DOT/FAA/TC-15/3

Federal Aviation Administration
William J. Hughes Technical Center
Aviation Research Division
Atlantic City International Airport
New Jersey 08405

Adhesively Bonded Repairs to Metallic Fuselage Structure: Test 2, Monitoring Damage Growth

September 2015

Final Report

U.S. Department of Transportation
Federal Aviation Administration

NOTICE

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
DOT/FAA/TC-15/3		

4. Title and Subtitle	5. Report Date
ADHESIVELY BONDED REPAIRS TO METALLIC FUSELAGE STRUCTURE: TEST 2, MONITORING DAMAGE GROWTH	September 2015
	6. Performing Organization Code ANG-E231
7. Author(s) Reewanshu Chadha[1], John G. Bakuckas, Jr.[2], Cong Duong[3], and Ken Hunziker[3] [1] FAA (Drexel Fellow) [2] FAA [3] Boeing Research and Technology	8. Performing Organization Report No.
9. Performing Organization Name and Address William J. Hughes Technical Center Federal Aviation Administration Aviation Research Division Structures and Materials Section Atlantic City International Airport, NJ 08405	10. Work Unit No. (TRAIS)
	11. Contract or Grant No.
12. Sponsoring Agency Name and Address U.S. Department of Transportation Federal Aviation Administration FAA Transport Airplane Directorate Airframe/Cabin Safety, ANM-115 1601 Lind Avenue SW Renton, WA 98057	13. Phase of Report and Period Covered
	14. Sponsoring Agency Code ANM-115

15. Supplementary Notes

The Federal Aviation Administration William J. Hughes Technical Center Aviation Research Division COR was John G. Bakuckas, Jr.

16. Abstract

In a joint effort, the Federal Aviation Administration (FAA) and The Boeing Company are investigating safety and structural integrity issues of bonded repair technology through the testing and analysis of metallic B727 fuselage panels using the FAA's Full-Scale Aircraft Structural Test Evaluation and Research (FASTER) facility at the William J. Hughes Technical Center. The program objectives are to characterize the fatigue performance of bonded repairs under simulated service load (SL) conditions and to investigate tools for evaluating and monitoring the repair integrity over the life of the part. A phased approach is being taken involving the testing and analysis of several panels.

This report summarizes the results of the second panel tested in which the fatigue behavior of underdesigned, partially disbonded, compliant, and impact-damaged repairs to mid-bay cracks in metallic fuselage were characterized to evaluate repair integrity. Repair patches were made intentionally deficient to allow damage growth in the form of crack growth and disbonding during fatigue cycling to assess the abilities of analytical methods and monitoring systems. Both boron/epoxy and aluminum repair patches with various anomalies were tested under simulated SL conditions. Several patches were impacted with simulated hail and tool drop events. The damage formation and growth of cracks and disbonds were monitored throughout the tests using a variety of nondestructive inspection (NDI) methods, including visual inspections, eddy current, flash thermography, and resonance ultrasonics. In addition, a prototype piezoelectric-based structural health monitoring (SHM) system was used to assess and demonstrate its capabilities for determining the condition of damage in the repair patches. Full-field strain and displacement measurements on the patch and surrounding regions were obtained using the digital image correlation method. Test and analysis correlations were conducted to further calibrate models and demonstrate the capabilities to design and analyze bonded repairs.

In general, the ability to detect growing flaws under bonded patches and monitor the effectiveness of repairs using NDI and SHM was demonstrated. Results revealed that the fatigue performance of a repair to effectively contain damage decreases as the repair quality degrades. Impacting caused both crack extension and disbonding in the repairs; however, there was no subsequent damage growth during fatigue cycling. Model predictions were in good agreement with crack growth test results for the majority of the repair patch configurations. However, the test and analysis correlations revealed that further research is needed to better account for thermal residual stresses and thick patch configurations.

17. Key Words	18. Distribution Statement
Bonded repairs, Boron/epoxy, Disbond, Crack, Nondestructive inspection, Structural health monitoring, Inspection, Test, Analysis	This document is available to the U.S. public through the National Technical Information Service (NTIS), Springfield, Virginia 22161. This document is also available from the Federal Aviation Administration William J. Hughes Technical Center at actlibrary.tc.faa.gov.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	404	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

ACKNOWLEDGEMENTS

This report summarizes a team effort consisting of representatives from several organizations, including the Federal Aviation Administration (FAA), The Boeing Company, and Drexel University.

From the FAA, the authors wish to acknowledge Yongzhe Tian, Jeff Panco, Patrick Sheehan, and Kevin Stonaker for their diligent efforts conducting the tests using the Full-Scale Aircraft Structural Test Evaluation and Research (FASTER) facility at the FAA William J. Hughes Technical Center; Dave Galella and Paul Swindell for providing nondestructive inspection (NDI) support; Curtis Davies for providing digital image correlation equipment; and Ian Won for his co-sponsorship.

From Boeing, the authors thank Ron Turner and Bud Westerman for their co-sponsorship; Russell Keller, Nick Room, Keith McIver, Carly Schlottman, and Kelly Greene for managing the activities of Boeing; Ching Hsu and Tricia Carr for their technical contributions in the design and analysis of the repairs; Chris Davis for providing structural health monitoring support; Mike Evans and Joel Baldwin for installing the repairs; and Paul Rutherford, Bill Tapia, and Tom Williams for their efforts in providing NDI support.

Finally, the authors would like to recognize Professors Jonathan Awerbuch and Tein-Min Tan from the Department of Mechanical Engineering and Mechanics, of Drexel University, for their input and guidance regarding all aspects of the work detailed in this report.

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LIST OF ACRONYMS

B/Ep	Boron/Epoxy
CRAS	Composite Repair of Aircraft Structure
DIC	Digital image correlation
DSG	Design service goal
FAA	Federal Aviation Administration
FASTER	Full-Scale Aircraft Structural Test Evaluation and Research
FE	Finite element
FEA	Finite element analysis
FEP	Fluorinated Ethylene Propylene
FS	Frame station
Fwd	Forward
HFEC	High frequency eddy current
LFEC	Low frequency eddy current
MCCI	Modified crack closure integral
NDI	Nondestruction inspection
RMS	Root mean square
SHM	Structural health monitoring
SIF	Stress intensity factor
SL	Service load
SRM	Structural repair manual

EXECUTIVE SUMMARY

In a joint effort, the Federal Aviation Administration (FAA) and The Boeing Company are investigating safety and structural integrity issues of bonded repair technology through the testing and analysis of metallic B727 fuselage panels using the FAA's Full-Scale Aircraft Structural Test Evaluation and Research (FASTER) facility at the William J. Hughes Technical Center. The program objectives are to characterize the fatigue performance of bonded repairs under simulated service load (SL) conditions and to investigate tools for evaluating and monitoring the repair integrity over the life of the part. A phased approach is being taken involving the testing and analysis of several panels.

This report summarizes the results of the second panel tested, during which the fatigue behavior of underdesigned, partially disbonded, compliant and impact damaged repairs to mid-bay cracks in metallic fuselage were characterized to evaluate repair integrity. Repair patches were made intentionally deficient to allow damage growth in the form of crack growth and disbonding during fatigue cycling to assess the abilities of analytical methods and monitoring systems. Both boron/epoxy and aluminum repair patches with various anomalies were tested under simulated SL conditions. Several patches were impacted with simulated hail and tool drop events. The damage formation and growth of cracks and disbonds were monitored throughout the tests using a variety of nondestructive inspection (NDI) methods, including visual inspections, eddy current, flash thermography, and resonance ultrasonics. In addition, a prototype piezoelectric-based structural health monitoring (SHM) system was used to assess and demonstrate its capabilities for determining the condition of damage in the repair patches. Full-field strain and displacement measurements on the patch and surrounding regions were obtained using the digital image correlation method. Test and analysis correlations were conducted to further calibrate models and demonstrate the capabilities to design and analyze bonded repairs.

In general, the ability to detect growing flaws under bonded patches and monitor the effectiveness of repairs using NDI and SHM was demonstrated. Results revealed that fatigue performance of a repair to effectively contain damage decreases as the repair quality degrades. Impacting caused both crack extension and disbonding in the repairs; however, there was no subsequent damage growth during fatigue cycling. Model predictions were in good agreement with crack growth test results for the majority of the repair patch configurations. However, the test and analysis correlations revealed that further research is needed to better account for thermal residual stresses and thick patch configurations.

1. INTRODUCTION

The Federal Aviation Administration (FAA) and The Boeing Company have collaborated in an effort to study the fatigue and residual strength performance of bonded repairs using boron/epoxy (B/Ep) and aluminum patches. The FAA's Full-Scale Aircraft Structure Test Evaluation and Research (FASTER) facility, located at the William J. Hughes Technical Center, is being used to conduct structural tests of various damage/repair scenarios on several metallic B727 fuselage panels. A phased approach is being taken involving the testing and analysis of several panels. The first panel tested provided baseline data and was completed in 2010. The results revealed that properly designed and installed bonded repairs are durable under fatigue and can effectively contain large damage under severe static loads in excess of ultimate load requirements [1].

In this current follow-on phase, another B727 panel was used to assess the fatigue performance of underdesigned, flawed, compliant, and damaged repairs. Repair patches (both B/Ep and aluminum) were made to be intentionally deficient and contained imperfections to allow damage growth in the form of crack propagation and disbonding during fatigue cycling. The goals were to: (1) collect experimental data on the performance of bonded repairs that can be used to verify the ability of analytical tools to predict the behavior of bonded patches, and (2) demonstrate the capabilities of a prototype structural heath monitoring (SHM) system and other nondestructive inspection (NDI) methods to assess the integrity of bonded repairs.

To simplify analysis and correlate with test results, repairs to mid-bay through-thickness cracks were considered. The test phases were classified based on the type of anomalies introduced in the bonded repairs:

- Reference B/Ep Repair: An optimally designed and defect-free reference patch was installed to serve as a baseline. The reference patch was subjected to one design service goal (DSG) (60,000 cycles) using simulated service load (SL) conditions.

- Phase 1–Underdesigned Repairs: Repair patches were intentionally underdesigned to allow the cracks to grow by reducing the patch footprint and reducing the number of reinforcing plies or aluminum doublers. One B/Ep and two aluminum underdesigned patches were installed to mid-bay through-thickness cracks and subjected to one DSG under SL conditions.

- Phase 2–Partial Disbond Repairs: Phase 2 patches had similar patch configurations to Phase 1 under-designed repairs but with intentional partial disbonds. These repairs were fatigued one DSG under SL conditions.

- Phase 3–Compliant Repairs: The Phase 1 and Phase 2 patches had the fibers oriented in the hoop direction to provide a stiff repair. The Phase 3 patches had the same dimensions but with fibers oriented in the axial direction to yield low stiffness, compliant repairs. These repairs were fatigued to 20,000 cycles under SL conditions.

- Phase 4–Repairs With Impact Damage: Several patches were impacted and then subjected to 20,000 fatigue cycles under SL conditions to study the effectiveness of repairs after impact.

For all phases, a digital image correlation (DIC) method was used to obtain full-field displacement and strain measurements in the patch and surrounding regions. Several NDI methods were used, including flash thermography, resonance ultrasonics, and computer-aided tap techniques to scan for patch disbonds and eddy current to monitor crack growth. In addition, a prototype piezoelectric-based SHM system was used to assess and demonstrate its capabilities in determining the condition of damage and repair patches.

This report provides an overview of the experimental and analytical procedures used and the corresponding results obtained from all four test phases. Details are provided in the appendices. In general, results revealed that the fatigue performance of a repair in effectively containing damage reduces as the repair quality degrades. The NDI methods used were successful in detecting and monitoring damage. Crack growth was detected and reconstructed by a prototype SHM system. For the majority of repair patch configurations, predictions of fatigue crack growth were in agreement with test results. However, further work is needed to account for thermal residual stresses and thick patch configurations.

2. EXPERIMENTAL PROCEDURE

Testing was conducted using the FASTER facility, which is capable of testing large curved panels representative of aircraft fuselage structures under realistic flight load conditions, located at the FAA William J. Hughes Technical Center. To gain a better understanding of the durability and damage tolerance aspects of bonded repair technology, enhancements were made to the FASTER fixture for axial tension-compression loading capabilities, as shown in figure 1. Details of these modifications will be published in a separate report.

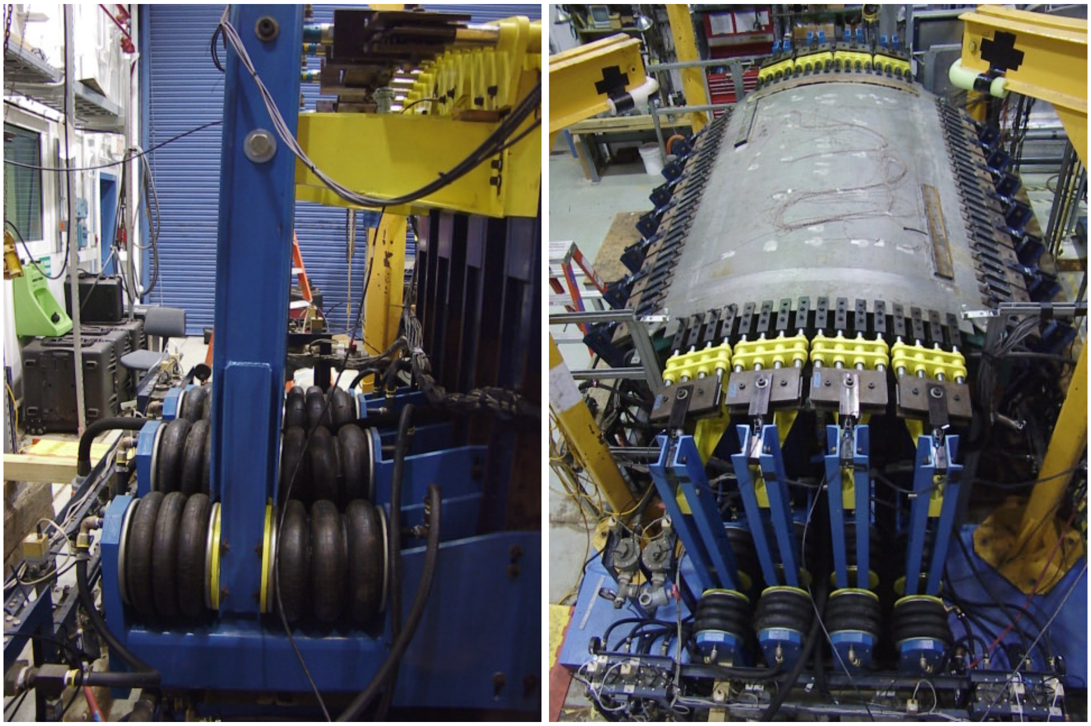


Figure 1. Modifications to the FAA's FASTER fixture for axial tension-compression loading capabilities

2.1 TEST PANEL DESCRIPTION

The fuselage panel used in this study was removed from a retired passenger service airplane—specifically, a Boeing 727-232, serial number 20751, line number 1000, and registration number N474DA (see figure 2). The airplane was placed into service in 1974 and retired in 1998. While in service, the airplane accumulated 59,497 flight cycles and 66,412 flight hours and was near its DSG of 60,000 flight cycles. The airplane was owned and operated exclusively by Delta Air Lines, was well maintained and stored, and had a well-documented and accessible service history. Its use is representative of typical Title 14 Code of Federal Regulations Part 121 revenue service passenger aircraft currently in the domestic fleet. Reference 2 provides further information regarding the airplane.

