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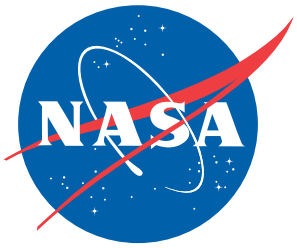

Space Transportation System (STS)-133/ External Tank (ET)-137 Intertank (IT) Stringer Cracking Issue and Repair Assessment: Proximate Cause Determination and Material Characterization Study

Robert S. Piascik/NESC
Langley Research Center, Hampton, Virginia

December 2011

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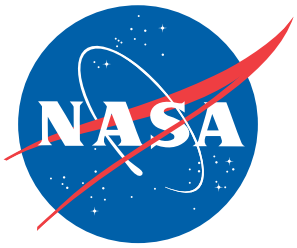

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National Aeronautics and
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September 29, 2011

Approval and Document Revision History

NOTE: This document was approved at the September 29, 2011, NRB. This document was submitted to the NESC Director on November 17, 2011, for configuration control.

Approved:	*Original Signature on File*	11/17/11
	NESC Director	Date

Version	Description of Revision	Office of Primary Responsibility	Effective Date
1.0	Initial Release	Dr. Robert S. Piascik, NASA Technical Fellow for Materials, LaRC	9/29/11

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Appendices

1.0 Notification and Authorization

The NASA Engineering and Safety Center (NESC) Director requested the NESC team to augment the Space Shuttle Program (SSP)-led team with appropriate technical subject matter expertise, facility and test equipment, and other resources to address the observed intertank (IT) foam crack in External Tank (ET)-137. This support ranged from inline support to independent analyses, testing, and inspections.

As part of the multi-discipline investigation, Dr. Robert S. Piascik, the NASA Technical Fellow for Materials, requested a detailed metallurgical and mechanical property characterization of the aluminum-lithium (Al-Li) 2090-T83 material used in the IT stringer fabrication.

An out-of-board activity was approved on November 9, 2010. An assessment plan was waived for this activity due to the dynamic nature of the developing investigation.

The primary stakeholders for this assessment are the SSP Manager, the NASA Chief Engineer, and the NASA Chief of Safety and Mission Assurance.

2.0 Signature Page

Submitted by:

Original Signature on File – 12/7/11

Dr. Robert S. Piascik Date

The signatory declares the findings and observations compiled in the report are factually based from data extracted from Program/Project documents, contractor reports, and open literature, and/or generated from independently conducted tests, analysis, and inspections.

3.0 Team List

Name	Discipline	Organization
Core Team		
Robert Piascik	NESC Lead	LaRC
David Dawicke	Fracture Mechanics	AS&M, Inc.
William Johnston	Experimental Mechanics	Lockheed Martin
Laura Leybold	MTSO Program Analyst	LaRC
Greg Shanks	Fracture Testing	LaRC
Jim Baughman	SEM Analysis	Lockheed Martin
Harold “Clay” Claytor	Materials Technician	Lockheed Martin
Stewart Walker	Tensile and Shear Testing	Lockheed Martin
Scott Willard	SEM Analysis	Lockheed Martin
Roy Crooks	Materials Analysis	Black Laboratories, LLC
Administrative Support		
Terri Derby	Project Coordinator	LaRC/ATK
Erin Moran	Technical Writer	LaRC/ATK

3.1 Acknowledgements

The Langley Research Center (LaRC) Metals Application Technology Branch (Engineering Directorate) provided outstanding support for this investigation by providing rapid turnaround time of machined specimen and components, accurate handling and labeling of specimens, and the resourcefulness of extracting the specimens from the stringer material. In particular, Johnnie West and George West provided exceptional support to this investigation.

4.0 Executive Summary

Several cracks were detected in stringers located beneath the foam on the External Tank (ET) following the launch scrub of Space Transportation System (STS)-133 on November 5, 2010. The stringer material was aluminum-lithium (AL-Li) 2090-T83 fabricated from sheets that were nominally 0.064 inches thick. The mechanical properties of the stringer material were known to vary between different material lots, with the stringers from ET-137 (predominately lots 620853 and 620854) having the highest yield and ultimate stresses. Subsequent testing determined that these same lots also had the lowest fracture toughness properties.

The objective of this investigation was to develop a database of test results to provide validation for structural analysis models, independently confirm test results obtained from other investigators, and determine the proximate cause of the anomalous low fracture toughness observed in stringer lots 620853 and 620854. The investigation revealed that the proximate cause of the low fracture toughness was a microstructure evolution process, termed *recovery*, which occurred prior to stringer processing. Recovery in the two affected lots resulted in material with higher yield and ultimate stresses and lower fracture toughness.

5.0 Background

5.0.1 External Tank Stringer Cracking

Following the launch scrub of STS-133 on November 5, 2010, a foam crack was observed on the ET adjacent to the IT-to-liquid oxygen (LO_2) tank flange (Figure 5.0-1). Subsequent imagery analysis determined the foam crack occurred during the ET propellant fill when the LO_2 level was at this location. Non-destructive evaluation and foam removal revealed axial cracking in five Al-Li 2090-T83 stringers (Figure 5.0-2). Two cracked stringers, S6 and S7, were on Panel 2, and three cracked stringers, S6, S7, and S11, were on Panel 6 (Figure 5.0-3). The cracks were in the stringer "foot" near the radius transition. The crack lengths ranged from approximately 4 to 9 inches, with the longest crack allowing sufficient radial displacement during the cryogenic propellant fill to exceed the foam tensile strength.

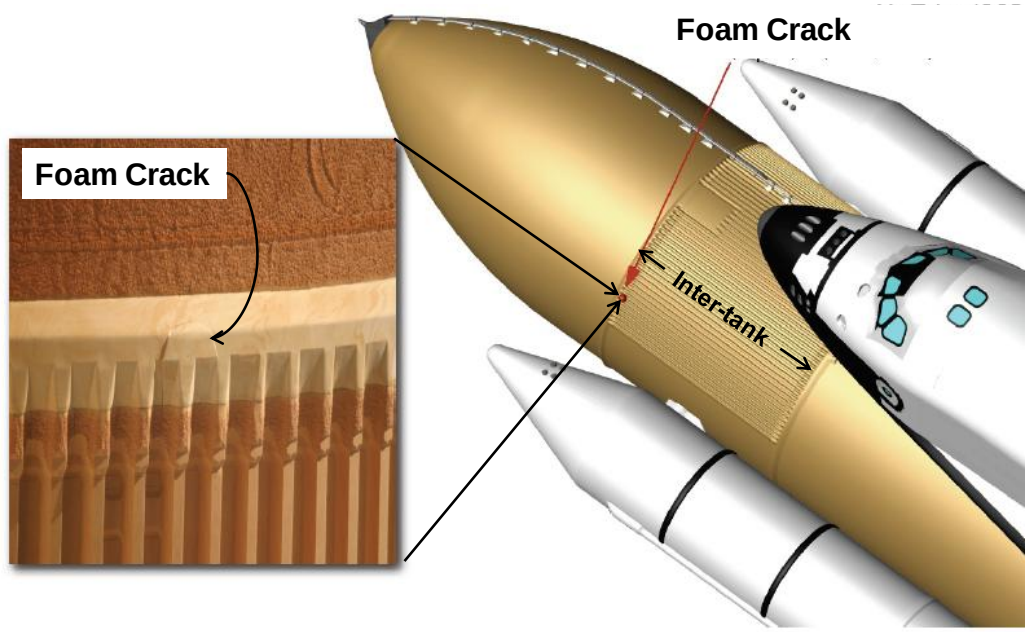


Figure 5.0-1. Location of the ET IT Cracked Foam [ref. 1]

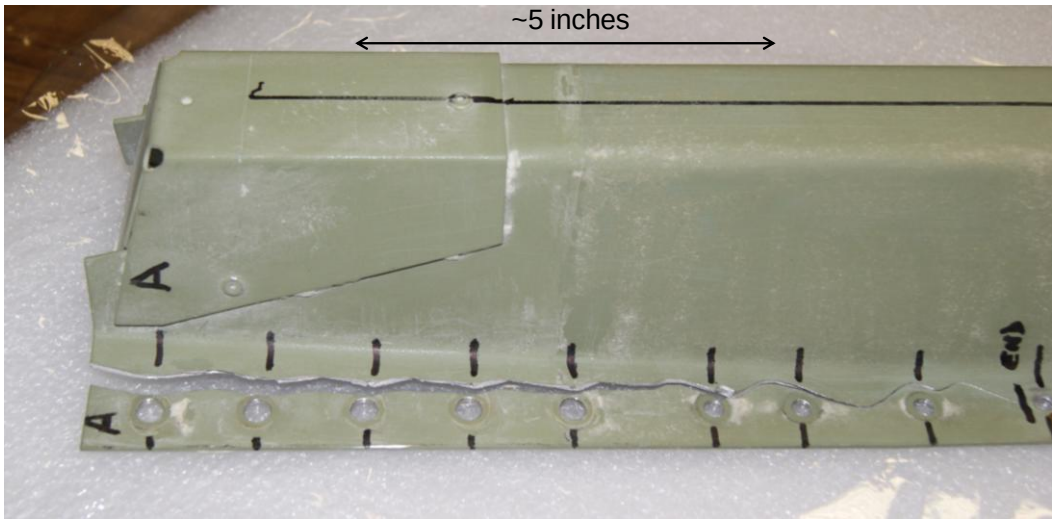


Figure 5.0-2. Panel 2, S7 Cracked Stringer (LO_2 flange end) after IT Removal

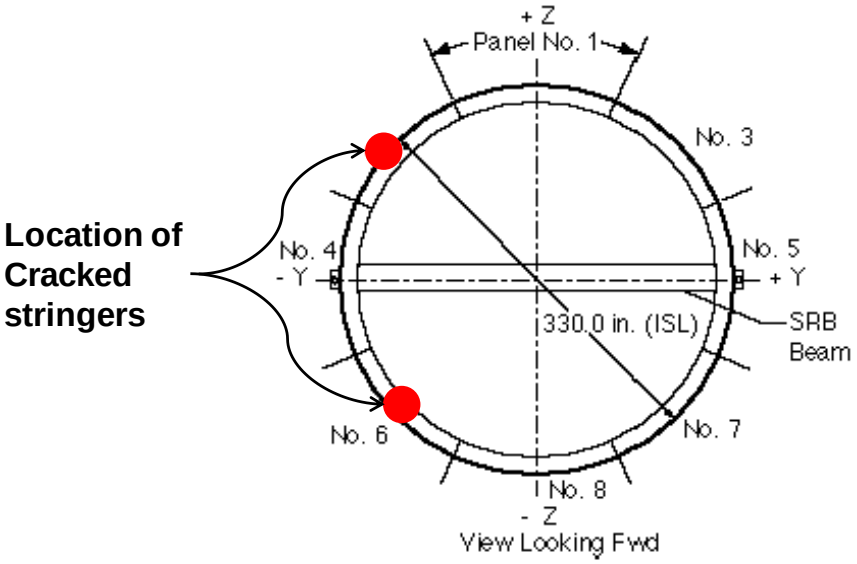


Figure 5.0-3. Cracked Stringers Locations Relative to the IT Circumference [ref. 2]

Stringer fractographic examination generated the following observations [ref. 3]:

- Crack growth was along the rolling direction (axial).
- Multiple thumbnail cracks nucleated on the stringer bottom surface, away from the end of the stringer, and propagated through the thickness.
- No indications of pre-existing defects at the region of crack nucleation or along the crack path.
- The crack path relative to the fastener clamping and IT construction suggests a complex stress state consistent with the expected mixture of bending and shear stresses during cryogenic tanking.

5.0.2 Stringer Material and Fabrication

The 2090 Al-Li alloy used to manufacture the stringers was obtained in sheet (coil) T3 product form. Each coil was identified by a unique lot number. The material exhibited a nominal thickness of about 0.064 inches and a width of about 8.5 inches. Prior to incoming receipt lot acceptance, tensile coupons were extracted from each lot and aged using the nominal peak aging process (T8 condition of 25 hours at 325°F) and tensile tests were conducted to certify that the yield stress, ultimate stress, and elongation minimums could be achieved after peak aging. A plot of lot acceptance test data is shown in Figure 5.0-4. The plot shows the lot-to-lot and within-lot tensile property variation. Note that the yield and ultimate stress data for the lots used to fabricate most of the ET-137 stringers (lots 620853 and 620854) are greater than the measured values for the other lots.

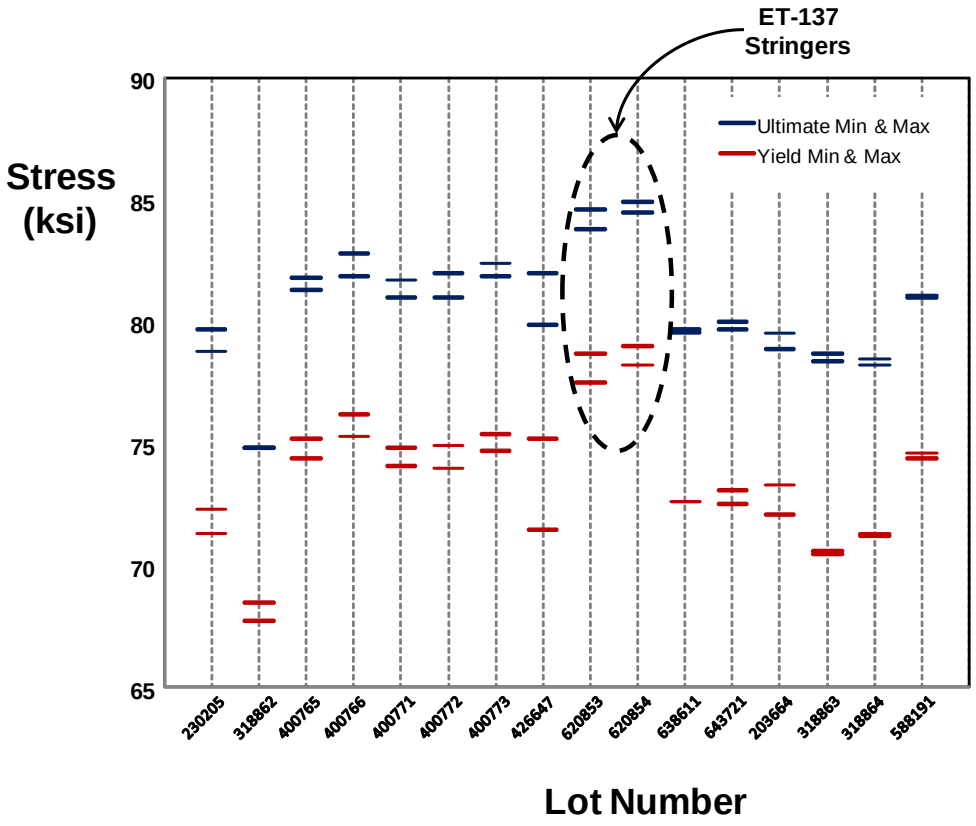


Figure 5.0-4. Lot-to-Lot and Within-Lot Variation in Yield Stress and Ultimate Stress for 2090 Al-Li Lots Aged to the T8 Condition and Tested in the Long-Transverse Orientation [ref. 3]

Using the Al-Li 2090-T3 coil material, the stringers were manufactured in the 3-step process illustrated in Figure 5.0-5. The coil material is first cold-formed to obtain the stringer general shape and length of approximately 20 feet. Hot forming (i.e., exposure to temperatures less than 325°F for less than 10 minutes) was performed to obtain the final stringer shape. This hot forming step included bending the stringer ends to conform to the IT upper LO_2 and lower liquid hydrogen flanges. The stringers were then peak aged at 325°F for 25 hours to obtain the desired -T83 temper. The nominal stringer final thickness varied from 0.058 to 0.064 inches. The stringers (total of 108 stringers per IT) are riveted to 6 of the 8 panels that are assembled into the completed IT (2 of the panels are integrally machined).

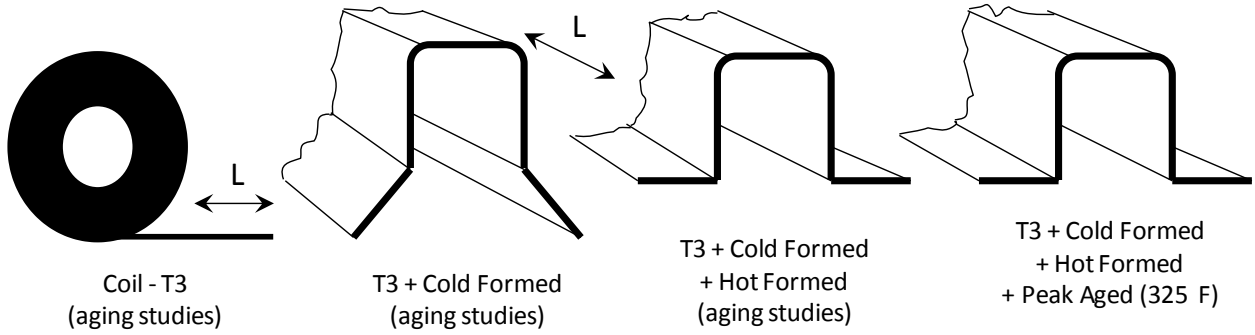


Figure 5.0-5. Schematic of IT Stringer Forming Steps

(Note: "L" indicates the longitudinal or rolling direction)

5.0.3 Fracture Toughness Testing and Initial Microstructural Examinations

Initial fracture toughness testing of specimens extracted from the ET-137 cracked stringers showed that suspect lots 620853 and 620854 exhibited brittle behavior in the form of low toughness and little or no stable crack growth. In addition, microstructural examinations revealed that the amount of grain and subgrain boundary precipitation was abnormally high in the suspect lots when compared to that observed in the control lots, as shown in Figure 5.0-6. The materials shown in the micrographs of Figure 5.0-6 were in the -T83 temper following cold forming and hot forming.

Excessive grain boundary precipitation suggested that off-nominal thermo-mechanical processing (high temperature and/or excessive time at temperature) resulted in poor fracture toughness without substantial influence on tensile properties. Subtle changes in aging temperature or time, temperature excursions during the hot forming process, and/or thermal excursions prior to delivery of the coil could account for the anomalous boundary precipitation.

Based on these observations, a test plan was created to understand the effect of process time and temperature on microstructure and fracture properties.

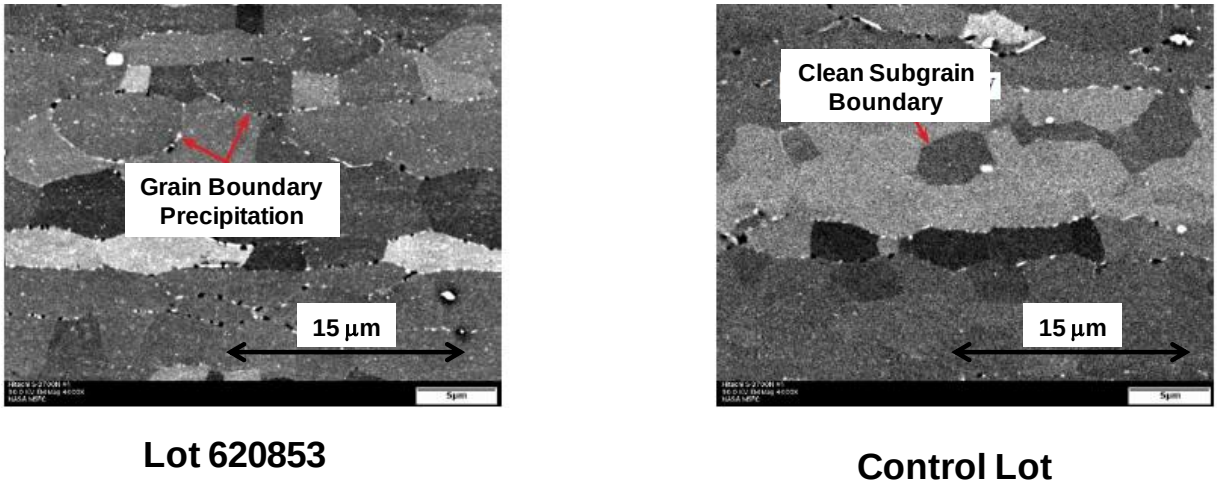


Figure 5.0-6. Example of Grain Boundary Precipitation in Lot 620853 and a Control Lot [ref. 3]

5.0.4 Initial Assessment

The failure analysis of the ET-137 cracked stringers indicated that the cracks initiated on the side of the stringer flange that mated with the IT skin, as illustrated in Figure 5.0-7. This region is subjected to a complex combination of tensile and bending loading due to the installation process, material processing, and the cryogenic thermal loading. Given the complex loading, material anisotropy must be considered. Alloy 2090 rolled products are known to have dramatically reduced mechanical properties in specific directions relative to the rolling direction, especially in thin sheet material. Short transverse and longitudinal (long transverse) properties are important for the initial stages of stringer crack propagation and later stages of through-the-thickness cracking, respectively. The observations of the complex loading, crack path, material anisotropy, and the lack of publically available data for these variables led to the development of unique test methods in an attempt to understand the complex failure mode. Furthermore, the limited cross-sectional size of the stringer and the localized hot forming area preclude the generation of American Society for Testing and Materials (ASTM) standard size test coupons in the required orientation. This required additional testing to validate sub-sized specimen data.

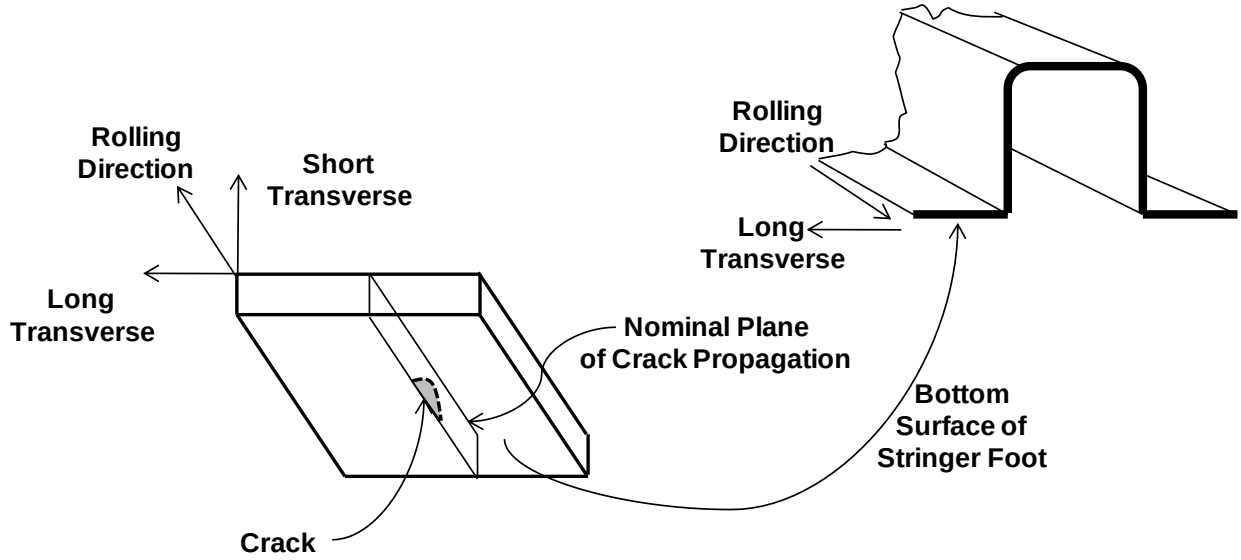


Figure 5.0-7. Schematic of Crack Location and Nominal Plane of Propagation

The failure analysis revealed the suspect material lots 620853 and 620854 were likely linked to the ET-137 stringer cracking. Both suspect lots exhibited anomalous microstructure and low toughness properties. Therefore, test parameters (i.e., heat treatment time and temperatures) were thought to be important variables and needed to be replicated in the laboratory to develop the understanding of proximate cause (see Section 11.0) for the observed anomalous microstructure and low toughness properties.

5.1 Investigation Objectives

In concert with parallel materials and process (M&P) efforts that were being conducted at Marshall Space Flight Center (MSFC), Michoud Assembly Facility (MAF), and Johnson Space Center (JSC), the NESC investigation examined the mechanical and fracture properties (e.g., tensile, shear, fracture toughness, and bend behavior) of the 2090-T83 material from the two suspect lots (620853 and 620854) used to manufacture the ET-137 stringers and several control lots (i.e., 400751, 400766, and 400768) that exhibited nominal tensile and fracture toughness properties. The primary objectives of the study were:

- Develop a tensile and fracture properties database.
    - Perform mechanical property characterization tests to compare behavior of suspect and control material lots.
    - Provide independent validation of tests conducted by the MSFC, MAF, and JSC from sub-sized specimens taken from stringers.

- Conduct tests to replicate complex local loading to understand the influence of anisotropy effects.
    - 3-point bend tests were conducted to understand through-the-thickness fracture to replicate stringer fracture mode.
    - Pure shear and combined tensile/shear tests were conducted to characterize mechanical properties under stringer failure mode loading conditions.
- Characterize microstructures to determine proximate cause(s) of the low toughness of stringers from suspect lots 620853 and 620854.
    - Perform a thermal aging (precipitation strengthening) study to characterize the influence of elevated aging temperature on microstructure and fracture toughness.
    - Conduct thermal exposure study to examine the effect of stringer process excursions on fracture toughness behavior.
    - Conduct detailed microstructure characterization using transmission electron microscopy (TEM) and electron back-scatter diffraction methods (EBSD).

5.2 Materials Examined

Material was provided in several product forms (i.e., sheet/coil, and several stages of stringer manufacture) from five different lots. Table 5.2-1 describes the material form, designations used to identify the material, and the types of tests that were conducted. The designation “mottled” (i.e., L4MCR and L5MCR) refers to the visible condition of the stringer surfaces, as shown in Table 5.2-1. This study did not address any differences in behavior due to the visible material surface condition.

Table 5.2-1. Description of Materials Examined

LaRC Designation	Other Designations	Lot Number	Description	Tests/Characterization
L1		400751*	Four sheets in T3 condition ~ 4-ft. long by ~8.5-in. wide by 0.063-in. thick	• Tensile • Bend • Fracture • EBSD
L2		400768*	Four sheets in T3 condition ~ 4-ft. long by ~8.5-in. wide by 0.063-in. thick	• Tensile • Bend • Fracture • EBSD
L3		400766*	Coil in T3 condition ~16-ft. long by ~8.5-in. wide by 0.065-in. thick	• Tensile • Bend • Fracture • EBSD
L4CR	J1 902D138	620854**	8-ft. stringer cold formed, but in T3 condition	• Bend • Fracture
L4MCR	G1 902D130	620854**	8-ft. stringer cold formed, but in T3 condition, labeled mottled	• Bend • Fracture
L4HR	K1	620854**	8-ft. stringer cold formed and hot formed, but in T3 condition	• Bend • Fracture
L5CR	L1 903D615	620853**	8-ft. stringer cold formed, but in T3 condition	• Bend • Fracture
L5MCR	I1 903D689	620853**	8-ft. stringer cold formed, but in T3 condition, labeled mottled	• Bend • Fracture
L5HR	H1	620853**	8-ft. stringer cold formed and hot formed, but in T3 condition	• Bend • Fracture
Stringer-7 Sister		620853**	~12-in. stringer	• Bend • Fracture
C-1D	Control 1D	400766*	~12-in. stringer	• Bend • Fracture

Note: * control lots and ** suspect lots

5.3 Mechanical Property Characterization Tests

Tensile, shear, and 3-point bend tests were conducted to characterize the behavior under possible stringer local loading conditions that resulted in cracking. Tensile tests were only conducted on the sheet and coil material because the stringers were not large enough to accommodate the standard size tensile specimens. However, sub-sized tensile coupons were made from the suspect stringer material and tested by MSFC.

5.3.1 Tensile Tests

Tensile tests were performed using 4-inch gage length, 0.25-inch-wide specimens according to ASTM E8/E8M [ref. 4] standards. The tests were conducted using a 20-kip servo-hydraulic controlled load frame with a 2-kip range card. The strain was determined from two 1-inch displacement gages placed on opposite specimen sides. The specimens were loaded to failure at a constant displacement rate of 0.01 inch/minute and data readings were collected every 0.1 seconds.

Tests were conducted on material that was peak aged (i.e., 325°F for 24 hours), over aged (i.e., >325°F for 24 hours), and for different orientations (L – loaded parallel to the rolling direction, T – loaded perpendicular to the rolling direction, and 45 – loaded at 45 degrees to the rolling direction). A representative set of tests for the three different loading orientations is provided in Figure 5.3-1 for the L2 (lot 400768) sheet material. A complete summary of the tensile test results is provided in Appendix A.

A summary of the measured yield and ultimate strengths for long-transverse orientation data for the control and suspect lots [ref. 3] is shown in Figure 5.3-2. The average yield and ultimate strengths for the suspect lot materials were about 2 ksi higher than the corresponding averages for the control lot materials. **Comparisons of the tensile test results indicate that the suspect material had higher yield and ultimate strengths than the control material (Observation 1)**.

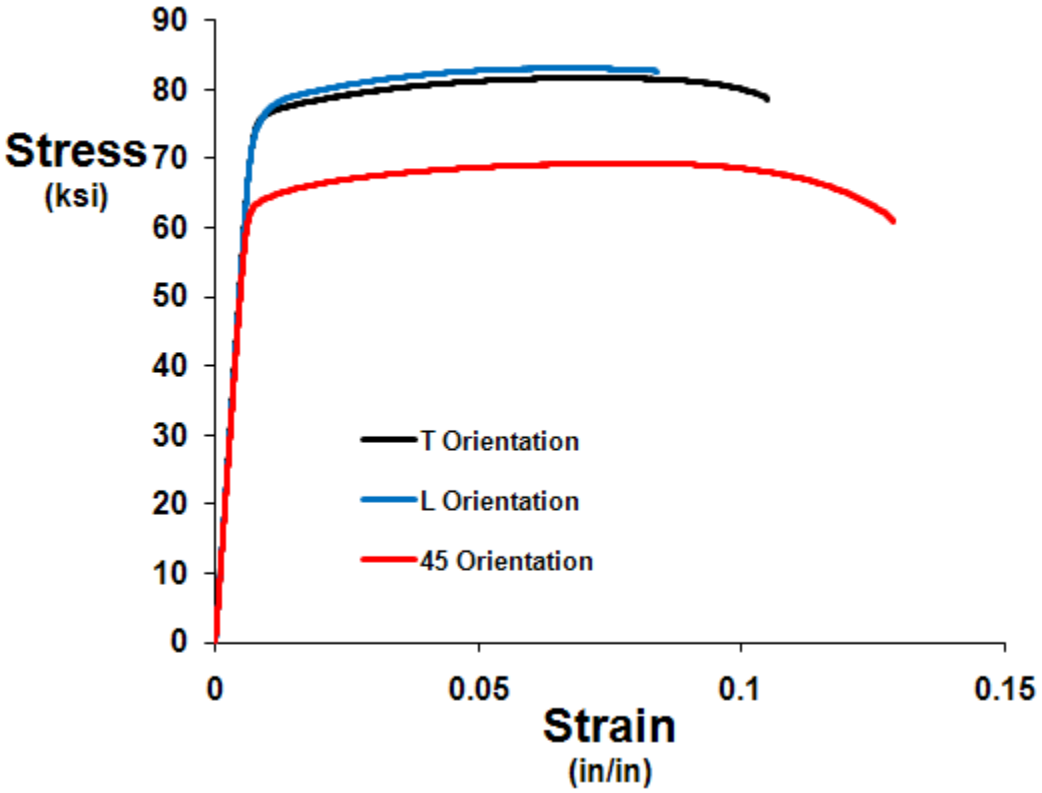


Figure 5.3-1. Tensile Test Results for Three Loading Orientations of the L2 Material (Lot 400768)

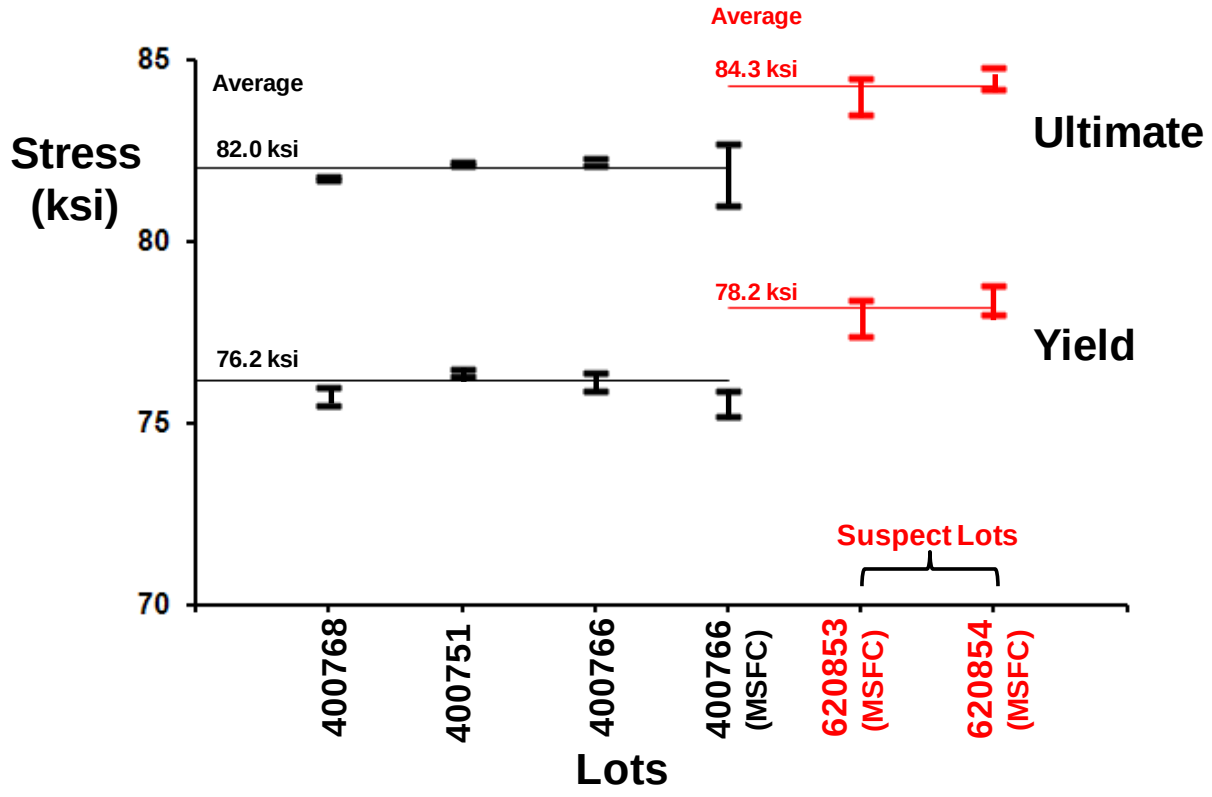


Figure 5.3-2. Summary of Tensile Test Results for All Lots (Long-transverse Orientation)

5.3.2 Shear and Combined Tensile/Shear Tests

Shear tests were performed using single shear specimens, double shear specimens, and a specially designed combined tensile/shear fixture. Alloy 2090 material is anisotropic and exhibits reduced properties in the short transverse (through-the-thickness) direction. The stringer failure analysis showed that the local tensile stress in the short transverse direction and the local shear stress in the short transverse direction produced cracking, with the combined loading potentially exacerbating the weakness (reduced properties) in the short transverse direction. The tests described in this section were conducted to investigate the influence of combined loading on the weaker through-the-thickness properties. The details of the specimens, fixtures, and data are provided in Appendix B.

A representative set of shear, tensile, and combined tensile/shear results are shown in Figure 5.3-3 for the control lot 400751. The tensile test results (blue squares) represent the yield stress calculated from the 0.2 percent offset strain and the original cross sectional area. The maximum shear stress and maximum normal stress yield surfaces were calculated from the

tensile test results and assumed that the compressive yield was equal to the tensile yield. Both yield surfaces are used to represent the yield surface of brittle materials with the maximum yield surface being more conservative. These curves represent the theoretical principal stress (σ_1 and σ_2) boundary between elastic and plastic behavior for an isotropic material under multi-axial loading. An exacerbation of the weakness in the short direction due to combined tensile/shear loading would be manifested by test results that fell on the inside of the surfaces. The shear tests only provided a measurement of the peak loads, so the shear test results (red symbols) and the combined tensile/shear test results (green symbols) are more representative of an ultimate stress and not a yield stress. The small difference between the yield stress (76.5 ksi) and the ultimate stress (82.0 ksi) observed in the tensile tests suggest that the shear yield would be less than 10 percent lower than the shear ultimate, and move the red and green symbols closer to the theoretical yield surface. This indicates that the combined tensile/shear loading of the 2090 material may not adversely influence the stringer material yield behavior in the loading regime examined.

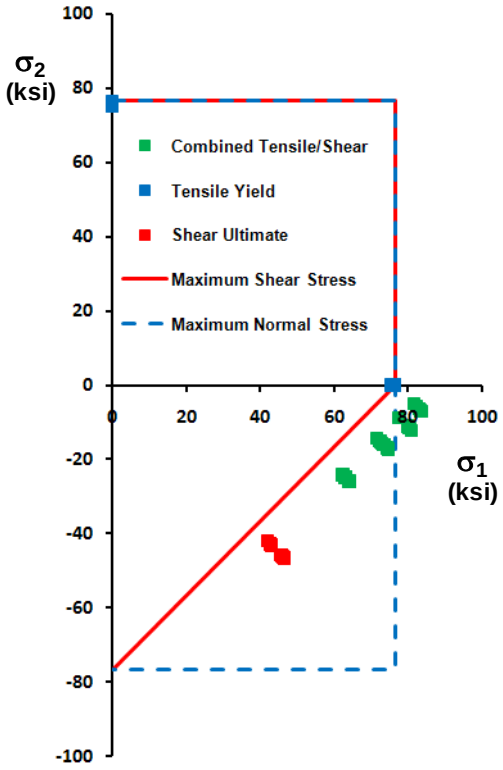


Figure 5.3-3. Combined Tensile/Shear Data for the L1 Material (Lot 400751)

5.3.3 3-Point Bend Tests

Rectangular coupons (2 inches long by 0.75 inches wide) were machined from the coil and the stringer materials and were tested in 3-point bending. The 3-point bend tests were conducted to simulate the bending loading present in the stringers at the failure location. The tests provide data for computational model verification and to evaluate a screening test for stringer material with brittle behavior.

The specimens were oriented with the rolling direction perpendicular to the long side of the specimen. This bending orientation produces cracking in the same plane (short longitudinal) as the stringer cracking plane. The distance between the two fixed boundaries was defined as "L" and the displacement of the center mandrel was defined as "δ", as shown in Figure 5.3-4. The tests were conducted by applying a constant displacement rate of 0.05 inches/minute until the specimen either failed suddenly into two pieces (defined as brittle behavior) or emitted an audible sound that indicated damage, producing an intact ligament and rapidly dropping the load, without complete failure (defined as less-brittle behavior). The applied displacement and load were measured for each test. Several tests had strain gages on the specimen tensile side opposite the mandrel. The strain to failure, or cracking, was noted for each test and was plotted as a function of the normalized displacement ($\delta t/L^2$) in Figure 5.3-5. The open square symbols represent the maximum strain observed in individual tests on suspect lot material and likewise, the solid circular symbols represent tests on control lot materials. The failure strains of the control and suspect lots overlap on the lower end of the control lot and the upper end of the suspect lot failure strains. **The 3-point bend tests demonstrated that the suspect lot materials were more brittle and had lower strains to failure than the control lot materials (Observation 2).**

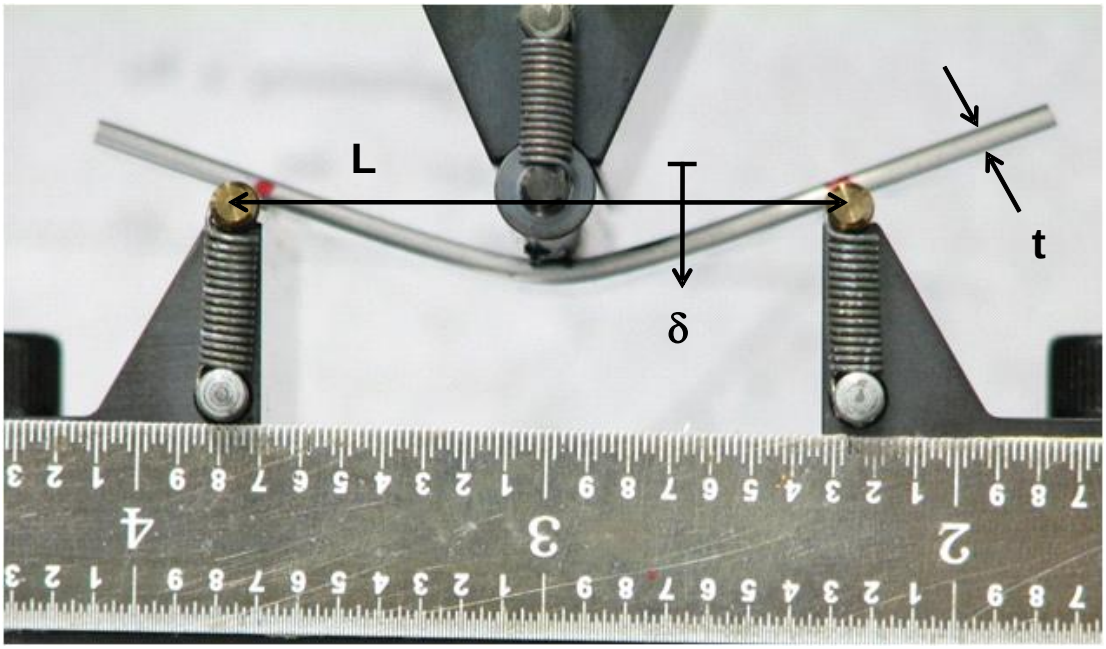


Figure 5.3-4. 3-point Bend Fixture

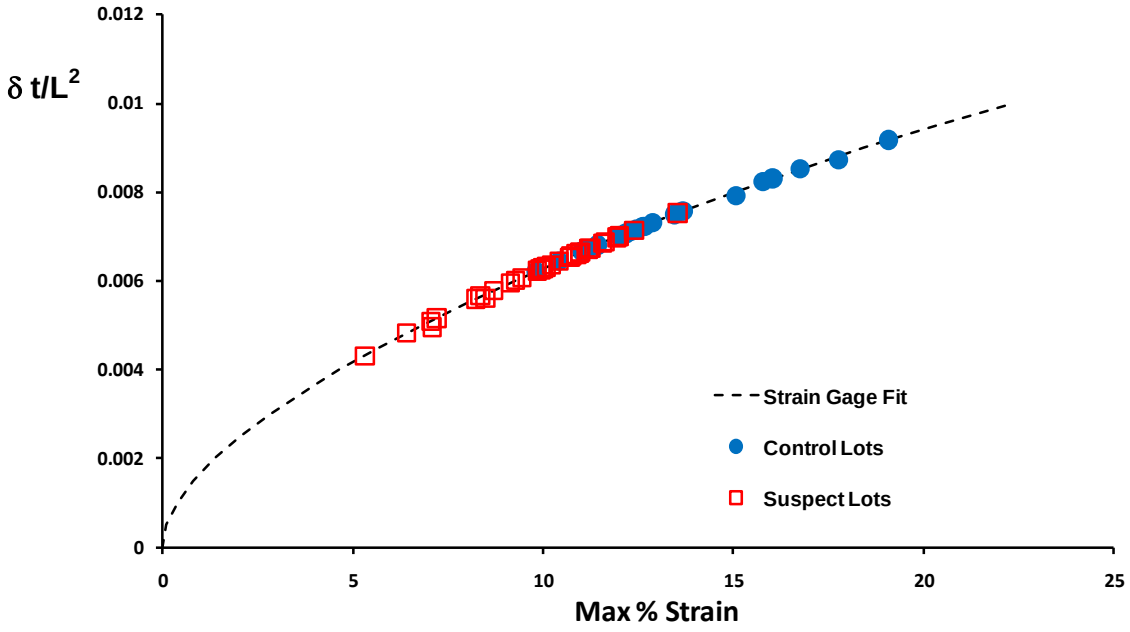


Figure 5.3-5. Strain to Failure from 3-point Bend Tests

The measured center mandrel displacement (δ) was reported as a function of the applied load for model verification. Different span lengths (L) were tested, as shown in Figure 5.3-6. The failure load increased as the span length decreased, corresponding to a reduction in the outer surface bending stress for an equivalent center mandrel displacement. Likewise, the displacement at failure increased as the span increased. Additional details of the specimens, fixtures, and data are provided in Appendix C. **The 3-point bend test database was provided to the NESC structures assessment team for use in the 3-D elastic-plastic models for stringer-line loading conditions (ref. 6) (Observation 3).**

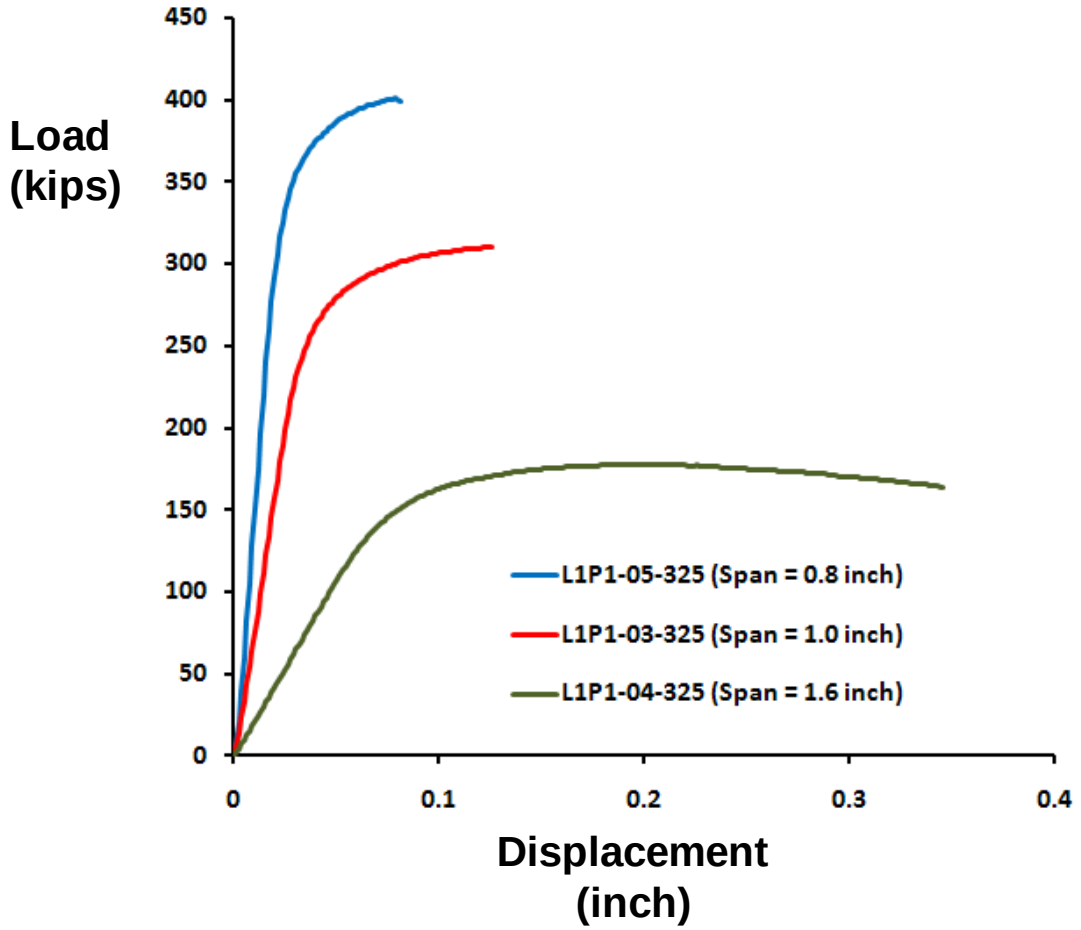


Figure 5.3-6. Measured Displacement and Load from 3-point Bend Tests for Different Spans

5.4 Fracture Toughness Tests

Fracture toughness tests were conducted using 1.5-inch-wide compact tension specimens according to ASTM E1820 [ref. 5] standard. The tests were conducted to evaluate the influence of processing variables (e.g., processing temperature and time at temperature) on the fracture toughness behavior, and to provide a database to assist in the independent validation of the fracture toughness test data produced by the MSFC M&P group. The two stringer thermal processing steps that could potentially alter the material and produce the abundant boundary precipitation and low toughness observed in the two suspect lots are hot rolling and peak aging. This could only have occurred if an off-nominal high temperature was not detected by normal process controls. A thermal treatment test matrix was developed to envelop the probable anomalous temperature and processing times that could occur during stringer processing. For each of these thermal test conditions, fracture toughness testing was used to characterize the influence of anomalous temperature and process time conditions.

Based on MSFC fracture criteria, the stress intensity factor (K) at peak load (P_{max}) was used to characterize the test specimen fracture behavior. Fracture tests were conducted on the control and suspect lot materials following nominal peak aging processing (325°F for 24 hours), as shown in Figure 5-4.1. The K at P_{max} for the suspect lot materials was about 6 ksi $in^{1/2}$ lower than the corresponding averages for the control lot materials. **The fracture test results showed that the suspect lot materials were less tough than the control lot materials (Observation 4).**

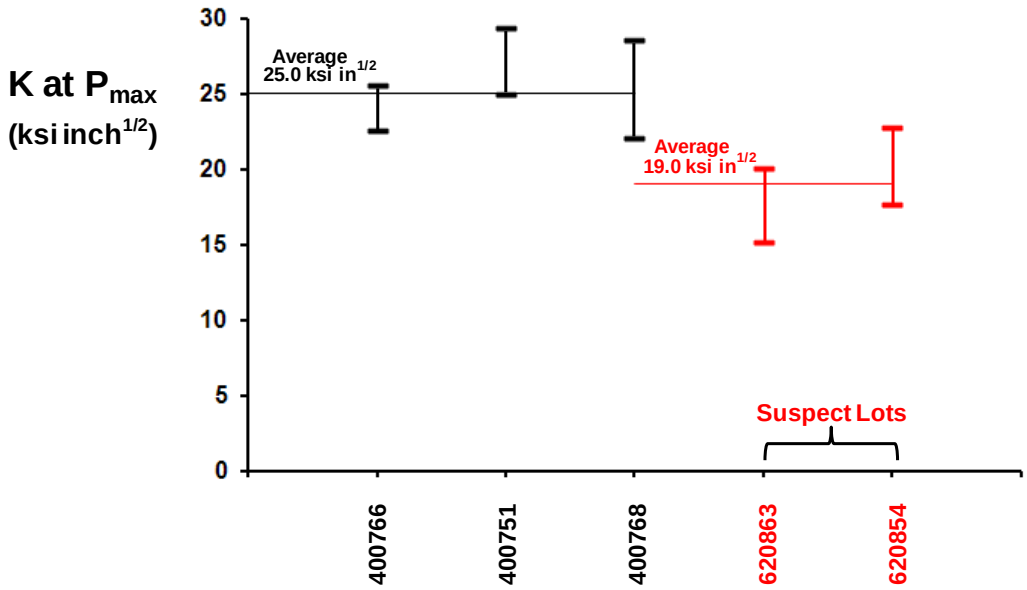


Figure 5.4-1. Fracture Test Results from Suspect and Control Lot Materials Following Nominal Peak Aging

Testing was conducted on a variety of specimens that had experienced different thermal exposures to examine the influence of both thermal aging temperature and brief, high temperature exposures on the fracture behavior for coil and stringer materials. The nominal peak aged condition (T83) was produced by exposing the alloy 2090-T3 stringer material to a temperature of 325°F for 24 hours in an air environment. (Note that the production stringer aging process aged at 325°F for 25 hours and started with the oven at room temperature.) The thermal aging study examined the influence of temperatures to 400°F on K at peak load and the fracture surface morphology. In addition, a thermal exposure study examined 10- and 20-minute exposures to temperatures to 500°F prior to the nominal aging process. These tests were performed to simulate temperature excursions during the hot forming process. Additional information on the test specimens, test conditions, and data are provided in Appendix D. Photographs of representative fracture surfaces are provided in Appendix E.

5.4.1 Thermal Aging Study

The thermal aging (precipitation strengthening) study was performed by aging the 2090-T3 control material and suspect material at temperatures that ranged from the nominal 325 to 400°F, as summarized in Table 5.4-1. The results for the individual tests are provided in Appendix D. The goal of the tests was to reproduce the process conditions that produce low toughness during the thermal aging process. Multiple tests were conducted at each temperature and material combination and the K at P_{max} was plotted for each aging temperature, as shown in Figure 5.4-2. The red symbols in this figure represent individual tests conducted on the two suspect lot stringer materials ("plus" symbols for lot 620853, and "x" symbols for lot 620854). The circle symbols represent individual tests conducted on the control lots.

The measured fracture index (i.e., K at P_{max}) decreased with increasing temperatures for aging temperatures between 325 and 350°F. The micrographs in Figure 5.4-2 show representative crack surfaces for fracture specimens that were aged at different temperatures. Examinations of these micrographs reveal a general increase in grain boundary delamination with aging temperature (i.e., straight and parallel microstructural features along the crack length). For aging temperatures above 350°F (toughness minima), there is a dramatic increase in boundary delamination. The correlation of increasing toughness and boundary delamination with increasing thermal aging temperatures above 350°F suggests that the increase in toughness for aging temperatures greater than 350°F is the result of delamination toughening. The toughness increase is the result of the increased crack driving force required to propagate delamination cracking. **The suspect lot materials exhibited lower fracture toughness values compared to the control lot materials at elevated aging temperatures (Observation 5). Above 350°F, the observed increase in fracture toughness is related to delamination fracture mechanism (Observation 6)**.

Table 5.4-1. Summary of Fracture Thermal Aging Study

24 Hour Aging Temperature (°F)	Lot 400751 K at P_{max}			Lot 400768 K at Pmax			Lot 400766 K at Pmax		
	Average (ksi $inch^{1/2}$)	Std Dev. (ksi $inch^{1/2}$)	Delam.	Average (ksi $inch^{1/2}$)	Std Dev. (ksi $inch^{1/2}$)	Delam.	Average (ksi $inch^{1/2}$)	Std Dev. (ksi $inch^{1/2}$)	Delam.
325	25.2	2.2	N	26.7	2.1	N	24.3	0.9	N
333	21.0	0.8	N	22.3	0.1	N	22.7	1.5	N
340	21.4	0.9	N	20.1	0.7	N	20.3	1.8	N
350	19.1	0.4	N	19.7	0.7	N	17.6	0.3	N
375	18.7	1.0	Y	21.0	1.1	Y	18.1	0.6	Y
400	23.1	1.5	Y	25.6	0.3	Y			

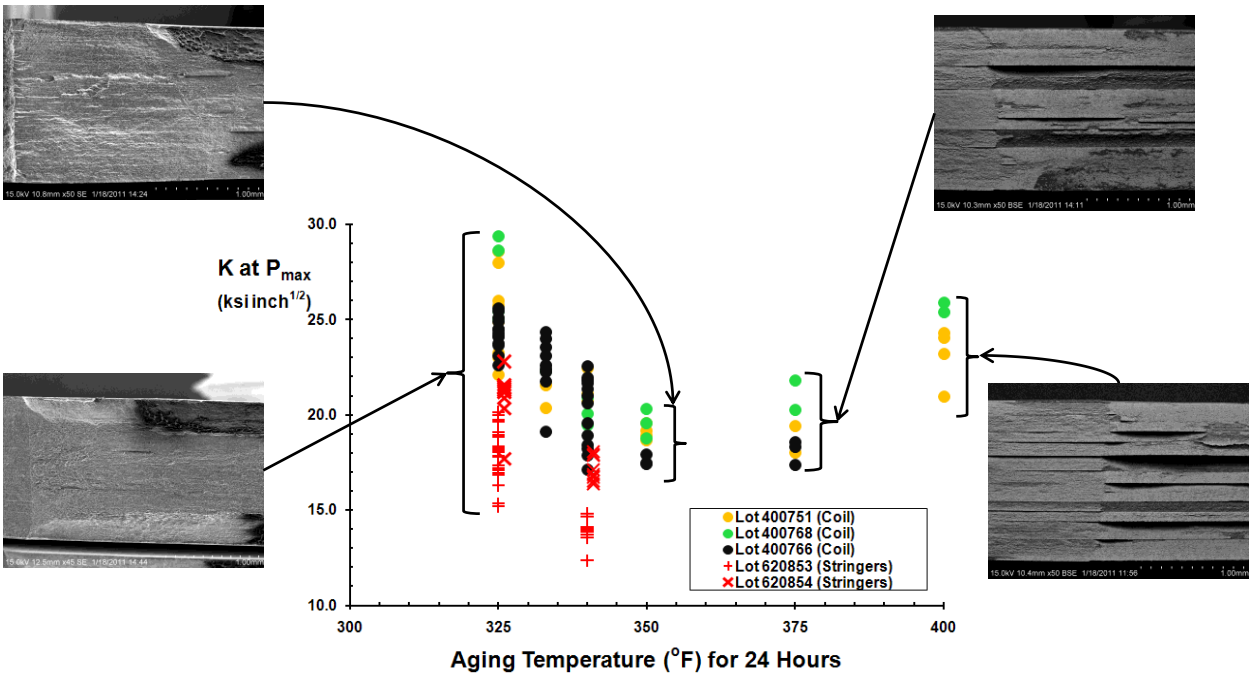


Figure 5.4-2. Fracture Test Results from the Thermal Aging Study

5.4.2 Thermal Exposure Study

The thermal exposure study was performed by heating the 2090-T3 coil materials to temperatures above the nominal aging temperature (325°F) for a brief period (10 and 20 minutes), as summarized in Table 5.4-2. The results for the individual tests are provided in Appendix D. The goal of the tests was to determine if short duration temperature anomalies during the hot forming process could influence the microstructure or material behavior. The specimens were aged for 24 hours at the nominal aging temperature after the brief thermal exposures. Multiple tests were conducted at each temperature and material combination, and K at P_{max} was plotted for each exposure temperature, as shown in Figure 5.4-3. The control material did not show a reduction in toughness until the exposure temperature exceeded 375°F. The toughness minima occurred at about 450°F, where delaminations were becoming visible on the fracture surfaces. **Further increases in the exposure temperature resulted in a higher density of fracture surface delaminations and little measureable change in the toughness index (Observation 7).**

Table 5.4-2. Summary of Fracture Exposure Aging Study

24 Hour Aging Temperature (°F)	Exposure Temperature (°F)	Exposure Time (min)	Lot 400751 K at P_{max}			Lot 400768 K at Pmax		
			Average (ksi inch$^{1/2}$)	Std Dev. (ksi inch$^{1/2}$)	Delam.	Average (ksi inch$^{1/2}$)	Std Dev. (ksi inch$^{1/2}$)	Delam.
325	-	-	25.2	2.2	N	26.7	2.1	N
325	340	10	25.1	0.6	N	24.9	2.2	N
325	350	10	25.6	-	N	24.4	1.1	N
325	375	10	25.6	-	Y	23.6	-	Y
325	400	10	20.9	0.5	Y	20.6	0.8	Y
325	425	10	20.3	0.7	Y	20.6	0.5	Y
325	450	10	18.7	-	Y	20.1	-	Y
325	475	10	19	-	Y	16.6	-	Y
325	500	10	17.5	-	Y	16.7	-	Y
325	340	20	24.6	1.1	N			N
325	350	20	24.1	0.8	N	24.6	-	N
325	400	20	22.3	-	Y	19.5	2.8	Y
325	450	20	17.3	-	Y			Y
325	500	20	20	-	Y	19.4	-	Y

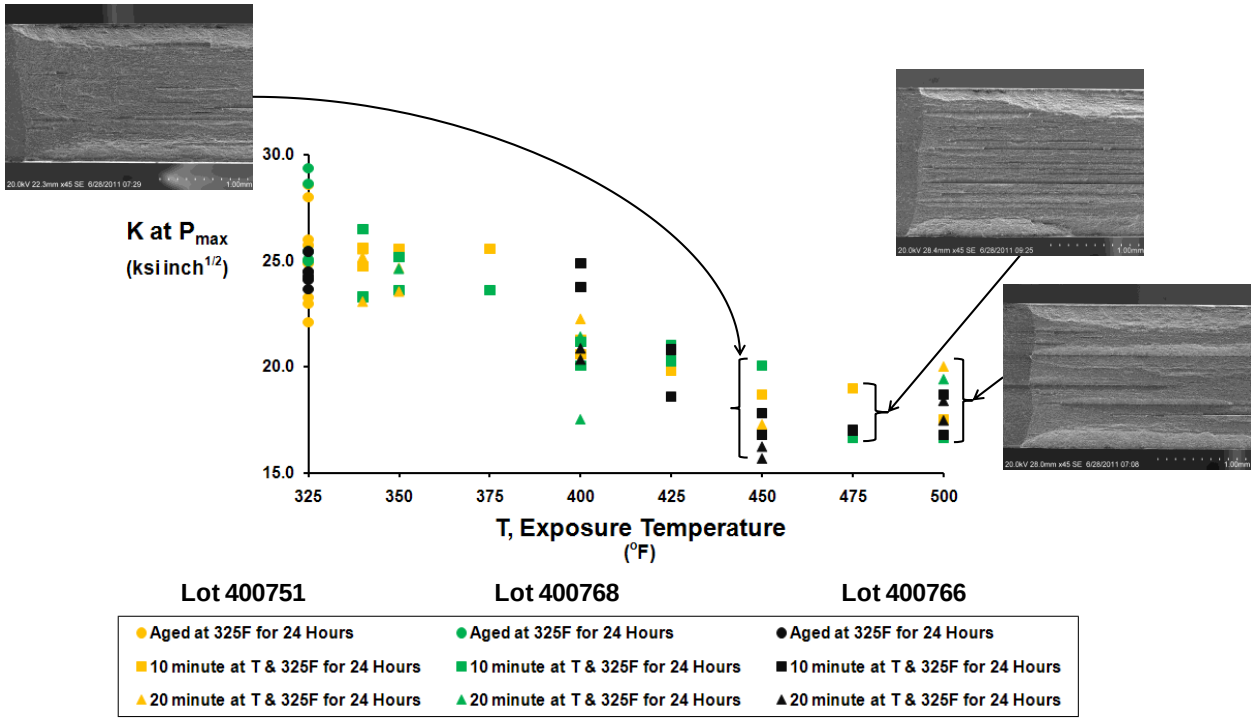


Figure 5.4-3. Fracture Test Results for the Thermal Exposure Study

5.5 Microstructure Characterization

The objective of this effort was to characterize the microstructure of the suspect materials compared to the control materials that exhibit good material properties. Anomalous microstructure is linked to poor properties and is likely that proximate cause(s) can be hypothesized by thoroughly characterizing the anomalous microstructure. Two critical characterization techniques, TEM and EBSD, were used to identify anomalous microstructures.

5.5.1 Transmission Electron Microscopy (TEM) Analysis

Alloy 2090 is a well-known precipitation strengthened alloy, thus important precipitate features can be linked to mechanical and fracture properties. The TEM analysis of the suspect and control material lots characterized the δ' (Al_3Li), T_1 (Al_2CuLi) and T_2 (Al_6CuLi_3) precipitate morphology. Evidence of classical and deleterious microstructure morphologies, such as grain boundary precipitation free zones (PFZs), can assist in determining the cause of the observed low fracture toughness exhibited by the two suspect lots.

TEM analysis was performed on suspect (Stringer-7 Sister) and control (C-1D) stringer material. **The TEM examinations of high angle grain boundaries, refer to Figure 5.5-1, revealed that PFZs were present in suspect lot material, but not in the control lot (Observation 8)**. Examinations revealed large quantities of grain boundary precipitates (likely T_2 precipitate); the formation of large grain boundary precipitates consume nearby solute (Li) atoms preventing the formation of δ' precipitate, and resulting in the observed δ' PFZ. Classically, the presence of PFZs suggests reduced fracture toughness; the PFZ exhibits reduced mechanical properties compared to the matrix, resulting in crack-tip-process-zone void nucleation (strain localization), which results in reduced crack growth resistance (lower toughness).

Multiple dark and bright field TEM images were used to obtain an estimate of the size and number of matrix T_1 and δ' precipitates, as summarized in Table 5.5-1. **The TEM examinations revealed that the suspect material had fewer and larger matrix T_1 precipitates compared to the control material (Observation 9). The sizes of the matrix δ' precipitates were about the same in the suspect and control stringer material, but more precipitate particles were present in the control stringer material (Observation 10).** These are significant observations and will be discussed further relative to the EBSD analysis results discussed in the following section.

