WJE

Wellsys Coupler System

AC133 Test Program

707-20, Inje-ro, Saengnim-myeon,
Gimhae-si, Gyeongnam Korea

FINAL REPORT

March 31, 2021
WJE No. 2020.6557

PREPARED FOR:

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Project Manager

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CONTENTS

INTRODUCTION

Wiss, Janney, Elstner Associates, Inc. (WJE) has conducted a series of compression and reversed-loading cyclic tests on reinforcing bar mechanical splices for Wellsys Metal Co., Ltd (Wellsys). The tests were conducted on the Type D splice system for use with ASTM A615 Grade 60 steel reinforcing bars in U.S. Customary sizes No. 5, 6, 7, 8, 9 and 10. The tests were conducted in general accordance with the Type 1 cyclic and compression testing requirements of AC133, Acceptance Criteria for Mechanical Splice Systems for Steel Reinforcing Bars (October 2020), issued by ICC Evaluation Services (ICC ES). The intent of the testing is to provide test data on splices to be submitted to various authorities that are reviewing the splice system as part of these authorities' product review and acceptance process.

Unspliced control bar specimens were also tested. The control bars were sampled from the same lots of reinforcing bar that were used to make the spliced bar specimens. The control bar tests were performed to determine the yield strength, yield strain, tensile strength, uniform elongation, and final elongation after fracture of the unspliced reinforcing bar.

DESCRIPTION OF THE SPLICE SYSTEM

The Type D splice system consists of various components that are assembled to form a completed splice. Each splice consists of three general components: two reinforcing bars and a proprietary steel coupling sleeve with internal serrated wedges. Final assembly of the splice occurs by inserting the reinforcing bar into the steel coupling sleeve until the end of the bar contacts the stopper plate internal to the coupler, near the mid-length of the coupler body. A photograph of a representative Wellsys Type D mechanical splices is given in Figure 1.

Figure 1. Representative photograph of Type D mechanical splice

TEST PLAN, SPECIMEN ASSEMBLY AND TEST PROCEDURES

At the request of Wellsys, the general test plan was made in accordance with the Type 1 testing requirements of AC133. Tests were planned for splices assembled with ASTM A615 Grade 60 reinforcing bar in U.S. Customary bar size No. 5, 6, 7, 8, 9 and 10. Wellsys requested that, for each bar size for which Type 1 recognition is sought, three spliced bar specimens be tested in monotonic compression and three spliced bar specimens be tested under the reversed cyclic loading procedure described in Table 1 of AC133 (as modified by Section 4.2.3). Unspliced control bar tests were also planned. Table 1 summarizes the requested distribution of test specimens.

Table 1. Test Plan Matrix

Bar Size	AC133 Cyclic Test	AC133 Compression Test	Control Bar Test
5	3	3	1
6	3	3	1
7	3	3	1
8	3	3	1
9	3	3	1
10	3	3	1

Control Bar Specimens and Reinforcing Bar Sources

WJE acquired sufficient reinforcing bar to conduct unspliced control bar tests. WJE also acquired sufficient reinforcing bar to assemble the specimens targeted for splice testing. All of the pieces of reinforcing bar in each size, whether an unspliced control-bar specimen or a bar to be assembled into a spliced bar specimen, came from the same lot of reinforcing steel. The reinforcing bars used in this test program were procured as conforming to ASTM A615 Grade 60 reinforcing bar.

Connector Identification and Spliced Bar Specimen Assembly

Wellsys provided the factory-fabricated splice components to WJE in the unassembled condition. WJE completed assembly of all specimens in accordance with the assembly instructions provided by Wellsys. Selected dimensional measurements were taken on representative components in each size. Tabulated dimensional data provided by Wellsys are listed in Table 2. Dimensions, as measured by WJE, are also summarized in Table 2. Measured dimensions generally agree with dimensional data provided by Wellsys (Appendix A).

Table 2. Dimensional Data

	Dimensional Data From Wellsys			Measured Coupler Dimensions	
Coupler Size	Outside Diameter (mm)	Length (mm)		Outside Diameter (mm)	Length (mm)
5	34	125		33.9	124.8
6	40	140		40.1	140.0
7	46	156		46.0	156.1
8	52	178		51.9	178.1
9	60	208		59.9	208.0
10	66	231		66.0	230.9

Test Procedures for Control Bar Specimen

Unspliced control bar specimens were tested monotonically in axial tension, in accordance with ASTM A370-20, *Standard Test Methods and Definitions for Mechanical Testing of Steel Products*. A clip-on strain extensometer measured elongation of the unspliced control bar test specimen. The electrical signal output from the clip-on strain extensometer and an electrical signal indication of the test machine load were recorded digitally using a computer. Force-elongation plots for the control bar specimen were produced by plotting the digital record. For the unspliced control bar specimen, the gauge length of the clip-on strain extensometer was 4 inches.

Two different elongation measurements were made on the bar after fracture: uniform elongation and final elongation after fracture. Uniform elongation was determined by first taking the untested specimen and scribing a series of gauge marks onto the central length of the specimen at 2-inch intervals over a total length of at least 16 inches. After the test, a measurement was made of the distance between two scribe points, away from the fracture and having an original gauge length of 8 inches. The uniform elongation was calculated as the increase in length of the gauge length. Final elongation after fracture was determined in a similar fashion as with uniform elongation, with the exception that the measurement was made on the reinforcing bar approximately centered across the fracture location. The final elongation was calculated as the increase in length of the gauge length.

Test Procedures for Compression Loaded Spliced Bar Specimens

Spliced bar specimens were tested in axial compression, in accordance with ASTM A370-20. Shortening of all compression test spliced bar specimens was measured by using a linear variable differential transformer (LVDT) internal to the test machine that monitored test machine piston position. The clear length between the test machine grips was kept to a minimum in order to minimize the chance for buckling of the specimen in compression. Therefore, piston movement was taken as direct shortening of the compression specimens because the clear length of reinforcing bar between the ends of the coupler and the test machine grip was relatively short. The electrical signal output from the internal LVDT and an electrical signal indication of the test machine load were digitally recorded using a computer.

Test Procedure for Cyclically Loaded Spliced Bar Specimens

Reversed-load cyclic tests utilized the loading protocol shown in Table 3, as established by ICC-ES AC133. In the table, f_y is the specified minimum yield strength of the reinforcing bar (60 ksi).

Table 3. AC133 Cyclic Test Protocol

Load Stage	Tension Load	Compression Load	No. of Cycles
1	$0.95f_y$	$0.5f_y$	20
2	Not required to be applied (refer to AC133 Section 4.2.3)		
3			
4	Load in monotonic tension to failure		

Elongation (slip) across the splice during Stage 1 was monitored by a pair of LVDTs installed in a frame having a gauge length of 8 inches. Strain in the reinforcing bar was monitored for reference purposes during Stage 1 at a point away from the affected zone (as defined in AC133, Section 1.4.4), using a clip-on strain extensometer with a gauge length of 2 inches. The test machine piston position was also monitored. The instrumentation set-up is schematically illustrated in Figure 2.

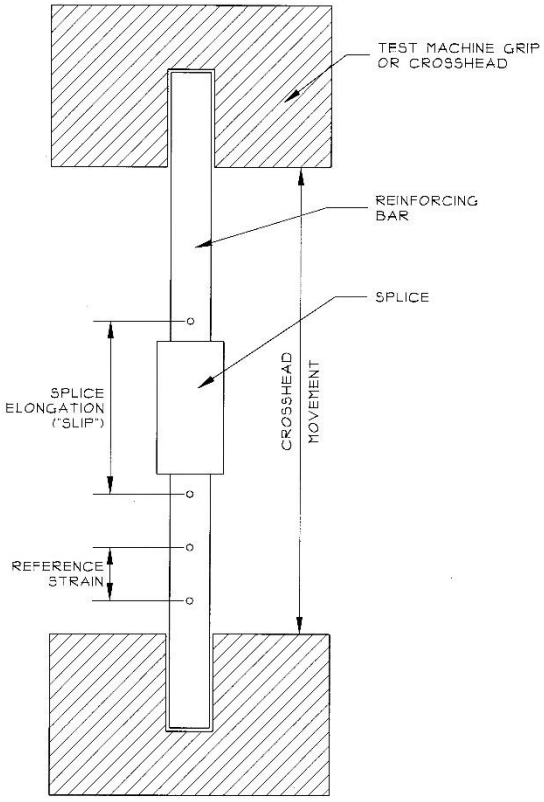


Figure 2. Schematic illustration of test setup

Compression loads and tension loads for Stage 1 were programmed into the test machine controller, which was operated under load control for Stage 1 cycling. The compression load was set to $0.5(A_s*f_y)$, where A_s is the nominal bar area, and f_y is the specified minimum yield strength of 60 ksi. The tension load for Stage 1 was set to $0.95(A_s*f_y)$.

After Stage 1 cyclic loading, both the slip and strain extensometers were removed, and each spliced bar specimen was monotonically loaded in tension to failure. The Stage 4 tests were carried out in accordance with ASTM A370 loading rates. The test machine was operated under displacement control during Stage 4.

Test machine piston position and applied load were monitored by computer throughout the test, up to and including specimen fracture. After a fracture occurred, the peak load indicated by the test machine and the observed type of fracture were recorded for each specimen.

For all types of mechanical splices, AC133 Section 3.2.3 requires assessment of preload slack, which is defined in Section 1.4.5 as "any movements of the reinforcing bars within the mechanical splice prior to the application of loads." WJE assessed preload slack by reviewing the first tensile excursion of the stress-slip chart of each test specimen (starting at zero stress and zero slip) and recording the largest slip value that occurs before stress increases significantly above zero.

Laboratory Accreditation and Test Machine Certifications

WJE is an independent accredited testing laboratory recognized by the ANSI-ASQ National Accreditation Board (Certificate No. AT-2564). All tests were directed by a licensed professional engineer who is a WJE staff member. The Stage 1 cycling on all specimens and the Stage 4 tensile test on specimens in size No. 5, 6, 7 and 8 were performed on a 100-kip MTS universal test machine having hydraulic grips. The MTS test machine is located at the Newmark Structural Engineering Laboratory (NSEL) of the University of Illinois in Urbana, Illinois. The current calibration certificate for the MTS test machine is provided in Appendix B. The Stage 4 tensile test on specimens in Size No. 9 and 10 were performed on a 400-kip Riehle universal test machine having hydraulic grips. The Riehle test machine is located at the WJE headquarters office in Northbrook, Illinois. The current calibration certificate for the WJE test machine is provided in Appendix B.

TEST RESULTS

The tests were carried out between February 19 and February 23, 2021. The results of the tests are described in the following paragraphs.

Unspliced Control Bar

Unspliced control bars were tested in U.S. Customary bar sizes No. 5, 6, 7, 8, 9 and 10. The results of the tests are summarized in Table 4 at the end of this report. The unspliced control bars met the specified minimum yield strength, tensile strength and elongation requirements of ASTM A615 Grade 60. The control bars also met the yield strength, tensile strength and elongation requirements of ASTM A706 Grade 60 reinforcing bar. Stress-strain curves for the control bar tests can be found in Appendix C.

Spliced Bar Specimens Tested in Compression According to ICC-ES AC133

Five spliced bar specimens were tested in compression. Results of the compression tests are summarized in Table 5 at the end of this report. A load-deformation plot was recorded for each test; the plots are presented in Appendix D.

Comparison to AC133 Type 1 Requirements

AC133 Type 1 Compressive Strength Requirements. The AC133 acceptance criteria for Type 1 (Section 4.2.2) mechanical splices requires that a mechanical splice develop, in compression, a strength of 125 percent of specified yield strength, f_y, of the bar. This corresponds to a value of 75 ksi (1.25 x 60 ksi = 75 ksi) for ASTM A615 Grade 60 reinforcement and ASTM A706 Grade 60 reinforcement, both of which have a specified yield strength of 60 ksi minimum. The compressive strength of all couplers summarized in Table 6 meet the AC133 compressive strength requirements for Type 1 mechanical splices assembled with ASTM A615 Grade 60 reinforcing bars and also with ASTM A706 Grade 60 reinforcing bars.

Spliced Bar Specimens Tested Cyclically According to ICC-ES AC133

Results of the cyclic tests on spliced bar specimens tested in accordance with AC133 are summarized in Table 6 at the end of this report. Stress-slip (load-elongation) curves for slip across the mechanical splice, stress-strain curves for the reference strain in the reinforcing bar and test machine load-crosshead movement curves, which trace overall specimen lengthening through the occurrence of fracture, can be found in Appendix E.

Minimum and maximum loads for the cycling of Stage 1 are noted in Table 6, as are the numbers of cycles accomplished. The Stage 4 breaking strengths of the specimens are also noted in Table 6, along with the mode of fracture for the specimens.

During Stage 4, tensile testing to destruction, spliced bar specimens in size No. 5, 6, 7 and 8 fractured in the parent reinforcing bar away from the coupler. Spliced bar specimens in size No. 9 and 10 fractured in the parent reinforcing bar at an indentation created by the wedges that are internal to the coupler. A representative photograph illustrating these failure modes is given in Figure 3.

Figure 3. Representative fractured spliced bar test specimens. Top: Bar fracture away from the coupler. Bottom: Bar fracture at indentation in bar created by the wedges internal to the coupler.

Comparison to AC133 Type 1 Requirements

AC133 Type 1 Cyclic Endurance Requirements. AC133 acceptance criteria for Type 1 (Section 4.2.3), mechanical splices requires that each spliced bar test specimen survive the cyclic loading of Stage 1 without breaking. All spliced bar specimens summarized in Table 6 survived the prescribed number of cycles for Stage 1 without breaking.

AC133 Type 1 Residual Slip Requirements. AC133 acceptance criteria for Type 1 mechanical splices also requires that residual slip, u_{20}, be determined at the end of Stage 1 (refer to AC133 Figure 1). While Table 6 of AC133 has no numeric criteria for residual slip for Type 1 splices, the value has been recorded from the digital recorded and summarized in each stress-slip plot provided in Appendix D.

AC133 Type 1 Tensile Strength Requirements. AC133 acceptance criteria (Section 4.2.3 and subsequently Section 4.2.1) for Type 1 mechanical splices requires that the spliced bar specimens develop, in tension, a strength of 125 percent of specified yield strength f_y of the bar. This corresponds to a value of 75 ksi (1.25 x 60 ksi = 75 ksi) for ASTM A615 Grade 60 and ASTM A706 Grade 60 reinforcement, both of which have a specified yield strength of 60 ksi minimum. The tensile strength of all spliced bar specimens summarized in Table 6 meet the AC133 tensile strength requirements for a Type 1 mechanical splice assembled with ASTM A615 Grade 60 reinforcing bars and also with ASTM A706 Grade 60 reinforcing bars.

Preload Slack. AC133 Section 3.2.3 requires that all types of splices be assessed for preload slack. Our observations related to preload slack are summarized in each stress-slip plot provided in Appendix E. We believe that none of the Wellsys Type D splices in this test program exhibited any observable preload slack.

SUMMARY

Wiss, Janney, Elstner Associates, Inc., conducted a series of tests on reinforcing bar mechanical splices for Wellsys. The tests were conducted on the Wellsys Type D coupler system for use with ASTM A615 Grade 60 and ASTM A706 Grade 60 steel reinforcing bars in U.S. Customary sizes No. 5, 6, 7, 8, 9 and 10. During monotonic compression tests, all spliced bar specimens met or exceeded the specified minimum compressive strength requirements of AC133 (October 2020) for Type 1 mechanical splices when used with ASTM A615 Grade 60 and ASTM A706 Grade 60 reinforcement. During reversed-load cyclic tests, all specimens survived the cyclic loading as prescribed by AC133. No noticeable preload slack was observed in any spliced bar test specimen prior to the application of test load. These specimens were then loaded in monotonic tension to fracture. The tensile strength after cycling of all spliced bar specimens exceeded minimum tensile strength requirements of AC133 for Type 1 mechanical splices when used with ASTM A615 Grade 60 and ASTM A706 Grade 60 reinforcement.

Table 4. Control Bar Test Results

Test I.D. No.	Bar Size	Bar Area (in^2)	Yield Strength (0.2% Offset)			Yield Strain, ε_{ya} (percent)	Tensile Strength, f_{ua}				Uniform Elongation (percent)	Fracture Elongation (percent)
			(kips)	(ksi)	$\%f_y=60$		(kips)	(ksi)	$\%f_y=60$	$\%f_{ya}$		
8337	5	0.31	21.0	67.7	113%	0.23%	31.5	101.6	169%	150%	10%	14%
8338	6	0.44	30.0	68.2	114%	0.24%	46.2	105.0	175%	154%	10%	14%
8339	7	0.60	39.8	66.3	111%	0.23%	63.5	105.8	176%	160%	11%	16%
8340	8	0.79	51.7	65.4	109%	0.23%	80.2	101.5	169%	155%	13%	17%
8341	9	1.00	68.7	68.7	115%	0.24%	103.6	103.6	173%	151%	11%	15%
8342	10	1.27	81.2	63.9	107%	0.22%	129.4	101.9	170%	159%	11%	14%

Table 5. AC133 Compression Test Results

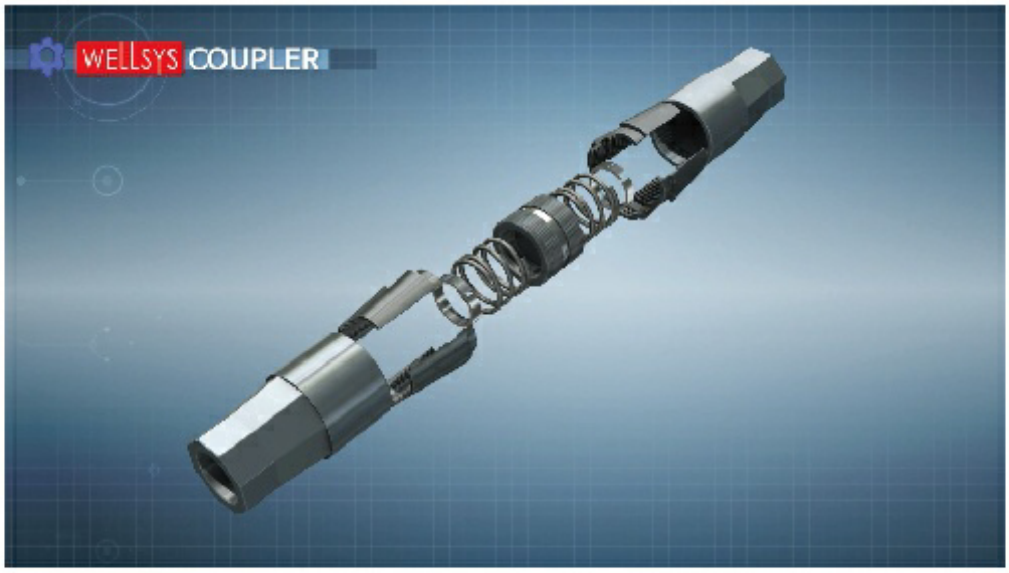
Test I.D. No.	Bar Size	Coupler Type	Bar Area (in^2)	Compressive Strength			Final Result
				(kips)	(ksi)	(%f_y=60)	
8379	5	Type D	0.31	28.9	93.2	155%	No failure
8380	5	Type D	0.31	28.9	93.2	155%	No failure
8381	5	Type D	0.31	29.0	93.5	156%	No failure
8382	6	Type D	0.44	40.0	90.9	152%	No failure
8383	6	Type D	0.44	40.2	91.4	152%	No failure
8384	6	Type D	0.44	40.0	90.9	152%	No failure
8385	7	Type D	0.60	55.3	92.2	154%	No failure
8386	7	Type D	0.60	56.0	93.3	156%	No failure
8387	7	Type D	0.60	55.4	92.3	154%	No failure
8388	8	Type D	0.79	71.5	90.5	151%	No failure
8389	8	Type D	0.79	73.0	92.4	154%	No failure
8390	8	Type D	0.79	72.1	91.3	152%	No failure
8391	9	Type D	1.00	90.3	90.3	151%	No failure
8392	9	Type D	1.00	90.5	90.5	151%	No failure
8393	9	Type D	1.00	90.6	90.6	151%	No failure
8394	10	Type D	1.27	114.9	90.5	151%	No failure
8395	10	Type D	1.27	114.8	90.4	151%	No failure
8396	10	Type D	1.27	114.8	90.4	151%	No failure

Table 6. AC133 Cyclic Test Results - Wellsys Type D Coupler

Test I.D. No.	Bar Size	Bar Area (in^2)	Cyclic Load Levels (Stages 1)		Cycles Applied	Tensile Strength (Stage 4)				Final Result
			P_{min} (kips)	P_{max1} (kips)	n_1	(kips)	(ksi)	(%f_y=60)	(%f_u=80)	
8358	5	0.31	-9.3	17.7	20	31.6	102.0	170%	127%	Bar break
8359	5	0.31	-9.3	17.7	20	31.7	102.4	171%	128%	Bar break
8360	5	0.31	-9.3	17.7	20	31.8	102.5	171%	128%	Bar break
8355	6	0.44	-13.2	25.1	20	45.5	103.4	172%	129%	Bar break
8356	6	0.44	-13.2	25.1	20	45.5	103.5	172%	129%	Bar break
8357	6	0.44	-13.2	25.1	20	45.8	104.0	173%	130%	Bar break
8352	7	0.60	-18.0	34.2	20	63.3	105.5	176%	132%	Bar break
8353	7	0.60	-18.0	34.2	20	63.4	105.7	176%	132%	Bar break
8354	7	0.60	-18.0	34.2	20	63.3	105.5	176%	132%	Bar break
8349	8	0.79	-23.7	45.0	20	80.2	101.5	169%	127%	Bar break
8350	8	0.79	-23.7	45.0	20	80.7	102.1	170%	128%	Bar break
8351	8	0.79	-23.7	45.0	20	80.2	101.5	169%	127%	Bar break
8346	9	1.00	-30.0	57.0	20	102.2	102.2	170%	128%	Bar break at wedge indentation
8347	9	1.00	-30.0	57.0	20	107.4	107.4	179%	134%	Bar break at wedge indentation
8348	9	1.00	-30.0	57.0	20	103.7	103.7	173%	130%	Bar break at wedge indentation
8343	10	1.27	-38.1	72.4	20	126.9	99.9	167%	125%	Bar break at wedge indentation
8344	10	1.27	-38.1	72.4	20	128.5	101.2	169%	126%	Bar break at wedge indentation
8345	10	1.27	-38.1	72.4	20	125.1	98.5	164%	123%	Bar break at wedge indentation

APPENDIX A. WELLSYS PRODUCT BROCHURE

TYPE-D
(Self Locking Type)



TYPE(타입)	SPECIFICATION(제원)	LOCKING TYPE(조임 방식)
TYPE D (D 타입)	ONE TOUCH COUPLER (원터치 커플러)	SELF LOCKING (조임 불필요)

APPENDIX B. TEST MACHINE CALIBRATION CERTIFICATES

UNIVERSITY OF ILLINOIS
AT URBANA-CHAMPAIGN

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1206 West Green Street
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James W. Phillips
Professor Emeritus

2019 Calibration report on the NCEL 100,000-lb MTS uniaxial load frame in compression

On August 23, 2019, the load cell in the 100-kip MTS uniaxial load frame, Model 3156-150k, S/N 351, was calibrated by means of a 200-kip reference load cell according to ASTM standard procedures E4-18 and E74-18. This memorandum sets forth the procedures and results of the calibration.

Procedure

1. A 200-kip reference load cell (University of Illinois UIUC-TAM-200K-2) was placed between the grip housings of the MTS load frame and loaded in compression twice to 90 kips, or 90% of the capacity of the machine. See Fig. 1.

2. Calibration load values of 0, 9, 18, ..., 90 kips were chosen.

   For each indicated load value on the MTS testing machine, the actual value of the compressive load was determined by reading the output x of the reference load cell on a calibrated Vishay Measurements Group P-3500 strain indicator (S/N 130705), with its gage factor set equal to 2.000. The value of x, in microstrain (με), is related to a reference load P_1 from the 2018 National Institute of Standards and Technology (NIST) quartic fit of the calibration data for the reference load cell:

$$x = a_0 + a_1 P_1 + a_2 P_1^2 + a_3 P_1^3 + a_4 P_1^4 , \tag{1}$$

   at a load cell reference temperature T_{NIST} of 23.0°C, where a_0, a_1, …, are least-squares quartic fit coefficients traceable to NIST. For a given x, Eqn. (1) can be solved for P_1 with sufficient accuracy by means of the recursion formula[1]

$$P_1 = b_0 + b_1 x + b_2 x^2 + b_3 x^3 + b_4 x^4 . \tag{2}$$

   The temperature-corrected value of the load P at the temperature T of the MTS calibration, determined by a thermocouple in contact with the load cell, was calculated from the ASTM formula

$$P = F \cdot P_1 , \tag{3}$$

   where F is the temperature correction factor given by

[1] See, for example, *CRC Standard Mathematical Tables*, 12th ed. (Cleveland, Ohio: Chemical Rubber Publishing Co., 1959), 370–371. As a practical matter, both a_0 and b_0 are set equal to zero, since the strain indicator is normally zeroed when the load cell is subjected to zero load.

$$F = 1 - 0.000315(T - T_{\mathrm{NIST}}). \tag{4}$$

The temperature T was measured to be 23.2°C. Therefore,

$$F = 1 - 0.000315(23.2 - 23.0) = 0.99994. \tag{5}$$

3. The reference load cell was rotated 120° and the procedure in Step 2 was repeated. The reference load cell was then rotated an additional 120° and the procedure in Step 2 was repeated again, for a total of three runs.

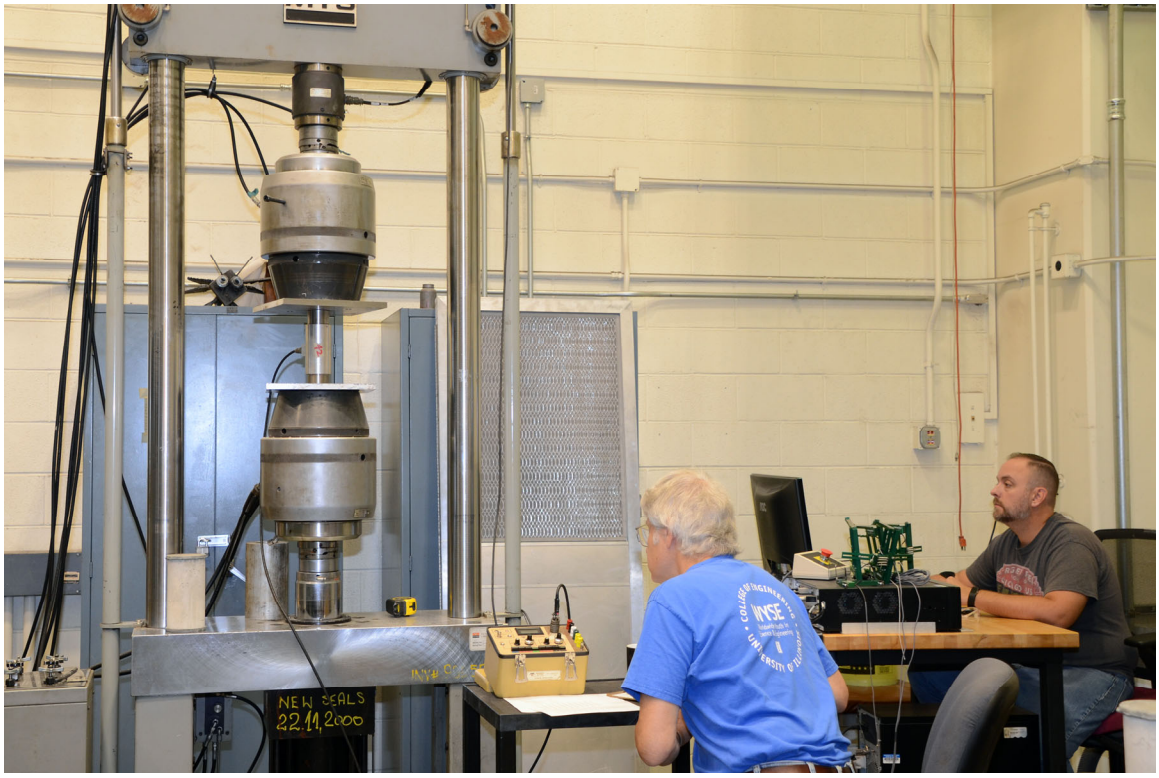


Fig. 1. Calibration setup. Pictured (l–r) are James W. Phillips and Donald E. Marrow (UIUC).

Results of the calibration

Calibration data are presented in Table 1. A complete Microsoft Excel spreadsheet accompanies this report. The data in Table 1 for the difference between the actual (NIST-traceable) load and the indicated load are also plotted in Fig. 2. It will be seen that this difference falls within ±1% of the NIST standard over the complete operating range of the load cell.