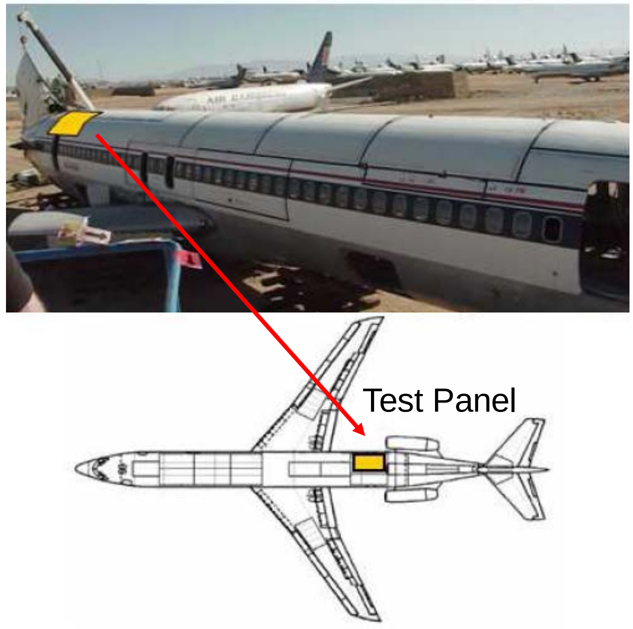


Figure 2. Retired airplane and location of panel tested

The panel was removed from the crown of the airplane and had dimensions of 125″ by 73″ and a radius of 74″ (see figure 3). The substructure included six stringers, S-1R–S-6R, in the longitudinal direction with 9.5″ spacing, and six frame stations (FS), FS-990–FS-1090, in the hoop direction with 20″ spacing. The Z-shaped frames, stringer clips, and hat-shaped stringers are made from 7075-T6 aluminum.

The panel skin was 2024-T3 aluminum with a thickness varying from 0.040″–0.080″ at various bays (see figure 4). The skin thickness between FS-1050 and FS-1090, as well as between FS-1030 and FS-1050 and S-4R and S-6R, was 0.04″. These locations, with the same skin thickness, were chosen as the test section. A longitudinal lap joint was located along stringer S-4R and a circumferential butt joint was located along FS-1010. The longitudinal lap joint consisted of two skin layers and a 0.02″-thick 2024-T3 aluminum doubler layer sandwiched between the two skin layers, which were connected together by three rows of rivets. The doubler was bonded to the outer skin and there was a sealant between the doubler and the inner skin of the lap joint. Appendix A provides the fuselage panel engineering drawings.

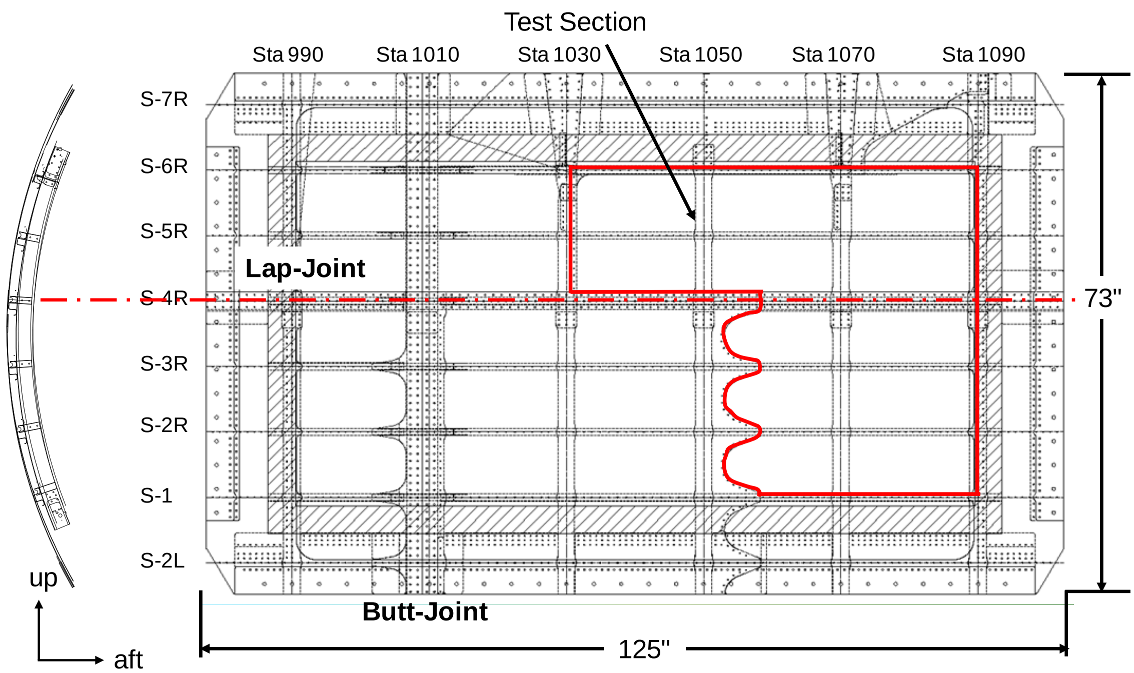
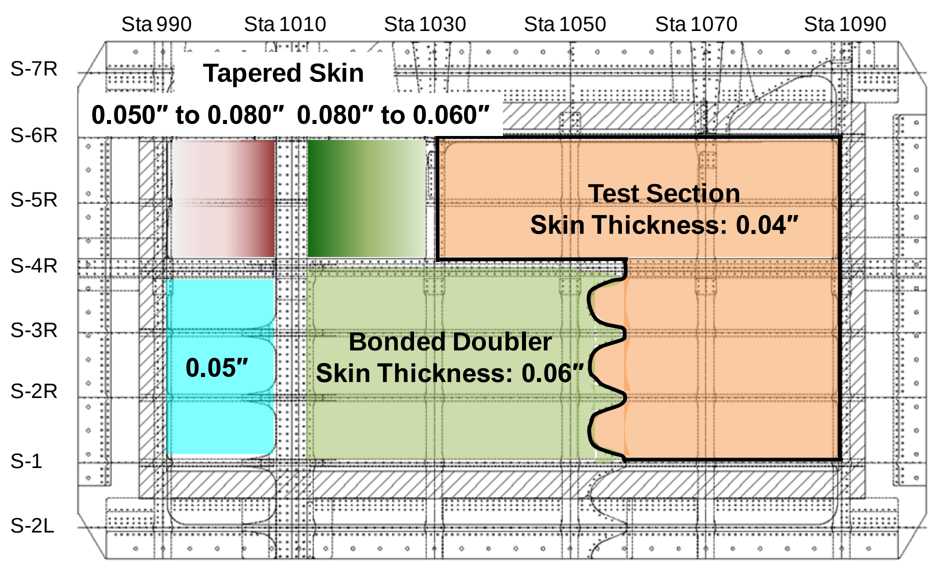


Figure 3. Panel configuration



Sta = Station; S = Stringer

Figure 4. Skin thickness variation of the fuselage panel

The panel was reinforced along the four edges with aluminum doublers. In both longitudinal doublers, 28 half-inch-diameter holes were inserted and spaced 4″ apart. In both hoop doublers, 16 half-inch-diameter holes were inserted and spaced 3.5″ apart. These holes were used to attach the panel edges to the loading mechanisms of the FASTER fixture, which had seven hoop loaders on each side and four longitudinal loaders on both ends. Each actuator was attached to the panel at the four holes using a whiffle tree assembly. The two ends of each frame, where the frame load is applied, were also reinforced with aluminum doublers. An elastomeric seal was bonded along the perimeter of the inner surface of the curved panel to attach it to the pressure box of the FASTER fixture.

2.2 TEST PHASES

The repairs were categorized as underdesigned, partial disbonds, compliant, damaged, and reference repairs. Appendix B explains the rationale behind the types of repairs. For each phase of the test, mid-bay, through-thickness notches of 2.8″ in length were introduced on the fuselage skin and fatigue-presharpened to approximately 3″. Both B/Ep and aluminum patches were used to repair these cracks. Figure 5 shows the location of the cracks and repair patches. These simplified damage and patch configurations were chosen to enable test and analysis correlation. The nomenclature used in the figure is explained in the following sections. Appendix C explains the complete details of the damages and repairs.

For the B/Ep patches, B/Ep 5521 prepreg tape was used; for the aluminum patches, 2024-T3 bare aluminum sheet was used. All patches had a taper ratio of 20:1 for all eight sides and a 45° corner truncation angle. The bonding adhesive used was EA9696 Grade 10 film adhesive. The aluminum skin panel surface preparation included paint removal, solvent cleaning, leak testing, sol-gel application, and primer application. The B/Ep patches were precured on a flat surface. Both B/Ep and aluminum patches were then bonded to the test panel by portable composite repair equipment, vacuum bags, and heat blankets at a cure temperture of 250°F ±10°F for 90 minutes. During the curing process, the strains on the panel were also monitored. Appendix D describes the details of the patch installation procedure and strains measured during the cure process at selected repairs.

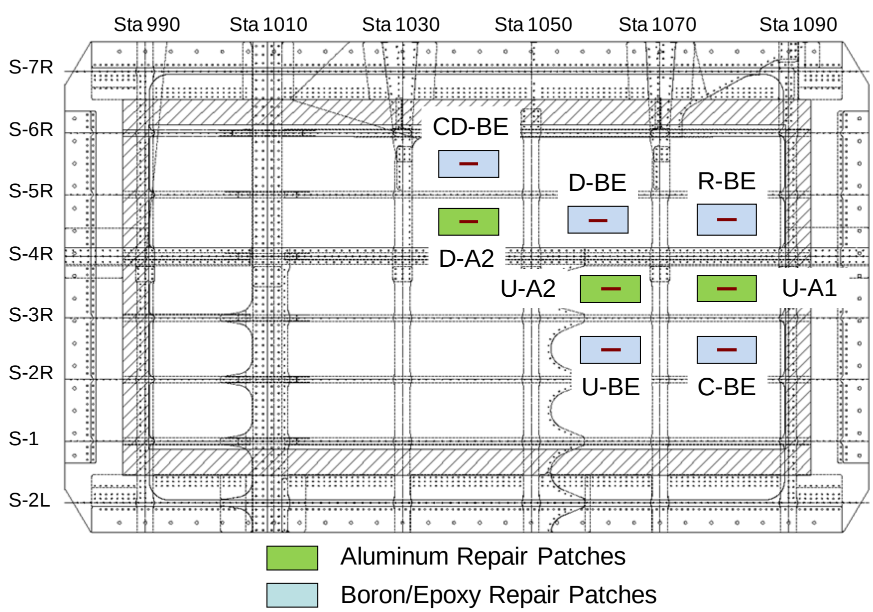


Figure 5. Locations of repair patches

2.2.1 Reference Boron/Epoxy Repair

The reference boron/epoxy (R-BE) repair is an optimally designed (8″ by 5″ in size and octagon in shape) patch of a 3″ crack in a 0.040″ skin thickness (see figure 6). This repair was installed to serve as a reference to the other B/Ep patches. It has nine plies and the fiber direction was [20°/-20°/20°/-20°/0/-20°/20°/-20°/20°] with an approximate taper ratio of 20:1. The 0° fiber direction was perpendicular to the crack. The R-BE patch was subjected to 60,000 fatigue cycles. During the test, crack progression and patch/skin disbonding were monitored using NDI systems (section 2.4: inspection methods described below).

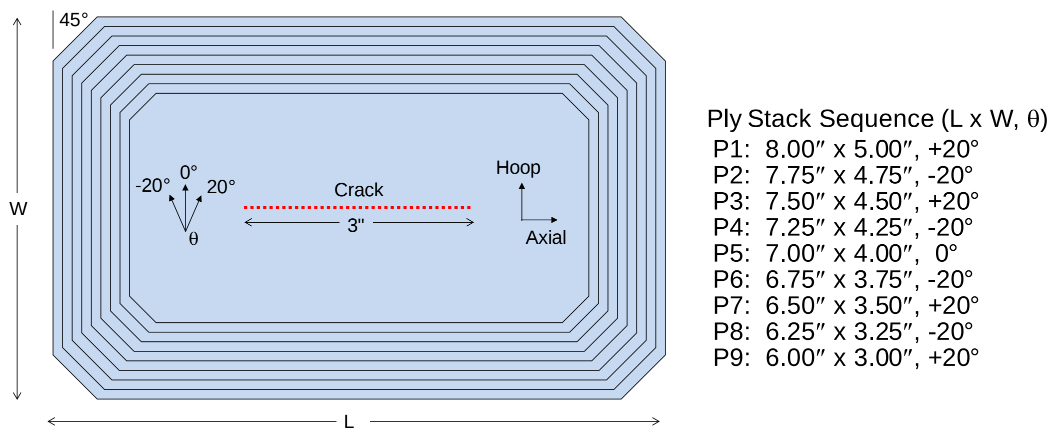


Figure 6. The R-BE repair patch configuration

2.2.2 Phase 1–Underdesigned Repairs

The Phase 1 repair patches were intentionally underdesigned to allow the cracks to grow by reducing the patch footprint and reducing the number of reinforcing B/Ep plies or aluminum doublers. For example, the optimal design B/Ep patch is 8″ by 5″ and has nine plies, whereas the underdesigned B/Ep repair patch is 8″ by 3″ and has five plies. Similarly, the standard design aluminum repair patch is 6″ by 3″ and has three sheets (each 0.02″ thick), whereas the underdesigned aluminum repair patch is 8″ by 3″ and has two sheets. Therefore, the underdesigned B/Ep (U-BE) patch for the 3″ crack was an 8″ by 3″ octagon shape consisting of five plies (figure 7(a)). The fiber direction was [20°/-20°/0/-20°/20°] with an approximate taper ratio of 20:1. The 0° fiber direction was perpendicular to the crack. The two underdesigned aluminum patches (U-A2 and U-A1) for the mid-bay cracks were the same shape and dimensions with a thickness of 0.040″ and 0.020″, respectively, and a taper ratio of 20:1 for both patches. The U-A2 patch had two 0.020″-thick aluminum doublers and the U-A1 patch had just one 0.020″-thick aluminum doubler, as shown in figure 7 (b) and (c), respectively. The U-BE and U-A2 patches were subjected to 60,000 fatigue cycles and the U-A1 patch was subjected to 54,250 fatigue cycles as the patch was no longer able to restrict the crack growth. During the tests, crack progression and disbonding were monitored using NDI and the SHM system.

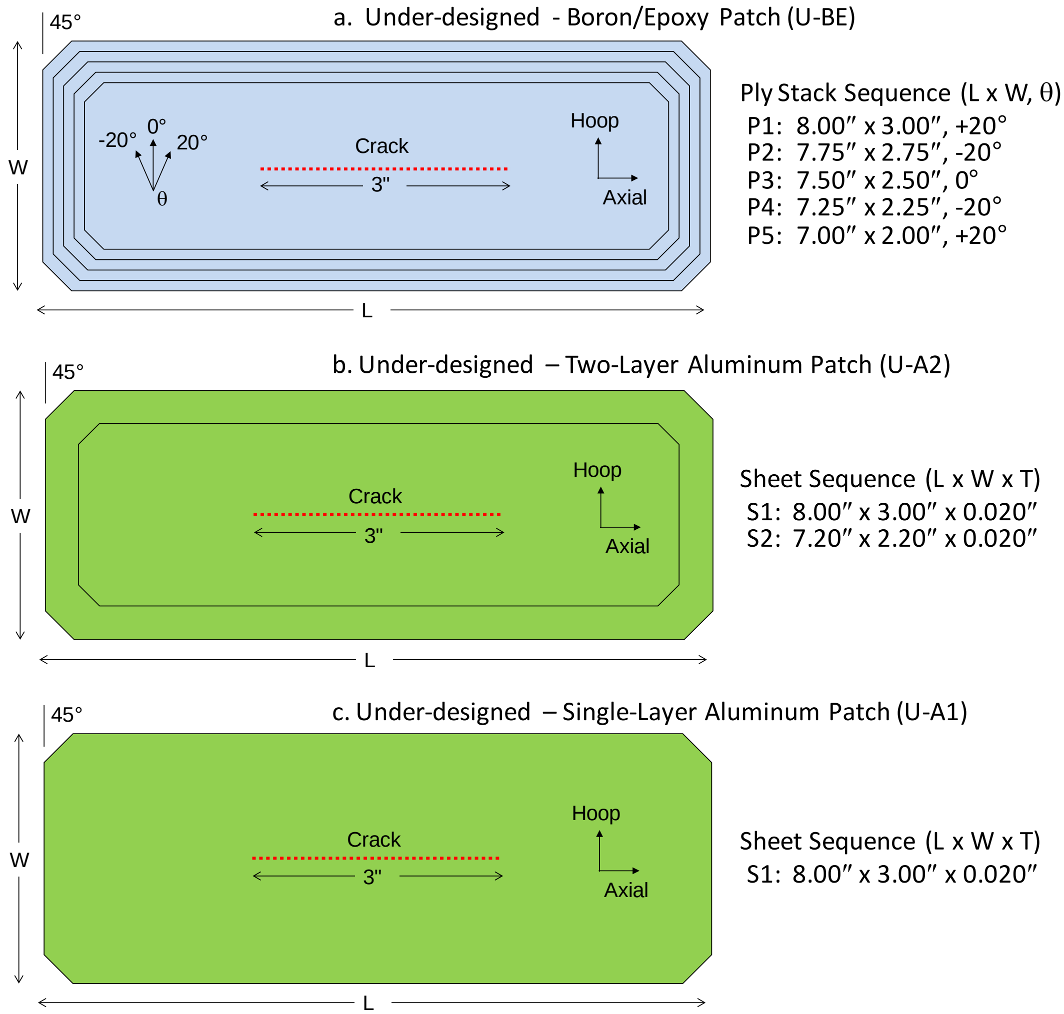


Figure 7. Phase 1 underdesigned repair configuration: (a) B/Ep patch (U-BE), (b) two-layer aluminum patch (U-A2), and (c) single-layer aluminum patch (U-A1)

2.2.3 Phase 2–Partial Disbond Repairs

The Phase 2 repairs included a B/Ep patch, D-BE, and a two-layer aluminum patch, D-A2, with intentional disbonded regions. Figure 8 shows the patch configurations. The disbonds were introduced using Fluorinated Ethylene Propylene (FEP) tabs and aluminum shims (coated with a mold release agent). The FEP tabs were placed between the fuselage skin and adhesive during the curing process. The FEP tabs were located around the crack region and the aluminum shims were located at the patch boundary. After curing, the aluminum shims at the patch edge were removed, and the FEPs at the crack region were left within the repair. The D-BE patch disbonds were 0.5″ in diameter at both ends of the crack. The edge disbonds were 0.5″ in diameter and inserted only 0.25″ deep into the patch at three locations. A 0.5″ diameter disbond is a typical minimum detectable flaw size for the available NDI methods. For the D-A2 patch, the edge disbonds were similar to the B/Ep patch edge disbonds ; however, the disbond at the center was 3.5″ by 0.5″ around the crack region. Figure 8 (a and b) show the patch configurations, locations of disbonds, and the dimensions of the disbonds for the D-BE and D-A2 patches. The repairs were fatigue-tested for 60,000 cycles and damage progression was recorded using SHM and NDI techniques.

