TEST DATA REPORT ON

6032-106551-1 REV. 1

SBIR Fatigue Testing Program of Eccentric Cut E-Drilled AL7075-T651 Specimens; No Rectification, X Rectification & Y Rectification

Purchase Order No. 1073-SBIR2

Contact: Mervyn Rudgley
Perfect Point EDM Corp.
15192 Triton Lane
Huntington Beach, CA 92649

Conducted By:
Metcut Research, Inc.

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William T. Grieszmer
Chief Engineer & Laboratory Manager

Jeff Barnett
Test Engineer III

Report prepared by: JAB

Metcut Research, Inc. · 3980 Rosslyn Drive. · Cincinnati, Ohio 45209 · Tel (513) 271-5100 · Fax (513) 271-9511

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All testing was conducted in accordance with customer specified instructions. Exceptions to these instructions, if any, are noted in the report.

Revision Control

Revision Number	Purpose / Changes	Author	Date
0	Initial Release	JAB	6/4/2021
1	Added statements referencing accreditations, fatigue results, fractography specimens, and arrows for initiations sites on post-test photos	JAB	6/16/2021

Project Scope:

In accordance with customer requests referenced in the supplied document *RFP Rectification Fatigue v0.2.docx*, a fatigue testing project was performed consisting of (117) total tests. All test specimen manufacturing and material procurement was performed by Metcut Research. Table 1 details the test quantities, variables and responsibilities of this fatigue project. All testing was performed per ASTM E466-15 at room temperature ambient conditions utilizing a 15 Hz, sine wave with a R ratio of 0.1 for cyclic load application.

Total Tests	Test Designation	IDs	Nominal Fastener Installation / Removal	Oversize Rectification	Oversize Fastener Installation / Removal
9	Set-up	SU 1 - 9	Metcut - 4/26/21	N/A	N/A
18	Nominal Baseline	NB 1 - 18	Metcut - 4/29/21	N/A	N/A
18	Baseline X Oversized	BX 1 - 18	N/A	Metcut	Metcut - 5/7/21
18	Baseline Y Oversized	BY 1 - 18	N/A	Metcut	Metcut - 5/17/21
18	0.012" Eccentric Cut No Rectification	ECNR 1 - 18	PPEDM	N/A	N/A
18	0.015" Eccentric Cut - X Rectification	XREC 1 - 18	PPEDM	Metcut	Metcut - 5/10/21
18	0.021" Eccentric Cut - Y Rectification	YREC 1 - 18	PPEDM	Metcut	Metcut - 5/17/21

117 Total

Table 1: Configuration Summary

The nine (9) Set-up specimens were tested to generate a baseline S-N curve from which three (3) stress levels were selected to target fatigue lives of 25k, 100k, & 250k cycles. The following net stress levels were applied to each group:

Target Life	Net Stress (ksi)
25k	34
100k	28
250k	26

Six (6) replicates from each of the groups (excluding set-up) were tested at the three (3) stress levels established from the baseline S-N curve.

Three (3) 50-kip axial test stations identified as #23, #62 & #63 were employed to facilitate fatigue loading (see Figure 1: Frame 62 pictured). Test frame calibrations are included in Appendix A. The test station components included a closed-loop servo hydraulic actuator, load cell calibrated per ASTM E4-20, a LVDT calibrated per ASTM E2309/E2309M-20 Class B, hydraulic wedge grips aligned per ASTM E1012-19, control & data acquisition software and digital temperature monitoring.

The aim of this project was to provide fatigue data for the comparison of baseline nominal 3/16" countersunk holes (suitable for HI LOK HL11-6 fasteners), X oversized (1/64") & Y oversized (1/32") to their respective E-Drilled and rectified counterparts. These results are intended to aid the customer in their confirmation that the E-Drill fastener removal and subsequent hole rectification does not result in a larger fatigue strength knock-down factor (KDF) than conventional rectified fastener damage removal activity.

Metcut is accredited to ISO/IEC 17025:2017 and NADCAP AC7101. Impeccable Workmanship and quality are verified through both internal and external auditing processes. All results and data contained herein are valid and scientifically accurate. The fatigue performance of the specimens tested in this project regarding data scatter would be considered typical to better than expected as the groups showed three distinct lifetimes and at the lowest stress level, fractures were observed on all specimens and no specimens reached a removal point of 1.3 million cycles (24 hours runtime @ 15 Hz).

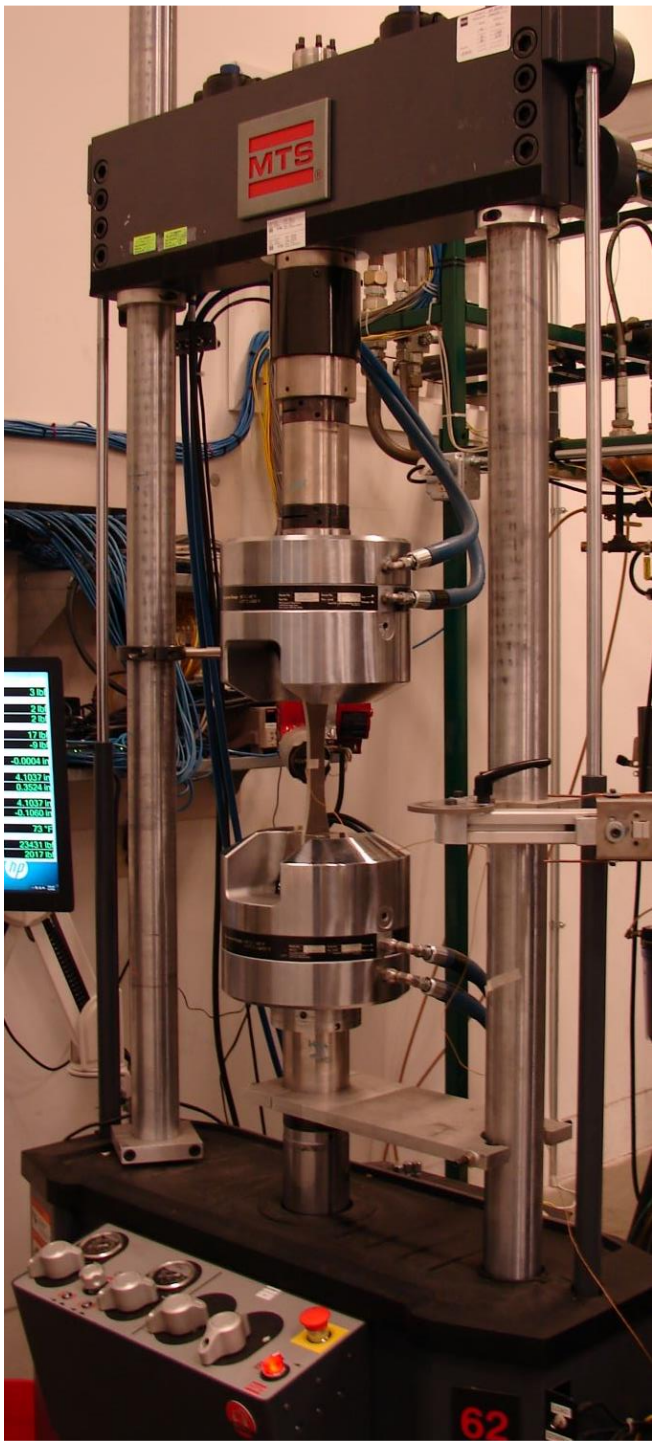


Figure 1: Fatigue Test Station

Specimen Manufacturing Details:

(126) Total specimens were manufactured by Metcut Research from 0.25" thick sheets of 24" x 24" aluminum 7075-T651 (material certifications are included in Appendix B). The specimen geometry consisted of a dogbone coupon with three (3) hole variations:

- Drawing #106551-1; Nominal baseline: 3/16" through hole +0.002/-0.000", 100° countersink (see Figure 2)
- Drawing #106551-2; X Oversized: 13/64" through hole +0.002/-0.000", 100° countersink (see Figure 3)
- Drawing #106551-3; Y Oversized: 7/32" through hole +0.002/-0.000", 100° countersink (see Figure 4)

Finished specimens from the ECNR, XREC & YREC (drawing #106551-1) groups were provided to PPEDM for fastener installation and removal prior to testing at Metcut Research. The holes of the XREC & YREC coupons were rectified to their respective oversized hole configurations by Metcut prior to testing after return from PPEDM. Table 2 shows the total specimen quantities manufactured for this project.

TEST DESIGNATION	Drawing #	Total Coupons	IDs
Setup	106551-1	9	SU 1 thru 9
Nominal baseline	106551-1	19	NB 1 thru 19
Baseline X-oversize	106551-2	19	BX 1 thru 19
Baseline Y-oversize	106551-3	19	BY t thru 19
0.012" Eccentric cut – no rectification	106551-1	19	ECNR 1 thru 19
0.015" Eccentric cut – X rectification	106551-1 (2)	19	XREC 1 thru 19
0.021" Eccentric cut – Y rectification	106551-1 (3)	19	YREC 1 thru 19
Spares	106551-1	3	A1 thru 3
TOTAL		126	

Table 2: Specimen Quantities

Fastener installation/removal for the SU, NB, BX, BY and post rectified XREC & YREC specimens was performed by Metcut prior to testing per the following procedure:

- The fastener, hole and countersink were inspected to ensure there were no burrs or debris.
- The fastener was installed in the coupon, verifying a sliding fit. The fastener was not permitted to rotate in the coupon.
- A spacer washer and nut were installed and a 5/64" hex key was used to keep the fastener from rotating.
- All nuts were torqued to 40 inch-pounds using a crow's foot and torque wrench #18065.
- The fastener, nut & spacer was removed while continuing to ensure the fastener did not rotate. Fasteners, spacers and nuts were reused.

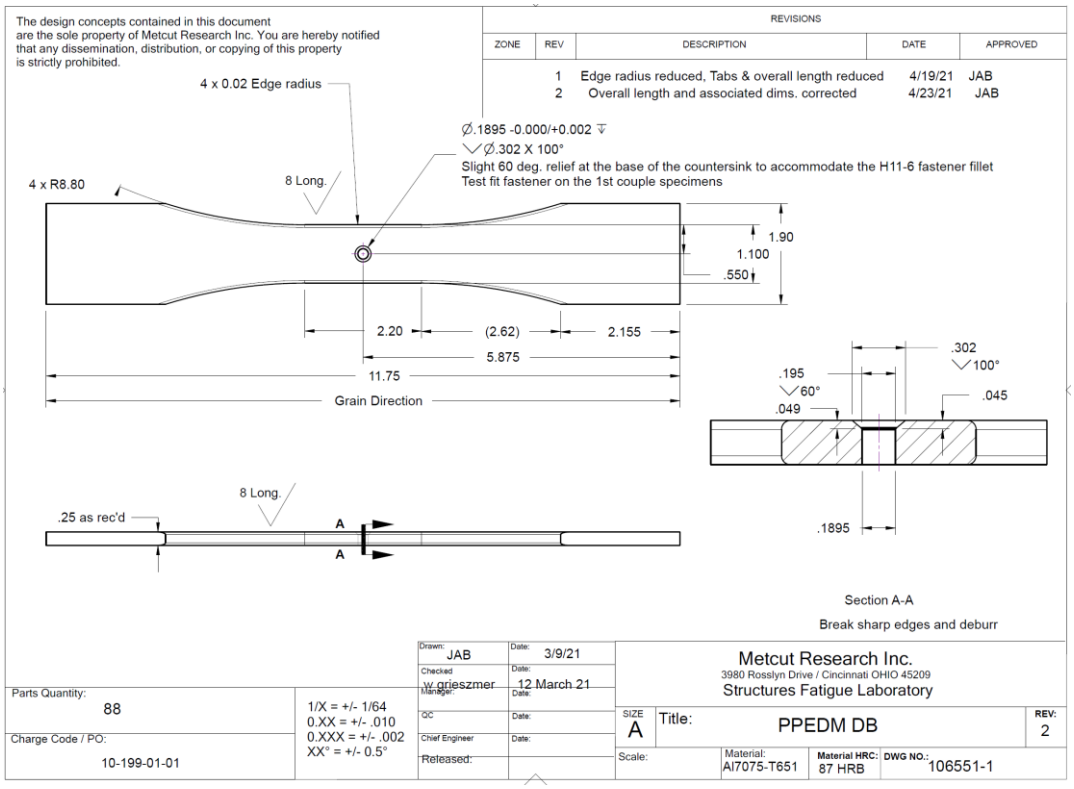


Figure 2: Drawing 106551-1 Nominal Hole

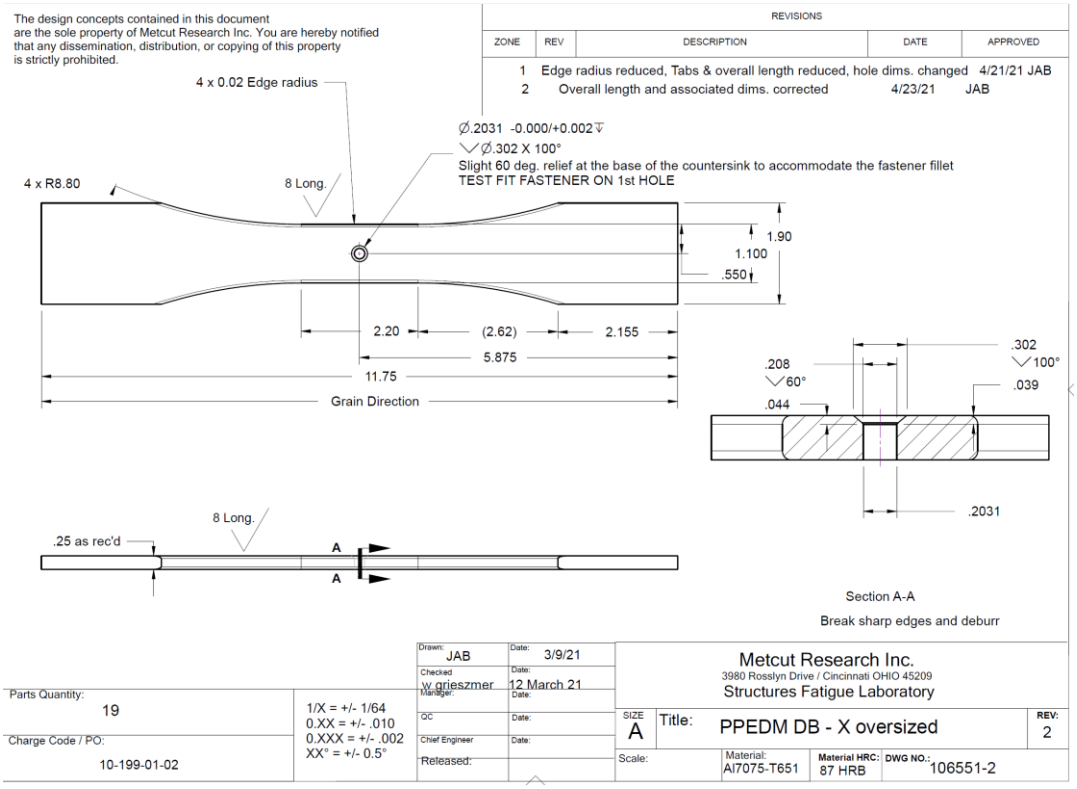


Figure 3: Drawing 106551-2 X Oversized

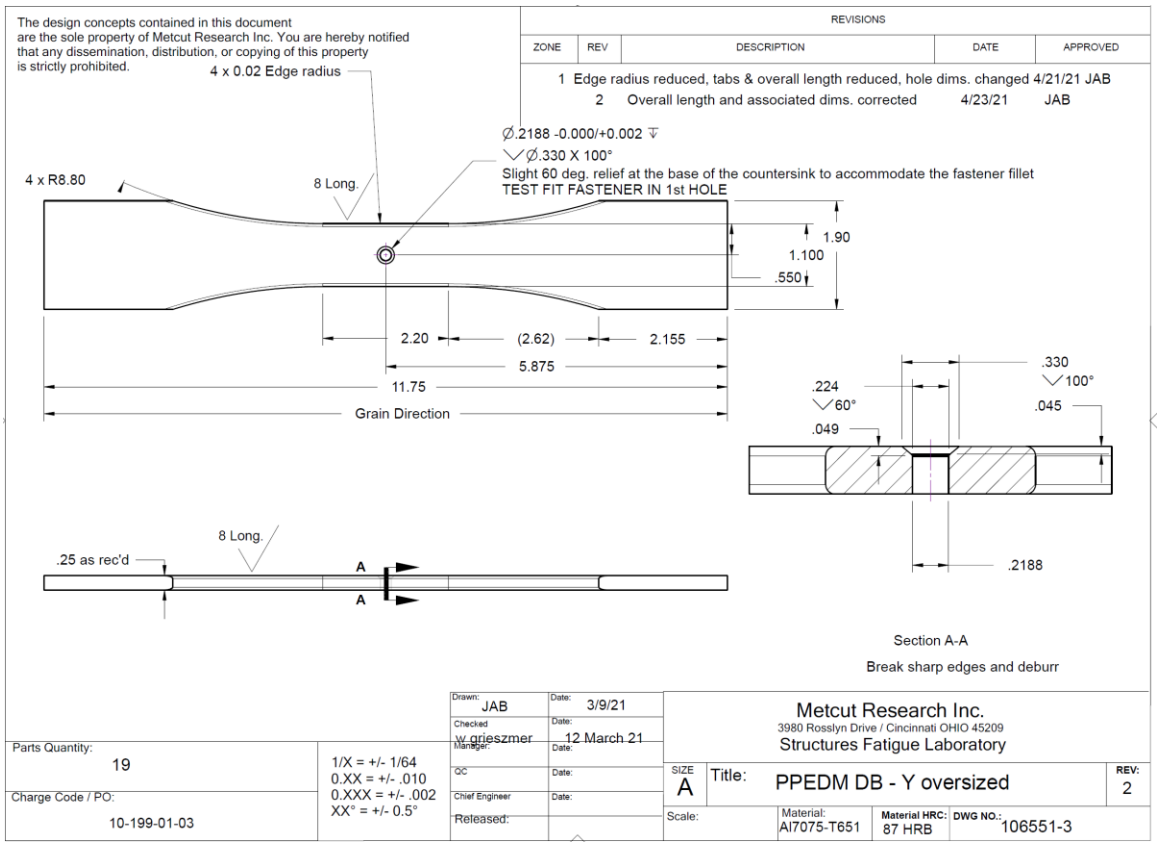


Figure 4: 106551-3 Y Oversize

Fatigue Testing Results

Post-test fracture surfaces of all specimens were reviewed under 14x magnification to provide additional detail as to the initiation sites and to verify the random assortment of sites/lack of induced failures. The following codes were used to classify the fractures:

- S = Surface initiation
- SS = Sub-surface initiation
- L = Initiation left side of hole as oriented in the test frame
- R = Initiation right side of hole as oriented in the test frame
- B = Initiation sites on both sides of hole
- H = Initiation in the through hole
- CSK = Initiation in/at countersink
- F = Initiation site on the rear face, opposite CSK
- P = Facture propagation is predominately oriented with the eccentric cut
- N/A = Not available

Prior to installation of the specimens in the test frame, the orientation was marked on the specimens (top, bottom, left, right). For fracture evaluation left/right orientation is based on the observer facing the countersink. PPEDM marked the direction of the eccentric cut via a black dot on the tab of the ECNR, XREC & YREC specimens. Particular attention was paid to any indication that the fractures propagated in the direction of the eccentric cut (code P). Table 3 is a condensed summary of the fatigue results.