Table 1. Calibration data

MTS indicated load (kips)	P-3500 readout, *x* (με)					NIST-traceable load (kips)					Diff NIST – MTS (kips)
	S	NW	NE	Avg	Std dev	S	NW	NE	Avg	Std dev	
0	0	0	0	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.00
9	325	325	326	325.3	0.6	9.01	9.01	9.04	9.02	0.02	0.02
18	649	648	650	649.0	1.0	18.00	17.97	18.03	18.00	0.03	0.00
27	972	971	974	972.3	1.5	26.96	26.94	27.02	26.97	0.04	–0.03
36	1296	1296	1299	1297.0	1.7	35.96	35.96	36.04	35.98	0.05	–0.02
45	1621	1620	1623	1621.3	1.5	44.98	44.95	45.04	44.99	0.04	–0.01
54	1945	1944	1947	1945.3	1.5	53.98	53.95	54.04	53.99	0.04	–0.01
63	2269	2269	2271	2269.7	1.2	62.99	62.99	63.04	63.01	0.03	0.01
72	2593	2593	2595	2593.7	1.2	72.00	72.00	72.05	72.01	0.03	0.01
81	2917	2916	2919	2917.3	1.5	81.01	80.98	81.07	81.02	0.04	0.02
90	3240	3240	3243	3241.0	1.7	90.00	90.00	90.09	90.03	0.05	0.03
0	0	0	0	0.0	0.0						

An examination of the data in Fig. 2 also reveals that the response of the MTS load cell is nearly linear. The degree of nonlinearity can be determined by taking the differences between the observed load-cell output and the values given by the least-squares linear fit of the data, as shown in Table 2. The maximum deviation from linearity is found to be 0.03 kips, which is approximately 0.03% of the maximum load in this calibration.

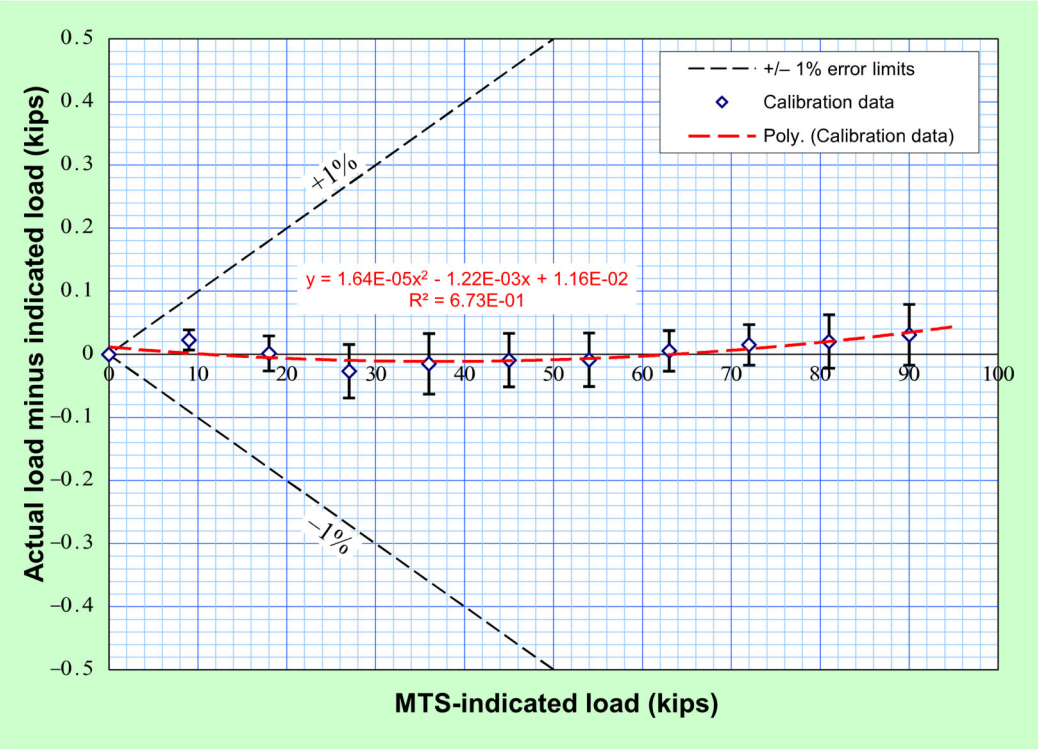


Fig. 2. Difference between the indicated and actual (NIST-traceable) load, as a function of the indicated load, for the August 23, 2019, calibration.

Table 2. Nonlinearity calculation

Linear fit

b = –0.01 kips
m = 1.0003 kips/kip

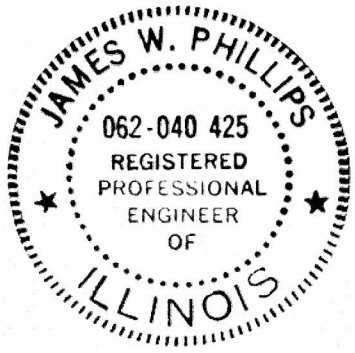
Nonlinearity

Indicated load (kips)	NIST-traceable load (kips) Average	Linear fit	Difference
0	0.00	–0.01	0.01
9	9.02	8.99	0.03
18	18.00	18.00	0.01
27	26.97	27.00	–0.03
36	35.98	36.00	–0.02
45	44.99	45.00	–0.01
54	53.99	54.01	–0.01
63	63.01	63.01	0.00
72	72.01	72.01	0.00
81	81.02	81.01	0.01
90	90.03	90.01	0.02
		Max |Difference| =	0.03 kips
		% FS =	0.03%

The procedures in ASTM E4 (Load Verification of Testing Machines) require that the accuracy be stated as a percentage of the indicated reading, and that the range over which this accuracy holds also be stated. Accordingly, it can be stated that without any correction, the MTS load cell is accurate to within 0.1% over the range of 20 to 90 kips. It should be noted that ASTM E4 requires that the stated accuracy shall not exceed 1.0%.

The calibration procedure outlined in this memorandum meets the requirements of ASTM E4 and ASTM E74 (Calibration of Force-Measuring Instruments for Verifying the Load Indication of Testing Machines). It is recommended that the 100-kip MTS be recalibrated yearly.

James W Phillips



1795-A W. Cortland Ct. P: (630)613-9350
Addison, IL 60101 www.GreatLakesCalibration.com
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ACCREDITED
Calibration Laboratory
CERT #3312.01

Calibration Certificate

Certificate #: **20173-18**

This calibration was performed on-site at the address below for:

WISS JANNEY ELSTNER ASSOCIATES INC
330 PFINGSTEN ROAD
NORTHBROOK, IL 60062

Date of Calibration:	Friday, March 6, 2020
Calibration Interval:	12 - Months
Calibration Due Date:	3/6/2021
Purchase Order:	00985
Condition Received:	Within Tolerance
Condition Returned:	Within Tolerance

Equipment Information

Manufacturer:	RIEHLE	***External Cell Mfg:***	N/A	***Display Mfg:***	N/A
Model Number:	500FH	***External Cell Model:***	N/A	***Display Model #:***	N/A
Serial Number:	0258347-458	***External Cell Serial:***	N/A	***Display Serial #:***	N/A
Asset ID:	N/A	***External Cell Asset ID:***	N/A	***Software Version:***	N/A
Work instruction:	MECH-001	***Calibration Direction:***	COMPRESSION	***Temp / Hum:***	70.6°F / 21 %RH
Revision:	Rev-05	***Calibration Device:***	E-74 LOAD CELL	***Technician:***	Robert Southern
Specification:	ASTM E4-16	***Calibration Method:***	FOLLOW THE FORCE	***Page:***	1 of 2
Description:	500,000-LB Test Frame				

The calibration was performed in accordance with the most current revision of work instruction MECH-001 (which is based off the requirements of ASTM E-4) and the governing specification listed above and is compliant with ISO/IEC 17025:2005, ANS/NCSL Z540-1-1994, ISO9000, and TS-16949.
The calibration device(s) used is either a Class-A load cell that has been certified by an accredited laboratory in accordance with ASTM E-74 or Class-F certified Dead weights.

Calibration Data

500,000-LB RANGE - COMPRESSION

Certified Range: 50000 to 500000 - lbf **Max Error (%):** 0.34% **Tolerance (+/-):** 1.00% **Load Module SN:** N/A
Range Capacity: 500,000.00 **units:** lbf **Indicator:** DIGITAL

Reading	Nominal	Resolution	As Found	As Found Error (lbf)	As Found Error (%)	As Left	Max Error As Left (LB)	Max Error As Left (%)	Repeatability (%)	Uncertainty	Pass/Fail	Eqpt Used
0%	return to zero	100.0	0.00	0.00	0.000%	0.00	0.00	0.000%	0.000%	1.0E+02	PASS	A
10%	50,000.0	100.0	49,978.00	22.00	0.044%	49,967.10	32.90	0.066%	-0.022%	2.4E+02	PASS	A
25%	125,000.0	100.0	124,728.00	272.00	0.218%	124,719.60	280.40	0.225%	-0.007%	4.1E+02	PASS	A
50%	250,000.0	100.0	249,157.40	842.60	0.338%	249,210.90	842.60	0.338%	0.021%	7.5E+02	PASS	A
75%	375,000.0	100.0	373,953.90	1,046.10	0.280%	374,018.10	1,046.10	0.280%	0.017%	1.1E+03	PASS	A
100%	500,000.0	100.0	498,914.00	1,086.00	0.218%	499,151.60	1,086.00	0.218%	0.048%	1.5E+03	PASS	A

250,000-LB RANGE - COMPRESSION

Certified Range: 25000 to 250000 - lbf **Max Error (%):** 0.42% **Tolerance (+/-):** 1.00% **Load Module SN:** N/A
Range Capacity: 250,000.00 **units:** lbf **Indicator:** DIGITAL

Reading	UUT Indication	Resolution	As Found	As Found Error (lbf)	As Found Error (%)	As Left	Max Error As Left (LB)	Max Error As Left (%)	Repeatability (%)	Uncertainty	Pass/Fail	Eqpt Used
0%	return to zero	100.0	0.00	0.00	0.000%	0.00	0.00	0.000%	0.000%	1.0E+02	PASS	A
10%	25,000.00	100.0	24,928.90	71.10	0.285%	24,927.20	72.80	0.292%	-0.007%	1.5E+02	PASS	A
25%	62,500.00	100.0	62,277.50	222.50	0.357%	62,274.80	225.20	0.362%	-0.004%	2.2E+02	PASS	A
50%	125,000.00	100.0	124,478.10	521.90	0.419%	124,473.60	526.40	0.423%	-0.004%	3.7E+02	PASS	A
75%	187,500.00	100.0	186,745.40	754.60	0.404%	186,732.00	768.00	0.411%	-0.007%	5.4E+02	PASS	A
100%	250,000.00	100.0	248,987.30	1,012.70	0.407%	249,084.50	1,012.70	0.407%	0.039%	7.1E+02	PASS	A

Reported uncertainty values have been estimated at the 95% confidence level with a coverage factor of K=2 and are a combination of the reference standard uncertainty, the UUT resolution, and the UUT repeatability. Uncertainties are reported but not combined with the UUT error for the determination of the "PASS/FAIL" status.
* Denotes that the As Found reading was Out of Tolerance.

Check any that apply:
- ☑ All applicable clauses of ASTM E4 have been met unless otherwise noted below
- ☐ Adjustments Were Made
- ☐ 3.1.12 (The Resolution is stated as 1/2 the fluctuation of the indicator)
- ☐ 10.1 (Readings taken below 200 times the resolution)
- ☐ 10.5 (Does not return to zero within 30-seconds)
- ☐ 7.3 (Interchangeability established)
- ☐ Annex A1 (Verified outside of testing machine)
- ☐ 17.1 (Error or repeatability greater than 1.0%)

Calibration Standards Used: All verification devices used are traceable to the National Institute of Standards and Technology (NIST)

Eqpt Used	ID#:	Description:	Cal Date:	Cal Due:	Class-A Ten	Class-A Comp	Calibrated By:
A	M-012	600-KIP Class-A LOAD CELL	2/19/2019	2/19/2021	N/A	17180	MOREHOUSE
B	M-130	120-KIP Class-A LOAD CELL	6/21/2019	6/21/2021	3584	2556	MOREHOUSE
C	M-139A	10-KIP Class-A LOAD CELL	11/19/2019	11/19/2021	210.4	200	MOREHOUSE
D	T-058	Thermohygrometer	8/15/2019	8/15/2020	N/A	N/A	GREAT LAKES CALIBRATION

Marya Black

Customer Approval

QA Approval - Marya Black (QM)

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Addison, IL 60101 www.GreatLakesCalibration.com
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ACCREDITED
Calibration Laboratory
CERT #3312.01

Calibration Certificate

Certificate #: 20173-18

This calibration was performed on-site at the address below for:

WISS JANNEY ELSTNER ASSOCIATES INC
330 PFINGSTEN ROAD
NORTHBROOK, IL 60062

Date of Calibration:	Friday, March 6, 2020
Calibration Interval:	12 - Months
Calibration Due Date:	3/6/2021
Purchase Order:	00985
Condition Received:	Within Tolerance
Condition Returned:	Within Tolerance

Equipment Information

Manufacturer:	RIEHLE	***External Cell Mfg:***	N/A	***Display Mfg:***	N/A
Model Number:	500FH	***External Cell Model:***	N/A	***Display Model #:***	N/A
Serial Number:	0258347-458	***External Cell Serial:***	N/A	***Display Serial #:***	N/A
Asset ID:	N/A	***External Cell Asset ID:***	N/A	***Software Version:***	N/A
Work instruction:	MECH-001	***Calibration Direction:***	COMPRESSION	***Temp / Hum:***	70.6°F / 21 %RH
Revision:	Rev-05	***Calibration Device:***	E-74 LOAD CELL	***Technician:***	Robert Southern
Specification:	ASTM E4-16	***Calibration Method:***	FOLLOW THE FORCE	***Page:***	2 OF 2
Description:	500,000-LB Test Frame				

The data contained within this report pertains only to the item(s) as described above and shall not be reproduced or distributed without prior written consent from Great Lakes Calibration, Inc.
The calibration was performed in accordance with the most current revision of work instruction MECH-001 (which is based off the requirements of ASTM E-4) and the governing specification listed above and is compliant with ISO/IEC 17025:2005, ANS/NCSL Z540-1-1994, ISO9000, and TS-16949.
The calibration device(s) used is either a Class-A load cell that has been certified by an accredited laboratory in accordance with ASTM E-74 or Class-F certified Dead weights.

Calibration Data

100,000-LB RANGE - COMPRESSION

rtified Range: 20000 to 100000 - lbf **Max Error (%):** 0.63% **Tolerance (+/-):** 1.00% **Load Module SN:** N/A
Range Capacity: 100,000.00 **units:** lbf **Indicator:** Digital

Reading	Nominal	Resolution	As Found	As Found Error (lbf)	As Found Error (%)	As Left	Max Error As Left (LB)	Max Error As Left (%)	Repeatability (%)	Uncertainty	Pass/Fail	Eqpt Used
0%	return to zero	100.00	0.00	0.00	0.000%	0.00	0.00	0.000%	0.000%	5.8E+01	PASS	A
20%	20,000.00	100.00	19,875.80	124.20	0.625%	19,877.10	124.20	0.625%	0.006%	1.3E+02	PASS	A
40%	40,000.00	100.00	39,750.90	249.10	0.627%	39,752.00	249.10	0.627%	0.003%	1.7E+02	PASS	A
60%	60,000.00	100.00	59,681.00	319.00	0.535%	59,703.60	319.00	0.535%	0.038%	2.1E+02	PASS	A
80%	80,000.00	100.00	79,562.50	437.50	0.550%	79,565.10	437.50	0.550%	0.003%	2.6E+02	PASS	A
100%	100,000.00	100.00	99,451.60	548.40	0.551%	99,483.70	548.40	0.551%	0.032%	3.1E+02	PASS	A

20,000-LB RANGE - COMPRESSION

Certified Range: 2000 to 20000 - lbf **Max Error (%):** 0.62% **Tolerance (+/-):** 1.00% **Load Module SN:** N/A
Range Capacity: 20,000.00 **units:** lbf **Indicator:** Digital

Reading	UUT Indication	Resolution	As Found	As Found Error (lbf)	As Found Error (%)	Adjusted	As Left	Max Error As Left (LB)	Max Error As Left (%)	Repeatability (%)	Uncertainty	Pass/Fail	Eqpt Used
0%	return to zero	10.00	0.00	0.00	0.000%		0.00	0.00	0.000%	0.000%	5.8E+00	PASS	B
10%	2,000.00	10.00	1,987.60	12.40	0.624%		1,987.90	12.40	0.624%	0.015%	1.5E+01	PASS	C
25%	5,000.00	10.00	4,972.00	28.00	0.563%		4,973.40	28.00	0.563%	0.028%	2.0E+01	PASS	B
50%	10,000.00	10.00	9,948.30	51.70	0.520%		9,949.10	51.70	0.520%	0.008%	3.1E+01	PASS	B
75%	15,000.00	10.00	14,923.60	76.40	0.512%		14,925.60	76.40	0.512%	0.013%	4.4E+01	PASS	B
100%	20,000.00	10.00	19,903.80	96.20	0.483%		19,916.70	96.20	0.483%	0.065%	5.8E+01	PASS	B

Reported uncertainty values have been estimated at the 95% confidence level with a coverage factor of K=2 and are a combination of the reference standard uncertainty, the UUT resolution, and the UUT repeatability. Uncertainties are reported but not combined with the UUT error for the determination of the "PASS/FAIL" status.

* Denotes that the As Found reading was Out of Tolerance.

Check any that apply:

- ☐ All applicable clauses of ASTM E4 have been met unless otherwise noted below
- ☐ Adjustments Were Made
- ☐ 3.1.12 (The Resolution is stated as 1/2 the fluctuation of the indicator)
- ☐ 10.1 (Readings taken below 200 times the resolution)
- ☐ 10.5 (Does not return to zero within 30-seconds)
- ☐ 7.3 (Interchangeability established)
- ☐ Annex A1 (Verified outside of testing machine)
- ☐ 17.1 (Error or repeatability greater than 1.0%)

Calibration Standards Used: All verification devices used are traceable to the National Institute of Standards and Technology (NIST)

Eqpt Used	ID#:	Description:	Cal Date:	Cal Due:	Class-A Ten	Class-A Comp	Calibrated By:
A	M-012	600-KIP Class-A LOAD CELL	2/19/2019	2/19/2021	N/A	17180	MOREHOUSE
B	M-130	120-KIP Class-A LOAD CELL	6/21/2019	6/21/2021	3584	2556	MOREHOUSE
C	M-139A	10-KIP Class-A LOAD CELL	11/19/2019	11/19/2021	210.4	200	MOREHOUSE
	T-058	Thermohygrometer	8/15/2019	8/15/2020			GREAT LAKES CALIBRATION

Marya Black

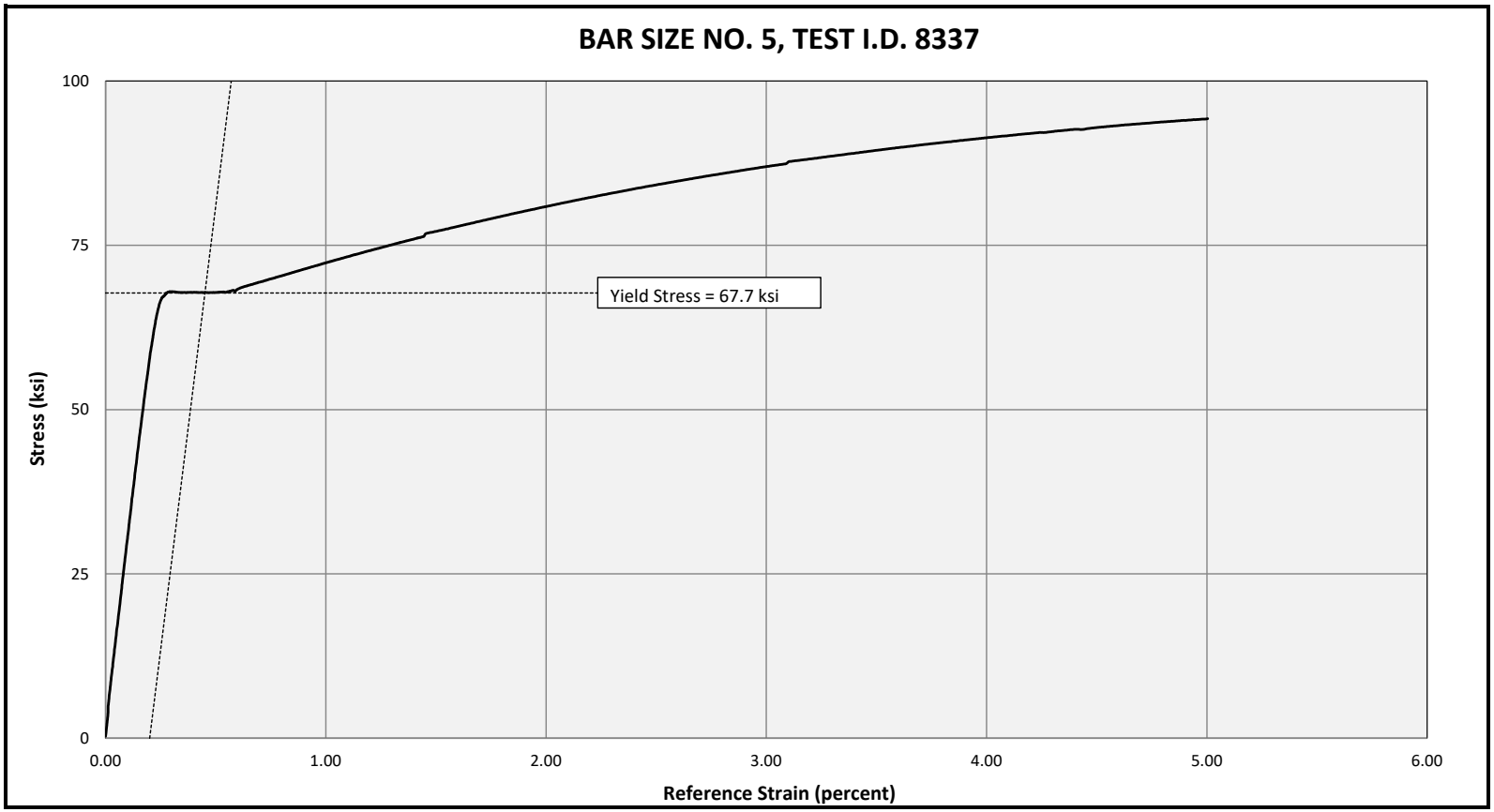
Customer Approval

QA Approval - Marya Black (QM)

APPENDIX C. CONTROL BAR STRESS-STRAIN CURVE

Test I.D. No.	Bar Size	Bar Area (in^2)	Yield Strength, f_{ya} 0.2% Offset		Yield Strain ε_{ya}	Tensile Strength, f_{ua}			Uniform Elongation (percent)	Fracture Elongation (percent)
			(kips)	(ksi)	(percent)	(kips)	(ksi)	$\%f_{ya}$		
8337	5	0.31	21.0	67.7	0.23%	31.5	101.6	150%	10%	14%

WJE ENGINEERS ARCHITECTS MATERIALS SCIENTISTS



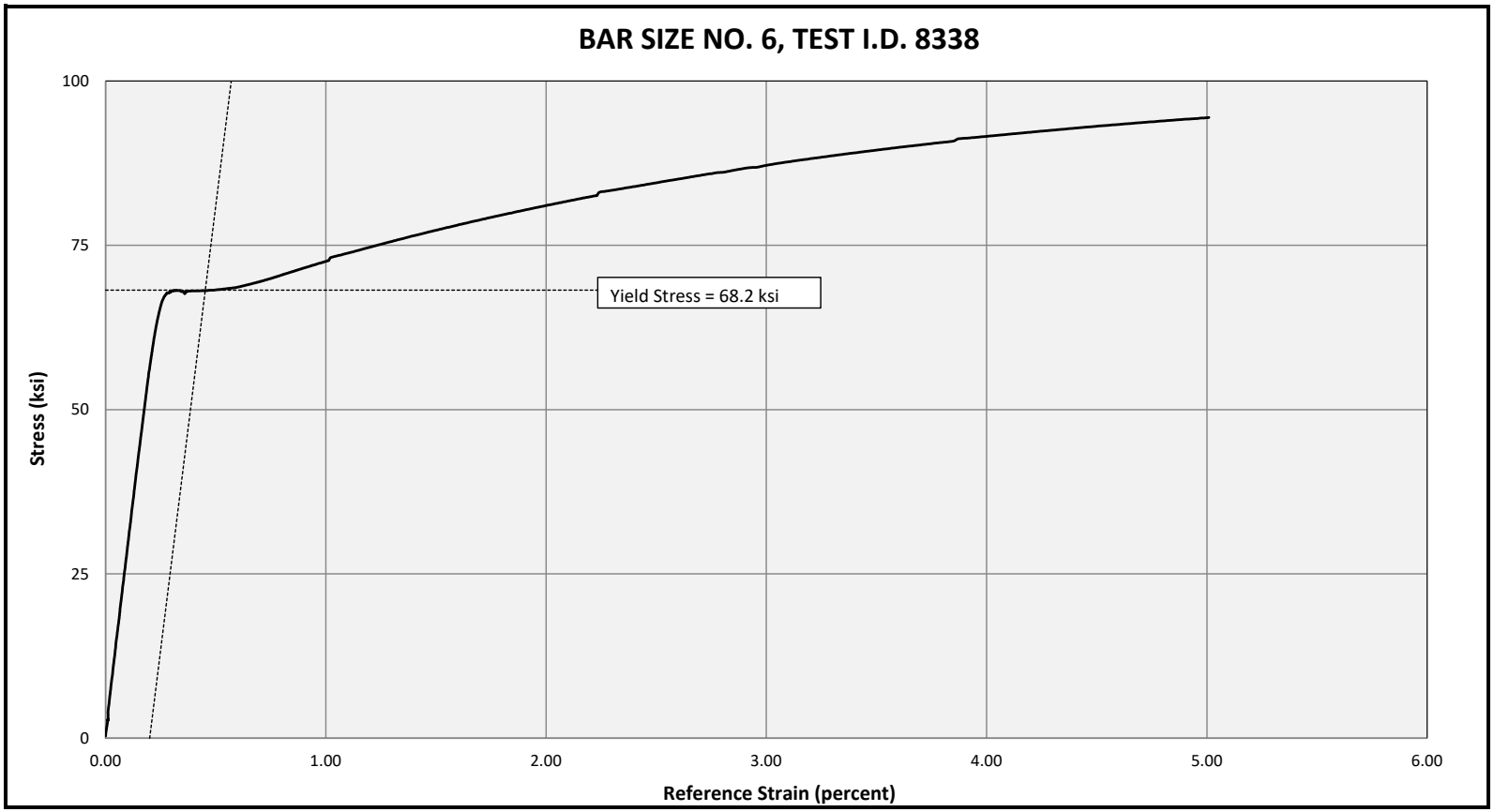
Product Tested	ASTM A615 Grade 60
Reinforcing Bar	ASTM A615 Grade 60
WJE Job Number	2020.6557

Test Location	Champaign, IL
Test Operator	SKG
Test Date	2/19/2021
Test Methods	ASTM A370

Wiss, Janney, Elstner Associates, Inc.
10 S. LaSalle Street, Suite 2600
Chicago, Illinois 60603
312.372.0555 tel | 312.372.0873 fax
www.wje.com

Test I.D. No.	Bar Size	Bar Area (in^2)	Yield Strength, f_{ya} 0.2% Offset		Yield Strain ε_{ya}	Tensile Strength, f_{ua}			Uniform Elongation (percent)	Fracture Elongation (percent)
			(kips)	(ksi)	(percent)	(kips)	(ksi)	$\%f_{ya}$		
8338	6	0.44	30.0	68.2	0.24%	46.2	105.0	154%	10%	14%

WJE ENGINEERS ARCHITECTS MATERIALS SCIENTISTS



Product Tested	ASTM A615 Grade 60
Reinforcing Bar	ASTM A615 Grade 60
WJE Job Number	2020.6557

Test Location	Champaign, IL
Test Operator	SKG
Test Date	2/19/2021
Test Methods	ASTM A370