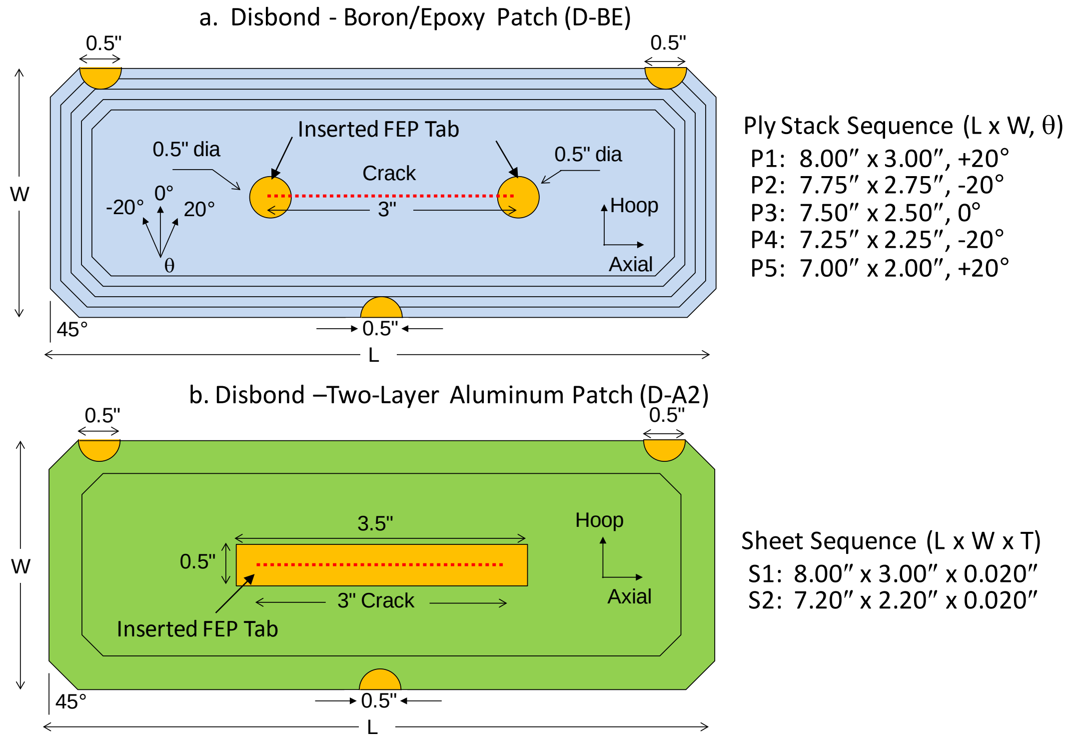


Figure 8. Phase 2 partial disbond repair configuration: (a) B/Ep patch (D-BE) and (b) two-layer aluminum patch (D-A2)

2.2.4 Phase 3–Compliant Repairs

The purpose of Phase 3 repairs was to study the effect of repair stiffness on fatigue crack growth. Two B/Ep patches with fibers oriented in the axial direction were tested in this phase, as shown in figure 9. The first B/Ep patch, C-BE, had the same dimensions as Phase 1, U-BE patch (figure 9a). The second B/Ep patch, CD-BE, contained partial disbonds and had the same dimensions as Phase 2, D-BE patch (figure 9b). These Phase 3 repairs were fatigue-tested for 20,000 cycles. Damage progression was recorded using SHM and NDI techniques.

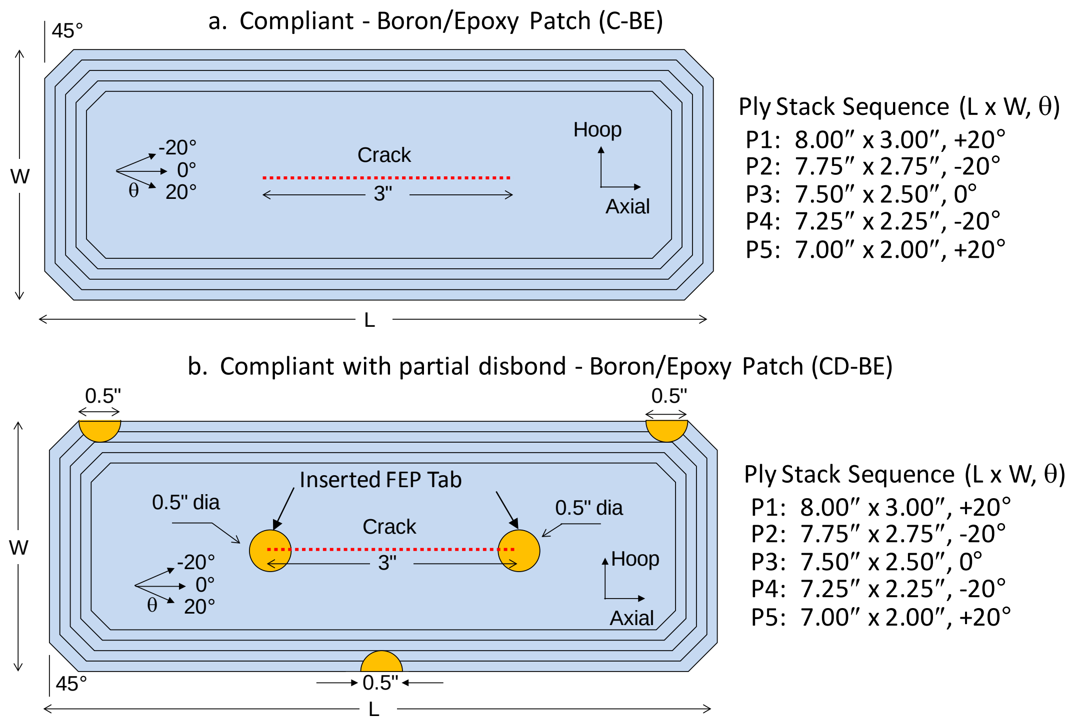


Figure 9. Phase 3 compliant repair configuration: (a) B/Ep patch (C-BE), (b) B/Ep patch with partial disbonds (CD-BE)

2.2.5 Phase 4–Repairs With Impact Damage

Subsequent to 60,000 fatigue cycles, R-BE, U-BE, and U-A2 patches were impacted at the crack tips. The impact location for all three patches was right at the crack tip on the surface of the patch. The impact energy levels used were 300 in-lb and 500 in-lb, which correspond to an impact event from a tool drop and severe hail damage, respectively. A 15 lb tup was dropped from a height of 20″ to produce 300 in-lb energy and from a height of 33.3″ for 500 in-lb energy. The R-BE patch was impacted at the forward end of the crack tip with 500 in-lb energy (figure 10a). Similarly, the U-BE patch was impacted at the forward end of the crack tip with 500 in-lb energy (figure 10b). Patch U-A2 was impacted both at the forward and after crack tips—500 in-lb energy for forward and 300 in-lb energy for the after side (figure 10c).

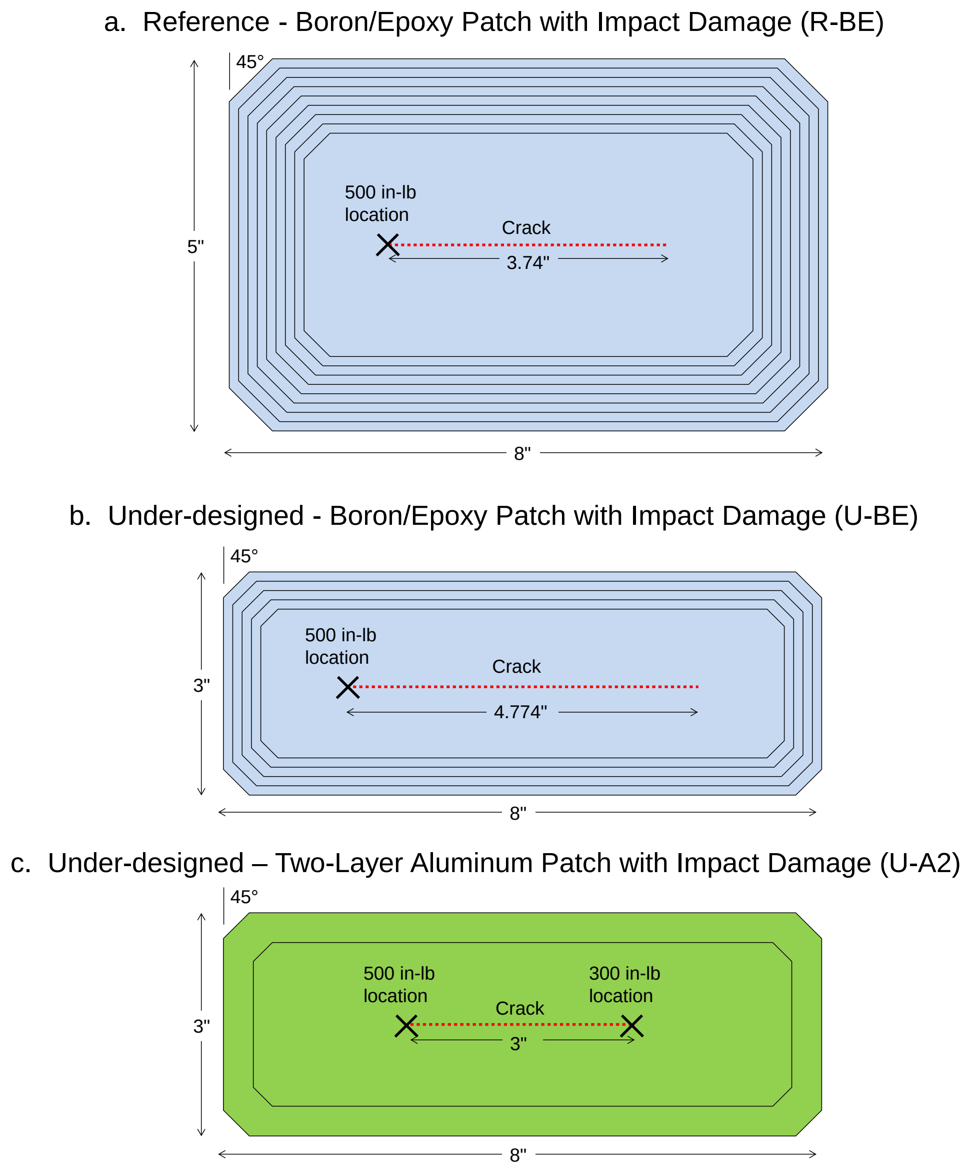


Figure 10. Phase 4 repairs with impact damage configuration: (a) R-BE patch, (b) B/Ep patch (U-BE), and (c) two-layer aluminum patch (U-A2)

2.3 APPLIED LOADS

The test sequence for each phase consisted of a baseline strain survey, fatigue pre-cracking, and fatigue cycling. The loads used for the fatigue test simulated the SL conditions, including cabin pressurization (8.9 psi) and fuselage vertical bending, and were represented by an equivalent constant-amplitude spectrum. The magnitude of the applied loads used in the strain survey and pre-cracking was 75% of the SL conditions used for the fatigue test. For the baseline strain survey tests, quasi-static loadings were applied in 10 increments up to the maximum loads listed in table 1. For the pre-cracking and fatigue test, constant-amplitude loading was applied at a frequency of 0.033 Hz, with an *R* ratio (minimum to maximum load) of 0.1. Table 1 shows the details of the loads and repair types for each phase. In addition, appendix C provides the complete details of all the phases of the test.

Table 1. Summary of test phases and applied loads

Test Phases	Description (test phase, applied load, number of cycles)	Load Phase	Maximum Load			
			Pressure (psi)	Hoop (lb)	Axial (lb)	Frame (lb)
Reference Repair	Strain survey, 75% of SL	Quasi-static	6.7	7140	6675	1133
	Fatigue pre-cracking, 75% of SL	Cyclic, R = 0.1	6.7	7140	6675	1133
	Fatigue, SL, 60,000 cycles	Cyclic, R = 0.1	8.9	9520	8900	1510
Phase 1: Underdesigned Repairs	Strain survey, 75% of SL	Quasi-static	6.7	7140	6675	1133
	Fatigue pre-cracking, 75% of SL	Cyclic, R = 0.1	6.7	7140	6675	1133
	Fatigue, SL, 60,000 cycles	Cyclic, R = 0.1	8.9	9520	8900	1510
Phase 2: Partial Disbond Repairs	Strain survey, 75% of SL	Quasi-static	6.7	7140	6675	1133
	Fatigue pre-cracking, 75% of SL	Cyclic, R = 0.1	6.7	7140	6675	1133
	Fatigue, SL, 60,000 cycles	Cyclic, R = 0.1	8.9	9520	8900	1510
Phase 3: Compliant Repairs	Strain survey, 75% of SL	Quasi-static	6.7	7140	6675	1133
	Fatigue pre-cracking, 75% of SL	Cyclic, R = 0.1	6.7	7140	6675	1133
	Fatigue, SL, 20,000 cycles	Cyclic, R = 0.1	8.9	9520	8900	1510
Phase 4: Repairs With Impact Damage	Strain survey, 75% of SL	Quasi-static	6.7	7140	6675	1133
	Fatigue, SL, 20,000 cycles	Cyclic, R = 0.1	8.9	9520	8900	1510

2.4 INSPECTION METHODS

Table 2 shows several NDI methods that were used to monitor and record damage formation and growth of cracks and disbonds. Reference 1 provides the details of the inspection methods and strain monitoring methods. For disbond detection, a flash thermography system and resonance ultrasonic technique using the Olympus BondMaster were used. Visual inspections and eddy current systems were used to monitor crack growth. Low frequency eddy current (LFEC) was used on the external surface of the patch for composite B/Ep repairs. High-frequency eddy current (HFEC) was used on the internal surfaces of all the patches. Along with these inspection methods, the strain gages and deformation and strain digital image correlation equipment were used to monitor strains throughout the tests.