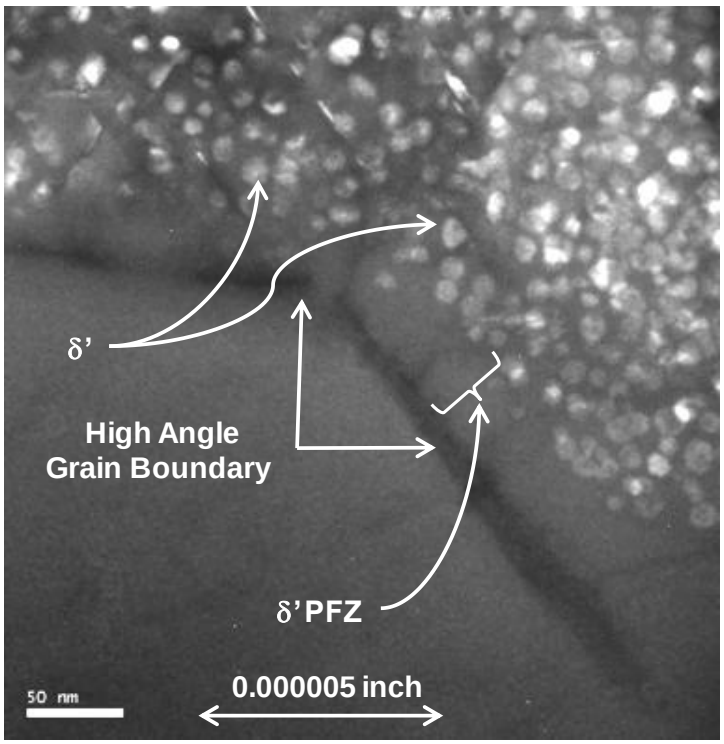


Figure 5.5-1. Example of a High Angle Grain Boundary δ' PFZ

Table 5.5-1. Summary of TEM Matrix T_1 and δ' Precipitate Measurements

Material	Number of Micrographs	Number of Precipitates	Average Size (nm)	Std. Deviation
T_1 Precipitate Measurements				
Suspect (Lot 620843)	7	32	87	24
Control (Lot 400766)	5	80	61	29
δ' Precipitate Measurements				
Suspect (Lot 620843)	2	13	14	2
Control (Lot 400766)	2	22	14	3

5.5.2 Electron Backscatter Diffraction EBSD Analysis

EBSD analysis characterizes the crystallographic orientation and thereby gives a qualitative measure of dislocation morphology. This information in combination with the TEM analysis of the precipitate characterizations can yield important understanding relative to the proximate cause of the low toughness material. EBSD was performed on the suspect lot 620853 and control lots 400766 and 400768. The grain orientation spread (GOS) is a quantification of EBSD data. Grains (high angle) and sub-grains (low angle) are regions of similarly oriented crystallographic material that are defined by boundaries with neighboring grains. Boundaries are detected by point-to-point crystallographic orientation changes greater than a defined value. A high-angle boundary may be defined by a point-to-point change of 15 degrees, while a low-angle boundary may be just a few degrees. The orientation measurements within a grain are averaged and the GOS, or average grain misorientation, is calculated, as shown in Figure 5.5-2. For this investigation, the boundary threshold was set at the default value of 5 degrees. Areas with high dislocation densities show high GOS values. Regions within these boundaries with a low average grain misorientation (blue and green colors) would suggest that these regions contain lower dislocation density and that these regions exhibit a higher degree of recovery. Recovery is an elevated temperature process that reduces the stored energy in deformed grains by the removal or rearrangement of dislocations. The EBSD analyses showed these regions to be recovered and not recrystallized because no evidence of grain nucleation and growth was observed.

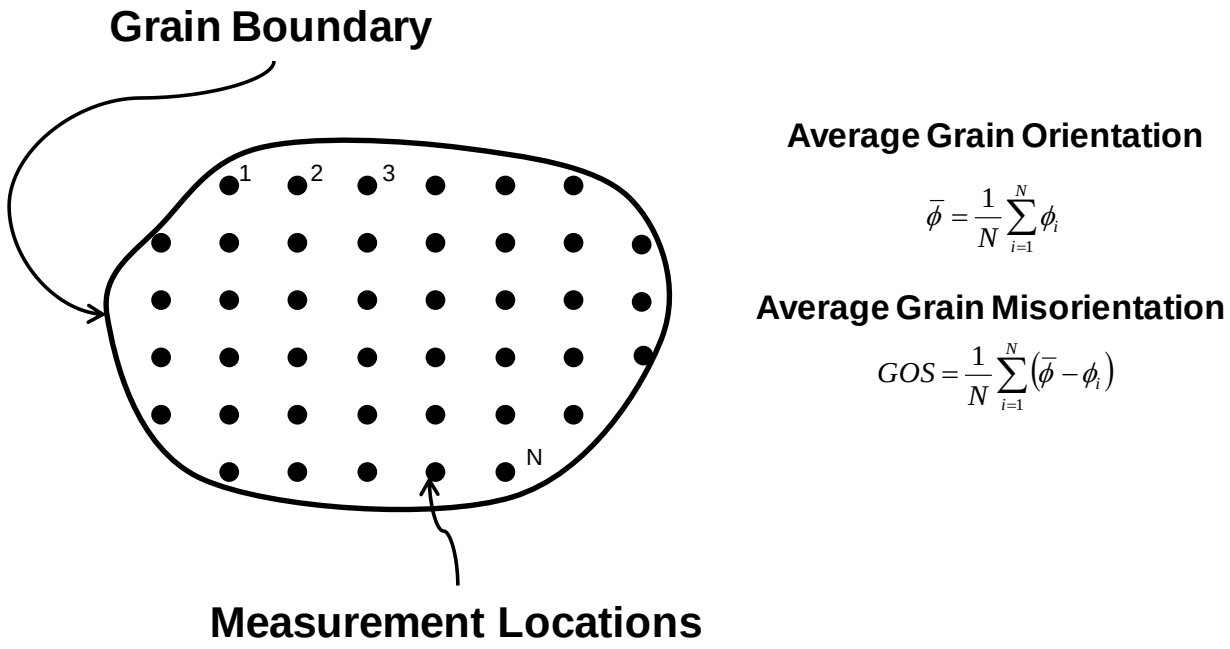


Figure 5.5-2. Schematic of GOS Calculation

Figure 5.5-3 shows all of the material conditions examined (coil, cold form, etc) and location (red X) where the EBSD samples were obtained. Note that the location of the EBSD samples was in a region away from where the material was cold worked. The examined locations were taken from regions where no bending (cold work) was conducted. The figure also defines the through-the-thickness EBSD analysis region relative to the rolling or longitudinal direction. The GOS data are presented in a crystallographic orientation (colored) map that indicates the average misorientation; blue corresponding to low misorientation measurement and red corresponding to a high misorientation measurement.

Figure 5.5-4 summarizes the EBSD data from control material (lot 400751) in both the as-received (T3) condition and after peak aging at 325°F for 24 hours. The EBSD crystallographic orientation maps reveal little difference in the as-received and peak aged materials. The EBSD results shown in Figure 5.5-5 for the control coil lots 400768 and 400766 in the peak-aged condition (325°F for 24 hours) also exhibit no difference in orientation or dislocation morphology. **These EBSD data shows that stringer processing had no influence on the microstructure (no change in crystallographic misorientation) of the control lot material (Observation 11).**

Figure 5.5-6 shows the results of EBSD analysis conducted on the suspect materials (lot 620853), including processed stringers (as-received), cold-formed stringers, and cold + hot

formed stringers. All the suspect materials showed a higher percentage material that exhibited recovery; the interior of the sheet (middle 1/3) had fewer blue regions compared to the exterior regions (remaining 2/3). Conversely, a comparison of the suspect lot material EBSD results compared to the control lot (Figures 5.5-6 and 5.5-5, respectively) revealed a dramatic difference in misorientation or dislocation morphology.

The EBSD data revealed that the suspect material exhibits evidence of grain recovery parallels the TEM observations 8, 9, and 10. Grain recovery (removal or redistribution of dislocations) reduces or changes the number of energetic sites for precipitation; removal or redistribution of dislocations could alter precipitate morphology (alter precipitate size, number, and location). **Thus, the EBSD analysis revealed that the as-received suspect lot microstructure exhibits grain recovery (reduced dislocation density) and confirms the TEM observations relative to differences in precipitate morphology (Observation 12).**

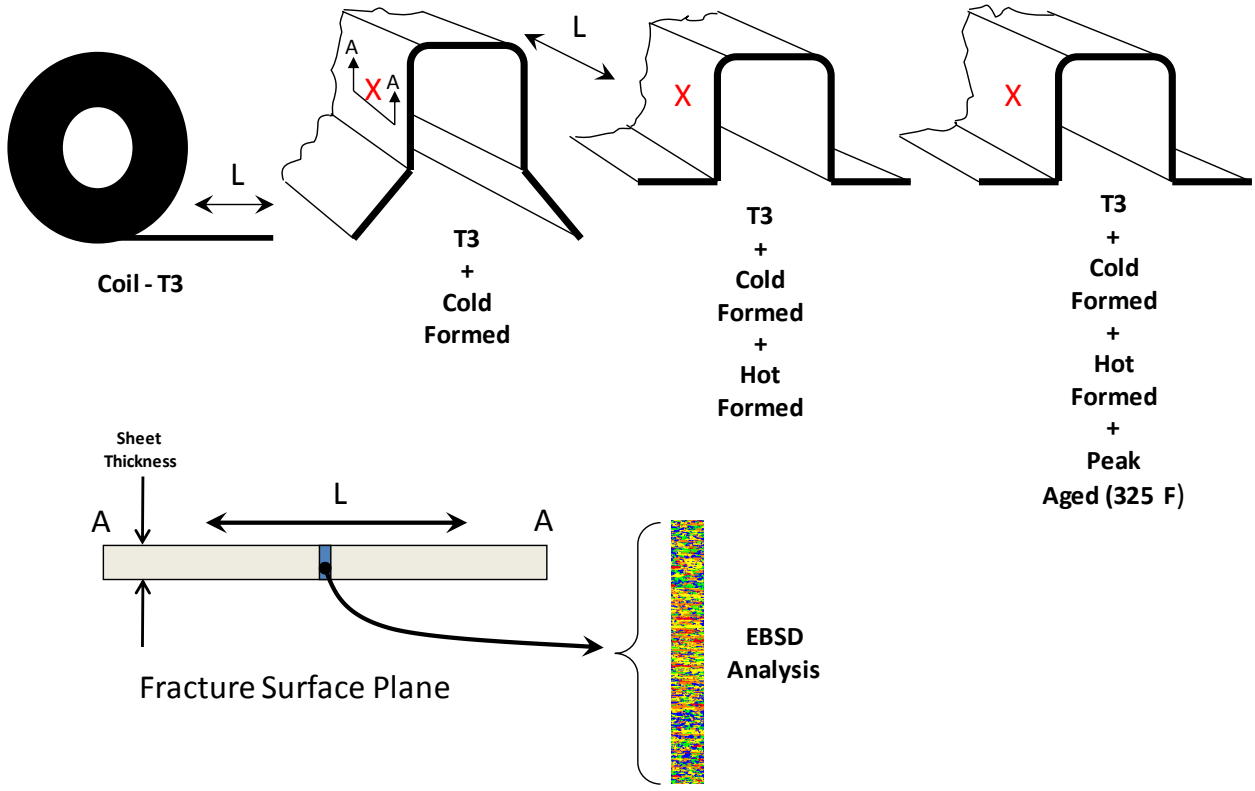


Figure 5.5-3. Schematic Describing the Location of the EBSD Analysis for the Stringer Materials

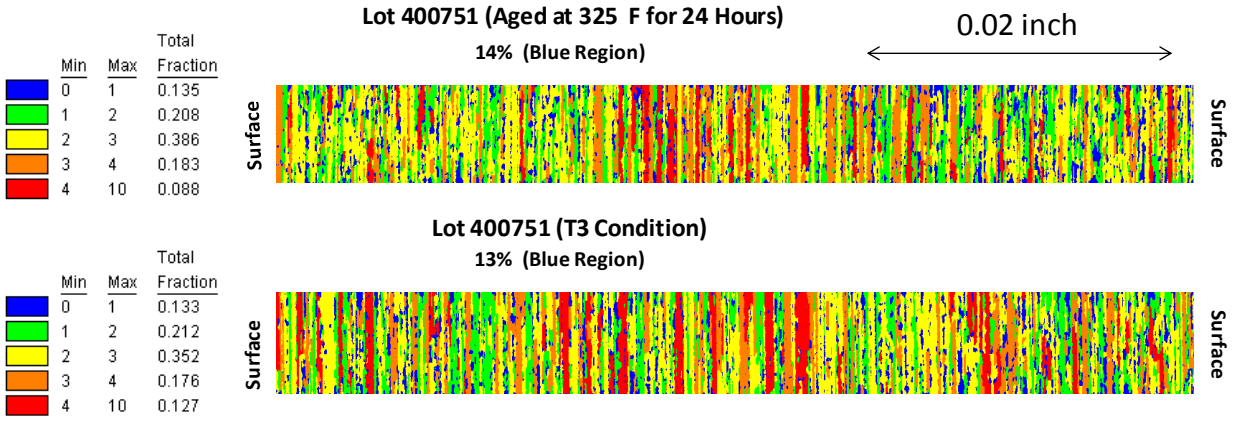


Figure 5.5-4. GOS Values for a Through-the-Thickness Strip of Control Coil Lot 400751 in the as-received (T3) and Peak Aged Condition

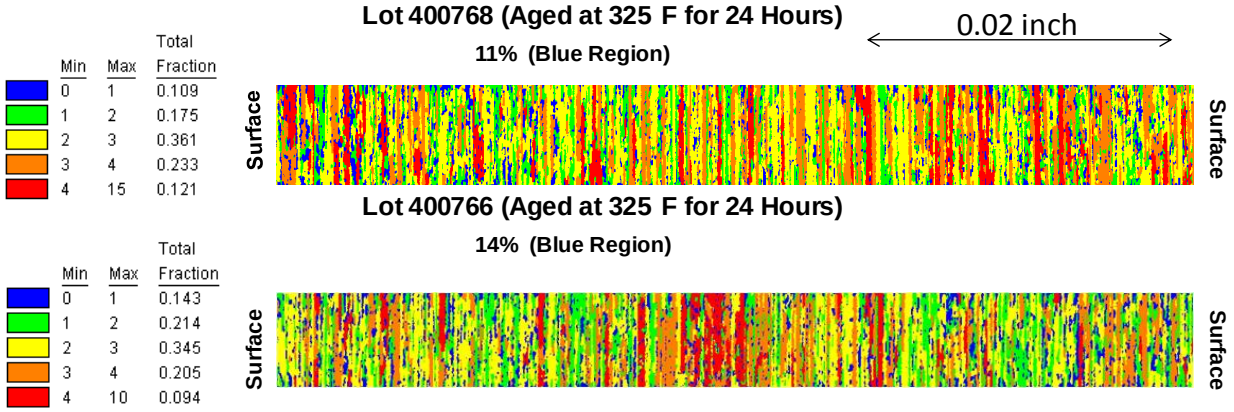


Figure 5.5-5. GOS Values for a Through-the-Thickness Strips of Control Coil Lots 400768 and 400766 in the Peak-Aged Condition

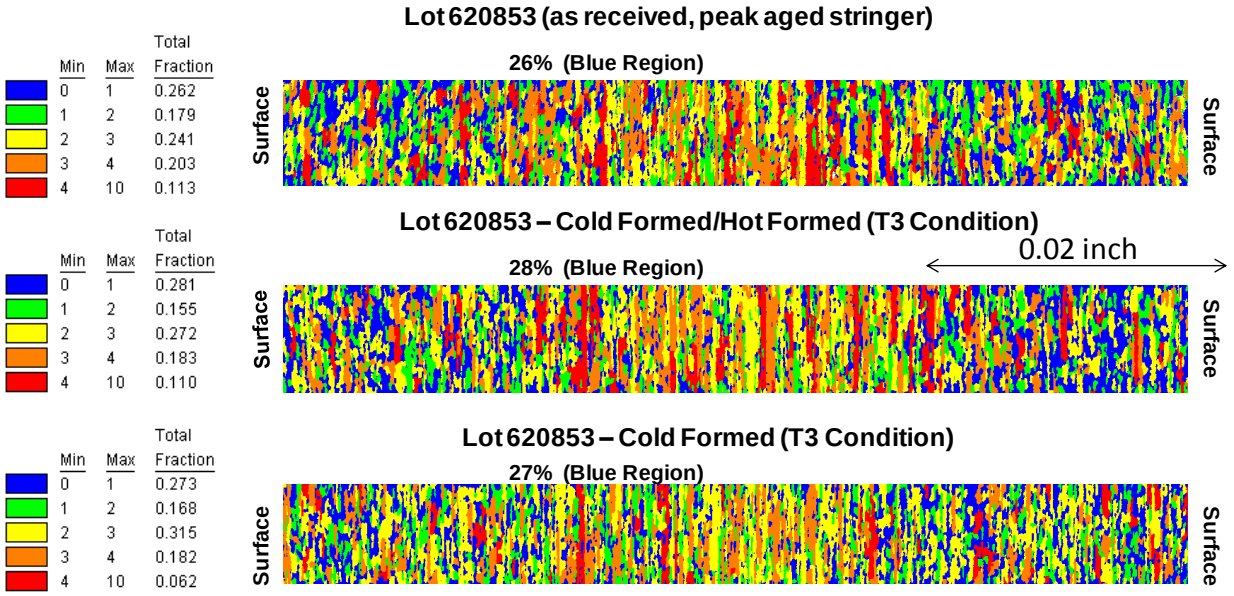


Figure 5.5-6. GOS Values for a Through-the-Thickness Strip of Stringer Lot 620853 in the as-received Peak-Aged, Cold-Formed + Hot-Formed, and Cold-Formed Conditions

6.0 Findings

F-1. The proximate cause (see Section 11.0) leading to Alloy 2090 ET stringer lot-to-lot variability in mechanical and fracture properties (**O-1**, **O-2**, and **O-4**) is linked to a metallurgical process termed grain recovery (**O-8**, **O-9**, **O-10**, and **O-12**).

- The EBSD microstructural characterization of the as-received suspect material showed that grain recovery had occurred prior to stringer processing (**O-11**).
- Grain recovery caused the two suspect lots to age differently than the control lots for the specified (325°F for 25 hours) process parameters. This produced a microstructure in the suspect lots that resulted in low fracture toughness.
- Fracture-test-aging studies showed that nominal and possible off-nominal stringer processing would not cause the low fracture toughness, brittle behavior, and fracture morphology exhibited by the suspect lot material (**O-5, O-6,** and **O-7**).

F-2. The 3-point bend tests generated a stringer damage mode understanding and a database for validating the structural analysis models (**O-3**).

7.0 NESC Recommendation

R-1. Alloy 2090 T8 sheet should not be used for "hat" configured stringer applications that are attached by fasteners.

- These stringers can develop complex, concentrated through-the-thickness bending and shear stresses near the fasteners.
- Alloy 2090 through-the-thickness properties are marginal (i.e., low ductility) and material processing variations (within specification) can alter microstructure/ properties and unknowingly exacerbate cracking under bending and shear stress stringer environments.

8.0 Alternate Viewpoints

There were no alternate viewpoints during the course of this assessment.

9.0 Other Deliverables

No unique hardware, software, or data packages, outside those contained in this report, were disseminated to other parties outside this assessment.

10.0 Lessons Learned

No applicable lessons learned were identified for entry into the NASA Lessons Learned Information System.

11.0 Definition of Terms

Corrective Actions

Changes to design processes, work instructions, workmanship practices, training, inspections, tests, procedures, specifications, drawings, tools, equipment, facilities, resources, or material that result in preventing, minimizing, or limiting the potential for recurrence of a problem.

Finding

A conclusion based on facts established during the assessment/inspection by the investigating authority.

Lessons Learned

Knowledge or understanding gained by experience. The experience may be positive, as in a successful test or mission, or negative, as in a mishap or failure. A lesson must be significant in

that it has real or assumed impact on operations; valid in that it is factually and technically correct; and applicable in that it identifies a specific design, process, or decision that reduces or limits the potential for failures and mishaps, or reinforces a positive result.

Observation

A significant factor established during this assessment that supports and influences the conclusions reached in the statement of Findings and Recommendations.

Problem

The subject of the independent technical assessment/inspection.

Proximate Cause

The event(s) that occurred, including any condition(s) that existed immediately before the undesired outcome, directly resulted in its occurrence and, if eliminated or modified, would have prevented the undesired outcome. Also known as the direct cause(s).

Recommendation

An action identified by the assessment/inspection team to correct a root cause or deficiency identified during the investigation. The recommendations may be used by the responsible C/P/P/O in the preparation of a corrective action plan.

Root Cause

Along a chain of events leading to a mishap or close call, the first causal action or failure to act that could have been controlled systemically either by policy/practice/procedure or individual adherence to policy/practice/procedure.

12.0 Acronyms List

Al-Li	aluminum-lithium
AS&M, Inc.	Analytical Services & Materials, Inc.
ASTM	American Society for Testing and Materials
ATK	Alliant Techsystems Inc.
EBSD	electron backscatter diffraction
ET	external tank
GOS	grain orientation spread
IT	intertank
JSC	Johnson Space Center
ksi	kilopounds per square inch

LaRC	Langley Research Center
LLC	Limited Liability Corporation
LO_2	liquid oxygen
M&P	materials and process
MAF	Michoud Assembly Facility
MSFC	Marshall Space Flight Center
MTSO	Management and Technical Support Office
NESC	NASA Engineering and Safety Center
NRB	NESC Review Board
PFZ	precipitation free zone
SEM	scanning electron microscope
SSP	Space Shuttle Program
STS	Space Transportation System
TEM	transmission electron microscopy

13.0 References

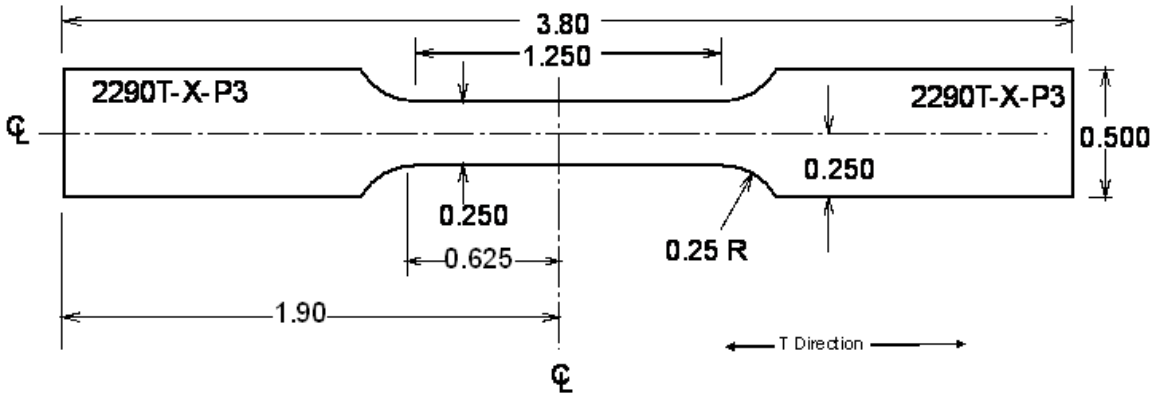
1. Gomez, R. J., III, "Estimated Airloads for IPR 133V-072 Crack Location," Space Shuttle Systems ICB, November 16, 2010.
2. "SR4851 STS-133/ET-137 Intertank Stringer Crack Joint SERB/SICB," November 16, 2010.
3. Jerman, G., "ET-137 Stringer Fractography Update," NASA MSFC EM31 Failure Analysis & Metallurgy Branch, December 9, 2010.
4. "Annual Book of ASTM Standards," Standard E8/E8M, Volume 03.01, 2010.
5. "Annual Book of ASTM Standards," Standard E1820, Volume 03.01, 2010.
6. Burkholder, J. "Effect of Tensile Specimen Geometry on Test Results for Al-Li 2090-T83 ET Stringer Material," MSFC Materials and Processes Laboratory Flash Report, MPFR-11-015, February 24, 2011.

14.0 Appendices

A. Tensile Test Results
B. Shear Test Results
C. 3-Point Bend Test Results
D. Fracture Test Results
E. Fractographic Photographs

Appendix A. Tensile Test Results

Tensile tests were conducted on 4-inch long, 0.25-inch-wide dogbone specimens, as shown in Figure A-1. The tests were performed on a 20-kip load frame with a 2-kip range card. The strain was determined from 1-inch displacement gages placed on opposite sides of the specimen. The specimens were loaded to failure at a constant displacement rate of 0.01 in/min and data readings were taken every 0.1 seconds. The elastic modulus (E) was calculated by calculating the slope of a linear least–squares-fit to the initial elastic portion of the calculated stress (S) and measured strain (e). The yield stress (S_{ys}) was determined by calculating the stress at the point where the plastic component of the strain ($e_p = e - S/E$) was 0.002. The ultimate stress (S_{ult}) was calculated from the maximum load observed in the test and the initial specimen cross sectional area. A summary of the tensile test results is provided in Tables A-1, A-2, and A-3 for control lots 400766, 400751, and 400768, respectively. Preliminary tensile tests were conducted on specimens machined from a sheet of 2090-T85 stock material (lot P3) that was not related to the stringer material, as summarized in Table A-4. The tensile data for each test was reduced to 41 pointes (evenly spaced in time) and presented in Table A-5.



NOTES:
(1) All dimensions are in inches.
(2) Scribe specimen number at each half of specimen as shown in the drawing layout.
(3) Use the full thickness of the provided material.
(4) Cut specimens and Orientate as shown in layout drawings.

Figure A-1. Tensile Specimen Drawing

Table A-1. Tensile Test Summary for Control Coil Lot 400766

Aged at 325°F for 24 hours						
Specimen	**Lot**	**Orientation**	**E (ksi)**	**Sys (ksi)**	**Sult (ksi)**	**Max Strain**
L3C1-T-01	400766	T	12133	76.4	82.3	0.113
L3C1-T-03	400766	T	11995	76.2	82.1	0.110
Average	400766	**T**	**12064**	**76.3**	**82.2**	**0.112**
Exposed to 400°F for 10 minutes and Aged at 325°F for 24 hours						
Specimen	**Lot**	**Orientation**	**E (ksi)**	**Sys (ksi)**	**Sult (ksi)**	**Max Strain**
L3C1-T-10	400766	T	12287	77.6	83.5	0.095
L3C1-T-11	400766	T	12196	77.9	83.3	0.105
L3C1-T-12	400766	T	11911	77.4	83.2	0.099
Average	**400766**	**T**	**12131**	**77.7**	**83.3**	**0.100**
Aged at 350°F for 24 hours						
Specimen	**Lot**	**Orientation**	**E (ksi)**	**Sys (ksi)**	**Sult (ksi)**	**Max Strain**
L3C1-T-04	400766	T	12080	75.6	80.6	0.101
L3C1-T-05	400766	T	12128	76.0	80.9	0.101
L3C1-T-06	400766	T	12326	75.9	80.9	0.101
Average	**400766**	**T**	**12178**	**75.8**	**80.8**	**0.101**
Aged at 375°F for 24 hours						
Specimen	**Lot**	**Orientation**	**E (ksi)**	**Sys (ksi)**	**Sult (ksi)**	**Max Strain**
L3C1-T-07	400766	T	12304	71.8	78.1	0.088
L3C1-T-08	400766	T	12242	72.1	78.5	0.086
L3C1-T-09	400766	T	12026	70.9	77.4	0.082
Average	**400766**	**T**	**12191**	**71.6**	**78.0**	**0.086**
Aged at 340°F for 24 hours						
Specimen	**Lot**	**Orientation**	**E (ksi)**	**Sys (ksi)**	**Sult (ksi)**	**Max Strain**
L3C1-T-13	400766	T	11351	78.7	83.4	0.079
L3C1-T-14	400766	T	11443	78.3	83.0	0.084
L3C1-T-15	400766	T	11443	78.1	82.8	0.096
L3C1-T-16	400766	T	11371	77.9	82.5	0.089
Average	**400766**	**T**	**11402**	**78.3**	**82.9**	**0.087**

Table A-2. Tensile Test Summary for Control Coil Lot 400751

Aged at 325°F for 24 hours						
Specimen	**Lot**	**Orientation**	**E (ksi)**	**Sys (ksi)**	**Sult (ksi)**	**Max Strain**
L1P1-T1-325	400751	T	11240	76.3	82.1	0.101
L1P1-T2-325	400751	T	11208	76.4	82.1	0.109
L1P1-T3-325	400751	T	11412	76.5	82.2	0.105
L1P1-T4-325	400751	T	11437	76.5	82.1	0.099
Average	**400751**	**T**	**11425**	**76.5**	**82.2**	**0.102**
L1P1-L1-325	400751	L	10892	75.7	83.4	0.080
L1P1-L2-325	400751	L	10994	76.4	83.5	0.079
L1P1-L3-325	400751	L	11412	76.5	82.2	0.105
L1P1-L4-325	400751	L	11125	76.5	83.5	0.063
Average	**400751**	**L**	**11269**	**76.5**	**82.8**	**0.084**
L1P1-45-1-325	400751	45	10792	63.4	69.2	0.115
L1P1-45-2-325	400751	45	10892	63.6	69.4	0.121
L1P1-45-3-325	400751	45	10865	63.8	69.6	0.134
L1P1-45-4-325	400751	45	10863	63.4	69.2	0.127
Average	**400751**	**45**	**10864**	**63.6**	**69.4**	**0.131**
Aged at 350°F for 24 hours						
Specimen	**Lot**	**Orientation**	**E (ksi)**	**S_{ys} (ksi)**	**S_{ult} (ksi)**	**Max Strain**
L1P2-T1-350	400751	T	11279	76.4	81.1	0.104
L1P2-T2-350	400751	T	11119	76.4	81.1	0.099
L1P2-T3-350	400751	T	11105	76.4	81.1	0.105
L1P2-T3-350	400751	T	11114	76.3	81.0	0.101
Average	400751	**T**	**11154**	**76.4**	**81.1**	**0.102**

Table A-3. Tensile Test Summary for Control Coil Lot 400768

Aged at 325°F for 24 hours						
Specimen	**Lot**	**Orientation**	**E (ksi)**	**Sys (ksi)**	**Sult (ksi)**	**Max Strain**
L2P1-T1-325	400768	T	11165	75.5	81.8	0.076
L2P1-T2-325	400768	T	11182	76.0	81.8	0.109
L2P1-T3-325	400768	T	11313	76.0	81.8	0.103
L2P1-T4-325	400768	T	11257	75.9	81.7	0.105
Average	**400768**	**T**	**11229**	**75.8**	**81.8**	**0.098**
L2P1-L1-325	400768	L	11257	75.2	80.0	0.023
L2P1-L2-325	400768	L	11559	75.2	79.8	0.024
L2P1-L3-325	400768	L	11152	75.4	82.8	0.070
L2P1-L4-325	400768	L	11152	75.8	83.1	0.084
Average	**400768**	**L**	**11152**	**75.6**	**82.9**	**0.077**
L2P1-45-1-325	400768	45	10840	63.5	69.0	0.112
L2P1-45-2-325	400768	45	10742	63.4	69.4	0.131
L2P1-45-3-325	400768	45	10735	63.3	69.3	0.134
L2P1-45-4-325	400768	45	10691	63.5	69.3	0.129
Average	**400768**	**45**	**10713**	**63.4**	**69.3**	**0.131**

Table A-4. Tensile Test Summary for Control Coil Lot 400766

P3 2090-T85						
Specimen	**Lot**	**Orientation**	**E (ksi)**	**Sys (ksi)**	**Sult (ksi)**	**Max Strain**
P3-T-01	P3	T	11002	68.3	79.7	0.073
P3-T-02	P3	T	11077	68.2	79.5	0.077
P3-T-03	P3	T	10971	68.3	79.5	0.072
P3-T-04	P3	T	11092	68.2	79.4	0.072
Average	**P3**	**T**	**11036**	**68.3**	**79.5**	**0.074**
P3-L-01	P3	L	11172	76.38	84.08104	0.034
P3-L-02	P3	L	11237	76.13	84.12141	0.035
P3-L-03	P3	L	11230	76.06	84.26082	0.035
P3-L-04	P3	L	11169	75.7	83.62265	0.036
Average	**P3**	**L**	**11202**	**76.1**	**84.0**	**0.035**
P3-45-01	P3	45	10816	59.88	72.63121	0.085
P3-45-02	P3	45	10836	59.33	72.32395	0.082
P3-45-03	P3	45	10821	59.36	72.57665	0.09
P3-45-04	P3	45	10897	59.59	72.80638	0.0914
Average	**P3**	45	**10843**	**59.5**	**72.6**	**0.087**

Table A-5. Tensile Test Results by Specimen Number

400768		400768		400768		400768	
L2P1-L1-325		L2P1-L2-325		L2P1-L3-325		L2P1-L4-325	
Strain	Stress	Strain	Stress	Strain	Stress	Strain	Stress
(in/in)	(ksi)	(in/in)	(ksi)	(in/in)	(ksi)	(in/in)	(ksi)
0	0	0	0	0	0	0	0
0.0003	3.45289	0.000213	2.402423	0.001197	13.37328	0.001497	16.31242
0.000657	7.286021	0.000579	6.689174	0.002163	24.19853	0.002449	26.90852
0.000996	11.0577	0.00106	12.34216	0.003202	35.69167	0.00364	40.19238
0.001513	16.85348	0.001555	17.96828	0.004191	46.68679	0.004784	52.90692
0.001852	20.60596	0.001875	21.67937	0.005162	57.1144	0.005947	64.72684
0.002296	25.65279	0.002246	25.97764	0.006164	66.76216	0.007316	73.04184
0.002722	30.43844	0.002667	30.70956	0.00741	73.02412	0.009152	76.23694
0.00312	34.87458	0.003056	35.28415	0.008985	75.6455	0.01113	77.80931
0.003537	39.58341	0.003445	39.67835	0.010656	77.12413	0.013226	78.64197
0.003962	44.18087	0.003867	44.33353	0.012432	77.96575	0.015465	79.19192
0.004361	48.50562	0.004283	48.96567	0.014263	78.49466	0.017676	79.57533
0.004764	52.85342	0.004672	53.27545	0.016131	78.89231	0.01986	79.92776
0.005176	57.27035	0.005066	57.5008	0.018013	79.22818	0.022039	80.23371
0.005579	61.23407	0.005455	61.4268	0.019876	79.53317	0.024187	80.57065
0.005995	65.08641	0.005872	65.35281	0.021744	79.83044	0.026334	80.84949
0.006439	68.42791	0.006307	68.69548	0.02358	80.09297	0.028476	81.10898
0.006906	71.07807	0.006769	71.31665	0.02542	80.35935	0.030624	81.34522
0.007469	73.01	0.007309	73.14341	0.027238	80.57941	0.032771	81.56984
0.008078	74.30436	0.007941	74.40219	0.029078	80.83421	0.034927	81.78285
0.008728	75.27608	0.008591	75.33092	0.030905	81.01952	0.037083	81.95326
0.009388	76.04424	0.009278	76.0409	0.032755	81.20869	0.039263	82.12753
0.010061	76.66646	0.009978	76.61273	0.034586	81.41331	0.041442	82.29407
0.010756	77.16192	0.010693	77.07325	0.036431	81.56387	0.043644	82.43349
0.011443	77.56905	0.011416	77.41481	0.038285	81.73374	0.045837	82.53418
0.012162	77.88015	0.012158	77.71799	0.040144	81.86114	0.048071	82.64649
0.012881	78.14517	0.012904	77.9521	0.042003	82.00399	0.050305	82.75106
0.013613	78.36025	0.013673	78.15933	0.043875	82.13139	0.052562	82.84788
0.01435	78.56766	0.014433	78.309	0.045757	82.24335	0.054833	82.90597
0.015087	78.73665	0.015198	78.49705	0.047652	82.336	0.057113	82.96794
0.015847	78.88261	0.015976	78.63137	0.049525	82.39391	0.059439	83.01829
0.016594	79.0324	0.016754	78.75418	0.051438	82.51359	0.061737	83.02991
0.017349	79.16298	0.017523	78.89234	0.053347	82.5522	0.064086	83.05702
0.018118	79.28973	0.018302	79.01899	0.055284	82.61011	0.066462	83.06476
0.018869	79.41648	0.019075	79.14947	0.05723	82.68732	0.068842	83.05702
0.019615	79.54707	0.019854	79.26076	0.059194	82.71821	0.071232	83.05314
0.020357	79.65077	0.020614	79.3759	0.061153	82.70662	0.073668	83.03765
0.021112	79.76215	0.021387	79.48719	0.063126	82.77226	0.076122	82.9873
0.021854	79.87738	0.022143	79.57162	0.065118	82.78384	0.078598	82.93696
0.022587	79.98876	0.022907	79.7021	0.067137	82.7877	0.081135	82.85176
0.023328	79.99644	0.023681	79.73664	0.06917	82.79156	0.083703	82.71233

Table A-5. Tensile Test Results by Specimen Number (cont.)

400751		400751		400751		400751	
L1P1-L1-325		L1P1-L2-325		L1P1-L3-325		L1P1-L4-325	
Strain (in/in)	Stress (ksi)	Strain (in/in)	Stress (ksi)	Strain (in/in)	Stress (ksi)	Strain (in/in)	Stress (ksi)
0	0	0	0	0	0	0	0
0.001122	11.98942	0.001305	14.38347	0.001415	15.90034	0.000765	8.277678
0.002486	26.86702	0.002303	25.38462	0.00261	29.58284	0.001836	20.23645
0.003516	38.23207	0.003379	37.27828	0.003978	45.05416	0.002774	30.62856
0.004679	50.84203	0.00451	49.52434	0.005306	59.62533	0.003759	41.57991
0.005846	62.5365	0.005627	61.11922	0.006794	71.60325	0.004674	51.55833
0.007133	71.34278	0.006835	70.87546	0.008873	76.62502	0.005595	61.2303
0.008781	75.48354	0.008392	75.65208	0.011496	77.60179	0.006597	69.80293
0.010631	77.42559	0.010232	77.66691	0.014142	78.1802	0.00781	74.72893
0.012604	78.54026	0.012178	78.73179	0.016788	78.62453	0.009321	76.96976
0.014623	79.16463	0.014206	79.34466	0.019416	79.02673	0.010892	78.26064
0.01671	79.63961	0.016275	79.76985	0.022044	79.40212	0.012526	78.98077
0.018816	80.03032	0.018377	80.13374	0.024649	79.73537	0.014206	79.55534
0.020918	80.35974	0.02046	80.46317	0.027259	80.04947	0.015877	79.89242
0.023015	80.67767	0.022525	80.76961	0.029873	80.3291	0.017612	80.1912
0.025079	80.95347	0.02458	81.05689	0.032482	80.58574	0.019347	80.45167
0.027158	81.24075	0.026618	81.3097	0.035119	80.80408	0.021064	80.75811
0.029227	81.48591	0.02866	81.55485	0.037752	81.03008	0.022813	81.01093
0.031301	81.71957	0.030697	81.78468	0.040393	81.21777	0.024512	81.20245
0.03338	81.92641	0.032748	81.99919	0.04304	81.39397	0.026224	81.43994
0.035463	82.13326	0.034808	82.19072	0.045713	81.54336	0.027945	81.65445
0.037546	82.31329	0.036859	82.37841	0.048401	81.68126	0.029658	81.86512
0.039638	82.47417	0.038938	82.54695	0.05112	81.8115	0.031351	82.03367
0.04173	82.62356	0.040993	82.68102	0.053858	81.91109	0.03305	82.19455
0.043841	82.7538	0.043085	82.81891	0.056605	81.99153	0.034753	82.35543
0.045974	82.8802	0.045191	82.93383	0.059375	82.07197	0.036474	82.48949
0.048117	82.98746	0.047288	83.02193	0.062176	82.11411	0.0382	82.65803
0.050264	83.07173	0.049412	83.11769	0.064997	82.16007	0.039908	82.74614
0.052448	83.15217	0.05156	83.20579	0.067849	82.18305	0.041634	82.87254
0.054622	83.22878	0.053702	83.27091	0.070729	82.19455	0.04341	82.95298
0.056834	83.26325	0.055854	83.30922	0.073631	82.2137	0.045132	83.09088
0.059059	83.30539	0.058029	83.382	0.07657	82.19072	0.046858	83.1943
0.061288	83.33986	0.060226	83.42413	0.079555	82.14858	0.048625	83.22495
0.063545	83.34369	0.062428	83.44711	0.082559	82.11411	0.05036	83.29773
0.065825	83.3705	0.064644	83.47393	0.085589	82.05282	0.0521	83.38966
0.068128	83.35901	0.066887	83.4701	0.088652	81.97621	0.053853	83.38966
0.070449	83.35518	0.06914	83.47393	0.091752	81.88045	0.055598	83.43945
0.072807	83.33986	0.071406	83.45478	0.094879	81.74638	0.057342	83.45861
0.075188	83.29389	0.073686	83.43179	0.098033	81.6238	0.059082	83.47776
0.077596	83.21729	0.075984	83.38966	0.101238	81.42079	0.060817	83.47393
0.080054	83.13301	0.078283	83.32454	0.10452	80.89984	0.06252	83.4203

Table A-5. Tensile Test Results by Specimen Number (cont.)

400751		400751		400751		400751	
L1P1-T1-325		L1P1-T2-325		L1P1-T3-325		L1P1-T4-325	
Strain	Stress	Strain	Stress	Strain	Stress	Strain	Stress
(in/in)	(ksi)	(in/in)	(ksi)	(in/in)	(ksi)	(in/in)	(ksi)
0	0	0	0	0	0	0	0
0.001459	16.38681	0.00152	17.03034	0.00152	17.03034	0.001525	16.96522
0.002659	29.97354	0.002784	31.27591	0.002784	31.27591	0.002637	29.73605
0.004014	45.05416	0.004157	46.50975	0.004157	46.50975	0.003887	44.04292
0.005305	59.19248	0.005444	60.57529	0.005444	60.57529	0.005123	57.71392
0.00672	70.84099	0.006959	72.05142	0.006959	72.05142	0.006437	69.59225
0.008684	76.18451	0.009038	76.50628	0.009038	76.50628	0.008268	76.02746
0.011234	77.26088	0.01161	77.41793	0.01161	77.41793	0.010608	77.32217
0.013811	77.85078	0.014225	78.01932	0.014225	78.01932	0.013062	77.92355
0.016384	78.31809	0.016834	78.46748	0.016834	78.46748	0.015543	78.37938
0.018962	78.72796	0.019453	78.88118	0.019453	78.88118	0.017997	78.80074
0.021512	79.10717	0.022058	79.24124	0.022058	79.24124	0.020469	79.14548
0.024062	79.44043	0.024681	79.57832	0.024681	79.57832	0.022937	79.47107
0.026607	79.76219	0.027268	79.90009	0.027268	79.90009	0.025395	79.78134
0.029158	80.0533	0.029868	80.1912	0.029868	80.1912	0.027849	80.05713
0.031703	80.32144	0.032464	80.45934	0.032464	80.45934	0.030308	80.31378
0.034248	80.55893	0.035078	80.70449	0.035078	80.70449	0.032784	80.56659
0.036803	80.78493	0.037715	80.91899	0.037715	80.91899	0.035252	80.78876
0.039376	80.99177	0.040339	81.10286	0.040339	81.10286	0.037743	80.9956
0.04194	81.17564	0.042976	81.29055	0.042976	81.29055	0.040238	81.16415
0.044517	81.34418	0.045631	81.44377	0.045631	81.44377	0.042728	81.30204
0.047118	81.50123	0.048323	81.58933	0.048323	81.58933	0.045251	81.46292
0.049746	81.61614	0.05101	81.70424	0.05101	81.70424	0.047787	81.60082
0.052369	81.73872	0.053716	81.80767	0.053716	81.80767	0.050351	81.7119
0.055024	81.82299	0.056458	81.89194	0.056458	81.89194	0.052906	81.8115
0.057689	81.9379	0.059219	81.97238	0.059219	81.97238	0.055497	81.8996
0.060381	81.97238	0.061994	82.01451	0.061994	82.01451	0.058102	81.96089
0.063077	82.02983	0.0648	82.05665	0.0648	82.05665	0.060725	82.01834
0.065806	82.07963	0.067638	82.08729	0.067638	82.08729	0.063358	82.05282
0.068562	82.09112	0.070514	82.09878	0.070514	82.09878	0.066031	82.08346
0.07135	82.11411	0.073393	82.0758	0.073393	82.0758	0.068714	82.08729
0.074161	82.11411	0.076328	82.05282	0.076328	82.05282	0.071434	82.0758
0.077009	82.09878	0.079308	81.99536	0.079308	81.99536	0.074199	82.01451
0.079884	82.04516	0.082334	81.88428	0.082334	81.88428	0.076996	81.92641
0.082828	81.95706	0.085406	81.70424	0.085406	81.70424	0.079848	81.77319
0.085781	81.82682	0.088561	81.45526	0.088561	81.45526	0.082751	81.5357
0.088811	81.64296	0.094503	80.66618	0.094503	80.66618	0.085731	81.15648
0.091874	81.37099	0.097818	80.015	0.097818	80.015	0.088785	80.65086
0.095038	80.98794	0.101169	79.20294	0.101169	79.20294	0.091935	79.98436
0.09822	80.467	0.104594	78.15338	0.104594	78.15338	0.095121	79.13782
0.101479	79.74304	0.108169	76.5216	0.108169	76.5216	0.098381	78.01932

Table A-5. Tensile Test Results by Specimen Number (cont.)

400768		400768		400768		400768	
L2P1-T1-325		L2P1-T2-325		L2P1-T3-325		L2P1-T4-325	
Strain	Stress	Strain	Stress	Strain	Stress	Strain	Stress
(in/in)	(ksi)	(in/in)	(ksi)	(in/in)	(ksi)	(in/in)	(ksi)
0	0	0	0	0	0	0	0
0.000824	8.908427	0.001628	18.12561	0.001563	17.60982	0.001563	17.24578
0.002051	22.50509	0.002905	32.5545	0.002712	30.75038	0.002753	30.62258
0.003031	33.4946	0.00432	48.47764	0.003999	45.25806	0.004109	45.78089
0.004065	44.99858	0.00568	62.94545	0.005276	59.30486	0.005381	59.6418
0.005073	55.95328	0.007328	73.38966	0.006659	70.77235	0.006823	71.14415
0.006094	65.91772	0.009754	76.4988	0.008655	75.98908	0.008888	76.03942
0.007371	72.88432	0.01246	77.31208	0.011241	77.04249	0.011562	77.05023
0.009092	75.6346	0.015193	77.87242	0.013856	77.63503	0.014236	77.63503
0.01112	76.42371	0.01799	78.33159	0.016447	78.10365	0.016877	78.0959
0.013167	76.91496	0.020714	78.7285	0.019015	78.47544	0.019496	78.49093
0.0152	77.31726	0.023439	79.09818	0.021574	78.84723	0.022119	78.83949
0.017223	77.677	0.026153	79.4445	0.02412	79.18417	0.024715	79.1803
0.019247	77.99419	0.028868	79.73635	0.026647	79.48625	0.027306	79.50949
0.021261	78.27657	0.031579	80.01263	0.029174	79.77284	0.029907	79.76897
0.023285	78.528	0.034298	80.28891	0.031724	80.03232	0.032503	80.02458
0.025295	78.7949	0.037031	80.50682	0.034261	80.26857	0.035098	80.2647
0.0273	79.02699	0.03976	80.71306	0.036769	80.48932	0.037717	80.48932
0.029296	79.24748	0.042516	80.9193	0.039324	80.68296	0.04034	80.67134
0.031297	79.46023	0.045267	81.07106	0.041837	80.88048	0.042982	80.83013
0.03332	79.66138	0.048042	81.22671	0.044415	81.01603	0.045628	81.0199
0.035325	79.83931	0.050834	81.37458	0.046869	81.17094	0.048293	81.13609
0.037358	80.00178	0.05365	81.46408	0.04962	81.27938	0.050989	81.25614
0.039382	80.16424	0.05647	81.55747	0.05218	81.41493	0.053704	81.35296
0.04141	80.30349	0.059318	81.63529	0.054743	81.50013	0.056442	81.44979
0.043438	80.41567	0.062184	81.69366	0.05739	81.57759	0.059203	81.52724
0.045475	80.55879	0.065059	81.72869	0.060494	81.69765	0.061972	81.58146
0.04754	80.65937	0.067961	81.78705	0.06319	81.67828	0.06477	81.62794
0.0496	80.77154	0.070896	81.8104	0.066056	81.72088	0.067613	81.66666
0.051679	80.88372	0.07384	81.79873	0.068853	81.75574	0.070474	81.66666
0.053762	80.94948	0.076811	81.81429	0.071806	81.74025	0.073358	81.65505
0.055859	81.01524	0.079805	81.79095	0.074668	81.73638	0.076275	81.64343
0.057955	81.081	0.082809	81.73647	0.077575	81.71314	0.079228	81.6047
0.06008	81.13902	0.085871	81.70534	0.0805	81.65505	0.082222	81.54661
0.062213	81.18544	0.088957	81.62751	0.08344	81.58534	0.08523	81.45753
0.064365	81.21638	0.092075	81.51466	0.086434	81.43817	0.088256	81.33747
0.066526	81.25893	0.095243	81.38625	0.089501	81.23678	0.091355	81.1477
0.068696	81.27441	0.098439	81.16056	0.092628	80.91921	0.094505	80.84562
0.070884	81.27828	0.101717	80.81034	0.095824	80.44285	0.097696	80.44285
0.073105	81.28214	0.1051	80.26945	0.099074	79.78059	0.100942	79.85805
0.075334	81.27828	0.108739	78.20707	0.102357	78.63423	0.104279	78.9518

Table A-5. Tensile Test Results by Specimen Number (cont.)

400751		400751		400751		400751	
L1P1-45-1-325		L1P1-45-2-325		L1P1-45-3-325		L1P1-45-4-325	
Strain	Stress	Strain	Stress	Strain	Stress	Strain	Stress
(in/in)	(ksi)	(in/in)	(ksi)	(in/in)	(ksi)	(in/in)	(ksi)
0	0	0	0	0	0	0	0
0.001557	16.52295	0.001667	18.14726	0.0017	18.4756	0.001678	18.13753
0.002866	30.64361	0.003091	33.71026	0.003242	35.10403	0.003138	34.08005
0.004262	45.60564	0.004574	49.34601	0.004872	52.0942	0.004622	49.72812
0.00575	58.5042	0.006259	61.33698	0.006896	62.91557	0.006416	61.57507
0.008035	63.47632	0.008891	64.12416	0.009954	64.65499	0.009255	64.02247
0.010763	64.58039	0.011711	65.04301	0.013058	65.52855	0.012217	64.92877
0.013497	65.2809	0.014573	65.70534	0.016208	66.15967	0.01522	65.56739
0.016257	65.84435	0.017439	66.20305	0.019385	66.66764	0.018224	66.08747
0.019018	66.28598	0.020341	66.62802	0.022562	67.07941	0.021241	66.49282
0.021778	66.68573	0.023267	66.99556	0.025744	67.4296	0.024258	66.8561
0.024557	66.99411	0.026183	67.30184	0.028944	67.74131	0.027302	67.1735
0.027355	67.28726	0.029113	67.58516	0.032172	68.01839	0.030337	67.46413
0.030166	67.54614	0.032052	67.83018	0.035404	68.26853	0.033396	67.6974
0.032995	67.77457	0.035001	68.07521	0.038668	68.47633	0.036454	67.91537
0.035824	67.98396	0.037972	68.26281	0.041937	68.6649	0.03953	68.10275
0.038654	68.18193	0.04092	68.44658	0.045206	68.83807	0.042621	68.2863
0.04151	68.34945	0.043914	68.60355	0.048516	68.99585	0.04572	68.44691
0.044363	68.50935	0.046913	68.73755	0.051849	69.119	0.048843	68.58458
0.047224	68.63117	0.04993	68.87154	0.055173	69.24984	0.051974	68.69165
0.050127	68.74539	0.05297	68.97874	0.058556	69.33835	0.055151	68.81402
0.053052	68.8558	0.05601	69.0936	0.061935	69.42686	0.058347	68.91727
0.055968	68.9662	0.059059	69.174	0.065391	69.48074	0.061565	68.98228
0.058917	69.04996	0.062131	69.23525	0.068848	69.55001	0.064798	69.05111
0.061897	69.10326	0.065249	69.30034	0.072359	69.59618	0.068076	69.09318
0.064887	69.16417	0.06838	69.33863	0.075894	69.61543	0.07139	69.13524
0.067931	69.18321	0.071544	69.38457	0.079479	69.61158	0.074741	69.1926
0.070976	69.20224	0.074703	69.39605	0.083118	69.61927	0.078143	69.17348
0.074094	69.16417	0.077907	69.39988	0.086799	69.58464	0.081581	69.15054
0.077243	69.11468	0.081181	69.36925	0.090503	69.52692	0.08507	69.11995
0.080434	69.00427	0.084477	69.31948	0.094243	69.43456	0.088609	69.0167
0.083685	68.86722	0.087842	69.2008	0.098039	69.31526	0.092203	68.86756
0.086981	68.62356	0.091257	69.05914	0.101861	69.13054	0.095856	68.64576
0.090337	68.31899	0.094764	68.84474	0.10573	68.86116	0.099541	68.3016
0.093734	67.91163	0.098312	68.5576	0.109635	68.52251	0.103264	67.88095
0.097145	67.39005	0.101906	68.18241	0.113577	68.07996	0.107022	67.32646
0.10062	66.72761	0.105555	67.66555	0.117528	67.50272	0.110818	66.63048
0.104122	65.89385	0.10925	67.04916	0.121529	66.77924	0.114677	65.728
0.107688	64.81262	0.112976	66.24517	0.125567	65.86335	0.1186	64.55402
0.111287	63.38875	0.116804	65.03152	0.129651	64.64729	0.122616	62.91349
0.114991	61.46615	0.120901	62.42429	0.133817	62.92326	0.126892	60.56934

Table A-5. Tensile Test Results by Specimen Number (cont.)

400768		400768		400768		400768	
L2P1-45-1-325		L2P1-45-2-325		L2P1-45-3-325		L2P1-45-4-325	
Strain	Stress	Strain	Stress	Strain	Stress	Strain	Stress
(in/in)	(ksi)	(in/in)	(ksi)	(in/in)	(ksi)	(in/in)	(ksi)
0	0	0	0	0	0	0	0
0.001643	17.78017	0.001715	18.46735	0.001818	19.47151	0.001854	19.80358
0.002806	30.4841	0.003327	35.71585	0.00331	35.641	0.003324	35.73993
0.004226	45.74703	0.004957	52.48372	0.00494	52.21307	0.004889	51.73037
0.005681	58.72811	0.006994	62.74977	0.007064	62.70756	0.006862	62.61345
0.007842	63.48923	0.009956	64.29929	0.010214	64.24825	0.009792	64.29015
0.01047	64.56371	0.012982	65.13749	0.013345	65.10762	0.012773	65.13622
0.013089	65.25092	0.016022	65.75653	0.016523	65.73474	0.015795	65.74277
0.015726	65.80145	0.019071	66.26022	0.019705	66.23798	0.01883	66.25273
0.018372	66.24947	0.022152	66.67548	0.022891	66.65605	0.021897	66.65839
0.021055	66.64813	0.025302	67.04075	0.026077	67.03155	0.024951	67.01768
0.023729	66.94427	0.02842	67.36757	0.029291	67.34511	0.028037	67.31902
0.026402	67.2632	0.031556	67.63287	0.032505	67.60834	0.031127	67.60104
0.029094	67.50619	0.034697	67.88279	0.035737	67.87157	0.034222	67.85216
0.031791	67.75298	0.037847	68.10965	0.038988	68.08448	0.037349	68.05306
0.034506	67.95801	0.041005	68.3019	0.042234	68.27416	0.040485	68.24623
0.037202	68.14405	0.04416	68.46338	0.045503	68.45223	0.043621	68.42394
0.039931	68.30731	0.047333	68.63256	0.04879	68.61482	0.046771	68.59006
0.042646	68.46677	0.050533	68.75945	0.0521	68.75418	0.049939	68.72528
0.04537	68.59966	0.053737	68.89786	0.055428	68.87418	0.053116	68.84891
0.048126	68.70976	0.056979	68.99014	0.058789	68.98644	0.056316	68.95322
0.050868	68.80848	0.060257	69.0978	0.062176	69.06386	0.059548	69.04594
0.053615	68.8996	0.063544	69.17855	0.065573	69.12967	0.062785	69.11934
0.056385	68.96794	0.066872	69.24776	0.069025	69.21096	0.066059	69.20434
0.059164	69.0135	0.070228	69.29005	0.0725	69.25742	0.069369	69.2507
0.061966	69.03628	0.073607	69.33234	0.07603	69.27677	0.072711	69.27774
0.064786	69.0211	0.077022	69.35157	0.079564	69.28452	0.07608	69.31638
0.067643	68.96414	0.080492	69.36695	0.083158	69.28064	0.079491	69.3241
0.070541	68.88441	0.083981	69.3285	0.086803	69.2458	0.082943	69.29706
0.073567	68.74773	0.087547	69.26314	0.090479	69.18	0.086441	69.25843
0.076694	68.5541	0.091173	69.14779	0.094192	69.06386	0.090002	69.16184
0.079931	68.29212	0.094873	68.98245	0.097941	68.91289	0.093592	69.02662
0.083213	67.93902	0.098631	68.73638	0.101741	68.71934	0.097245	68.82187
0.086537	67.53657	0.102422	68.39033	0.10555	68.43288	0.100949	68.50893
0.089906	67.01641	0.106291	67.94816	0.109405	68.06126	0.104666	68.11101
0.093317	66.37097	0.110191	67.36372	0.113301	67.58511	0.108439	67.60877
0.096787	65.55846	0.114115	66.64472	0.117225	66.95026	0.112234	66.96359
0.100313	64.52575	0.118084	65.7027	0.121176	66.16056	0.116075	66.13683
0.103929	63.18929	0.122136	64.47616	0.125195	65.09214	0.119967	65.05509
0.107656	61.38963	0.126206	62.79207	0.129325	63.63662	0.123927	63.6102
0.111493	59.02046	0.130422	60.46586	0.133638	61.43784	0.128024	61.64375

Table A-5. Tensile Test Results by Specimen Number (cont.)

400751		400751		400751		400751	
L1P2-T1-350		L1P2-T2-350		L1P2-T3-350		L1P2-T4-350	
Strain	Stress	Strain	Stress	Strain	Stress	Strain	Stress
(in/in)	(ksi)	(in/in)	(ksi)	(in/in)	(ksi)	(in/in)	(ksi)
0	0	0	0	0	0	0	0
0.001252	14.12091	0.001191	13.28098	0.001361	14.90305	0.00127	14.17485
0.002625	29.6019	0.002551	28.3998	0.002689	29.94481	0.002598	28.98929
0.003967	44.6976	0.003879	43.15644	0.004071	45.24472	0.003889	43.299
0.005281	58.88402	0.005183	57.18488	0.005404	59.49277	0.005171	57.05774
0.006682	70.95903	0.006516	69.24834	0.006805	71.13241	0.006485	69.06725
0.008618	76.31843	0.00831	75.76361	0.008787	76.34155	0.008252	75.6827
0.011058	77.31248	0.010618	77.11213	0.011305	77.28166	0.010633	77.06204
0.013622	77.84418	0.01309	77.6708	0.013901	77.83262	0.013128	77.61301
0.016168	78.34506	0.015576	78.14086	0.016469	78.32194	0.0156	78.08692
0.018686	78.75347	0.018034	78.57238	0.019024	78.73035	0.018054	78.52615
0.021208	79.13876	0.020488	78.95382	0.021574	79.11564	0.020508	78.89603
0.023722	79.49708	0.02291	79.29288	0.024124	79.45085	0.022962	79.23123
0.026258	79.7899	0.025346	79.5857	0.026669	79.7244	0.025416	79.52405
0.028803	80.02878	0.027786	79.84384	0.029251	79.9864	0.027874	79.7899
0.03134	80.24069	0.030231	80.07887	0.031834	80.21757	0.030347	79.99796
0.033904	80.42948	0.032689	80.28307	0.034425	80.39866	0.032828	80.20602
0.036486	80.61057	0.035166	80.4526	0.037039	80.56048	0.035323	80.3794
0.039095	80.73001	0.037656	80.59901	0.039662	80.68763	0.03785	80.53351
0.041714	80.83789	0.040152	80.72616	0.042313	80.81092	0.040377	80.64525
0.044333	80.93422	0.042679	80.82633	0.044968	80.89183	0.042932	80.74542
0.047011	80.99586	0.045201	80.89183	0.04766	80.94963	0.0455	80.81478
0.049698	81.05366	0.047747	80.96119	0.050375	81.00357	0.048092	80.89183
0.052409	81.09989	0.05032	81.01513	0.053113	81.0421	0.05071	80.92651
0.055142	81.09604	0.052911	81.03824	0.055832	81.05366	0.053352	80.96504
0.057902	81.1076	0.055521	81.0498	0.058625	81.06522	0.056026	80.9766
0.060691	81.09989	0.058153	81.05366	0.061432	81.05366	0.058704	80.98045
0.063497	81.06907	0.060804	81.03824	0.064275	81.03439	0.061433	80.9766
0.066335	81.02669	0.0635	81.02669	0.067136	80.99201	0.064184	80.94192
0.069215	80.9843	0.066215	80.9843	0.070039	80.92651	0.066968	80.88028
0.072113	80.9111	0.068967	80.91495	0.072973	80.85716	0.069788	80.81478
0.075052	80.81863	0.071764	80.83019	0.075944	80.73001	0.072654	80.68763
0.078047	80.68378	0.074598	80.69534	0.078961	80.58745	0.075556	80.52966
0.081068	80.5104	0.077491	80.53351	0.082043	80.39481	0.078495	80.30619
0.084163	80.2484	0.08044	80.27922	0.085169	80.07887	0.081503	80.00181
0.087322	79.89393	0.083461	79.92861	0.088338	79.68202	0.084539	79.5934
0.090559	79.40461	0.08651	79.47396	0.091579	79.15802	0.087638	79.07326
0.093814	78.76888	0.089633	78.87676	0.094857	78.46065	0.090783	78.399
0.097133	77.9983	0.092796	78.16783	0.098185	77.63613	0.093951	77.55521
0.100471	77.04663	0.09601	77.26625	0.101518	76.64593	0.097184	76.57658
0.103886	75.4207	0.099251	76.13734	0.104952	75.29741	0.100439	75.31667

Table A-5. Tensile Test Results by Specimen Number (cont.)

400766		400766		400766	
L3C1-T-01		L3C1-T-03		L3C1-T-04	
Strain	Stress	Strain	Stress	Strain	Stress
(in/in)	(ksi)	(in/in)	(ksi)	(in/in)	(ksi)
0	0	0	0	0	0
0.001069	13.02482	0.001372	16.50498	0.001372	16.50498
0.00242	29.27643	0.002631	31.42251	0.002631	31.42251
0.003802	45.43693	0.003954	46.71221	0.003954	46.71221
0.005171	60.66356	0.005296	61.5234	0.005296	61.5234
0.006641	72.21165	0.006811	72.70775	0.006811	72.70775
0.008902	76.80887	0.009077	76.70297	0.009077	76.70297
0.011732	77.71237	0.011829	77.57265	0.011829	77.57265
0.014579	78.30458	0.014594	78.13092	0.014594	78.13092
0.017418	78.7867	0.017345	78.57526	0.017345	78.57526
0.020238	79.1815	0.020175	79.16391	0.020175	79.16391
0.023044	79.56492	0.023018	79.38038	0.023018	79.38038
0.025842	79.89519	0.025737	79.71838	0.025737	79.71838
0.028662	80.24445	0.028443	80.03359	0.028443	80.03359
0.031459	80.52916	0.031167	80.31462	0.031167	80.31462
0.034284	80.7873	0.033882	80.58426	0.033882	80.58426
0.037095	81.03026	0.03662	80.82352	0.03662	80.82352
0.03992	81.20868	0.039366	81.01721	0.039366	81.01721
0.042772	81.38331	0.042113	81.1919	0.042113	81.1919
0.045633	81.5959	0.044769	81.40458	0.044769	81.40458
0.048513	81.70979	0.047561	81.51851	0.047561	81.51851
0.051374	81.81228	0.050372	81.65523	0.050372	81.65523
0.054291	81.92617	0.053193	81.76916	0.053193	81.76916
0.057253	82.03246	0.056017	81.8679	0.056017	81.8679
0.060206	82.1008	0.058902	81.93626	0.058902	81.93626
0.063209	82.14635	0.061777	81.98943	0.061777	81.98943
0.066235	82.1919	0.064675	82.0426	0.064675	82.0426
0.06927	82.1995	0.0676	82.08437	0.0676	82.08437
0.072347	82.22987	0.07059	82.09197	0.07059	82.09197
0.075456	82.20709	0.073584	82.09576	0.073584	82.09576
0.078596	82.15394	0.076596	82.05779	0.076596	82.05779
0.081787	82.15394	0.079659	82.01601	0.079659	82.01601
0.085015	82.08941	0.082763	81.96284	0.082763	81.96284
0.088261	81.97932	0.085899	81.84132	0.085899	81.84132
0.091589	81.78951	0.089081	81.67421	0.089081	81.67421
0.094945	81.47442	0.092327	81.42736	0.092327	81.42736
0.098365	81.12517	0.095642	81.05518	0.095642	81.05518
0.101849	80.52157	0.098997	80.5197	0.098997	80.5197
0.105429	79.70159	0.10244	79.83991	0.10244	79.83991
0.109023	78.69179	0.105929	78.97022	0.105929	78.97022
0.112717	77.32515	0.109491	77.80432	0.109491	77.80432

Table A-5. Tensile Test Results by Specimen Number (cont.)