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10 S. LaSalle Street, Suite 2600
Chicago, Illinois 60603
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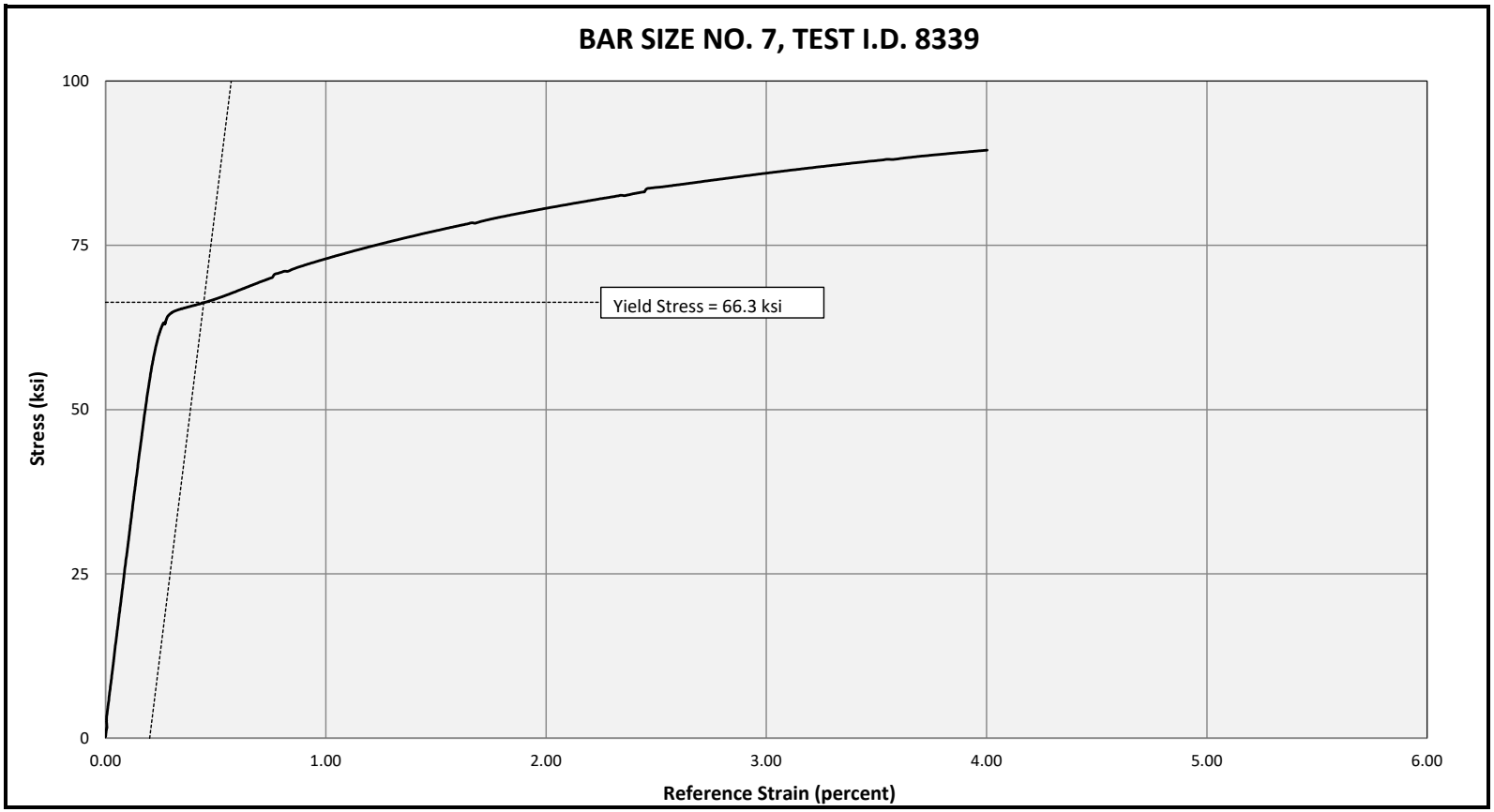
www.wje.com

Test I.D. No.	Bar Size	Bar Area (in^2)	Yield Strength, f_{ya} 0.2% Offset		Yield Strain ε_{ya}	Tensile Strength, f_{ua}			Uniform Elongation (percent)	Fracture Elongation (percent)
			(kips)	(ksi)	(percent)	(kips)	(ksi)	$\%f_{ya}$		
8339	7	0.60	39.8	66.3	0.23%	63.5	105.8	160%	11%	16%

WJE ENGINEERS ARCHITECTS MATERIALS SCIENTISTS



Product Tested	ASTM A615 Grade 60
Reinforcing Bar	ASTM A615 Grade 60
WJE Job Number	2020.6557

Test Location	Champaign, IL
Test Operator	SKG
Test Date	2/19/2021
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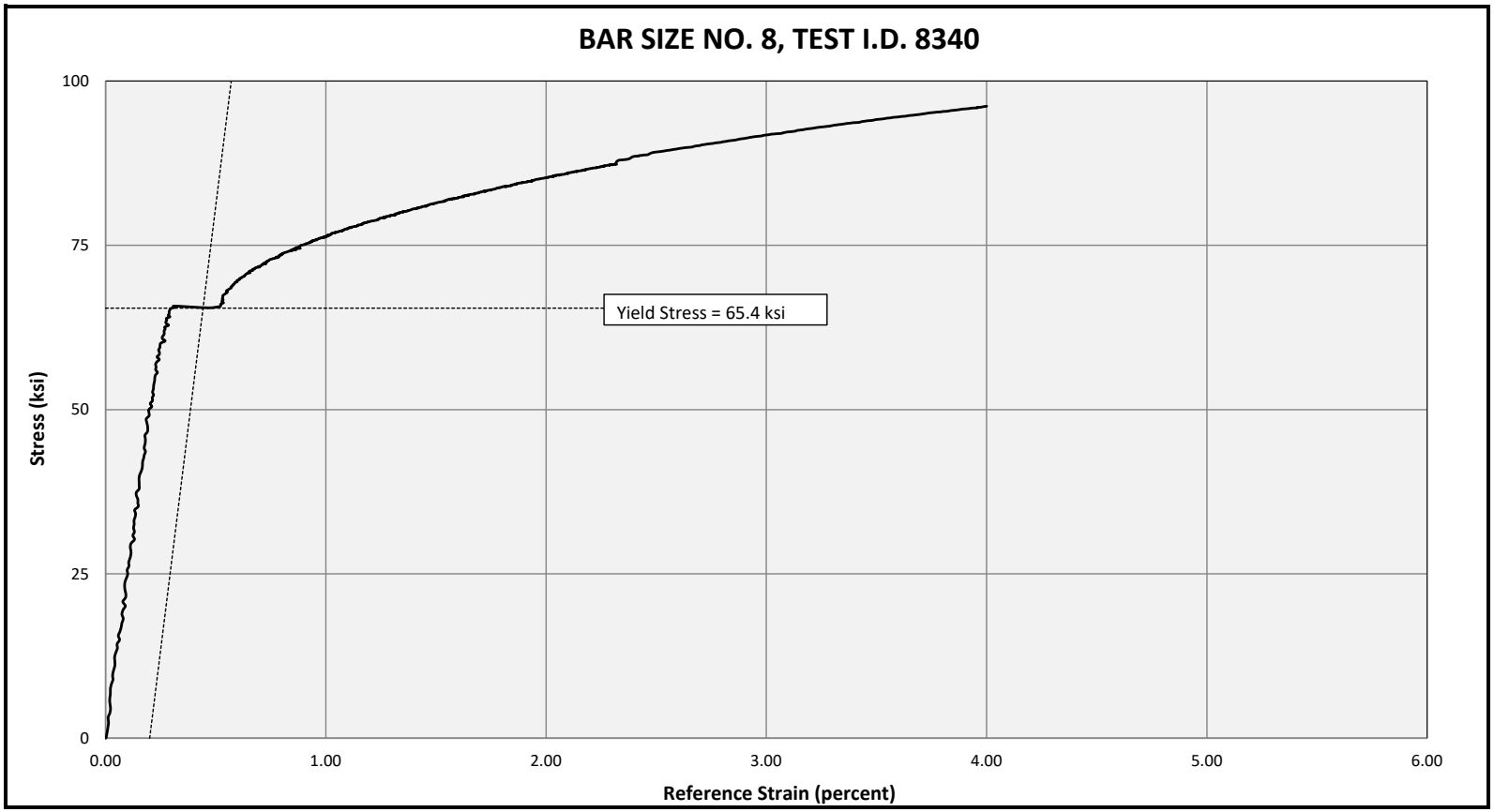
www.wje.com

Test I.D. No.	Bar Size	Bar Area (in^2)	Yield Strength, f_{ya} 0.2% Offset		Yield Strain ε_{ya}	Tensile Strength, f_{ua}			Uniform Elongation (percent)	Fracture Elongation (percent)
			(kips)	(ksi)	(percent)	(kips)	(ksi)	$\%f_{ya}$		
8340	8	0.79	51.7	65.4	0.23%	80.2	101.5	155%	13%	17%

WJE ENGINEERS ARCHITECTS MATERIALS SCIENTISTS



Product Tested	ASTM A615 Grade 60
Reinforcing Bar	ASTM A615 Grade 60
WJE Job Number	2020.6557

Test Location	Champaign, IL
Test Operator	SKG
Test Date	2/19/2021
Test Methods	ASTM A370

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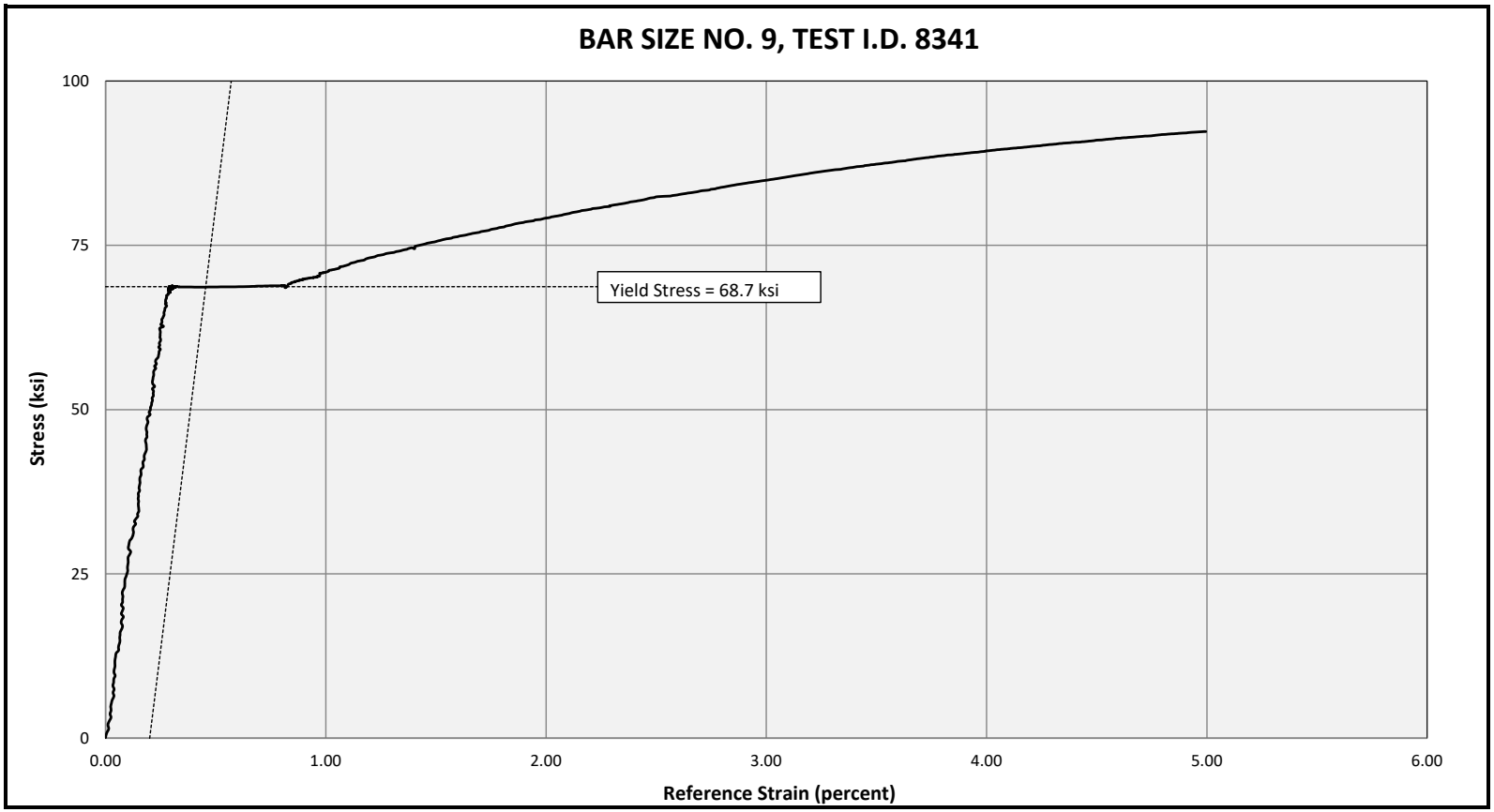
www.wje.com

Test I.D. No.	Bar Size	Bar Area (in^2)	Yield Strength, f_{ya} 0.2% Offset		Yield Strain ε_{ya}	Tensile Strength, f_{ua}			Uniform Elongation (percent)	Fracture Elongation (percent)
			(kips)	(ksi)	(percent)	(kips)	(ksi)	$\%f_{ya}$		
8341	9	1.00	68.7	68.7	0.24%	103.6	103.6	151%	11%	15%

WJE ENGINEERS ARCHITECTS MATERIALS SCIENTISTS



Product Tested	ASTM A615 Grade 60
Reinforcing Bar	ASTM A615 Grade 60
WJE Job Number	2020.6557

Test Location	Champaign, IL
Test Operator	SKG
Test Date	2/19/2021
Test Methods	ASTM A370

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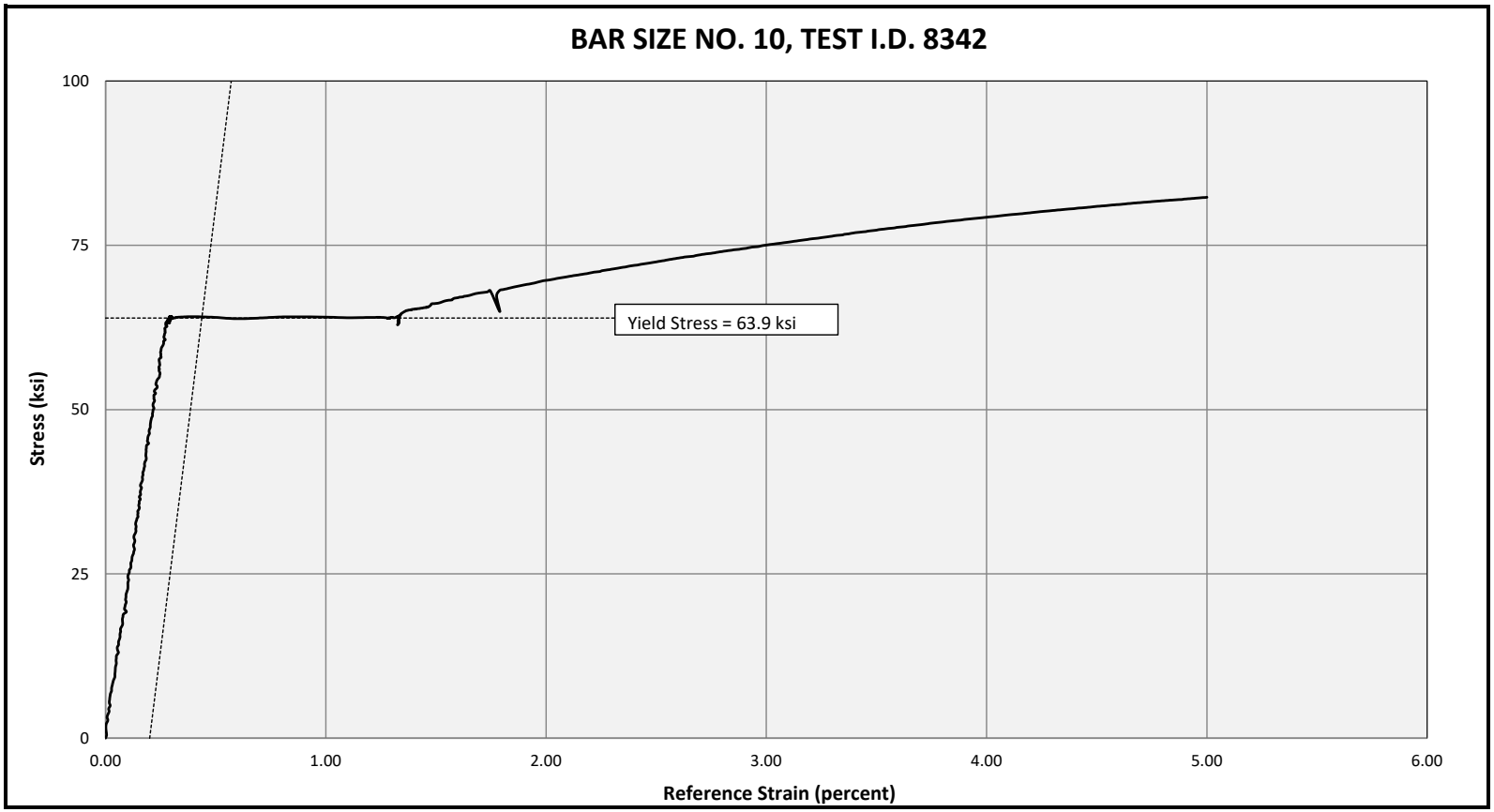
www.wje.com

Test I.D. No.	Bar Size	Bar Area (in^2)	Yield Strength, f_{ya} 0.2% Offset		Yield Strain ε_{ya}	Tensile Strength, f_{ua}			Uniform Elongation (percent)	Fracture Elongation (percent)
			(kips)	(ksi)	(percent)	(kips)	(ksi)	$\%f_{ya}$		
8342	10	1.27	81.2	63.9	0.22%	129.4	101.9	159%	11%	14%

WJE ENGINEERS ARCHITECTS MATERIALS SCIENTISTS



Product Tested	ASTM A615 Grade 60
Reinforcing Bar	ASTM A615 Grade 60
WJE Job Number	2020.6557

Test Location	Champaign, IL
Test Operator	SKG
Test Date	2/19/2021
Test Methods	ASTM A370

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312.372.0555 tel | 312.372.0873 fax
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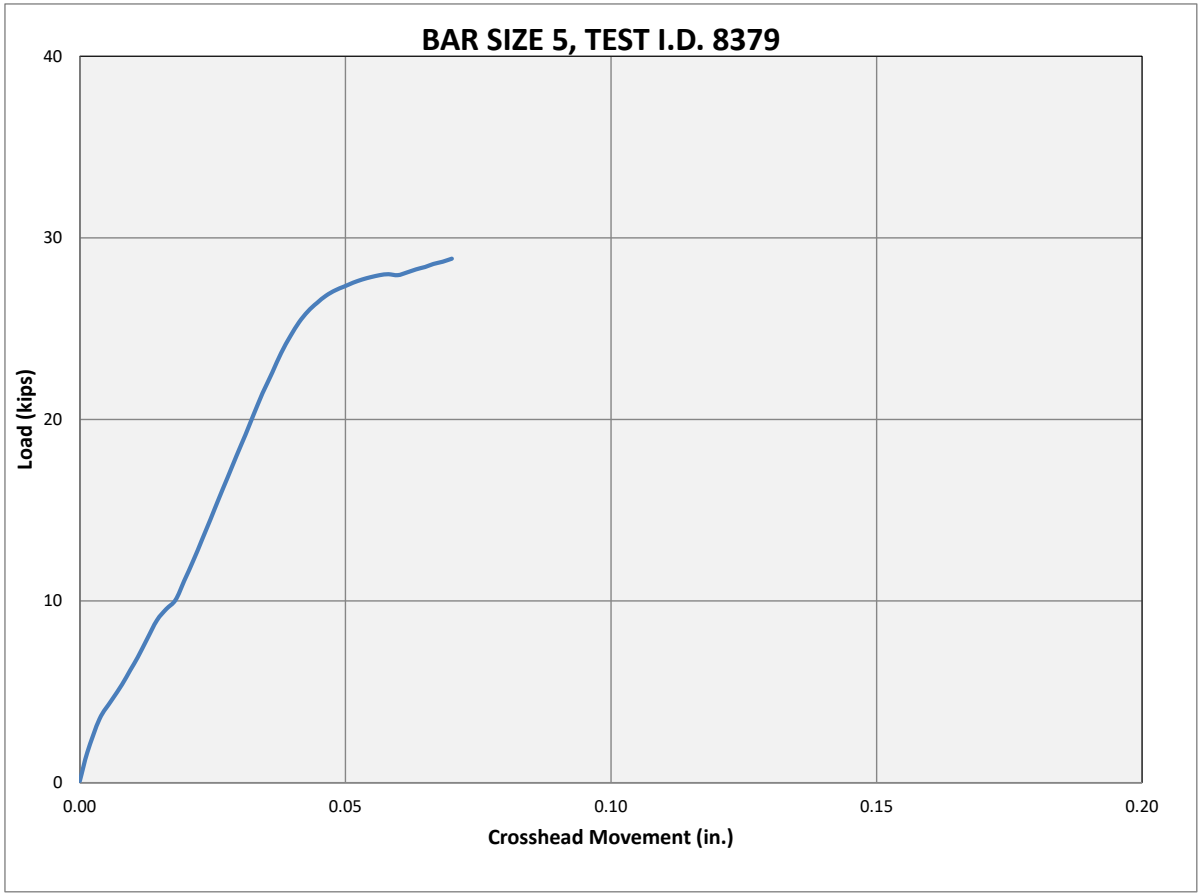
APPENDIX D. COMPRESSION TEST LOAD-DISPLACEMENT CURVES

Test I.D. No.	Bar Size	Bar Area (in^2)	Compressive Strength				Final Result
			(kips)	(ksi)	($\%f_{y=60}$)	($\%f_{u=80}$)	
8379	5	0.31	28.9	93.1	155%	116%	No failure



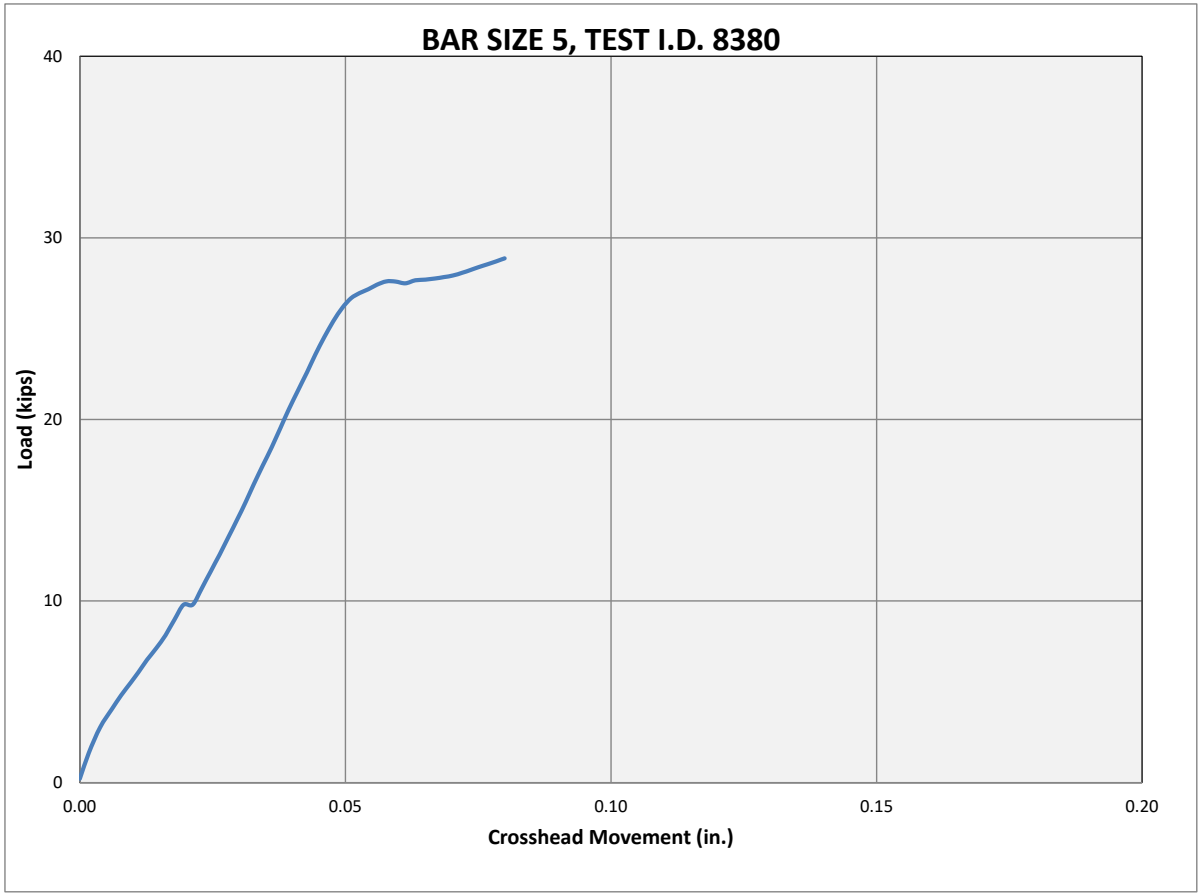
Product Tested	Wellsys Type A Coupler
Reinforcing Bar	ASTM A615 Grade 60
WJE Job Number	2020.6557

Test Location	Champaign, IL
Test Operator	SKG
Test Date	3/2/2021
Test Methods	ASTM A370

WJE ENGINEERS ARCHITECTS MATERIALS SCIENTISTS

Wiss, Janney, Elstner Associates, Inc.
10 S. LaSalle Street, Suite 2600
Chicago, Illinois 60603
312.372.0555 tel | 312.372.0873 fax
www.wje.com

Test I.D. No.	Bar Size	Bar Area (in^2)	Compressive Strength				Final Result
			(kips)	(ksi)	($\%f_{y=60}$)	($\%f_{u=80}$)	
8380	5	0.31	28.9	93.1	155%	116%	No failure



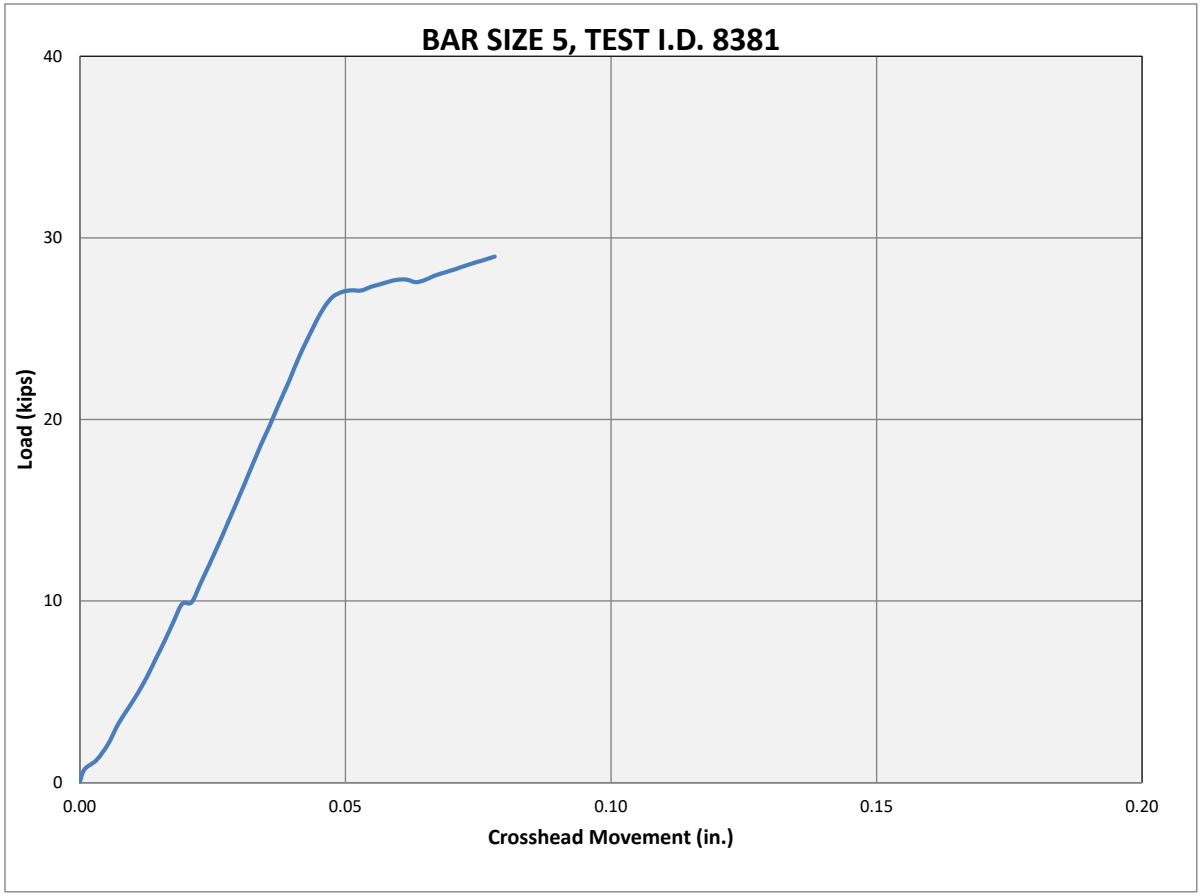
Product Tested	Wellsys Type A Coupler
Reinforcing Bar	ASTM A615 Grade 60
WJE Job Number	2020.6557

Test Location	Champaign, IL
Test Operator	SKG
Test Date	3/2/2021
Test Methods	ASTM A370

WJE ENGINEERS ARCHITECTS MATERIALS SCIENTISTS

Wiss, Janney, Elstner Associates, Inc.
10 S. LaSalle Street, Suite 2600
Chicago, Illinois 60603
312.372.0555 tel | 312.372.0873 fax
www.wje.com

Test I.D. No.	Bar Size	Bar Area (in^2)	Compressive Strength				Final Result
			(kips)	(ksi)	($\%f_{y=60}$)	($\%f_{u=80}$)	
8381	5	0.31	29.0	93.5	156%	117%	No failure