Table 2. Inspection methods

Method	Inspection	Interval
High-magnification visual from interior surface	Crack growth monitored at inner surface under all patches	Continuous
HFEC from internal surface	Crack growth monitored at inner surface under all patches	5000 cycles
LFEC from external surface of patch	Crack growth monitored from outer surface of B/Ep patches	5000 cycles
Flash thermography from exterior surface of patch	Disbonding of all patches	5000 cycles
Resonance ultrasonic from exterior surface of patch	Disbonding of all patches	5000 cycles

2.5 DESCRIPTION OF SHM SYSTEM

A prototype piezoelectric-based SHM system for detecting crack growth for bonded repairs was developed. This type of system had been researched previously in a laboratory environment similar to the one discussed in reference 3; however, this study considers implementation on real aircraft structure. It should be recognized that a robust solution for monitoring bonded repair integrity is an overall structural health management system that uses a multidisciplinary systems engineering-based approach. Such a system would be developed using the SHM design framework and focus on determining the current state of the structure to make decisions based on overall system-level requirements. Reference 4 describes the SHM design framework in more detail. The prototype SHM system detailed in this study is focused on collecting and processing crack length data; it is just one piece of an overall SHM system.

The monitoring system in this study consisted of a network of surface-mounted piezoelectric actuators and sensors at each repair location and the associated hardware for collecting data. Figure 11 shows the sensor layout and the actual panel for a typical B/Ep and aluminum repair. The actuators were used to create guided ultrasonic waves that propagate through the structure and are sensed by other piezoelectric elements. These waves were used to interrogate the structure and correlate changes to crack length. Data from each repair location was collected and processed at 5000-cycle intervals. Instead of using specific requirements for crack length detection, this prototype was used as a demonstration of system capability and to identify potential implementation challenges. The hardware installed on the test panel is not an actual flight-ready system but is similar to a laboratory setup.

2.5.1 Monitoring System

Figure 12 shows a schematic of the monitoring system hardware. Seven Acellent SMART layer piezoelectric sensors/actuators (0.45″ by 1.5″ by 0.3″) with 3-pin Molex connectors were placed at each repair location. The data acquisition hardware was acquired from Metis Design and consisted of an MD7 high-speed digital sensor node with a breakout board and MD7 hub. Each of the piezoelectric elements was connected to the MD7 node using an SMA connector mounted on the breakout board. Data collection was controlled by the MD7 node and stored on the MD7 hub via a Category-5 cable. Data collection for each repair involved connecting each Molex cable to the breakout board and running a preprogrammed data acquisition program on the MD7 hub.

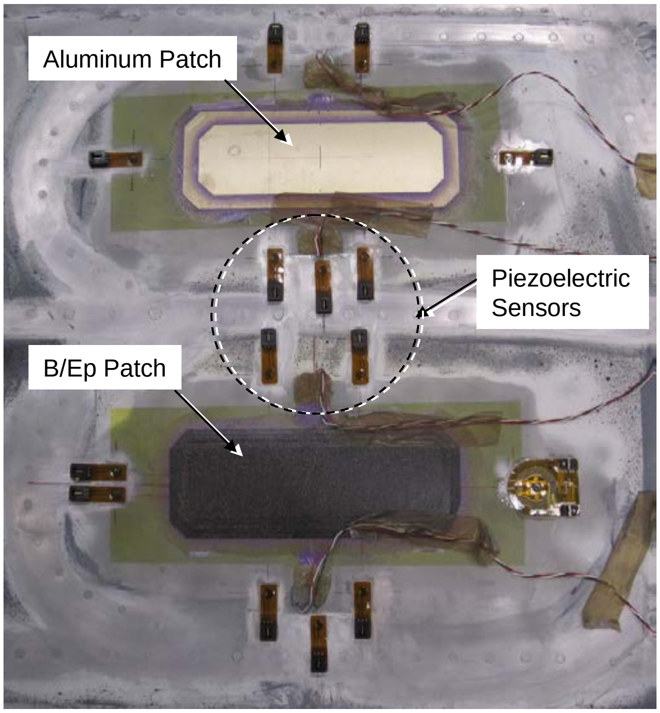


Figure 11. The SHM piezoelectric sensor layout for an aluminum and B/Ep patch

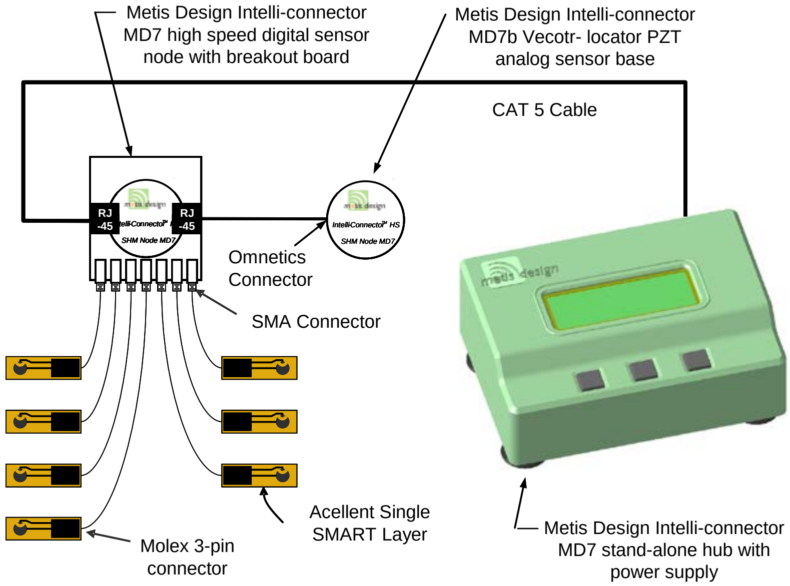


Figure 12. Monitoring system hardware

2.5.2 Data Collection and Processing

The prototype piezoelectric-based monitoring system used in this study was based on a pitch-catch method for detecting changes in the structure. Figure 13 shows an example pitch-catch path where A is the actuator and B is the sensor. At all repair locations, each piezoelectric element was used as an actuator, and the other six were used as sensors.

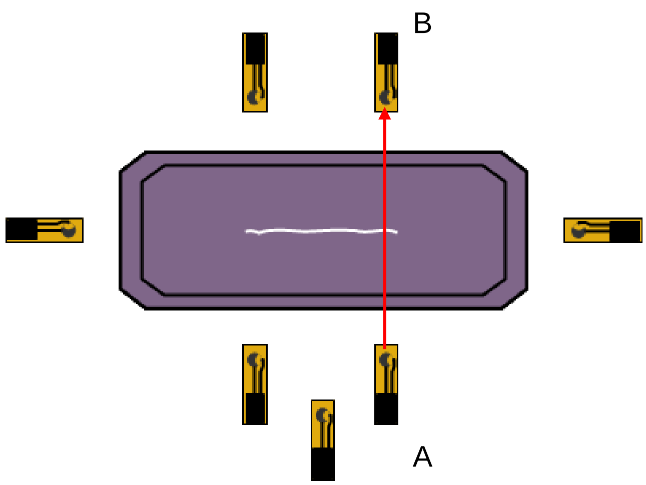


Figure 13. The SHM piezoelectric pitch-catch path example

Each piezoelectric actuator sends an input waveform that creates ultrasonic waves that propagate through the structure and are received by the sensing element. The input waveform is, generally, a windowed burst signal in the 100–400 kHz range. The signal received along a specific path may change due to damage in the structure; these changes can be analyzed to reveal information about the damage. In this study, the changes to the signals are quantified by damage index algorithms. Each of these algorithms compares various characteristics of the received signals and returns a damage index value. The damage indices can be correlated with the actual crack length data to build a model for predicting crack growth. In this case, a multivariable linear regression was used to build a model to convert damage index values to crack length, as shown in figure 14.

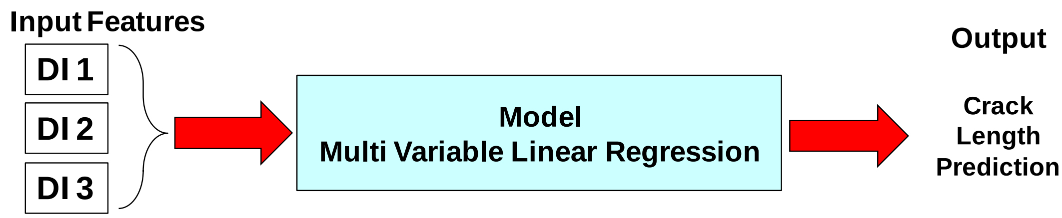


Figure 14. Convert damage index values to crack length

3. ANALYTICAL PROCEDURE

The analytical procedure consisted of global finite element (FE) structural analyses of the curved panel with and without bonded patch repairs and Composite Repair of Aircraft Structure (CRAS) closed-form analysis [5]. Stress and strain distributions obtained from the global FE structural model of the curved panel were verified with strain gage data. They were also used to provide the far field loads for CRAS analysis. Other predictions, such as thermal residual stresses due to adhesive curing and fatigue crack growth, were also made and compared with test results. Section 5 delineates all analytical predictions and their comparison with test results.

3.1 GLOBAL FE STRUCTURAL ANALYSIS OF THE CURVED PANEL

The global FE structural analysis was conducted using the commercial FE code ABAQUS. The FE model of the 727 fuselage Panel 2 was made by modifying the existing Panel 1 model. The longitudinal splice was relocated, and frame geometries were updated. Stringer and skin thickness were also redefined. Figures 15 and 16 show the stringer thickness of the panel. Figures 17 and 18 show the skin thicknesses of the panel. These thicknesses were verified by inspection of the actual panel geometry.