400766		400766		400766		400766	
L3C1-T-05		L3C1-T-06		L3C1-T-07		L3C1-T-08	
Strain	Stress	Strain	Stress	Strain	Stress	Strain	Stress
(in/in)	(ksi)	(in/in)	(ksi)	(in/in)	(ksi)	(in/in)	(ksi)
0	0	0	0	0	0	0	0
0.001363	16.6086	0.001237	15.3894	0.000966	11.88174	0.001133	13.9185
0.00253	30.63127	0.002372	29.18248	0.002069	25.54175	0.002172	26.55613
0.003771	45.09953	0.003586	43.54947	0.003132	38.14543	0.003234	39.18236
0.004989	58.7147	0.004794	57.04608	0.004217	50.50973	0.004255	50.82798
0.006325	70.42946	0.006053	68.85894	0.005306	61.41874	0.005359	61.78946
0.008161	75.85267	0.007775	75.36969	0.006629	69.34497	0.006672	69.54308
0.010588	76.97616	0.010137	76.8444	0.008488	72.39615	0.008417	72.65593
0.01311	77.57409	0.012673	77.44872	0.010617	73.45247	0.010504	73.75815
0.015647	78.06919	0.015168	77.95423	0.012773	74.21241	0.012583	74.52591
0.018123	78.53381	0.017645	78.41412	0.01493	74.86597	0.014657	75.17965
0.020619	78.91847	0.020136	78.80561	0.017063	75.42453	0.016722	75.72316
0.023114	79.26123	0.022603	79.14768	0.019206	75.89569	0.018809	76.20967
0.025609	79.53924	0.025085	79.44034	0.021371	76.31366	0.020892	76.63155
0.028108	79.81726	0.027571	79.69879	0.023532	76.65564	0.023007	76.97743
0.03064	80.01911	0.030089	79.94204	0.02573	76.95202	0.025132	77.25868
0.033167	80.21714	0.032607	80.14348	0.027941	77.199	0.027288	77.55134
0.035736	80.38852	0.035152	80.30312	0.030166	77.40038	0.029463	77.72998
0.038304	80.53705	0.037707	80.43234	0.032405	77.56757	0.031637	77.90482
0.040895	80.62846	0.040293	80.56157	0.03468	77.71576	0.03384	78.05685
0.043496	80.7389	0.042889	80.64899	0.036964	77.82975	0.036042	78.17848
0.046115	80.81888	0.045494	80.706	0.039267	77.92474	0.03828	78.26969
0.04877	80.84935	0.048131	80.76681	0.041579	78.00834	0.040519	78.34951
0.051425	80.89124	0.0508	80.82383	0.04391	78.06153	0.04279	78.40652
0.054126	80.92171	0.053483	80.85043	0.046272	78.09573	0.045079	78.46734
0.056823	80.9179	0.056203	80.84663	0.048657	78.10713	0.047396	78.49774
0.059556	80.9179	0.05894	80.83523	0.051052	78.11473	0.049717	78.50534
0.062321	80.89505	0.06171	80.82003	0.053487	78.11473	0.052074	78.50914
0.065105	80.89505	0.064494	80.77061	0.055946	78.08813	0.054441	78.49774
0.067907	80.83411	0.067314	80.7212	0.058422	78.03874	0.056845	78.48634
0.070745	80.77318	0.070152	80.64139	0.06094	77.95894	0.059271	78.44833
0.073616	80.71224	0.073046	80.55017	0.063481	77.87155	0.061721	78.36851
0.076495	80.60941	0.075981	80.41714	0.066063	77.73856	0.064211	78.3001
0.079421	80.48374	0.078947	80.2195	0.068696	77.53717	0.066716	78.18228
0.082374	80.36567	0.081955	79.93064	0.071365	77.27499	0.069279	78.02644
0.085373	80.17144	0.085013	79.56576	0.074103	76.91782	0.071875	77.8022
0.088417	79.88581	0.088108	79.07166	0.076863	76.47705	0.074512	77.51714
0.091494	79.49354	0.091244	78.42933	0.079656	75.93749	0.077163	77.13706
0.094643	78.9794	0.094435	77.66157	0.082485	75.27254	0.079869	76.66196
0.09783	78.33958	0.097654	76.68476	0.085347	74.50119	0.082616	76.08424
0.101071	77.40652	0.100932	75.48371	0.088213	73.52846	0.08539	75.38109

Table A-5. Tensile Test Results by Specimen Number (cont.)

400766		400766		400766		400766	
L3C1-T-09		L3C1-T-10		L3C1-T-11		L3C1-T-12	
Strain	Stress	Strain	Stress	Strain	Stress	Strain	Stress
(in/in)	(ksi)	(in/in)	(ksi)	(in/in)	(ksi)	(in/in)	(ksi)
0	0	0	0	0	0	0	0
0.001107	13.31426	0.001147	14.11418	0.001316	16.55208	0.001124	13.41275
0.002078	25.00778	0.002259	27.77368	0.002447	30.23453	0.002296	27.39091
0.003144	37.58362	0.003321	40.40635	0.003647	44.38334	0.003514	41.51137
0.004179	49.20519	0.004448	53.51264	0.004878	58.35163	0.004754	55.4783
0.005232	59.68316	0.005606	65.79293	0.00621	70.72149	0.005995	67.89127
0.006477	67.67323	0.006989	74.62898	0.008014	77.27312	0.007597	75.80712
0.008167	71.1722	0.00898	78.2172	0.010454	78.943	0.009832	78.40953
0.010149	72.40289	0.011402	79.17962	0.013087	79.60117	0.012391	79.16966
0.012237	73.20948	0.013856	79.74797	0.015719	80.07505	0.014932	79.70138
0.014265	73.89488	0.016282	80.19508	0.018333	80.485	0.017454	80.13574
0.01632	74.47804	0.018713	80.58535	0.020961	80.84982	0.019981	80.51768
0.018339	74.99683	0.021126	80.93773	0.02358	81.17326	0.022495	80.84345
0.020372	75.42852	0.023525	81.25222	0.026194	81.4779	0.02499	81.15424
0.022405	75.79205	0.025929	81.55156	0.028817	81.73741	0.027508	81.43508
0.024465	76.09499	0.028337	81.80921	0.031441	81.99692	0.030012	81.6897
0.02653	76.35249	0.03074	82.04413	0.034069	82.20753	0.032526	81.92561
0.028622	76.57591	0.033162	82.2639	0.03671	82.3843	0.035048	82.13904
0.030723	76.7501	0.035598	82.44956	0.039366	82.55354	0.037571	82.31129
0.032839	76.90535	0.038033	82.65038	0.042039	82.71526	0.040126	82.49477
0.034963	77.02653	0.040492	82.79057	0.044718	82.85442	0.042676	82.62582
0.037096	77.14013	0.042959	82.93077	0.047432	82.95597	0.045235	82.75314
0.039248	77.2083	0.045432	83.0596	0.050175	83.06503	0.04784	82.86922
0.041427	77.28403	0.047927	83.1619	0.052922	83.12145	0.050449	82.96283
0.043588	77.32947	0.050454	83.25284	0.055705	83.20043	0.053082	83.04895
0.045777	77.35598	0.052981	83.32483	0.058507	83.2418	0.055719	83.09388
0.048006	77.38249	0.055545	83.38545	0.061327	83.25684	0.058402	83.1538
0.050231	77.37113	0.058127	83.4385	0.064189	83.27565	0.061098	83.1875
0.052456	77.34462	0.060732	83.46881	0.067064	83.26437	0.063822	83.19873
0.054722	77.32947	0.063369	83.48397	0.069985	83.26813	0.06656	83.20996
0.056993	77.2651	0.066029	83.48397	0.072956	83.19291	0.06933	83.19499
0.059282	77.18558	0.068712	83.46881	0.075945	83.11017	0.072145	83.1538
0.061622	77.08333	0.071431	83.42713	0.078985	82.97853	0.074988	83.10137
0.064007	76.90157	0.074183	83.36272	0.082062	82.76792	0.077877	83.02274
0.066443	76.67436	0.07698	83.21116	0.085202	82.44823	0.080794	82.89543
0.068942	76.36763	0.079805	83.02549	0.088389	82.027	0.083751	82.7082
0.071534	75.97002	0.082698	82.75268	0.091594	81.53808	0.086764	82.43486
0.074157	75.47396	0.085596	82.4003	0.094876	80.84982	0.089836	82.08662
0.076817	74.8908	0.088549	81.93804	0.098186	80.03368	0.092949	81.61856
0.079541	74.18646	0.091543	81.36589	0.101524	79.05959	0.096108	81.03816
0.082306	73.23598	0.094551	80.57777	0.104935	77.75077	0.09929	80.2331

Table A-5. Tensile Test Results by Specimen Number (cont.)

400766		400766		400766		400766	
L3C1-T-13		L3C1-T-14		L3C1-T-15		L3C1-T-16	
Strain	Stress	Strain	Stress	Strain	Stress	Strain	Stress
(in/in)	(ksi)	(in/in)	(ksi)	(in/in)	(ksi)	(in/in)	(ksi)
0	0	0	0	0	0	0	0
0.001223	13.88508	0.001249	14.30493	0.00146	16.47154	0.001477	16.87529
0.002129	24.16286	0.002279	26.12453	0.002536	28.81856	0.002498	28.41237
0.003228	36.76179	0.003405	38.97241	0.003827	43.51811	0.003675	41.83753
0.00429	48.63013	0.00449	51.31943	0.005031	56.96551	0.00486	54.97455
0.005357	60.43378	0.005603	63.37048	0.006253	69.10384	0.006019	66.89455
0.00641	70.55174	0.006748	72.85651	0.007805	76.71922	0.007406	75.34926
0.007746	77.03576	0.008336	77.84996	0.009998	78.67714	0.009315	78.15486
0.009573	79.02206	0.010401	78.95034	0.012415	79.23112	0.011554	78.78422
0.01162	79.58142	0.012635	79.4512	0.014837	79.64471	0.013847	79.20885
0.013694	79.95432	0.014869	79.83064	0.017277	80.01277	0.01615	79.57662
0.015777	80.31582	0.017103	80.15696	0.01969	80.35427	0.018458	79.91405
0.017837	80.60501	0.019315	80.47569	0.022084	80.64264	0.020756	80.20598
0.019892	80.88279	0.021508	80.75268	0.024493	80.9462	0.02305	80.49033
0.021934	81.15676	0.023691	81.02209	0.026905	81.19663	0.025334	80.75193
0.023967	81.38888	0.025871	81.27252	0.029318	81.42809	0.027619	81.00216
0.026009	81.63621	0.028059	81.50777	0.031717	81.6254	0.029908	81.19931
0.028064	81.8493	0.030243	81.70129	0.034157	81.84168	0.032215	81.40405
0.030102	82.02814	0.032427	81.90618	0.036597	82.00104	0.034518	81.57845
0.032153	82.22221	0.034638	82.06555	0.039042	82.14903	0.03683	81.74148
0.034208	82.37061	0.03684	82.22112	0.041501	82.27045	0.03916	81.88934
0.036264	82.52282	0.039051	82.36531	0.043973	82.39566	0.041481	81.9955
0.038338	82.66741	0.041276	82.46396	0.04644	82.49811	0.043816	82.11303
0.040375	82.78157	0.043474	82.44878	0.048954	82.60056	0.04616	82.21539
0.042495	82.88811	0.045658	82.70301	0.051467	82.64609	0.048536	82.28364
0.044546	82.99846	0.04791	82.74475	0.054017	82.7068	0.050913	82.36705
0.04662	83.06696	0.050181	82.83581	0.056581	82.72578	0.053307	82.40496
0.048456	83.13165	0.052447	82.87376	0.059159	82.75993	0.055706	82.43908
0.050456	83.21155	0.054759	82.93447	0.061764	82.76752	0.058123	82.46562
0.052938	83.2458	0.057071	82.98759	0.064378	82.78269	0.060568	82.49216
0.055149	83.26102	0.059401	83.00277	0.067033	82.74475	0.063022	82.49216
0.057379	83.31049	0.061736	83.01795	0.069721	82.72957	0.065494	82.48458
0.059585	83.31429	0.064094	82.99897	0.072435	82.69163	0.067985	82.45804
0.061842	83.34093	0.066475	82.99897	0.075178	82.61574	0.070503	82.46183
0.064118	83.3219	0.068869	82.97621	0.077948	82.52467	0.073039	82.40496
0.066375	83.30668	0.071291	82.95344	0.080777	82.36531	0.075607	82.35188
0.06865	83.28385	0.073736	82.90032	0.083629	82.17938	0.078185	82.29122
0.070967	83.242	0.076194	82.82823	0.086545	81.92136	0.08079	82.19265
0.073288	83.15828	0.078694	82.72578	0.089521	81.54571	0.083445	82.07511
0.075664	83.05554	0.081244	82.58538	0.092525	81.05624	0.086142	81.89692
0.078068	82.85006	0.083817	82.38428	0.095597	80.35806	0.088925	81.28272

Table A-5. Tensile Test Results by Specimen Number (cont.)

P3		P3		P3		P3	
P3-T-01		P3-T-02		P3-T-03		P3-T-04	
Strain	Stress	Strain	Stress	Strain	Stress	Strain	Stress
(in/in)	(ksi)	(in/in)	(ksi)	(in/in)	(ksi)	(in/in)	(ksi)
0	0	0	0	0	0	0	0
0.00146	16.0435	0.00138	15.3042	0.00135	14.8243	0.00146	16.1736
0.00273	30.0345	0.0026	28.8411	0.00266	29.2519	0.00253	28.1262
0.00405	44.4429	0.00385	42.5737	0.00394	43.202	0.00371	41.1319
0.00537	57.9903	0.00511	56.053	0.0052	56.5557	0.00491	54.149
0.00709	65.8729	0.00672	64.8953	0.00684	65.1619	0.00628	63.4256
0.00921	69.462	0.0087	68.9768	0.00887	69.0786	0.0081	68.1157
0.01165	70.8565	0.01098	70.4505	0.01125	70.5231	0.01027	69.9227
0.01406	71.8132	0.01331	71.4666	0.01366	71.5189	0.0125	70.9499
0.01645	72.6568	0.01562	72.2984	0.01602	72.3728	0.01471	71.7124
0.01883	73.3497	0.01794	73.018	0.01835	73.0821	0.0169	72.5123
0.02124	73.9817	0.02025	73.6455	0.0207	73.7073	0.01911	73.1454
0.02362	74.5441	0.02256	74.2183	0.02304	74.2747	0.0213	73.7352
0.02601	75.0311	0.02486	74.7076	0.02539	74.79	0.02349	74.233
0.0284	75.495	0.02719	75.1681	0.02772	75.2474	0.02568	74.7222
0.03078	75.9038	0.02951	75.5826	0.03006	75.6729	0.02788	75.1566
0.03316	76.2893	0.03183	75.9654	0.03239	76.0782	0.03007	75.5451
0.03555	76.6285	0.03417	76.3252	0.03474	76.4371	0.03228	75.9019
0.03794	76.988	0.03652	76.6533	0.0371	76.7758	0.03446	76.25
0.04034	77.2721	0.03887	76.9613	0.03947	77.0798	0.03668	76.5665
0.04273	77.5446	0.04123	77.2319	0.04185	77.3374	0.03891	76.8629
0.04514	77.823	0.04357	77.5053	0.04423	77.6095	0.04113	77.1334
0.04755	78.0404	0.04593	77.7471	0.04661	77.8527	0.04335	77.378
0.04999	78.2578	0.0483	77.9515	0.04902	78.0988	0.04559	77.6225
0.05243	78.4724	0.0507	78.1587	0.05145	78.3159	0.04784	77.8556
0.05488	78.655	0.0531	78.3487	0.05389	78.4896	0.05012	78.0426
0.05734	78.8057	0.0555	78.507	0.05634	78.6546	0.0524	78.221
0.05984	78.9739	0.05793	78.6682	0.05878	78.8138	0.05469	78.3994
0.06233	79.1015	0.06036	78.8121	0.06126	78.973	0.057	78.5577
0.06486	79.229	0.06281	78.9445	0.06375	79.1033	0.05933	78.6929
0.0674	79.3421	0.06529	79.0568	0.06626	79.2046	0.06165	78.831
0.06995	79.4435	0.06778	79.1604	0.06881	79.3117	0.06402	78.9375
0.07254	79.5276	0.0703	79.2352	0.07138	79.3754	0.0664	79.0497
0.07515	79.5914	0.07283	79.3216	0.07399	79.4564	0.0688	79.1447
0.07781	79.6494	0.07537	79.3791	0.07664	79.5027	0.07122	79.2454
0.08048	79.6813	0.07797	79.4309	0.07934	79.5114	0.07365	79.3
0.08321	79.69	0.0806	79.4741	0.08209	79.4796	0.07615	79.3605
0.08598	79.661	0.08324	79.4943	0.08494	79.3898	0.07865	79.3835
0.08882	79.5943	0.08593	79.4971	0.08785	79.2364	0.08122	79.3892
0.09174	79.4406	0.08869	79.4741	0.09086	79.0048	0.08383	79.3576
0.09471	79.2029	0.09149	79.4252	0.09391	78.669	0.08651	79.3029

Table A-5. Tensile Test Results by Specimen Number (cont.)

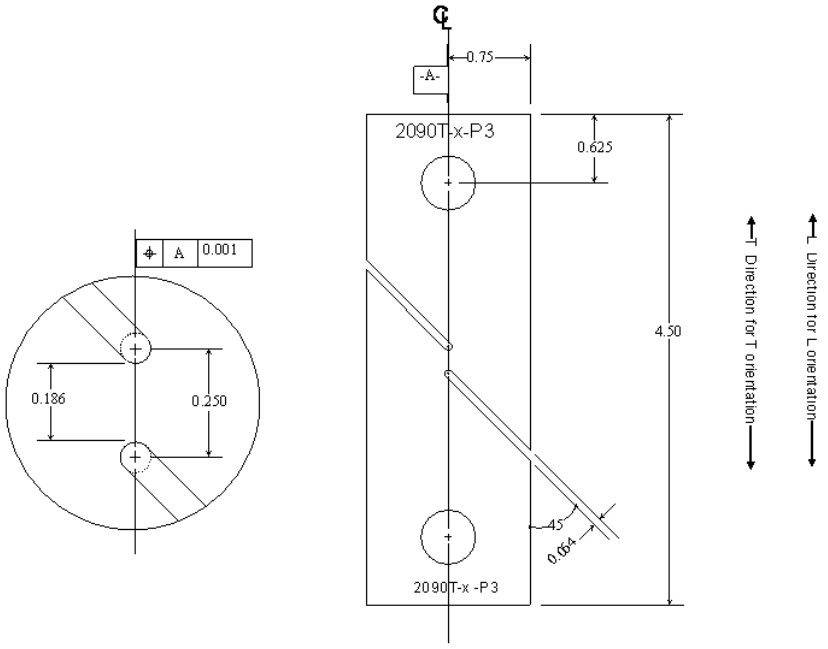
P3		P3		P3		P3	
P3-L-01		P3-L-02		P3-L-03		P3-L-04	
Strain	Stress	Strain	Stress	Strain	Stress	Strain	Stress
(in/in)	(ksi)	(in/in)	(ksi)	(in/in)	(ksi)	(in/in)	(ksi)
0	0	0	0	0	0	0	0
0.00056	6.26145	0.0005	5.6875	0.00052	5.79412	0.00049	5.37243
0.00154	17.1952	0.00124	13.7775	0.0012	13.5599	0.00133	14.8844
0.00187	20.9013	0.00171	19.1997	0.0017	19.118	0.00176	19.7325
0.00241	26.8138	0.0023	25.8995	0.00229	25.6029	0.00228	25.3642
0.00298	33.3405	0.00289	32.5272	0.00286	32.085	0.00286	31.9091
0.00355	39.7174	0.00348	38.9617	0.00343	38.4951	0.00344	38.4712
0.00414	46.1749	0.00403	45.3068	0.004	44.7324	0.00401	44.7222
0.00471	52.4133	0.0046	51.5481	0.00455	50.8633	0.00457	50.8897
0.00524	58.2623	0.00517	57.6941	0.00511	56.9338	0.00513	56.9333
0.0058	64.1402	0.00572	63.6816	0.00564	62.6876	0.00568	62.8992
0.00636	69.5046	0.00627	68.9451	0.00619	67.9751	0.00626	68.2601
0.00706	72.9714	0.007	72.6397	0.00686	71.9501	0.00694	71.9819
0.00792	74.8807	0.00788	74.6182	0.00769	74.0859	0.00782	74.056
0.00882	76.3458	0.00879	76.1439	0.00858	75.6315	0.00871	75.5914
0.00971	77.5917	0.00971	77.4273	0.00947	76.9124	0.00962	76.8906
0.01063	78.5723	0.01062	78.431	0.01038	77.9774	0.01056	77.9276
0.01155	79.3395	0.01159	79.2097	0.01132	78.7776	0.01154	78.7313
0.01252	79.9279	0.0126	79.801	0.01229	79.3993	0.01254	79.3305
0.01351	80.3692	0.01361	80.2538	0.01329	79.8857	0.01358	79.8
0.01453	80.747	0.01466	80.6547	0.01431	80.2714	0.01461	80.2062
0.01554	81.0585	0.01569	80.9748	0.01534	80.6139	0.01567	80.5288
0.01657	81.3555	0.01673	81.2748	0.01636	80.9248	0.0167	80.8342
0.01759	81.6151	0.01778	81.5603	0.01738	81.181	0.01772	81.1222
0.01863	81.843	0.01883	81.791	0.01841	81.44	0.01876	81.3729
0.01965	82.0795	0.01983	81.6786	0.01944	81.6818	0.01979	81.6091
0.02067	82.2813	0.02058	81.9352	0.02046	81.8977	0.02083	81.8338
0.02169	82.4919	0.0216	82.3419	0.02148	82.1193	0.02187	82.0585
0.0222	82.3563	0.02284	82.3852	0.0225	82.3208	0.02276	81.9692
0.02268	82.4717	0.02409	82.5438	0.02352	82.5108	0.0234	82.1996
0.02361	82.6534	0.02543	82.463	0.02455	82.7036	0.0244	82.4243
0.02494	82.5409	0.02675	82.5553	0.02556	82.8619	0.02559	82.456
0.0262	82.8524	0.0281	82.3967	0.02658	83.0462	0.02683	82.6259
0.02756	82.6361	0.02938	82.7774	0.02759	83.2045	0.02809	82.721
0.02889	82.6707	0.03039	82.5323	0.0286	83.3887	0.02937	82.842
0.03019	82.8841	0.03074	82.6649	0.02961	83.5384	0.03072	82.77
0.03154	82.9043	0.03106	83.1581	0.03063	83.6823	0.03209	82.6317
0.03286	82.7486	0.03159	83.7407	0.03164	83.8319	0.03338	82.8938
0.03331	82.9764	0.03263	83.5734	0.03265	83.9528	0.03474	82.8938
0.03372	83.6225	0.03384	83.6628	0.03366	84.0968	0.03538	82.7037
0.03409	83.9801	0.03508	83.9599	0.03467	84.2263	0.03567	83.2366

Table A-5. Tensile Test Results by Specimen Number (concluded)

P3		P3		P3		P3	
P3-45-01		P3-45-02		P3-45-03		P3-45-04	
Strain	Stress	Strain	Stress	Strain	Stress	Strain	Stress
(in/in)	(ksi)	(in/in)	(ksi)	(in/in)	(ksi)	(in/in)	(ksi)
0	0	0	0	0	0	0	0
0.00163	17.6316	0.00165	17.9187	0.00174	18.9152	0.00166	18.0451
0.003	32.4748	0.00304	32.9142	0.00324	35.088	0.00304	33.2502
0.00451	48.1767	0.00461	49.0296	0.00492	51.1632	0.00455	48.8142
0.00637	57.9344	0.00678	58.4513	0.00725	59.1117	0.00654	58.3249
0.00895	60.9496	0.00959	61.0644	0.01025	61.5268	0.00926	61.1334
0.01161	62.7587	0.01249	62.819	0.01329	63.2756	0.01201	62.9224
0.01429	64.1514	0.01543	64.1715	0.01637	64.5907	0.01481	64.3294
0.01701	65.2455	0.01841	65.2139	0.01953	65.6159	0.01768	65.4178
0.01977	66.1271	0.0214	66.084	0.02271	66.4745	0.02059	66.2879
0.02253	66.8708	0.02443	66.8363	0.02589	67.2183	0.0235	67.0373
0.02531	67.5399	0.02745	67.4997	0.02907	67.8615	0.02642	67.6921
0.02811	68.1199	0.03049	68.0826	0.03227	68.4502	0.02937	68.2721
0.03092	68.6454	0.03354	68.6139	0.03549	68.9642	0.0323	68.789
0.03374	69.1193	0.03659	69.0819	0.03872	69.4294	0.03528	69.26
0.0366	69.5442	0.03965	69.5098	0.04197	69.8515	0.03824	69.6821
0.03945	69.9377	0.04273	69.8975	0.04523	70.2334	0.04122	70.0726
0.04231	70.2794	0.04581	70.2564	0.0485	70.5924	0.04421	70.4258
0.04519	70.6039	0.04891	70.5723	0.05181	70.8882	0.04722	70.7417
0.04811	70.891	0.05203	70.8652	0.05513	71.1523	0.05026	71.0289
0.05103	71.1667	0.05517	71.1236	0.05849	71.4165	0.0533	71.2787
0.054	71.3878	0.05831	71.3677	0.06186	71.6434	0.05638	71.5228
0.05699	71.6118	0.06146	71.5544	0.06528	71.8329	0.05946	71.7295
0.05999	71.8128	0.06463	71.7525	0.06872	72.0081	0.06259	71.9191
0.06303	71.9908	0.06783	71.9133	0.07219	72.1488	0.06572	72.0914
0.0661	72.1402	0.07103	72.0569	0.07572	72.2866	0.06888	72.2493
0.0692	72.2723	0.07425	72.1689	0.07927	72.3871	0.07206	72.367
0.07231	72.3756	0.07746	72.2464	0.08287	72.479	0.07529	72.4905
0.07548	72.4761	0.08071	72.3038	0.08654	72.5364	0.07855	72.5939
0.07871	72.5594	0.08391	72.301	0.09025	72.5623	0.08183	72.6657
0.08197	72.5996	0.08711	72.2407	0.09406	72.5422	0.08517	72.7174
0.08529	72.6197	0.09033	72.1086	0.09791	72.479	0.08852	72.7662
0.08868	72.5853	0.09357	71.9133	0.10186	72.3584	0.09194	72.7891
0.09212	72.5221	0.09686	71.6434	0.10585	72.1488	0.0954	72.7719
0.09561	72.3929	0.10023	71.2471	0.10989	71.8329	0.09891	72.7116
0.09914	72.1746	0.10367	70.7704	0.11399	71.428	0.1025	72.6025
0.10272	71.8645	0.10719	70.1904	0.11812	70.8968	0.10614	72.4273
0.10635	71.4625	0.11078	69.5098	0.12229	70.2449	0.10984	72.1488
0.10999	70.9398	0.11448	68.6627	0.12648	69.438	0.11359	71.7697
0.11368	70.2593	0.11829	67.5887	0.13072	68.4301	0.11734	71.2844
0.11764	67.7495	0.12223	66.1443	0.13501	67.112	0.12115	70.6096

Appendix B. Shear Test Results

Shear tests were performed using four types of specimens: single shear, thin double shear, wide double shear, and tension/shear. The single shear specimens, shown in Figure B-1, were in accordance with the ASTM standard B831-05. The specimens were loaded in tension, creating a shear stress between the two notches. The specimens were machined with the loading orientated in the L (Longitudinal) and T (Long Transverse) direction, resulting in shear along the LS and TS planes, respectively, as shown in Figure B-2. A displacement rate of 0.05 inches/minute was applied and the peak load recorded. The ultimate shear stress was calculated from the peak load and the area between the notches. The test configuration was not possible to generate a shear yield stress. The results from the longitudinal shear tests are provided in Table B-1.



NOTES:
(1) All dimensions are in inches.
(2) Scribe specimen number at each half of specimen as shown in the drawing layout.
(3) Use the full thickness of the provided material.

Figure B-1. Schematic of the Single Shear Specimen

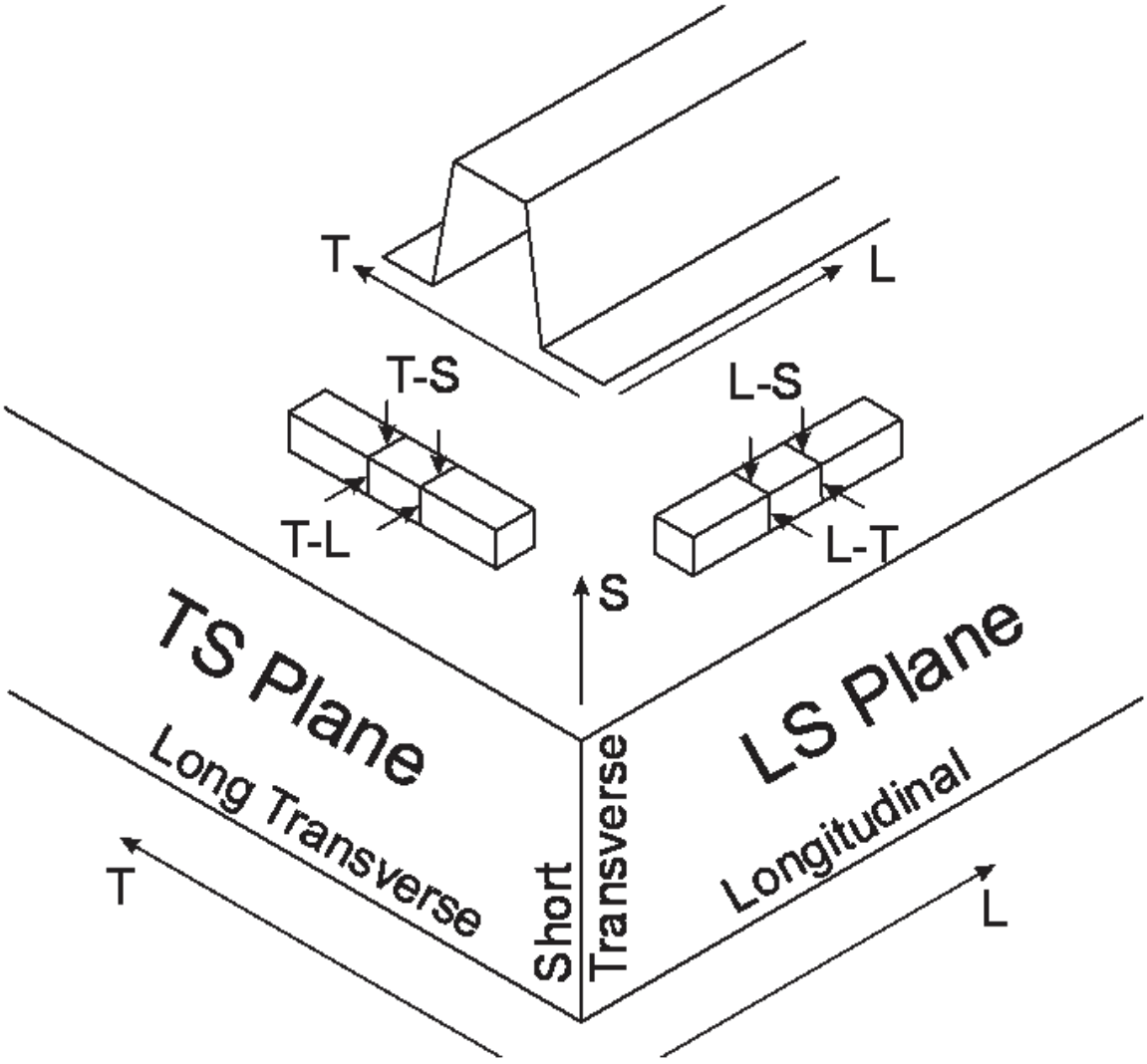


Figure B-2. Testing Orientations for all of the Shear Specimens

Table B-1. Results from the Single Shear Tests

325°F for 24 hours									
Specimen	Lot	Type	Shear Direction	Shear Plane	Width (inch)	Thickness (inch)	Load (lbs.)	Stress (ksi)	Axial Load (% S_{ys})
L2P1-L-01	400768	Longitudinal Shear	L	LS	0.1851	0.0633	478.4	40.8	0
L2P1-L-02	400768	Longitudinal Shear	L	LS	0.1850	0.0631	481.2	41.2	0
L2P1-L-03	400768	Longitudinal Shear	L	LS	0.1847	0.0632	476.0	40.8	0
L1P1-L-01	400751	Longitudinal Shear	L	LS	0.1851	0.0641	485.0	40.9	0
L1P1-L-02	400751	Longitudinal Shear	L	LS	0.1850	0.0642	485.2	40.9	0
L1P1-L-03	400751	Longitudinal Shear	L	LS	0.1848	0.0641	486.0	41.0	0
L2P1-T-01	400768	Longitudinal Shear	T	TS	0.1850	0.0633	543.4	46.4	0
L2P1-T-02	400768	Longitudinal Shear	T	TS	0.1852	0.0632	545.6	46.6	0
L2P1-T-03	400768	Longitudinal Shear	T	TS	0.1850	0.0632	537.6	46.0	0
L1P1-T-01	400751	Longitudinal Shear	T	TS	0.1854	0.0643	547.6	45.9	0
L1P1-T-02	400751	Longitudinal Shear	T	TS	0.1845	0.0644	550.2	46.3	0
L1P1-T-03	400751	Longitudinal Shear	T	TS	0.1850	0.0645	544.6	45.7	0

The thin double shear and wide double shear tests were conducted using a test fixture that was designed based upon the concepts presented in the ASTM standard D769 for thick, round specimens. The test fixture allowed shear testing with loading in the S (Short Transverse) direction on sheet material. The thickness of the coil and stringer materials precluded the use of the specimen sizes required by the ASTM D769 standard. The fixture, an exploded view is shown in Figure B-3, held the small specimens in tool steel shearing blocks and a precise plunger was pressed into a slot in the stainless steel block, shearing the specimen. The fixture accommodated different size specimens and a schematic of the wide double shear is shown in Figure B-4. The thin double shear specimens were identical to the wide double shear specimens, but at a width of 0.06 inches rather than 0.25 inches and allowed loading in the L or T directions. The orientations of the double shear tests are shown in Figure B-5. The results from the wide and think double shear tests are provided in Table B-2.

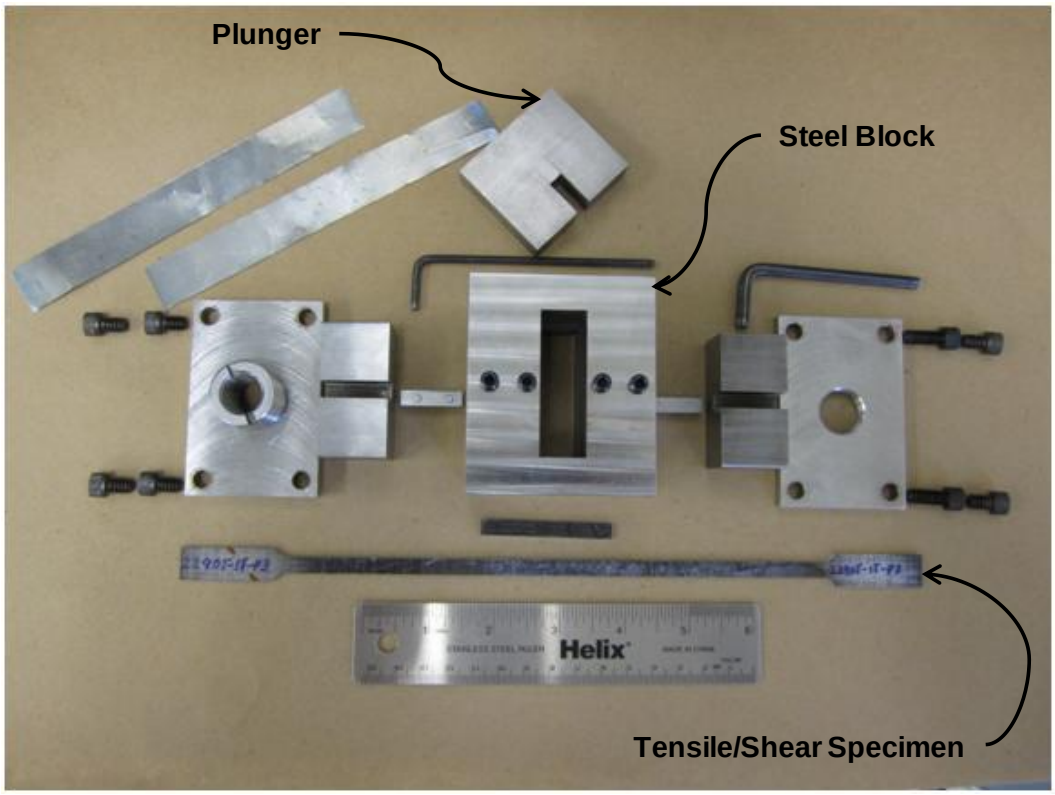
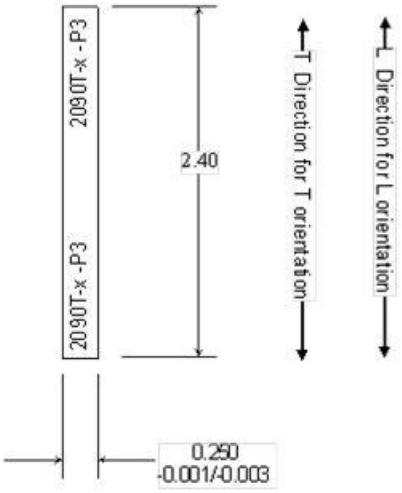


Figure B-3. Exploded View of the Fixture used for the Double Shear and Combined Tensile/Shear Tests



NOTES:
(1) All dimensions are in inches.
(2) Scribe specimen number at each half of specimen as shown in the drawing layout. (Don't Scribe The Center 1 Inch)
(3) Use the full thickness of the provided material.
(4) Make (4) with a T orientation and L orientation.
(5) Cut specimens and orientate as shown in layout drawings.

Figure B-4. Schematic of the Wide Double Shear Specimen

Table B-2. Results from the Wide and Thin Double Shear Tests

325°F for 24 hours									
Specimen	Lot	Type	Shear Direction	Shear Plane	Width (inch)	Thickness (inch)	Load (lbs.)	Stress (ksi)	Axial Load (% S_{ys})
L1P1-TL-Thin-01	400751	Thin Double Shear	L	LS	0.0640	0.0615	368.8	46.8	0
L1P1-TL-Thin-02	400751	Thin Double Shear	L	LS	0.0635	0.0615	358.0	45.8	0
L1P1-TL-Thin-03	400751	Thin Double Shear	L	LS	0.0635	0.0610	366.8	47.3	0
L1P1-TS-Thin-01	400751	Thin Double Shear	S	LS	0.0610	0.0635	313.2	40.4	0
L1P1-TS-Thin-02	400751	Thin Double Shear	S	LS	0.0610	0.0635	328.4	42.4	0
L1P1-TS-Thin-03	400751	Thin Double Shear	S	LS	0.0610	0.0635	310.4	40.1	0
L1P1-TS-Wide-01	400751	Wide Double Shear	S	LS	0.2480	0.0635	1256.4	39.9	0
L1P1-TS-Wide-02	400751	Wide Double Shear	S	LS	0.2480	0.0634	1263.6	40.2	0
L1P1-TS-Wide-03	400751	Wide Double Shear	S	LS	0.2480	0.0635	1248.0	39.6	0
L1P1-LS-Wide-01	400751	Wide Double Shear	S	TS	0.2480	0.0645	1369.2	42.8	0
L1P1-LS-Wide-02	400751	Wide Double Shear	S	TS	0.2480	0.0645	1380.8	43.2	0
L1P1-LS-Wide-03	400751	Wide Double Shear	S	TS	0.2480	0.0650	1377.2	42.7	0
L2P1-LS-Wide-01	400768	Wide Double Shear	S	TS	0.2480	0.0640	1358.8	42.8	0
L2P1-LS-Wide-02	400768	Wide Double Shear	S	TS	0.2480	0.0640	1361.2	42.9	0
L2P1-LS-Wide-03	400768	Wide Double Shear	S	TS	0.2480	0.0645	1344.8	42.0	0

The combined tension/shear tests were conducted using the same fixture (Figure B-3) as was used for the wide and thin double shear tests. The tensile/shear specimens were similar to the double shear specimens shown in Figure B-4, except that the length was 8.5 inches to allow the ends to extend outside of the stainless steel block. The ends of the specimen were loaded using a servo-hydraulic load frame to obtain the constant axial load and the shear plunger was loaded using a hand-operated hydraulic ram. A load cell that was inline with the hydraulic ram was used to obtain the peak shear load. The specimen orientation and loading directions were the same as shown in Figure B-2. The results from the wide and think double shear tests are provided in Table B-3.

Table B-3. Results from the Wide and Thin Double Shear Tests

Specimen	Lot	Type	Shear Direction	Shear Plane	Width (inch)	Thickness (inch)	Load (lbs.)	Stress (ksi)	Axial Load (% S_{ys})
TC-Wide-L1P1-T-01	400751	Tension/Shear 50% S_{ys}	S	LS	0.2490	0.0635	1253.0	39.6	50
TC-Wide-L1P1-T-02	400751	Tension/Shear 50% S_{ys}	S	LS	0.2480	0.0635	1222.5	38.8	50
TC-Wide-L1P1-T-03	400751	Tension/Shear 50% S_{ys}	S	LS	0.2480	0.0635	1247.0	39.6	50
TC-Wide-L1P1-T-04	400751	Tension/Shear 75% Sy_s	S	LS	0.248	0.0635	1049.0	33.3	75
TC-Wide-L1P1-T-05	400751	Tension/Shear 75% Sy_s	S	LS	0.248	0.0635	1117.0	35.5	75
TC-Wide-L1P1-T-06	400751	Tension/Shear 75% Sy_s	S	LS	0.248	0.0635	1084.0	34.4	75
TC-Wide-L1P1-T-07	400751	Tension/Shear 90% Sy_s	S	LS	0.248	0.0635	989.5	31.4	90
TC-Wide-L1P1-T-08	400751	Tension/Shear 90% Sy_s	S	LS	0.248	0.0635	936.5	29.7	90
TC-Wide-L1P1-T-09	400751	Tension/Shear 90% Sy_s	S	LS	0.248	0.064	831.0	26.2	90
TC-Wide-L1P1-T-10	400751	Tension/Shear 100% Sy_s	S	LS	0.248	0.0635	638.0	20.3	100
TC-Wide-L1P1-T-11	400751	Tension/Shear 100% Sy_s	S	LS	0.248	0.0635	686.0	21.8	100
TC-Wide-L1P1-T-12	400751	Tension/Shear 100% Sy_s	S	LS	0.248	0.0635	766.5	24.3	100
TC-Wide-L2P1-T-01	400768	Tension/Shear 50% S_{ys}	S	LS	0.2490	0.0630	1281.0	40.8	50
TC-Wide-L2P1-T-02	400768	Tension/Shear 50% S_{ys}	S	LS	0.2485	0.063	1275.0	40.7	50
TC-Wide-L2P1-T-03	400768	Tension/Shear 50% S_{ys}	S	LS	0.2485	0.063	1234.0	39.4	50
TC-Wide-L2P1-T-04	400768	Tension/Shear 75% S_{ys}	S	LS	0.2485	0.063	1032.5	33.0	75
TC-Wide-L2P1-T-05	400768	Tension/Shear 75% S_{ys}	S	LS	0.2485	0.063	1124.0	35.9	75
TC-Wide-L2P1-T-06	400768	Tension/Shear 75% S_{ys}	S	LS	0.2485	0.063	1056.0	33.7	75
TC-Wide-L2P1-T-07	400768	Tension/Shear 90% S_{ys}	S	LS	0.248	0.063	935.5	29.9	90
TC-Wide-L2P1-T-08	400768	Tension/Shear 90% S_{ys}	S	LS	0.2485	0.063	957.0	30.6	90
TC-Wide-L2P1-T-09	400768	Tension/Shear 90% S_{ys}	S	LS	0.248	0.063	935.5	29.9	90
TC-Wide-L2P1-T-10	400768	Tension/Shear 100% S_{ys}	S	LS	0.2485	0.063	727.0	23.2	100
TC-Wide-L2P1-T-11	400768	Tension/Shear 100% S_{ys}	S	LS	0.2485	0.063	744.0	23.8	100
TC-Wide-L2P1-T-12	400768	Tension/Shear 100% S_{ys}	S	LS	0.2485	0.063	724.5	23.1	100
TC-Wide-L1P1-L-02	400751	Tension/Shear 50% S_{ys}	S	TS	0.2475	0.0640	1259.0	39.7	50
TC-Wide-L1P1-L-03	400751	Tension/Shear 50% S_{ys}	S	TS	0.247	0.064	1246.5	39.4	50
TC-Wide-L1P1-L-04	400751	Tension/Shear 50% S_{ys}	S	TS	0.2475	0.064	1258.5	39.7	50
TC-Wide-L1P1-L-05	400751	Tension/Shear 75% S_{ys}	S	TS	0.2475	0.064	1011.5	31.9	75
TC-Wide-L1P1-L-06	400751	Tension/Shear 75% S_{ys}	S	TS	0.2475	0.064	1091.0	34.4	75
TC-Wide-L1P1-L-07	400751	Tension/Shear 75% S_{ys}	S	TS	0.247	0.064	1040.5	32.9	75

Appendix C. 3-Point Bend Test Results

The 3-point bend tests were conducted on small rectangular coupons that were approximately 2 inches long and 0.75 inches wide (W). The thickness of the specimens (t) ranged between 0.05 inches to 0.065 inches depending on the material being tested. The test fixture had two fixed rollers (diameter D_f) separated by a distance or span (L) and a center mandrel (diameter D_m) that loaded the specimen, as shown in Figure C-1. The displacement (δ) of the center mandrel was increased at a rate of 0.06 inches/minute and the data recorded at a rate of 10 readings per second.

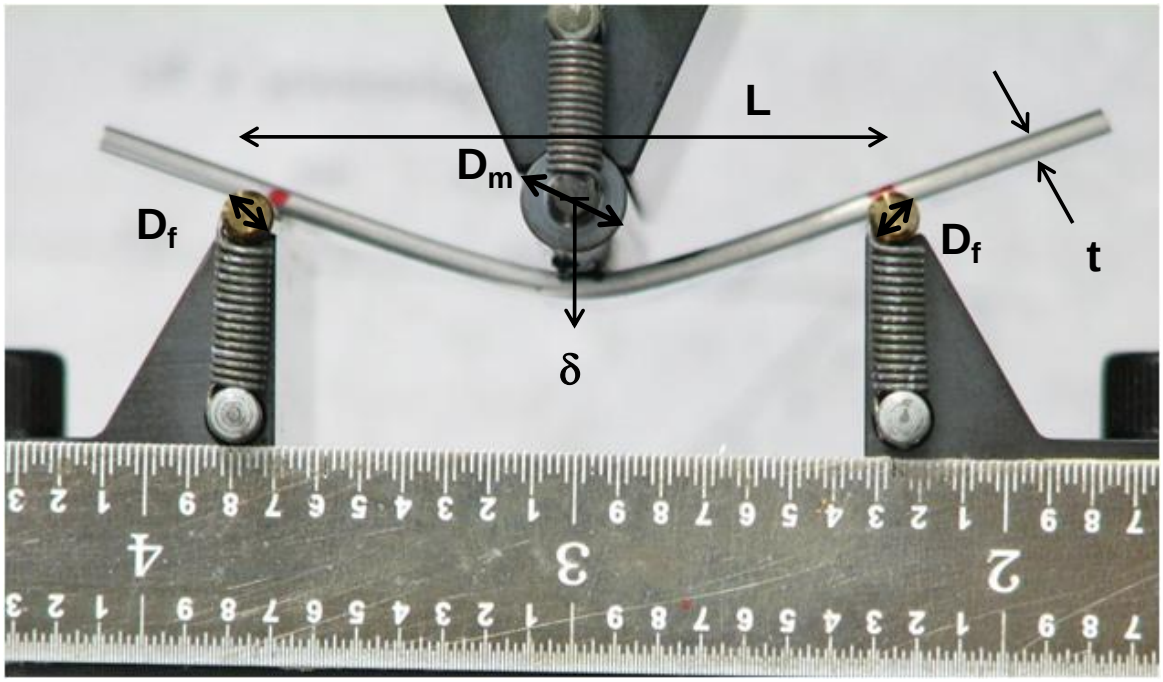


Figure C-1. 3-point Bend Test Fixture and Nomenclature

Strain gages were placed on the tensile side of several test specimens, directly below the center mandrel. These tests considered different specimen thicknesses, different spans, and different lots of the 2090 material. The measured axial strain was plotted as a function of the normalized displacement ($\delta t/L^2$) for spans of L = 0.8, 1.0, and 1.6 inches, as shown in Figure C-2. The normalized displacement vs. strain behavior provided a good correlation of the different thicknesses (0.05 inch < t < 0.065 inch), but did not correlate the different span lengths. Polynomial curve fits were calculated for the data for each span length to allow estimates of the strain for tests conducted without strain gages. The parameters to the curve fits are provided in Table C-1.

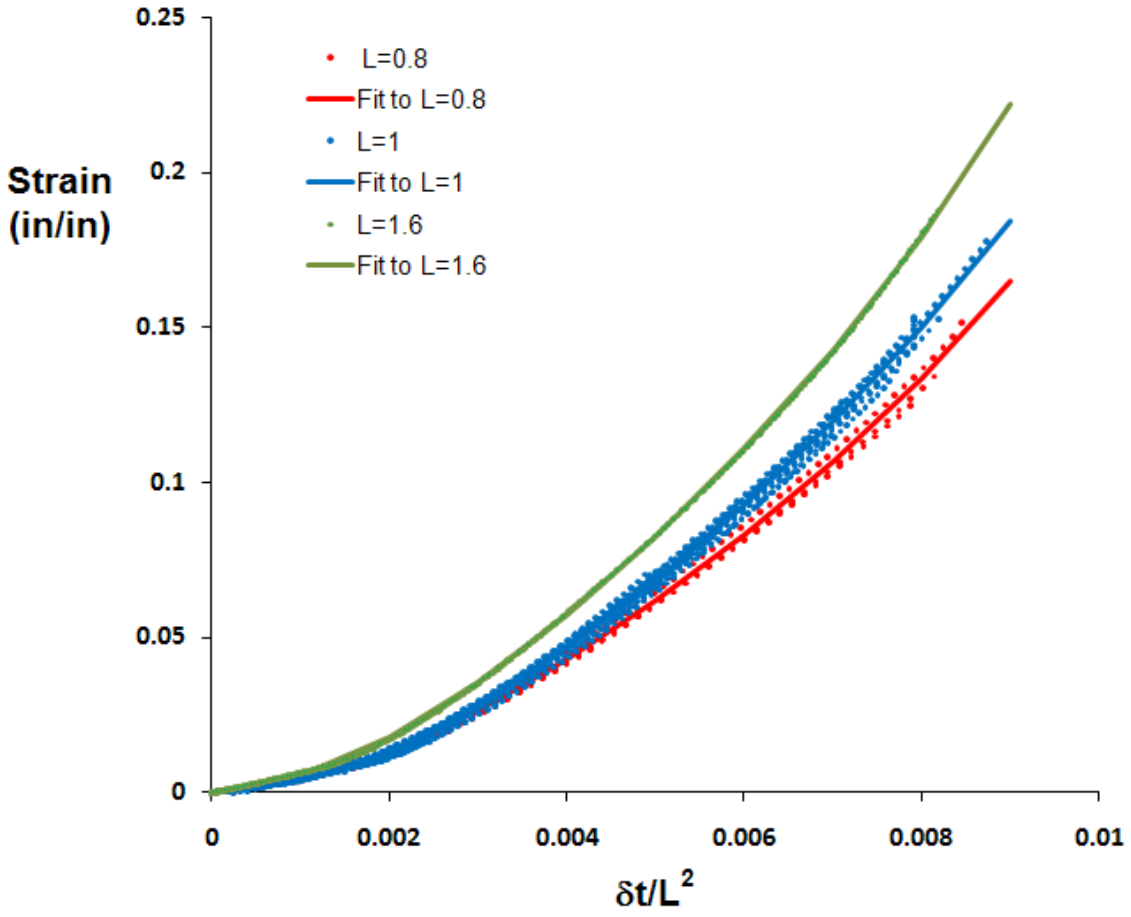


Figure C-2. Strain and Normalized Displacement Data from 3-point Bend Tests and Polynomial Curve Fits

Table C-1. Polynomial Curve Fits to the Normalized Displacement vs. Axial Strain Data

$$e = a_0 + a_1\left(\frac{\delta t}{L^2}\right) + a_2\left(\frac{\delta t}{L^2}\right)^2 + a_3\left(\frac{\delta t}{L^2}\right)^3 + a_4\left(\frac{\delta t}{L^2}\right)^4$$

	a_0	a_1	a_2	a_3	a_4
L = 0.8	0	0.2202	3784.6	-365547	18726597
L = 1.0	0	0.1809	3835.8	-297336	13512671
L = 1.6	0	1.0121	4745.8	-450453	23946859

A summary of the 3-point bend test on the coil and stringer materials is provided in Table C-2. The summary contains the specimen number, material thickness, maximum load, maximum normalized displacement, the strain at failure, and an indication of the failure (brittle or less brittle). The initial conditions (specimen width and thickness, and span length), normalized displacement, measured load, and the strains (estimated or measured) for each of the 3-point bend tests are provided in Table C-3.

Table C-2. Summary of 3-point Bend Test Results by Specimen Number

Stringer-7 Sister (Lot 620853)						
Specimen	Thickness	Max Load	d t/L^2	Span	% Strain	Failure
S7-04	0.058	258.1	0.00645	1	10.4	Brittle
S7-05	0.06	270.1	0.00567	1	8.3	Brittle
S7-01	0.06	271.5	0.00561	1	8.5	Brittle
S7-06	0.058	247.6	0.0051	1	7.0	Brittle
S7-02	0.059	265.0	0.00496	1	7.1	Brittle
S7-03	0.059	264.9	0.00432	1	5.3	Brittle
S7-08	0.058	246.5	0.00483	1	6.4	Brittle
Control-1D (Lot 400766)						
Specimen	Thickness	Max Load	d t/L^2	Span	% Strain	Failure
C10-01	0.052	198.3	0.00831	1	16.0	LB
C10-02	0.052	198.6	0.00808	1	14.2	LB
C10-03	0.052	198.3	0.00819	1	14.7	LB
C10-04	0.051	187.0	0.00671	1	11.1	LB
C10-05	0.051	188.1	0.00667	1	11.0	LB
C10-06	0.052	99.4	0.00743	1.8	15.1	LB
C10-07	0.052	257.5	0.00846	0.8	15.2	LB
Coil Aged at 325F for 24 Hours (Lot 400751)						
Specimen	Thickness	Max Load	d t/L^2	Span	% Strain	Failure
L1P1-01-325	0.064	158.4	0.00807	1.8	18.8	LB
L1P1-02-325	0.063	309.2	0.00757	1	13.7	LB
L1P1-03-325	0.063	309.9	0.00792	1	15.1	LB
L1P1-04-325	0.064	177.9	0.00818	1.6	18.7	LB
L1P1-05-325	0.064	400.8	0.00814	0.8	13.4	LB
L1P1-06-325	0.063	311.9	0.00873	1	17.8	LB
L1P1-07-325	0.063	307.9	0.00701	1	12.0	LB
L1P1-08-325	0.063	304.5	0.00723	1	12.6	LB
L1P1-09-325	0.063	309.4	0.00724	1	12.7	LB
Coil Aged at 325F for 24 Hours (Lot 400768)						
Specimen	Thickness	Max Load	d t/L^2	Span	% Strain	Failure
L2P1-01-325	0.062	287.5	0.00707	1	12.2	LB
L2P1-02-325	0.062	291.0	0.00681	1	11.4	LB
L2P1-07-325	0.062	297.2	0.00824	1	15.8	LB
L2P1-08-325	0.062	294.7	0.00711	1	12.3	LB

Table C-2. Summary of 3-point Bend Test Results by Specimen Number (concluded)

Cold Formed Aged at 325F for 24 Hours (Lot 620853)						
Specimen	Thickness	Max Load	d t/L^2	Span	% Strain	Failure
L5CR-01-325	0.058	243.4	0.00665	1	11.0	LB
L5CR-29-325	0.057	232.5	0.007	1	12.0	LB
L5CR-22-325	0.057	238.5	0.00699	1	11.9	Brittle
L5CR-27-325	0.057	234.6	0.00664	1	11.0	Brittle
L5CR-02-325	0.057	240.8	0.00654	1	10.7	Brittle
Cold Formed Aged at 325F for 24 Hours (Lot 620853)						
Specimen	Thickness	Max Load	d t/L^2	Span	% Strain	Failure
L5MCR-01-325	0.057	240.3	0.00601	1	9.3	LB
L5MCR-03-325	0.0575	237.5	0.0056	1	8.2	LB
L5MCR-13-325	0.057	240.4	0.00688	1	11.6	LB
L5MCR-17-325	0.057	245.9	0.00672	1	11.2	LB
L5MCR-04-325	0.057	240.3	0.00675	1	11.3	Brittle
L5MCR-28-325	0.056	222.6	0.00686	1	11.6	Brittle
L5MCR-20-325	0.058	242.2	0.00701	1	12.0	Brittle
Cold/Hot Formed Aged at 325F for 24 Hours (Lot 620853)						
Specimen	Thickness	Max Load	d t/L^2	Span	% Strain	Failure
L5HR-01-325	0.062	277.3	0.00596	1	9.1	Brittle
L5HR-02-325	0.06	255.1	0.00626	1	9.9	Brittle
L5HR-03-325	0.06	261.0	0.00626	1	9.9	Brittle
L5HR-04-325	0.06	258.8	0.00656	1	10.7	Brittle
L5HR-17-325	0.059	256.7	0.00655	1	10.7	Brittle
L5HR-19-325	0.06	260.3	0.00607	1	9.4	Brittle
L5HR-09-325	0.0575	316.3	0.00789	0.8	13.0	Brittle
L5HR-14-325	0.059	328.7	0.00651	0.8	9.5	Brittle
L5HR-13-325	0.059	325.7	0.00695	0.8	10.5	Brittle
L5HR-12-325	0.059	334.0	0.00688	0.8	10.4	Brittle
L5HR-11-325	0.059	319.3	0.00704	0.8	10.8	Brittle
L5HR-16-325	0.059	331.4	0.00655	0.8	9.5	Brittle
L5HR-15-325	0.057	319.1	0.00672	0.8	10.0	Brittle
L5HR-20-325	0.059	148.5	0.00637	1.6	12.2	Brittle
L5HR-21-325	0.057	141.2	0.00623	1.6	11.8	Brittle
L5HR-18-325	0.06	151.6	0.00643	1.6	12.4	Brittle
L5HR-23-325	0.059	148.0	0.00642	1.6	12.4	Brittle

Table C-3. 3-point Bend Test Results by Specimen Number

P3-BD-01			P3-BD-02			P3-BD-03		
L	1	inch	L	1	inch	L	1	inch
W	0.746	inch	W	0.748	inch	W	0.748	inch
t	0.057	inch	t	0.06	inch	t	0.058	inch
Load (Lbs.)	dt/L^2	Est. Strain (in/in)	Load (Lbs.)	dt/L^2	Est. Strain (in/in)	Load (Lbs.)	dt/L^2	Strain (in/in)
0	0	0	0	0	0	0	0	0
22.6	0.00026	0.0003	19.3	0.00023	0.0002	23.1	0.00027	0.0016
49.6	0.00051	0.0011	45.3	0.00045	0.0008	55.1	0.00054	0.0031
76.9	0.00077	0.0023	72.3	0.00068	0.0018	88.5	0.00082	0.0047
104.3	0.00103	0.0040	99.5	0.00091	0.0031	90.6	0.00084	0.0048
130.2	0.00129	0.0060	126.8	0.00114	0.0048	90.7	0.00084	0.0048
151.0	0.00155	0.0085	151.5	0.00137	0.0067	90.6	0.00084	0.0048
166.3	0.00181	0.0113	171.3	0.00160	0.0089	90.6	0.00084	0.0048
177.5	0.00207	0.0144	186.0	0.00182	0.0114	90.6	0.00084	0.0048
186.0	0.00233	0.0179	197.3	0.00205	0.0142	90.7	0.00084	0.0048
193.1	0.00259	0.0216	205.7	0.00228	0.0172	90.6	0.00084	0.0048
199.0	0.00285	0.0256	212.2	0.00251	0.0205	90.7	0.00084	0.0048
203.6	0.00310	0.0299	217.6	0.00274	0.0239	108.5	0.00098	0.0056
207.4	0.00336	0.0344	222.6	0.00297	0.0276	140.2	0.00126	0.0075
210.4	0.00362	0.0392	230.1	0.00319	0.0313	166.2	0.00153	0.0099
213.1	0.00388	0.0442	231.2	0.00342	0.0354	185.3	0.00180	0.0127
215.2	0.00414	0.0494	233.5	0.00365	0.0396	199.1	0.00208	0.0159
217.4	0.00440	0.0548	236.0	0.00387	0.0440	209.2	0.00235	0.0195
219.1	0.00466	0.0604	238.4	0.00410	0.0486	216.8	0.00262	0.0235
220.9	0.00492	0.0662	240.4	0.00433	0.0533	223.2	0.00290	0.0278
222.3	0.00518	0.0723	242.3	0.00456	0.0582	227.9	0.00317	0.0324
223.5	0.00544	0.0784	244.0	0.00479	0.0632	231.5	0.00344	0.0372
224.5	0.00570	0.0848	245.5	0.00502	0.0685	234.8	0.00371	0.0422
225.6	0.00596	0.0913	247.0	0.00524	0.0738	237.8	0.00399	0.0474
226.3	0.00621	0.0980	248.5	0.00547	0.0793	240.2	0.00426	0.0528
227.1	0.00647	0.1050	249.7	0.00570	0.0849	242.4	0.00454	0.0583
227.6	0.00673	0.1121	250.9	0.00593	0.0906	243.9	0.00481	0.0640
228.1	0.00699	0.1194	252.0	0.00616	0.0966	245.3	0.00508	0.0697
228.4	0.00725	0.1270	252.8	0.00639	0.1027	246.7	0.00536	0.0756
228.7	0.00751	0.1348	253.6	0.00662	0.1089	248.0	0.00563	0.0817
228.7	0.00777	0.1427	254.1	0.00685	0.1153	249.3	0.00590	0.0881
228.5	0.00803	0.1509	254.7	0.00707	0.1218	250.5	0.00618	0.0945
228.4	0.00829	0.1594	254.9	0.00730	0.1285	251.3	0.00645	0.1011
227.8	0.00855	0.1682	255.2	0.00916	0.1902	251.7	0.00672	0.1080
227.3	0.00880	0.1772	253.8	0.00939	0.1989	252.1	0.00700	0.1151
226.4	0.00906	0.1866	252.5	0.00962	0.2078	252.1	0.00727	
225.6	0.00932	0.1962	251.2	0.00985	0.2170	251.9	0.00754	
225.2	0.00958	0.2063				251.6	0.00782	
224.4	0.00984	0.2166				251.3	0.00809	

Table C-3. 3-point Bend Test Results by Specimen Number (cont.)