Specimen Group	Net Stress (ksi)	Average Nf - Cycles	P Code per Group
NB	34.0	20,352	17% (3 out of 18)
ECNR	34.0	19,840	
NB	28.0	61,080	
ECNR	28.0	56,657	
NB	26.0	292,834	
ECNR	26.0	205,983	
BX	34.0	23,292	22% (4 out of 18)
XREC	34.0	32,391	
BX	28.0	87,520	
XREC	28.0	88,842	
BX	26.0	285,575	
XREC	26.0	368,897	
BY	34.0	20,340	56% (10 out of 18)
YREC	34.0	20,688	
BY	28.0	60,284	
YREC	28.0	57,153	
BY	26.0	128,454	
YREC	26.0	170,112	

Table 3: Fatigue Results Summary

Additionally, six (6) specimens were allocated for fracture analysis and SEM by the Metcut Materials Laboratory. The following specimens were selected for comparison and the results are available in their respective supplemental reports:

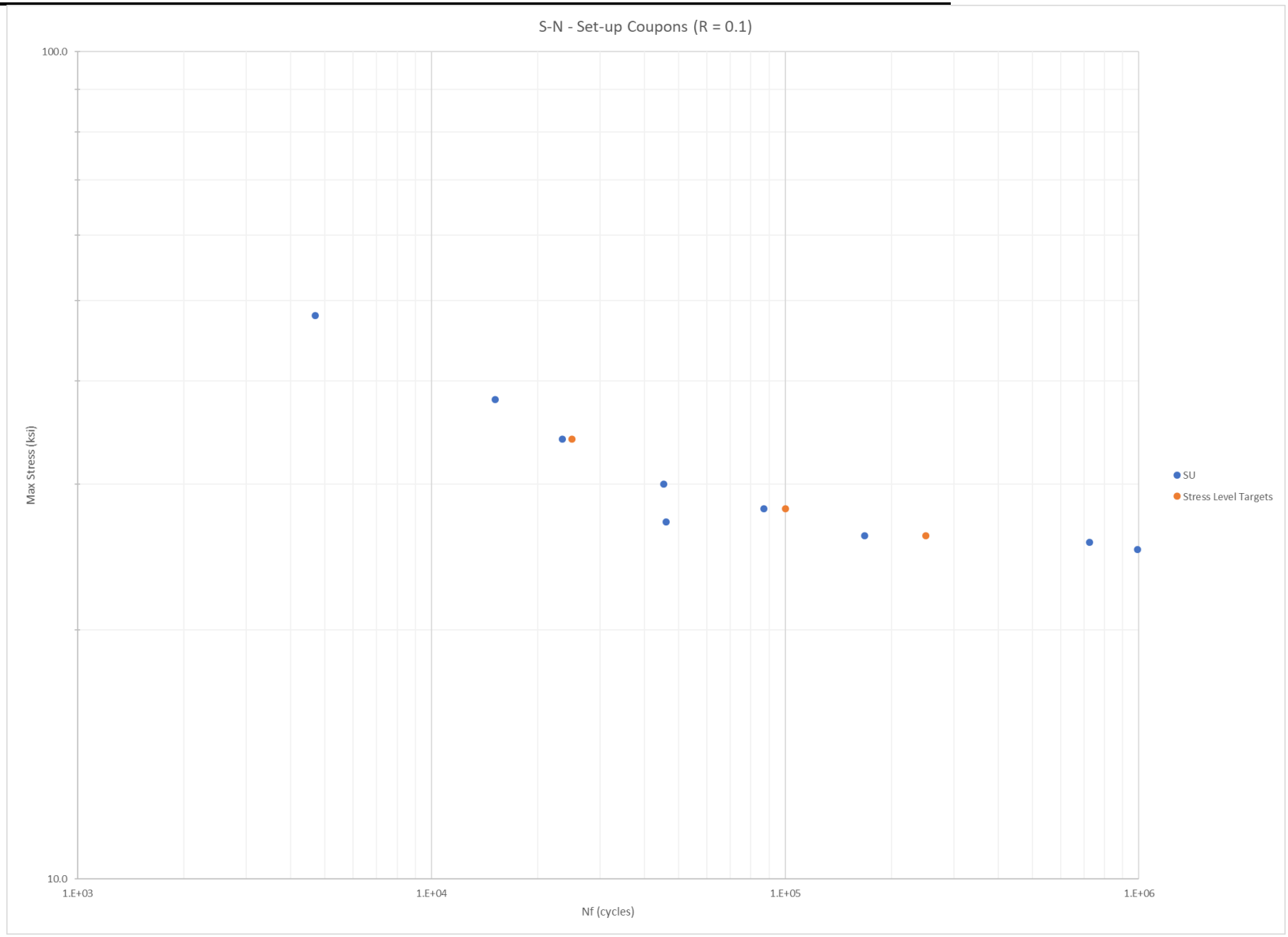
- NB 9 & ECNR 8; Report 106551-2
- BX 7 & XREC 7; Report 106551-3
- BY 14 & YREC 14; Report 106551-4

Fatigue Testing Results – Set-up:

Project: 6032-106551
Material: 7075-T651
Test Specification: ASTM E466-16
Drawing Number: 106551-1 Rev. 2
Description: Set-up: stress level determination

Test Temperature (°F): 73
Waveform: Sine
Frequency (Hz): 15
Stress Ratio: R = 0.1
Removal Point: Fracture / 24 hours
Fastener Installation/Removal: Metcut 4/26/21; 40 in*lbs.

Test Number	Coupon ID	Width (in)	Thickness (in)	Hole Diameter (in)	Net Area (in^2)	Net Stress (ksi)	Stress Amplitude (ksi)	Max. Load (lbs.)	Min. Load (lbs.)	Nf - Cycles	Result	Failure Location / Comment	Test Operator	Test Station	Log Number
1	SU 1	1.1016	0.2472	0.1905	0.2252	48.0	21.60	10,810	1,081	4,688	Failure	S, B, H	BJS	63	180590-1
2	SU 2	1.0999	0.2477	0.1905	0.2253	38.0	17.10	8,561	856	15,142	Failure	S, B, H	BJS	63	180591-1
3	SU 3	1.1012	0.2475	0.1905	0.2254	**28.0**	12.60	6,311	631	87,058	Failure	S, L, H	JZR	63	180593-1
4	SU 4	1.1003	0.2480	0.1906	0.2256	25.0	11.25	5,640	564	990,597	Failure	S, L, H	JZR	63	180594-1
5	SU 5	1.1015	0.2474	0.1906	0.2254	30.0	13.50	6,762	676	45,348	Failure	S, B, CSK	WS/CW	62	180622-1
6	SU 6	1.1016	0.2477	0.1904	0.2257	27.0	12.15	6,094	609	46,005	Failure	S, L, CSK	CW	62	180636-1
7	SU 7	1.1007	0.2473	0.1904	0.2251	**34.0**	15.30	7,653	765	23,420	Failure	S, L, H / S, R, CSK	JZR	63	180638-1
8	SU 8	1.1019	0.2477	0.1905	0.2258	**26.0**	11.70	5,871	587	167,717	Failure	S, R, H	JZR	63	180640-1
9	SU 9	1.1016	0.2470	0.1904	0.2251	25.5	11.48	5,740	574	726,156	Failure	S, R, CSK	JZR	62	180658-1


S-N - Set-up Coupons (R = 0.1)
100.0
10.0
Max Stress (ksi)
1.E+03
1.E+04
1.E+05
1.E+06
Nf (cycles)
SU
Stress Level Targets

Fatigue Testing Results – Nominal Baseline & Eccentric Cut No Rectification:

Project: 6032-106551
Material: 7075-T651
Test Specification: ASTM E466-16
Drawing Number: 106551-1 Rev. 2

Description: **Nominal Baseline**

Test Temperature (°F): 73
Waveform: Sine
Frequency (Hz): 15
Stress Ratio: R = 0.1

Removal Point: Fracture / 24 hours

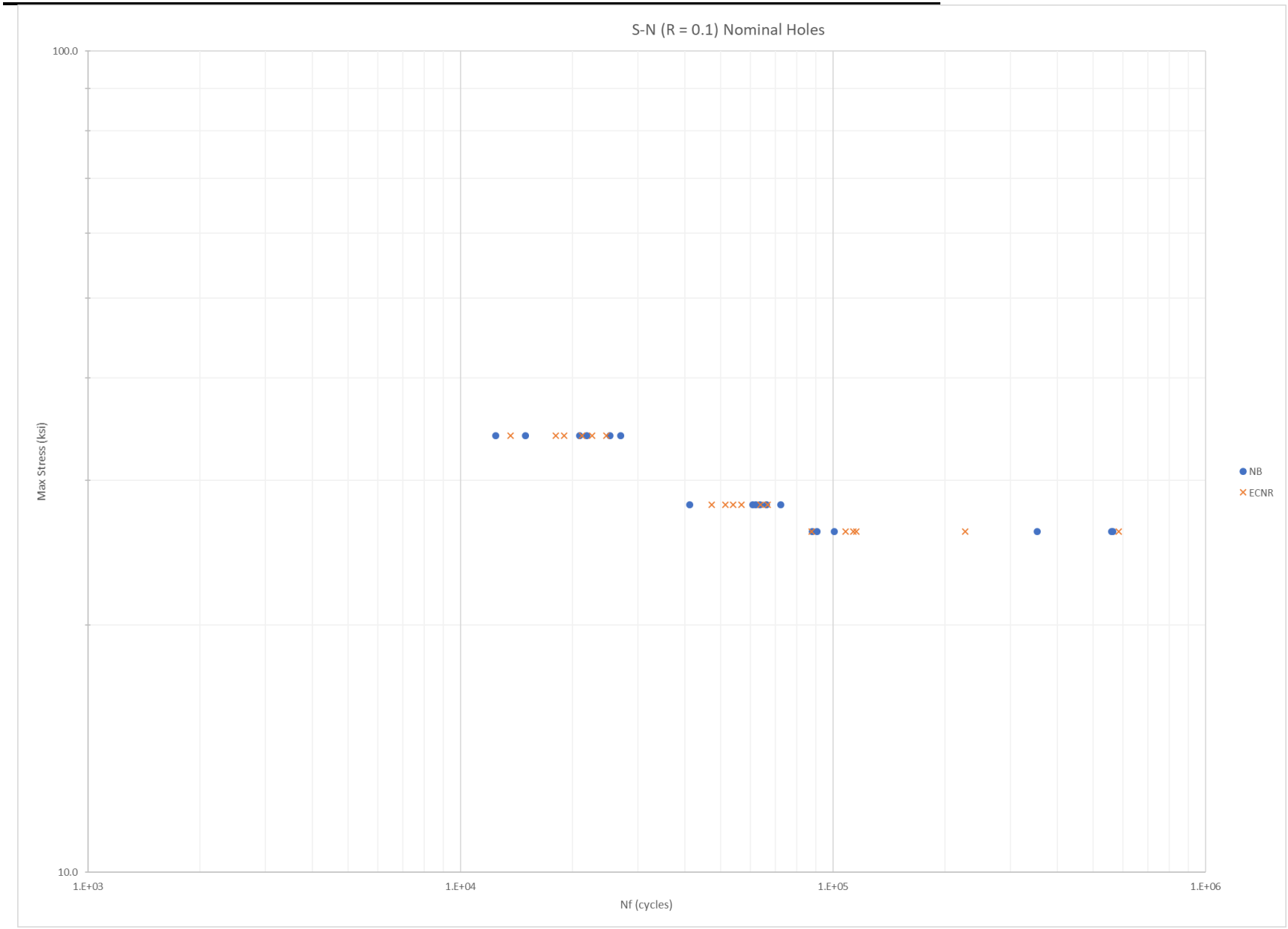
Fastener Installation/Removal: Metcut 4/29/21; 40 in*lbs.

Test Number	Coupon ID	Width (in)	Thickness (in)	Hole Diameter (in)	Net Area (in^2)	Net Stress (ksi)	Stress Amplitude (ksi)	Max. Load (lbs.)	Min. Load (lbs.)	Nf - Cycles	Result	Failure Location / Comment	Test Operator	Test Station	Log Number
10	NB 1	1.1003	0.2470	0.1901	0.2248	34.0	15.30	7,643	764	25,162	Failure	S, B, H	BG	62	182274-1
11	NB 2	1.1019	0.2475	0.1897	0.2258	34.0	15.30	7,677	768	12,440	Failure	S, B, H	BG	63	182275-1
12	NB 3	1.1011	0.2479	0.1902	0.2258	34.0	15.30	7,677	768	20,892	Failure	S, B, H	JZR	62	180705-1
13	NB 4	1.1013	0.2469	0.1907	0.2248	34.0	15.30	7,643	764	26,902	Failure	S, L, CSK / S, R, H	JZR	63	180706-1
14	NB 5	1.1015	0.2463	0.1901	0.2245	34.0	15.30	7,633	763	14,921	Failure	S, R, H	JZR	62	180711-1
15	NB 6	1.1019	0.2483	0.1904	0.2263	34.0	15.30	7,694	769	21,792	Failure	S, L, H / S, R, CSK	JZR	63	180712-1
16	NB 7	1.1008	0.2478	0.1905	0.2256	28.0	12.60	6,317	632	60,949	Failure	S, R, H	JAL	62	180719-1
17	NB 8	1.1018	0.2477	0.1911	0.2256	28.0	12.60	6,317	632	62,014	Failure	S, L, CSK	JAL	63	180720-1
19	NB 9	1.1010	0.2470	0.1909	0.2248	28.0	12.60	6,294	629	63,579	Failure	S, L, H / S, R, CSK	CW	23	180740-1
18	NB 10	1.1004	0.2477	0.1908	0.2253	28.0	12.60	6,308	631	66,284	Failure	S, B, CSK	JAL	63	180789-1
20	NB 11	1.1010	0.2473	0.1909	0.2251	28.0	12.60	6,303	630	41,303	Failure	S, B, CSK	JAL	62	180790-1
21	NB 12	1.1011	0.2477	0.1910	0.2254	28.0	12.60	6,311	631	72,351	Failure	S, L, H	JAL	63	180791-1
23	NB 13	1.0999	0.2472	0.1908	0.2247	26.0	11.70	5,842	584	559,843	Failure	S, R, H	JAL	62	180793-1
22	NB 14	1.1015	0.2480	0.1908	0.2259	26.0	11.70	5,873	587	87,978	Failure	S, L, CSK	WS	23	180784-1
24	NB 15	1.1006	0.2469	0.1909	0.2246	26.0	11.70	5,840	584	90,623	Failure	S, L, CSK	JAL	63	180794-1
25	NB 16	1.1003	0.2477	0.1908	0.2253	26.0	11.70	5,858	586	100,760	Failure	S, B, H	WS	23	180786-1
26	NB 17	1.1001	0.2472	0.1909	0.2248	26.0	11.70	5,845	585	564,653	Failure	S, L, CSK	JAL	62	180937-1
27	NB 18	1.0998	0.2479	0.1908	0.2253	26.0	11.70	5,858	586	353,145	Failure	S, L, H	JAL	63	180930-1

Project: 6032-106551
Material: 7075-T651
Test Specification: ASTM E466-16
Drawing Number: 106551-1 Rev. 2
Description: **0.012" Eccentric Cut – No Rectification**

Test Temperature (°F): 73
Waveform: Sine
Frequency (Hz): 15
Stress Ratio: R = 0.1
Removal Point: Fracture / 24 hours
Fastener Installation/Removal: PPEDM

Test Number	Coupon ID	Width (in)	Thickness (in)	Hole Diameter (in)	Net Area (in^2)	Net Stress (ksi)	Stress Amplitude (ksi)	Max. Load (lbs.)	Min. Load (lbs.)	Nf - Cycles	Result	Failure Location / Comment	Eccentric Cut Test Orientation (L/R)	Test Operator	Test Station	Log Number
28	ECNR 1	1.1010	0.2467	0.1877	0.2253	34.0	15.30	7,660	766	21,161	Failure	S, R, H / S, L, CSK	N/A	BAB	23	180852-1
29	ECNR 2	1.1015	0.2468	0.1904	0.2249	34.0	15.30	7,647	765	24,691	Failure	S, R, H / S, L, CSK	R	BAB	23	180923-1
30	ECNR 3	1.1003	0.2475	0.1880	0.2258	34.0	15.30	7,677	768	19,017	Failure	S, B, H, P	L	BAB	23	180928-1
31	ECNR 4	1.1010	0.2465	0.1895	0.2247	34.0	15.30	7,640	764	13,630	Failure	S, L, CSK / S, R, H	R	JZR	23	180929-1
32	ECNR 5	1.1007	0.2466	0.1896	0.2247	34.0	15.30	7,640	764	22,530	Failure	S, B, H	L	JZR	63	180931-1
33	ECNR 6	1.1014	0.2474	0.1896	0.2256	34.0	15.30	7,670	767	18,008	Failure	S, B, H	L	JZR	23	180932-1
34	ECNR 7	1.1011	0.2476	0.1891	0.2258	28.0	12.60	6,322	632	47,187	Failure	S, B, H	L	BAB	63	180938-1
35	ECNR 8	1.1017	0.2471	0.1900	0.2253	28.0	12.60	6,308	631	63,905	Failure	S, L, H / S, R, CSK	R	BAB	23	180939-1
36	ECNR 9	1.1014	0.2471	0.1893	0.2254	28.0	12.60	6,311	631	66,699	Failure	S, R, H	L	JAL	62	180940-1
37	ECNR 10	1.1006	0.2468	0.1898	0.2248	28.0	12.60	6,294	629	56,748	Failure	S, B, H	R	JAL	63	182273-1
38	ECNR 11	1.1002	0.2471	0.1900	0.2249	28.0	12.60	6,297	630	51,523	Failure	S, B, H	L	BAB	23	180962-1
39	ECNR 12	1.1000	0.2466	0.1899	0.2244	28.0	12.60	6,283	628	53,879	Failure	S, B, H	R	BAB	23	180972-1
40	ECNR 13	1.1004	0.2469	0.1894	0.2249	26.0	11.70	5,847	585	108,298	Failure	S, B, H	L	BG	62	180978-1
41	ECNR 14	1.0998	0.2466	0.1895	0.2245	26.0	11.70	5,837	584	87,821	Failure	S, L, CSK	R	JAL	63	181091-1
42	ECNR 15	1.1013	0.2471	0.1898	0.2252	26.0	11.70	5,855	586	113,278	Failure	S, R, H, P	R	BAB	23	181022-1
43	ECNR 16	1.1011	0.2471	0.1900	0.2251	26.0	11.70	5,853	585	584,731	Failure	S, L, H, P	L	BAB	63	181060-1
44	ECNR 17	1.1011	0.2471	0.1900	0.2251	26.0	11.70	5,853	585	115,545	Failure	S, L, H	R	BAB	23	181099-1
45	ECNR 18	1.0998	0.2474	0.1896	0.2252	26.0	11.70	5,855	586	226,222	Failure	S, L, H	R	BAB	23	181159-1


S-N (R = 0.1) Nominal Holes
100.0
10.0
Max Stress (ksi)
1.E+03
1.E+04
1.E+05
1.E+06
Nf (cycles)
NB
ECNR

Fatigue Testing Results – Baseline X & X Rectified:

Project: 6032-106551
Material: 7075-T651
Test Specification: ASTM E466-16
Drawing Number: 106551-1 Rev. 2
Description: **Baseline X Rectification (1/64" Oversized)**

Test Temperature (°F): 73
Waveform: Sine
Frequency (Hz): 15
Stress Ratio: R = 0.1
Removal Point: Fracture / 24 hours

Fastener Installation/Removal: Metcut 5/10/21; 40 in*lbs.

Test Number	Coupon ID	Width (in)	Thickness (in)	Hole Diameter (in)	Net Area (in^2)	Net Stress (ksi)	Stress Amplitude (ksi)	Max. Load (lbs.)	Min. Load (lbs.)	Nf - Cycles	Result	Failure Location / Comment	Test Operator	Test Station	Log Number
64	BX 1	1.1011	0.2480	0.2043	0.2224	34.0	15.30	7,562	756	23,595	Failure	S, L, H	CW	63	181425-1
65	BX 2	1.1009	0.2474	0.2042	0.2218	34.0	15.30	7,541	754	23,319	Failure	S, B, CSK	RB	62	181423-1
66	BX 3	1.0998	0.2476	0.2042	0.2218	34.0	15.30	7,541	754	23,844	Failure	S, B, CSK	CW/BG	63	181462-1
67	BX 4	1.1003	0.2472	0.2041	0.2215	34.0	15.30	7,531	753	20,301	Failure	S, B, CSK	BG	62	181521-1
68	BX 5	1.1000	0.2473	0.2041	0.2216	34.0	15.30	7,534	753	26,113	Failure	S, B, H	CW	63	181501-1
69	BX 6	1.1004	0.2471	0.2041	0.2215	34.0	15.30	7,531	753	22,580	Failure	S, L, CSK / S, R, H	RB	62	181525-1
70	BX 7	1.1007	0.2475	0.2041	0.2219	28.0	12.60	6,213	621	58,299	Failure	S, B, CSK	RB	63	181527-1
71	BX 8	1.1011	0.2481	0.2041	0.2225	28.0	12.60	6,230	623	54,133	Failure	S, L, CSK	BAB	23	181529-1
72	BX 9	1.1007	0.2475	0.2042	0.2219	28.0	12.60	6,213	621	128,729	Failure	S, L, H / S, R, CSK	RB	62	181530-1
73	BX 10	1.1010	0.2476	0.2042	0.2220	28.0	12.60	6,216	622	83,312	Failure	S, L, H	RB	63	181538-1
74	BX 11	1.1007	0.2472	0.2041	0.2216	28.0	12.60	6,205	620	123,710	Failure	S, L, H	RB	62	181597-1
75	BX 12	1.1014	0.2473	0.2041	0.2219	28.0	12.60	6,213	620	76,937	Failure	S, L, CSK/H	BAB	23	181598-1
76	BX 13	1.1005	0.2476	0.2042	0.2219	26.0	11.70	5,769	577	117,724	Failure	S, L, CSK	RB	63	181606-1
77	BX 14	1.1011	0.2475	0.2041	0.2220	26.0	11.70	5,772	577	101,390	Failure	S, R, H	BAB	23	181637-1
78	BX 15	1.1015	0.2479	0.2040	0.2225	26.0	11.70	5,785	579	105,753	Failure	S, R, H	RB	62	181675-1
79	BX 16	1.1011	0.2471	0.2041	0.2216	26.0	11.70	5,762	576	282,865	Failure	S, L, CSK/H	RB	63	181676-1
80	BX 17	1.1011	0.2474	0.2040	0.2219	26.0	11.70	5,769	577	90,223	Failure	S, B, H	BAB	23	181714-2
81	BX 18	1.1010	0.2472	0.2040	0.2217	26.0	11.70	5,764	576	1,015,497	Failure	S, L, CSK/H	RB	62	181715-1

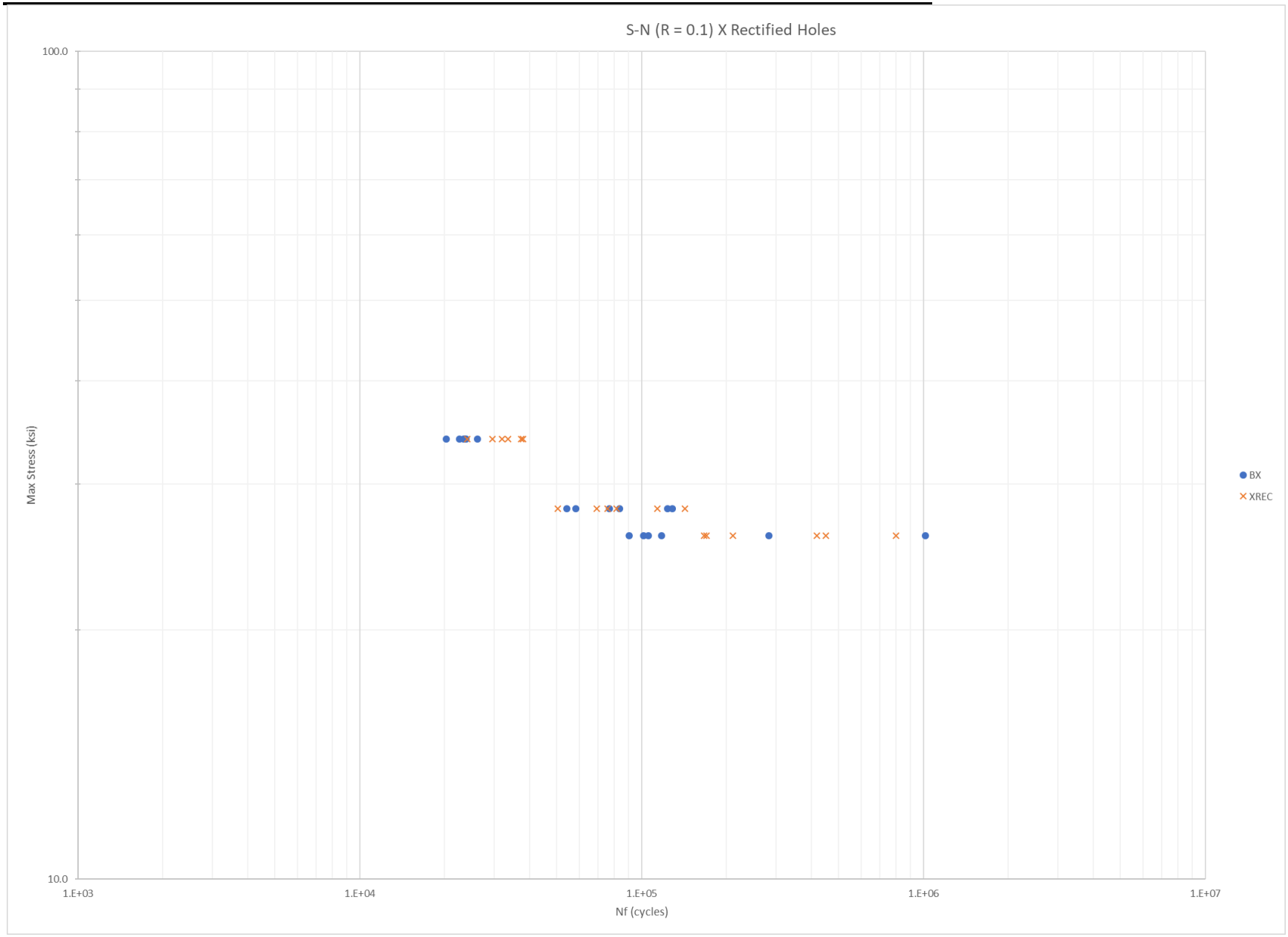
METCUT RESEARCH, INC.
Structures Laboratory

Project: 6032-106551
Material: 7075-T651
Test Specification: ASTM E466-16
Drawing Number: 106551-1 Rev. 2
Description: **0.015" Eccentric Cut – X Rectification (1/64" Oversized)**

Test Temperature (°F): 73
Waveform: Sine
Frequency (Hz): 15
Stress Ratio: R = 0.1
Removal Point: Fracture / 24 hours

Fastener Installation/Removal: Metcut 5/7/21; 40 in*lbs.