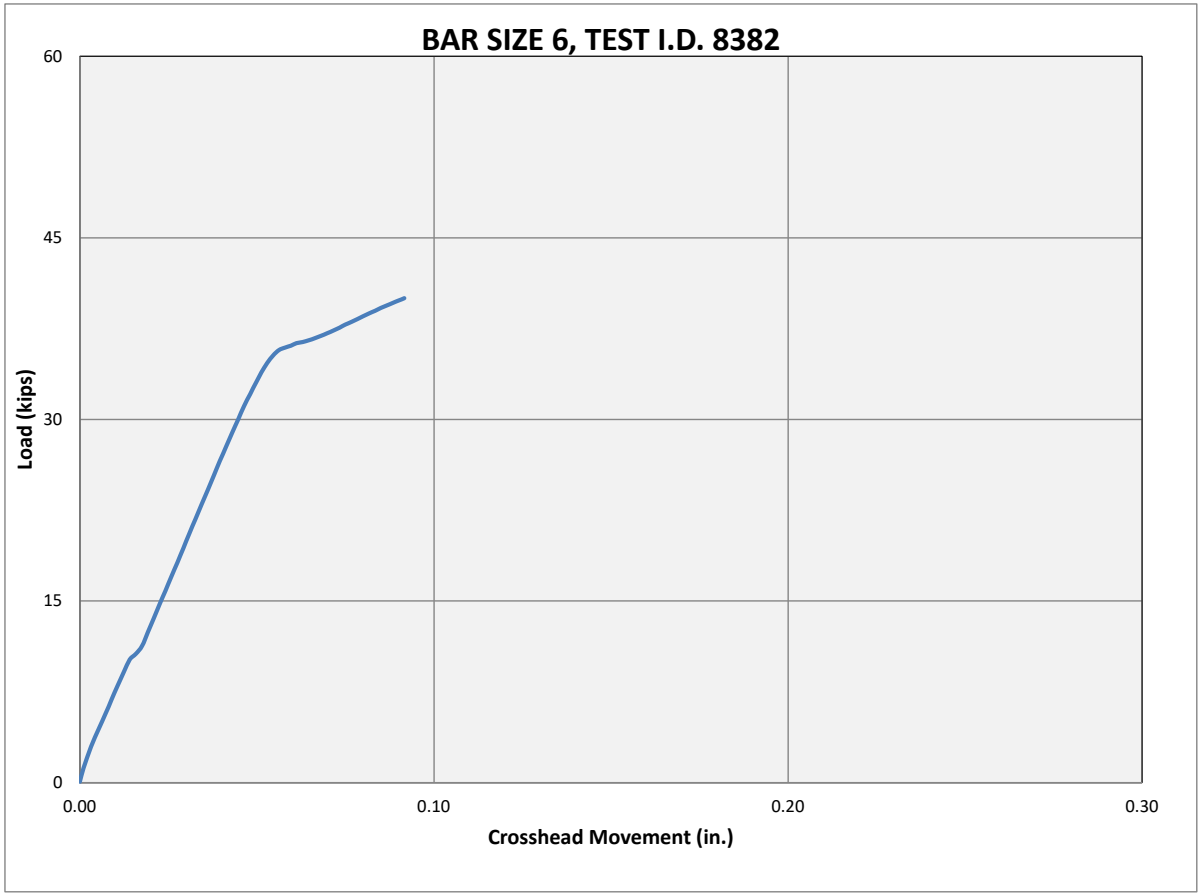
Product Tested	Wellsys Type A Coupler
Reinforcing Bar	ASTM A615 Grade 60
WJE Job Number	2020.6557

Test Location	Champaign, IL
Test Operator	SKG
Test Date	3/2/2021
Test Methods	ASTM A370

WJE ENGINEERS ARCHITECTS MATERIALS SCIENTISTS

Wiss, Janney, Elstner Associates, Inc.
10 S. LaSalle Street, Suite 2600
Chicago, Illinois 60603
312.372.0555 tel | 312.372.0873 fax
www.wje.com

Test I.D. No.	Bar Size	Bar Area (in^2)	Compressive Strength				Final Result
			(kips)	(ksi)	($\%f_{y=60}$)	($\%f_{u=80}$)	
8382	6	0.44	40.0	90.9	152%	114%	No failure



Product Tested	Wellsys Type A Coupler
Reinforcing Bar	ASTM A615 Grade 60
WJE Job Number	2020.6557

Test Location	Champaign, IL
Test Operator	SKG
Test Date	3/2/2021
Test Methods	ASTM A370

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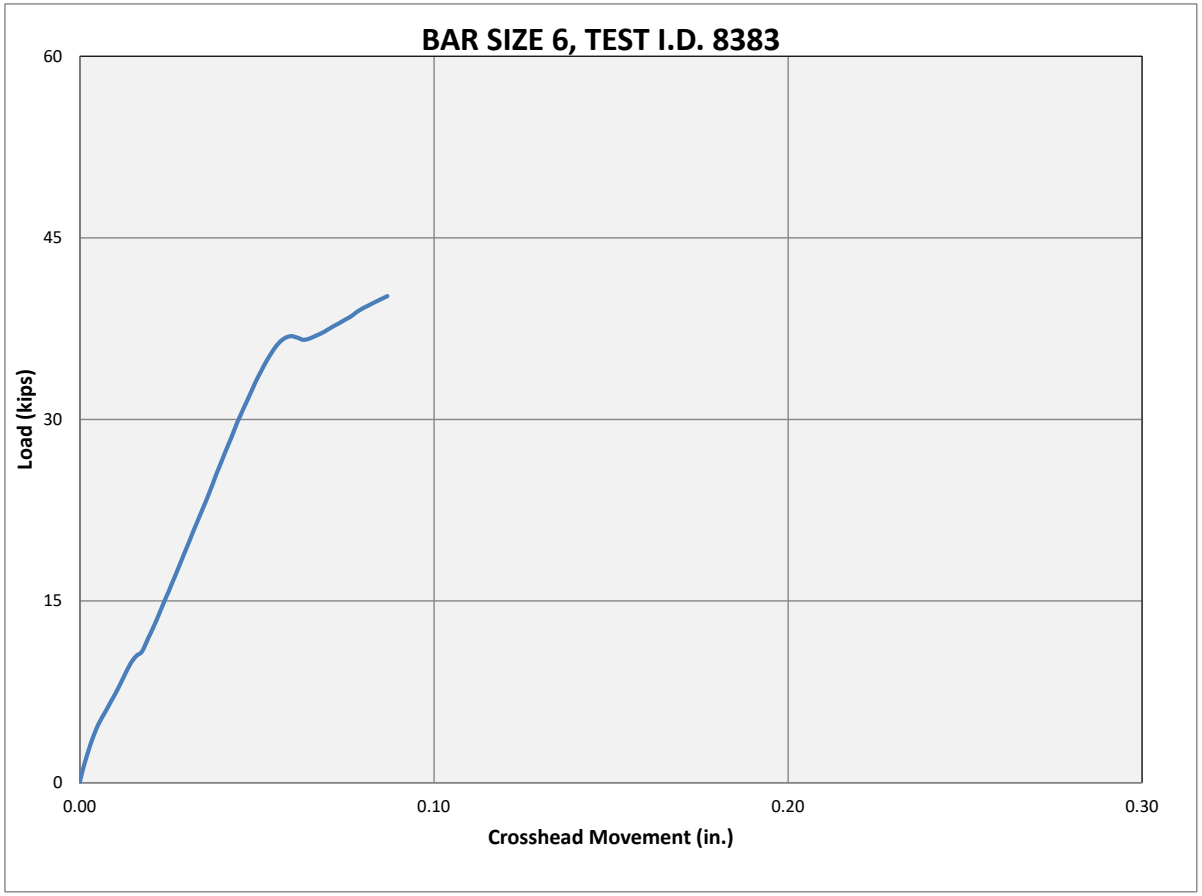
Test I.D. No.	Bar Size	Bar Area (in^2)	Compressive Strength				Final Result
			(kips)	(ksi)	($\%f_{y=60}$)	($\%f_{u=80}$)	
8383	6	0.44	40.2	91.3	152%	114%	No failure



Product Tested	Wellsys Type A Coupler
Reinforcing Bar	ASTM A615 Grade 60
WJE Job Number	2020.6557

Test Location	Champaign, IL
Test Operator	SKG
Test Date	3/2/2021
Test Methods	ASTM A370

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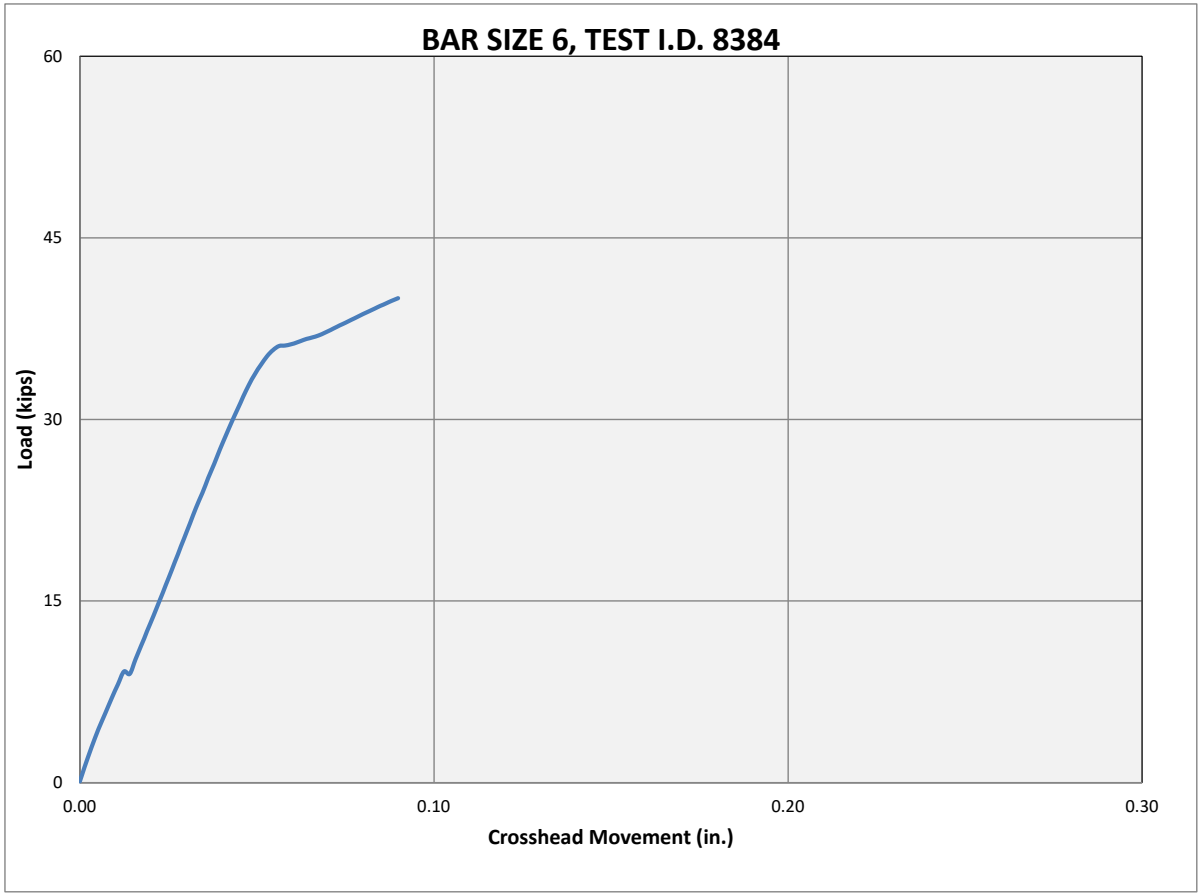
312.372.0555 tel | 312.372.0873 fax
www.wje.com

Test I.D. No.	Bar Size	Bar Area (in^2)	Compressive Strength				Final Result
			(kips)	(ksi)	($\%f_{y=60}$)	($\%f_{u=80}$)	
8384	6	0.44	40.0	90.9	152%	114%	No failure



Product Tested	Wellsys Type A Coupler
Reinforcing Bar	ASTM A615 Grade 60
WJE Job Number	2020.6557

Test Location	Champaign, IL
Test Operator	SKG
Test Date	3/2/2021
Test Methods	ASTM A370

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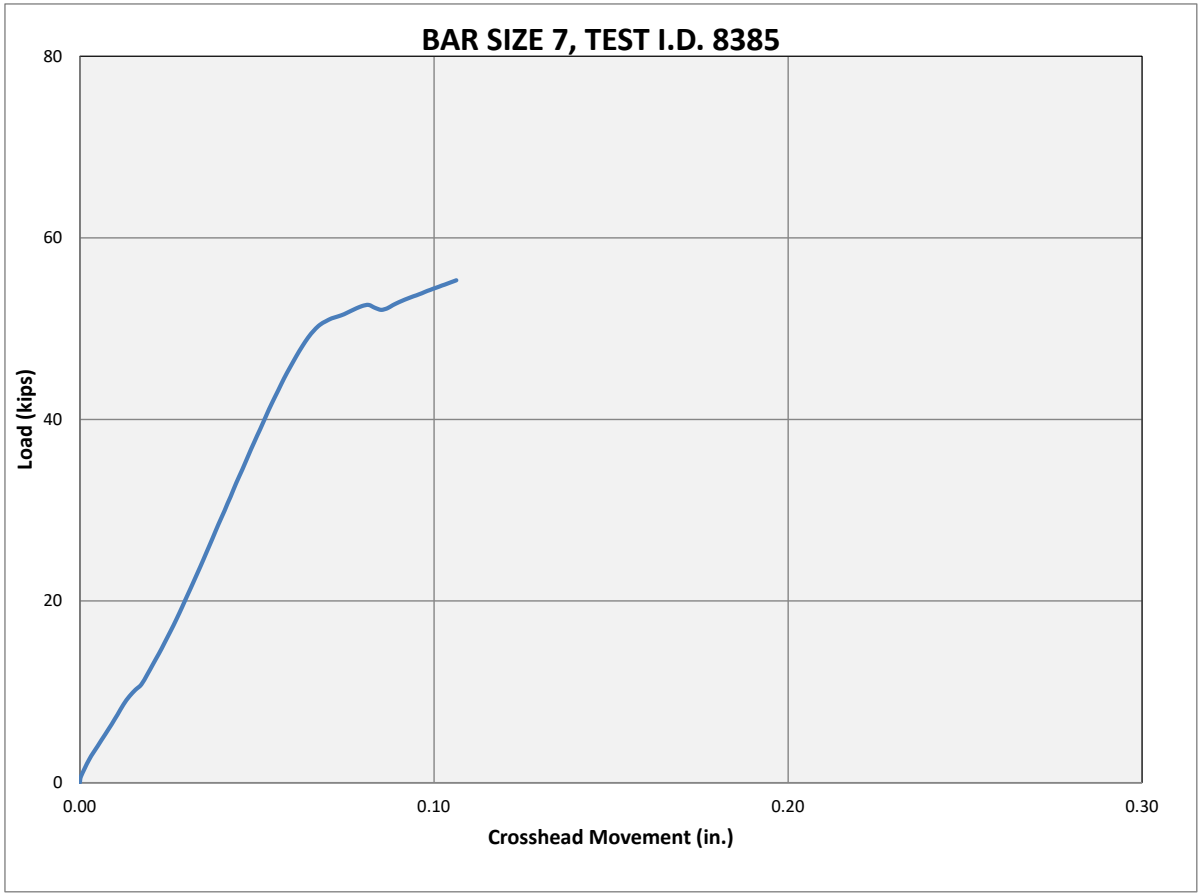
312.372.0555 tel | 312.372.0873 fax
www.wje.com

Test I.D. No.	Bar Size	Bar Area (in^2)	Compressive Strength				Final Result
			(kips)	(ksi)	($\%f_{y=60}$)	($\%f_{u=80}$)	
8385	7	0.60	55.3	92.2	154%	115%	No failure



Product Tested	Wellsys Type A Coupler
Reinforcing Bar	ASTM A615 Grade 60
WJE Job Number	2020.6557

Test Location	Champaign, IL
Test Operator	SKG
Test Date	3/2/2021
Test Methods	ASTM A370

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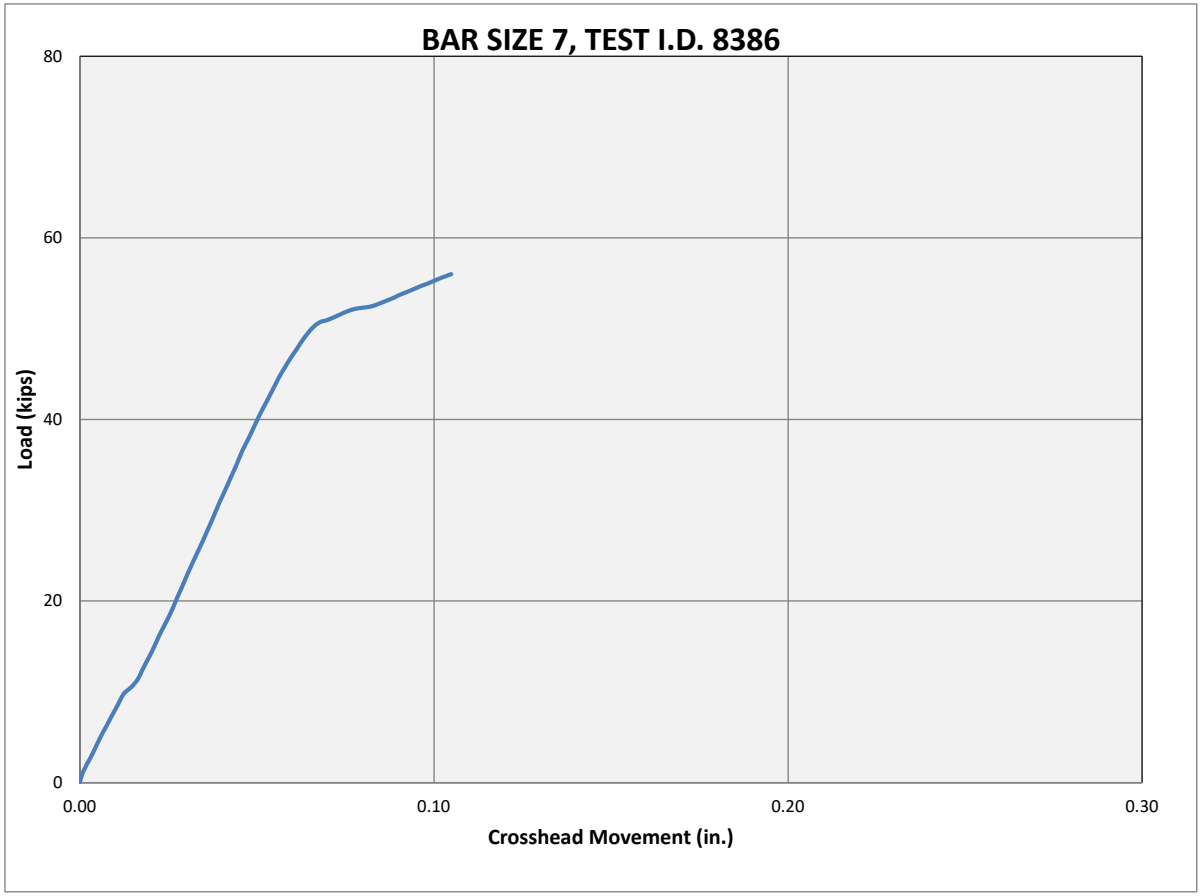
Chicago, Illinois 60603
312.372.0555 tel | 312.372.0873 fax
www.wje.com

Test I.D. No.	Bar Size	Bar Area (in^2)	Compressive Strength				Final Result
			(kips)	(ksi)	($\%f_{y=60}$)	($\%f_{u=80}$)	
8386	7	0.60	56.0	93.3	156%	117%	No failure



Product Tested	Wellsys Type A Coupler
Reinforcing Bar	ASTM A615 Grade 60
WJE Job Number	2020.6557

Test Location	Champaign, IL
Test Operator	SKG
Test Date	3/2/2021
Test Methods	ASTM A370

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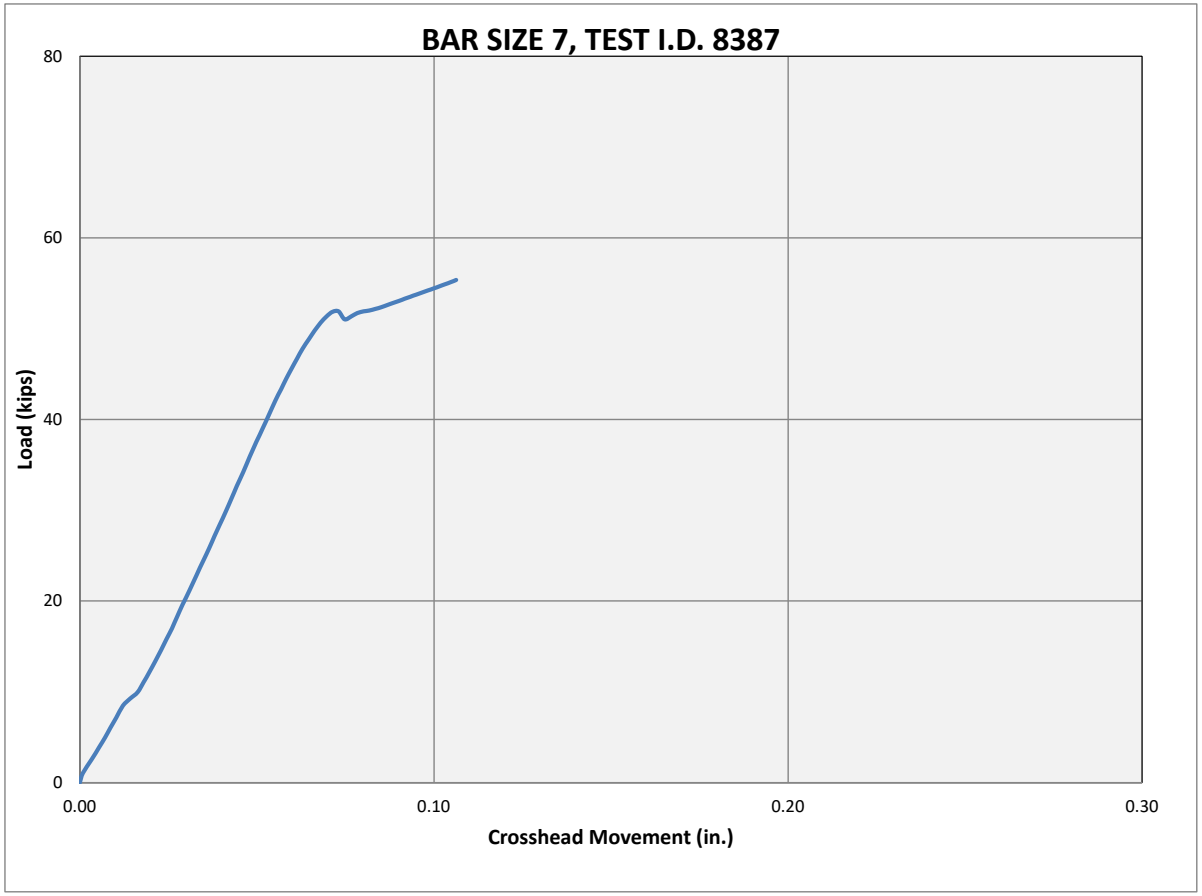
312.372.0555 tel | 312.372.0873 fax
www.wje.com

Test I.D. No.	Bar Size	Bar Area (in^2)	Compressive Strength				Final Result
			(kips)	(ksi)	($\%f_{y=60}$)	($\%f_{u=80}$)	
8387	7	0.60	55.4	92.3	154%	115%	No failure



Product Tested	Wellsys Type A Coupler
Reinforcing Bar	ASTM A615 Grade 60
WJE Job Number	2020.6557

Test Location	Champaign, IL
Test Operator	SKG
Test Date	3/2/2021
Test Methods	ASTM A370

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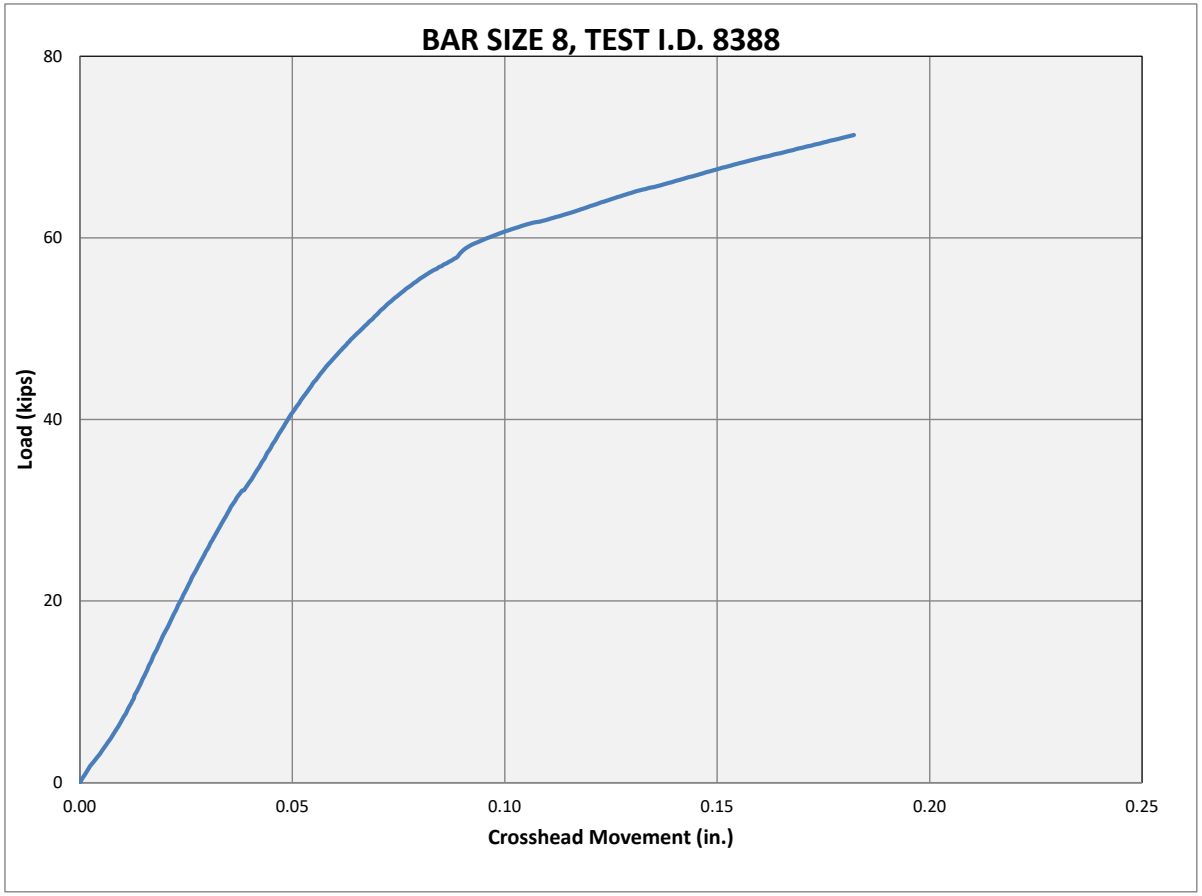
www.wje.com

Test I.D. No.	Bar Size	Bar Area (in^2)	Compressive Strength				Final Result
			(kips)	(ksi)	($\%f_{y=60}$)	($\%f_{u=80}$)	
8388	8	0.79	71.5	90.5	151%	113%	No failure



Product Tested	Wellsys Type A Coupler
Reinforcing Bar	ASTM A615 Grade 60
WJE Job Number	2020.6557

Test Location	Northbrook, IL
Test Operator	SKG
Test Date	3/2/2021
Test Methods	ASTM A370

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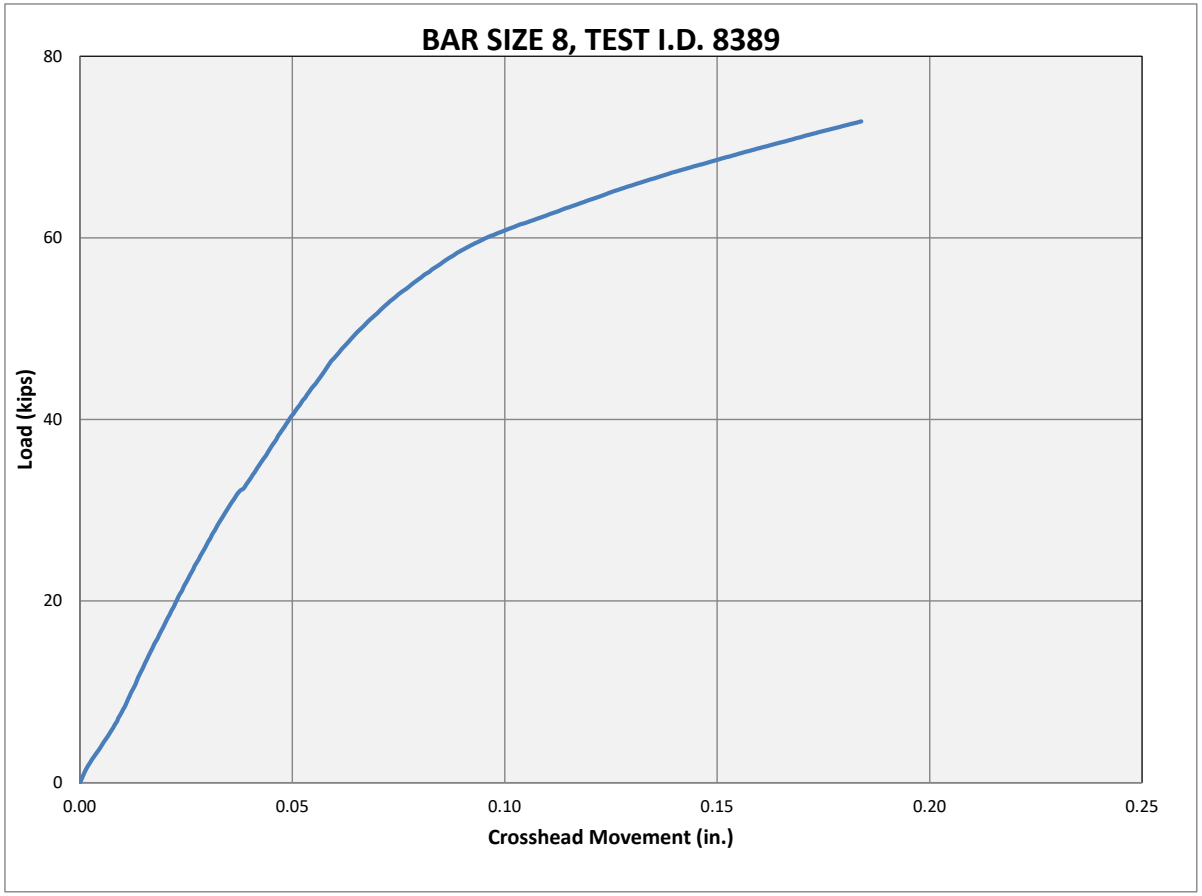
Chicago, Illinois 60603
312.372.0555 tel | 312.372.0873 fax
www.wje.com

