941	291.4	NO DAMAGE	
-5	-100	7	0.00052	12.2	12.2	11.4	12.2	0.938	276.0	NO DAMAGE	
-5	-105	13	0.00097	12.2	12.2	11.4	12.2	0.935	262.2	NO DAMAGE	
-5	-110	1	0.00007	12.2	12.2	11.3	12.2	0.932	249.7	NO DAMAGE	
-5	-115	14	0.00104	12.2	12.2	11.3	12.2	0.928	238.4	NO DAMAGE	
-5	-125	4	0.00030	12.2	12.2	11.2	12.2	0.922	218.5	NO DAMAGE	
-5	-135	3	0.00022	12.2	12.2	11.1	12.2	0.915	201.7	NO DAMAGE	
-5	-145	3	0.00022	12.2	12.2	11.1	12.2	0.909	187.3	NO DAMAGE	
-5	-155	1	0.00007	12.2	12.2	11.0	12.2	0.902	174.8	NO DAMAGE	
-5	-165	1	0.00007	12.2	12.2	10.9	12.2	0.896	163.9	NO DAMAGE	
-5	-175	1	0.00007	12.2	12.2	10.8	12.2	0.889	154.3	NO DAMAGE	
-5	-185	1	0.00007	12.2	12.2	10.8	12.2	0.883	145.7	NO DAMAGE	
-5	-205	2	0.00015	12.2	12.2	10.6	12.2	0.870	131.1	NO DAMAGE	
-5	-215	1	0.00007	12.2	12.2	10.5	12.2	0.863	124.9	NO DAMAGE	
-5	-235	1	0.00007	12.2	12.2	10.4	12.2	0.850	114.0	NO DAMAGE	
-10	-20	31560	2.35289	12.2	12.1	12.1	12.1	0.993	2613.7	NO DAMAGE	
-10	-25	5740	0.42793	12.2	12.1	12.0	12.1	0.990	1742.5	NO DAMAGE	
-10	-30	19970	1.48882	12.2	12.1	12.0	12.1	0.987	1306.9	NO DAMAGE	
-10	-35	956	0.07127	12.2	12.1	11.9	12.1	0.984	1045.5	NO DAMAGE	
-10	-40	5567	0.41504	12.2	12.1	11.9	12.1	0.980	871.2	NO DAMAGE	
-10	-45	300	0.02237	12.2	12.1	11.9	12.1	0.977	746.8	NO DAMAGE	
-10	-50	1639	0.12219	12.2	12.1	11.8	12.1	0.974	653.4	NO DAMAGE	
-10	-55	37	0.00276	12.2	12.1	11.8	12.1	0.971	580.8	NO DAMAGE	
-10	-60	645	0.04809	12.2	12.1	11.7	12.1	0.967	522.7	NO DAMAGE	

cycles per mile 153.8
Yield stress 50 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
-10	-65	11	0.00082	12.2	12.1	11.7	12.1	0.964	475.2	NO DAMAGE	
-10	-70	300	0.02237	12.2	12.1	11.7	12.1	0.961	435.6	NO DAMAGE	
-10	-75	2	0.00015	12.2	12.1	11.6	12.1	0.957	402.1	NO DAMAGE	
-10	-80	215	0.01603	12.2	12.1	11.6	12.1	0.954	373.4	NO DAMAGE	
-10	-85	7	0.00052	12.2	12.1	11.5	12.1	0.951	348.5	NO DAMAGE	
-10	-90	114	0.00850	12.2	12.1	11.5	12.1	0.948	326.7	NO DAMAGE	
-10	-95	1	0.00007	12.2	12.1	11.5	12.1	0.944	307.5	NO DAMAGE	
-10	-100	63	0.00470	12.2	12.1	11.4	12.1	0.941	290.4	NO DAMAGE	
-10	-105	2	0.00015	12.2	12.1	11.4	12.1	0.938	275.1	NO DAMAGE	
-10	-110	46	0.00343	12.2	12.1	11.3	12.1	0.935	261.4	NO DAMAGE	
-10	-115	3	0.00022	12.2	12.1	11.3	12.1	0.931	248.9	NO DAMAGE	
-10	-120	21	0.00157	12.2	12.1	11.3	12.1	0.928	237.6	NO DAMAGE	
-10	-125	1	0.00007	12.2	12.1	11.2	12.1	0.925	227.3	NO DAMAGE	
-10	-130	12	0.00089	12.2	12.1	11.2	12.1	0.921	217.8	NO DAMAGE	
-10	-140	6	0.00045	12.2	12.1	11.1	12.1	0.915	201.1	NO DAMAGE	
-10	-150	6	0.00045	12.2	12.1	11.0	12.1	0.908	186.7	NO DAMAGE	
-10	-155	2	0.00015	12.2	12.1	11.0	12.1	0.905	180.3	NO DAMAGE	
-10	-160	2	0.00015	12.2	12.1	10.9	12.1	0.902	174.2	NO DAMAGE	
-10	-170	5	0.00037	12.2	12.1	10.9	12.1	0.895	163.4	NO DAMAGE	
-10	-180	1	0.00007	12.2	12.1	10.8	12.1	0.889	153.7	NO DAMAGE	
-10	-190	1	0.00007	12.2	12.1	10.7	12.1	0.882	145.2	NO DAMAGE	
-10	-195	1	0.00007	12.2	12.1	10.7	12.1	0.879	141.3	NO DAMAGE	
-10	-200	1	0.00007	12.2	12.1	10.6	12.1	0.876	137.6	NO DAMAGE	
-10	-210	1	0.00007	12.2	12.1	10.6	12.1	0.869	130.7	NO DAMAGE	
-10	-220	1	0.00007	12.2	12.1	10.5	12.1	0.863	124.5	NO DAMAGE	
-15	-25	15612	1.16392	12.2	12.1	12.0	12.1	0.993	2605.2	NO DAMAGE	
-15	-30	4802	0.35800	12.2	12.1	12.0	12.1	0.990	1736.8	NO DAMAGE	
-15	-35	11214	0.83603	12.2	12.1	11.9	12.1	0.987	1302.6	NO DAMAGE	
-15	-40	1636	0.12197	12.2	12.1	11.9	12.1	0.984	1042.1	NO DAMAGE	
-15	-45	2753	0.20524	12.2	12.1	11.9	12.1	0.980	868.4	NO DAMAGE	
-15	-50	106	0.00790	12.2	12.1	11.8	12.1	0.977	744.3	NO DAMAGE	
-15	-55	686	0.05114	12.2	12.1	11.8	12.1	0.974	651.3	NO DAMAGE	
-15	-60	20	0.00149	12.2	12.1	11.7	12.1	0.970	578.9	NO DAMAGE	
-15	-65	218	0.01625	12.2	12.1	11.7	12.1	0.967	521.0	NO DAMAGE	
-15	-70	12	0.00089	12.2	12.1	11.7	12.1	0.964	473.7	NO DAMAGE	
-15	-75	106	0.00790	12.2	12.1	11.6	12.1	0.961	434.2	NO DAMAGE	
-15	-80	3	0.00022	12.2	12.1	11.6	12.1	0.957	400.8	NO DAMAGE	
-15	-85	68	0.00507	12.2	12.1	11.5	12.1	0.954	372.2	NO DAMAGE	
-15	-90	1	0.00007	12.2	12.1	11.5	12.1	0.951	347.4	NO DAMAGE	
-15	-95	28	0.00209	12.2	12.1	11.5	12.1	0.947	325.6	NO DAMAGE	
-15	-100	3	0.00022	12.2	12.1	11.4	12.1	0.944	306.5	NO DAMAGE	
-15	-105	13	0.00097	12.2	12.1	11.4	12.1	0.941	289.5	NO DAMAGE	
-15	-110	1	0.00007	12.2	12.1	11.3	12.1	0.938	274.2	NO DAMAGE	
-15	-115	5	0.00037	12.2	12.1	11.3	12.1	0.934	260.5	NO DAMAGE	
-15	-120	1	0.00007	12.2	12.1	11.3	12.1	0.931	248.1	NO DAMAGE	
-15	-125	3	0.00022	12.2	12.1	11.2	12.1	0.928	236.8	NO DAMAGE	
-15	-135	2	0.00015	12.2	12.1	11.1	12.1	0.921	217.1	NO DAMAGE	
-15	-145	4	0.00030	12.2	12.1	11.1	12.1	0.915	200.4	NO DAMAGE	
-15	-155	1	0.00007	12.2	12.1	11.0	12.1	0.908	186.1	NO DAMAGE	
-15	-160	1	0.00007	12.2	12.1	10.9	12.1	0.905	179.7	NO DAMAGE	
-15	-165	3	0.00022	12.2	12.1	10.9	12.1	0.902	173.7	NO DAMAGE	
-15	-170	2	0.00015	12.2	12.1	10.9	12.1	0.898	168.1	NO DAMAGE	
-15	-185	1	0.00007	12.2	12.1	10.8	12.1	0.888	153.2	NO DAMAGE	
-15	-205	1	0.00007	12.2	12.1	10.6	12.1	0.875	137.1	NO DAMAGE	
-15	-240	1	0.00007	12.2	12.1	10.3	12.1	0.852	115.8	NO DAMAGE	
-15	-245	1	0.00007	12.2	12.1	10.3	12.1	0.849	113.3	NO DAMAGE	
-20	-30	30520	2.27535	12.2	12.1	12.0	12.1	0.993	2596.6	NO DAMAGE	
-20	-35	6326	0.47162	12.2	12.1	11.9	12.1	0.990	1731.1	NO DAMAGE	
-20	-40	18311	1.36514	12.2	12.1	11.9	12.1	0.987	1298.3	NO DAMAGE	
-20	-45	518	0.03862	12.2	12.1	11.9	12.1	0.984	1038.6	NO DAMAGE	
-20	-50	5081	0.37880	12.2	12.1	11.8	12.1	0.980	865.5	NO DAMAGE	
-20	-55	59	0.00440	12.2	12.1	11.8	12.1	0.977	741.9	NO DAMAGE	
-20	-60	1465	0.10922	12.2	12.1	11.7	12.1	0.974	649.2	NO DAMAGE	
-20	-65	29	0.00216	12.2	12.1	11.7	12.1	0.970	577.0	NO DAMAGE	
-20	-70	431	0.03213	12.2	12.1	11.7	12.1	0.967	519.3	NO DAMAGE	
-20	-75	8	0.00060	12.2	12.1	11.6	12.1	0.964	472.1	NO DAMAGE	
-20	-80	196	0.01461	12.2	12.1	11.6	12.1	0.960	432.8	NO DAMAGE	
-20	-85	3	0.00022	12.2	12.1	11.5	12.1	0.957	399.5	NO DAMAGE	
-20	-90	52	0.00388	12.2	12.1	11.5	12.1	0.954	370.9	NO DAMAGE	
-20	-95	2	0.00015	12.2	12.1	11.5	12.1	0.951	346.2	NO DAMAGE	
-20	-100	34	0.00253	12.2	12.1	11.4	12.1	0.947	324.6	NO DAMAGE	
-20	-110	11	0.00082	12.2	12.1	11.3	12.1	0.941	288.5	NO DAMAGE	
-20	-120	13	0.00097	12.2	12.1	11.3	12.1	0.934	259.7	NO DAMAGE	
-20	-130	4	0.00030	12.2	12.1	11.2	12.1	0.928	236.1	NO DAMAGE	
-20	-150	1	0.00007	12.2	12.1	11.0	12.1	0.914	199.7	NO DAMAGE	
-20	-155	1	0.00007	12.2	12.1	11.0	12.1	0.911	192.3	NO DAMAGE	
-20	-160	3	0.00022	12.2	12.1	10.9	12.1	0.908	185.5	NO DAMAGE	
-20	-170	1	0.00007	12.2	12.1	10.9	12.1	0.901	173.1	NO DAMAGE	
-25	-35	14163	1.05589	12.2	12.0	11.9	12.0	0.993	2588.1	NO DAMAGE	
-25	-40	2509	0.18705	12.2	12.0	11.9	12.0	0.990	1725.4	NO DAMAGE	
-25	-45	7096	0.52903	12.2	12.0	11.9	12.0	0.987	1294.0	NO DAMAGE	
-25	-50	460	0.03429	12.2	12.0	11.8	12.0	0.983	1035.2	NO DAMAGE	
-25	-55	2477	0.18467	12.2	12.0	11.8	12.0	0.980	862.7	NO DAMAGE	
-25	-60	92	0.00686	12.2	12.0	11.7	12.0	0.977	739.4	NO DAMAGE	
-25	-65	885	0.06598	12.2	12.0	11.7	12.0	0.974	647.0	NO DAMAGE	
-25	-70	46	0.00343	12.2	12.0	11.7	12.0	0.970	575.1	NO DAMAGE	
-25	-75	446	0.03325	12.2	12.0	11.6	12.0	0.967	517.6	NO DAMAGE	
-25	-80	10	0.00075	12.2	12.0	11.6	12.0	0.964	470.6	NO DAMAGE	

cycles per mile 153.8
Yield stress 50 ksi

					Dynamic					to	
			α	Static	Stress		Max	R	Endurance	Failure	
Max	Min	No.	Pct	Stress	Max	Min	Adjusted	Min/Max	Limit	N	α/N
-25	-85	155	0.01156	12.2	12.0	11.5	12.0	0.960	431.3	NO DAMAGE	
-25	-90	4	0.00030	12.2	12.0	11.5	12.0	0.957	398.2	NO DAMAGE	
-25	-95	55	0.00410	12.2	12.0	11.5	12.0	0.954	369.7	NO DAMAGE	
-25	-100	1	0.00007	12.2	12.0	11.4	12.0	0.950	345.1	NO DAMAGE	
-25	-105	13	0.00097	12.2	12.0	11.4	12.0	0.947	323.5	NO DAMAGE	
-25	-115	10	0.00075	12.2	12.0	11.3	12.0	0.941	287.6	NO DAMAGE	
-25	-120	2	0.00015	12.2	12.0	11.3	12.0	0.937	272.4	NO DAMAGE	
-25	-125	9	0.00067	12.2	12.0	11.2	12.0	0.934	258.8	NO DAMAGE	
-25	-135	2	0.00015	12.2	12.0	11.1	12.0	0.927	235.3	NO DAMAGE	
-25	-145	2	0.00015	12.2	12.0	11.1	12.0	0.921	215.7	NO DAMAGE	
-25	-155	3	0.00022	12.2	12.0	11.0	12.0	0.914	199.1	NO DAMAGE	
-25	-165	1	0.00007	12.2	12.0	10.9	12.0	0.907	184.9	NO DAMAGE	
-25	-180	1	0.00007	12.2	12.0	10.8	12.0	0.898	167.0	NO DAMAGE	
-25	-205	1	0.00007	12.2	12.0	10.6	12.0	0.881	143.8	NO DAMAGE	
-25	-225	1	0.00007	12.2	12.0	10.4	12.0	0.868	129.4	NO DAMAGE	
-25	-235	1	0.00007	12.2	12.0	10.4	12.0	0.861	123.2	NO DAMAGE	
-30	-40	19532	1.45616	12.2	12.0	11.9	12.0	0.993	2579.5	NO DAMAGE	
-30	-45	2909	0.21687	12.2	12.0	11.9	12.0	0.990	1719.7	NO DAMAGE	
-30	-50	13716	1.02257	12.2	12.0	11.8	12.0	0.987	1289.8	NO DAMAGE	
-30	-55	553	0.04123	12.2	12.0	11.8	12.0	0.983	1031.8	NO DAMAGE	
-30	-60	3849	0.28695	12.2	12.0	11.7	12.0	0.980	859.8	NO DAMAGE	
-30	-65	168	0.01252	12.2	12.0	11.7	12.0	0.977	737.0	NO DAMAGE	
-30	-70	1165	0.08685	12.2	12.0	11.7	12.0	0.973	644.9	NO DAMAGE	
-30	-75	39	0.00291	12.2	12.0	11.6	12.0	0.970	573.2	NO DAMAGE	
-30	-80	266	0.01983	12.2	12.0	11.6	12.0	0.967	515.9	NO DAMAGE	
-30	-85	5	0.00037	12.2	12.0	11.5	12.0	0.964	469.0	NO DAMAGE	
-30	-90	68	0.00507	12.2	12.0	11.5	12.0	0.960	429.9	NO DAMAGE	
-30	-95	2	0.00015	12.2	12.0	11.5	12.0	0.957	396.8	NO DAMAGE	
-30	-100	35	0.00261	12.2	12.0	11.4	12.0	0.954	368.5	NO DAMAGE	
-30	-110	12	0.00089	12.2	12.0	11.3	12.0	0.947	322.4	NO DAMAGE	
-30	-120	3	0.00022	12.2	12.0	11.3	12.0	0.940	286.6	NO DAMAGE	
-30	-125	1	0.00007	12.2	12.0	11.2	12.0	0.937	271.5	NO DAMAGE	
-30	-130	5	0.00037	12.2	12.0	11.2	12.0	0.934	258.0	NO DAMAGE	
-30	-140	5	0.00037	12.2	12.0	11.1	12.0	0.927	234.5	NO DAMAGE	
-30	-145	2	0.00015	12.2	12.0	11.1	12.0	0.924	224.3	NO DAMAGE	
-30	-150	1	0.00007	12.2	12.0	11.0	12.0	0.920	215.0	NO DAMAGE	
-30	-160	1	0.00007	12.2	12.0	10.9	12.0	0.914	198.4	NO DAMAGE	
-30	-170	1	0.00007	12.2	12.0	10.9	12.0	0.907	184.3	NO DAMAGE	
-30	-180	1	0.00007	12.2	12.0	10.8	12.0	0.901	172.0	NO DAMAGE	
-30	-190	1	0.00007	12.2	12.0	10.7	12.0	0.894	161.2	NO DAMAGE	
-30	-195	1	0.00007	12.2	12.0	10.7	12.0	0.891	156.3	NO DAMAGE	
-30	-200	1	0.00007	12.2	12.0	10.6	12.0	0.887	151.7	NO DAMAGE	
-30	-215	1	0.00007	12.2	12.0	10.5	12.0	0.877	139.4	NO DAMAGE	
-30	-255	1	0.00007	12.2	12.0	10.2	12.0	0.851	114.6	NO DAMAGE	
-35	-45	12272	0.91491	12.2	11.9	11.9	11.9	0.993	2571.0	NO DAMAGE	
-35	-50	2344	0.17475	12.2	11.9	11.8	11.9	0.990	1714.0	NO DAMAGE	
-35	-55	8732	0.65099	12.2	11.9	11.8	11.9	0.987	1285.5	NO DAMAGE	
-35	-60	676	0.05040	12.2	11.9	11.7	11.9	0.983	1028.4	NO DAMAGE	
-35	-65	3860	0.28777	12.2	11.9	11.7	11.9	0.980	857.0	NO DAMAGE	
-35	-70	154	0.01148	12.2	11.9	11.7	11.9	0.977	734.6	NO DAMAGE	
-35	-75	1443	0.10758	12.2	11.9	11.6	11.9	0.973	642.7	NO DAMAGE	
-35	-80	32	0.00239	12.2	11.9	11.6	11.9	0.970	571.3	NO DAMAGE	
-35	-85	453	0.03377	12.2	11.9	11.5	11.9	0.967	514.2	NO DAMAGE	
-35	-90	6	0.00045	12.2	11.9	11.5	11.9	0.963	467.4	NO DAMAGE	
-35	-95	105	0.00783	12.2	11.9	11.5	11.9	0.960	428.5	NO DAMAGE	
-35	-100	4	0.00030	12.2	11.9	11.4	11.9	0.957	395.5	NO DAMAGE	
-35	-105	28	0.00209	12.2	11.9	11.4	11.9	0.953	367.3	NO DAMAGE	
-35	-115	14	0.00104	12.2	11.9	11.3	11.9	0.947	321.4	NO DAMAGE	
-35	-120	1	0.00007	12.2	11.9	11.3	11.9	0.943	302.5	NO DAMAGE	
-35	-125	4	0.00030	12.2	11.9	11.2	11.9	0.940	285.7	NO DAMAGE	
-35	-130	1	0.00007	12.2	11.9	11.2	11.9	0.937	270.6	NO DAMAGE	
-35	-135	5	0.00037	12.2	11.9	11.1	11.9	0.933	257.1	NO DAMAGE	
-35	-150	1	0.00007	12.2	11.9	11.0	11.9	0.924	223.6	NO DAMAGE	
-35	-165	2	0.00015	12.2	11.9	10.9	11.9	0.914	197.8	NO DAMAGE	
-35	-175	1	0.00007	12.2	11.9	10.8	11.9	0.907	183.6	NO DAMAGE	
-35	-180	1	0.00007	12.2	11.9	10.8	11.9	0.904	177.3	NO DAMAGE	
-35	-215	1	0.00007	12.2	11.9	10.5	11.9	0.880	142.8	NO DAMAGE	
-40	-50	14077	1.04948	12.2	11.9	11.8	11.9	0.993	2562.4	NO DAMAGE	
-40	-55	2298	0.17132	12.2	11.9	11.8	11.9	0.990	1708.3	NO DAMAGE	
-40	-60	10806	0.80562	12.2	11.9	11.7	11.9	0.987	1281.2	NO DAMAGE	
-40	-65	770	0.05741	12.2	11.9	11.7	11.9	0.983	1025.0	NO DAMAGE	
-40	-70	2852	0.21262	12.2	11.9	11.7	11.9	0.980	854.1	NO DAMAGE	
-40	-75	135	0.01006	12.2	11.9	11.6	11.9	0.977	732.1	NO DAMAGE	
-40	-80	567	0.04227	12.2	11.9	11.6	11.9	0.973	640.6	NO DAMAGE	
-40	-85	32	0.00239	12.2	11.9	11.5	11.9	0.970	569.4	NO DAMAGE	
-40	-90	154	0.01148	12.2	11.9	11.5	11.9	0.967	512.5	NO DAMAGE	
-40	-95	8	0.00060	12.2	11.9	11.5	11.9	0.963	465.9	NO DAMAGE	
-40	-100	43	0.00321	12.2	11.9	11.4	11.9	0.960	427.1	NO DAMAGE	
-40	-105	5	0.00037	12.2	11.9	11.4	11.9	0.957	394.2	NO DAMAGE	
-40	-110	13	0.00097	12.2	11.9	11.3	11.9	0.953	366.1	NO DAMAGE	
-40	-115	2	0.00015	12.2	11.9	11.3	11.9	0.950	341.7	NO DAMAGE	
-40	-120	7	0.00052	12.2	11.9	11.3	11.9	0.947	320.3	NO DAMAGE	
-40	-125	1	0.00007	12.2	11.9	11.2	11.9	0.943	301.5	NO DAMAGE	
-40	-130	7	0.00052	12.2	11.9	11.2	11.9	0.940	284.7	NO DAMAGE	
-40	-140	2	0.00015	12.2	11.9	11.1	11.9	0.933	256.2	NO DAMAGE	
-40	-160	2	0.00015	12.2	11.9	10.9	11.9	0.920	213.5	NO DAMAGE	
-40	-165	1	0.00007	12.2	11.9	10.9	11.9	0.917	205.0	NO DAMAGE	
-40	-180	1	0.00007	12.2	11.9	10.8	11.9	0.907	183.0	NO DAMAGE	

cycles per mile 153.8
Yield stress 50 ksi

			α	Static	Dynamic Stress		Max	R	Endurance	to Failure	
Max	Min	No.	Pct	Stress	Max	Min	Adjusted	Min/Max	Limit	N	α/N
-45	-55	13228	0.98618	12.2	11.9	11.8	11.9	0.993	2553.9	NO DAMAGE	
-45	-60	2591	0.19317	12.2	11.9	11.7	11.9	0.990	1702.6	NO DAMAGE	
-45	-65	13577	1.01220	12.2	11.9	11.7	11.9	0.987	1276.9	NO DAMAGE	
-45	-70	751	0.05599	12.2	11.9	11.7	11.9	0.983	1021.5	NO DAMAGE	
-45	-75	4721	0.35196	12.2	11.9	11.6	11.9	0.980	851.3	NO DAMAGE	
-45	-80	159	0.01185	12.2	11.9	11.6	11.9	0.977	729.7	NO DAMAGE	
-45	-85	1270	0.09468	12.2	11.9	11.5	11.9	0.973	638.5	NO DAMAGE	
-45	-90	32	0.00239	12.2	11.9	11.5	11.9	0.970	567.5	NO DAMAGE	
-45	-95	224	0.01670	12.2	11.9	11.5	11.9	0.967	510.8	NO DAMAGE	
-45	-100	7	0.00052	12.2	11.9	11.4	11.9	0.963	464.3	NO DAMAGE	
-45	-105	59	0.00440	12.2	11.9	11.4	11.9	0.960	425.6	NO DAMAGE	
-45	-110	6	0.00045	12.2	11.9	11.3	11.9	0.956	392.9	NO DAMAGE	
-45	-115	31	0.00231	12.2	11.9	11.3	11.9	0.953	364.8	NO DAMAGE	
-45	-120	5	0.00037	12.2	11.9	11.3	11.9	0.950	340.5	NO DAMAGE	
-45	-125	12	0.00089	12.2	11.9	11.2	11.9	0.946	319.2	NO DAMAGE	
-45	-135	7	0.00052	12.2	11.9	11.1	11.9	0.940	283.8	NO DAMAGE	
-45	-145	3	0.00022	12.2	11.9	11.1	11.9	0.933	255.4	NO DAMAGE	
-45	-175	1	0.00007	12.2	11.9	10.8	11.9	0.913	196.5	NO DAMAGE	
-45	-215	1	0.00007	12.2	11.9	10.5	11.9	0.886	150.2	NO DAMAGE	
-45	-230	1	0.00007	12.2	11.9	10.4	11.9	0.876	138.0	NO DAMAGE	
-50	-60	13667	1.01891	12.2	11.8	11.7	11.8	0.993	2545.3	NO DAMAGE	
-50	-65	2746	0.20472	12.2	11.8	11.7	11.8	0.990	1696.9	NO DAMAGE	
-50	-70	9048	0.67455	12.2	11.8	11.7	11.8	0.987	1272.7	NO DAMAGE	
-50	-75	799	0.05957	12.2	11.8	11.6	11.8	0.983	1018.1	NO DAMAGE	
-50	-80	1862	0.13882	12.2	11.8	11.6	11.8	0.980	848.4	NO DAMAGE	
-50	-85	159	0.01185	12.2	11.8	11.5	11.8	0.976	727.2	NO DAMAGE	
-50	-90	403	0.03004	12.2	11.8	11.5	11.8	0.973	636.3	NO DAMAGE	
-50	-95	32	0.00239	12.2	11.8	11.5	11.8	0.970	565.6	NO DAMAGE	
-50	-100	122	0.00910	12.2	11.8	11.4	11.8	0.966	509.1	NO DAMAGE	
-50	-105	12	0.00089	12.2	11.8	11.4	11.8	0.963	462.8	NO DAMAGE	
-50	-110	33	0.00246	12.2	11.8	11.3	11.8	0.960	424.2	NO DAMAGE	
-50	-115	2	0.00015	12.2	11.8	11.3	11.8	0.956	391.6	NO DAMAGE	
-50	-120	11	0.00082	12.2	11.8	11.3	11.8	0.953	363.6	NO DAMAGE	
-50	-125	2	0.00015	12.2	11.8	11.2	11.8	0.950	339.4	NO DAMAGE	
-50	-130	5	0.00037	12.2	11.8	11.2	11.8	0.946	318.2	NO DAMAGE	
-50	-135	1	0.00007	12.2	11.8	11.1	11.8	0.943	299.4	NO DAMAGE	
-50	-140	2	0.00015	12.2	11.8	11.1	11.8	0.940	282.8	NO DAMAGE	
-50	-150	1	0.00007	12.2	11.8	11.0	11.8	0.933	254.5	NO DAMAGE	
-50	-160	3	0.00022	12.2	11.8	10.9	11.8	0.926	231.4	NO DAMAGE	
-50	-170	1	0.00007	12.2	11.8	10.9	11.8	0.919	212.1	NO DAMAGE	
-50	-180	2	0.00015	12.2	11.8	10.8	11.8	0.913	195.8	NO DAMAGE	
-50	-215	1	0.00007	12.2	11.8	10.5	11.8	0.889	154.3	NO DAMAGE	
-55	-65	16459	1.22706	12.2	11.8	11.7	11.8	0.993	2536.8	NO DAMAGE	
-55	-70	2658	0.19816	12.2	11.8	11.7	11.8	0.990	1691.2	NO DAMAGE	
-55	-75	14709	1.09660	12.2	11.8	11.6	11.8	0.987	1268.4	NO DAMAGE	
-55	-80	1037	0.07731	12.2	11.8	11.6	11.8	0.983	1014.7	NO DAMAGE	
-55	-85	3097	0.23089	12.2	11.8	11.5	11.8	0.980	845.6	NO DAMAGE	
-55	-90	215	0.01603	12.2	11.8	11.5	11.8	0.976	724.8	NO DAMAGE	
-55	-95	683	0.05092	12.2	11.8	11.5	11.8	0.973	634.2	NO DAMAGE	
-55	-100	56	0.00417	12.2	11.8	11.4	11.8	0.970	563.7	NO DAMAGE	
-55	-105	306	0.02281	12.2	11.8	11.4	11.8	0.966	507.4	NO DAMAGE	
-55	-110	6	0.00045	12.2	11.8	11.3	11.8	0.963	461.2	NO DAMAGE	
-55	-115	132	0.00984	12.2	11.8	11.3	11.8	0.960	422.8	NO DAMAGE	
-55	-120	3	0.00022	12.2	11.8	11.3	11.8	0.956	390.3	NO DAMAGE	
-55	-125	30	0.00224	12.2	11.8	11.2	11.8	0.953	362.4	NO DAMAGE	
-55	-135	4	0.00030	12.2	11.8	11.1	11.8	0.946	317.1	NO DAMAGE	
-55	-145	3	0.00022	12.2	11.8	11.1	11.8	0.939	281.9	NO DAMAGE	
-55	-155	1	0.00007	12.2	11.8	11.0	11.8	0.933	253.7	NO DAMAGE	
-55	-160	1	0.00007	12.2	11.8	10.9	11.8	0.929	241.6	NO DAMAGE	
-55	-165	1	0.00007	12.2	11.8	10.9	11.8	0.926	230.6	NO DAMAGE	
-55	-195	1	0.00007	12.2	11.8	10.7	11.8	0.906	181.2	NO DAMAGE	
-55	-205	1	0.00007	12.2	11.8	10.6	11.8	0.899	169.1	NO DAMAGE	
-55	-225	1	0.00007	12.2	11.8	10.4	11.8	0.885	149.2	NO DAMAGE	
-55	-235	1	0.00007	12.2	11.8	10.4	11.8	0.879	140.9	NO DAMAGE	
-55	-270	1	0.00007	12.2	11.8	10.1	11.8	0.855	118.0	NO DAMAGE	
-60	-70	12251	0.91335	12.2	11.7	11.7	11.7	0.993	2528.2	NO DAMAGE	
-60	-75	2961	0.22075	12.2	11.7	11.6	11.7	0.990	1685.5	NO DAMAGE	
-60	-80	7155	0.53342	12.2	11.7	11.6	11.7	0.986	1264.1	NO DAMAGE	
-60	-85	1139	0.08492	12.2	11.7	11.5	11.7	0.983	1011.3	NO DAMAGE	
-60	-90	1533	0.11429	12.2	11.7	11.5	11.7	0.980	842.7	NO DAMAGE	
-60	-95	213	0.01588	12.2	11.7	11.5	11.7	0.976	722.3	NO DAMAGE	
-60	-100	311	0.02319	12.2	11.7	11.4	11.7	0.973	632.1	NO DAMAGE	
-60	-105	44	0.00328	12.2	11.7	11.4	11.7	0.970	561.8	NO DAMAGE	
-60	-110	70	0.00522	12.2	11.7	11.3	11.7	0.966	505.6	NO DAMAGE	
-60	-115	11	0.00082	12.2	11.7	11.3	11.7	0.963	459.7	NO DAMAGE	
-60	-120	23	0.00171	12.2	11.7	11.3	11.7	0.959	421.4	NO DAMAGE	
-60	-125	1	0.00007	12.2	11.7	11.2	11.7	0.956	389.0	NO DAMAGE	
-60	-130	3	0.00022	12.2	11.7	11.2	11.7	0.953	361.2	NO DAMAGE	
-60	-140	3	0.00022	12.2	11.7	11.1	11.7	0.946	316.0	NO DAMAGE	
-60	-150	1	0.00007	12.2	11.7	11.0	11.7	0.939	280.9	NO DAMAGE	
-60	-160	3	0.00022	12.2	11.7	10.9	11.7	0.932	252.8	NO DAMAGE	
-60	-170	2	0.00015	12.2	11.7	10.9	11.7	0.926	229.8	NO DAMAGE	
-60	-190	1	0.00007	12.2	11.7	10.7	11.7	0.912	194.5	NO DAMAGE	
-60	-195	1	0.00007	12.2	11.7	10.7	11.7	0.909	187.3	NO DAMAGE	
-65	-75	16359	1.21961	12.2	11.7	11.6	11.7	0.993	2519.7	NO DAMAGE	
-65	-80	3270	0.24379	12.2	11.7	11.6	11.7	0.990	1679.8	NO DAMAGE	
-65	-85	10064	0.75030	12.2	11.7	11.5	11.7	0.986	1259.8	NO DAMAGE	
-65	-90	1010	0.07530	12.2	11.7	11.5	11.7	0.983	1007.9	NO DAMAGE	

cycles per mile 153.8
Yield stress 50 ksi

					Dynamic					to	
			α	Static	Stress		Max	R	Endurance	Failure	
Max	Min	No.	Pct	Stress	Max	Min	Adjusted	Min/Max	Limit	N	α/N
-65	-95	2428	0.18101	12.2	11.7	11.5	11.7	0.980	839.9	NO DAMAGE	
-65	-100	173	0.01290	12.2	11.7	11.4	11.7	0.976	719.9	NO DAMAGE	
-65	-105	939	0.07001	12.2	11.7	11.4	11.7	0.973	629.9	NO DAMAGE	
-65	-110	22	0.00164	12.2	11.7	11.3	11.7	0.969	559.9	NO DAMAGE	
-65	-115	235	0.01752	12.2	11.7	11.3	11.7	0.966	503.9	NO DAMAGE	
-65	-125	34	0.00253	12.2	11.7	11.2	11.7	0.959	419.9	NO DAMAGE	
-65	-130	1	0.00007	12.2	11.7	11.2	11.7	0.956	387.6	NO DAMAGE	
-65	-135	4	0.00030	12.2	11.7	11.1	11.7	0.952	360.0	NO DAMAGE	
-65	-140	1	0.00007	12.2	11.7	11.1	11.7	0.949	336.0	NO DAMAGE	
-65	-145	4	0.00030	12.2	11.7	11.1	11.7	0.946	315.0	NO DAMAGE	
-65	-155	1	0.00007	12.2	11.7	11.0	11.7	0.939	280.0	NO DAMAGE	
-65	-160	2	0.00015	12.2	11.7	10.9	11.7	0.936	265.2	NO DAMAGE	
-65	-165	2	0.00015	12.2	11.7	10.9	11.7	0.932	252.0	NO DAMAGE	
-65	-175	2	0.00015	12.2	11.7	10.8	11.7	0.925	229.1	NO DAMAGE	
-65	-195	1	0.00007	12.2	11.7	10.7	11.7	0.912	193.8	NO DAMAGE	
-65	-205	1	0.00007	12.2	11.7	10.6	11.7	0.905	180.0	NO DAMAGE	
-65	-215	1	0.00007	12.2	11.7	10.5	11.7	0.898	168.0	NO DAMAGE	
-70	-80	10471	0.78064	12.2	11.7	11.6	11.7	0.993	2511.1	NO DAMAGE	
-70	-85	3301	0.24610	12.2	11.7	11.5	11.7	0.990	1674.1	NO DAMAGE	
-70	-90	5651	0.42130	12.2	11.7	11.5	11.7	0.986	1255.6	NO DAMAGE	
-70	-95	952	0.07097	12.2	11.7	11.5	11.7	0.983	1004.4	NO DAMAGE	
-70	-100	1144	0.08529	12.2	11.7	11.4	11.7	0.980	837.0	NO DAMAGE	
-70	-105	124	0.00924	12.2	11.7	11.4	11.7	0.976	717.5	NO DAMAGE	
-70	-110	229	0.01707	12.2	11.7	11.3	11.7	0.973	627.8	NO DAMAGE	
-70	-115	16	0.00119	12.2	11.7	11.3	11.7	0.969	558.0	NO DAMAGE	
-70	-120	40	0.00298	12.2	11.7	11.3	11.7	0.966	502.2	NO DAMAGE	
-70	-125	2	0.00015	12.2	11.7	11.2	11.7	0.963	456.6	NO DAMAGE	
-70	-130	9	0.00067	12.2	11.7	11.2	11.7	0.959	418.5	NO DAMAGE	
-70	-140	3	0.00022	12.2	11.7	11.1	11.7	0.952	358.7	NO DAMAGE	
-70	-150	2	0.00015	12.2	11.7	11.0	11.7	0.946	313.9	NO DAMAGE	
-70	-160	1	0.00007	12.2	11.7	10.9	11.7	0.939	279.0	NO DAMAGE	
-70	-165	1	0.00007	12.2	11.7	10.9	11.7	0.935	264.3	NO DAMAGE	
-70	-170	1	0.00007	12.2	11.7	10.9	11.7	0.932	251.1	NO DAMAGE	
-70	-180	2	0.00015	12.2	11.7	10.8	11.7	0.925	228.3	NO DAMAGE	
-70	-190	1	0.00007	12.2	11.7	10.7	11.7	0.918	209.3	NO DAMAGE	
-70	-200	3	0.00022	12.2	11.7	10.6	11.7	0.911	193.2	NO DAMAGE	
-75	-85	14182	1.05731	12.2	11.6	11.5	11.6	0.993	2502.6	NO DAMAGE	
-75	-90	2967	0.22120	12.2	11.6	11.5	11.6	0.990	1668.4	NO DAMAGE	
-75	-95	9334	0.69588	12.2	11.6	11.5	11.6	0.986	1251.3	NO DAMAGE	
-75	-100	735	0.05480	12.2	11.6	11.4	11.6	0.983	1001.0	NO DAMAGE	
-75	-105	2065	0.15395	12.2	11.6	11.4	11.6	0.980	834.2	NO DAMAGE	
-75	-110	86	0.00641	12.2	11.6	11.3	11.6	0.976	715.0	NO DAMAGE	
-75	-115	338	0.02520	12.2	11.6	11.3	11.6	0.973	625.6	NO DAMAGE	
-75	-120	14	0.00104	12.2	11.6	11.3	11.6	0.969	556.1	NO DAMAGE	
-75	-125	45	0.00335	12.2	11.6	11.2	11.6	0.966	500.5	NO DAMAGE	
-75	-130	3	0.00022	12.2	11.6	11.2	11.6	0.962	455.0	NO DAMAGE	
-75	-135	5	0.00037	12.2	11.6	11.1	11.6	0.959	417.1	NO DAMAGE	
-75	-140	1	0.00007	12.2	11.6	11.1	11.6	0.956	385.0	NO DAMAGE	
-75	-145	2	0.00015	12.2	11.6	11.1	11.6	0.952	357.5	NO DAMAGE	
-75	-150	1	0.00007	12.2	11.6	11.0	11.6	0.949	333.7	NO DAMAGE	
-75	-155	1	0.00007	12.2	11.6	11.0	11.6	0.945	312.8	NO DAMAGE	
-75	-160	3	0.00022	12.2	11.6	10.9	11.6	0.942	294.4	NO DAMAGE	
-75	-165	2	0.00015	12.2	11.6	10.9	11.6	0.939	278.1	NO DAMAGE	
-75	-195	2	0.00015	12.2	11.6	10.7	11.6	0.918	208.5	NO DAMAGE	
-75	-205	1	0.00007	12.2	11.6	10.6	11.6	0.911	192.5	NO DAMAGE	
-75	-215	1	0.00007	12.2	11.6	10.5	11.6	0.904	178.8	NO DAMAGE	
-80	-90	8101	0.60395	12.2	11.6	11.5	11.6	0.993	2494.0	NO DAMAGE	
-80	-95	2409	0.17960	12.2	11.6	11.5	11.6	0.990	1662.7	NO DAMAGE	
-80	-100	3830	0.28554	12.2	11.6	11.4	11.6	0.986	1247.0	NO DAMAGE	
-80	-105	649	0.04838	12.2	11.6	11.4	11.6	0.983	997.6	NO DAMAGE	
-80	-110	766	0.05711	12.2	11.6	11.3	11.6	0.979	831.3	NO DAMAGE	
-80	-115	61	0.00455	12.2	11.6	11.3	11.6	0.976	712.6	NO DAMAGE	
-80	-120	135	0.01006	12.2	11.6	11.3	11.6	0.973	623.5	NO DAMAGE	
-80	-125	1	0.00007	12.2	11.6	11.2	11.6	0.969	554.2	NO DAMAGE	
-80	-130	33	0.00246	12.2	11.6	11.2	11.6	0.966	498.8	NO DAMAGE	
-80	-135	2	0.00015	12.2	11.6	11.1	11.6	0.962	453.5	NO DAMAGE	
-80	-140	10	0.00075	12.2	11.6	11.1	11.6	0.959	415.7	NO DAMAGE	
-80	-145	2	0.00015	12.2	11.6	11.1	11.6	0.955	383.7	NO DAMAGE	
-80	-150	2	0.00015	12.2	11.6	11.0	11.6	0.952	356.3	NO DAMAGE	
-80	-170	1	0.00007	12.2	11.6	10.9	11.6	0.938	277.1	NO DAMAGE	
-80	-180	1	0.00007	12.2	11.6	10.8	11.6	0.931	249.4	NO DAMAGE	
-80	-200	1	0.00007	12.2	11.6	10.6	11.6	0.918	207.8	NO DAMAGE	
-85	-95	13290	0.99081	12.2	11.5	11.5	11.5	0.993	2485.5	NO DAMAGE	
-85	-100	2275	0.16961	12.2	11.5	11.4	11.5	0.990	1657.0	NO DAMAGE	
-85	-105	6479	0.48303	12.2	11.5	11.4	11.5	0.986	1242.7	NO DAMAGE	
-85	-110	483	0.03601	12.2	11.5	11.3	11.5	0.983	994.2	NO DAMAGE	
-85	-115	766	0.05711	12.2	11.5	11.3	11.5	0.979	828.5	NO DAMAGE	
-85	-120	50	0.00373	12.2	11.5	11.3	11.5	0.976	710.1	NO DAMAGE	
-85	-125	69	0.00514	12.2	11.5	11.2	11.5	0.972	621.4	NO DAMAGE	
-85	-130	7	0.00052	12.2	11.5	11.2	11.5	0.969	552.3	NO DAMAGE	
-85	-135	8	0.00060	12.2	11.5	11.1	11.5	0.966	497.1	NO DAMAGE	
-85	-140	2	0.00015	12.2	11.5	11.1	11.5	0.962	451.9	NO DAMAGE	
-85	-145	2	0.00015	12.2	11.5	11.1	11.5	0.959	414.2	NO DAMAGE	
-85	-150	1	0.00007	12.2	11.5	11.0	11.5	0.955	382.4	NO DAMAGE	
-85	-155	8	0.00060	12.2	11.5	11.0	11.5	0.952	355.1	NO DAMAGE	
-85	-160	1	0.00007	12.2	11.5	10.9	11.5	0.948	331.4	NO DAMAGE	
-85	-165	2	0.00015	12.2	11.5	10.9	11.5	0.945	310.7	NO DAMAGE	
-85	-175	1	0.00007	12.2	11.5	10.8	11.5	0.938	276.2	NO DAMAGE	

cycles per mile 153.8
Yield stress 50 ksi

					Dynamic					to	
			α	Static	Stress		Max	R	Endurance	Failure	
Max	Min	No.	Pct	Stress	Max	Min	Adjusted	Min/Max	Limit	N	α/N
-85	-205	2	0.00015	12.2	11.5	10.6	11.5	0.917	207.1	NO DAMAGE	
-90	-100	5702	0.42510	12.2	11.5	11.4	11.5	0.993	2476.9	NO DAMAGE	
-90	-105	1616	0.12048	12.2	11.5	11.4	11.5	0.990	1651.3	NO DAMAGE	
-90	-110	2362	0.17609	12.2	11.5	11.3	11.5	0.986	1238.5	NO DAMAGE	
-90	-115	348	0.02594	12.2	11.5	11.3	11.5	0.983	990.8	NO DAMAGE	
-90	-120	508	0.03787	12.2	11.5	11.3	11.5	0.979	825.6	NO DAMAGE	
-90	-125	42	0.00313	12.2	11.5	11.2	11.5	0.976	707.7	NO DAMAGE	
-90	-130	85	0.00634	12.2	11.5	11.2	11.5	0.972	619.2	NO DAMAGE	
-90	-135	5	0.00037	12.2	11.5	11.1	11.5	0.969	550.4	NO DAMAGE	
-90	-140	17	0.00127	12.2	11.5	11.1	11.5	0.965	495.4	NO DAMAGE	
-90	-145	3	0.00022	12.2	11.5	11.1	11.5	0.962	450.3	NO DAMAGE	
-90	-150	5	0.00037	12.2	11.5	11.0	11.5	0.959	412.8	NO DAMAGE	
-90	-155	2	0.00015	12.2	11.5	11.0	11.5	0.955	381.1	NO DAMAGE	
-90	-160	6	0.00045	12.2	11.5	10.9	11.5	0.952	353.8	NO DAMAGE	
-90	-170	2	0.00015	12.2	11.5	10.9	11.5	0.945	309.6	NO DAMAGE	
-90	-180	1	0.00007	12.2	11.5	10.8	11.5	0.938	275.2	NO DAMAGE	
-90	-190	2	0.00015	12.2	11.5	10.7	11.5	0.931	247.7	NO DAMAGE	
-90	-200	1	0.00007	12.2	11.5	10.6	11.5	0.924	225.2	NO DAMAGE	
-90	-250	1	0.00007	12.2	11.5	10.2	11.5	0.890	154.8	NO DAMAGE	
-95	-105	8428	0.62833	12.2	11.5	11.4	11.5	0.993	2468.4	NO DAMAGE	
-95	-110	1303	0.09714	12.2	11.5	11.3	11.5	0.990	1645.6	NO DAMAGE	
-95	-115	3709	0.27652	12.2	11.5	11.3	11.5	0.986	1234.2	NO DAMAGE	
-95	-120	265	0.01976	12.2	11.5	11.3	11.5	0.983	987.3	NO DAMAGE	
-95	-125	319	0.02378	12.2	11.5	11.2	11.5	0.979	822.8	NO DAMAGE	
-95	-130	31	0.00231	12.2	11.5	11.2	11.5	0.976	705.2	NO DAMAGE	
-95	-135	43	0.00321	12.2	11.5	11.1	11.5	0.972	617.1	NO DAMAGE	
-95	-140	3	0.00022	12.2	11.5	11.1	11.5	0.969	548.5	NO DAMAGE	
-95	-145	6	0.00045	12.2	11.5	11.1	11.5	0.965	493.7	NO DAMAGE	
-95	-150	4	0.00030	12.2	11.5	11.0	11.5	0.962	448.8	NO DAMAGE	
-95	-155	5	0.00037	12.2	11.5	11.0	11.5	0.958	411.4	NO DAMAGE	
-95	-160	3	0.00022	12.2	11.5	10.9	11.5	0.955	379.7	NO DAMAGE	
-95	-165	3	0.00022	12.2	11.5	10.9	11.5	0.952	352.6	NO DAMAGE	
-95	-175	1	0.00007	12.2	11.5	10.8	11.5	0.945	308.5	NO DAMAGE	
-95	-195	1	0.00007	12.2	11.5	10.7	11.5	0.931	246.8	NO DAMAGE	
-95	-225	1	0.00007	12.2	11.5	10.4	11.5	0.910	189.9	NO DAMAGE	
-100	-110	4039	0.30112	12.2	11.4	11.3	11.4	0.993	2459.8	NO DAMAGE	
-100	-115	1147	0.08551	12.2	11.4	11.3	11.4	0.990	1639.9	NO DAMAGE	
-100	-120	1845	0.13755	12.2	11.4	11.3	11.4	0.986	1229.9	NO DAMAGE	
-100	-125	199	0.01484	12.2	11.4	11.2	11.4	0.983	983.9	NO DAMAGE	
-100	-130	436	0.03251	12.2	11.4	11.2	11.4	0.979	819.9	NO DAMAGE	
-100	-135	20	0.00149	12.2	11.4	11.1	11.4	0.976	702.8	NO DAMAGE	
-100	-140	67	0.00500	12.2	11.4	11.1	11.4	0.972	615.0	NO DAMAGE	
-100	-145	2	0.00015	12.2	11.4	11.1	11.4	0.969	546.6	NO DAMAGE	
-100	-150	14	0.00104	12.2	11.4	11.0	11.4	0.965	492.0	NO DAMAGE	
-100	-160	7	0.00052	12.2	11.4	10.9	11.4	0.958	410.0	NO DAMAGE	
-100	-170	1	0.00007	12.2	11.4	10.9	11.4	0.951	351.4	NO DAMAGE	
-100	-175	1	0.00007	12.2	11.4	10.8	11.4	0.948	328.0	NO DAMAGE	
-100	-180	2	0.00015	12.2	11.4	10.8	11.4	0.944	307.5	NO DAMAGE	
-100	-185	1	0.00007	12.2	11.4	10.8	11.4	0.941	289.4	NO DAMAGE	
-100	-190	1	0.00007	12.2	11.4	10.7	11.4	0.937	273.3	NO DAMAGE	
-105	-115	6351	0.47348	12.2	11.4	11.3	11.4	0.993	2451.3	NO DAMAGE	
-105	-120	994	0.07411	12.2	11.4	11.3	11.4	0.990	1634.2	NO DAMAGE	
-105	-125	2749	0.20495	12.2	11.4	11.2	11.4	0.986	1225.6	NO DAMAGE	
-105	-130	177	0.01320	12.2	11.4	11.2	11.4	0.983	980.5	NO DAMAGE	
-105	-135	305	0.02274	12.2	11.4	11.1	11.4	0.979	817.1	NO DAMAGE	
-105	-140	16	0.00119	12.2	11.4	11.1	11.4	0.976	700.4	NO DAMAGE	
-105	-145	18	0.00134	12.2	11.4	11.1	11.4	0.972	612.8	NO DAMAGE	
-105	-150	4	0.00030	12.2	11.4	11.0	11.4	0.969	544.7	NO DAMAGE	
-105	-155	4	0.00030	12.2	11.4	11.0	11.4	0.965	490.3	NO DAMAGE	
-105	-160	2	0.00015	12.2	11.4	10.9	11.4	0.962	445.7	NO DAMAGE	
-105	-165	5	0.00037	12.2	11.4	10.9	11.4	0.958	408.5	NO DAMAGE	
-105	-175	3	0.00022	12.2	11.4	10.8	11.4	0.951	350.2	NO DAMAGE	
-105	-185	2	0.00015	12.2	11.4	10.8	11.4	0.944	306.4	NO DAMAGE	
-105	-190	2	0.00015	12.2	11.4	10.7	11.4	0.941	288.4	NO DAMAGE	
-105	-195	1	0.00007	12.2	11.4	10.7	11.4	0.937	272.4	NO DAMAGE	
-105	-210	1	0.00007	12.2	11.4	10.6	11.4	0.927	233.5	NO DAMAGE	
-110	-120	3584	0.26720	12.2	11.3	11.3	11.3	0.993	2442.7	NO DAMAGE	
-110	-125	852	0.06352	12.2	11.3	11.2	11.3	0.989	1628.5	NO DAMAGE	
-110	-130	1577	0.11757	12.2	11.3	11.2	11.3	0.986	1221.4	NO DAMAGE	
-110	-135	127	0.00947	12.2	11.3	11.1	11.3	0.982	977.1	NO DAMAGE	
-110	-140	260	0.01938	12.2	11.3	11.1	11.3	0.979	814.2	NO DAMAGE	
-110	-145	13	0.00097	12.2	11.3	11.1	11.3	0.975	697.9	NO DAMAGE	
-110	-150	38	0.00283	12.2	11.3	11.0	11.3	0.972	610.7	NO DAMAGE	
-110	-155	5	0.00037	12.2	11.3	11.0	11.3	0.968	542.8	NO DAMAGE	
-110	-160	10	0.00075	12.2	11.3	10.9	11.3	0.965	488.5	NO DAMAGE	
-110	-165	1	0.00007	12.2	11.3	10.9	11.3	0.961	444.1	NO DAMAGE	
-110	-170	2	0.00015	12.2	11.3	10.9	11.3	0.958	407.1	NO DAMAGE	
-110	-175	2	0.00015	12.2	11.3	10.8	11.3	0.954	375.8	NO DAMAGE	
-110	-180	2	0.00015	12.2	11.3	10.8	11.3	0.951	349.0	NO DAMAGE	
-110	-205	2	0.00015	12.2	11.3	10.6	11.3	0.933	257.1	NO DAMAGE	
-115	-125	5236	0.39036	12.2	11.3	11.2	11.3	0.993	2434.2	NO DAMAGE	
-115	-130	840	0.06262	12.2	11.3	11.2	11.3	0.989	1622.8	NO DAMAGE	
-115	-135	1968	0.14672	12.2	11.3	11.1	11.3	0.986	1217.1	NO DAMAGE	
-115	-140	141	0.01051	12.2	11.3	11.1	11.3	0.982	973.7	NO DAMAGE	
-115	-145	138	0.01029	12.2	11.3	11.1	11.3	0.979	811.4	NO DAMAGE	
-115	-150	9	0.00067	12.2	11.3	11.0	11.3	0.975	695.5	NO DAMAGE	
-115	-155	21	0.00157	12.2	11.3	11.0	11.3	0.972	608.5	NO DAMAGE	
-115	-160	2	0.00015	12.2	11.3	10.9	11.3	0.968	540.9	NO DAMAGE	

cycles per mile 153.8
Yield stress 50 ksi

			α	Static	Dynamic Stress		Max	R	Endurance	to Failure	
Max	Min	No.	Pct	Stress	Max	Min	Adjusted	Min/Max	Limit	N	α/N
-115	-165	8	0.00060	12.2	11.3	10.9	11.3	0.965	486.8	NO DAMAGE	
-115	-170	1	0.00007	12.2	11.3	10.9	11.3	0.961	442.6	NO DAMAGE	
-115	-175	5	0.00037	12.2	11.3	10.8	11.3	0.958	405.7	NO DAMAGE	
-115	-185	1	0.00007	12.2	11.3	10.8	11.3	0.951	347.7	NO DAMAGE	
-115	-245	1	0.00007	12.2	11.3	10.3	11.3	0.909	187.2	NO DAMAGE	
-120	-130	2973	0.22165	12.2	11.3	11.2	11.3	0.993	2425.6	NO DAMAGE	
-120	-135	831	0.06195	12.2	11.3	11.1	11.3	0.989	1617.1	NO DAMAGE	
-120	-140	1120	0.08350	12.2	11.3	11.1	11.3	0.986	1212.8	NO DAMAGE	
-120	-145	100	0.00746	12.2	11.3	11.1	11.3	0.982	970.2	NO DAMAGE	
-120	-150	164	0.01223	12.2	11.3	11.0	11.3	0.979	808.5	NO DAMAGE	
-120	-155	8	0.00060	12.2	11.3	11.0	11.3	0.975	693.0	NO DAMAGE	
-120	-160	25	0.00186	12.2	11.3	10.9	11.3	0.972	606.4	NO DAMAGE	
-120	-170	2	0.00015	12.2	11.3	10.9	11.3	0.965	485.1	NO DAMAGE	
-120	-180	3	0.00022	12.2	11.3	10.8	11.3	0.958	404.3	NO DAMAGE	
-120	-190	1	0.00007	12.2	11.3	10.7	11.3	0.951	346.5	NO DAMAGE	
-120	-200	1	0.00007	12.2	11.3	10.6	11.3	0.944	303.2	NO DAMAGE	
-120	-205	1	0.00007	12.2	11.3	10.6	11.3	0.940	285.4	NO DAMAGE	
-120	-215	1	0.00007	12.2	11.3	10.5	11.3	0.933	255.3	NO DAMAGE	
-125	-135	4276	0.31879	12.2	11.2	11.1	11.2	0.993	2417.1	NO DAMAGE	
-125	-140	683	0.05092	12.2	11.2	11.1	11.2	0.989	1611.4	NO DAMAGE	
-125	-145	1552	0.11571	12.2	11.2	11.1	11.2	0.986	1208.5	NO DAMAGE	
-125	-150	97	0.00723	12.2	11.2	11.0	11.2	0.982	966.8	NO DAMAGE	
-125	-155	88	0.00656	12.2	11.2	11.0	11.2	0.979	805.7	NO DAMAGE	
-125	-160	17	0.00127	12.2	11.2	10.9	11.2	0.975	690.6	NO DAMAGE	
-125	-165	13	0.00097	12.2	11.2	10.9	11.2	0.972	604.3	NO DAMAGE	
-125	-170	4	0.00030	12.2	11.2	10.9	11.2	0.968	537.1	NO DAMAGE	
-125	-175	3	0.00022	12.2	11.2	10.8	11.2	0.965	483.4	NO DAMAGE	
-125	-180	1	0.00007	12.2	11.2	10.8	11.2	0.961	439.5	NO DAMAGE	
-125	-185	3	0.00022	12.2	11.2	10.8	11.2	0.958	402.8	NO DAMAGE	
-125	-190	1	0.00007	12.2	11.2	10.7	11.2	0.954	371.9	NO DAMAGE	
-125	-195	1	0.00007	12.2	11.2	10.7	11.2	0.950	345.3	NO DAMAGE	
-130	-140	2817	0.21002	12.2	11.2	11.1	11.2	0.993	2408.5	NO DAMAGE	
-130	-145	656	0.04891	12.2	11.2	11.1	11.2	0.989	1605.7	NO DAMAGE	
-130	-150	896	0.06680	12.2	11.2	11.0	11.2	0.986	1204.3	NO DAMAGE	
-130	-155	95	0.00708	12.2	11.2	11.0	11.2	0.982	963.4	NO DAMAGE	
-130	-160	94	0.00701	12.2	11.2	10.9	11.2	0.979	802.8	NO DAMAGE	
-130	-165	10	0.00075	12.2	11.2	10.9	11.2	0.975	688.1	NO DAMAGE	
-130	-170	15	0.00112	12.2	11.2	10.9	11.2	0.972	602.1	NO DAMAGE	
-130	-175	4	0.00030	12.2	11.2	10.8	11.2	0.968	535.2	NO DAMAGE	
-130	-180	2	0.00015	12.2	11.2	10.8	11.2	0.965	481.7	NO DAMAGE	
-130	-185	1	0.00007	12.2	11.2	10.8	11.2	0.961	437.9	NO DAMAGE	
-130	-190	2	0.00015	12.2	11.2	10.7	11.2	0.957	401.4	NO DAMAGE	
-130	-195	1	0.00007	12.2	11.2	10.7	11.2	0.954	370.5	NO DAMAGE	
-130	-220	1	0.00007	12.2	11.2	10.5	11.2	0.936	267.6	NO DAMAGE	
-130	-230	1	0.00007	12.2	11.2	10.4	11.2	0.929	240.9	NO DAMAGE	
-135	-145	3311	0.24684	12.2	11.1	11.1	11.1	0.993	2400.0	NO DAMAGE	
-135	-150	514	0.03832	12.2	11.1	11.0	11.1	0.989	1600.0	NO DAMAGE	
-135	-155	1106	0.08246	12.2	11.1	11.0	11.1	0.986	1200.0	NO DAMAGE	
-135	-160	58	0.00432	12.2	11.1	10.9	11.1	0.982	960.0	NO DAMAGE	
-135	-165	81	0.00604	12.2	11.1	10.9	11.1	0.979	800.0	NO DAMAGE	
-135	-170	10	0.00075	12.2	11.1	10.9	11.1	0.975	685.7	NO DAMAGE	
-135	-175	14	0.00104	12.2	11.1	10.8	11.1	0.971	600.0	NO DAMAGE	
-135	-180	3	0.00022	12.2	11.1	10.8	11.1	0.968	533.3	NO DAMAGE	
-135	-185	4	0.00030	12.2	11.1	10.8	11.1	0.964	480.0	NO DAMAGE	
-135	-190	1	0.00007	12.2	11.1	10.7	11.1	0.961	436.4	NO DAMAGE	
-135	-195	1	0.00007	12.2	11.1	10.7	11.1	0.957	400.0	NO DAMAGE	
-140	-150	1992	0.14851	12.2	11.1	11.0	11.1	0.993	2391.4	NO DAMAGE	
-140	-155	454	0.03385	12.2	11.1	11.0	11.1	0.989	1594.3	NO DAMAGE	
-140	-160	517	0.03854	12.2	11.1	10.9	11.1	0.986	1195.7	NO DAMAGE	
-140	-165	61	0.00455	12.2	11.1	10.9	11.1	0.982	956.6	NO DAMAGE	
-140	-170	54	0.00403	12.2	11.1	10.9	11.1	0.979	797.1	NO DAMAGE	
-140	-175	20	0.00149	12.2	11.1	10.8	11.1	0.975	683.3	NO DAMAGE	
-140	-180	20	0.00149	12.2	11.1	10.8	11.1	0.971	597.9	NO DAMAGE	
-140	-185	1	0.00007	12.2	11.1	10.8	11.1	0.968	531.4	NO DAMAGE	
-140	-190	1	0.00007	12.2	11.1	10.7	11.1	0.964	478.3	NO DAMAGE	
-140	-195	1	0.00007	12.2	11.1	10.7	11.1	0.961	434.8	NO DAMAGE	
-140	-200	1	0.00007	12.2	11.1	10.6	11.1	0.957	398.6	NO DAMAGE	
-140	-210	1	0.00007	12.2	11.1	10.6	11.1	0.950	341.6	NO DAMAGE	
-145	-155	2955	0.22030	12.2	11.1	11.0	11.1	0.993	2382.9	NO DAMAGE	
-145	-160	431	0.03213	12.2	11.1	10.9	11.1	0.989	1588.6	NO DAMAGE	
-145	-165	765	0.05703	12.2	11.1	10.9	11.1	0.986	1191.4	NO DAMAGE	
-145	-170	78	0.00582	12.2	11.1	10.9	11.1	0.982	953.1	NO DAMAGE	
-145	-175	50	0.00373	12.2	11.1	10.8	11.1	0.978	794.3	NO DAMAGE	
-145	-180	16	0.00119	12.2	11.1	10.8	11.1	0.975	680.8	NO DAMAGE	
-145	-185	6	0.00045	12.2	11.1	10.8	11.1	0.971	595.7	NO DAMAGE	
-145	-190	4	0.00030	12.2	11.1	10.7	11.1	0.968	529.5	NO DAMAGE	
-145	-195	8	0.00060	12.2	11.1	10.7	11.1	0.964	476.6	NO DAMAGE	
-145	-205	2	0.00015	12.2	11.1	10.6	11.1	0.957	397.1	NO DAMAGE	
-145	-225	1	0.00007	12.2	11.1	10.4	11.1	0.943	297.9	NO DAMAGE	
-150	-160	1535	0.11444	12.2	11.0	10.9	11.0	0.993	2374.3	NO DAMAGE	
-150	-165	428	0.03191	12.2	11.0	10.9	11.0	0.989	1582.9	NO DAMAGE	
-150	-170	353	0.02632	12.2	11.0	10.9	11.0	0.986	1187.2	NO DAMAGE	
-150	-175	44	0.00328	12.2	11.0	10.8	11.0	0.982	949.7	NO DAMAGE	
-150	-180	54	0.00403	12.2	11.0	10.8	11.0	0.978	791.4	NO DAMAGE	
-150	-185	5	0.00037	12.2	11.0	10.8	11.0	0.975	678.4	NO DAMAGE	
-150	-190	10	0.00075	12.2	11.0	10.7	11.0	0.971	593.6	NO DAMAGE	
-150	-195	1	0.00007	12.2	11.0	10.7	11.0	0.968	527.6	NO DAMAGE	
-150	-200	4	0.00030	12.2	11.0	10.6	11.0	0.964	474.9	NO DAMAGE	