Test Number	Coupon ID	Width (in)	Thickness (in)	Hole Diameter (in)	Net Area (in^2)	Net Stress (ksi)	Stress Amplitude (ksi)	Max. Load (lbs.)	Min. Load (lbs.)	Nf - Cycles	Result	Failure Location / Comment	Eccentric Cut Test Orientation (L/R)	Test Operator	Test Station	Log Number
46	XREC 1	1.1017	0.2477	0.2050	0.2221	34.0	15.30	7,551	755	24,020	Failure	S, B, H	R	BAB	23	181186-1
47	XREC 2	1.1008	0.2474	0.2047	0.2217	34.0	15.30	7,538	754	37,887	Failure	S, B, CSK	R	RB	63	181246-1
49	XREC 3	1.1014	0.2479	0.2043	0.2224	34.0	15.30	7,562	756	31,952	Failure	S, B, CSK	L	RB	63	181309-1
50	XREC 4	1.1006	0.2466	0.2042	0.2211	34.0	15.30	7,517	752	37,379	Failure	S, B, H	L	RB	63	181319-1
51	XREC 5	1.1013	0.2477	0.2042	0.2222	34.0	15.30	7,555	755	33,501	Failure	S, B, CSK	L	RB	63	181325-1
52	XREC 6	1.1013	0.2480	0.2041	0.2225	34.0	15.30	7,565	757	29,604	Failure	S, B, CSK	L	RB	63	181327-1
53	XREC 7	1.1016	0.2475	0.2043	0.2221	28.0	12.60	6,219	622	69,362	Failure	S, B, CSK, P	L	RB	63	181329-1
54	XREC 8	1.1007	0.2473	0.2041	0.2217	28.0	12.60	6,208	621	50,419	Failure	S, R, H / S, L, F, H	L	RB	63	181332-1
56	XREC 9	1.1016	0.2475	0.2043	0.2221	28.0	12.60	6,219	622	113,548	Failure	S, L, CSK, P	L	RB	63	181336-1
57	XREC 10	1.1017	0.2478	0.2042	0.2224	28.0	12.60	6,227	623	142,680	Failure	S, R, H	L	BAB	63	181362-1
58	XREC 11	1.1013	0.2471	0.2042	0.2224	28.0	12.60	6,208	621	75,651	Failure	S, B, CSK	L	BAB	23	181363-1
60	XREC 12	1.1009	0.2479	0.2041	0.2223	28.0	12.60	6,224	622	81,393	Failure	S, R, CSK, P	R	BAB	63	181375-1
55	XREC 13	1.1017	0.2469	0.2041	0.2216	26.0	11.70	5,762	576	210,744	Failure	S, L, CSK, P	L	CRC	23	181331-7
48	XREC 14	1.1006	0.2462	0.2041	0.2207	26.0	11.70	5,738	574	166,119	Failure	S, L, CSK	N/A	CRC	23	181247-1
59	XREC 15	1.1013	0.2466	0.2041	0.2212	26.0	11.70	5,751	575	449,724	Failure	S, R, CSK	L	BAB	23	181366-1
61	XREC 16	1.1008	0.2462	0.2041	0.2208	26.0	11.70	5,741	574	798,945	Failure	S, R, H	L	BAB	23	181378-1
62	XREC 17	1.1013	0.2471	0.2041	0.2217	26.0	11.70	5,764	576	418,121	Failure	S, L, CSK	R	BAB	63	181379-1
63	XREC 18	1.1010	0.2466	0.2042	0.2212	26.0	11.70	5,751	575	169,726	Failure	S, R, CSK	L	RB	62	181381-1


S-N (R = 0.1) X Rectified Holes
100.0
10.0
Max Stress (ksi)
1.E+03
1.E+04
1.E+05
1.E+06
1.E+07
Nf (cycles)
BX
XREC

Fatigue Testing Results – Baseline Y & Y Rectified:

Project: 6032-106551
Material: 7075-T651
Test Specification: ASTM E466-16
Drawing Number: 106551-1 Rev. 2
Description: **Baseline Y Rectification (1/32" Oversized)**

Test Temperature (°F): 73
Waveform: Sine
Frequency (Hz): 15
Stress Ratio: R = 0.1
Removal Point: Fracture / 24 hours

Fastener Installation/Removal: Metcut 5/17/21; 40 in* lbs.

Test Number	Coupon ID	Width (in)	Thickness (in)	Hole Diameter (in)	Net Area (in^2)	Net Stress (ksi)	Stress Amplitude (ksi)	Max. Load (lbs.)	Min. Load (lbs.)	Nf - Cycles	Result	Failure Location / Comment	Test Operator	Test Station	Log Number
82	BY 1	1.1017	0.2471	0.2200	0.2179	34.0	15.30	7,409	741	21,742	Failure	S, B, CSK	RB	63	181726-1
83	BY 2	1.1015	0.2471	0.2199	0.2178	34.0	15.30	7,405	741	22,031	Failure	S, R, H	BAB	23	181725-1
84	BY 3	1.1011	0.2468	0.2199	0.2175	34.0	15.30	7,395	740	18,845	Failure	S, B, CSK	BAB	23	181762-1
85	BY 4	1.1015	0.2472	0.2199	0.2179	34.0	15.30	7,409	741	21,864	Failure	S, B, CSK	RB	63	181780-1
86	BY 5	1.1011	0.2470	0.2199	0.2177	34.0	15.30	7,402	740	20,244	Failure	S, B, CSK	RB	62	181782-1
87	BY 6	1.1013	0.2472	0.2199	0.2179	34.0	15.30	7,409	741	17,315	Failure	S, L, CSK	BAB	23	181793-1
88	BY 7	1.1010	0.2471	0.2200	0.2177	28.0	12.60	6,096	610	57,341	Failure	S, B, CSK	RB	63	181798-1
89	BY 8	1.1008	0.2467	0.2199	0.2173	28.0	12.60	6,084	608	47,450	Failure	S, B, CSK	RB	62	181799-1
90	BY 9	1.1014	0.2471	0.2198	0.2178	28.0	12.60	6,098	610	82,590	Failure	S, R, CSK / S, L H	BAB	23	181800-1
91	BY 10	1.1011	0.2468	0.2199	0.2175	28.0	12.60	6,090	609	45,451	Failure	S, L, H / S, R, CSK	RB	63	181802-1
92	BY 11	1.1011	0.2472	0.2198	0.2179	28.0	12.60	6,101	610	88,750	Failure	S, R, CSK	RB	62	181833-1
93	BY 12	1.1010	0.2471	0.2198	0.2177	28.0	12.60	6,096	610	40,121	Failure	S, R, CSK	RB	63	181838-1
94	BY 13	1.1013	0.2481	0.2197	0.2187	26.0	11.70	5,686	569	67,380	Failure	S, L, CSK	BAB	23	181841-1
95	BY 14	1.1009	0.2473	0.2199	0.2179	26.0	11.70	5,665	567	134,557	Failure	S, R, H	RB	62	181843-1
96	BY 15	1.1010	0.2472	0.2199	0.2178	26.0	11.70	5,663	566	174,019	Failure	S, R, CSK	RB	63	181874-1
97	BY 16	1.1014	0.2466	0.2197	0.2174	26.0	11.70	5,652	565	105,392	Failure	S, L, CSK / S, R, H	RB	62	181877-1
98	BY 17	1.1009	0.2468	0.2199	0.2174	26.0	11.70	5,652	565	191,057	Failure	S, B, H	BEA	62	181907-1
99	BY 18	1.1016	0.2474	0.2200	0.2181	26.0	11.70	5,671	567	98,321	Failure	S, R, CSK	BEA	63	181908-1

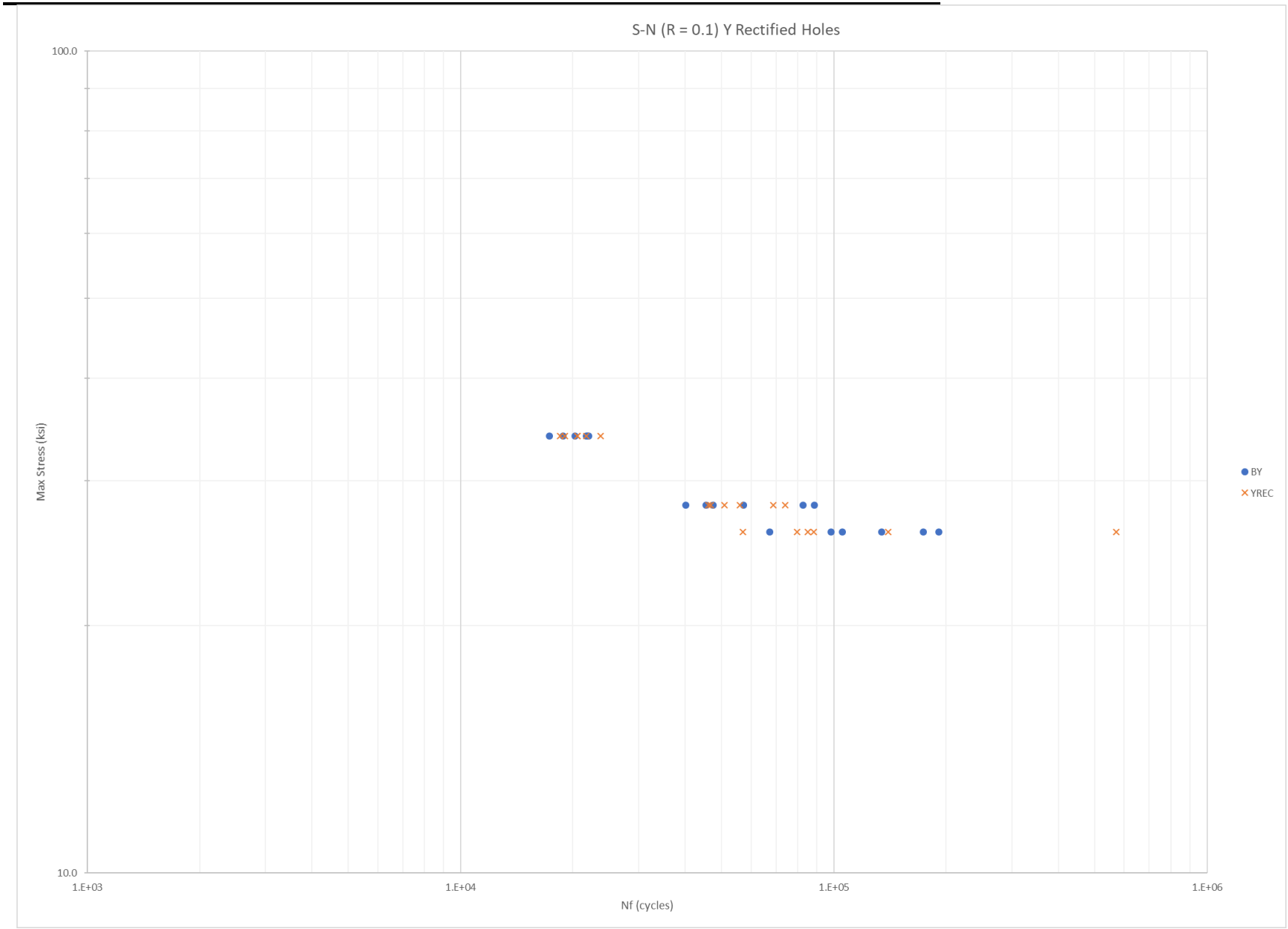
METCUT RESEARCH, INC.
Structures Laboratory

Project: 6032-106551
Material: 7075-T651
Test Specification: ASTM E466-16
Drawing Number: 106551-1 Rev. 2
Description: **0.021" Eccentric Cut – Y Rectification (1/32" Oversized)**

Test Temperature (°F): 73
Waveform: Sine
Frequency (Hz): 15
Stress Ratio: R = 0.1
Removal Point: Fracture / 24 hours

Fastener Installation/Removal: Metcut 5/17/21; 40 in*lbs.

Test Number	Coupon ID	Width (in)	Thickness (in)	Hole Diameter (in)	Net Area (in^2)	Net Stress (ksi)	Stress Amplitude (ksi)	Max. Load (lbs.)	Min. Load (lbs.)	Nf - Cycles	Result	Failure Location / Comment	Eccentric Cut Test Orientation (L/R)	Test Operator	Test Station	Log Number
100	YREC 1	1.1008	0.2466	0.2198	0.2173	34.0	15.30	7,388	739	21,717	Failure	S, L, H / S, R, CSK	R	BAB	23	182106-1
101	YREC 2	1.1014	0.2462	0.2197	0.2171	34.0	15.30	7,381	738	23,750	Failure	S, B, CSK, P	L	RB	62	182107-1
102	YREC 3	1.1018	0.2467	0.2197	0.2176	34.0	15.30	7,398	740	20,557	Failure	S, B, CSK	L	RB	63	182108-1
103	YREC 4	1.1020	0.2473	0.2198	0.2182	34.0	15.30	7,419	742	19,045	Failure	S, B, CSK	L	BAB	23	182109-1
104	YREC 5	1.1015	0.2469	0.2198	0.2177	34.0	15.30	7,402	740	20,563	Failure	S, B, CSK, P	L	RB	62	182110-1
105	YREC 6	1.1019	0.2467	0.2199	0.2176	34.0	15.30	7,398	740	18,496	Failure	S, B, CSK	L	RB	63	182111-1
106	YREC 7	1.1011	0.2466	0.2198	0.2173	28.0	12.60	6,084	608	46,179	Failure	S, L, CSK, P	L	RB	62	182113-1
107	YREC 8	1.1012	0.2473	0.2198	0.2180	28.0	12.60	6,104	610	46,880	Failure	S, B, CSK, P	L	RB	63	182114-1
108	YREC 9	1.1009	0.2471	0.2198	0.2177	28.0	12.60	6,096	610	51,031	Failure	S, L, CSK, P	L	BAB	23	182115-1
109	YREC 10	1.1010	0.2462	0.2198	0.2170	28.0	12.60	6,076	608	68,798	Failure	S, B, H, P	R	BEA	62	182183-1
110	YREC 11	1.1017	0.2470	0.2196	0.2179	28.0	12.60	6,101	610	74,082	Failure	S, B, CSK, P	L	BEA	63	182184-1
111	YREC 12	1.1004	0.2464	0.2198	0.2170	28.0	12.60	6,076	608	55,950	Failure	S, L, CSK	R	BEA	23	182187-1
112	YREC 13	1.1009	0.2471	0.2197	0.2177	26.0	11.70	5,660	566	57,111	Failure	S, B, CSK	R	BEA	63	182190-1
113	YREC 14	1.1004	0.2469	0.2198	0.2176	26.0	11.70	5,658	566	79,790	Failure	S, R, H, P	R	BEA	62	182191-1
114	YREC 15	1.1019	0.2471	0.2198	0.2180	26.0	11.70	5,668	567	570,458	Failure	S, L, H	R	BEA	23	182192-1
115	YREC 16	1.0995	0.2469	0.2198	0.2172	26.0	11.70	5,647	565	88,381	Failure	S, L, H	R	CW	62	182225-1
116	YREC 17	1.1013	0.2470	0.2198	0.2177	26.0	11.70	5,660	566	85,214	Failure	S, L, CSK, P	L	RB	63	182193-1
117	YREC 18	1.1011	0.2471	0.2198	0.2178	26.0	11.70	5,663	566	139,717	Failure	S, L, H, P	L	RB	63	182226-1


S-N (R = 0.1) Y Rectified Holes
100.0
10.0
Max Stress (ksi)
1.E+03
1.E+04
1.E+05
1.E+06
Nf (cycles)
BY
YREC