P3-BD-04			P3-BD-05			P3-BD-06		
L	1.4	inch	L	0.8	inch	L	1.2	inch
W	0.745	inch	W	0.748	inch	W	0.746	inch
t	0.059	inch	t	0.06	inch	t	0.06	inch
Load (Lbs.)	dt/L^2	Strain (in/in)	Load (Lbs.)	dt/L^2	Strain (in/in)	Load (Lbs.)	dt/L^2	Strain (in/in)
0	0	0	0	0	0	0	0	0
14.2	0.00020	0.00128	30.0	0.00031	0.0018	24.0508	0.00027	0.00167
30.7	0.00041	0.00244	72.1	0.00063	0.0035	51.9473	0.00054	0.00321
47.4	0.00061	0.00363	115.6	0.00094	0.0052	80.21	0.00082	0.00479
64.0	0.00082	0.00483	159.6	0.00126	0.0071	107.862	0.00109	0.00647
80.4	0.00102	0.00608	197.8	0.00158	0.0097	131.486	0.00136	0.00867
95.8	0.00123	0.00751	225.7	0.00189	0.0130	149.066	0.00164	0.01146
108.9	0.00144	0.00921	245.1	0.00221	0.0167	162.068	0.00191	0.01481
119.4	0.00164	0.0112	258.8	0.00252	0.0209	171.652	0.00218	0.0186
127.5	0.00185	0.01349	268.8	0.00284	0.0254	178.733	0.00245	0.02277
134.0	0.00205	0.01601	276.3	0.00316	0.0301	184.288	0.00273	0.02719
139.0	0.00226	0.01875	282.0	0.00347	0.0352	188.5	0.003	0.03188
142.8	0.00246	0.02171	286.9	0.00379	0.0403	191.796	0.00327	0.03676
146.2	0.00267	0.02485	291.3	0.00411	0.0456	194.787	0.00355	0.04178
149.0	0.00287	0.0282	295.3	0.00442	0.0511	197.046	0.00382	0.04696
151.6	0.00308	0.0317	299.4	0.00474	0.0566	198.999	0.00409	0.05225
153.5	0.00328	0.03532	302.8	0.00506	0.0622	200.952	0.00437	0.0577
155.3	0.00349	0.03904	305.7	0.00537	0.0679	202.356	0.00464	0.06329
157.0	0.00369	0.04288	308.2	0.00569	0.0738	203.455	0.00491	0.06901
158.6	0.00390	0.04681	310.1	0.00601	0.0799	204.004	0.00518	
160.1	0.00410	0.05087	311.9	0.00632	0.0860	204.92	0.00546	
161.3	0.00431	0.05505	313.6	0.00664	0.0922	205.958	0.00573	
162.2	0.00451	0.05928	315.0	0.00696	0.0985	206.629	0.006	
163.2	0.00472	0.0636	316.1	0.00727	0.1049	207.118	0.00627	
163.9	0.00492	0.06798	317.2	0.00759	0.1114	207.484	0.00655	
164.0	0.00513	0.07243	318.2	0.00791	0.1181	207.606	0.00682	
164.6	0.00533	0.07691	318.9	0.00822	0.1249	207.911	0.00709	
164.9	0.00554	0.08148	319.6	0.00854	0.1318	207.789	0.00737	
165.3	0.00574	0.08616	319.7	0.00885	0.1390	207.362	0.00764	
165.2	0.00595	0.09101	320.2	0.00917	0.1492	206.69	0.00791	
165.4	0.00615	0.09591	320.4	0.00949		205.714	0.00819	
165.1	0.00636	0.101	320.5	0.00980		204.859	0.00846	
164.8	0.00657	0.10622	320.2	0.01012		204.31	0.00873	
164.4	0.00677	0.11154	319.7	0.01044		203.455	0.009	
163.8	0.00698	0.11691	318.9	0.01075		202.539	0.00928	
162.9	0.00718	0.1224	318.3	0.01107		201.38	0.00955	
162.1	0.00739	0.12822	317.8	0.01139		200.342	0.00982	
161.4	0.00759	0.13493	317.4	0.01170		198.816	0.0101	
161.0	0.00780		316.3	0.01202		194.97	0.01037	

Table C-3. 3-point Bend Test Results by Specimen Number (cont.)

S7-01			S7-02			S7-03			S7-04		
L	1	inch	L	1	inch	L	1	inch	L	1	inch
W	0.747	inch	W	0.745	inch	W	0.746	inch	W	0.746	inch
t	0.06	inch	t	0.059	inch	t	0.059	inch	t	0.058	inch
Load (Lbs.)	dt/L^2	Strain (in/in)	Load (Lbs.)	dt/L^2	Strain (in/in)	Load (Lbs.)	dt/L^2	Strain (in/in)	Load (Lbs.)	dt/L^2	Strain (in/in)
0	0	0	0	0	0	0	0	0	0	0	0
9.0	0.00014	0.00039	13.2	0.00013	0.00046	11.6	0.00010	0.00005	5.4	0.00009	0.00005
21.5	0.00029	0.00094	23.6	0.00026	0.00096	17.4	0.00016	0.00013	11.3	0.00018	0.00016
35.6	0.00044	0.00160	35.0	0.00039	0.00152	17.3	0.00016	0.00013	18.4	0.00028	0.00034
51.5	0.00059	0.00236	47.6	0.00052	0.00218	22.2	0.00021	0.00021	26.7	0.00037	0.00058
68.2	0.00074	0.00315	61.5	0.00066	0.00291	31.9	0.00031	0.00042	36.0	0.00046	0.00088
86.1	0.00089	0.00401	76.6	0.00079	0.00368	42.4	0.00041	0.00070	45.7	0.00056	0.00124
104.0	0.00104	0.00489	92.1	0.00092	0.00447	53.4	0.00051	0.00105	55.5	0.00065	0.00166
122.1	0.00118	0.00580	107.3	0.00105	0.00528	64.6	0.00061	0.00146	65.7	0.00075	0.00215
139.9	0.00133	0.00672	122.7	0.00118	0.00607	76.1	0.00071	0.00195	76.2	0.00084	0.00267
157.4	0.00148	0.00767	138.3	0.00132	0.00690	87.9	0.00080	0.00248	86.5	0.00093	0.00326
174.0	0.00163	0.00872	153.7	0.00145	0.00777	99.8	0.00090	0.00309	96.9	0.00102	0.00390
188.9	0.00178	0.00995	168.4	0.00158	0.00872	111.3	0.00100	0.00377	156.0	0.00157	0.00867
201.5	0.00193	0.01141	181.9	0.00171	0.00984	123.3	0.00110	0.00449	165.7	0.00166	0.00967
212.1	0.00207	0.01307	194.0	0.00184	0.01111	135.2	0.00120	0.00526	174.5	0.00176	0.01070
220.5	0.00222	0.01496	204.4	0.00198	0.01256	147.1	0.00130	0.00610	182.3	0.00185	0.01170
227.6	0.00237	0.01701	213.0	0.00211	0.01418	158.8	0.00140	0.00699	189.4	0.00194	0.01280
233.3	0.00252	0.01919	220.5	0.00224	0.01594	170.0	0.00150	0.00794	195.6	0.00204	0.01400
238.2	0.00267	0.02152	226.6	0.00237	0.01785	181.6	0.00161	0.00907	202.7	0.00217	0.01570
242.6	0.00282	0.02397	231.8	0.00251	0.01986	191.5	0.00171	0.01010	208.3	0.00227	0.01700
246.6	0.00296	0.02654	236.3	0.00264	0.02199	200.1	0.00181	0.01120	212.1	0.00236	0.01830
249.8	0.00312	0.02923	240.1	0.00277	0.02423	207.7	0.00190	0.01240	215.7	0.00245	0.01960
252.7	0.00326	0.03199	243.4	0.00290	0.02656	217.1	0.00205	0.01420	219.0	0.00254	0.02100
254.9	0.00341	0.03485	246.4	0.00304	0.02898	222.4	0.00215	0.01550	221.9	0.00264	0.02240
256.9	0.00356	0.03777	248.8	0.00317	0.03147	227.0	0.00225	0.01680	226.0	0.00283	0.02530
258.9	0.00371	0.04078	251.1	0.00330	0.03403	232.2	0.00242	0.01920	230.6	0.00292	0.02680
260.8	0.00385	0.04386	252.9	0.00343	0.03667	238.4	0.00252	0.02060	232.0	0.00301	0.02840
262.1	0.00400	0.04699	254.7	0.00356	0.03938	241.2	0.00262	0.02210	233.4	0.00311	0.02990
263.6	0.00415	0.05020	256.3	0.00369	0.04214	243.8	0.00272	0.02360	234.8	0.00320	0.03150
264.9	0.00430	0.05345	257.7	0.00383	0.04498	249.8	0.00292	0.02690	236.1	0.00329	0.03320
265.8	0.00445	0.05676	259.0	0.00396	0.04793	251.8	0.00302	0.02850	237.3	0.00339	0.03480
266.9	0.00460	0.06015	260.1	0.00409	0.05089	253.0	0.00312	0.03020	238.6	0.00348	0.03650
267.7	0.00475	0.06359	261.1	0.00422	0.05393	254.2	0.00322	0.03190	242.9	0.00372	0.04110
268.6	0.00490	0.06708	262.3	0.00436	0.05702	255.5	0.00332	0.03370	246.2	0.00427	0.05200
269.2	0.00504	0.07063	263.1	0.00449	0.06013	256.6	0.00342	0.03540	248.9	0.00436	0.05390
269.9	0.00519	0.07424	263.9	0.00462	0.06333	257.8	0.00352	0.03720	252.0	0.00505	0.06930
270.5	0.00534	0.07790	264.7	0.00475	0.06660	258.8	0.00361	0.03900	254.9	0.00553	0.08060
270.9	0.00549	0.08162	265.1	0.00488	0.07019	263.8	0.00391	0.04480	256.5	0.00595	0.09110
271.4	0.00564	0.08543	265.0	0.00502		264.7	0.00401	0.04670	257.8	0.00639	0.10300

Table C-3. 3-point Bend Test Results by Specimen Number (cont.)

S7-05			S7-06			S7-08		
L	1	inch	L	1	inch	L	1	inch
W	0.747	inch	W	0.746	inch	W	0.746	inch
t	0.06	inch	t	0.058	inch	t	0.058	inch
Load (Lbs.)	dt/L^2	Strain (in/in)	Load (Lbs.)	dt/L^2	Strain (in/in)	Load (Lbs.)	dt/L^2	Strain (in/in)
0	0	0	0	0	0	0	0	0
5.4	0.00017	0.00015	6.3	0.00010	0.00006	6.8	0.00009	0.00005
5.3	0.00018	0.00015	13.1	0.00021	0.00021	14.1	0.00019	0.00017
7.7	0.00021	0.00020	21.2	0.00032	0.00044	22.7	0.00029	0.00036
19.3	0.00036	0.00056	30.8	0.00043	0.00075	32.1	0.00038	0.00060
32.9	0.00052	0.00108	41.6	0.00054	0.00115	41.9	0.00047	0.00092
47.3	0.00067	0.00177	52.7	0.00065	0.00164	52.1	0.00057	0.00129
64.7	0.00083	0.00261	64.5	0.00075	0.00219	62.0	0.00066	0.00173
82.5	0.00098	0.00360	76.3	0.00086	0.00282	72.2	0.00076	0.00222
101.0	0.00113	0.00473	88.2	0.00097	0.00353	82.6	0.00086	0.00281
119.6	0.00129	0.00602	100.9	0.00109	0.00439	93.3	0.00096	0.00342
138.4	0.00144	0.00743	113.2	0.00120	0.00524	103.9	0.00105	0.00409
156.8	0.00160	0.00896	125.3	0.00131	0.00618	114.6	0.00114	0.00480
174.0	0.00175	0.01062	136.9	0.00142	0.00717	125.3	0.00125	0.00566
189.8	0.00191	0.01241	148.5	0.00153	0.00822	135.9	0.00134	0.00650
203.2	0.00206	0.01432	161.0	0.00165	0.00954	146.2	0.00144	0.00737
214.1	0.00221	0.01631	171.0	0.00176	0.01070	156.1	0.00153	0.00831
223.0	0.00237	0.01845	181.7	0.00190	0.01230	167.5	0.00166	0.00956
230.1	0.00253	0.02068	189.6	0.00201	0.01360	176.2	0.00175	0.01060
235.9	0.00268	0.02301	196.3	0.00211	0.01500	183.7	0.00185	0.01170
240.8	0.00283	0.02542	204.8	0.00229	0.01730	190.6	0.00194	0.01280
245.0	0.00299	0.02794	210.0	0.00240	0.01890	196.5	0.00204	0.01400
248.6	0.00314	0.03054	213.8	0.00251	0.02050	203.6	0.00220	0.01610
251.6	0.00330	0.03325	217.4	0.00262	0.02210	209.4	0.00229	0.01740
254.1	0.00345	0.03600	223.4	0.00283	0.02530	212.9	0.00239	0.01870
256.3	0.00361	0.03889	226.7	0.00294	0.02710	216.0	0.00248	0.02010
258.3	0.00376	0.04182	232.5	0.00329	0.03300	219.9	0.00271	0.02350
259.9	0.00392	0.04484	235.1	0.00339	0.03500	225.7	0.00280	0.02500
261.5	0.00407	0.04792	235.7	0.00351	0.03700	227.3	0.00290	0.02650
263.0	0.00422	0.05109	236.6	0.00361	0.03900	229.9	0.00317	0.03090
264.1	0.00438	0.05434	237.4	0.00372	0.04100	234.3	0.00326	0.03260
265.2	0.00453	0.05766	238.3	0.00383	0.04320	235.1	0.00335	0.03430
266.4	0.00469	0.06102	242.1	0.00415	0.04950	235.8	0.00345	0.03600
267.5	0.00484	0.06444	246.7	0.00462	0.05960	236.5	0.00354	0.03770
268.4	0.00500	0.06798	247.8	0.00473	0.06190	237.5	0.00364	0.03950
269.0	0.00515	0.07151	247.2	0.00484	0.06440	238.3	0.00374	0.04130
269.7	0.00530	0.07520	247.3	0.00495	0.06680	240.3	0.00403	0.04720
269.7	0.00546	0.07895	247.5	0.00505	0.06930	244.4	0.00438	0.05440
270.1	0.00561	0.08269	247.8	0.00516	0.07190	247.5	0.00476	0.06260

Table C-3. 3-point Bend Test Results by Specimen Number (cont.)

C10-01			C10-02			C10-03			C10-04		
L	1	inch	L	1	inch	L	1	inch	L	1	inch
W	0.746	inch	W	0.752	inch	W	0.752	inch	W	0.747	inch
t	0.052	inch	t	0.052	inch	t	0.052	inch	t	0.051	inch
Load (Lbs.)	dt/L^2	Strain (in/in)	Load (Lbs.)	dt/L^2	Strain (in/in)	Load (Lbs.)	dt/L^2	Strain (in/in)	Load (Lbs.)	dt/L^2	Strain (in/in)
0	0	0	0	0	0	0	0	0	0	0	0
8.2	0.00017	0.00013	9.4	0.00021	0.00054	9.6	0.00021	0.00058	9.0	0.00015	0.00011
20.6	0.00033	0.00048	23.8	0.00042	0.00141	24.3	0.00043	0.00151	20.1	0.00030	0.00040
35.0	0.00050	0.00102	39.7	0.00063	0.00243	40.8	0.00064	0.00269	32.4	0.00046	0.00086
49.9	0.00067	0.00176	57.1	0.00085	0.00357	58.5	0.00086	0.00393	52.2	0.00071	0.00195
65.1	0.00084	0.00269	75.3	0.00106	0.00477	77.0	0.00107	0.00522	56.5	0.00076	0.00223
80.6	0.00101	0.00379	94.1	0.00127	0.00605	96.2	0.00129	0.00654	69.0	0.00092	0.00316
95.8	0.00118	0.00507	112.5	0.00148	0.00740	114.8	0.00150	0.00801	81.4	0.00107	0.00422
110.4	0.00135	0.00650	129.4	0.00169	0.00900	131.5	0.00172	0.00979	93.8	0.00122	0.00543
124.2	0.00151	0.00811	143.3	0.00190	0.01100	145.2	0.00193	0.01200	123.1	0.00163	0.00925
136.2	0.00168	0.00987	154.4	0.00212	0.01330	155.9	0.00215	0.01460	132.4	0.00178	0.01090
146.3	0.00185	0.01180	162.9	0.00233	0.01600	164.1	0.00237	0.01750	140.0	0.00197	0.01320
154.6	0.00202	0.01380	169.4	0.00254	0.01900	170.0	0.00258	0.02080	148.1	0.00213	0.01510
161.3	0.00219	0.01590	174.5	0.00275	0.02240	174.8	0.00280	0.02440	156.3	0.00237	0.01840
167.0	0.00236	0.01830	181.3	0.00318	0.02960	178.5	0.00301	0.02820	161.2	0.00263	0.02220
171.5	0.00252	0.02070	183.9	0.00339	0.03350	181.4	0.00323	0.03210	164.6	0.00278	0.02460
175.3	0.00269	0.02320	186.3	0.00360	0.03750	184.0	0.00344	0.03630	166.3	0.00293	0.02700
178.4	0.00286	0.02590	188.1	0.00381	0.04150	186.4	0.00366	0.04060	168.1	0.00309	0.02960
181.1	0.00303	0.02870	190.0	0.00403	0.04570	190.4	0.00409	0.04960	172.8	0.00340	0.03510
183.4	0.00320	0.03150	191.8	0.00424	0.04990	192.2	0.00431	0.05430	173.7	0.00355	0.03780
185.4	0.00337	0.03450	193.1	0.00445	0.05430	193.3	0.00452	0.05910	174.2	0.00370	0.04070
187.1	0.00354	0.03760	194.1	0.00466	0.05870	194.2	0.00474	0.06400	175.2	0.00386	0.04370
188.5	0.00371	0.04080	195.0	0.00487	0.06330	194.9	0.00495	0.06890	176.0	0.00401	0.04670
189.9	0.00387	0.04400	195.6	0.00509	0.06790	195.8	0.00517	0.07400	177.0	0.00416	0.04990
191.3	0.00404	0.04740	196.1	0.00530	0.07270	196.4	0.00538	0.07920	177.9	0.00432	0.05300
192.5	0.00421	0.05080	196.6	0.00551	0.07750	196.9	0.00560	0.08450	178.7	0.00447	0.05630
193.4	0.00438	0.05430	197.0	0.00572	0.08240	197.4	0.00582	0.08990	179.3	0.00462	0.05960
194.3	0.00455	0.05800	197.6	0.00593	0.08740	197.8	0.00603	0.09540	180.0	0.00478	0.06300
195.0	0.00472	0.06170	198.4	0.00615	0.09250	198.1	0.00625	0.10100	180.6	0.00493	0.06650
195.5	0.00488	0.06540	198.6	0.00636	0.09770	198.1	0.00646	0.10685	181.1	0.00508	0.07000
195.9	0.00505	0.06930	198.4	0.00657	0.10300	198.3	0.00668	0.11278	181.5	0.00524	0.07360
196.4	0.00522	0.07330	198.4	0.00678	0.10847	198.3	0.00689	0.11891	182.0	0.00539	0.07720
196.9	0.00539	0.07730	198.3	0.00700	0.11409	198.1	0.00711	0.12525	182.7	0.00554	0.08100
197.0	0.00556	0.08140	197.8	0.00721	0.11990	197.9	0.00732	0.13183	182.9	0.00570	0.08480
197.5	0.00573	0.08560	197.6	0.00742	0.12588	197.4	0.00754	0.13868	185.1	0.00624	0.09870
197.7	0.00590	0.08980	197.2	0.00763	0.13250	197.4	0.00775	0.14583	187.0	0.00639	0.10300
197.9	0.00607	0.09410	197.0	0.00784		197.0	0.00797	0.15350	186.1	0.00655	0.10700
196.7	0.00811	0.15400	196.6	0.00806		196.3	0.00819	0.16163	185.9	0.00670	0.11100

Table C-3. 3-point Bend Test Results by Specimen Number (cont.)

C10-05			C10-06			C10-07		
L	1	inch	L	1.8	inch	L	0.8	inch
W	0.749	inch	W	0.75	inch	W	0.75	inch
t	0.051	inch	t	0.052	inch	t	0.052	inch
Load (Lbs.)	dt/L^2	Strain (in/in)	Load (Lbs.)	dt/L^2	Strain (in/in)	Load (Lbs.)	dt/L^2	Strain (in/in)
0	0	0	0	0	0	0	0	0
7.9	0.00017	0.00014	11.1	0.00025	0.00125	14.2	0.00022	0.00059
20.5	0.00035	0.00052	23.3	0.00050	0.00284	32.9	0.00044	0.00153
34.7	0.00052	0.00111	35.8	0.00074	0.00449	56.9	0.00066	0.00287
49.1	0.00070	0.00189	48.7	0.00099	0.00613	82.2	0.00088	0.00422
63.5	0.00087	0.00290	60.9	0.00124	0.00793	108.0	0.00111	0.00559
78.3	0.00105	0.00408	72.0	0.00149	0.01017	133.6	0.00133	0.00699
93.0	0.00122	0.00545	80.6	0.00174	0.01305	157.6	0.00155	0.00858
107.5	0.00140	0.00701	86.7	0.00198	0.01663	177.9	0.00177	0.01052
120.4	0.00158	0.00873	90.7	0.00223	0.02074	194.1	0.00200	0.01281
131.6	0.00175	0.01060	93.7	0.00248	0.02529	206.0	0.00222	0.01544
148.3	0.00210	0.01490	95.8	0.00273	0.03015	214.9	0.00244	0.01840
154.7	0.00228	0.01720	97.2	0.00298	0.03525	221.5	0.00266	0.02161
159.9	0.00245	0.01960	98.2	0.00323	0.04053	226.6	0.00289	0.02507
164.0	0.00263	0.02220	98.6	0.00347	0.04590	231.0	0.00311	0.02870
167.4	0.00280	0.02490	99.0	0.00372	0.05136	234.9	0.00333	0.03251
170.1	0.00298	0.02780	99.1	0.00397	0.05693	238.4	0.00355	0.03646
172.4	0.00315	0.03070	99.4	0.00422	0.06259	241.0	0.00378	0.04052
174.5	0.00333	0.03380	99.1	0.00447	0.06838	243.6	0.00400	0.04468
176.1	0.00351	0.03700	98.8	0.00472	0.07425	245.5	0.00422	0.04896
177.6	0.00368	0.04030	98.5	0.00496	0.08019	247.3	0.00445	0.05334
179.0	0.00386	0.04370	98.0	0.00521	0.08619	249.0	0.00467	0.05783
180.1	0.00403	0.04710	97.3	0.00546	0.09229	250.4	0.00489	0.06243
181.4	0.00421	0.05080	96.6	0.00571	0.09849	251.7	0.00511	0.06708
182.3	0.00438	0.05440	96.1	0.00596	0.10476	252.7	0.00534	0.07181
183.1	0.00456	0.05820	95.3	0.00620	0.11113	253.9	0.00556	0.07662
183.9	0.00473	0.06210	94.2	0.00645	0.11762	254.5	0.00578	0.08147
184.7	0.00491	0.06600	93.4	0.00670	0.12426	255.3	0.00601	0.08641
185.4	0.00508	0.07000	91.6	0.00695	0.13100	255.8	0.00623	0.09146
185.9	0.00526	0.07420	89.4	0.00720	0.13776	256.3	0.00645	0.09664
186.4	0.00544	0.07840	85.8	0.00745	0.14437	256.7	0.00667	0.10191
186.8	0.00561	0.08270	79.5	0.00763	0.14997	257.1	0.00689	0.10732
187.0	0.00579	0.08700	75.1		0.15086	257.2	0.00712	0.11284
187.3	0.00596	0.09150	73.2		0.15124	257.4	0.00734	0.11855
187.6	0.00614	0.09610	72.5		0.15151	257.5	0.00756	0.12440
187.8	0.00631	0.10100	71.9		0.15169	257.4	0.00778	0.13040
187.8	0.00649	0.10500	71.4		0.15183	257.1	0.00823	0.14306
187.9	0.00667	0.11000	71.2		0.15195	255.1	0.00845	0.15145

Table C-3. 3-point Bend Test Results by Specimen Number (cont.)

L1P1-01-325			L1P1-02-325			L1P1-03-325		
L	1	inch	L	1	inch	L	1	inch
W	0.75	inch	W	0.748	inch	W	0.746	inch
t	0.064	inch	t	0.063	inch	t	0.063	inch
Load (Lbs.)	dt/L^2	Strain (in/in)	Load (Lbs.)	dt/L^2	Strain (in/in)	Load (Lbs.)	dt/L^2	Strain (in/in)
0	0	0	0	0	0	0	0	0
15.4	0.00021	0.00119	41.7	0.00041	0.00064	18.2	0.00021	0.00071
32.1	0.00043	0.00260	65.6	0.00061	0.00161	43.2	0.00042	0.00181
49.6	0.00064	0.00403	91.6	0.00080	0.00265	69.3	0.00062	0.00293
66.2	0.00085	0.00546	117.7	0.00100	0.00379	98.0	0.00083	0.00420
82.6	0.00106	0.00692	144.1	0.00119	0.00494	127.2	0.00104	0.00547
98.8	0.00128	0.00860	169.8	0.00138	0.00613	155.8	0.00125	0.00678
113.2	0.00149	0.01073	193.6	0.00157	0.00739	182.9	0.00146	0.00825
124.3	0.00170	0.01339	214.1	0.00177	0.00888	206.9	0.00167	0.01008
132.6	0.00192	0.01650	230.7	0.00196	0.01067	226.5	0.00188	0.01228
139.0	0.00213	0.01995	243.4	0.00216	0.01281	241.4	0.00208	0.01486
143.7	0.00234	0.02372	253.5	0.00235	0.01524	252.8	0.00229	0.01774
147.2	0.00256	0.02772	261.4	0.00254	0.01789	261.4	0.00250	0.02084
149.8	0.00277	0.03193	267.7	0.00274	0.02075	268.3	0.00271	0.02411
152.2	0.00298	0.03639	272.7	0.00293	0.02378	273.9	0.00292	0.02758
153.7	0.00320	0.04106	277.2	0.00312	0.02693	278.6	0.00313	0.03119
155.0	0.00341	0.04593	281.2	0.00332	0.03026	282.5	0.00333	0.03497
156.5	0.00362	0.05096	284.6	0.00351	0.03374	285.9	0.00354	0.03892
157.5	0.00383	0.05616	287.4	0.00371	0.03736	288.7	0.00375	0.04298
157.9	0.00405	0.06146	289.9	0.00390	0.04113	291.1	0.00396	0.04722
158.3	0.00426	0.06688	291.8	0.00409	0.04500	293.3	0.00417	0.05155
158.3	0.00447	0.07242	293.9	0.00429	0.04901	295.3	0.00438	0.05603
158.2	0.00469	0.07805	295.7	0.00448	0.05310	297.1	0.00459	0.06060
158.0	0.00490	0.08384	297.3	0.00468	0.05729	298.7	0.00479	0.06530
157.9	0.00511	0.08975	298.9	0.00487	0.06159	300.2	0.00500	0.07007
157.3	0.00533	0.09581	300.3	0.00506	0.06597	301.7	0.00521	0.07498
156.9	0.00554	0.10200	301.8	0.00526	0.07049	302.6	0.00542	0.08000
156.8	0.00575	0.10836	302.8	0.00545	0.07511	304.1	0.00563	0.08512
156.0	0.00597	0.11490	303.8	0.00564	0.07986	304.8	0.00583	0.09037
155.4	0.00618	0.12162	304.7	0.00584	0.08465	305.6	0.00605	0.09568
154.7	0.00639	0.12850	305.8	0.00603	0.08954	306.4	0.00625	0.10110
153.7	0.00661	0.13558	306.6	0.00623	0.09454	307.1	0.00646	0.10663
153.2	0.00682	0.14289	307.3	0.00642	0.09962	307.6	0.00667	0.11228
152.2	0.00703	0.15047	307.8	0.00661	0.10480	308.0	0.00688	0.11806
151.2	0.00724	0.15832	308.4	0.00681	0.11013	308.6	0.00709	0.12399
150.1	0.00746	0.16649	309.0	0.00700	0.11562	309.0	0.00730	0.13007
148.7	0.00767	0.17502	309.4	0.00719		309.4	0.00750	0.13628
147.6	0.00788	0.18396	308.9	0.00739		309.6	0.00771	0.14266
146.0	0.00810					309.8	0.00792	0.14925

Table C-3. 3-point Bend Test Results by Specimen Number (cont.)

L1P1-04-325			L1P1-05-325			L1P1-06-325		
L	1.6	inch	L	0.8	inch	L	1	inch
W	0.745	inch	W	0.745	inch	W	0.748	inch
t	0.064	inch	t	0.064	inch	t	0.063	inch
Load (Lbs.)	dt/L^2	Strain (in/in)	Load (Lbs.)	dt/L^2	Strain (in/in)	Load (Lbs.)	dt/L^2	Strain (in/in)
0	0	0	0	0	0	0	0	0
17.6	0.00023	0.00129	13.6	0.00021	0.00032	20.7	0.00023	0.00083
37.2	0.00045	0.00273	43.5	0.00042	0.00122	48.8	0.00046	0.00204
56.9	0.00068	0.00419	77.9	0.00064	0.00228	77.7	0.00069	0.00331
77.0	0.00091	0.00570	114.0	0.00085	0.00343	108.7	0.00092	0.00466
96.5	0.00113	0.00726	151.0	0.00106	0.00464	140.8	0.00115	0.00607
115.1	0.00136	0.00911	188.0	0.00128	0.00589	171.8	0.00138	0.00759
130.6	0.00159	0.01150	224.1	0.00149	0.00722	200.3	0.00160	0.00941
142.6	0.00182	0.01443	256.4	0.00170	0.00878	223.4	0.00183	0.01169
151.5	0.00204	0.01784	283.7	0.00192	0.01070	240.9	0.00206	0.01445
157.9	0.00227	0.02162	305.5	0.00213	0.01298	253.8	0.00229	0.01755
162.6	0.00250	0.02567	321.8	0.00234	0.01558	263.4	0.00252	0.02096
165.9	0.00272	0.02994	334.5	0.00256	0.01842	271.0	0.00275	0.02459
168.7	0.00295	0.03443	344.4	0.00277	0.02144	276.8	0.00298	0.02843
170.7	0.00318	0.03912	352.6	0.00299	0.02462	281.6	0.00321	0.03248
172.8	0.00341	0.04403	358.7	0.00320	0.02791	285.7	0.00344	0.03673
174.2	0.00363	0.04912	364.0	0.00341	0.03132	289.2	0.00367	0.04114
175.5	0.00386	0.05438	368.5	0.00363	0.03486	292.3	0.00390	0.04574
176.2	0.00409	0.05977	372.2	0.00384	0.03852	294.8	0.00413	0.05050
176.7	0.00431	0.06528	375.4	0.00405	0.04233	297.2	0.00436	0.05541
177.1	0.00454	0.07095	378.1	0.00427	0.04625	299.3	0.00459	0.06045
177.5	0.00477	0.07671	380.7	0.00448	0.05028	301.2	0.00482	0.06563
177.7	0.00500	0.08261	383.0	0.00470	0.05443	302.8	0.00505	0.07093
177.8	0.00522	0.08865	385.1	0.00491	0.05864	304.4	0.00528	0.07638
177.1	0.00545	0.09482	387.4	0.00512	0.06300	305.8	0.00551	0.08197
176.7	0.00568	0.10118	389.3	0.00534	0.06745	307.3	0.00574	0.08771
176.1	0.00590	0.10771	390.8	0.00556	0.07195	308.4	0.00597	0.09361
175.3	0.00613	0.11441	392.1	0.00576	0.07651	309.3	0.00620	0.09961
174.6	0.00636	0.12131	393.4	0.00598	0.08118	309.7	0.00643	0.10574
174.0	0.00659	0.12841	394.6	0.00619	0.08592	310.3	0.00665	0.11197
173.4	0.00681	0.13573	396.0	0.00641	0.09078	310.8	0.00689	0.11837
172.4	0.00704	0.14338	396.7	0.00662	0.09569	311.1	0.00711	0.12495
171.3	0.00727	0.15138	397.6	0.00683	0.10073	311.5	0.00734	0.13170
170.2	0.00749	0.15979	398.4	0.00705	0.10588	311.8	0.00757	0.13865
169.0	0.00772	0.16860	399.4	0.00726	0.11113	311.7	0.00780	0.14581
168.2	0.00795	0.17776	399.9	0.00748	0.11649	311.8	0.00803	0.15324
166.7	0.00818	0.18730	400.7	0.00769	0.12198	311.7	0.00826	0.16095
165.5	0.00840		400.9	0.00791	0.12760	311.5	0.00849	0.16896
163.7	0.00863		399.8	0.00812	0.13342	311.1	0.00872	0.17727

Table C-3. 3-point Bend Test Results by Specimen Number (cont.)

L1P1-07-325			L1P1-08-325			L1P1-09-325		
L	1	inch	L	1	inch	L	1	inch
W	0.751	inch	W	0.746	inch	W	0.746	inch
t	0.063	inch	t	0.063	inch	t	0.063	inch
Load (Lbs.)	dt/L^2	Strain (in/in)	Load (Lbs.)	dt/L^2	Strain (in/in)	Load (Lbs.)	dt/L^2	Strain (in/in)
0	0	0	0	0	0	0	0	0
46.7	0.00040	0.00066	18.1	0.00018	0.00016	15.4	0.00019	0.00061
101.2	0.00080	0.00247	41.4	0.00038	0.00059	40.1	0.00037	0.00159
155.2	0.00120	0.00529	66.0	0.00057	0.00128	65.7	0.00056	0.00262
199.9	0.00158	0.00879	91.2	0.00075	0.00220	91.8	0.00075	0.00373
199.2	0.00158	0.00878	117.0	0.00094	0.00334	117.6	0.00094	0.00487
199.2	0.00158	0.00877	142.3	0.00113	0.00472	143.8	0.00113	0.00606
198.9	0.00158	0.00876	167.1	0.00132	0.00630	169.3	0.00132	0.00728
197.7	0.00158	0.00877	190.2	0.00151	0.00810	192.9	0.00151	0.00871
221.3	0.00181	0.01128	209.9	0.00170	0.01005	213.0	0.00170	0.01042
245.4	0.00221	0.01628	225.4	0.00189	0.01222	228.9	0.00189	0.01248
245.9	0.00231	0.01758	237.4	0.00208	0.01456	241.2	0.00208	0.01484
244.7	0.00231	0.01760	246.7	0.00227	0.01703	251.1	0.00227	0.01744
244.1	0.00231	0.01758	254.0	0.00246	0.01972	258.6	0.00246	0.02022
243.7	0.00231	0.01760	260.0	0.00265	0.02252	264.5	0.00265	0.02318
257.5	0.00249	0.02009	264.9	0.00284	0.02549	269.6	0.00284	0.02627
267.5	0.00289	0.02629	269.5	0.00303	0.02859	274.0	0.00303	0.02948
276.0	0.00329	0.03311	273.7	0.00322	0.03183	278.4	0.00322	0.03284
281.9	0.00369	0.04048	277.0	0.00341	0.03519	282.3	0.00341	0.03636
286.4	0.00410	0.04846	279.6	0.00360	0.03868	285.0	0.00360	0.03997
290.1	0.00450	0.05688	282.0	0.00379	0.04229	287.6	0.00379	0.04370
293.6	0.00490	0.06576	284.1	0.00398	0.04605	289.8	0.00397	0.04756
285.4	0.00495	0.06700	286.0	0.00416	0.04986	291.8	0.00416	0.05150
282.9	0.00495	0.06700	288.0	0.00436	0.05386	293.7	0.00435	0.05557
280.9	0.00495	0.06700	289.8	0.00454	0.05786	295.3	0.00454	0.05972
266.8	0.00495	0.06703	291.4	0.00473	0.06204	297.0	0.00473	0.06395
298.7	0.00528	0.07454	292.9	0.00492	0.06630	298.4	0.00492	0.06827
292.5	0.00550	0.07991	294.2	0.00511	0.07069	299.9	0.00511	0.07269
289.1	0.00550	0.07995	295.6	0.00530	0.07515	301.2	0.00530	0.07720
287.4	0.00550	0.07993	296.8	0.00549	0.07967	302.2	0.00549	0.08181
286.0	0.00550	0.07998	298.1	0.00568	0.08438	303.4	0.00568	0.08649
300.9	0.00576	0.08631	299.2	0.00587	0.08915	304.4	0.00587	0.09127
303.0	0.00616	0.09659	300.3	0.00606	0.09404	305.4	0.00606	0.09611
303.7	0.00656	0.10739	301.1	0.00625	0.09897	306.4	0.00625	0.10104
293.8	0.00657	0.10763	302.0	0.00644	0.10401	307.3	0.00644	0.10607
291.4	0.00657	0.10760	302.7	0.00663	0.10929	308.1	0.00663	0.11118
289.8	0.00657	0.10760	303.4	0.00682	0.11451	308.6	0.00682	0.11642
278.1	0.00659	0.10805	303.9	0.00701	0.11985	309.0	0.00701	0.12174
307.9	0.00699	0.11940	304.5	0.00720	0.12537	309.6	0.00720	0.12722

Table C-3. 3-point Bend Test Results by Specimen Number (cont.)

L2P1-01-325			L2P1-02-325			L2P1-07-325			L2P1-08-325		
L	1	inch	L	1	inch	L	1	inch	L	1	inch
W	0.752	inch	W	0.745	inch	W	0.747	inch	W	0.746	inch
t	0.062	inch	t	0.062	inch	t	0.062	inch	t	0.062	inch
Load (Lbs.)	dt/L^2	Strain (in/in)	Load (Lbs.)	dt/L^2	Strain (in/in)	Load (Lbs.)	dt/L^2	Strain (in/in)	Load (Lbs.)	dt/L^2	Strain (in/in)
0	0	0	0	0	0	0	0	0	0	0	0
15.9	0.00035	0.00051	14.2	0.00034	0.00048	19.9	0.00022	0.00021	15.6	0.00013	0.00009
38.6	0.00072	0.00202	35.5	0.00069	0.00186	47.6	0.00043	0.00076	32.9	0.00027	0.00032
62.9	0.00110	0.00443	59.0	0.00104	0.00402	76.2	0.00065	0.00165	50.3	0.00041	0.00068
87.6	0.00147	0.00770	82.7	0.00139	0.00690	105.1	0.00087	0.00285	68.0	0.00054	0.00118
112.3	0.00184	0.01170	106.6	0.00174	0.01050	134.4	0.00109	0.00435	85.6	0.00068	0.00179
136.7	0.00222	0.01630	130.4	0.00209	0.01470	163.1	0.00130	0.00611	103.7	0.00082	0.00254
160.7	0.00259	0.02160	153.8	0.00245	0.01960	190.0	0.00152	0.00816	121.8	0.00095	0.00340
182.9	0.00296	0.02750	176.0	0.00280	0.02490	211.8	0.00174	0.01040	139.5	0.00109	0.00439
202.1	0.00333	0.03390	196.0	0.00315	0.03070	228.4	0.00195	0.01300	157.0	0.00123	0.00550
217.5	0.00371	0.04080	212.6	0.00350	0.03700	241.0	0.00217	0.01570	174.2	0.00136	0.00668
229.5	0.00408	0.04810	225.9	0.00385	0.04360	250.1	0.00239	0.01870	189.8	0.00150	0.00798
238.9	0.00445	0.05600	236.2	0.00421	0.05070	257.4	0.00261	0.02190	203.5	0.00164	0.00940
246.1	0.00483	0.06410	244.5	0.00456	0.05820	263.4	0.00283	0.02530	217.0	0.00180	0.01110
252.4	0.00519	0.07260	251.3	0.00491	0.06600	268.6	0.00304	0.02880	226.2	0.00194	0.01280
257.6	0.00557	0.08160	256.6	0.00527	0.07430	273.2	0.00326	0.03260	233.8	0.00207	0.01450
262.1	0.00594	0.09100	261.6	0.00561	0.08270	276.2	0.00348	0.03650	240.2	0.00221	0.01630
265.6	0.00632	0.10100	265.8	0.00597	0.09160	278.8	0.00370	0.04060	245.6	0.00235	0.01810
268.6	0.00669	0.11100	269.0	0.00632	0.10100	281.2	0.00391	0.04480	250.1	0.00248	0.02010
271.2	0.00706	0.12100	271.8	0.00667	0.11000	283.3	0.00413	0.04920	254.1	0.00262	0.02210
273.5	0.00743	0.13200	274.3	0.00703	0.12000	285.3	0.00435	0.05370	257.7	0.00276	0.02420
275.4	0.00781	0.14400	276.5	0.00738	0.13100	286.9	0.00457	0.05840	257.6	0.00282	0.02520
277.0	0.00818	0.15600	278.5	0.00773	0.14200	288.5	0.00478	0.06320	262.2	0.00296	0.02750
278.7	0.00855	0.16800	280.1	0.00808	0.15300	290.1	0.00500	0.06810	268.1	0.00323	0.03210
280.1	0.00892	0.18100	281.6	0.00843	0.16400	291.4	0.00522	0.07320	270.2	0.00337	0.03450
281.3	0.00930	0.19500	282.9	0.00879	0.17700	292.5	0.00544	0.07840	271.4	0.00351	0.03700
282.3	0.00967	0.21000	284.2	0.00914	0.18900	293.3	0.00565	0.08370	272.7	0.00364	0.03960
283.2	0.01000	0.22500	285.2	0.00949	0.20200	294.2	0.00587	0.08920	274.1	0.00378	0.04220
284.0	0.01040	0.24100	286.3	0.00984	0.21700	294.7	0.00609	0.09480	275.2	0.00392	0.04490
284.6	0.01080	0.25800	287.0	0.01020	0.23100	295.4	0.00631	0.10100	276.3	0.00405	0.04760
285.3	0.01120	0.27600	287.9	0.01050	0.24700	295.8	0.00653	0.10600	277.6	0.00419	0.05040
285.7	0.01150	0.29500	288.5	0.01090	0.26300	296.3	0.00674	0.11200	278.6	0.00433	0.05330
286.2	0.01190	0.31600	289.2	0.01120	0.28100	296.7	0.00696	0.11900	279.6	0.00447	0.05620
286.5	0.01230	0.33700	289.4	0.01160	0.29900	296.9	0.00718	0.12500	280.6	0.00460	0.05920
286.8	0.01270	0.36100	289.9	0.01200	0.31800	297.0	0.00740	0.13100	281.4	0.00474	0.06210
287.1	0.01300	0.38500	290.3	0.01230	0.33900	297.0	0.00761	0.13800	285.4	0.00506	0.06950
287.4	0.01340	0.41100	290.6	0.01270	0.36100	296.9	0.00783	0.14500	289.2	0.00555	0.08110
287.5	0.01380	0.44000	290.9	0.01300	0.38400	296.9	0.00805	0.15200	293.4	0.00625	0.09890
286.5	0.01410	0.47000	291.0	0.01340	0.40900	296.7	0.00826	0.15900	294.8	0.00700	0.12000

Table C-3. 3-point Bend Test Results by Specimen Number (cont.)

L5CR-01-325			L5CR-02-325			L5CR-22-325		
L	1	inch	L	1	inch	L	1	inch
W	0.743	inch	W	0.745	inch	W	0.745	inch
t	0.058	inch	t	0.057	inch	t	0.057	inch
Load (Lbs.)	dt/L^2	Strain (in/in)	Load (Lbs.)	dt/L^2	Strain (in/in)	Load (Lbs.)	dt/L^2	Strain (in/in)
0	0	0	0	0	0	0	0	0
9.0	0.00017	0.00014	9.1	0.00017	0.00013	8.5	0.00018	0.00016
20.8	0.00034	0.00050	22.3	0.00034	0.00049	23.0	0.00036	0.00055
34.4	0.00052	0.00109	38.6	0.00051	0.00105	40.6	0.00055	0.00119
51.4	0.00069	0.00187	56.8	0.00068	0.00181	59.7	0.00073	0.00205
70.3	0.00087	0.00287	75.8	0.00085	0.00275	79.8	0.00091	0.00313
89.4	0.00104	0.00402	94.9	0.00102	0.00390	99.4	0.00109	0.00442
108.8	0.00121	0.00537	113.4	0.00120	0.00522	119.0	0.00128	0.00589
127.5	0.00139	0.00692	131.9	0.00137	0.00670	138.1	0.00146	0.00756
145.8	0.00156	0.00861	149.2	0.00154	0.00834	155.8	0.00164	0.00942
162.4	0.00174	0.01048	164.9	0.00171	0.01015	171.2	0.00183	0.01145
176.7	0.00191	0.01248	177.8	0.00188	0.01210	183.2	0.00201	0.01363
188.0	0.00209	0.01464	188.4	0.00205	0.01420	193.0	0.00219	0.01597
197.0	0.00226	0.01694	196.6	0.00222	0.01643	200.7	0.00237	0.01850
204.2	0.00244	0.01939	203.3	0.00239	0.01877	207.0	0.00256	0.02113
210.1	0.00261	0.02196	209.1	0.00257	0.02128	212.4	0.00274	0.02391
215.2	0.00279	0.02467	213.8	0.00274	0.02388	216.1	0.00292	0.02683
219.3	0.00296	0.02745	217.6	0.00291	0.02662	219.3	0.00310	0.02986
222.7	0.00313	0.03038	220.7	0.00308	0.02949	222.1	0.00329	0.03305
225.5	0.00331	0.03342	223.2	0.00325	0.03245	224.3	0.00347	0.03636
227.8	0.00348	0.03659	225.4	0.00342	0.03549	226.3	0.00365	0.03973
229.9	0.00366	0.03981	227.3	0.00359	0.03864	227.7	0.00384	0.04326
231.7	0.00383	0.04316	229.0	0.00377	0.04195	229.2	0.00402	0.04685
233.1	0.00401	0.04666	230.5	0.00394	0.04528	230.4	0.00420	0.05063
234.5	0.00418	0.05016	231.7	0.00411	0.04872	231.5	0.00438	0.05444
235.7	0.00435	0.05382	232.7	0.00428	0.05226	232.6	0.00457	0.05838
236.8	0.00453	0.05756	233.9	0.00445	0.05590	233.3	0.00475	0.06233
237.8	0.00470	0.06138	234.7	0.00462	0.05965	234.2	0.00493	0.06652
238.7	0.00488	0.06527	235.6	0.00479	0.06340	234.9	0.00511	0.07073
239.6	0.00505	0.06928	236.4	0.00496	0.06726	235.4	0.00530	0.07502
240.3	0.00522	0.07330	237.0	0.00514	0.07124	235.9	0.00548	0.07944
240.9	0.00540	0.07750	237.7	0.00531	0.07531	236.5	0.00566	0.08391
241.2	0.00557	0.08175	238.1	0.00548	0.07940	236.8	0.00585	0.08854
241.8	0.00575	0.08608	238.7	0.00565	0.08361	237.2	0.00603	0.09323
242.3	0.00592	0.09049	239.3	0.00582	0.08796	237.4	0.00621	0.09796
242.7	0.00610	0.09497	239.6	0.00599	0.09229	237.6	0.00639	0.10282
243.1	0.00627	0.09957	240.0	0.00617	0.09677	238.1	0.00658	0.10783
243.2	0.00645	0.10425	240.2	0.00634	0.10126	238.2	0.00676	0.11287
243.4	0.00662	0.10903	240.7	0.00651	0.10590	238.5	0.00694	0.11803

Table C-3. 3-point Bend Test Results by Specimen Number (cont.)

L5CR-27-325			L5CR-29-325		
L	1	inch	L	1	inch
W	0.745	inch	W	0.745	inch
t	0.057	inch	t	0.057	inch
Load (Lbs.)	dt/L^2	Strain (in/in)	Load (Lbs.)	dt/L^2	Strain (in/in)
0	0	0	0	0	0
8.1	0.00017	0.00014	2.6	0.00018	0.00015
18.9	0.00034	0.00050	7.9	0.00036	0.00056
31.0	0.00052	0.00107	16.7	0.00055	0.00119
46.7	0.00069	0.00187	27.0	0.00073	0.00205
64.3	0.00086	0.00283	38.9	0.00091	0.00313
82.5	0.00104	0.00400	52.5	0.00109	0.00442
100.8	0.00121	0.00534	68.7	0.00128	0.00590
118.8	0.00138	0.00685	86.8	0.00146	0.00756
136.3	0.00156	0.00853	105.3	0.00164	0.00941
152.3	0.00173	0.01037	123.6	0.00182	0.01143
166.6	0.00190	0.01236	140.9	0.00201	0.01364
178.2	0.00208	0.01451	156.9	0.00219	0.01597
187.4	0.00225	0.01678	170.6	0.00237	0.01847
195.0	0.00242	0.01921	181.5	0.00256	0.02113
201.2	0.00259	0.02171	190.1	0.00274	0.02391
206.6	0.00277	0.02439	197.5	0.00292	0.02682
210.4	0.00294	0.02717	203.4	0.00310	0.02989
213.8	0.00312	0.03010	208.0	0.00329	0.03305
216.6	0.00329	0.03308	211.7	0.00347	0.03635
219.0	0.00346	0.03620	214.7	0.00365	0.03977
221.0	0.00363	0.03941	217.3	0.00383	0.04325
222.6	0.00381	0.04276	219.5	0.00402	0.04689
224.0	0.00398	0.04619	221.3	0.00420	0.05059
225.6	0.00415	0.04964	223.0	0.00438	0.05440
226.7	0.00433	0.05328	224.4	0.00457	0.05834
227.9	0.00450	0.05697	225.6	0.00475	0.06241
228.8	0.00467	0.06074	226.8	0.00493	0.06648
229.6	0.00485	0.06465	227.6	0.00511	0.07069
230.4	0.00502	0.06860	228.5	0.00530	0.07502
231.2	0.00519	0.07261	229.3	0.00548	0.07940
231.8	0.00537	0.07675	229.8	0.00566	0.08393
232.5	0.00554	0.08091	230.6	0.00585	0.08851
232.9	0.00571	0.08523	230.9	0.00603	0.09319
233.4	0.00589	0.08962	231.5	0.00621	0.09793
233.7	0.00606	0.09402	231.7	0.00639	0.10282
234.2	0.00623	0.09858	232.0	0.00657	0.10773
234.5	0.00641	0.10320	232.1	0.00676	0.11287
234.6	0.00658	0.10790	232.3	0.00694	0.11800

Table C-3. 3-point Bend Test Results by Specimen Number (cont.)

L5MCR-01-325			L5MCR-02-325			L5MCR-03-325		
L	1	inch	L	1	inch	L	1	inch
W	0.745	inch	W	0.745	inch	W	0.745	inch
t	0.058	inch	t	0.058	inch	t	0.057	inch
Load (Lbs.)	dt/L^2	Strain (in/in)	Load (Lbs.)	dt/L^2	Strain (in/in)	Load (Lbs.)	dt/L^2	Strain (in/in)
0	0	0	0	0	0	0	0	0
8.7	0.00016	0.00013	7.9	0.00016	0.00013	8.5	0.00014	0.00010
19.7	0.00032	0.00044	18.6	0.00033	0.00046	18.3	0.00029	0.00037
32.6	0.00048	0.00094	31.5	0.00049	0.00097	30.6	0.00044	0.00078
48.9	0.00064	0.00161	48.0	0.00066	0.00168	44.6	0.00058	0.00134
66.0	0.00080	0.00246	65.8	0.00082	0.00257	60.6	0.00073	0.00206
83.5	0.00096	0.00348	83.9	0.00099	0.00363	76.4	0.00088	0.00290
100.9	0.00112	0.00464	102.2	0.00115	0.00484	92.8	0.00102	0.00389
118.2	0.00128	0.00596	120.5	0.00131	0.00622	108.8	0.00117	0.00499
135.3	0.00145	0.00744	138.0	0.00148	0.00775	124.8	0.00131	0.00623
151.6	0.00161	0.00906	154.6	0.00165	0.00946	140.4	0.00146	0.00759
166.0	0.00177	0.01077	169.3	0.00181	0.01125	154.6	0.00161	0.00907
178.5	0.00193	0.01265	181.5	0.00197	0.01321	167.9	0.00176	0.01066
188.6	0.00209	0.01464	191.3	0.00214	0.01528	178.5	0.00190	0.01235
196.7	0.00225	0.01676	199.2	0.00230	0.01750	187.9	0.00205	0.01415
203.1	0.00241	0.01900	205.5	0.00247	0.01984	194.8	0.00220	0.01606
208.6	0.00257	0.02136	210.8	0.00263	0.02225	201.1	0.00234	0.01803
213.2	0.00273	0.02381	215.5	0.00280	0.02483	205.7	0.00249	0.02013
217.0	0.00289	0.02638	219.1	0.00296	0.02750	210.5	0.00263	0.02232
220.2	0.00305	0.02903	222.0	0.00312	0.03021	214.0	0.00278	0.02460
222.9	0.00321	0.03177	224.6	0.00329	0.03313	217.2	0.00293	0.02694
225.2	0.00337	0.03462	226.9	0.00345	0.03605	219.8	0.00307	0.02937
227.3	0.00354	0.03758	228.9	0.00362	0.03911	222.6	0.00322	0.03188
229.1	0.00370	0.04060	230.7	0.00378	0.04227	224.3	0.00337	0.03450
230.6	0.00386	0.04370	232.4	0.00395	0.04550	226.3	0.00352	0.03718
232.2	0.00402	0.04688	233.6	0.00411	0.04883	227.8	0.00366	0.03993
233.4	0.00418	0.05018	234.8	0.00428	0.05221	229.1	0.00381	0.04274
234.5	0.00434	0.05352	236.0	0.00444	0.05570	230.2	0.00395	0.04561
235.6	0.00450	0.05693	236.8	0.00461	0.05928	231.5	0.00410	0.04859
236.4	0.00466	0.06044	237.7	0.00477	0.06290	232.6	0.00425	0.05158
237.3	0.00482	0.06405	238.4	0.00494	0.06662	233.7	0.00439	0.05468
237.8	0.00498	0.06769	239.2	0.00510	0.07043	234.2	0.00454	0.05781
238.4	0.00514	0.07141	239.8	0.00527	0.07428	235.3	0.00469	0.06101
238.9	0.00530	0.07521	240.1	0.00543	0.07823	235.7	0.00483	0.06428
239.3	0.00546	0.07906	240.8	0.00559	0.08225	236.4	0.00498	0.06758
239.7	0.00563	0.08301	241.0	0.00576	0.08639	236.6	0.00513	0.07102
240.1	0.00579	0.08708	241.5	0.00593	0.09056	237.2	0.00527	0.07444
240.1	0.00595	0.09108	242.0	0.00609	0.09481	237.3	0.00542	0.07796
240.3	0.00611	0.09527	242.5	0.00625	0.09908	237.5	0.00557	0.08154

Table C-3. 3-point Bend Test Results by Specimen Number (cont.)

L5MCR-04-325			L5MCR-13-325			L5MCR-17-325		
L	1	inch	L	1	inch	L	1	inch
W	0.745	inch	W	0.746	inch	W	0.745	inch
t	0.057	inch	t	0.056	inch	t	0.057	inch
Load (Lbs.)	dt/L^2	Strain (in/in)	Load (Lbs.)	dt/L^2	Strain (in/in)	Load (Lbs.)	dt/L^2	Strain (in/in)
0	0	0	0	0	0	0	0	0
9.4	0.00017	0.00014	9.0	0.00018	0.00015	7.6	0.00017	0.00014
23.6	0.00035	0.00052	21.7	0.00036	0.00054	19.3	0.00035	0.00052
40.0	0.00053	0.00112	38.2	0.00053	0.00115	33.3	0.00053	0.00112
59.5	0.00070	0.00193	55.7	0.00072	0.00199	51.2	0.00071	0.00194
78.8	0.00088	0.00295	73.6	0.00089	0.00302	70.6	0.00088	0.00293
98.5	0.00106	0.00415	91.4	0.00107	0.00426	91.0	0.00106	0.00415
117.9	0.00124	0.00555	109.0	0.00125	0.00570	110.9	0.00124	0.00556
136.9	0.00141	0.00713	126.5	0.00143	0.00733	130.7	0.00141	0.00712
154.7	0.00159	0.00888	142.7	0.00161	0.00909	149.6	0.00159	0.00888
169.9	0.00177	0.01079	157.1	0.00179	0.01107	166.3	0.00177	0.01078
182.4	0.00195	0.01288	168.7	0.00197	0.01319	180.9	0.00194	0.01285
192.0	0.00212	0.01506	177.9	0.00215	0.01547	192.0	0.00212	0.01508
199.6	0.00230	0.01744	185.4	0.00233	0.01789	200.9	0.00230	0.01743
205.7	0.00248	0.01995	191.7	0.00251	0.02045	207.9	0.00247	0.01994
211.1	0.00265	0.02261	196.6	0.00269	0.02315	214.0	0.00265	0.02257
215.2	0.00283	0.02535	200.3	0.00287	0.02601	219.3	0.00283	0.02538
218.5	0.00301	0.02823	203.5	0.00305	0.02893	223.0	0.00301	0.02824
221.4	0.00318	0.03123	205.8	0.00323	0.03205	226.6	0.00318	0.03123
223.8	0.00336	0.03436	208.1	0.00341	0.03522	228.9	0.00336	0.03438
226.1	0.00354	0.03760	209.9	0.00359	0.03853	231.3	0.00354	0.03758
227.9	0.00372	0.04096	211.7	0.00377	0.04196	233.4	0.00371	0.04091
229.6	0.00389	0.04437	213.0	0.00395	0.04546	234.8	0.00389	0.04436
231.0	0.00407	0.04792	214.3	0.00413	0.04906	236.4	0.00407	0.04792
232.1	0.00425	0.05157	215.5	0.00431	0.05282	237.6	0.00424	0.05153
233.4	0.00442	0.05527	216.5	0.00449	0.05663	238.7	0.00442	0.05529
234.3	0.00460	0.05912	217.4	0.00467	0.06054	240.0	0.00460	0.05910
235.3	0.00478	0.06304	218.0	0.00484	0.06452	240.6	0.00478	0.06303
236.0	0.00495	0.06704	218.8	0.00502	0.06864	241.6	0.00495	0.06704
236.7	0.00513	0.07110	219.3	0.00520	0.07282	242.5	0.00513	0.07110
237.3	0.00531	0.07529	220.0	0.00538	0.07713	242.7	0.00531	0.07527
237.8	0.00549	0.07957	220.5	0.00556	0.08146	243.6	0.00549	0.07959
238.4	0.00566	0.08393	220.8	0.00574	0.08595	243.9	0.00566	0.08395
238.7	0.00584	0.08840	221.3	0.00592	0.09045	244.4	0.00584	0.08836
239.3	0.00602	0.09290	221.6	0.00610	0.09510	244.8	0.00602	0.09287
239.7	0.00619	0.09752	222.4	0.00628	0.09982	245.0	0.00620	0.09755
240.0	0.00637	0.10219	222.6	0.00646	0.10464	245.5	0.00637	0.10224
240.2	0.00655	0.10702	222.6	0.00664	0.10955	245.6	0.00655	0.10704
240.3	0.00673	0.11192	222.6	0.00682	0.11458			

Table C-3. 3-point Bend Test Results by Specimen Number (cont.)

L5MCR-20-325			L5MCR-28-325		
L	1	inch	L	1	inch
W	0.745	inch	W	0.746	inch
t	0.058	inch	t	0.057	inch
Load (Lbs.)	dt/L^2	Strain (in/in)	Load (Lbs.)	dt/L^2	Strain (in/in)
0	0	0	0	0	0
9.0	0.00018	0.00015	8.4	0.00018	0.00015
21.3	0.00036	0.00055	22.2	0.00036	0.00055
36.4	0.00055	0.00120	38.1	0.00054	0.00117
55.6	0.00073	0.00207	57.3	0.00072	0.00201
75.7	0.00092	0.00317	77.2	0.00090	0.00306
96.0	0.00110	0.00445	97.2	0.00108	0.00432
115.9	0.00128	0.00596	116.8	0.00126	0.00577
135.5	0.00147	0.00767	136.0	0.00144	0.00741
153.8	0.00165	0.00951	153.9	0.00162	0.00923
169.9	0.00183	0.01155	169.6	0.00181	0.01123
182.8	0.00202	0.01377	182.1	0.00199	0.01337
193.2	0.00220	0.01614	191.9	0.00217	0.01567
201.2	0.00239	0.01866	199.7	0.00235	0.01813
207.7	0.00257	0.02135	206.2	0.00253	0.02074
213.2	0.00276	0.02419	211.6	0.00271	0.02348
217.5	0.00294	0.02712	215.9	0.00289	0.02633
221.0	0.00312	0.03020	219.3	0.00307	0.02931
223.9	0.00331	0.03342	222.1	0.00325	0.03246
226.3	0.00349	0.03677	224.3	0.00343	0.03568
228.5	0.00368	0.04021	226.4	0.00362	0.03905
230.3	0.00386	0.04375	228.2	0.00379	0.04245
231.8	0.00404	0.04740	229.7	0.00398	0.04603
233.4	0.00423	0.05120	231.1	0.00416	0.04970
234.6	0.00441	0.05507	232.3	0.00434	0.05346
235.8	0.00460	0.05905	233.4	0.00452	0.05732
236.8	0.00478	0.06308	234.2	0.00470	0.06126
237.5	0.00496	0.06724	235.3	0.00488	0.06534
238.6	0.00515	0.07151	236.1	0.00506	0.06948
239.3	0.00533	0.07586	236.7	0.00524	0.07370
239.7	0.00552	0.08031	237.3	0.00542	0.07805
240.4	0.00570	0.08484	237.9	0.00560	0.08244
240.8	0.00588	0.08950	238.4	0.00578	0.08698
241.1	0.00607	0.09425	238.7	0.00597	0.09157
241.5	0.00625	0.09901	239.2	0.00615	0.09629
241.7	0.00644	0.10396	239.5	0.00633	0.10105
241.9	0.00662	0.10898	239.8	0.00651	0.10593
242.0	0.00680	0.11411	240.1	0.00669	0.11088
242.1	0.00699	0.11931	240.4	0.00687	0.11593

Table C-3. 3-point Bend Test Results by Specimen Number (cont.)

L5HR-01-325			L5HR-02-325			L5HR-03-325		
L	1	inch	L	1	inch	L	1	inch
W	0.745	inch	W	0.746	inch	W	0.746	inch
t	0.062	inch	t	0.06	inch	t	0.06	inch
Load (Lbs.)	dt/L^2	Strain (in/in)	Load (Lbs.)	dt/L^2	Strain (in/in)	Load (Lbs.)	dt/L^2	Strain (in/in)
9.3	0.0002	0.0001	8.4	0.0002	0.0001	9.0	0.0002	0.0001
22.3	0.0003	0.0004	21.7	0.0003	0.0004	21.0	0.0003	0.0005
38.0	0.0005	0.0009	36.6	0.0005	0.0009	36.7	0.0005	0.0010
56.7	0.0006	0.0015	53.8	0.0007	0.0015	55.0	0.0007	0.0017
76.3	0.0008	0.0023	72.2	0.0008	0.0024	73.7	0.0008	0.0026
95.9	0.0009	0.0033	91.0	0.0010	0.0033	92.5	0.0010	0.0036
115.5	0.0011	0.0044	109.9	0.0011	0.0044	111.2	0.0011	0.0048
134.8	0.0013	0.0057	128.4	0.0013	0.0057	129.8	0.0013	0.0062
153.7	0.0014	0.0071	146.2	0.0015	0.0071	148.0	0.0015	0.0077
171.7	0.0016	0.0087	163.4	0.0016	0.0087	165.2	0.0016	0.0094
188.1	0.0017	0.0103	178.4	0.0018	0.0103	180.6	0.0018	0.0112
202.2	0.0019	0.0121	190.8	0.0020	0.0121	193.2	0.0020	0.0132
214.0	0.0020	0.0141	200.8	0.0021	0.0141	203.5	0.0021	0.0152
223.5	0.0022	0.0161	208.5	0.0023	0.0161	211.6	0.0023	0.0175
230.8	0.0024	0.0182	215.1	0.0025	0.0183	218.3	0.0025	0.0197
237.0	0.0025	0.0205	220.3	0.0026	0.0205	223.7	0.0026	0.0222
242.1	0.0027	0.0229	224.9	0.0028	0.0229	228.5	0.0028	0.0247
246.8	0.0028	0.0253	229.0	0.0030	0.0254	232.9	0.0030	0.0274
251.0	0.0030	0.0279	232.3	0.0031	0.0279	236.2	0.0031	0.0301
254.5	0.0031	0.0305	235.1	0.0033	0.0306	239.3	0.0033	0.0330
257.2	0.0033	0.0333	237.5	0.0034	0.0333	241.6	0.0034	0.0359
259.7	0.0035	0.0361	239.8	0.0036	0.0361	243.9	0.0036	0.0390
262.0	0.0036	0.0390	241.7	0.0038	0.0391	245.8	0.0038	0.0421
264.0	0.0038	0.0421	243.3	0.0039	0.0421	247.8	0.0039	0.0453
265.8	0.0039	0.0452	244.8	0.0041	0.0452	249.3	0.0041	0.0486
267.4	0.0041	0.0483	246.4	0.0043	0.0483	250.6	0.0043	0.0520
268.9	0.0042	0.0515	247.4	0.0044	0.0516	251.9	0.0044	0.0555
270.2	0.0044	0.0548	248.4	0.0046	0.0549	253.1	0.0046	0.0591
271.6	0.0046	0.0582	249.6	0.0048	0.0583	254.2	0.0048	0.0627
272.9	0.0047	0.0617	250.5	0.0049	0.0617	255.2	0.0049	0.0664
273.6	0.0049	0.0652	251.3	0.0051	0.0652	256.1	0.0051	0.0702
274.4	0.0050	0.0688	252.1	0.0053	0.0688	257.0	0.0053	0.0741
275.2	0.0052	0.0724	252.7	0.0054	0.0725	257.8	0.0054	0.0780
275.9	0.0053	0.0762	253.5	0.0056	0.0763	258.7	0.0056	0.0820
276.3	0.0055	0.0800	254.1	0.0058	0.0800	259.2	0.0057	0.0861
276.8	0.0057	0.0839	254.7	0.0059	0.0840	259.9	0.0059	0.0902
277.3	0.0058	0.0878	255.0	0.0061	0.0879	260.4	0.0061	0.0945
277.1	0.0060	0.0918	255.0	0.0062	0.0919	261.0	0.0062	0.0988

Table C-3. 3-point Bend Test Results by Specimen Number (cont.)