cycles per mile 153.8
Yield stress 50 ksi

					Dynamic					to	
			α	Static	Stress		Max	R	Endurance	Failure	
Max	Min	No.	Pct	Stress	Max	Min	Adjusted	Min/Max	Limit	N	α/N
-150	-210	2	0.00015	12.2	11.0	10.6	11.0	0.957	395.7	NO DAMAGE	
-155	-165	2322	0.17311	12.2	11.0	10.9	11.0	0.993	2365.8	NO DAMAGE	
-155	-170	392	0.02922	12.2	11.0	10.9	11.0	0.989	1577.2	NO DAMAGE	
-155	-175	511	0.03810	12.2	11.0	10.8	11.0	0.986	1182.9	NO DAMAGE	
-155	-180	47	0.00350	12.2	11.0	10.8	11.0	0.982	946.3	NO DAMAGE	
-155	-185	35	0.00261	12.2	11.0	10.8	11.0	0.978	788.6	NO DAMAGE	
-155	-190	2	0.00015	12.2	11.0	10.7	11.0	0.975	675.9	NO DAMAGE	
-155	-195	6	0.00045	12.2	11.0	10.7	11.0	0.971	591.4	NO DAMAGE	
-155	-200	1	0.00007	12.2	11.0	10.6	11.0	0.967	525.7	NO DAMAGE	
-155	-205	4	0.00030	12.2	11.0	10.6	11.0	0.964	473.2	NO DAMAGE	
-155	-210	1	0.00007	12.2	11.0	10.6	11.0	0.960	430.1	NO DAMAGE	
-155	-215	2	0.00015	12.2	11.0	10.5	11.0	0.957	394.3	NO DAMAGE	
-155	-225	1	0.00007	12.2	11.0	10.4	11.0	0.949	338.0	NO DAMAGE	
-160	-170	1521	0.11339	12.2	10.9	10.9	10.9	0.993	2357.2	NO DAMAGE	
-160	-175	311	0.02319	12.2	10.9	10.8	10.9	0.989	1571.5	NO DAMAGE	
-160	-180	371	0.02766	12.2	10.9	10.8	10.9	0.985	1178.6	NO DAMAGE	
-160	-185	35	0.00261	12.2	10.9	10.8	10.9	0.982	942.9	NO DAMAGE	
-160	-190	29	0.00216	12.2	10.9	10.7	10.9	0.978	785.7	NO DAMAGE	
-160	-200	8	0.00060	12.2	10.9	10.6	10.9	0.971	589.3	NO DAMAGE	
-160	-205	1	0.00007	12.2	10.9	10.6	10.9	0.967	523.8	NO DAMAGE	
-160	-210	4	0.00030	12.2	10.9	10.6	10.9	0.964	471.4	NO DAMAGE	
-160	-215	1	0.00007	12.2	10.9	10.5	10.9	0.960	428.6	NO DAMAGE	
-160	-220	1	0.00007	12.2	10.9	10.5	10.9	0.956	392.9	NO DAMAGE	
-160	-240	1	0.00007	12.2	10.9	10.3	10.9	0.942	294.7	NO DAMAGE	
-160	-300	1	0.00007	12.2	10.9	9.8	10.9	0.898	168.4	NO DAMAGE	
-165	-175	1805	0.13457	12.2	10.9	10.8	10.9	0.993	2348.7	NO DAMAGE	
-165	-180	295	0.02199	12.2	10.9	10.8	10.9	0.989	1565.8	NO DAMAGE	
-165	-185	382	0.02848	12.2	10.9	10.8	10.9	0.985	1174.3	NO DAMAGE	
-165	-190	19	0.00142	12.2	10.9	10.7	10.9	0.982	939.5	NO DAMAGE	
-165	-195	11	0.00082	12.2	10.9	10.7	10.9	0.978	782.9	NO DAMAGE	
-165	-200	4	0.00030	12.2	10.9	10.6	10.9	0.975	671.0	NO DAMAGE	
-165	-205	10	0.00075	12.2	10.9	10.6	10.9	0.971	587.2	NO DAMAGE	
-165	-210	1	0.00007	12.2	10.9	10.6	10.9	0.967	521.9	NO DAMAGE	
-165	-215	1	0.00007	12.2	10.9	10.5	10.9	0.964	469.7	NO DAMAGE	
-165	-225	4	0.00030	12.2	10.9	10.4	10.9	0.956	391.4	NO DAMAGE	
-165	-235	2	0.00015	12.2	10.9	10.4	10.9	0.949	335.5	NO DAMAGE	
-165	-245	1	0.00007	12.2	10.9	10.3	10.9	0.942	293.6	NO DAMAGE	
-165	-255	1	0.00007	12.2	10.9	10.2	10.9	0.934	261.0	NO DAMAGE	
-170	-180	1099	0.08193	12.2	10.9	10.8	10.9	0.993	2340.1	NO DAMAGE	
-170	-185	240	0.01789	12.2	10.9	10.8	10.9	0.989	1560.1	NO DAMAGE	
-170	-190	237	0.01767	12.2	10.9	10.7	10.9	0.985	1170.1	NO DAMAGE	
-170	-195	21	0.00157	12.2	10.9	10.7	10.9	0.982	936.0	NO DAMAGE	
-170	-200	32	0.00239	12.2	10.9	10.6	10.9	0.978	780.0	NO DAMAGE	
-170	-205	6	0.00045	12.2	10.9	10.6	10.9	0.974	668.6	NO DAMAGE	
-170	-210	3	0.00022	12.2	10.9	10.6	10.9	0.971	585.0	NO DAMAGE	
-170	-215	3	0.00022	12.2	10.9	10.5	10.9	0.967	520.0	NO DAMAGE	
-170	-220	1	0.00007	12.2	10.9	10.5	10.9	0.963	468.0	NO DAMAGE	
-175	-185	1609	0.11996	12.2	10.8	10.8	10.8	0.993	2331.6	NO DAMAGE	
-175	-190	240	0.01789	12.2	10.8	10.7	10.8	0.989	1554.4	NO DAMAGE	
-175	-195	304	0.02266	12.2	10.8	10.7	10.8	0.985	1165.8	NO DAMAGE	
-175	-200	10	0.00075	12.2	10.8	10.6	10.8	0.982	932.6	NO DAMAGE	
-175	-205	16	0.00119	12.2	10.8	10.6	10.8	0.978	777.2	NO DAMAGE	
-175	-210	5	0.00037	12.2	10.8	10.6	10.8	0.974	666.2	NO DAMAGE	
-175	-215	6	0.00045	12.2	10.8	10.5	10.8	0.971	582.9	NO DAMAGE	
-175	-225	2	0.00015	12.2	10.8	10.4	10.8	0.963	466.3	NO DAMAGE	
-175	-235	3	0.00022	12.2	10.8	10.4	10.8	0.956	388.6	NO DAMAGE	
-175	-255	1	0.00007	12.2	10.8	10.2	10.8	0.941	291.4	NO DAMAGE	
-180	-190	1003	0.07478	12.2	10.8	10.7	10.8	0.993	2323.0	NO DAMAGE	
-180	-195	213	0.01588	12.2	10.8	10.7	10.8	0.989	1548.7	NO DAMAGE	
-180	-200	183	0.01364	12.2	10.8	10.6	10.8	0.985	1161.5	NO DAMAGE	
-180	-205	19	0.00142	12.2	10.8	10.6	10.8	0.982	929.2	NO DAMAGE	
-180	-210	18	0.00134	12.2	10.8	10.6	10.8	0.978	774.3	NO DAMAGE	
-180	-215	1	0.00007	12.2	10.8	10.5	10.8	0.974	663.7	NO DAMAGE	
-180	-220	1	0.00007	12.2	10.8	10.5	10.8	0.971	580.8	NO DAMAGE	
-180	-240	1	0.00007	12.2	10.8	10.3	10.8	0.956	387.2	NO DAMAGE	
-185	-195	1474	0.10989	12.2	10.8	10.7	10.8	0.993	2314.5	NO DAMAGE	
-185	-200	295	0.02199	12.2	10.8	10.6	10.8	0.989	1543.0	NO DAMAGE	
-185	-205	300	0.02237	12.2	10.8	10.6	10.8	0.985	1157.2	NO DAMAGE	
-185	-210	14	0.00104	12.2	10.8	10.6	10.8	0.982	925.8	NO DAMAGE	
-185	-215	15	0.00112	12.2	10.8	10.5	10.8	0.978	771.5	NO DAMAGE	
-185	-220	2	0.00015	12.2	10.8	10.5	10.8	0.974	661.3	NO DAMAGE	
-185	-225	10	0.00075	12.2	10.8	10.4	10.8	0.970	578.6	NO DAMAGE	
-185	-235	11	0.00082	12.2	10.8	10.4	10.8	0.963	462.9	NO DAMAGE	
-185	-245	2	0.00015	12.2	10.8	10.3	10.8	0.956	385.7	NO DAMAGE	
-190	-200	1217	0.09073	12.2	10.7	10.6	10.7	0.993	2305.9	NO DAMAGE	
-190	-205	282	0.02102	12.2	10.7	10.6	10.7	0.989	1537.3	NO DAMAGE	
-190	-210	125	0.00932	12.2	10.7	10.6	10.7	0.985	1153.0	NO DAMAGE	
-190	-215	10	0.00075	12.2	10.7	10.5	10.7	0.981	922.4	NO DAMAGE	
-190	-220	6	0.00045	12.2	10.7	10.5	10.7	0.978	768.6	NO DAMAGE	
-190	-230	2	0.00015	12.2	10.7	10.4	10.7	0.970	576.5	NO DAMAGE	
-190	-400	1	0.00007	12.2	10.7	9.0	10.7	0.844	109.8	NO DAMAGE	
-195	-205	1915	0.14277	12.2	10.7	10.6	10.7	0.993	2297.4	NO DAMAGE	
-195	-210	306	0.02281	12.2	10.7	10.6	10.7	0.989	1531.6	NO DAMAGE	
-195	-215	280	0.02087	12.2	10.7	10.5	10.7	0.985	1148.7	NO DAMAGE	
-195	-220	2	0.00015	12.2	10.7	10.5	10.7	0.981	918.9	NO DAMAGE	
-195	-225	15	0.00112	12.2	10.7	10.4	10.7	0.978	765.8	NO DAMAGE	
-195	-235	5	0.00037	12.2	10.7	10.4	10.7	0.970	574.3	NO DAMAGE	
-195	-240	1	0.00007	12.2	10.7	10.3	10.7	0.967	510.5	NO DAMAGE	

cycles per mile 153.8
Yield stress 50 ksi

					Dynamic Stress						
Max	Min	No.	α Pct	Static Stress	Max	Min	Max Adjusted	R Min/Max	Endurance Limit	to Failure N	α/N
-195	-245	5	0.00037	12.2	10.7	10.3	10.7	0.963	459.5	NO DAMAGE	
-195	-255	1	0.00007	12.2	10.7	10.2	10.7	0.955	382.9	NO DAMAGE	
-200	-210	1092	0.08141	12.2	10.6	10.6	10.6	0.993	2288.8	NO DAMAGE	
-200	-215	185	0.01379	12.2	10.6	10.5	10.6	0.989	1525.9	NO DAMAGE	
-200	-220	66	0.00492	12.2	10.6	10.5	10.6	0.985	1144.4	NO DAMAGE	
-200	-225	2	0.00015	12.2	10.6	10.4	10.6	0.981	915.5	NO DAMAGE	
-200	-230	1	0.00007	12.2	10.6	10.4	10.6	0.978	762.9	NO DAMAGE	
-205	-215	1078	0.08037	12.2	10.6	10.5	10.6	0.993	2280.3	NO DAMAGE	
-205	-220	63	0.00470	12.2	10.6	10.5	10.6	0.989	1520.2	NO DAMAGE	
-205	-225	152	0.01133	12.2	10.6	10.4	10.6	0.985	1140.1	NO DAMAGE	
-205	-230	4	0.00030	12.2	10.6	10.4	10.6	0.981	912.1	NO DAMAGE	
-205	-235	15	0.00112	12.2	10.6	10.4	10.6	0.978	760.1	NO DAMAGE	
-205	-245	15	0.00112	12.2	10.6	10.3	10.6	0.970	570.1	NO DAMAGE	
-205	-255	6	0.00045	12.2	10.6	10.2	10.6	0.963	456.1	NO DAMAGE	
-210	-220	338	0.02520	12.2	10.6	10.5	10.6	0.992	2271.7	NO DAMAGE	
-210	-225	56	0.00417	12.2	10.6	10.4	10.6	0.989	1514.5	NO DAMAGE	
-210	-230	23	0.00171	12.2	10.6	10.4	10.6	0.985	1135.9	NO DAMAGE	
-210	-240	4	0.00030	12.2	10.6	10.3	10.6	0.977	757.2	NO DAMAGE	
-210	-360	1	0.00007	12.2	10.6	9.4	10.6	0.887	151.4	NO DAMAGE	
-215	-225	503	0.03750	12.2	10.5	10.4	10.5	0.992	2263.2	NO DAMAGE	
-215	-230	11	0.00082	12.2	10.5	10.4	10.5	0.989	1508.8	NO DAMAGE	
-215	-235	172	0.01282	12.2	10.5	10.4	10.5	0.985	1131.6	NO DAMAGE	
-215	-245	29	0.00216	12.2	10.5	10.3	10.5	0.977	754.4	NO DAMAGE	
-215	-250	1	0.00007	12.2	10.5	10.2	10.5	0.974	646.6	NO DAMAGE	
-215	-255	4	0.00030	12.2	10.5	10.2	10.5	0.970	565.8	NO DAMAGE	
-220	-230	89	0.00664	12.2	10.5	10.4	10.5	0.992	2254.6	NO DAMAGE	
-220	-235	12	0.00089	12.2	10.5	10.4	10.5	0.989	1503.1	NO DAMAGE	
-220	-240	33	0.00246	12.2	10.5	10.3	10.5	0.985	1127.3	NO DAMAGE	
-220	-250	9	0.00067	12.2	10.5	10.2	10.5	0.977	751.5	NO DAMAGE	
-220	-260	1	0.00007	12.2	10.5	10.2	10.5	0.970	563.7	NO DAMAGE	
-225	-235	732	0.05457	12.2	10.4	10.4	10.4	0.992	2246.1	NO DAMAGE	
-225	-240	11	0.00082	12.2	10.4	10.3	10.4	0.989	1497.4	NO DAMAGE	
-225	-245	260	0.01938	12.2	10.4	10.3	10.4	0.985	1123.0	NO DAMAGE	
-225	-255	3	0.00022	12.2	10.4	10.2	10.4	0.977	748.7	NO DAMAGE	
-225	-260	1	0.00007	12.2	10.4	10.2	10.4	0.973	641.7	NO DAMAGE	
-225	-270	1	0.00007	12.2	10.4	10.1	10.4	0.966	499.1	NO DAMAGE	
-230	-240	86	0.00641	12.2	10.4	10.3	10.4	0.992	2237.5	NO DAMAGE	
-230	-245	12	0.00089	12.2	10.4	10.3	10.4	0.989	1491.7	NO DAMAGE	
-230	-250	14	0.00104	12.2	10.4	10.2	10.4	0.985	1118.8	NO DAMAGE	
-230	-265	1	0.00007	12.2	10.4	10.1	10.4	0.973	639.3	NO DAMAGE	
-230	-320	1	0.00007	12.2	10.4	9.7	10.4	0.931	248.6	NO DAMAGE	
-235	-245	440	0.03280	12.2	10.4	10.3	10.4	0.992	2229.0	NO DAMAGE	
-235	-250	5	0.00037	12.2	10.4	10.2	10.4	0.988	1486.0	NO DAMAGE	
-235	-255	45	0.00335	12.2	10.4	10.2	10.4	0.985	1114.5	NO DAMAGE	
-235	-260	1	0.00007	12.2	10.4	10.2	10.4	0.981	891.6	NO DAMAGE	
-235	-265	1	0.00007	12.2	10.4	10.1	10.4	0.977	743.0	NO DAMAGE	
-240	-250	42	0.00313	12.2	10.3	10.2	10.3	0.992	2220.4	NO DAMAGE	
-240	-255	2	0.00015	12.2	10.3	10.2	10.3	0.988	1480.3	NO DAMAGE	
-240	-260	8	0.00060	12.2	10.3	10.2	10.3	0.985	1110.2	NO DAMAGE	
-240	-270	2	0.00015	12.2	10.3	10.1	10.3	0.977	740.1	NO DAMAGE	
-240	-280	1	0.00007	12.2	10.3	10.0	10.3	0.969	555.1	NO DAMAGE	
-245	-255	86	0.00641	12.2	10.3	10.2	10.3	0.992	2211.9	NO DAMAGE	
-245	-260	6	0.00045	12.2	10.3	10.2	10.3	0.988	1474.6	NO DAMAGE	
-245	-265	12	0.00089	12.2	10.3	10.1	10.3	0.985	1105.9	NO DAMAGE	
-245	-270	1	0.00007	12.2	10.3	10.1	10.3	0.981	884.7	NO DAMAGE	
-250	-260	25	0.00186	12.2	10.2	10.2	10.2	0.992	2203.3	NO DAMAGE	
-250	-265	5	0.00037	12.2	10.2	10.1	10.2	0.988	1468.9	NO DAMAGE	
-250	-270	2	0.00015	12.2	10.2	10.1	10.2	0.984	1101.7	NO DAMAGE	
-250	-280	1	0.00007	12.2	10.2	10.0	10.2	0.977	734.4	NO DAMAGE	
-255	-265	49	0.00365	12.2	10.2	10.1	10.2	0.992	2194.8	NO DAMAGE	
-255	-270	8	0.00060	12.2	10.2	10.1	10.2	0.988	1463.2	NO DAMAGE	
-255	-275	6	0.00045	12.2	10.2	10.0	10.2	0.984	1097.4	NO DAMAGE	
-255	-285	1	0.00007	12.2	10.2	10.0	10.2	0.977	731.6	NO DAMAGE	
-255	-315	1	0.00007	12.2	10.2	9.7	10.2	0.953	365.8	NO DAMAGE	
-255	-535	2	0.00015	12.2	10.2	8.0	10.2	0.782	78.4	NO DAMAGE	
-260	-270	13	0.00097	12.2	10.2	10.1	10.2	0.992	2186.2	NO DAMAGE	
-260	-275	3	0.00022	12.2	10.2	10.0	10.2	0.988	1457.5	NO DAMAGE	
-260	-310	2	0.00015	12.2	10.2	9.8	10.2	0.961	437.2	NO DAMAGE	
-265	-275	22	0.00164	12.2	10.1	10.0	10.1	0.992	2177.7	NO DAMAGE	
-265	-280	3	0.00022	12.2	10.1	10.0	10.1	0.988	1451.8	NO DAMAGE	
-265	-285	1	0.00007	12.2	10.1	10.0	10.1	0.984	1088.8	NO DAMAGE	
-265	-295	1	0.00007	12.2	10.1	9.9	10.1	0.976	725.9	NO DAMAGE	
-265	-300	1	0.00007	12.2	10.1	9.8	10.1	0.973	622.2	NO DAMAGE	
-270	-280	6	0.00045	12.2	10.1	10.0	10.1	0.992	2169.1	NO DAMAGE	
-270	-285	2	0.00015	12.2	10.1	10.0	10.1	0.988	1446.1	NO DAMAGE	
-270	-290	1	0.00007	12.2	10.1	9.9	10.1	0.984	1084.6	NO DAMAGE	
-270	-295	1	0.00007	12.2	10.1	9.9	10.1	0.980	867.6	NO DAMAGE	
-275	-285	12	0.00089	12.2	10.0	10.0	10.0	0.992	2160.6	NO DAMAGE	
-275	-290	11	0.00082	12.2	10.0	9.9	10.0	0.988	1440.4	NO DAMAGE	
-275	-295	3	0.00022	12.2	10.0	9.9	10.0	0.984	1080.3	NO DAMAGE	
-275	-300	1	0.00007	12.2	10.0	9.8	10.0	0.980	864.2	NO DAMAGE	
-275	-305	1	0.00007	12.2	10.0	9.8	10.0	0.976	720.2	NO DAMAGE	
-275	-345	1	0.00007	12.2	10.0	9.5	10.0	0.945	308.7	NO DAMAGE	
-280	-290	19	0.00142	12.2	10.0	9.9	10.0	0.992	2152.0	NO DAMAGE	
-280	-295	4	0.00030	12.2	10.0	9.9	10.0	0.988	1434.7	NO DAMAGE	
-285	-295	8	0.00060	12.2	10.0	9.9	10.0	0.992	2143.5	NO DAMAGE	
-285	-300	1	0.00007	12.2	10.0	9.8	10.0	0.988	1429.0	NO DAMAGE	
-285	-315	2	0.00015	12.2	10.0	9.7	10.0	0.976	714.5	NO DAMAGE	

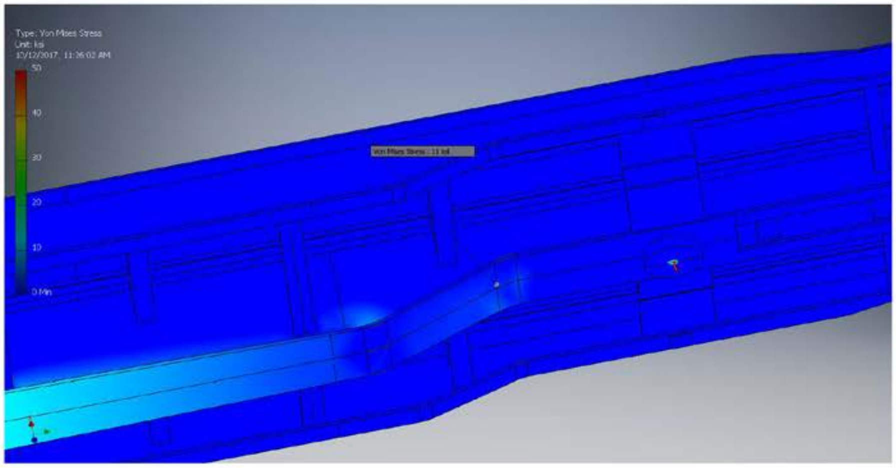
cycles per mile 153.8
Yield stress 50 ksi

			α	Static	Dynamic Stress		Max	R	Endurance	to Failure	
Max	Min	No.	Pct	Stress	Max	Min	Adjusted	Min/Max	Limit	N	α/N
-285	-325	1	0.00007	12.2	10.0	9.6	10.0	0.968	535.9	NO DAMAGE	
-285	-335	4	0.00030	12.2	10.0	9.6	10.0	0.960	428.7	NO DAMAGE	
-290	-300	3	0.00022	12.2	9.9	9.8	9.9	0.992	2134.9	NO DAMAGE	
-295	-305	6	0.00045	12.2	9.9	9.8	9.9	0.992	2126.4	NO DAMAGE	
-295	-315	11	0.00082	12.2	9.9	9.7	9.9	0.984	1063.2	NO DAMAGE	
-295	-325	16	0.00119	12.2	9.9	9.6	9.9	0.976	708.8	NO DAMAGE	
-295	-335	14	0.00104	12.2	9.9	9.6	9.9	0.968	531.6	NO DAMAGE	
-300	-315	1	0.00007	12.2	9.8	9.7	9.8	0.988	1411.9	NO DAMAGE	
-305	-315	63	0.00470	12.2	9.8	9.7	9.8	0.992	2109.3	NO DAMAGE	
-305	-325	124	0.00924	12.2	9.8	9.6	9.8	0.984	1054.6	NO DAMAGE	
-305	-335	25	0.00186	12.2	9.8	9.6	9.8	0.976	703.1	NO DAMAGE	
-305	-345	8	0.00060	12.2	9.8	9.5	9.8	0.968	527.3	NO DAMAGE	
-315	-325	133	0.00992	12.2	9.7	9.6	9.7	0.992	2092.2	NO DAMAGE	
-315	-335	114	0.00850	12.2	9.7	9.6	9.7	0.984	1046.1	NO DAMAGE	
-315	-345	13	0.00097	12.2	9.7	9.5	9.7	0.975	697.4	NO DAMAGE	
-325	-335	32	0.00239	12.2	9.6	9.6	9.6	0.992	2075.1	NO DAMAGE	
-325	-345	2	0.00015	12.2	9.6	9.5	9.6	0.984	1037.5	NO DAMAGE	
-345	-385	1	0.00007	12.2	9.5	9.2	9.5	0.966	510.2	NO DAMAGE	
-355	-375	1	0.00007	12.2	9.4	9.2	9.4	0.983	1011.9	NO DAMAGE	
-365	-385	2	0.00015	12.2	9.3	9.2	9.3	0.983	1003.3	NO DAMAGE	
-375	-385	1	0.00007	12.2	9.2	9.2	9.2	0.991	1989.6	NO DAMAGE	
			99.99940							Sum	4.01E-10
										N	2.49E+09
										Miles	1.62E+07

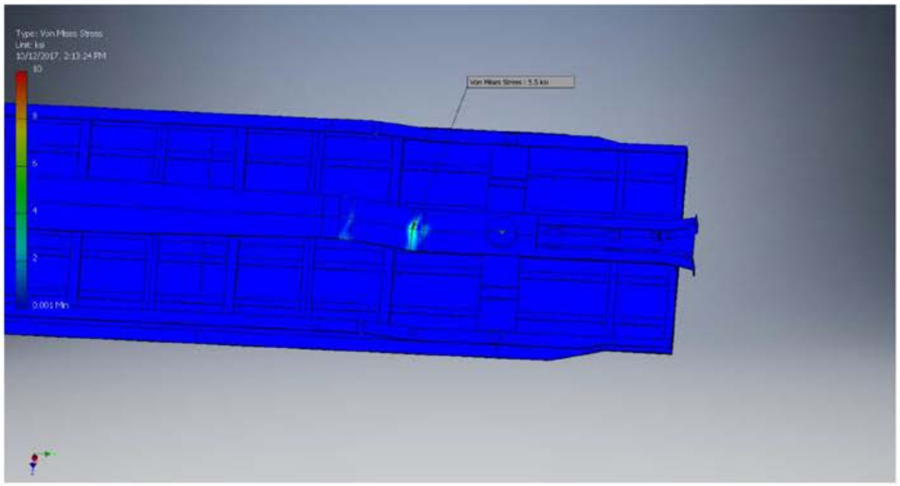
Torsional Loading

Below are screen shots of the maximum applied torque from the AAR shown on the following page. Stress is below the endurance limit of the steel os no further analysis is necessary.

Loaded



Empty



DATA FROM AAR SECTION 7.3

LOADED GONDOLA CAR BODY TWIST MOMENT DUE TO SIDE BEARING LOAD ENVIRONMENT

TEST DATE: March 2006 - Dec 2007
TEST MODE: Unit Train Coal Service - 286,000 lb. GRL
RECORDED MILEAGE: 8,480
TOTAL CYCLES: 6,786,405
AVERAGE CYCLES PER MILE: 800.3
AVERAGE TRAVEL SPEED: 25 mph
MAXIMUM SPEED: 52 mph
TRAVEL SPEED DISTRIBUTION:

RANGE (mph)		PERCENT AT LEVEL
0	5	5.4
5	10	9.3
10	15	11.0
15	20	11.7
20	25	16.1
25	30	10.3
30	35	14.3
35	40	11.0
40	45	5.0
45	50	4.5
50	55	1.5

VALUES SHOWN ARE IN UNITS OF IN-KIPS.

MAX VALUE kip	MIN VALUE kip	CYCLES	PERCENT OCCURANCE
2500	-1750	2	0.00003%
2500	-2000	3	0.00004%
2500	-2250	1	0.00001%
2250	-750	2	0.00003%
2250	-1000	3	0.00004%
2250	-1250	1	0.00001%
2250	-1500	1	0.00001%
2250	-1750	3	0.00004%
2250	-2000	1	0.00001%
2000	1500	2	0.00003%
2000	500	2	0.00003%
2000	0	1	0.00001%
2000	-250	2	0.00003%
2000	-500	1	0.00001%
2000	-750	2	0.00003%
2000	-1000	3	0.00004%
2000	-1250	7	0.00010%
2000	-1500	13	0.00019%
2000	-1750	8	0.00012%
2000	-2000	3	0.00004%
1750	1500	24	0.00035%
1750	1250	45	0.00066%

1750	1000	14	0.00021%
1750	750	6	0.00009%
1750	500	7	0.00010%
1750	250	7	0.00010%
1750	0	14	0.00021%
1750	-250	19	0.00028%
1750	-500	19	0.00028%
1750	-750	17	0.00025%
1750	-1000	25	0.00037%
1750	-1250	43	0.00063%
1750	-1500	28	0.00041%
1750	-1750	12	0.00018%
1750	-2000	5	0.00007%
1750	-2250	1	0.00001%
1750	-2500	1	0.00001%
1500	1250	362	0.00533%
1500	1000	409	0.00603%
1500	750	91	0.00134%
1500	500	35	0.00052%
1500	250	67	0.00099%
1500	0	62	0.00091%
1500	-250	88	0.00130%
1500	-500	73	0.00108%
1500	-750	95	0.00140%
1500	-1000	126	0.00186%
1500	-1250	108	0.00159%
1500	-1500	81	0.00119%
1500	-1750	41	0.00060%
1500	-2000	1	0.00001%
1250	1000	2300	0.03389%
1250	750	2729	0.04021%
1250	500	411	0.00606%
1250	250	292	0.00430%
1250	0	317	0.00467%
1250	-250	284	0.00418%
1250	-500	428	0.00631%
1250	-750	498	0.00734%
1250	-1000	494	0.00728%
1250	-1250	314	0.00463%
1250	-1500	150	0.00221%
1250	-1750	21	0.00031%
1000	750	10812	0.15932%
1000	500	11972	0.17641%
1000	250	2081	0.03066%
1000	0	1239	0.01826%
1000	-250	1872	0.02758%
1000	-500	2552	0.03760%
1000	-750	2496	0.03678%
1000	-1000	1297	0.01911%
1000	-1250	589	0.00868%
1000	-1500	112	0.00165%
1000	-1750	12	0.00018%
750	500	67742	0.99820%
750	250	66455	0.97924%
750	0	11782	0.17361%

750	-250	13952	0.20559%
750	-500	11564	0.17040%
750	-750	5876	0.08658%
750	-1000	2260	0.03330%
750	-1250	629	0.00927%
750	-1500	66	0.00097%
750	-1750	12	0.00018%
500	250	305999	4.50900%
500	0	815557	12.01751%
500	-250	150272	2.21431%
500	-500	32146	0.47368%
500	-750	11018	0.16235%
500	-1000	3126	0.04606%
500	-1250	407	0.00600%
500	-1500	71	0.00105%
500	-1750	5	0.00007%
500	-2000	2	0.00003%
250	0	2208739	32.54653%
250	-250	862740	12.71277%
250	-500	60276	0.88819%
250	-750	12856	0.18944%
250	-1000	2113	0.03114%
250	-1250	306	0.00451%
250	-1500	48	0.00071%
250	-1750	6	0.00009%
250	-2000	1	0.00001%
0	-250	1052114	15.50326%
0	-500	319565	4.70890%
0	-750	16203	0.23876%
0	-1000	1577	0.02324%
0	-1250	322	0.00474%
0	-1500	50	0.00074%
0	-1750	13	0.00019%
0	-2000	2	0.00003%
-250	-500	359587	5.29864%
-250	-750	166295	2.45041%
-250	-1000	2940	0.04332%
-250	-1250	227	0.00334%
-250	-1500	40	0.00059%
-250	-1750	11	0.00016%
-500	-750	120769	1.77957%
-500	-1000	19811	0.29192%
-500	-1250	522	0.00769%
-500	-1500	44	0.00065%
-500	-1750	3	0.00004%
-750	-1000	19840	0.29235%
-750	-1250	6182	0.09109%
-750	-1500	214	0.00315%
-750	-1750	6	0.00009%
-1000	-1250	5455	0.08038%
-1000	-1500	1741	0.02565%
-1000	-1750	43	0.00063%
-1250	-1500	1212	0.01786%
-1250	-1750	181	0.00267%
-1250	-2000	3	0.00004%

-1500	-1750	112	0.00165%
-1500	-2000	27	0.00040%
-1500	-2250	1	0.00001%
-1750	-2000	7	0.00010%
-2000	-2250	1	0.00001%

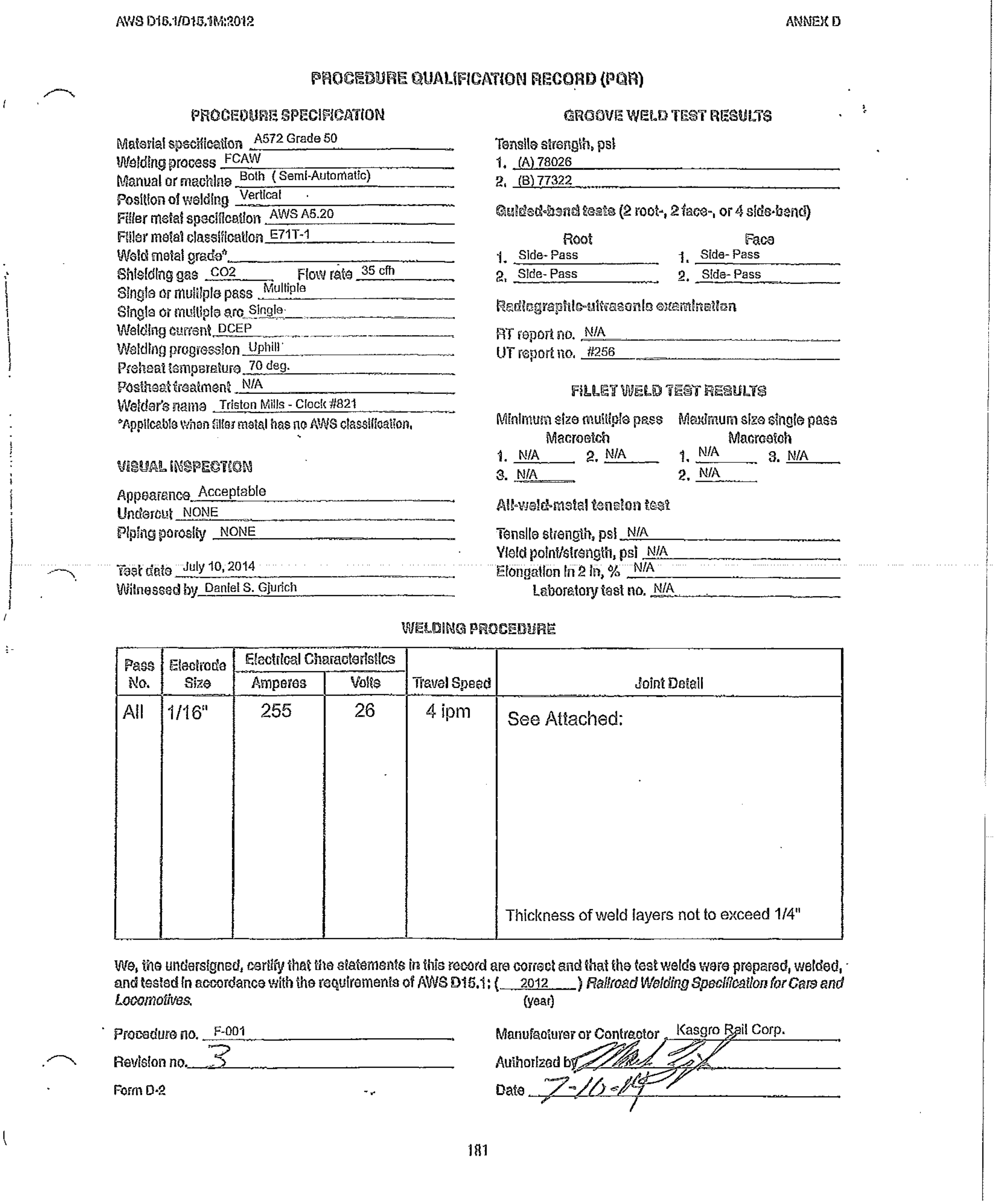
APPENDIX H-2

BUFFER RAILCAR SPECIAL PROCESS SPECIFICATIONS

APPENDIX H-2.1

BUFFER RAILCAR WELDING PROCEDURE QUALIFICATIONS AND SPECIFICATIONS

Appendix H-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		Travel Speed	Joint Detail
		Amperes	Volts		
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) *Railroad Welding Specification for Cars and Locomotives.*
(year)

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

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

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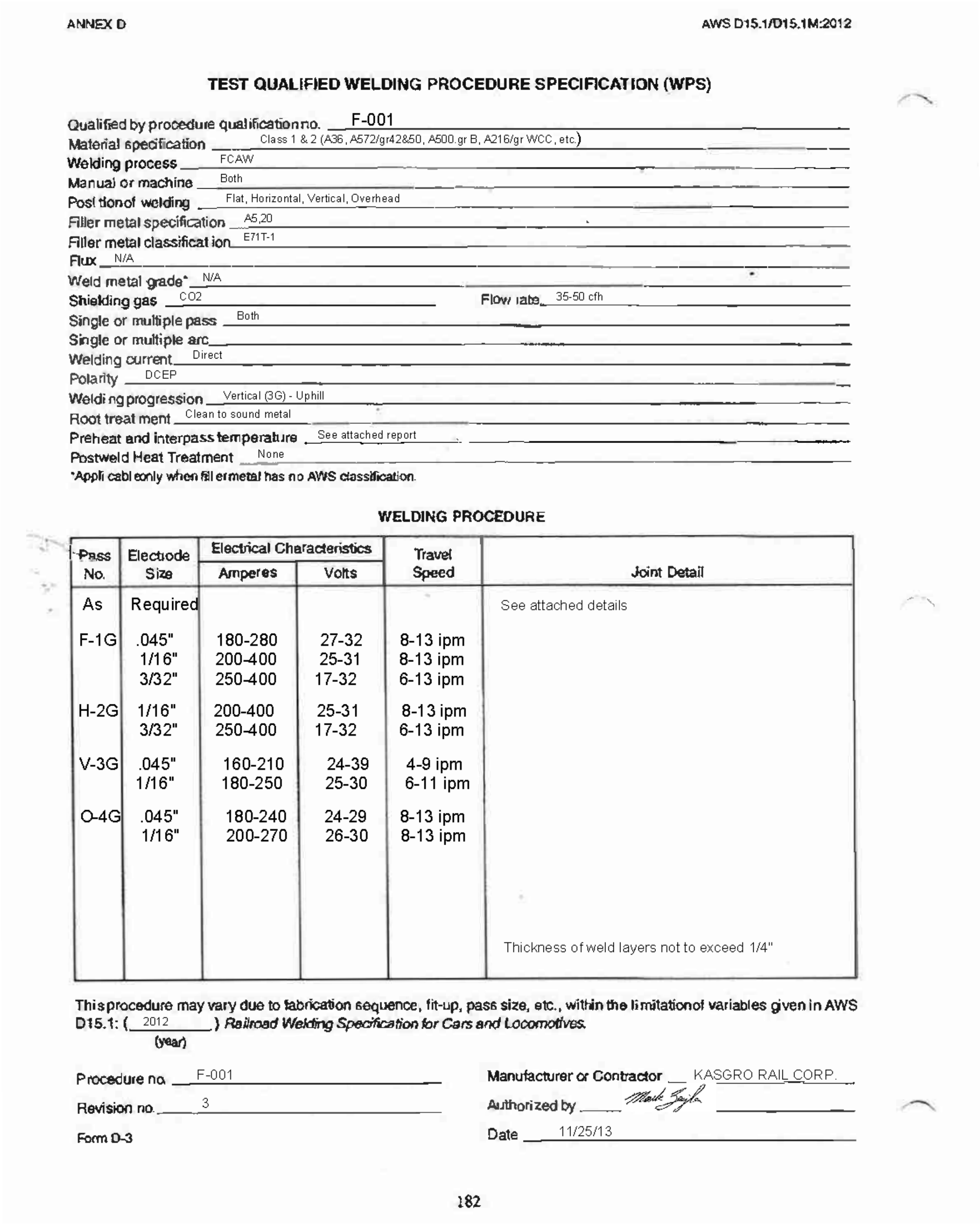
Appendix H-2.1.2 Prequalified Welding Procedure Specifications



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.

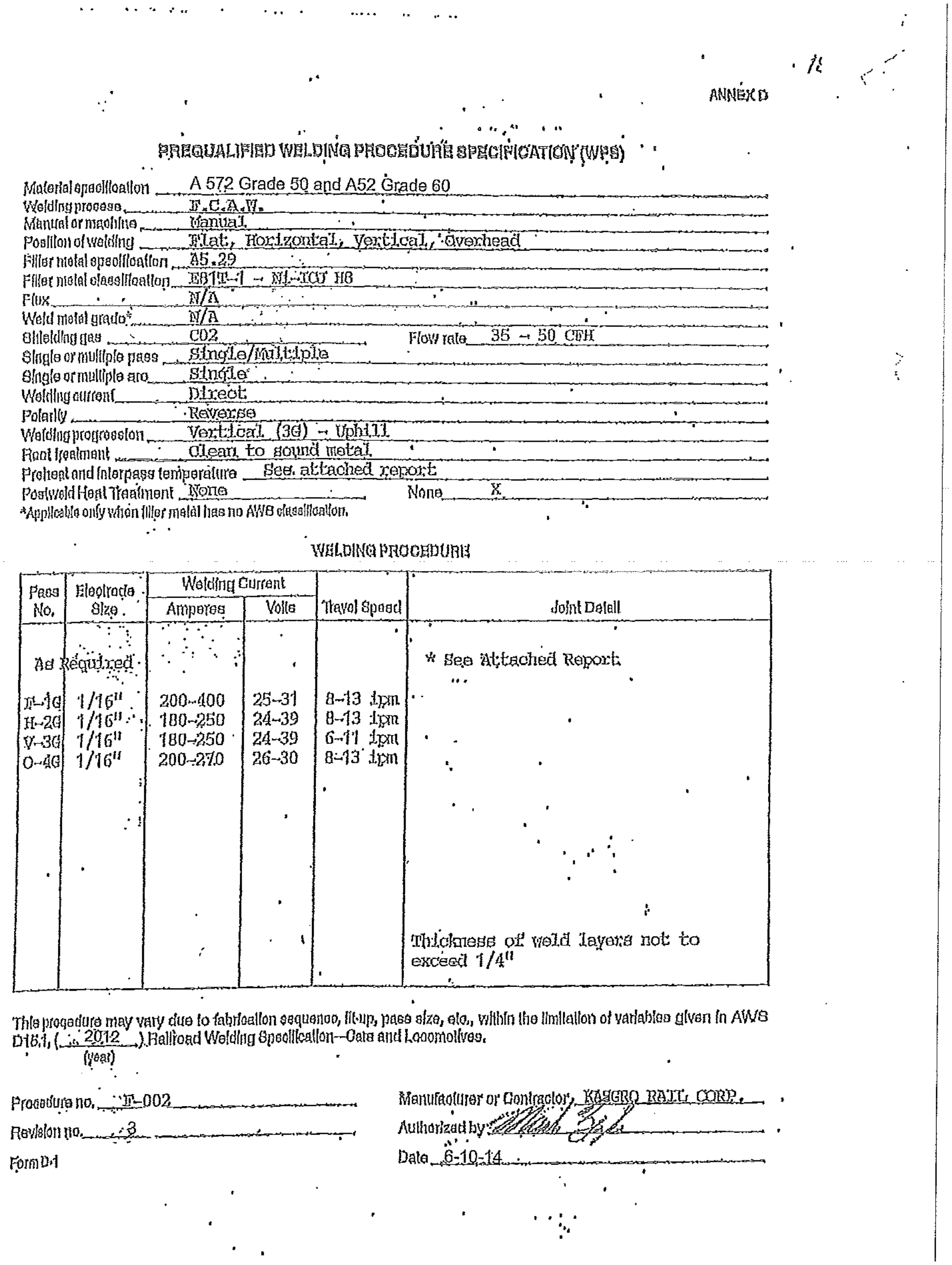
WELDING PROCEDURE

Pass No.	Electrode Size	Electrical Characteristics		Travel Speed	Joint Detail
		Amperes	Volts		
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
Date 11/25/13



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-1CJ H8
Flux N/A
Weld metal grade* N/A
Shielding gas CO2 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		Travel Speed	Joint Detail
		Amperes	Volts		
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
Date 6-10-14

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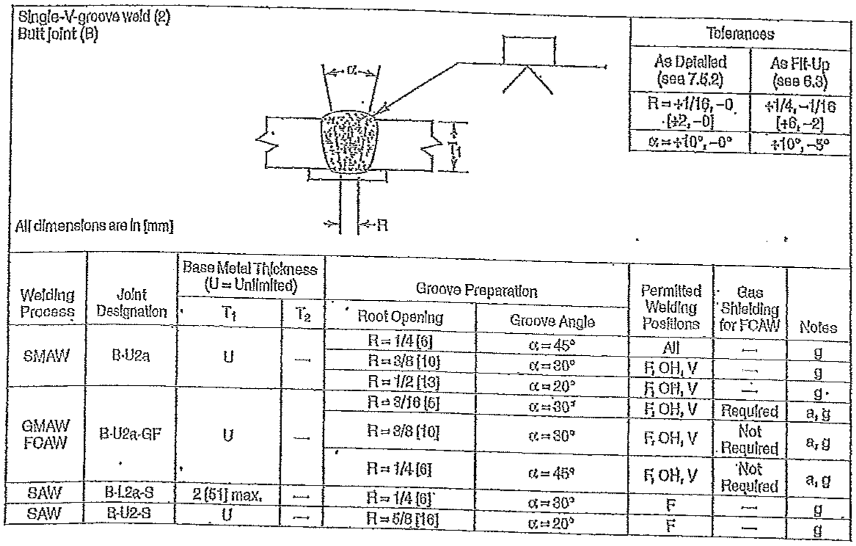


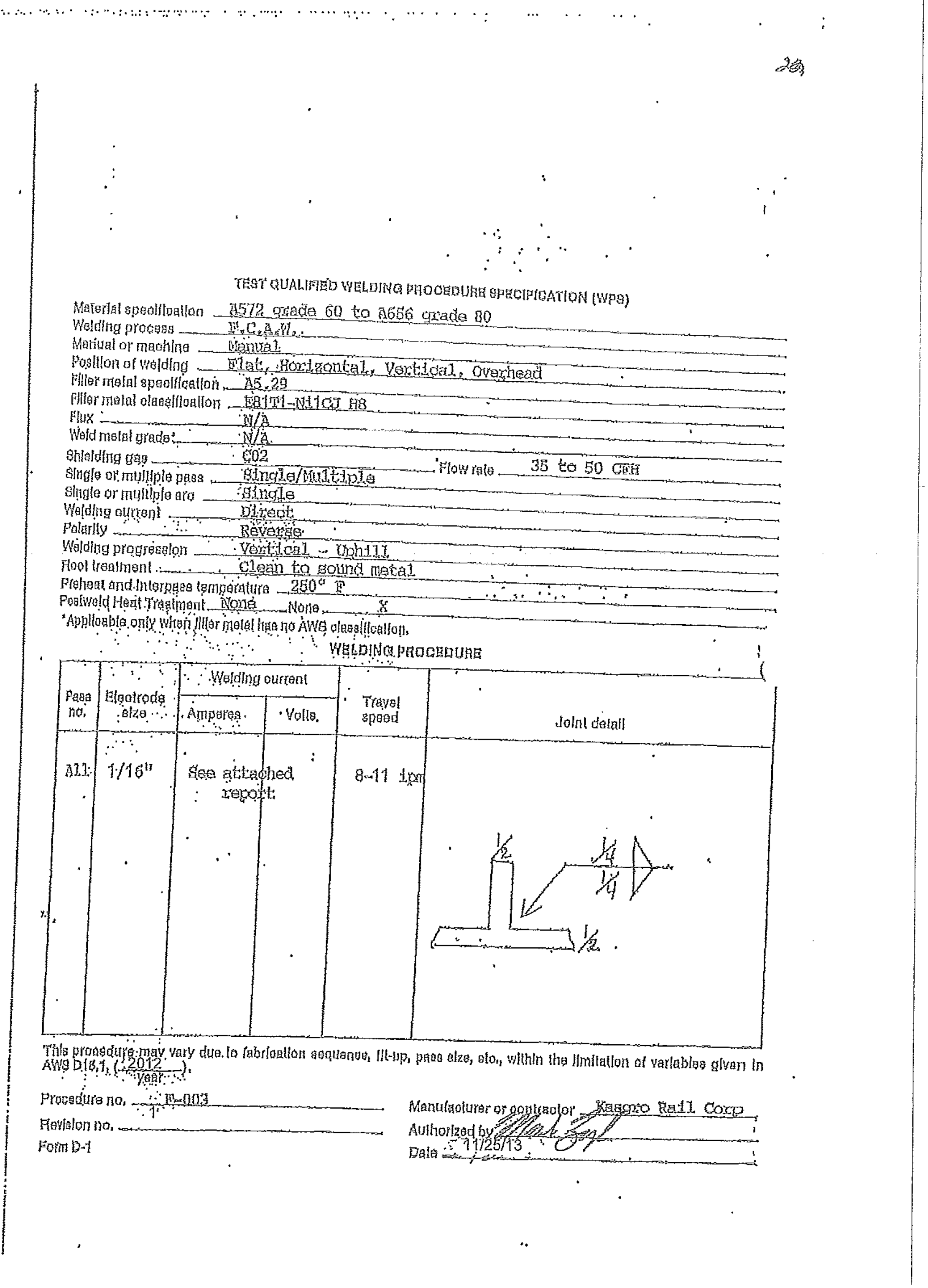
Single-V-groove weld (2)
Butt joint (B)

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
		T1	T2	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



20

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 C02 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.

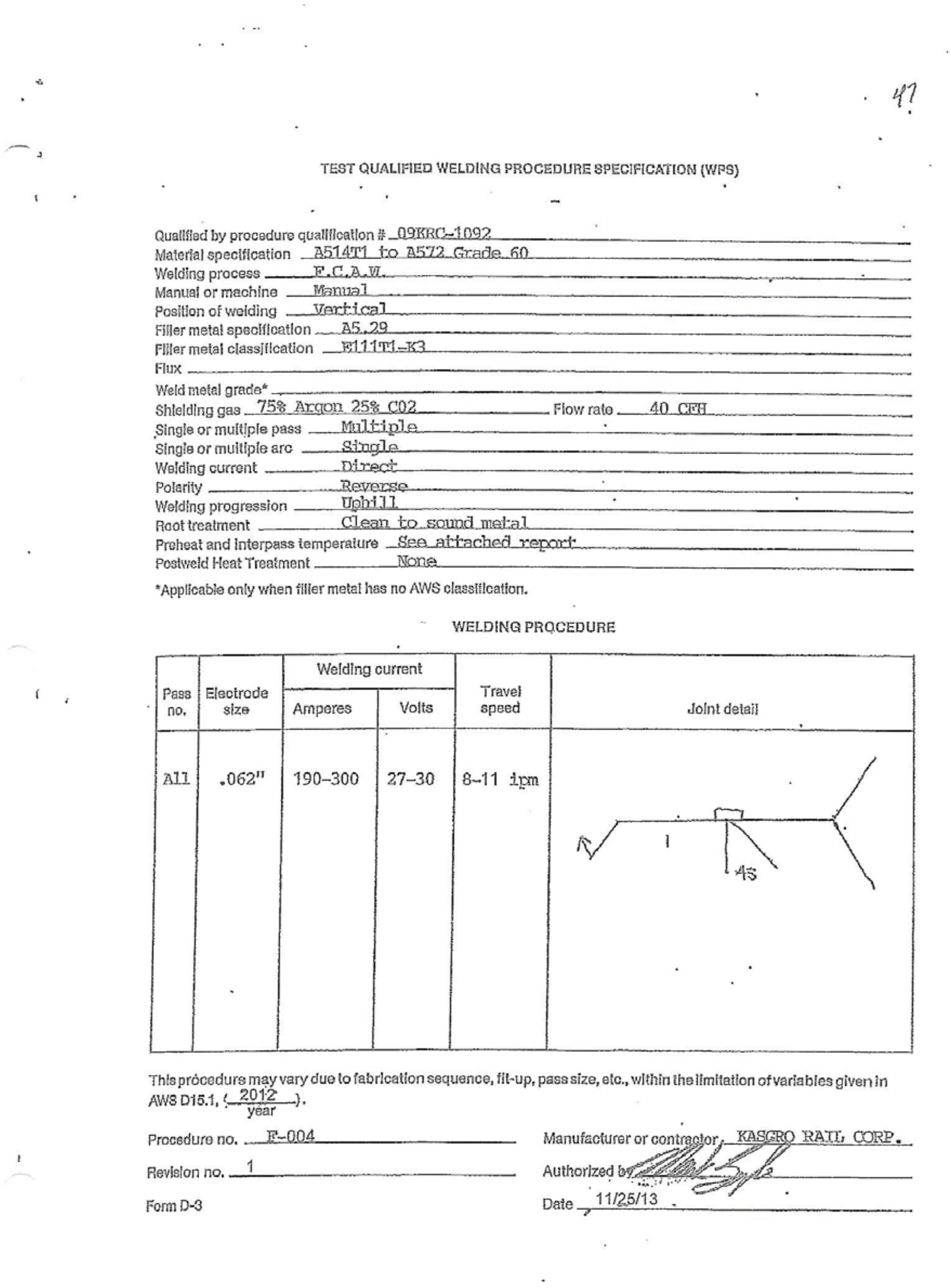
WELDING PROCEDURE

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

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
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
Date 11/25/13

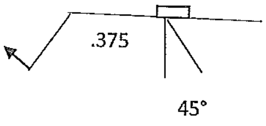
ANNEX D

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.
Material specification A572 GRADE 60 TO A240 GRADE 304.
elding process F.C.A.W..
anual or machine Manual.
osition of welding 1G Flat.
Filler 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

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

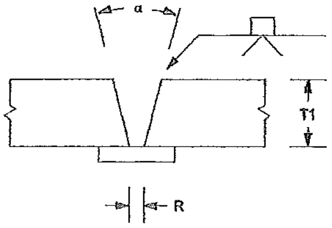
This procedure may vary due to fabrication sequence, fit-up, pass size, etc., within the limitation of variables given in AWS D15.1, (2012) Railroad Welding Specification for Cars and Locomotives.
(Year)

Procedure no. 08KR-F1087.
vision no. 2.

Manufacturer or Contractor KASGRO RAIL CORP.
Authorized by .
Date 07/27/15.

D-1

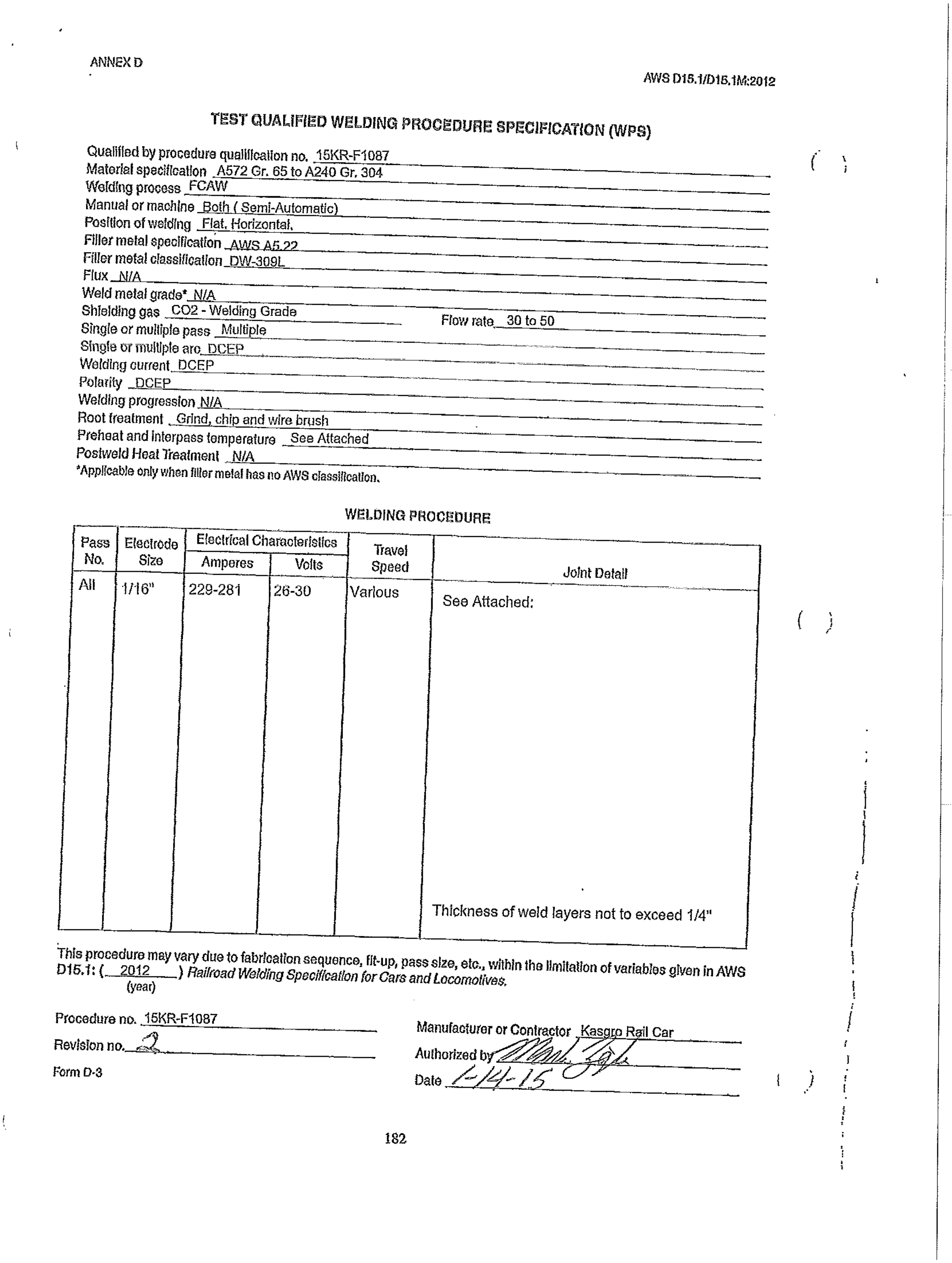
Single-V-groove weld (2)
Butt joint (B)



Welding Process	Joint Designation	Base Metal Thickness (U=unlimited)		Groove Preparation			
				Root Opening	Groove Angle	Tolerances	
		T1	T2			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 α = +10°, -0°	+1/4, -1/16 +10°, -5°
				R = 3/8	α = 30°		
				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.



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

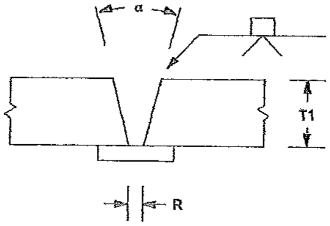
Pass No.	Electrode Size	Electrical Characteristics		Travel Speed	Joint Detail
		Amperes	Volts		
All	1/16"	229-281	26-30	Various	See Attached: Thickness of weld layers not to exceed 1/4"

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
Date 1-14-15

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



		Base Metal Thickness (U=unlimited)		Groove Preparation			
						Tolerances	
Welding Process	Joint Designation	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 α = +10°, -0°	+1/4, -1/16 +10°, -5°
				R = 3/8	α = 30°		
				R = 1/4	α = 45°		

b-u2a-gf.gfl

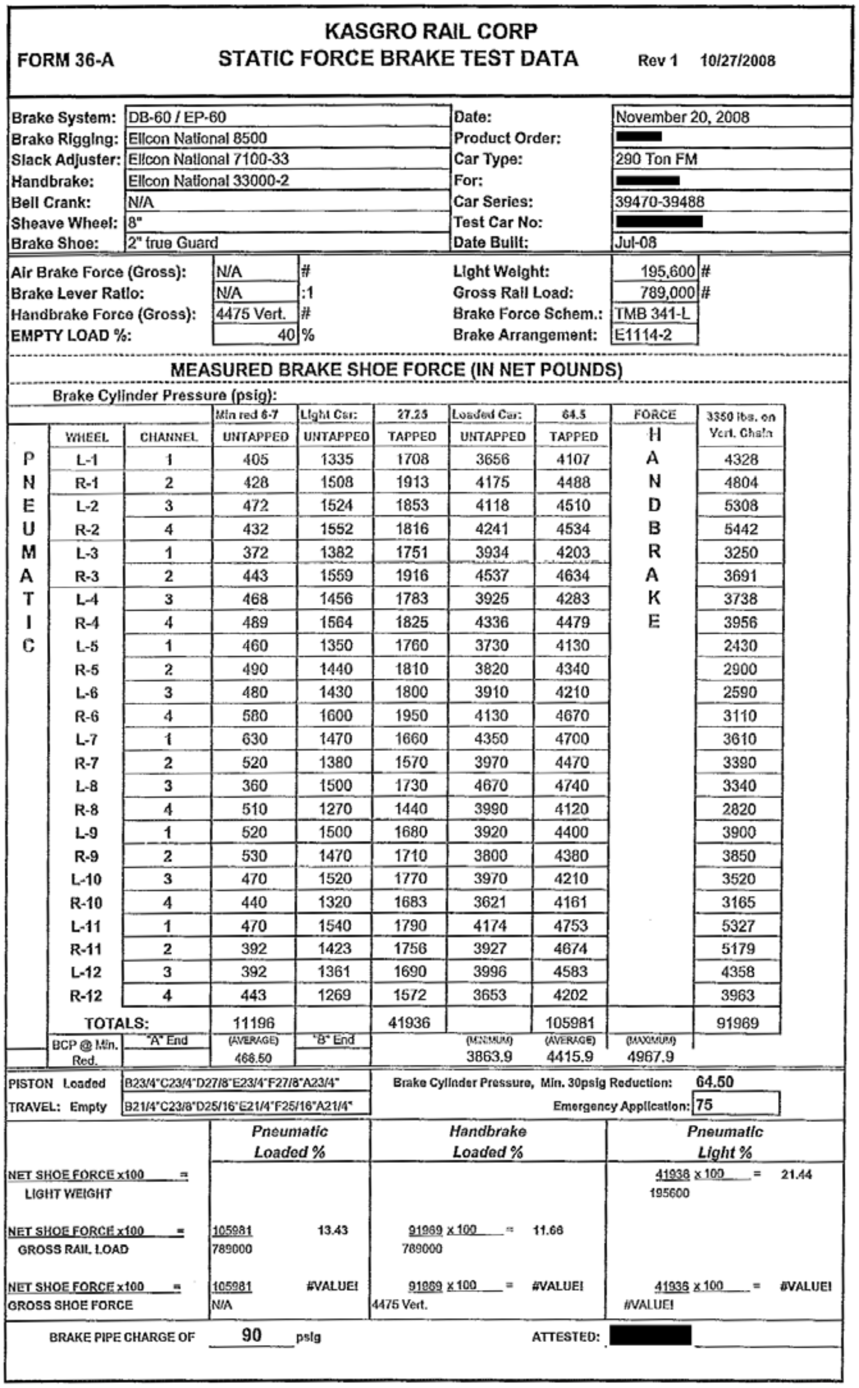
Preheat

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 H-2.2

BUFFER RAILCAR BRAKE TESTING

Appendix H-2.2.1 Static Force Brake Test Data, Form 36-A, Rev 1



KASGRO RAIL CORP

FORM 36-A **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	3925	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) 466.50	"B" End		(MINIMUM) 3863.9	(AVERAGE) 4415.9	(MAXIMUM) 4967.9	

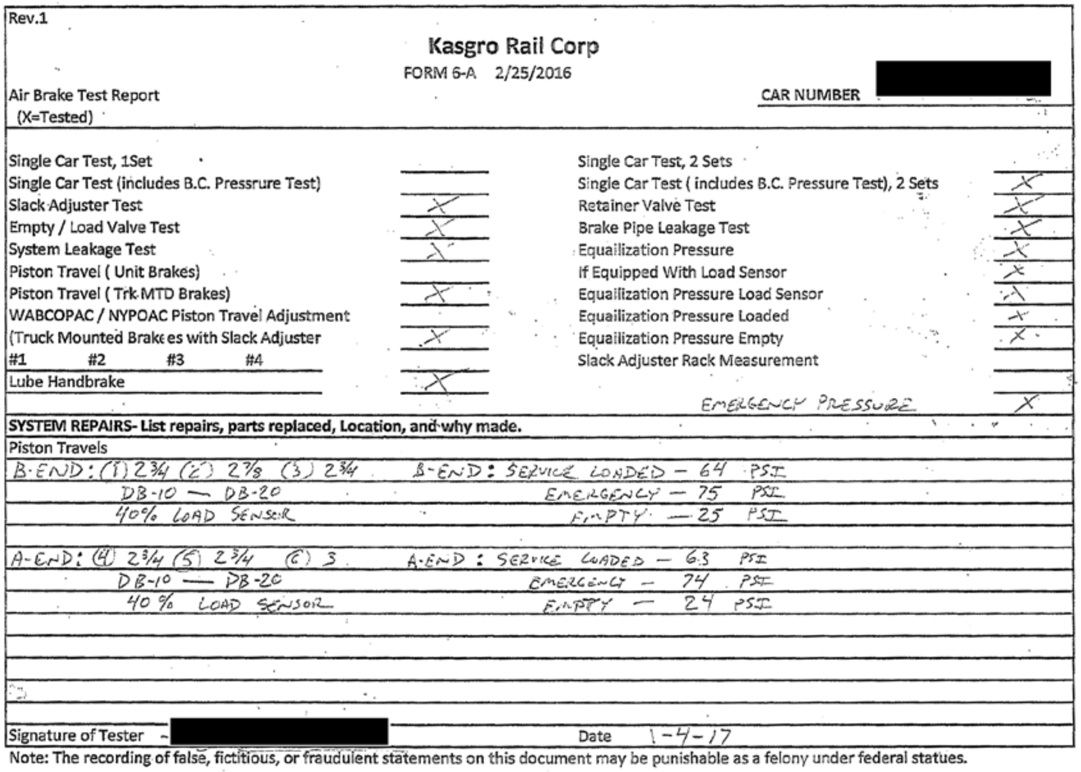
PISTON Loaded	B23/4"C23/4"D27/8"E23/4"F27/8"A23/4"	Brake Cylinder Pressure, Min. 30psig Reduction:	64.50
TRAVEL: Empty	B21/4"C23/8"D25/16"E21/4"F25/16"A21/4"	Emergency Application:	75

	Pneumatic Loaded %	*Handbrake Loaded %*	*Pneumatic Light %*
NET SHOE FORCE x100 = LIGHT WEIGHT			41938 x 100 = 21.44 195600
NET SHOE FORCE x100 = GROSS RAIL LOAD	105981 13.43 789000	91969 x 100 = 11.66 789000	
NET SHOE FORCE x100 = GROSS SHOE FORCE	105981 #VALUE! N/A	91969 x 100 = #VALUE! 4475 Vert.	41936 x 100 = #VALUE! #VALUE!