Representative Post-test Photographs

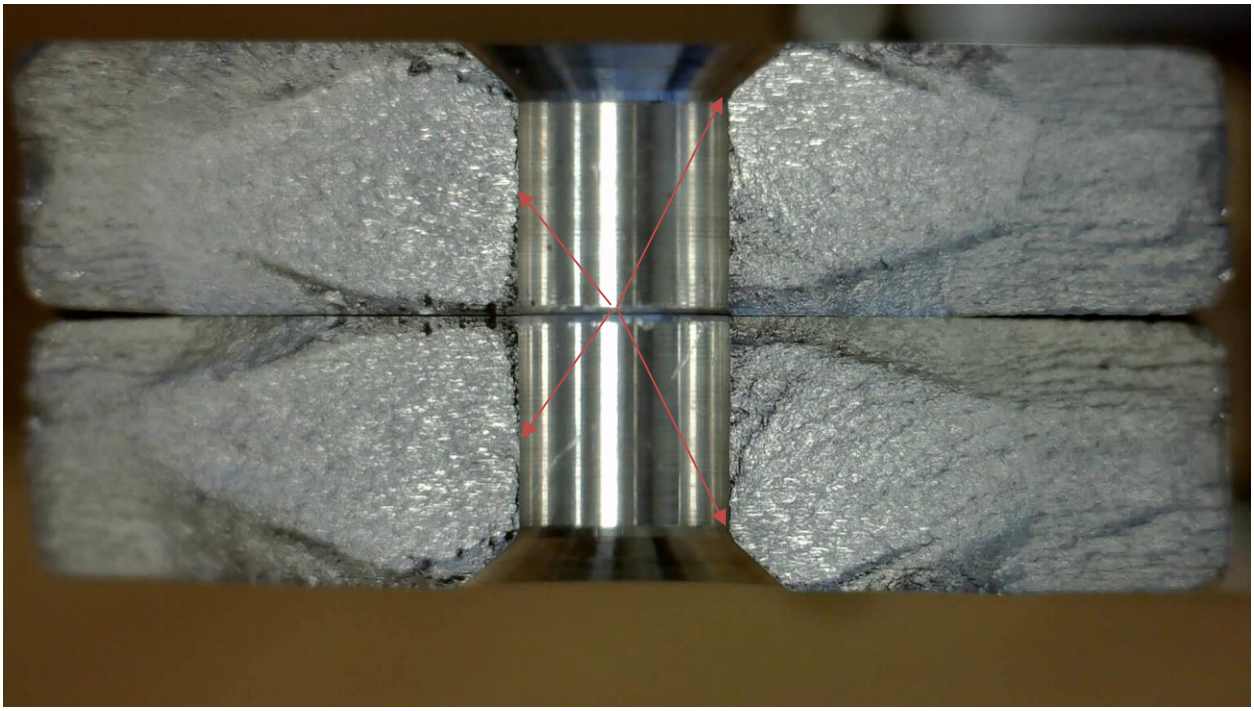


Figure 5: Specimen NB-9; S, L, H / S, R, CSK failure mode

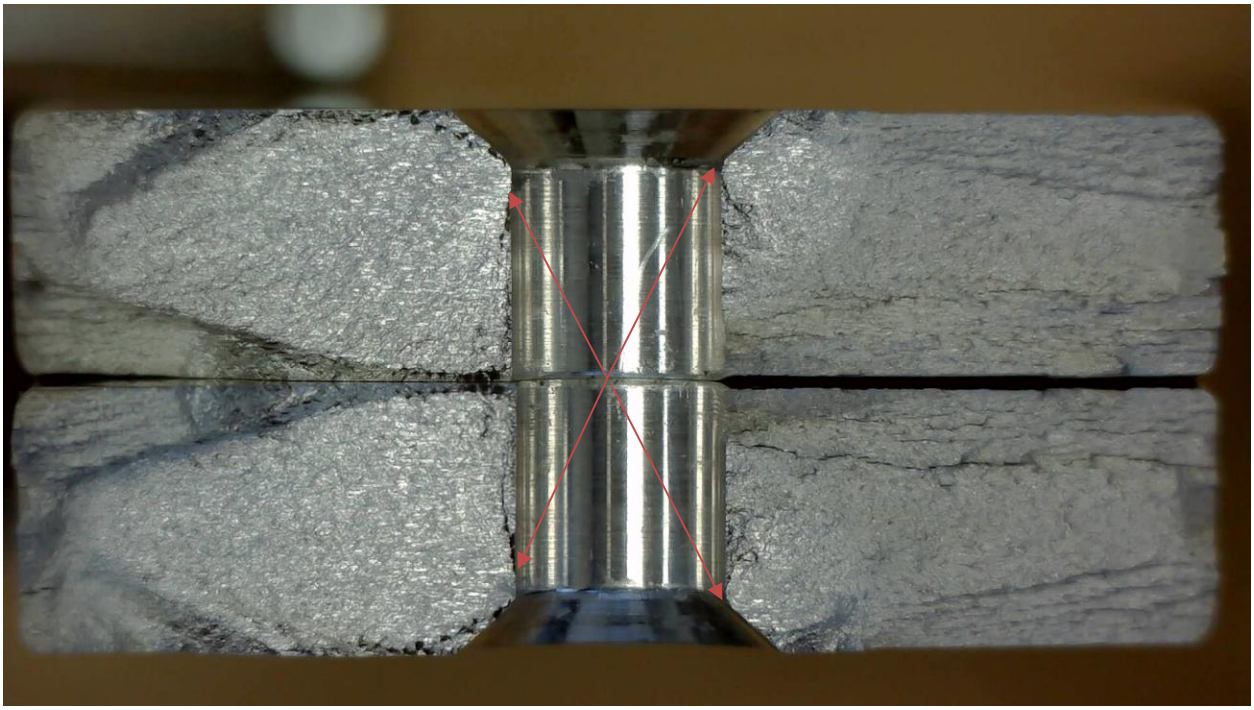


Figure 6: Specimen ECNR-8; S, L, H / S, R, CSK failure mode

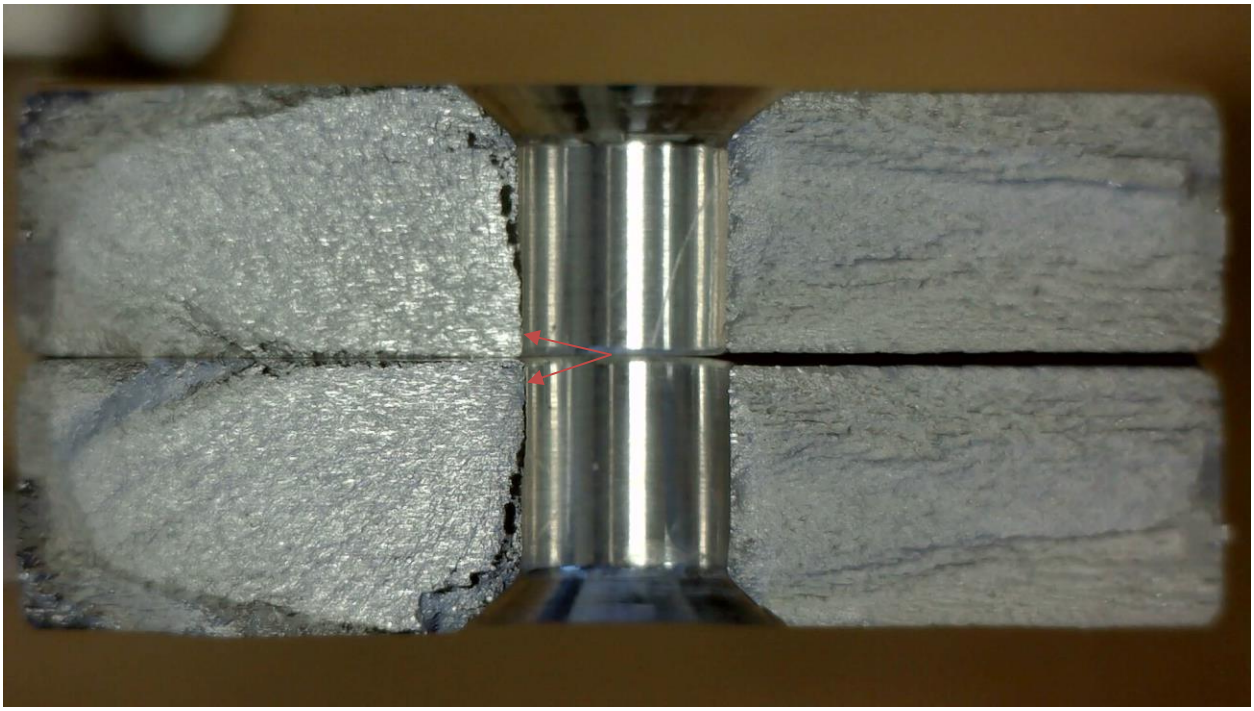


Figure 7: Specimen ECNR-16; S, L, H, P failure mode

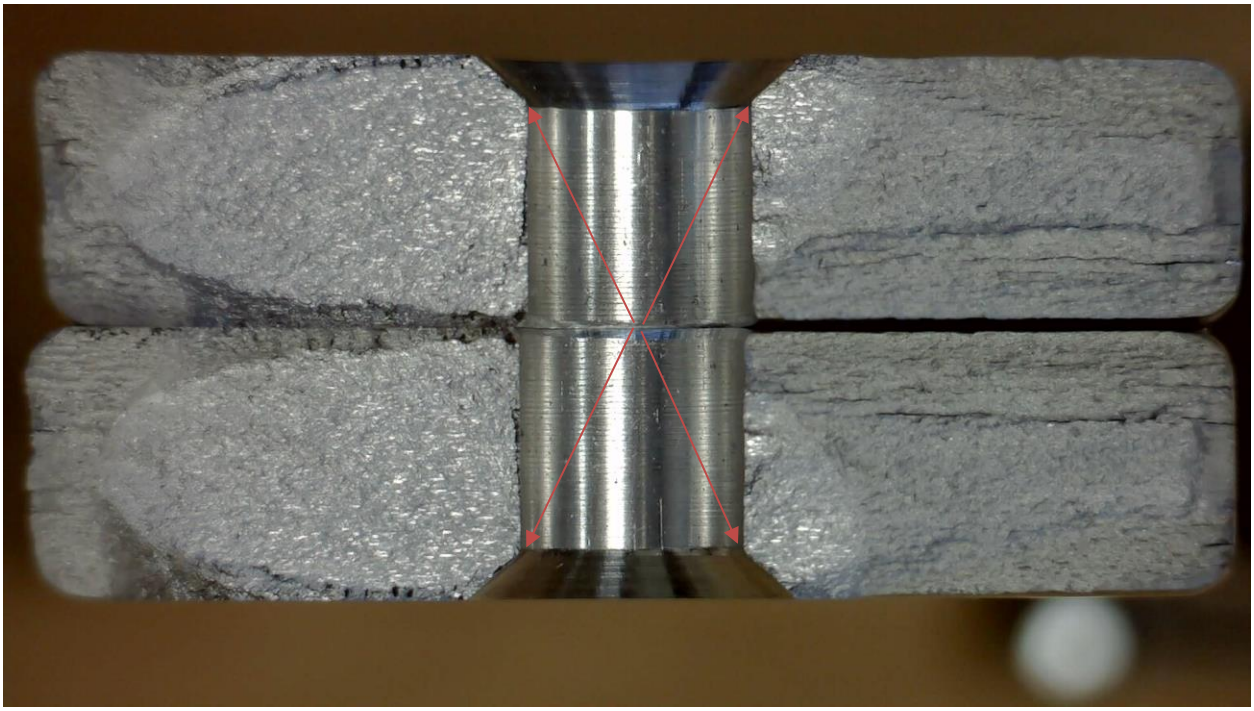


Figure 8: Specimen BX-7; S, B, CSK failure mode

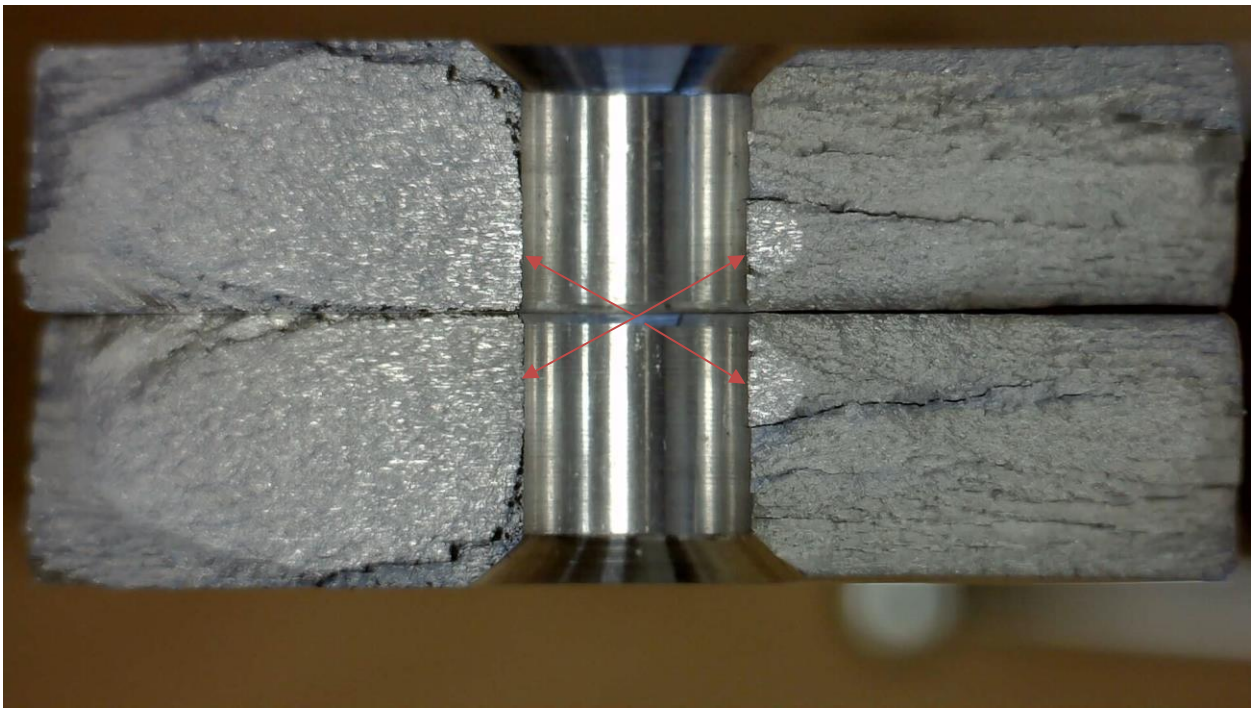


Figure 9: Specimen BX-17; S, B, H failure mode

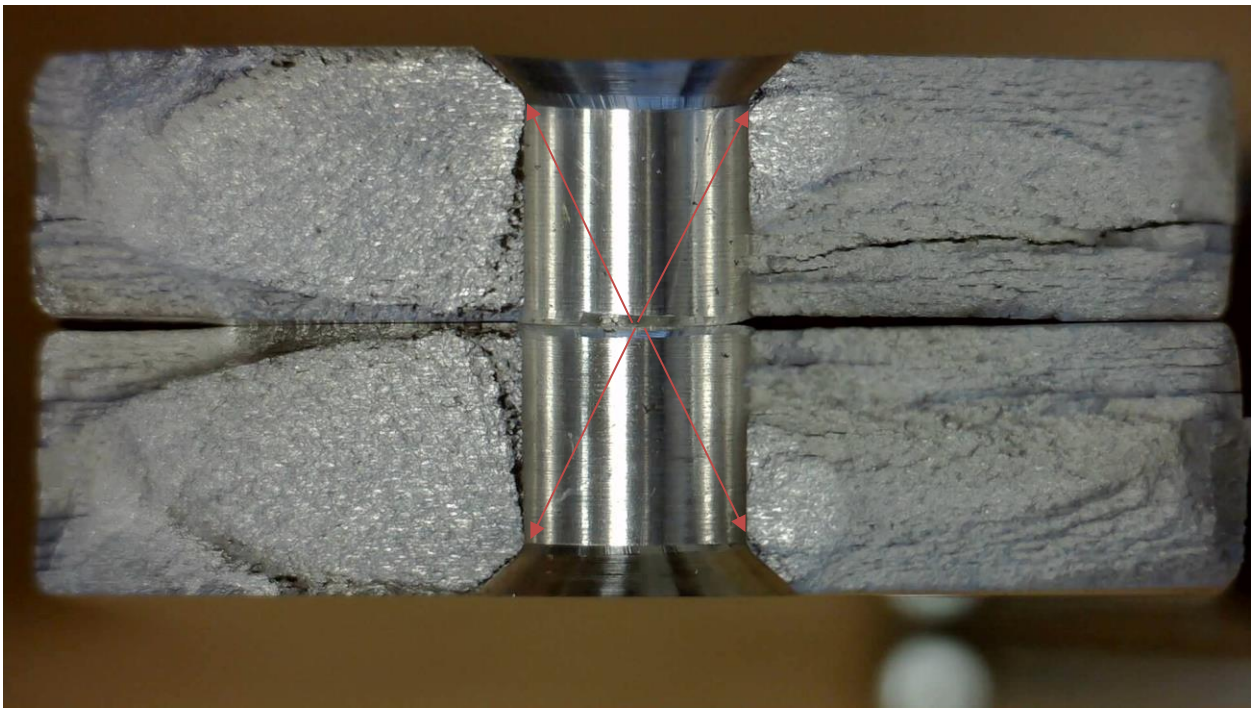


Figure 10: Specimen XREC-7; S, B, CSK, P failure mode

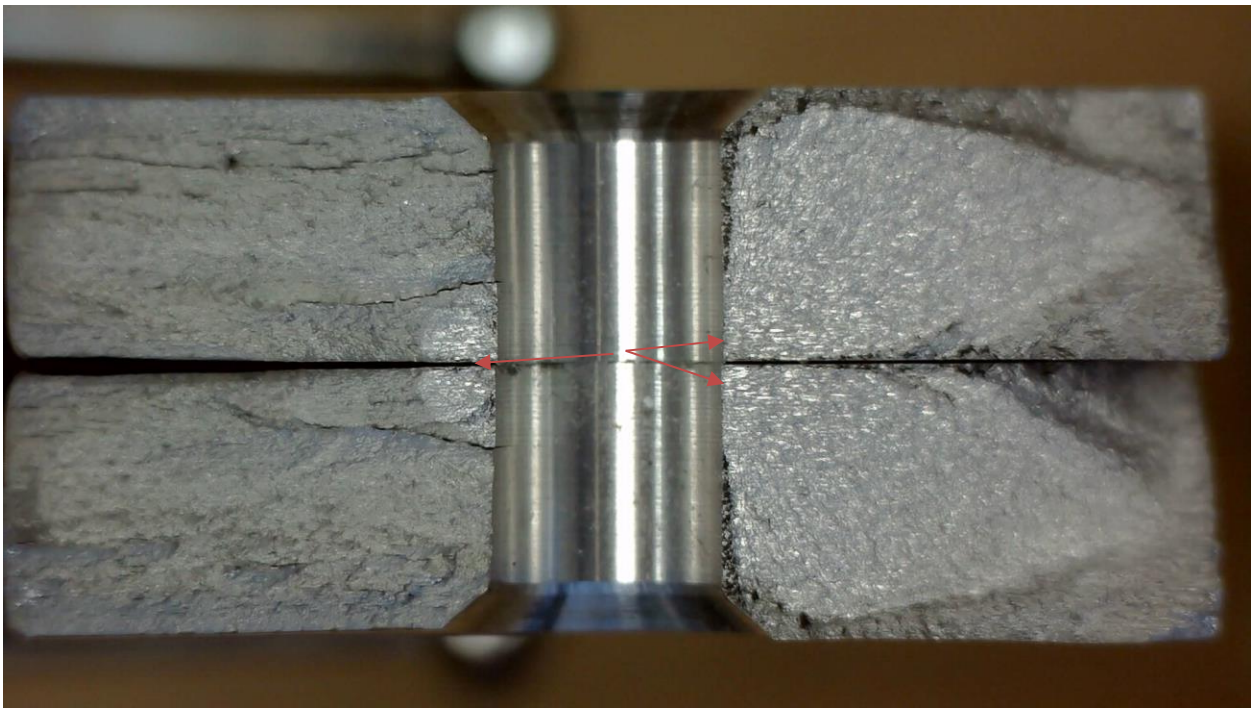


Figure 11: Specimen XREC-8; S, R, H / S, L, F, H failure mode

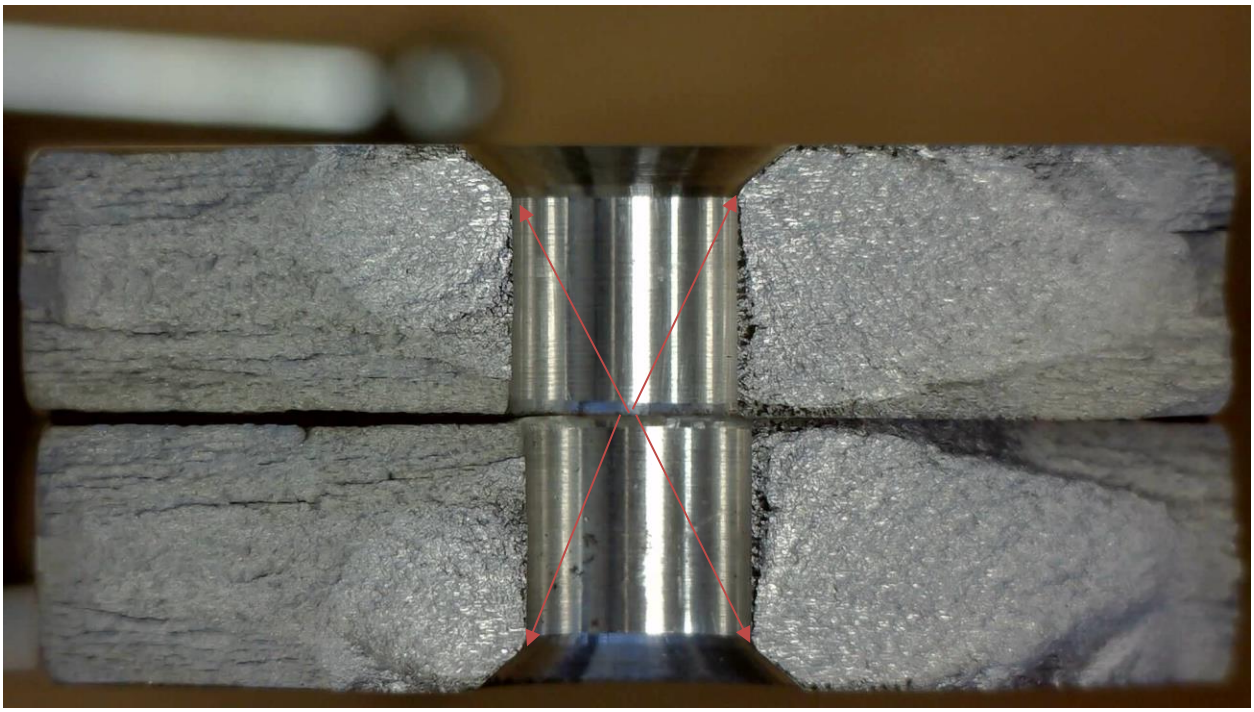


Figure 12: Specimen XREC-11; S, B, CSK failure mode

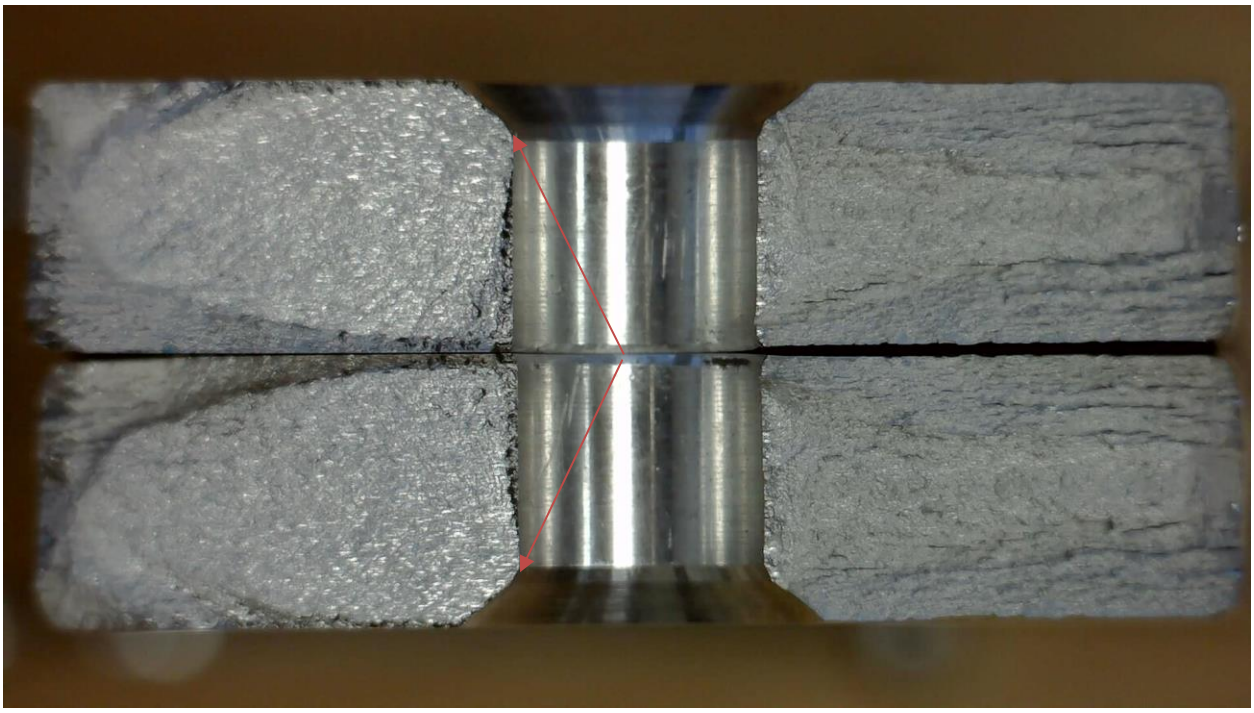


Figure 13: Specimen BY-13; S, L, CSK failure mode

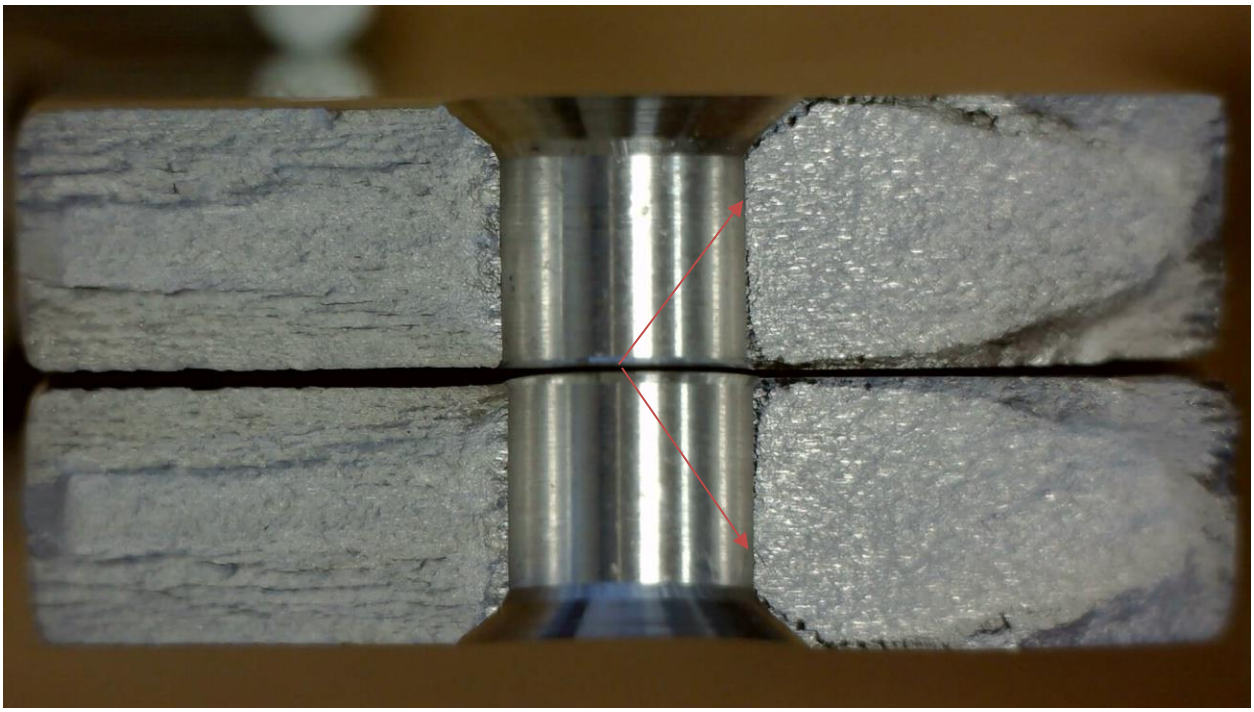


Figure 14: Specimen BY-14; S, R, H failure mode

Appendix A

Calibration Records

MTS

Customer Address:
1775 Carillon Boulevard
Cincinnati, OH 45240
US

MTS Field Service

MTS Systems Corporation
14000 Technology Drive
Eden Prairie, MN 55344-2290

ilac-MRA A2LA ACCREDITED CERT #1145.01

Certificate of Calibration

Customer
Name: Cincinnati Testing Labs
System ID: 23
Device ID: Load 23 (60227)
MTS System No: 60227
Location: Lab B
Certificate Number: 7096-5154
Site: 505296
Country: US

Equipment
Device Type: Force
Conditioner Model: 458.11
Readout Device Model: 458.11
Model: 661.22C-01
Serial No.: 0189425A
Serial No.: 0189425A
Serial No.: 0189238
Channel: Load 23 (60227)

MTS Field Service is accredited by the American Association for Laboratory Accreditation (A2LA Cert. No. 1145.01).
The basis for this accreditation is the international standard for calibration laboratories, ISO/IEC 17025 "General Requirements for the Competence of Testing and Calibration Laboratories".
Defined and documented measurement assurance techniques or uncertainty analyses are used to verify the adequacy of the measurement processes.

Calibrations are performed with standards whose values and measurements are traceable to the International System of Units (SI) through a National Metrology Institute (NMI).
MTS Reference Force Transducers are calibrated in compliance with ASTM E74.
The results of this calibration relate only to the items calibrated.
When parameter(s) are certified to be within specified tolerance(s), the measured value(s) shall fall within the appropriate specification limit and the uncertainty of the measured value(s) shall be stated.

CALIBRATION INFORMATION

As Found: In Tolerance — Max. Error As Found: -0.58 % — Calibration Date: 17-Sep-2020
As Left: In Tolerance — Max. Error As Left: -0.58 % — Calibration Due: 17-Sep-2021
Tolerance: +/-1.0% of Applied Force
Calibration Procedure: FS-CA 2122 Rev. F — ASTM E4-20
Full Scale Ranges: 50 kip, 25 kip, 10 kip, 5 kip
Note:

STANDARDS USED FOR CALIBRATION

MTS Asset Number	Manufacturer	Model Number	Description	Cal. Date	Cal. Due
18756	Interface Inc.	9840	mV/V Indicator	29-Apr-20	29-Apr-21
19941	Fluke	189	DMM	29-Apr-20	29-Apr-21
26828	Rotronic	HL-20D	Temperature & Humidity M	29-Apr-20	29-Apr-21
18757	Interface	CX-0220-1	Standardizer	29-Apr-20	29-Apr-21
18526	Interface	1232AJF-50K	50 KIP Force Standard	11-Jun-19	9-Apr-21

Certified by: Ed Rajz
Issued on: 17-Sep-20

ACS Version: 10.45

ACSRepRevBD

MTS

MTS Systems Corporation
14000 Technology Drive
Eden Prairie, MN 55344-2290

Calibration Report

ilac-MRA A2LA ACCREDITED CERT #1145.01

Report Number: 7096-5154
Site: 505296
Country: US

Customer
Name: Cincinnati Testing Labs
System ID: 23
Device ID: Load 23 (60227)
MTS System No: 60227
Location: Lab B

Equipment
Device Type: Force
Model: 661.22C-01
Serial No.: 0189238
Conditioner Model: 458.11
Serial No.: 0189425A
Readout Device Model: 458.11
Serial No.: 0189425A
Channel: Load 23 (60227)

Procedure
MTS Procedure: FS-CA 2122 Rev. F
ACS Version: 10.45
Calibration has been performed in accordance with: ASTM E4-20
Method of Verification: Follow-the-Force Method using Elastic Calibration Devices

Calibration Equipment Asset No.
Dead Weight Set:
HighLevel Board:
LowLevel Board:
Standard Asset No.: 18526
DW Compensation:
DMM: 19941
Digital Indicator: 18756
Lower Limit: 1 kip
Temperature Readout: 26828
Additional Equipment:
Standardizer: 18757

Conditions
Ambient Temperature: 74 °F
Polarity(+): Tension
Bidirectional:
Cable Length: 25 Feet

In Tolerance X
Out of Tolerance
As Found: X
As Adjusted:
Tolerance: +/-1.0% of Applied Force
As Found System Condition: Good

Conditioner Parameters
Polarity: Normal
Excitation: 7.986 Volts
Total Gain:
Pre-amp gain:
Post-amp gain:
Fine zero: 0.0530
Shunt Cal (+): 9.015 Volts

Calibration Data
Compression
Range: 1
Resolution: 0.0008
Full Scale: 50
Report Units: kip

Applied Percent of Full Scale Force	Series 1 Indicated Reading Ascending	Series 1 Indicated Reading Descending	Series 1 Errors Units Error Asc	Series 1 Errors Percent Error Asc	Series 1 Errors Units Error Desc	Series 1 Errors Percent Error Desc	Series 2 Indicated Reading Ascending	Series 2 Indicated Reading Descending	Series 2 Errors Units Error Asc	Series 2 Errors Percent Error Asc	Series 2 Errors Units Error Desc	Series 2 Errors Percent Error Desc	Repeatability Percent Error Asc	Repeatability Percent Error Desc
0	0.0007	-0.0005	0.0007	0.00	-0.0005	0.00	0.0085	-0.0035	0.0085	0.02	-0.0035	-0.01	0.02	0.01
-10	-5.0066		0.0066	0.13			-5.0036		0.0036	0.07			0.06	
-20	-9.9963		-0.0037	-0.04			-10.0020		0.0020	0.02			0.06	
-40	-19.9830		-0.0170	-0.09			-19.9710		-0.0290	-0.14			0.06	
-60	-29.9510		-0.0490	-0.16			-29.9370		-0.0630	-0.21			0.05	
-80	-39.8960		-0.1040	-0.26			-39.8870		-0.1130	-0.28			0.02	
-100	-49.8380		-0.1620	-0.32			-49.8270		-0.1730	-0.35			0.02	

Tension
Range: 1
Report Units: kip

Applied Percent of Full Scale Force	Series 1 Indicated Reading Ascending	Series 1 Indicated Reading Descending	Series 1 Errors Units Error Asc	Series 1 Errors Percent Error Asc	Series 1 Errors Units Error Desc	Series 1 Errors Percent Error Desc	Series 2 Indicated Reading Ascending	Series 2 Indicated Reading Descending	Series 2 Errors Units Error Asc	Series 2 Errors Percent Error Asc	Series 2 Errors Units Error Desc	Series 2 Errors Percent Error Desc	Repeatability Percent Error Asc	Repeatability Percent Error Desc
0	0.0008	0.0010	0.0008	0.00	0.0010	0.00	0.0029	-0.0025	0.0029	0.01	-0.0025	-0.01	0.00	0.01
10	4.9765		-0.0235	-0.47			4.9910		-0.0090	-0.18			0.29	
20	9.9432		-0.0568	-0.57			9.9627		-0.0373	-0.37			0.19	
40	19.8840		-0.1160	-0.58			19.9180		-0.0820	-0.41			0.17	
60	29.8420		-0.1580	-0.53			29.8830		-0.1170	-0.39			0.14	
80	39.7990		-0.2010	-0.50			39.8650		-0.1350	-0.34			0.17	
100	49.7770		-0.2230	-0.45			49.8630		-0.1370	-0.27			0.17	

Errors at Zero are computed in % of Range.
Uncertainty of the data supplied is equal to or less than ±0.25% of reading for a coverage factor of k=2 and an approximate confidence level of 95%.

[ ] Out of Tolerance in % column

American Association of Laboratory Accreditation Certificate Number: 1145.01

Notes: Shunt and Zero values taken with grips attached.

Performed By: Ed Reip
Field Service Engineer:
Date: 17-Sep-20

Signature: Ed Reip

Next Customer Agreed Upon Calibration Date: 17-Sep-21