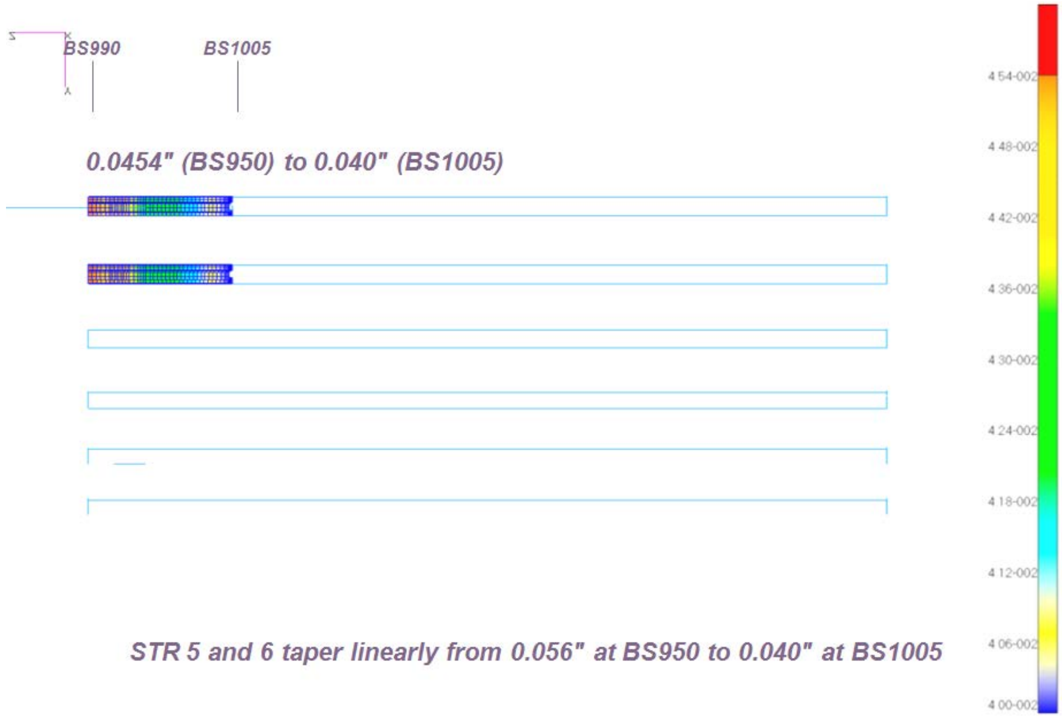


Figure 15. Stringer 5 and 6 taper

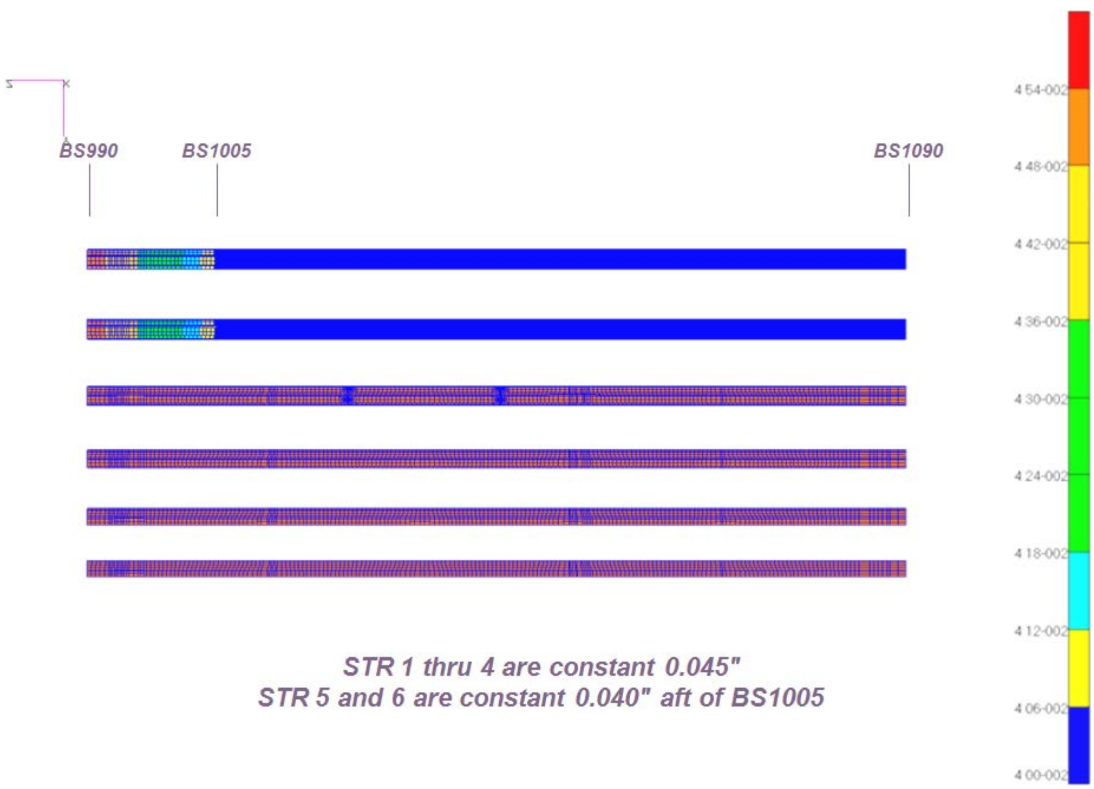


Figure 16. Stringer thicknesses

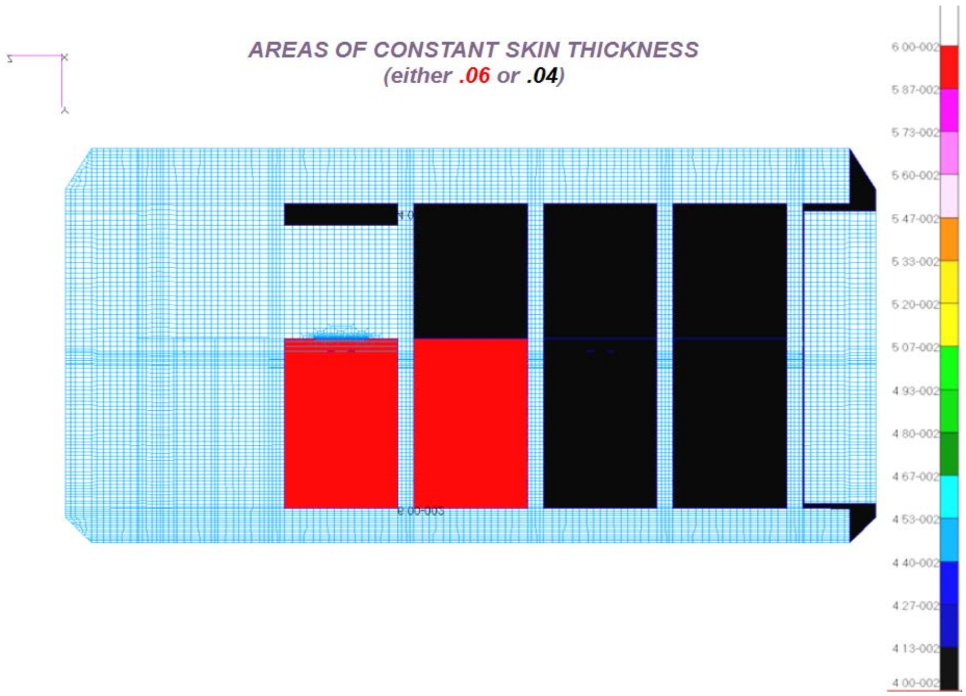


Figure 17. Skin thicknesses

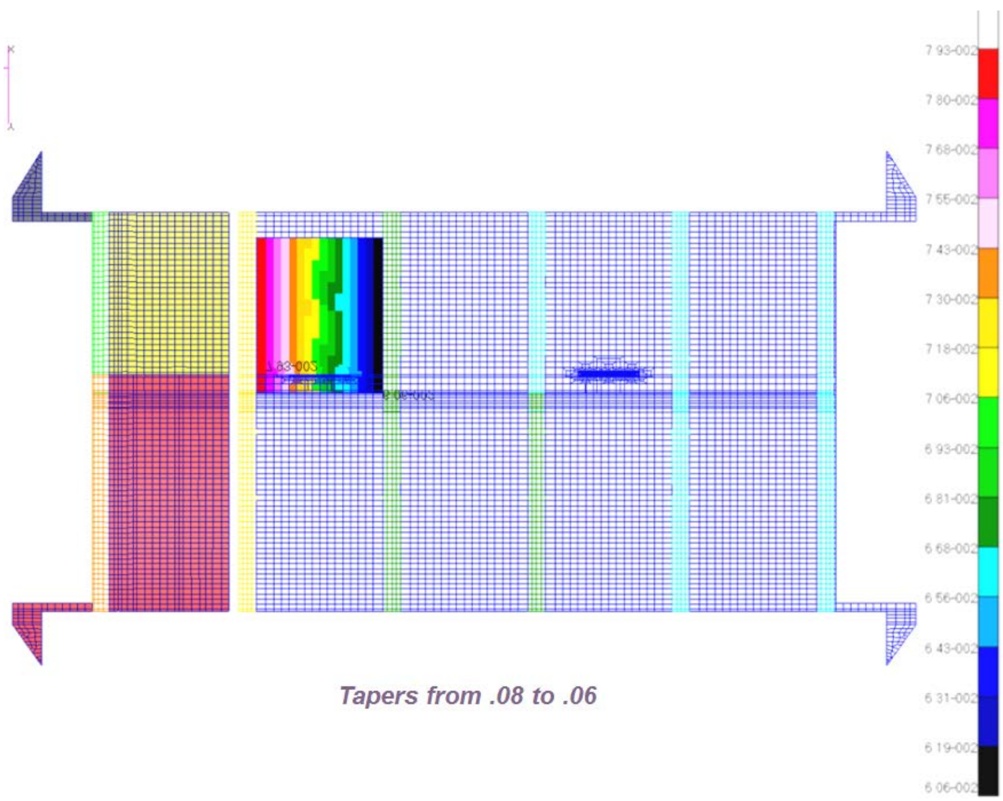


Figure 18. Skin thicknesses—taper area station 1010-1030 between S4 and S6

The panel was modeled using shell elements, with each node having 6 degrees of freedom. Figure 19 shows the global view of a typical FE model of the panel. The model contained the major geometric details and dimensions of the panels, including the cross-section properties of the substructure (frames, stringers, and clips) and the load attachment doublers. Typically, the panel model had 250,000 degrees of freedom. Four-noded shell elements were used throughout to model the skin, frames, stringers, clips, and repair patches (not shown) and beam elements were used to model the rivets. In contrast, the adhesive was modeled as a single layer of 3D solid elements, C3D8, to connect the shell elements. Using this modeling technique, the thicknesses of the solid elements for the adhesive layer were the average thickness of the bonded parts (see figure 20), rather than the actual thickness of the adhesive. The material modulus of the adhesive elements was therefore adjusted to match the actual adhesive stiffness as follows.

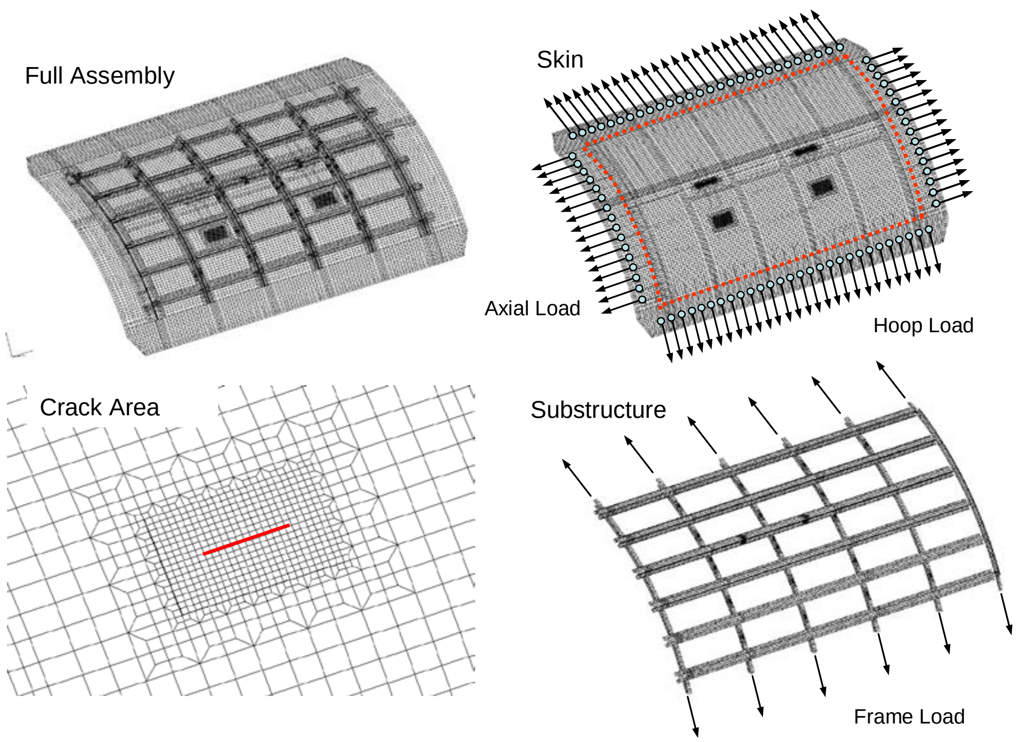


Figure 19. The FE model showing full assembly, substructure, and boundary conditions

For out-of-plane tension and compression modulus:

$$E_{33}\left(FEM\right) = \frac{E_{33}\left(Actual\right) \times t_g}{t_b} \tag{1}$$

For in-plane tension and compression modulus:

$$E_{11}(FEM) = \frac{E_{11}(Actual) \times t_b}{t_g}, \; \mathrm{E}_{22} = \mathrm{E}_{11} \tag{2}$$

For shear modulus:

$$G_{12}\left(FEM\right)=G_3\left(FEM\right)=\frac{G_{12}\left(Actual\right)\times t_g}{t_b}$$
$$G_{23}\left(FEM\right)=\frac{G_{12}\left(Actual\right)\times t_b}{t_g} \tag{3}$$

where t_g is the distance between the mid-plane of the shell elements that are joined by the 3D solids and is equal to the thickness of the adhesive plus the average thickness of the shells; t_b, is the actual thickness of the adhesive ($t_b = 0.005''$).

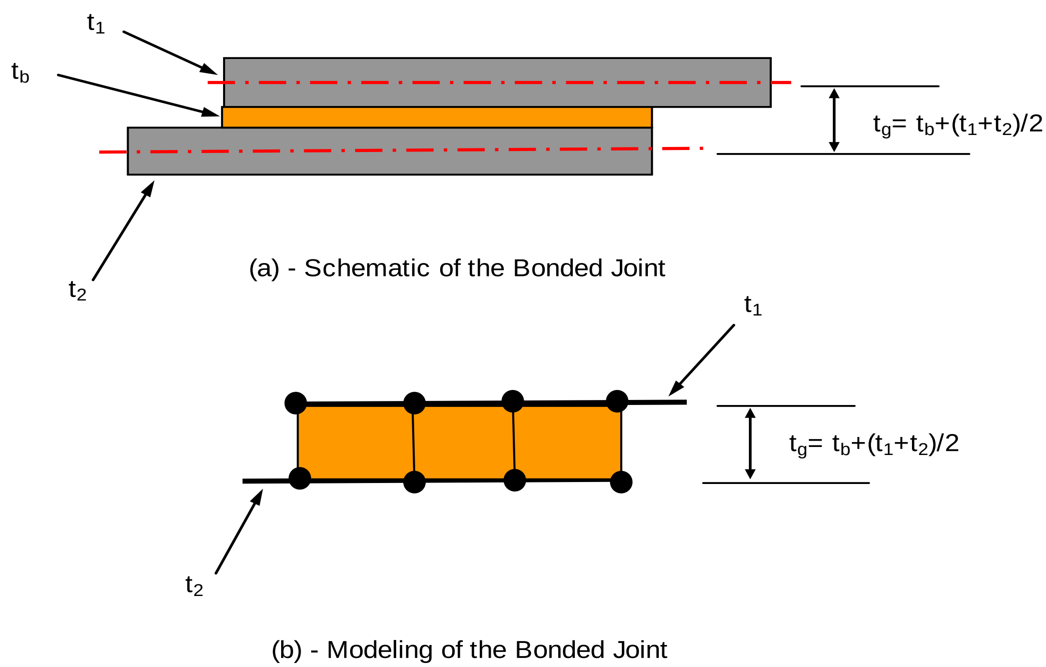


Figure 20. The FE modeling of bonded joint

The mesh of the skin at the crack tip was defined with mostly square elements, with the smallest element size being 0.06625″. Special crack tips, or singular elements, were not used. The material properties used in the analysis are listed in table 3 for various structural components of a curved panel, repair patch, and filler. Table 4 shows the material properties of the adhesive before and after adjustment made for the FE simulation mentioned above.

A load case representing an 8.9 psi cabin pressurization was applied to the skin inner surface of the panel model. The longitudinal load was applied via 16 points along the panel's circumferential edge at 2225 lb per location, as shown by the arrows in figure 19. The hoop loads were distributed to six frames at 1540 lb each and 28 points along the straight edges at 2380 lb each, shown by the arrows in figure 19. For every load application point, to stabilize the panel, it was constrained in the direction normal to the skin. In addition, constraints were added to the mid-point of each edge to prevent rigid body motion.

Table 3. Material properties used in the analysis for various structural components of a curved panel, patches, and filler

Aluminum Filler	
Material Type	2024-T3 sheet
Young's Modulus	E = 1.05E+07 psi
Poisson's Ratio	$\mu = 0.3$
Tensile Yield	FTY = 45,000 psi (A-basis)
Tensile Ultimate	FTU = 62,000 psi (A-basis)
Coefficient of Thermal Expansion	α = 1.25E-05 in/in/°F
Frame and Stringer	
Material Type	7075-T76511 Extrusion
Young's Modulus	E = 1.03E+07 psi
Poisson's Ratio	$\mu = 0.3$
Tensile Yield	FTY = 69,000 psi (A-basis)
Tensile Ultimate	FTU = 79,000 psi (A-basis)
Coefficient of Thermal Expansion	α = 1.25E-05 in/in/°F
Skin	
Material Type	2024-T3 Clad sheet, LT
Young's Modulus	E = 1.05E+07 psi
Poisson's Ratio	$\mu = 0.33$
Tensile Yield	FTY = 39,000 psi (A-basis)
Tensile Ultimate	FTU = 59,000 psi (A-basis)
Coefficient of Thermal Expansion	α = 1.25E-05 in/in/°F
Patch	
Material Type	Boron/Epoxy 5521 tape
(Vacuum bag 250°F, 15″ Hg)	
Nominal thickness	t = 0.005″ per ply
Material Properties at RT	
Young's Modulus	E_1 = 26.3 msi
	E_2 = 2.3 msi
Poisson's Ratio	$\mu_{12} = 0.21$
Modulus	G_{12} = 0.74 msi
Tensile Ultimate	F_{TU} = 190 ksi
Coefficient of Thermal Expansion	α_1 = 1.55E-05 in/in/°F
	α_2 = 2.50E-06 in/in/°F

Table 4. Material properties for the adhesive

Henkel EA9696 OS Grade 10		
Original Properties		
E11 =	2.926E+05 psi	
E33 =	2.926E+05 psi	
G12 =	1.100E+05 psi	
Adjusted Properties		
	For Boron Patch	For Alum Patch
t skin =	0.047	0.0745
t Patch =	0.030	0.060
tg =	0.0435	0.0723
tb =	0.005	0.005
tg/tb =	8.70	14.45
E11	2.546E+06	4.228E+06
E22	3.363E+04	2.025E+04
E33	3.363E+04	2.025E+04
G12	9.570E+05	1.590E+06
G13	9.570E+05	1.590E+06
G23	1.264E+04	7.612E+03

Geometric nonlinear finite element analyses (FEAs) were conducted to predict the strain distributions and compute the stress intensity factor (SIF) solutions using the commercial FE code ABAQUS. However, the effect of thermal stresses due to curing of an adhesive bond was not accounted for in the FEA. This latter effect would be estimated by the CRAS closed-form methods. The SIFs at the crack tip were computed by using the modified crack closure integral (MCCI) approach. The four components of SIF were the Mode I SIF caused by tensile load, K_I; the Mode II SIF caused by in-plane shear load, K_{II}; the SIF due to symmetric bending loads, k_1; and the SIF due to out-of-plane shear and twist loads, k_2, as shown in figure 21. For four node elements, the components of the SIFs were given in terms of nodal displacements u, rotations φ, forces F, and moments M by [8]:

$$
\begin{aligned}
K_I &= \sqrt{E \cdot G_I} \\
K_{II} &= \sqrt{E \cdot G_{II}} \\
k_1 &= \sqrt{\frac{3(3+v)E \cdot g_1}{\pi(1+v)}} \\
k_2 &= \sqrt{\frac{3(3+v)E \cdot g_2}{\pi(1+v)}} \\
G_I &= \frac{F_y^n \Delta u_y^{n-1} + M_{zz}^n \Delta\varphi_z^{n-1}}{2t\Delta a} \\
G_{II} &= \frac{F_x^n \Delta u_x^{n-1}}{2t\Delta a} \\
g_1 &= \frac{M_{xx}^n \Delta\varphi_x^{n-1}}{2t\Delta a} \\
g_2 &= \frac{F_z^n \Delta u_z^{n-1} + M_{yy}^n \Delta\varphi_y^{n-1}}{2t\Delta a}
\end{aligned}
\tag{4}
$$

where x, y, and z were the three local coordinates parallel, in-plane normal, and out-of-plane normal to a crack; t was skin thickness; E and v were Young's Modulus of skin and Poisson's ratio; n was the node number at a crack tip; n-1 was a node directly behind a crack tip; and Δa was an element size of a square element at a crack tip, as shown in figure 21.

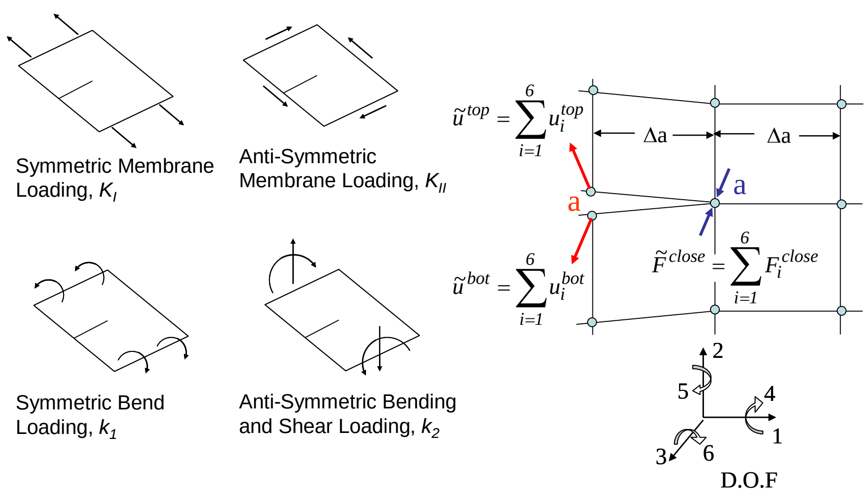


Figure 21. Definition of four SIFs for thin cracked shells and crack tip element and nodes for computing the rate of work done to close a crack using the MCCI method

3.2 THE CRAS CLOSED-FORM SOLUTION

In the CRAS closed-form model, a cracked flat panel repaired with a bonded composite or metallic patch under biaxial loading was analyzed. Even though the closed-form model was limited to such simple geometry, as a first-order approximation, CRAS analytical methods were also used to analyze the bonded repairs on the curved 727 fuselage panel under pressure loading. The CRAS analysis also estimated the thermal effect due to the curing of the adhesive. The CRAS analysis of a curved panel involved the following four basic steps:

1. Determination of far field loads for CRAS analysis. The input of the far field loads to the CRAS closed-form model were determined from the geometrically nonlinear FEM of an intact and unrepaired curved panel (the baseline configuration). These far field loads were assumed to be equal to the skin stresses at the prospective crack or repair location on the curved panel. Because CRAS allowed the modeling of biaxial loading, both hoop and longitudinal components of the skin stress were used in the CRAS analysis.