BRAKE PIPE CHARGE OF 90 psig

ATTESTED: [redacted]

Appendix H-2.2.2 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 Brakes 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

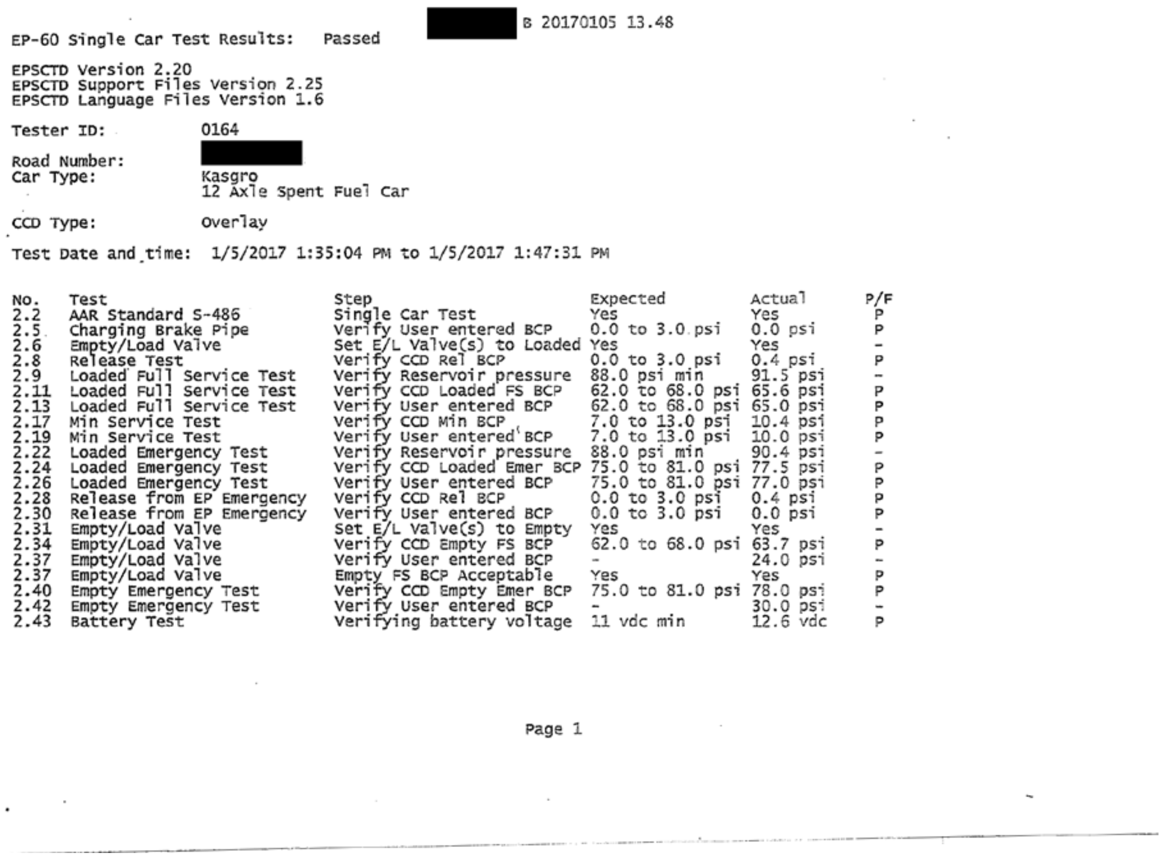
B-END: (1) 2¾ (2) 2⅞ (3) 2¾ B-END: SERVICE LOADED – 64 PSI
DB-10 — DB-20 EMERGENCY – 75 PSI
40% LOAD SENSOR EMPTY – 25 PSI

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 H-2.2.3 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
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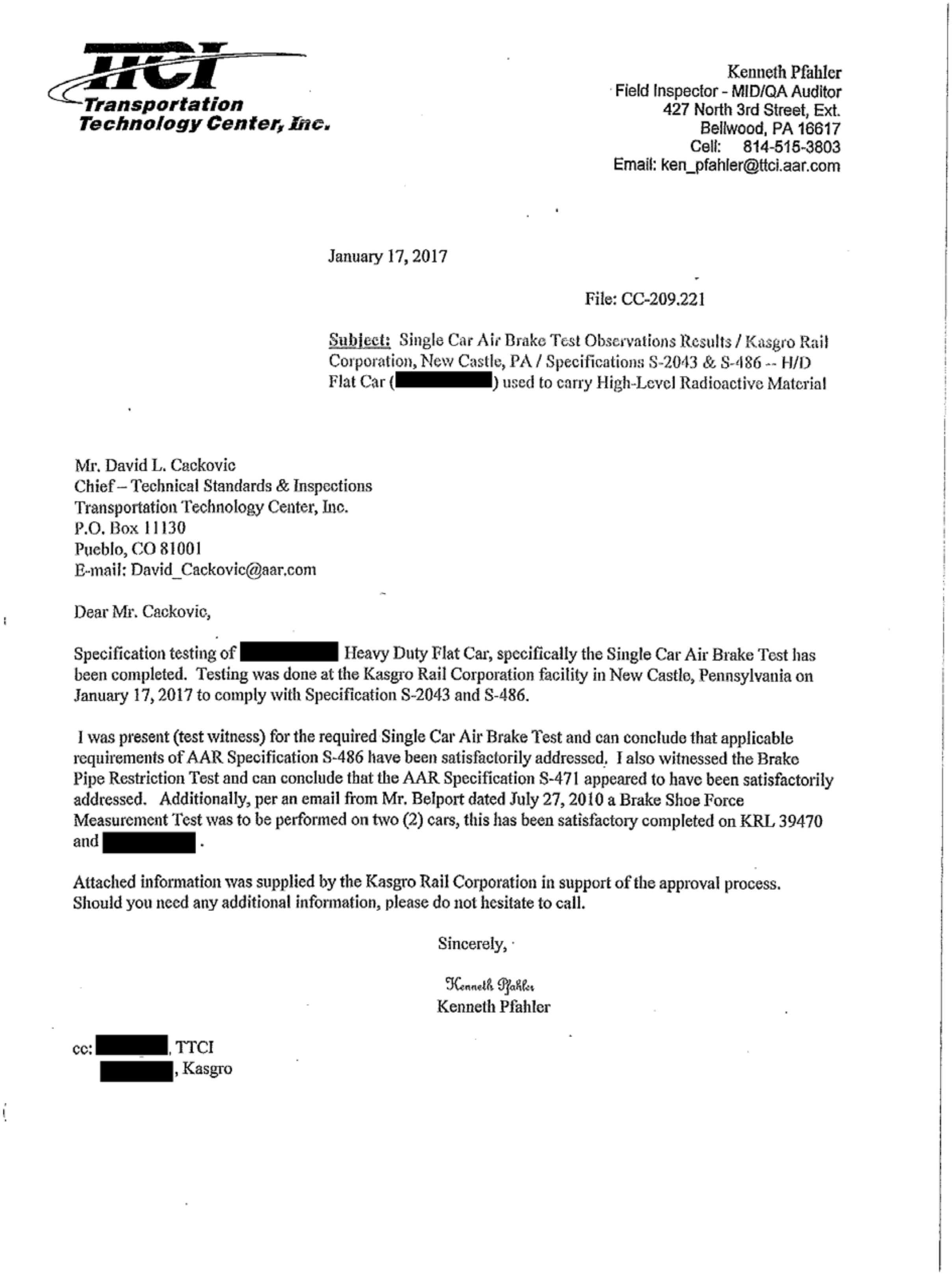
Appendix H-2.2.4 Example of AAR Air Brake Test Witness Letter
TTCI Letter #CC-209-221 dated January 17, 2017



TTCI
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].

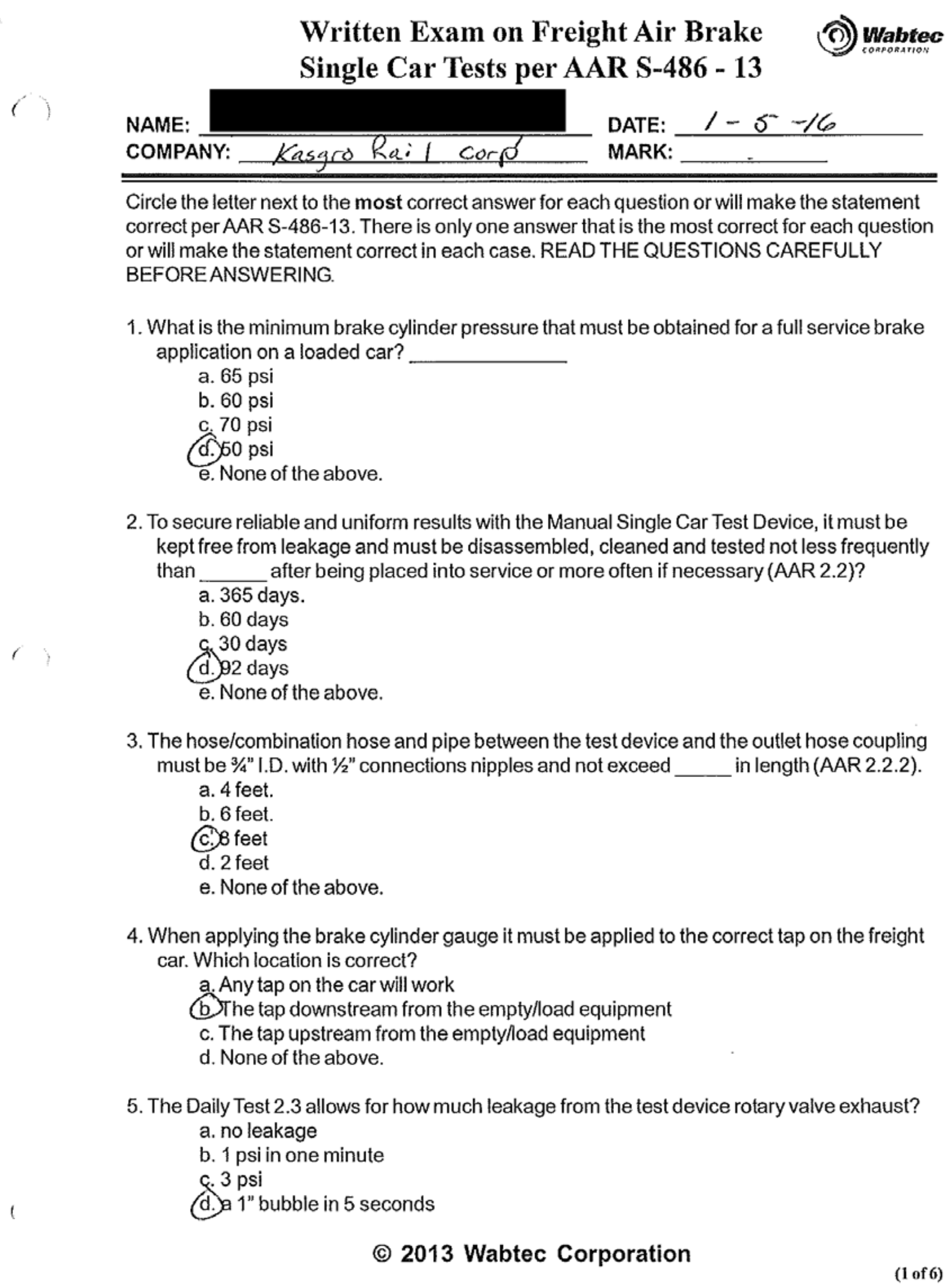
Attached information was supplied by the Kasgro Rail Corporation in support of the approval process. Should you need any additional information, please do not hesitate to call.

Sincerely,

Kenneth Pfahler
Kenneth Pfahler

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

Appendix H-2.2.5 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

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.

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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.

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

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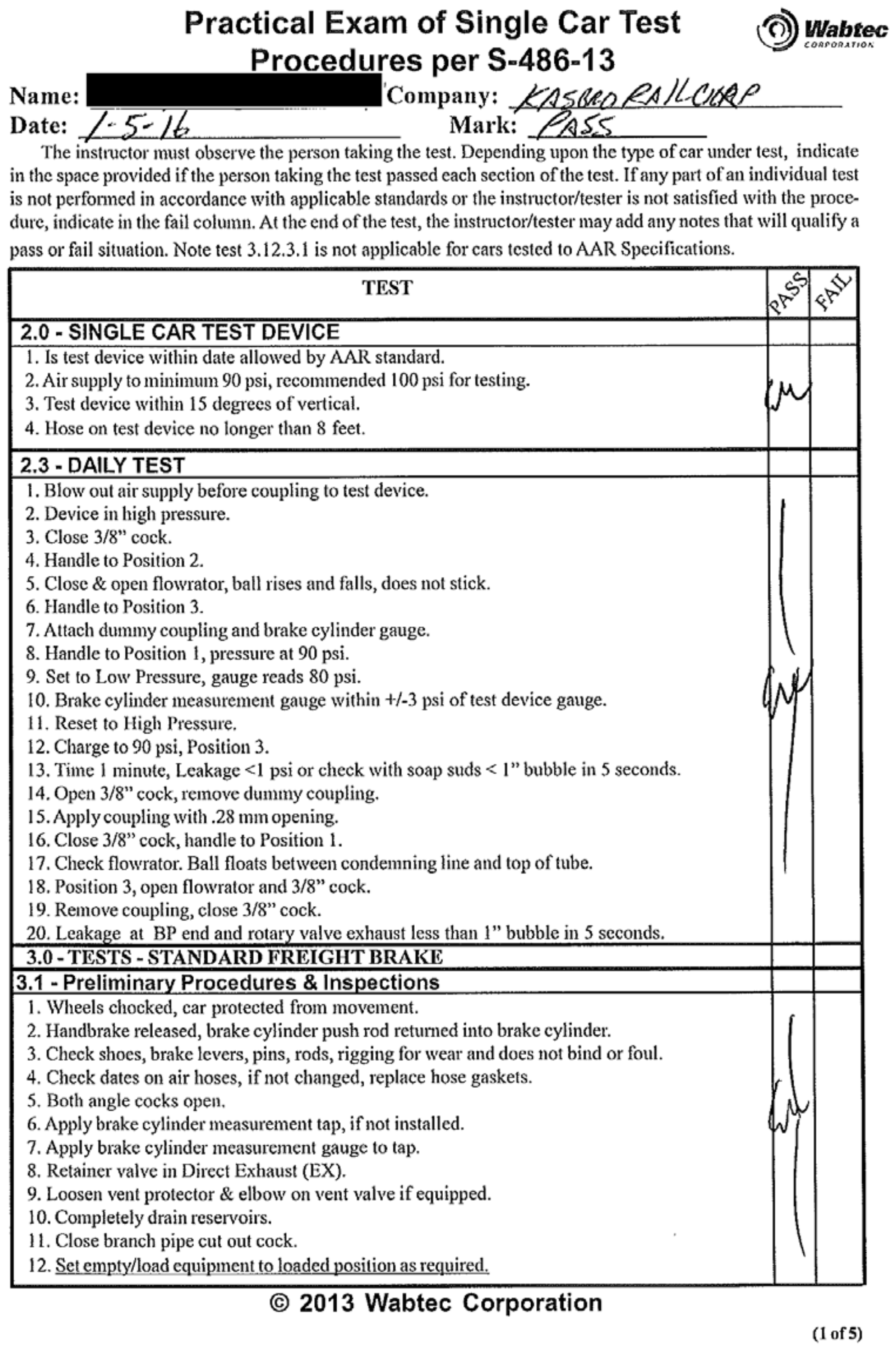
26. When completing the Empty/Load Test 3.20, the brake cylinder pressure noted in 3.20.2 must be at least _________ lower than pressure noted in Test 3.9.4.
    a. 5 psi
    b. 10 psi.
    [✓ c.] 17 psi.
    d. 20 psi.
    e. None of the above.

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.		

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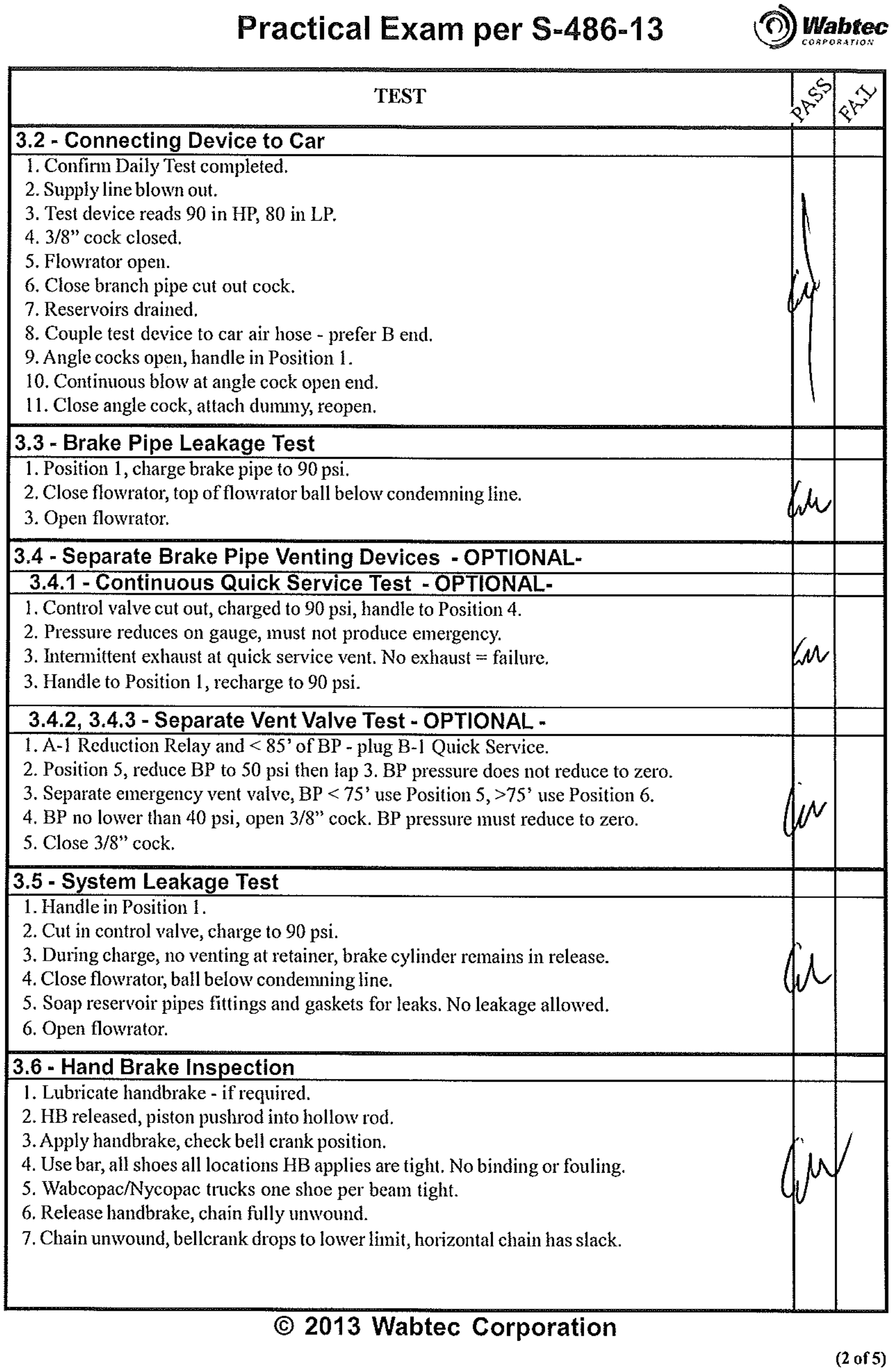

Practical Exam per S-486-13

Wabtec CORPORATION

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.		
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.		
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.		
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.		
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.		
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.		

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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.		

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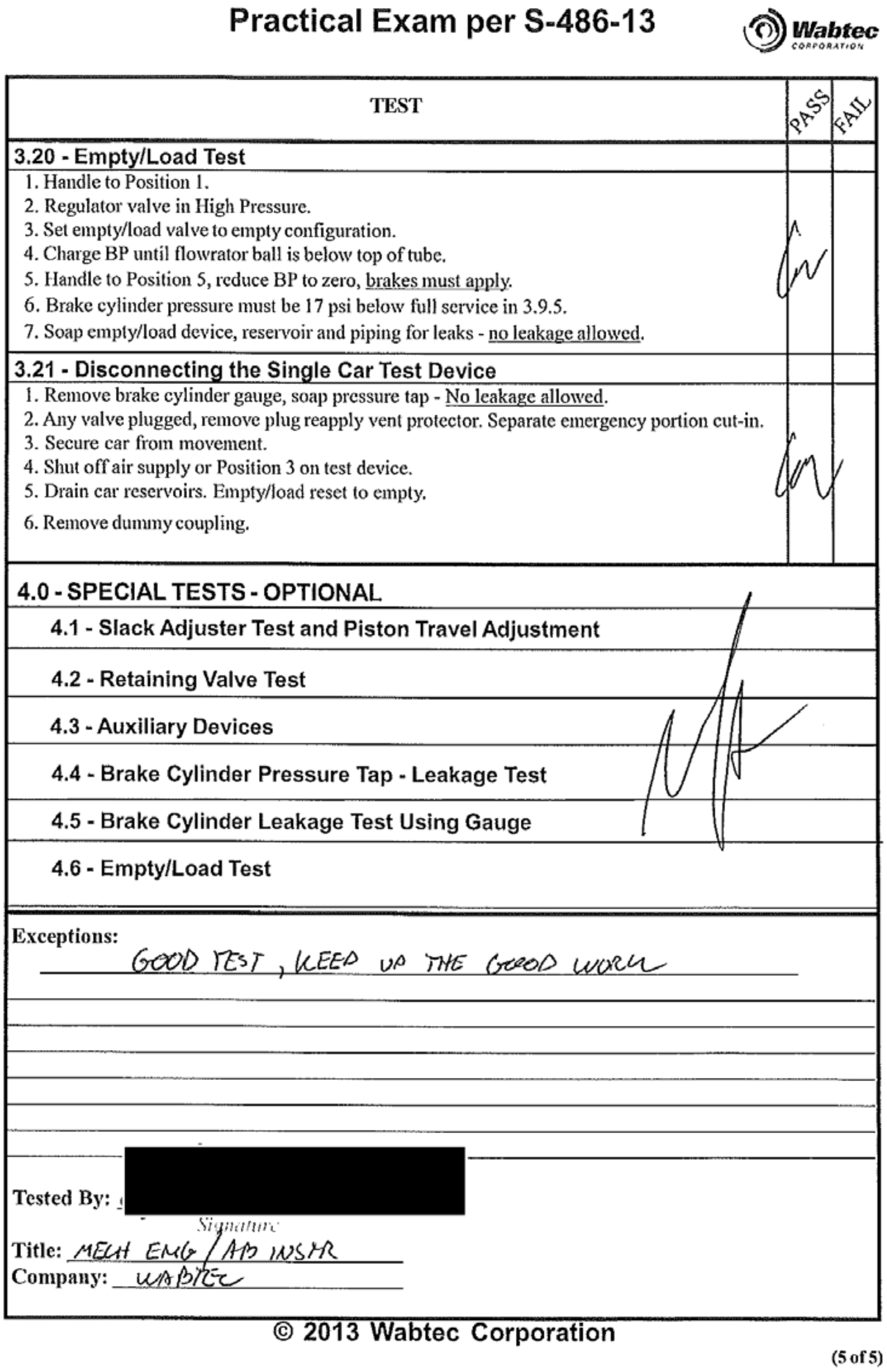
Practical Exam per S-486-13

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.		
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).		
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.		
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.		
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.		
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		



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.		
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.		
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		

Exceptions: GOOD TEST, KEEP UP THE GOOD WORK

Tested By: [redacted]
Signature

Title: MECH ENG / AB INSTR

Company: WABTEC

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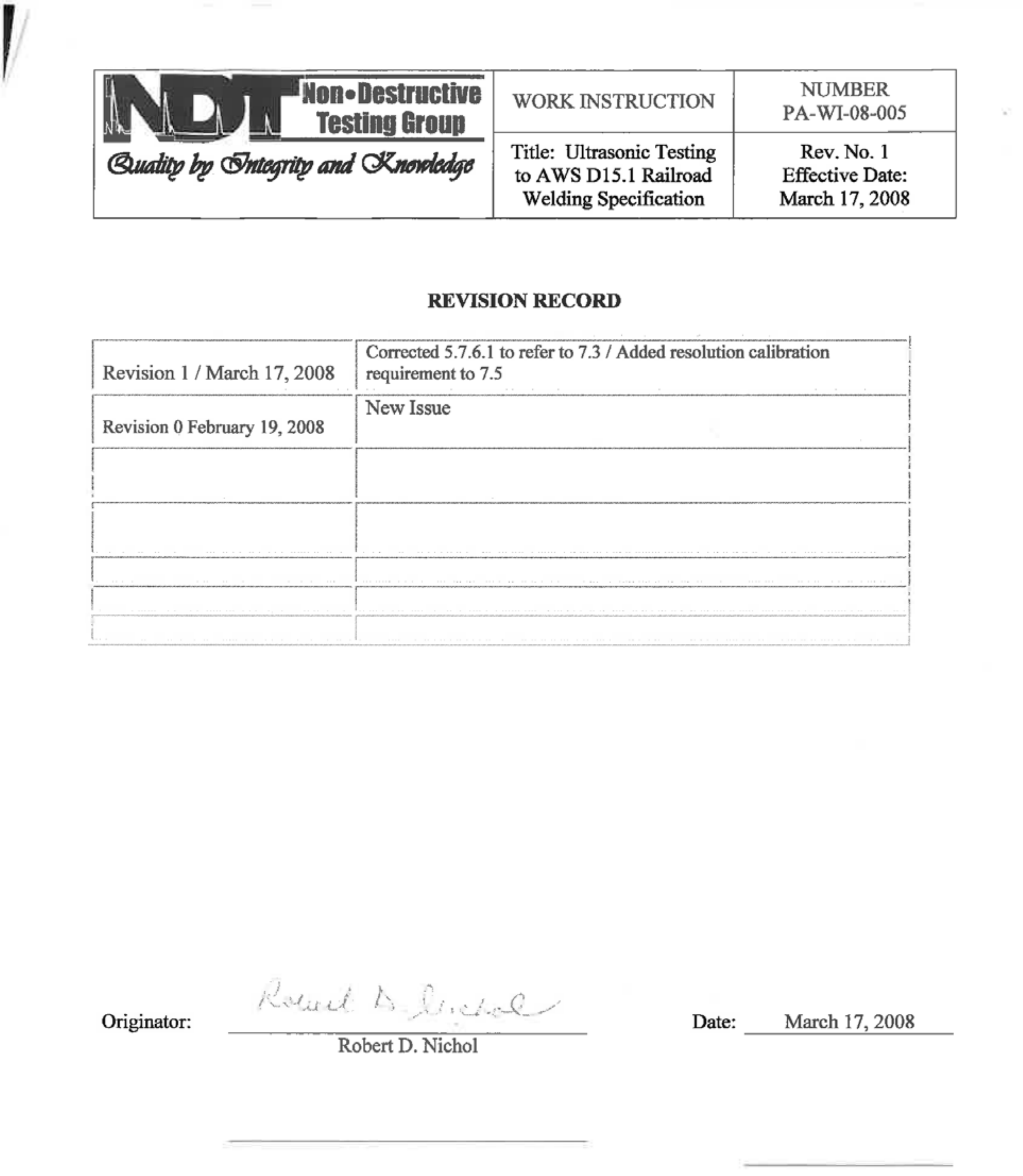
APPENDIX H-2.3

BUFFER RAILCAR NDE EXAMINATIONS AND TESTING

Appendix H-2.3.1 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 **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]

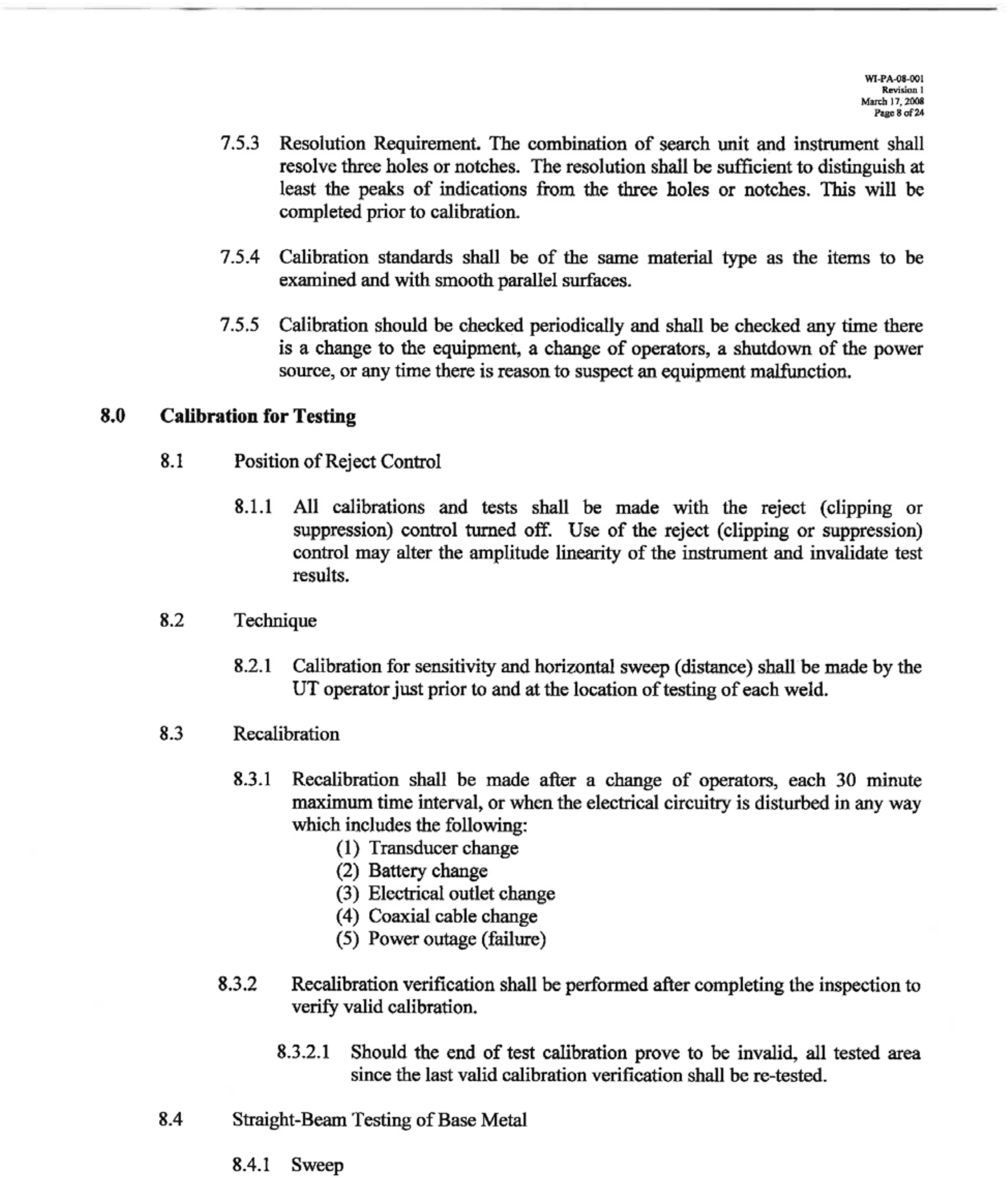
For 60° transducer
X = 1-7/16 inches [37 mm]

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.

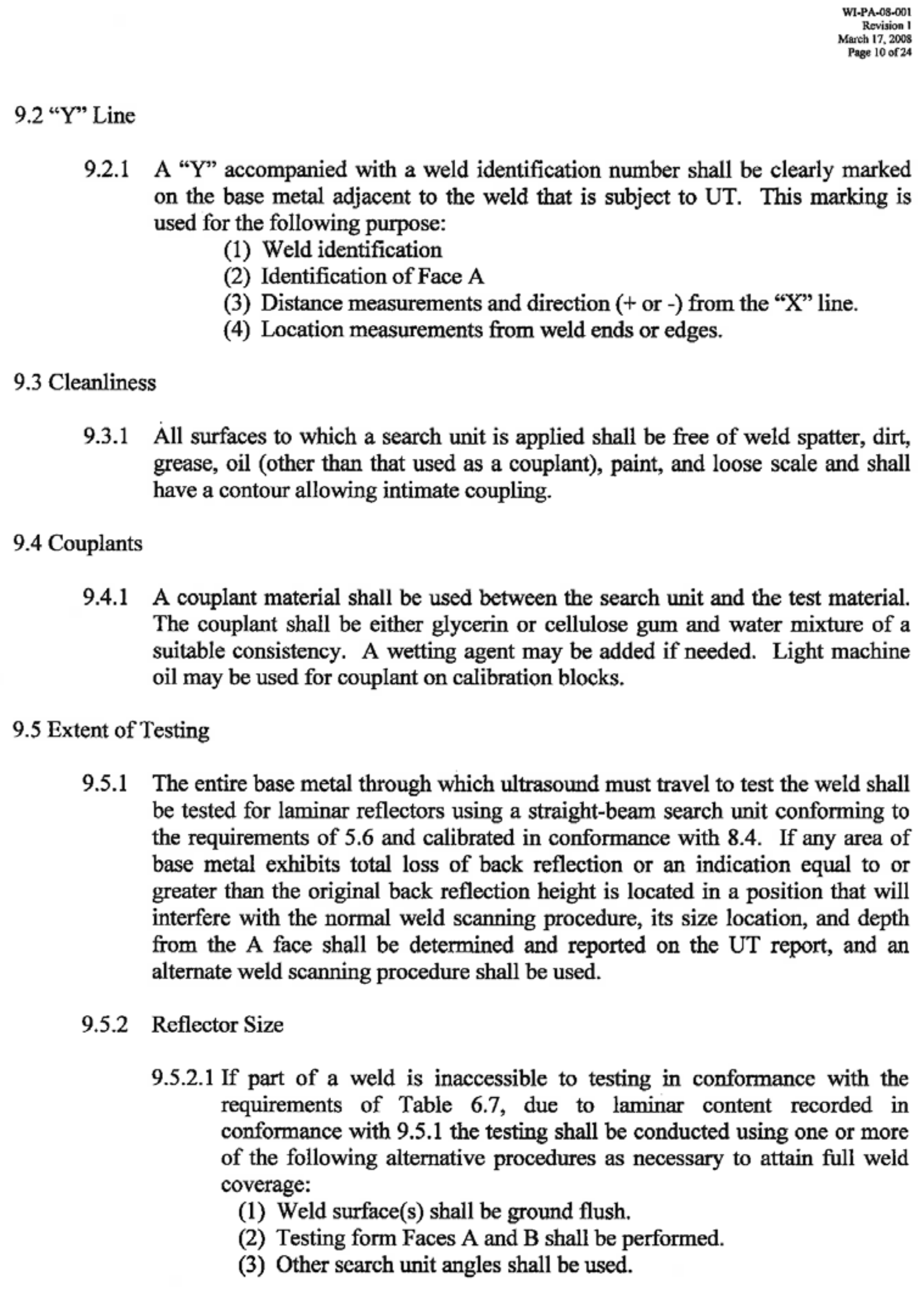
8.5.2.2 Zero Reference Level

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

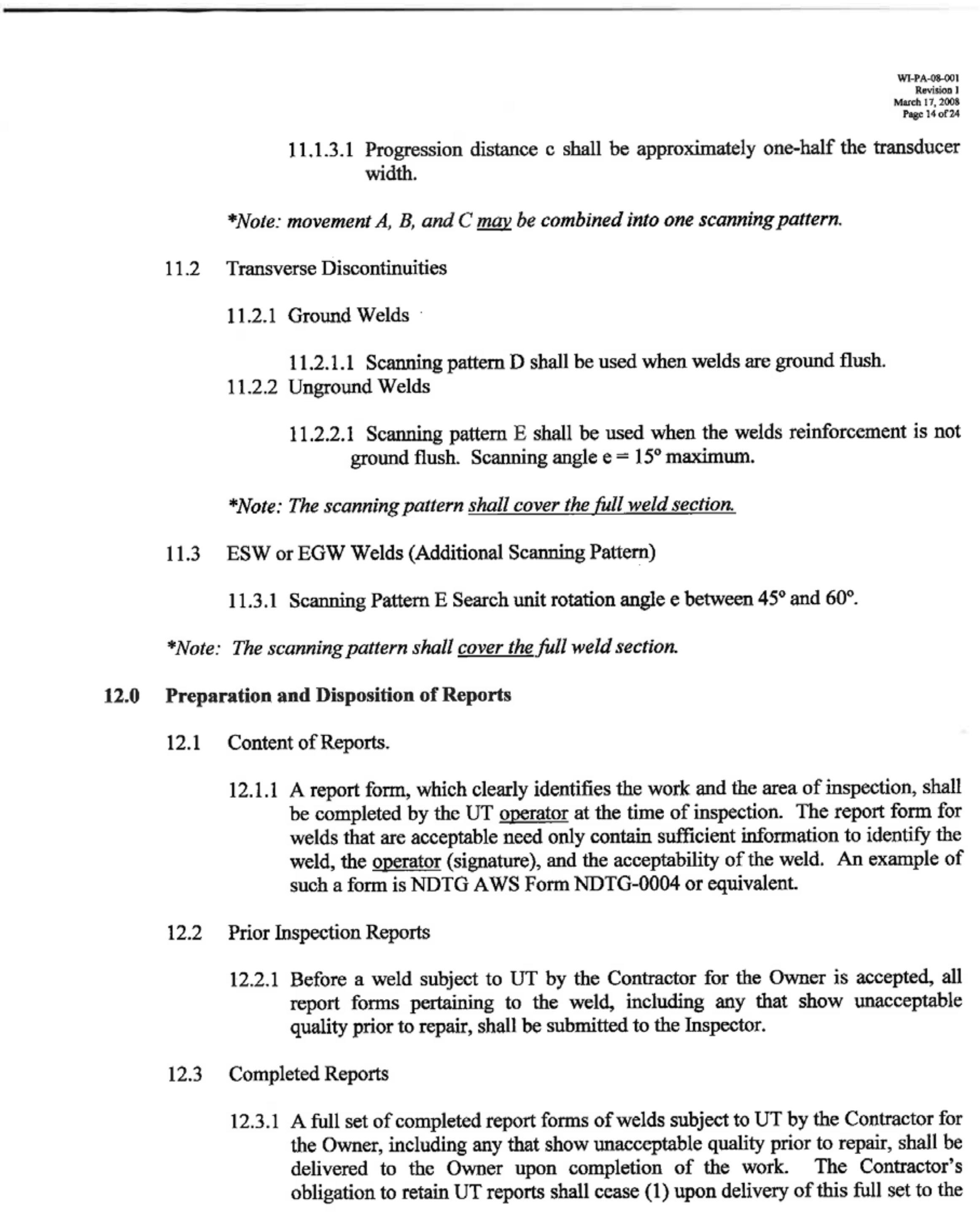
11.1.1 Scanning Movement A.

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

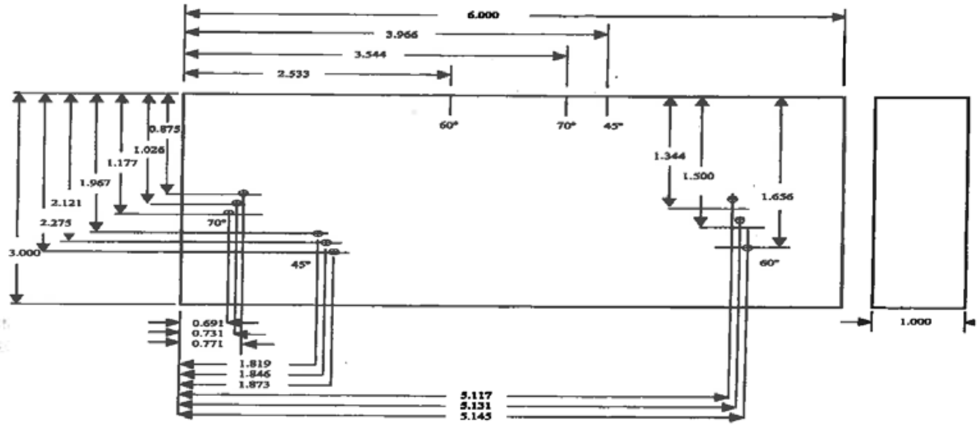
Owner, or (5) years after completion of the Contractor's work, provided that the Owner is given prior written notice.

13.0 Marking

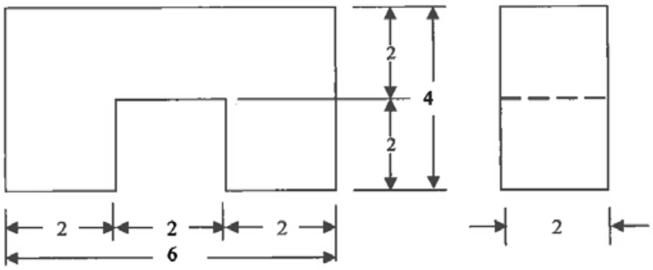
13.1 Each rejectable discontinuity shall be indicated on the weld by a mark directly over the discontinuity for it's entire length. The depth from the surface and the type of the discontinuity shall be noted nearby on base metal.

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)

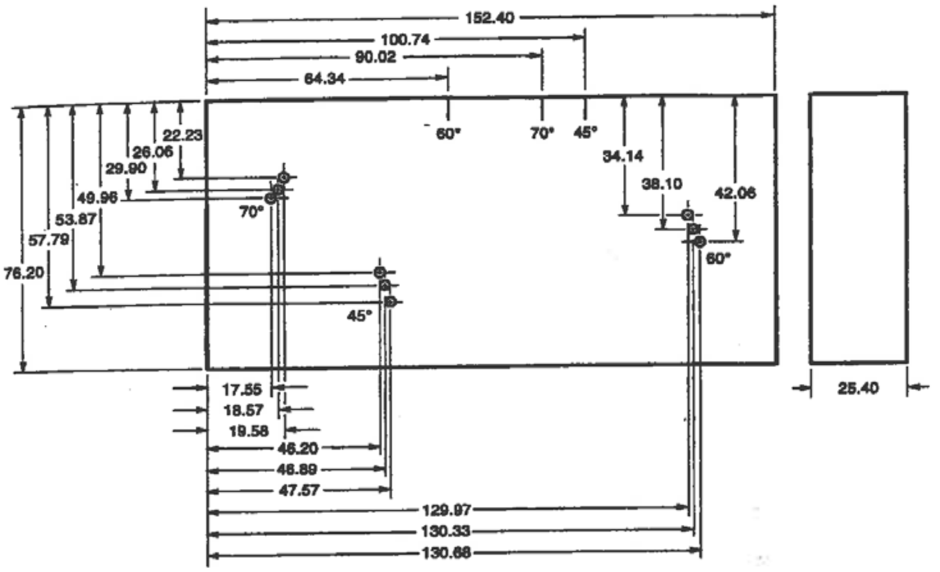


RC – RESOLUTION REFERENCE BLOCK



TYPE – DISTANCE AND SENSITIVITY REFERENCE BLOCK

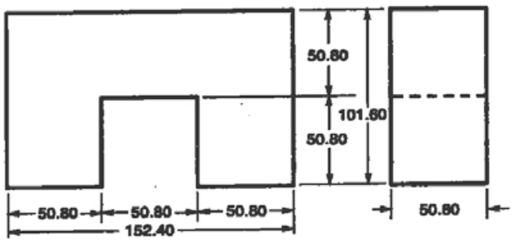
Figure 6.3 – Qualification Blocks (see 6.3)



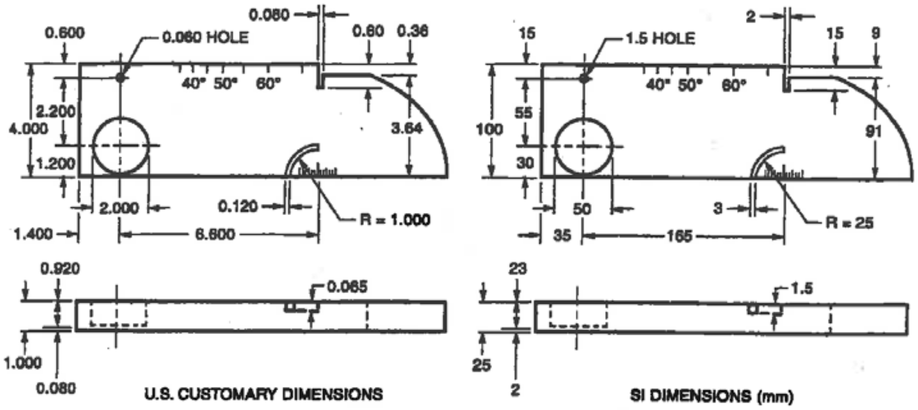
General Note: All holes are1.59 mm in diameter.

DIMENSIONS IN MILLIMETERS

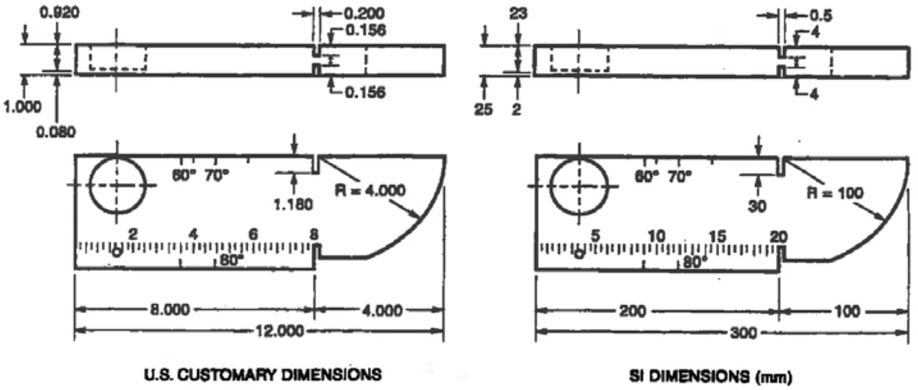
RC – RESOLUTION REFERENCE BLOCK



TYPE – DISTANCE AND SENSITIVITY REFERENCE BLOCK



(A) TYPE 1 (TYPICAL)



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

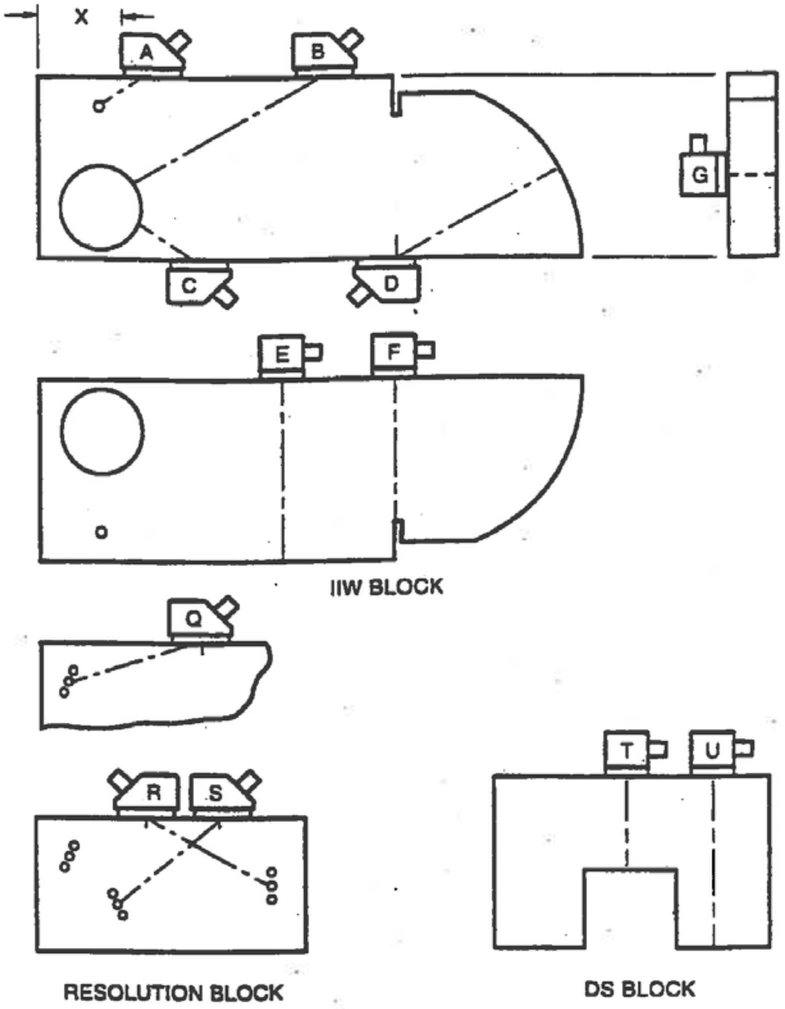


Figure 7.4.1- Transducer Positions (Typical)

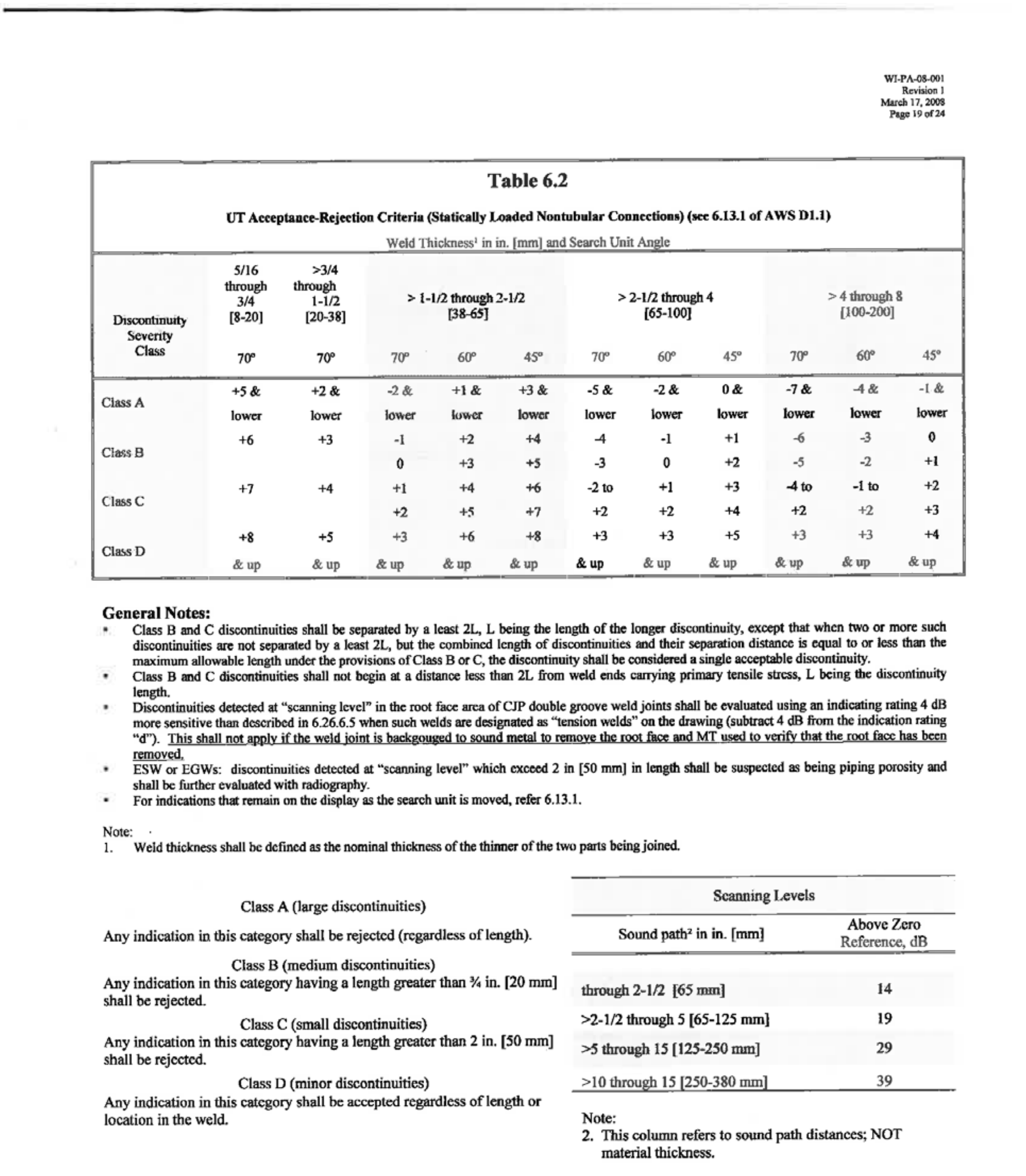


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Table 6.2

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 & lower	+2 & lower	-2 & lower	+1 & lower	+3 & lower	-5 & lower	-2 & lower	0 & lower	-7 & lower	-4 & lower	-1 & lower
Class B	+6	+3	-1 0	+2 +3	+4 +5	-4 -3	-1 0	+1 +2	-6 -5	-3 -2	0 +1
Class C	+7	+4	+1 +2	+4 +5	+6 +7	-2 to +2	+1 +2	+3 +4	-4 to +2	-1 to +2	+2 +3
Class D	+8 & up	+5 & up	+3 & up	+6 & up	+8 & up	+3 & up	+3 & up	+5 & up	+3 & up	+3 & up	+4 & 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"). 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.
- 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

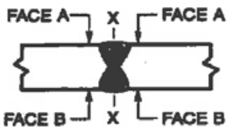
Sound path² in in. [mm]	Above Zero Reference, dB
through 2-1/2 [65 mm]	20
>2-1/2 through 5 [65-125 mm]	25
>5 through 15 [125-250 mm]	35
>10 through 15 [250-380 mm]	45

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

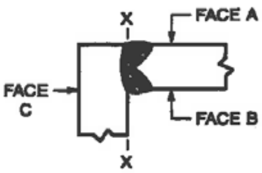
Table 6.7
Testing Angle
Procedure Chart

Material Thickness in. [mm]

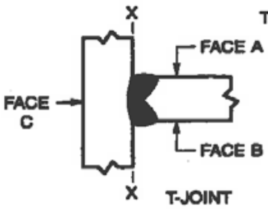
Weld Type	5/16 [8] to 1-1/2 [38]		>1-1/2 [38] to 1-3/4 [45]		>1-3/42 [45] to 2-1/2 [60]		>2-1/2 [60] to 3-1/2 [90]		>3-1/2 [90] to 4-1/2 [110]		>4-1/2 [110] to 5 [130]		>5 [130] to 6-1/2 [160]		>6-1/2 [160] to 7 [180]		>7 [180] to 8 [200]	
	*		*		*		*		*		*		*		*		*	
Butt	1	0	1	F	1G or 4	F	1G or 5	F	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	---	---



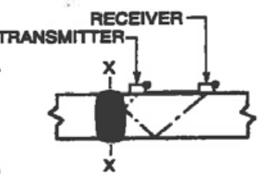
BUTT JOINT



CORNER JOINT



T-JOINT



PITCH-AND-CATCH

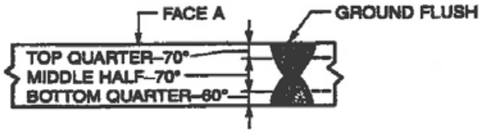


Table 6.7 (Continued)

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.

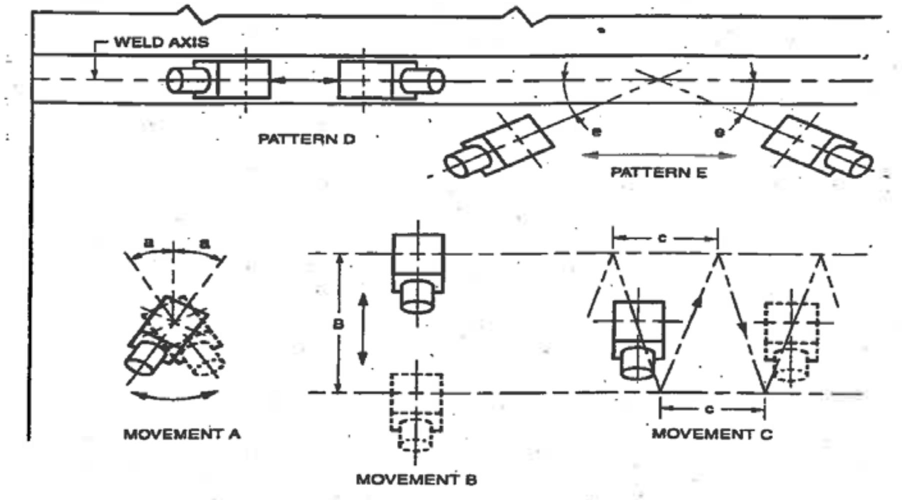
General Notes:

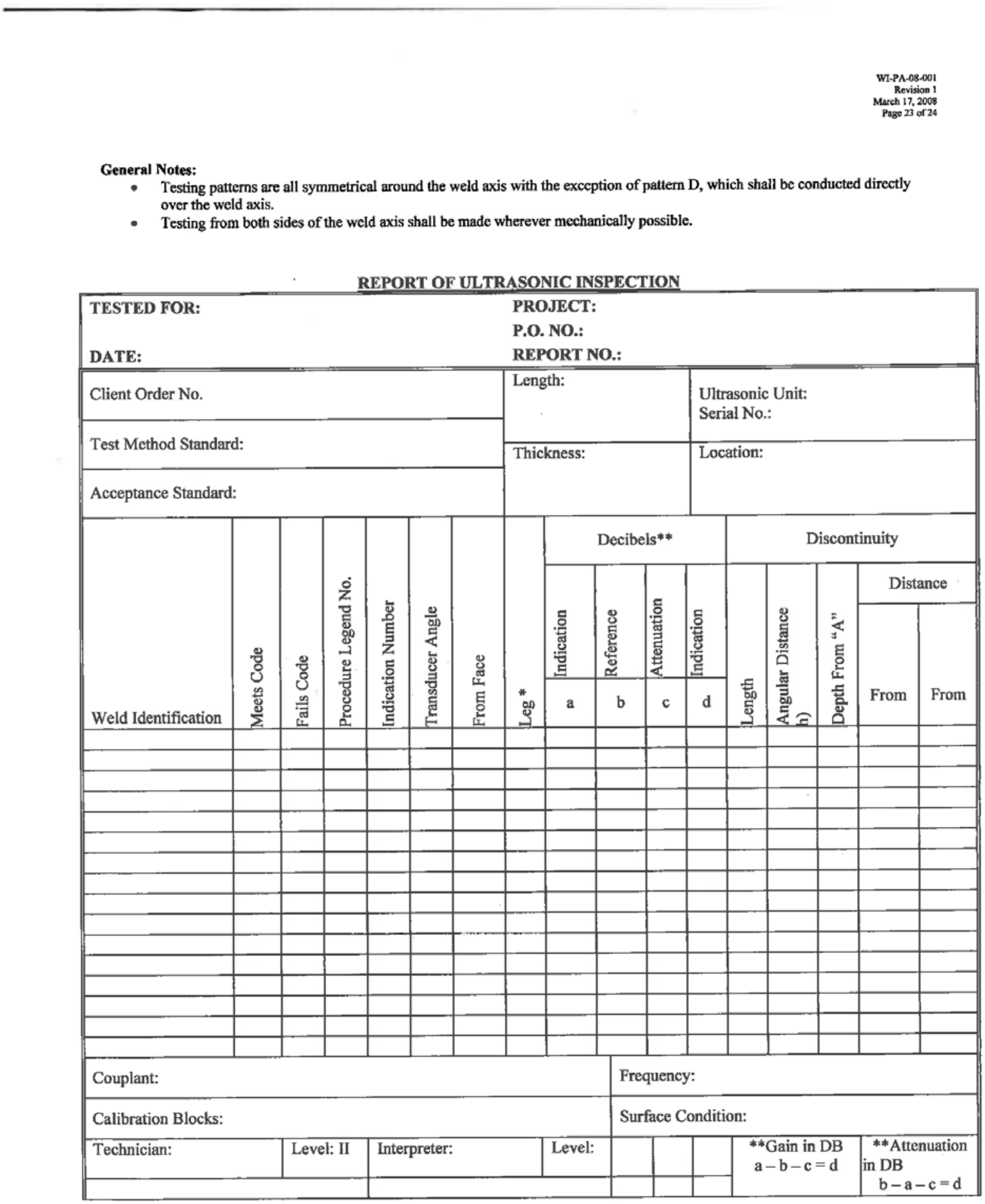
- Where possible, all examinations shall be made from Face A and n Leg 1, unless otherwise specified in this table.
- Root areas of single groove weld joints which have backing not requiring removal by contract, shall be tested in Leg 1, where possible, with Face A being that opposite the backing. (Grinding 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			
	Area of Weld Thickness		
No.	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





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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

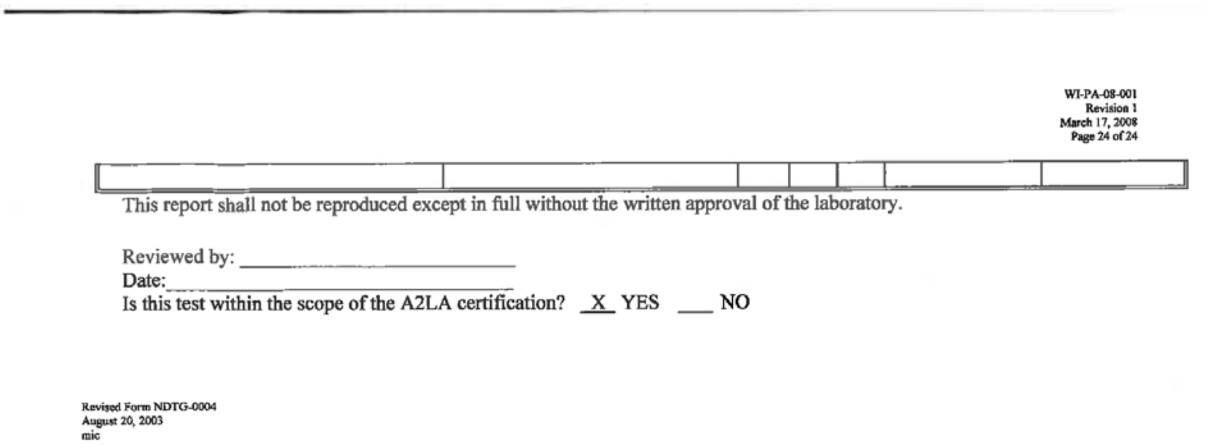
TESTED FOR:
DATE:
PROJECT:
P.O. NO.:
REPORT NO.:

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

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



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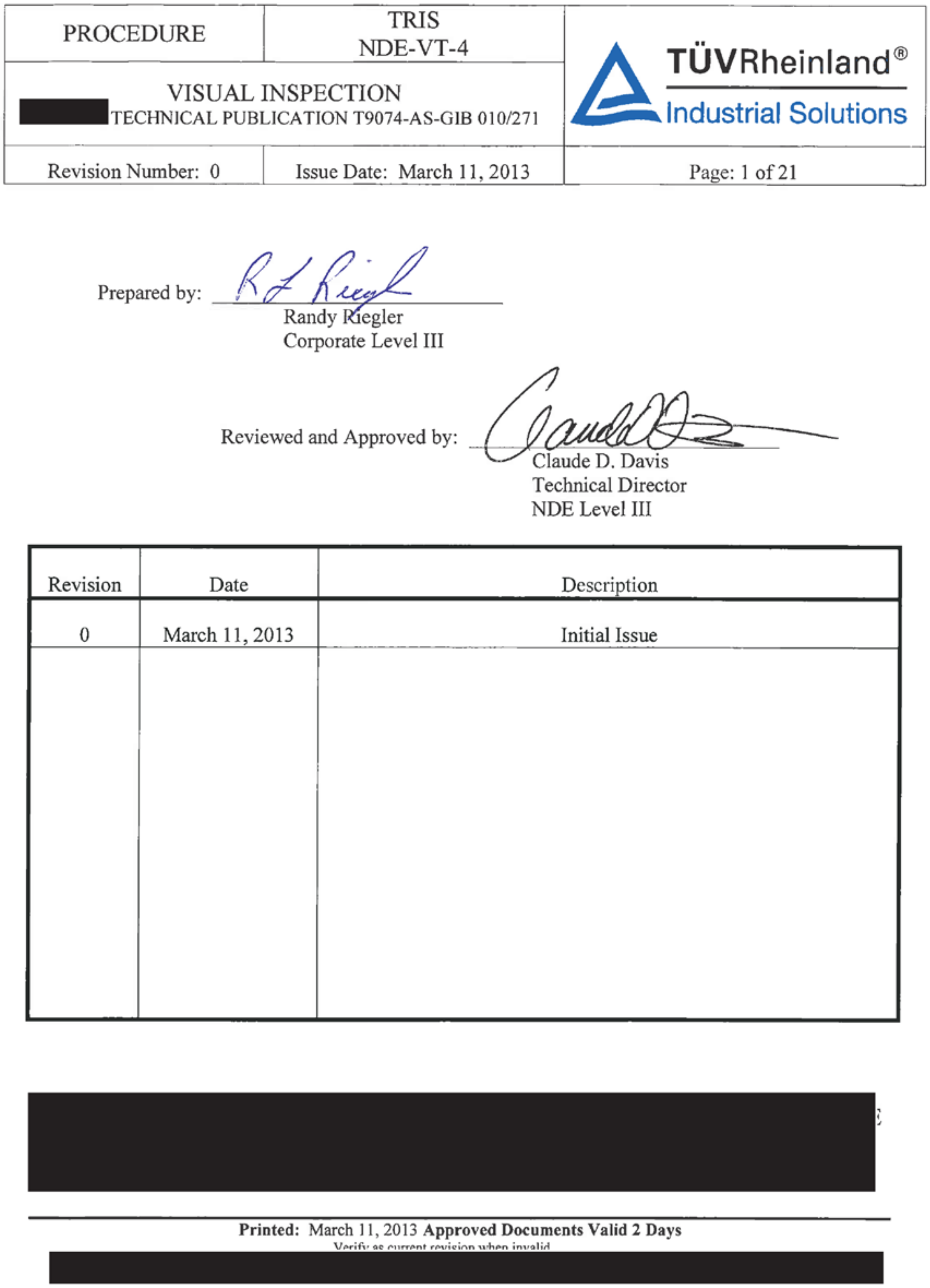
This report shall not be reproduced except in full without the written approval of the laboratory.