ACSRepRevBD

MTS Systems Corporation
14000 Technology Drive
Eden Prairie, MN 55344-2290

Calibration Report

Report Number: 7096-5154
Site: 505296
Country: US

Customer
Name: Cincinnati Testing Labs
System ID: 23
Device ID: Load 23 (60227)
MTS System No: 60227
Location: Lab B

Equipment
Device Type: Force
Model: 661.22C-01
Serial No.: 0189238
Conditioner Model: 458.11
Serial No.: 0189425A
Readout Device Model: 458.11
Serial No.: 0189425A
Channel: Load 23 (60227)

Procedure
MTS Procedure: FS-CA 2122 Rev. F
ACS Version: 10.45
Calibration has been performed in accordance with: ASTM E4-20
Method of Verification: Follow-the-Force Method using Elastic Calibration Devices

Calibration Equipment Asset No.
Dead Weight Set:
HighLevel Board:
LowLevel Board:
Standard Asset No.: 18526
DW Compensation:
DMM: 19941
Digital Indicator: 18756
Lower Limit: 1 kip
Temperature Readout: 26828
Additional Equipment:
Standardizer: 18757

Conditions
Ambient Temperature: 72.8 °F
Polarity(+): Tension
Bidirectional:
Cable Length: 25 Feet

In Tolerance X
Out of Tolerance
As Found: X
As Adjusted:
Tolerance: +/-1.0% of Applied Force
As Found System Condition: Good

Conditioner Parameters
Polarity: Normal
Excitation: 9.111 Volts
Total Gain:
Pre-amp gain:
Post-amp gain:
Fine zero: 0.1058
Shunt Cal (+): 9.071 Volts

Calibration Data
Compression
Range: 2
Resolution: 0.0036
Full Scale: 25
Report Units: kip

Applied Percent of Full Scale Force	Series 1 Indicated Reading Ascending	Series 1 Indicated Reading Descending	Series 1 Errors Units Error Asc	Series 1 Errors Percent Error Asc	Series 1 Errors Units Error Desc	Series 1 Errors Percent Error Desc	Series 2 Indicated Reading Ascending	Series 2 Indicated Reading Descending	Series 2 Errors Units Error Asc	Series 2 Errors Percent Error Asc	Series 2 Errors Units Error Desc	Series 2 Errors Percent Error Desc	Repeatability Percent Error Asc	Repeatability Percent Error Desc
0	0.0002	-0.0045	0.0002	0.00	-0.0045	-0.02	0.0002	-0.0030	0.0002	0.00	-0.0030	-0.01	0.00	0.01
-10	-2.5009		0.0009	0.04			-2.5063		0.0063	0.25			0.22	
-20	-5.0018		0.0018	0.04			-5.0011		0.0011	0.02			0.01	
-40	-9.9952		-0.0048	-0.05			-10.0020		0.0020	0.02			0.07	
-60	-14.9880		-0.0120	-0.08			-14.9920		-0.0080	-0.05			0.03	
-80	-19.9740		-0.0260	-0.13			-19.9830		-0.0170	-0.09			0.04	
-100	-24.9490		-0.0510	-0.20			-24.9650		-0.0350	-0.14			0.06	

Tension
Range: 2
Report Units: kip

Applied Percent of Full Scale Force	Series 1 Indicated Reading Ascending	Series 1 Indicated Reading Descending	Series 1 Errors Units Error Asc	Series 1 Errors Percent Error Asc	Series 1 Errors Units Error Desc	Series 1 Errors Percent Error Desc	Series 2 Indicated Reading Ascending	Series 2 Indicated Reading Descending	Series 2 Errors Units Error Asc	Series 2 Errors Percent Error Asc	Series 2 Errors Units Error Desc	Series 2 Errors Percent Error Desc	Repeatability Percent Error Asc	Repeatability Percent Error Desc
0	-0.0005	-0.0011	-0.0005	0.00	-0.0011	0.00	0.0055	-0.0010	0.0055	0.02	-0.0010	0.00	0.02	0.00
10	2.4973		-0.0027	-0.11			2.5038		0.0038	0.15			0.26	
20	4.9909		-0.0091	-0.18			5.0017		0.0017	0.03			0.22	
40	9.9841		-0.0159	-0.16			9.9989		-0.0011	-0.01			0.15	
60	14.9780		-0.0220	-0.15			15.0010		0.0010	0.01			0.15	
80	19.9740		-0.0260	-0.13			20.0030		0.0030	0.02			0.14	
100	24.9770		-0.0230	-0.09			25.0080		0.0080	0.03			0.12	

Errors at Zero are computed in % of Range.
Uncertainty of the data supplied is equal to or less than ±0.25% of reading for a coverage factor of k=2 and an approximate confidence level of 95%.

☐ Out of Tolerance in % column

American Association of Laboratory Accreditation Certificate Number: 1145.01

Notes:

Performed By: Ed Reip
Field Service Engineer:
Date: 17-Sep-20

Signature: Ed Reip
Next Customer Agreed Upon Calibration Date: 17-Sep-21

ACSRepRevBD

MTS Systems Corporation
14000 Technology Drive
Eden Prairie, MN 55344-2290

Calibration Report

ilac-MRA ACCREDITED CERT #1145.01

Report Number: 7096-5154
Site: 505296
Country: US

Customer
Name: Cincinnati Testing Labs
System ID: 23 MTS System No: 60227
Device ID: Load 23 (60227) Location: Lab B

Equipment
Device Type: Force Model: 661.22C-01 Serial No.: 0189238
Conditioner Model: 458.11 Serial No.: 0189425A
Readout Device Model: 458.11 Serial No.: 0189425A Channel: Load 23 (60227)

Procedure
MTS Procedure: FS-CA 2122 Rev. F ACS Version: 10.45
Calibration has been performed in accordance with: ASTM E4-20
Method of Verification: Follow-the-Force Method using Elastic Calibration Devices

Calibration Equipment Asset No.
Dead Weight Set: HighLevel Board: LowLevel Board: Standard Asset No.: 18526
DW Compensation: DMM: 19941 Digital Indicator: 18756 Lower Limit: 1 kip
Temperature Readout: 26828 Additional Equipment: Standardizer: 18757

Conditions
Ambient Temperature: 72.5 °F Polarity(+): Tension Bidirectional: Cable Length: 25 Feet

In Tolerance [X] **As Found:** [X] **Tolerance: +/-1.0% of Applied Force**
Out of Tolerance [ ] **As Adjusted:** [ ] **As Found System Condition: Good**

Conditioner Parameters
Polarity: Normal Total Gain: Fine zero: 0.2647 Shunt Cal (+): 9.115 Volts
Excitation: 9.987 Volts Pre-amp gain:
Post-amp gain:

Calibration Data Range: 3
Compression Resolution: 0.0013 Full Scale: 10
Report Units: kip

Applied	Series 1		Series 1 Errors				Series 2		Series 2 Errors				Repeatability
Percent of Full Scale Force	Indicated Reading Ascending	Indicated Reading Descending	Units Error Asc	Percent Error Asc	Units Error Desc	Percent Error Desc	Indicated Reading Ascending	Indicated Reading Descending	Units Error Asc	Percent Error Asc	Units Error Desc	Percent Error Desc	Percent Error Asc	Percent Error Desc
0	-0.0014	-0.0002	-0.0014	-0.01	-0.0002	0.00	-0.0003	-0.0018	-0.0003	0.00	-0.0018	-0.02	0.01	0.02
-10	-1.0021		0.0021	0.21			-1.0013		0.0013	0.13			0.08	
-20	-2.0014		0.0014	0.07			-2.0021		0.0021	0.10			0.03	
-40	-4.0030		0.0030	0.07			-4.0033		0.0033	0.08			0.01	
-60	-5.9998		-0.0002	0.00			-6.0013		0.0013	0.02			0.02	
-80	-7.9933		-0.0067	-0.08			-7.9986		-0.0014	-0.02			0.07	
-100	-9.9925		-0.0075	-0.07			-9.9963		-0.0037	-0.04			0.04	

Tension Range: 3
Report Units: kip

Applied	Series 1		Series 1 Errors				Series 2		Series 2 Errors				Repeatability
Percent of Full Scale Force	Indicated Reading Ascending	Indicated Reading Descending	Units Error Asc	Percent Error Asc	Units Error Desc	Percent Error Desc	Indicated Reading Ascending	Indicated Reading Descending	Units Error Asc	Percent Error Asc	Units Error Desc	Percent Error Desc	Percent Error Asc	Percent Error Desc
0	0.0007	0.0066	0.0007	0.01	0.0066	0.07	0.0009	-0.0051	0.0009	0.01	-0.0051	-0.05	0.00	0.12
10	1.0006		0.0006	0.06			1.0007		0.0007	0.07			0.01	
20	2.0007		0.0007	0.03			2.0017		0.0017	0.08			0.05	
40	4.0011		0.0011	0.03			4.0043		0.0043	0.11			0.08	
60	6.0022		0.0022	0.04			6.0046		0.0046	0.08			0.04	
80	8.0029		0.0029	0.04			8.0070		0.0070	0.09			0.05	
100	10.0040		0.0040	0.04			10.0100		0.0100	0.10			0.06	

Errors at Zero are computed in % of Range.
Uncertainty of the data supplied is equal to or less than ±0.25% of reading for a coverage factor of k=2 and an approximate confidence level of 95%.

[ ] Out of Tolerance in % column

American Association of Laboratory Accreditation Certificate Number: 1145.01

Notes: Shunt and Zero values taken with grips attached.