L5HR-04-325			L5HR-09-325			L5HR-11-325		
L	1	inch	L	0.8	inch	L	0.8	inch
W	0.744	inch	W	0.748	inch	W	0.747	inch
t	0.06	inch	t	0.0575	inch	t	0.059	inch
Load (Lbs.)	dt/L^2	Strain (in/in)	Load (Lbs.)	dt/L^2	Strain (in/in)	Load (Lbs.)	dt/L^2	Strain (in/in)
8.4	0.0002	0.0001	8.9	0.0002	0.0002	8.9	0.0002	0.0002
19.9	0.0003	0.0005	26.4	0.0004	0.0007	21.9	0.0004	0.0006
34.1	0.0005	0.0011	47.4	0.0006	0.0015	39.6	0.0005	0.0012
51.4	0.0007	0.0019	72.3	0.0008	0.0026	62.6	0.0007	0.0020
70.9	0.0009	0.0028	100.0	0.0010	0.0039	87.2	0.0009	0.0031
90.6	0.0010	0.0040	127.8	0.0012	0.0054	112.3	0.0011	0.0044
110.3	0.0012	0.0053	156.1	0.0014	0.0072	137.7	0.0013	0.0058
129.7	0.0014	0.0068	183.1	0.0017	0.0092	162.7	0.0015	0.0074
148.4	0.0016	0.0085	208.2	0.0019	0.0114	186.9	0.0017	0.0092
165.9	0.0017	0.0103	228.9	0.0021	0.0138	209.2	0.0018	0.0112
181.2	0.0019	0.0123	245.0	0.0023	0.0163	228.4	0.0020	0.0133
193.7	0.0021	0.0144	257.2	0.0025	0.0190	244.2	0.0022	0.0155
203.6	0.0022	0.0167	266.5	0.0027	0.0218	256.3	0.0024	0.0178
211.1	0.0024	0.0190	273.9	0.0029	0.0249	265.8	0.0026	0.0203
217.7	0.0026	0.0216	279.5	0.0031	0.0280	273.5	0.0028	0.0229
222.9	0.0028	0.0242	284.0	0.0033	0.0312	279.4	0.0029	0.0256
227.6	0.0029	0.0270	288.0	0.0035	0.0345	284.2	0.0031	0.0284
231.4	0.0031	0.0299	291.1	0.0037	0.0380	288.3	0.0033	0.0313
234.6	0.0033	0.0328	294.2	0.0039	0.0416	291.8	0.0035	0.0343
237.2	0.0034	0.0359	297.0	0.0041	0.0453	294.8	0.0037	0.0374
239.7	0.0036	0.0391	299.8	0.0043	0.0491	297.4	0.0039	0.0406
241.8	0.0038	0.0424	301.9	0.0046	0.0530	300.0	0.0041	0.0438
243.7	0.0040	0.0458	303.9	0.0048	0.0570	302.5	0.0042	0.0472
245.4	0.0041	0.0493	305.5	0.0050	0.0611	304.5	0.0044	0.0506
247.1	0.0043	0.0528	306.9	0.0052	0.0653	306.4	0.0046	0.0541
248.5	0.0045	0.0565	308.4	0.0054	0.0696	308.0	0.0048	0.0577
249.8	0.0047	0.0603	309.6	0.0056	0.0738	309.5	0.0050	0.0613
251.1	0.0048	0.0641	310.8	0.0058	0.0784	310.8	0.0052	0.0650
252.1	0.0050	0.0680	312.0	0.0060	0.0829	312.2	0.0053	0.0688
252.9	0.0052	0.0720	312.9	0.0062	0.0876	313.3	0.0055	0.0728
253.8	0.0053	0.0761	313.6	0.0064	0.0924	314.2	0.0057	0.0767
254.8	0.0055	0.0803	314.2	0.0066	0.0974	315.3	0.0059	0.0807
255.6	0.0057	0.0845	314.9	0.0068	0.1024	316.1	0.0061	0.0849
256.3	0.0059	0.0888	315.2	0.0070	0.1075	316.7	0.0063	0.0891
257.0	0.0060	0.0933	315.8	0.0072	0.1128	317.4	0.0065	0.0933
257.6	0.0062	0.0978	315.9	0.0074	0.1182	318.2	0.0066	0.0979
258.2	0.0064	0.1023	316.3	0.0077	0.1239	318.6	0.0068	0.1023
258.8	0.0065	0.1071	316.2	0.0079	0.1297	319.2	0.0070	0.1069

Table C-3. 3-point Bend Test Results by Specimen Number (cont.)

L5HR-12-325			L5HR-13-325			L5HR-14-325		
L	0.8	inch	L	0.8	inch	L	0.8	inch
W	0.747	inch	W	0.746	inch	W	0.746	inch
t	0.059	inch	t	0.059	inch	t	0.059	inch
Load (Lbs.)	dt/L^2	Strain (in/in)	Load (Lbs.)	dt/L^2	Strain (in/in)	Load (Lbs.)	dt/L^2	Strain (in/in)
9.9	0.0002	0.0001	10.1	0.0002	0.0002	10.4	0.0002	0.0001
25.7	0.0003	0.0005	23.9	0.0004	0.0006	25.4	0.0003	0.0005
45.5	0.0005	0.0011	44.3	0.0005	0.0012	45.2	0.0005	0.0010
69.3	0.0007	0.0019	68.6	0.0007	0.0020	68.4	0.0007	0.0017
94.5	0.0009	0.0029	93.8	0.0009	0.0030	92.5	0.0008	0.0026
120.7	0.0011	0.0041	119.3	0.0011	0.0043	116.6	0.0010	0.0037
147.3	0.0012	0.0055	144.7	0.0013	0.0057	140.9	0.0012	0.0049
173.1	0.0014	0.0070	169.2	0.0014	0.0072	165.2	0.0013	0.0064
198.1	0.0016	0.0087	193.5	0.0016	0.0090	188.8	0.0015	0.0079
221.0	0.0018	0.0105	215.9	0.0018	0.0108	211.3	0.0017	0.0095
241.1	0.0020	0.0124	235.1	0.0020	0.0129	230.9	0.0019	0.0113
257.0	0.0021	0.0146	250.6	0.0022	0.0150	247.3	0.0020	0.0133
269.0	0.0023	0.0168	262.7	0.0024	0.0173	260.3	0.0022	0.0153
278.7	0.0025	0.0191	272.1	0.0025	0.0198	270.6	0.0024	0.0174
286.4	0.0027	0.0215	279.8	0.0027	0.0223	278.9	0.0025	0.0196
292.3	0.0028	0.0241	285.9	0.0029	0.0249	285.6	0.0027	0.0221
297.5	0.0030	0.0268	290.7	0.0031	0.0277	291.0	0.0029	0.0244
301.7	0.0032	0.0296	294.9	0.0033	0.0304	295.4	0.0030	0.0270
304.8	0.0034	0.0324	298.4	0.0034	0.0334	299.3	0.0032	0.0296
307.9	0.0036	0.0353	301.4	0.0036	0.0364	302.5	0.0034	0.0323
310.6	0.0037	0.0383	304.1	0.0038	0.0395	305.1	0.0035	0.0351
313.0	0.0039	0.0414	306.7	0.0040	0.0427	307.7	0.0037	0.0379
315.3	0.0041	0.0447	309.0	0.0042	0.0460	310.0	0.0039	0.0408
317.8	0.0043	0.0479	311.3	0.0044	0.0492	312.2	0.0041	0.0439
319.9	0.0045	0.0512	313.1	0.0045	0.0527	314.4	0.0042	0.0469
321.7	0.0046	0.0546	314.6	0.0047	0.0562	316.3	0.0044	0.0501
323.4	0.0048	0.0580	316.0	0.0049	0.0597	317.8	0.0046	0.0533
324.7	0.0050	0.0616	317.4	0.0051	0.0634	319.3	0.0047	0.0565
326.0	0.0052	0.0652	318.7	0.0053	0.0671	320.7	0.0049	0.0598
327.5	0.0054	0.0689	319.8	0.0054	0.0708	321.9	0.0051	0.0632
328.6	0.0055	0.0726	320.9	0.0056	0.0747	323.0	0.0052	0.0667
329.5	0.0057	0.0765	321.8	0.0058	0.0786	324.1	0.0054	0.0702
330.3	0.0059	0.0803	322.7	0.0060	0.0827	325.2	0.0056	0.0737
331.2	0.0061	0.0843	323.5	0.0062	0.0868	326.0	0.0058	0.0774
332.1	0.0062	0.0883	324.2	0.0064	0.0909	327.1	0.0059	0.0811
332.6	0.0064	0.0925	324.9	0.0065	0.0952	327.9	0.0061	0.0848
333.3	0.0066	0.0968	325.4	0.0067	0.0996	328.5	0.0063	0.0887
333.9	0.0068	0.1010	325.7	0.0069	0.1040	327.7	0.0064	0.0927

Table C-3. 3-point Bend Test Results by Specimen Number (cont.)

L5HR-15-325			L5HR-16-325			L5HR-17-325		
L	0.8	inch	L	0.8	inch	L	1	inch
W	0.747	inch	W	0.747	inch	W	0.745	inch
t	0.059	inch	t	0.059	inch	t	0.059	inch
Load (Lbs.)	dt/L^2	Strain (in/in)	Load (Lbs.)	dt/L^2	Strain (in/in)	Load (Lbs.)	dt/L^2	Strain (in/in)
9.5	0.0002	0.0002	10.6	0.0002	0.0001	10.1	0.0002	0.0001
21.6	0.0004	0.0005	25.6	0.0003	0.0005	24.8	0.0003	0.0005
38.0	0.0005	0.0012	45.1	0.0005	0.0011	43.2	0.0005	0.0011
58.8	0.0007	0.0020	68.3	0.0007	0.0018	63.1	0.0007	0.0018
82.8	0.0009	0.0030	92.6	0.0009	0.0028	83.4	0.0009	0.0028
107.4	0.0011	0.0043	117.6	0.0010	0.0039	103.4	0.0010	0.0039
132.6	0.0013	0.0057	142.7	0.0012	0.0052	123.6	0.0012	0.0052
157.2	0.0014	0.0072	167.5	0.0014	0.0066	143.3	0.0014	0.0067
181.4	0.0016	0.0090	191.6	0.0015	0.0082	162.2	0.0015	0.0084
203.8	0.0018	0.0109	214.4	0.0017	0.0099	178.9	0.0017	0.0102
223.6	0.0020	0.0129	234.4	0.0019	0.0117	193.0	0.0019	0.0121
240.1	0.0022	0.0151	250.9	0.0021	0.0137	204.0	0.0021	0.0142
253.5	0.0024	0.0173	263.9	0.0022	0.0159	212.7	0.0022	0.0164
263.8	0.0025	0.0197	274.3	0.0024	0.0180	219.4	0.0024	0.0188
272.1	0.0027	0.0223	282.7	0.0026	0.0204	225.1	0.0026	0.0213
278.7	0.0029	0.0249	289.1	0.0028	0.0228	230.1	0.0027	0.0240
284.0	0.0031	0.0276	294.7	0.0029	0.0253	234.2	0.0029	0.0267
288.3	0.0033	0.0304	299.1	0.0031	0.0279	237.3	0.0031	0.0295
292.1	0.0034	0.0334	303.0	0.0033	0.0306	240.1	0.0033	0.0325
295.0	0.0036	0.0364	306.1	0.0034	0.0334	242.4	0.0034	0.0355
297.9	0.0038	0.0395	308.6	0.0036	0.0362	244.2	0.0036	0.0387
300.4	0.0040	0.0427	311.3	0.0038	0.0392	245.9	0.0038	0.0420
302.8	0.0042	0.0459	313.6	0.0040	0.0422	247.3	0.0039	0.0453
305.1	0.0044	0.0493	315.9	0.0041	0.0453	248.7	0.0041	0.0488
306.9	0.0045	0.0527	318.1	0.0043	0.0484	249.8	0.0043	0.0523
308.4	0.0047	0.0562	320.2	0.0045	0.0516	250.9	0.0045	0.0559
309.9	0.0049	0.0598	321.6	0.0046	0.0548	252.0	0.0046	0.0597
311.1	0.0051	0.0634	323.0	0.0048	0.0582	252.7	0.0048	0.0635
312.4	0.0053	0.0671	324.4	0.0050	0.0617	253.5	0.0050	0.0673
313.5	0.0054	0.0709	325.4	0.0052	0.0652	253.9	0.0051	0.0714
314.7	0.0056	0.0748	326.6	0.0053	0.0687	254.5	0.0053	0.0754
315.5	0.0058	0.0786	327.6	0.0055	0.0724	255.2	0.0055	0.0796
316.3	0.0060	0.0827	328.5	0.0057	0.0761	255.6	0.0057	0.0837
317.1	0.0062	0.0867	329.4	0.0059	0.0798	256.0	0.0058	0.0880
317.7	0.0064	0.0910	330.1	0.0060	0.0836	256.2	0.0060	0.0924
318.5	0.0065	0.0952	330.7	0.0062	0.0875	256.4	0.0062	0.0968
319.2	0.0067	0.0996	331.4	0.0064	0.0915	256.6	0.0063	0.1014
318.5	0.0069	0.1040				256.7	0.0065	0.1060

Table C-3. 3-point Bend Test Results by Specimen Number (cont.)

L5HR-18-325			L5HR-19-325			L5HR-20-325		
L	1.6	inch	L	1	inch	L	1.6	inch
W	0.746	inch	W	0.745	inch	W	0.746	inch
t	0.06	inch	t	0.06	inch	t	0.059	inch
Load (Lbs.)	dt/L^2	Strain (in/in)	Load (Lbs.)	dt/L^2	Strain (in/in)	Load (Lbs.)	dt/L^2	Strain (in/in)
9.5	0.0002	0.0003	9.1	0.0002	0.0001	9.2	0.0002	0.0003
20.5	0.0003	0.0009	21.5	0.0003	0.0004	20.2	0.0003	0.0008
32.8	0.0005	0.0017	37.9	0.0005	0.0009	32.0	0.0005	0.0016
45.4	0.0007	0.0027	56.2	0.0006	0.0016	44.3	0.0007	0.0027
58.0	0.0008	0.0040	75.3	0.0008	0.0024	56.6	0.0008	0.0039
70.2	0.0010	0.0054	94.4	0.0009	0.0034	68.7	0.0010	0.0053
82.8	0.0012	0.0071	113.2	0.0011	0.0045	81.1	0.0012	0.0070
95.0	0.0014	0.0090	131.9	0.0013	0.0058	92.7	0.0013	0.0088
106.1	0.0015	0.0110	150.0	0.0014	0.0072	103.7	0.0015	0.0108
115.7	0.0017	0.0133	167.3	0.0016	0.0088	113.1	0.0017	0.0130
123.4	0.0019	0.0157	182.7	0.0017	0.0105	120.7	0.0018	0.0154
129.3	0.0020	0.0182	195.6	0.0019	0.0123	126.8	0.0020	0.0178
134.4	0.0022	0.0209	206.0	0.0021	0.0142	131.5	0.0022	0.0205
138.1	0.0024	0.0237	214.4	0.0022	0.0163	135.3	0.0023	0.0233
141.1	0.0025	0.0267	221.1	0.0024	0.0184	138.0	0.0025	0.0262
143.5	0.0027	0.0298	226.8	0.0025	0.0207	140.2	0.0027	0.0292
145.4	0.0029	0.0330	231.8	0.0027	0.0232	142.0	0.0028	0.0324
146.8	0.0030	0.0364	236.1	0.0028	0.0256	143.5	0.0030	0.0356
148.0	0.0032	0.0398	239.3	0.0030	0.0282	144.9	0.0032	0.0390
148.9	0.0034	0.0434	242.2	0.0032	0.0309	145.9	0.0033	0.0425
149.8	0.0035	0.0470	244.4	0.0033	0.0336	146.6	0.0035	0.0461
150.4	0.0037	0.0508	246.6	0.0035	0.0365	147.1	0.0037	0.0498
150.8	0.0039	0.0547	248.3	0.0036	0.0395	147.7	0.0038	0.0536
151.1	0.0041	0.0586	249.9	0.0038	0.0425	148.1	0.0040	0.0575
151.4	0.0042	0.0627	251.3	0.0040	0.0456	148.3	0.0042	0.0615
151.5	0.0044	0.0668	252.7	0.0041	0.0488	148.4	0.0043	0.0655
151.4	0.0046	0.0711	253.6	0.0043	0.0521	148.4	0.0045	0.0697
151.3	0.0047	0.0754	254.7	0.0044	0.0554	148.3	0.0047	0.0739
151.3	0.0049	0.0798	255.6	0.0046	0.0588	148.3	0.0048	0.0782
151.1	0.0051	0.0843	256.4	0.0047	0.0623	148.0	0.0050	0.0826
150.8	0.0052	0.0889	257.2	0.0049	0.0659	148.0	0.0052	0.0872
150.5	0.0054	0.0936	257.8	0.0051	0.0695	147.7	0.0053	0.0918
150.4	0.0056	0.0984	258.6	0.0052	0.0732	147.4	0.0055	0.0964
150.1	0.0057	0.1032	259.1	0.0054	0.0770	146.9	0.0057	0.1012
149.7	0.0059	0.1082	259.6	0.0055	0.0808	146.4	0.0058	0.1061
149.1	0.0061	0.1133	259.9	0.0057	0.0847	145.9	0.0060	0.1111
148.5	0.0063	0.1184	260.3	0.0059	0.0887	145.5	0.0062	0.1161
147.8	0.0064	0.1238	260.0	0.0060	0.0928	145.0	0.0063	0.1213

Table C-3. 3-point Bend Test Results by Specimen Number (concluded)

L5HR-21-325			L5HR-23-325		
L	1.6	inch	L	1.6	inch
W	0.747	inch	W	0.745	inch
t	0.057	inch	t	0.059	inch
Load (Lbs.)	dt/L^2	Strain (in/in)	Load (Lbs.)	dt/L^2	Strain (in/in)
8.4	0.0002	0.0003	8.9	0.0002	0.0003
18.4	0.0003	0.0008	19.2	0.0003	0.0009
30.0	0.0005	0.0016	31.4	0.0005	0.0017
41.6	0.0007	0.0026	43.4	0.0007	0.0027
53.0	0.0008	0.0038	55.6	0.0008	0.0040
64.8	0.0010	0.0052	67.6	0.0010	0.0054
76.2	0.0011	0.0067	79.4	0.0012	0.0071
87.5	0.0013	0.0085	91.5	0.0013	0.0090
97.9	0.0015	0.0104	102.0	0.0015	0.0110
106.7	0.0016	0.0125	111.3	0.0017	0.0132
114.3	0.0018	0.0148	118.8	0.0019	0.0156
120.0	0.0020	0.0172	124.8	0.0020	0.0181
124.6	0.0021	0.0198	129.3	0.0022	0.0208
128.1	0.0023	0.0225	133.0	0.0024	0.0236
131.0	0.0025	0.0253	135.6	0.0025	0.0266
133.2	0.0026	0.0282	138.1	0.0027	0.0297
135.0	0.0028	0.0312	139.8	0.0029	0.0329
136.6	0.0029	0.0344	141.4	0.0030	0.0362
137.4	0.0031	0.0377	142.7	0.0032	0.0396
138.4	0.0033	0.0411	143.8	0.0034	0.0432
139.3	0.0034	0.0446	144.5	0.0035	0.0468
139.8	0.0036	0.0481	145.5	0.0037	0.0506
140.6	0.0038	0.0518	146.0	0.0039	0.0544
140.8	0.0039	0.0556	146.6	0.0040	0.0583
141.0	0.0041	0.0594	147.2	0.0042	0.0624
141.0	0.0043	0.0633	147.8	0.0044	0.0665
141.2	0.0044	0.0674	147.6	0.0046	0.0707
141.2	0.0046	0.0715	147.8	0.0047	0.0750
141.3	0.0047	0.0757	147.8	0.0049	0.0794
141.0	0.0049	0.0799	147.8	0.0051	0.0839
140.9	0.0051	0.0843	147.8	0.0052	0.0885
140.3	0.0052	0.0887	147.8	0.0054	0.0931
140.0	0.0054	0.0932	147.7	0.0056	0.0979
139.3	0.0056	0.0979	147.4	0.0057	0.1027
138.9	0.0057	0.1026	147.1	0.0059	0.1077
138.7	0.0059	0.1074	146.6	0.0061	0.1127
138.3	0.0061	0.1123	146.1	0.0062	0.1179
137.7	0.0062	0.1173	145.3	0.0064	0.1231

Appendix D. Fracture Test Results

The fracture test results are presented in Tables D-1 to D-8 for the different material lots in terms of the test conditions and the stress intensity factor calculated at the peak load of the test. The measured crack mouth opening displacement and load for each fracture test is provided in Figures D-1 to D-191.

Table D-1. Thermal Aging Fracture Test Results for Lot 400751

ID	Lot	Elevated Temp (^{o}F)	Hold Time (min)	24 Hour Aging Temp (^{o}F)	K at P_{max} (ksi inch$^{1/2}$)
L1P1-07-325	400751	-	-	325	28.0
L1P1-13-325	400751	-	-	325	28.6
L1P2-03-325	400751	-	-	325	26.0
L1P1-04T-325	400751			325	24.9
L1P1-05T-325	400751			325	23.3
L1P1-06T-325	400751			325	25.0
L1P1-07T-325	400751	-	-	325	23.0
L1P1-08T-325	400751	-	-	325	22.1
L1P1-09T-325	400751	-	-	325	25.7
L1P3-15-333	400751	-	-	333	20.4
L1P3-16-333	400751	-	-	333	21.6
L1P3-12-340	400751	-	-	340	22.4
L1P3-13-340	400751	-	-	340	21.1
L1P3-14-340	400751	-	-	340	20.7
L1P1-02-350	400751	-	-	350	19.6
L1P1-08-350	400751	-	-	350	18.9
L1P2-06-350	400751	-	-	350	18.7
L1P2-10-350	400751	-	-	350	19.2
L1P1-04-375	400751	-	-	375	18.0
L1P1-09-375	400751	-	-	375	19.4
L1P1-03-400	400751	-	-	400	24.0
L1P1-10-400	400751	-	-	400	20.9
L1P1-19-400	400751	-	-	400	24.3
L1P1-20-400	400751	-	-	400	23.2

Table D-2. Thermal Aging Fracture Test Results for Lot 400768

ID	Lot	Elevated Temp (^{o}F)	Hold Time (min)	24 Hour Aging Temp (^{o}F)	K at P_{max} (ksi inch$^{1/2}$)
L2P1-07-325	400768	-	-	325	28.6
L2P1-13-325	400768	-	-	325	29.4
L2P1-07T-325	400768	-	-	325	25.0
L2P1-08T-325	400768	-	-	325	25.4
L2P1-09T-325	400768	-	-	325	25.0
L2P3-15-333	400768	-	-	333	22.3
L2P3-16-333	400768	-	-	333	22.3
L2P3-12-340	400768	-	-	340	19.5
L2P3-13-340	400768	-	-	340	20.1
L2P3-14-340	400768	-	-	340	20.9
L2P1-03-350	400768	-	-	350	20.3
L2P1-08-350	400768	-	-	350	20.3
L2P2-03-350	400768	-	-	350	19.6
L2P2-10-350	400768	-	-	350	18.8
L2P1-03-375	400768	-	-	375	21.8
L2P1-09-375	400768	-	-	375	20.2
L2P1-04-400	400768	-	-	400	25.4
L2P1-10-400	400768	-	-	400	25.9

Table D-3. Thermal Aging Fracture Test Results for Lot 400766

ID	Lot	Elevated Temp (^{o}F)	Hold Time (min)	Aging Temp (^{o}F)	K at P_{max} (ksi inch$^{1/2}$)
L3C1-01-325	400766	-	-	325	25.4
L3C1-12-325	400766	-	-	325	23.7
L3C1-23-325	400766	-	-	325	24.5
L3C1-51-325	400766	-	-	325	24.1
L3C1-52-325	400766	-	-	325	24.2
L3C1-53-325	400766	-	-	325	24.3
L3C1-60-325	400766	-	-	325	24.5
L3C1-61-325	400766	-	-	325	25.1
L3C1-67-325	400766	-	-	325	23.1
L3C1-59-325	400766	-	-	325	25.6
L3C1-68-325	400766	-	-	325	22.6
L3C1-75-325	400766	-	-	325	24.9
L3C1-76-325	400766	-	-	325	23.7
L3C1-37-333	400766	-	-	333	21.8
L3C1-32-333	400766	-	-	333	19.1
L3C1-44-333	400766	-	-	333	23.1
L3C1-46-333	400766	-	-	333	24.0
L3C1-48-333	400766	-	-	333	23.6
L3C1-50-333	400766	-	-	333	23.6
L3C1-43-333	400766	-	-	333	22.4
L3C1-45-333	400766	-	-	333	22.6
L3C1-47-333	400766	-	-	333	24.3
L3C1-49-333	400766	-	-	333	22.3
L3C1-26-340	400766	-	-	340	18.9
L3C1-30-340	400766	-	-	340	18.4
L3C1-31-340	400766	-	-	340	19.6
L3C1-29-340	400766	-	-	340	18.2
L3C1-27-340	400766	-	-	340	17.9
L3C1-28-340	400766	-	-	340	17.1
L3C1-34-340	400766	-	-	340	21.9
L3C1-35-340	400766	-	-	340	21.4
L3C1-40-340	400766	-	-	340	21.8
L3C1-33-340	400766	-	-	340	21.6
L3C1-36-340	400766	-	-	340	22.6
L3C1-41-340	400766	-	-	340	21.0
L3C1-42-340	400766	-	-	340	21.0
L3C1-38-340	400766	-	-	340	20.6
L3C1-39-340	400766	-	-	340	22.0
L3C1-02-350	400766	-	-	350	17.4
L3C1-13-350	400766	-	-	350	17.9
L3C1-24-350	400766	-	-	350	17.5
L3C1-03-375	400766	-	-	375	18.3
L3C1-14-375	400766	-	-	375	17.4
L3C1-25-375	400766	-	-	375	18.5

Table D-4. Thermal Aging Fracture Test Results for Lot 620853

LaRC ID	Description	MSFC Designation	Lot	K at P_{max} (ksi inch$^{1/2}$)
S7-01	Stringer7-Sister		620853	17.8
S170-35-01	Stringer-170-35		620853	18.3
S170-35-02	Stringer-170-36		620853	20.1
L5HR-01-325	Cold/Hot Formed (325F for 24 Hrs.)	H1	620853	16.3
L5HR-02-325	Cold/Hot Formed (325F for 24 Hrs.)	H1	620853	15.3
L5HR-03-325	Cold/Hot Formed (325F for 24 Hrs.)	H1	620853	16.8
L5HR-04-325	Cold/Hot Formed (325F for 24 Hrs.)	H1	620853	17.2
L5CR-01-325	Cold Formed (325F for 24 Hrs.)	L1	620853	19.6
L5CR-02-325	Cold Formed (325F for 24 Hrs.)	L1	620853	17.8
L5CR-03-325	Cold Formed (325F for 24 Hrs.)	L1	620853	19.6
L5CR-04-325	Cold Formed (325F for 24 Hrs.)	L1	620853	19.7
L5MCR-01-325	Mottled Cold Formed (325F for 24 Hrs.)	I1	620853	18.3
L5MCR-02-325	Mottled Cold Formed (325F for 24 Hrs.)	I1	620853	18.8
L5MCR-03-325	Mottled Cold Formed (325F for 24 Hrs.)	I1	620853	15.2
L5MCR-04-325	Mottled Cold Formed (325F for 24 Hrs.)	I1	620853	17.1
L5MCR-08-325	Mottled Cold Formed (325F for 24 Hrs.)	I1	620853	18.9
L5MCR-09-325	Mottled Cold Formed (325F for 24 Hrs.)	I1	620853	20.0
L5MCR-10-325	Mottled Cold Formed (325F for 24 Hrs.)	I1	620853	18.1
L5MCR-11-325	Mottled Cold Formed (325F for 24 Hrs.)	I1	620853	18.2
L5MCR-12-325	Mottled Cold Formed (325F for 24 Hrs.)	I1	620853	18.1
L5MCR-13-325	Mottled Cold Formed (325F for 24 Hrs.)	I1	620853	17.3
L5MCR-14-325	Mottled Cold Formed (325F for 24 Hrs.)	I1	620853	18.0
L5MCR-15-325	Mottled Cold Formed (325F for 24 Hrs.)	I1	620853	17.0
L5MCR-16-325	Mottled Cold Formed (325F for 24 Hrs.)	I1	620853	19.1
L4HR-01-325	Cold/Hot Formed (325F for 24 Hrs.)	K1	620854	21.3
L4HR-02-325	Cold/Hot Formed (325F for 24 Hrs.)	K1	620854	17.7
L4HR-03-325	Cold/Hot Formed (325F for 24 Hrs.)	K1	620854	21.2
L4HR-04-325	Cold/Hot Formed (325F for 24 Hrs.)	K1	620854	20.3
L4CR-01-325	Cold Formed (325F for 24 Hrs.)	J1	620854	21.6
L4CR-02-325	Cold Formed (325F for 24 Hrs.)	J1	620854	21.4
L4CR-03-325	Cold Formed (325F for 24 Hrs.)	J1	620854	20.9
L4CR-04-325	Cold Formed (325F for 24 Hrs.)	J1	620854	21.4
L4MCR-01-325	Mottled Cold Formed (325F for 24 Hrs.)	G1	620854	21.2
L4MCR-02-325	Mottled Cold Formed (325F for 24 Hrs.)	G1	620854	22.8
L4MCR-03-325	Mottled Cold Formed (325F for 24 Hrs.)	G1	620854	21.5
L4MCR-04-325	Mottled Cold Formed (325F for 24 Hrs.)	G1	620854	21.6

Table D-5. Thermal Aging Fracture Test Results for Lot 620853

LaRC ID	Description	MSFC Designation	Lot	K at P_{max} (ksi inch$^{1/2}$)
L5HR-05-340	Cold/Hot Formed (340F for 24 Hrs.)	H1	620853	13.9
L5HR-06-340	Cold/Hot Formed (340F for 24 Hrs.)	H1	620853	12.4
L5HR-07-340	Cold/Hot Formed (340F for 24 Hrs.)	H1	620853	13.6
L5CR-05-340	Cold Formed (340F for 24 Hrs.)	L1	620853	14.0
L5CR-06-340	Cold Formed (340F for 24 Hrs.)	L1	620853	14.7
L5CR-07-340	Cold Formed (340F for 24 Hrs.)	L1	620853	13.9
L5MCR-05-340	Mottled Cold Formed (340F for 24 Hrs.)	I1	620853	13.7
L5MCR-06-340	Mottled Cold Formed (340F for 24 Hrs.)	I1	620853	14.8
L5MCR-07-340	Mottled Cold Formed (340F for 24 Hrs.)	I1	620853	14.1
L4HR-05-340	Cold/Hot Formed (340F for 24 Hrs.)	K1	620854	16.9
L4HR-06-340	Cold/Hot Formed (340F for 24 Hrs.)	K1	620854	17.9
L4HR-07-340	Cold/Hot Formed (340F for 24 Hrs.)	K1	620854	18.1
L4CR-05-340	Cold Formed (340F for 24 Hrs.)	L1	620853	16.7
L4CR-06-340	Cold Formed (340F for 24 Hrs.)	L1	620853	16.5
L4CR-07-340	Cold Formed (340F for 24 Hrs.)	L1	620853	16.4
L4MCR-05-340	Mottled Cold Formed (340F for 24 Hrs.)	G1	620854	16.7
L4MCR-06-340	Mottled Cold Formed (340F for 24 Hrs.)	G1	620854	17.1
L4MCR-07-340	Mottled Cold Formed (340F for 24 Hrs.)	G1	620854	17.9

Table D-6. Thermal Exposure Fracture Test Results for Lot 400751

ID	Lot	Elevated Temp (^{o}F)	Hold Time (min)	24 Hour Aging Temp (^{o}F)	K at P_{max} (ksi inch$^{1/2}$)
L1P2-14-340-325	400751	340	10	325	25.6
L1P2-16-340-325	400751	340	10	325	24.7
L1P1-05-350-325	400751	350	10	325	25.6
L1P1-06-375-325	400751	375	10	325	25.6
L1P2-01-400-325	400751	400	10	325	21.3
L1P2-05-400-325	400751	400	10	325	20.6
L1P2-02-425-325	400751	425	10	325	19.8
L1P2-06-425-325	400751	425	10	325	20.8
L1P2-03-450-325	400751	450	10	325	18.7
L1P2-11-475-325	400751	475	10	325	19.0
L1P2-13-500-325	400751	500	10	325	17.5
L1P2-07-340B-325	400751	340	20	325	23.1
L1P2-10-340B-325	400751	340	20	325	25.5
L1P2-15-340B-325	400751	340	20	325	24.8
L1P2-16-340B-325	400751	340	20	325	25.2
L1P2-08-350B-325	400751	350	20	325	24.7
L1P2-12-350B-325	400751	350	20	325	23.5
L1P2-09-400B-325	400751	400	20	325	22.3
L1P2-04-450B-325	400751	450	20	325	17.3
L1P2-15-500B-325	400751	500	20	325	20.0

Table D-7. Thermal Exposure Fracture Test Results for Lot 400768

ID	Lot	Elevated Temp (^{o}F)	Hold Time (min)	24 Hour Aging Temp (^{o}F)	K at P_{max} (ksi inch$^{1/2}$)
L2P2-03-340-325	400768	340	10	325	23.3
L2P2-04-340-325	400768	340	10	325	26.5
L2P1-05-350-325	400768	350	10	325	25.2
L2P1-06-375-325	400768	375	10	325	23.6
L2P2-01-400-325	400768	400	10	325	21.2
L2P2-05-400-325	400768	400	10	325	20.1
L2P2-02-425-325	400768	425	10	325	21.0
L2P2-06-425-325	400768	425	10	325	20.3
L2P2-10-450-325	400768	450	10	325	20.1
L2P2-09-475-325	400768	475	10	325	16.6
L2P2-08-500-325	400768	500	10	325	16.7
L2P2-13-350B-325	400768	350	20	325	24.6
L2P2-12-400B-325	400768	400	20	325	17.5
L2P2-10-400B-325	400768	400	20	325	21.4
L2P2-07-500B-325	400768	500	20	325	19.4

Table D-8. Thermal Exposure Fracture Test Results for Lot 400766

ID	Lot	Elevated Temp (^{o}F)	Hold Time (min)	24 Hour Aging Temp (^{o}F)	K at P_{max} (ksi inch$^{1/2}$)
L3C1-04-400/325	400766	400	10	325	24.9
L3C1-15-400/325	400766	400	10	325	23.8
L3C1-05-425/325	400766	425	10	325	20.8
L3C1-16-425/325	400766	425	10	325	18.6
L3C1-06-450/325	400766	450	10	325	16.8
L3C1-17-450/325	400766	450	10	325	17.8
L3C1-07-475/325	400766	475	10	325	17.0
L3C1-18-475/325	400766	475	10	325	17.0
L3C1-19-500/325	400766	500	10	325	18.7
L3C1-08-500/325	400766	500	10	325	16.8
L3C1-09-400/400/325	400766	400	20	325	20.9
L3C1-20-400/400/325	400766	400	20	325	20.3
L3C1-10-450/450/325	400766	450	20	325	16.3
L3C1-21-450/450/325	400766	450	20	325	15.7
L3C1-11-500/500/325	400766	500	20	325	17.5
L3C1-22-500/500/325	400766	500	20	325	18.4

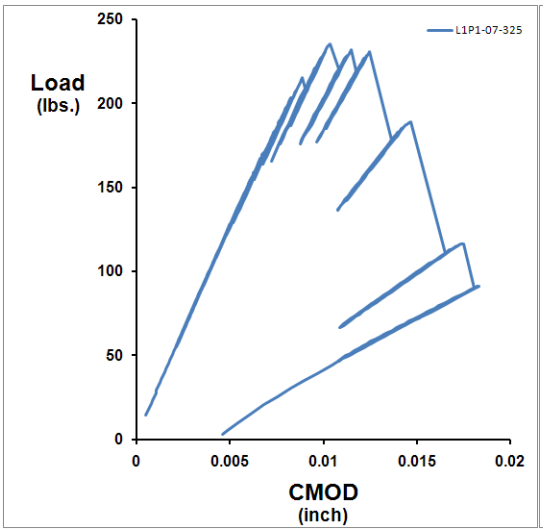


Figure D-1 CMOD vs. Load for fracture test L1P1-07-325 (Lot 400751 aged at 325 F for 24 hours)

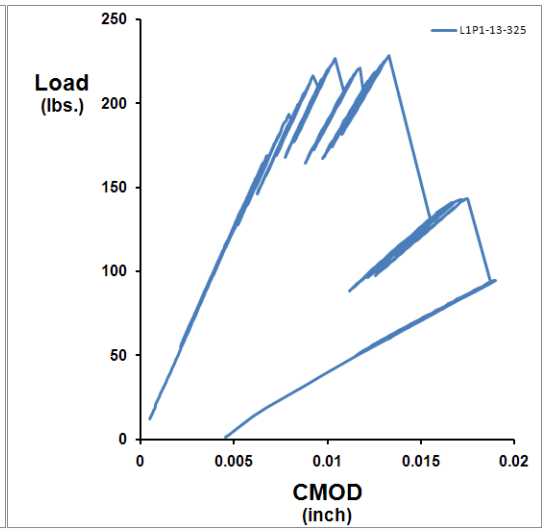


Figure D-2 CMOD vs. Load for fracture test L1P1-13-325 (Lot 400751 aged at 325 F for 24 hours)

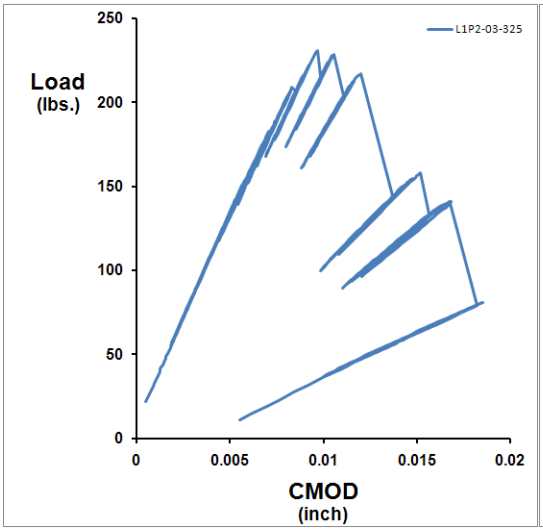


Figure D-3 CMOD vs. Load for fracture test L1P2-03-325 (Lot 400751 aged at 325 F for 24 hours)

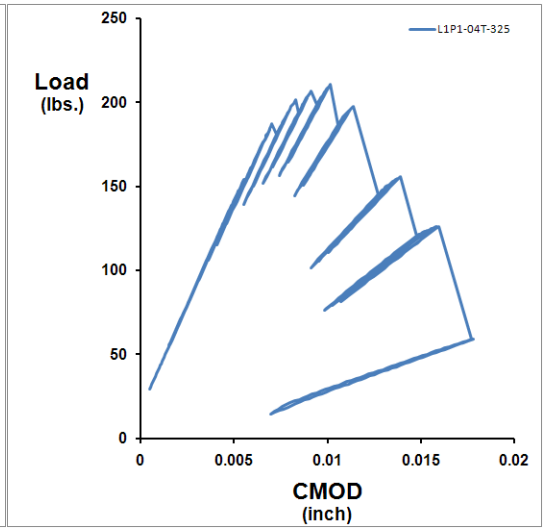


Figure D-4 CMOD vs. Load for fracture test L1P1-04T-325 (Lot 400751 aged at 325 F for 24 hours)

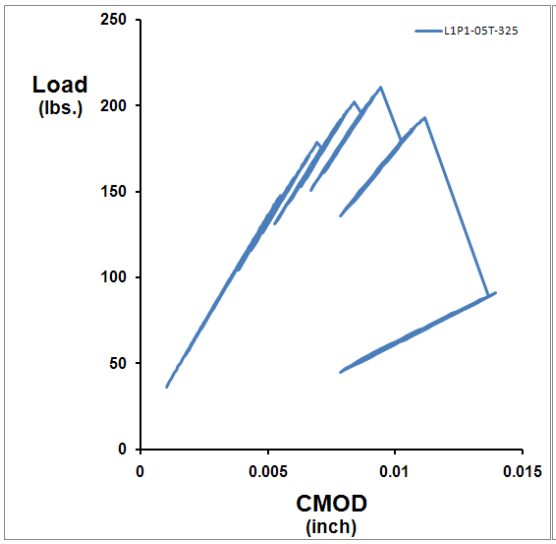


Figure D-5 CMOD vs. Load for fracture test L1P1-05T-325 (Lot 400751 aged at 325 F for 24 hours)

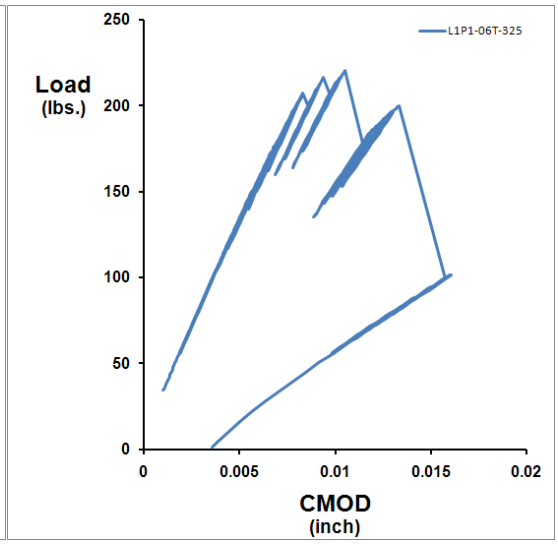


Figure D-6 CMOD vs. Load for fracture test L1P1-06T-325 (Lot 400751 aged at 325 F for 24 hours)

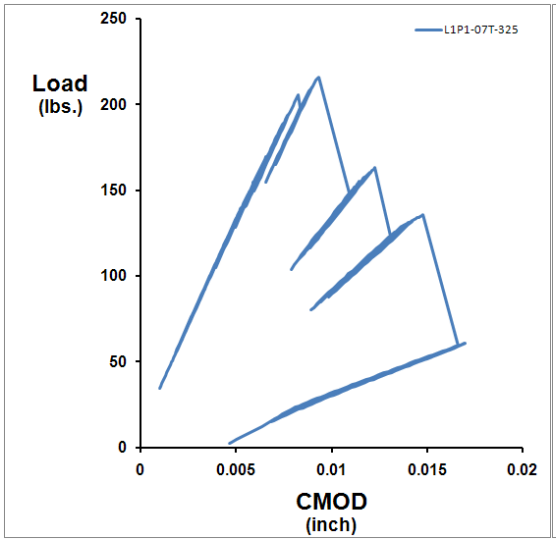


Figure D-7 CMOD vs. Load for fracture test L1P2-07T-325 (Lot 400751 aged at 325 F for 24 hours)

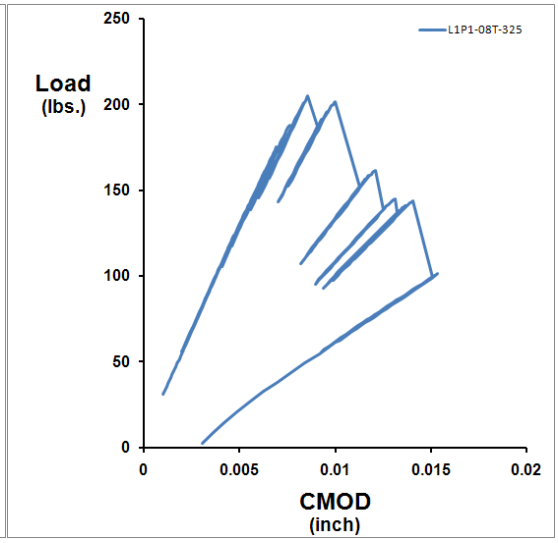


Figure D-8 CMOD vs. Load for fracture test L1P1-08T-325 (Lot 400751 aged at 325 F for 24 hours)

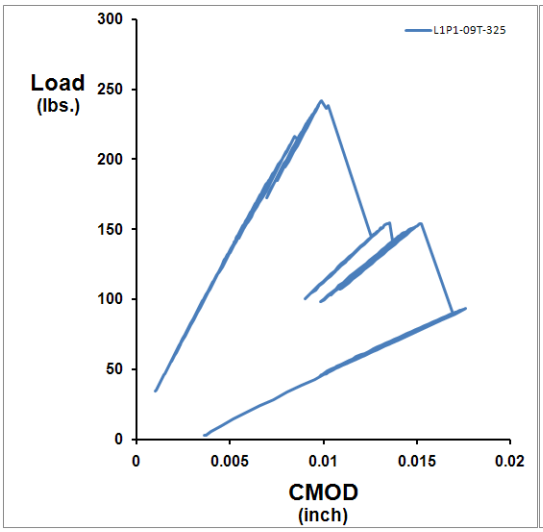


Figure D-9 CMOD vs. Load for fracture test L1P1-09T-325 (Lot 400751 aged at 325 F for 24 hours)

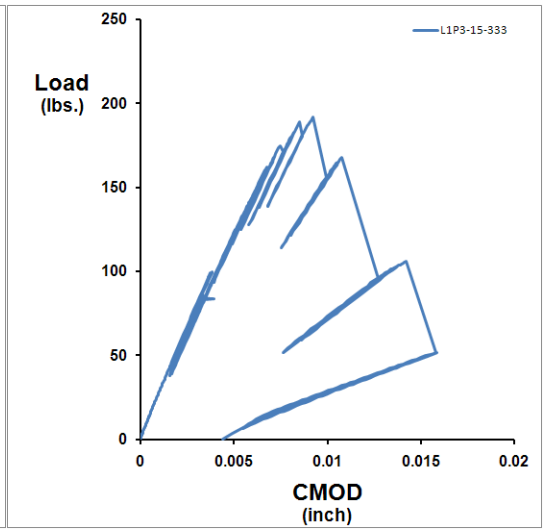


Figure D-10 CMOD vs. Load for fracture test L1P3-15-333 (Lot 400751 aged at 333 F for 24 hours)

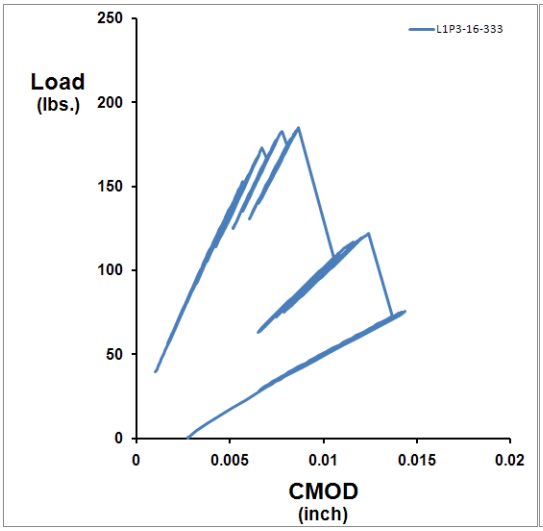


Figure D-11 CMOD vs. Load for fracture test L1P3-16-333 (Lot 400751 aged at 333 F for 24 hours)

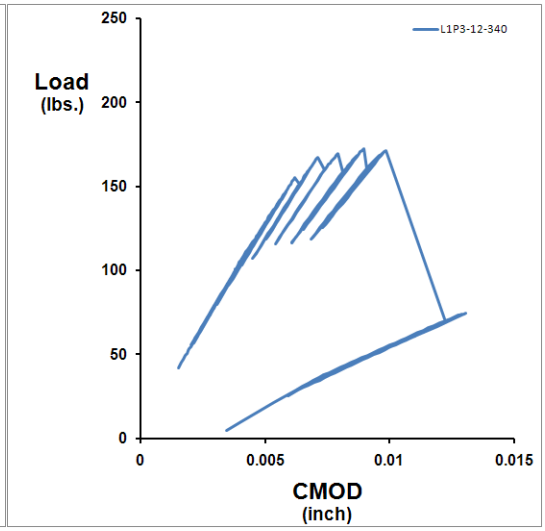


Figure D-12 CMOD vs. Load for fracture test L1P3-12-340 (Lot 400751 aged at 340 F for 24 hours)

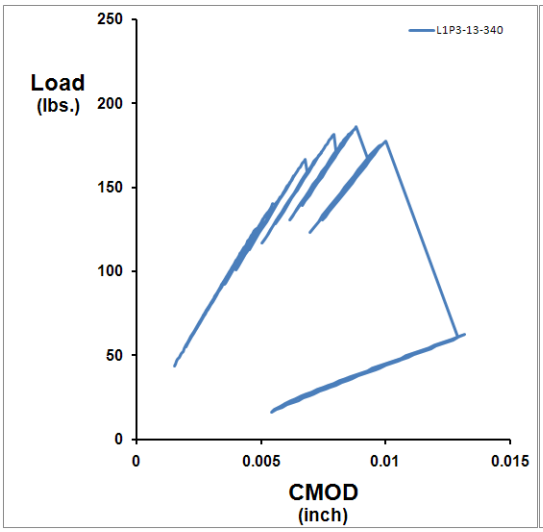


Figure D-13 CMOD vs. Load for fracture test L1P3-13-340 (Lot 400751 aged at 340 F for 24 hours)

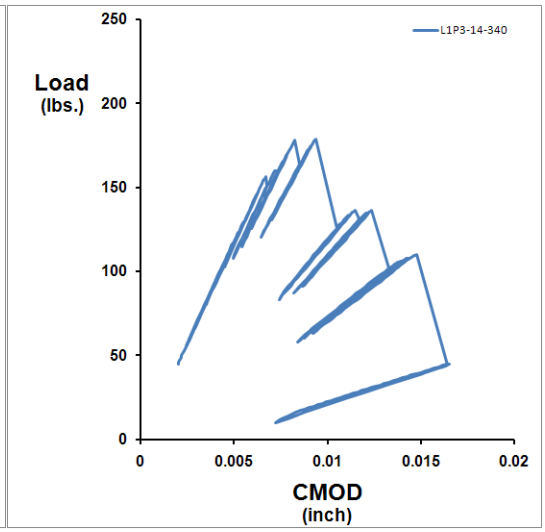


Figure D-14 CMOD vs. Load for fracture test L1P3-14-340 (Lot 400751 aged at 340 F for 24 hours)

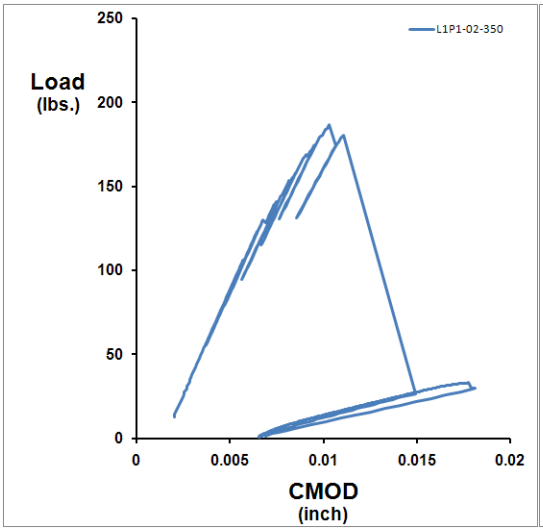


Figure D-15 CMOD vs. Load for fracture test L1P1-02-350 (Lot 400751 aged at 350 F for 24 hours)

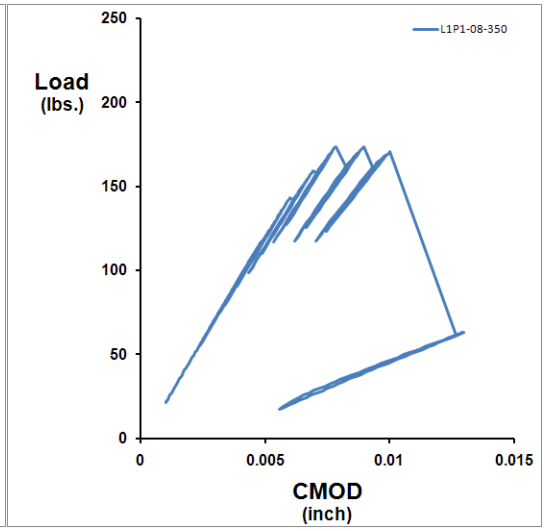


Figure D-16 CMOD vs. Load for fracture test L1P1-08-350 (Lot 400751 aged at 350 F for 24 hours)

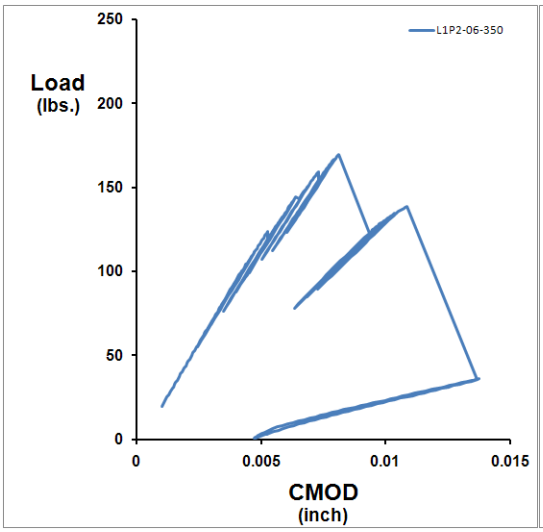


Figure D-17 CMOD vs. Load for fracture test L1P2-06-350 (Lot 400751 aged at 350 F for 24 hours)

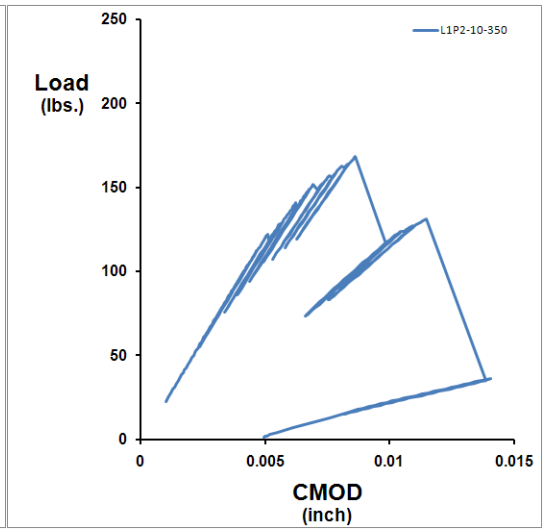


Figure D-18 CMOD vs. Load for fracture test L1P2-10-350 (Lot 400751 aged at 350 F for 24 hours)

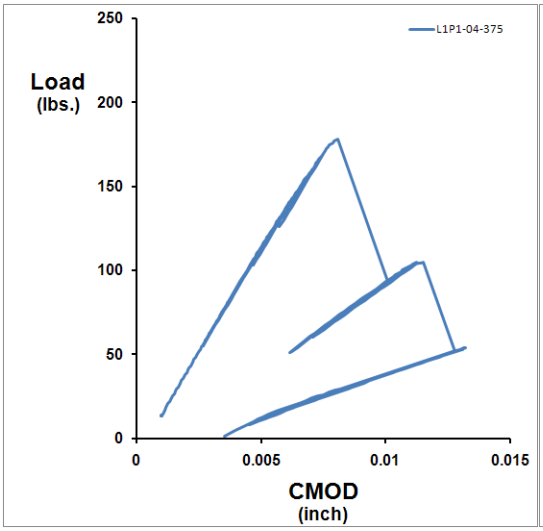


Figure D-19 CMOD vs. Load for fracture test L1P1-04-3750 (Lot 400751 aged at 375 F for 24 hours)

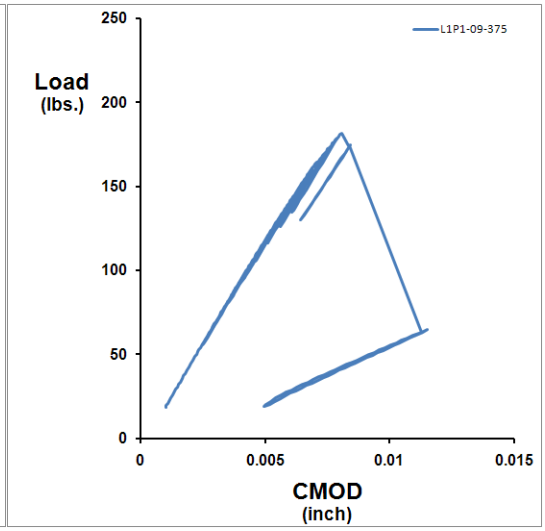


Figure D-20 CMOD vs. Load for fracture test L1P1-09-375 (Lot 400751 aged at 375 F for 24 hours)

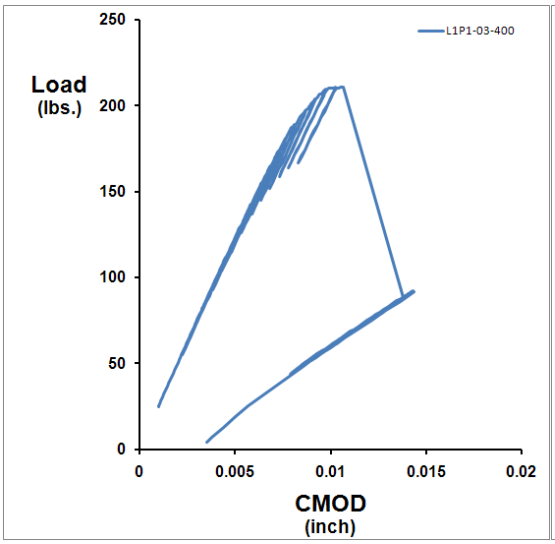


Figure D-21 CMOD vs. Load for fracture test L1P1-03-400 (Lot 400751 aged at 400 F for 24 hours)

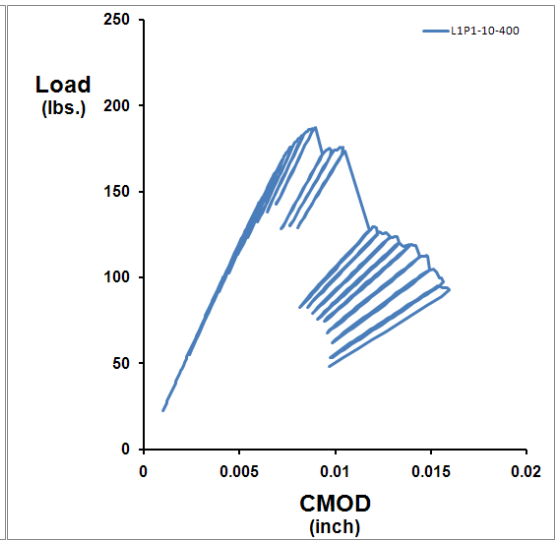


Figure D-22 CMOD vs. Load for fracture test L1P1-10-400 (Lot 400751 aged at 400 F for 24 hours)

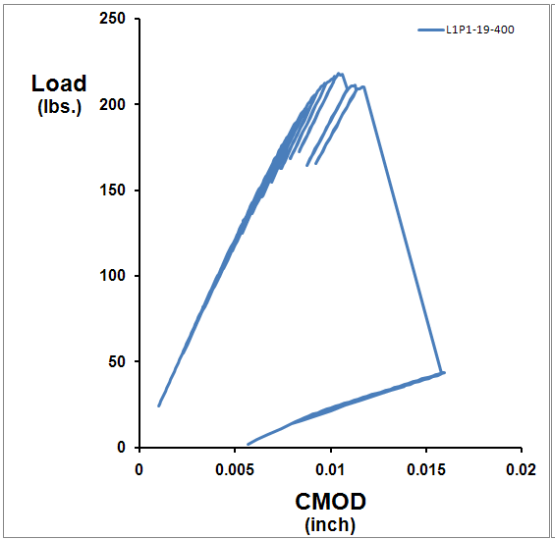


Figure D-23 CMOD vs. Load for fracture test L1P1-19-400 (Lot 400751 aged at 400 F for 24 hours)

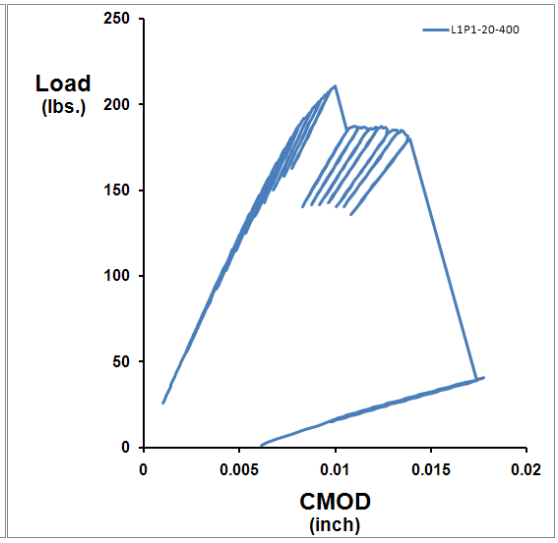


Figure D-24 CMOD vs. Load for fracture test L1P1-20-400 (Lot 400751 aged at 400 F for 24 hours)

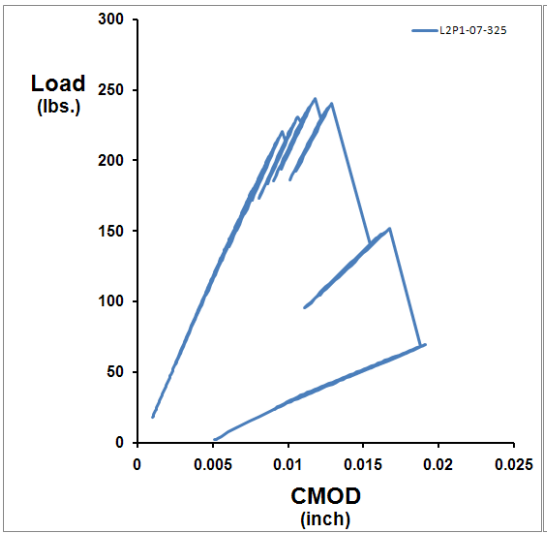


Figure D-25 CMOD vs. Load for fracture test L2P1-07-325 (Lot 400768 aged at 325 F for 24 hours)

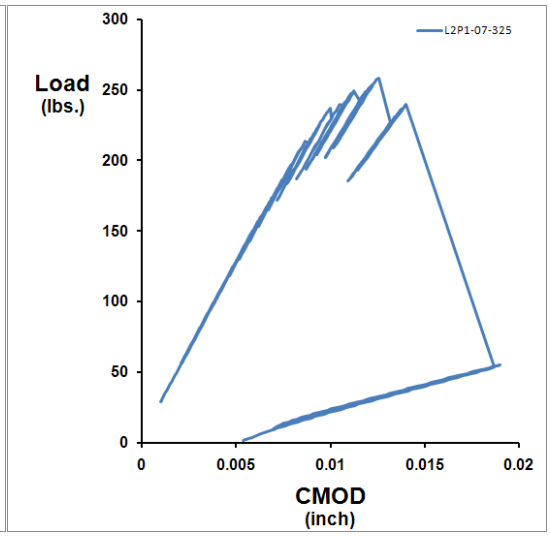


Figure D-26 CMOD vs. Load for fracture test L2P1-13-325 (Lot 400768 aged at 325 F for 24 hours)

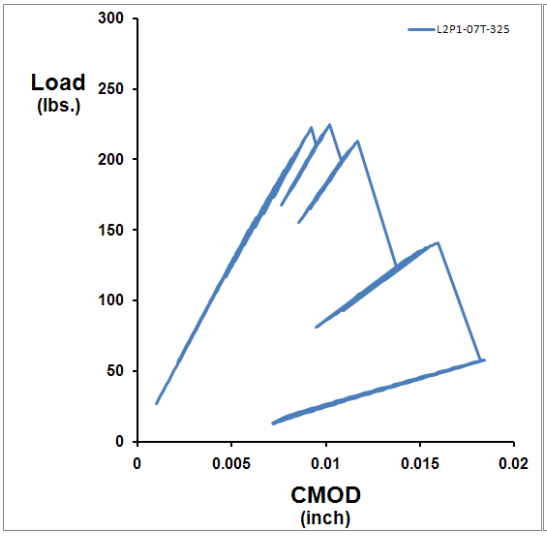


Figure D-27 CMOD vs. Load for fracture test L2P1-07T-325 (Lot 400768 aged at 325 F for 24 hours)