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 H-2.3.2 TUV Rheinland Industrial Solutions Procedure TRIS NDE-VT-4, Rev No. 0, Visual Inspection NAVSEA 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

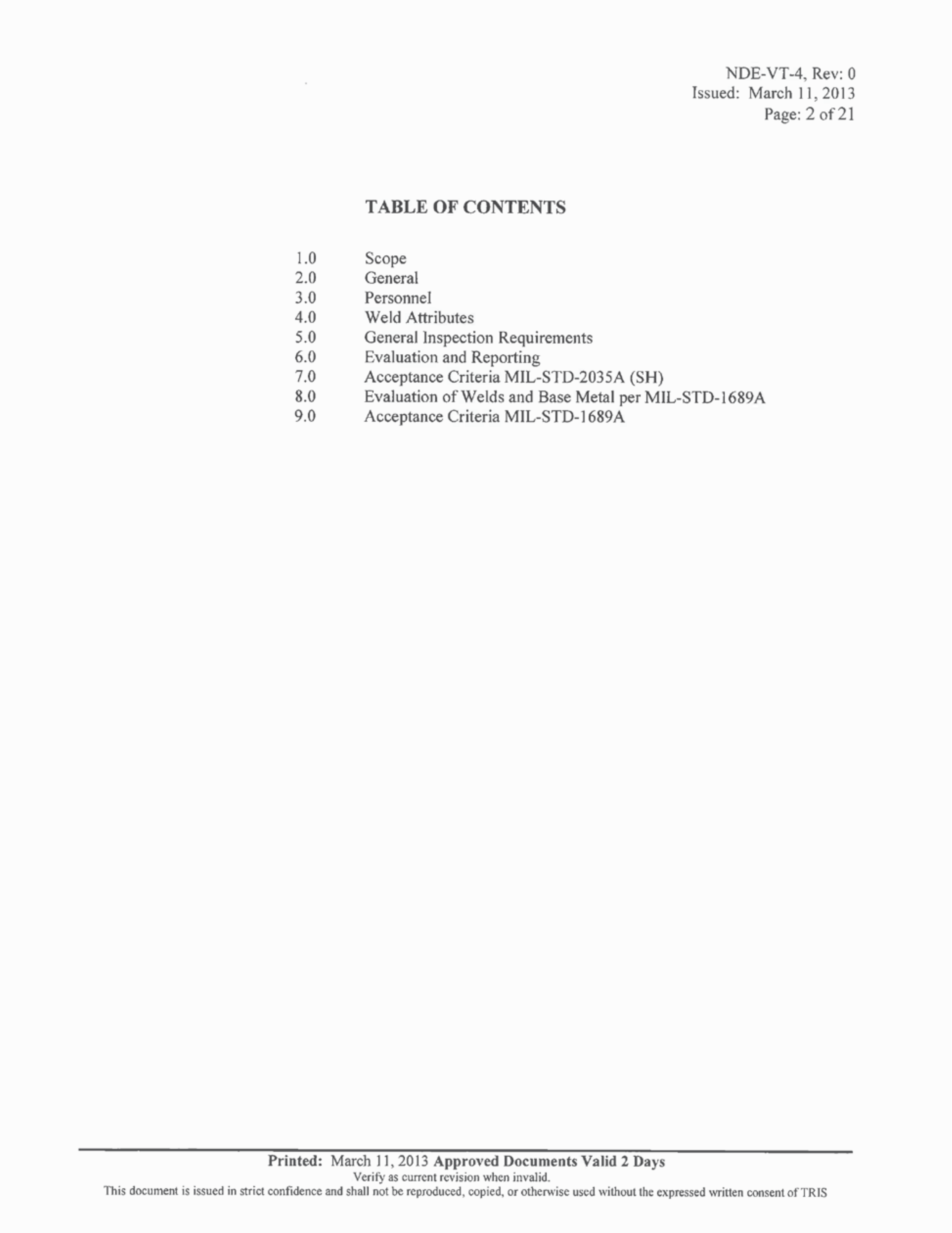
Reviewed and Approved by: Claude D. Davis
Technical Director
NDE Level III

Revision	Date	Description
0	March 11, 2013	Initial Issue

[redacted]

Printed: March 11, 2013 **Approved Documents Valid 2 Days**

[redacted]



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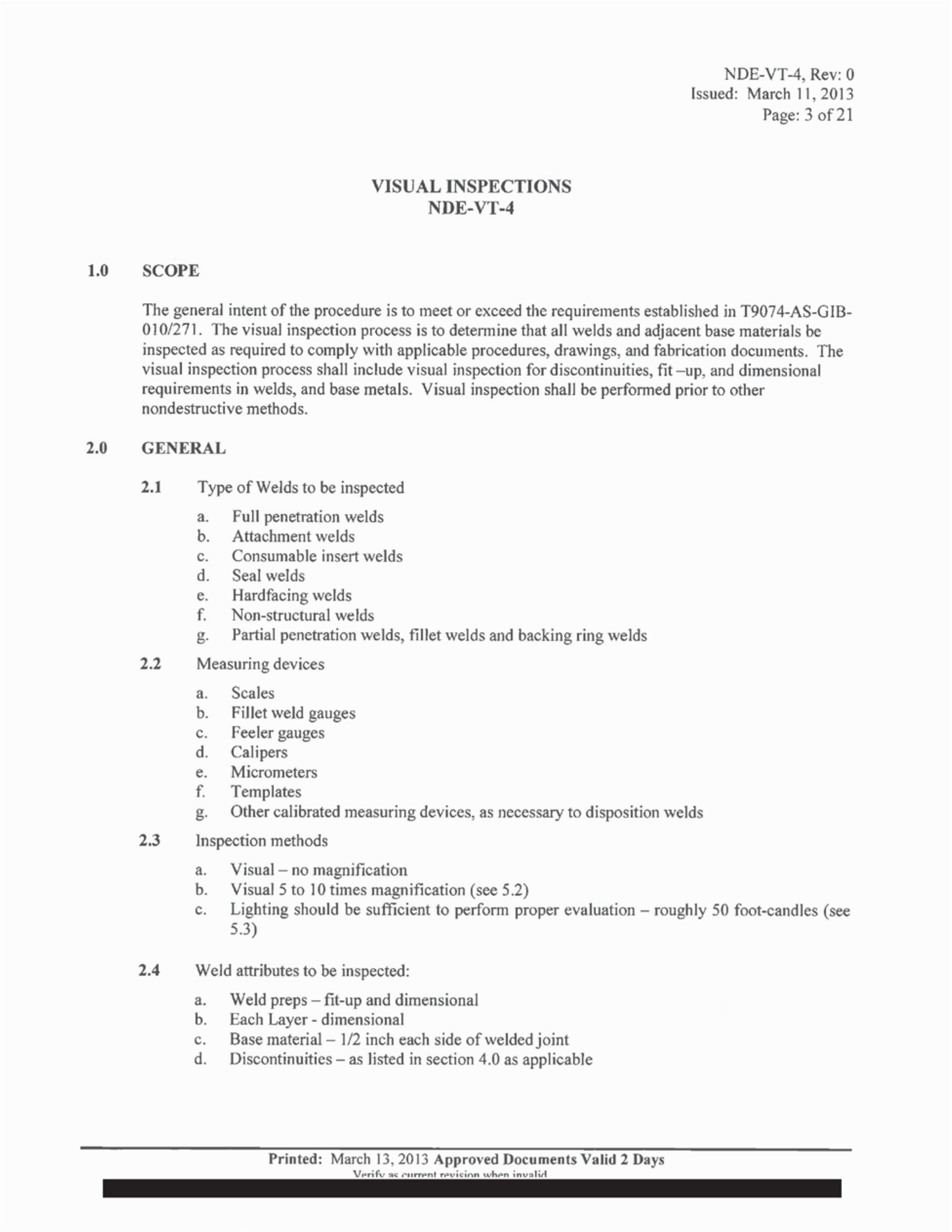

NDE-VT-4, Rev: 0
Issued: March 11, 2013
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VISUAL INSPECTIONS
NDE-VT-4

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

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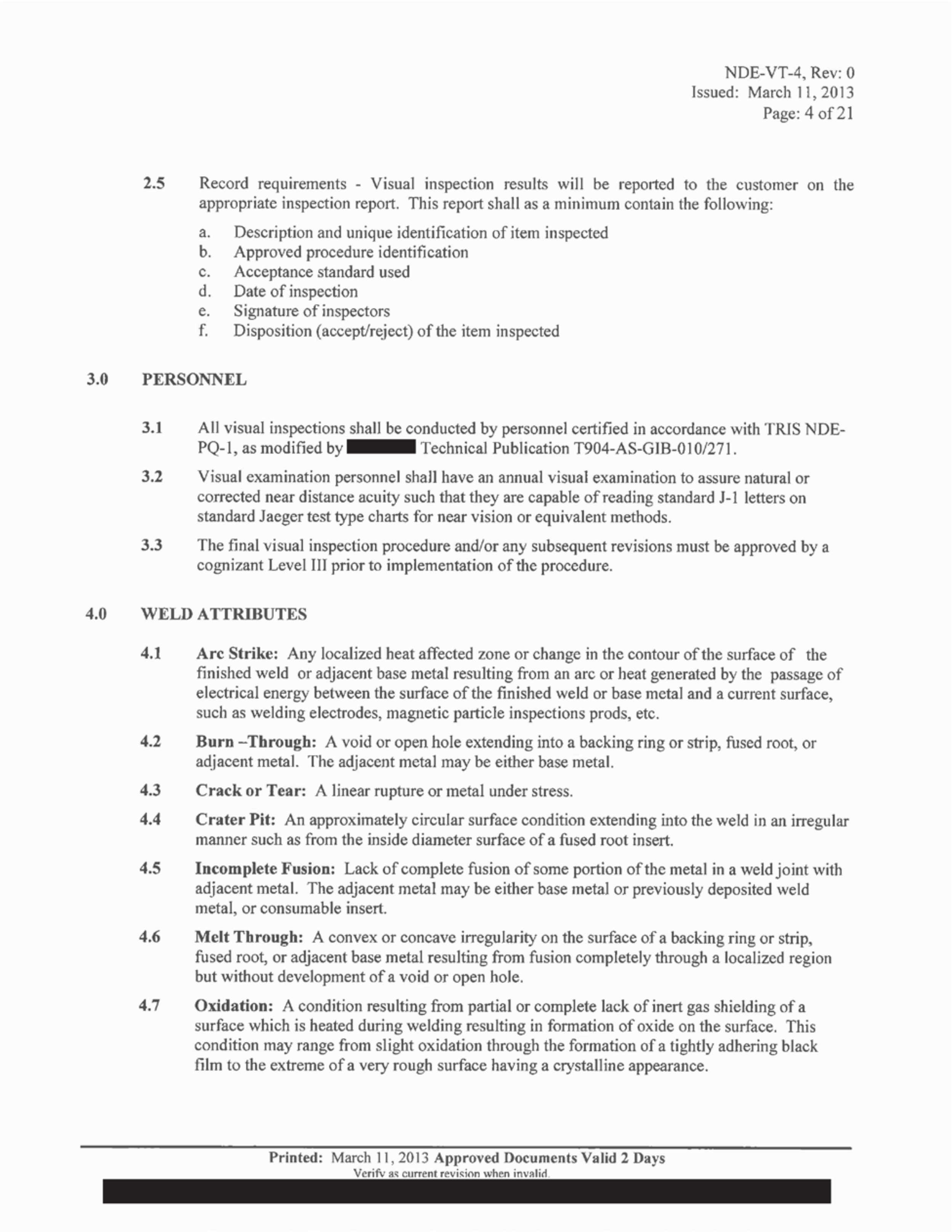
Verify as current revision when invalid

[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.

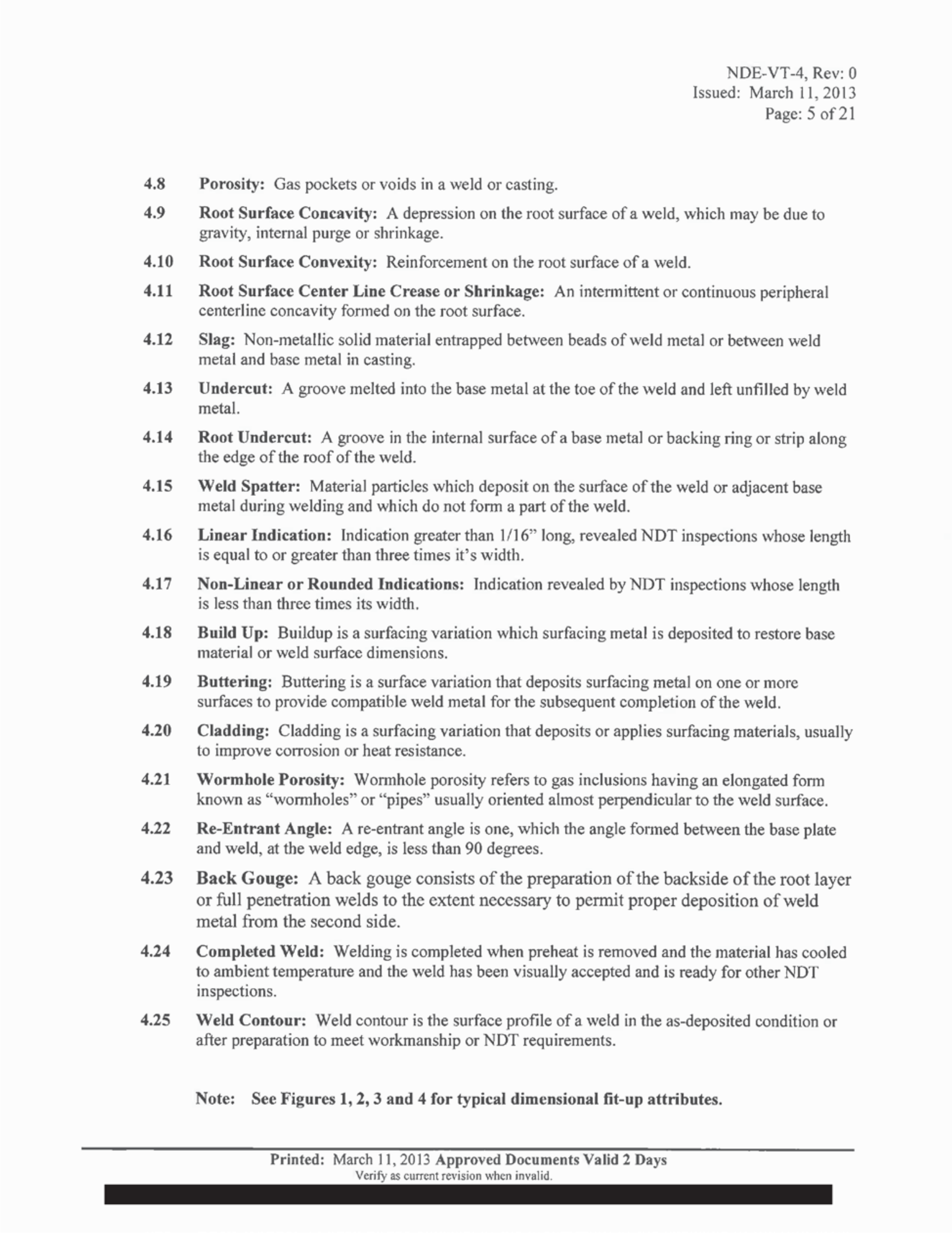
4.3 **Crack or Tear:** A linear rupture or metal under stress.

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.

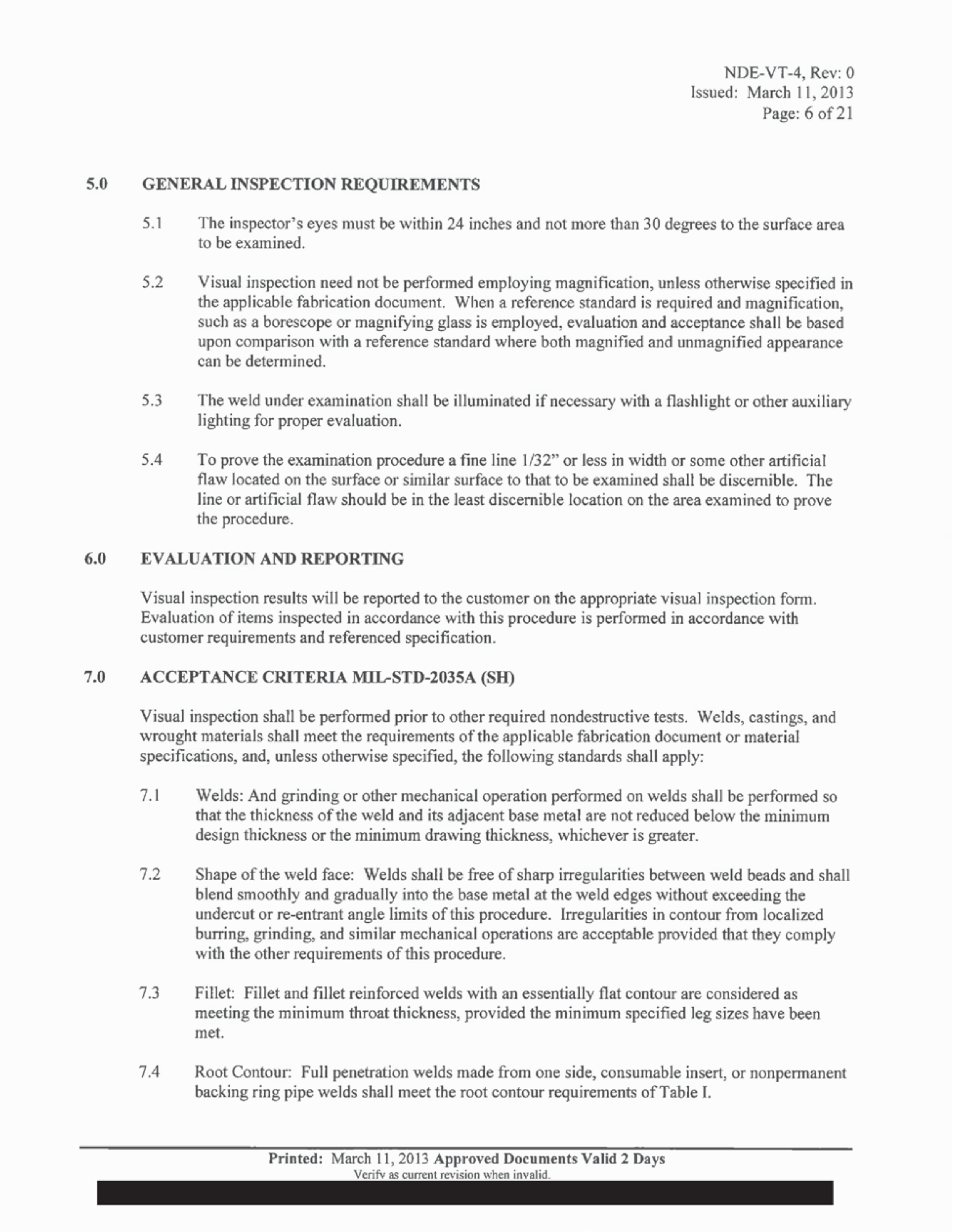
4.23 **Back Gouge:** A back gouge consists of the preparation of the backside of the root layer or full penetration welds to the extent necessary to permit proper deposition of weld metal from the second side.

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.

[redacted]



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]

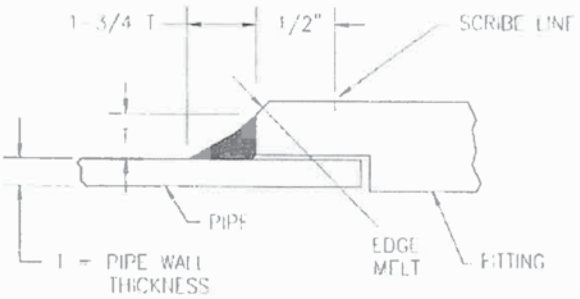
Condition	Material size (nominal)	Maximum (inch)
Convexity	Pipe less than 2 inches in diameter and other shapes less than 5/32 thick.	1/16 [2]
Convexity	Pipe 2 inches and over in diameter and other shapes 5/32 inch and over in thickness	3/32 [3]
Convexity	Pipe less than 2 inches in diameter and other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

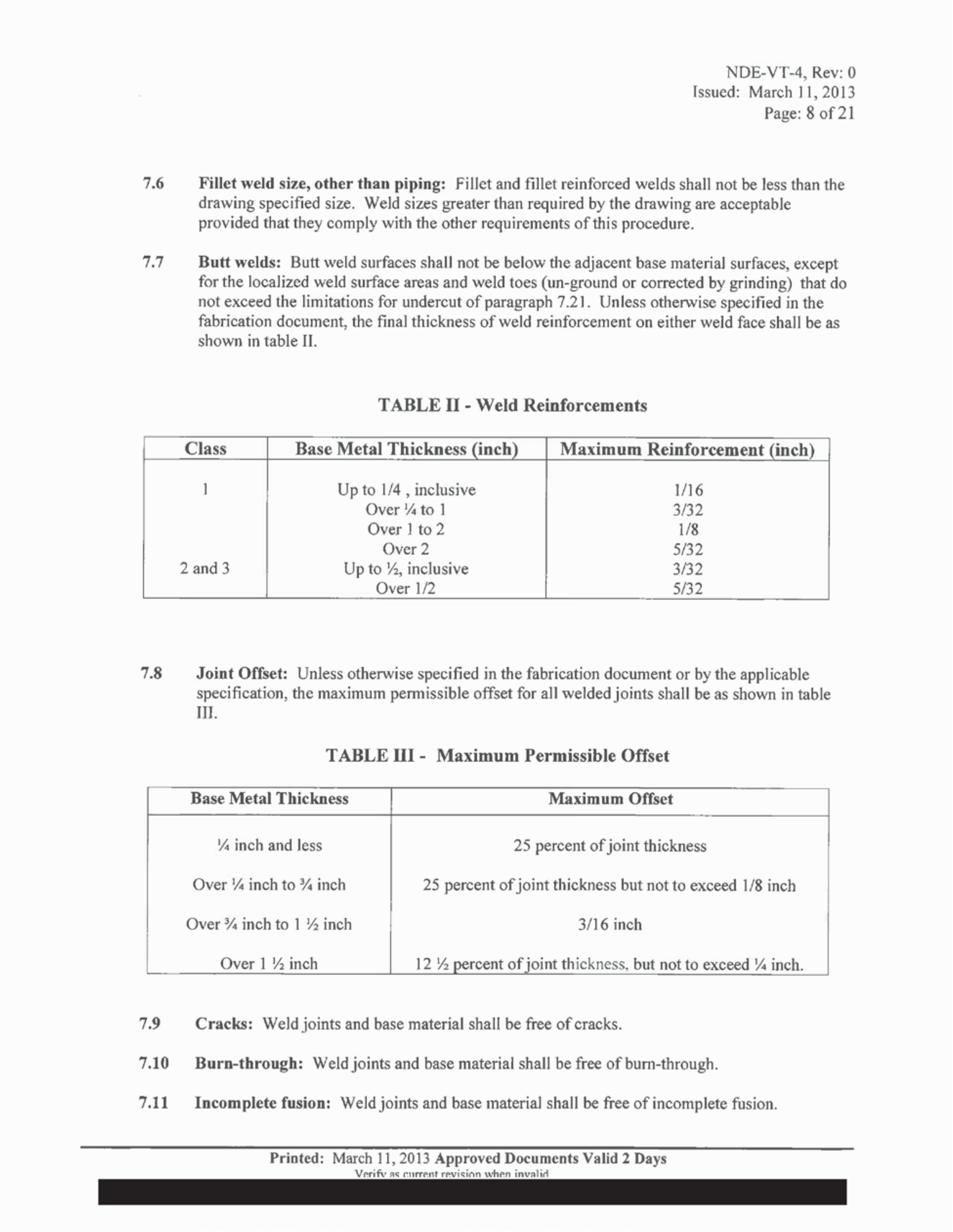
[1] Except for centerline shrinkage or wrinkling, the contour of the root shall have a uniform radius and shall blend smoothly into the base metal. No concavity of contour is permitted unless the resulting thickness of weld metal is not less than the minimum thickness of the adjacent base metal.

[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]

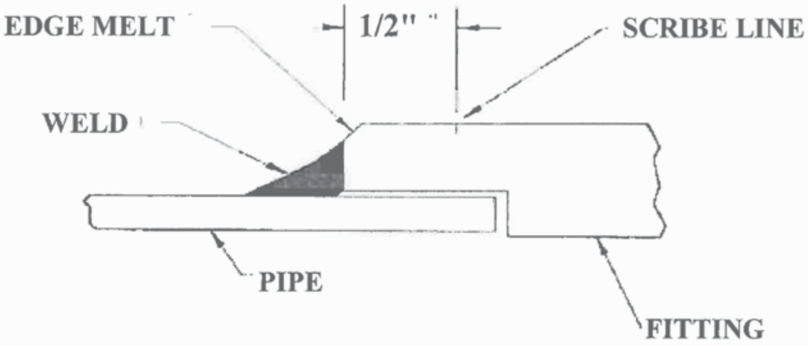
7.12 **Melt through:** Melt-through and repaired burn-through areas are acceptable provided the areas do not contain cracks, crevices, excessive oxidation, or globules, and provided the root convexity and concavity limits are not exceeded.

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.

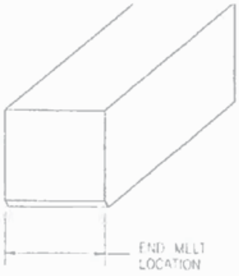
Class 2 and 3. The maximum undercut shall be 1/32 inch or 10 percent of the minimum thickness (see paragraph 7.1), whichever is less. For base metal thickness ½ inch or greater, undercut up to 1/16 inch is allowed if the accumulated length of undercut exceeding 1/32 inch does not exceed 15 percent of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

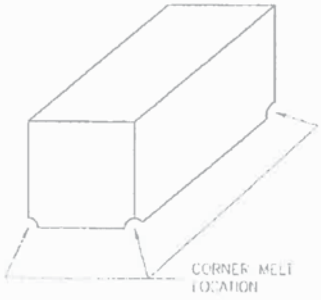
Class 2 and 3. For welds across the end of a ¼ inch thick or less member, the maximum as-welded end-melt is 1/16 inch. If end –melt is greater than 1/16 inch and less than or equal to 3/32 inch, it may be repaired by mechanical means to a maximum depth of 3/32 inch.



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.

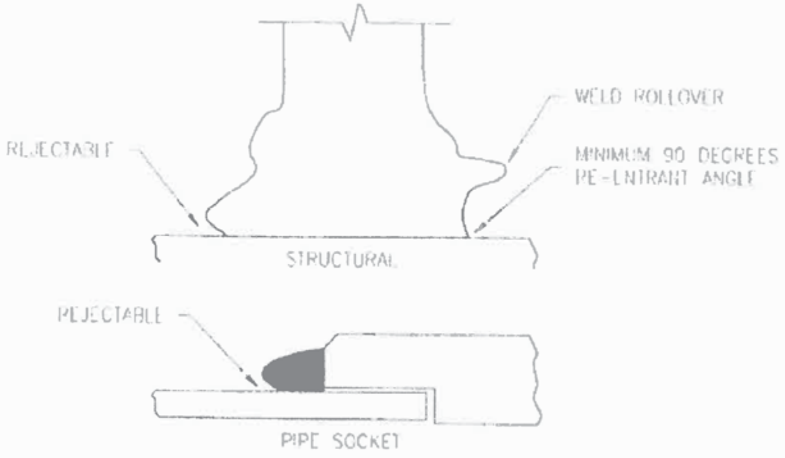
Class 1. Maximum depth, measured from the un-ground adjacent base metal surface, shall not exceed 1/64 inch or 10 percent of the adjacent base material's nominal thickness, whichever is less.

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.

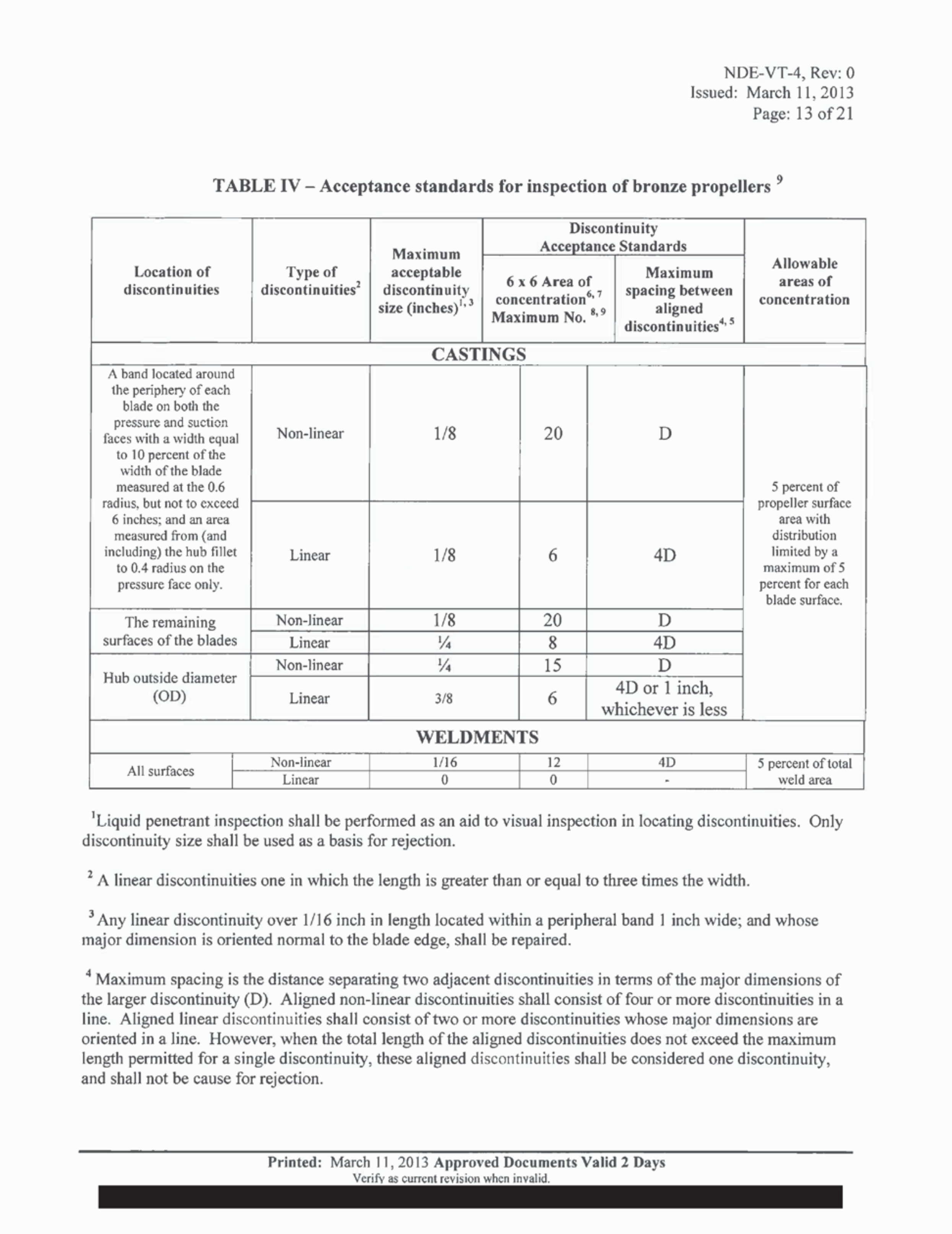


TABLE IV – Acceptance standards for inspection of bronze propellers [9]

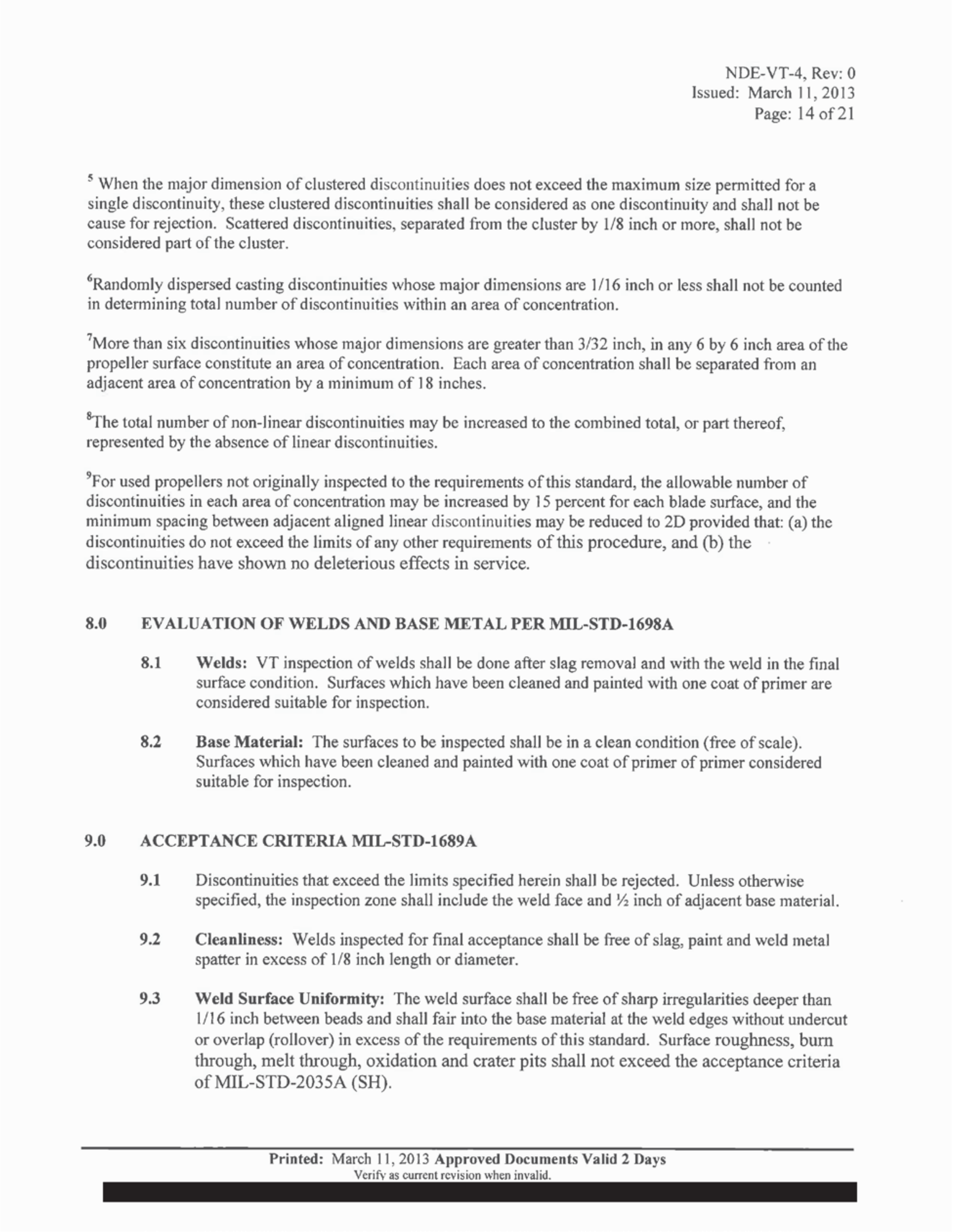
Location of discontinuities	Type of discontinuities[2]	Maximum acceptable discontinuity size (inches)[1, 3]	Discontinuity Acceptance Standards		Allowable areas of concentration
			6 x 6 Area of concentration[6, 7] Maximum No. [8, 9]	Maximum spacing between aligned discontinuities[4, 5]	
CASTINGS					
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.



[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.

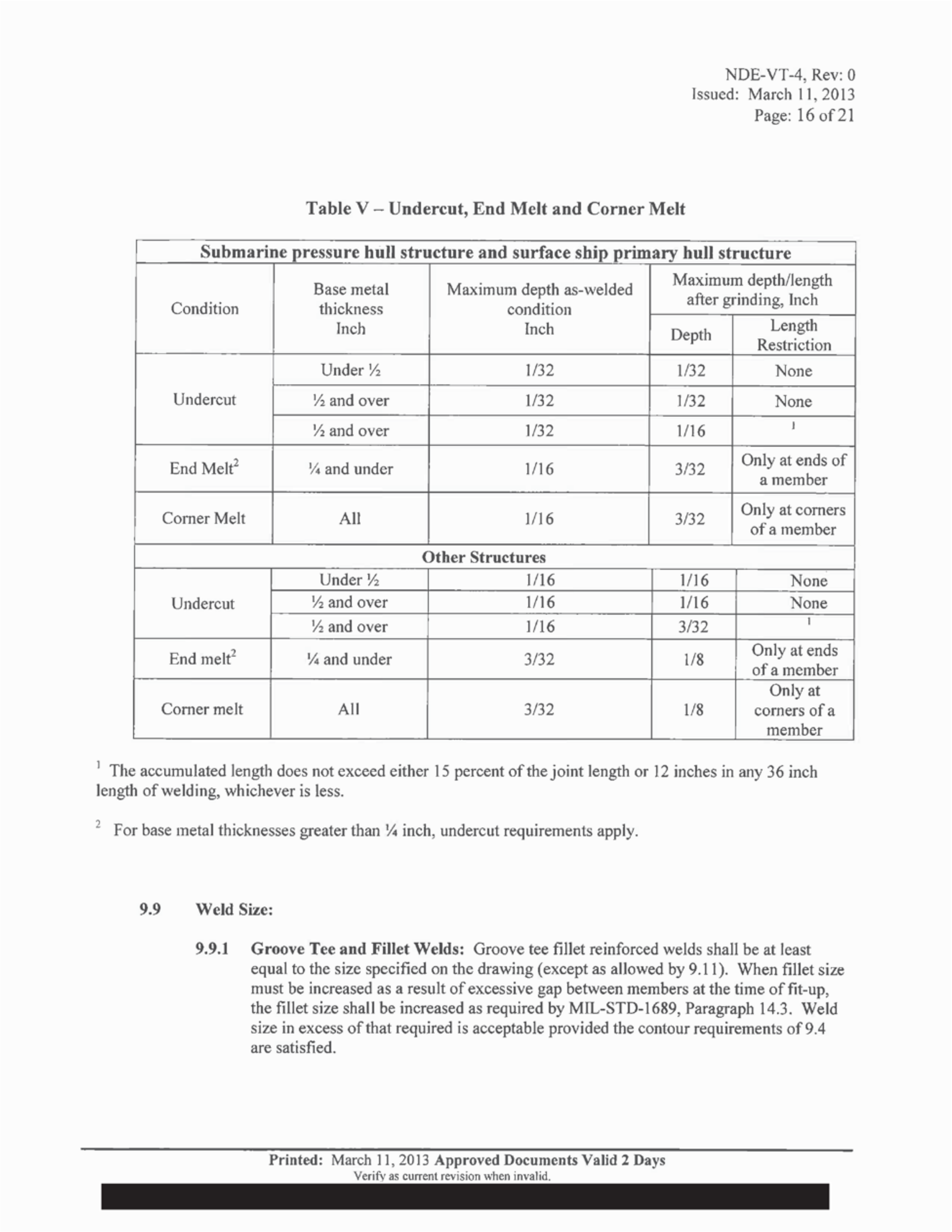


Table V – Undercut, End Melt and Corner Melt

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

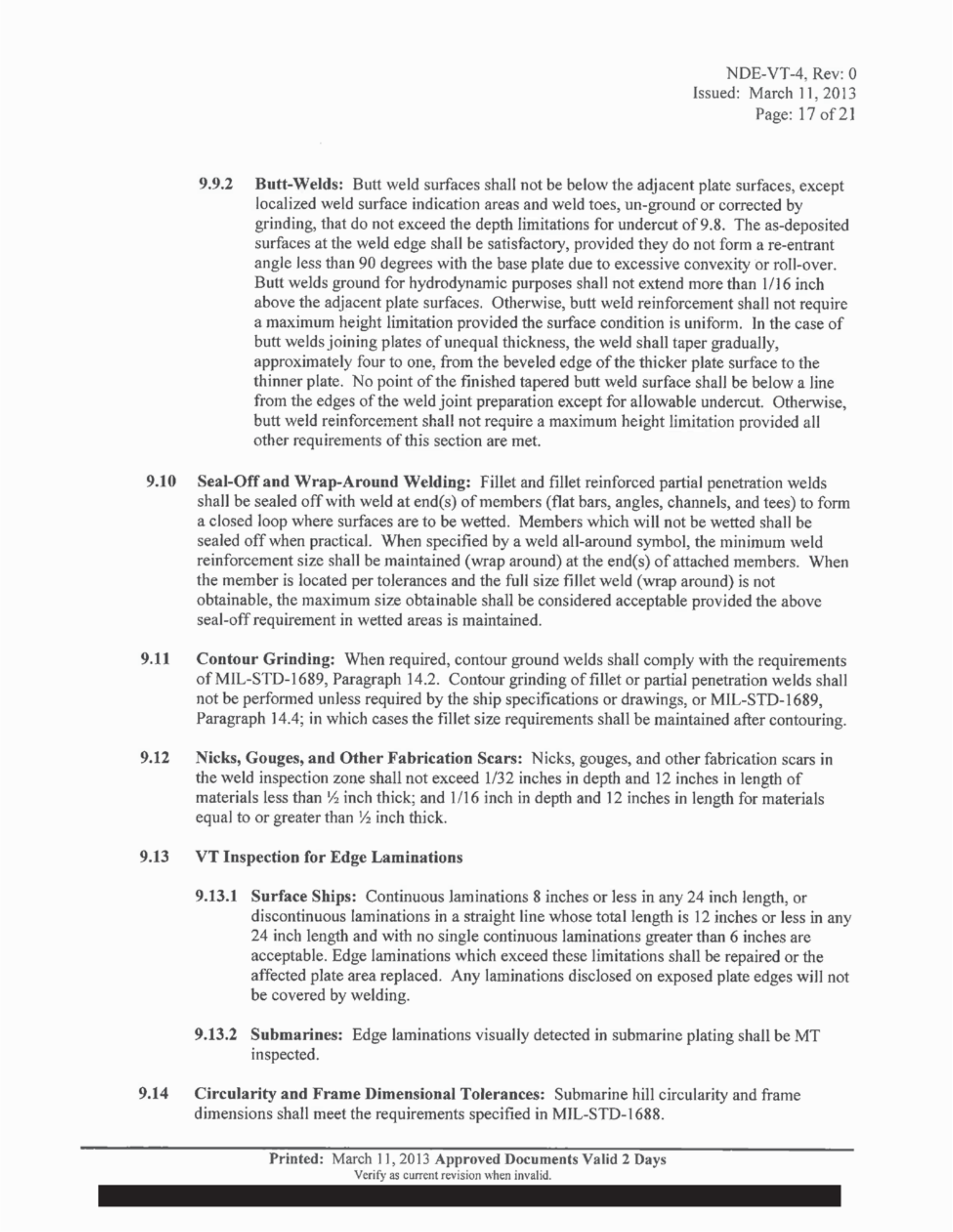
[1] The accumulated length does not exceed either 15 percent of the joint length or 12 inches in any 36 inch length of welding, whichever is less.

[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.

[redacted]



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]

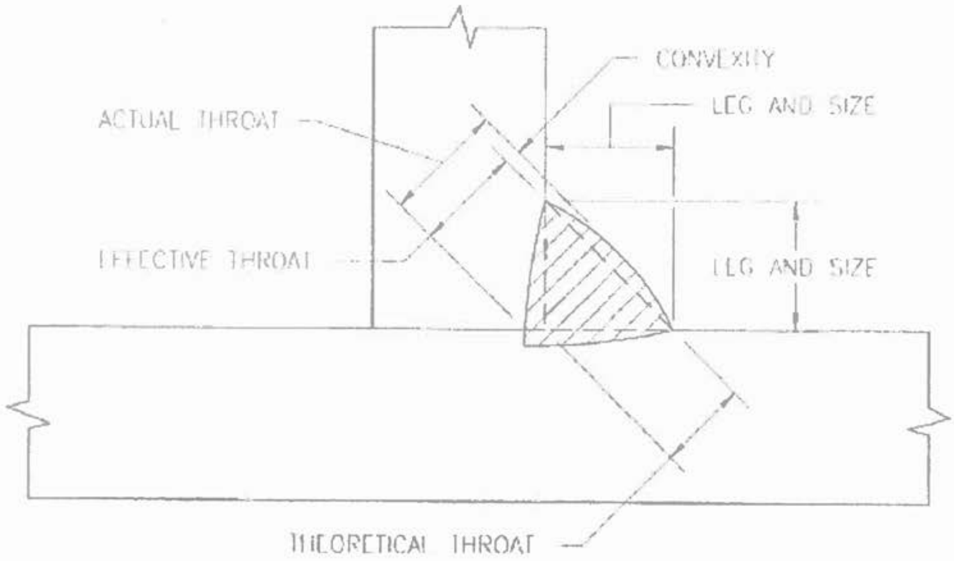


Figure 1. Convex Fillet Weld

[redacted]

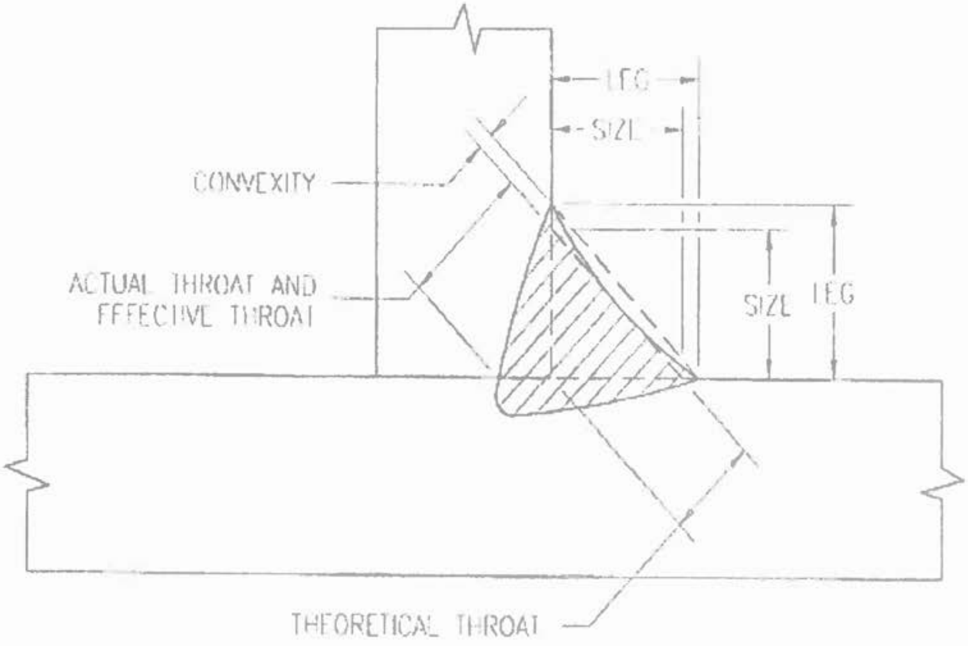
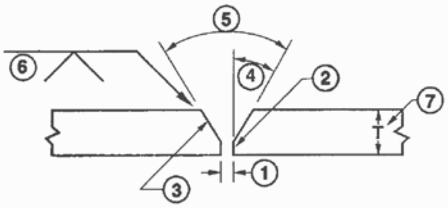
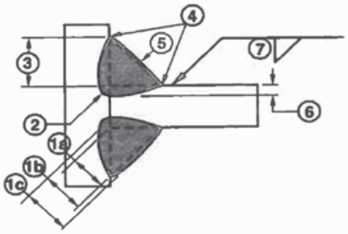


Figure 2. Concave Fillet Weld



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

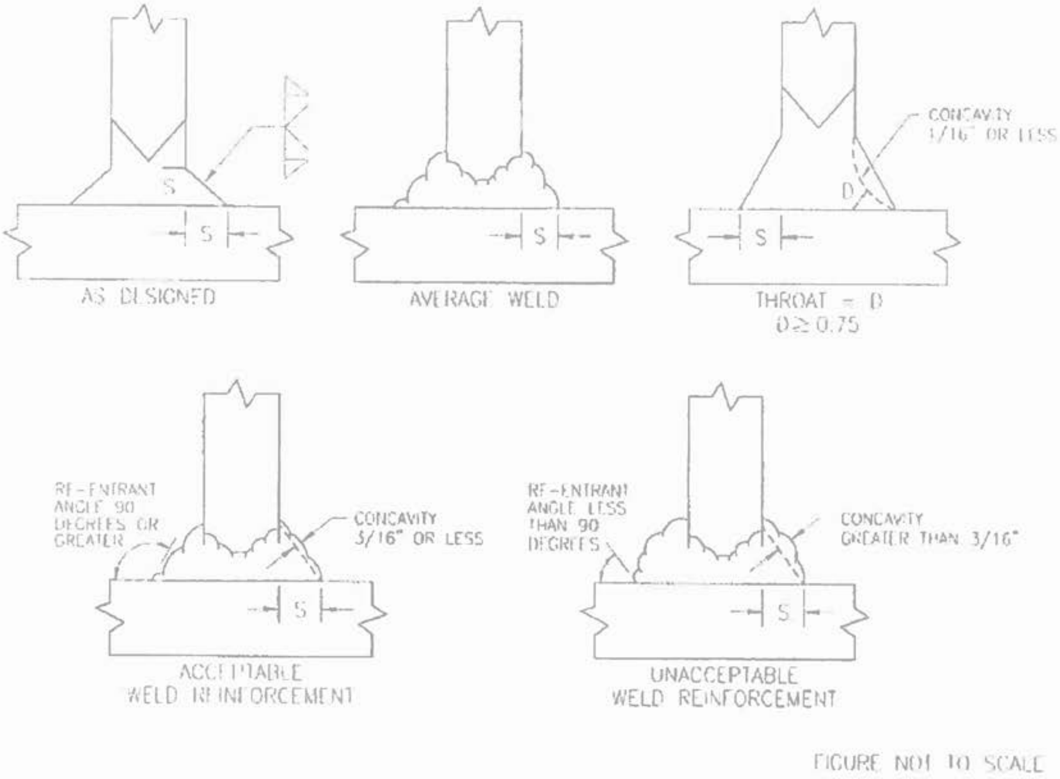
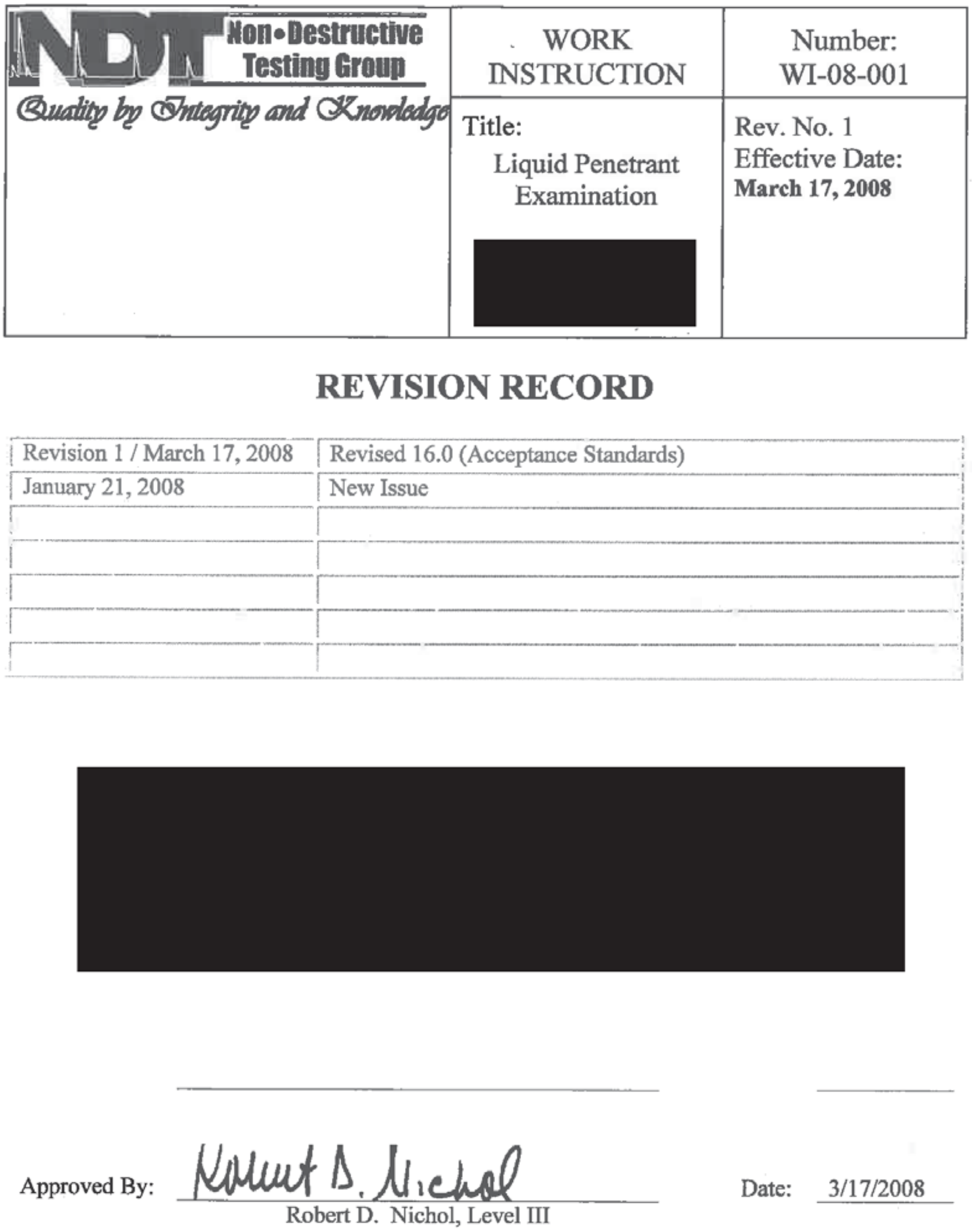


Figure 4. Typical Contour for Fillet Groove Tee Welds and Fillet Welds.

[redacted]

Appendix H-2.3.3 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
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.

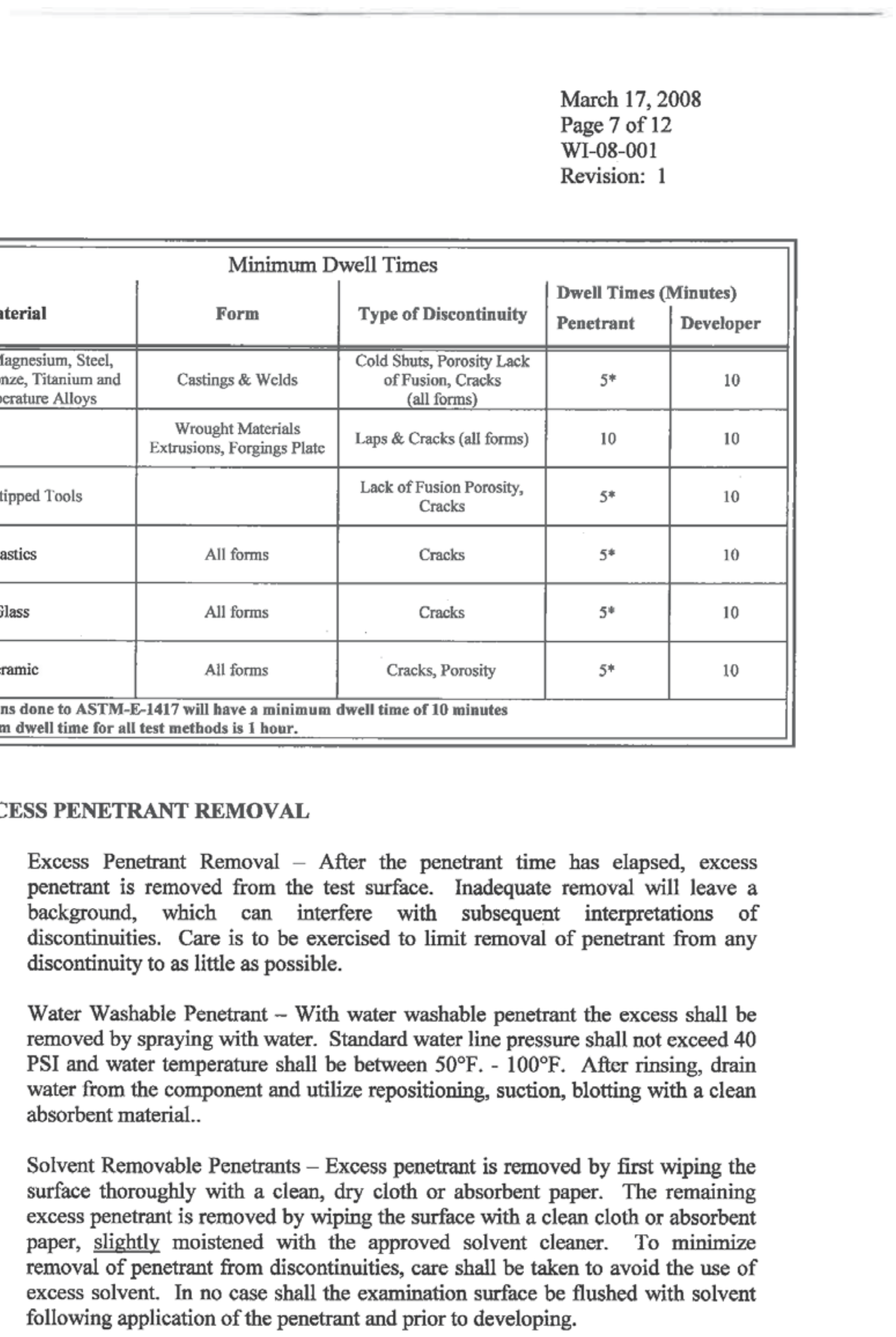


Table 1 Minimum Dwell Times

Material	Form	Type of Discontinuity	Dwell Times (Minutes)	
			Penetrant	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.