Test I.D. No.	Bar Size	Bar Area (in^2)	Compressive Strength				Final Result
			(kips)	(ksi)	($\%f_{y=60}$)	($\%f_{u=80}$)	
8389	8	0.79	73.0	92.4	154%	116%	No failure



Product Tested	Wellsys Type A Coupler
Reinforcing Bar	ASTM A615 Grade 60
WJE Job Number	2020.6557

Test Location	Northbrook, IL
Test Operator	SKG
Test Date	3/2/2021
Test Methods	ASTM A370

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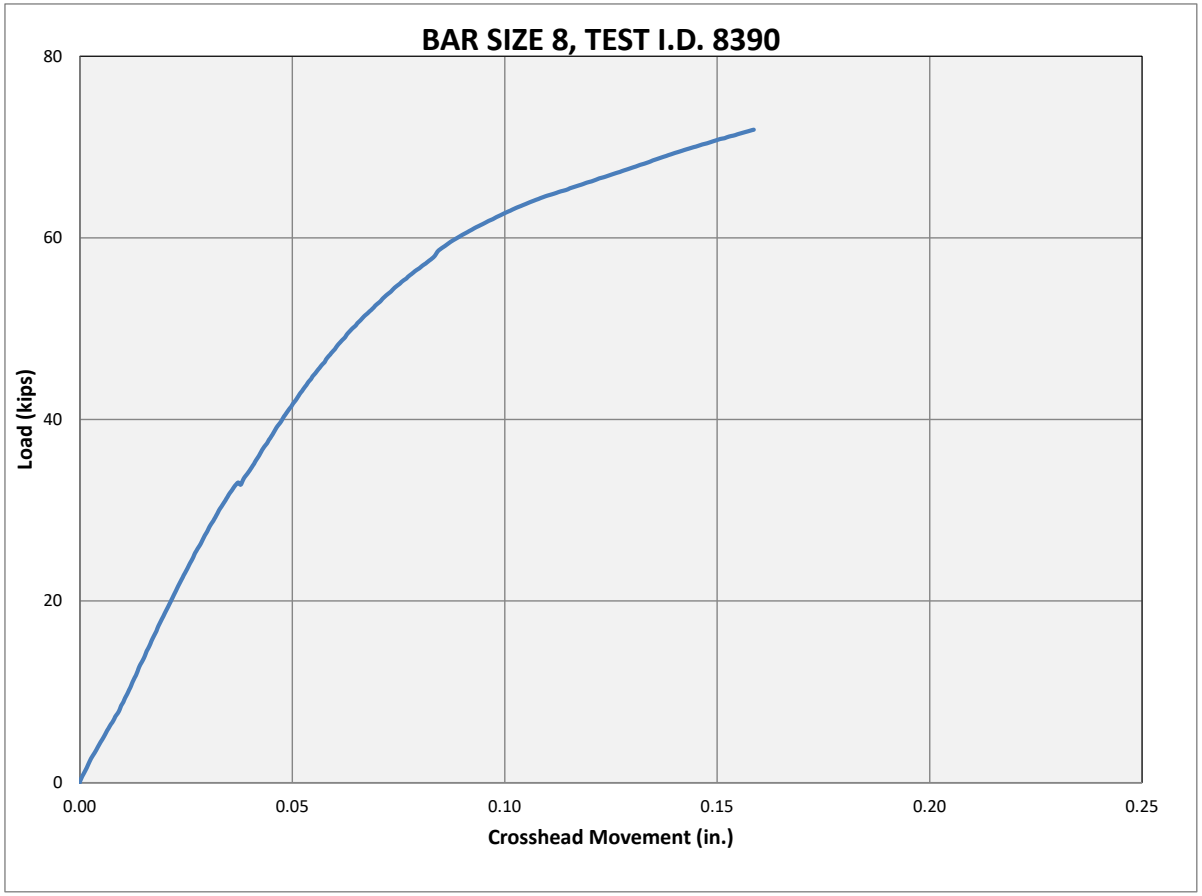
Chicago, Illinois 60603
312.372.0555 tel | 312.372.0873 fax
www.wje.com

Test I.D. No.	Bar Size	Bar Area (in^2)	Compressive Strength				Final Result
			(kips)	(ksi)	($\%f_{y=60}$)	($\%f_{u=80}$)	
8390	8	0.79	72.1	91.3	152%	114%	No failure



Product Tested	Wellsys Type A Coupler
Reinforcing Bar	ASTM A615 Grade 60
WJE Job Number	2020.6557

Test Location	Northbrook, IL
Test Operator	SKG
Test Date	3/2/2021
Test Methods	ASTM A370

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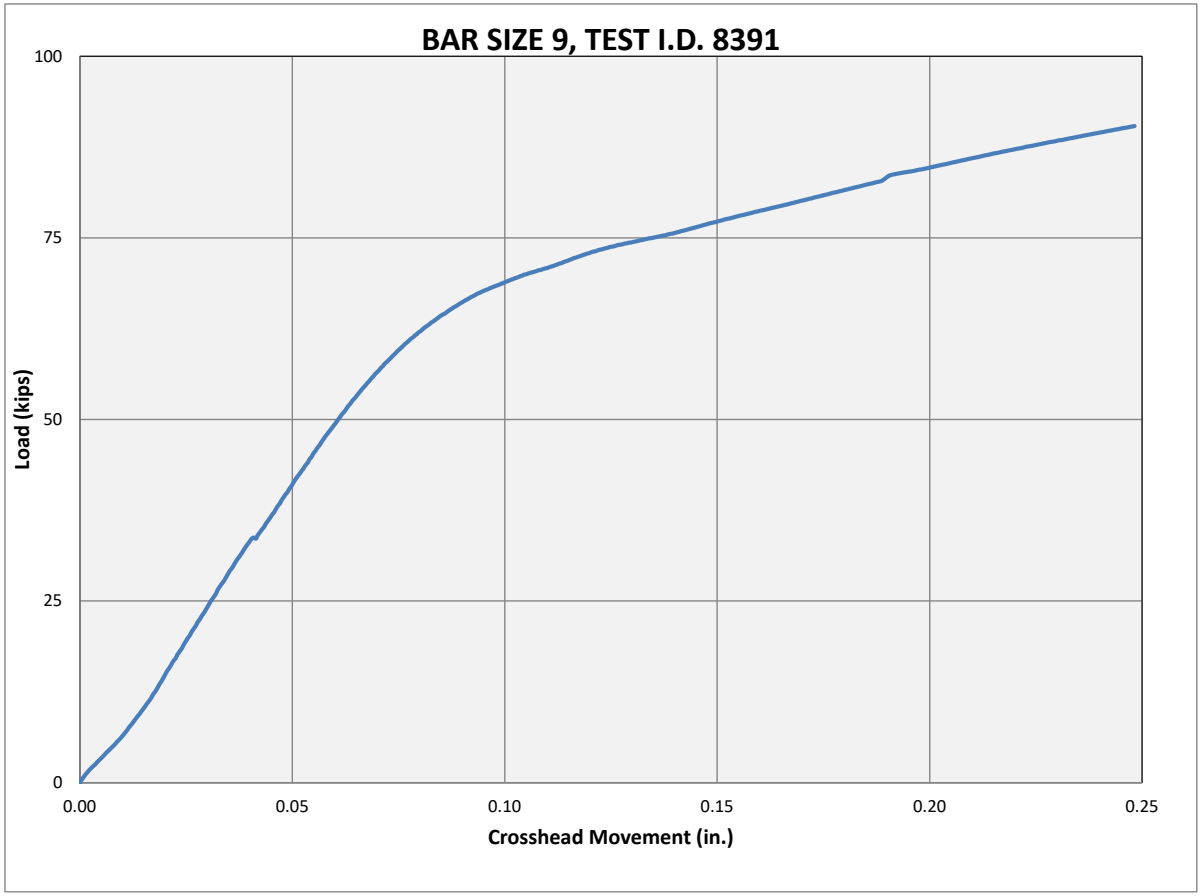
www.wje.com

Test I.D. No.	Bar Size	Bar Area (in^2)	Compressive Strength				Final Result
			(kips)	(ksi)	($\%f_{y=60}$)	($\%f_{u=80}$)	
8391	9	1.00	90.3	90.3	151%	113%	No failure



Product Tested	Wellsys Type A Coupler
Reinforcing Bar	ASTM A615 Grade 60
WJE Job Number	2020.6557

Test Location	Northbrook, IL
Test Operator	SKG
Test Date	3/2/2021
Test Methods	ASTM A370

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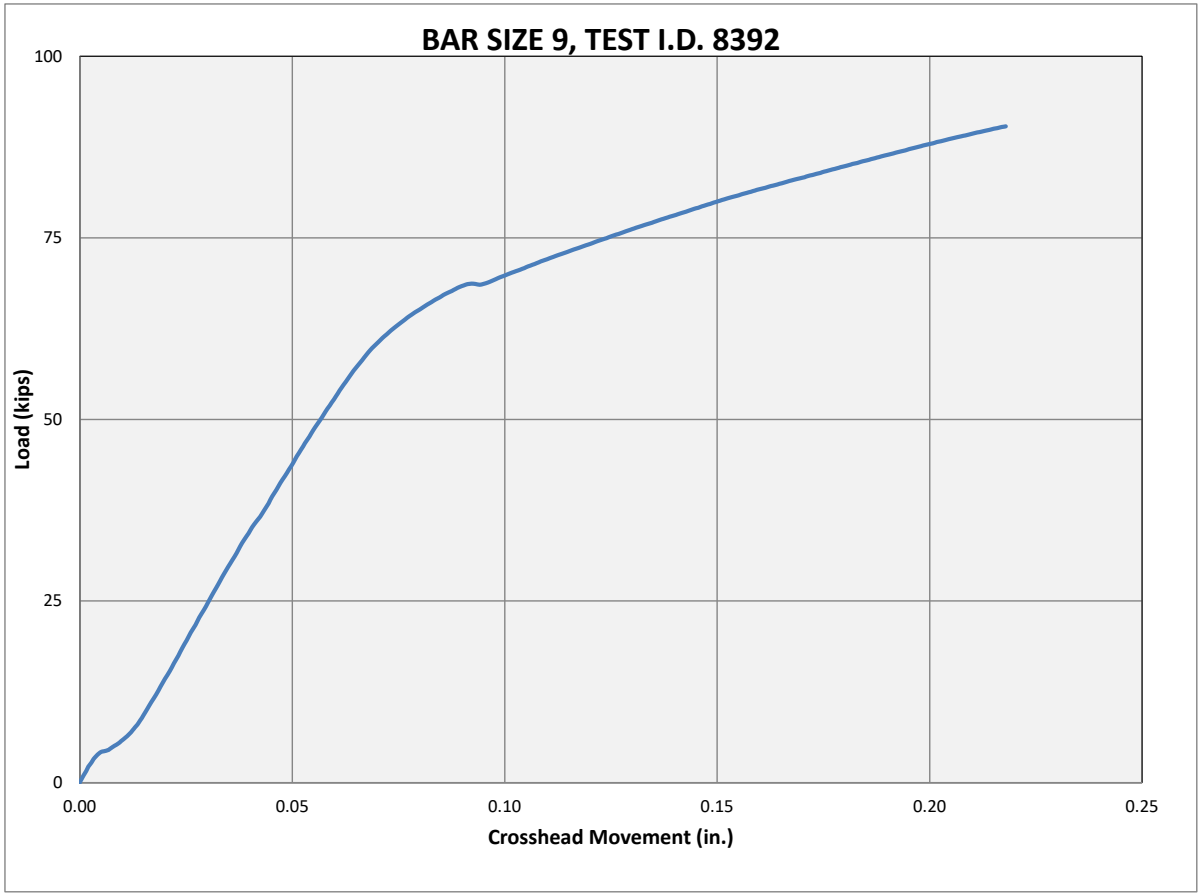
Test I.D. No.	Bar Size	Bar Area (in^2)	Compressive Strength				Final Result
			(kips)	(ksi)	($\%f_{y=60}$)	($\%f_{u=80}$)	
8392	9	1.00	90.5	90.5	151%	113%	No failure



Product Tested	Wellsys Type A Coupler
Reinforcing Bar	ASTM A615 Grade 60
WJE Job Number	2020.6557

Test Location	Northbrook, IL
Test Operator	SKG
Test Date	3/2/2021
Test Methods	ASTM A370

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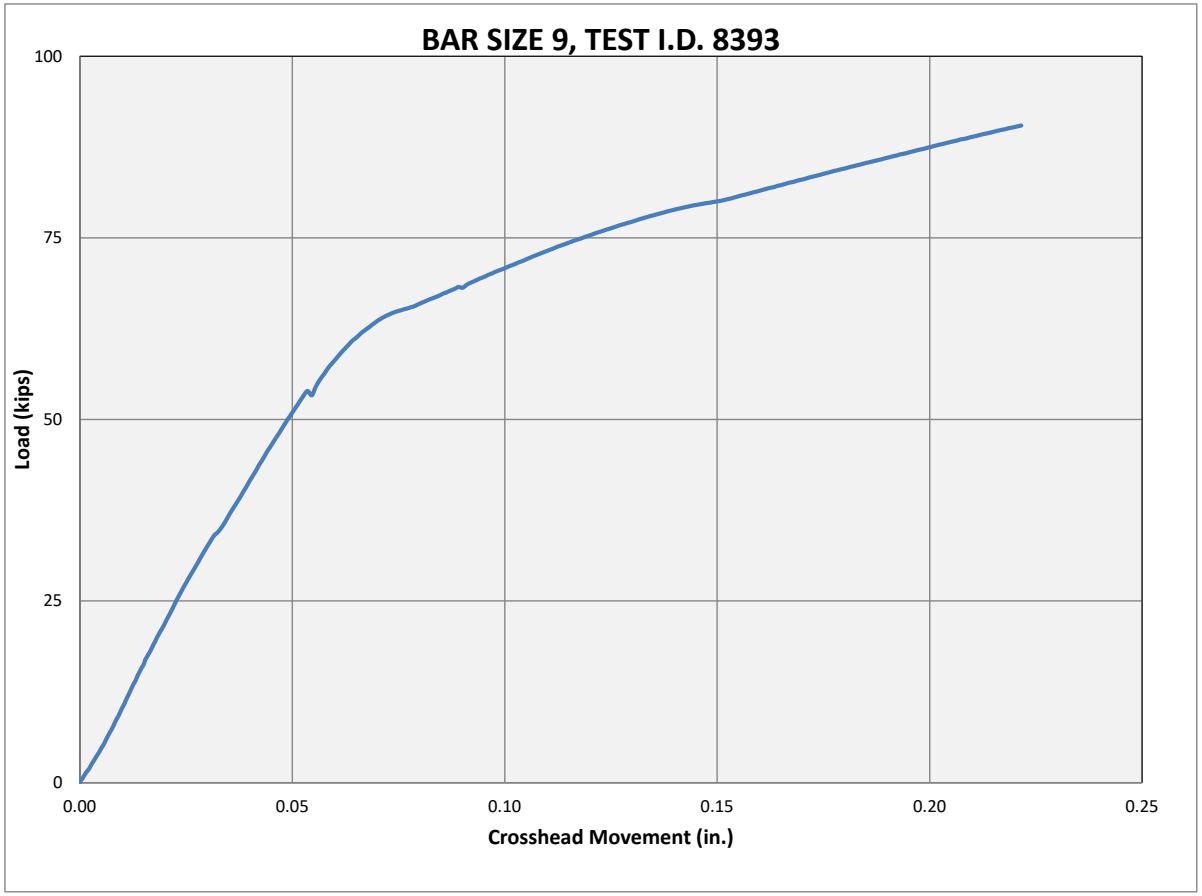
Test I.D. No.	Bar Size	Bar Area (in^2)	Compressive Strength				Final Result
			(kips)	(ksi)	($\%f_{y=60}$)	($\%f_{u=80}$)	
8393	9	1.00	90.6	90.6	151%	113%	No failure



Product Tested	Wellsys Type A Coupler
Reinforcing Bar	ASTM A615 Grade 60
WJE Job Number	2020.6557

Test Location	Northbrook, IL
Test Operator	SKG
Test Date	3/2/2021
Test Methods	ASTM A370

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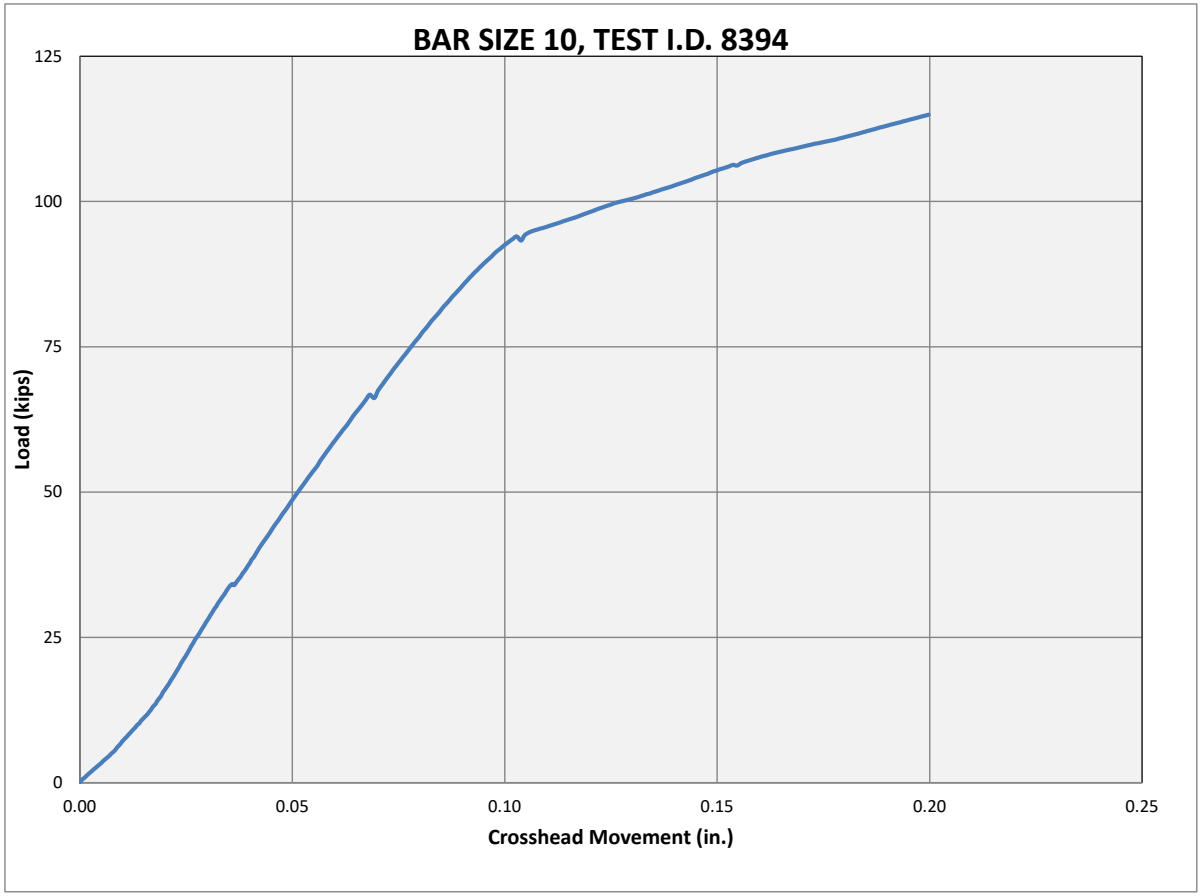
10 S. LaSalle Street, Suite 2600
Chicago, Illinois 60603
312.372.0555 tel | 312.372.0873 fax
www.wje.com

Test I.D. No.	Bar Size	Bar Area (in^2)	Compressive Strength				Final Result
			(kips)	(ksi)	($\%f_{y=60}$)	($\%f_{y=90}$)	
8394	10	1.27	114.9	90.5	151%	101%	No failure



Product Tested	Wellsys Type A Coupler
Reinforcing Bar	ASTM A615 Grade 60
WJE Job Number	2020.6557

Test Location	Northbrook, IL
Test Operator	SKG
Test Date	3/2/2021
Test Methods	ASTM A370

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312.372.0555 tel | 312.372.0873 fax
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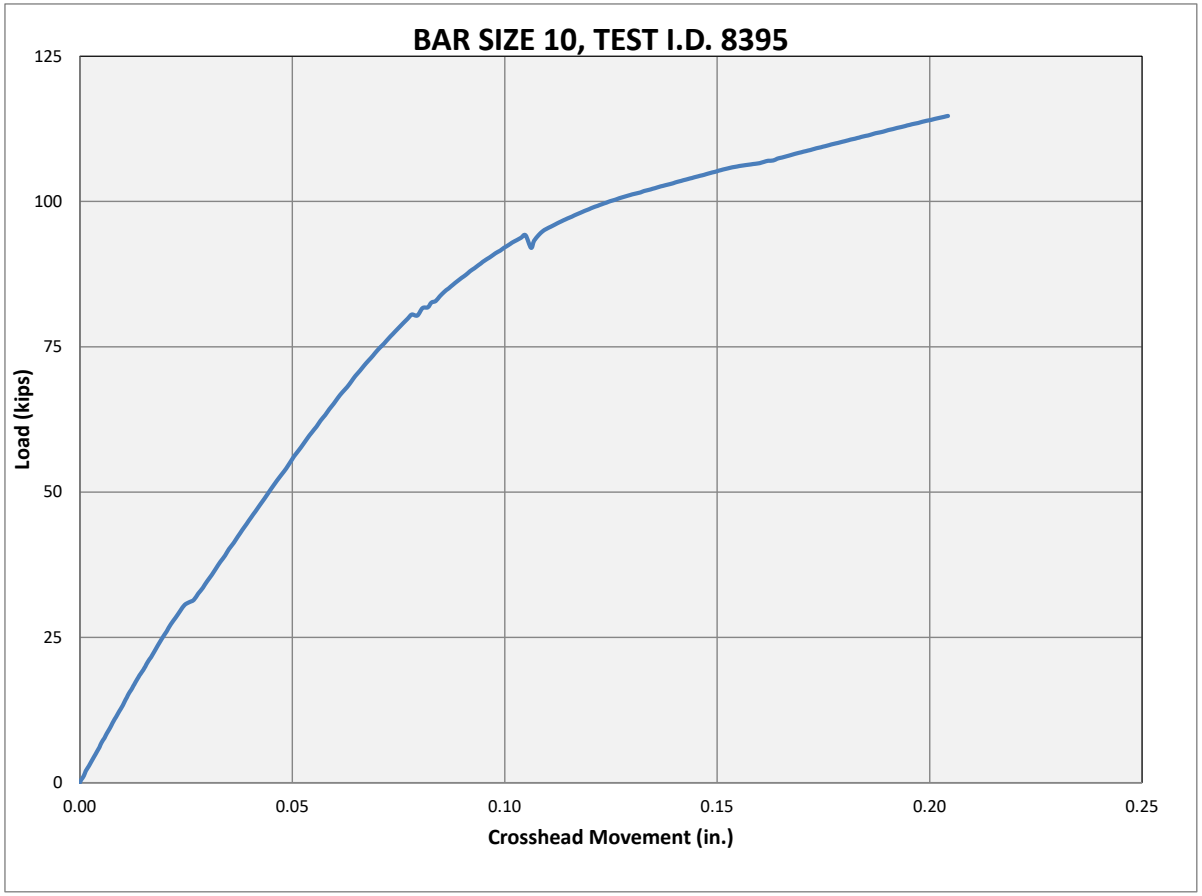
Test I.D. No.	Bar Size	Bar Area (in^2)	Compressive Strength				Final Result
			(kips)	(ksi)	($\%f_{y=60}$)	($\%f_{u=80}$)	
8395	10	1.27	114.8	90.4	151%	113%	No failure



Product Tested	Wellsys Type A Coupler
Reinforcing Bar	ASTM A615 Grade 60
WJE Job Number	2020.6557

Test Location	Northbrook, IL
Test Operator	SKG
Test Date	3/2/2021
Test Methods	ASTM A370

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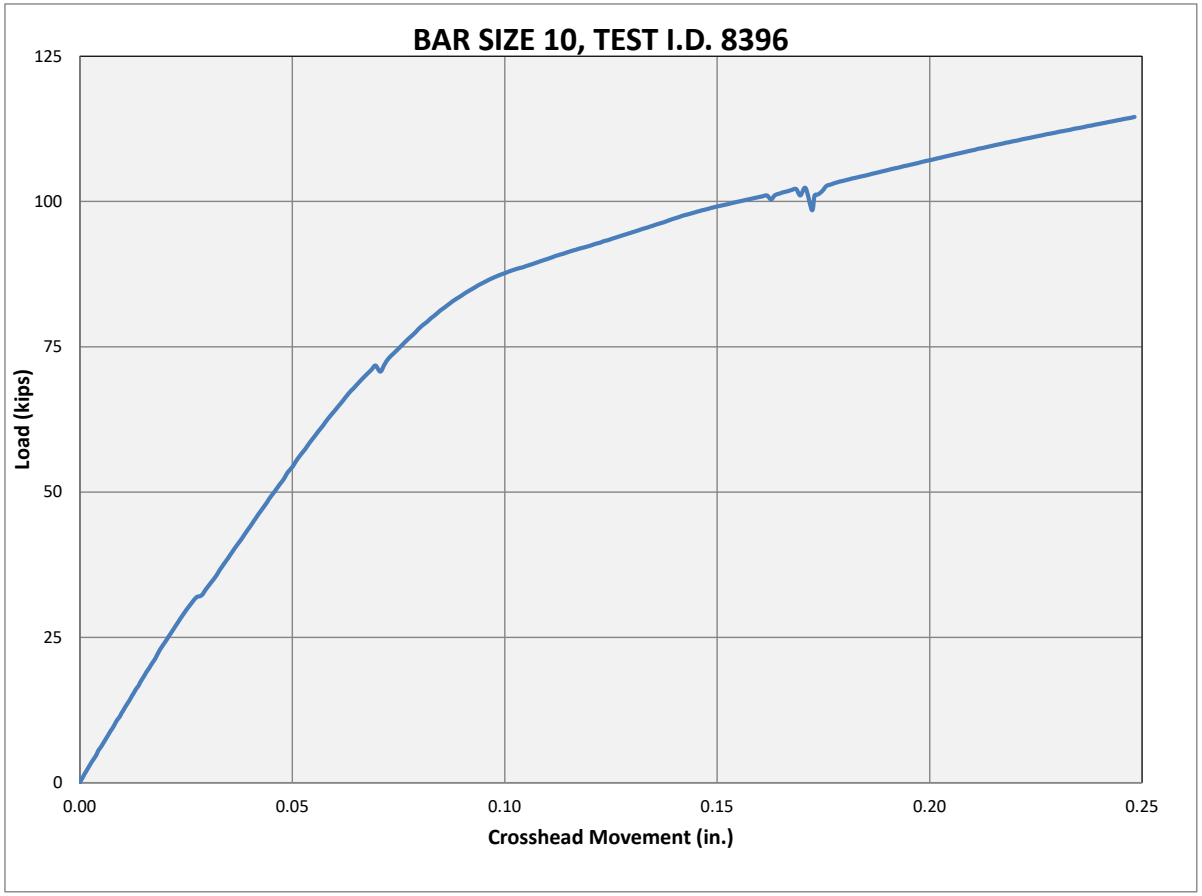
Test I.D. No.	Bar Size	Bar Area (in^2)	Compressive Strength				Final Result
			(kips)	(ksi)	($\%f_{y=60}$)	($\%f_{u=80}$)	
8396	10	1.27	114.8	90.4	151%	113%	No failure



Product Tested	Wellsys Type A Coupler
Reinforcing Bar	ASTM A615 Grade 60
WJE Job Number	2020.6557