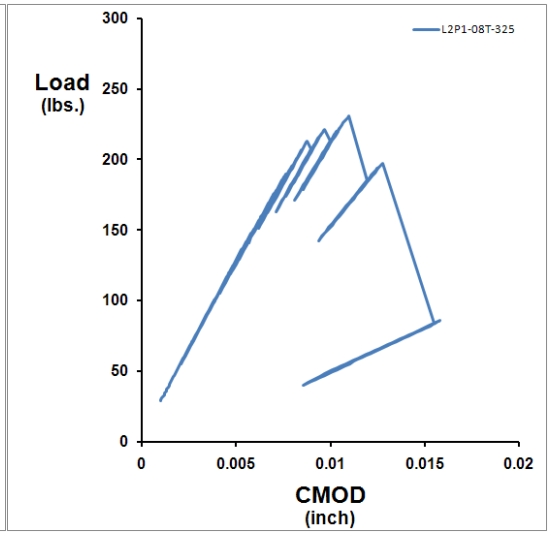


Figure D-28 CMOD vs. Load for fracture test L2P1-08T-325 (Lot 400768 aged at 325 F for 24 hours)

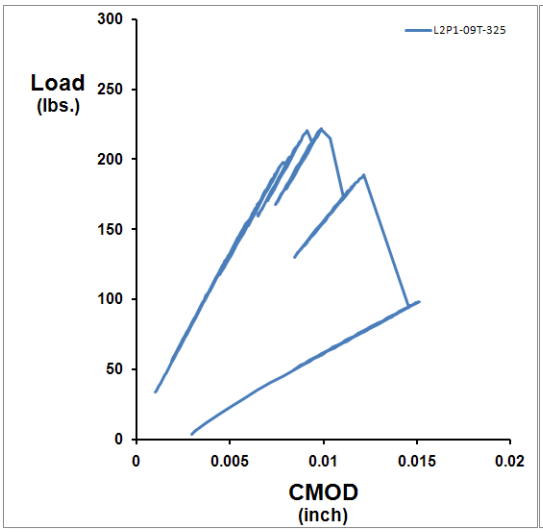


Figure D-29 CMOD vs. Load for fracture test L2P1-09T-325 (Lot 400768 aged at 325 F for 24 hours)

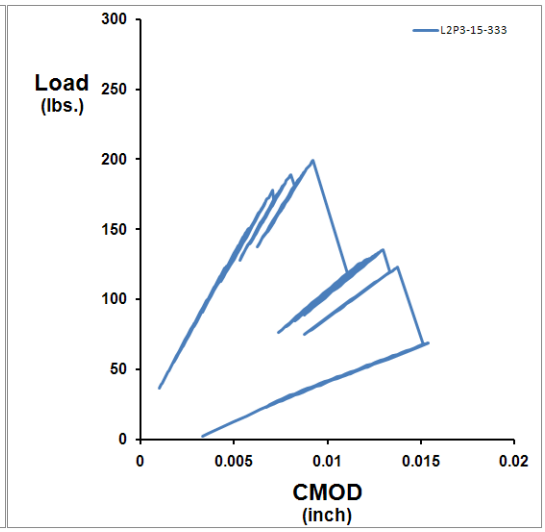


Figure D-30 CMOD vs. Load for fracture test L2P3-15-333 (Lot 400768 aged at 333 F for 24 hours)

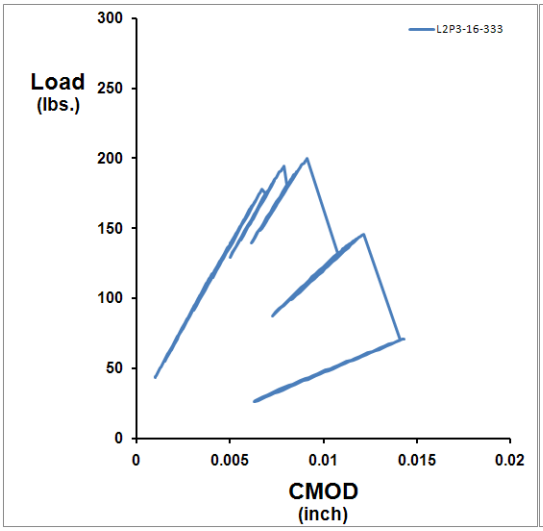


Figure D-31 CMOD vs. Load for fracture test L2P3-16-333 (Lot 400768 aged at 333 F for 24 hours)

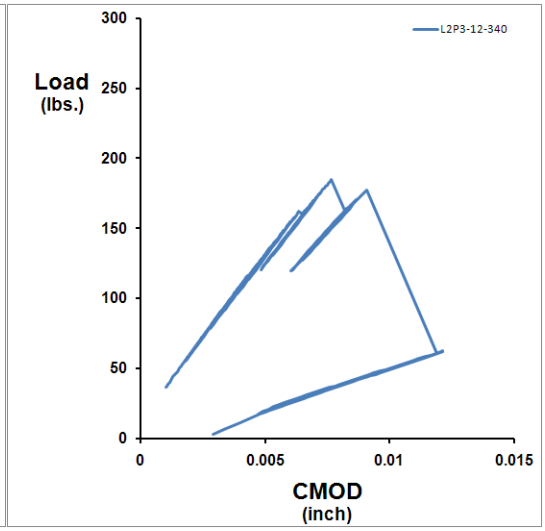


Figure D-32 CMOD vs. Load for fracture test L2P3-12-340 (Lot 400768 aged at 340 F for 24 hours)

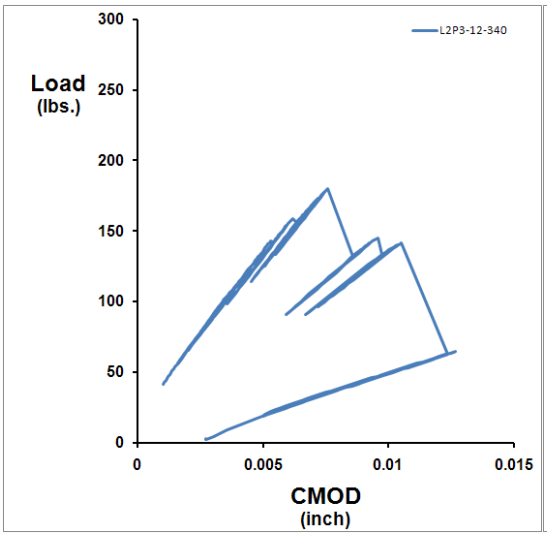


Figure D-33 CMOD vs. Load for fracture test L2P3-13-340 (Lot 400768 aged at 340 F for 24 hours)

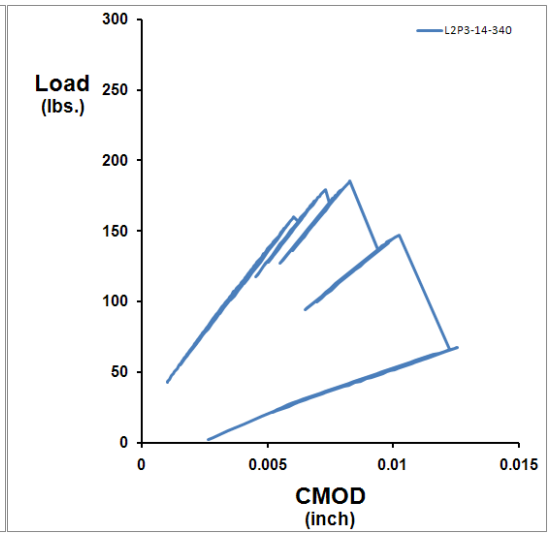


Figure D-34 CMOD vs. Load for fracture test L2P3-14-340 (Lot 400768 aged at 340 F for 24 hours)

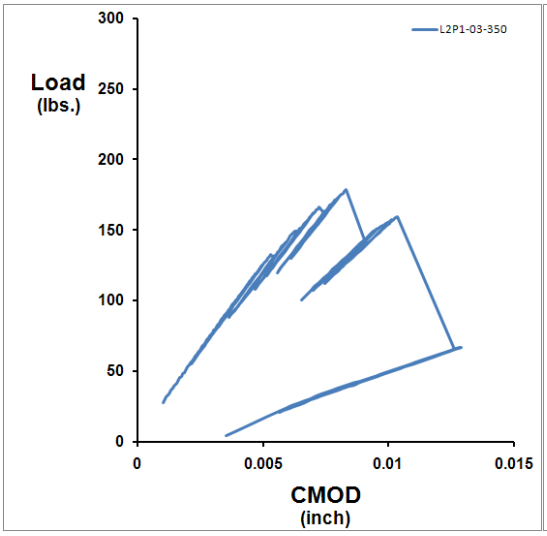


Figure D-35 CMOD vs. Load for fracture test L2P1-03-350 (Lot 400768 aged at 350 F for 24 hours)

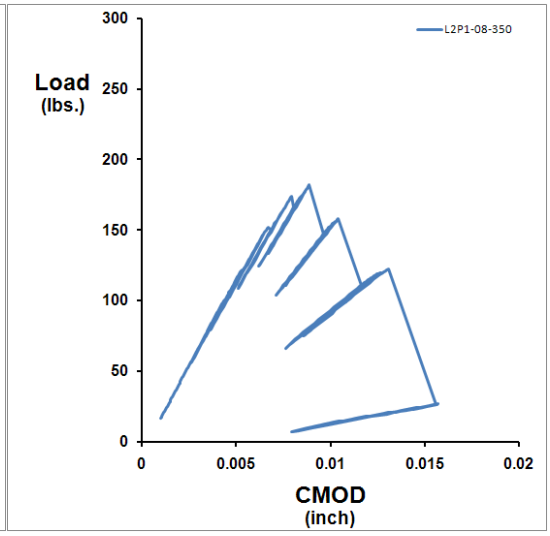


Figure D-36 CMOD vs. Load for fracture test L2P1-08-350 (Lot 400768 aged at 350 F for 24 hours)

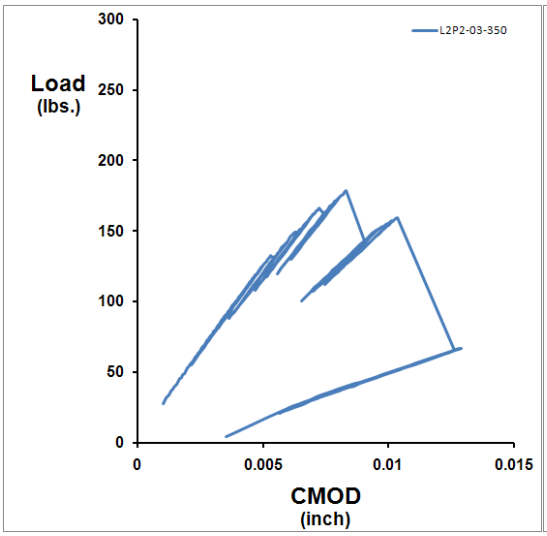


Figure D-37 CMOD vs. Load for fracture test L2P2-03-350 (Lot 400768 aged at 350 F for 24 hours)

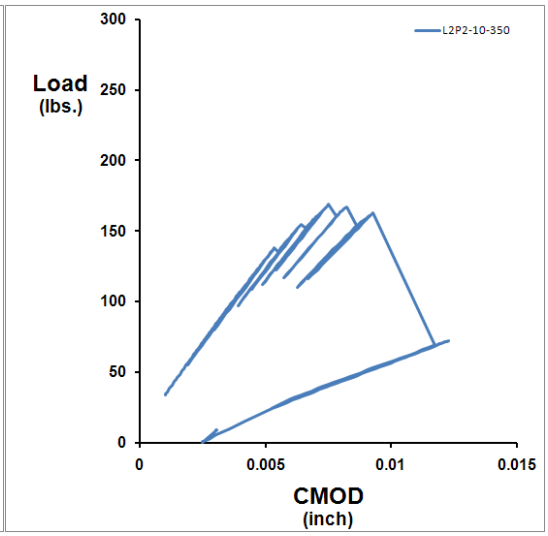


Figure D-38 CMOD vs. Load for fracture test L2P2-10-350 (Lot 400768 aged at 350 F for 24 hours)

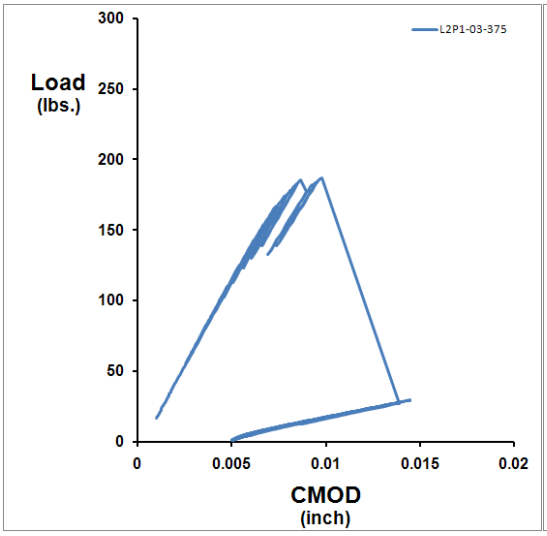


Figure D-39 CMOD vs. Load for fracture test L2P1-03-375 (Lot 400768 aged at 375 F for 24 hours)

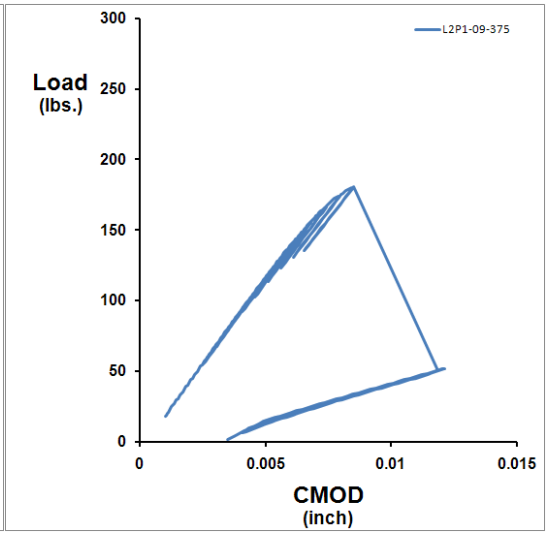


Figure D-40 CMOD vs. Load for fracture test L2P1-09-375 (Lot 400768 aged at 375 F for 24 hours)

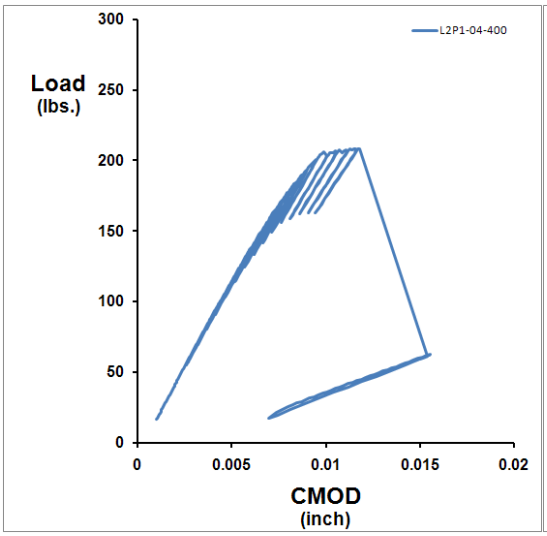


Figure D-41 CMOD vs. Load for fracture test L2P1-04-400 (Lot 400768 aged at 400 F for 24 hours)

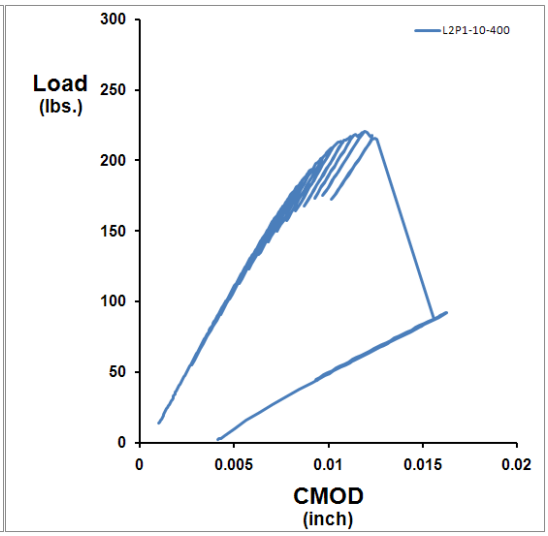


Figure D-42 CMOD vs. Load for fracture test L2P1-10-400 (Lot 400768 aged at 400 F for 24 hours)

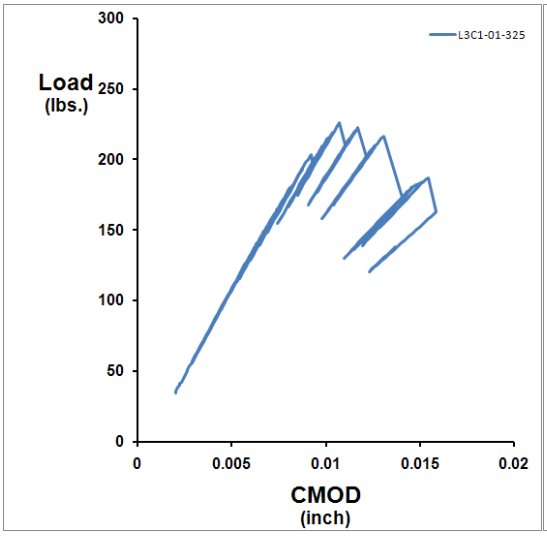


Figure D-43 CMOD vs. Load for fracture test L3C1-01-325 (Lot 400766 aged at 325 F for 24 hours)

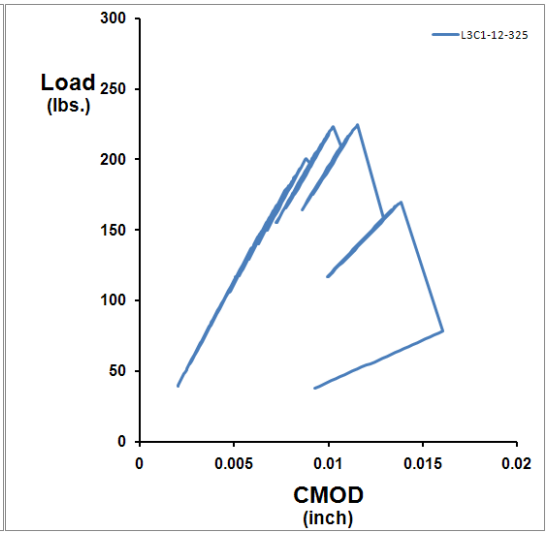


Figure D-44 CMOD vs. Load for fracture test L3C1-12-325 (Lot 400766 aged at 325 F for 24 hours)

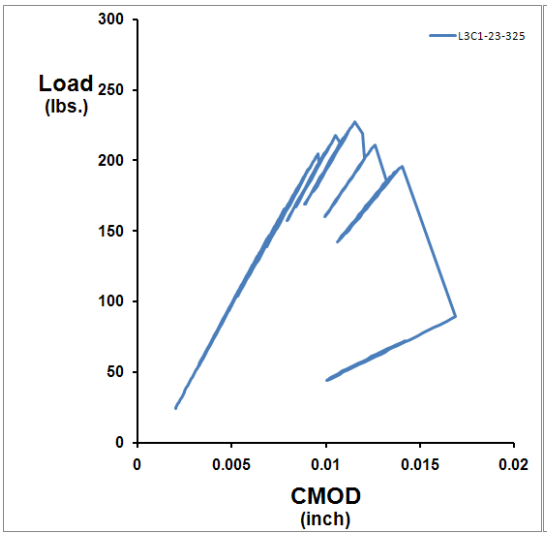


Figure D-45 CMOD vs. Load for fracture test L3C1-23-325 (Lot 400766 aged at 325 F for 24 hours)

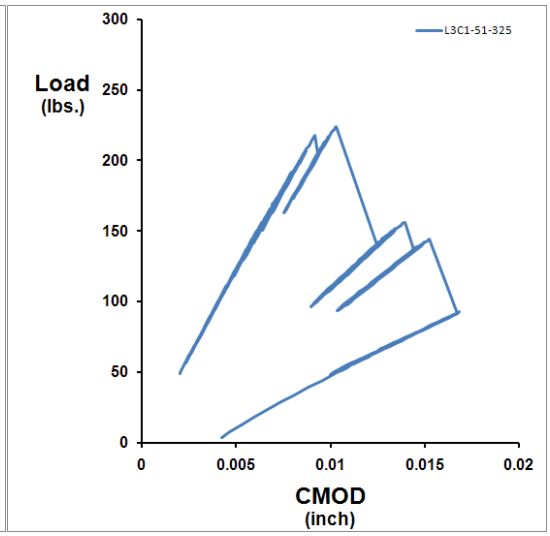


Figure D-46 CMOD vs. Load for fracture test L3C1-51-325 (Lot 400766 aged at 325 F for 24 hours)

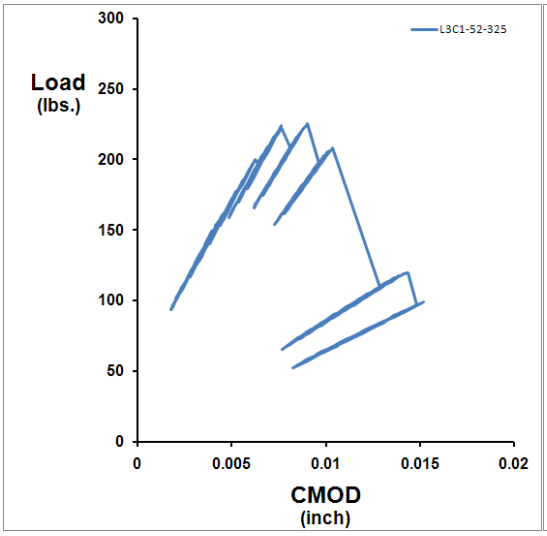


Figure D-47 CMOD vs. Load for fracture test L3C1-52-325 (Lot 400766 aged at 325 F for 24 hours)

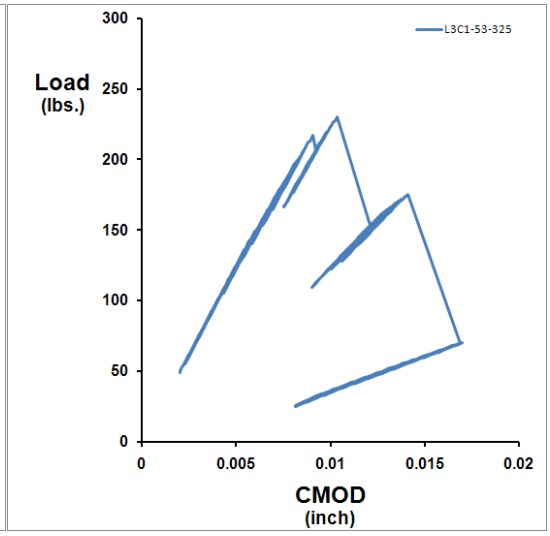


Figure D-48 CMOD vs. Load for fracture test L3C1-53-325 (Lot 400766 aged at 325 F for 24 hours)

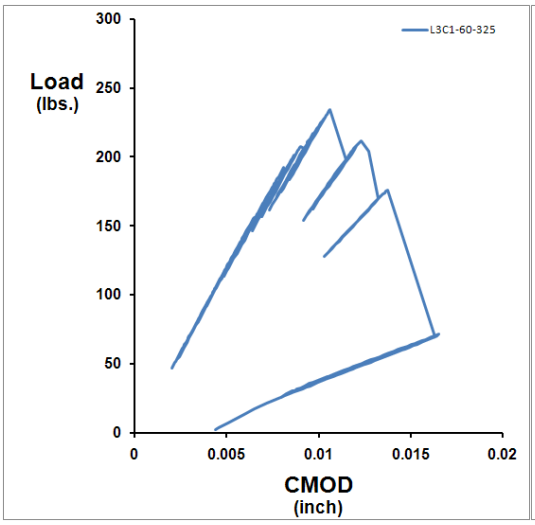


Figure D-49 CMOD vs. Load for fracture test L3C1-60-325 (Lot 400766 aged at 325 F for 24 hours)

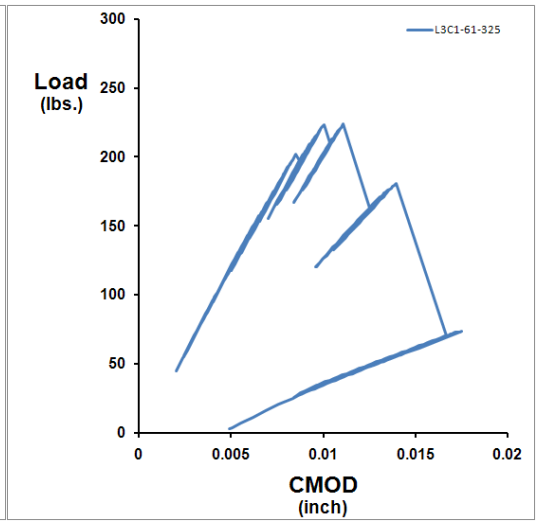


Figure D-50 CMOD vs. Load for fracture test L3C1-61-325 (Lot 400766 aged at 325 F for 24 hours)

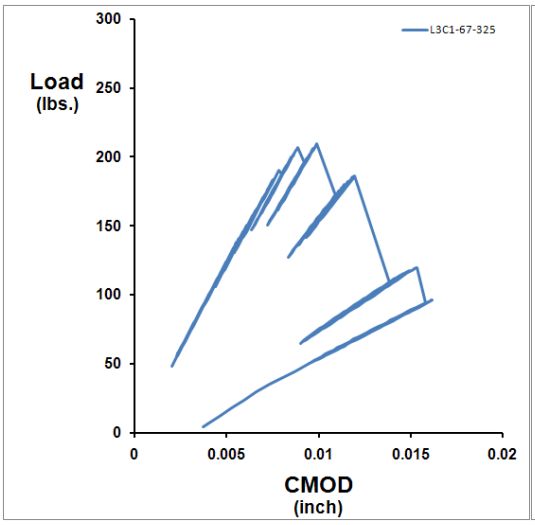


Figure D-51 CMOD vs. Load for fracture test L3C1-67-325 (Lot 400766 aged at 325 F for 24 hours)

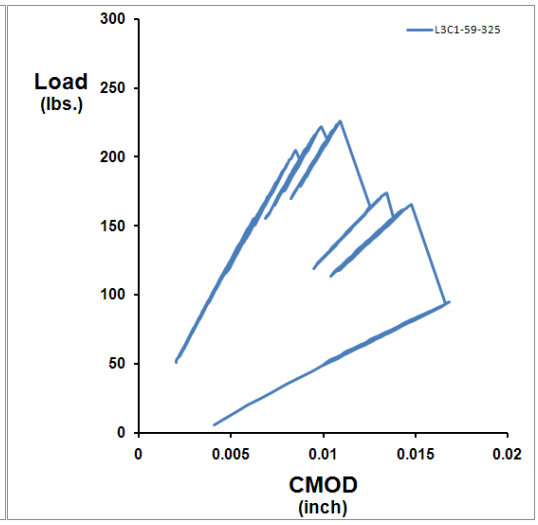


Figure D-52 CMOD vs. Load for fracture test L3C1-59-325 (Lot 400766 aged at 325 F for 24 hours)

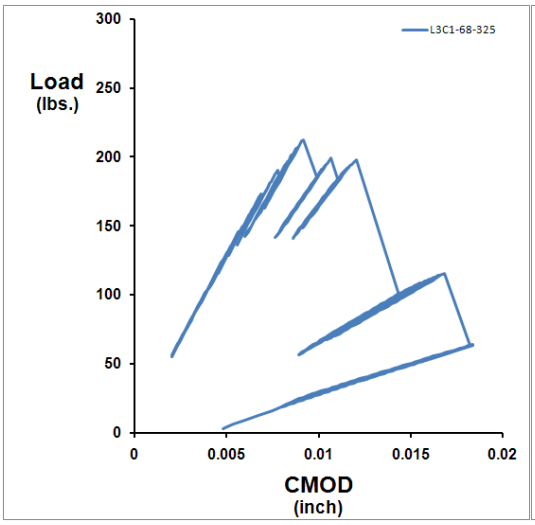


Figure D-53 CMOD vs. Load for fracture test L3C1-68-325 (Lot 400766 aged at 325 F for 24 hours)

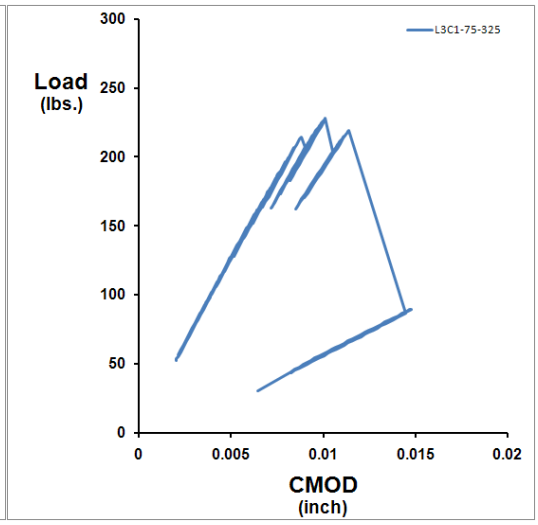


Figure D-54 CMOD vs. Load for fracture test L3C1-75-325 (Lot 400766 aged at 325 F for 24 hours)

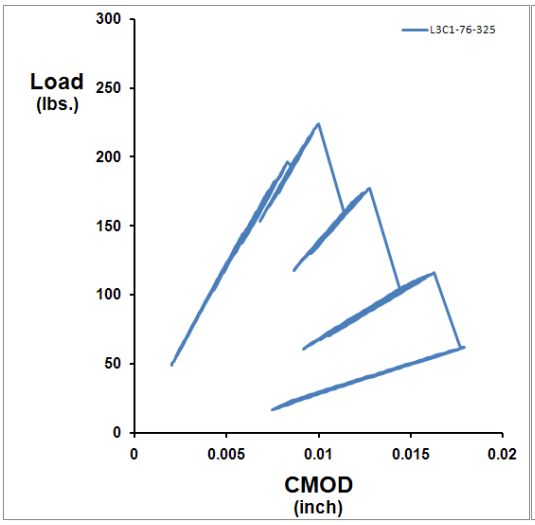


Figure D-55 CMOD vs. Load for fracture test L3C1-76-325 (Lot 400766 aged at 325 F for 24 hours)

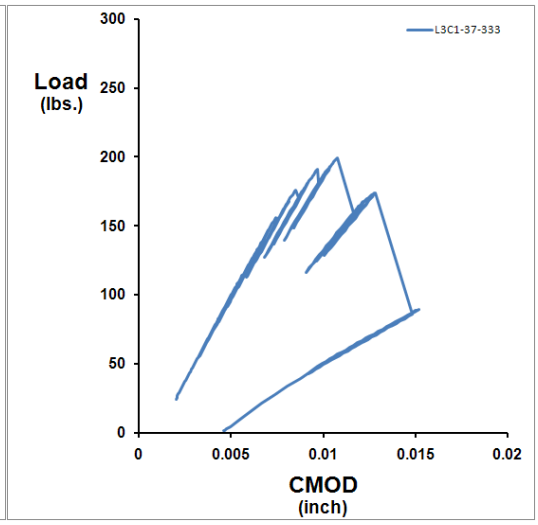


Figure D-56 CMOD vs. Load for fracture test L3C1-37-333 (Lot 400766 aged at 333 F for 24 hours)

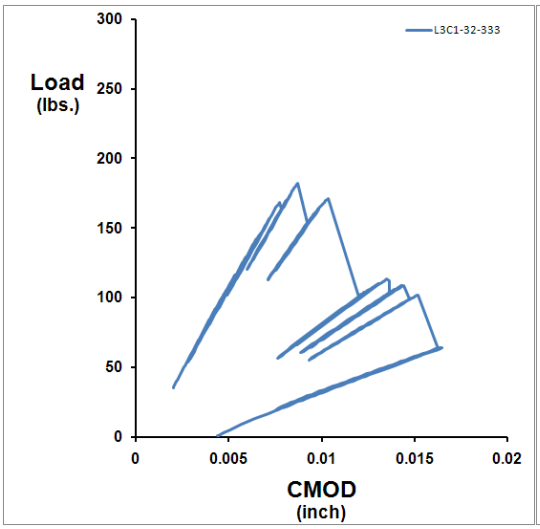


Figure D-57 CMOD vs. Load for fracture test L3C1-32-333 (Lot 400766 aged at 333 F for 24 hours)

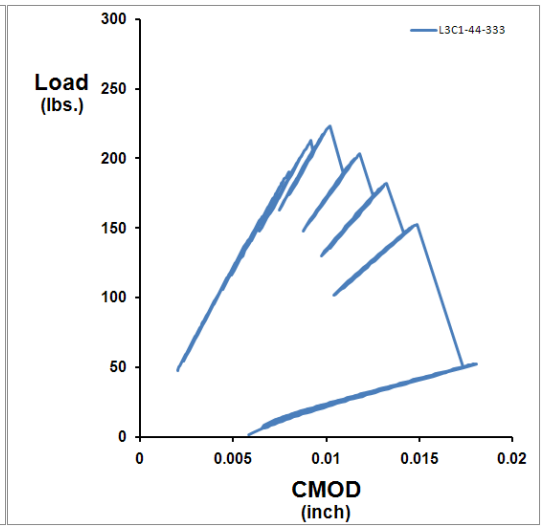


Figure D-58 CMOD vs. Load for fracture test L3C1-44-333 (Lot 400766 aged at 333 F for 24 hours)

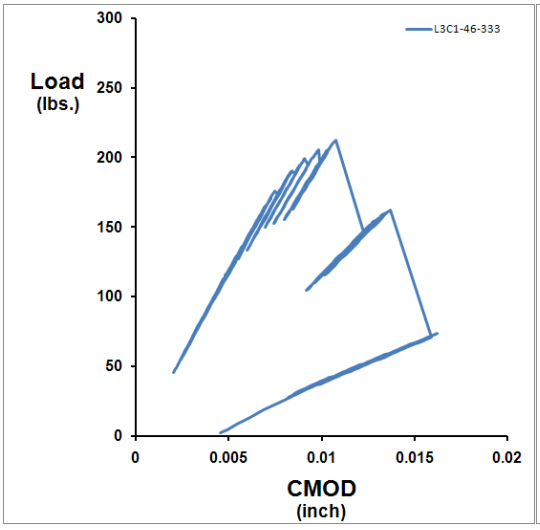


Figure D-59 CMOD vs. Load for fracture test L3C1-46-333 (Lot 400766 aged at 333 F for 24 hours)

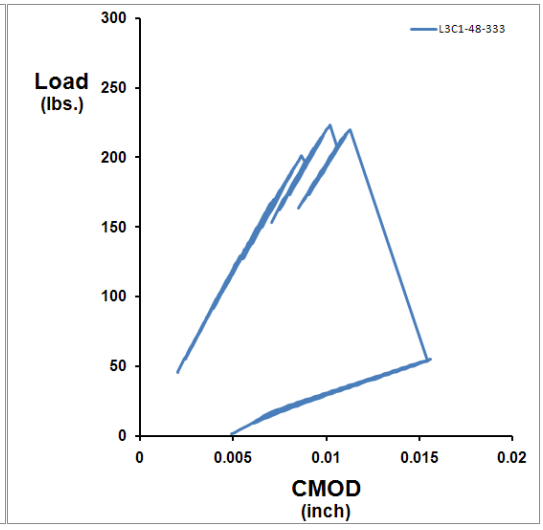


Figure D-60 CMOD vs. Load for fracture test L3C1-48-333 (Lot 400766 aged at 333 F for 24 hours)

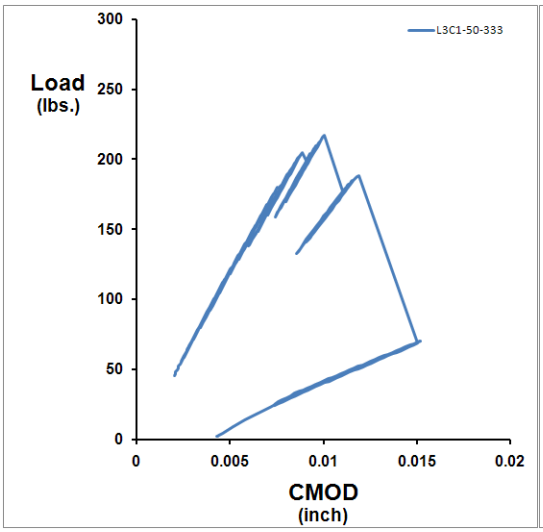


Figure D-61 CMOD vs. Load for fracture test L3C1-50-333 (Lot 400766 aged at 333 F for 24 hours)

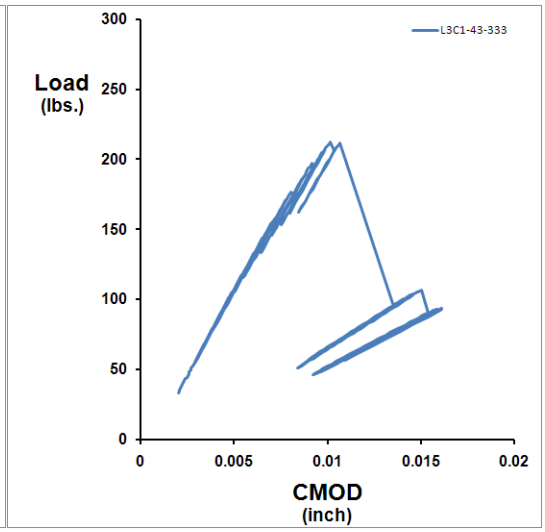


Figure D-62 CMOD vs. Load for fracture test L3C1-43-333 (Lot 400766 aged at 333 F for 24 hours)

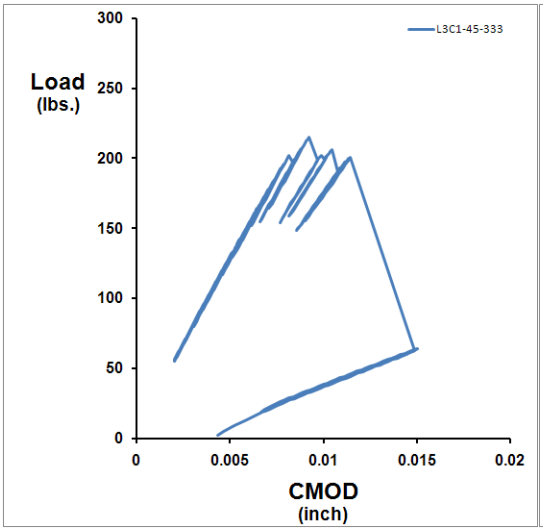


Figure D-63 CMOD vs. Load for fracture test L3C1-45-333 (Lot 400766 aged at 333 F for 24 hours)

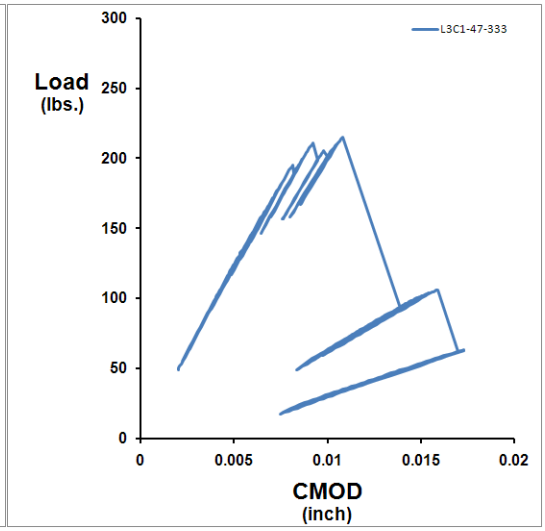


Figure D-64 CMOD vs. Load for fracture test L3C1-47-333 (Lot 400766 aged at 333 F for 24 hours)

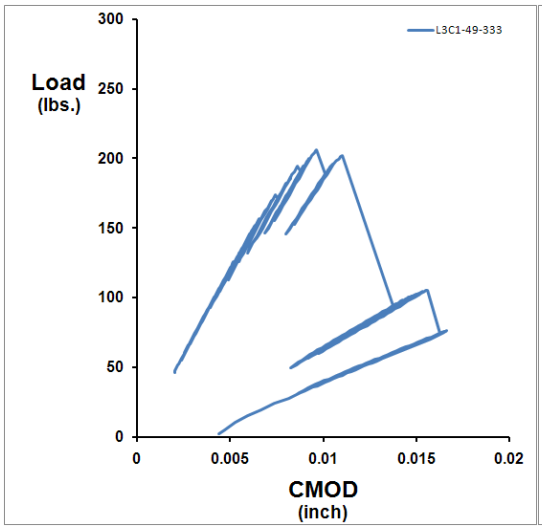


Figure D-65 CMOD vs. Load for fracture test L3C1-49-333 (Lot 400766 aged at 333 F for 24 hours)

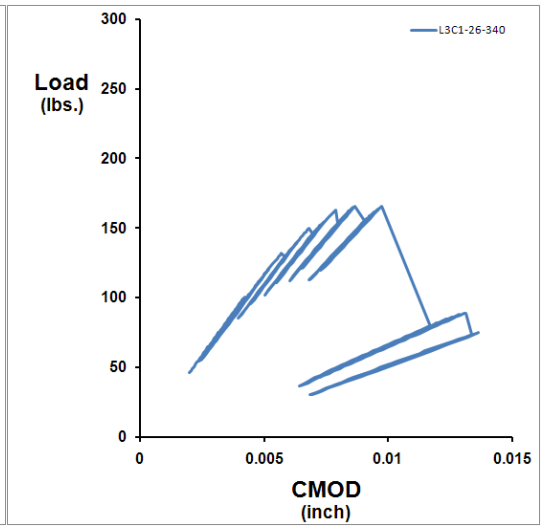


Figure D-66 CMOD vs. Load for fracture test L3C1-26-340 (Lot 400766 aged at 340 F for 24 hours)

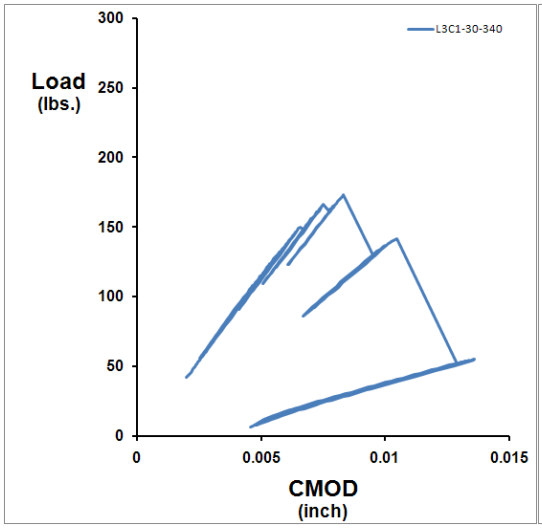


Figure D-67 CMOD vs. Load for fracture test L3C1-30-340 (Lot 400766 aged at 340 F for 24 hours)

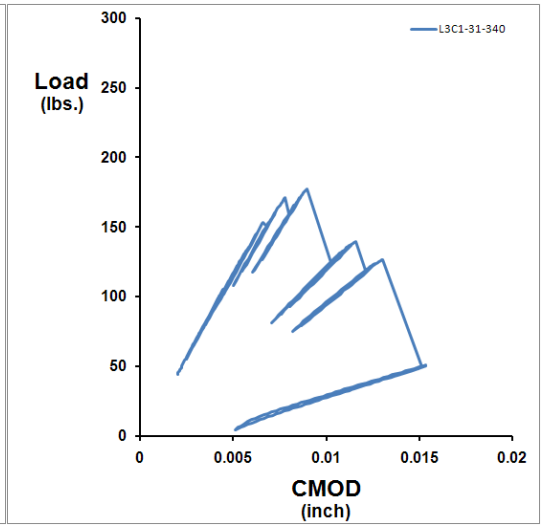


Figure D-68 CMOD vs. Load for fracture test L3C1-31-340 (Lot 400766 aged at 340 F for 24 hours)

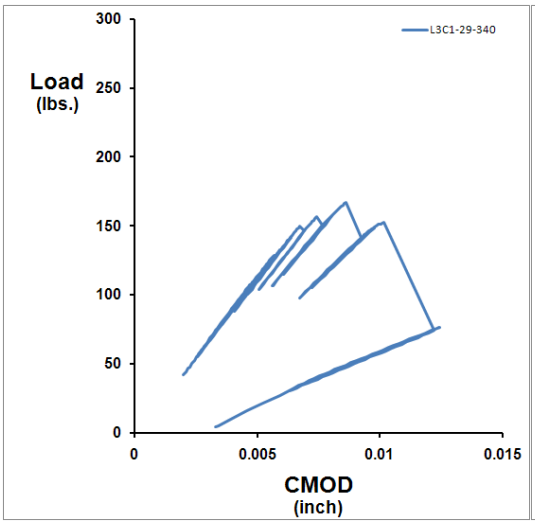


Figure D-69 CMOD vs. Load for fracture test L3C1-49-340 (Lot 400766 aged at 340 F for 24 hours)

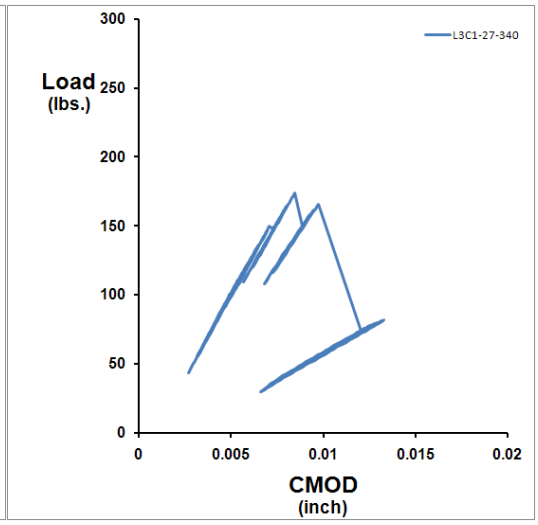


Figure D-70 CMOD vs. Load for fracture test L3C1-27-340 (Lot 400766 aged at 340 F for 24 hours)

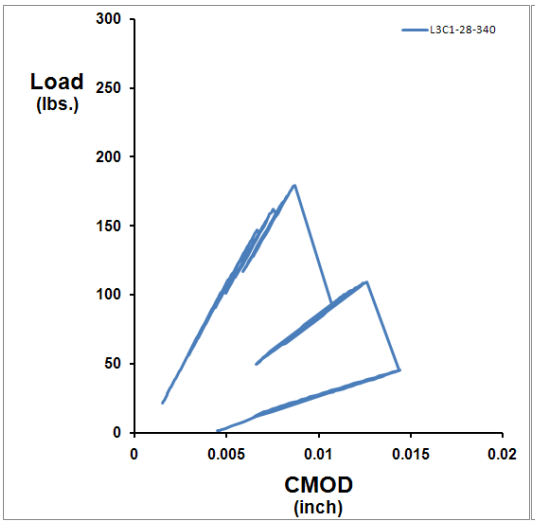


Figure D-71 CMOD vs. Load for fracture test L3C1-28-340 (Lot 400766 aged at 340 F for 24 hours)

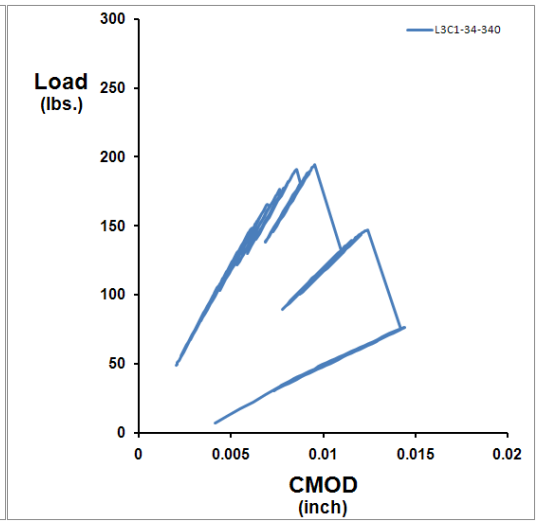


Figure D-72 CMOD vs. Load for fracture test L3C1-34-340 (Lot 400766 aged at 340 F for 24 hours)

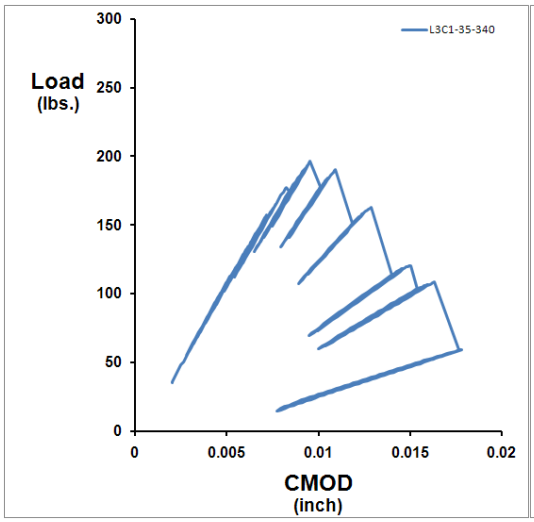


Figure D-73 CMOD vs. Load for fracture test L3C1-35-340 (Lot 400766 aged at 340 F for 24 hours)

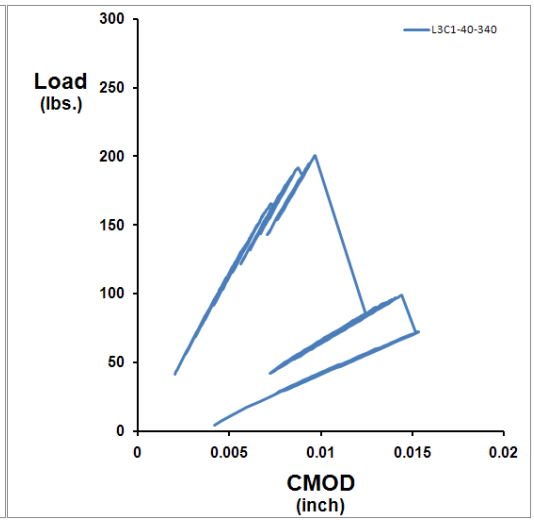


Figure D-74 CMOD vs. Load for fracture test L3C1-40-340 (Lot 400766 aged at 340 F for 24 hours)

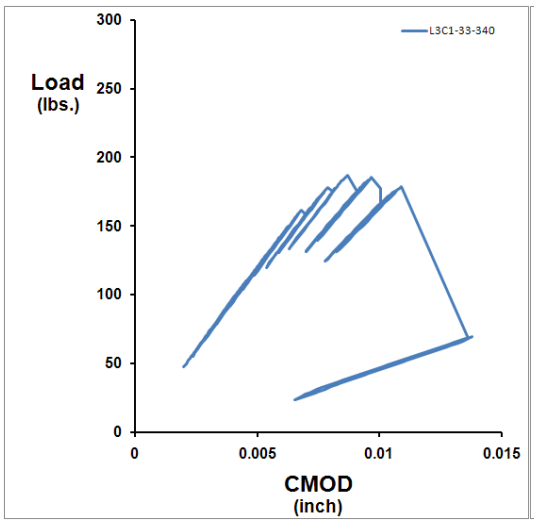


Figure D-75 CMOD vs. Load for fracture test L3C1-33-340 (Lot 400766 aged at 340 F for 24 hours)

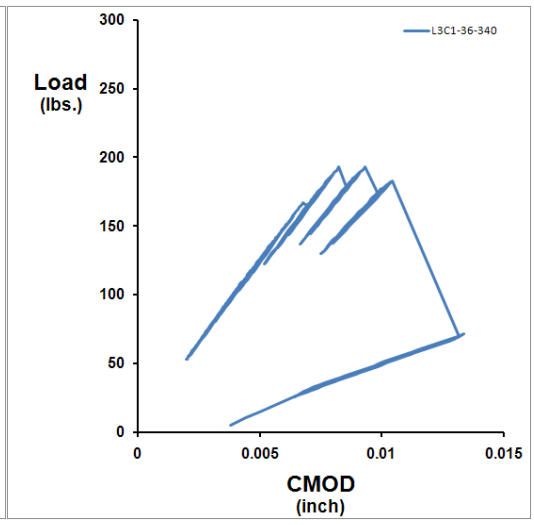


Figure D-76 CMOD vs. Load for fracture test L3C1-36-340 (Lot 400766 aged at 340 F for 24 hours)

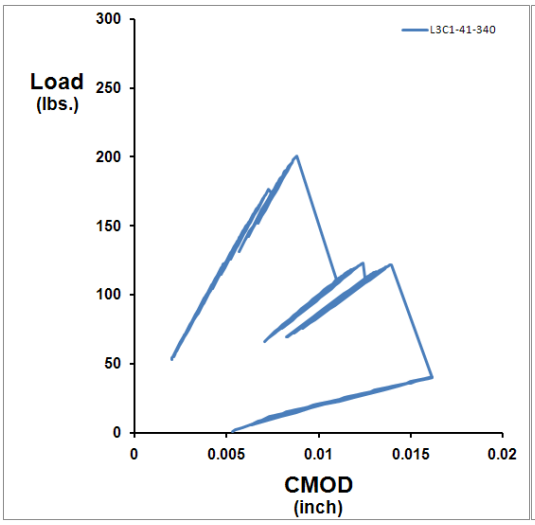


Figure D-77 CMOD vs. Load for fracture test L3C1-41-340 (Lot 400766 aged at 340 F for 24 hours)

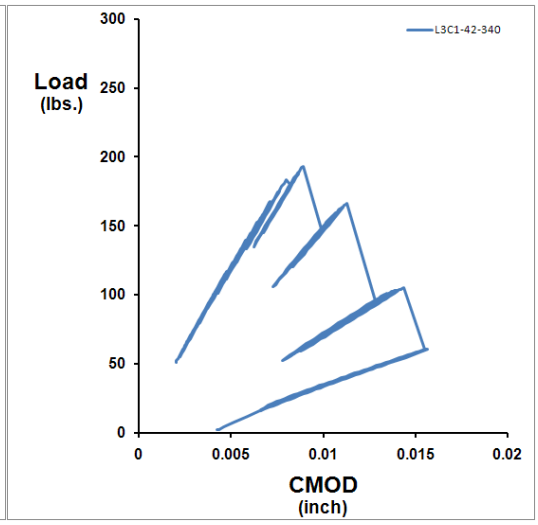


Figure D-78 CMOD vs. Load for fracture test L3C1-42-340 (Lot 400766 aged at 340 F for 24 hours)

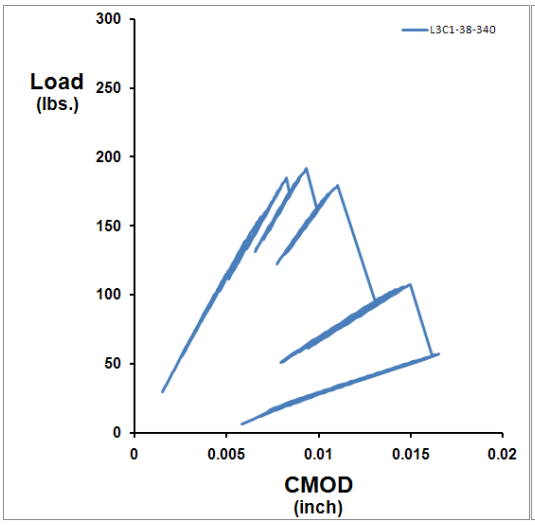


Figure D-79 CMOD vs. Load for fracture test L3C1-38-340 (Lot 400766 aged at 340 F for 24 hours)

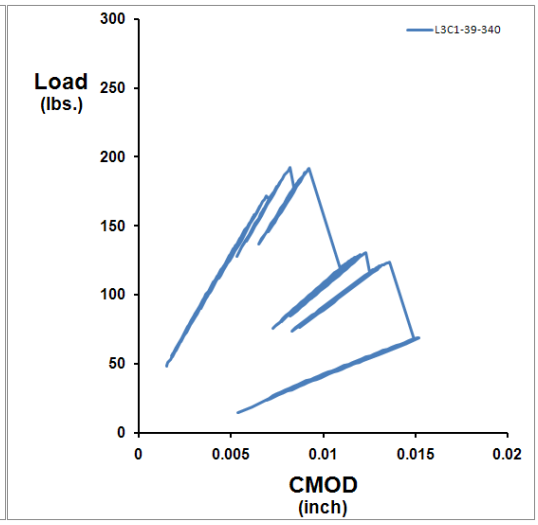


Figure D-80 CMOD vs. Load for fracture test L3C1-39-340 (Lot 400766 aged at 340 F for 24 hours)

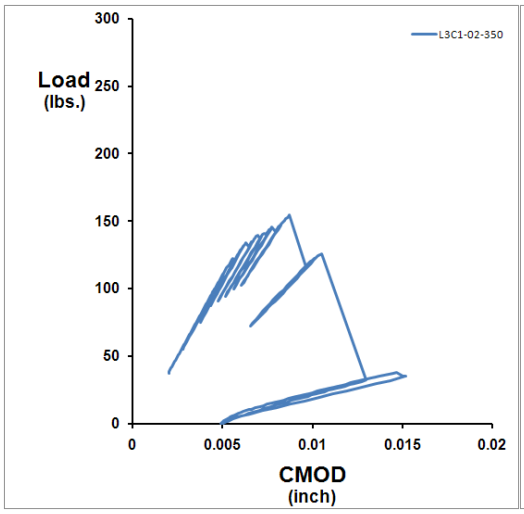


Figure D-81 CMOD vs. Load for fracture test L3C1-02-350 (Lot 400766 aged at 350 F for 24 hours)

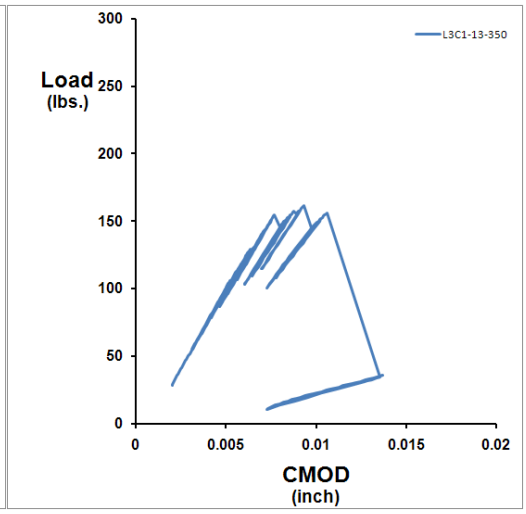


Figure D-82 CMOD vs. Load for fracture test L3C1-13-350 (Lot 400766 aged at 350 F for 24 hours)

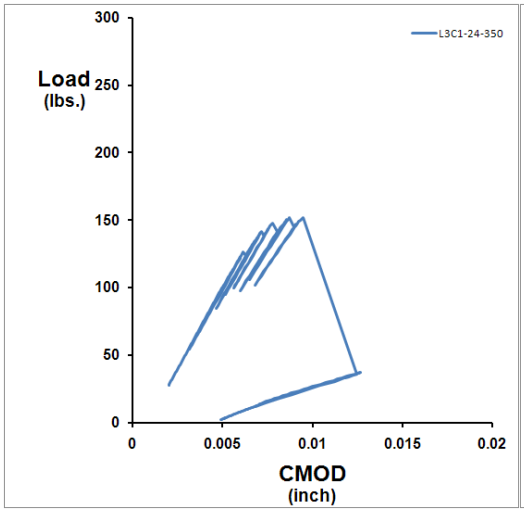


Figure D-83 CMOD vs. Load for fracture test L3C1-24-350 (Lot 400766 aged at 350 F for 24 hours)

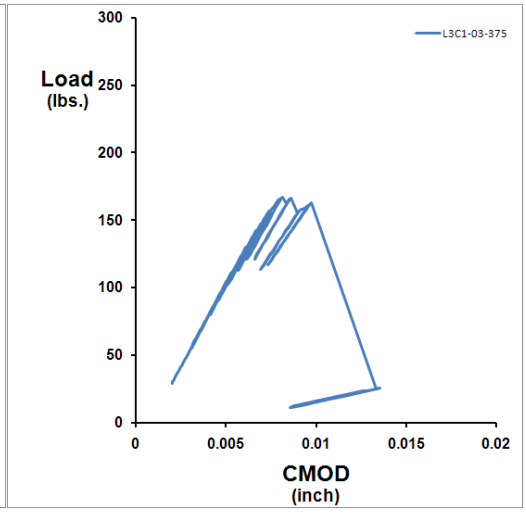


Figure D-84 CMOD vs. Load for fracture test L3C1-03-375 (Lot 400766 aged at 375 F for 24 hours)

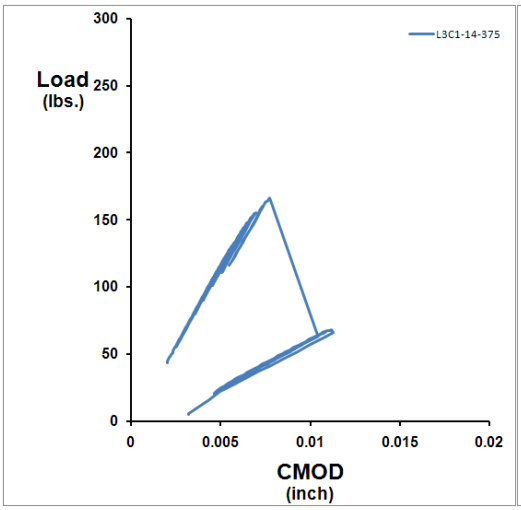


Figure D-85 CMOD vs. Load for fracture test L3C1-14-375 (Lot 400766 aged at 375 F for 24 hours)

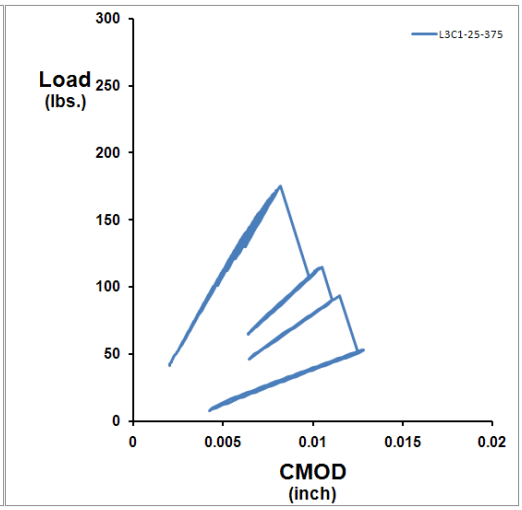


Figure D-86 CMOD vs. Load for fracture test L3C1-25-375 (Lot 400766 aged at 375 F for 24 hours)

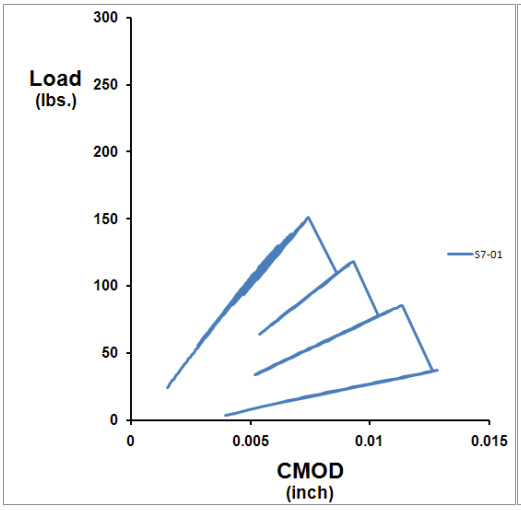


Figure D-87 CMOD vs. Load for fracture test S7-01 (Lot 620853 as received)

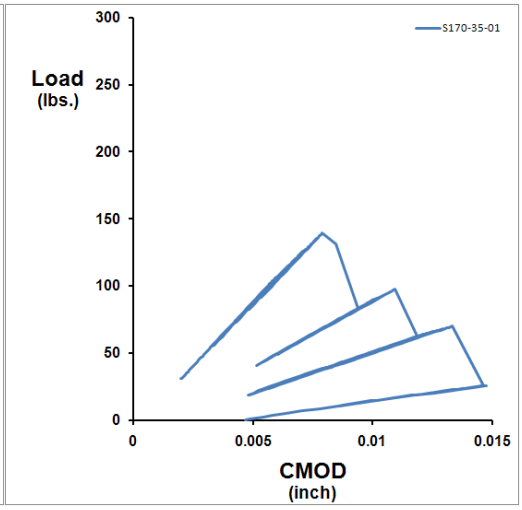


Figure D-88 CMOD vs. Load for fracture test S170-35-01 (Lot 620853 as received)

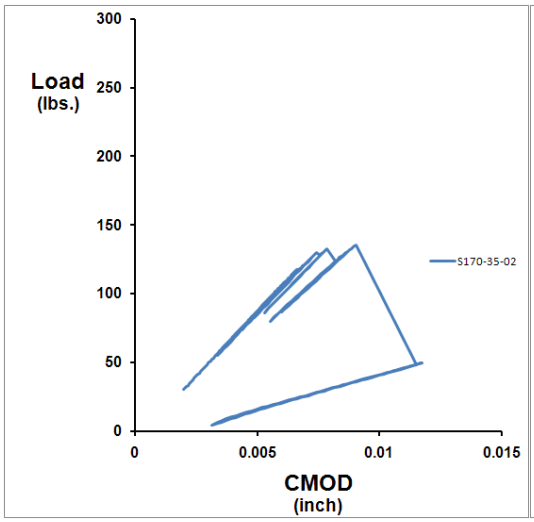


Figure D-89 CMOD vs. Load for fracture test S170-35-02 (Lot 620853 as received)