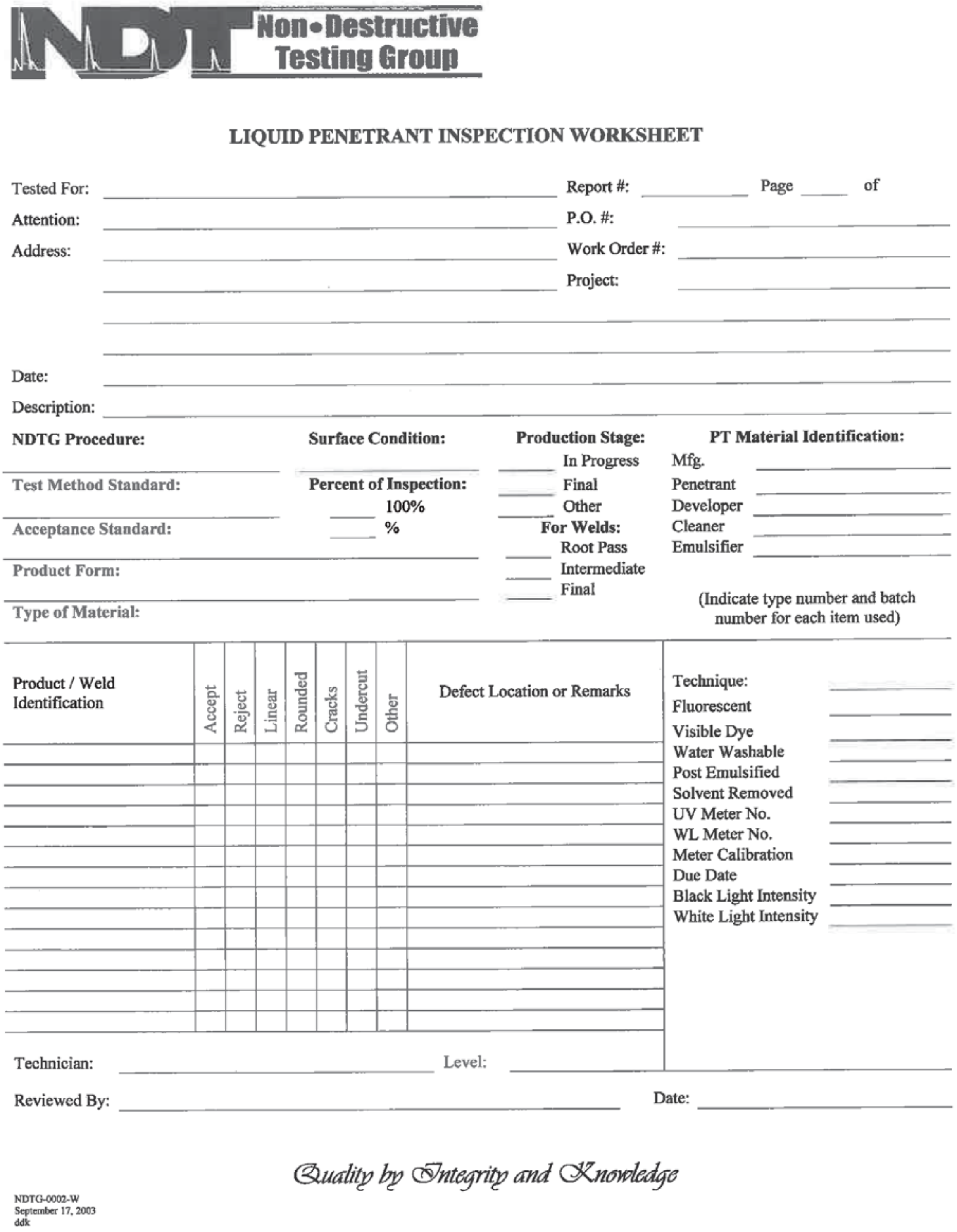
Appendix A

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



NDT 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 __________

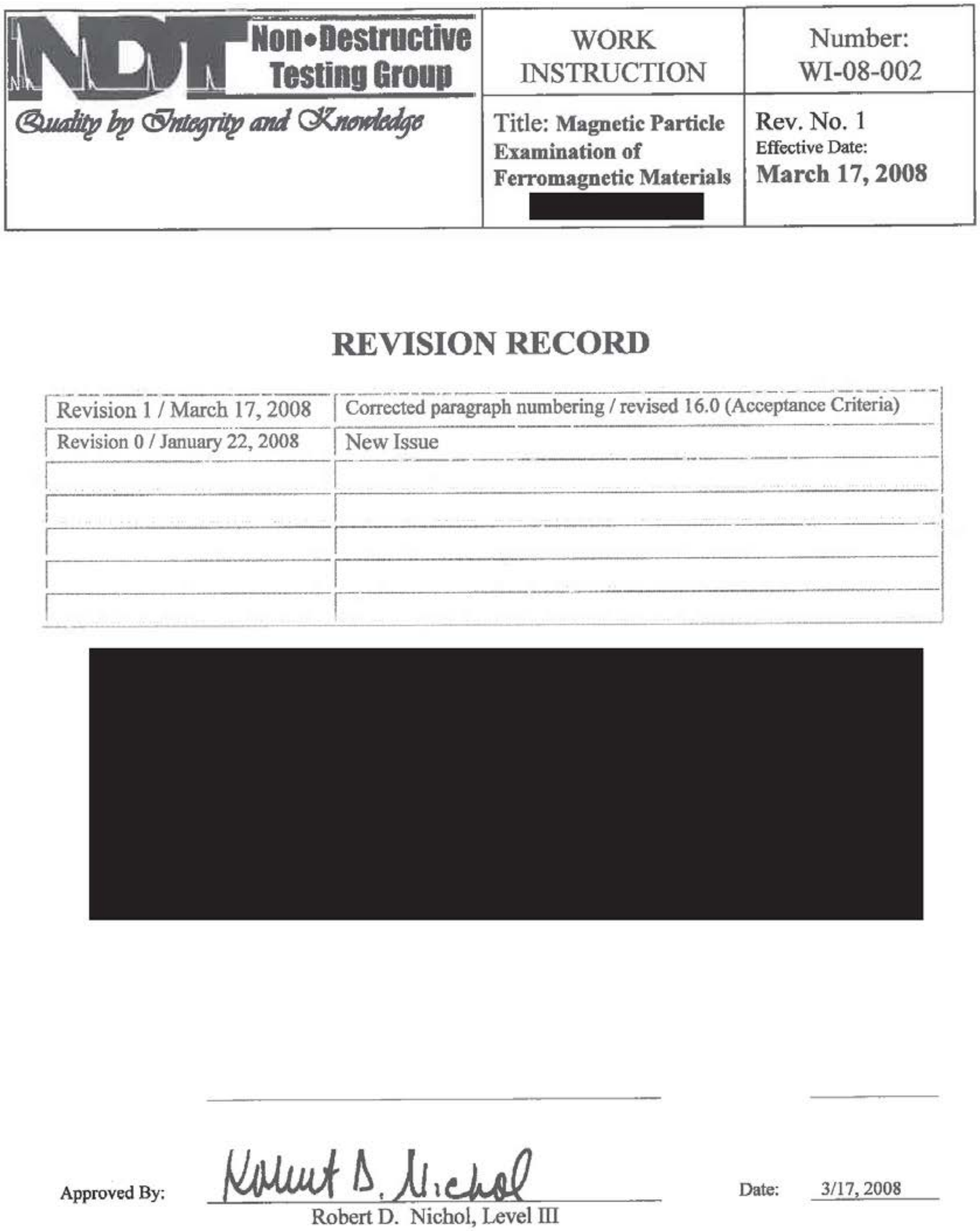
Technician: ______________________ Level: __________

Reviewed By: ______________________ Date: __________

Quality by Integrity and Knowledge

NDTG-0002-W
September 17, 2003
ddk

Appendix H-2.3.4 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
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

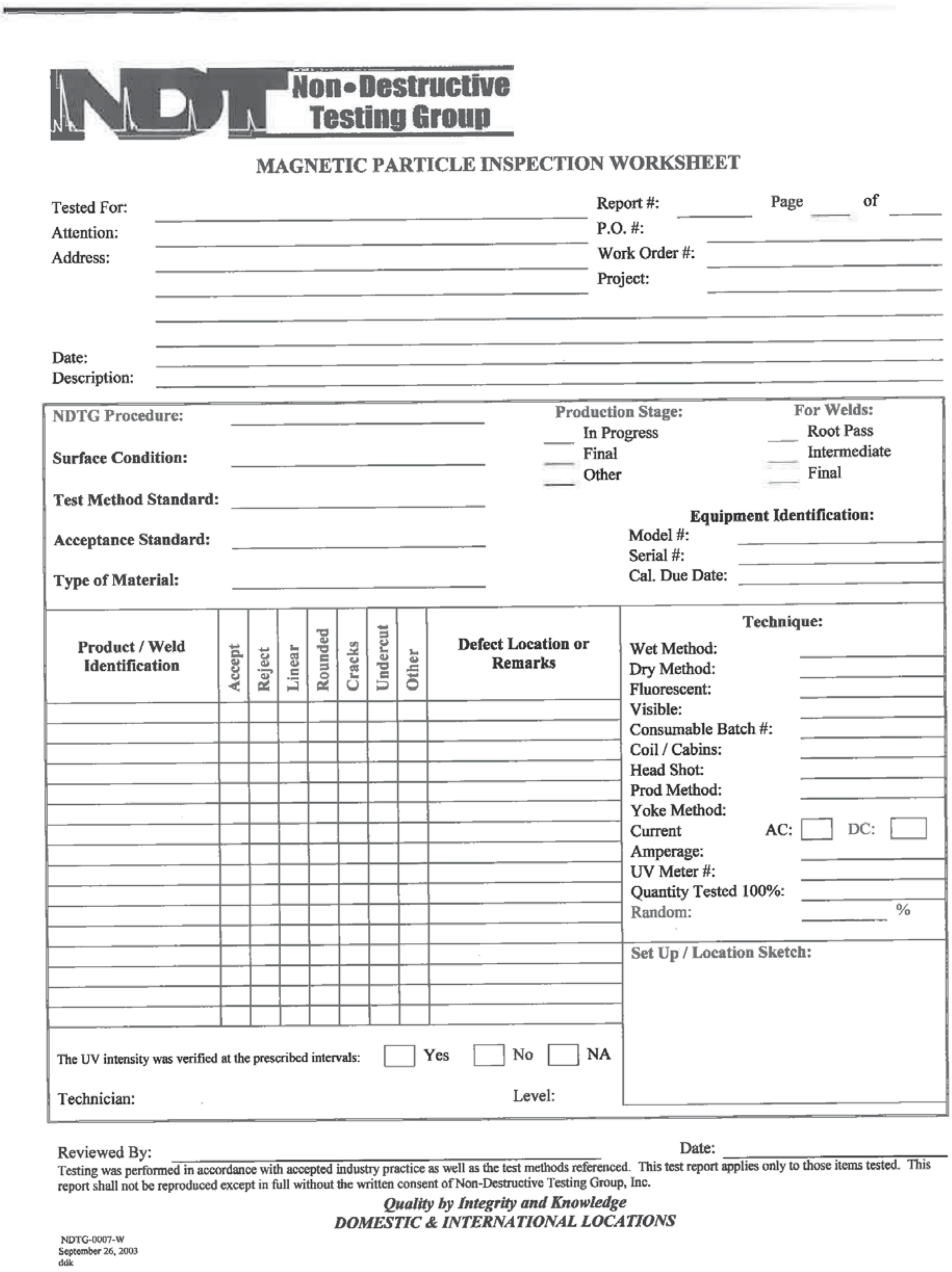
16.0 ACCEPTANCE

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: ________
Attention: ________
Address: ________

Report #: ____ Page ___ of ___
P.O. #: ________
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
ddk

APPENDIX H-2.4

BUFFER RAILCAR SAFETY MONITORING SYSTEM

Appendix H-2.4.1 System Safety Monitoring Procurement Specifications for use with AAR Standard S-2043 HLRW Railcars

Procurement Specification SSM Procurement Spec RF

SYSTEM SAFETY MONTORING PROCUREMENT SPECIFICATION FOR USE WITH AAR STANDARD S-2043 HLRW RAILCARS

Rick Ford

Kasgro Rail Corp., Inc.
121 Rundle Road
New Castle, PA 16102
Tel: 724-658-9061

System Safety Monitoring Procurement Specification for AAR S-2043 HLRW Trains

1.0 Scope of Work

1.1 S-2043 System Safety Monitoring (SSM) Equipment for use with railcars to be used for transport of High Level Radioactive Materials (HLRM) by rail. The system supplied must be 100% compatible with current SSM equipment currently being utilized on DODX railcars for transport of HLRM. Supply of SSM equipment for use with one (1) 12-axle cask flat car and two (2) 4-axle buffer flat cars to meet the requirements of American Association of American Railroads (AAR) Standards S-2043 and S-2045, unless otherwise specified, herein.

"Note: SSM communication utilizing CDMA 1XRTT technology is not acceptable as it planned for sunsetting at the end of December 2019."

2.0 Applicable Documents and Drawings

2.1 The documents identified herein a part of this specification and revision dates shall be the date of Request for Proposals.
2.2 Commercial documents listed herein (i.e. AAR. ASTM, AWS), the latest revision is acceptable.
2.3 Should a conflict occur between this procurement specification and the references listed herein, the text of this procurement specification shall take precedence. Any conflicts shall be identified to the Buyer for information.
2.4 Association of American Railroads (AAR) Specifications, Standards and Recommended Practices.
2.2 S-2043 Performance Standard for Trains Used to Carry High-Level Radioactive Material, Effective 2003, Revised 2009, or latest version.
2.4 S-2045 Standard Operating Procedure for Installation of Remote Monitoring Equipment.
2.5 S-5700 Railroad Electronics Standards Configuration Management.
2.6 S-5702 Railroad Electronics Environmental Requirements
2.7 American Welding Society (AWS)
  2.7.1 D1.1 Structural Welding Code – Steel
  2.7.2 D15.1 Railroad Welding Specification, Cars and Locomotives
2.8 Railcar General Arrangement Drawings for cask and buffer cars.

3.0 Quality Assurance Provisions

3.1 Unless otherwise approved by the Buyer, the Seller shall maintain a quality management and inspection system with a nationally recognized quality standard during the term of the contract. The Seller's quality manual shall be available for Buyer review, upon request.

4.0 Buyer Supplied Equipment

4.1 The Buyer will provide one (1) 12-axle cask Flat car and two (2) 4-axle buffer cars. Buyer shall perform testing as required by Sections 6.2 and 6.3 to AAR standard S-2043 (reference paragraph 5.21 below).

5.0 Requirements

5.1 The Seller shall design and provide all of the software, materials, equipment, resources, and documentation necessary to satisfy the requirements in AAR Standard S-2043 for system safety monitoring. The monitoring system shall satisfy all of the requirements for real-time and remote monitoring including, data collection, data storage, data download, data transmission, operating displays, train stop alarms, warning signals, internal self-test circuitry, report generation, etc. Sensors may be wireless, hardwired, or a combination of both at the option of the Seller. All requirements in S-2043 shall apply (reference Sections 4.5, 4.7.8, 6.2, Appendix A Section 4.6, and Appendix B Sections 5.4 and 5.5) with the following exceptions

(1) The system is not required to monitor the braking performance parameters monitored by the Electronically Controlled Pneumatic (ECP) brake system.

(2) The monitoring system is not required to function over the ECP braking system, but the design shall not preclude the ability to develop and incorporate communication via the ECP braking system in the future as required by Paragraph 4.4.1 of S-2043.

5.2 In lieu of real-time ECP brake system communication per Paragraph 4.5.4.2.1 of S-2043, the monitoring equipment shall communicate real-time with the locomotive, buffer cask, and escort vehicles via other direct connection such as radio frequency. Remote communication per Paragraph 4.5.4.2.2 of S-2043 may be via cellular, satellite, or combinations thereof. The system shall:

(1) Monitor and record all required parameters simultaneously at a sampling rate acceptable to the AAR/EEC (i.e., a polling refresh rate no slower than once per second and a maximum notification dwell time of 10 seconds).

(2) Save all data/variances at times when communication coverage (cellular or satellite), is temporarily unavailable, and transmit the data when coverage is re-established.

(3) Save all data collected in the event of a power failure or railcar derailment. The system shall exhibit the same robust capabilities of modern locomotive event recorders (reference: 49 CFR, Part 229 Appendix D).

(4) Provide secure encrypted data transmission that is Federal Information Processing Standard (FIPS) PUB 140-2 compliant or greater. The Security Level applied per FIPS PUB 140-2 shall be at the option of the Seller.

(5) Provide secure password protected access to the data, both real-time and remotely.

(6) Immediately provide remote notification of alarms via cell phone or E-mail to pre-established personnel designated by the Buyer.
(7) Conform to technology that utilizes the equivalent of Long-term Evolution (LTE, 4G or latest technology).

5.3 The monitoring system shall be designed for use on the cask and buffer flat cars as shown on Kasgro drawings XXXXX, in both the loaded and empty conditions. The loaded conditions are shown on drawing XXXXX. The number of railcars to be equipped with the monitoring system shall be defined in the purchase order.

5.4 The monitoring system shall be capable of operating with multiple SSM equipped flatcars in a train, and shall differentiate the data being collected, recorded, and reported for each specific railcar.

5.5 The railcar monitoring equipment and system shall be designed for operation and storage under the range of environmental conditions and requirements specified in Section 3.0 of AAR Standard S-5702; for the appropriate class/category of the equipment as delineated in Table 3.1 of S-5702 except at follows:

5.6 The railcar monitoring equipment and system shall satisfy the requirements in Section 4.0 of S- 5702 relating to electromagnetic interference and compatibility as clarified below:

(1) The Radiated Limits per Paragraph 4.2.1 of S-5702 shall apply only to equipment that utilizes train line or other railcar supplied power, or resides in the locomotive. In addition, supplied equipment shall not operate on any frequency used by railroad communications (150, 220, 450 and 900 MHz) and any cellular frequencies.
(2) The requirements for Conducted Emissions, Conducted Susceptibility, and ESD Susceptibility per Paragraphs 4.2.2.1, 4.2.2.2 and 4.2.3 of S-5702, respectively, shall only apply to equipment that utilizes train line or other railcar supplied power, or resides in the locomotive.

The Seller shall provide evidence in writing that the equipment has met the applicable electromagnetic interference (EMI) acceptance tests required by S-5702.

5.7 The Safety System Monitoring Equipment shall:

(1) Be capable of substantial down-time (3 to 4 years) in outside storage between uses without degradation to the instrumentation or power supply.
(2) Be designed to allow for easily integrating future sensor types/models with minimal or no redesign.

5.8 If required by the AAR, the railcar monitoring equipment and system shall:

(1) Comply with the Vendors configuration management guidelines of AAR Standard S-5700.

(2) Comply with the standards established by the Railway Electronics Task Force (RETF). The Seller's configuration management processes shall be compatible with the configuration management plan used by the RETF so that the Seller's products clearly indicate the version of the standard(s) with which they are compliant.

5.9 The Seller shall provide a complete parts list and an assembly drawing to show the arrangement of the monitoring system as it will be installed on the 12-axle cask and 4-axle buffer flatcars (i.e., sensor locations, mounting and wiring arrangements, location of power supplies and data processing equipment, etc.). Enlarged views or supplemental drawings shall be provided, as necessary, to show the details for sensor and equipment mounting. The drawings and subsequent revisions shall be subject to Buyer approval.

5.10 The Seller shall provide an assembly, operating, maintenance, and troubleshooting manual for the monitoring system specific to both the cask and buffer flat car application. The manual shall be subject to Buyer approval and shall include:

(1) A complete description of the monitoring system, including a detailed description of the method of sampling/collecting, storing, and reporting information for both the real-time and remote systems.
(2) A system schematic and high level block diagram.
(3) A copy of the assembly drawing(s) and parts list.
(4) A copy of the manufacturer's specification sheets for each sensor and component.
(5) Assembly and equipment checkout instructions.
(6) Operating instructions including methods to confirm proper system/equipment calibration, sensor response, and communication.
(7) Maintenance instructions including a list of required spare parts.
(8) A fault tree analysis per Section 4.5.5 of S-2043.
(9) Any custom software developed by the Seller.

5.11 The Seller shall obtain or confirm AAR/EEC acceptance of the System Safety Monitoring design in accordance with Section 4. 7 .8 of S-2043 and Section 3 of S-2045, prior to installation of the lead monitoring system on a cask and buffer flatcar test vehicles. The design package shall be provided for Buyer review and information at least 30-days prior to submittal to the AAR/EEC. AAR acceptance of the monitoring system (in writing) shall be provided to the Buyer as evidence of compliance with this requirement.

5.12 The real-time limits/situations requiring a train stop signal shall be as specified in Paragraph 4.5.4.2.1 of S-2043. The real-time limits requiring a warning for train inspection at the next scheduled stop shall be as specified in paragraph 4.5.4.2.2 of S-2043. In addition, the real-time and remote systems shall specifically identify and notify of any detected variances to: (1) the overheated roller bearing criteria specified in Rule 36 of the Field Manual of the AAR Interchange Rules (IR), and (2) the wheel out of round (flats) impact criterion specified in Rule 41 of the AAR IR and AAR Report No. R-829 (Wheel Impact Load Detector Tests and Development of Wheel Flat Specification).

5.13 Unless otherwise accepted by the Buyer, instrumentation for measuring lateral acceleration and hunting shall be mounted near the lateral centerline of one of the car-body bolsters and on each span bolster in line with the lateral centerline of Truck-A and Truck-B. Alternate sensor mounting locations as recommended by the Seller are acceptable subject to Buyer approval.

5.14 The power supply for the monitoring system shall be capable of continuous operation and monitoring of all required parameters for a period of no less than 1 year without the need to replace any portion of the power supply (e.g., batteries).

All sensors with an independent power supply (i.e. sensors that do not rely on the source that powers the central processing unit) shall be equipped with a feature that minimizes (e.g. nanoamps) or precludes the draw of power until activated for use.

5.15 The system shall include self-test circuitry to internally check power levels and to assess the performance status of the equipment/sensors installed to monitor all of the parameters required by paragraph 4.5.4.1 of S-2043, except as excluded in paragraph 5.1 above.

5.16 The system shall be capable of preparing reports showing the measured conditions and system response while monitoring all of the parameters listed in Section 4.5.4 of S-2043, except as excluded in paragraph 5.1 above. The data shall be collected and recorded in such a manner to identify specific railcar location and train speed for all other parameters monitored. Report generation shall be available in both tabular and graphical formats (e.g., .xls, .csv) to facilitate trend analyses.

5.17 The monitoring system shall be designed to provide the flexibility to:

(1) Only transmit and archive the exception data, including the raw data for 60 minutes prior to the exception.
(2) Delete the remotely stored data at the end of each trip.

(3) Limit or exclude either the real-time or remote data transmissions at the operating option of the Buyer.

(4) Exclude the locomotive warning or stop-train display lights at the operating option of the Buyer for each individual trip (i.e. portable).

(5) Relocate the readout display panel between escort vehicles and trains (i.e., portable).

(6) Remotely delete the data stored on the system's removable media (i.e., without physical work on the railcar-mounted equipment.)

All sensors of the same type shall be interchangeable with one another. The Seller shall ensure any programming required to activate or incorporate replacement sensors into the monitoring system can be performed remotely.

Portable display units shall include an audio alarm that sounds when a warning/exception occurs. The alarm shall have the ability to be turned off once the warning/exception has been acknowledged. The Seller shall provide protective carrying cases (e.g., hard plastic outer shell with internal padding) for the portable display units to facilitate handling and to minimize the potential for handling damage. One case shall be provided per display or per set of displays.

5.18 All welds used for assembly of the monitoring equipment to the cask and buffer flatcars shall be made and subjected to a 1X visual inspection in accordance with AWS D1 .1 or AWS D15.1.

5.19 Equipment and sensors located on the car body or end platforms shall be protected from potential inadvertent damage due to personnel walking or working on the railcar.

5.20 Unless otherwise approved by the Buyer, central onboard power/monitoring units shall be stenciled or decaled per S-2045 to identify the unit function and the applicable contact phone number for information related to the device. The stencil/decal shall be highly visible and shall be a minimum of 2" x 3" in size. Stencil/decal color shall be as agreed between the Buyer and Seller, but shall not be bright yellow.

5.21 Prior to full system production, the Seller shall provide and install lead monitoring systems on cask and buffer test vehicles. The test cars and the monitoring systems shall be tested and operated by the Buyer in accordance with Sections 6.2 (System Monitoring Tests) and 6.3 (Revenue Service Tests) of AAR Standard S-2043. Seller personnel shall be on location at the test facility (Transportation Technology Center) to provide technical support during the testing performed per Section 6.2 of S-2043, and shall be responsible to resolve any system design/hardware issues. Lessons learned or necessary equipment improvements determined from lead unit testing shall be implemented on all subsequent production units.

5.22 When required by the purchase order, the Seller's personnel shall install the monitoring systems on the production cask and buffer flat cars, and confirm that each system is fully functional and is operating in compliance with the technical requirements specified herein and by the applicable AAR standards and specifications. Seller installations shall be field service operations at the locations of the flatcars at the time of system installation. If third party installation is performed, Seller shall package, pack, and ship all equipment to the required destinations. Packaging and packing shall be per good commercial practice and shall ensure the equipment arrives at destination without damage during handling or shipment.

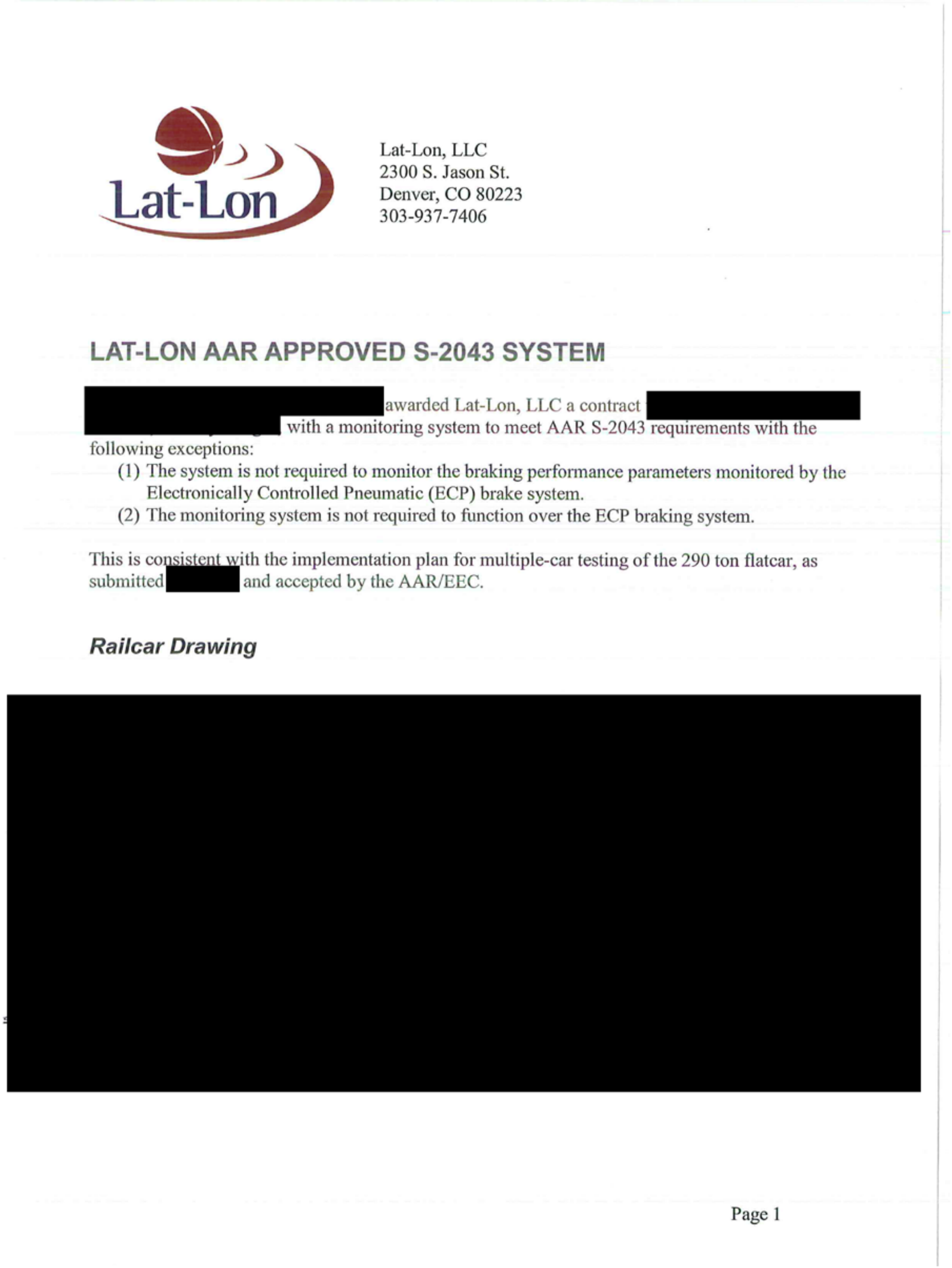
5.23 Over the course of the development, testing, and production of the monitoring system various meetings/conferences shall be conducted between the Buyer and Seller including:

(1) A kickoff meeting (within 1 month after order placement) to review the overall development plan and schedule.
(2) Periodic meetings (approximately every 6 weeks) at the Sellers facility to review overall status and emergent issues.
(3) Weekly status calls.
(4) A meeting at the Sellers facility to review the design package prepared for submittal to the AAR/EEC per paragraph 5.11 above.

5.24 The Seller shall install tamper-indicating security seals around the outermost enclosures that contain the removable data storage media. The Seller shall provide all tools and materials necessary for seal installation, and one set of seal equipment (wire spool, package of security seals, seal press) shall be provided for each railcar to be equipped with monitoring equipment, with the total quantity identified by the purchase order.

It is recommended that the same type of security seals currently used on DODX railcar SSM equipment be used to maintain consistency.

Appendix H-2.4.2 Lat-Lon AAR Approved S-2043 System Procurement Specification SSM Procurement Spec RF



Lat-Lon, LLC
2300 S. Jason St.
Denver, CO 80223
303-937-7406

LAT-LON AAR APPROVED S-2043 SYSTEM

[redacted] awarded Lat-Lon, LLC a contract [redacted] with a monitoring system to meet AAR S-2043 requirements with the following exceptions:

(1) The system is not required to monitor the braking performance parameters monitored by the Electronically Controlled Pneumatic (ECP) brake system.
(2) The monitoring system is not required to function over the ECP braking system.

This is consistent with the implementation plan for multiple-car testing of the 290 ton flatcar, as submitted [redacted] and accepted by the AAR/EEC.

Railcar Drawing

[redacted]

SYSTEM DESCRIPTION

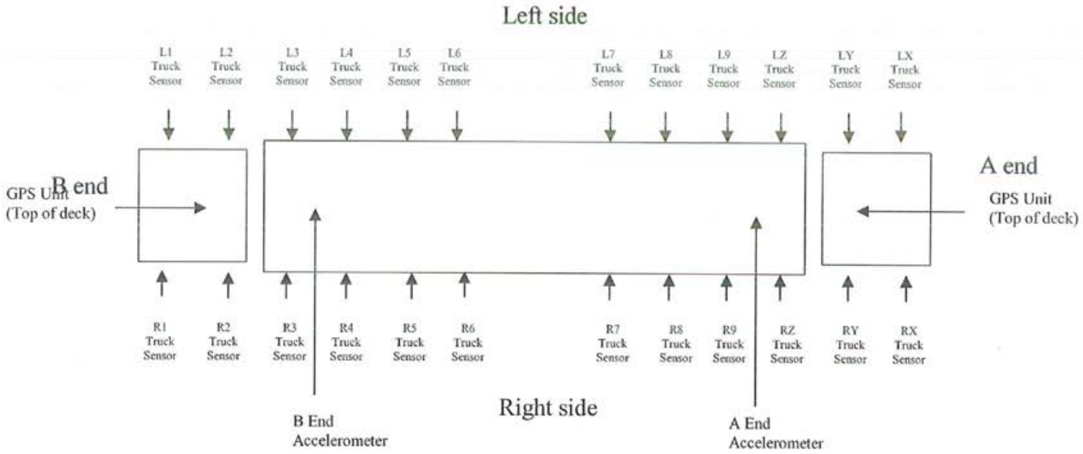
Design Overview

Two monitoring systems are installed on each car. One system is positioned at the A end platform and is responsible for the A end readings and the other system is mounted on the B end platform and responsible for the B end readings. This creates redundant car body measurements on each car while making the system more failsafe and cost effective.

Orientation

The general layout for the 12 axle flat car monitoring system is shown on the diagram below.

Flat Car Diagram - Top View



System Components

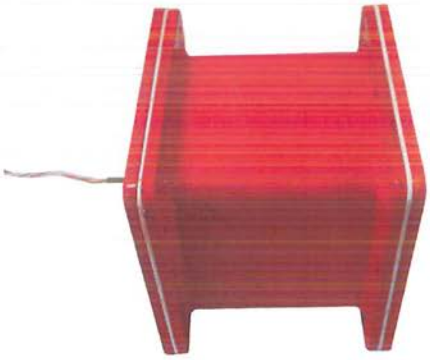
The monitoring system is broken down into nine component groups. Each component group has a number of sub assemblies. The system is maintained on a component basis. These components are designated as follows:

Mounting Pedestal
  A End
  B End

Pedestal Cover (qty 2 per pedestal)
  A End
  B End

GPS Base Unit
- A End GPS Base Unit
- B End GPS Base Unit

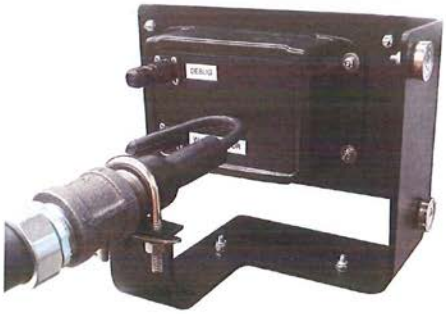
Memory Module
- A End
- B End



Battery Module
- A End
- B End

Solar/Antenna Cap
- A End
    - Cellular Antenna
    - VHF Antenna
    - Wireless Sensor Antenna
    - Solar Panels
- B End
    - Cellular Antenna
    - VHF Antenna
    - Wireless Sensor Antenna
    - Solar Panels

Wired Sensor & Wire Harness
- A End
- B End

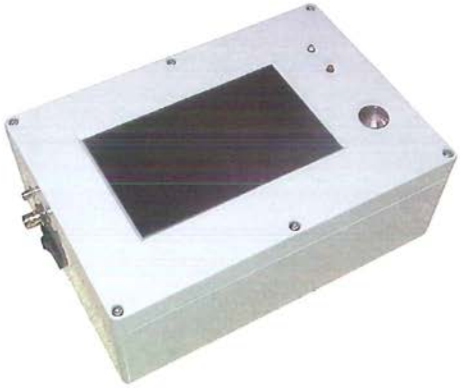


Wireless Truck Mounted Sensors – Each of these sensors are identical but its position is designated into the unit's database.

R1 Sensor
R2 Sensor
R3 Sensor
R4 Sensor
R5 Sensor
R6 Sensor Associated with B end
L1 Sensor
L2 Sensor
L3 Sensor
L4 Sensor
L5 Sensor
L6 Sensor

R7 Sensor
R8 Sensor
R9 Sensor
RZ Sensor
RY Sensor
RX Sensor Associated with A end
L7 Sensor
L8 Sensor
L9 Sensor
LZ Sensor
LY Sensor
LX Sensor

Portable Display Units (set)
Two units provided per set



APPENDIX H-3

BUFFER RAILCAR BILL OF MATERIAL

DATE: Jun-17
LISTED BY; JO
CHECKED BY: NH

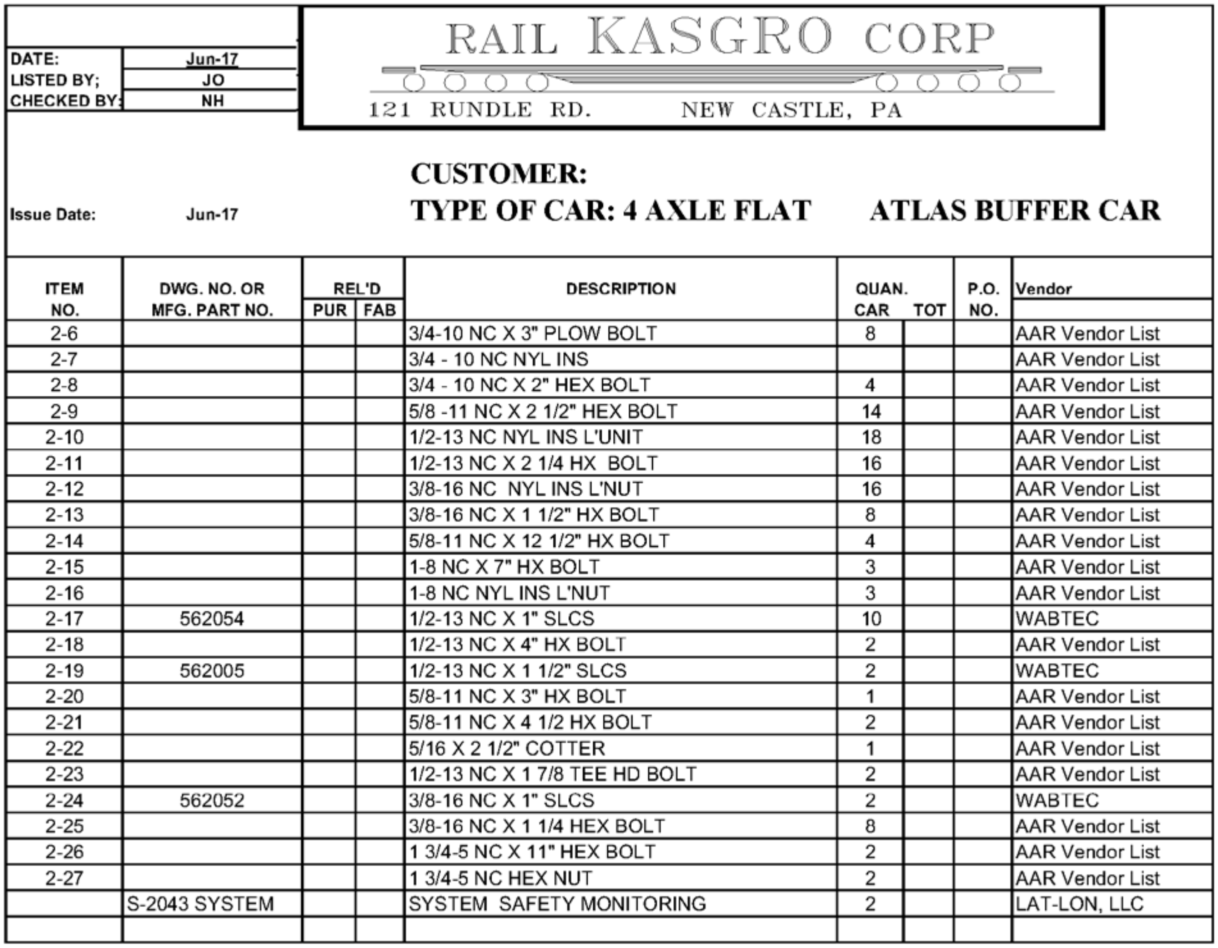
RAIL KASGRO CORP
121 RUNDLE RD. NEW CASTLE, PA

Issue Date: Jan-2018

CUSTOMER:
TYPE OF CAR: 4 AXLE FLAT ATLAS BUFFER CAR

ITEM NO.	DWG. NO. OR MFG. PART NO.	REL'D PUR	REL'D FAB	DESCRIPTION	QUAN. CAR	QUAN. TOT	P.O. NO.	Vendor
1-1	AS-541-1			SWING MOTION TRUCK ASSEMBLY	2			Amsted Rail
1-2	N53272-1			KONI DAMPER ASSEMBLY	4			Amsted Rail
1-3	11865			E15GB CUSHIONING UNIT	2			Amsted Rail
1-4	F-15 J			YOKE ASSEMBLY	2			Amsted Rail
1-5	DB60II			PNEUMATIC AIR BRAKE	1			New York Air Brake
1-6	D-1160-32			TRUCK SPRING ASSEMBLY	2			Wabtec
1-7	V-674			BRAKE SHOE	8			Airek
1-8	TTEF-15W			UNCOUPLING LEVER ASSEMBLY	2			Rollform Group
1-9	AAR Y-47			COUPLER PIN	2			McConway & Torley
1-10	EF-511			COUPLER TYPE E-43 F Shank	2			McConway & Torley
1-11	4067			16" DIA LOW PROFILE CENTER PLATE	2			Amsted Rail
1-12	BB624-RH			#24 BRAKE BEAM-RH	2			Miner Ent
1-13	BB624-LH			#24 BRAKE BEAM-LH	2			Miner Ent
1-14	TCC-III-60LT			TRUCK SIDE BEARING	4			Miner Ent
1-15	61936			WHEEL SET ASSEMBLIES	4			Progress Rail
1-21	F4638			DROP IN TRUCK WEAR LINER	2			Astralloy
1-22	1025			RETAINING KEY	8			PA Railcar
1-24	343-L			TRUCK MOUNTED BRAKE SYSTEM	2			Amsted Rail
1-27	7900			HAND BRAKE	1			Amsted
1-28	S4D-6511-09			GRAB IRON	1			ARI
1-29	S4D-6513-03			GRAB IRON	7			ARI
1-31	791-8			SIDE BEARING WEDGE	4			Stucki
1-32	8030			1 3/32 X 3 1/2" BRAKE PIN	4			General Bearing
1-33	3700011			5/16 X 2 1/2 LOCKTITE COTTER	4			General Bearing
1-34	1026			JAW FOR 3/4" ROD	3			Wabtec
1-35	SCHAEFER			EYE FOR 3/4 ROD	1			Wabtec
1-36	7264			1/2" HAMMERLOCK FITTING	1			Amsted Rail
1-37	1749			SHEAVE WHEEL	1			Amsted Rail
1-38	D-1003-20			BRAKE BADGE PLATE	1			Specialty Metals
1-39	8015			1 3/32 X 6" BRAKE PIN	1			General Bearing
1-40	458			CLEVIS	1			Amsted Rail
1-41	240			RIVET	1			Amsted Rail
1-42	565256			3/4 SOCKET WELD FTG	15			Wabtec
1-43	93841			3/4 GASKET	15			Wabtec
1-44	565252			3/8 SOCKET WELD FTG	2			Wabtec
1-45	93839			3/8 GASKET	2			Wabtec
1-46	565262			1 1/4 SOCKET WELD FTG	6			Wabtec
1-47	94790			1 1/4 GASKET	6			Wabtec
1-48	565259			1" SOCKET WELD FTG	2			Wabtec
1-49	93986			1" GASKET	2			Wabtec
1-50	580042			3/4 SOCK FTG NO GASKET	5			Wabtec
1-61	EHS			HOSE SUPPORT	2			Strat0
1-63	AAR-300			1 1/4 COUPLING	4			Wabtec
1-64	93839			3/8 GASKET	2			Wabtec
1-65	90034-281			ANGLE COCK U-BOLT	2			Wabtec
1-66	98903			3/4 X 3/4 X 3/4 TEE BODY	1			Wabtec
1-67	578219			HOSE ASSEMBLY	2			Wabtec
2-1				7/8 - 9 NC X 3 1/2" HEX BLT	28			AAR Vendor List
2-2				7/8 - 9 NYL INS L'NUT	28			AAR Vendor List
2-3				5/8 - 11 NC NYL INS L'NUT	50			AAR Vendor List
2-4				5/8-11 NC X 2" HEX BOLT	16			AAR Vendor List
2-5				5/8-11 NC X 2 1/4" HEX BOLT	8			AAR Vendor List

Page 1 1160-BOM ATLAS BUFFER CAR.xlsx



DATE:	Jun-17
LISTED BY;	JO
CHECKED BY:	NH

RAIL KASGRO CORP
121 RUNDLE RD. NEW CASTLE, PA

Issue Date: Jun-17

CUSTOMER:

TYPE OF CAR: 4 AXLE FLAT ATLAS BUFFER CAR

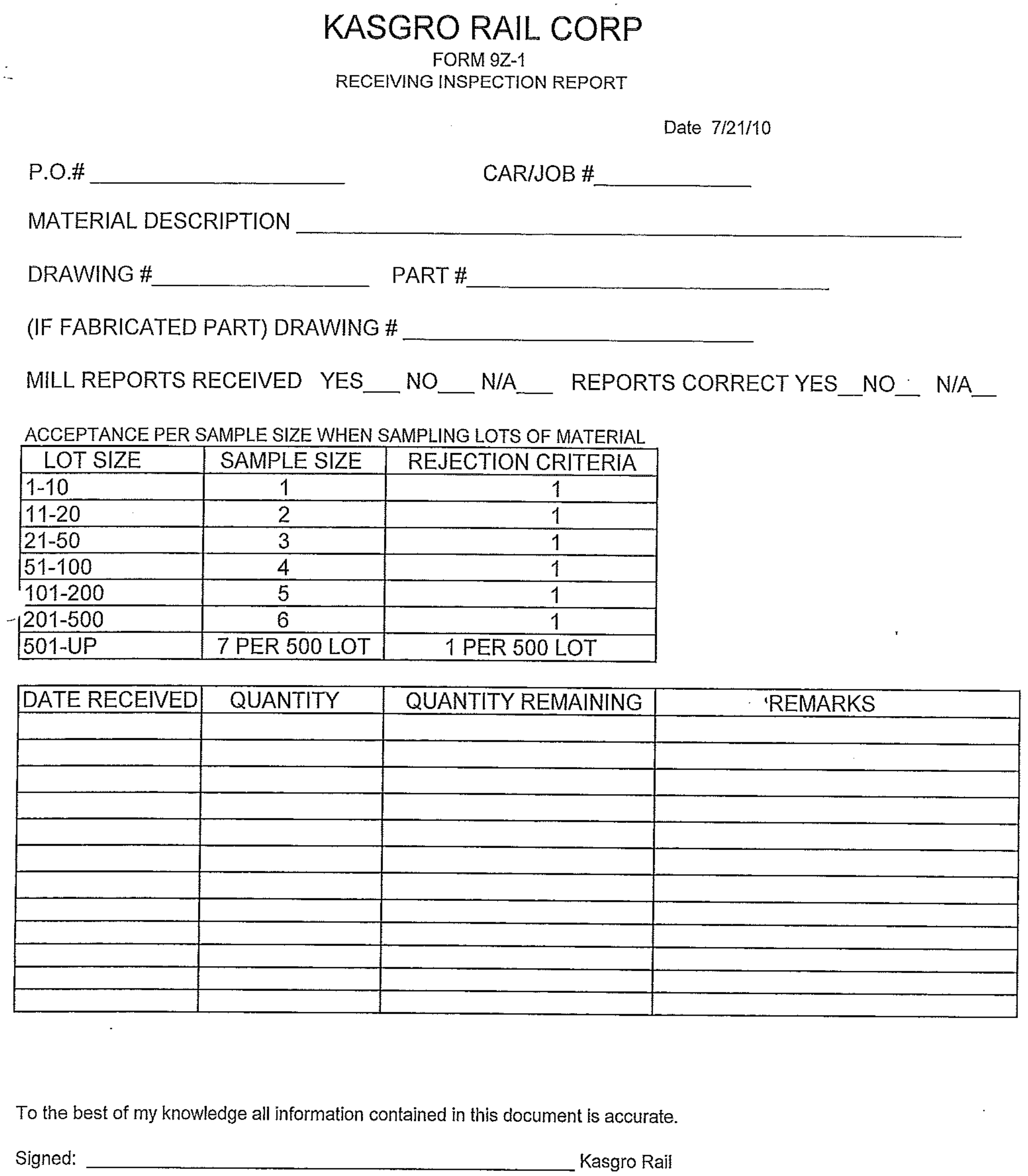
ITEM NO.	DWG. NO. OR MFG. PART NO.	REL'D PUR	REL'D FAB	DESCRIPTION	QUAN. CAR	QUAN. TOT	P.O. NO.	Vendor
2-6				3/4-10 NC X 3" PLOW BOLT	8			AAR Vendor List
2-7				3/4 - 10 NC NYL INS				AAR Vendor List
2-8				3/4 - 10 NC X 2" HEX BOLT	4			AAR Vendor List
2-9				5/8 -11 NC X 2 1/2" HEX BOLT	14			AAR Vendor List
2-10				1/2-13 NC NYL INS L'UNIT	18			AAR Vendor List
2-11				1/2-13 NC X 2 1/4 HX BOLT	16			AAR Vendor List
2-12				3/8-16 NC NYL INS L'NUT	16			AAR Vendor List
2-13				3/8-16 NC X 1 1/2" HX BOLT	8			AAR Vendor List
2-14				5/8-11 NC X 12 1/2" HX BOLT	4			AAR Vendor List
2-15				1-8 NC X 7" HX BOLT	3			AAR Vendor List
2-16				1-8 NC NYL INS L'NUT	3			AAR Vendor List
2-17	562054			1/2-13 NC X 1" SLCS	10			WABTEC
2-18				1/2-13 NC X 4" HX BOLT	2			AAR Vendor List
2-19	562005			1/2-13 NC X 1 1/2" SLCS	2			WABTEC
2-20				5/8-11 NC X 3" HX BOLT	1			AAR Vendor List
2-21				5/8-11 NC X 4 1/2 HX BOLT	2			AAR Vendor List
2-22				5/16 X 2 1/2" COTTER	1			AAR Vendor List
2-23				1/2-13 NC X 1 7/8 TEE HD BOLT	2			AAR Vendor List
2-24	562052			3/8-16 NC X 1" SLCS	2			WABTEC
2-25				3/8-16 NC X 1 1/4 HEX BOLT	8			AAR Vendor List
2-26				1 3/4-5 NC X 11" HEX BOLT	2			AAR Vendor List
2-27				1 3/4-5 NC HEX NUT	2			AAR Vendor List
	S-2043 SYSTEM			SYSTEM SAFETY MONITORING	2			LAT-LON, LLC

APPENDIX H-4

BUFFER RAILCAR FABRICATION INSPECTION PLAN

SUPPORTING DOCUMENTS

Appendix H-4.1 Kasgro Rail Receiving Inspection Report Form 9Z-1



KASGRO RAIL CORP

FORM 9Z-1
RECEIVING INSPECTION REPORT

Date 7/21/10

P.O.# ______________________ CAR/JOB #_____________

MATERIAL DESCRIPTION ____

DRAWING #__________________ PART #______________________________

(IF FABRICATED PART) DRAWING # ______________________________

MILL REPORTS RECEIVED YES___ NO___ N/A___ REPORTS CORRECT YES__NO__ N/A__

ACCEPTANCE PER SAMPLE SIZE WHEN SAMPLING LOTS OF MATERIAL

LOT SIZE	SAMPLE SIZE	REJECTION CRITERIA
1-10	1	1
11-20	2	1
21-50	3	1
51-100	4	1
101-200	5	1
201-500	6	1
501-UP	7 PER 500 LOT	1 PER 500 LOT

DATE RECEIVED	QUANTITY	QUANTITY REMAINING	REMARKS

To the best of my knowledge all information contained in this document is accurate.

Signed: ____ Kasgro Rail

Appendix H-4.2 Railcar Dimensional Inspection and Sampling Plan Forms 9B and 9C

PURCHASE ORDER: RAILCAR DIMENSIONAL INSPECTION AND SAMPLING PLAN 1

DRAWING NO.		REV LEVEL	

FORM 9B 3/17/10

ITEM NO.	NO. PER CAR	SAMPLING PLAN		
3-14	8	1 OF	8	LIMITED DIMENSIONS (SEE DATA SHEET)
3-15	8	1 OF	8	LIMITED DIMENSIONS (SEE DATA SHEET)
3-16	8	1 OF	8	LIMITED DIMENSIONS (SEE DATA SHEET)

INSPECTION ACCEPTANCE PER SAMPLE SIZE

LOT SIZE	SAMPLE SIZE	REJECTION CRITERIA
1-10	1	1
11-20	2	1
21-50	3	1
51-100	4	1
101-200	5	1
501-UP	6	1

To the best of my knowledge all information contained in this document is accurate.

Signed: ______________________________ Kasgro Rail

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

PURCHASE ORDER: RAILCAR DIMENSIONAL INSPECTION AND SAMPLING PLAN 2

DRAWING NO.	0	REV LEVEL	0
Item no.	3-14	Qty	8

FORM 9C 3/17/10

Inspected By: ______________________ Date: __________

Dimension/ Tolerance	Frequency of Inspection	Method of Inspection	Tool No.	Record Actual Dimension	Results
					Piece 1
22'-8"	1 OF 8	A	NA	OK/UNSAT	
3' 6"	1 OF 8	A	NA	OK/UNSAT	
2" Thickness	1 OF 8	A	NA	OK/UNSAT	

Inspection Method Legend
A-TAPE MEASURE
B-VARIABLE GAGE
C-FIXED GAGE

Inspection Symbol
Check Mark = OK
x = UNSAT
Yes = Record Actual Dimension
NA = No Inspection Required

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

PURCHASE ORDER: RAILCAR DIMENSIONAL INSPECTION AND SAMPLING PLAN 3

DRAWING NO.	0	REV LEVEL	0
Item no.	3-15	Qty	8

FORM 9C 3/17/10

Inspected By: Date:

Dimension/ Tolerance	Frequency of Inspection	Method of Inspection	Tool No.	Record Actual Dimension	Results
					Piece 1
22'-11 3/16"	1 OF 8	A	NA	OK/UNSAT	
3' 1"	1 OF 8	A	NA	OK/UNSAT	
2" Thickness	1 OF 8	A	NA	OK/UNSAT	

Inspection Method Legend
A-TAPE MEASURE
B-VARIABLE GAGE
C-FIXED GAGE

Inspection Symbol
Check Mark = OK
x = UNSAT
Yes = Record Actual Dimension
NA = No Inspection Required

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

PURCHASE ORDER: RAILCAR DIMENSIONAL INSPECTION AND SAMPLING PLAN 4

DRAWING NO.	0	REV LEVEL	0
Item no.	3-16	Qty	8

FORM 9C 3/17/10

Inspected By: ______________________ Date: ____________

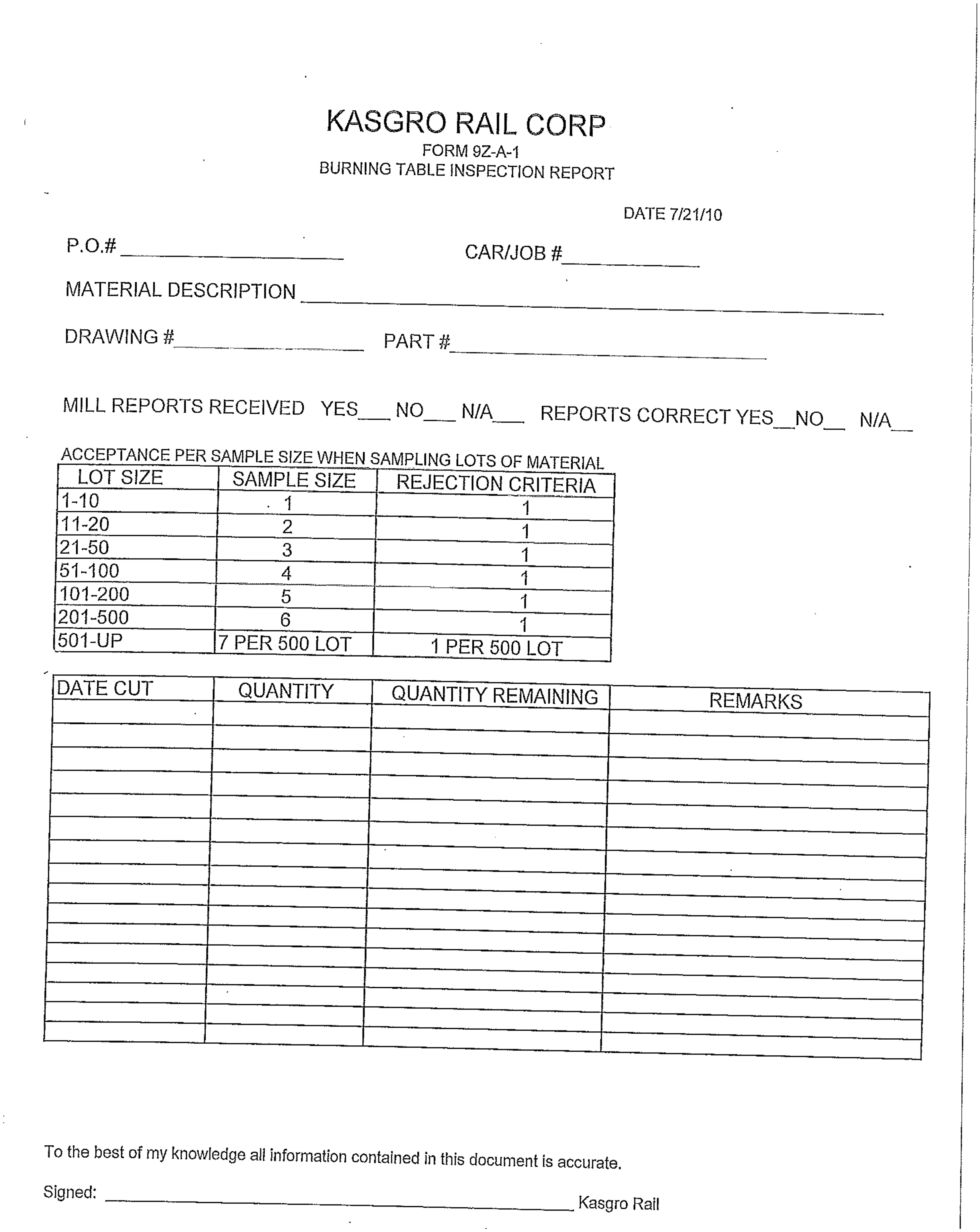
Dimension/ Tolerance	Frequency of Inspection	Method of Inspection	Tool No.	Record Actual Dimension	Results
					Piece 1
22'-11 3/16"	1 OF 8	A	NA	OK/UNSAT	
4"	1 OF 8	A	NA	OK/UNSAT	
2" Thickness	1 OF 8	A	NA	OK/UNSAT	

Inspection Method Legend
A-TAPE MEASURE
B-VARIABLE GAGE
C-FIXED GAGE

Inspection Symbol
Check Mark = OK
x = UNSAT
Yes = Record Actual Dimension
NA = No Inspection Required

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

Appendix H-4.3 Kasgro Rail Burning Table Inspection Report Form 9Z-A-1



KASGRO RAIL CORP

FORM 9Z-A-1
BURNING TABLE INSPECTION REPORT

DATE 7/21/10

P.O.# ____________________ CAR/JOB #____________

MATERIAL DESCRIPTION ____

DRAWING #_________________ PART #____________________________

MILL REPORTS RECEIVED YES___ NO___ N/A___ REPORTS CORRECT YES__NO__ N/A__

ACCEPTANCE PER SAMPLE SIZE WHEN SAMPLING LOTS OF MATERIAL

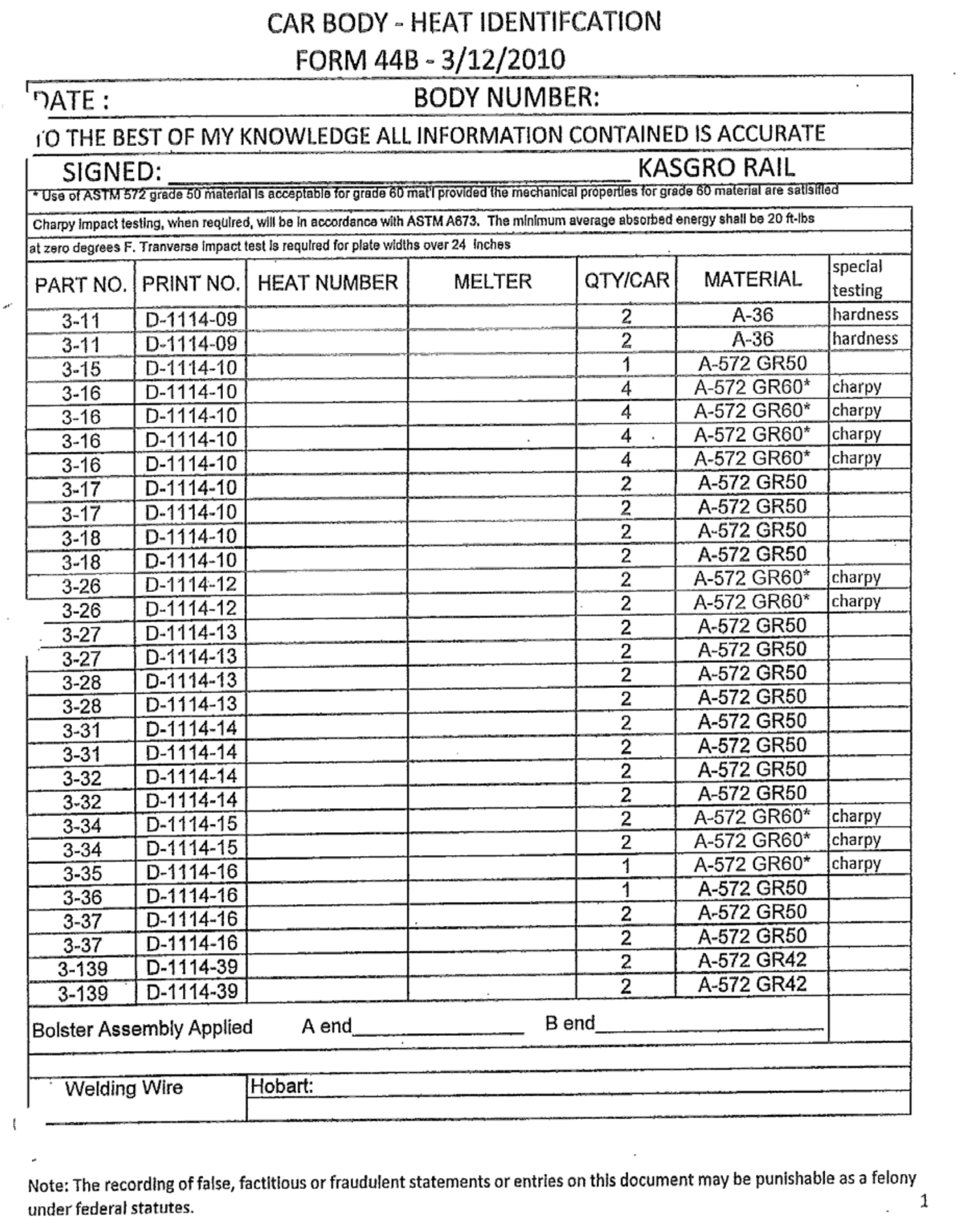
LOT SIZE	SAMPLE SIZE	REJECTION CRITERIA
1-10	1	1
11-20	2	1
21-50	3	1
51-100	4	1
101-200	5	1
201-500	6	1
501-UP	7 PER 500 LOT	1 PER 500 LOT

DATE CUT	QUANTITY	QUANTITY REMAINING	REMARKS

To the best of my knowledge all information contained in this document is accurate.