Performed By: Ed Reip Field Service Engineer: Date: 17-Sep-20

Signature: Ed Reip Next Customer Agreed Upon Calibration Date: 17-Sep-21 ACSRepRevBD

MTS Systems Corporation
14000 Technology Drive
Eden Prairie, MN 55344-2290

Calibration Report

ilac-MRA ACCREDITED CERT #1145.01

Report Number: 7096-5154

Customer Name: Cincinnati Testing Labs | Site: 505296
System ID: 23 | MTS System No: 60227 | Country: US
Device ID: Load 23 (60227) | Location: Lab B

Equipment
Device Type: Force | Model: 661.22C-01 | Serial No.: 0189238
Conditioner Model: 458.11 | Serial No.: 0189425A
Readout Device Model: 458.11 | Serial No.: 0189425A | Channel: Load 23 (60227)

Procedure
MTS Procedure: FS-CA 2122 Rev. F | ACS Version: 10.45
Calibration has been performed in accordance with: ASTM E4-20
Method of Verification: Follow-the-Force Method using Elastic Calibration Devices

Calibration Equipment Asset No.
Dead Weight Set: | HighLevel Board: | LowLevel Board: | Standard Asset No.: 18526
DW Compensation: | DMM: 19941 | Digital Indicator: 18756 | Lower Limit: 1 kip
Temperature Readout: 26828 | Additional Equipment: | Standardizer: 18757

Conditions
Ambient Temperature: 72.2 °F | Polarity(+): Tension | Bidirectional: | Cable Length: 25 Feet

In Tolerance [X] | **As Found:** [X] | **Tolerance: +/-1.0% of Applied Force**
Out of Tolerance [ ] | **As Adjusted:** [ ] | **As Found System Condition:** Good

Conditioner Parameters Total Gain: | Fine zero: 0.5296 | Shunt Cal (+): 9.093 Volts
Polarity: Normal | Pre-amp gain:
Excitation: 9.986 Volts | Post-amp gain:

Calibration Data Range: 4
Compression Resolution: 0.00103 | Full Scale: 5
Report Units: kip

Applied	Series 1		Series 1 Errors				Series 2		Series 2 Errors				Repeatability
Percent of Full Scale Force	Indicated Reading Ascending	Indicated Reading Descending	Units Error Asc	Percent Error Asc	Units Error Desc	Percent Error Desc	Indicated Reading Ascending	Indicated Reading Descending	Units Error Asc	Percent Error Asc	Units Error Desc	Percent Error Desc	Percent Error Asc	Percent Error Desc
0	0.00059	-0.00015	0.00059	0.01	-0.00015	0.00	0.00041	0.00050	0.00041	0.01	0.00050	0.01	0.00	0.01
-20	-1.00280		0.00280	0.28			-1.00030		0.00030	0.03			0.25	
-40	-2.00200		0.00200	0.10			-2.00230		0.00230	0.12			0.01	
-60	-3.00370		0.00370	0.12			-3.00320		0.00320	0.11			0.02	
-80	-4.00290		0.00290	0.07			-4.00030		0.00030	0.01			0.07	
-100	-5.00270		0.00270	0.05			-5.00210		0.00210	0.04			0.01	

Tension Range: 4
Report Units: kip

Applied	Series 1		Series 1 Errors				Series 2		Series 2 Errors				Repeatability
Percent of Full Scale Force	Indicated Reading Ascending	Indicated Reading Descending	Units Error Asc	Percent Error Asc	Units Error Desc	Percent Error Desc	Indicated Reading Ascending	Indicated Reading Descending	Units Error Asc	Percent Error Asc	Units Error Desc	Percent Error Desc	Percent Error Asc	Percent Error Desc
0	0.00020	0.00025	0.00020	0.00	0.00025	0.01	0.00134	-0.00045	0.00134	0.03	-0.00045	-0.01	0.02	0.01
20	1.00140		0.00140	0.14			1.00100		0.00100	0.10			0.04	
40	2.00130		0.00130	0.07			2.00360		0.00360	0.18			0.11	
60	3.00300		0.00300	0.10			3.00360		0.00360	0.12			0.02	
80	4.00390		0.00390	0.10			4.00330		0.00330	0.08			0.01	
100	5.00450		0.00450	0.09			5.00550		0.00550	0.11			0.02	

Errors at Zero are computed in % of Range.
Uncertainty of the data supplied is equal to or less than ±0.25% of reading for a coverage factor of k=2 and an approximate confidence level of 95%.

[ ] Out of Tolerance in % column

American Association of Laboratory Accreditation Certificate Number: 1145.01

Notes: Shunt and Zero values taken with grips attached.

Performed By: Ed Reip | Field Service Engineer: | Date: 17-Sep-20

Signature: Ed Reip | Next Customer Agreed Upon Calibration Date: 17-Sep-21 | ACSRepRevBD

MTS Systems Corporation
14000 Technology Drive
Eden Prairie, MN 55344-2290

Calibration Report

ilac-MRA ACCREDITED CERT #1145.01

Report Number: 7096-5153
Site: 505296
Country: US

Customer
Name: Cincinnati Testing Labs
System ID: 23
Device ID: Disp. 23(60227)
MTS System No: 60227
Location: Lab B

Equipment
Device Type: Length
Conditioner Model: 458.13
Readout Device Model: 458.13
Model: 318.25
Serial No.: 0189391A
Serial No.: 0189391A
Serial No.: 0191997
Channel: Displacement 23 (60227)

Procedure
MTS Procedure: FS-CA 2124 Rev. F
Calibration has been performed in accordance with: ASTM E2309/E2309M-20
ACS Version: 10.45
Method of Verification: Follow-the-Displacement Method

Calibration Equipment Asset No.
Dead Weight Set:
DW Compensation:
Temperature Readout: 26828
HighLevel Board:
DMM: 19941
Additional Equipment:
LowLevel Board:
Digital Indicator:
Standardizer:
Standard Asset No.: 22595
Lower Limit:

Conditions
Ambient Temperature: 74.6 °F
Polarity(+): Retraction
Bidirectional:
Cable Length: 25 Feet

In Tolerance X
Out of Tolerance
As Found: X
As Adjusted:
ASTM E2309 Classification: A
As Found System Condition: Good

Conditioner Parameters

Calibration Data
Extension
Report Units: in
Range: 1
Resolution: 0.000025
Full Scale: 0.5

Applied Percent of Full Scale Length	Series 1 Indicated Reading Ascending	Series 1 Indicated Reading Descending	Series 1 Errors Units Error Asc	Series 1 Errors Percent Error Asc	Series 1 Errors Units Error Desc	Series 1 Errors Percent Error Desc	Series 2 Indicated Reading Ascending	Series 2 Indicated Reading Descending	Series 2 Errors Units Error Asc	Series 2 Errors Percent Error Asc	Series 2 Errors Units Error Desc	Series 2 Errors Percent Error Desc	Repeatability Percent Error Asc	Repeatability Percent Error Desc
0	-0.00001	0.00034	0.00000	0.00	0.00034	0.07	0.00000	-0.00009	0.00000	0.00	-0.00009	-0.02	0.00	0.08
-10	-0.05046		0.00046	0.91			-0.05036		0.00036	0.72			0.19	
-20	-0.10082		0.00082	0.82			-0.10064		0.00064	0.64			0.18	
-40	-0.20081		0.00081	0.41			-0.20067		0.00067	0.34			0.07	
-60	-0.30045		0.00045	0.15			-0.30049		0.00049	0.16			0.01	
-80	-0.40041		0.00041	0.10			-0.40069		0.00069	0.17			0.07	
-100	-0.50071		0.00071	0.14			-0.50109		0.00109	0.22			0.08	

Retraction
Report Units: in
Range: 1

Applied Percent of Full Scale Length	Series 1 Indicated Reading Ascending	Series 1 Indicated Reading Descending	Series 1 Errors Units Error Asc	Series 1 Errors Percent Error Asc	Series 1 Errors Units Error Desc	Series 1 Errors Percent Error Desc	Series 2 Indicated Reading Ascending	Series 2 Indicated Reading Descending	Series 2 Errors Units Error Asc	Series 2 Errors Percent Error Asc	Series 2 Errors Units Error Desc	Series 2 Errors Percent Error Desc	Repeatability Percent Error Asc	Repeatability Percent Error Desc
0	0.00000	0.00001	0.00000	0.00	0.00001	0.00	0.00000	-0.00029	0.00000	0.00	-0.00029	-0.06	0.00	0.06
10	0.05016		0.00016	0.33			0.05022		0.00021	0.43			0.10	
20	0.10031		0.00031	0.31			0.10039		0.00039	0.39			0.08	
40	0.20064		0.00064	0.32			0.20074		0.00074	0.37			0.05	
60	0.30113		0.00113	0.38			0.30122		0.00122	0.41			0.03	
80	0.40147		0.00147	0.37			0.40154		0.00154	0.39			0.02	
100	0.50200		0.00200	0.40			0.50202		0.00202	0.40			0.00	

Errors at Zero are computed in % of Range.
Uncertainty of the calibration data supplied is equal to or less than the greater of, ±0.25% of reading or ±50µ inches, for a coverage factor of k=2 and an approximate confidence level of 95%.

[ ] Out of Tolerance in % column

American Association of Laboratory Accreditation Certificate Number: 1145.01

Notes: 2-point cursory spot check performed on 5 inch, 2.5 inch and 1.25 inch Ranges to verify functionality.

Performed By: Ed Reip
Field Service Engineer:
Date: 17-Sep-20

Signature: Ed Reip
Next Customer Agreed Upon Calibration Date: 17-Sep-21

ACSRepRevBD

MTS Field Service

Customer Address:
1775 Carillon Boulevard
Cincinnati, OH 45240
US

MTS Systems Corporation
14000 Technology Drive
Eden Prairie, MN 55344-2290

Certificate of Calibration

Customer
Name: Cincinnati Testing Labs
System ID: 62
Device ID: Force 62(60278)
MTS System No: 60278
Location: Lab A
Certificate Number: 7096-5269
Site: 505296
Country: US

Equipment
Device Type: Force
Conditioner Model: 494.16
Readout Device Model: 494.16
Model: 661.22H-01
Serial No.: 0009052242
Serial No.: 0009052242
Serial No.: 10476205C
Channel: Force 62 (60278)

MTS Field Service is accredited by the American Association for Laboratory Accreditation (A2LA Cert. No. 1145.01).
The basis for this accreditation is the international standard for calibration laboratories, ISO/IEC 17025 "General Requirements for the Competence of Testing and Calibration Laboratories".
Defined and documented measurement assurance techniques or uncertainty analyses are used to verify the adequacy of the measurement processes.

Calibrations are performed with standards whose values and measurements are traceable to the International System of Units (SI) through a National Metrology Institute (NMI).
MTS Reference Force Transducers are calibrated in compliance with ASTM E74.
The results of this calibration relate only to the items calibrated.
When parameter(s) are certified to be within specified tolerance(s), the measured value(s) shall fall within the appropriate specification limit and the uncertainty of the measured value(s) shall be stated.

CALIBRATION INFORMATION

As Found: In Tolerance Max. Error As Found: 0.45 % Calibration Date: 30-Oct-2020
As Left: In Tolerance Max. Error As Left: 0.45 % Calibration Due: 30-Oct-2021
Tolerance: +/-1.0% of Applied Force
Calibration Procedure: FS-CA 2122 Rev. F ASTM E4-20
Full Scale Ranges: 50000 lbf, 10000 lbf
Note:

STANDARDS USED FOR CALIBRATION

MTS Asset Number	Manufacturer	Model Number	Description	Cal. Date	Cal. Due
18756	Interface Inc.	9840	mV/V Indicator	29-Apr-20	29-Apr-21
26828	Rotronic	HL-20D	Temperature & Humidity M	29-Apr-20	29-Apr-21
18757	Interface	CX-0220-1	Standardizer	29-Apr-20	29-Apr-21
18526	Interface	1232AJF-50K	50 KIP Force Standard	11-Jun-19	9-Apr-21

Certified by: A. Reyes
Issued on: 30-Oct-20

ACS Version: 10.45

ACSRepRevBD

MTS Systems Corporation
14000 Technology Drive
Eden Prairie, MN 55344-2290

Calibration Report

ilac-MRA A2LA ACCREDITED CERT #1145.01

Report Number: 7096-5269
Site: 505296
Country: US

Customer
Name: Cincinnati Testing Labs
System ID: 62
Device ID: Force 62(60278)
MTS System No: 60278
Location: Lab A

Equipment
Device Type: Force
Conditioner Model: 494.16
Readout Device Model: 494.16
Model: 661.22H-01
Serial No.: 0009052242
Serial No.: 0009052242
Serial No.: 10476205C
Channel: Force 62 (60278)

Procedure
MTS Procedure: FS-CA 2122 Rev. F
ACS Version: 10.45
Calibration has been performed in accordance with: ASTM E4-20
Method of Verification: Follow-the-Force Method using Elastic Calibration Devices

Calibration Equipment Asset No.
Dead Weight Set:
DW Compensation:
Temperature Readout: 26828
HighLevel Board:
DMM:
Additional Equipment:
LowLevel Board:
Digital Indicator: 18756
Standardizer: 18757
Standard Asset No.: 18526
Lower Limit: 1000 lbf

Conditions
Ambient Temperature: 71.3 °F
Polarity(+): Tension
Bidirectional:
Cable Length: 25 Feet

In Tolerance X
Out of Tolerance
As Found: X
As Adjusted:
Tolerance: +/-1.0% of Applied Force
As Found System Condition: Good

Conditioner Parameters
Polarity: Normal
Excitation: 10.0 Volts
Total Gain: 511.71219
Pre-amp gain: 285.98
Post-amp gain: 1.78933
Fine zero: -0.08323
Delta K: 0.9965
Shunt Cal (+): 7364.03675 lbf.

Calibration Data
Compression
Report Units: lbf
Range: 1
Resolution: 5
Full Scale: 50000

Applied Percent of Full Scale Force	Series 1 Indicated Reading Ascending	Series 1 Indicated Reading Descending	Series 1 Errors Units Error Asc	Series 1 Errors Percent Error Asc	Series 1 Errors Units Error Desc	Series 1 Errors Percent Error Desc	Series 2 Indicated Reading Ascending	Series 2 Indicated Reading Descending	Series 2 Errors Units Error Asc	Series 2 Errors Percent Error Asc	Series 2 Errors Units Error Desc	Series 2 Errors Percent Error Desc	Repeatability Percent Error Asc	Repeatability Percent Error Desc
0	3.5	-0.9	3.5	0.01	-0.9	0.00	0.3	6.0	0.3	0.00	6.0	0.01	0.01	0.01
-2	-999.1		-0.9	-0.09			-999.9		-0.1	-0.01			0.08	
-4	-1999.3		-0.7	-0.03			-2002.0		2.0	0.10			0.13	
-6	-3005.9		5.9	0.20			-3002.5		2.5	0.08			0.11	
-8	-4000.3		0.3	0.01			-4002.9		2.9	0.07			0.06	
-10	-5005.4		5.4	0.11			-5006.7		6.7	0.13			0.03	
-20	-9997.1		-2.9	-0.03			-9999.9		-0.1	0.00			0.03	
-40	-19989.0		-11.0	-0.06			-19989.0		-11.0	-0.06			0.00	
-70	-34936.0		-64.0	-0.18			-34938.0		-62.0	-0.18			0.01	
-100	-49837.0		-163.0	-0.33			-49875.0		-125.0	-0.25			0.08	

Tension
Report Units: lbf
Range: 1

Applied Percent of Full Scale Force	Series 1 Indicated Reading Ascending	Series 1 Indicated Reading Descending	Series 1 Errors Units Error Asc	Series 1 Errors Percent Error Asc	Series 1 Errors Units Error Desc	Series 1 Errors Percent Error Desc	Series 2 Indicated Reading Ascending	Series 2 Indicated Reading Descending	Series 2 Errors Units Error Asc	Series 2 Errors Percent Error Asc	Series 2 Errors Units Error Desc	Series 2 Errors Percent Error Desc	Repeatability Percent Error Asc	Repeatability Percent Error Desc
0	-3.3	0.0	-3.3	-0.01	0.0	0.00	-0.3	1.8	-0.3	0.00	1.8	0.00	0.01	0.00
2	998.8		-1.2	-0.12			1002.4		2.4	0.24			0.36	
4	1996.3		-3.7	-0.18			1994.4		-5.6	-0.28			0.10	
6	2991.8		-8.2	-0.27			2998.0		-2.0	-0.07			0.21	
8	3997.4		-2.6	-0.07			3995.5		-4.5	-0.11			0.05	
10	4989.5		-10.5	-0.21			4990.6		-9.4	-0.19			0.02	
20	9982.3		-17.7	-0.18			9985.0		-15.0	-0.15			0.03	
40	19966.0		-34.0	-0.17			19962.0		-38.0	-0.19			0.02	
70	34964.0		-36.0	-0.10			34970.0		-30.0	-0.09			0.02	
100	50140.0		140.0	0.28			50190.0		190.0	0.38			0.10	

Errors at Zero are computed in % of Range.
Uncertainty of the data supplied is equal to or less than ±0.25% of reading for a coverage factor of k=2 and an approximate confidence level of 95%.

[ ] Out of Tolerance in % column

American Association of Laboratory Accreditation Certificate Number: 1145.01

Notes:

Performed By: Ed Reip
Field Service Engineer:
Date: 30-Oct-20

Signature: Ed Reip
Next Customer Agreed Upon Calibration Date: 30-Oct-21
ACSRepRevBD

MTS Systems Corporation
14000 Technology Drive
Eden Prairie, MN 55344-2290

Calibration Report

ilac-MRA ACCREDITED CERT #1145.01

Report Number: 7096-5269
Site: 505296
Country: US

Customer
Name: Cincinnati Testing Labs
System ID: 62
Device ID: Force 62(60278)
MTS System No: 60278
Location: Lab A

Equipment
Device Type: Force
Conditioner Model: 494.16
Readout Device Model: 494.16
Model: 661.22H-01
Serial No.: 0009052242
Serial No.: 0009052242
Serial No.: 10476205C
Channel: Force 62 (60278)

Procedure
MTS Procedure: FS-CA 2122 Rev. F
Calibration has been performed in accordance with: ASTM E4-20
ACS Version: 10.45
Method of Verification: Follow-the-Force Method using Elastic Calibration Devices

Calibration Equipment Asset No.
Dead Weight Set:
DW Compensation:
Temperature Readout: 26828
HighLevel Board:
DMM:
Additional Equipment:
LowLevel Board:
Digital Indicator: 18756
Standardizer: 18757
Standard Asset No.: 18526
Lower Limit: 1000 lbf

Conditions
Ambient Temperature: 72.9 °F
Polarity(+): Tension
Bidirectional:
Cable Length: 25 Feet

In Tolerance [X]
Out of Tolerance [ ]
As Found: [X]
As Adjusted: [ ]
Tolerance: +/-1.0% of Applied Force
As Found System Condition: Good

Conditioner Parameters
Polarity: Normal
Excitation: 10.0 Volts
Total Gain: 2558.56107
Pre-amp gain: 1805.95
Post-amp gain: 1.41674
Fine zero: -0.4265
Delta K: 0.9985
Shunt Cal (+): 7377.43297 lbf.

Calibration Data
Compression
Report Units: lbf
Range: 2
Resolution: 5
Full Scale: 10000

Applied Percent of Full Scale Force	Series 1 Indicated Reading Ascending	Series 1 Indicated Reading Descending	Series 1 Errors Units Error Asc	Series 1 Errors Percent Error Asc	Series 1 Errors Units Error Desc	Series 1 Errors Percent Error Desc	Series 2 Indicated Reading Ascending	Series 2 Indicated Reading Descending	Series 2 Errors Units Error Asc	Series 2 Errors Percent Error Asc	Series 2 Errors Units Error Desc	Series 2 Errors Percent Error Desc	Repeatability Percent Error Asc	Repeatability Percent Error Desc
0	1.5	0.4	1.5	0.02	0.4	0.00	-3.2	1.9	-3.2	-0.03	1.9	0.02	0.05	0.02
-10	-998.9		-1.1	-0.11			-1000.5		0.5	0.05			0.16	
-20	-1998.0		-2.0	-0.10			-2002.1		2.1	0.10			0.20	
-40	-4000.2		0.2	0.00			-4000.8		0.8	0.02			0.02	
-60	-6003.9		3.9	0.06			-6006.1		6.1	0.10			0.04	
-80	-7997.9		-2.1	-0.03			-8006.3		6.3	0.08			0.10	
-100	-9999.0		-1.0	-0.01			-9994.2		-5.8	-0.06			0.05	

Tension
Report Units: lbf
Range: 2

Applied Percent of Full Scale Force	Series 1 Indicated Reading Ascending	Series 1 Indicated Reading Descending	Series 1 Errors Units Error Asc	Series 1 Errors Percent Error Asc	Series 1 Errors Units Error Desc	Series 1 Errors Percent Error Desc	Series 2 Indicated Reading Ascending	Series 2 Indicated Reading Descending	Series 2 Errors Units Error Asc	Series 2 Errors Percent Error Asc	Series 2 Errors Units Error Desc	Series 2 Errors Percent Error Desc	Repeatability Percent Error Asc	Repeatability Percent Error Desc
0	-1.9	-3.4	-1.9	-0.02	-3.4	-0.03	0.1	-0.4	0.1	0.00	-0.4	0.00	0.02	0.03
10	1000.6		0.6	0.06			1000.7		0.7	0.07			0.01	
20	1996.7		-3.3	-0.17			2005.6		5.6	0.28			0.45	
40	3997.5		-2.5	-0.06			4006.2		6.2	0.15			0.22	
60	5996.2		-3.8	-0.06			6003.9		3.9	0.06			0.13	
80	7995.4		-4.6	-0.06			8000.0		0.0	0.00			0.06	
100	9999.1		-0.9	-0.01			9998.8		-1.2	-0.01			0.00	

Errors at Zero are computed in % of Range.
Uncertainty of the data supplied is equal to or less than ±0.25% of reading for a coverage factor of k=2 and an approximate confidence level of 95%.

[ ] Out of Tolerance in % column

American Association of Laboratory Accreditation Certificate Number: 1145.01

Notes:

Performed By: Ed Reip
Field Service Engineer:
Date: 30-Oct-20

Signature: Ed Reip
Next Customer Agreed Upon Calibration Date: 30-Oct-21

ACSRepRevBD

MTS Field Service

MTS Systems Corporation
14000 Technology Drive
Eden Prairie, MN 55344-2290

Customer Address:
1775 Carillon Boulevard
Cincinnati, OH 45240
US

Certificate of Calibration

Customer
Name: Cincinnati Testing Labs
System ID: 62
Device ID: Disp. 62(60278)
MTS System No: 60278
Location: Lab A
Certificate Number: 7096-5270
Site: 505296
Country: US

Equipment
Device Type: Length
Conditioner Model: 494.26 S3-J3A
Readout Device Model: 494.26 S3-J3A
Model: 370.25
Serial No.: 0009063480
Serial No.: 0009063480
Serial No.: 9764
Channel: Displacement 62 (60278)

MTS Field Service is accredited by the American Association for Laboratory Accreditation (A2LA Cert. No. 1145.01). The basis for this accreditation is the international standard for calibration laboratories, ISO/IEC 17025 "General Requirements for the Competence of Testing and Calibration Laboratories". Defined and documented measurement assurance techniques or uncertainty analyses are used to verify the adequacy of the measurement processes.

Calibrations are performed with standards whose values and measurements are traceable to the International System of Units (SI) through a National Metrology Institute (NMI).

The results of this calibration relate only to the items calibrated.
When parameter(s) are certified to be within specified tolerance(s), the measured value(s) shall fall within the appropriate specification limit and the uncertainty of the measured value(s) shall be stated.

CALIBRATION INFORMATION

As Found: In Tolerance — Max. Error As Found: -0.95 % — Calibration Date: 30-Oct-2020
As Left: In Tolerance — Max. Error As Left: -0.95 % — Calibration Due: 30-Oct-2021
Class: B, A
Calibration Procedure: FS-CA 2124 Rev. F — ASTM E2309/E2309M-20
Full Scale Ranges: 5 in, 1.5 in
Note: * The reported Class may be the result of criteria other than the Maximum % Error listed
Return to zero errors are not included in the Classification Criteria.