Test Location	Northbrook, IL
Test Operator	SKG
Test Date	3/2/2021
Test Methods	ASTM A370

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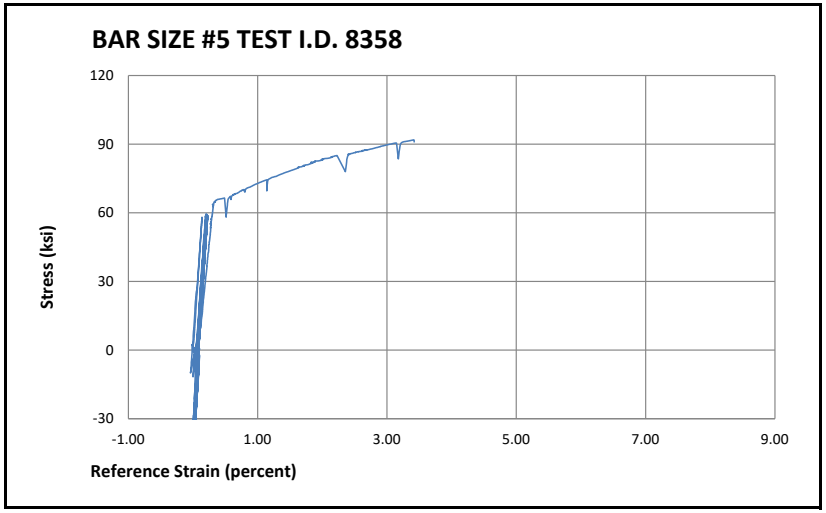
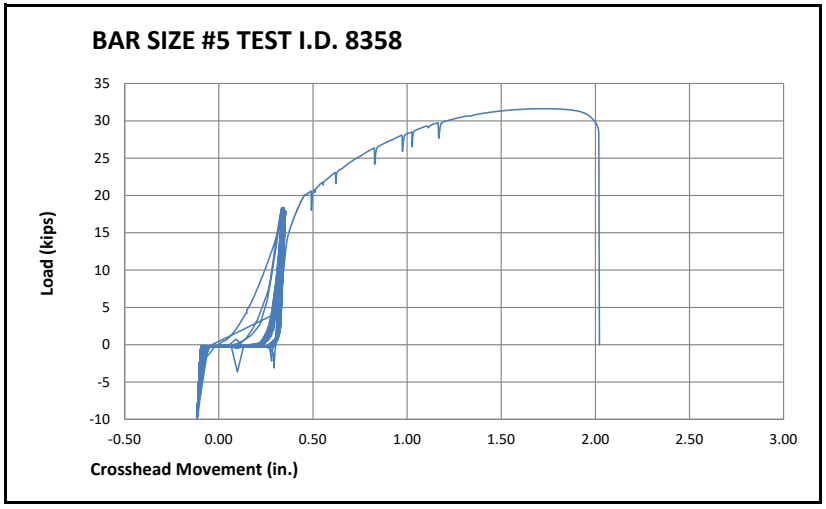
APPENDIX E. CYCLIC TEST STRESS STRAIN, LOAD-CROSSHEAD MOVEMENT, STRESS-SLIP CURVES

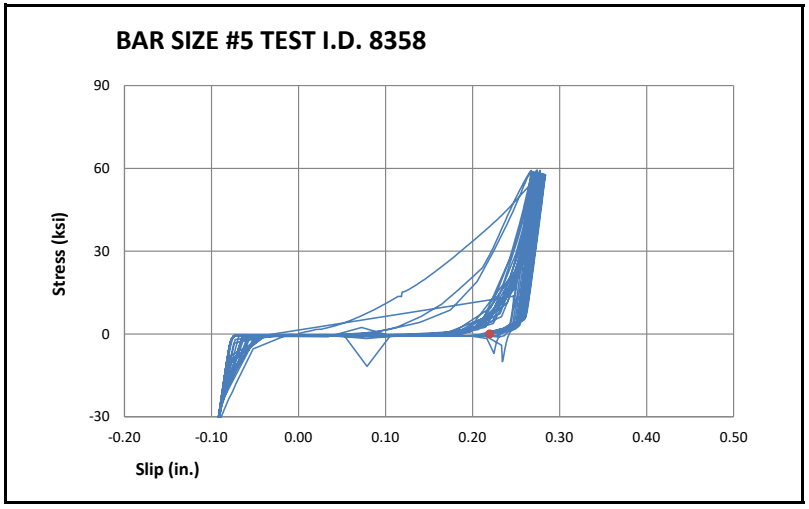
Test I.D. No.	Bar Size	Bar Area (in^2)	Cyclic Load Levels (Stages 1, 2, 3)				Cycles Applied			Tensile Strength (Stage 4)				Strain (Stage 4)	Final Result
			P_{min} (kips)	P_{max1} (kips)	P_{max2} (kips)	P_{max3} (kips)	n_1	n_2	n_3	(kips)	(ksi)	(%fy=60)	(%fu=80)	(%)	
8358	5	0.31	-9.3	17.7	-	-	20	-	-	31.6	102.0	170%	127%	-	Bar break
													Preload Slack:		None Observed



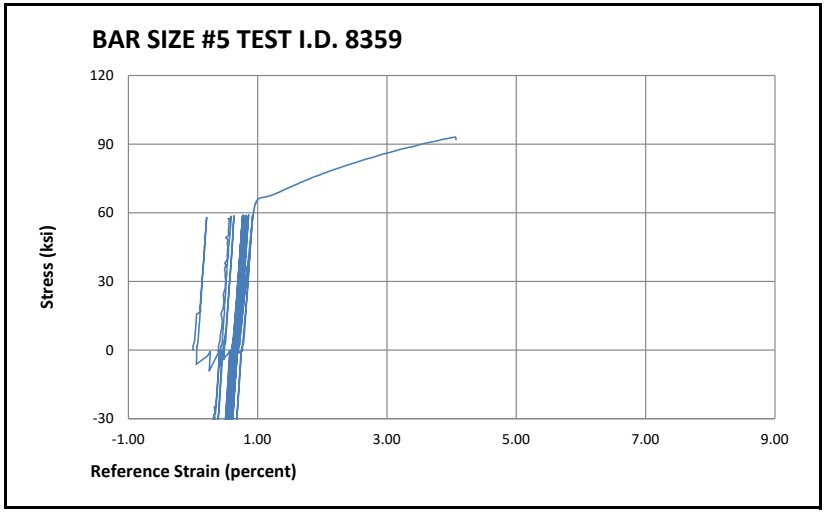
Product Tested:	Wellsys Type A
Reinforcing Bar:	ASTM A615, Grade 60
WJE Job Number:	2020.6557
Test Location:	Champaign, IL
Test Operator:	SKG
Test Date:	2/19/2021
Test Methods:	AC133 Cyclic

	Residual Slip (in.)
U20	0.2197



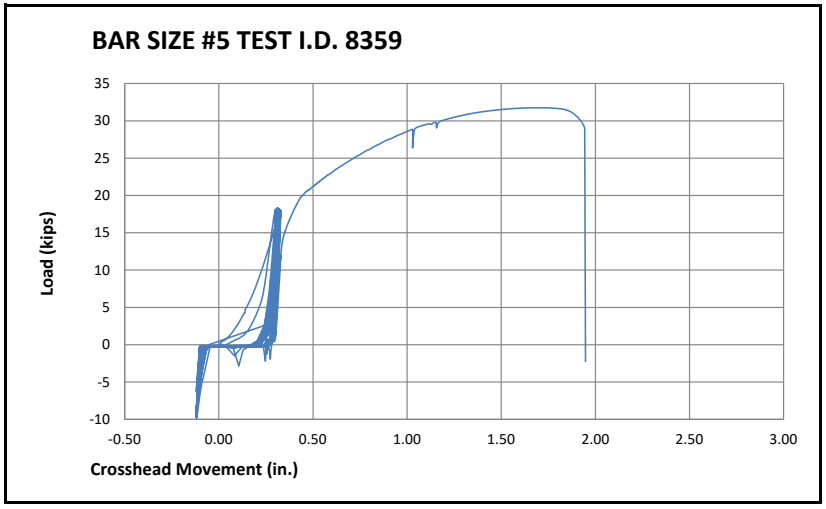


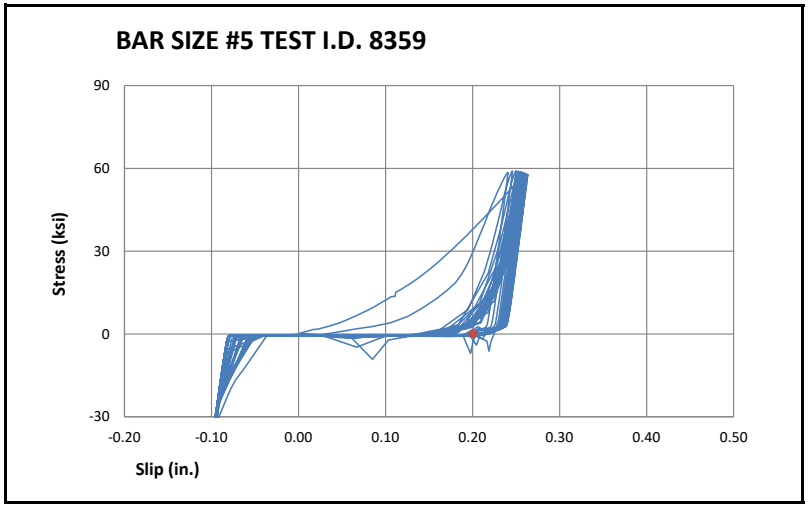
Test I.D. No.	Bar Size	Bar Area (in^2)	Cyclic Load Levels (Stages 1, 2, 3)				Cycles Applied			Tensile Strength (Stage 4)				Strain (Stage 4)	Final Result
			P_{min} (kips)	P_{max1} (kips)	P_{max2} (kips)	P_{max3} (kips)	n_1	n_2	n_3	(kips)	(ksi)	(%fy=60)	(%fu=80)	(%)	
8359	5	0.31	-9.3	17.7	-	-	20	-	-	31.7	102.4	171%	128%	-	Bar break
														Preload Slack:	None Observed



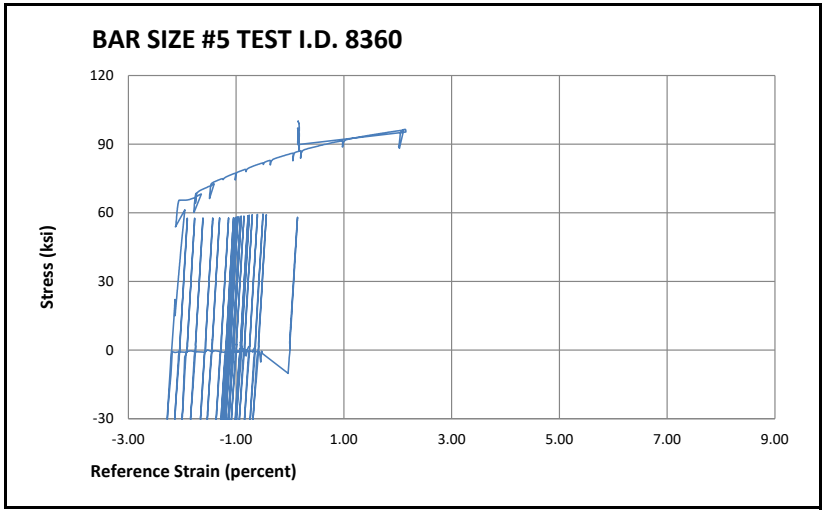
Product Tested:	Wellsys Type A
Reinforcing Bar:	ASTM A615, Grade 60
WJE Job Number:	2020.6557
Test Location:	Champaign, IL
Test Operator:	SKG
Test Date:	2/19/2021
Test Methods:	AC133 Cyclic

	Residual Slip (in.)
U20	0.2006



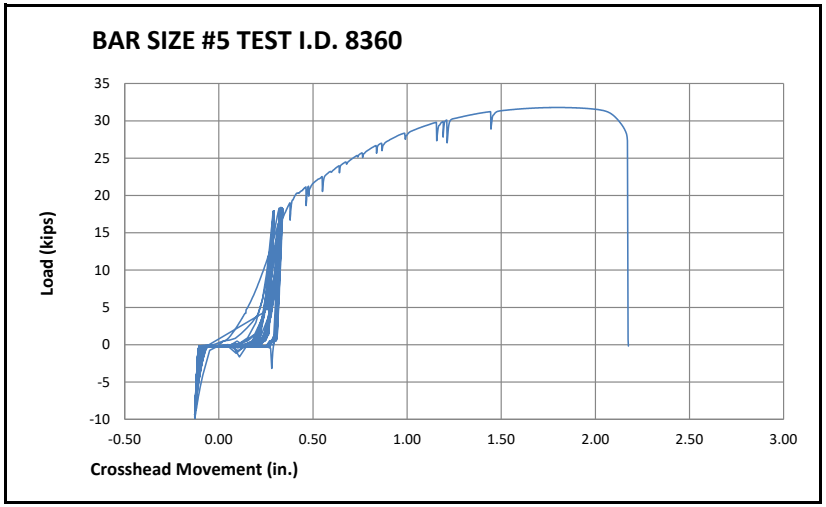


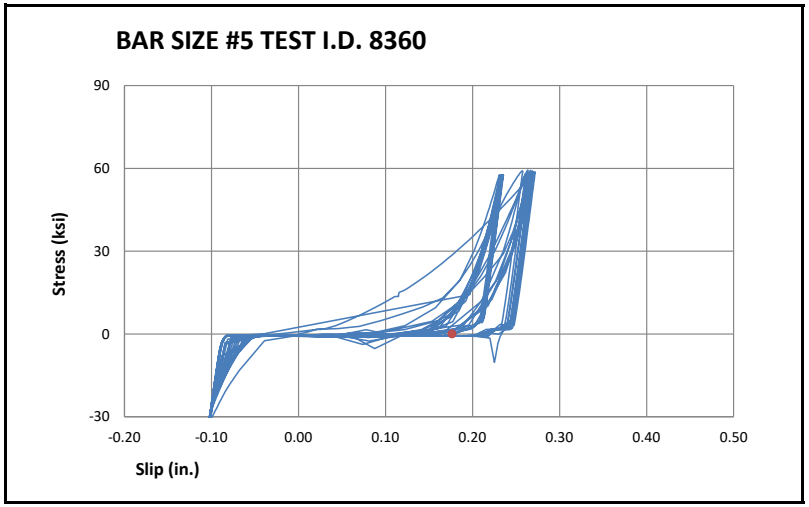
Test I.D. No.	Bar Size	Bar Area (in^2)	Cyclic Load Levels (Stages 1, 2, 3)				Cycles Applied			Tensile Strength (Stage 4)				Strain (Stage 4)	Final Result
			P_{min} (kips)	P_{max1} (kips)	P_{max2} (kips)	P_{max3} (kips)	n_1	n_2	n_3	(kips)	(ksi)	(%fy=60)	(%fu=80)	(%)	
8360	5	0.31	-9.3	17.7	-	-	20	-	-	31.8	102.5	171%	128%	-	Bar break
													Preload Slack:		None Observed



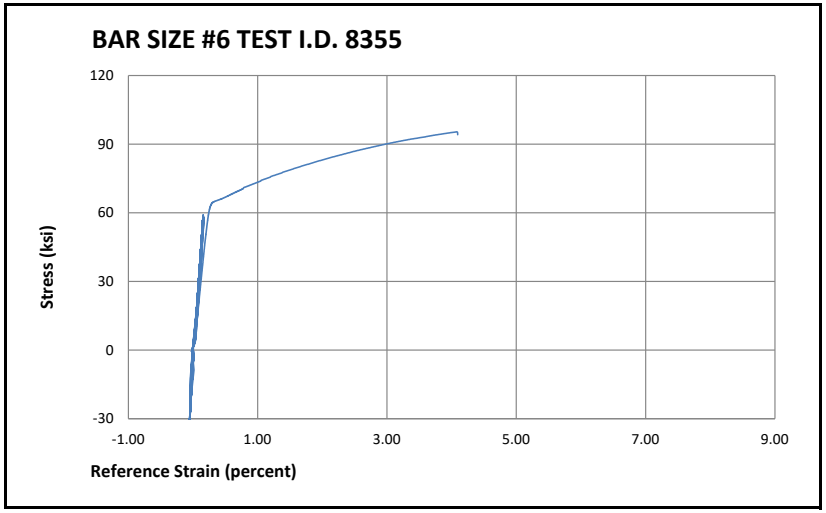
Product Tested:	Wellsys Type A
Reinforcing Bar:	ASTM A615, Grade 60
WJE Job Number:	2020.6557
Test Location:	Champaign, IL
Test Operator:	SKG
Test Date:	2/19/2021
Test Methods:	AC133 Cyclic

	Residual Slip (in.)
U20	0.1764



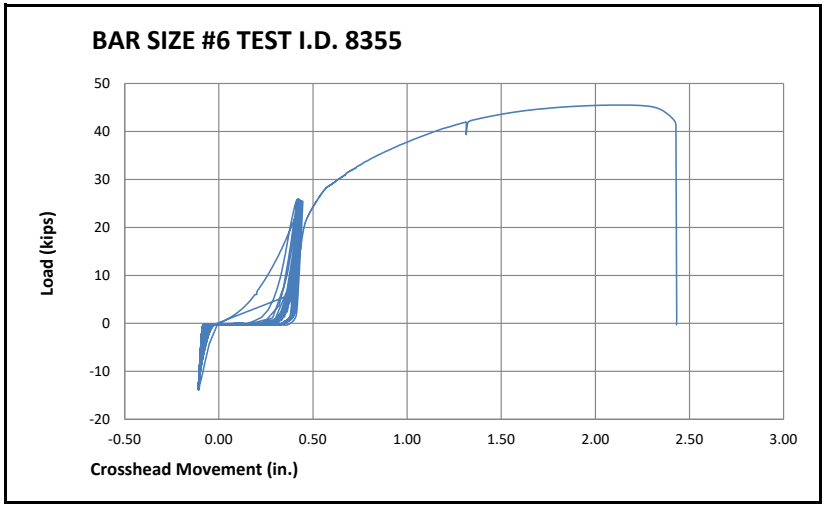


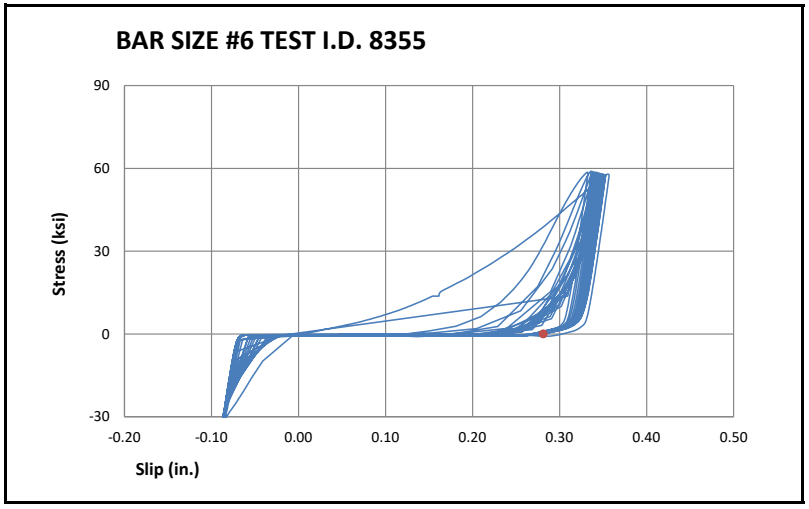
Test I.D. No.	Bar Size	Bar Area (in^2)	Cyclic Load Levels (Stages 1, 2, 3)				Cycles Applied			Tensile Strength (Stage 4)				Strain (Stage 4)	Final Result
			P_{min} (kips)	P_{max1} (kips)	P_{max2} (kips)	P_{max3} (kips)	n_1	n_2	n_3	(kips)	(ksi)	(%fy=60)	(%fu=80)	(%)	
8355	6	0.44	-13.2	25.1	-	-	20	-	-	45.5	103.4	172%	129%	-	Bar break
														Preload Slack:	None Observed



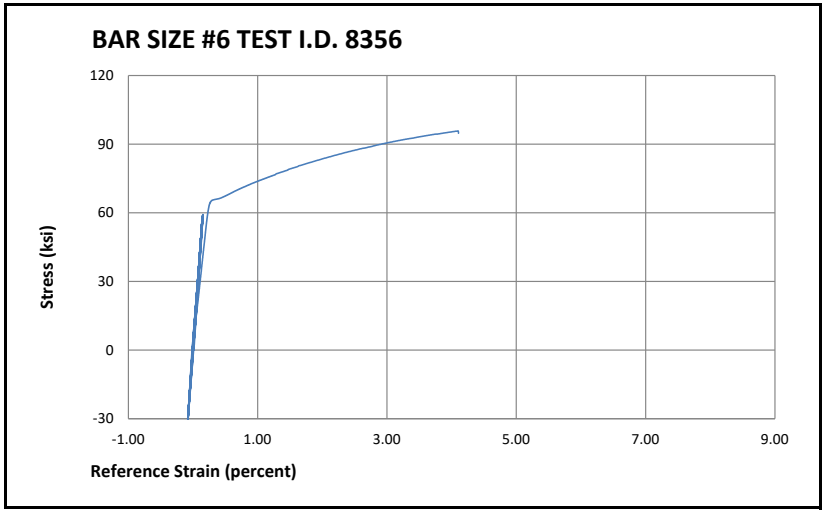
Product Tested:	Wellsys Type A
Reinforcing Bar:	ASTM A615, Grade 60
WJE Job Number:	2020.6557
Test Location:	Champaign, IL
Test Operator:	SKG
Test Date:	2/19/2021
Test Methods:	AC133 Cyclic

	Residual Slip (in.)
U20	0.2813



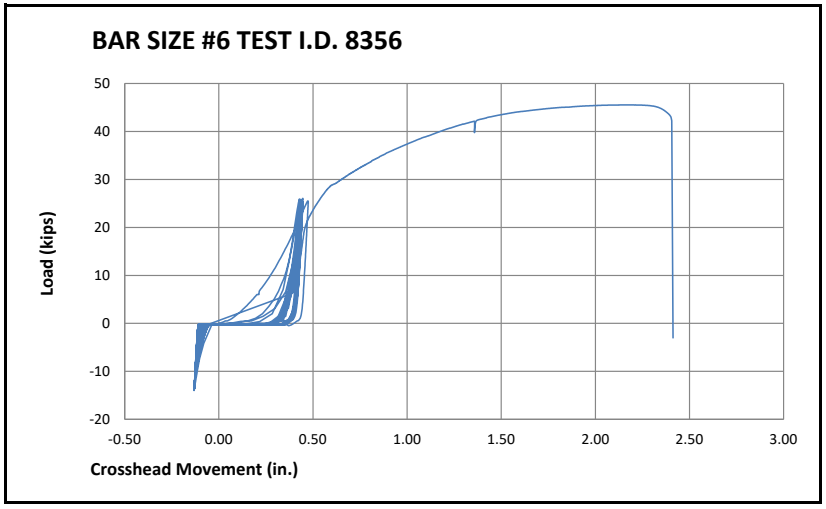


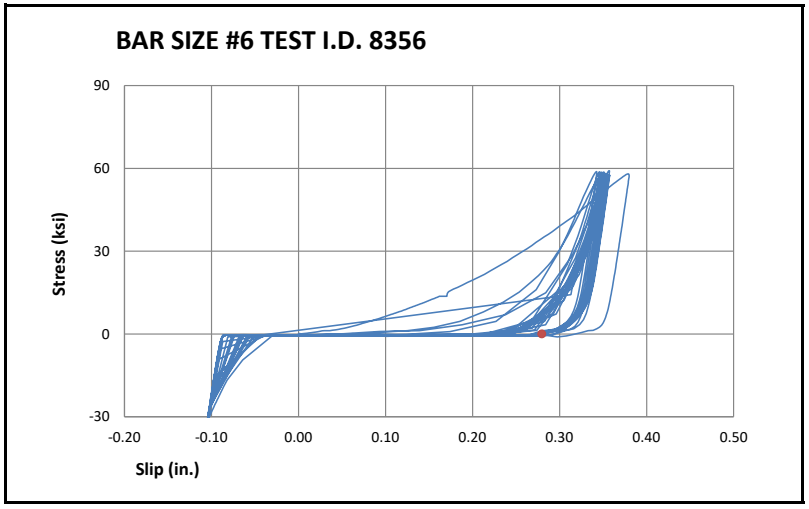
Test I.D. No.	Bar Size	Bar Area (in^2)	Cyclic Load Levels (Stages 1, 2, 3)				Cycles Applied			Tensile Strength (Stage 4)				Strain (Stage 4)	Final Result
			P_{min} (kips)	P_{max1} (kips)	P_{max2} (kips)	P_{max3} (kips)	n_1	n_2	n_3	(kips)	(ksi)	(%fy=60)	(%fu=80)	(%)	
8356	6	0.44	-13.2	25.1	-	-	20	-	-	45.5	103.5	172%	129%	-	Bar break
													Preload Slack:		None Observed



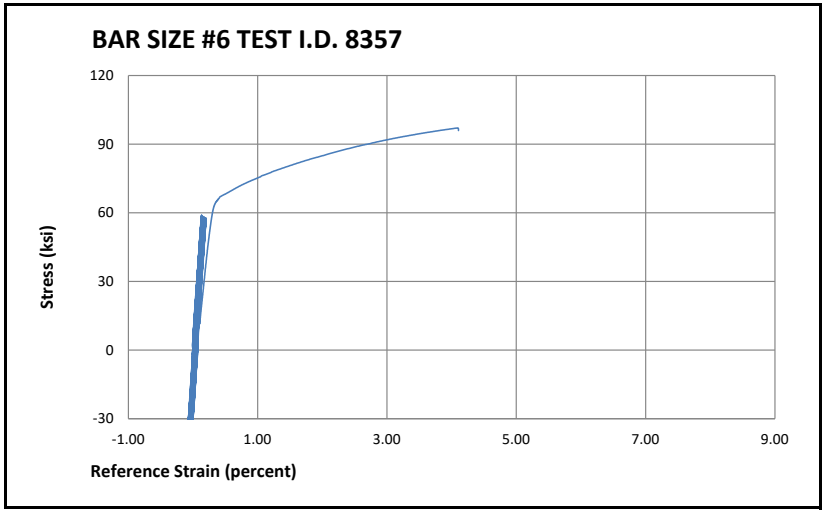
Product Tested:	Wellsys Type A
Reinforcing Bar:	ASTM A615, Grade 60
WJE Job Number:	2020.6557
Test Location:	Champaign, IL
Test Operator:	SKG
Test Date:	2/19/2021
Test Methods:	AC133 Cyclic

	Residual Slip (in.)
U20	0.2796



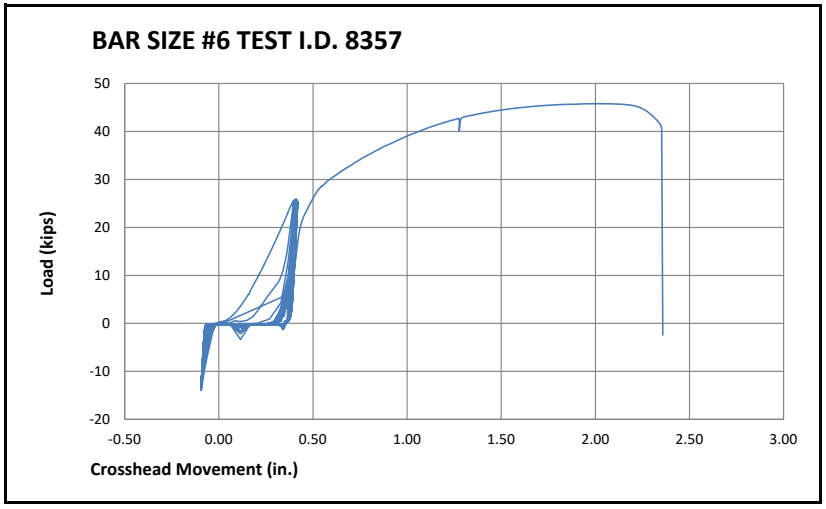


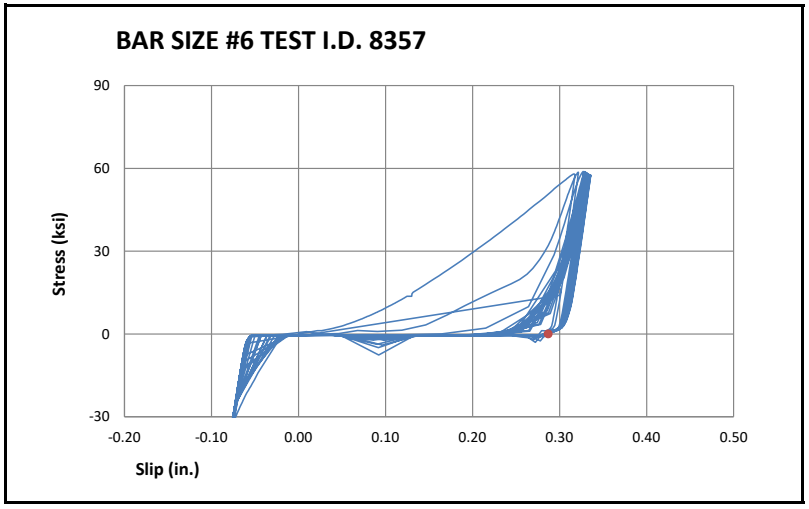
Test I.D. No.	Bar Size	Bar Area (in^2)	Cyclic Load Levels (Stages 1, 2, 3)				Cycles Applied			Tensile Strength (Stage 4)				Strain (Stage 4)	Final Result
			P_{min} (kips)	P_{max1} (kips)	P_{max2} (kips)	P_{max3} (kips)	n_1	n_2	n_3	(kips)	(ksi)	(%fy=60)	(%fu=80)	(%)	
8357	6	0.44	-13.2	25.1	-	-	20	-	-	45.8	104.0	173%	130%	-	Bar break
														Preload Slack:	None Observed