Signed: ____ Kasgro Rail

Appendix H-4.4 Car Body – Heat Identification Form
Form 44B, Rev 3/12/2010



CAR BODY - HEAT IDENTIFCATION
FORM 44B - 3/12/2010

DATE : BODY NUMBER:

TO THE BEST OF MY KNOWLEDGE ALL INFORMATION CONTAINED IS ACCURATE

SIGNED: ______________________________ KASGRO RAIL

* Use of ASTM 572 grade 50 material is acceptable for grade 60 mat'l provided the mechanical properties for grade 60 material are satisified

Charpy impact testing, when required, will be in accordance with ASTM A673. The minimum average absorbed energy shall be 20 ft-lbs at zero degrees F. Tranverse impact test is required for plate widths over 24 inches

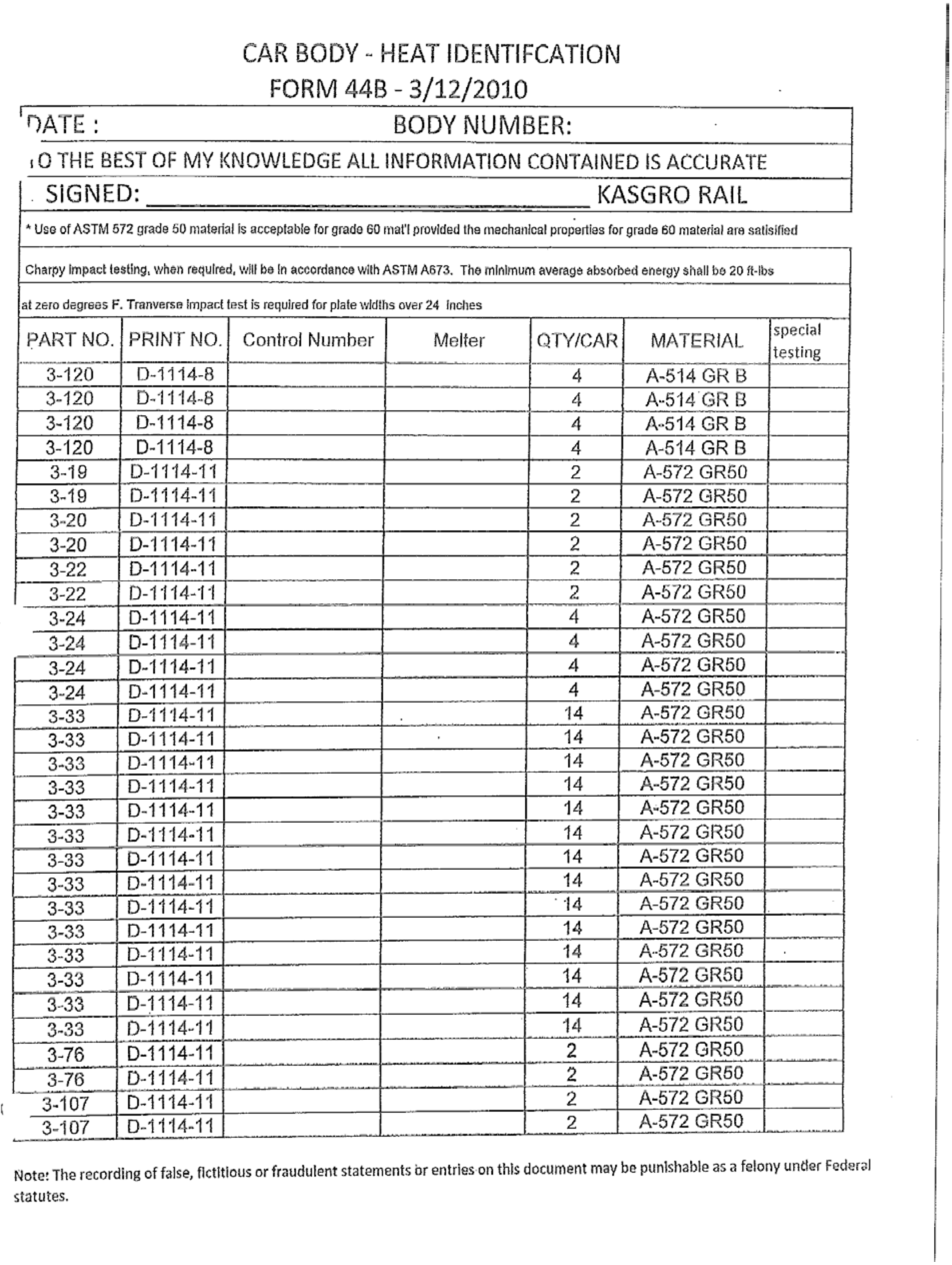
PART NO.	PRINT NO.	HEAT NUMBER	MELTER	QTY/CAR	MATERIAL	special testing
3-11	D-1114-09			2	A-36	hardness
3-11	D-1114-09			2	A-36	hardness
3-15	D-1114-10			1	A-572 GR50	
3-16	D-1114-10			4	A-572 GR60*	charpy
3-16	D-1114-10			4	A-572 GR60*	charpy
3-16	D-1114-10			4	A-572 GR60*	charpy
3-16	D-1114-10			4	A-572 GR60*	charpy
3-17	D-1114-10			2	A-572 GR50	
3-17	D-1114-10			2	A-572 GR50	
3-18	D-1114-10			2	A-572 GR50	
3-18	D-1114-10			2	A-572 GR50	
3-26	D-1114-12			2	A-572 GR60*	charpy
3-26	D-1114-12			2	A-572 GR60*	charpy
3-27	D-1114-13			2	A-572 GR50	
3-27	D-1114-13			2	A-572 GR50	
3-28	D-1114-13			2	A-572 GR50	
3-28	D-1114-13			2	A-572 GR50	
3-31	D-1114-14			2	A-572 GR50	
3-31	D-1114-14			2	A-572 GR50	
3-32	D-1114-14			2	A-572 GR50	
3-32	D-1114-14			2	A-572 GR50	
3-34	D-1114-15			2	A-572 GR60*	charpy
3-34	D-1114-15			2	A-572 GR60*	charpy
3-35	D-1114-16			1	A-572 GR60*	charpy
3-36	D-1114-16			1	A-572 GR50	
3-37	D-1114-16			2	A-572 GR50	
3-37	D-1114-16			2	A-572 GR50	
3-139	D-1114-39			2	A-572 GR42	
3-139	D-1114-39			2	A-572 GR42	

Bolster Assembly Applied A end________________ B end____________________

Welding Wire	Hobart:

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

1



CAR BODY - HEAT IDENTIFCATION
FORM 44B - 3/12/2010

DATE : BODY NUMBER:

TO THE BEST OF MY KNOWLEDGE ALL INFORMATION CONTAINED IS ACCURATE

SIGNED: ________________________________ KASGRO RAIL

* Use of ASTM 572 grade 50 material is acceptable for grade 60 mat'l provided the mechanical properties for grade 60 material are satisified

Charpy impact testing, when required, will be in accordance with ASTM A673. The minimum average absorbed energy shall be 20 ft-lbs at zero degrees F. Tranverse impact test is required for plate widths over 24 inches

PART NO.	PRINT NO.	Control Number	Melter	QTY/CAR	MATERIAL	special testing
3-120	D-1114-8			4	A-514 GR B	
3-120	D-1114-8			4	A-514 GR B	
3-120	D-1114-8			4	A-514 GR B	
3-120	D-1114-8			4	A-514 GR B	
3-19	D-1114-11			2	A-572 GR50	
3-19	D-1114-11			2	A-572 GR50	
3-20	D-1114-11			2	A-572 GR50	
3-20	D-1114-11			2	A-572 GR50	
3-22	D-1114-11			2	A-572 GR50	
3-22	D-1114-11			2	A-572 GR50	
3-24	D-1114-11			4	A-572 GR50	
3-24	D-1114-11			4	A-572 GR50	
3-24	D-1114-11			4	A-572 GR50	
3-24	D-1114-11			4	A-572 GR50	
3-33	D-1114-11			14	A-572 GR50	
3-33	D-1114-11			14	A-572 GR50	
3-33	D-1114-11			14	A-572 GR50	
3-33	D-1114-11			14	A-572 GR50	
3-33	D-1114-11			14	A-572 GR50	
3-33	D-1114-11			14	A-572 GR50	
3-33	D-1114-11			14	A-572 GR50	
3-33	D-1114-11			14	A-572 GR50	
3-33	D-1114-11			14	A-572 GR50	
3-33	D-1114-11			14	A-572 GR50	
3-33	D-1114-11			14	A-572 GR50	
3-33	D-1114-11			14	A-572 GR50	
3-33	D-1114-11			14	A-572 GR50	
3-33	D-1114-11			14	A-572 GR50	
3-76	D-1114-11			2	A-572 GR50	
3-76	D-1114-11			2	A-572 GR50	
3-107	D-1114-11			2	A-572 GR50	
3-107	D-1114-11			2	A-572 GR50	

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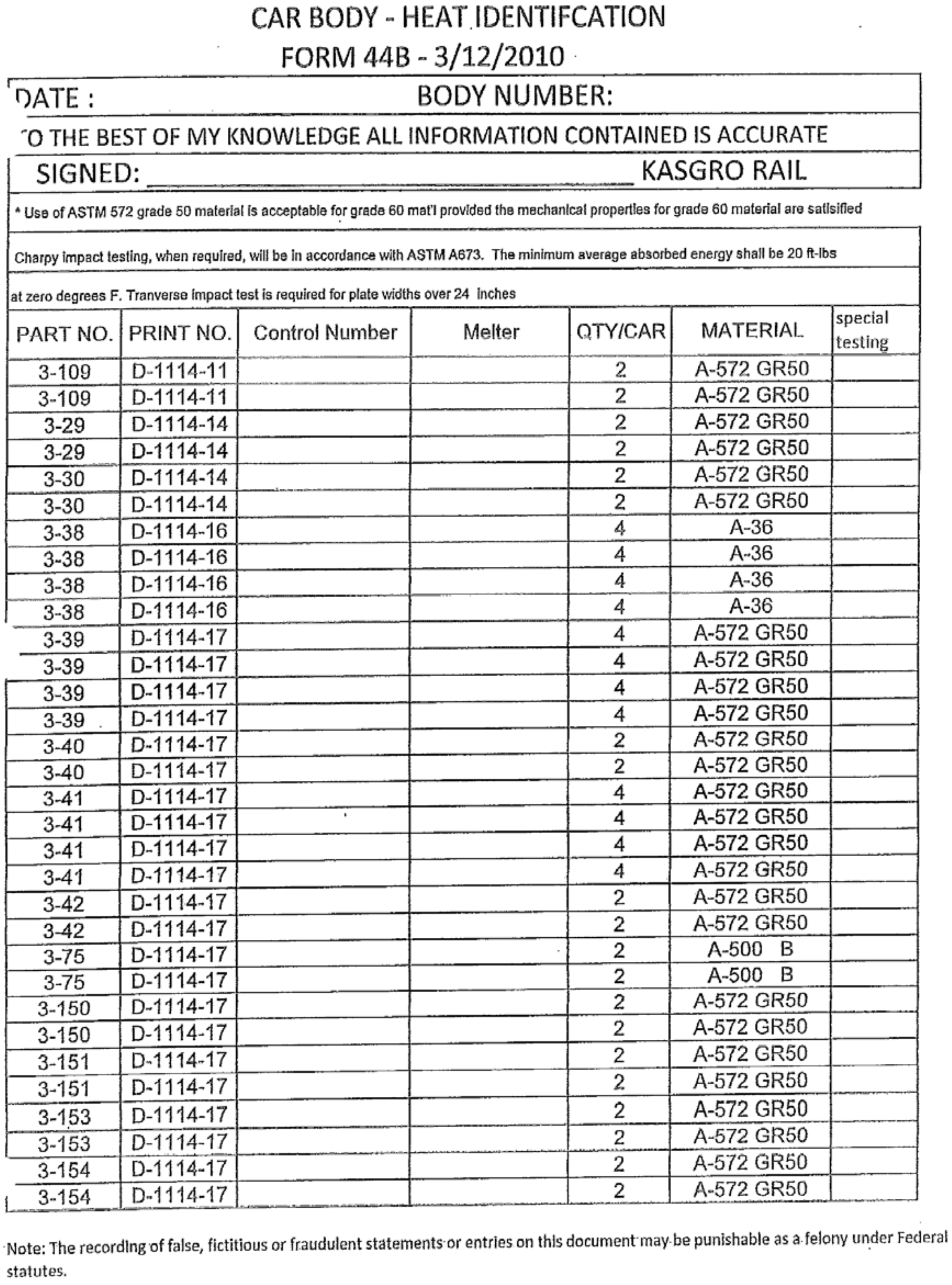

CAR BODY - HEAT IDENTIFCATION
FORM 44B - 3/12/2010

DATE : BODY NUMBER:

TO THE BEST OF MY KNOWLEDGE ALL INFORMATION CONTAINED IS ACCURATE

SIGNED: ______________________________ KASGRO RAIL

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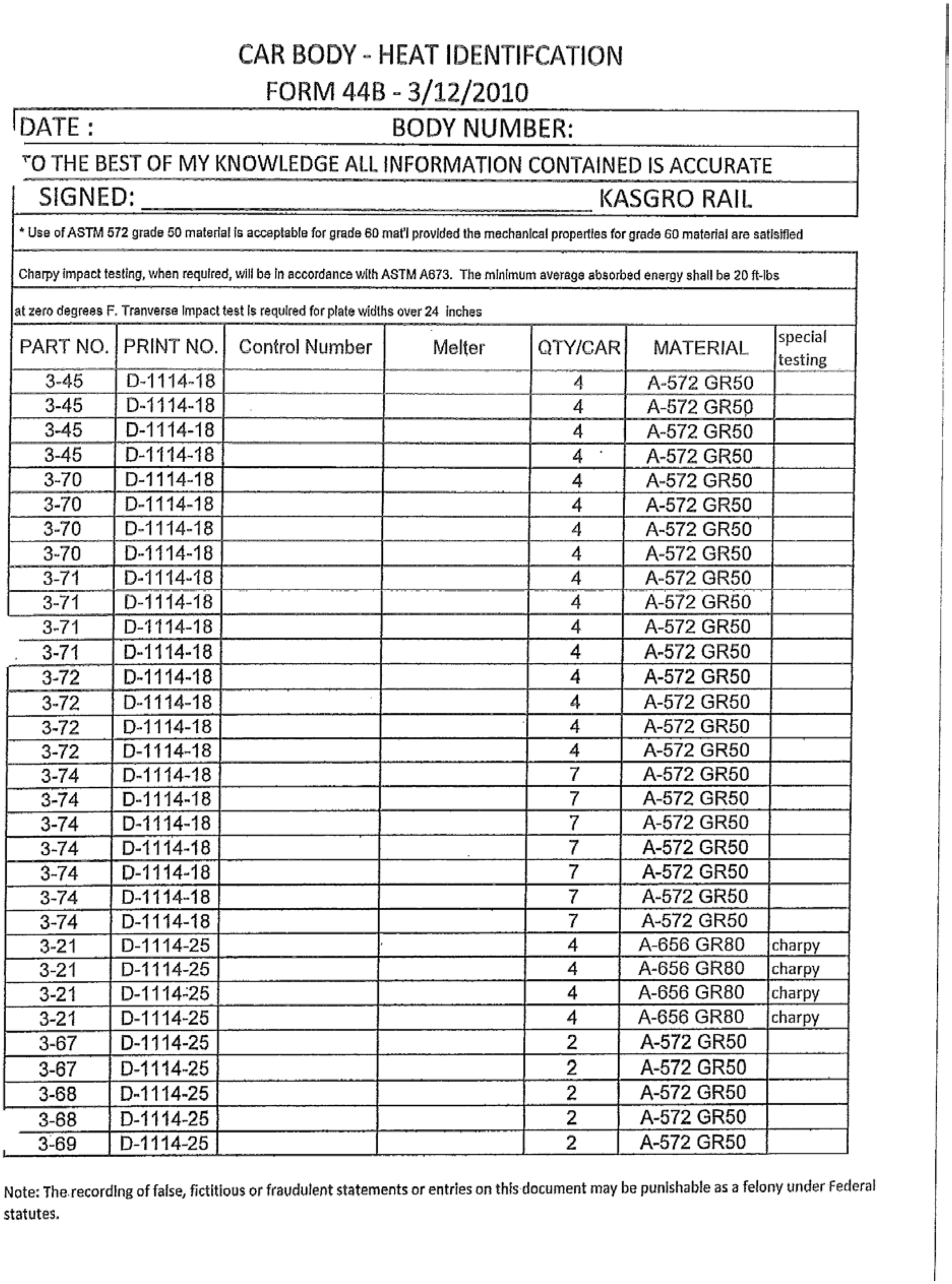
at zero degrees F. Tranverse impact test is required for plate widths over 24 inches

PART NO.	PRINT NO.	Control Number	Melter	QTY/CAR	MATERIAL	special testing
3-109	D-1114-11			2	A-572 GR50	
3-109	D-1114-11			2	A-572 GR50	
3-29	D-1114-14			2	A-572 GR50	
3-29	D-1114-14			2	A-572 GR50	
3-30	D-1114-14			2	A-572 GR50	
3-30	D-1114-14			2	A-572 GR50	
3-38	D-1114-16			4	A-36	
3-38	D-1114-16			4	A-36	
3-38	D-1114-16			4	A-36	
3-38	D-1114-16			4	A-36	
3-39	D-1114-17			4	A-572 GR50	
3-39	D-1114-17			4	A-572 GR50	
3-39	D-1114-17			4	A-572 GR50	
3-39	D-1114-17			4	A-572 GR50	
3-40	D-1114-17			2	A-572 GR50	
3-40	D-1114-17			2	A-572 GR50	
3-41	D-1114-17			4	A-572 GR50	
3-41	D-1114-17			4	A-572 GR50	
3-41	D-1114-17			4	A-572 GR50	
3-41	D-1114-17			4	A-572 GR50	
3-42	D-1114-17			2	A-572 GR50	
3-42	D-1114-17			2	A-572 GR50	
3-75	D-1114-17			2	A-500 B	
3-75	D-1114-17			2	A-500 B	
3-150	D-1114-17			2	A-572 GR50	
3-150	D-1114-17			2	A-572 GR50	
3-151	D-1114-17			2	A-572 GR50	
3-151	D-1114-17			2	A-572 GR50	
3-153	D-1114-17			2	A-572 GR50	
3-153	D-1114-17			2	A-572 GR50	
3-154	D-1114-17			2	A-572 GR50	
3-154	D-1114-17			2	A-572 GR50	

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



CAR BODY - HEAT IDENTIFCATION

FORM 44B - 3/12/2010

DATE : BODY NUMBER:

TO THE BEST OF MY KNOWLEDGE ALL INFORMATION CONTAINED IS ACCURATE

SIGNED: ______________________________ KASGRO RAIL

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PART NO.	PRINT NO.	Control Number	Melter	QTY/CAR	MATERIAL	special testing
3-45	D-1114-18			4	A-572 GR50	
3-45	D-1114-18			4	A-572 GR50	
3-45	D-1114-18			4	A-572 GR50	
3-45	D-1114-18			4	A-572 GR50	
3-70	D-1114-18			4	A-572 GR50	
3-70	D-1114-18			4	A-572 GR50	
3-70	D-1114-18			4	A-572 GR50	
3-70	D-1114-18			4	A-572 GR50	
3-71	D-1114-18			4	A-572 GR50	
3-71	D-1114-18			4	A-572 GR50	
3-71	D-1114-18			4	A-572 GR50	
3-71	D-1114-18			4	A-572 GR50	
3-72	D-1114-18			4	A-572 GR50	
3-72	D-1114-18			4	A-572 GR50	
3-72	D-1114-18			4	A-572 GR50	
3-72	D-1114-18			4	A-572 GR50	
3-74	D-1114-18			7	A-572 GR50	
3-74	D-1114-18			7	A-572 GR50	
3-74	D-1114-18			7	A-572 GR50	
3-74	D-1114-18			7	A-572 GR50	
3-74	D-1114-18			7	A-572 GR50	
3-74	D-1114-18			7	A-572 GR50	
3-74	D-1114-18			7	A-572 GR50	
3-21	D-1114-25			4	A-656 GR80	charpy
3-21	D-1114-25			4	A-656 GR80	charpy
3-21	D-1114-25			4	A-656 GR80	charpy
3-21	D-1114-25			4	A-656 GR80	charpy
3-67	D-1114-25			2	A-572 GR50	
3-67	D-1114-25			2	A-572 GR50	
3-68	D-1114-25			2	A-572 GR50	
3-68	D-1114-25			2	A-572 GR50	
3-69	D-1114-25			2	A-572 GR50	

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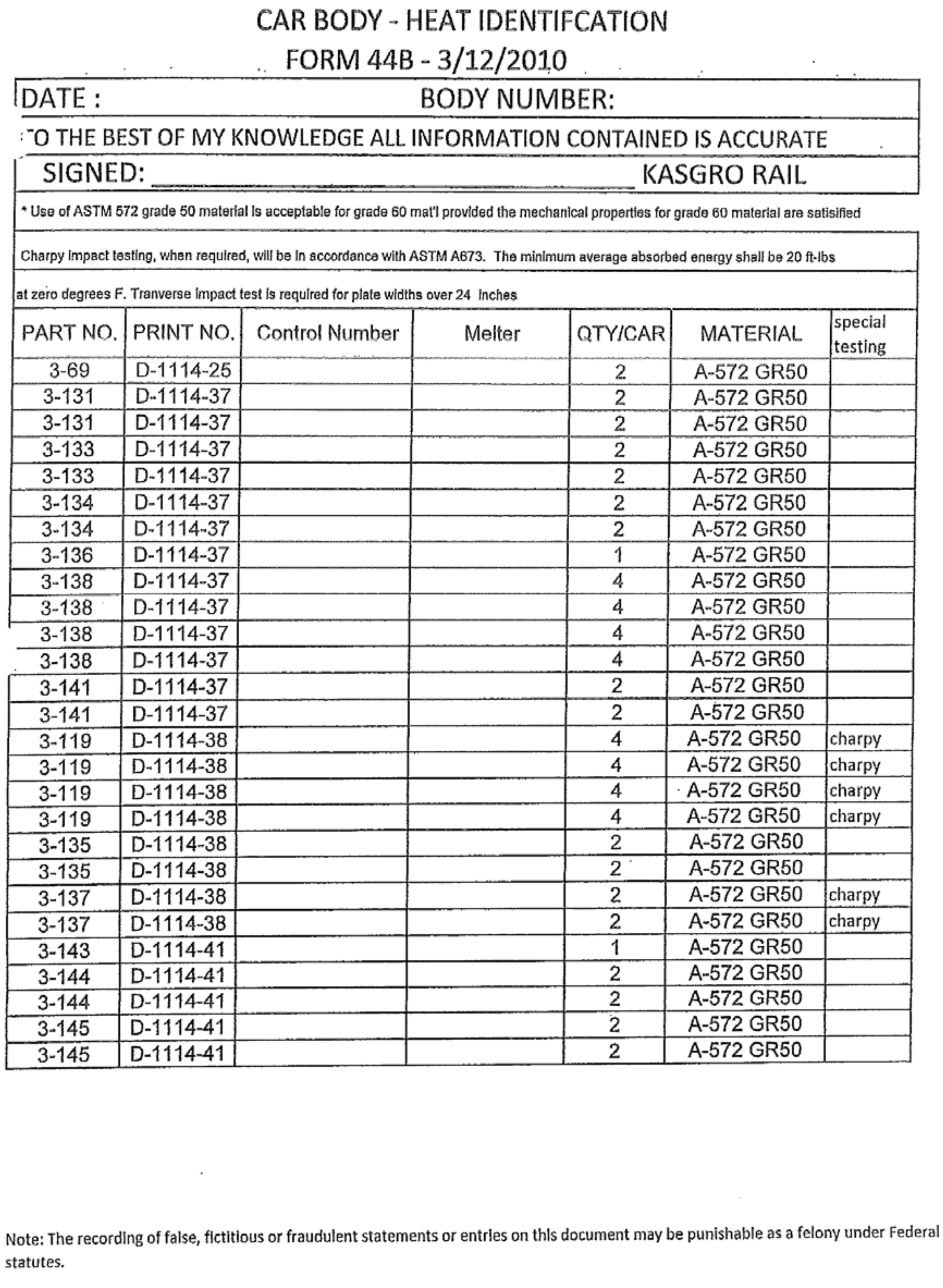

CAR BODY - HEAT IDENTIFCATION

FORM 44B - 3/12/2010

DATE : BODY NUMBER:

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PART NO.	PRINT NO.	Control Number	Melter	QTY/CAR	MATERIAL	special testing
3-69	D-1114-25			2	A-572 GR50	
3-131	D-1114-37			2	A-572 GR50	
3-131	D-1114-37			2	A-572 GR50	
3-133	D-1114-37			2	A-572 GR50	
3-133	D-1114-37			2	A-572 GR50	
3-134	D-1114-37			2	A-572 GR50	
3-134	D-1114-37			2	A-572 GR50	
3-136	D-1114-37			1	A-572 GR50	
3-138	D-1114-37			4	A-572 GR50	
3-138	D-1114-37			4	A-572 GR50	
3-138	D-1114-37			4	A-572 GR50	
3-138	D-1114-37			4	A-572 GR50	
3-141	D-1114-37			2	A-572 GR50	
3-141	D-1114-37			2	A-572 GR50	
3-119	D-1114-38			4	A-572 GR50	charpy
3-119	D-1114-38			4	A-572 GR50	charpy
3-119	D-1114-38			4	A-572 GR50	charpy
3-119	D-1114-38			4	A-572 GR50	charpy
3-135	D-1114-38			2	A-572 GR50	
3-135	D-1114-38			2	A-572 GR50	
3-137	D-1114-38			2	A-572 GR50	charpy
3-137	D-1114-38			2	A-572 GR50	charpy
3-143	D-1114-41			1	A-572 GR50	
3-144	D-1114-41			2	A-572 GR50	
3-144	D-1114-41			2	A-572 GR50	
3-145	D-1114-41			2	A-572 GR50	
3-145	D-1114-41			2	A-572 GR50	

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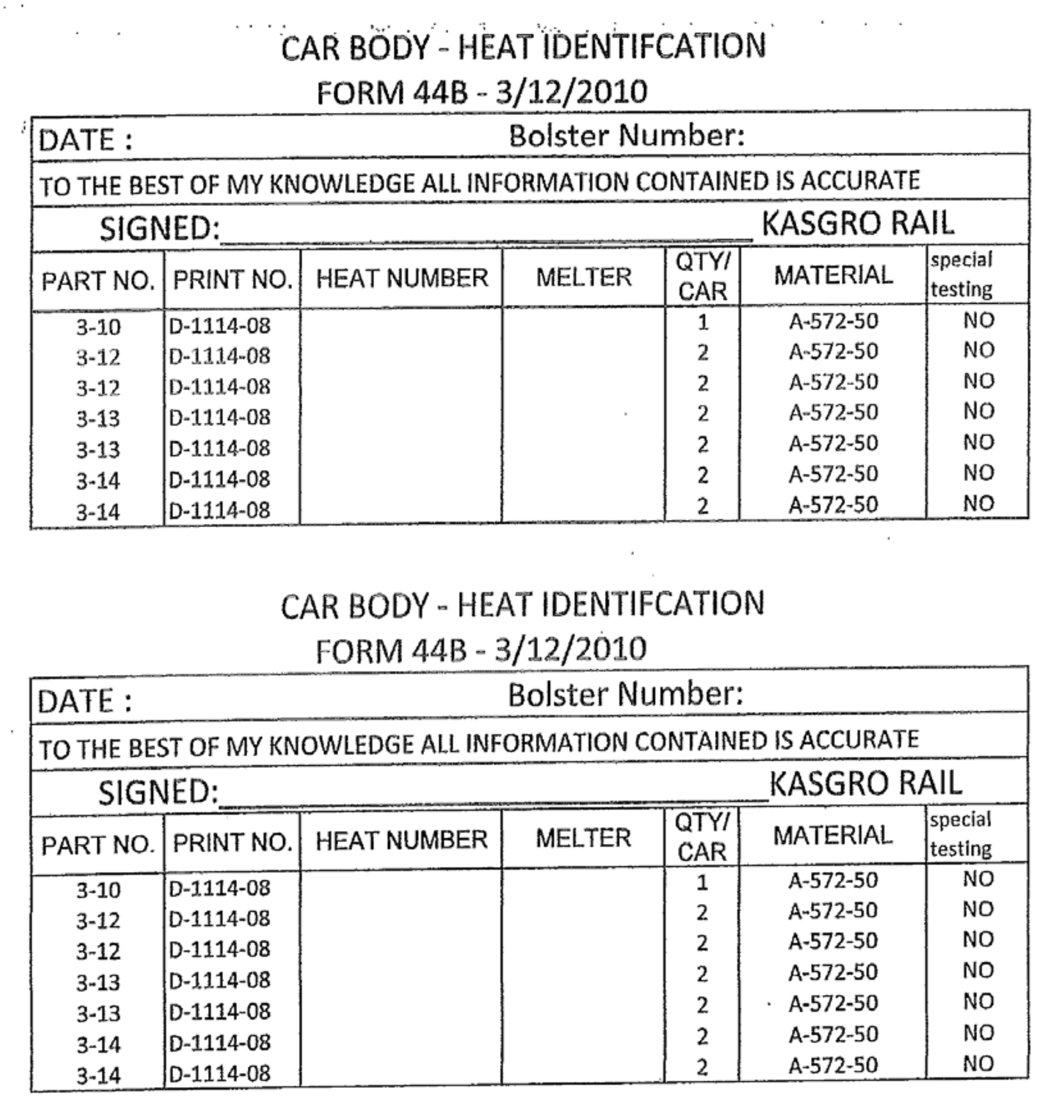

CAR BODY - HEAT IDENTIFCATION

FORM 44B - 3/12/2010

DATE : Bolster Number:

TO THE BEST OF MY KNOWLEDGE ALL INFORMATION CONTAINED IS ACCURATE

SIGNED:______________________________ KASGRO RAIL

PART NO.	PRINT NO.	HEAT NUMBER	MELTER	QTY/ CAR	MATERIAL	special testing
3-10	D-1114-08			1	A-572-50	NO
3-12	D-1114-08			2	A-572-50	NO
3-12	D-1114-08			2	A-572-50	NO
3-13	D-1114-08			2	A-572-50	NO
3-13	D-1114-08			2	A-572-50	NO
3-14	D-1114-08			2	A-572-50	NO
3-14	D-1114-08			2	A-572-50	NO

CAR BODY - HEAT IDENTIFCATION

FORM 44B - 3/12/2010

DATE : Bolster Number:

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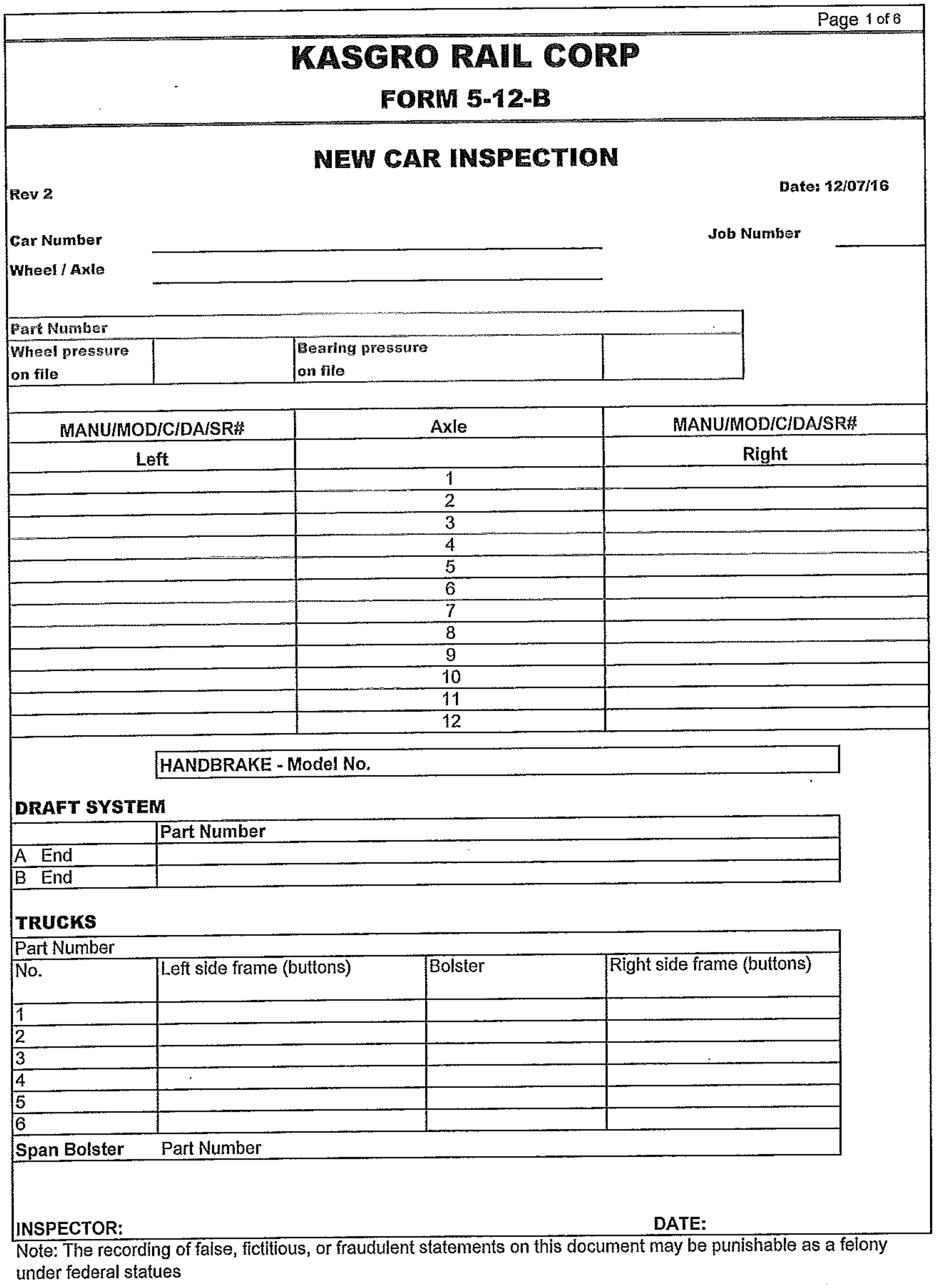
SIGNED:______________________________ KASGRO RAIL

PART NO.	PRINT NO.	HEAT NUMBER	MELTER	QTY/ CAR	MATERIAL	special testing
3-10	D-1114-08			1	A-572-50	NO
3-12	D-1114-08			2	A-572-50	NO
3-12	D-1114-08			2	A-572-50	NO
3-13	D-1114-08			2	A-572-50	NO
3-13	D-1114-08			2	A-572-50	NO
3-14	D-1114-08			2	A-572-50	NO
3-14	D-1114-08			2	A-572-50	NO

Appendix H-4.5 Kasgro Rail New Car Inspection Form Form 5-12-B, Rev 2



Page 1 of 6

KASGRO RAIL CORP

FORM 5-12-B

NEW CAR INSPECTION

Rev 2

Date: 12/07/16

Car Number ______________________

Job Number ______

Wheel / Axle ______________________

Part Number			
Wheel pressure on file		**Bearing pressure on file**	

MANU/MOD/C/DA/SR#	Axle	MANU/MOD/C/DA/SR#
Left		Right
	1	
	2	
	3	
	4	
	5	
	6	
	7	
	8	
	9	
	10	
	11	
	12	

HANDBRAKE - Model No.

DRAFT SYSTEM

	Part Number
A End	
B End	

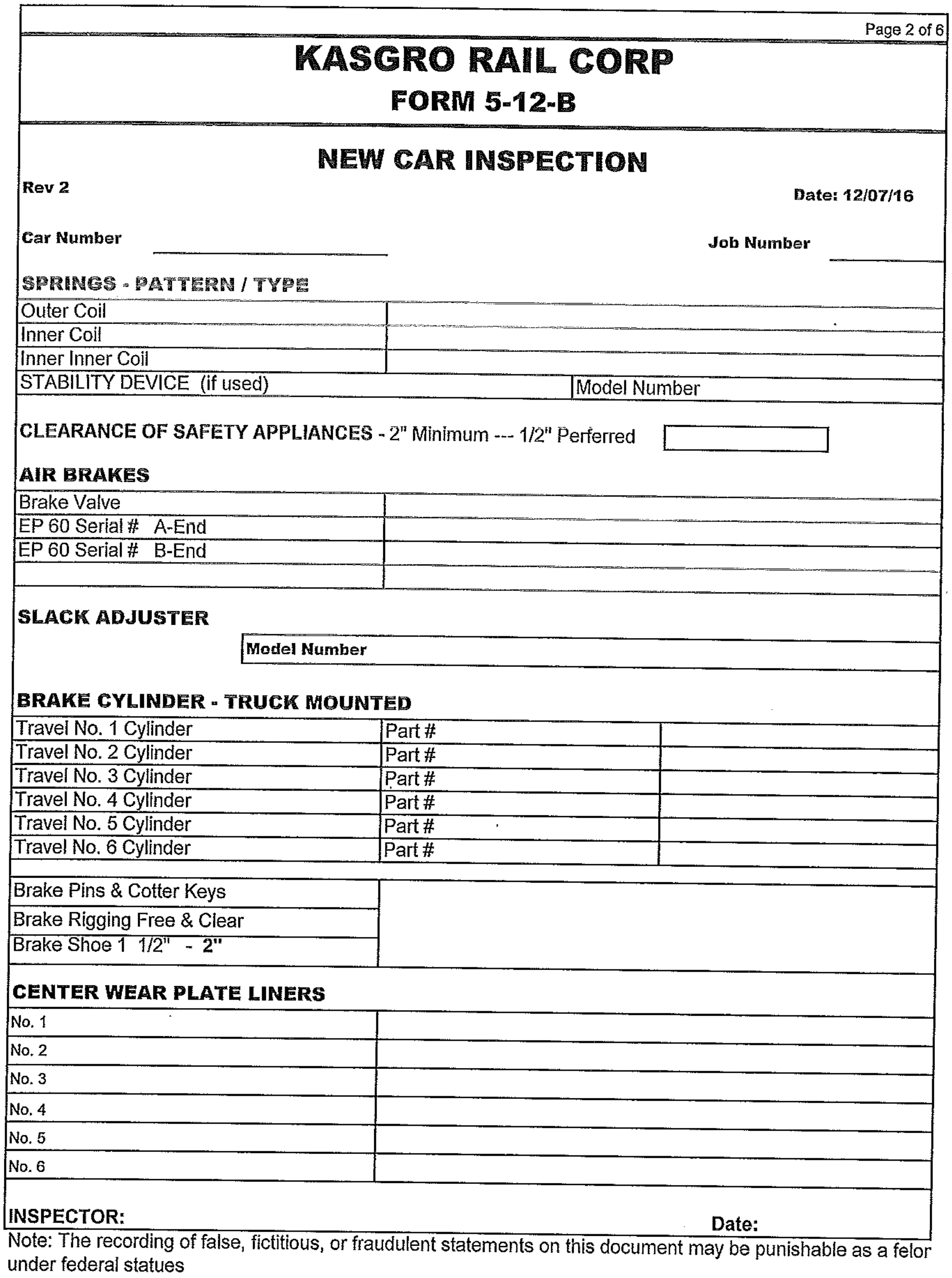
TRUCKS

Part Number			
No.	Left side frame (buttons)	Bolster	Right side frame (buttons)
1			
2			
3			
4			
5			
6			
Span Bolster	Part Number		

INSPECTOR:

DATE:

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



Page 2 of 6

KASGRO RAIL CORP

FORM 5-12-B

NEW CAR INSPECTION

Rev 2

Date: 12/07/16

Car Number ____________

Job Number ____________

SPRINGS - PATTERN / TYPE

Outer Coil	
Inner Coil	
Inner Inner Coil	
STABILITY DEVICE (if used)	Model Number

CLEARANCE OF SAFETY APPLIANCES - 2" Minimum --- 1/2" Perferred ☐

AIR BRAKES

Brake Valve	
EP 60 Serial # A-End	
EP 60 Serial # B-End	

SLACK ADJUSTER

Model Number

BRAKE CYLINDER - TRUCK MOUNTED

Travel No. 1 Cylinder	Part #	
Travel No. 2 Cylinder	Part #	
Travel No. 3 Cylinder	Part #	
Travel No. 4 Cylinder	Part #	
Travel No. 5 Cylinder	Part #	
Travel No. 6 Cylinder	Part #	

Brake Pins & Cotter Keys	
Brake Rigging Free & Clear	
Brake Shoe 1 1/2" - **2"**	

CENTER WEAR PLATE LINERS

No. 1	
No. 2	
No. 3	
No. 4	
No. 5	
No. 6	

INSPECTOR: **Date:**

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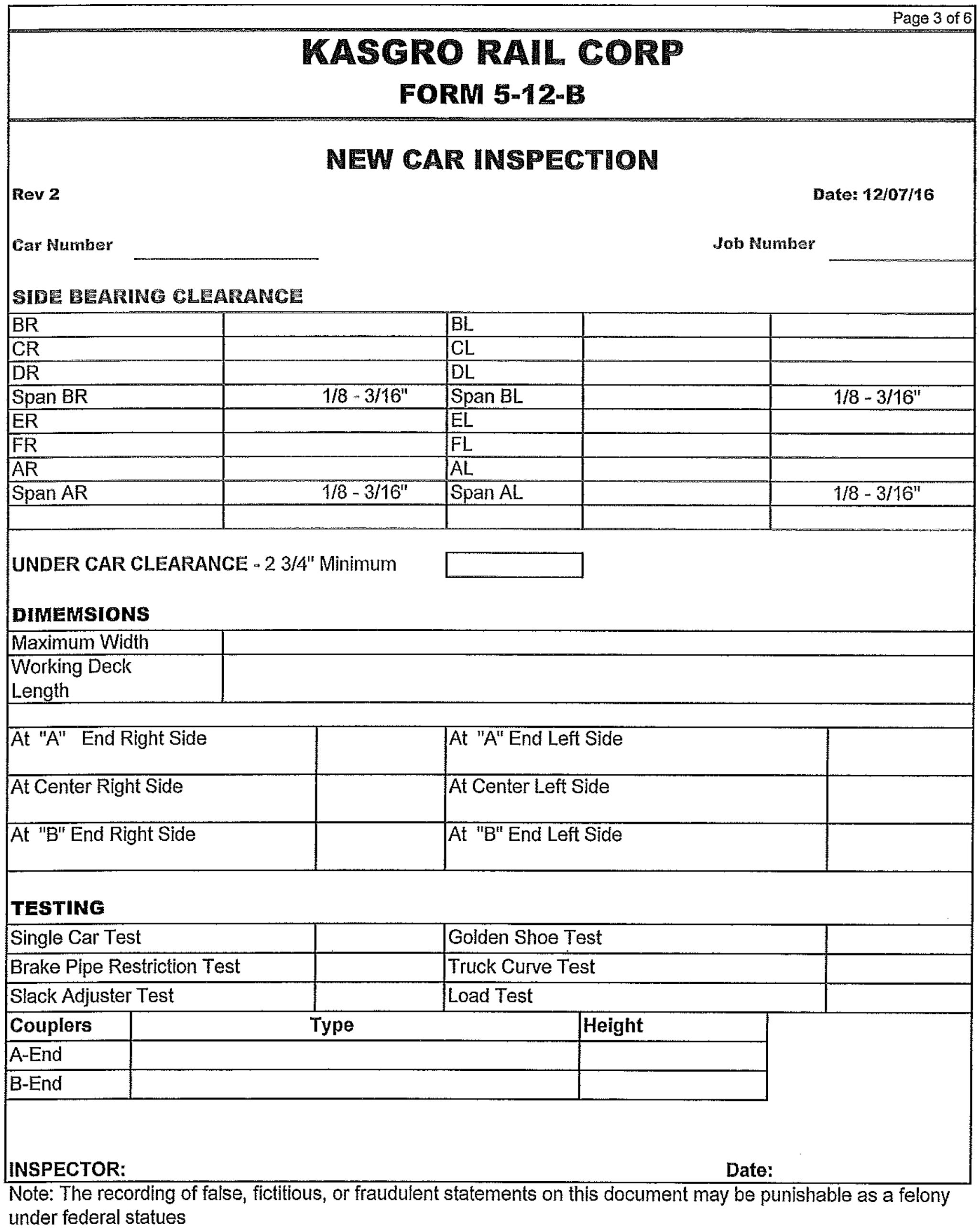

Page 3 of 6

KASGRO RAIL CORP

FORM 5-12-B

NEW CAR INSPECTION

Rev 2 **Date: 12/07/16**

Car Number ____________ **Job Number** ____________

SIDE BEARING CLEARANCE

BR		BL		
CR		CL		
DR		DL		
Span BR	1/8 - 3/16"	Span BL		1/8 - 3/16"
ER		EL		
FR		FL		
AR		AL		
Span AR	1/8 - 3/16"	Span AL		1/8 - 3/16"

UNDER CAR CLEARANCE - 2 3/4" Minimum ☐

DIMEMSIONS

Maximum Width	
Working Deck Length	

At "A" End Right Side		At "A" End Left Side	
At Center Right Side		At Center Left Side	
At "B" End Right Side		At "B" End Left Side	

TESTING

Single Car Test		Golden Shoe Test	
Brake Pipe Restriction Test		Truck Curve Test	
Slack Adjuster Test		Load Test	

Couplers	**Type**	**Height**
A-End		
B-End		

INSPECTOR: **Date:**

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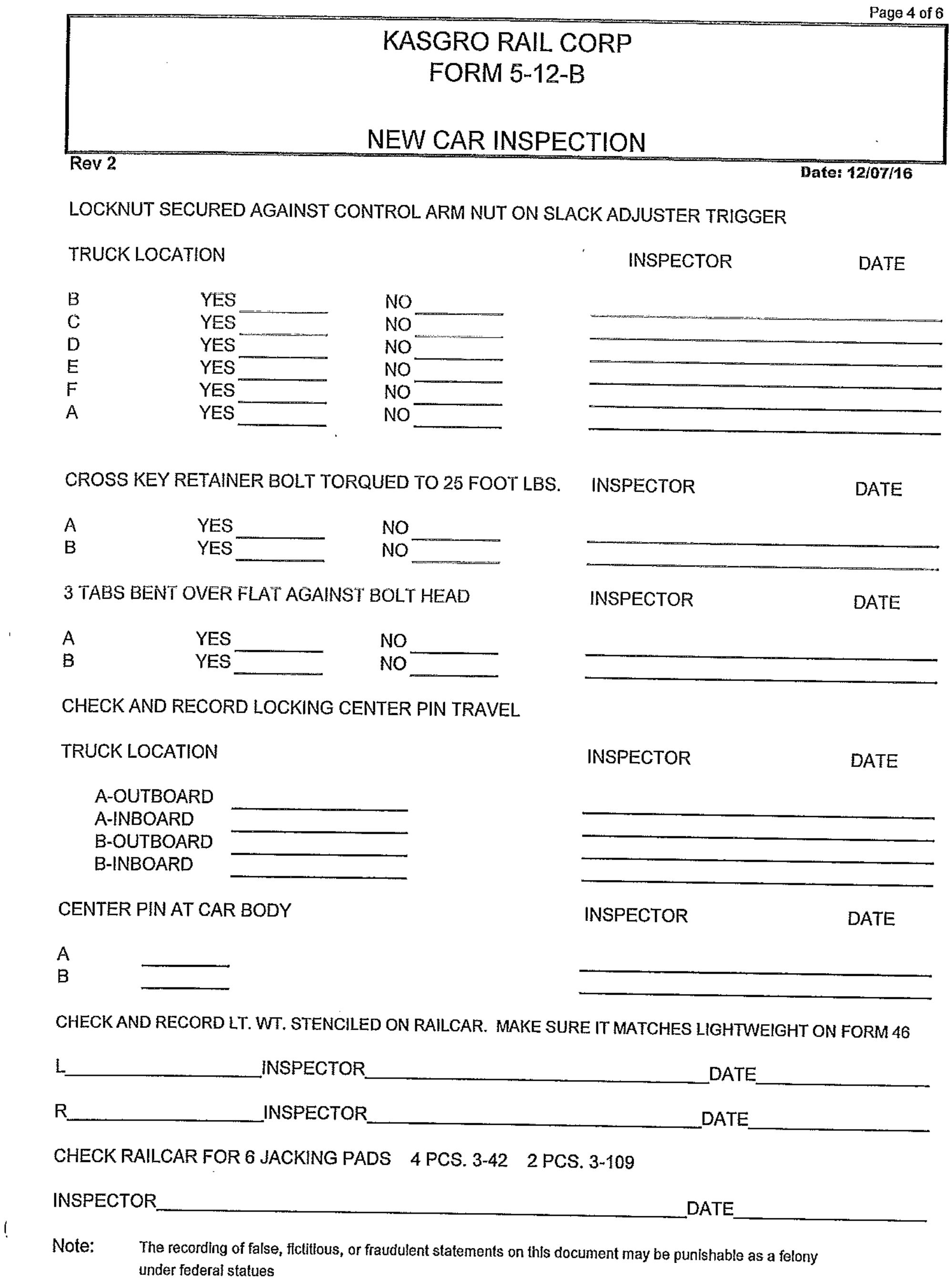

Page 4 of 6

KASGRO RAIL CORP
FORM 5-12-B

NEW CAR INSPECTION

Rev 2

Date: 12/07/16

LOCKNUT SECURED AGAINST CONTROL ARM NUT ON SLACK ADJUSTER TRIGGER

TRUCK LOCATION			INSPECTOR	DATE
B	YES ________	NO ________	____________	________
C	YES ________	NO ________	____________	________
D	YES ________	NO ________	____________	________
E	YES ________	NO ________	____________	________
F	YES ________	NO ________	____________	________
A	YES ________	NO ________	____________	________

CROSS KEY RETAINER BOLT TORQUED TO 25 FOOT LBS.			INSPECTOR	DATE
A	YES ________	NO ________	____________	________
B	YES ________	NO ________	____________	________

3 TABS BENT OVER FLAT AGAINST BOLT HEAD			INSPECTOR	DATE
A	YES ________	NO ________	____________	________
B	YES ________	NO ________	____________	________

CHECK AND RECORD LOCKING CENTER PIN TRAVEL

TRUCK LOCATION		INSPECTOR	DATE
A-OUTBOARD	____________	____________	________
A-INBOARD	____________	____________	________
B-OUTBOARD	____________	____________	________
B-INBOARD	____________	____________	________

CENTER PIN AT CAR BODY		INSPECTOR	DATE
A	________	____________	________
B	________	____________	________

CHECK AND RECORD LT. WT. STENCILED ON RAILCAR. MAKE SURE IT MATCHES LIGHTWEIGHT ON FORM 46

L________________INSPECTOR____________________________DATE____________

R________________INSPECTOR____________________________DATE____________

CHECK RAILCAR FOR 6 JACKING PADS 4 PCS. 3-42 2 PCS. 3-109

INSPECTOR____DATE____________

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

KASGRO RAIL CORP
FORM 5-12-B

NEW CAR INSPECTION

Rev 2 **Date: 12/07/16**

MIDDLE TRUCK COVER PLATES LOCATED IN THE CORRECT POSITION-BOLTS SHOULD BE TOWARD THE OUTBOARD END OF CAR

			INSPECTOR	DATE
A	YES ________	NO ________		
B	YES ________	NO ________		

TRUCK BOWLS LUBRICATED

			INSPECTOR	DATE
B	YES ________	NO ________		
C	YES ________	NO ________		
D	YES ________	NO ________		
E	YES ________	NO ________		
F	YES ________	NO ________		
A	YES ________	NO ________		

SPAN BOLSTER BOWLS LUBRICATED

			INSPECTOR	DATE
A	YES ________	NO ________		
B	YES ________	NO ________		

PROTECTING COVERS INSTALLED OVER ECP PIGTAIL CONNECTION PINS

			INSPECTOR	DATE
A	YES ________	NO ________		
B	YES ________	NO ________		

COMPLETE AND PROPER MARKING APPLIED TO RAILCAR AND END PLATFORMS PER STENCIL DRAWING E-1114-3 REV. I

INSPECTOR ______________________ DATE ____________

AFTER ALL AIRBRAKE TESTING IS DONE FINAL INSPECTION OF ALL SPRING SETS WHEN RAILCARS ARE FULLY ASSEMBLED, AND WITH THE RAILCAR JACKED TO REMOVE THE WEIGHT OF THE CARBODY FROM THE SPAN BOLSTER/TRUCK ASSEMBLIES

INSPECTOR ______________________ DATE ____________

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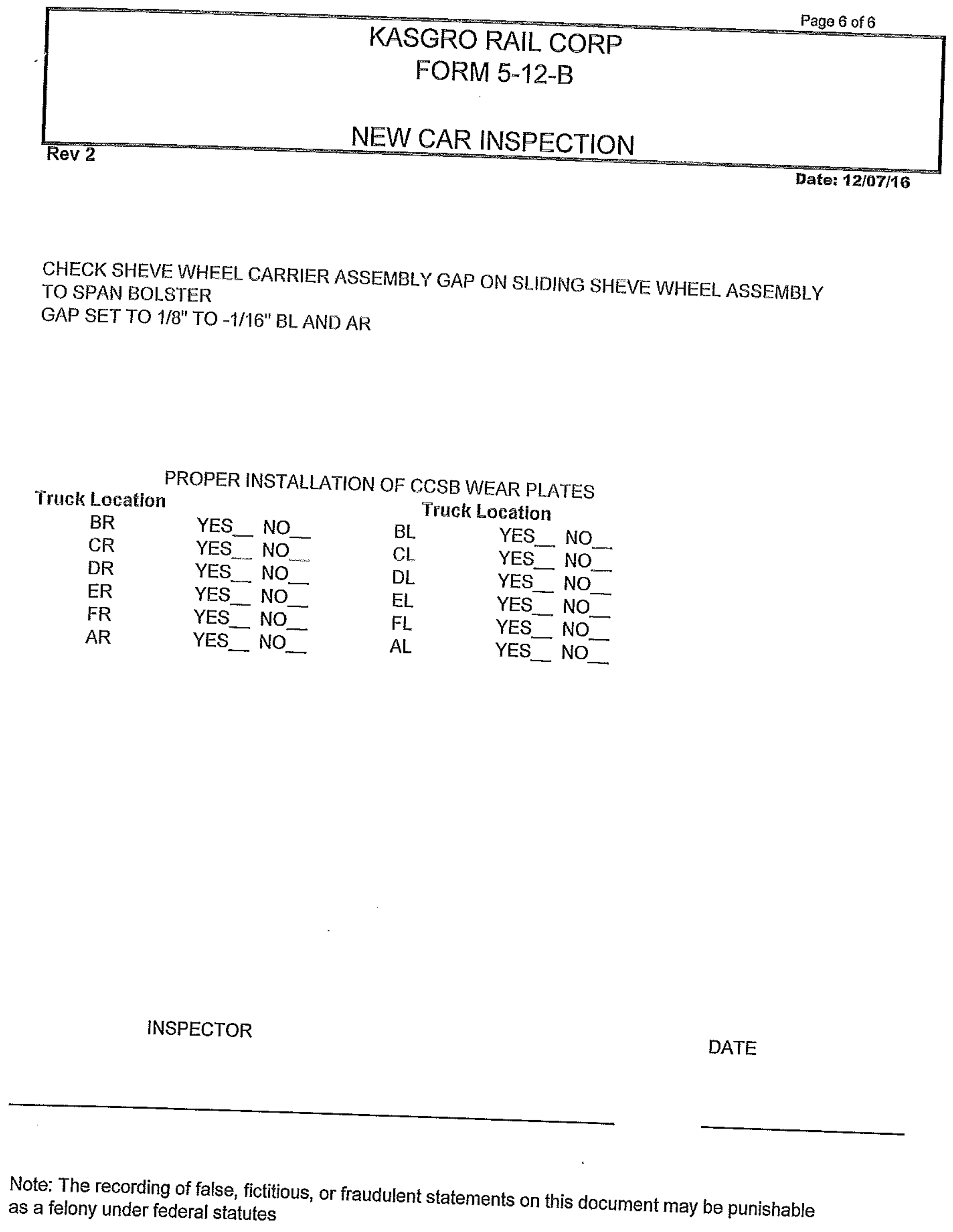

Page 6 of 6

KASGRO RAIL CORP
FORM 5-12-B

NEW CAR INSPECTION

Rev 2

Date: 12/07/16

CHECK SHEVE WHEEL CARRIER ASSEMBLY GAP ON SLIDING SHEVE WHEEL ASSEMBLY TO SPAN BOLSTER
GAP SET TO 1/8" TO -1/16" BL AND AR

PROPER INSTALLATION OF CCSB WEAR PLATES

Truck Location		Truck Location	
BR	YES__ NO__	BL	YES__ NO__
CR	YES__ NO__	CL	YES__ NO__
DR	YES__ NO__	DL	YES__ NO__
ER	YES__ NO__	EL	YES__ NO__
FR	YES__ NO__	FL	YES__ NO__
AR	YES__ NO__	AL	YES__ NO__

INSPECTOR

DATE

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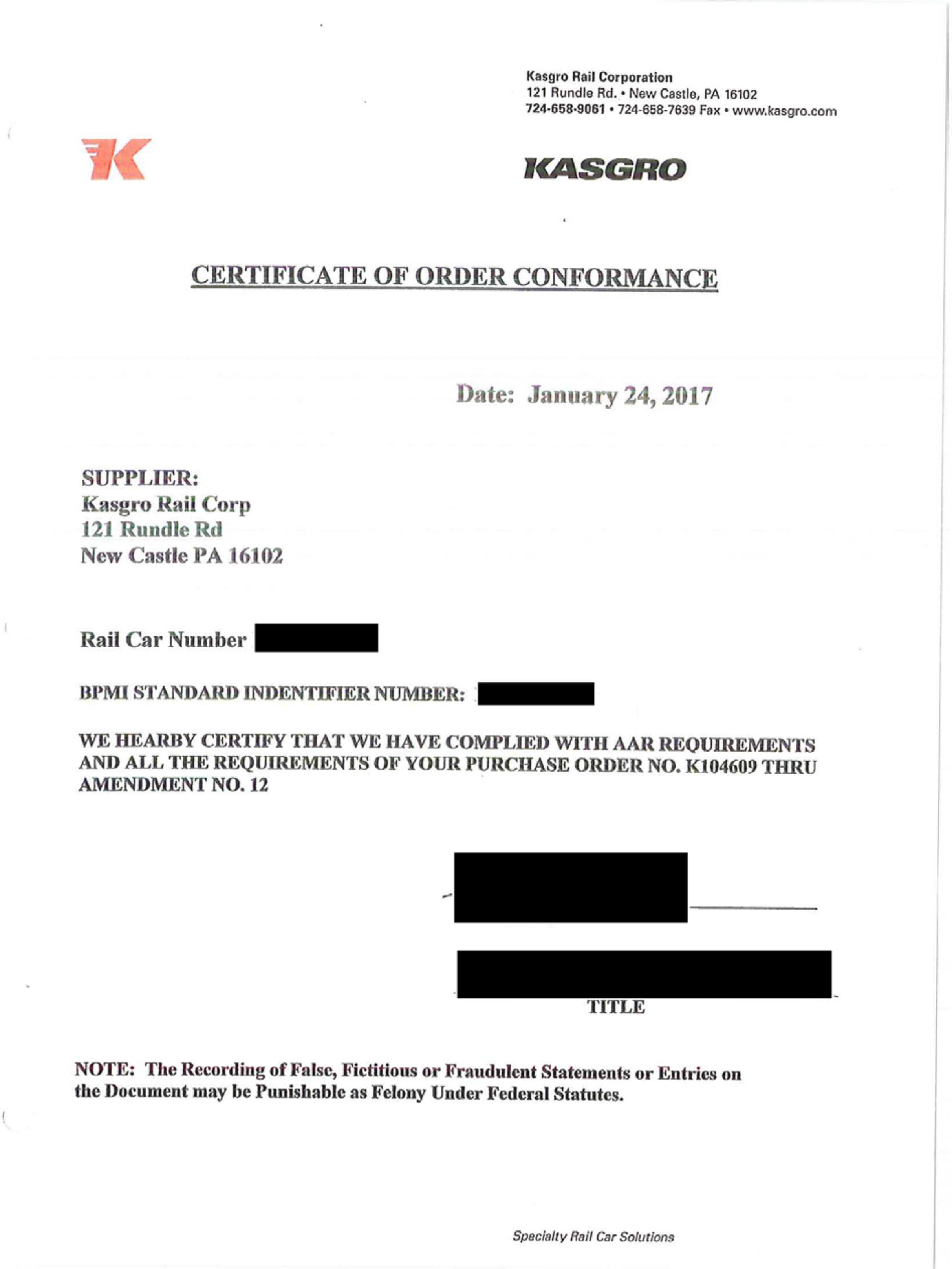
Appendix H-4.6 Kasgro Rail Certificate of Order Conformance Example



Kasgro Rail Corporation
121 Rundle Rd. • New Castle, PA 16102
724-658-9061 • 724-658-7639 Fax • www.kasgro.com

KASGRO

CERTIFICATE OF ORDER CONFORMANCE

Date: January 24, 2017

SUPPLIER:
Kasgro Rail Corp
121 Rundle Rd
New Castle PA 16102

Rail Car Number [redacted]

BPMI STANDARD INDENTIFIER NUMBER: [redacted]

WE HEARBY CERTIFY THAT WE HAVE COMPLIED WITH AAR REQUIREMENTS AND ALL THE REQUIREMENTS OF YOUR PURCHASE ORDER NO. K104609 THRU AMENDMENT NO. 12

[redacted]

[redacted]
TITLE

NOTE: The Recording of False, Fictitious or Fraudulent Statements or Entries on the Document may be Punishable as Felony Under Federal Statutes.

Specialty Rail Car Solutions

APPENDIX H-5

BUFFER RAILCAR FABRICATION TRAVELERS

KASGRO SPECIALTY RAILCAR SOLUTIONS, FORM 84, FLAT CAR ASSEMBLY FORM

QA FORM 84, REV APRIL 11, 2017

Kasgro Specialty Railcar Solutions

Form 84

Flat Car Assembly

Quality Assurance
Car Body Bolster Reporting Form
Fit and Weld Car Body Bolster

Car #:____________________________________

Inspect fit-up: ______________________________________

Weld

Inspect all welds:________________________________

Welders Clock #_____________
____
____
____

All repairs to be made and forms completed before moving assembly

Group leader or foreman's Signature: ____________________________
Date______________

Inspector's signature: ____Date_____________

Kasgro Specialty Railcar Solutions

Form 84

Flat Car Assembly

Quality Assurance
Railcar Car Body Reporting Form

Fit – Side sills, Center sill, Center plates, End sills, Body bolsters and Cross bearers to railcar deck plate

Check fit-up for proper application to drawings___________________________________

Weld

Inspect all welds:_________________________________

Welders Clock #__________________
____
____
____

All repairs to be made and forms completed before moving assembly

Group leader or foreman's signature: ____________________________Date_______________

Inspector's signature: ____Date_______________

Kasgro Specialty Railcar Solutions

Form 84

Flat Car Assembly

Quality Assurance
Railcar Reporting Form

Fit – Bottom Cover Plate and Side Sill Gussets

Check fit-up for proper application to drawings_____________________________________

Weld

Inspect all welds:____

Welders Clock #_______________
____
____
____

All repairs to be made and forms completed before moving assembly

Group leader or foreman's signature: ______________________________Date_____________

Inspector's signature: ____Date_____________

Kasgro Specialty Railcar Solutions

Form 84

Flat Car Assembly

Quality Assurance
Reporting form

Position #7
Apply Airbrake, Piping

Inspection
Inspect all parts/sub-assemblies for proper application to drawings

Inspect all welds and fastenings: ____

Welders Clock #________________
____
____
____

All repairs to be made and forms completed before moving assembly

Group leader or foreman's signature: ______________________________Date_____________

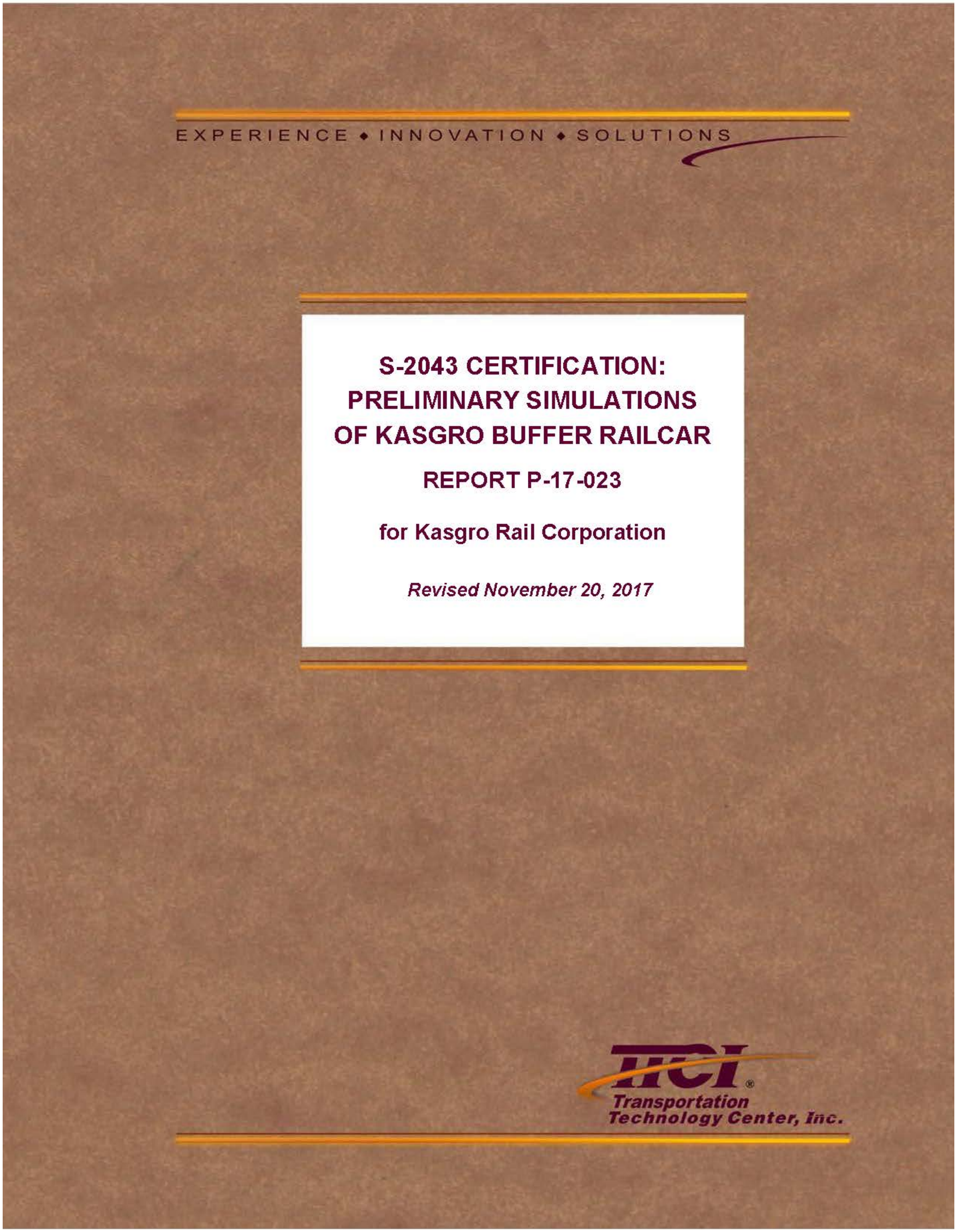
Inspector's signature: ____Date_____________

APPENDIX H-6

BUFFER RAILCAR OPERATION AND MAINTENANCE INFORMATION

(SEE ENCLOSED APPENDIX H-6 DOCUMENT)

APPENDIX H-7
AAR EEC SUBMITTAL
FOR BUFFER RAILCAR



EXPERIENCE ◆ INNOVATION ◆ SOLUTIONS

S-2043 CERTIFICATION: PRELIMINARY SIMULATIONS OF KASGRO BUFFER RAILCAR

REPORT P-17-023

for Kasgro Rail Corporation

Revised November 20, 2017

TTCI®
Transportation
Technology Center, Inc.

S-2043 CERTIFICATION: PRELIMINARY SIMULATIONS OF KASGRO BUFFER RAILCAR

P-17-023

for Kasgro Rail Corporation

Prepared by
Russell Walker
Shawn Trevithick

Transportation Technology Center, Inc.
A subsidiary of the Association of American Railroads
Pueblo, Colorado USA

Revised November 20, 2017

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EXECUTIVE SUMMARY

Kasgro Rail Corporation (Kasgro) contracted with Transportation Technology Center, Inc. (TTCI) to perform vehicle dynamics modeling of their buffer railcar design according to the Association of American Railroads (AAR) *Manual of Standards and Recommended Practices* (MSRP) Standard S-2043, (S-2043) "Performance Specification for Trains Used to Carry High-Level Radioactive Material (HLRM)."[1] Kasgro designed the buffer railcar as part of a project with AREVA Federal Services LLC (AFS). The United States Department of Energy contracted with AFS to design the ATLAS cask car and buffer railcars for transportation of high level radioactive material.

The buffer railcar met S-2043 criteria for all S-2043 regimes except the truck side L/V criterion in buff and draft curving. The cases that did not meet were 250,000 pound draft load cases when the car was coupled between two base cars, or when coupled between the Atlas Cask car and the Rail Escort Vehicle (REV) and traveling at 15 mph. The truck side L/V ratio for both of these cases was 0.51. The S-2043 criterion for truck side L/V ratio is 0.50 and the corresponding AAR Chapter 11 criterion is 0.60. [2]

The four-axle car was fitted with Swing Motion® trucks. The secondary suspension uses six D7 outer springs, six D7 inner springs, two 49427-1 outer side coils, and two 49427-2 inner side coils. Primary suspension pads connect the side frames to the axles and allow the truck to steer in curves. Four vertical hydraulic dampers control the motions of the railcar. Increased lateral secondary suspension clearance (0.75 inch) and increased clearance between the transom rocker plate and side frame (0.37 inch) improve performance in the hunting analysis regime. The car is 66 feet 4 5/8 inches over pulling faces and has a truck center spacing of 44 feet 6 inches. The side bearings are long travel constant contact with a nominal preload of 8,000 pounds. The car was designed to use the AAR-1B narrow flange wheel profile.