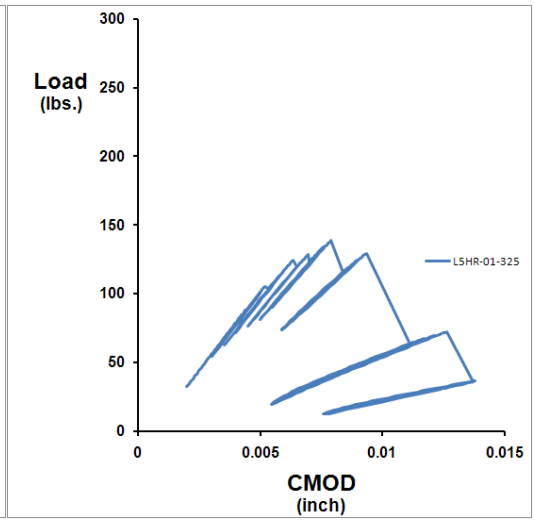


Figure D-90 CMOD vs. Load for fracture test L5HR-01-325 (Lot 620853 aged at 325 F for 24 hours)

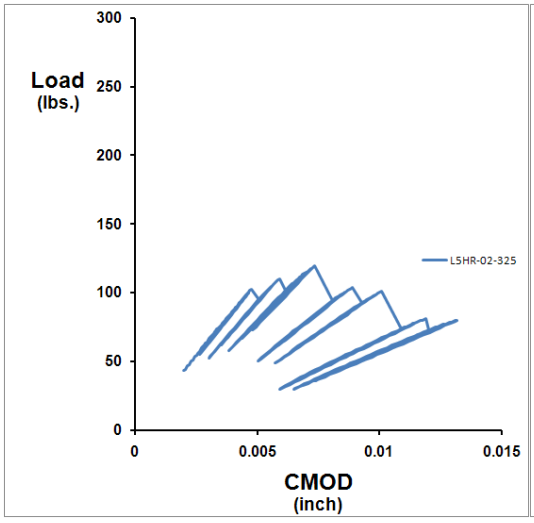


Figure D-91 CMOD vs. Load for fracture test L5HR-02-325 (Lot 620853 aged at 325 F for 24 hours)

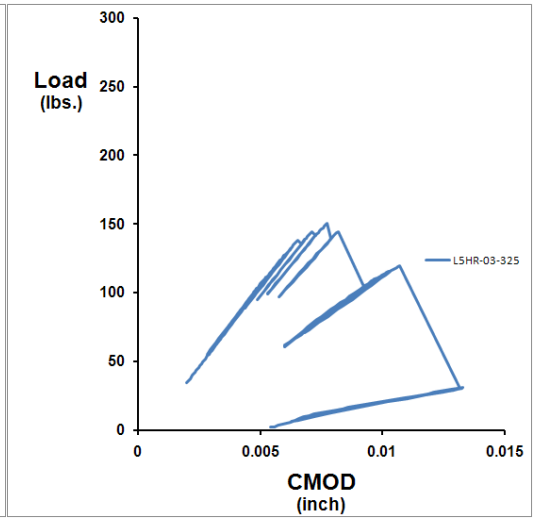


Figure D-92 CMOD vs. Load for fracture test L5HR-03-325 (Lot 620853 aged at 325 F for 24 hours)

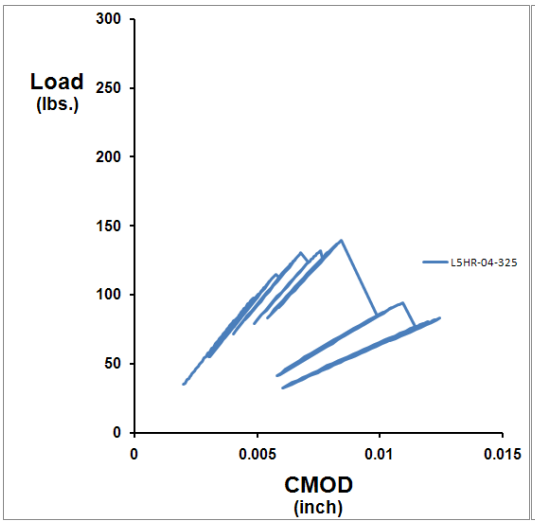


Figure D-93 CMOD vs. Load for fracture test L5HR-04-325 (Lot 620853 aged at 325 F for 24 hours)

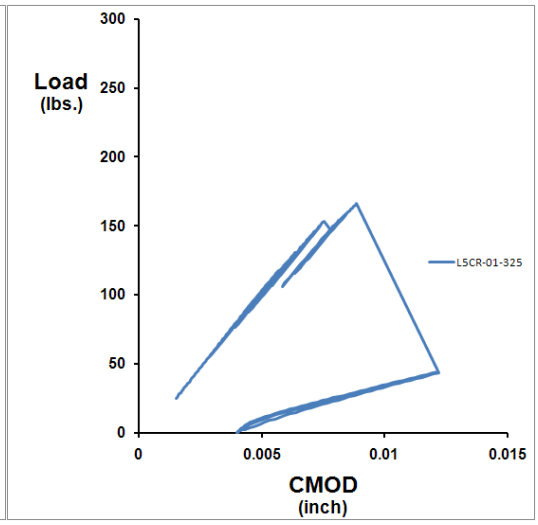


Figure D-94 CMOD vs. Load for fracture test L5CR-01-325 (Lot 620853 aged at 325 F for 24 hours)

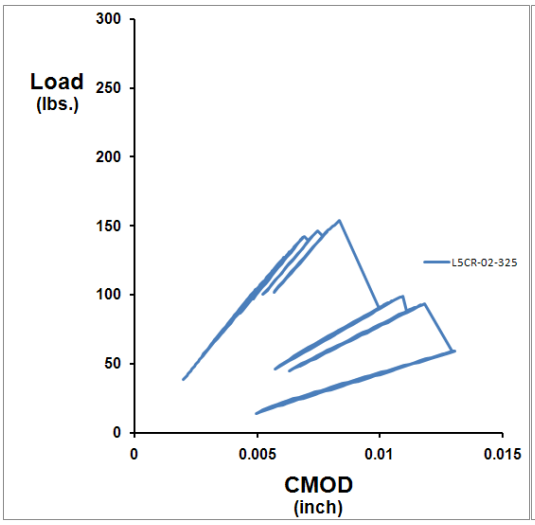


Figure D-95 CMOD vs. Load for fracture test L5CR-02-325 (Lot 620853 aged at 325 F for 24 hours)

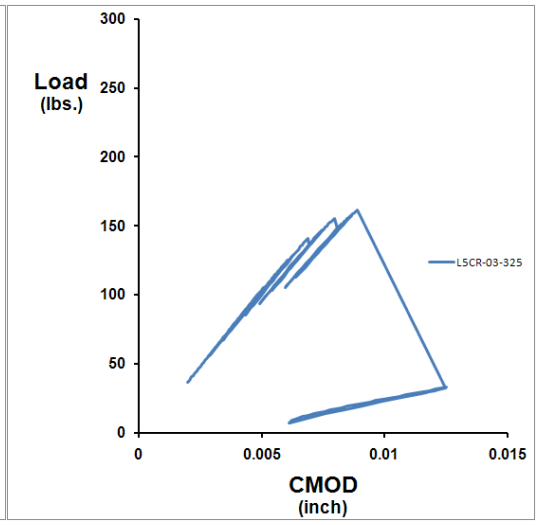


Figure D-96 CMOD vs. Load for fracture test L5CR-03-325 (Lot 620853 aged at 325 F for 24 hours)

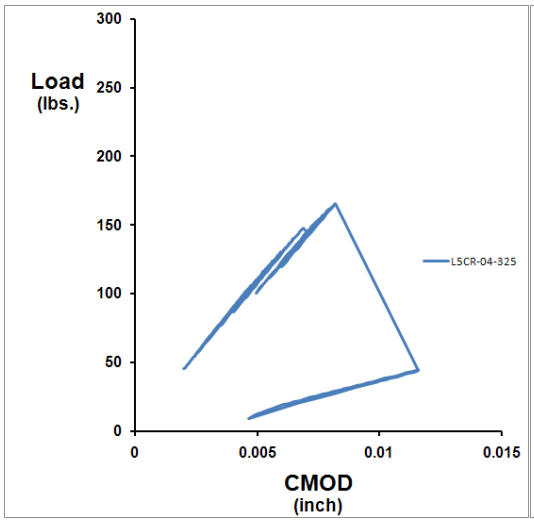


Figure D-97 CMOD vs. Load for fracture test L5CR-04-325 (Lot 620853 aged at 325 F for 24 hours)

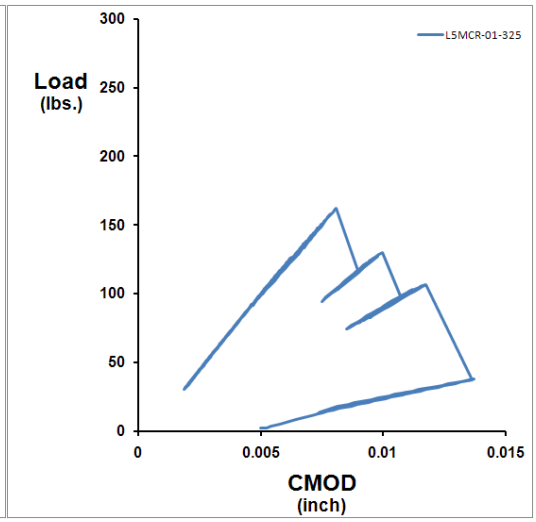


Figure D-98 CMOD vs. Load for fracture test L5MCR-01-325 (Lot 620853 aged at 325 F for 24 hours)

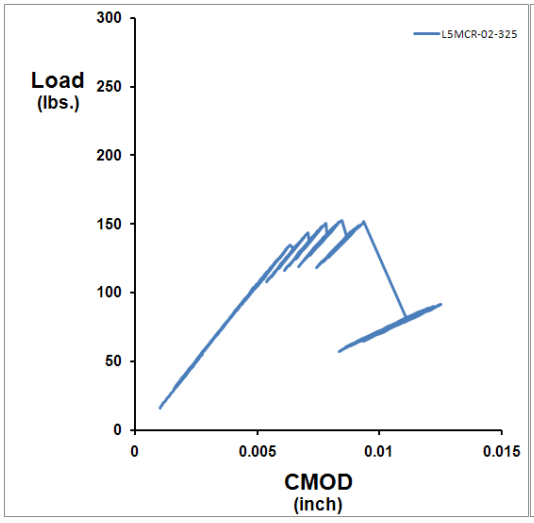


Figure D-99 CMOD vs. Load for fracture test L5MCR-02-325 (Lot 620853 aged at 325 F for 24 hours)

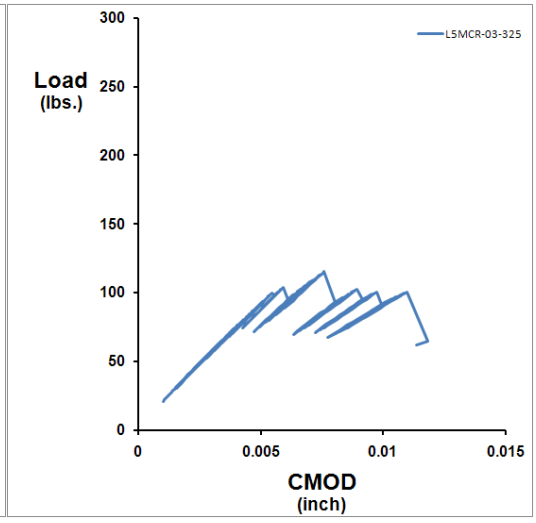


Figure D-100 CMOD vs. Load for fracture test L5MCR-03-325 (Lot 620853 aged at 325 F for 24 hours)

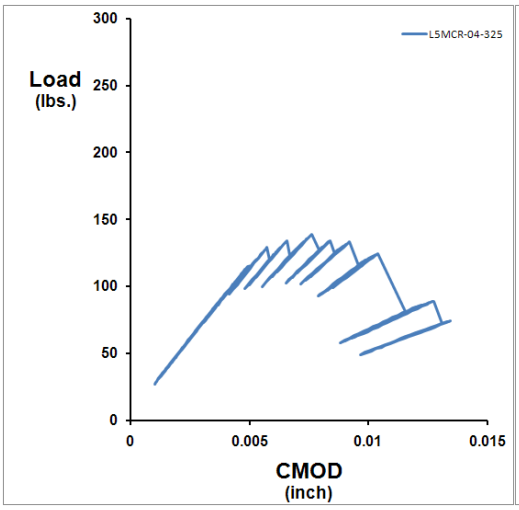


Figure D-101 CMOD vs. Load for fracture test L5MCR-04-325 (Lot 620853 aged at 325 F for 24 hours)

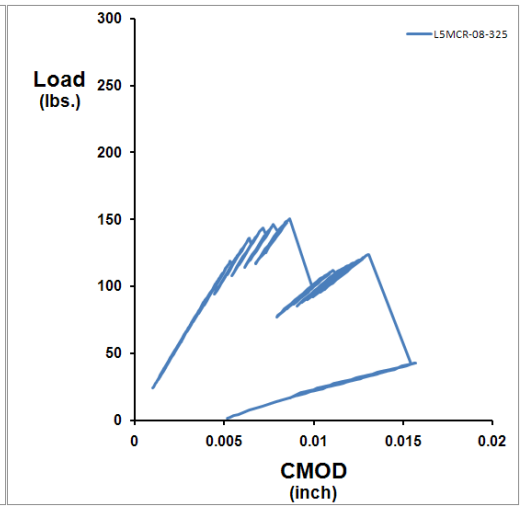


Figure D-102 CMOD vs. Load for fracture test L5MCR-08-325 (Lot 620853 aged at 325 F for 24 hours)

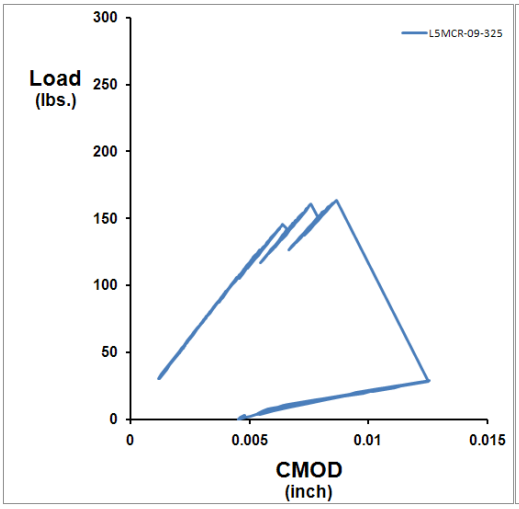


Figure D-103 CMOD vs. Load for fracture test L5MCR-09-325 (Lot 620853 aged at 325 F for 24 hours)

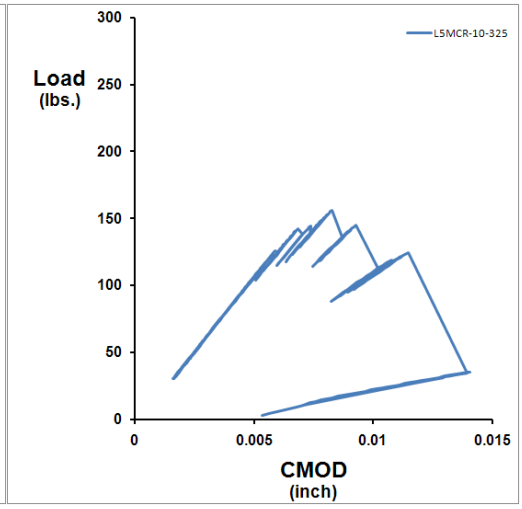


Figure D-104 CMOD vs. Load for fracture test L5MCR-10-325 (Lot 620853 aged at 325 F for 24 hours)

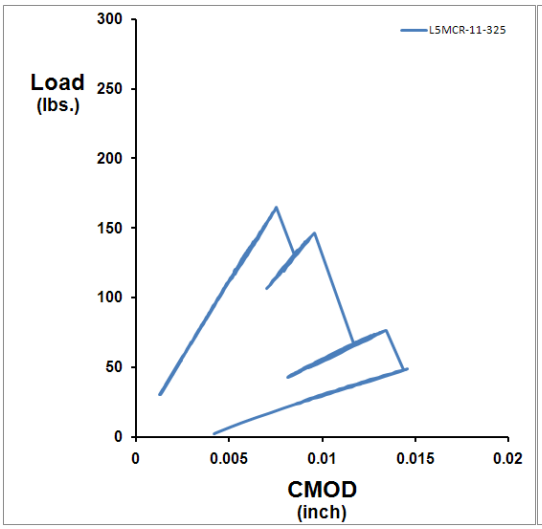


Figure D-105 CMOD vs. Load for fracture test L5MCR-11-325 (Lot 620853 aged at 325 F for 24 hours)

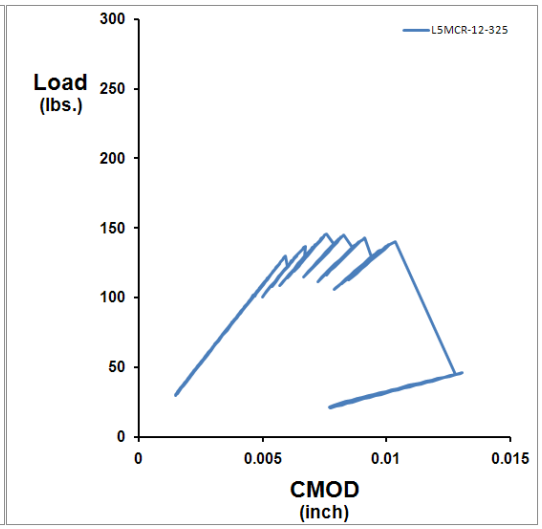


Figure D-106 CMOD vs. Load for fracture test L5MCR-12-325 (Lot 620853 aged at 325 F for 24 hours)

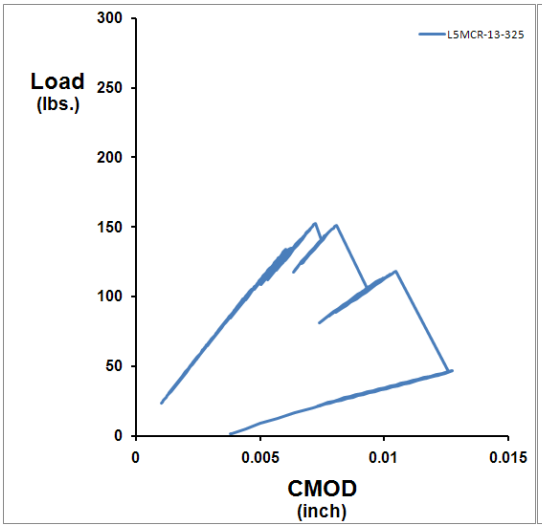


Figure D-107 CMOD vs. Load for fracture test L5MCR-13-325 (Lot 620853 aged at 325 F for 24 hours)

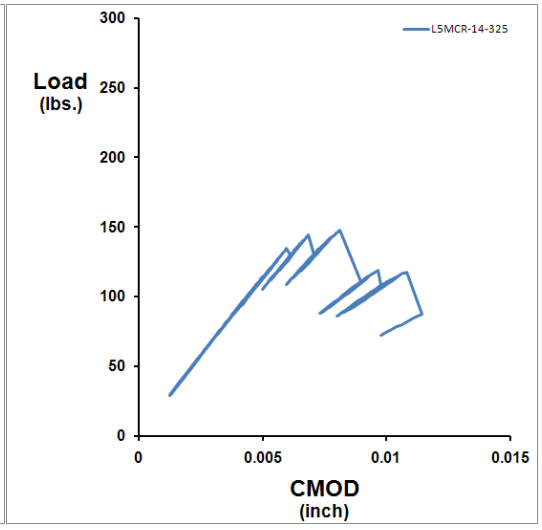


Figure D-108 CMOD vs. Load for fracture test L5MCR-14-325 (Lot 620853 aged at 325 F for 24 hours)

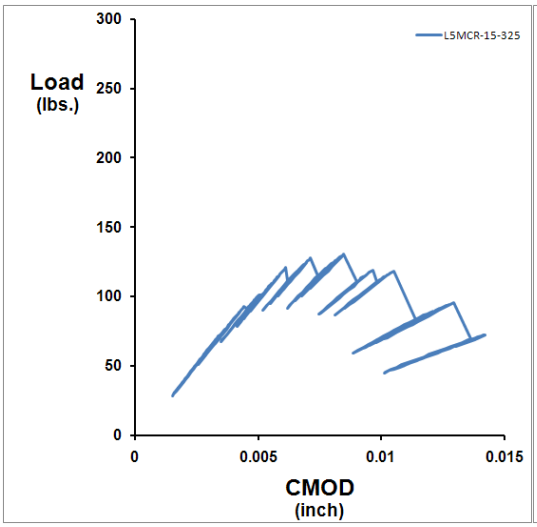


Figure D-109 CMOD vs. Load for fracture test L5MCR-15-325 (Lot 620853 aged at 325 F for 24 hours)

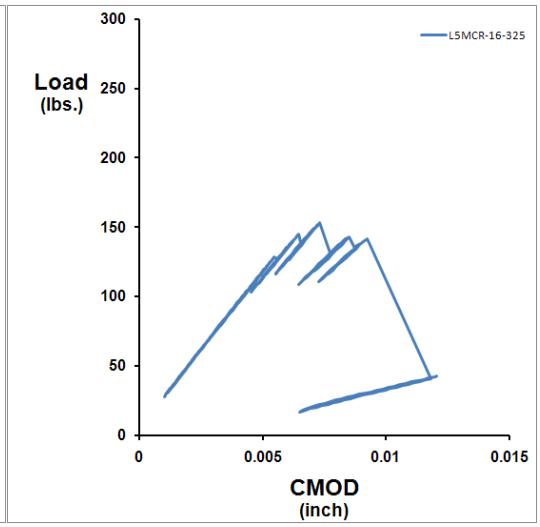


Figure D-110 CMOD vs. Load for fracture test L5MCR-16-325 (Lot 620853 aged at 325 F for 24 hours)

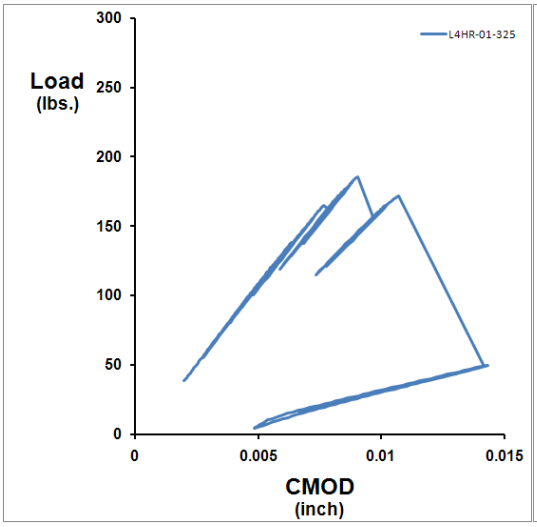


Figure D-111 CMOD vs. Load for fracture test L4HR-01-325 (Lot 620854 aged at 325 F for 24 hours)

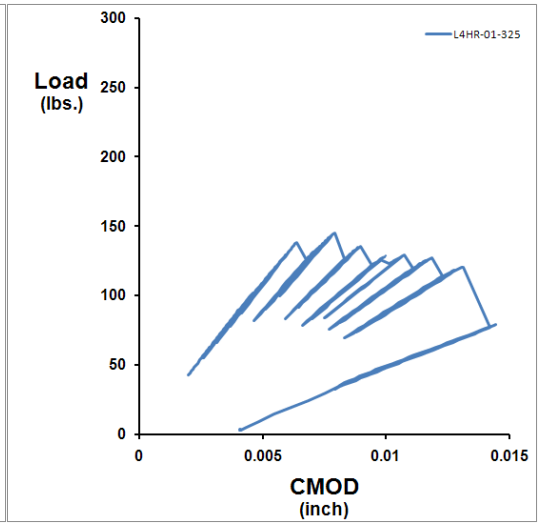


Figure D-112 CMOD vs. Load for fracture test L4HR-02-325 (Lot 620854 aged at 325 F for 24 hours)

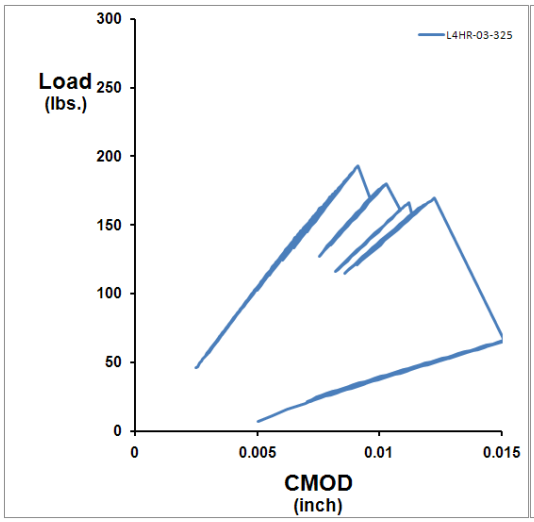


Figure D-113 CMOD vs. Load for fracture test L4HR-03-325 (Lot 620854 aged at 325 F for 24 hours)

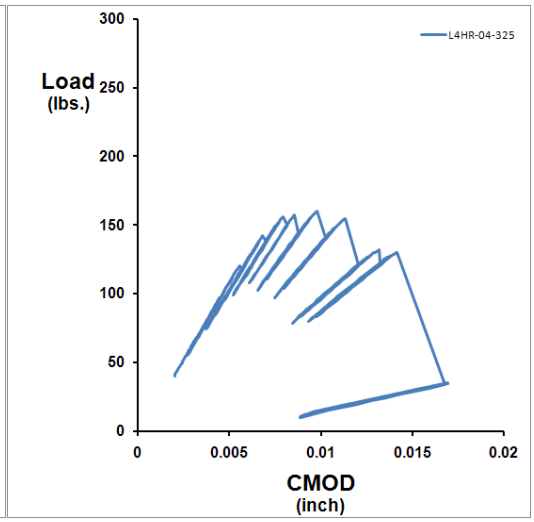


Figure D-114 CMOD vs. Load for fracture test L4HR-04-325 (Lot 620854 aged at 325 F for 24 hours)

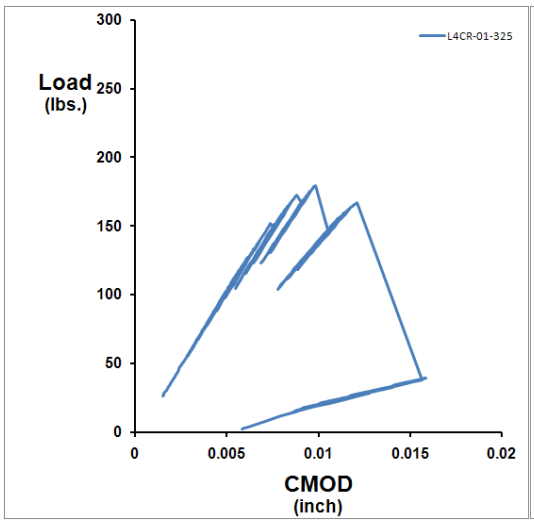


Figure D-115 CMOD vs. Load for fracture test L4CR-01-325 (Lot 620854 aged at 325 F for 24 hours)

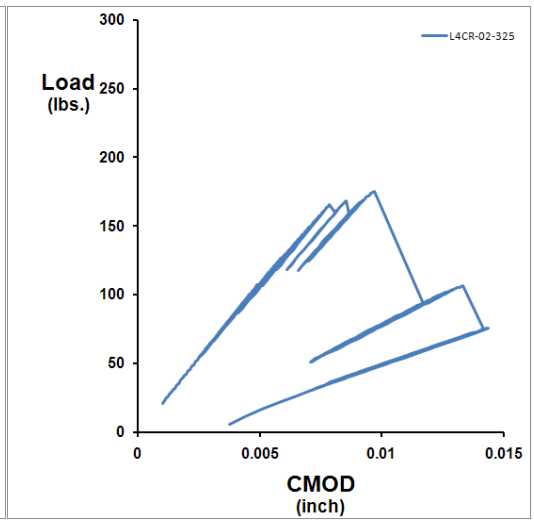


Figure D-116 CMOD vs. Load for fracture test L4CR-02-325 (Lot 620854 aged at 325 F for 24 hours)

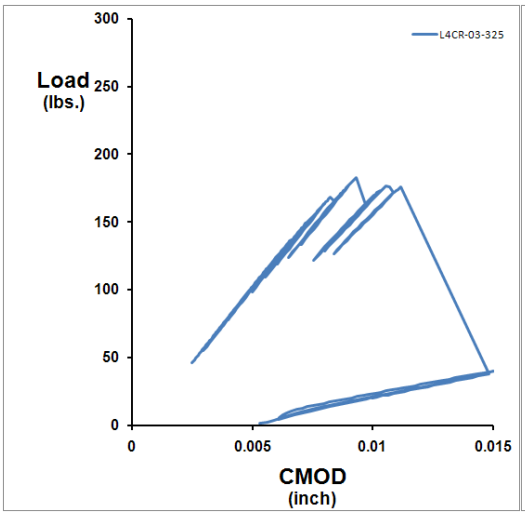


Figure D-117 CMOD vs. Load for fracture test L4CR-03-325 (Lot 620854 aged at 325 F for 24 hours)

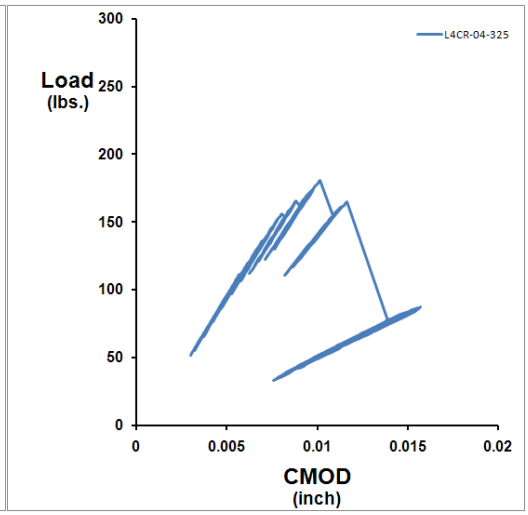


Figure D-118 CMOD vs. Load for fracture test L4CR-04-325 (Lot 620854 aged at 325 F for 24 hours)

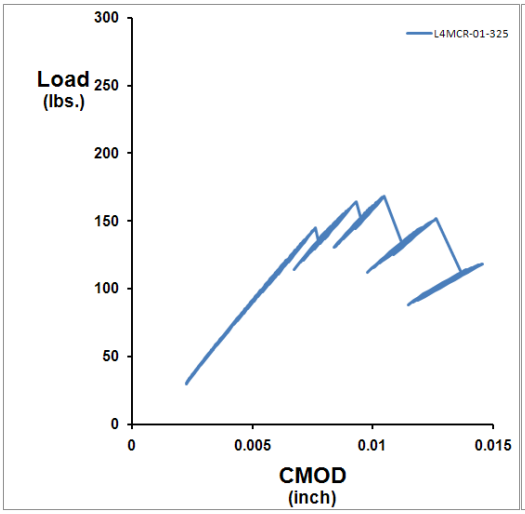


Figure D-119 CMOD vs. Load for fracture test L4MCR-01-325 (Lot 620854 aged at 325 F for 24 hours)

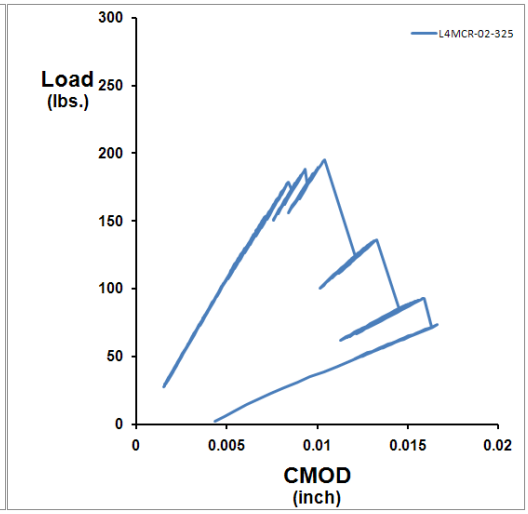


Figure D-120 CMOD vs. Load for fracture test L4MCR-02-325 (Lot 620854 aged at 325 F for 24 hours)

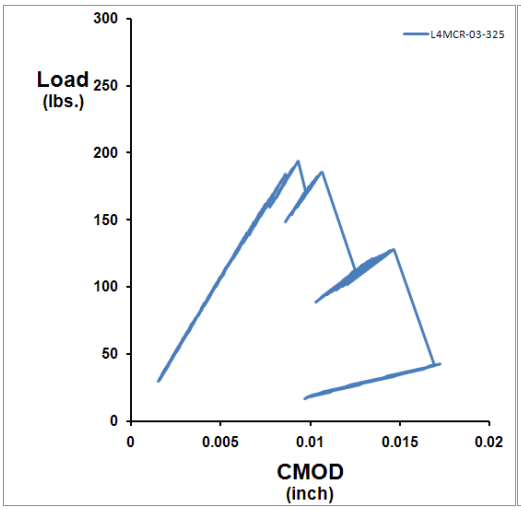


Figure D-121 CMOD vs. Load for fracture test L4MCR-03-325 (Lot 620854 aged at 325 F for 24 hours)

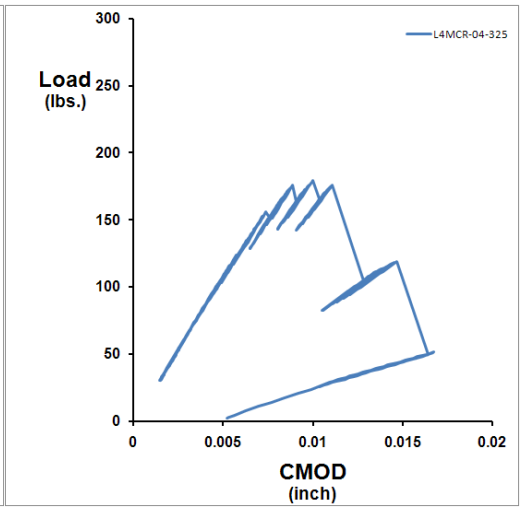


Figure D-122 CMOD vs. Load for fracture test L4CR-04-325 (Lot 620854 aged at 325 F for 24 hours)

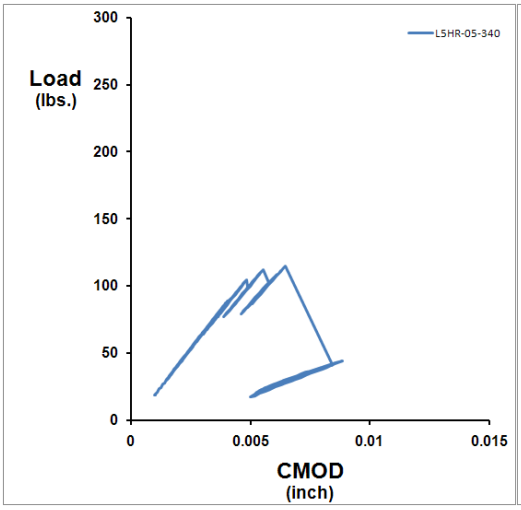


Figure D-123 CMOD vs. Load for fracture test L5HR-05-340 (Lot 620853 aged at 340 F for 24 hours)

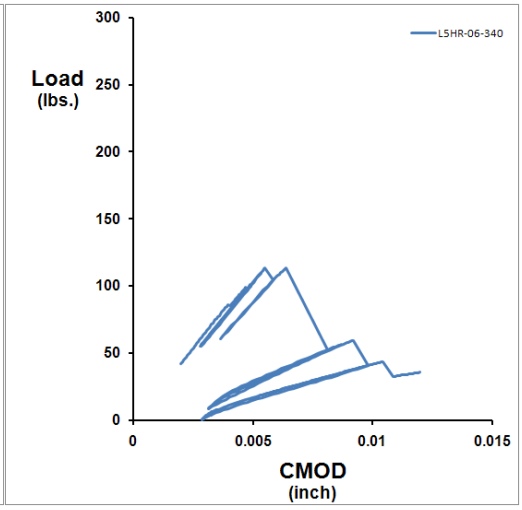


Figure D-124 CMOD vs. Load for fracture test L5HR-06-340 (Lot 620853 aged at 340 F for 24 hours)

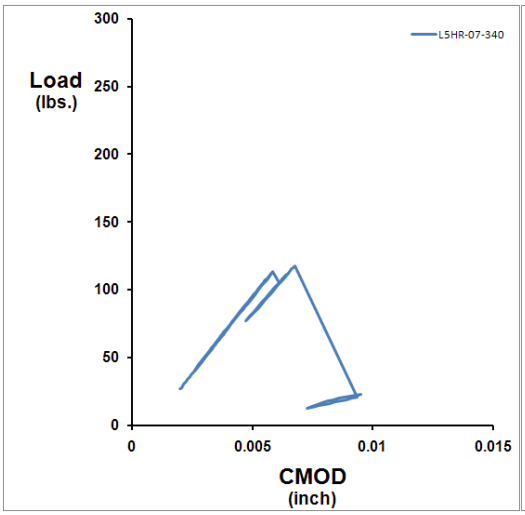


Figure D-125 CMOD vs. Load for fracture test L5HR-07-340 (Lot 620853 aged at 340 F for 24 hours)

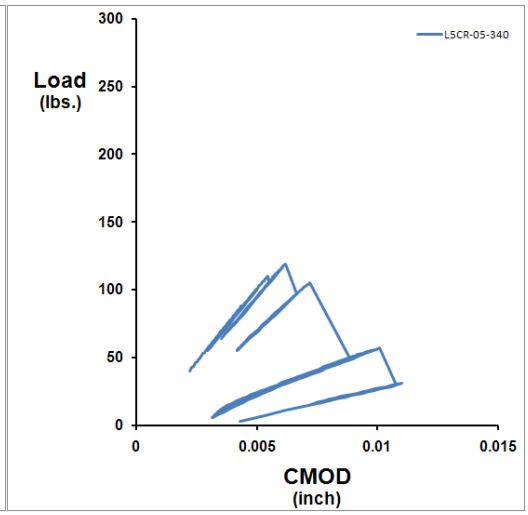


Figure D-126 CMOD vs. Load for fracture test L5CR-05-340 (Lot 620853 aged at 340 F for 24 hours)

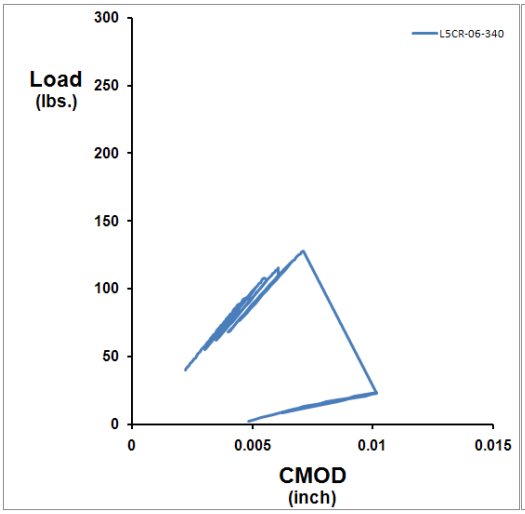


Figure D-127 CMOD vs. Load for fracture test L5CR-06-340 (Lot 620853 aged at 340 F for 24 hours)

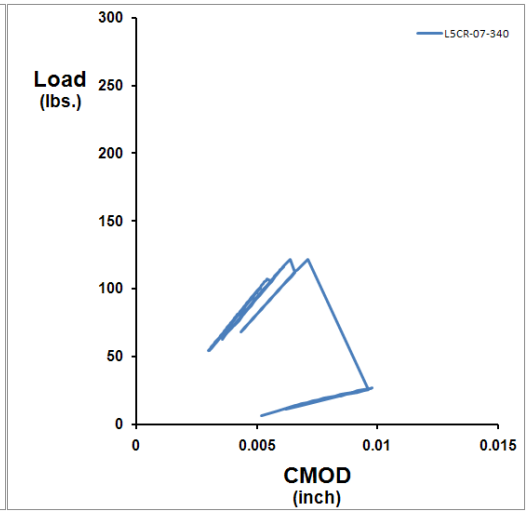


Figure D-128 CMOD vs. Load for fracture test L4CR-07-340 (Lot 620853 aged at 340 F for 24 hours)

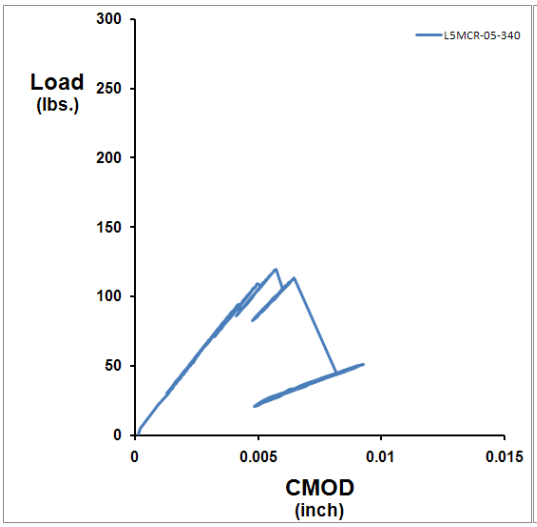


Figure D-129 CMOD vs. Load for fracture test L5MCR-05-340 (Lot 620853 aged at 340 F for 24 hours)

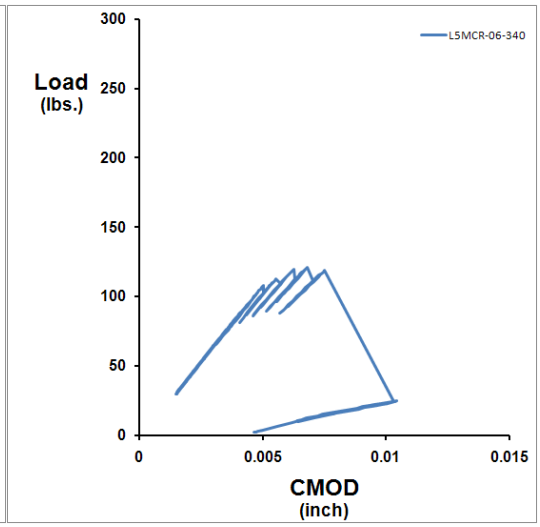


Figure D-130 CMOD vs. Load for fracture test L5MCR-06-340 (Lot 620853 aged at 340 F for 24 hours)

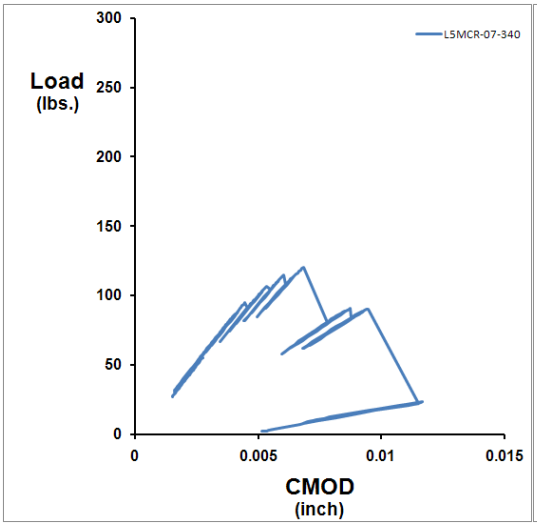


Figure D-131 CMOD vs. Load for fracture test L5MCR-07-340 (Lot 620853 aged at 340 F for 24 hours)

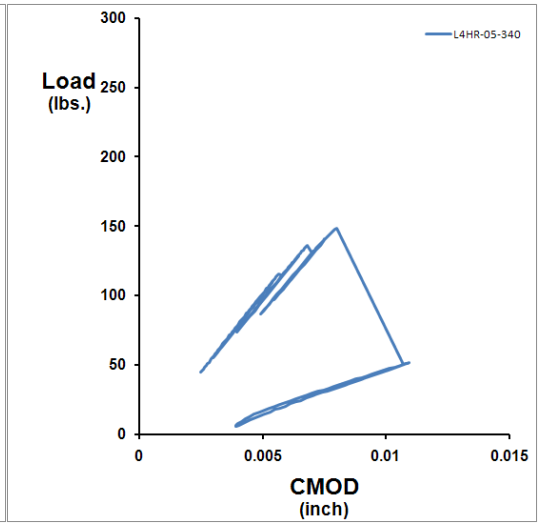


Figure D-132 CMOD vs. Load for fracture test L4HR-05-340 (Lot 620854 aged at 340 F for 24 hours)

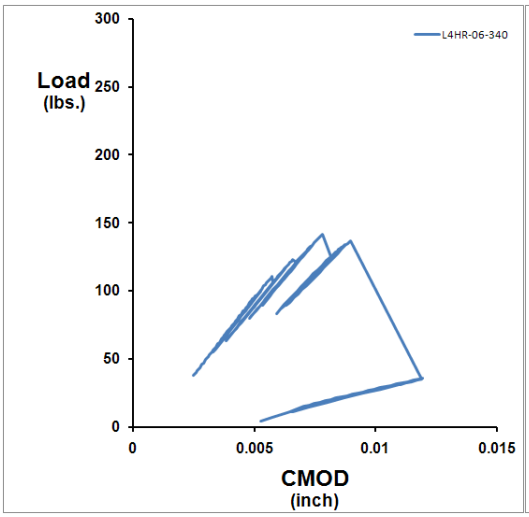


Figure D-133 CMOD vs. Load for fracture test L4HR-06-340 (Lot 620854 aged at 340 F for 24 hours)

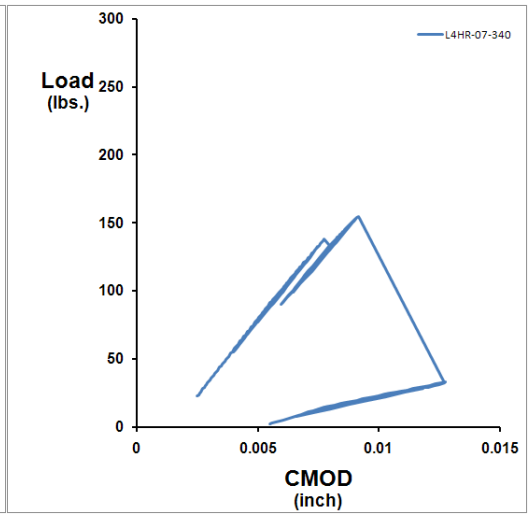


Figure D-134 CMOD vs. Load for fracture test L4HR-07-340 (Lot 620854 aged at 340 F for 24 hours)

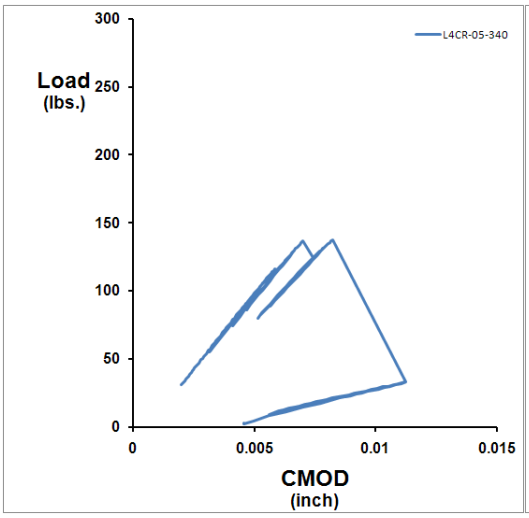


Figure D-135 CMOD vs. Load for fracture test L4CR-05-340 (Lot 620854 aged at 340 F for 24 hours)

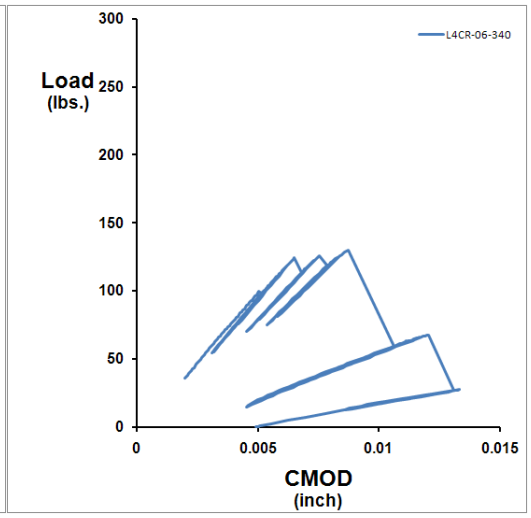


Figure D-136 CMOD vs. Load for fracture test L4CR-06-340 (Lot 620854 aged at 340 F for 24 hours)

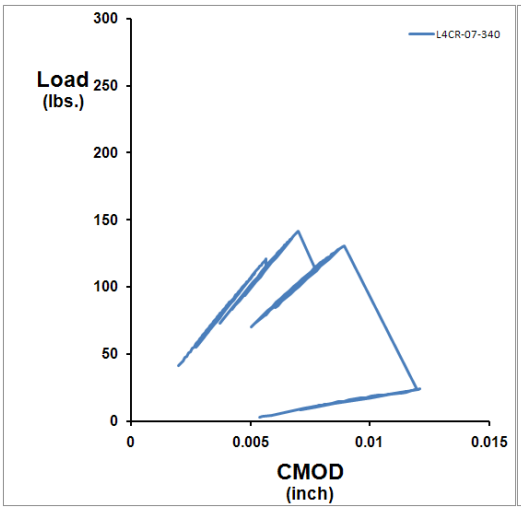


Figure D-137 CMOD vs. Load for fracture test L4CR-07-340 (Lot 620854 aged at 340 F for 24 hours)

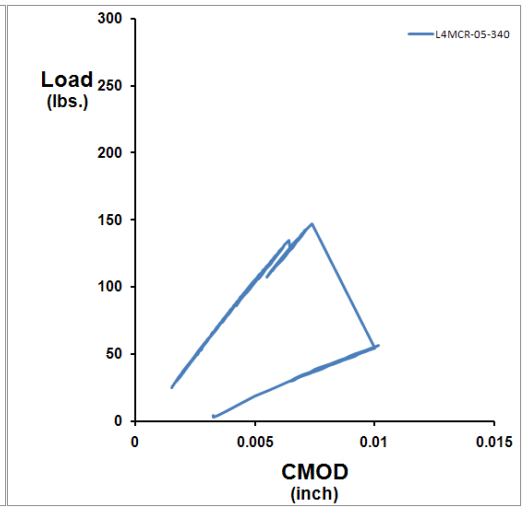


Figure D-138 CMOD vs. Load for fracture test L4MCR-05-340 (Lot 620854 aged at 340 F for 24 hours)

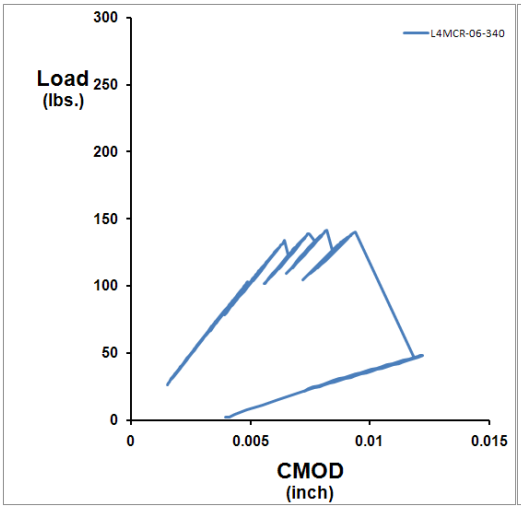


Figure D-139 CMOD vs. Load for fracture test L4MCR-06-340 (Lot 620854 aged at 340 F for 24 hours)

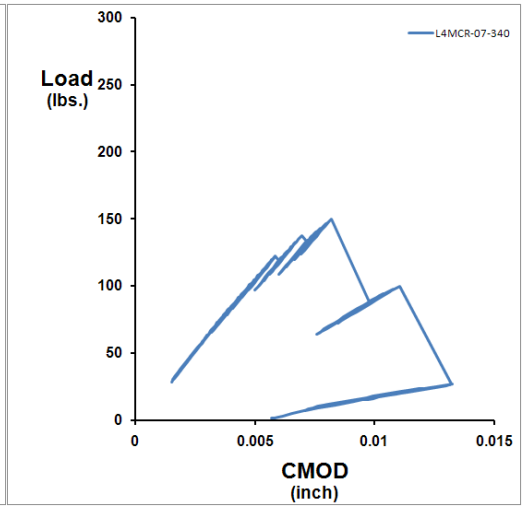


Figure D-140 CMOD vs. Load for fracture test L4MCR-07-340 (Lot 620854 aged at 340 F for 24 hours)

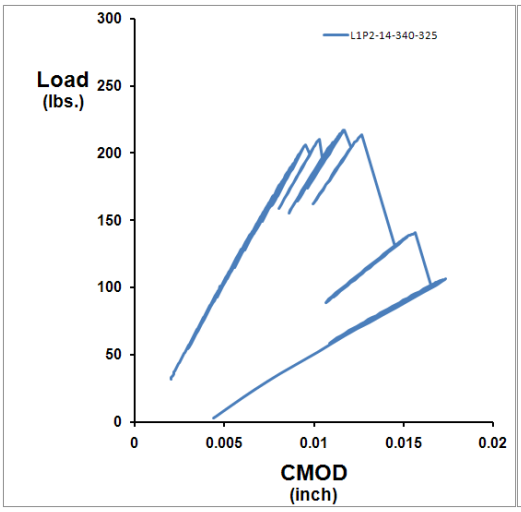


Figure D-141 CMOD vs. Load for fracture test L1P2-14-340-325 (Lot 400751 exposed to 340 F for 10 min. & aged at 325 F for 24 hrs.)

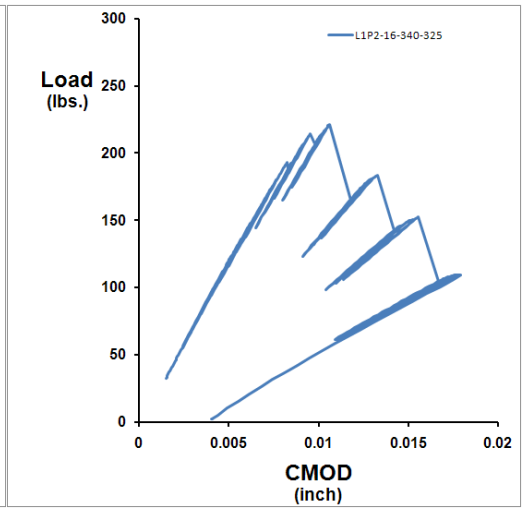


Figure D-142 CMOD vs. Load for fracture test L1P2-16-340-325 (Lot 400751 exposed to 340 F for 10 min. & aged at 325 F for 24 hrs.)

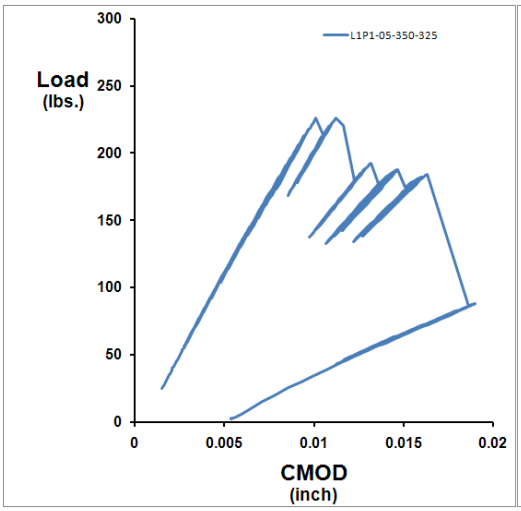


Figure D-143 CMOD vs. Load for fracture test L1P1-15-350-325 (Lot 400751 exposed to 350 F for 10 min. & aged at 325 F for 24 hrs.)

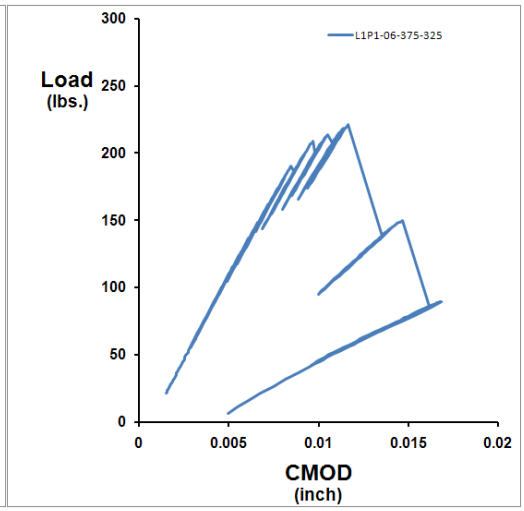


Figure D-144 CMOD vs. Load for fracture test L1P1-06-375-325 (Lot 400751 exposed to 375 F for 10 min. & aged at 325 F for 24 hrs.)

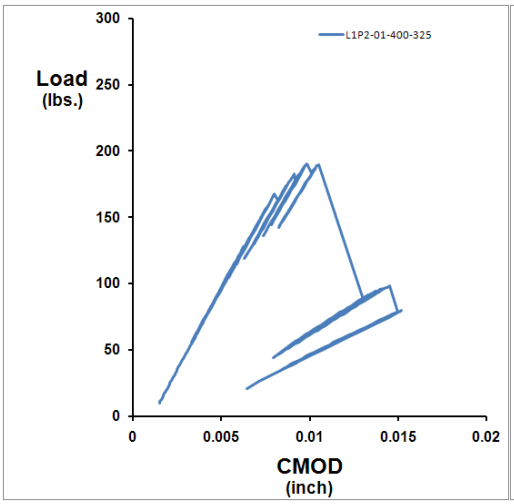


Figure D-145 CMOD vs. Load for fracture test L1P2-01-400-325 (Lot 400751 exposed to 400 F for 10 min. & aged at 325 F for 24 hrs.)

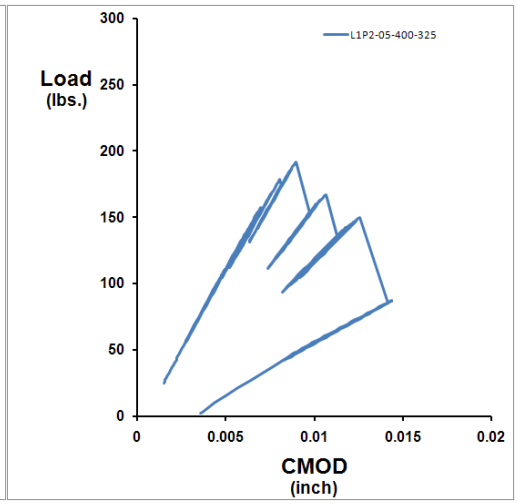


Figure D-146 CMOD vs. Load for fracture test L1P2-05-400-325 (Lot 400751 exposed to 400 F for 10 min. & aged at 325 F for 24 hrs.)

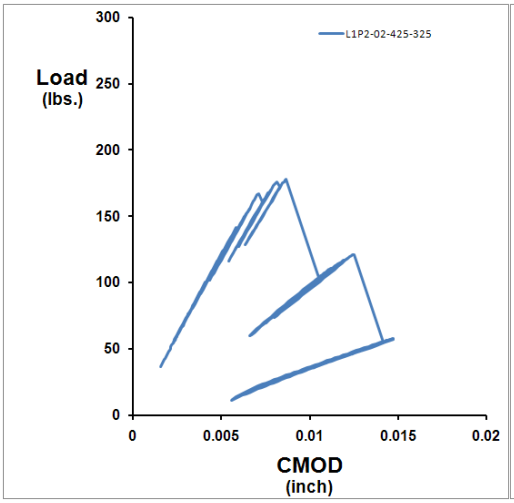


Figure D-147 CMOD vs. Load for fracture test L1P2-02-425-325 (Lot 400751 exposed to 425 F for 10 min. & aged at 325 F for 24 hrs.)

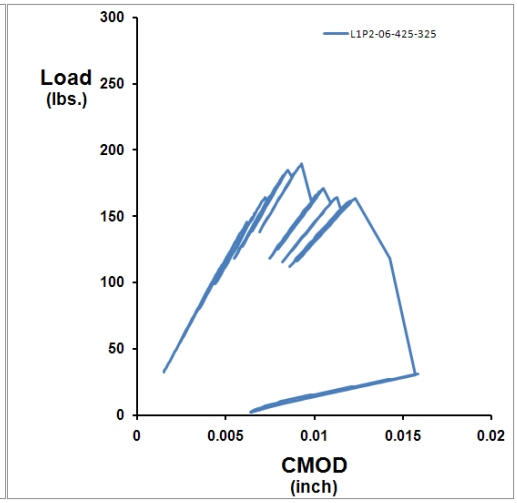


Figure D-148 CMOD vs. Load for fracture test L1P1-06-425-325 (Lot 400751 exposed to 425 F for 10 min. & aged at 325 F for 24 hrs.)

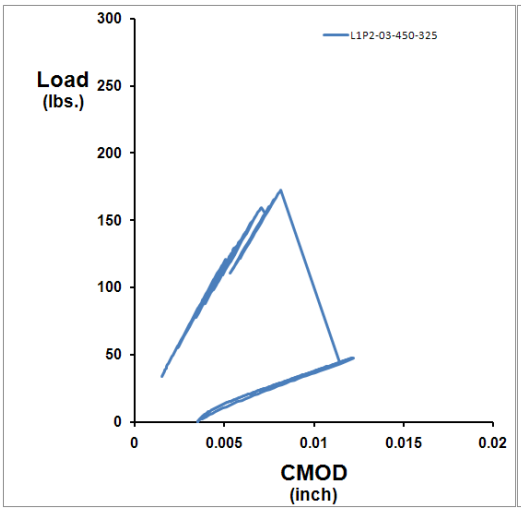


Figure D-149 CMOD vs. Load for fracture test L1P2-03-450-325 (Lot 400751 exposed to 450 F for 10 min. & aged at 325 F for 24 hrs.)

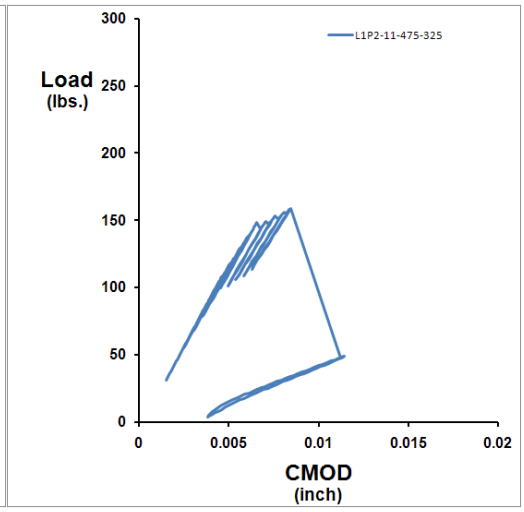


Figure D-150 CMOD vs. Load for fracture test L1P2-11-475-325 (Lot 400751 exposed to 475 F for 10 min. & aged at 325 F for 24 hrs.)

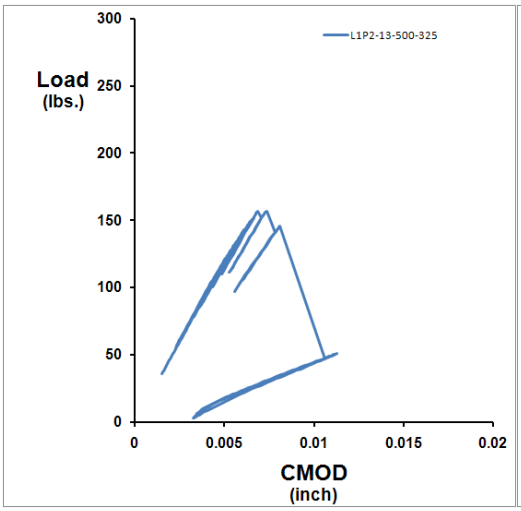


Figure D-151 CMOD vs. Load for fracture test L1P2-13-500-325 (Lot 400751 exposed to 500 F for 10 min. & aged at 325 F for 24 hrs.)

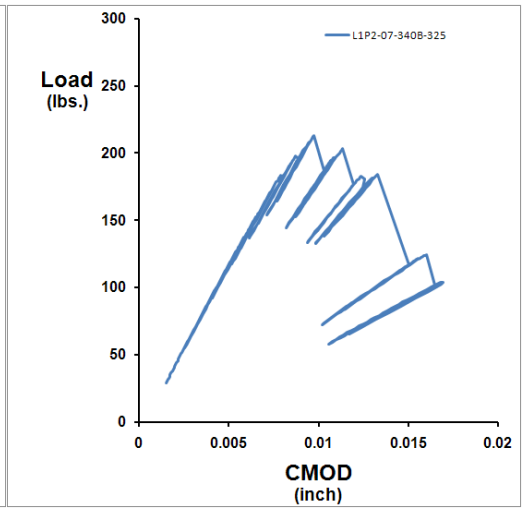


Figure D-152 CMOD vs. Load for fracture test L1P2-07-340B-325 (Lot 400751 exposed to 340 F for 20 min. & aged at 325 F for 24 hrs.)