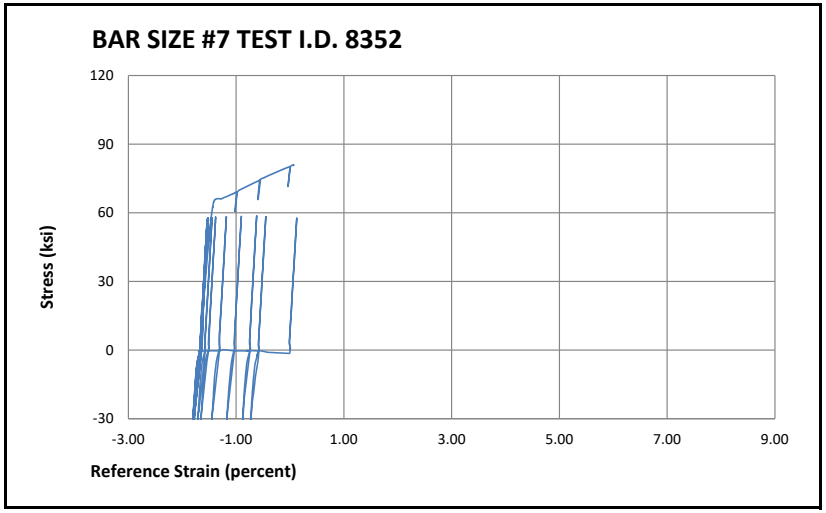
Product Tested:	Wellsys Type A
Reinforcing Bar:	ASTM A615, Grade 60
WJE Job Number:	2020.6557
Test Location:	Champaign, IL
Test Operator:	SKG
Test Date:	2/19/2021
Test Methods:	AC133 Cyclic

	Residual Slip (in.)
U20	0.2870



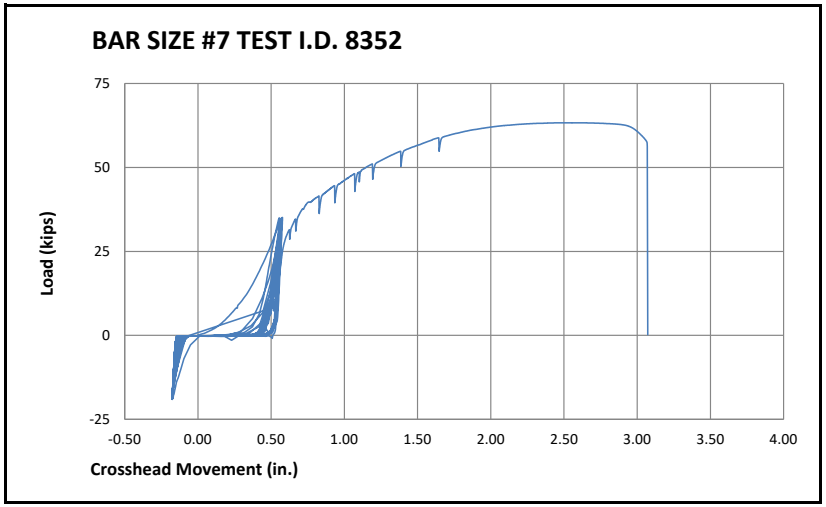


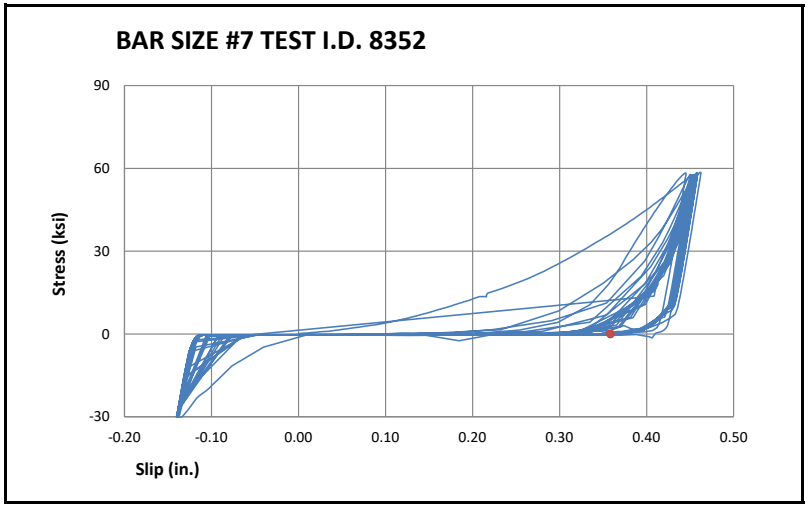
Test I.D. No.	Bar Size	Bar Area (in^2)	Cyclic Load Levels (Stages 1, 2, 3)				Cycles Applied			Tensile Strength (Stage 4)				Strain (Stage 4)	Final Result
			P_{min} (kips)	P_{max1} (kips)	P_{max2} (kips)	P_{max3} (kips)	n_1	n_2	n_3	(kips)	(ksi)	(%fy=60)	(%fu=80)	(%)	
8352	7	0.60	-18.0	34.2	-	-	20	-	-	63.3	105.5	176%	132%	-	Bar break
													Preload Slack:		None Observed



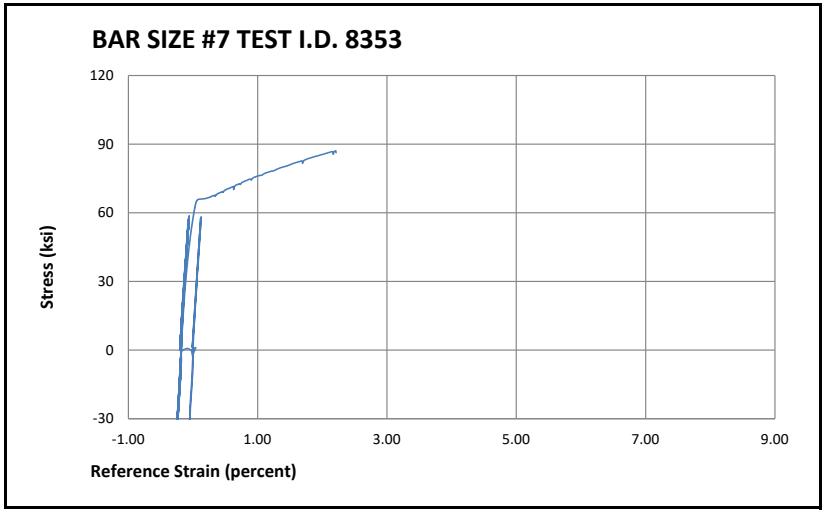
Product Tested:	Wellsys Type A
Reinforcing Bar:	ASTM A615, Grade 60
WJE Job Number:	2020.6557
Test Location:	Champaign, IL
Test Operator:	SKG
Test Date:	2/19/2021
Test Methods:	AC133 Cyclic

	Residual Slip (in.)
U20	0.3585



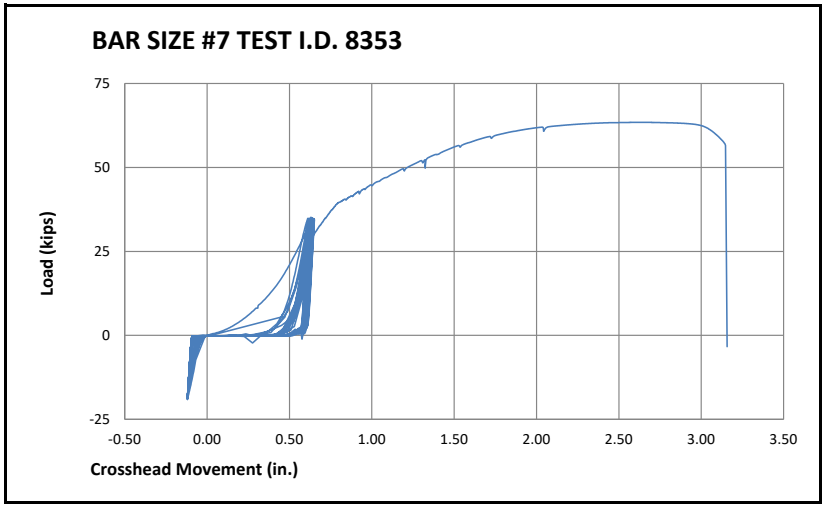


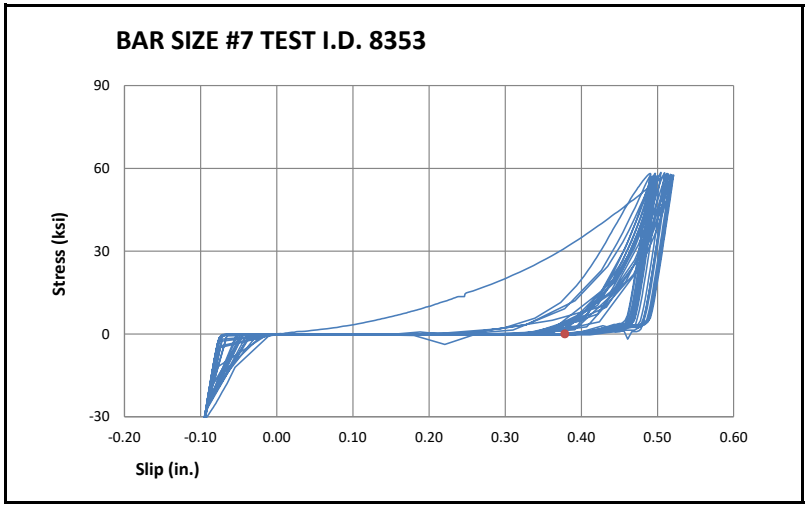
Test I.D. No.	Bar Size	Bar Area (in^2)	Cyclic Load Levels (Stages 1, 2, 3)				Cycles Applied			Tensile Strength (Stage 4)				Strain (Stage 4)	Final Result
			P_{min} (kips)	P_{max1} (kips)	P_{max2} (kips)	P_{max3} (kips)	n_1	n_2	n_3	(kips)	(ksi)	(%fy=60)	(%fu=80)	(%)	
8353	7	0.60	-18.0	34.2	-	-	20	-	-	63.4	105.7	176%	132%	-	Bar break
														Preload Slack:	None Observed



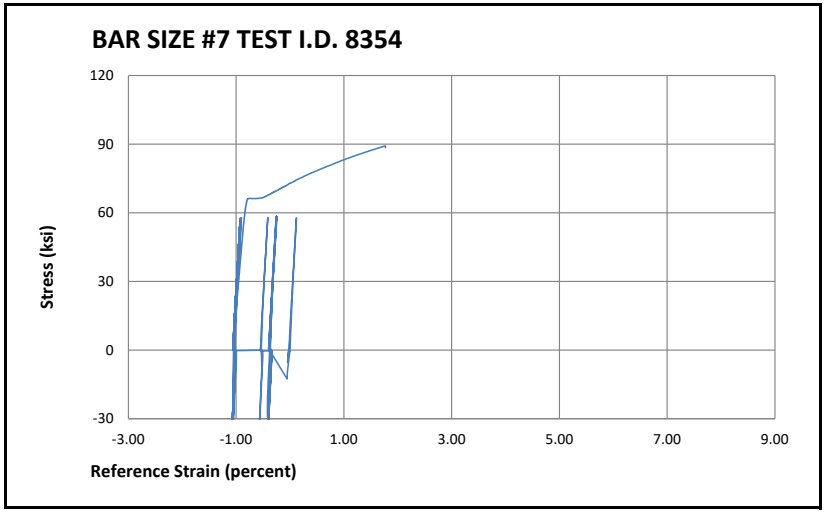
Product Tested:	Wellsys Type A
Reinforcing Bar:	ASTM A615, Grade 60
WJE Job Number:	2020.6557
Test Location:	Champaign, IL
Test Operator:	SKG
Test Date:	2/19/2021
Test Methods:	AC133 Cyclic

	Residual Slip (in.)
U20	0.3785



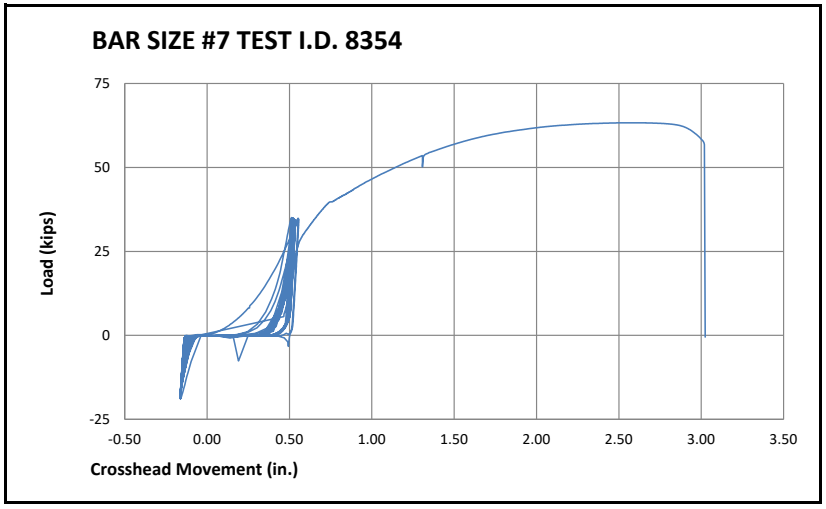


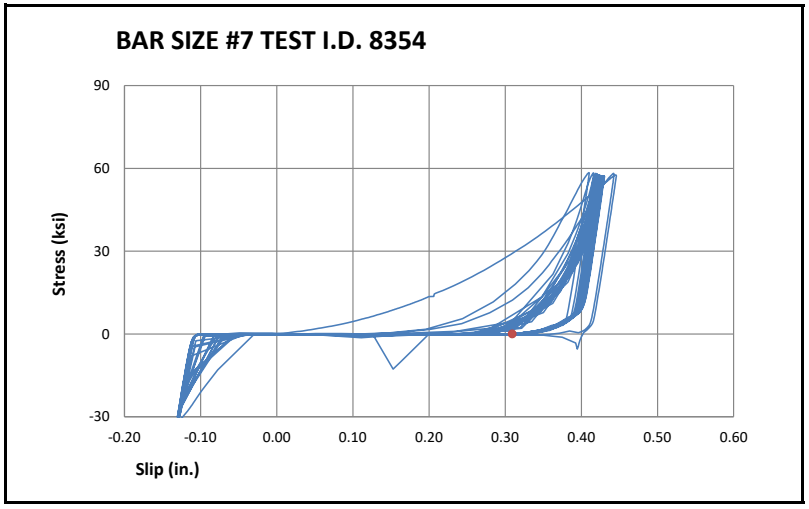
Test I.D. No.	Bar Size	Bar Area (in^2)	Cyclic Load Levels (Stages 1, 2, 3)				Cycles Applied			Tensile Strength (Stage 4)				Strain (Stage 4)	Final Result
			P_{min} (kips)	P_{max1} (kips)	P_{max2} (kips)	P_{max3} (kips)	n_1	n_2	n_3	(kips)	(ksi)	(%fy=60)	(%fu=80)	(%)	
8354	7	0.60	-18.0	34.2	-	-	20	-	-	63.3	105.5	176%	132%	-	Bar break
													Preload Slack:		None Observed



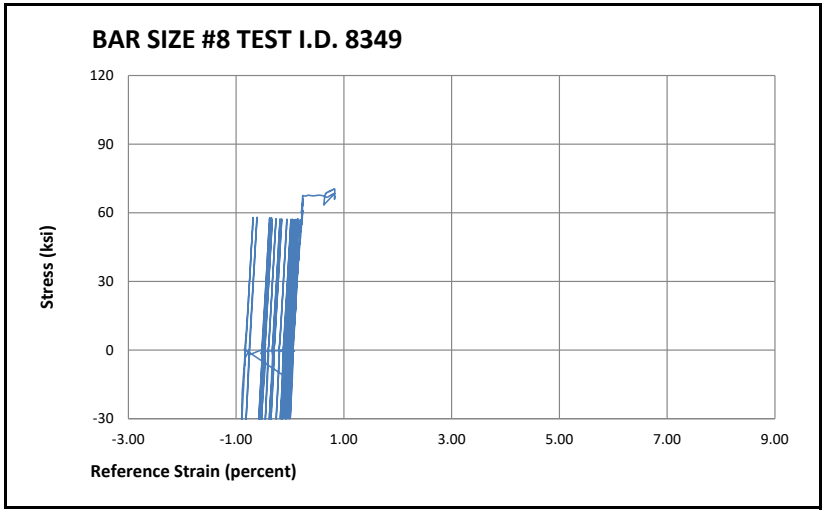
Product Tested:	Wellsys Type A
Reinforcing Bar:	ASTM A615, Grade 60
WJE Job Number:	2020.6557
Test Location:	Champaign, IL
Test Operator:	SKG
Test Date:	2/19/2021
Test Methods:	AC133 Cyclic

	Residual Slip (in.)
U20	0.3092



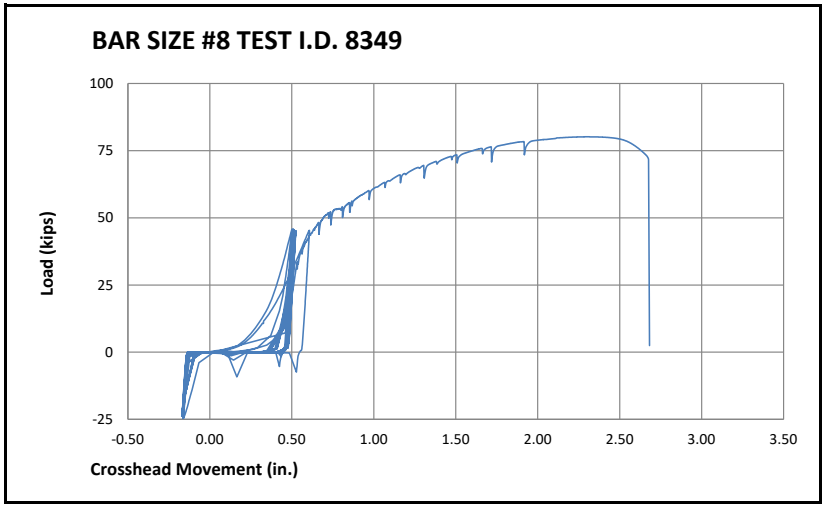


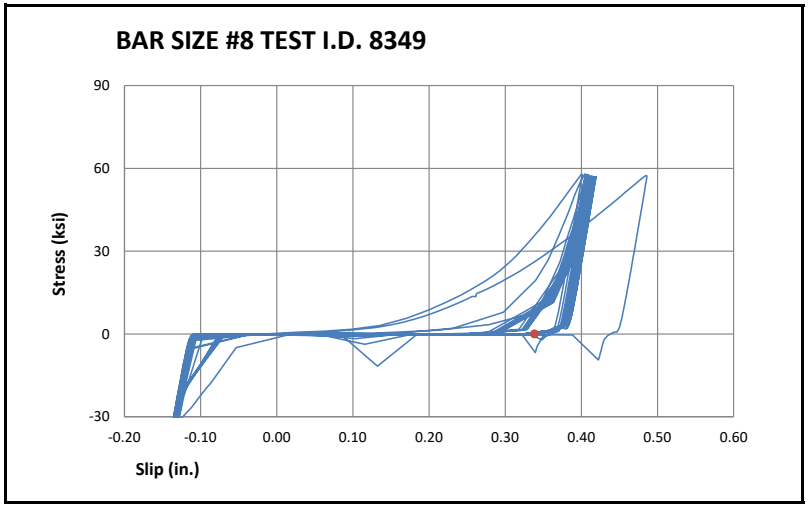
Test I.D. No.	Bar Size	Bar Area (in^2)	Cyclic Load Levels (Stages 1, 2, 3)				Cycles Applied			Tensile Strength (Stage 4)				Strain (Stage 4)	Final Result
			P_{min} (kips)	P_{max1} (kips)	P_{max2} (kips)	P_{max3} (kips)	n_1	n_2	n_3	(kips)	(ksi)	(%fy=60)	(%fu=80)	(%)	
8349	8	0.79	-23.7	45.0	-	-	20	-	-	80.2	101.5	169%	127%	-	Bar break
														Preload Slack:	None Observed



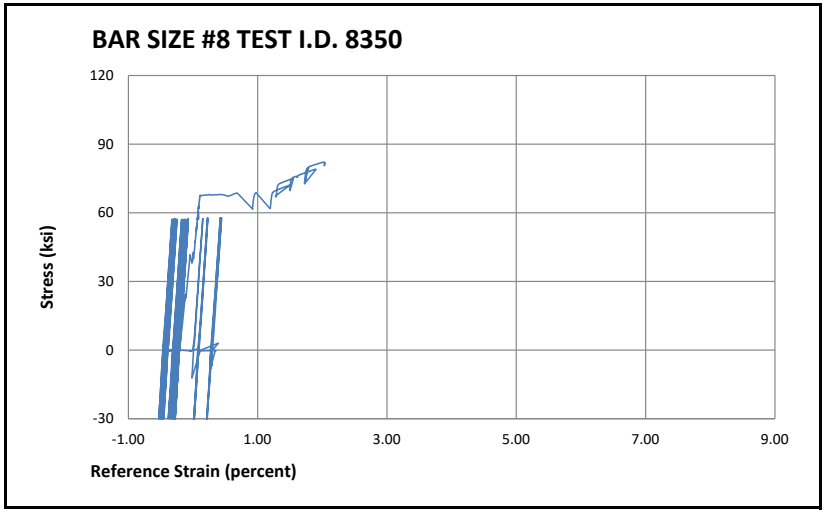
Product Tested:	Wellsys Type A
Reinforcing Bar:	ASTM A615, Grade 60
WJE Job Number:	2020.6557
Test Location:	Champaign, IL
Test Operator:	SKG
Test Date:	2/19/2021
Test Methods:	AC133 Cyclic

	Residual Slip (in.)
U20	0.3385



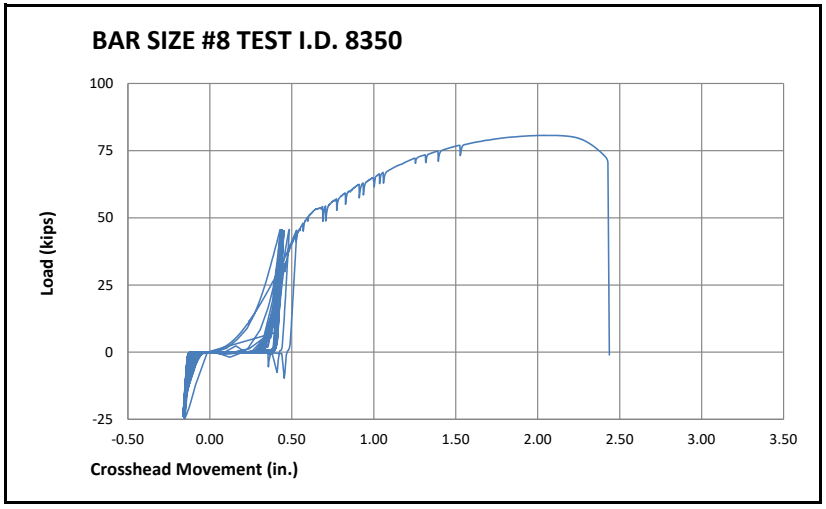


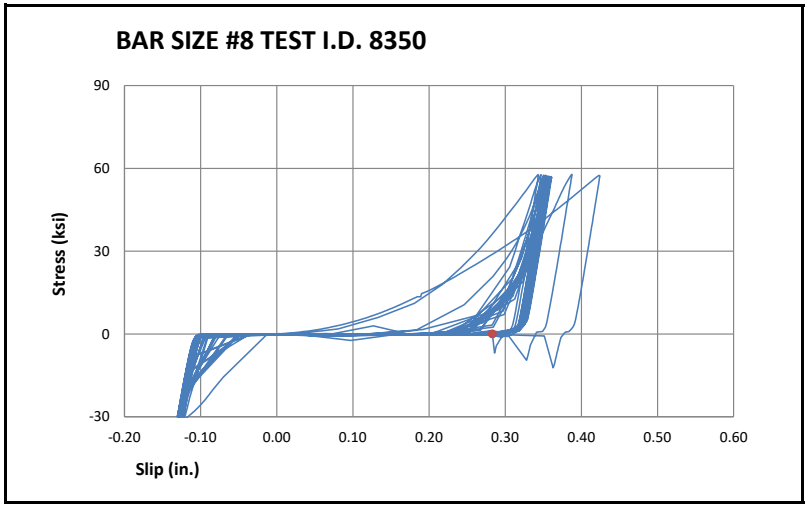
Test I.D. No.	Bar Size	Bar Area (in^2)	Cyclic Load Levels (Stages 1, 2, 3)				Cycles Applied			Tensile Strength (Stage 4)				Strain (Stage 4)	Final Result
			P_{min} (kips)	P_{max1} (kips)	P_{max2} (kips)	P_{max3} (kips)	n_1	n_2	n_3	(kips)	(ksi)	(%fy=60)	(%fu=80)	(%)	
8350	8	0.79	-23.7	45.0	-	-	20	-	-	80.7	102.1	170%	128%	-	Bar break
													Preload Slack:		None Observed



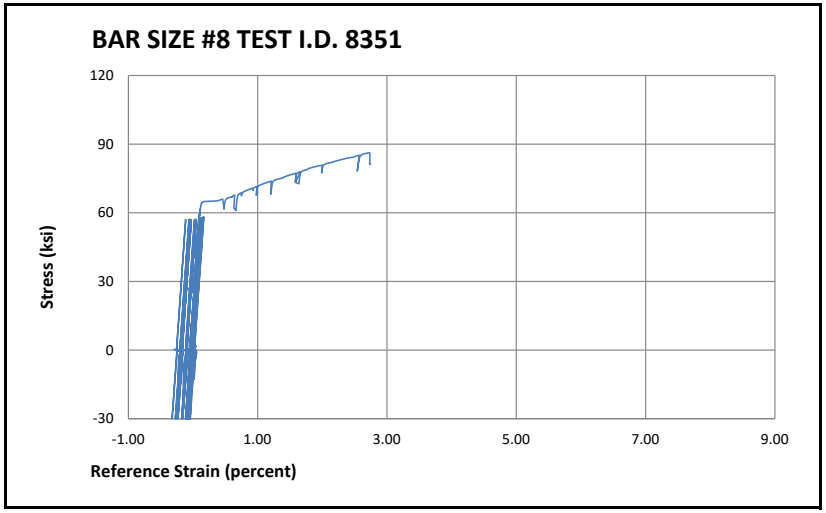
Product Tested:	Wellsys Type A
Reinforcing Bar:	ASTM A615, Grade 60
WJE Job Number:	2020.6557
Test Location:	Champaign, IL
Test Operator:	SKG
Test Date:	2/19/2021
Test Methods:	AC133 Cyclic

	Residual Slip (in.)
U20	0.2833



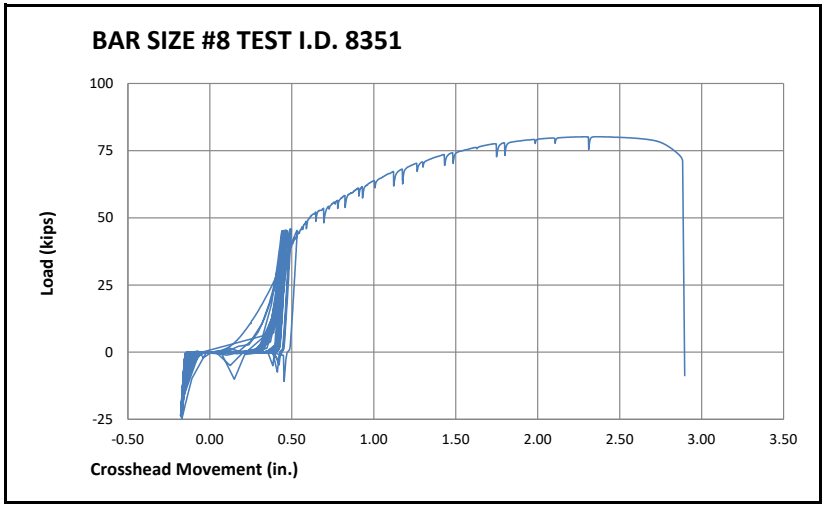


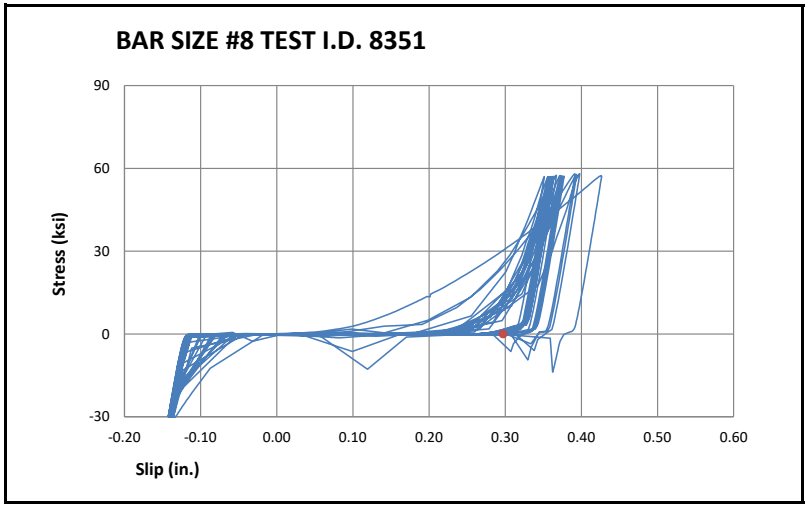
Test I.D. No.	Bar Size	Bar Area (in^2)	Cyclic Load Levels (Stages 1, 2, 3)				Cycles Applied			Tensile Strength (Stage 4)				Strain (Stage 4)	Final Result
			P_{min} (kips)	P_{max1} (kips)	P_{max2} (kips)	P_{max3} (kips)	n_1	n_2	n_3	(kips)	(ksi)	(%fy=60)	(%fu=80)	(%)	
8351	8	0.79	-23.7	45.0	-	-	20	-	-	80.2	101.5	169%	127%	-	Bar break
														Preload Slack:	None Observed