STANDARDS USED FOR CALIBRATION

MTS Asset Number	Manufacturer	Model Number	Description	Cal. Date	Cal. Due
26828	Rotronic	HL-20D	Temperature & Humidity M	29-Apr-20	29-Apr-21
22354	MTS	MTS 1800	Displacement Calibrator	16-Sep-20	16-Sep-21

Certified by:

Issued on: 30-Oct-20

ACS Version: 10.45

ACSRepRevBD

MTS Systems Corporation
14000 Technology Drive
Eden Prairie, MN 55344-2290

Calibration Report

ilac-MRA ACCREDITED CERT 1145.01

Report Number: 7096-5270
Site: 505296
Country: US

Customer
Name: Cincinnati Testing Labs
System ID: 62
Device ID: Disp. 62(60278)
MTS System No: 60278
Location: Lab A

Equipment
Device Type: Length
Model: 370.25
Serial No.: 9764
Conditioner Model: 494.26 S3-J3A
Serial No.: 0009063480
Readout Device Model: 494.26 S3-J3A
Serial No.: 0009063480
Channel: Displacement 62 (60278)

Procedure
MTS Procedure: FS-CA 2124 Rev. F
ACS Version: 10.45
Calibration has been performed in accordance with: ASTM E2309/E2309M-20
Method of Verification: Follow-the-Displacement Method

Calibration Equipment Asset No.
Dead Weight Set:
HighLevel Board:
LowLevel Board:
Standard Asset No.: 22354
DW Compensation:
DMM:
Digital Indicator:
Lower Limit:
Temperature Readout: 26828
Additional Equipment:
Standardizer:

Conditions
Ambient Temperature: 72.3 °F
Polarity(+): Retraction
Bidirectional:
Cable Length: 25 Feet

In Tolerance [X]
Out of Tolerance [ ]
As Found: [X]
As Adjusted: [ ]
ASTM E2309 Classification: B
As Found System Condition: Good

Conditioner Parameters
Polarity: Normal
Excitation: 8.0 Volts
Total Gain: 1.56499
Pre-amp gain: 0.9025
Post-amp gain: 1.73406
Fine zero: 0.0
Delta K: 0.994
Phase: 56.0 deg

Calibration Data
Extension
Range: 1
Resolution: 0.00011
Full Scale: 5
Report Units: in

Applied	Series 1		Series 1 Errors				Series 2		Series 2 Errors				Repeatability	
Percent of Full Scale Length	Indicated Reading Ascending	Indicated Reading Descending	Units Error Asc	Percent Error Asc	Units Error Desc	Percent Error Desc	Indicated Reading Ascending	Indicated Reading Descending	Units Error Asc	Percent Error Asc	Units Error Desc	Percent Error Desc	Percent Error Asc	Percent Error Desc
0	-0.00018	-0.00036	-0.00018	0.00	-0.00036	-0.01	-0.00011	-0.00004	-0.00011	0.00	-0.00004	0.00	0.00	0.01
-1	-0.04980		-0.00020	-0.39			-0.04975		-0.00025	-0.51			0.11	
-2	-0.09953		-0.00047	-0.47			-0.09949		-0.00051	-0.51			0.04	
-4	-0.19886		-0.00114	-0.57			-0.19877		-0.00123	-0.61			0.05	
-8	-0.39738		-0.00262	-0.66			-0.39729		-0.00271	-0.68			0.02	
-10	-0.49675		-0.00325	-0.65			-0.49670		-0.00330	-0.66			0.01	
-20	-0.99530		-0.00470	-0.47			-0.99523		-0.00477	-0.48			0.01	
-30	-1.49820		-0.00180	-0.12			-1.49830		-0.00170	-0.11			0.01	
-40	-2.00080		0.00080	0.04			-2.00080		0.00080	0.04			0.00	
-60	-3.01070		0.01070	0.36			-3.01070		0.01070	0.36			0.00	

Retraction
Range: 1
Report Units: in

Applied	Series 1		Series 1 Errors				Series 2		Series 2 Errors				Repeatability	
Percent of Full Scale Length	Indicated Reading Ascending	Indicated Reading Descending	Units Error Asc	Percent Error Asc	Units Error Desc	Percent Error Desc	Indicated Reading Ascending	Indicated Reading Descending	Units Error Asc	Percent Error Asc	Units Error Desc	Percent Error Desc	Percent Error Asc	Percent Error Desc
0	0.00016	-0.00001	0.00016	0.00	-0.00001	0.00	0.00018	-0.00002	0.00018	0.00	-0.00002	0.00	0.00	0.00
1	0.04955		-0.00045	-0.90			0.04959		-0.00042	-0.83			0.07	
2	0.09905		-0.00095	-0.95			0.09913		-0.00087	-0.87			0.08	
4	0.19814		-0.00186	-0.93			0.19818		-0.00182	-0.91			0.02	
8	0.39683		-0.00317	-0.79			0.39683		-0.00317	-0.79			0.00	
10	0.49618		-0.00382	-0.76			0.49624		-0.00376	-0.75			0.01	
20	0.99602		-0.00398	-0.40			0.99612		-0.00388	-0.39			0.01	
30	1.49970		-0.00030	-0.02			1.49980		-0.00020	-0.01			0.01	
40	2.00920		0.00920	0.46			2.00930		0.00930	0.46			0.00	
60	3.01880		0.01880	0.63			3.01870		0.01870	0.62			0.00	

Errors at Zero are computed in % of Range.
Uncertainty of the calibration data supplied is equal to or less than the greater of, ±0.25% of reading or ±50µ inches, for a coverage factor of k=2 and an approximate confidence level of 95%.

[ ] Out of Tolerance in % column

American Association of Laboratory Accreditation Certificate Number: 1145.01

Notes:

Performed By: Ed Reip
Field Service Engineer:
Date: 30-Oct-20

Signature: Ed Reip
Next Customer Agreed Upon Calibration Date: 30-Oct-21

ACSRepRevBD

MTS Systems Corporation
14000 Technology Drive
Eden Prairie, MN 55344-2290

Calibration Report

Report Number: 7096-5270
Site: 505296
Country: US

Customer
Name: Cincinnati Testing Labs
System ID: 62
Device ID: Disp. 62(60278)
MTS System No: 60278
Location: Lab A

Equipment
Device Type: Length
Model: 370.25
Serial No.: 9764
Conditioner Model: 494.26 S3-J3A
Serial No.: 0009063480
Readout Device Model: 494.26 S3-J3A
Serial No.: 0009063480
Channel: Displacement 62 (60278)

Procedure
MTS Procedure: FS-CA 2124 Rev. F
ACS Version: 10.45
Calibration has been performed in accordance with: ASTM E2309/E2309M-20
Method of Verification: Follow-the-Displacement Method

Calibration Equipment Asset No.
Dead Weight Set:
HighLevel Board:
LowLevel Board:
Standard Asset No.: 22354
DW Compensation:
DMM:
Digital Indicator:
Lower Limit:
Temperature Readout: 26828
Additional Equipment:
Standardizer:

Conditions
Ambient Temperature: 72.6 °F
Polarity(+): Retraction
Bidirectional:
Cable Length: 25 Feet

In Tolerance X
Out of Tolerance
As Found: X
As Adjusted:
ASTM E2309 Classification: A
As Found System Condition: Good

Conditioner Parameters
Polarity: Normal
Excitation: 8.0 Volts
Total Gain: 5.23381
Pre-amp gain: 3.249
Post-amp gain: 1.6109
Fine zero: 0.0
Delta K: 0.996
Phase: 55.0 deg

Calibration Data
Extension
Range: 2
Resolution: 0.00005
Full Scale: 1.5
Report Units: in

Applied Percent of Full Scale Length	Series 1 Indicated Reading Ascending	Series 1 Indicated Reading Descending	Series 1 Errors Units Error Asc	Series 1 Errors Percent Error Asc	Series 1 Errors Units Error Desc	Series 1 Errors Percent Error Desc	Series 2 Indicated Reading Ascending	Series 2 Indicated Reading Descending	Series 2 Errors Units Error Asc	Series 2 Errors Percent Error Asc	Series 2 Errors Units Error Desc	Series 2 Errors Percent Error Desc	Repeatability Percent Error Asc	Repeatability Percent Error Desc
0	-0.00006	-0.00001	-0.00006	0.00	-0.00001	0.00	-0.00006	0.00044	-0.00006	0.00	0.00044	0.03	0.00	0.03
-3.32999992	-0.04980		-0.00015	-0.29			-0.04979		-0.00016	-0.32			0.02	
-4	-0.05987		-0.00013	-0.21			-0.05986		-0.00014	-0.23			0.02	
-6	-0.08969		-0.00031	-0.35			-0.08970		-0.00030	-0.33			0.02	
-8	-0.11957		-0.00043	-0.36			-0.11959		-0.00041	-0.34			0.02	
-10	-0.14947		-0.00053	-0.35			-0.14948		-0.00052	-0.35			0.01	
-20	-0.29883		-0.00117	-0.39			-0.29884		-0.00116	-0.39			0.00	
-40	-0.59749		-0.00251	-0.42			-0.59750		-0.00250	-0.42			0.00	
-70	-1.04800		-0.00200	-0.19			-1.04790		-0.00210	-0.20			0.01	
-100	-1.50200		0.00200	0.13			-1.50200		0.00200	0.13			0.00	

Retraction
Range: 2
Report Units: in

Applied Percent of Full Scale Length	Series 1 Indicated Reading Ascending	Series 1 Indicated Reading Descending	Series 1 Errors Units Error Asc	Series 1 Errors Percent Error Asc	Series 1 Errors Units Error Desc	Series 1 Errors Percent Error Desc	Series 2 Indicated Reading Ascending	Series 2 Indicated Reading Descending	Series 2 Errors Units Error Asc	Series 2 Errors Percent Error Asc	Series 2 Errors Units Error Desc	Series 2 Errors Percent Error Desc	Repeatability Percent Error Asc	Repeatability Percent Error Desc
0	0.00004	0.00000	0.00004	0.00	0.00000	0.00	0.00005	0.00003	0.00005	0.00	0.00003	0.00	0.00	0.00
3.32999992	0.04962		-0.00033	-0.66			0.04964		-0.00031	-0.63			0.03	
4	0.05966		-0.00034	-0.57			0.05966		-0.00034	-0.56			0.01	
6	0.08952		-0.00048	-0.54			0.08954		-0.00047	-0.52			0.02	
8	0.11936		-0.00064	-0.53			0.11939		-0.00061	-0.51			0.03	
10	0.14922		-0.00078	-0.52			0.14923		-0.00077	-0.51			0.01	
20	0.29878		-0.00122	-0.41			0.29882		-0.00118	-0.39			0.01	
40	0.59870		-0.00130	-0.22			0.59869		-0.00131	-0.22			0.00	
70	1.05130		0.00130	0.12			1.05130		0.00130	0.12			0.00	
100	1.50690		0.00690	0.46			1.50690		0.00690	0.46			0.00	

Errors at Zero are computed in % of Range.
Uncertainty of the calibration data supplied is equal to or less than the greater of, ±0.25% of reading or ±50µ inches, for a coverage factor of k=2 and an approximate confidence level of 95%.

[ ] Out of Tolerance in % column

American Association of Laboratory Accreditation Certificate Number: 1145.01

Notes:

Performed By: Ed Reip
Field Service Engineer:
Date: 30-Oct-20

Signature:
Next Customer Agreed Upon Calibration Date: 30-Oct-21
ACSRepRevBD

MTS

Customer Address:
1775 Carillon Boulevard
Cincinnati, OH 45240
US

MTS Field Service

MTS Systems Corporation
14000 Technology Drive
Eden Prairie, MN 55344-2290

ilac-MRA A2LA ACCREDITED CERT #1145.01

Certificate of Calibration

Customer
Name: Cincinnati Testing Labs — Certificate Number: 7096-5356
System ID: 63 — MTS System No: 60279 — Site: 505296
Device ID: Force 63(60279) — Location: Lab A — Country: US

Equipment
Device Type: Force — Model: 661.22H-01 — Serial No.: 10476205D
Conditioner Model: 494.16 — Serial No.: 0009036185
Readout Device Model: 494.16 — Serial No.: 0009036185 — Channel: Force 63 (60279)

MTS Field Service is accredited by the American Association for Laboratory Accreditation (A2LA Cert. No. 1145.01). The basis for this accreditation is the international standard for calibration laboratories, ISO/IEC 17025 "General Requirements for the Competence of Testing and Calibration Laboratories". Defined and documented measurement assurance techniques or uncertainty analyses are used to verify the adequacy of the measurement processes.

Calibrations are performed with standards whose values and measurements are traceable to the International System of Units (SI) through a National Metrology Institute (NMI). MTS Reference Force Transducers are calibrated in compliance with ASTM E74. The results of this calibration relate only to the items calibrated. When parameter(s) are certified to be within specified tolerance(s), the measured value(s) shall fall within the appropriate specification limit and the uncertainty of the measured value(s) shall be stated.

CALIBRATION INFORMATION

As Found: In Tolerance — Max. Error As Found: 0.53 % — Calibration Date: 30-Nov-2020
As Left: In Tolerance — Max. Error As Left: 0.53 % — Calibration Due: 30-Nov-2021
Tolerance: +/-1.0% of Applied Force
Calibration Procedure: FS-CA 2122 Rev. F — ASTM E4-20
Full Scale Ranges: 50000 lbf, 10000 lbf
Note:

STANDARDS USED FOR CALIBRATION

MTS Asset Number	Manufacturer	Model Number	Description	Cal. Date	Cal. Due
18756	Interface Inc.	9840	mV/V Indicator	29-Apr-20	29-Apr-21
26828	Rotronic	HL-20D	Temperature & Humidity M	29-Apr-20	29-Apr-21
18757	Interface	CX-0220-1	Standardizer	29-Apr-20	29-Apr-21
18526	Interface	1232AJF-50K	50 KIP Force Standard	11-Jun-19	9-Apr-21

Certified by: Ed Rojo — Issued on: 30-Nov-20

ACS Version: 10.45

ACSRepRevBD

MTS Systems Corporation
14000 Technology Drive
Eden Prairie, MN 55344-2290

Calibration Report

Report Number: 7096-5356
Site: 505296
Country: US

Customer
Name: Cincinnati Testing Labs
System ID: 63
Device ID: Force 63(60279)
MTS System No: 60279
Location: Lab A

Equipment
Device Type: Force
Conditioner Model: 494.16
Readout Device Model: 494.16
Model: 661.22H-01
Serial No.: 0009036185
Serial No.: 0009036185
Serial No.: 10476205D
Channel: Force 63 (60279)

Procedure
MTS Procedure: FS-CA 2122 Rev. F
Calibration has been performed in accordance with: ASTM E4-20
ACS Version: 10.45
Method of Verification: Follow-the-Force Method using Elastic Calibration Devices

Calibration Equipment Asset No.
Dead Weight Set:
DW Compensation:
Temperature Readout: 26828
HighLevel Board:
DMM:
Additional Equipment:
LowLevel Board:
Digital Indicator: 18756
Standardizer: 18757
Standard Asset No.: 18526
Lower Limit: 1000 lbf

Conditions
Ambient Temperature: 76.8 °F
Polarity(+): Tension
Bidirectional:
Cable Length: 25 Feet

In Tolerance [X]
Out of Tolerance [ ]
As Found: [X]
As Adjusted: [ ]
Tolerance: +/-1.0% of Applied Force
As Found System Condition: Good

Conditioner Parameters
Polarity: Normal
Excitation: 10.0 Volts
Total Gain: 510.96776
Pre-amp gain: 285.98
Post-amp gain: 1.78673
Fine zero: -0.09073
Delta K: 0.996
Shunt Cal (+): 7369.88972 lbf.

Calibration Data
Compression
Range: 1
Resolution: 2.6
Full Scale: 50000
Report Units: lbf

Applied Percent of Full Scale Force	Series 1 Indicated Reading Ascending	Series 1 Indicated Reading Descending	Series 1 Errors Units Error Asc	Series 1 Errors Percent Error Asc	Series 1 Errors Units Error Desc	Series 1 Errors Percent Error Desc	Series 2 Indicated Reading Ascending	Series 2 Indicated Reading Descending	Series 2 Errors Units Error Asc	Series 2 Errors Percent Error Asc	Series 2 Errors Units Error Desc	Series 2 Errors Percent Error Desc	Repeatability Percent Error Asc	Repeatability Percent Error Desc
0	-3.2	25.4	-3.2	-0.01	25.4	0.05	-0.9	-1.8	-0.9	0.00	-1.8	0.00	0.00	0.05
-2	-1005.3		5.3	0.53			-1001.5		1.5	0.15			0.38	
-4	-2009.0		9.0	0.45			-2003.7		3.7	0.18			0.27	
-6	-3012.0		12.0	0.40			-3006.3		6.3	0.21			0.19	
-8	-4014.3		14.3	0.36			-4008.1		8.1	0.20			0.15	
-10	-5015.6		15.6	0.31			-5011.2		11.2	0.22			0.09	
-20	-10024.0		24.0	0.24			-10018.0		18.0	0.18			0.06	
-40	-20027.0		27.0	0.14			-20020.0		20.0	0.10			0.04	
-70	-35010.0		10.0	0.03			-35000.0		0.0	0.00			0.03	
-100	-49995.0		-5.0	-0.01			-49984.0		-16.0	-0.03			0.02	

Tension
Range: 1
Report Units: lbf

Applied Percent of Full Scale Force	Series 1 Indicated Reading Ascending	Series 1 Indicated Reading Descending	Series 1 Errors Units Error Asc	Series 1 Errors Percent Error Asc	Series 1 Errors Units Error Desc	Series 1 Errors Percent Error Desc	Series 2 Indicated Reading Ascending	Series 2 Indicated Reading Descending	Series 2 Errors Units Error Asc	Series 2 Errors Percent Error Asc	Series 2 Errors Units Error Desc	Series 2 Errors Percent Error Desc	Repeatability Percent Error Asc	Repeatability Percent Error Desc
0	2.6	-23.5	2.6	0.01	-23.5	-0.05	0.1	1.2	0.1	0.00	1.2	0.00	0.00	0.05
2	1003.4		3.4	0.34			998.3		-1.7	-0.17			0.51	
4	2000.5		0.5	0.03			1996.6		-3.4	-0.17			0.20	
6	2998.3		-1.7	-0.06			2994.6		-5.4	-0.18			0.12	
8	3996.3		-3.7	-0.09			3991.6		-8.4	-0.21			0.12	
10	4995.1		-4.9	-0.10			4989.0		-11.0	-0.22			0.12	
20	9975.2		-24.8	-0.25			9968.9		-31.1	-0.31			0.06	
40	19922.0		-78.0	-0.39			19913.0		-87.0	-0.44			0.05	
70	34941.0		-59.0	-0.17			34935.0		-65.0	-0.19			0.02	
100	50214.0		214.0	0.43			50206.0		206.0	0.41			0.02	

Errors at Zero are computed in % of Range.
Uncertainty of the data supplied is equal to or less than ±0.25% of reading for a coverage factor of k=2 and an approximate confidence level of 95%.

[ ] Out of Tolerance in % column

American Association of Laboratory Accreditation Certificate Number: 1145.01

Notes:

Performed By: Ed Reip
Field Service Engineer:
Date: 30-Nov-20

Signature: Ed Reip

Next Customer Agreed Upon Calibration Date: 30-Nov-21

ACSRepRevBD

MTS Systems Corporation
14000 Technology Drive
Eden Prairie, MN 55344-2290

Calibration Report

ACCREDITED CERT #1145.01

Page: 3 of 3
Report Number: 7096-5356
Site: 505296
Country: US

Customer
Name: Cincinnati Testing Labs
System ID: 63
Device ID: Force 63(60279)
MTS System No: 60279
Location: Lab A

Equipment
Device Type: Force
Model: 661.22H-01
Serial No.: 10476205D
Conditioner Model: 494.16
Serial No.: 0009036185
Readout Device Model: 494.16
Serial No.: 0009036185
Channel: Force 63 (60279)

Procedure
MTS Procedure: FS-CA 2122 Rev. F
ACS Version: 10.45
Calibration has been performed in accordance with: ASTM E4-20
Method of Verification: Follow-the-Force Method using Elastic Calibration Devices

Calibration Equipment Asset No.
Dead Weight Set:
HighLevel Board:
LowLevel Board:
Standard Asset No.: 18526
DW Compensation:
DMM:
Digital Indicator: 18756
Lower Limit: 1000 lbf
Temperature Readout: 26828
Additional Equipment:
Standardizer: 18757

Conditions
Ambient Temperature: 77.2 °F
Polarity(+): Tension
Bidirectional:
Cable Length: 25 Feet

In Tolerance X
Out of Tolerance
As Found: X
As Adjusted:
Tolerance: +/-1.0% of Applied Force
As Found System Condition: Good

Conditioner Parameters
Polarity: Normal
Excitation: 10.0 Volts
Total Gain: 2554.83899
Pre-amp gain: 1805.95
Post-amp gain: 1.41468
Fine zero: -0.463
Delta K: 0.9994
Shunt Cal (+): 7393.7827 lbf.