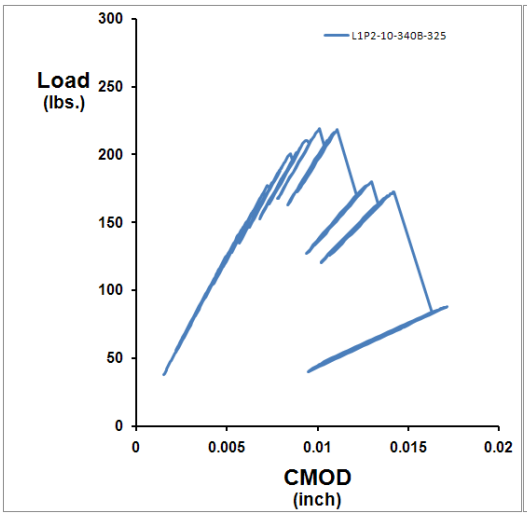


Figure D-153 CMOD vs. Load for fracture test L1P2-10-340-325 (Lot 400751 exposed to 340 F for 20 min. & aged at 325 F for 24 hrs.)

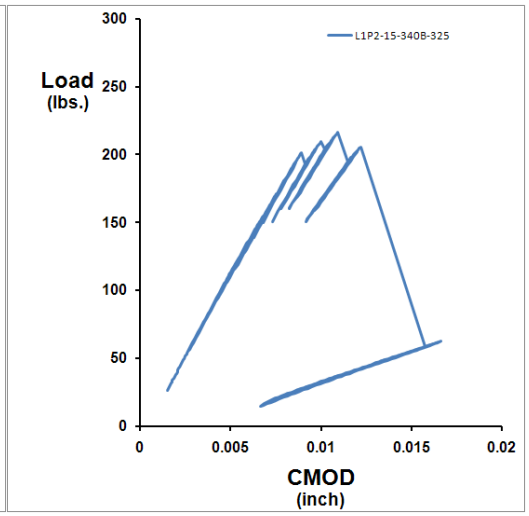


Figure D-154 CMOD vs. Load for fracture test L1P2-15-340-325 (Lot 400751 exposed to 340 F for 20 min. & aged at 325 F for 24 hrs.)

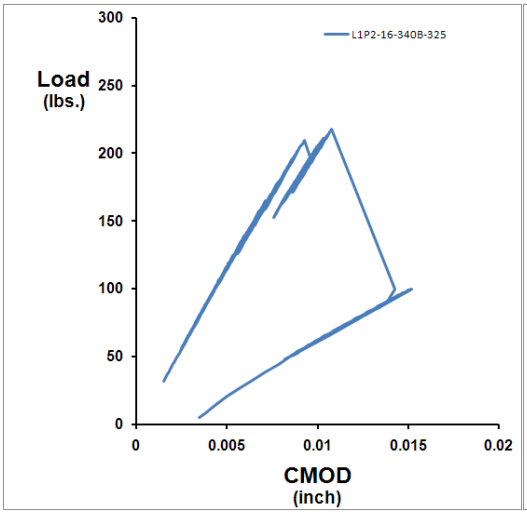


Figure D-155 CMOD vs. Load for fracture test L1P2-16-340-325 (Lot 400751 exposed to 340 F for 20 min. & aged at 325 F for 24 hrs.)

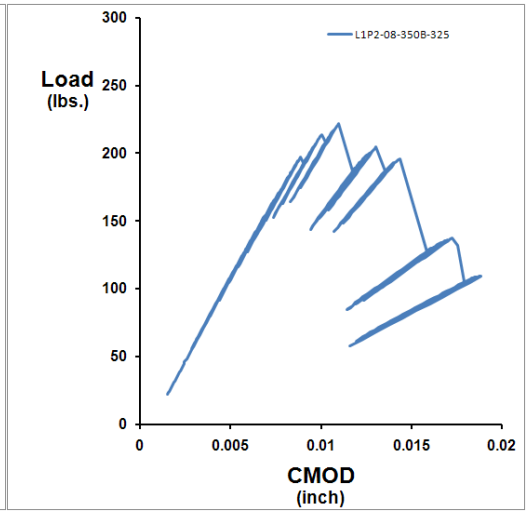


Figure D-156 CMOD vs. Load for fracture test L1P2-08-350B-325 (Lot 400751 exposed to 350 F for 20 min. & aged at 325 F for 24 hrs.)

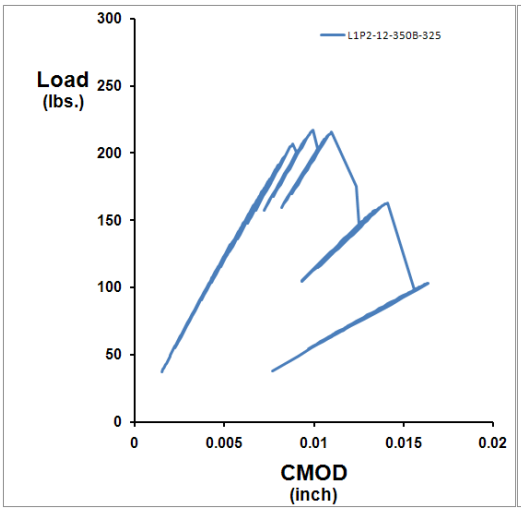


Figure D-157 CMOD vs. Load for fracture test L1P2-12-350-325 (Lot 400751 exposed to 350 F for 20 min. & aged at 325 F for 24 hrs.)

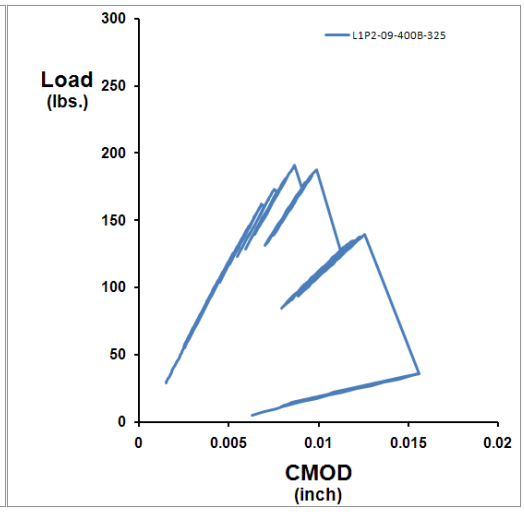


Figure D-158 CMOD vs. Load for fracture test L1P2-09-400-325 (Lot 400751 exposed to 400 F for 20 min. & aged at 325 F for 24 hrs.)

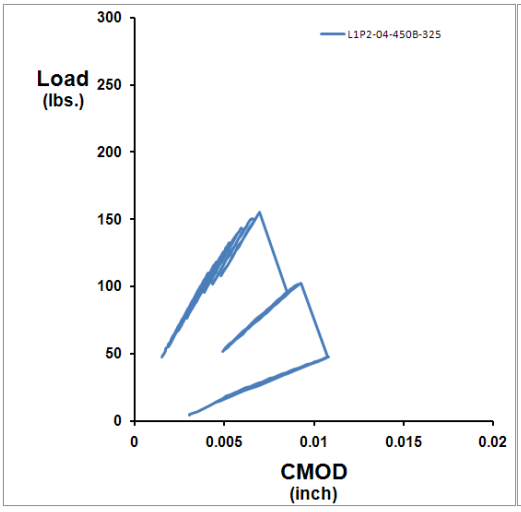


Figure D-159 CMOD vs. Load for fracture test L1P2-04-400-325 (Lot 400751 exposed to 400 F for 20 min. & aged at 325 F for 24 hrs.)

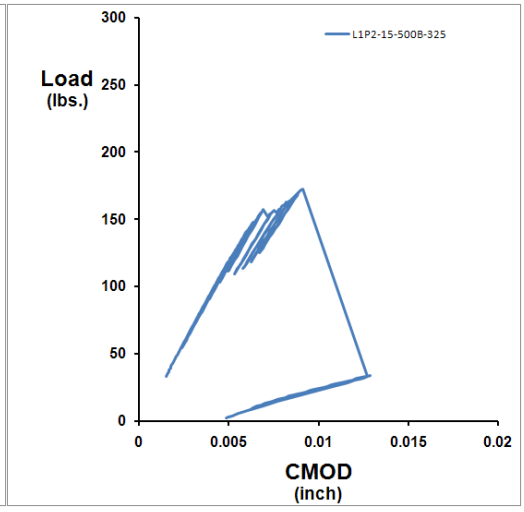


Figure D-160 CMOD vs. Load for fracture test L1P2-15-500B-325 (Lot 400751 exposed to 500 F for 20 min. & aged at 325 F for 24 hrs.)

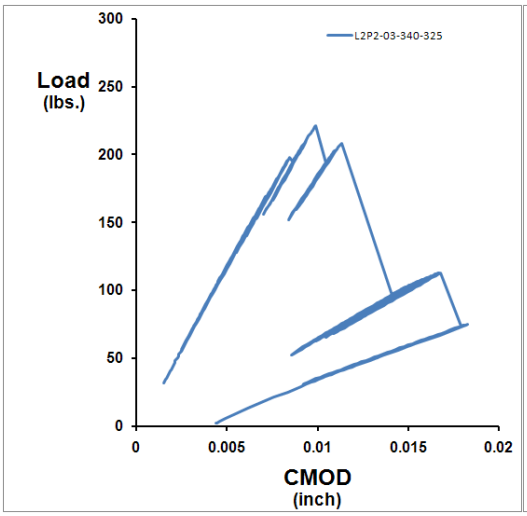


Figure D-161 CMOD vs. Load for fracture test L2P2-03-340-325 (Lot 400768 exposed to 340 F for 10 min. & aged at 325 F for 24 hrs.)

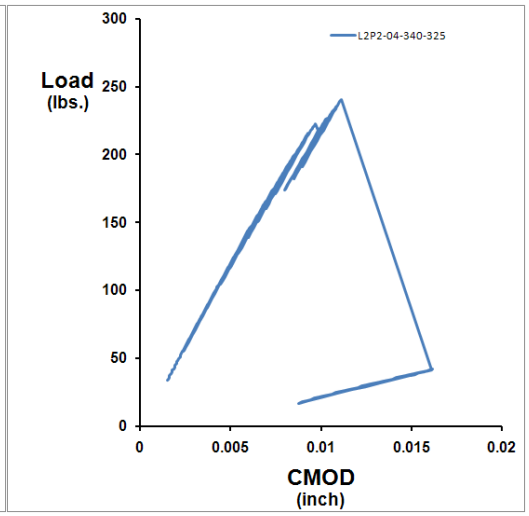


Figure D-162 CMOD vs. Load for fracture test L2P2-04-340-325 (Lot 400768 exposed to 340 F for 10 min. & aged at 325 F for 24 hrs.)

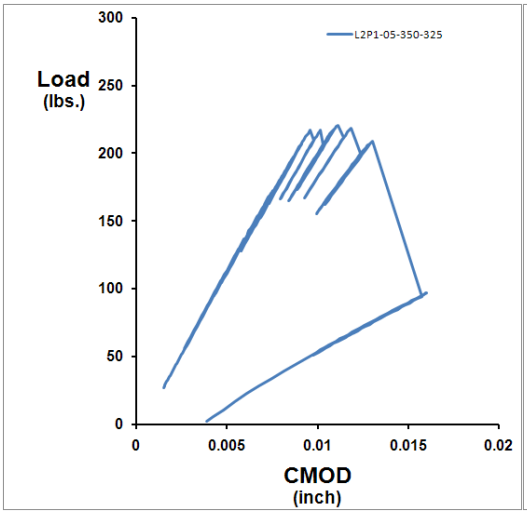


Figure D-163 CMOD vs. Load for fracture test L2P2-05-350-325 (Lot 400768 exposed to 350 F for 10 min. & aged at 325 F for 24 hrs.)

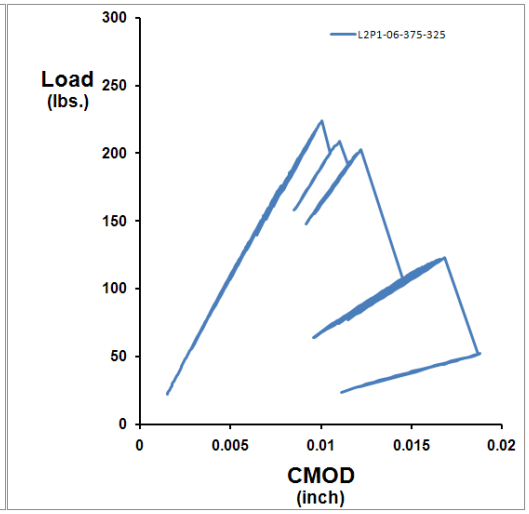


Figure D-164 CMOD vs. Load for fracture test L2P1-06-375-325 (Lot 400768 exposed to 375 F for 10 min. & aged at 325 F for 24 hrs.)

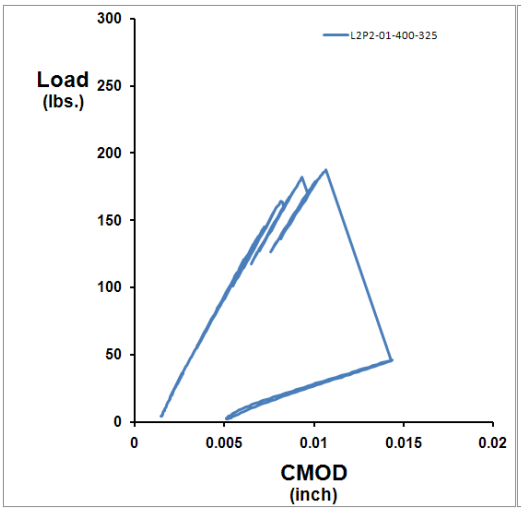


Figure D-165 CMOD vs. Load for fracture test L2P2-01-400-325 (Lot 400768 exposed to 400 F for 10 min. & aged at 325 F for 24 hrs.)

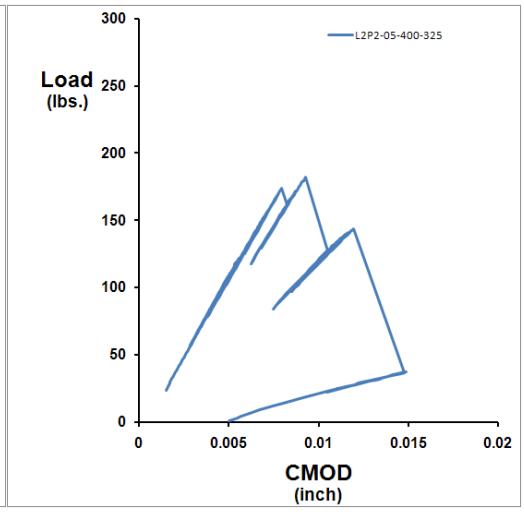


Figure D-166 CMOD vs. Load for fracture test L2P2-05-400-325 (Lot 400768 exposed to 400 F for 10 min. & aged at 325 F for 24 hrs.)

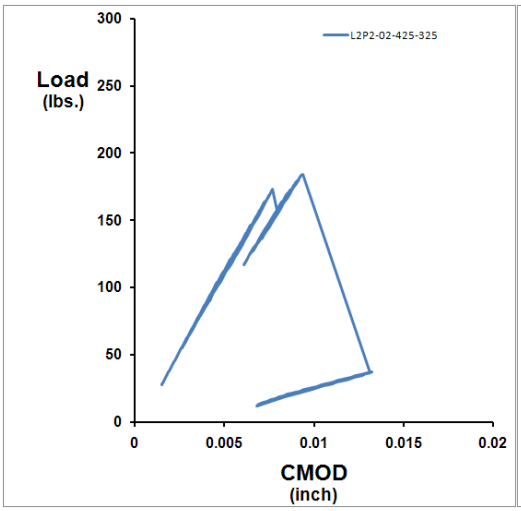


Figure D-167 CMOD vs. Load for fracture test L2P2-02-425-325 (Lot 400768 exposed to 425 F for 10 min. & aged at 325 F for 24 hrs.)

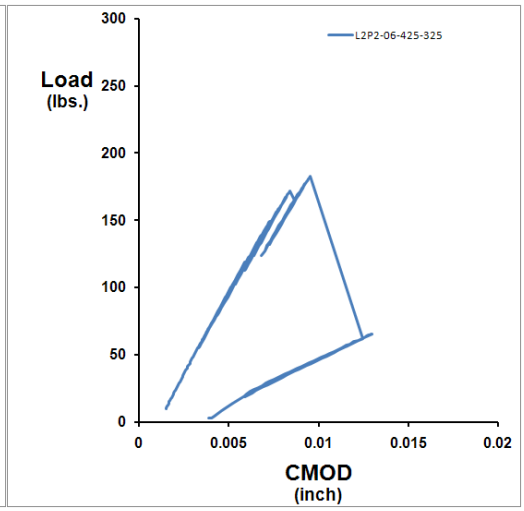


Figure D-168 CMOD vs. Load for fracture test L2P2-06-425-325 (Lot 400768 exposed to 425 F for 10 min. & aged at 325 F for 24 hrs.)

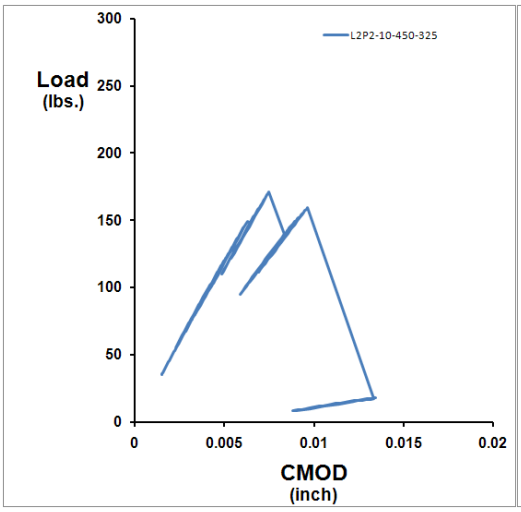


Figure D-169 CMOD vs. Load for fracture test L2P2-10-450-325 (Lot 400768 exposed to 450 F for 10 min. & aged at 325 F for 24 hrs.)

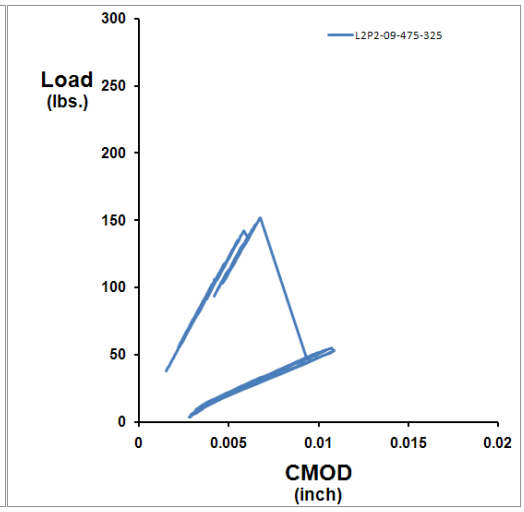


Figure D-170 CMOD vs. Load for fracture test L2P2-09-475-325 (Lot 400768 exposed to 475 F for 10 min. & aged at 325 F for 24 hrs.)

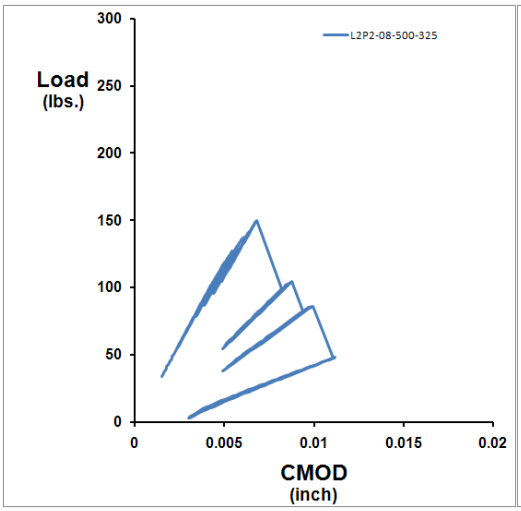


Figure D-171 CMOD vs. Load for fracture test L2P2-08-500-325 (Lot 400768 exposed to 500 F for 10 min. & aged at 325 F for 24 hrs.)

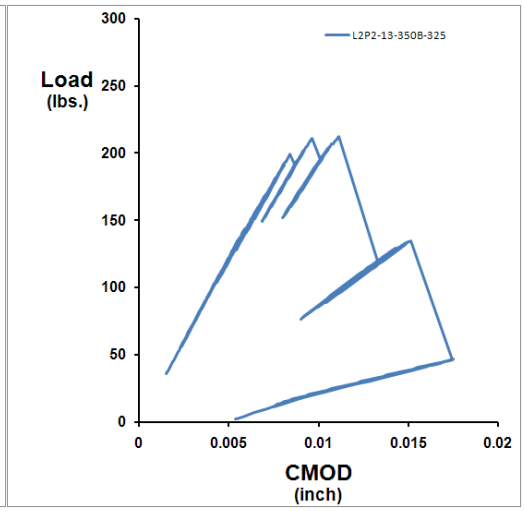


Figure D-172 CMOD vs. Load for fracture test L2P2-13-350B-325 (Lot 400768 exposed to 350 F for 20 min. & aged at 325 F for 24 hrs.)

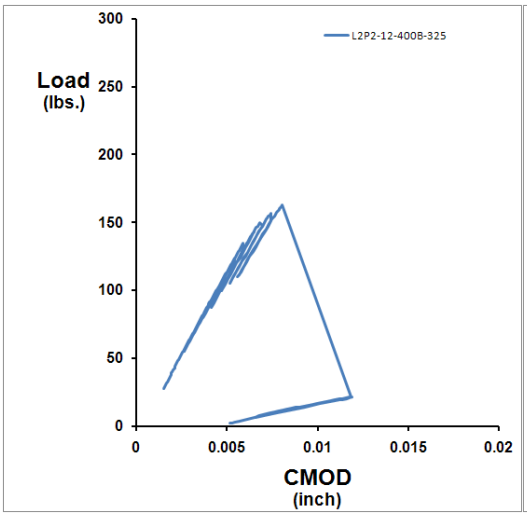


Figure D-173 CMOD vs. Load for fracture test L2P2-12-400B-325 (Lot 400768 exposed to 400 F for 20 min. & aged at 325 F for 24 hrs.)

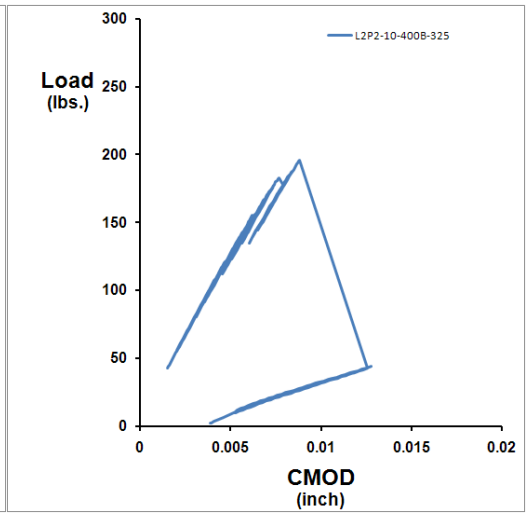


Figure D-174 CMOD vs. Load for fracture test L2P2-10-400B-325 (Lot 400768 exposed to 400 F for 20 min. & aged at 325 F for 24 hrs.)

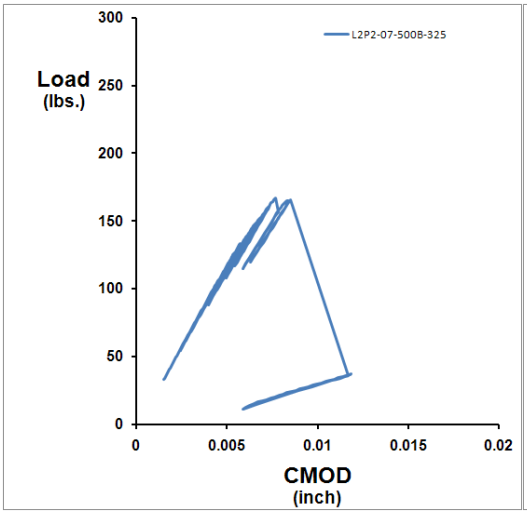


Figure D-175 CMOD vs. Load for fracture test L2P2-07-500-325 (Lot 400768 exposed to 500 F for 20 min. & aged at 325 F for 24 hrs.)

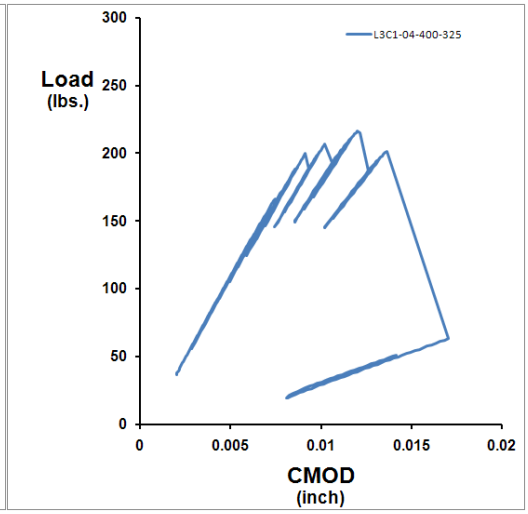


Figure D-176 CMOD vs. Load for fracture test L3C1-04-400-325 (Lot 400766 exposed to 400 F for 10 min. & aged at 325 F for 24 hrs.)

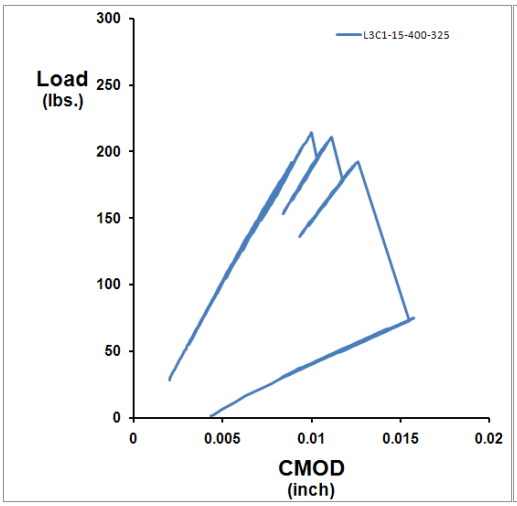


Figure D-177 CMOD vs. Load for fracture test L3C1-15-400-325 (Lot 400766 exposed to 400 F for 10 min. & aged at 325 F for 24 hrs.)

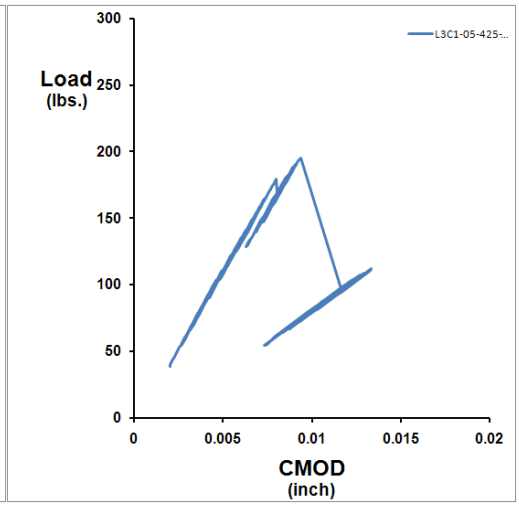


Figure D-178 CMOD vs. Load for fracture test L3C1-05-425-325 (Lot 400766 exposed to 400 F for 10 min. & aged at 325 F for 24 hrs.)

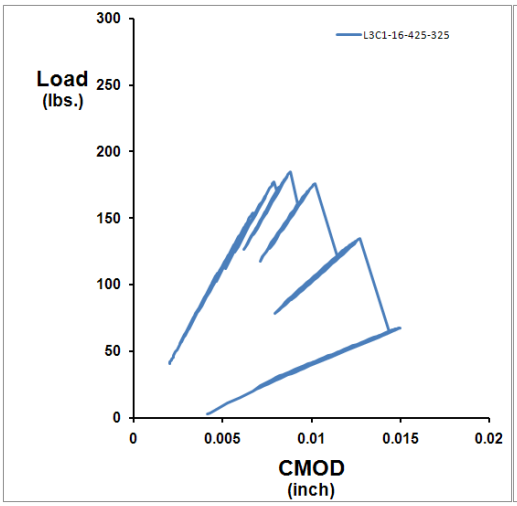


Figure D-179 CMOD vs. Load for fracture test L3C1-16-425-325 (Lot 400766 exposed to 425 F for 10 min. & aged at 325 F for 24 hrs.)

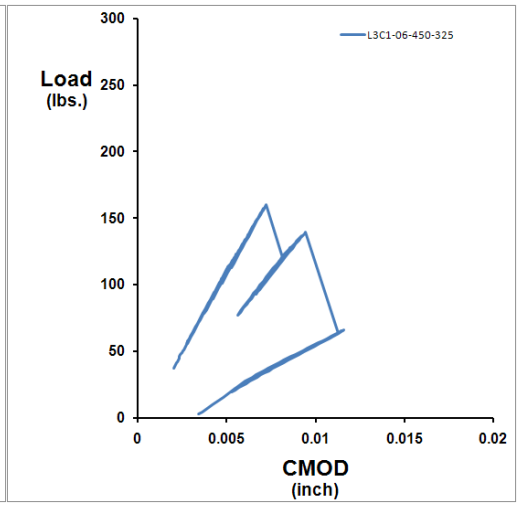


Figure D-180 CMOD vs. Load for fracture test L3C1-06-450-325 (Lot 400766 exposed to 450 F for 10 min. & aged at 325 F for 24 hrs.)

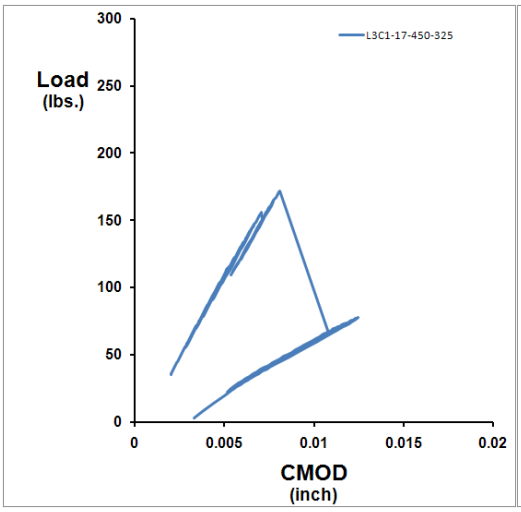


Figure D-181 CMOD vs. Load for fracture test L3C1-17-450-325 (Lot 400766 exposed to 450 F for 10 min. & aged at 325 F for 24 hrs.)

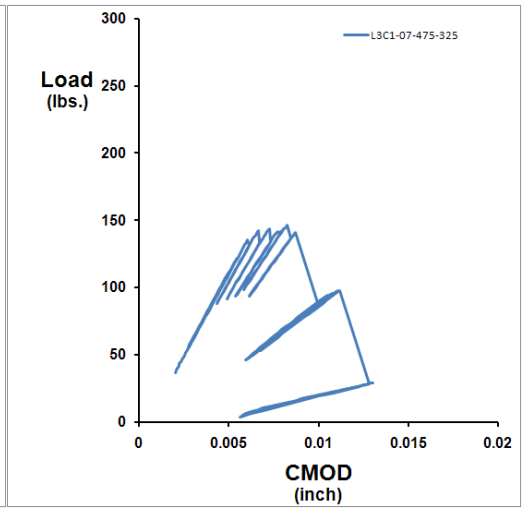


Figure D-182 CMOD vs. Load for fracture test L3C1-07-475-325 (Lot 400766 exposed to 475 F for 10 min. & aged at 325 F for 24 hrs.)

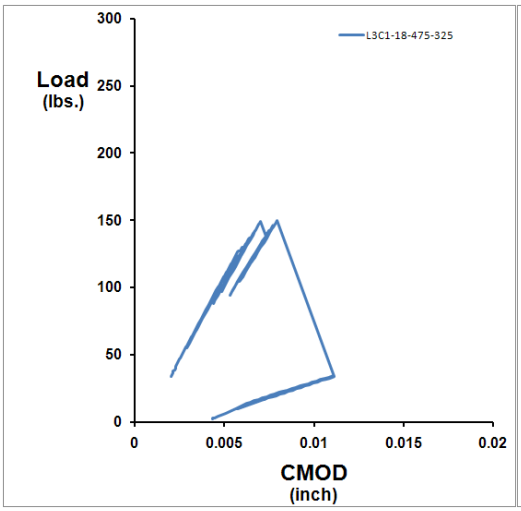


Figure D-183 CMOD vs. Load for fracture test L3C1-18-475-325 (Lot 400766 exposed to 475 F for 10 min. & aged at 325 F for 24 hrs.)

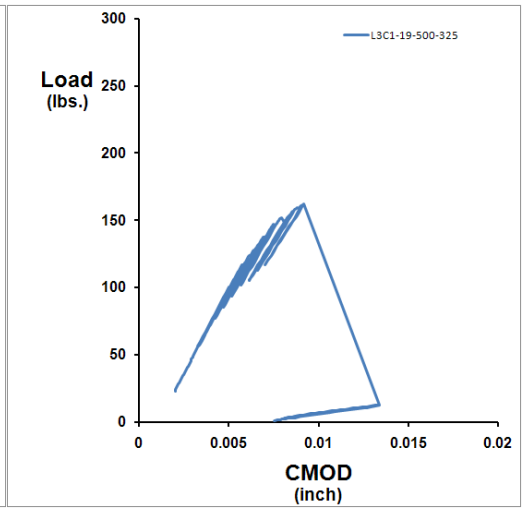


Figure D-184 CMOD vs. Load for fracture test L3C1-19-500-325 (Lot 400766 exposed to 500 F for 10 min. & aged at 325 F for 24 hrs.)

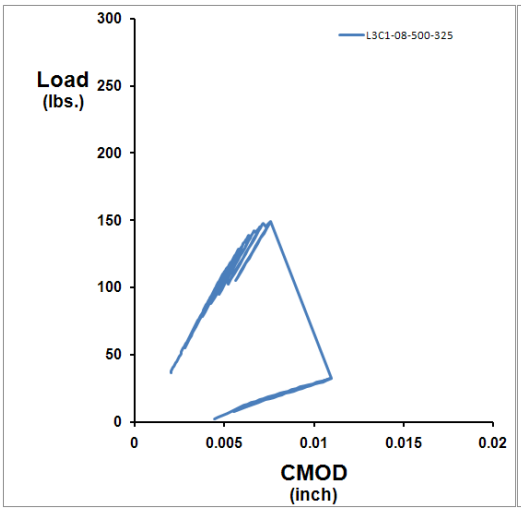


Figure D-185 CMOD vs. Load for fracture test L3C1-08-500-325 (Lot 400766 exposed to 500 F for 10 min. & aged at 325 F for 24 hrs.)

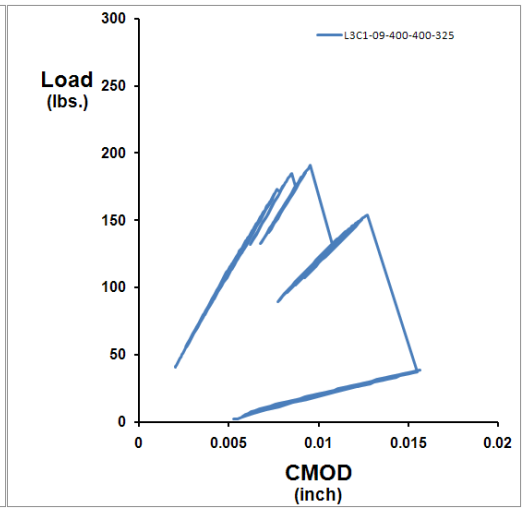


Figure D-186 CMOD vs. Load for fracture test L3C1-09-400B-325 (Lot 400766 exposed to 400 F for 20 min. & aged at 325 F for 24 hrs.)

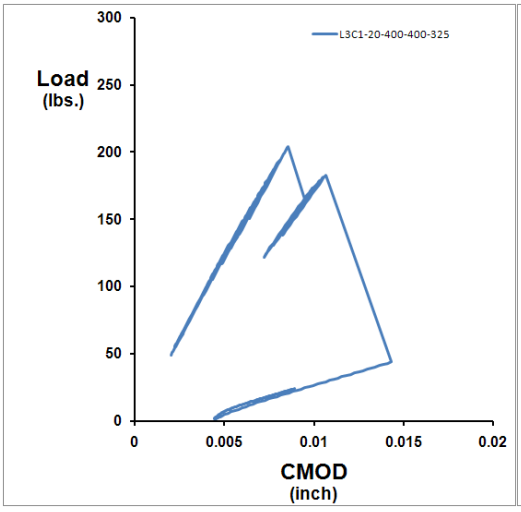


Figure D-187 CMOD vs. Load for fracture test L3C1-20-400B-325 (Lot 400766 exposed to 400 F for 20 min. & aged at 325 F for 24 hrs.)

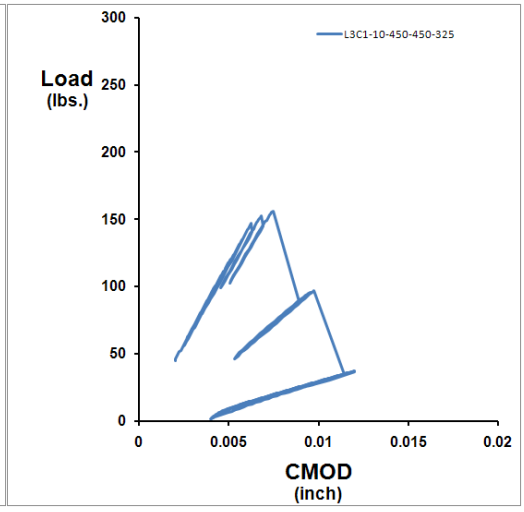


Figure D-188 CMOD vs. Load for fracture test L3C1-10-450B-325 (Lot 400766 exposed to 450 F for 20 min. & aged at 325 F for 24 hrs.)

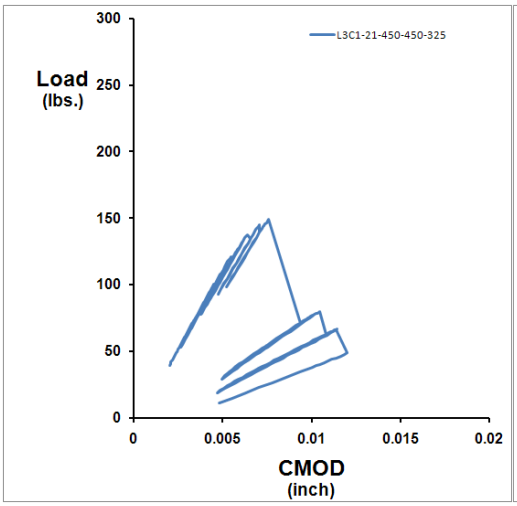


Figure D-189 CMOD vs. Load for fracture test L3C1-21-450B-325 (Lot 400766 exposed to 450 F for 20 min. & aged at 325 F for 24 hrs.)

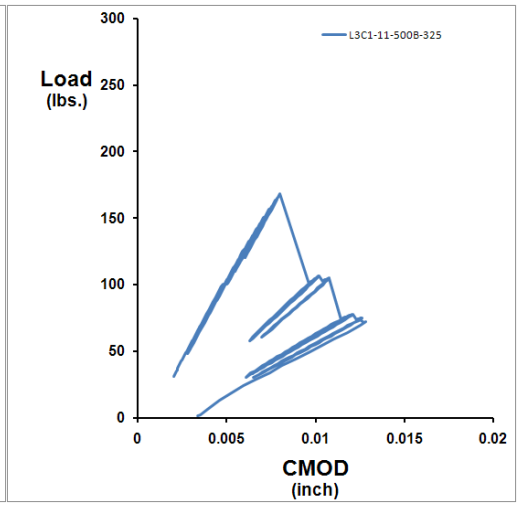


Figure D-190 CMOD vs. Load for fracture test L3C1-11-500B-325 (Lot 400766 exposed to 500 F for 20 min. & aged at 325 F for 24 hrs.)

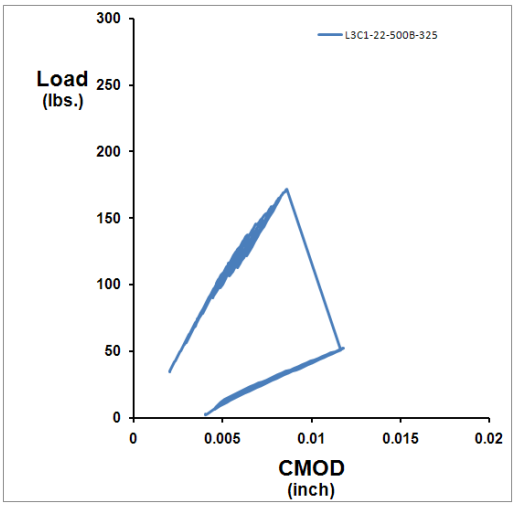


Figure D-191 CMOD vs. Load for fracture test L3C1-22-500B-325 (Lot 400766 exposed to 500 F for 20 min. & aged at 325 F for 24 hrs.)

Appendix E. Fractographic Photographs

Examinations of the fracture surfaces from the tests were performed using a scanning electron microscope (SEM). Low magnification examinations (~50x) were performed to characterize the surface texture and identify delaminations. Higher magnification examinations (up to 5,000x) were performed to identify features that indicate ductile or brittle behavior. Two sets of photographs are presented to illustrated differences in the material lots and thermal aging temperatures. The first set of photographs (Figures E-1 to E-5) contains low magnification images of the fracture surface of compact tension fracture specimens (see Appendix D) made from the control material (lot 400766) and aged at temperatures from 325°F to 375°F for 24 hours. The second set of photographs (Figures E-6 to E-12) contains high magnification images of the fracture surface for each lot of material tested, all aged at 325°F for 24 hours.

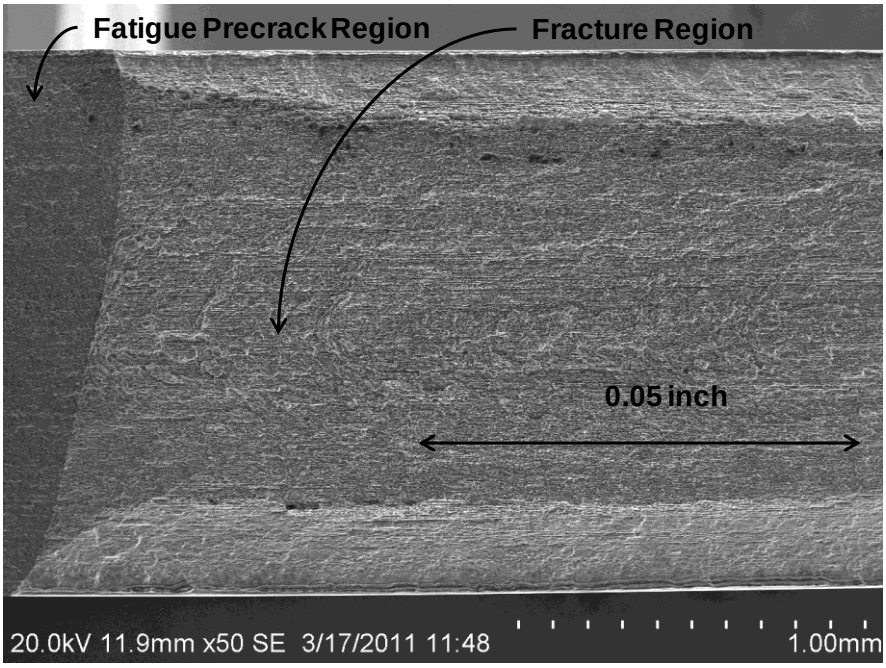


Figure E-1. Fracture Surface from Specimen L3C1-23-325 (lot 400766) that was Aged at 325°F for 24 hours

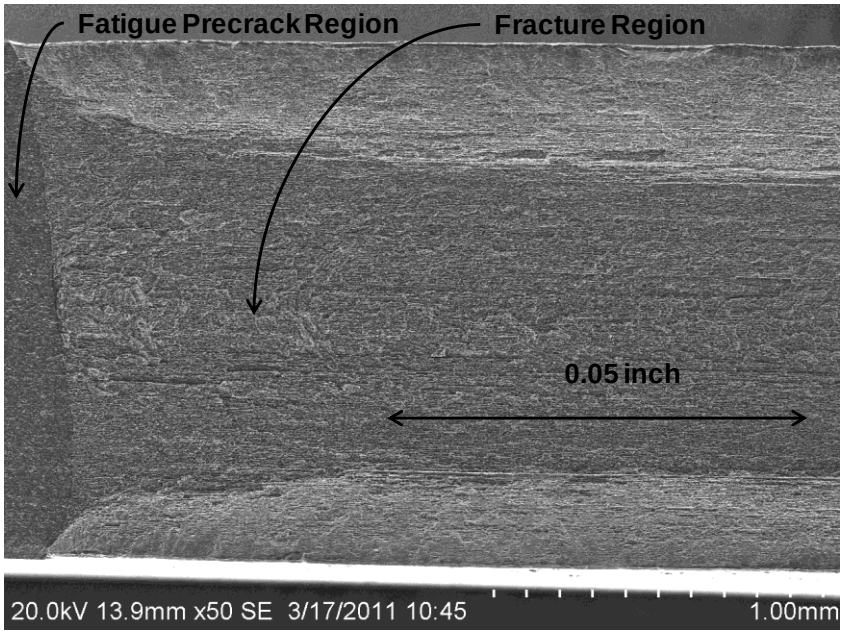


Figure E-2. Fracture Surface from Specimen L3C1-50-333 (lot 400766) that was Aged at 333°F for 24 hours

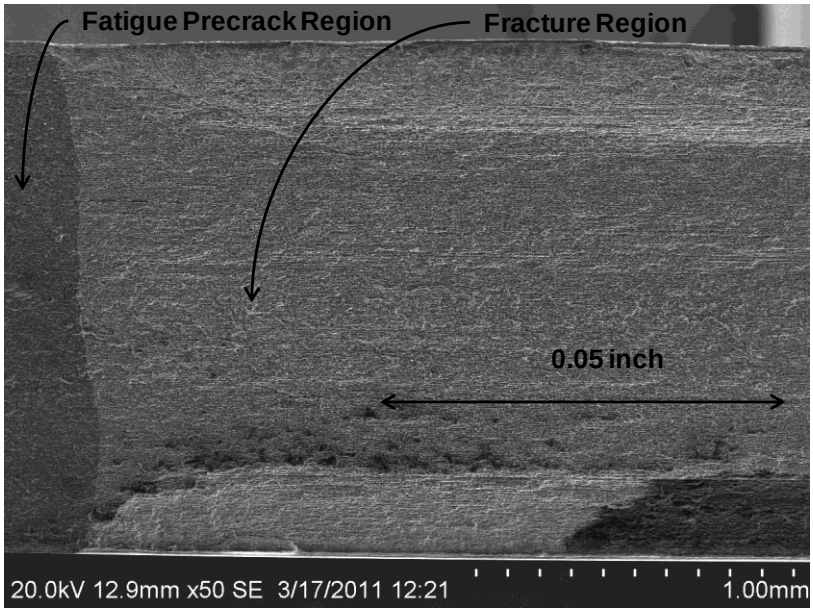


Figure E-3. Fracture Surface from Specimen L3C1-27-340 (lot 400766) that was Aged at 340°F for 24 hours

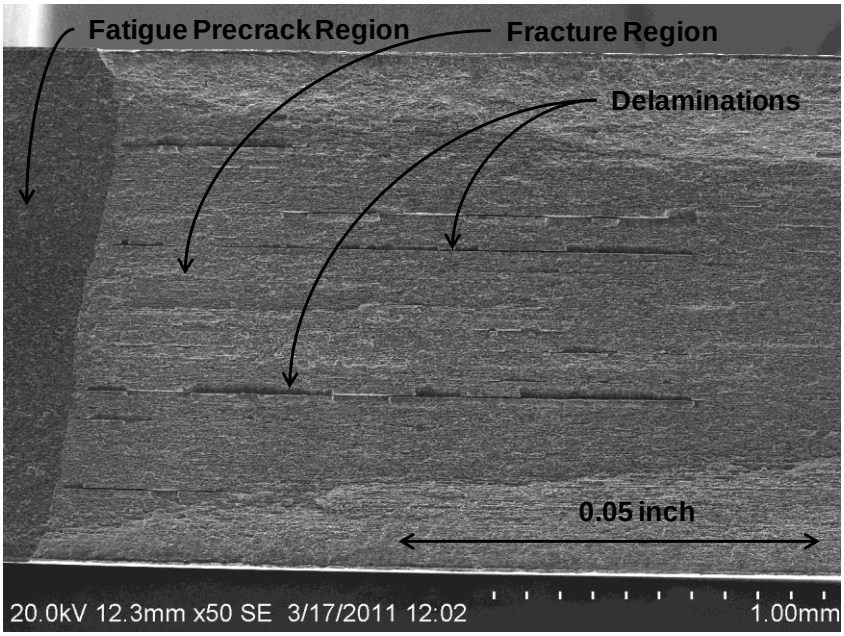


Figure E-4. Fracture Surface from Specimen L3C1-24-350 (lot 400766) that was Aged at 350°F for 24 hours

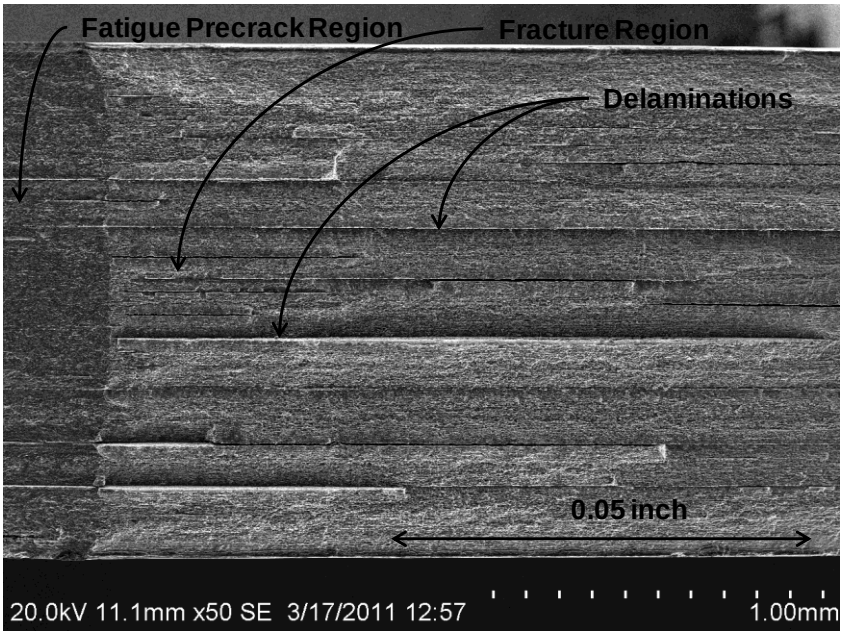


Figure E-5. Fracture Surface from Specimen L3C1-14-375 (lot 400766) that was Aged at 375°F for 24 hours

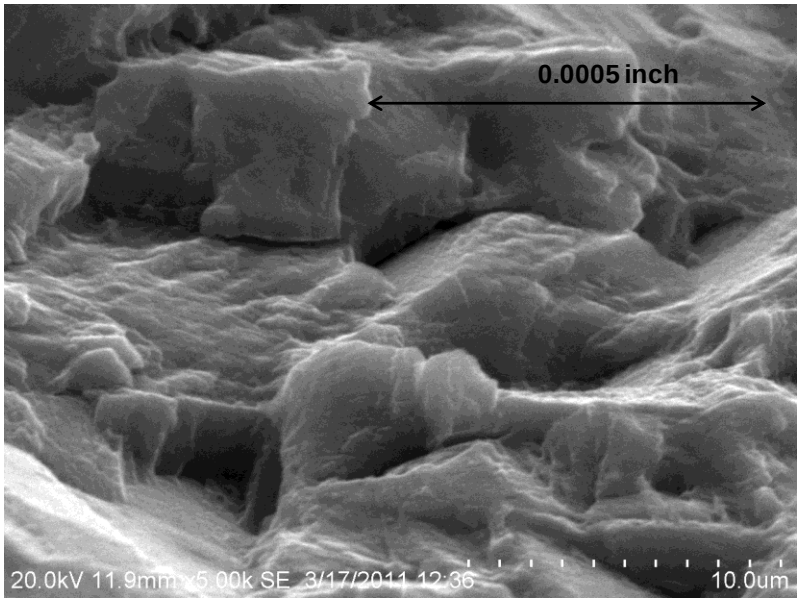


Figure E-6. Fracture Surface from Specimen S7-07 (lot 620853) from as-received Stringer-7 Sister

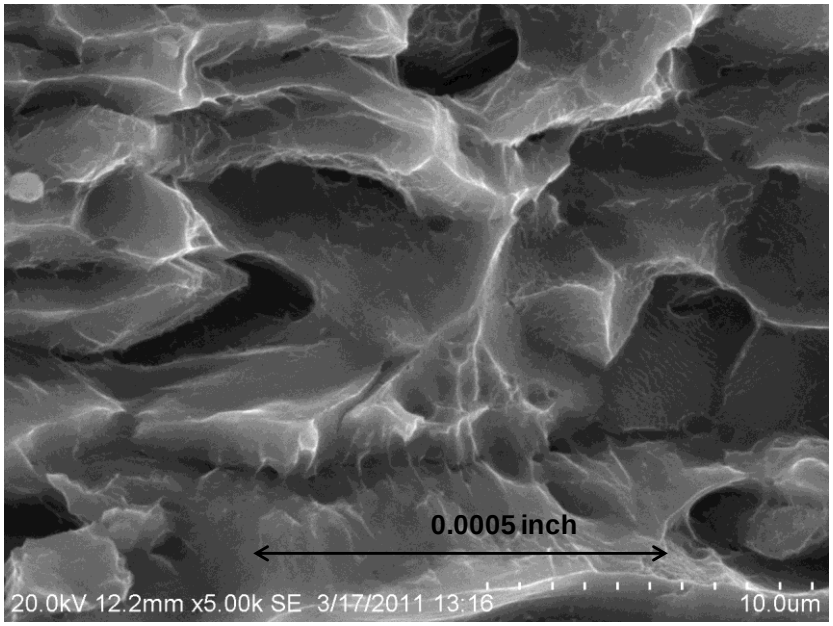


Figure E-7. Fracture Surface from Specimen L1P1-05-325 (lot 400751) that was Aged at 325°F for 24 hours

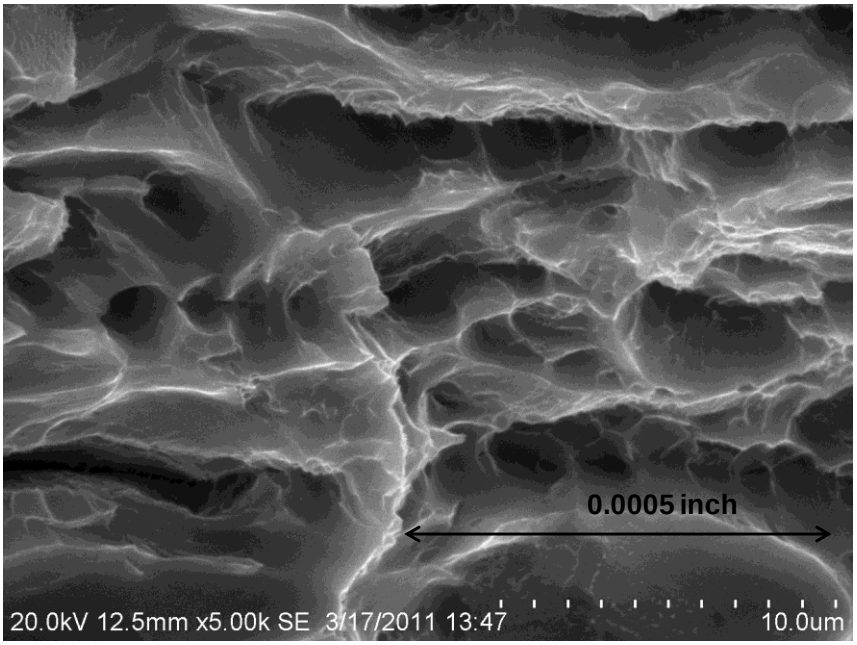


Figure E-8. Fracture Surface from Specimen L2P1-09-325 (lot 400768) that was Aged at 325°F for 24 hours

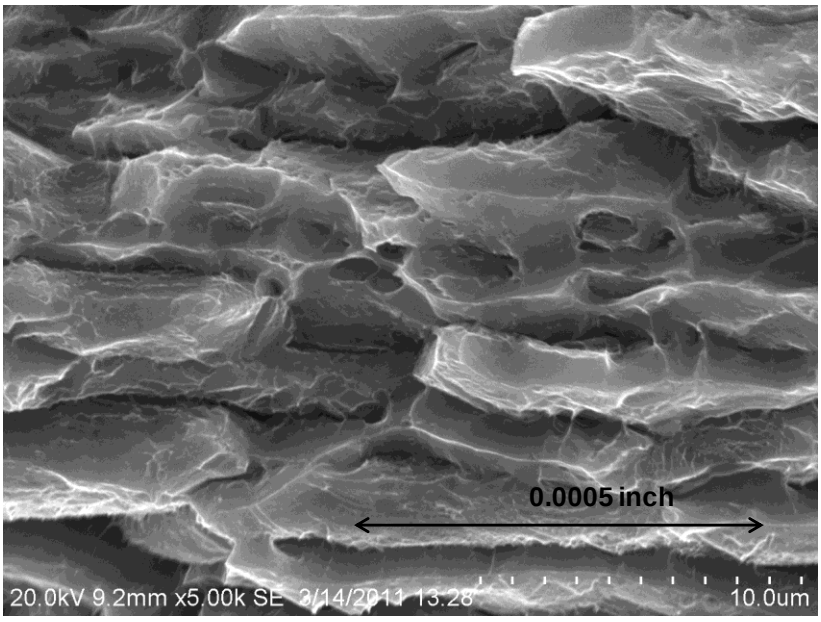


Figure E-9. Fracture Surface from Specimen L3C1-12-325 (lot 400766) that was Aged at 325°F for 24 hours

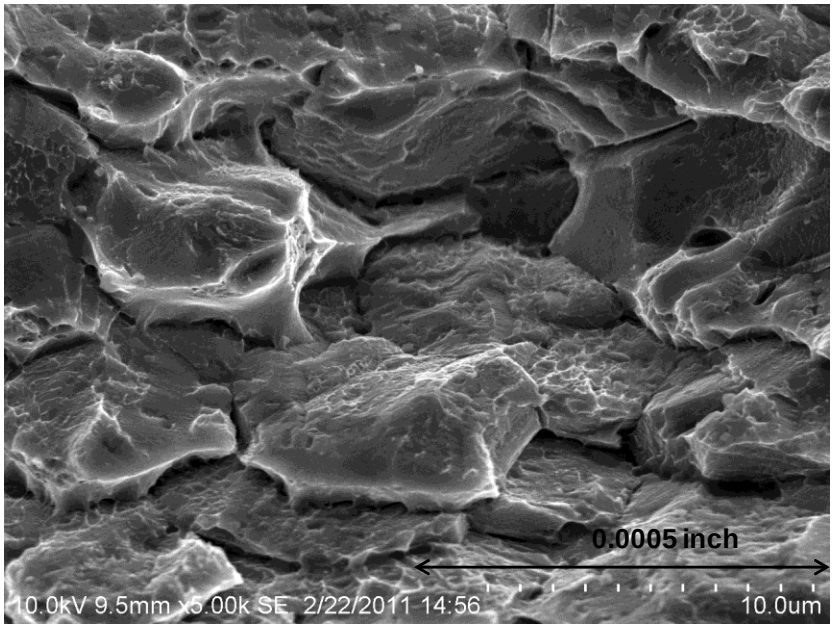


Figure E-10. Fracture Surface from Specimen L5CR-02-325 (lot 620853) that was Aged at 325°F for 24 hours

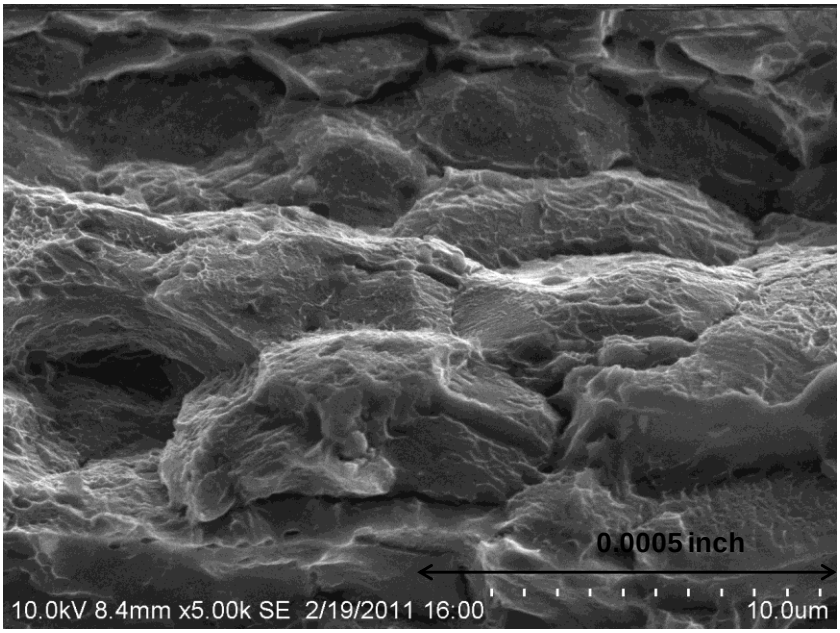


Figure E-11. Fracture Surface from Specimen L5HR-04-325 (lot 620853) that was Aged at 325°F for 24 hours

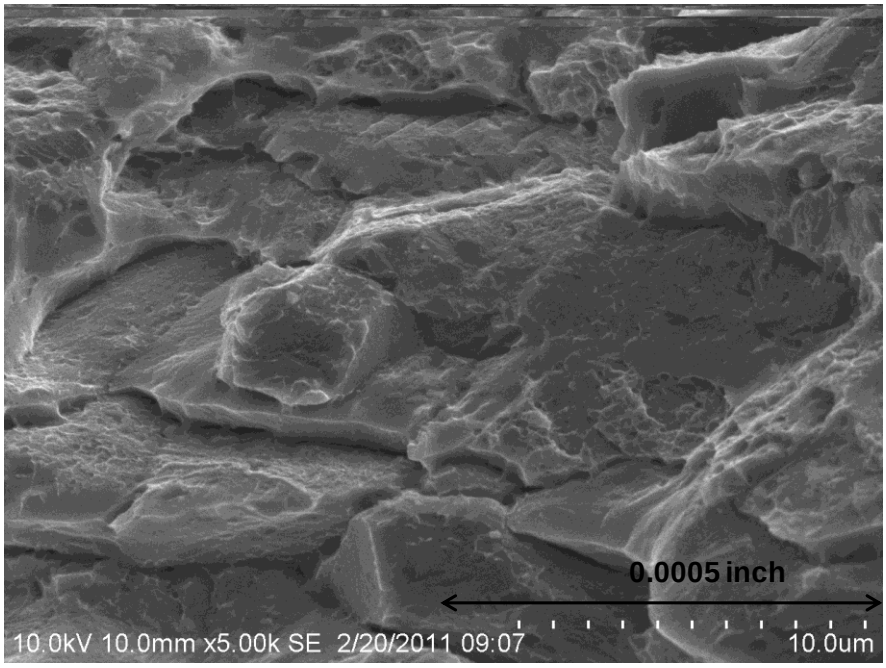


Figure E-12. Fracture Surface from Specimen L5MCR-04-325 (lot 620853) that was Aged at 325°F for 24 hours

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13. SUPPLEMENTARY NOTES

14. ABSTRACT

Several cracks were detected in stringers located beneath the foam on the External Tank (ET) following the launch scrub of Space Transportation System (STS)-133 on November 5, 2010. The stringer material was aluminum-lithium (AL-Li) 2090-T83 fabricated from sheets that were nominally 0.064 inches thick. The mechanical properties of the stringer material were known to vary between different material lots, with the stringers from ET-137 (predominately lots 620853 and 620854) having the highest yield and ultimate stresses. Subsequent testing determined that these same lots also had the lowest fracture toughness properties. The NASA Engineering and Safety Center (NESC) supported the Space Shuttle Program (SSP)-led investigation. The objective of this investigation was to develop a database of test results to provide validation for structural analysis models, independently confirm test results obtained from other investigators, and determine the proximate cause of the anomalous low fracture toughness observed in stringer lots 620853 and 620854. This document contains the outcome of the investigation.

15. SUBJECT TERMS

Space Transportation System; intertank; NASA Engineering and Safety Center; External Tank; thermal protection system; transmission electron microscopy

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