2. Determination of skin stresses around and inside the patched areas. The skin stress distribution around and inside the patched area was determined by the CRAS closed-form model using the Eshelby equivalent inclusion method [5]. The patch was assumed to be rigidly bonded to the skin and the skin contained no crack (i.e., it was pristine). The effect of the out-of-plane deflection for a one-sided doubler repair was also properly accounted for by the method.

3. Determination of the crack tip SIFs for crack growth analysis. The SIFs were calculated by CRAS using a crack bridging model. Both membrane and bending components of the mode I SIFs were computed. In this crack bridging model, an infinite skin containing a crack repaired with an adhesively bonded patch of an infinite extent was analyzed. Furthermore, the crack was also subjected to a prescribed traction load applied to its two surfaces while the external boundary of the skin was stress-free. The traction load applied to the crack surfaces was equal to the skin stress underneath the patch at the prospective crack location, as determined from step 2 for a patched, intact skin. This approach for calculating the SIF was well-known in a bonded repair community and referred to in literature as Rose’s two-stage analysis approach for determining the SIF of a patched crack. It provided the theoretical foundation for all CRAS analytical methods.

4. Crack growth prediction. The characterization of fatigue crack growth in a one-sided patch repair posed a challenge. This was because the SIF varied across the skin thickness because of the out-of-plane bending and a lack of clarity regarding which thickness value of the SIF was to be used to characterize the fatigue crack growth. As a common practice, either the maximum value or the root mean square (rms) value of the SIF across the skin thickness (K_{max} and K_{rms}, respectively) was used to predict the fatigue crack growth. K_{max} and K_{rms} were defined by:

$$
\begin{aligned}
K_{\mathrm{max}} &= K_{\mathrm{mem}} + K_b \\
K_{rms} &= \sqrt{K_{\mathrm{mem}}^2 + \frac{K_b^2}{3}}
\end{aligned}
\tag{5}
$$

where K_{mem} and K_b were the membrane and bending components of the SIF. However, it was found during the development of CRAS that the following effective or equivalent SIF defined as:

$$K_{\text{eff}} = K_{\max} + \left(1-\sqrt{3}\right)\frac{K_b}{K_{\max}} K_{\text{rms}}$$

or (6)

$$K_{\text{eff}} = \max\left\{K_{\text{mem}} + \frac{S}{S+1}K_b ; K_{\text{rms}}\right\}$$

where S = a ratio of patch stiffness to skin stiffness would consistently yield best crack growth predictions when compared with the test data generated under the CRAS program. The physical significance of K_{eff} is discussed in reference 6. In contrast, crack growth predictions based on $K_{\max}$ were always higher than those based on K_{eff} and sometimes they were much too conservative. There were several lessons that were documented from the first panel test, and would be implemented for the panel 2 analysis, including the finding that crack growth predictions for the aluminum patches correlated well with test results when K_{eff} and NASGRO® da/dN data were used. In contrast, crack growth predictions for boron patches correlated well with test results when $K_{\max}$ (through-thickness) and NASGRO da/dN data were used because CRAS analysis tended to underpredict the thermally residual stresses because of adhesive curing in the boron-patched repair. Thus, all predictions for panel 2 followed the above guidelines.

4. RESULTS AND DISCUSSION

Tests and analyses were performed to study the fatigue performance of intentionally deficient and degraded B/Ep and aluminium repairs bonded to a metallic fuselage structure. Fatigue loading simulating SL conditions was applied. Strains and damage growth were monitored and recorded for all repair patches. Representative DIC, strain gages, NDI, and crack growth results are outlined in the following sections for the test phases considered.

4.1 THE REFERENCE BORON/EPOXY (R-BE) REPAIR

The strain gage results for reference B/Ep repair revealed that the installation of the mid-bay repairs resulted in eccentric loading and inward deformation of the mid-bay region, with high tensile strains on the skin surface and compressive strain on the outer patch surface. Figure 22 shows the results for the mid-bay R-BE patch measured from several strain gages. Gage S16 is located in the center of the patch on the outer surface and is under compression. Gages S10 and S11 are located on the outer surface of the skin 0.75″ from the patch boundary. Gages IS10 and IS11 were at the same location on the inner skin surface. Comparing the back-to-back gages, there is a large amount of bending along the patch boundary, with the outer surface in tension and inner surface in compression, as shown in figure 22(b). The bending strains remained relatively constant throughout the fatigue test, as shown in figure 22(c). In the center of the patch, along the notch centerline, the patch region is under compression. The results of strain gage S16 show that the compressive strain decreased with fatigue cycles. However, these results are inconsistent as strain gages at the S16 location repeatedly disbonded and were reapplied during the test. Even a slight variation in the new strain gage location resulted in inconsistent results as the patch center was subjected to a high compressive strain gradient. The DIC results in the next section discuss the high compressive strain gradient region along the patch center.

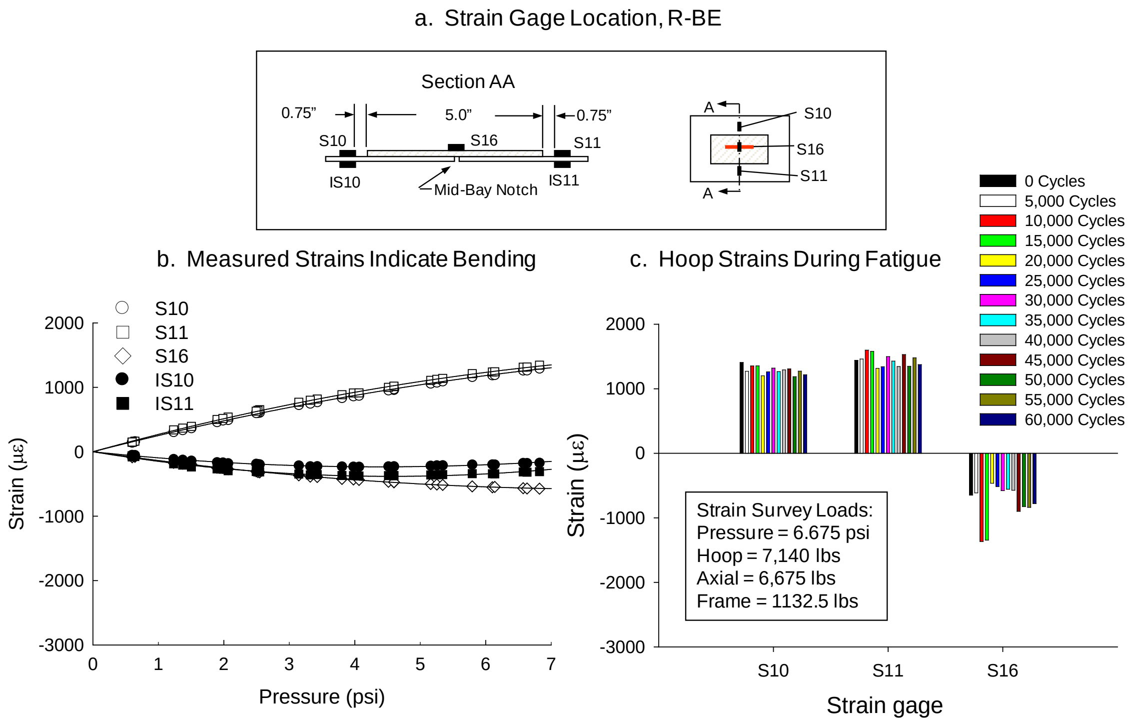


Figure 22. Strain gage results for R-BE repair showing eccentric loading as a result of patch installation

In general for the reference patch, there were no global changes in the strain field that would indicate load redistribution due to disbonding or crack growth. Figure 23 shows representative results of the full-field hoop strain in the vicinity of R-BE, measured via DIC at selected fatigue cycles. The magnitude of applied load used during the strain survey was 75% of the SL conditions. The patch boundary and initial defect are shown in figure 23. The white regions are areas where data could not be processed because of interference from strain gage wires. In general, the strain increased in the panel skin along the edges of the repair patches (indicated by the red and yellow fringe patterns) and decreased in the repair patch region. In the center of the patch, along the notch centerline, the patch region was in compression (indicated by the blue fringe patterns). The plots show details of the hoop strain variation in the vicinity of the patch along three vertical sections. As indicated, the hoop strain varied most toward the middle of the patch (section 1, located 0.75″ from the patch vertical centerline), where the values ranged from approximately 3000 με in the skin outside the patch to approximately -1500 με in the center of the patch. The strain gradient was quite high in a narrow band of approximately ±0.5″ around the crack (section 1). Over this short distance, the strain ranged from 0 to -1500 με. Strain also changed rapidly at the patch boundary crossing from the skin into the patch (sections 1–2) at 2.25″ about the notch centerline. The severity of the strain gradient did reduce substantially in sections of the patch ahead of the crack (section 2) and more so outside the patch in the skin (section 3).

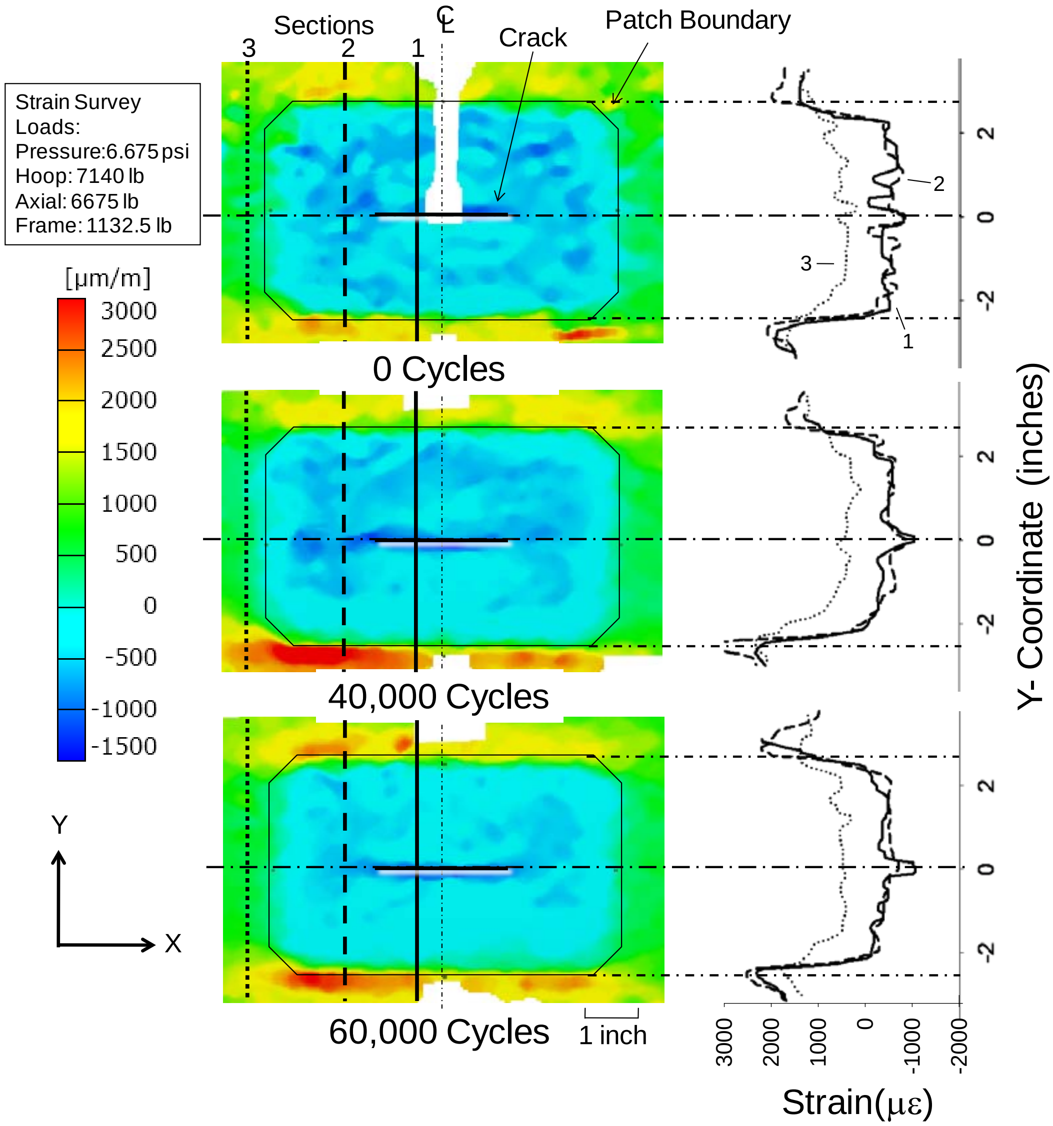


Figure 23. Strain field in the vicinity of R-BE patch, measured via DIC

The R-BE patch was also monitored using flash thermography and resonance ultrasonics for any disbonds throughout the test, showing no indication of any disbond growth. The observed crack growth was measured during the fatigue test using visual and eddy current inspections. Figure 24(a) shows that crack growth was self-similar and co-linear. Figure 24(b) shows the comparison of the crack lengths measured visually using external LFEC and internal HFEC. The measurements made by the three methods were in good agreement. The crack growth rate for the R-BE patch was 0.64 x 10^{-5} inch/cycle.