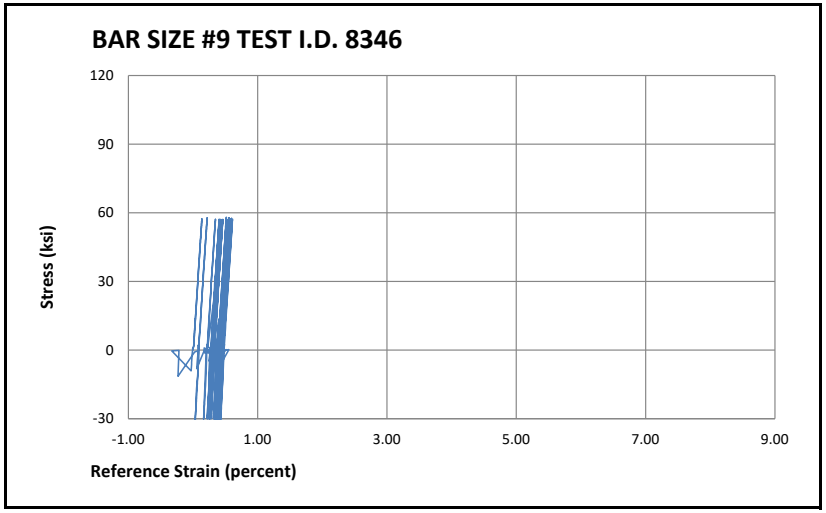
Product Tested:	Wellsys Type A
Reinforcing Bar:	ASTM A615, Grade 60
WJE Job Number:	2020.6557
Test Location:	Champaign, IL
Test Operator:	SKG
Test Date:	2/19/2021
Test Methods:	AC133 Cyclic

	Residual Slip (in.)
U20	0.2973



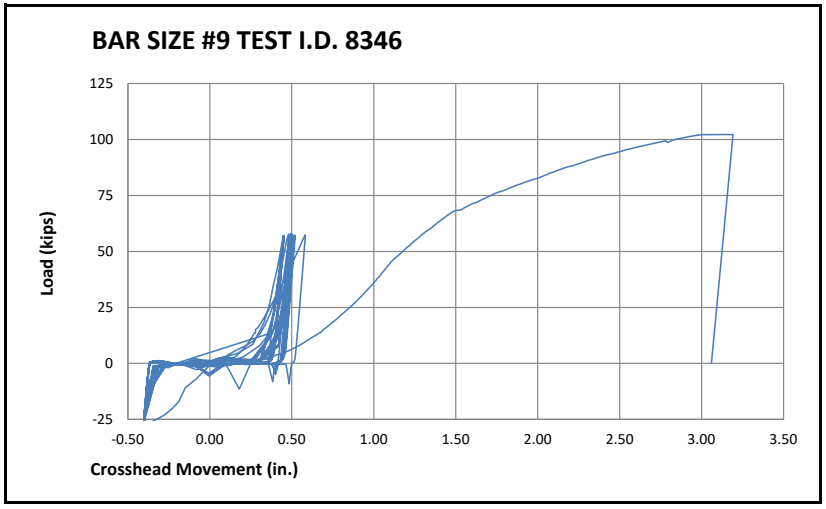


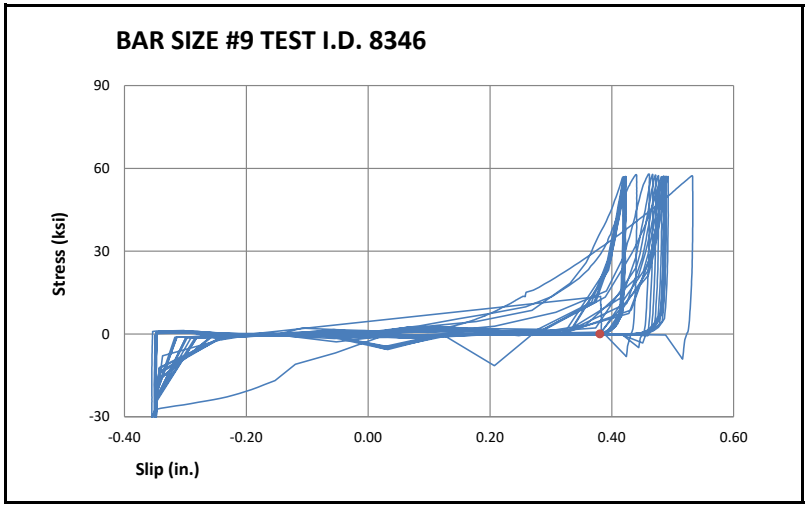
Test I.D. No.	Bar Size	Bar Area (in^2)	Cyclic Load Levels (Stages 1, 2, 3)				Cycles Applied			Tensile Strength (Stage 4)				Strain (Stage 4)	Final Result
			P_{min} (kips)	P_{max1} (kips)	P_{max2} (kips)	P_{max3} (kips)	n_1	n_2	n_3	(kips)	(ksi)	(%fy=60)	(%fu=80)	(%)	
8346	9	1.00	-30.0	57.0	-	-	20	-	-	102.2	102.2	170%	128%	-	Bar break at wedge indentation
													Preload Slack:		None Observed



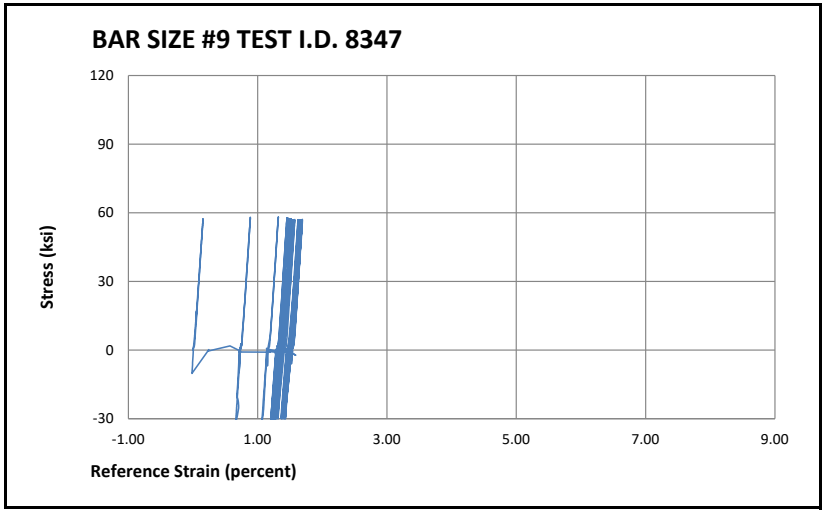
Product Tested:	Wellsys Type A
Reinforcing Bar:	ASTM A615, Grade 60
WJE Job Number:	2020.6557
Test Location:	Champaign, IL
Test Operator:	SKG
Test Date:	2/19/2021
Test Methods:	AC133 Cyclic

	Residual Slip (in.)
U20	0.3805



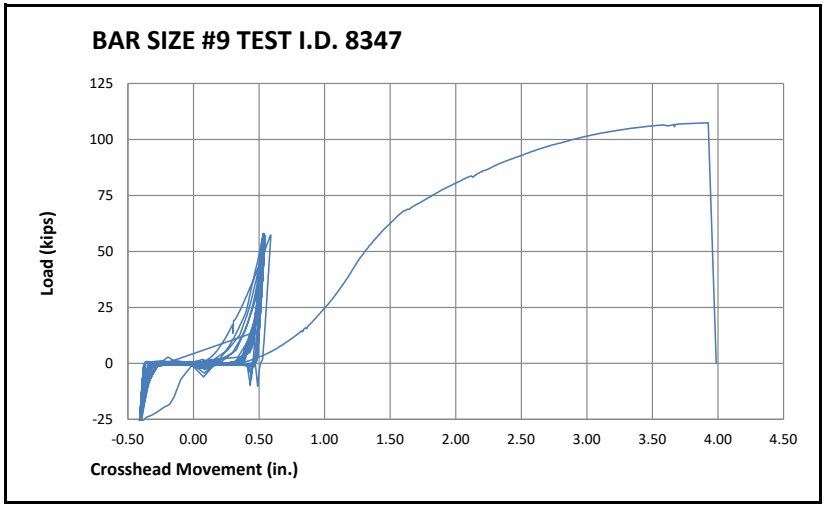


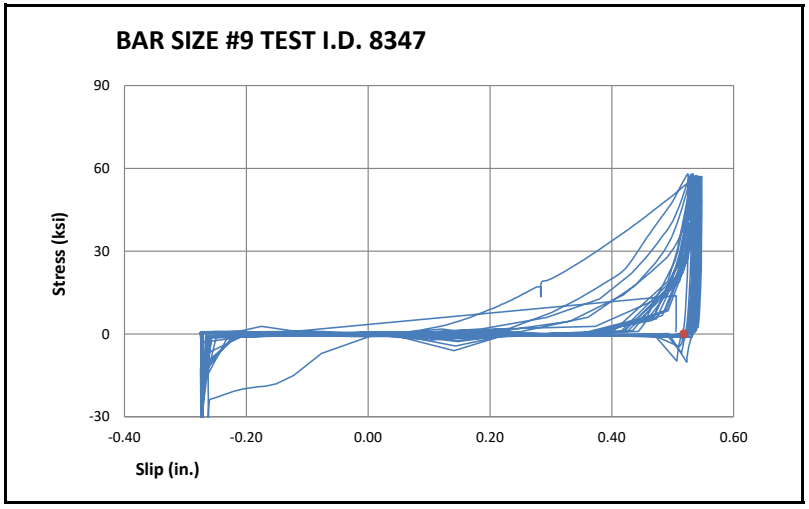
Test I.D. No.	Bar Size	Bar Area (in^2)	Cyclic Load Levels (Stages 1, 2, 3)				Cycles Applied			Tensile Strength (Stage 4)				Strain (Stage 4)	Final Result
			P_{min} (kips)	P_{max1} (kips)	P_{max2} (kips)	P_{max3} (kips)	n_1	n_2	n_3	(kips)	(ksi)	(%fy=60)	(%fu=80)	(%)	
8347	9	1.00	-30.0	57.0	-	-	20	-	-	107.4	107.4	179%	134%	-	Bar break at wedge indentation
													Preload Slack:		None Observed



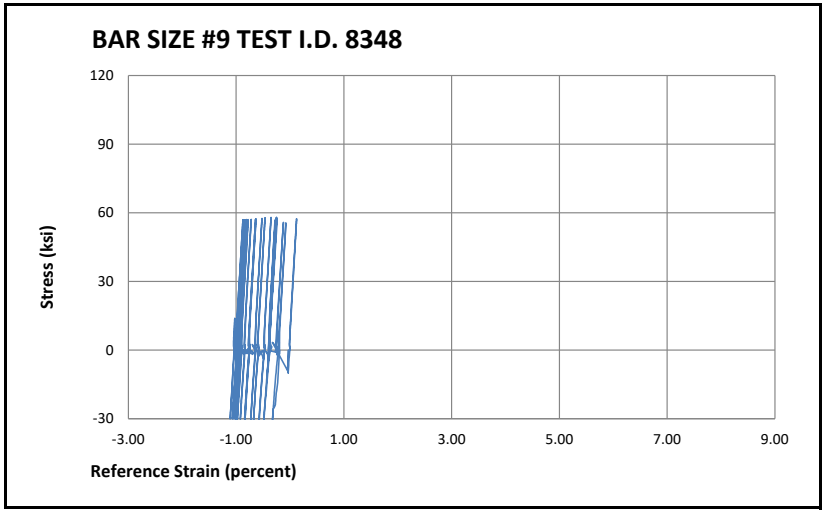
Product Tested:	Wellsys Type A
Reinforcing Bar:	ASTM A615, Grade 60
WJE Job Number:	2020.6557
Test Location:	Champaign, IL
Test Operator:	SKG
Test Date:	2/19/2021
Test Methods:	AC133 Cyclic

	Residual Slip (in.)
U20	0.5182



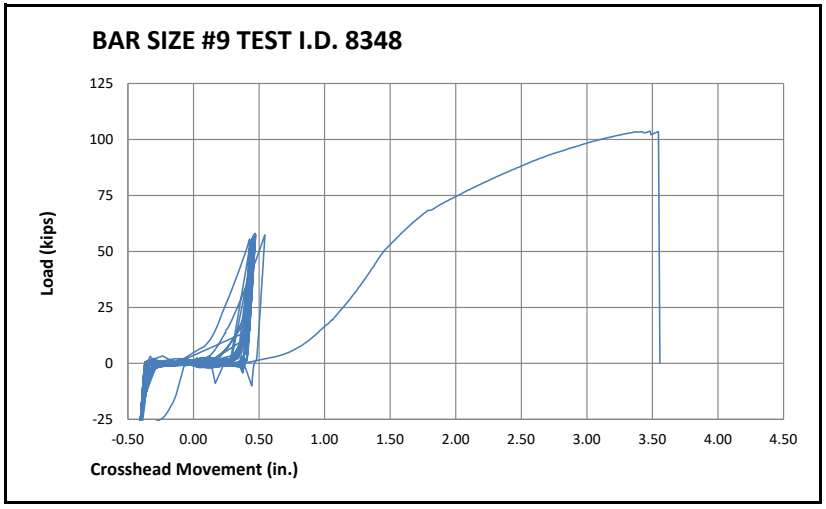


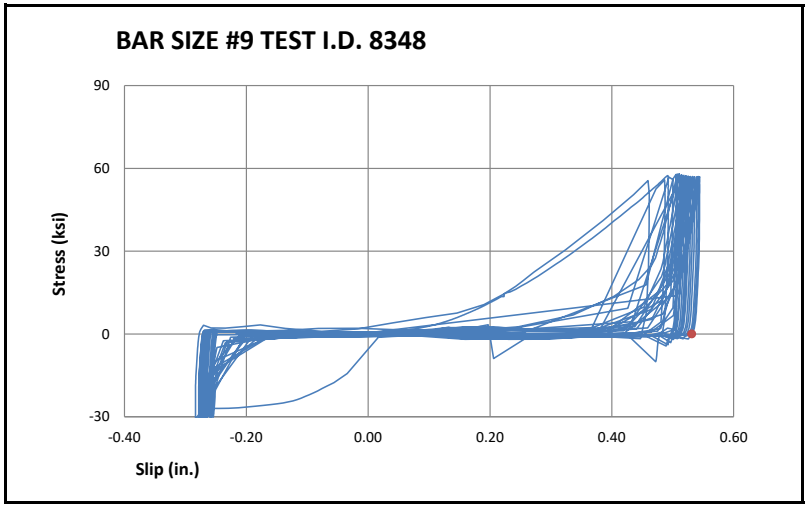
Test I.D. No.	Bar Size	Bar Area (in^2)	Cyclic Load Levels (Stages 1, 2, 3)				Cycles Applied			Tensile Strength (Stage 4)				Strain (Stage 4)	Final Result
			P_{min} (kips)	P_{max1} (kips)	P_{max2} (kips)	P_{max3} (kips)	n_1	n_2	n_3	(kips)	(ksi)	(%fy=60)	(%fu=80)	(%)	
8348	9	1.00	-30.0	57.0	-	-	20	-	-	103.7	103.7	173%	130%	-	Bar break at wedge indentation
													Preload Slack:		None Observed



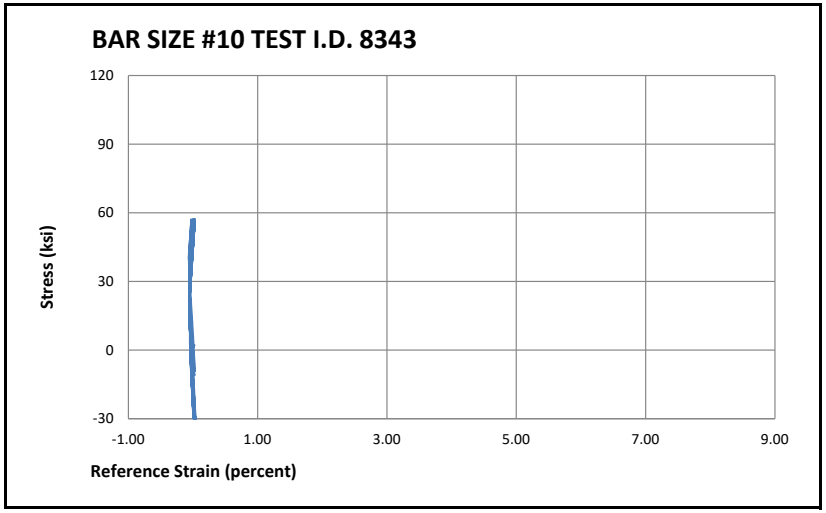
Product Tested:	Wellsys Type A
Reinforcing Bar:	ASTM A615, Grade 60
WJE Job Number:	2020.6557
Test Location:	Champaign, IL
Test Operator:	SKG
Test Date:	2/19/2021
Test Methods:	AC133 Cyclic

	Residual Slip (in.)
U20	0.5312



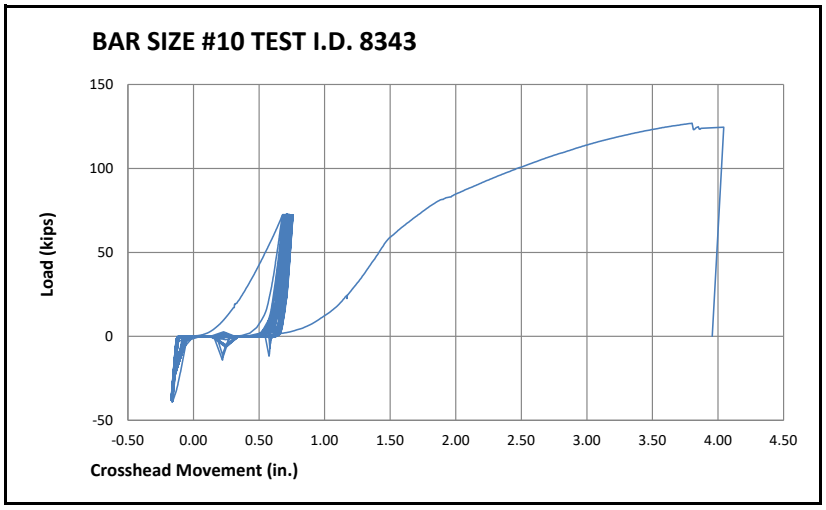


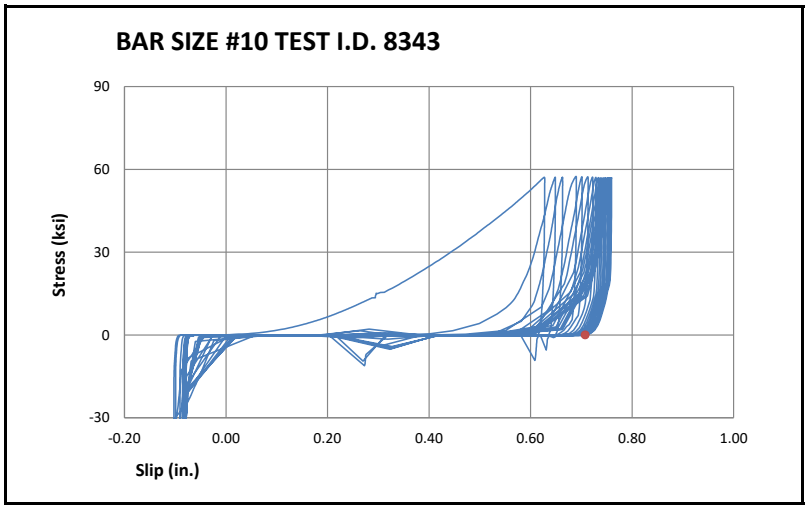
Test I.D. No.	Bar Size	Bar Area (in^2)	Cyclic Load Levels (Stages 1, 2, 3)				Cycles Applied			Tensile Strength (Stage 4)				Strain (Stage 4)	Final Result
			P_{min} (kips)	P_{max1} (kips)	P_{max2} (kips)	P_{max3} (kips)	n_1	n_2	n_3	(kips)	(ksi)	(%fy=60)	(%fu=80)	(%)	
8343	10	1.27	-38.1	72.4	-	-	20	-	-	126.9	99.9	167%	125%	-	Bar break at wedge indentation
														Preload Slack:	None Observed



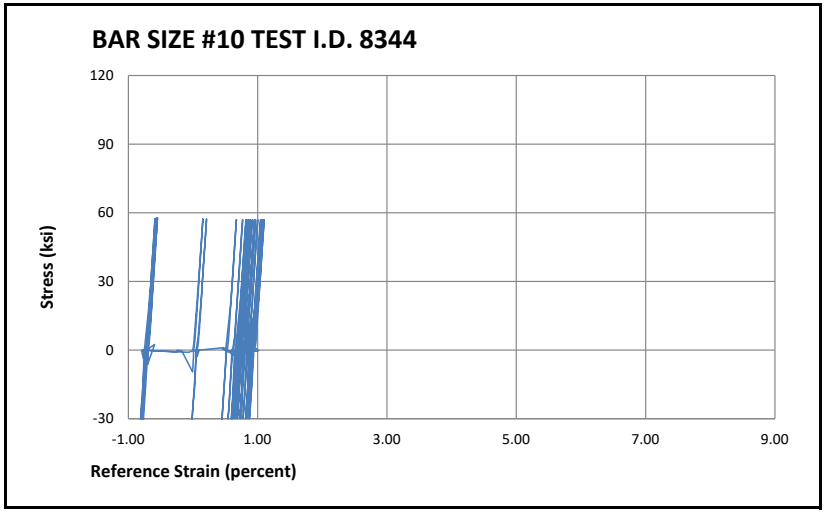
Product Tested:	Wellsys Type A
Reinforcing Bar:	ASTM A615, Grade 60
WJE Job Number:	2020.6557
Test Location:	Champaign, IL
Test Operator:	SKG
Test Date:	2/19/2021
Test Methods:	AC133 Cyclic

	Residual Slip (in.)
U20	0.7077



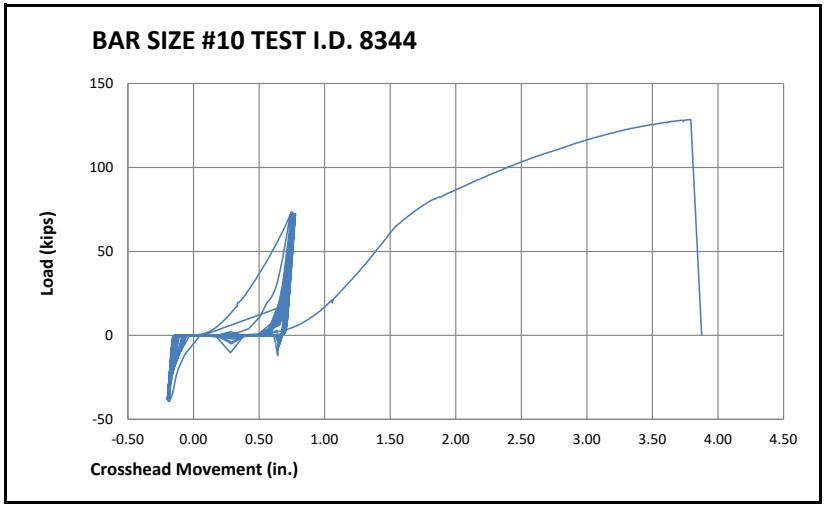


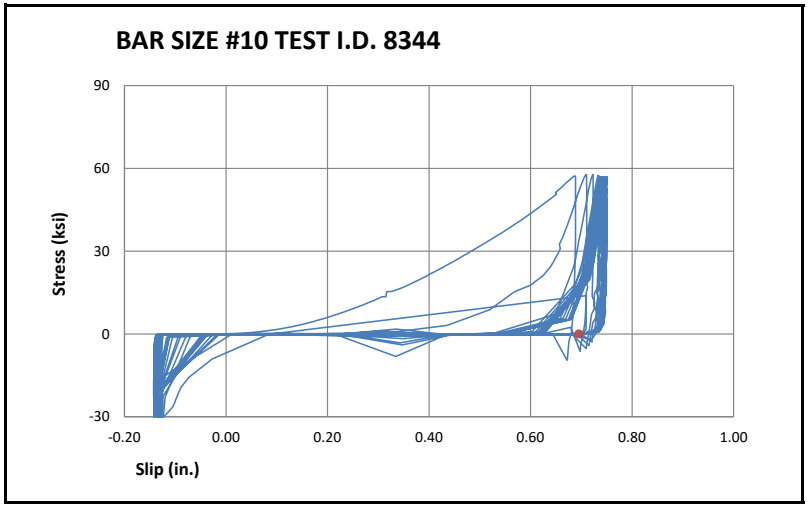
Test I.D. No.	Bar Size	Bar Area (in^2)	Cyclic Load Levels (Stages 1, 2, 3)				Cycles Applied			Tensile Strength (Stage 4)				Strain (Stage 4)	Final Result
			P_{min} (kips)	P_{max1} (kips)	P_{max2} (kips)	P_{max3} (kips)	n_1	n_2	n_3	(kips)	(ksi)	(%fy=60)	(%fu=80)	(%)	
8344	10	1.27	-38.1	72.4	-	-	20	-	-	128.5	101.2	169%	126%	-	Bar break at wedge indentation
													Preload Slack:		None Observed



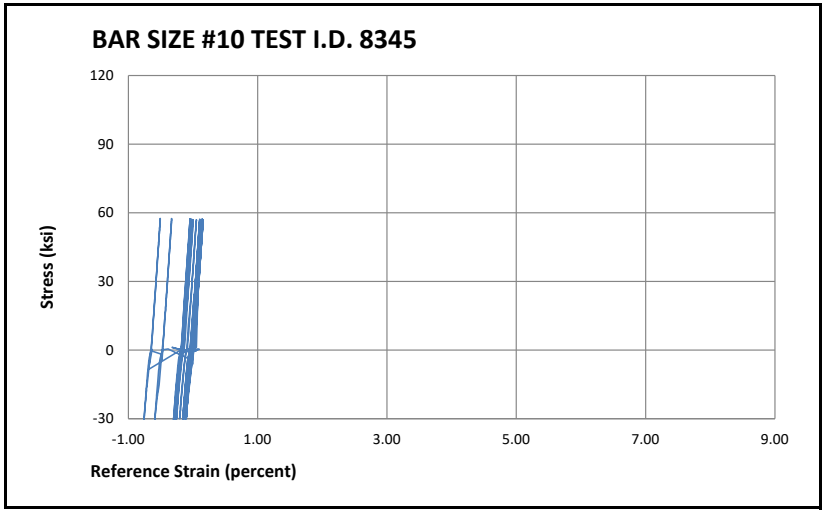
Product Tested:	Wellsys Type A
Reinforcing Bar:	ASTM A615, Grade 60
WJE Job Number:	2020.6557
Test Location:	Champaign, IL
Test Operator:	SKG
Test Date:	2/19/2021
Test Methods:	AC133 Cyclic

	Residual Slip (in.)
U20	0.6950





Test I.D. No.	Bar Size	Bar Area (in^2)	Cyclic Load Levels (Stages 1, 2, 3)				Cycles Applied			Tensile Strength (Stage 4)				Strain (Stage 4)	Final Result
			P_{min} (kips)	P_{max1} (kips)	P_{max2} (kips)	P_{max3} (kips)	n_1	n_2	n_3	(kips)	(ksi)	(%fy=60)	(%fu=80)	(%)	
8345	10	1.27	-38.1	72.4	-	-	20	-	-	125.1	98.5	164%	123%	-	Bar break at wedge indentation
													Preload Slack:		None Observed



Product Tested:	Wellsys Type A
Reinforcing Bar:	ASTM A615, Grade 60
WJE Job Number:	2020.6557
Test Location:	Champaign, IL
Test Operator:	SKG
Test Date:	2/19/2021
Test Methods:	AC133 Cyclic

	Residual Slip (in.)
U20	0.6806