The following three tables summarize simulation predictions for the buffer railcar in S-2043 preliminary analysis regimes. All of the cases shown in the tables that did not meet S-2043 criteria did meet the corresponding AAR Chapter 11 criteria.

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[1] Association of American Railroads. Last Revised: 2009. *Manual of Standards and Recommended Practices*. Section C, Car Construction Fundamentals and Details. Standard S-2043 "Performance Specification for Trains Used to Carry High-level Radioactive Material." Washington, DC.

[2] Association of American Railroads. 2011. *Manual of Standards and Recommended Practices*. Section C- Part II, Design, Fabrication, and Construction of Freight Cars, Standard M-1001, Chapter 11 "Service-worthiness Tests and Analyses for New Freight Cars." Washington, DC.

Summary Table (1/3)

Description	**S-2043 Paragraph**	**Subsection**	**Meets**	**Does Not Meet**	**Worst Example that does not Meet**
Truck Twist Equalization	4.2.1		X		
Carbody Twist Equalization	4.2.2		X		
Static Curve Stability	4.2.3	Base Car	X		
		Like Car	X		
		Long Car	X		
		Cask Car	X		
		Long-Short Car Combination	X		
Curve Negotiation	4.2.4	Uncoupled 125-foot radius curve	X		
		Coupled 250-foot radius curve	X		
		No. 7 crossover	X		
Twist and Roll	4.3.9.6	39-foot inputs	X		
		44-ft 6-in	X		
Pitch and Bounce	4.3.9.7	39-foot inputs	X		
		44-ft 6-in inputs	X		
Yaw and Sway	4.3.9.8	39-foot inputs	X		
		44-ft 6-in inputs	X		
Dynamic Curving	4.3.9.9	39-foot inputs	X		
		44-ft 6-in inputs	X		
Single Bump	4.3.10.1		X		
Curving with Single Rail Perturbation	4.3.10.2	1-inch bump	X		
		2-inch bump	X		
		3-inch bump	X		
		1-inch dip	X		
		2-inch dip	X		
		3-inch dip	X		
Hunting	4.3.11.3		X		
Constant Curving	4.3.11.4		X		

Summary Table (2/3)

Description	S-2043 Paragraph	Subsection	Meets	Does Not Meet	Worst Example that Does not Meet
Curving with Various Lubrication Conditions	4.3.11.5	Case 1 New	X		
		Case 2 New	X		
		Case 3 New	X		
		Case 4 New	X		
		Case 1 Worn	X		
		Case 2 Worn	X		
		Case 3 Worn	X		
		Case 4 Worn	X		
Limiting Spiral Negotiation	4.3.11.6	Entry A-End	X		
		Exit A-End	X		
		Entry B-End	X		
		Exit B-End	X		
Turnouts and Crossovers	4.3.11.7	RH Turnout	X		
		LH Turnout	X		
		Crossover	X		
Ride Quality	4.3.12	Class 2	X		
		Class 3	X		
		Class 4	X		
		Class 5	X		
		Class 6	X		
Buff and Draft Curving	4.3.13	Base-Buff	X		
		Long-Buff	X		
		Like-Buff	X		
		Cask Car-Buff	X		
		Cask Car-REV Buff	X		
		4 Axle Loco-Cask Car Buff	X		
		6 Axle Loco-Cask Car Buff	X		
		Base-Draft		X	Truck Side L/V 0.51, Limit=0.50
		Long-Draft	X		
		Like-Draft	X		
		Cask Car-Draft	X		
		Cask Car-REV Draft		X	Truck Side L/V 0.51, Limit=0.50
		4 Axle Loco-Cask Car Buff	X		
		6 Axle Loco-Cask Car Buff	X		
Braking Effects on Steering	4.3.1		X		

Summary Table (3/3)

Description	**S-2043 Paragraph**	**Subsection**	**Meets**	**Does Not Meet**	**Worst Example that Does Not Meet**
Worn Component Simulations	4.3.15				
Constant Contact Side Bearings	4.3.15	Constant Curving	X		
		Dynamic Curving	X		
		Hunting	X		
		Twist and Roll	X		
Center Plates	4.3.15	Constant Curving	X		
		Dynamic Curving	X		
		Hunting	X		
Primary Pad	4.3.15	Constant Curving – Soft	X		
		Dynamic Curving – Soft	X		
		Hunting – Soft	X		
		Constant Curving – Stiff	X		
		Dynamic Curving – Stiff	X		
		Hunting – Stiff	X		
Friction Wedges	4.3.15	Dynamic Curving	X		
		Pitch and Bounce	X		
		Twist and Roll	X		
Broken Springs	4.3.15	Dynamic Curving	X		
		Pitch and Bounce	X		
		Twist and Roll	X		
Vertical Damper	4.3.15	Dynamic Curving	X		
		Pitch and Bounce	X		
		Twist and Roll	X		

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1.0 INTRODUCTION

Kasgro Rail Corporation (Kasgro) contracted with Transportation Technology Center, Inc. (TTCI) to perform vehicle dynamics modeling of their buffer railcar design according to the Association of American Railroads (AAR) *Manual of Standards and Recommended Practices* (MSRP) Standard S-2043, "Performance Specification for Trains Used to Carry High-Level Radioactive Material (HLRM)." Kasgro designed the buffer railcar as part of a project with AREVA Federal Services LLC (AFS). The United States Department of Energy contracted with AFS to design the ATLAS cask car and buffer railcars for transportation of HLRM.

2.0 OBJECTIVE

The objective of this work is to estimate the performance of the buffer railcar in analysis regimes specified in Standard S-2043.

3.0 PROCEDURES

3.1 Car Description

Figure 1 shows an image of the buffer railcar. Figure 2 shows a wireframe model of the NUCARS®[3] system file.

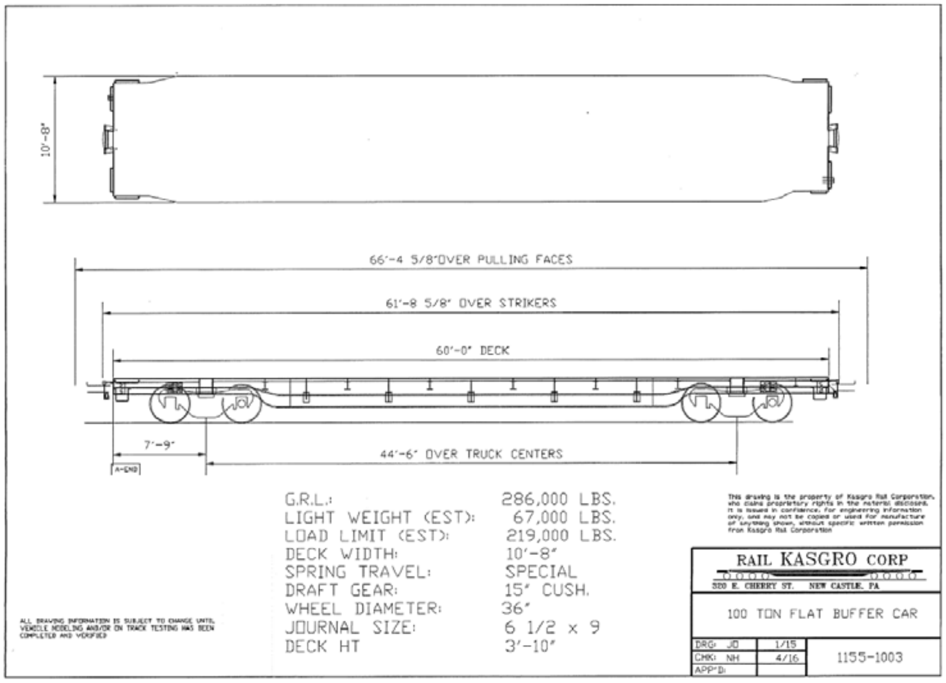

Figure 1. Buffer Railcar

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[3] NUCARS® is a registered trademark of Transportation Technology Center, Inc.

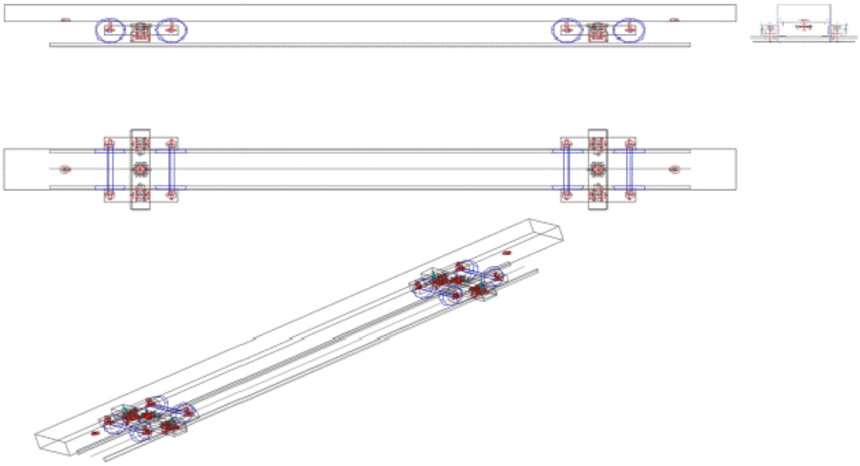

Figure 2. Top, Side, End, and ISO Views of the Wireframe Buffer Railcar Model

Table 1 shows the geometric properties of the railcar. Initial modeling showed that the empty buffer railcar (at a gross weight of 67,000 pounds) had high truck side L/V ratios in the buff and draft curving regime. To alleviate this, additional weight was added in the model. The model met buff and draft curving requirements at a gross rail load of 263,000 pounds. This required a ballast weight of 196,000 pounds, which would be permanently added to the railcar as steel plates, see Figure 3. Table 2 shows the mass properties of the buffer car. The empty car numbers are based on the data Kasgro provided for the carbody from the ANSYS® structural analysis model. They reflect an additional 3,000 pounds of weight and translation of the moments of inertia from their original location to the carbody center of gravity.

Table 1. Geometric Parameters

Parameter	Dimensions
Length over Pulling Faces (in Draft)	796.625 inches
Truck Center Spacing	534 inches
Axle Spacing	72 inches
Coupler Length (Pin to coupling line)	43 inches
Cushion Unit Travel	15 inches

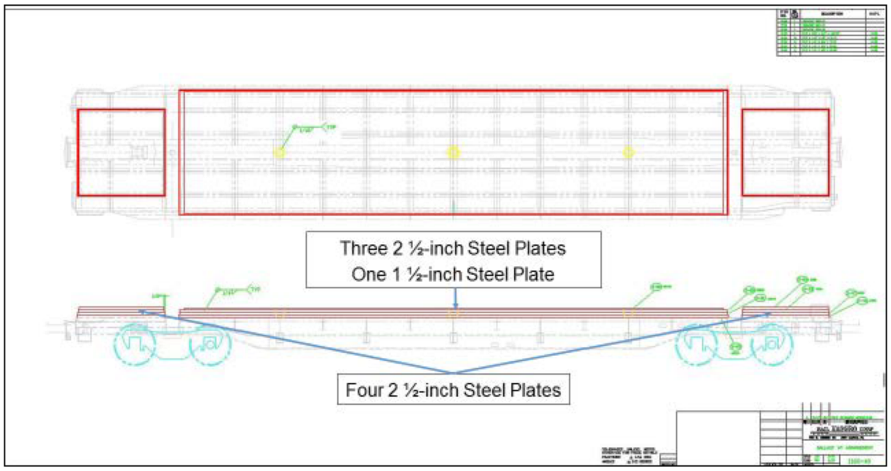

Figure 3. Drawing Showing the Type and Placement of Load Permanently Attached to the Car Deck

Table 2. Mass Parameters

Parameter	Value for Empty Car	Value for the Ballasted Car
Longitudinal CG offset	0 inch	0 inch
Lateral CG offset	0 inch	0 inch
Vertical CG from top of rail	33.28 inches	44.79 inches
Carbody Weight	45,088 pounds	241,001 pounds
Mass	116.78 lb-s^2/in	624.21 lb-s^2/in
Ixx (about the CG)	109,186 lb-s^2/in	666,491 lb-s^2/in
Iyy (about the CG)	4,806,665 lb-s^2/in	24,030,830 lb-s^2/in
Izz (about the CG)	4,895,437 lb-s^2/in	24,632,397 lb-s^2/in

The car is symmetrical. Simulations of the car were done in one orientation only.

The carbody and ballast load were modeled as one single body because the load is permanently attached to the car. The first mode of torsion, vertical, and lateral bending are modeled on the carbody. Bending properties were provided by Kasgro from finite element analysis (FEA) of the empty car body with known loads applied. FEA-predicted displacements were matched in NUCARS® using the same loads and restraints by adjusting the flexible body input parameters. In practice, the stiffness of the ballast load may affect the stiffness of the car. Care should be taken during single car tests to check this effect.

3.2 Truck Description

Kasgro plans to use Amsted 100-ton Swing Motion® trucks equipped with hydraulic vertical dampers in the buffer railcar. The truck model, including the geometry, mass properties, and pad stiffness values, is based on the model TTCI created of the Kasgro M290 12-axle HLRM railcar. The 12-axle railcar model predictions were compared to test results to develop confidence in the model inputs (TTCI proprietary report number P-10-044). This section contains a brief description of the trucks.

Table 3 shows the weight of the truck components in the NUCARS® model. The weights of smaller components like the rocker seats and the bearing adapters are not included in the model individually, but are lumped together with the side frames, bolster, and transom.

Table 3. Weights of Truck Components.

Truck Component	Modeled Weight
Two side frames	2,831 pounds
Bolster	1,750 pounds
Transom	539 pounds
Total Truck Weight including hardware and springs	5,120 pounds

Except for the transom, all of the bodies that make up the truck are modeled as rigid. The first torsional mode along the y-axis is modeled for the transom in order to more correctly predict the truck twist equalization performance.

Table 4 shows the truck configuration modeled.

Table 4. Truck Configuration

Part	Description
Secondary Suspension	Six D7 Outer Coils, Six D7 Inner Coils, Two 49427-1, Two 49427-2
Primary suspension	Adapter Plus Pads, ASF part number 10522A
Side bearings	Miner TCC-III 80LT
Friction wedge	Amsted part number 1-9249
Bearings and adapters	K class 61/2x9 bearings with 6 1/2x9 special adapter ASF part number 10532A
Center bowl liner	Metal horizontal liner
Vertical Hydraulic Dampers	Koni 04 Series using damping rate shown in Figure 4

Table 5 shows the primary suspension characteristics as modeled for the buffer railcar.

Table 5. Primary Suspension

Part	Description
Longitudinal Stiffness	22,500 lbs./in.
Longitudinal Clearance	0.625 inch
Lateral Stiffness	48,000 lbs./in.
Lateral Clearance	0.25 inch
Vertical Stiffness	500,000 lbs./in.

The friction wedges used in this truck have a 45-degree wedge angle, a composition vertical face, and a steel slope face.

The trucks are designed to use vertical hydraulic dampers. The damping characteristics used for the simulations are for a Koni 04 series damper using the damping rate shown in Figure 4.

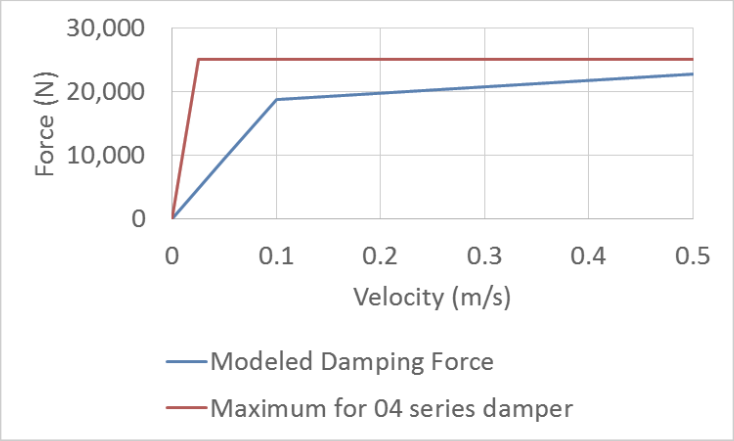

Figure 4. Damping Rate Modeled for the Buffer Railcar

3.3 Track Geometry Input Data

The regimes of twist and roll, pitch and bounce, yaw and sway, and dynamic curving were modeled using measured track geometry of the actual test zones at the Transportation Technology Center (TTC) in Pueblo, Colorado. TTCI’s experience has shown that simulations using measured track geometry as inputs generally produce more realistic results than simulations using mathematically generated inputs. In this section, measured track geometry inputs are compared to the track geometry standards listed in AAR MSRP Section C-II, Standard M-1001 Chapter 11, paragraph 11.5.2.5 for twist and roll, pitch and bounce, yaw and sway, and dynamic curving. Each relevant geometry measurement is shown on the plot and the tolerances specified in Chapter 11 table 11.2 are shown in red.

The wavelength of the inputs for each of the actual test zones at TTC is 39 feet. The inputs were scaled to perform additional simulations with wavelength equal to the buffer car’s truck center spacing of 44.5 feet.

The twist and roll regime consists of a series of 10 3/4-inch vertical track deviations offset on each rail to input roll motions to the car. Figure 5 shows the cross level and gage measurements from the inputs used for the twist and roll simulations. The cross level and gage measurements are within tolerances.

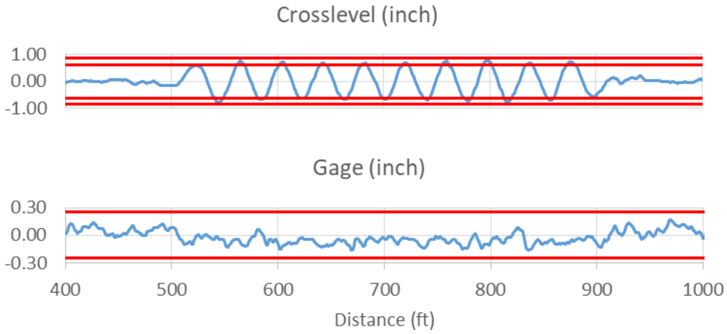

Figure 5. Twist and Roll Track Geometry Measurements and Tolerances

The pitch and bounce regime consists of a series of 10 3/4-inch vertical track deviations on each rail to input vertical motions to the car. Figure 6 shows profile, cross level and gage measurements from the inputs used for pitch and bounce simulations. One-half inch was added to the profile measurement so the bottom of the perturbations were about zero and the peak amplitude tolerance of 0.75-inch ±0.125 inch could be easily marked on the plot. The actual shape of the profile of the track at the ends of the zone is somewhat distorted by the measurement system filters. The cross level is slightly higher than the tolerance about 50 feet beyond the end of the zone, but is otherwise within tolerance. The gage is within tolerance.

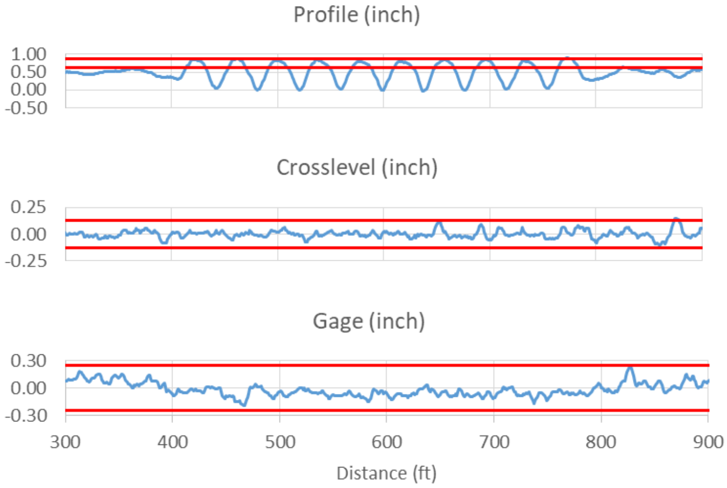

Figure 6. Pitch and Bounce Track Geometry Measurements and Tolerances

The dynamic curve section is on a 10-degree curve with 4 inches superelevation. The dynamic curving regime consists of a series of 0.5-inch vertical track deviations offset on each rail to input roll motions to the car. At the same time, the gage of the track changes from 56.5 inches to 57.5 inches to input lateral motions to the car. Figure 7 shows the gage, cross level, and superelevation measurements and tolerances for the inputs used for dynamic curving simulations. The gage and cross level are within the tolerance. The superelevation is consistently higher than the tolerance through most of the test zone. The effect of this will be to make the simulation regime more severe for the lower speed condition.

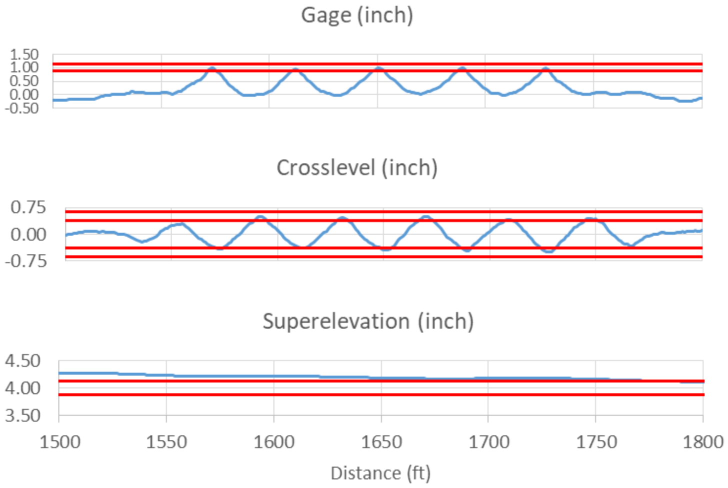

Figure 7. Dynamic Curving Track Geometry Measurements and Tolerances

The yaw and sway regime consists of a series of 1.25-inch lateral track deviations on a section with 1-inch wide gage to input lateral and yaw motions to the car. Figure 8 shows the gage, cross level, and alignment measurements and tolerance for the inputs used for yaw and sway simulations. The gage varies more than the tolerance allows, dropping below 0.875 and rising higher than 1.125 in a few locations. The cross level is within tolerance. The alignment has one perturbation at the beginning of the zone with amplitude slightly higher than the tolerance.

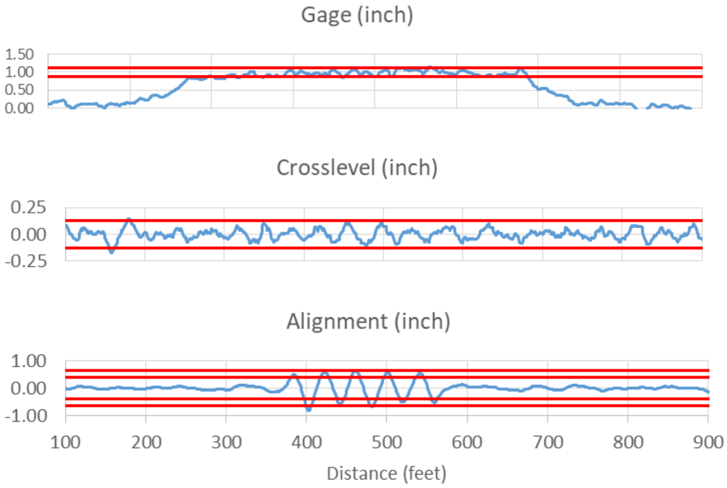

Figure 8. Yaw and Sway Track Geometry Measurements and Tolerances

4.0 NONSTRUCTURAL STATIC ANALYSIS RESULTS

Nonstructural static analysis simulations were conducted according to Paragraph 4.2 of Standard S-2043. The nonstructural static analysis regimes are designed to demonstrate truck and car performance under static conditions of track twist or curve negotiation. In each of the following sections the regime is briefly described and data relevant to the criterion is presented.

4.1 Truck Twist Equalization (S-2043, Paragraph 4.2.1)

S-2043 requires the truck twist equalization regime to verify the design has adequate truck load equalization performance. Truck load equalization performance is the ability of a truck to distribute vertical load to all the wheels in a truck when negotiating a short wavelength track twist deviation. The analysis is performed by simulating raising and lowering one wheel in a truck from 0 to 3 inches in 0.5-inch increments. This analysis was performed for each wheel in the car. The requirement is that all wheel loads must remain above 60 percent of the nominal static wheel load when displaced 2 inches, and above 40 percent of the nominal static wheel load when displaced 3 inches.

Figure 9 shows a plot of the simulation predictions. The worst-case predictions are 86.6 percent wheel load when a wheel is displaced 2 inches, and 81.1 percent wheel load when a wheel is displaced 3 inches. The simulation predictions meet the requirements of the truck twist equalization regime.

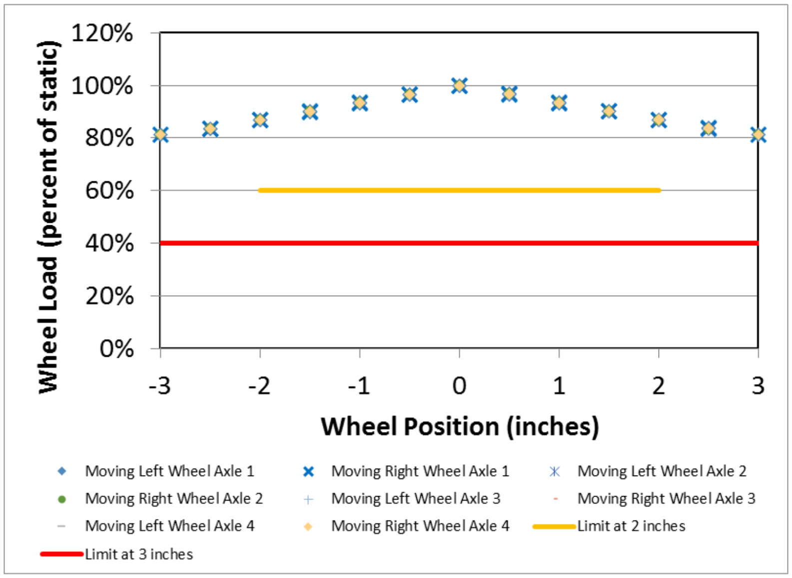

Figure 9 Truck Twist Equalization Simulation Predictions

4.2 Carbody Twist Equalization (S-2043 Paragraph 4.2.2)

S-2043 requires the carbody twist equalization regime to simulate wheel unloading during carbody twist. Carbody twist occurs when the car is negotiating a spiral or a long wavelength track-twist deviation. The analysis is performed by simulating the raising and lowering of the two wheels of the truck at one end of the car from 0 to 3 inches in 0.5-inch increments. This analysis was performed for each corner of the car. The requirement is that all wheel loads must remain above 60 percent of the nominal static wheel load when displaced 2 inches and above 40 percent of the nominal static wheel load when displaced 3 inches.

Figure 10 shows a plot of carbody twist performance. The worst-case simulation predictions are 79 percent minimum vertical wheel load when displaced 2 inches, and 76 percent minimum vertical wheel load when displaced 3 inches. The simulation predictions meet the requirements of the carbody twist regime.

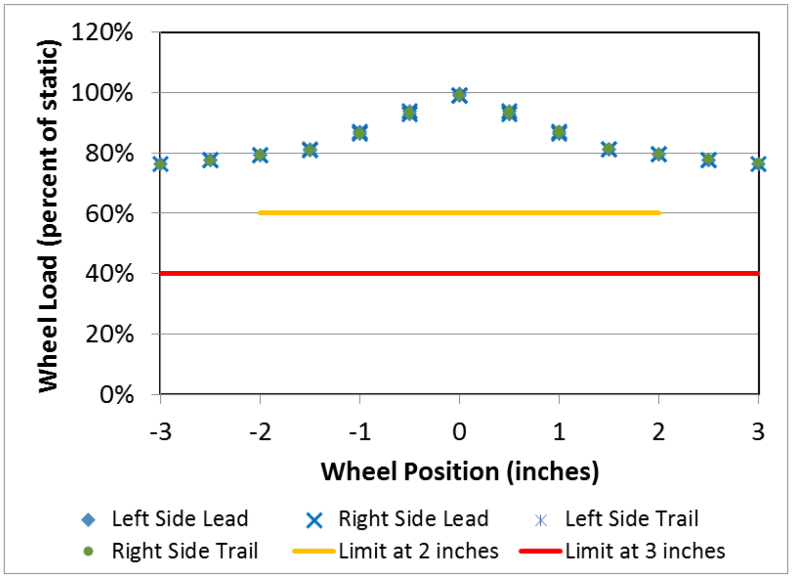

Figure 10. Carbody Twist Simulation Predictions

4.3 Static Curve Stability (S-2043, Paragraph 4.2.3)

The static curve stability analysis regime in S-2043 refers to the curve stability test in AAR Chapter 11, Paragraph 11.3.3.3. The curve stability regime requires the car be subjected to a 200,000-pound buff load and a 200,000-pound draft load while placed on a curve of no less than 10 degrees. The curve may have no more than 0.5 inch superelevation. The test car will be coupled to a base car or a like car (whichever is more severe) and a long car with 90-foot over strikers, 66-foot truck centers, 60-inch couplers, and conventional draft gear. The combination of the long car and base car is typically tested, and was included in the simulations. In addition, S-2043 requires that the analysis be performed with the car coupled to cars it will be coupled to in HLRM train operation. In this case, a cask car that is a span bolter design with length over pulling faces of 78 feet 1 1/4 inches, span bolster pivot spacing of 38 feet, span bolster spacing of 38 feet 6 inches, and a coupler length of 43 inches. The requirement is that no wheel lift and no suspension separation may occur for this analysis.

Figure 11 shows simulation predictions of minimum vertical wheel load for the five cases of coupled cars analyzed. No wheel lift occurred. The simulation predictions were checked for suspension separation at the centerplate, side bearings, coil springs, transom-to-sideframe connection, and primary pads by verifying that all of those connections were carrying vertical load. No suspension separation was found. The simulation predictions meet the requirements of the curve stability regime.

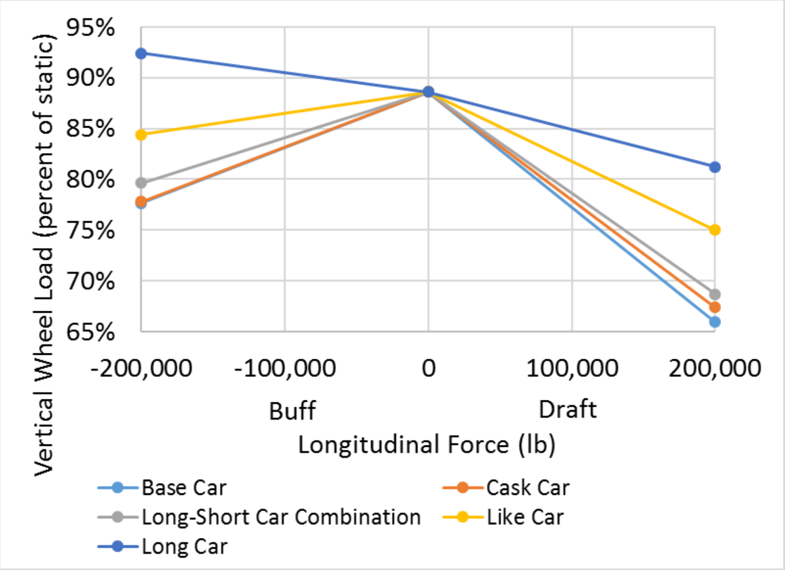

Figure 11. Simulation Predictions of Minimum Vertical Wheel Load in the Static Curve Stability Regime

4.4 Curve Negotiation (S-2043, Paragraph 4.2.4)

Curve negotiation calculations were performed with NUCARS® simulations. The buffer railcar has a truck center spacing of 44 feet 6 inches and a length over pulling faces of couplers of 66 feet 4 5/8 inches. For these dimensions, the AAR MSRP Section C-II, Standard M-1001, Chapter 2, Paragraph 2.1.4.2[4] requires the car be designed to negotiate a 275-foot radius curve when coupled and a 150-foot radius curve when uncoupled.

TTCI simulated the uncoupled car negotiating a 150-foot radius curve using NUCARS®. No wheel lift occurred. The simulations predictions were checked for suspension separation at the centerplate, side bearings, the coil springs, the transom-to-sideframe connection, and the primary pads by verifying that all of those connections were carrying vertical load. No suspension separation was found.

TTCI simulated the car negotiating a 275-foot radius curve while coupled to a base car, a like car, and a cask car that the buffer railcar may be coupled to in HLRM service. No wheel lift occurred. The simulations predictions were checked for suspension separation at the centerplate, side bearings, the coil springs, the transom-to-sideframe connection, and the primary pads by verifying that all of those connections were carrying vertical load. No suspension separation was found.

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[4] Association of American Railroads. 2011. *Manual of Standards of Recommended Practices*. Section C-II Design, Fabrication, and Construction of Freight Cars, Standard M-1001, Chapter 2, General Data, Paragraph 2.1.4.2 "Horizontal Curve and Tangent." Washington, DC.

TTCI simulated the car negotiating a No. 7 crossover on 13-foot centers while coupled to a base car, a like car, and a cask car that the buffer railcar may be coupled to in HLRM service. No wheel lift occurred. The simulations predictions were checked for suspension separation at the centerplate, side bearings, coil springs, transom-to-sideframe connection, and the primary pads by verifying that all of those connections were carrying vertical load. No suspension separation was found.

The simulation predictions meet the requirements of the curve negotiation regime.

5.0 DYNAMIC ANALYSIS RESULTS

Dynamic analysis simulations were conducted according to Paragraph 4.3 of S-2043.

In this section, each analysis regime is briefly described, followed by the simulation predictions for that analysis regime. Tables show predicted values for each regime compared to the criteria presented in Table 4.1 of AAR Standard S-2043. Predicted values that do not meet the criteria are shown in red bold font. Predicted values that are at the criteria level are shown in black bold font. Plots showing data trends are provided. Where criteria differ between S-2043 and AAR MSRP Section C-II, Standard M-1001, Chapter 11, “Service-worthiness Tests and Analyses for New Freight Cars” (AAR Chapter 11), criteria for both standards are shown on the plots.

Lateral carbody acceleration standard deviation is calculated over a 1,000-foot section. In many cases, the simulation regime is less than 1,000 feet. In those cases, that metric and criterion are not applicable and are designated with the term “NA.”

Simulations were performed using a coefficient of friction of 0.5 between the wheel and rail. AAR-1B narrow flange wheel profiles were used for all cases except those where specific worn profiles were called for in the specification.

Measured rail profiles from the actual test zones at Transportation Technology Center, Pueblo, CO were used where applicable. Where no actual test zone existed, new 136-pound rail with 10-inch crown radius was used.

Simulation predictions were made using inputs created with measured track geometry. TTCI’s experience has shown that simulations with measured track geometry produce better predictions of car performance than that obtained with analytic track inputs created via mathematical functions. Because the measured track geometry inputs contain short wavelengths that cause spurious peaks in the data, the 50-millisecond and 3-foot analysis windows described in AAR Chapter 11 and S-2043 are used when analyzing data to produce the most realistic results.

5.1 Twist and Roll (S-2043, Paragraph 4.3.9.6)

Simulations of the twist and roll regime were conducted according to Paragraph 4.3.9.6 of S-2043. The twist and roll regime consists of a series of 3/4-inch vertical track deviations offset on each rail to input roll motions to the car. Simulations of 39-foot and 44-foot 6-inch wavelengths were performed.

Table 6 shows the worst-case simulation predictions for twist and roll. Figure 12 shows the maximum peak-to-peak roll angles plotted against speed to show the trend in performance. Simulation predictions meet S-2043 criteria for twist and roll.

Table 6. Twist and Roll Simulation Predictions

Criterion	Limiting Value	39-foot inputs	44.5-foot inputs
Maximum carbody roll angle (degree)	4.0	1.6	1.8
Maximum wheel L/V	0.80	0.11	0.11
Maximum truck side L/V	0.50	0.09	0.09
Minimum vertical wheel load (%)	25	69	70
Peak-to-peak carbody lateral acceleration (g)	1.30	0.27	0.26
Maximum carbody lateral acceleration (g)	0.75	0.15	0.13
Lateral carbody acceleration standard deviation (g)	0.13	NA	NA
Maximum carbody vertical acceleration (g)	0.90	0.16	0.16
Maximum vertical suspension deflection (%)	95	40	40

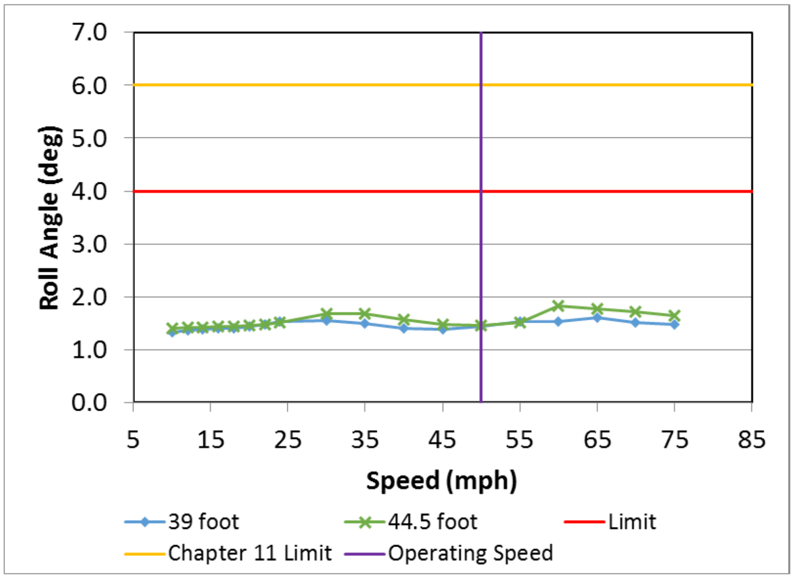

Figure 12. Predicted Maximum Peak-to-Peak Roll Angles in the Twist and Roll Regime

5.2 Pitch and Bounce (S-2043, Paragraph 4.3.9.7)

Simulations of the pitch and bounce regime were conducted according to Paragraph 4.3.9.7 of S-2043. The pitch and bounce regime consists of a series of 3/4-inch vertical track deviations in parallel on each rail to input vertical motions to the car. Simulations of 39-foot and 44-foot 6-inch wavelengths were performed.

Table 7 shows the worst-case simulation predictions for pitch and bounce. Figure 13 shows the maximum vertical suspension deflection plotted against speed to show the trend in performance. Simulation predictions meet S-2043 criteria for pitch and bounce.

Table 7. Pitch and Bounce Simulation Predictions

Criterion	Limiting Value	39-foot inputs A-End	44.5-foot inputs A-End
Maximum carbody roll angle (degree)	4.0	0.2	0.2
Maximum wheel L/V	0.80	0.06	0.08
Maximum truck side L/V	0.50	0.05	0.06
Minimum vertical wheel load (%)	25	60	65
Peak-to-peak carbody lateral acceleration (g)	1.30	0.12	0.19
Maximum carbody lateral acceleration (g)	0.75	0.06	0.12
Lateral carbody acceleration standard deviation (g)	0.13	NA	NA
Maximum carbody vertical acceleration (g)	0.90	0.65	0.47
Maximum vertical suspension deflection (%)	95	74	61

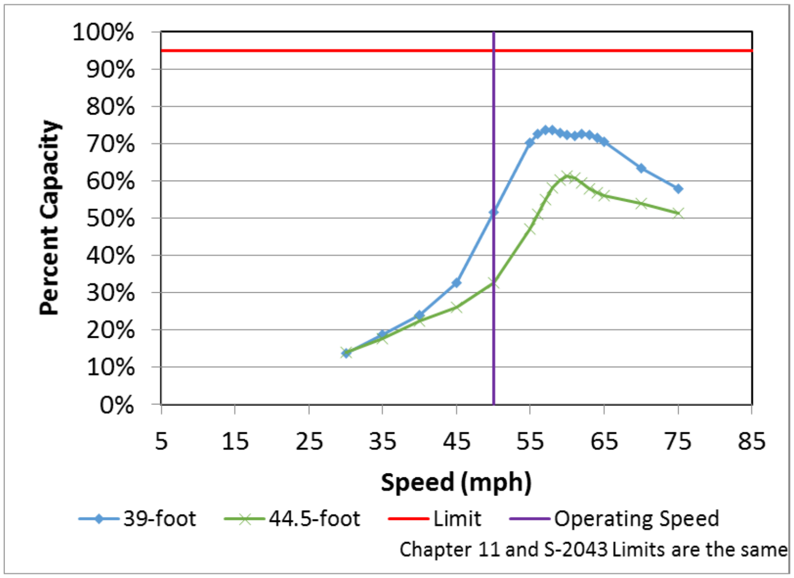

Figure 13. Predicted Maximum Vertical Suspension Deflections in the Pitch and Bounce Regime

5.3 Yaw and Sway (S-2043, Paragraph 4.3.9.8)

Simulations of the yaw and sway regime were conducted according to Paragraph 4.3.9.8 of S-2043. The yaw and sway regime consists of a series of 1.25-inch lateral track deviations on a section with 1-inch wide gage to input lateral and yaw motions to the car. Simulations of 39-foot and 44-foot 6-inch wavelengths were performed.

Table 8 shows the worst-case simulation predictions for yaw and sway. Figure 14 shows the maximum peak-to-peak lateral acceleration plotted against speed to show the trend in performance. Simulation predictions meet S-2043 criteria for yaw and sway

Table 8. Yaw and Sway Simulation Predictions

Criterion	Limiting Value	39-foot Inputs	44.5-foot Inputs
Maximum carbody roll angle (degree)	4.0	1.3	2.0
Maximum wheel L/V	0.80	0.62	0.51
Maximum truck side L/V	0.50	0.30	0.24
Minimum vertical wheel load (%)	25	56	51
Peak-to-peak carbody lateral acceleration (g)	1.30	1.16	1.25
Maximum carbody lateral acceleration (g)	0.75	0.59	0.65
Lateral carbody acceleration standard deviation (g)	0.13	NA	NA
Maximum carbody vertical acceleration (g)	0.90	0.18	0.16
Maximum vertical suspension deflection (%)	95	37	42

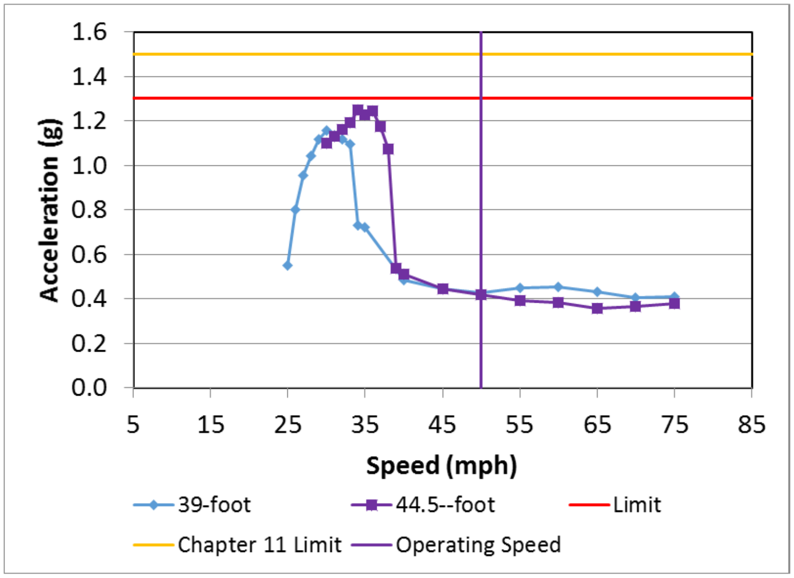

Figure 14. Predicted Maximum Peak-to-Peak Lateral Acceleration for the Yaw and Sway Regime

5.4 Dynamic Curving (S-2043, Paragraph 4.3.9.9)

Simulations of the dynamic curving regime were conducted according to Paragraph 4.3.9.9 of S-2043. The dynamic curve section is on a 10-degree curve with 4 inches superelevation. The dynamic curving regime consists of a series of 0.5-inch vertical track deviations offset on each rail to input roll motions to the car. At the same time, the gage of the track changes from 56.5 inches to 57.5 inches to input lateral motions to the car. Simulations of 39-foot and 44-foot 6-inch wavelengths were performed. Speeds ranging from 3 inches underbalance to 3 inches overbalance are simulated.

Table 9 shows the worst-case simulation predictions for dynamic curving. Figure 15 shows the maximum wheel L/V ratios plotted against speed to show the trend in performance. Simulation predictions meet S-2043 criteria for dynamic curving.

Table 9. Dynamic Curving Simulation Predictions

Criterion	Limiting Value	CW 39-foot	CCW 39-foot	CW 44.5-foot	CCW 44.5-foot
Maximum carbody roll angle (degree)	4.0	0.9	1.0	1.1	1.0
Maximum wheel L/V	0.80	0.53	0.50	0.50	0.47
Maximum truck side L/V	0.50	0.24	0.25	0.22	0.23
Minimum vertical wheel load (%)	25	62	62	64	63
Peak-to-peak carbody lateral acceleration (g)	1.30	0.40	0.41	0.32	0.27
Maximum carbody lateral acceleration (g)	0.75	0.27	0.28	0.23	0.19
Lateral carbody acceleration standard deviation (g)	0.13	NA	NA	NA	NA
Maximum carbody vertical acceleration (g)	0.90	0.09	0.09	0.10	0.08
Maximum vertical suspension deflection (%)	95	31	33	32	28

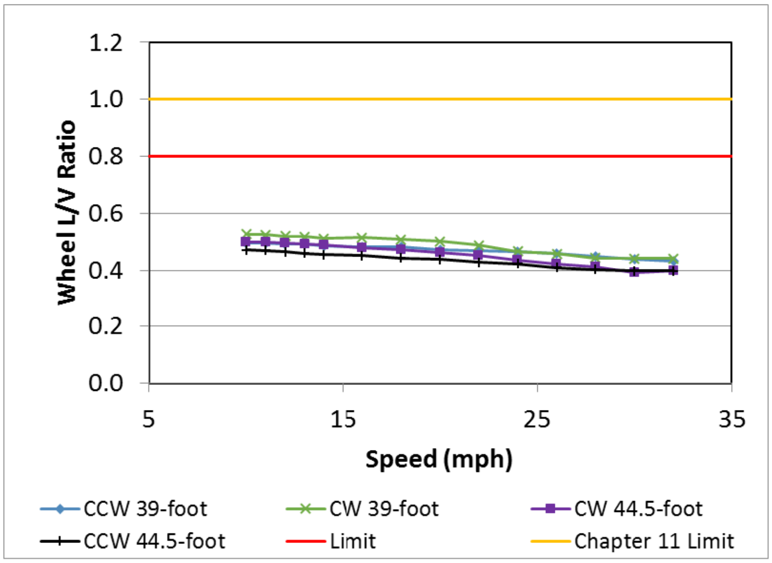

Figure 15. Predicted Maximum Wheel L/V Ratios in the Dynamic Curving Regime

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5.5 Single Bump (S-2043, Paragraph 4.3.10.1)

Simulations of the single-bump regime were conducted according to Paragraph 4.3.10.1 of S-2043. The single-bump regime consists of a flat-topped vertical profile deviation with 1-inch amplitude. The initial change is 1 inch in 7 feet, followed by a steady elevation of 1 inch for 20 feet, and finishing with a ramp back to normal elevation over 7 feet. No standard test zone exists for the single-bump regime, but measured track geometry from a test performed in 2009 was used as input for the simulation.

Table 10 shows the worst-case simulation predictions for the single bump. Figure 16 shows the maximum suspension deflection plotted against speed to show the trend in performance. Simulation predictions meet S-2043 criteria for the single bump.

Table 10. Single Bump Simulation Predictions

Criterion	Limiting Value	Single Bump
Maximum carbody roll angle (degree)	4.0	0.0
Maximum wheel L/V	0.80	0.02
Maximum truck side L/V	0.50	0.01
Minimum vertical wheel load (%)	25	94
Peak-to-peak carbody lateral acceleration (g)	1.30	0.02
Maximum carbody lateral acceleration (g)	0.75	0.01
Lateral carbody acceleration standard deviation (g)	0.13	NA
Maximum carbody vertical acceleration (g)	0.90	0.33
Maximum vertical suspension deflection (%)	95	31

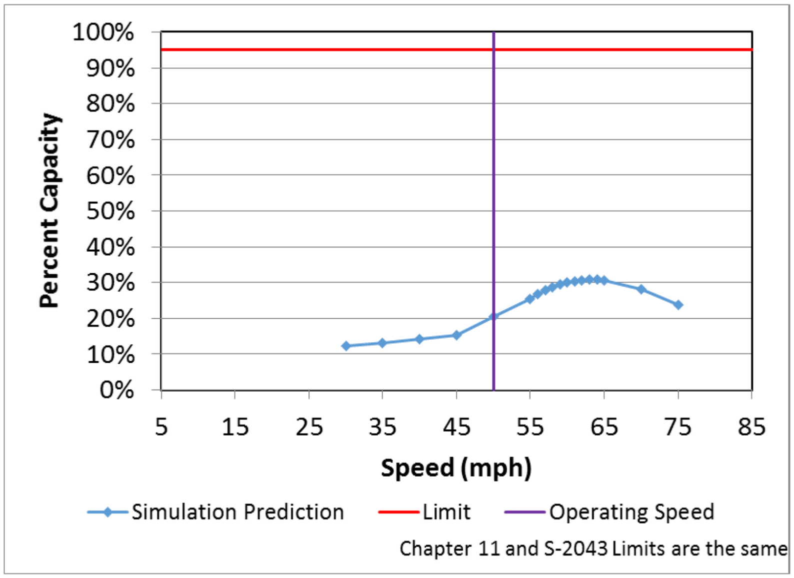

Figure 16. Simulation Predictions of Maximum Percent Spring Nest Capacity for the Single Bump Regime

5.6 Curving with Single Rail Perturbation (S-2043, Paragraph 4.3.10.2)

Simulations of the curving with single rail perturbation regime were conducted according to Paragraph 4.3.10.2 of S-2043. The curving with single rail perturbation regime is located on a 12-degree curve with no superelevation. Simulations were made for 1-, 2-, and 3-inch outside rail dips and for 1-, 2-, and 3-inch inside rail bumps. The perturbation is a flat-topped ramp with an elevation change over 6 feet, a steady elevation over 12 feet, ramping to the original elevation over 6 feet. The inputs for this simulation regime were mathematically generated because no actual test zone exists. Tests of a 2-inch bump and dip were performed in 2009, but inputs from measurements of those perturbations were less severe than the analytic inputs and were not used for the simulations reported here. S-2043 prescribes that the simulations be made in 2-mph increments from 4 mph to 14 mph for the 1- and 2-inch amplitude perturbations. The maximum speed over the 3-inch perturbations shall be 10 mph.

Table 11 shows the worst-case simulation predictions for the curving with single bump regime. Figure 17 shows the maximum wheel L/V ratio plotted against speed to show the trend in performance. Table 12 and Figure 18 show the corresponding information for the curving with single dip simulations. Simulation predictions meet S-2043 criteria for the curving with single rail perturbation regime.

Table 11. Curving with Single Bump Simulation Predictions

Criterion	Limiting Value	1-inch	2-inch	3-inch
Maximum carbody roll angle (degree)	4.0	0.7	1.7	2.6
Maximum wheel L/V	0.80	0.49	0.55	0.58
Maximum truck side L/V	0.50	0.28	0.29	0.31
Minimum vertical wheel load (%)	25	72	66	63
Peak-to-peak carbody lateral acceleration (g)	1.30	0.07	0.11	0.10
Maximum carbody lateral acceleration (g)	0.75	0.05	0.07	0.06
Lateral carbody acceleration standard deviation (g)	0.13	NA	NA	NA
Maximum carbody vertical acceleration (g)	0.90	0.07	0.10	0.10
Maximum vertical suspension deflection (%)	95	25	38	48

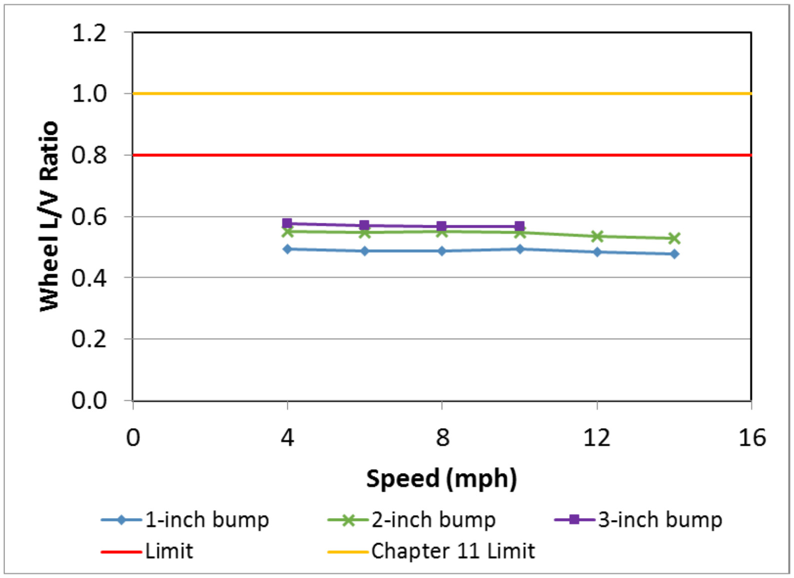

Figure 17. Predictions of Maximum Wheel L/V Ratios for the Curving with Single Bump Regime

Table 12. Curving with Single Dip Simulation Predictions

Criterion	Limiting Value	1-inch	2-inch	3-inch
Maximum carbody roll angle (degree)	4.0	0.7	1.7	2.6
Maximum wheel L/V	0.80	0.49	0.57	0.62
Maximum truck side L/V	0.50	0.28	0.29	0.31
Minimum vertical wheel load (%)	25	73	67	65
Peak-to-peak carbody lateral acceleration (g)	1.30	0.07	0.11	0.11
Maximum carbody lateral acceleration (g)	0.75	0.05	0.07	0.06
Lateral carbody acceleration standard deviation (g)	0.13	NA	NA	NA
Maximum carbody vertical acceleration (g)	0.90	0.07	0.11	0.11
Maximum vertical suspension deflection (%)	95	27	35	41

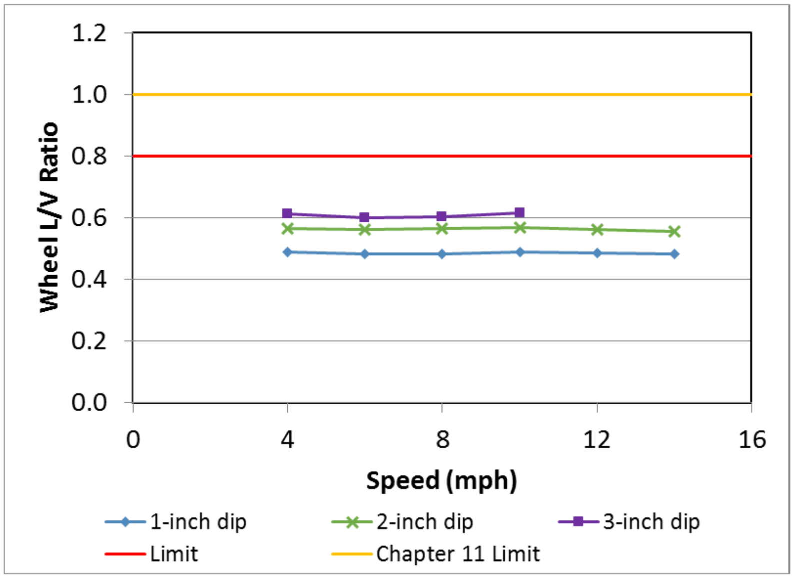

Figure 18. Predictions of Maximum Wheel L/V Ratios for the Curving with Single Dip Regime

5.7 Hunting (S-2043, Paragraph 4.3.11.3)

Simulations of the hunting regime were conducted according to Paragraph 4.3.11.3 of S-2043. The hunting regime was modeled using a 7,900-foot section of measured track geometry from the Railroad Test Track (RTT) at TTC. The inputs include 5,500 feet of tangent track followed by a 2,400-foot section with a spiral and a portion of a 50-minute curve with 6 inches of superelevation. These simulations were performed with KR wheel profiles as specified by AAR Chapter 11, Paragraph 11.7.2.

Table 13 shows the worst-case simulation predictions for the hunting regime. Figure 19 shows the maximum lateral carbody acceleration standard deviation over 1,000 feet plotted against speed to show the trend in performance. Simulation predictions meet S-2043 criteria for the hunting regime.

Table 13. Hunting Simulation Predictions

Criterion	Limiting Value	Simulation Predictions
Maximum carbody roll angle (degree)	4.0	0.4
Maximum wheel L/V	0.80	0.21
Maximum truck side L/V	0.50	0.19
Minimum vertical wheel load (%)	25	66
Peak-to-peak carbody lateral acceleration (g)	1.30	0.41
Maximum carbody lateral acceleration (g)	0.75	0.30
Lateral carbody acceleration standard deviation (g)	0.13	0.09
Maximum carbody vertical acceleration (g)	0.90	0.24
Maximum vertical suspension deflection (%)	95	31

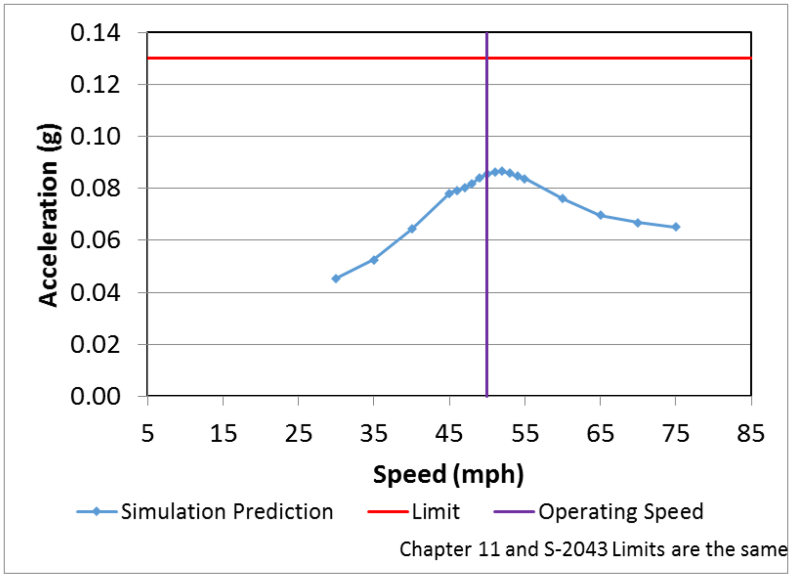

Figure 19. Predicted Maximum Carbody Lateral Acceleration for the Hunting Regime

5.8 Constant Curving (S-2043, Paragraph 4.3.11.4)

Simulations of the constant curving regime were conducted according to Paragraph 4.3.11.4 of S-2043. The constant curving test regime was modeled using measured track geometry from the 7.5-, 10-, and 12-degree curves of the Wheel-Rail Mechanism (WRM) loop at TTC.

Simulation predictions presented for constant curving include the 95th percentile wheel L/V ratio for the steady curve portion of the inputs. This criterion is not listed in Table 4.1 of the S-2043 design paragraph, but it is listed in Table 5.1 of the S-2043 single car test paragraph. The

95th percentile wheel L/V ratio is relevant to these simulations, because the simulations are performed with measured track geometry inputs rather than ideal track geometry.

Table 14 shows the worst-case simulation predictions for the constant curving regime. Figure 20 shows the 95th percentile wheel L/V ratio plotted against speed for the 12-degree curve to show the trend in performance. The simulation predictions meet S-2043 criteria.

Table 14. Constant Curving Simulation Predictions

Criterion	Limiting Value	CW	CCW
Maximum carbody roll angle (degree)	4.0	0.5	0.4
Maximum wheel L/V	0.80	0.52	0.50
95% Wheel L/V Ratio	0.60	0.40	0.44
Maximum truck side L/V	0.50	0.34	0.31
Minimum vertical wheel load (%)	25	69	68
Peak-to-peak carbody lateral acceleration (g)	1.30	0.21	0.24
Maximum carbody lateral acceleration (g)	0.75	0.15	0.16
Lateral carbody acceleration standard deviation (g)	0.13	0.04	0.04
Maximum carbody vertical acceleration (g)	0.90	0.15	0.14
Maximum vertical suspension deflection (%)	95	36	37

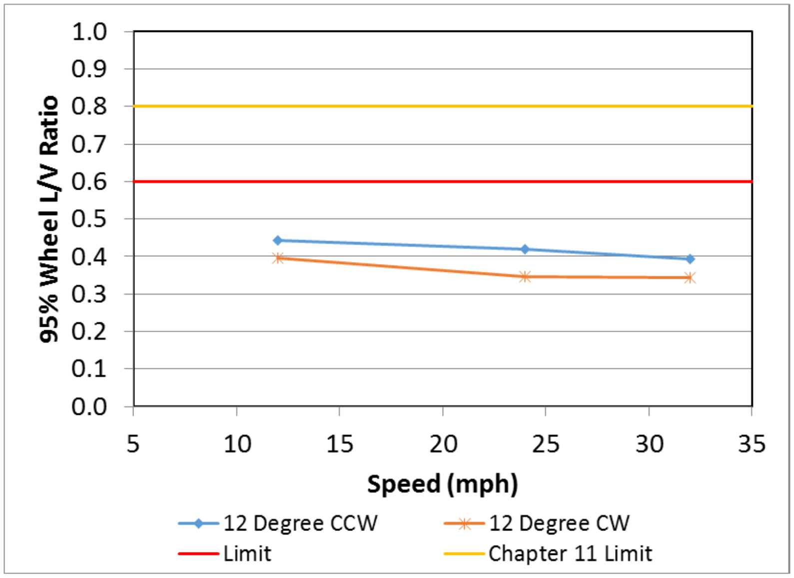

Figure 20. Predicted 95th Percentile Wheel L/V Ratio for the 12-degree Curve Regime

5.9 Curving with Various Lubrication Conditions (S-2043, Paragraph 4.3.11.5)

Simulation of curving with various lubrication conditions were performed according to S-2043, Paragraph 4.3.11.5. Constant curving simulations were repeated in a 10-degree curve with the coefficient of friction conditions shown in Table 15. Simulations were performed using a new wheel profile on a new rail profile and with a hollow wheel profile on a ground rail profile. Figure 21 shows the worn wheel and rail profiles used for the simulations. The right side is the high rail in this plot. The gap between the rail profile in red and the wheel profile in blue on the gage corner of the rail represents a distinctive two point contact condition. The lubrication and profile conditions are designed to show performance when the wheelset cannot provide normal steering forces. The metrics presented in this section were computed over the steady curve portion of the input, excluding the entry and exit spiral.

Table 15. Wheel/Rail Coefficients of Friction for the Curving with Various Lubrication Conditions Regime

Friction Coefficient	High Rail Crown	High Rail Gage Face	Low Rail Crown
Case 1	0.5	0.5	0.5
Case 2	0.5	0.2	0.5
Case 3	0.5	0.2	0.2
Case 4	0.2	0.2	0.5

Figure 21. Worn Wheel Profiles on the Ground Rail Profiles.
The wheelset is shifted to the high rail in the position it would be in a left hand curve.

Table 16 shows simulation predictions for the four friction cases with new wheel profiles. Table 17 shows simulation predictions for the four friction cases with hollow worn wheel profiles and ground rail profiles. Figure 22 shows a plot of maximum truck side L/V ratio versus speed for Case 2 friction with worn wheel profiles to show the trend in performance. Simulations predictions meet S-2043 criteria.