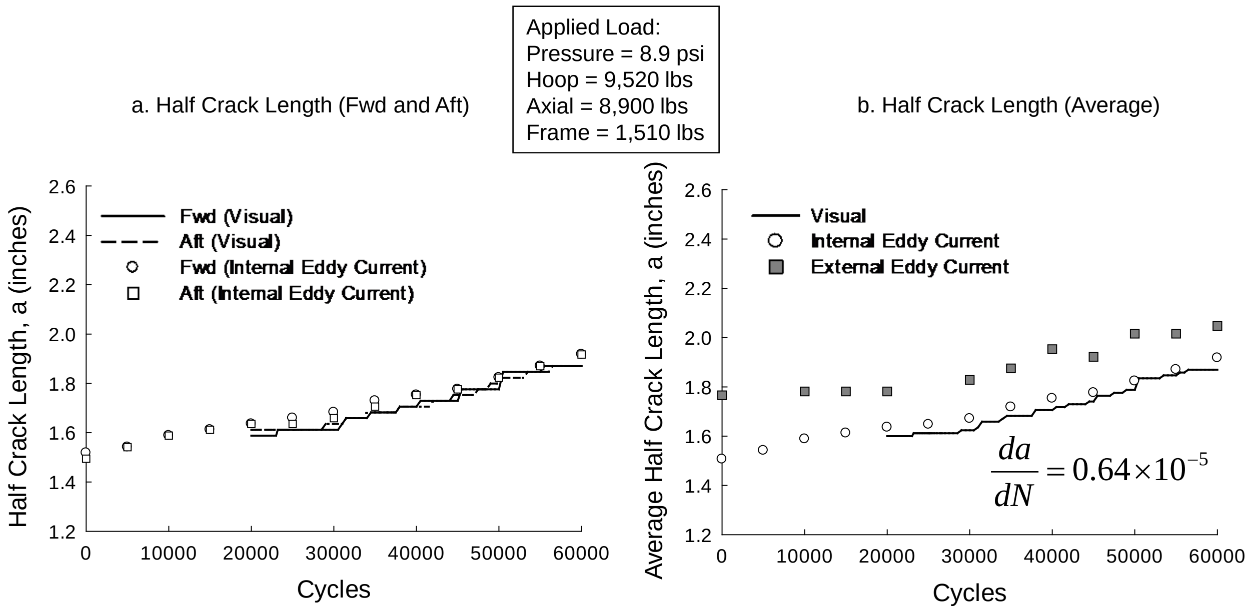


Figure 24. Crack growth for reference repair: (a) fwd and aft half-crack length showing self-similar and collinear crack growth and (b) average half-crack length showing good agreement among the three measurements

4.2 PHASE 1—UNDERDESIGNED REPAIRS

For the mid-bay Phase 1 repairs, a B/Ep patch, U-BE, and a two-layer aluminium repair patch, U-A2, were fatigue-tested to 60,000 cycles. In addition, a single-layer aluminium repair patch, U-A1, could withstand only 54,250 cycles because the repair was no longer able to restrict the crack growth. Similar to the R-BE repair, Phase 1 repairs resulted in eccentric loading and the inward deformation of the mid-bay region, with high tensile strains on the skin surface and compressive strain on the outer patch surface. Figure 25 shows representative results for the mid-bay patch, U-BE, measured from several strain gages. Gage S18 is located in the center of the patch on the outer surface and is under compression. Gages S14 and S15 are located on the outer surface of the skin, 0.75″ from the patch boundary. Gages IS14 and IS15 were at the same location on the inner skin surface. Comparing the back-to-back gages, there is a large amount of bending along the patch boundary with the outer surface in tension and inner surface in compression, as shown in figure 25(b). The bending strains remained relatively constant throughout the fatigue test, as shown in figure 25(c). The center of the patch, along the notch, the centerline shows compressive strains. The results of strain gage S18 shows that these compressive strains decreased with fatigue cycles. However, these results are inconsistent as strain gage S18 was repeatedly disbonded and reapplied during the test. Even a slight variation in the new strain gage location resulted in inconsistent results, as the patch center was subjected to a high compressive strain gradient. The detailed raw strain gage data for all the repairs are presented in appendix E and the procedure for strain gage data reduction is provided in appendix F.

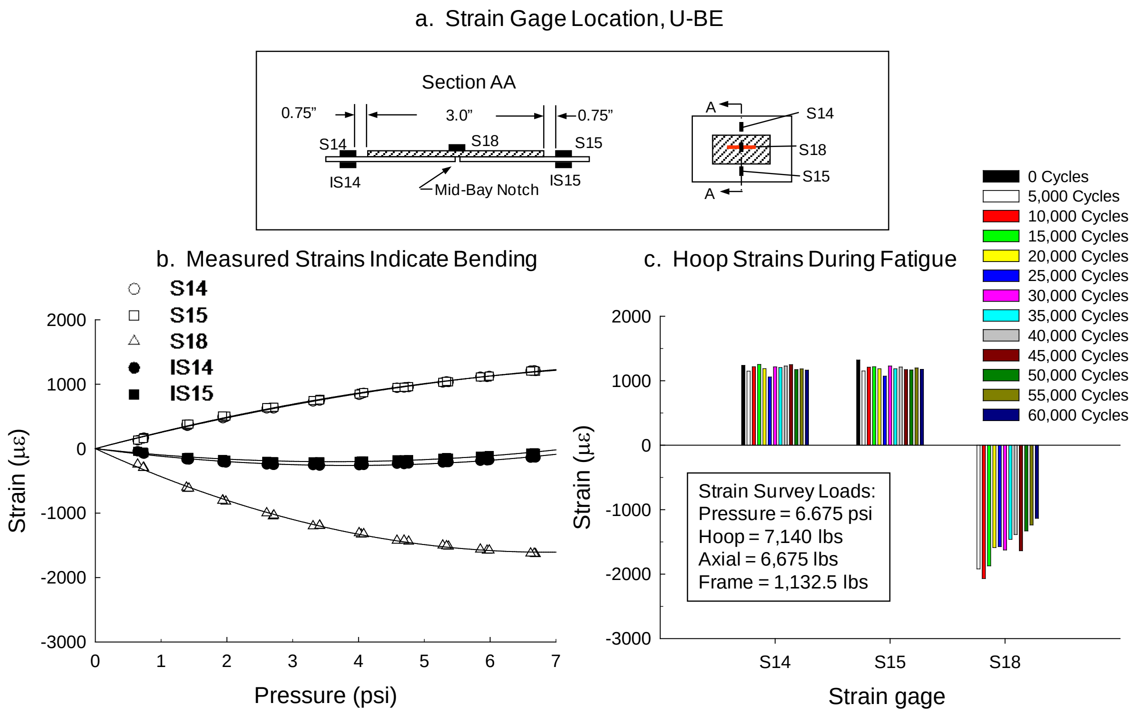


Figure 25. Strain gage results for U-BE repair

The DIC results showed that there were no significant changes in the strain field for the U-BE patch. That is, no load redistribution took place for the U-BE patch. Figure 26 shows representative results of the full-field hoop strain in the vicinity of the repair, measured via DIC at selected fatigue cycles. The magnitude of applied load used during the strain survey was 75% of the SL conditions. The patch boundary and initial defect are indicated in the figure. As in previous figures, the white regions are areas where data could not be processed because of interference from strain gage wires. Similar to the R-BE patch, the DIC images for the R-BE repair showed that the aluminum skin outside the patch was in tension and the patch in the center, along the notch centerline, was in compression. Appendix G presents the DIC results of all patches.

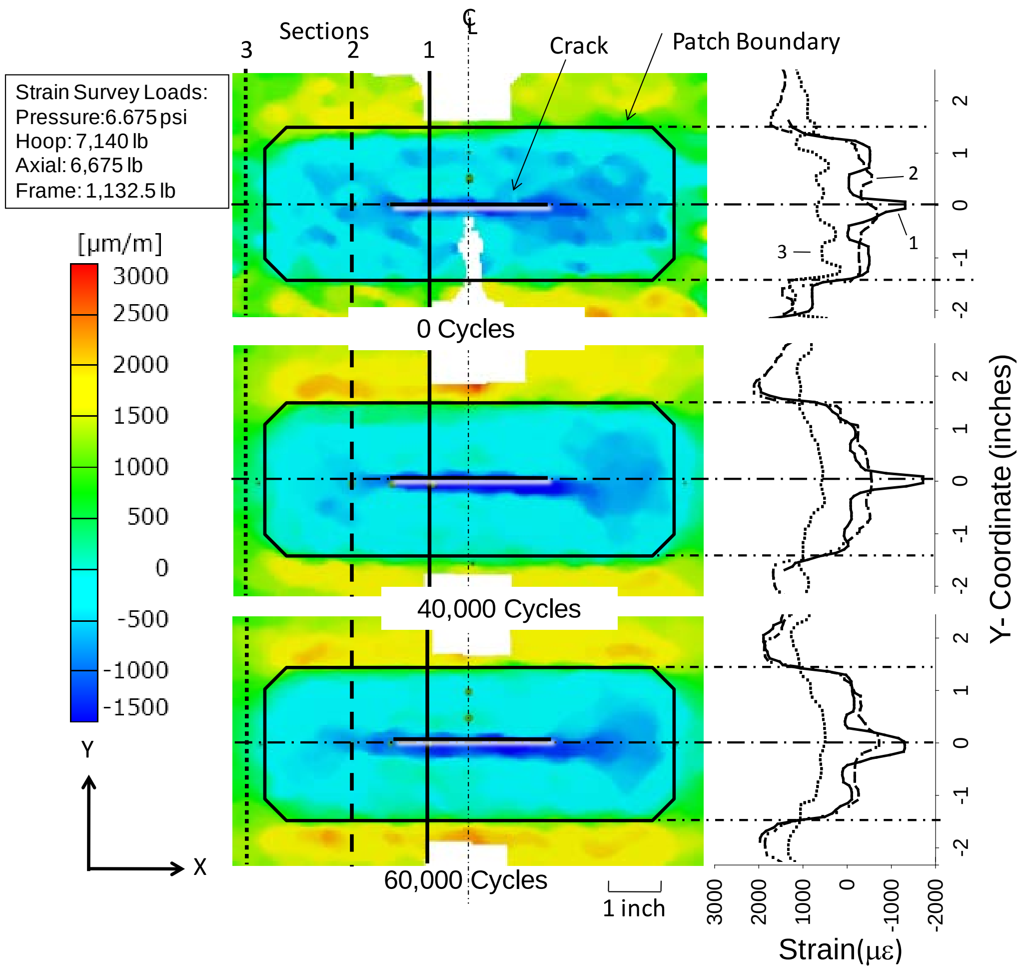


Figure 26. The DIC results for U-BE repair

Flash thermography and resonance ultrasonics revealed that there were no indications of damage development in the form of disbonding. Figure 27 shows representative results for U-BE repair, using flash thermography at the beginning and end of the fatigue test. The images indicate temperature variations at two different exposure times: 0.5 and 2.5 sec. The plots show the relative temperature profile across the patch. As shown, there was a modest difference in the data acquired throughout the fatigue test.

There were indications of slow, stable crack growth from the mid-bay notches under the Phase 1 repairs. Visual inspections for crack growth were made using a remote-controlled, high-magnification camera mounted on a tracking system. Figure 28 shows example images of the crack extension from the notch tips at several stages of fatigue cycling for the U-BE patch (note the symmetric and co-linear crack extension from the notch tips). In addition to the crack growth data shown, appendix H provides the complete crack growth data in tabular and graphical form.

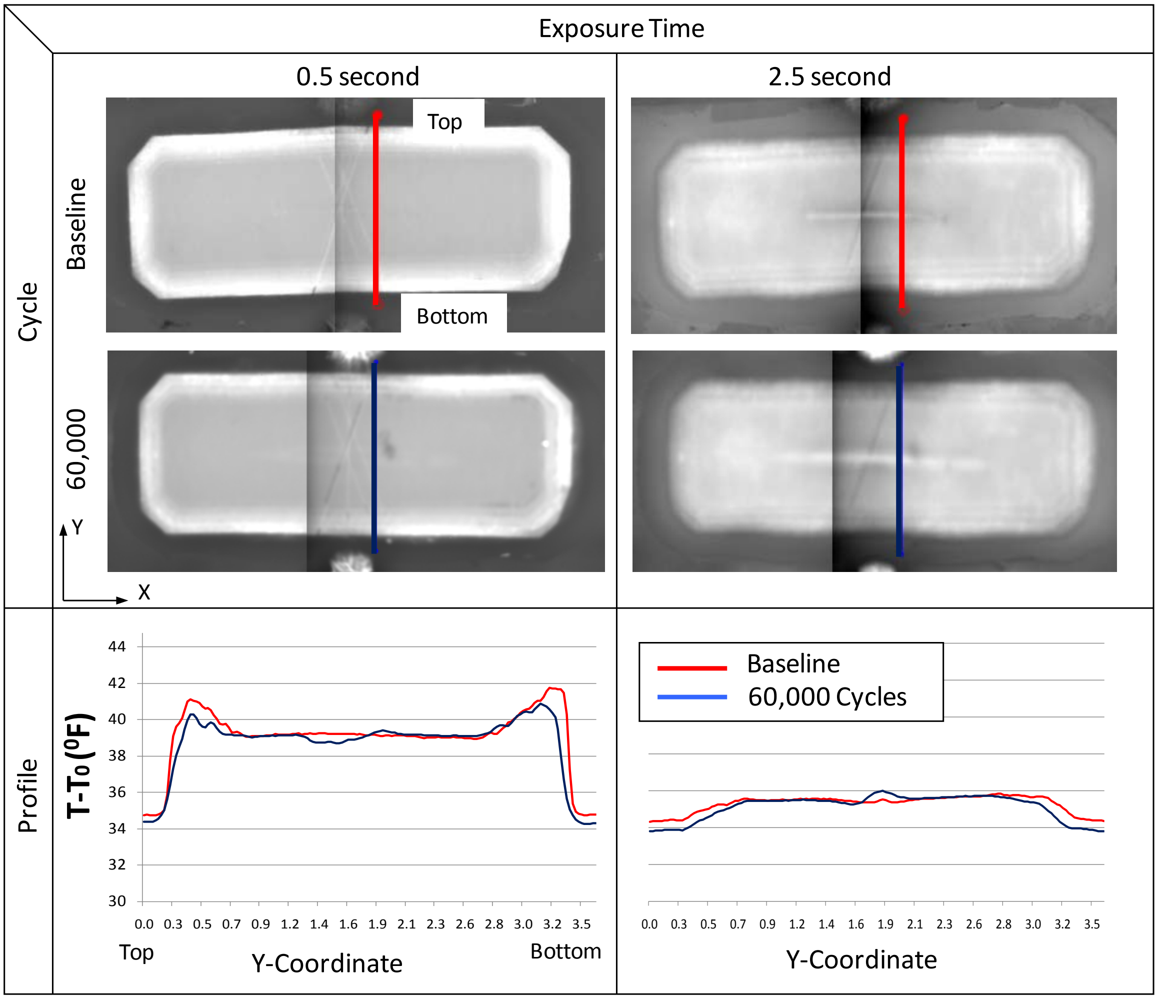


Figure 27. Flash thermography results for U-BE repair

The observed crack growth was measured during the fatigue test using visual and eddy current inspections. Figure 29 shows the Phase 1 U-BE repair patch results. Figure 29(a) shows that, similar to the R-BE repair, the crack growth was self-similar and collinear. Figure 29(b) shows good agreement among the crack lengths measured visually, using external LFEC and internal HFEC. For the two-layer aluminum patch, U-A2 negligible crack growth and disbonding were observed (see figure 30).