Calibration Data
Range: 2
Compression
Resolution: 4
Full Scale: 10000
Report Units: lbf

Applied Percent of Full Scale Force	Series 1 Indicated Reading Ascending	Series 1 Indicated Reading Descending	Series 1 Errors Units Error Asc	Series 1 Errors Percent Error Asc	Series 1 Errors Units Error Desc	Series 1 Errors Percent Error Desc	Series 2 Indicated Reading Ascending	Series 2 Indicated Reading Descending	Series 2 Errors Units Error Asc	Series 2 Errors Percent Error Asc	Series 2 Errors Units Error Desc	Series 2 Errors Percent Error Desc	Repeatability Percent Error Asc	Repeatability Percent Error Desc
0	-0.1	-0.1	-0.1	0.00	-0.1	0.00	-1.5	-0.7	-1.5	-0.02	-0.7	-0.01	0.01	0.01
-10	-1002.6		2.6	0.26			-1003.9		3.9	0.39			0.13	
-20	-2005.2		5.2	0.26			-2004.9		4.9	0.25			0.01	
-40	-4007.1		7.1	0.18			-4007.2		7.2	0.18			0.00	
-60	-6010.0		10.0	0.17			-6009.4		9.4	0.16			0.01	
-80	-8011.5		11.5	0.14			-8011.5		11.5	0.14			0.00	
-100	-10013.0		13.0	0.13			-10012.0		12.0	0.12			0.01	

Tension
Range: 2
Report Units: lbf

Applied Percent of Full Scale Force	Series 1 Indicated Reading Ascending	Series 1 Indicated Reading Descending	Series 1 Errors Units Error Asc	Series 1 Errors Percent Error Asc	Series 1 Errors Units Error Desc	Series 1 Errors Percent Error Desc	Series 2 Indicated Reading Ascending	Series 2 Indicated Reading Descending	Series 2 Errors Units Error Asc	Series 2 Errors Percent Error Asc	Series 2 Errors Units Error Desc	Series 2 Errors Percent Error Desc	Repeatability Percent Error Asc	Repeatability Percent Error Desc
0	-0.3	0.1	-0.3	0.00	0.1	0.00	0.1	0.3	0.1	0.00	0.3	0.00	0.00	0.00
10	999.6		-0.4	-0.04			999.5		-0.5	-0.05			0.01	
20	2000.2		0.2	0.01			1999.6		-0.4	-0.02			0.03	
40	4000.1		0.1	0.00			4000.6		0.6	0.02			0.01	
60	5999.8		-0.2	0.00			6000.8		0.8	0.01			0.02	
80	7998.8		-1.2	-0.02			7998.3		-1.7	-0.02			0.01	
100	9994.7		-5.3	-0.05			9994.0		-6.0	-0.06			0.01	

Errors at Zero are computed in % of Range.
Uncertainty of the data supplied is equal to or less than ±0.25% of reading for a coverage factor of k=2 and an approximate confidence level of 95%.

[ ] Out of Tolerance in % column

American Association of Laboratory Accreditation Certificate Number: 1145.01

Notes:

Performed By: Ed Reip
Field Service Engineer:
Date: 30-Nov-20

Signature: Ed Reip

Next Customer Agreed Upon Calibration Date: 30-Nov-21

ACSRepRevBD

MTS Field Service

MTS Systems Corporation
14000 Technology Drive
Eden Prairie, MN 55344-2290

Customer Address:
1775 Carillon Boulevard
Cincinnati, OH 45240
US

Certificate of Calibration

Customer
Name: Cincinnati Testing Labs
System ID: 63
Device ID: Disp. 63(60279)
MTS System No: 60279
Location: Lab A
Certificate Number: 7096-5355
Site: 505296
Country: US

Equipment
Device Type: Length
Conditioner Model: 494.26
Readout Device Model: 494.26
Model: 370.25
Serial No.: 0009063438
Serial No.: 0009063438
Serial No.: 9738
Channel: Displacement 63 (60279)

MTS Field Service is accredited by the American Association for Laboratory Accreditation (A2LA Cert. No. 1145.01). The basis for this accreditation is the international standard for calibration laboratories, ISO/IEC 17025 "General Requirements for the Competence of Testing and Calibration Laboratories". Defined and documented measurement assurance techniques or uncertainty analyses are used to verify the adequacy of the measurement processes.

Calibrations are performed with standards whose values and measurements are traceable to the International System of Units (SI) through a National Metrology Institute (NMI).

The results of this calibration relate only to the items calibrated.
When parameter(s) are certified to be within specified tolerance(s), the measured value(s) shall fall within the appropriate specification limit and the uncertainty of the measured value(s) shall be stated.

CALIBRATION INFORMATION

As Found:	In Tolerance	Max. Error As Found:	-0.91 %	Calibration Date:	30-Nov-2020
As Left:	In Tolerance	Max. Error As Left:	-0.91 %	Calibration Due:	30-Nov-2021
Class:	B, B				

Calibration Procedure: FS-CA 2124 Rev. F ASTM E2309/E2309M-20
Full Scale Ranges: 5 in, 1.5 in
Note: * The reported Class may be the result of criteria other than the Maximum % Error listed
Return to zero errors are not included in the Classification Criteria.

STANDARDS USED FOR CALIBRATION

MTS Asset Number	Manufacturer	Model Number	Description	Cal. Date	Cal. Due
26828	Rotronic	HL-20D	Temperature & Humidity M	29-Apr-20	29-Apr-21
22354	MTS	MTS 1800	Displacement Calibrator	16-Sep-20	16-Sep-21

Certified by:

Issued on: 30-Nov-20

ACS Version: 10.45

ACSRepRevBD

MTS

MTS Systems Corporation
14000 Technology Drive
Eden Prairie, MN 55344-2290

Calibration Report

ilac-MRA ACCREDITED CERT 4114.5.01

Report Number: 7096-5355
Site: 505296
Country: US

Customer
Name: Cincinnati Testing Labs
System ID: 63
Device ID: Disp. 63(60279)
MTS System No: 60279
Location: Lab A

Equipment
Device Type: Length
Conditioner Model: 494.26
Readout Device Model: 494.26
Model: 370.25
Serial No.: 0009063438
Serial No.: 0009063438
Serial No.: 9738
Channel: Displacement 63 (60279)

Procedure
MTS Procedure: FS-CA 2124 Rev. F
Calibration has been performed in accordance with: ASTM E2309/E2309M-20
ACS Version: 10.45
Method of Verification: Follow-the-Displacement Method

Calibration Equipment Asset No.
Dead Weight Set:
DW Compensation:
Temperature Readout: 26828
HighLevel Board:
DMM:
Additional Equipment:
LowLevel Board:
Digital Indicator:
Standardizer:
Standard Asset No.: 22354
Lower Limit:

Conditions
Ambient Temperature: 74.8 °F
Polarity(+): Retraction
Bidirectional:
Cable Length: 25 Feet

In Tolerance [X]
Out of Tolerance [ ]
As Found: [X]
As Adjusted: [ ]
ASTM E2309 Classification: B
As Found System Condition: Good

Conditioner Parameters
Polarity: Normal
Excitation: 9.0 Volts
Total Gain: 1.40096
Pre-amp gain: 0.9025
Post-amp gain: 1.55231
Fine zero: 0.0
Delta K: 0.9963
Phase: 56.0 deg

Calibration Data
Extension
Range: 1
Resolution: 0.00008
Full Scale: 5
Report Units: in

Applied Percent of Full Scale Length	Series 1 Indicated Reading Ascending	Series 1 Indicated Reading Descending	Series 1 Errors Units Error Asc	Series 1 Errors Percent Error Asc	Series 1 Errors Units Error Desc	Series 1 Errors Percent Error Desc	Series 2 Indicated Reading Ascending	Series 2 Indicated Reading Descending	Series 2 Errors Units Error Asc	Series 2 Errors Percent Error Asc	Series 2 Errors Units Error Desc	Series 2 Errors Percent Error Desc	Repeatability Percent Error Asc	Repeatability Percent Error Desc
0	-0.00006	-0.00012	-0.00006	0.00	-0.00012	0.00	-0.00015	0.00001	-0.00015	0.00	0.00001	0.00	0.00	0.00
-1	-0.04976		-0.00024	-0.49			-0.04988		-0.00012	-0.23			0.25	
-2	-0.09951		-0.00049	-0.49			-0.09966		-0.00034	-0.34			0.15	
-4	-0.19927		-0.00073	-0.37			-0.19942		-0.00058	-0.29			0.08	
-8	-0.39905		-0.00095	-0.24			-0.39919		-0.00081	-0.20			0.04	
-10	-0.49903		-0.00097	-0.19			-0.49915		-0.00085	-0.17			0.02	
-20	-1.00020		0.00020	0.02			-1.00040		0.00040	0.04			0.02	
-30	-1.50500		0.00500	0.33			-1.50520		0.00520	0.35			0.01	
-40	-2.01190		0.01190	0.59			-2.01220		0.01220	0.61			0.02	
-60	-3.01560		0.01560	0.52			-3.01590		0.01590	0.53			0.01	

Retraction
Range: 1
Report Units: in

Applied Percent of Full Scale Length	Series 1 Indicated Reading Ascending	Series 1 Indicated Reading Descending	Series 1 Errors Units Error Asc	Series 1 Errors Percent Error Asc	Series 1 Errors Units Error Desc	Series 1 Errors Percent Error Desc	Series 2 Indicated Reading Ascending	Series 2 Indicated Reading Descending	Series 2 Errors Units Error Asc	Series 2 Errors Percent Error Asc	Series 2 Errors Units Error Desc	Series 2 Errors Percent Error Desc	Repeatability Percent Error Asc	Repeatability Percent Error Desc
0	0.00002	-0.00002	0.00002	0.00	-0.00002	0.00	0.00016	0.00004	0.00016	0.00	0.00004	0.00	0.00	0.00
1	0.04955		-0.00045	-0.91			0.04964		-0.00036	-0.73			0.18	
2	0.09923		-0.00077	-0.77			0.09935		-0.00066	-0.66			0.12	
4	0.19853		-0.00147	-0.73			0.19857		-0.00143	-0.72			0.02	
8	0.39718		-0.00282	-0.71			0.39724		-0.00276	-0.69			0.02	
10	0.49668		-0.00332	-0.66			0.49673		-0.00327	-0.65			0.01	
20	0.99660		-0.00340	-0.34			0.99662		-0.00338	-0.34			0.00	
30	1.50290		0.00290	0.19			1.50290		0.00290	0.19			0.00	
40	2.01350		0.01350	0.67			2.01360		0.01360	0.68			0.01	
60	3.02210		0.02210	0.74			3.02190		0.02190	0.73			0.01	

Errors at Zero are computed in % of Range.
Uncertainty of the calibration data supplied is equal to or less than the greater of, ±0.25% of reading or ±50µ inches, for a coverage factor of k=2 and an approximate confidence level of 95%.

[ ] Out of Tolerance in % column

American Association of Laboratory Accreditation Certificate Number: 1145.01

Notes:

Performed By: Ed Reip
Field Service Engineer:
Date: 30-Nov-20

Signature: Ed Reip

Next Customer Agreed Upon Calibration Date: 30-Nov-21

ACSRepRevBD

MTS Systems Corporation
14000 Technology Drive
Eden Prairie, MN 55344-2290

Calibration Report

ilac-MRA A2LA ACCREDITED CERT #1145.01

Report Number: 7096-5355
Site: 505296
Country: US

Customer
Name: Cincinnati Testing Labs
System ID: 63
Device ID: Disp. 63(60279)
MTS System No: 60279
Location: Lab A

Equipment
Device Type: Length
Conditioner Model: 494.26
Readout Device Model: 494.26
Model: 370.25
Serial No.: 0009063438
Serial No.: 0009063438
Serial No.: 9738
Channel: Displacement 63 (60279)

Procedure
MTS Procedure: FS-CA 2124 Rev. F
Calibration has been performed in accordance with: ASTM E2309/E2309M-20
ACS Version: 10.45
Method of Verification: Follow-the-Displacement Method

Calibration Equipment Asset No.
Dead Weight Set:
DW Compensation:
Temperature Readout: 26828
HighLevel Board:
DMM:
Additional Equipment:
LowLevel Board:
Digital Indicator:
Standardizer:
Standard Asset No.: 22354
Lower Limit:

Conditions
Ambient Temperature: 75.7 °F
Polarity(+): Retraction
Bidirectional:
Cable Length: 25 Feet

In Tolerance [X]
Out of Tolerance [ ]
As Found: [X]
As Adjusted: [ ]
ASTM E2309 Classification: B
As Found System Condition: Good

Conditioner Parameters
Polarity: Normal
Excitation: 9.0 Volts
Total Gain: 4.67531
Pre-amp gain: 3.249
Post-amp gain: 1.439
Fine zero: 0.0
Delta K: 0.9963
Phase: 56.0 deg

Calibration Data
Extension
Range: 2
Resolution: 0.00002
Full Scale: 1.5
Report Units: in

Applied Percent of Full Scale Length	Series 1 Indicated Reading Ascending	Series 1 Indicated Reading Descending	Series 1 Errors Units Error Asc	Series 1 Errors Percent Error Asc	Series 1 Errors Units Error Desc	Series 1 Errors Percent Error Desc	Series 2 Indicated Reading Ascending	Series 2 Indicated Reading Descending	Series 2 Errors Units Error Asc	Series 2 Errors Percent Error Asc	Series 2 Errors Units Error Desc	Series 2 Errors Percent Error Desc	Repeatability Percent Error Asc	Repeatability Percent Error Desc
0	-0.00007	-0.00001	-0.00007	0.00	-0.00001	0.00	-0.00004	0.00000	-0.00004	0.00	0.00000	0.00	0.00	0.00
-3.32999992	-0.04970		-0.00025	-0.51			-0.04969		-0.00026	-0.51			0.01	
-4	-0.05976		-0.00024	-0.41			-0.05974		-0.00026	-0.43			0.02	
-6	-0.08959		-0.00041	-0.46			-0.08958		-0.00042	-0.46			0.00	
-8	-0.11948		-0.00052	-0.43			-0.11946		-0.00054	-0.45			0.02	
-10	-0.14942		-0.00058	-0.39			-0.14941		-0.00059	-0.39			0.01	
-20	-0.29922		-0.00078	-0.26			-0.29920		-0.00080	-0.27			0.01	
-40	-0.59919		-0.00081	-0.14			-0.59923		-0.00077	-0.13			0.01	
-70	-1.05130		0.00130	0.12			-1.05140		0.00140	0.13			0.01	
-100	-1.50610		0.00610	0.41			-1.50620		0.00620	0.41			0.01	

Retraction
Range: 2
Report Units: in

Applied Percent of Full Scale Length	Series 1 Indicated Reading Ascending	Series 1 Indicated Reading Descending	Series 1 Errors Units Error Asc	Series 1 Errors Percent Error Asc	Series 1 Errors Units Error Desc	Series 1 Errors Percent Error Desc	Series 2 Indicated Reading Ascending	Series 2 Indicated Reading Descending	Series 2 Errors Units Error Asc	Series 2 Errors Percent Error Asc	Series 2 Errors Units Error Desc	Series 2 Errors Percent Error Desc	Repeatability Percent Error Asc	Repeatability Percent Error Desc
0	0.00007	0.00003	0.00007	0.00	0.00003	0.00	0.00004	0.00004	0.00004	0.00	0.00004	0.00	0.00	0.00
3.32999992	0.04951		-0.00044	-0.87			0.04950		-0.00045	-0.90			0.03	
4	0.05959		-0.00041	-0.69			0.05958		-0.00043	-0.71			0.02	
6	0.08938		-0.00062	-0.69			0.08937		-0.00063	-0.70			0.02	
8	0.11922		-0.00078	-0.65			0.11925		-0.00075	-0.63			0.02	
10	0.14906		-0.00094	-0.63			0.14908		-0.00092	-0.61			0.01	
20	0.29809		-0.00191	-0.64			0.29810		-0.00190	-0.63			0.00	
40	0.59678		-0.00322	-0.54			0.59686		-0.00314	-0.52			0.01	
70	1.04770		-0.00230	-0.22			1.04770		-0.00230	-0.22			0.00	
100	1.50420		0.00420	0.28			1.50420		0.00420	0.28			0.00	

Errors at Zero are computed in % of Range.
Uncertainty of the calibration data supplied is equal to or less than the greater of, ±0.25% of reading or ±50µ inches, for a coverage factor of k=2 and an approximate confidence level of 95%.

[ ] Out of Tolerance in % column

American Association of Laboratory Accreditation Certificate Number: 1145.01

Notes:

Performed By: Ed Reip
Field Service Engineer:
Date: 30-Nov-20

Signature: Ed Reip
Next Customer Agreed Upon Calibration Date: 30-Nov-21
ACSRepRevBD

Appendix B

Material Certifications

Customer Name	Customer PO#	Shipper No	Heat Number
Metcut Research	36932	1975486	373478B7

KAISER ALUMINUM
FABRICATED PRODUCTS

Best in Class

CERTIFIED TEST REPORT

http://Online.KaiserAluminum.com

Kaiser Aluminum
Trentwood Works
PO Box 15108 Spokane Valley WA 99215-5108
15000 E Euclid
Spokane Valley, WA 99216
(800) 367-2586

CUSTOMER PO NUMBER:	WORK PACKAGE:	CUSTOMER PART NUMBER:	SHIP RUN/LOAD:	GOVT CONTRACT NUMBER:
5400514837-10		ALFLR00983-48.5	200011/3	

KAISER ORDER NUMBER:	SHIP DATE:	ALLOY:	CLAD:	TEMPER:	PRODUCT DESCRIPTION:
1325623-1	10/19/2020	7075	BARE	T651	Sawed Plate

WEIGHT SHIPPED:	QUANTITY:	TRUCK B/L #:	GAUGE:	DIAMTER/WIDTH:	LENGTH:
3320 LB	19 PCS EST.	2089901	0.2500 IN	48.500 IN	144.500 IN

SHIP TO:	SOLD TO:
COPPER & BRASS SALES THYSSENKRUPP MATERIALS NA 1500 CHEROKEE PARKWAY SUITE 120 ACWORTH, GA 30102 US	COPPER & BRASS SALES ATTN: ACCOUNTS PAYABLE P.O. Box 5116 SOUTHFIELD, MI 48086 US

MHU 2476659: LOT 373478B7: 7 pieces
MHU 2478767: LOT 370523B3: 12 pieces

Certified Specifications

AMS 4045/RevL-AMS-QQ-A-250/12/RevA-ASTM B 209/Rev14-CMMP 025/RevV

Test Code: 1512

Test Results:

Plant Serial: 4629480
Kaiser Order Number: 1325623
Line Item: 1

From: ThyssenKrupp Materials NA
Cust. ONLINE METALS - GA Del.: 2408062573
CstAr 10435 CstOr 150524
Wgt.: 169.714 LB Date 03/05/2021

Tomas Sanchez

Customer Name	Customer PO#	Shipper No	Heat Number
Metcut Research	36932	1975486	373478B7

KAISER ALUMINUM
FABRICATED PRODUCTS

Best in Class

CERTIFIED TEST REPORT

http://Online.KaiserAluminum.com

Kaiser Aluminum
Trentwood Works
PO Box 15108 Spokane Valley WA 99215-5108
15000 E Euclid
Spokane Valley, WA 99216
(800) 367-2586

LOT: 370523B3 CAST: 510 DROP: 13 INGOT: 4

Melted in USA
(ASTM E8/B557)
(EN 2002-1)

Tensile: Temper	Dir/#Tests	Ultimate KSI (MPA)	Yield KSI (MPA)	Elongation %
T651	LT / 02 (Min:Max)	85.4 : 86.4 (589 : 596)	76.0 : 77.2 (524 : 532)	11.9 : 12.7

(ASTM E1251)

Chemistry:	SI	FE	CU	MN	MG	CR	ZN	TI	V	ZR		OTHER
Actual	0.07	0.17	1.5	0.03	2.5	0.20	5.7	0.03	0.01	0.01	TOT	0.04

Plant Serial: 4629480
Kaiser Order Number: 1325623
Line Item: 1

From: ThyssenKrupp Materials NA
Cust. ONLINE METALS - GA Del.: 2408062573
CstAr 10435 CstOr 150524
Wgt.: 169.714 LB Date 03/05/2021

Thomas Sanchez

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Metcut Research	36932	1975486	373478B7

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Trentwood Works
PO Box 15108-Spokane Valley WA 99215-5108
15000 E Euclid
Spokane Valley, WA 99216
(800) 367-2586

LOT: 373478B7 CAST: 500 DROP: 06 INGOT: 3

Melted in USA
(ASTM E8/B557)
(EN 2002-1)

Tensile:	Temper	Dir/#Tests	Ultimate KSI (MPA)	Yield KSI (MPA)	Elongation %
	T651	LT / 02 (Min:Max)	86.1 : 87.0	75.3 : 78.0	11.5 : 13.4
			(594 : 600)	(519 : 538)	

(ASTM E1251)

Chemistry:	SI	FE	CU	MN	MG	CR	ZN	TI	V	ZR		OTHER
Actual	0.07	0.15	1.5	0.03	2.5	0.20	5.7	0.03	0.01	0.01	TOT	0.04

Chemistry:		SI	FE	CU	MN	MG	CR	ZN	TI	V	ZR		OTHER
7075	MIN	0.00	0.00	1.2	0.00	2.1	0.18	5.1	0.00	0.00	0.00	MAX	0.05
	MAX	0.40	0.50	2.0	0.30	2.9	0.28	6.1	0.20	0.05	0.05	TOT	0.15

Aluminum Remainder

CERTIFICATION

Kaiser Aluminum (Trentwood Works) has a Quality Management System in compliance with ISO 9001, AS9100, and ISO 14001. All material shipped under this order: * has been inspected, tested, and found to be in conformance with the requirements of the specifications indicated herein. All test equipment and measuring devices are calibrated and certified in accordance with applicable specifications. For material thicknesses outside specification limits, mechanical properties are as shown herein and chemical composition meets specification requirements. Reported elongation values have been measuredas elongation at fracture. * was melted in the United States of America or a qualifying country per DFARS 225.872-1(a), was manufactured in the United States of America, and meets the requirements of DFARS 252.225 for domestic content. * has been thermally processed in compliance with AMS 2772, where applicable. * is mercury free, within the limits of detection of ASTM E1251 (<1ppm). * is free of weld repair. * meets the reporting requirements of EN10204, Type 3.1. For additional information (Nadcap certifications, Safety Data Sheets, RoHS, REACH, Conflict Minerals, etc.), refer to Kaiser's corporate website at www.kaiseraluminum.com. Any and all warranties are limited to those shown on Kaiser Aluminum's standard general terms and conditions of sale. Test reports are on file, subject to examination. Test reports shall not be reproduced except in full, without the written approval of the Kaiser Aluminum laboratory. The recording of false, fictitious or fraudulent statements or entries on the certificate may be punished as a felony under federal law.

MICHAEL PESKE, PT LAB PROCESS ENGINEER

Plant Serial: 4629480
Kaiser Order Number: 1325623
Line Item: 1

From: ThyssenKrupp Materials NA
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End of Report