Table 16. Simulation Predictions for Curving with Rail Lubrication Cases 1 through 4 and New Wheels and Rails

Criterion	Limiting Value	Case 1 New	Case 2 New	Case 3 New	Case 4 New
Maximum carbody roll angle (degree)	4.0	0.5	0.5	0.5	0.5
Maximum wheel L/V	0.80	0.52	0.53	0.38	0.56
95% Wheel L/V Ratio	0.60	0.41	0.45	0.32	0.54
Maximum truck side L/V	0.50	0.28	0.30	0.24	0.45
Minimum vertical wheel load (%)	25	68	68	68	67
Peak-to-peak carbody lateral acceleration (g)	1.30	0.17	0.17	0.18	0.16
Maximum carbody lateral acceleration (g)	0.75	0.14	0.14	0.16	0.15
Lateral carbody acceleration standard deviation (g)	0.13	0.04	0.04	0.04	0.03
Maximum carbody vertical acceleration (g)	0.90	0.14	0.14	0.14	0.14
Maximum vertical suspension deflection (%)	95	35	35	35	35

Table 17. Simulation Predictions for Curving with Rail Lubrication Cases 1 through 4 and Hollow Worn Wheels and Ground Rails

Criterion	Limiting Value	Case 1 Worn	Case 2 Worn	Case 3 Worn	Case 4 Worn
Maximum carbody roll angle (degree)	4.0	0.5	0.5	0.5	0.5
Maximum wheel L/V	0.80	0.56	0.60	0.40	0.56
95% Wheel L/V Ratio	0.60	0.52	0.57	0.35	0.53
Maximum truck side L/V	0.50	0.46	0.49	0.23	0.48
Minimum vertical wheel load (%)	25	62	60	62	63
Peak-to-peak carbody lateral acceleration (g)	1.30	0.18	0.20	0.20	0.19
Maximum carbody lateral acceleration (g)	0.75	0.16	0.15	0.15	0.15
Lateral carbody acceleration standard deviation (g)	0.13	0.04	0.04	0.04	0.04
Maximum carbody vertical acceleration (g)	0.90	0.13	0.14	0.14	0.13
Maximum vertical suspension deflection (%)	95	35	35	35	35

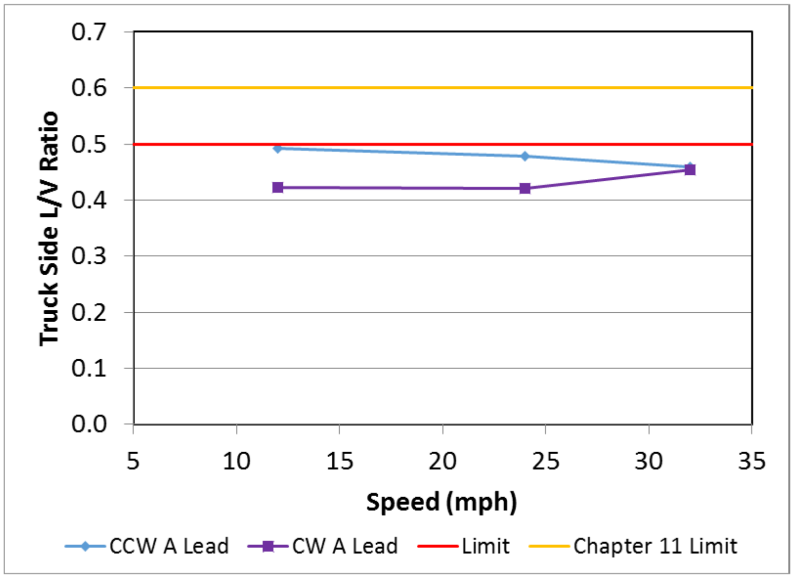

Figure 22. Predicted Maximum Truck Side L/V Ratio for Curving with Variation in Wheel Profile and Lubrication Conditions, Case 2 Friction with Worn Profiles

5.10 Limiting Spiral Negotiation (S-2043, Paragraph 4.3.11.6)

Simulations of the limiting spiral regime were conducted according to Paragraph 4.3.11.6 of S-2043. The limiting spiral has a steady curvature change from 0 to 10 degrees and a steady superelevation change from 0 to 4 3/8 inches in 89 feet.

Table 18 shows the worst-case simulation predictions for the limiting spiral regime. Figure 23 shows the maximum wheel L/V plotted against speed to show the trend in performance. Simulation predictions meet S-2043 criteria for the limiting spiral regime.

Table 18. Limiting Spiral Simulation Predictions

Criterion	Limiting Value	Spiral Entry	Spiral Exit
Maximum carbody roll angle (degree)	4.0	0.6	0.7
Maximum wheel L/V	0.80	0.42	0.51
Maximum truck side L/V	0.50	0.23	0.29
Minimum vertical wheel load (%)	25	67	64
Peak-to-peak carbody lateral acceleration (g)	1.30	0.14	0.20
Maximum carbody lateral acceleration (g)	0.75	0.10	0.15
Lateral carbody acceleration standard deviation (g)	0.13	NA	NA
Maximum carbody vertical acceleration (g)	0.90	0.10	0.10
Maximum vertical suspension deflection (%)	95	36	39

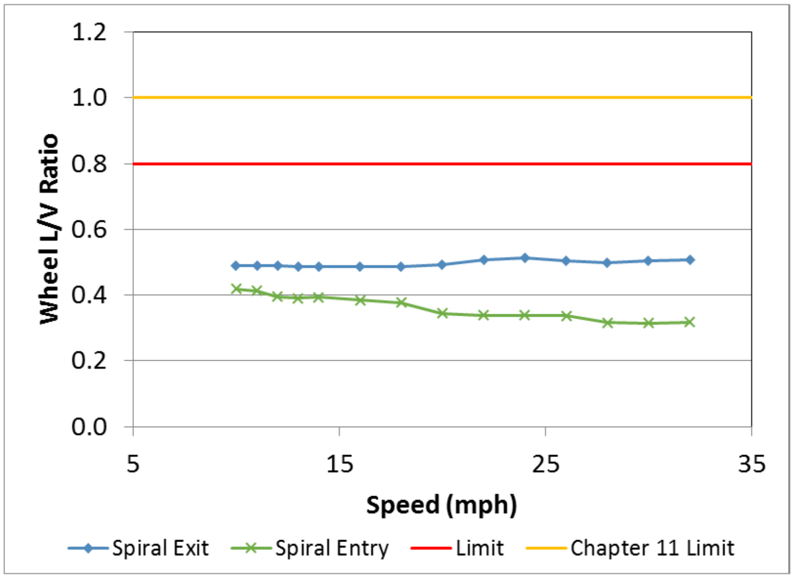

Figure 23. Predicted Maximum Wheel L/V Ratio for the Limiting Spiral Regime

5.11 Turnouts and Crossovers (S-2043, Paragraph 4.3.11.7)

Simulations of the turnout and crossover regime were conducted according to Paragraph 4.3.11.7 of S-2043. Simulations were performed through a No. 7 AREMA straight point turnout and a No. 7 crossover on 13-foot track centers at speeds up to 15 mph. The inputs for this simulation regime were mathematically generated because no actual test zone exists.

Table 19 shows the worst-case simulation predictions for the turnout regime. Figure 24 shows a plot of truck side L/V ratio in a No. 7 turnout. Simulation predictions meet S-2043 criteria for the turnout regimes.

Table 19. Turnout Simulation Predictions

Criterion	Limiting Value	No. 7 Turnout Left Hand	No. 7 Turnout Right Hand
Maximum carbody roll angle (degree)	4.0	0.3	0.3
Maximum wheel L/V	0.80	0.59	0.59
Maximum truck side L/V	0.50	0.47	0.47
Minimum vertical wheel load (%)	25	77	77
Peak-to-peak carbody lateral acceleration (g)	1.30	0.19	0.19
Maximum carbody lateral acceleration (g)	0.75	0.11	0.11
Lateral carbody acceleration standard deviation (g)	0.13	NA	NA
Maximum carbody vertical acceleration (g)	0.90	0.23	0.22
Maximum vertical suspension deflection (%)	95	16	16

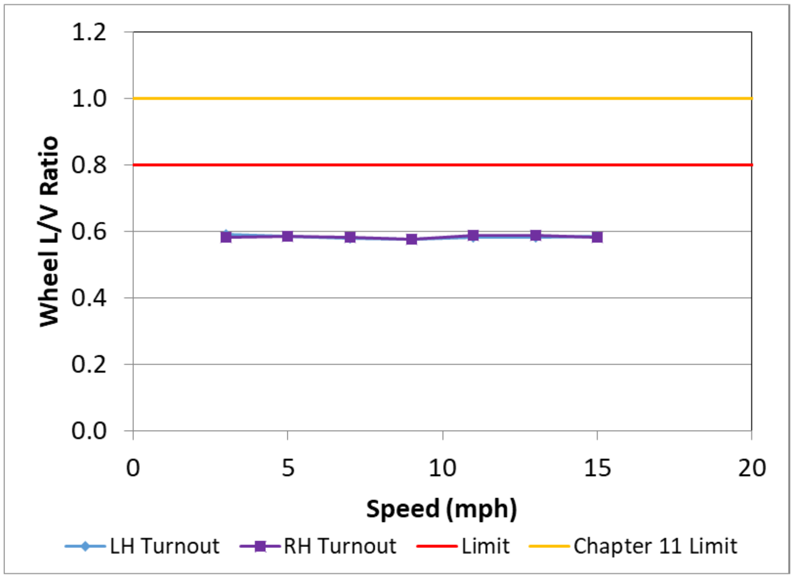

Figure 24. Simulation Predictions of Truck Side L/V Ratio for No. 7 Turnouts

Table 20 shows the worst-case simulation predictions for the crossover regime. Figure 25 shows a plot of truck side L/V ratio in the crossovers. Simulation predictions meet S-2043 criteria for the No. 7 crossover.

Table 20. Crossover Simulation Predictions

Criterion	Limiting Value	No. 7 Crossover
Maximum carbody roll angle (degree)	4.0	0.3
Maximum wheel L/V	0.80	0.68
Maximum truck side L/V	0.50	0.49
Minimum vertical wheel load (%)	25	75
Peak-to-peak carbody lateral acceleration (g)	1.30	0.21
Maximum carbody lateral acceleration (g)	0.75	0.13
Lateral carbody acceleration standard deviation (g)	0.13	NA
Maximum carbody vertical acceleration (g)	0.90	0.17
Maximum vertical suspension deflection (%)	95	23

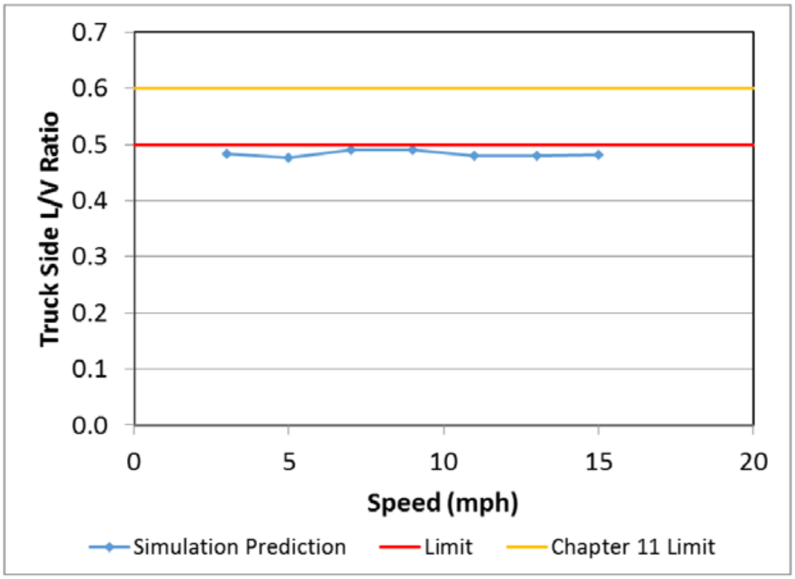

Figure 25. Simulation Predictions of Truck Side L/V Ratio on Crossovers

5.12 Ride Quality (S-2043, Paragraph 4.3.12)

Simulations of the ride quality regime were conducted according to Paragraph 4.3.12 of S-2043. Simulations were performed over standardized track geometry files representing track allowed under Federal Railroad Administration (FRA) designations of Class 2 through Class 6. These track geometry files are provided by the AAR. Simulations speeds were from 10 mph to the FRA freight speed limit for each track class. The track geometry files are described briefly below:

- Class 2 Inputs. 74,000 feet of track including curves up to 10 degrees
- Class 3 Inputs. 28,000 feet of track including curves up to 3 degrees
- Class 4 Inputs. 22,000 feet of tangent track
- Class 5 Inputs. 6,700 feet of tangent track
- Class 6 Inputs. 16,000 feet of tangent track

S-2043 Paragraph 4.3.12.4 requires simulation of non-passenger carrying railcars on these track classes. The predictions are compared to the performance criteria in Table 4.1 of S-2043.

Table 21 shows the worst-case simulation predictions for the ride quality simulations. Figure 26 shows a plot of the predicted maximum vertical acceleration in the ride quality regime. Figure 27 shows a plot of the maximum suspension displacement in the ride quality regime. Simulation predictions meet S-2043 criterion in the ride quality regime.

Table 21. Ride Quality Simulation Predictions

Criterion	Limiting Value	Class 2	Class 3	Class 4	Class 5	Class 6
Maximum carbody roll angle (degree)	4.0	1.6	0.9	0.7	0.7	0.9
Maximum wheel L/V	0.80	0.52	0.18	0.18	0.16	0.14
Maximum truck side L/V	0.50	0.34	0.13	0.12	0.11	0.11
Minimum vertical wheel load (%)	25	71	62	58	65	55
Peak-to-peak carbody lateral acceleration (g)	1.30	0.34	0.25	0.47	0.36	0.34
Maximum carbody lateral acceleration (g)	0.75	0.18	0.16	0.29	0.19	0.18
Lateral carbody acceleration standard deviation (g)	0.13	0.04	0.04	0.06	0.07	0.07
Maximum carbody vertical acceleration (g)	0.90	0.21	0.57	0.66	0.51	0.58
Maximum vertical suspension deflection (%)	95	36	71	91	56	63

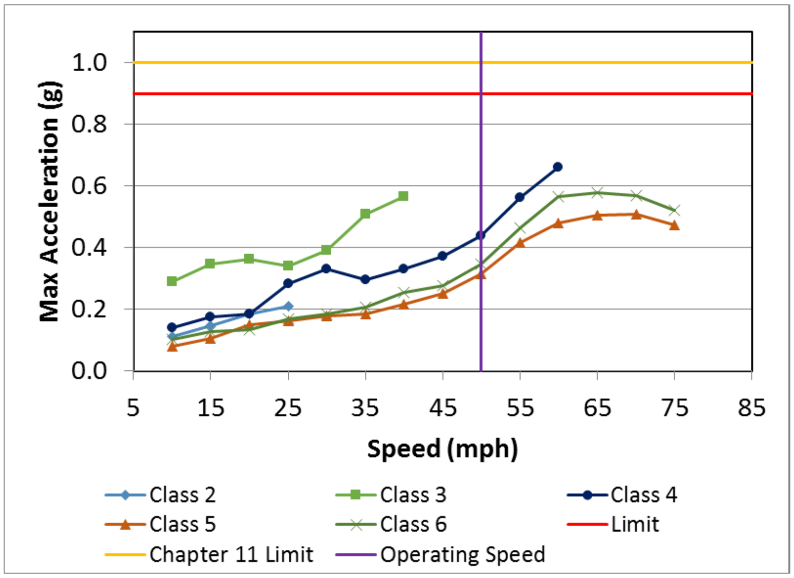

Figure 26. Predicted Maximum Vertical Acceleration in the Ride Quality Regime

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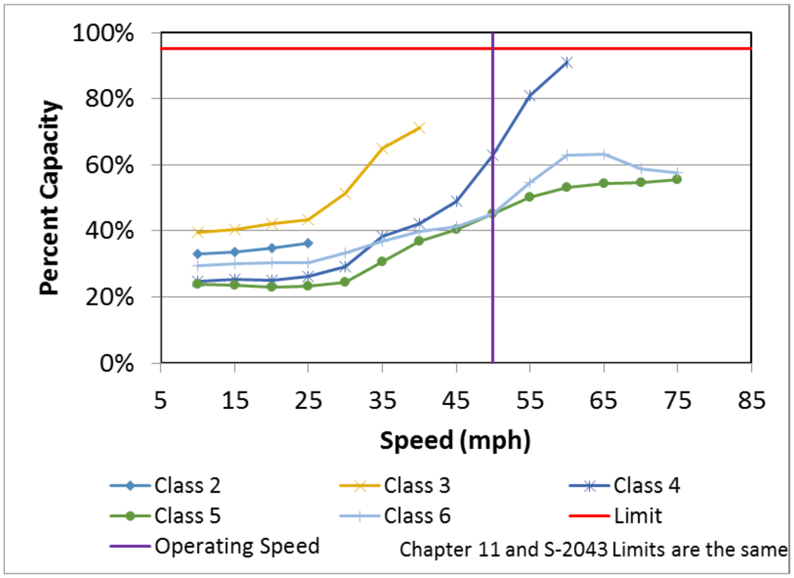

Figure 27. Predicted Maximum Suspension Deflection in the Ride Quality Regime

5.13 Buff and Draft Curving (S-2043, Paragraph 4.3.13)

Simulations of the buff and draft curving regime were conducted according to Paragraph 4.3.13 of S-2043. Simulations were performed using measured track geometry of the 12-degree curve of the WRM Loop at TTC. Simulations were designed to simulate the car coupled to:

- A base car as described in the AAR MSRP Section C-II, Standard M-1001 Chapter 2, Paragraph 2.1.4.2.3.[5]
- A long car having 90-foot over strikers, 66-foot truck centers, 60-inch couplers, and conventional draft gear.
- Like Car.
- Atlas cask car: a car the buffer railcar may be coupled to in HLRM service.
- Rail Escort Vehicle: a car the buffer railcar may be coupled to in HLRM service.
- Four-axle Locomotive: a vehicle to which the buffer railcar may be coupled in HLRM service.
- Six-axle Locomotive: a vehicle to which the buffer railcar may be coupled in HLRM service

The geometry of the coupled cars was modeled so that the longitudinal forces of 250,000-pounds buff and 250,000-pounds draft were applied to the car in the simulation. The lateral component of the force was calculated using the method presented in AAR MSRP Section C-II,

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[5] Association of American Railroads. 2011. *Manual of Standards of Recommended Practices*. Section C-II Design, Fabrication, and Construction of Freight Cars, Standard M-1001, Chapter 2. General Data, Paragraph 2.1.4.2.3 "Base Car." Washington, DC.

Standard M-1001 Chapter 2, Paragraph 2.1.6.4 and 2.1.6.5. The longitudinal and lateral forces were applied in the model using external force connection elements.

Table 22 shows the worst-case simulation predictions for draft force cases when the buffer railcar is coupled to the standard cars required in Chapter 2, and Table 23 shows the worst-case simulation predictions for the draft force cases when the car is coupled to cars it may be coupled to in S-2043 service. Table 24 and Table 25 show the corresponding data for buff loads. Simulation predictions do not meet S-2043 for the truck side L/V criterion when the buffer railcar is coupled to the base car or when coupled between the cask car and the rail escort vehicle (REV) under draft load. These truck side L/V exceptions occur in the body of the curve on the lead truck low rail at underbalance speed. Simulation predictions meet S-2043 criteria for all other conditions. Figure 28 shows a plot of the maximum truck side L/V ratio versus speed when the buffer railcar is coupled to the base car and the REV under 250,000-pounds draft load. Figure 29 shows a distance plot of the truck side L/V ratio for the buffer railcar coupled to the base car under 250,000-pounds draft load at 15 mph. The column headings in Tables 22 through 25 list the cars that the buffer car is coupled between.

Table 22. Simulation Predictions for 250,000 pounds Draft Force with Standard Cars

Criterion	Limiting Value	Base-Long	Base-Base	Long-Long	Like-Like
Maximum carbody roll angle (degree)	4.0	0.7	0.7	0.6	0.6
Maximum wheel L/V	0.80	0.54	0.54	0.51	0.53
Maximum truck side L/V	0.50	0.48	**0.51**	0.38	0.44
Minimum vertical wheel load (%)	25	58	59	76	69
Peak-to-peak carbody lateral acceleration (g)	1.30	0.12	0.13	0.12	0.12
Maximum carbody lateral acceleration (g)	0.75	0.13	0.14	0.12	0.13
Lateral carbody acceleration standard deviation (g)	0.13	0.03	0.03	0.04	0.03
Maximum carbody vertical acceleration (g)	0.90	0.12	0.13	0.12	0.12
Maximum vertical suspension deflection (%)	95	50	58	44	49

Table 23. Simulation Predictions for 250,000 pounds Draft Force with Cars it May be Coupled to in S-2043 Operation

Criterion	Limiting Value	Cask Car-Cask Car	Cask-REV	6-Axle Loco-Cask	4-Axle Loco-Cask
Maximum carbody roll angle (degree)	4.0	0.7	0.6	0.7	0.7
Maximum wheel L/V	0.80	0.54	0.54	0.53	0.53
Maximum truck side L/V	0.50	**0.50**	**0.51**	0.47	0.45
Minimum vertical wheel load (%)	25	61	61	67	61
Peak-to-peak carbody lateral acceleration (g)	1.30	0.13	0.14	0.12	0.13
Maximum carbody lateral acceleration (g)	0.75	0.13	0.13	0.13	0.13
Lateral carbody acceleration standard deviation (g)	0.13	0.03	0.03	0.04	0.03
Maximum carbody vertical acceleration (g)	0.90	0.13	0.13	0.12	0.12
Maximum vertical suspension deflection (%)	95	56	56	46	50

Table 24. Simulation Predictions for 250,000 pounds Buff Force with Standard Cars

Criterion	Limiting Value	Base-Long	Base-Base	Long-Long	Like-Like
Maximum carbody roll angle (degree)	4.0	0.5	0.6	0.5	0.5
Maximum wheel L/V	0.80	0.46	0.52	0.44	0.47
Maximum truck side L/V	0.50	0.38	0.39	0.29	0.33
Minimum vertical wheel load (%)	25	55	56	72	64
Peak-to-peak carbody lateral acceleration (g)	1.30	0.13	0.14	0.13	0.15
Maximum carbody lateral acceleration (g)	0.75	0.13	0.13	0.13	0.15
Lateral carbody acceleration standard deviation (g)	0.13	0.03	0.03	0.04	0.04
Maximum carbody vertical acceleration (g)	0.90	0.12	0.12	0.12	0.11
Maximum vertical suspension deflection (%)	95	52	54	41	47

Table 25. Simulation Predictions for 250,000 pounds Buff Force with Cars it May be Coupled to in S-2043 Operation

Criterion	Limiting Value	Cask Car-Cask Car	Cask-REV	6-Axle Loco-Cask	4-Axle Loco-Cask
Maximum carbody roll angle (degree)	4.0	0.6	0.6	0.5	0.5
Maximum wheel L/V	0.80	0.52	0.52	0.50	0.43
Maximum truck side L/V	0.50	0.38	0.39	0.39	0.37
Minimum vertical wheel load (%)	25	56	58	54	56
Peak-to-peak carbody lateral acceleration (g)	1.30	0.14	0.14	0.14	0.13
Maximum carbody lateral acceleration (g)	0.75	0.13	0.14	0.14	0.14
Lateral carbody acceleration standard deviation (g)	0.13	0.03	0.03	0.03	0.03
Maximum carbody vertical acceleration (g)	0.90	0.12	0.11	0.11	0.11
Maximum vertical suspension deflection (%)	95	54	53	52	52

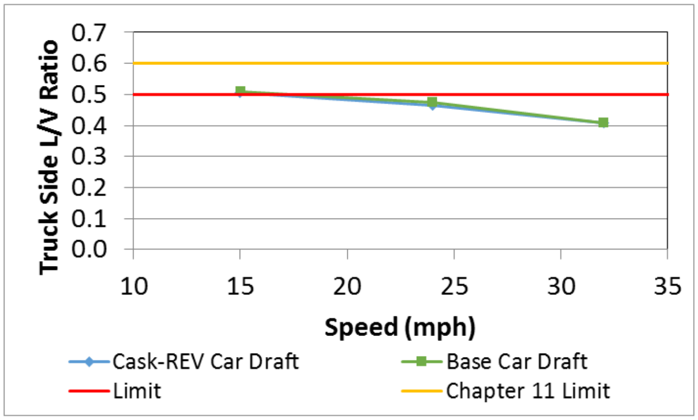


Figure 28. Simulation Predictions of Truck Side L/V for the Buffer Railcar under 250,000 pounds Draft Force when Coupled to the Two Worst-case Cars

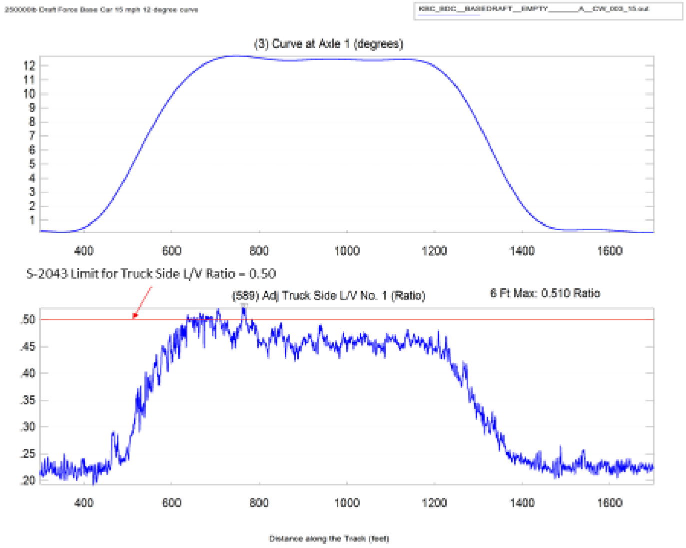


Figure 29. Truck side L/V Ratio for the Buffer Railcar Coupled to the Base Car under 250,000 Pounds Draft Load at 15 mph

5.14 Braking Effects on Steering (S-2043, Paragraph 4.3.14)

Simulations of the braking effects on steering regime were conducted according to Paragraph 4.3.14 of S-2043. Simulations were performed using measured track geometry of the 12-degree curve of the WRM loop at TTC.

The brake shoe could apply a 5,342-pound force to the wheel based on the gross rail load of 263,000 pounds and the maximum brake ratio of 16.25 percent specified in S-2043 Paragraph 4.4.2.3. “Loaded Brake Ratio.” The brake beam guide is inclined 14 degrees from horizontal on the Swing Motion® truck used on the buffer railcar. The longitudinal and vertical forces applied to the wheels were resolved from this data and applied to the axles using external force inputs in the NUCARS® model. The braking torque was calculated assuming a coefficient of friction of 0.33 between the brake shoe and wheel. This torque was applied to the axles for these simulations.

Table 26 shows the worst-case results from the braking in curves simulation. Simulation predictions meet S-2043 criteria for the braking in curves regime. Braking appears to have only a small effect on steering, with the largest detrimental change being a drop of the minimum vertical wheel load from 74 to 66 percent of the static wheel load for simulations when braking forces are simulated.

Table 26. Simulation Predictions for the Braking in Curves Simulation

Criterion	Limiting Value	No Braking	With Braking
Maximum carbody roll angle (degree)	4.0	0.4	0.4
Maximum wheel L/V	0.80	0.49	0.48
Maximum truck side L/V	0.50	0.30	0.31
Minimum vertical wheel load (%)	25	74	66
Peak-to-peak carbody lateral acceleration (g)	1.30	0.17	0.18
Maximum carbody lateral acceleration (g)	0.75	0.11	0.11
Lateral carbody acceleration standard deviation (g)	0.13	0.02	0.02
Maximum carbody vertical acceleration (g)	0.90	0.12	0.12
Maximum vertical suspension deflection (%)	95	34	34

6.0 WORN COMPONENT SIMULATIONS (S-2043, Paragraph 4.3.15)

Worn component simulations were conducted according to Paragraph 4.3.15 of S-2043. Wear of the following components was simulated:

- CCSB
- Center plates
- Primary pad
- Friction wedges
- Broken springs
- Vertical damper

In this section, worst-case simulation predictions for the worn components are summarized in tables together with the criteria and base line predictions for the new condition car. All worn component condition simulations meet S-2043 criteria.

The regimes chosen for each worn component case are not expected to identify every regime where the worn component may affect results; but rather, represent a set of cases that check the modes of performance that might be affected. The regimes used in worn component simulations were selected from those required by Chapter 11. For example, simulations of the effects of truck component wear in turnouts, crossovers, spiral entry/exit and curves with bumps/dips were not performed because these effects would also be evident in the regimes of curving and dynamic curving.

6.1 Constant Contact Side Bearing (CCSB)

Wear in a CCSB may result in a loss of side bearing preload. Wear of the carbody centerplate or the truck center bowl may result in a reduction of the CCSB setup height. To examine the effect of these types of CCSB wear, simulations were performed with:

- The CCSB having half the stiffness and half the preload of new CCSB (4,000-pound nominal preload).
- The setup height of the new CCSB reduced to 4 7/8 inch.

The performance of the car with worn CCSB was checked in constant curving, dynamic curving, hunting, and twist and roll.

Table 27 shows a comparison of constant curving simulation predictions for baseline and worn CCSB simulations. Simulations were performed in both directions using track geometry measurements for a section of track that includes 7.5-, 12-, and 10-degree curves and their entry and exit spirals. The spiral on the north end of the 12-degree curve is an old test zone known as the bunched spiral. The curvature changes linearly from 0 to 12 degrees over the 200-foot length of the bunched spiral and the superelevation changes from 0 to 5 inches in the center 100 feet. The bunched spiral is no longer a required AAR test regime, but serves in this case to check car performance under severe track twist conditions. Simulation predictions for worn CCSB meet S-2043 criteria for constant curving.

Table 27. Simulation Predictions of the Buffer Railcar with Worn CCSB in Constant Curving

Criterion	Limiting Value	Baseline	Low Preload CCSB	Low Setup Height CCSB
Maximum carbody roll angle (degree)	4.0	0.5	0.5	0.5
Maximum wheel L/V	0.80	0.52	0.52	0.52
Maximum truck side L/V	0.50	0.34	0.34	0.34
Minimum vertical wheel load (%)	25	68	67	68
Peak-to-peak carbody lateral acceleration (g)	1.30	0.24	0.23	0.23
Maximum carbody lateral acceleration (g)	0.75	0.16	0.15	0.15
Lateral carbody acceleration standard deviation (g)	0.13	0.04	0.04	0.04
Maximum carbody vertical acceleration (g)	0.90	0.15	0.15	0.15
Maximum vertical suspension deflection (%)	95	37	37	36

Table 28 shows a comparison of dynamic curving simulation predictions for baseline and worn CCSB simulations. Simulation predictions for worn CCSB meet S-2043 criteria for dynamic curving.

Table 28. Simulation Predictions of the Buffer Railcar with Worn CCSB in Dynamic Curving

Criterion	Limiting Value	Baseline	Low Preload CCSB	Low Setup Height CCSB
Maximum carbody roll angle (degree)	4.0	1.0	1.0	1.0
Maximum wheel L/V	0.80	0.53	0.53	0.53
Maximum truck side L/V	0.50	0.25	0.25	0.25
Minimum vertical wheel load (%)	25	62	62	62
Peak-to-peak carbody lateral acceleration (g)	1.30	0.41	0.41	0.41
Maximum carbody lateral acceleration (g)	0.75	0.28	0.29	0.28
Lateral carbody acceleration standard deviation (g)	0.13	NA	NA	NA
Maximum carbody vertical acceleration (g)	0.90	0.09	0.09	0.09
Maximum vertical suspension deflection (%)	95	33	33	33

Table 29 shows a comparison of hunting simulation predictions for baseline and worn CCSB simulations. Simulation predictions for low preload and low setup height CCSB meet the S-2043 criteria for hunting.

Table 29. Simulation Predictions of the Buffer Railcar with Worn CCSB in Hunting

Criterion	Limiting Value	Baseline	Low Preload CCSB	Low Setup Height CCSB
Maximum carbody roll angle (degree)	4.0	0.4	0.4	0.3
Maximum wheel L/V	0.80	0.21	0.22	0.21
Maximum truck side L/V	0.50	0.19	0.19	0.19
Minimum vertical wheel load (%)	25	66	66	66
Peak-to-peak carbody lateral acceleration (g)	1.30	0.40	0.40	0.40
Maximum carbody lateral acceleration (g)	0.75	0.29	0.29	0.29
Lateral carbody acceleration standard deviation (g)	0.13	0.09	0.08	0.08
Maximum carbody vertical acceleration (g)	0.90	0.24	0.24	0.24
Maximum vertical suspension deflection (%)	95	31	31	31

Table 30 shows a comparison of twist and roll simulation predictions for baseline and worn CCSB simulations. Simulation predictions for worn CCSB meet S-2043 criteria for twist and roll.

Table 30. Simulation Predictions of the Buffer Railcar with Worn CCSB in Twist and Roll

Criterion	Limiting Value	Baseline	Low Preload CCSB	Low Setup Height CCSB
Maximum carbody roll angle (degree)	4.0	1.6	1.6	1.6
Maximum wheel L/V	0.80	0.11	0.11	0.11
Maximum truck side L/V	0.50	0.09	0.09	0.09
Minimum vertical wheel load (%)	25	69	69	70
Peak-to-peak carbody lateral acceleration (g)	1.30	0.27	0.27	0.27
Maximum carbody lateral acceleration (g)	0.75	0.15	0.15	0.14
Lateral carbody acceleration standard deviation (g)	0.13	NA	NA	NA
Maximum carbody vertical acceleration (g)	0.90	0.16	0.16	0.16
Maximum vertical suspension deflection (%)	95	40	41	40

6.2 Centerplate

To examine the effect of centerplate wear, simulations were performed with centerplate friction increased from 0.3 for the baseline case to 0.5 for the worn case. The performance of the car with worn centerplates was checked in constant curving, dynamic curving, and hunting.

Table 31 shows a comparison of constant curving simulation predictions for baseline and worn centerplate simulations. Simulations were performed in both directions using track geometry measurements for a section of track that includes a 7.5-, 12-, and 10-degree curve and their entry and exit spirals. The bunched spiral, as described in the previous section, was used.

Table 31. Simulation Predictions of the Buffer Railcar with Worn Centerplate in Constant Curving

Criterion	Limiting Value	Baseline	Worn Centerplate
Maximum carbody roll angle (degree)	4.0	0.5	0.5
Maximum wheel L/V	0.80	0.52	0.52
Maximum truck side L/V	0.50	0.34	0.34
Minimum vertical wheel load (%)	25	68	68
Peak-to-peak carbody lateral acceleration (g)	1.30	0.24	0.24
Maximum carbody lateral acceleration (g)	0.75	0.16	0.15
Lateral carbody acceleration standard deviation (g)	0.13	0.04	0.04
Maximum carbody vertical acceleration (g)	0.90	0.15	0.15
Maximum vertical suspension deflection (%)	95	37	37

Table 32 shows a comparison of dynamic curving simulation predictions for baseline and worn centerplate simulations. Simulation predictions for worn centerplate meet S-2043 criteria for dynamic curving.

Table 32. Simulation Predictions of the Buffer Railcar with Worn Centerplate in Dynamic Curving

Criterion	Limiting Value	Baseline	Worn Centerplate
Maximum carbody roll angle (degree)	4.0	1.0	1.0
Maximum wheel L/V	0.80	0.53	0.52
Maximum truck side L/V	0.50	0.25	0.25
Minimum vertical wheel load (%)	25	62	62
Peak-to-peak carbody lateral acceleration (g)	1.30	0.41	0.41
Maximum carbody lateral acceleration (g)	0.75	0.28	0.28
Lateral carbody acceleration standard deviation (g)	0.13	NA	NA
Maximum carbody vertical acceleration (g)	0.90	0.09	0.09
Maximum vertical suspension deflection (%)	95	33	33

Table 33 shows a comparison of hunting simulation predictions for baseline and worn centerplate simulations. Simulation predictions for these conditions meet S-2043 criteria for hunting.

Table 33. Simulation Predictions of the Buffer Railcar with Worn Centerplate in Hunting

Criterion	Limiting Value	Baseline	Worn Centerplate
Maximum carbody roll angle (degree)	4.0	0.4	0.3
Maximum wheel L/V	0.80	0.21	0.21
Maximum truck side L/V	0.50	0.19	0.19
Minimum vertical wheel load (%)	25	66	66
Peak-to-peak carbody lateral acceleration (g)	1.30	0.40	0.40
Maximum carbody lateral acceleration (g)	0.75	0.29	0.29
Lateral carbody acceleration standard deviation (g)	0.13	0.09	0.08
Maximum carbody vertical acceleration (g)	0.90	0.24	0.24
Maximum vertical suspension deflection (%)	95	31	31

6.3 Primary Pad

It is not clear how the primary pads of the Swing Motion® trucks will wear over time. To examine the possible impact of different changes, the primary pads were simulated with both lower and higher longitudinal and lateral stiffness. For lower stiffness runs the stiffness was reduced by a factor of 2. For higher stiffness runs the stiffness was increased by a factor of 20.

Table 34 shows a comparison of constant curving simulation predictions for baseline and worn primary pad simulations. Simulations were performed in both directions using track geometry measurements for a section of track that includes a 7.5-, 12-, and 10-degree curve and their entry and exit spirals. The bunched spiral, as described in the previous section, was used. Simulation predictions for worn primary pads meet S-2043 criteria for constant curving.

Table 34. Simulation Predictions of the Buffer Railcar with Worn Primary Pads in Constant Curving

Criterion	Limiting Value	Baseline	Soft Primary Pad	Stiff Primary Pad
Maximum carbody roll angle (degree)	4.0	0.5	0.5	0.5
Maximum wheel L/V	0.80	0.52	0.52	0.62
Maximum truck side L/V	0.50	0.34	0.28	0.36
Minimum vertical wheel load (%)	25	68	67	67
Peak-to-peak carbody lateral acceleration (g)	1.30	0.24	0.25	0.19
Maximum carbody lateral acceleration (g)	0.75	0.16	0.19	0.17
Lateral carbody acceleration standard deviation (g)	0.13	0.04	0.05	0.04
Maximum carbody vertical acceleration (g)	0.90	0.15	0.15	0.14
Maximum vertical suspension deflection (%)	95	37	36	37

Table 35 shows a comparison of dynamic curving simulation predictions for baseline and worn primary pad simulations. Simulation predictions for worn primary pads meet S-2043 criteria for dynamic curving.

Table 35. Simulation Predictions of the Buffer Railcar with Worn Primary Pads in Dynamic Curving

Criterion	Limiting Value	Baseline	Soft Primary Pad	Stiff Primary Pad
Maximum carbody roll angle (degree)	4.0	1.0	1.0	1.0
Maximum wheel L/V	0.80	0.53	0.53	0.58
Maximum truck side L/V	0.50	0.25	0.23	0.32
Minimum vertical wheel load (%)	25	62	62	62
Peak-to-peak carbody lateral acceleration (g)	1.30	0.41	0.59	0.25
Maximum carbody lateral acceleration (g)	0.75	0.28	0.44	0.20
Lateral carbody acceleration standard deviation (g)	0.13	NA	NA	NA
Maximum carbody vertical acceleration (g)	0.90	0.09	0.09	0.09
Maximum vertical suspension deflection (%)	95	33	34	32

Table 36 shows a comparison of hunting simulation predictions for baseline and worn primary pad simulations. Simulation predictions for worn primary pads meet S-2043 criteria for hunting.

Table 36. Simulation Predictions of the Buffer Railcar with Worn Primary Pads in Hunting

Criterion	Limiting Value	Baseline	Soft Primary Pad	Stiff Primary Pad
Maximum carbody roll angle (degree)	4.0	0.4	0.3	0.4
Maximum wheel L/V	0.80	0.21	0.22	0.27
Maximum truck side L/V	0.50	0.19	0.20	0.19
Minimum vertical wheel load (%)	25	66	65	65
Peak-to-peak carbody lateral acceleration (g)	1.30	0.40	0.43	0.36
Maximum carbody lateral acceleration (g)	0.75	0.29	0.32	0.27
Lateral carbody acceleration standard deviation (g)	0.13	0.09	0.08	0.07
Maximum carbody vertical acceleration (g)	0.90	0.24	0.24	0.25
Maximum vertical suspension deflection (%)	95	31	32	30

6.4 Friction Wedges

The wedge rise limit for the Swing Motion® trucks used in the buffer railcar is 1 1/16 inch. Worn wedge simulations were performed with the wedges at this state of wear in all locations. The worn wedge condition was checked for limiting spiral, dynamic curving, pitch and bounce, and twist and roll regimes.

Table 37 shows a comparison of limiting spiral simulation predictions for baseline and worn wedge simulations. Simulation predictions for worn wedges meet S-2043 criteria in the limiting spiral regime.

Table 37. Simulation Predictions of the Buffer Railcar with Worn Wedges in Limiting Spiral

Criterion	Limiting Value	Baseline Spiral Entry	Baseline Spiral Exit	Worn Wedge Spiral Entry	Worn Wedge Spiral Exit
Maximum carbody roll angle (degree)	4.0	0.6	0.7	0.5	0.7
Maximum wheel L/V	0.80	0.42	0.51	0.42	0.51
Maximum truck side L/V	0.50	0.23	0.29	0.23	0.29
Minimum vertical wheel load (%)	25	67	64	68	64
Peak-to-peak carbody lateral acceleration (g)	1.30	0.14	0.20	0.13	0.19
Maximum carbody lateral acceleration (g)	0.75	0.10	0.15	0.10	0.15
Lateral carbody acceleration standard deviation (g)	0.13	NA	NA	NA	NA
Maximum carbody vertical acceleration (g)	0.90	0.10	0.10	0.09	0.10
Maximum vertical suspension deflection (%)	95	36	39	36	38

Table 38 shows a comparison of dynamic curving simulation predictions for baseline and worn friction wedge simulations. Simulation predictions for worn friction wedges meet S-2043 criteria for dynamic curving.

Table 38 Simulation Predictions of the Buffer Railcar with Worn Wedges in Dynamic Curving

Criterion	Limiting Value	Baseline	Worn Wedges
Maximum carbody roll angle (degree)	4.0	1.0	1.0
Maximum wheel L/V	0.80	0.53	0.52
Maximum truck side L/V	0.50	0.25	0.25
Minimum vertical wheel load (%)	25	62	63
Peak-to-peak carbody lateral acceleration (g)	1.30	0.41	0.47
Maximum carbody lateral acceleration (g)	0.75	0.28	0.33
Lateral carbody acceleration standard deviation (g)	0.13	NA	NA
Maximum carbody vertical acceleration (g)	0.90	0.09	0.08
Maximum vertical suspension deflection (%)	95	33	33

Table 39 shows a comparison of pitch and bounce simulation predictions for baseline and worn friction wedge simulations. Simulation predictions for worn friction wedges meet S-2043 criteria for pitch and bounce.

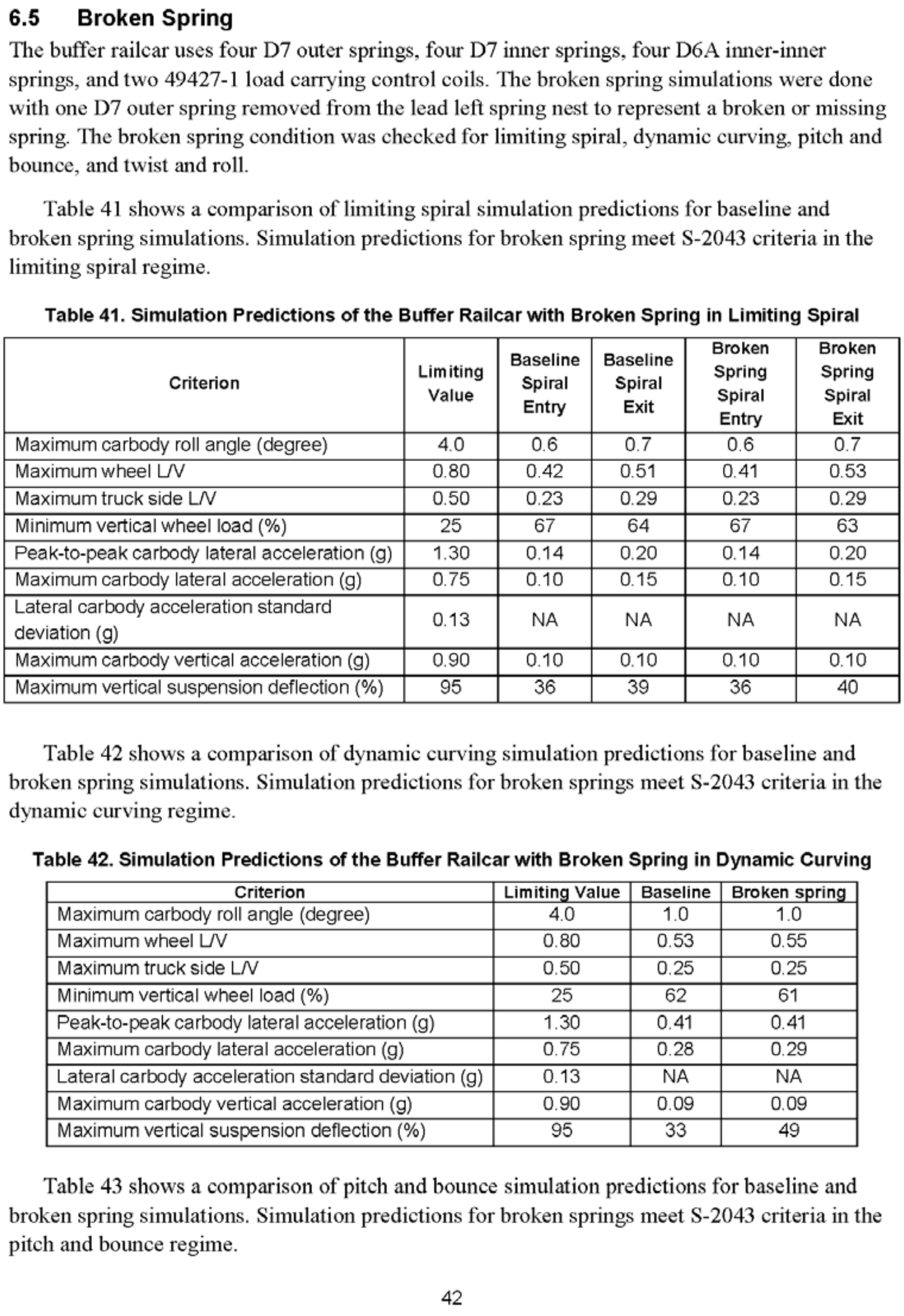
Table 39. Simulation Predictions of the Buffer Railcar with Worn Friction Wedges in Pitch and Bounce

Criterion	Limiting Value	Baseline	Worn Wedges
Maximum carbody roll angle (degree)	4.0	0.2	0.2
Maximum wheel L/V	0.80	0.06	0.05
Maximum truck side L/V	0.50	0.05	0.05
Minimum vertical wheel load (%)	25	60	59
Peak-to-peak carbody lateral acceleration (g)	1.30	0.12	0.11
Maximum carbody lateral acceleration (g)	0.75	0.06	0.06
Lateral carbody acceleration standard deviation (g)	0.13	NA	NA
Maximum carbody vertical acceleration (g)	0.90	0.65	0.67
Maximum vertical suspension deflection (%)	95	74	79

Table 40 shows a comparison of twist and roll simulation predictions for baseline and worn friction wedges. Simulation predictions for worn friction wedges meet S-2043 criteria for twist and roll.

Table 40. Simulation Predictions of the Buffer Railcar with Worn Wedges in Twist and Roll

Criterion	Limiting Value	Baseline	Worn Wedges
Maximum carbody roll angle (degree)	4.0	1.6	1.6
Maximum wheel L/V	0.80	0.11	0.11
Maximum truck side L/V	0.50	0.09	0.09
Minimum vertical wheel load (%)	25	69	70
Peak-to-peak carbody lateral acceleration (g)	1.30	0.27	0.27
Maximum carbody lateral acceleration (g)	0.75	0.15	0.14
Lateral carbody acceleration standard deviation (g)	0.13	NA	NA
Maximum carbody vertical acceleration (g)	0.90	0.16	0.15
Maximum vertical suspension deflection (%)	95	40	41



6.5 Broken Spring

The buffer railcar uses four D7 outer springs, four D7 inner springs, four D6A inner-inner springs, and two 49427-1 load carrying control coils. The broken spring simulations were done with one D7 outer spring removed from the lead left spring nest to represent a broken or missing spring. The broken spring condition was checked for limiting spiral, dynamic curving, pitch and bounce, and twist and roll.

Table 41 shows a comparison of limiting spiral simulation predictions for baseline and broken spring simulations. Simulation predictions for broken spring meet S-2043 criteria in the limiting spiral regime.

Table 41. Simulation Predictions of the Buffer Railcar with Broken Spring in Limiting Spiral

Criterion	Limiting Value	Baseline Spiral Entry	Baseline Spiral Exit	Broken Spring Spiral Entry	Broken Spring Spiral Exit
Maximum carbody roll angle (degree)	4.0	0.6	0.7	0.6	0.7
Maximum wheel L/V	0.80	0.42	0.51	0.41	0.53
Maximum truck side L/V	0.50	0.23	0.29	0.23	0.29
Minimum vertical wheel load (%)	25	67	64	67	63
Peak-to-peak carbody lateral acceleration (g)	1.30	0.14	0.20	0.14	0.20
Maximum carbody lateral acceleration (g)	0.75	0.10	0.15	0.10	0.15
Lateral carbody acceleration standard deviation (g)	0.13	NA	NA	NA	NA
Maximum carbody vertical acceleration (g)	0.90	0.10	0.10	0.10	0.10
Maximum vertical suspension deflection (%)	95	36	39	36	40

Table 42 shows a comparison of dynamic curving simulation predictions for baseline and broken spring simulations. Simulation predictions for broken springs meet S-2043 criteria in the dynamic curving regime.

Table 42. Simulation Predictions of the Buffer Railcar with Broken Spring in Dynamic Curving

Criterion	Limiting Value	Baseline	Broken spring
Maximum carbody roll angle (degree)	4.0	1.0	1.0
Maximum wheel L/V	0.80	0.53	0.55
Maximum truck side L/V	0.50	0.25	0.25
Minimum vertical wheel load (%)	25	62	61
Peak-to-peak carbody lateral acceleration (g)	1.30	0.41	0.41
Maximum carbody lateral acceleration (g)	0.75	0.28	0.29
Lateral carbody acceleration standard deviation (g)	0.13	NA	NA
Maximum carbody vertical acceleration (g)	0.90	0.09	0.09
Maximum vertical suspension deflection (%)	95	33	49

Table 43 shows a comparison of pitch and bounce simulation predictions for baseline and broken spring simulations. Simulation predictions for broken springs meet S-2043 criteria in the pitch and bounce regime.

Table 43. Simulation Predictions of the Buffer Railcar with a Broken Spring in Pitch and Bounce

Criterion	Limiting Value	Baseline	Broken spring
Maximum carbody roll angle (degree)	4.0	0.2	0.2
Maximum wheel L/V	0.80	0.06	0.05
Maximum truck side L/V	0.50	0.05	0.05
Minimum vertical wheel load (%)	25	60	58
Peak-to-peak carbody lateral acceleration (g)	1.30	0.12	0.12
Maximum carbody lateral acceleration (g)	0.75	0.06	0.07
Lateral carbody acceleration standard deviation (g)	0.13	NA	NA
Maximum carbody vertical acceleration (g)	0.90	0.65	0.65
Maximum vertical suspension deflection (%)	95	74	78

Table 44 shows a comparison of twist and roll simulation predictions for baseline and broken spring. Simulation predictions for broken springs meet S-2043 criteria for the twist and roll regime.

Table 44. Simulation Predictions of the Buffer Railcar with Broken Spring in Twist and Roll

Criterion	Limiting Value	Baseline	Broken spring
Maximum carbody roll angle (degree)	4.0	1.6	1.6
Maximum wheel L/V	0.80	0.11	0.12
Maximum truck side L/V	0.50	0.09	0.09
Minimum vertical wheel load (%)	25	69	70
Peak-to-peak carbody lateral acceleration (g)	1.30	0.27	0.27
Maximum carbody lateral acceleration (g)	0.75	0.15	0.15
Lateral carbody acceleration standard deviation (g)	0.13	NA	NA
Maximum carbody vertical acceleration (g)	0.90	0.16	0.15
Maximum vertical suspension deflection (%)	95	40	53

6.6 Worn Vertical Dampers

The buffer railcar uses four hydraulic vertical dampers. The worn vertical damper cases were modeled with one-half the damping rate of a new damper. The worn characteristic was applied at all four dampers. The worn damper condition was checked for limiting spiral, dynamic curving, pitch and bounce, and twist and roll regimes.

Table 45 shows a comparison of limiting spiral simulation predictions for baseline and worn vertical damper simulations. Simulation predictions for worn vertical dampers meet S-2043 criteria in the limiting spiral regime.

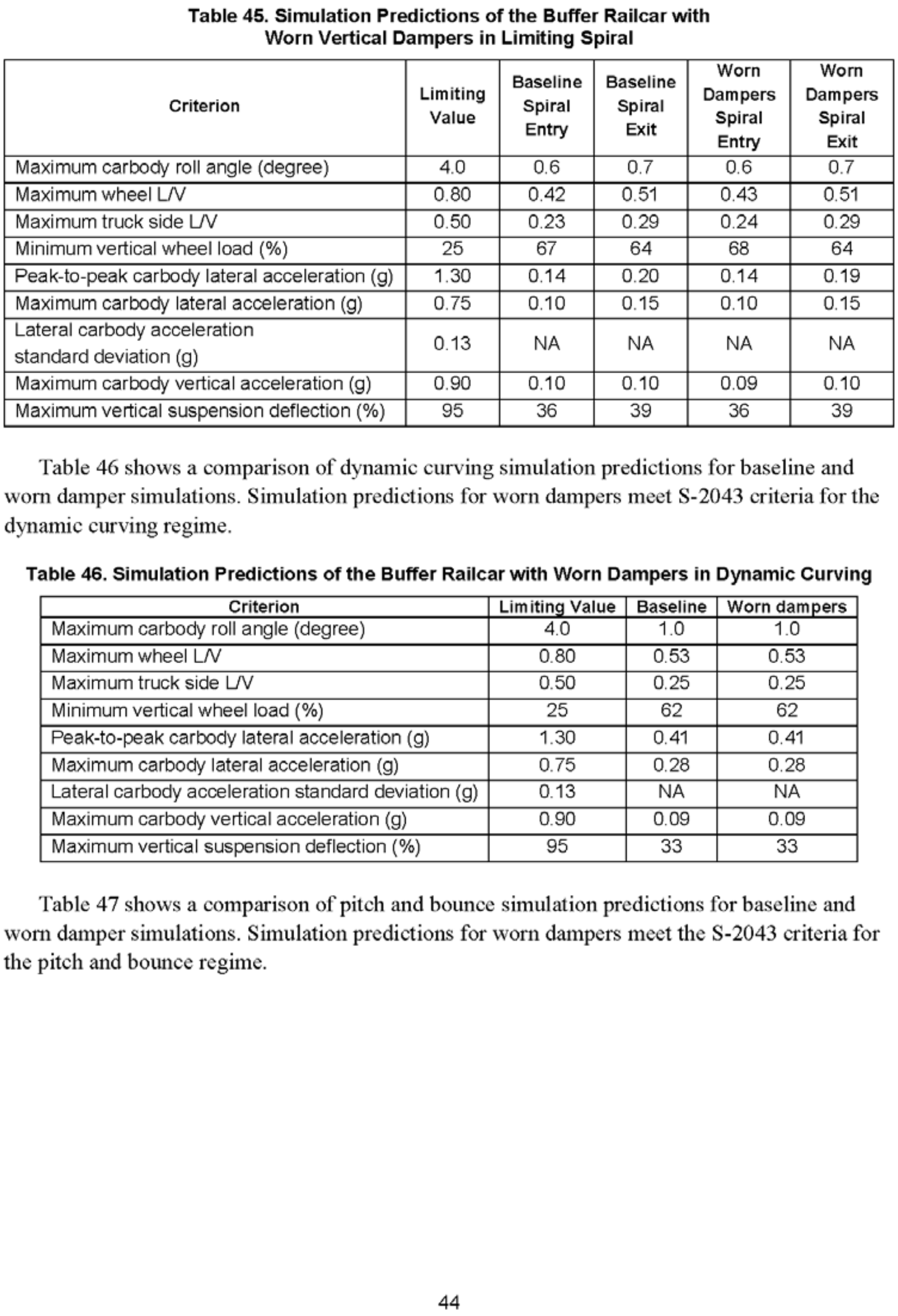


Table 45. Simulation Predictions of the Buffer Railcar with Worn Vertical Dampers in Limiting Spiral

Criterion	Limiting Value	Baseline Spiral Entry	Baseline Spiral Exit	Worn Dampers Spiral Entry	Worn Dampers Spiral Exit
Maximum carbody roll angle (degree)	4.0	0.6	0.7	0.6	0.7
Maximum wheel L/V	0.80	0.42	0.51	0.43	0.51
Maximum truck side L/V	0.50	0.23	0.29	0.24	0.29
Minimum vertical wheel load (%)	25	67	64	68	64
Peak-to-peak carbody lateral acceleration (g)	1.30	0.14	0.20	0.14	0.19
Maximum carbody lateral acceleration (g)	0.75	0.10	0.15	0.10	0.15
Lateral carbody acceleration standard deviation (g)	0.13	NA	NA	NA	NA
Maximum carbody vertical acceleration (g)	0.90	0.10	0.10	0.09	0.10
Maximum vertical suspension deflection (%)	95	36	39	36	39

Table 46 shows a comparison of dynamic curving simulation predictions for baseline and worn damper simulations. Simulation predictions for worn dampers meet S-2043 criteria for the dynamic curving regime.

Table 46. Simulation Predictions of the Buffer Railcar with Worn Dampers in Dynamic Curving

Criterion	Limiting Value	Baseline	Worn dampers
Maximum carbody roll angle (degree)	4.0	1.0	1.0
Maximum wheel L/V	0.80	0.53	0.53
Maximum truck side L/V	0.50	0.25	0.25
Minimum vertical wheel load (%)	25	62	62
Peak-to-peak carbody lateral acceleration (g)	1.30	0.41	0.41
Maximum carbody lateral acceleration (g)	0.75	0.28	0.28
Lateral carbody acceleration standard deviation (g)	0.13	NA	NA
Maximum carbody vertical acceleration (g)	0.90	0.09	0.09
Maximum vertical suspension deflection (%)	95	33	33

Table 47 shows a comparison of pitch and bounce simulation predictions for baseline and worn damper simulations. Simulation predictions for worn dampers meet the S-2043 criteria for the pitch and bounce regime.

Table 47. Simulation Predictions of the Buffer Railcar with Worn Vertical Dampers in Pitch and Bounce

Criterion	Limiting Value	Baseline	Worn dampers
Maximum carbody roll angle (degree)	4.0	0.2	0.2
Maximum wheel L/V	0.80	0.06	0.05
Maximum truck side L/V	0.50	0.05	0.05
Minimum vertical wheel load (%)	25	60	56
Peak-to-peak carbody lateral acceleration (g)	1.30	0.12	0.12
Maximum carbody lateral acceleration (g)	0.75	0.06	0.06
Lateral carbody acceleration standard deviation (g)	0.13	NA	NA
Maximum carbody vertical acceleration (g)	0.90	0.65	0.76
Maximum vertical suspension deflection (%)	95	74	94

Table 48 shows a comparison of twist and roll simulation predictions for baseline and worn damper simulations. Simulation predictions for worn dampers meet S-2043 criteria for twist and roll regime.

Table 48. Simulation Predictions of the Buffer Railcar with Worn Dampers in Twist and Roll

Criterion	Limiting Value	Baseline	Worn dampers
Maximum carbody roll angle (degree)	4.0	1.6	1.8
Maximum wheel L/V	0.80	0.11	0.12
Maximum truck side L/V	0.50	0.09	0.09
Minimum vertical wheel load (%)	25	69	69
Peak-to-peak carbody lateral acceleration (g)	1.30	0.27	0.27
Maximum carbody lateral acceleration (g)	0.75	0.15	0.15
Lateral carbody acceleration standard deviation (g)	0.13	NA	NA
Maximum carbody vertical acceleration (g)	0.90	0.16	0.14
Maximum vertical suspension deflection (%)	95	40	48

7.0 OBSERVATIONS AND CONCLUSIONS

The buffer railcar met S-2043 criteria for all S-2043 regimes except the truck side L/V criterion in buff and draft curving. The cases that did not meet were 250,000 pound draft load cases when the car was coupled between two base cars, or when coupled between the Atlas Cask car and the REV and traveling at 15 mph. The truck side L/V ratio for both of these cases was 0.51. The S-2043 criterion for truck side L/V ratio is 0.50 and the corresponding AAR Chapter 11 criterion is 0.60

TRANSPORTATION TECHNOLOGY CENTER, INC.
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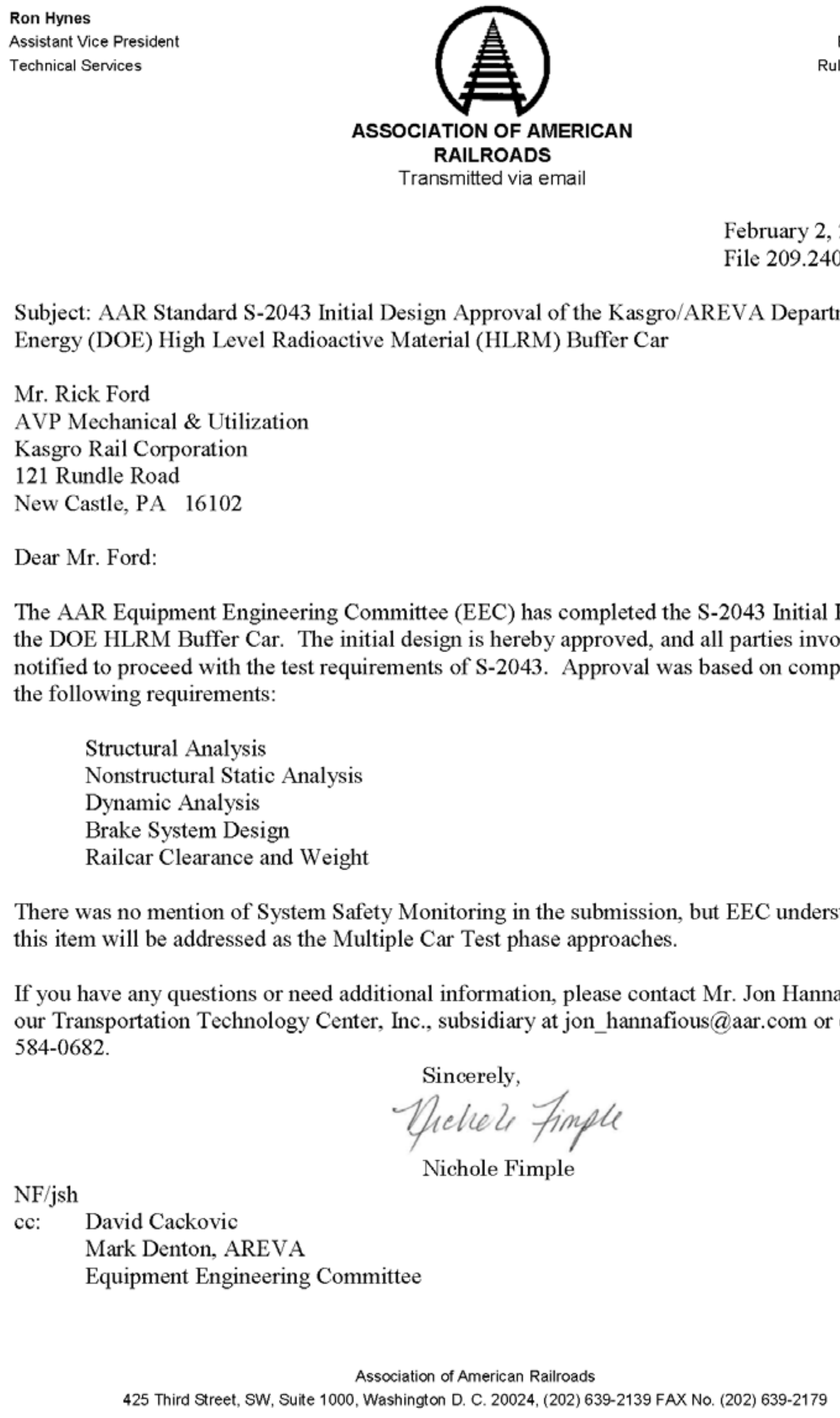
APPENDIX H-8
AAR EEC NOTICE TO PROCEED TO TEST PHASE FOR BUFFER RAILCAR



Ron Hynes
Assistant Vice President
Technical Services

Nichole Fimple
Executive Director
Rules and Standards

ASSOCIATION OF AMERICAN RAILROADS

Transmitted via email

February 2, 2018
File 209.240

Subject: AAR Standard S-2043 Initial Design Approval of the Kasgro/AREVA Department of Energy (DOE) High Level Radioactive Material (HLRM) Buffer Car

Mr. Rick Ford
AVP Mechanical & Utilization
Kasgro Rail Corporation
121 Rundle Road
New Castle, PA 16102

Dear Mr. Ford:

The AAR Equipment Engineering Committee (EEC) has completed the S-2043 Initial Review of the DOE HLRM Buffer Car. The initial design is hereby approved, and all parties involved are notified to proceed with the test requirements of S-2043. Approval was based on completion of the following requirements:

Structural Analysis
Nonstructural Static Analysis
Dynamic Analysis
Brake System Design
Railcar Clearance and Weight

There was no mention of System Safety Monitoring in the submission, but EEC understands that this item will be addressed as the Multiple Car Test phase approaches.

If you have any questions or need additional information, please contact Mr. Jon Hannafious of our Transportation Technology Center, Inc., subsidiary at jon_hannafious@aar.com or (719) 584-0682.

Sincerely,

Nichole Fimple

Nichole Fimple

NF/jsh
cc: David Cackovic
Mark Denton, AREVA
Equipment Engineering Committee

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