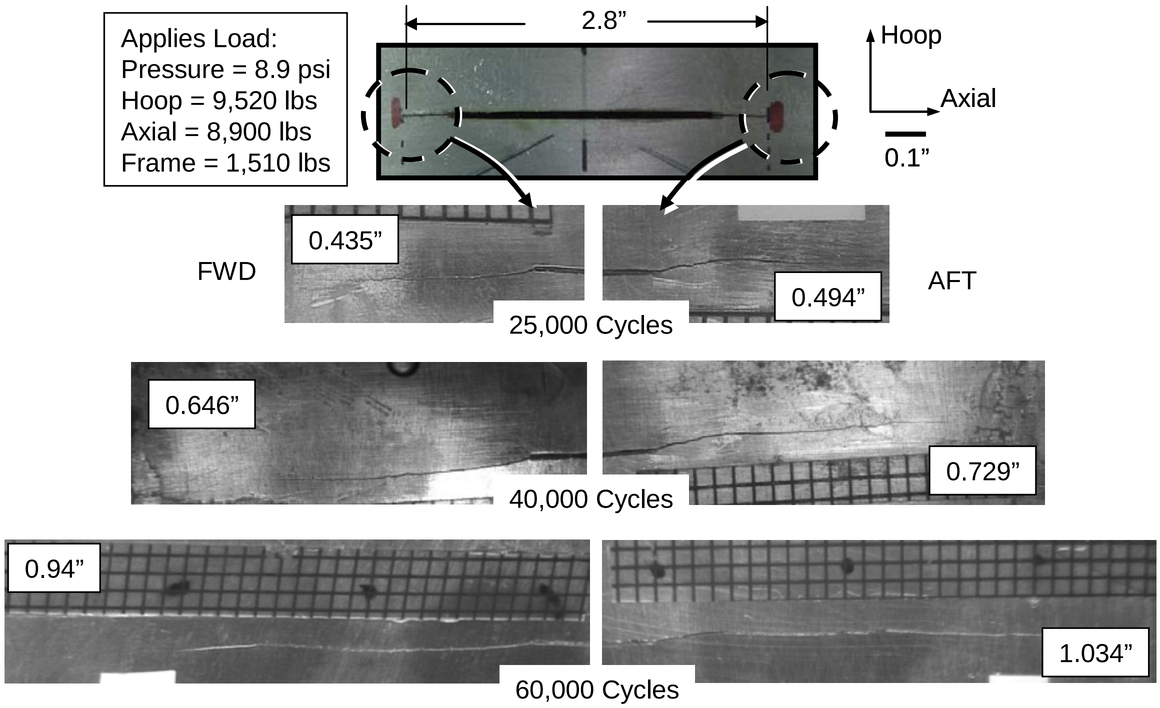


Figure 28. Crack extension from notch tips in U-BE repair

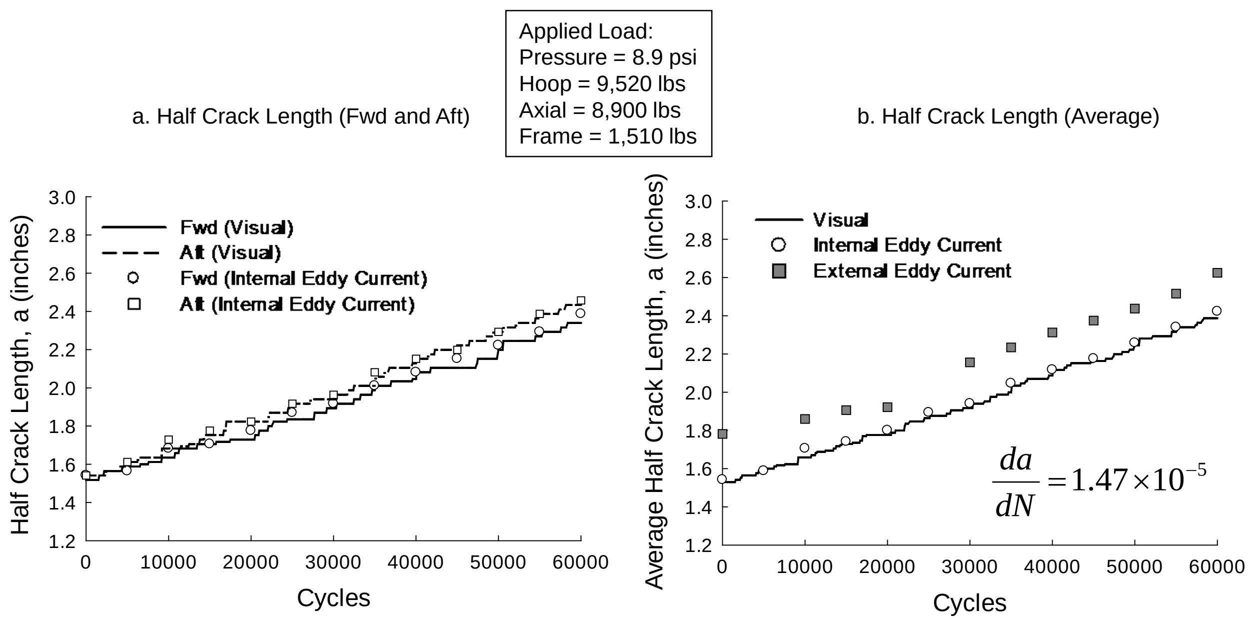


Figure 29. Crack growth for U-BE repair: (a) fwd and aft half-crack length showing self-similar and collinear crack growth and (b) average half-crack length showing good agreement among the three measurements

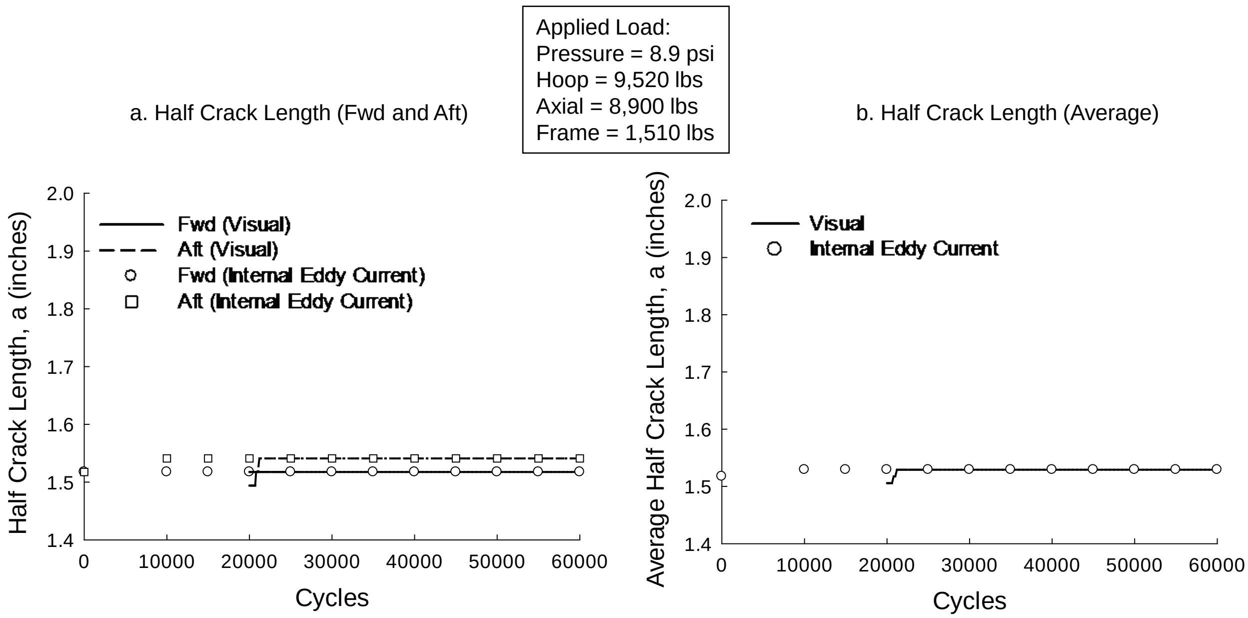
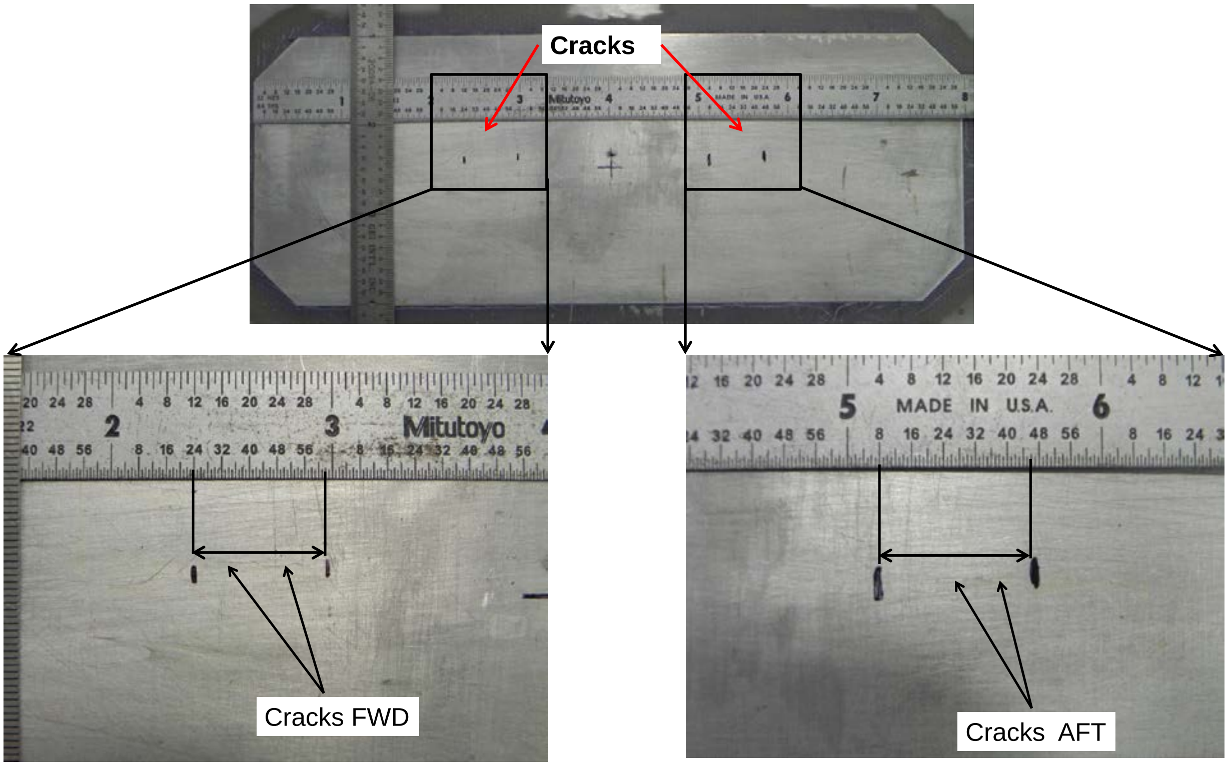


Figure 30. Crack Growth for U-A2 Repair: (a) fwd and aft half-crack length showing negligible crack growth and (b) average half-crack length showing good agreement among the three measurements

For the single-layer aluminum patch, U-A1, crack growth was slow and stable up to 40,000 fatigue cycles, where two cracks of approximately 0.625″ were observed on the external surface of the patch. Figure 31 shows the location of the two external cracks. At 45,000 cycles, another crack appeared on the patch. The lengths and location of the three cracks are shown in figure 32(a) and (b), where the abscissa shows the length of the patch and the ordinate shows the crack extension. The two cracks link up at 50,000 cycles and then they connect with the third crack at 53,600 cycles, resulting in a 6.7″-long crack on the patch (figure 32(c)). As the external cracks linked up, the crack growth rate of the skin underneath the patch increased substantially, causing highly nonlinear crack growth (see figure 33).

a. U-A1 Repair after 40,000 Cycles



b. Fwd Crack

c. Aft Crack

Figure 31. Cracks developed on the U-A1 patch at 40,000 cycles

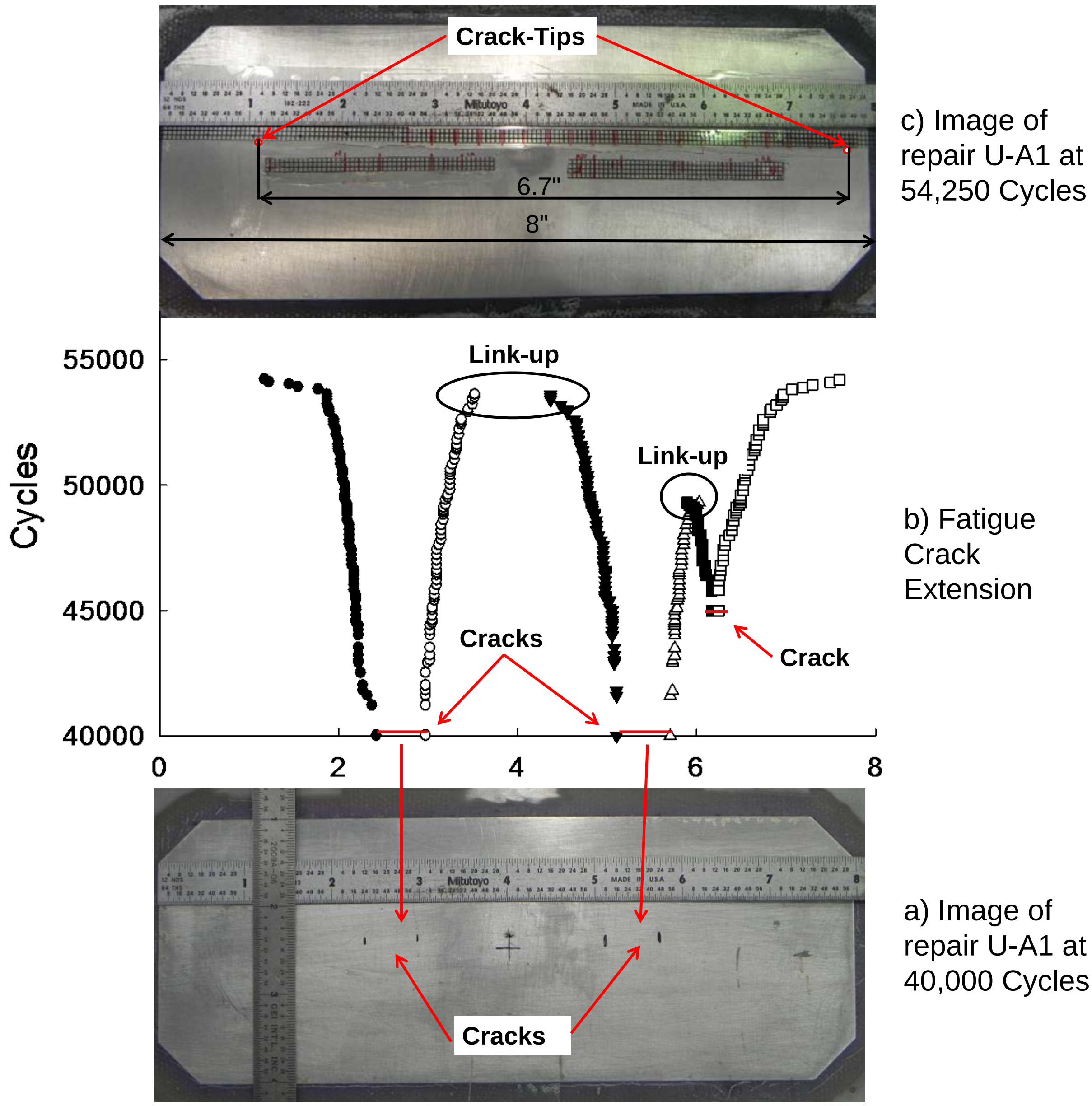


Figure 32. Link up of external cracks on U-A1 patch: (a) image of U-A1 repair at 40,000 cycles, (b) fatigue crack extension showing link up of cracks, and (c) image of U-A1 repair at 54,250 cycles showing 6.7″-long crack

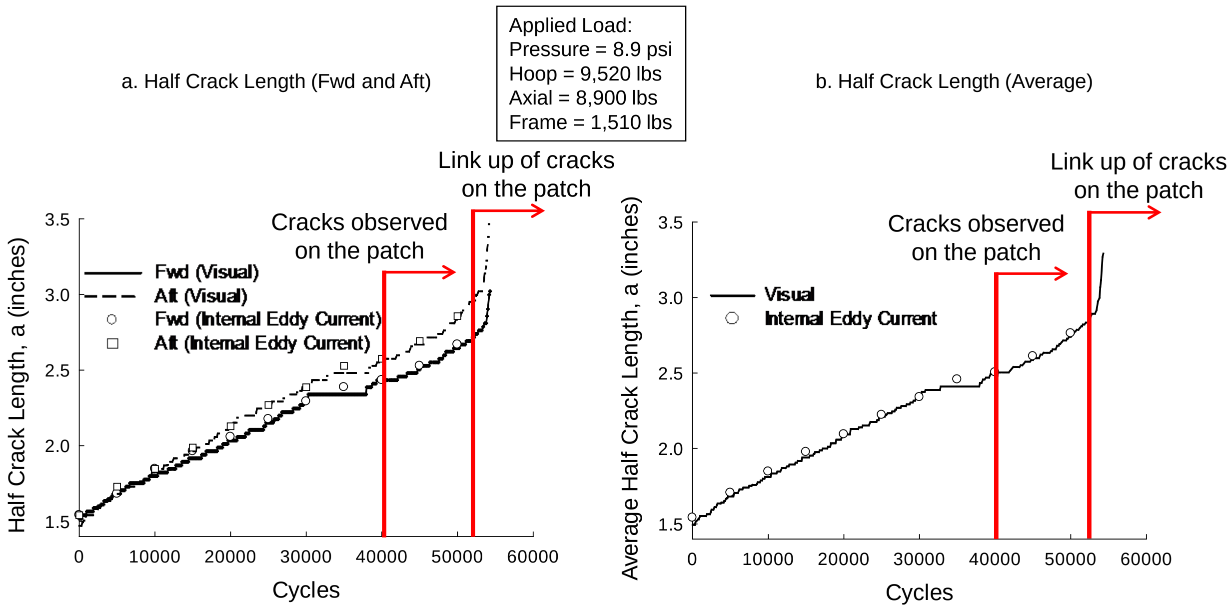


Figure 33. Crack growth for U-A1 repair: (a) fwd and aft half crack length and (b) average half-crack length

Figure 34 shows the results of the full-field hoop strain in the vicinity of the U-A1 patch measured using DIC. The images show that, prior to 40,000 cycles, the patch was under compression. As the cracks developed, the center of the patch showed high tensile strains, and as the cracks linked up, the magnitude of tensile strains along the center of the patch increased.

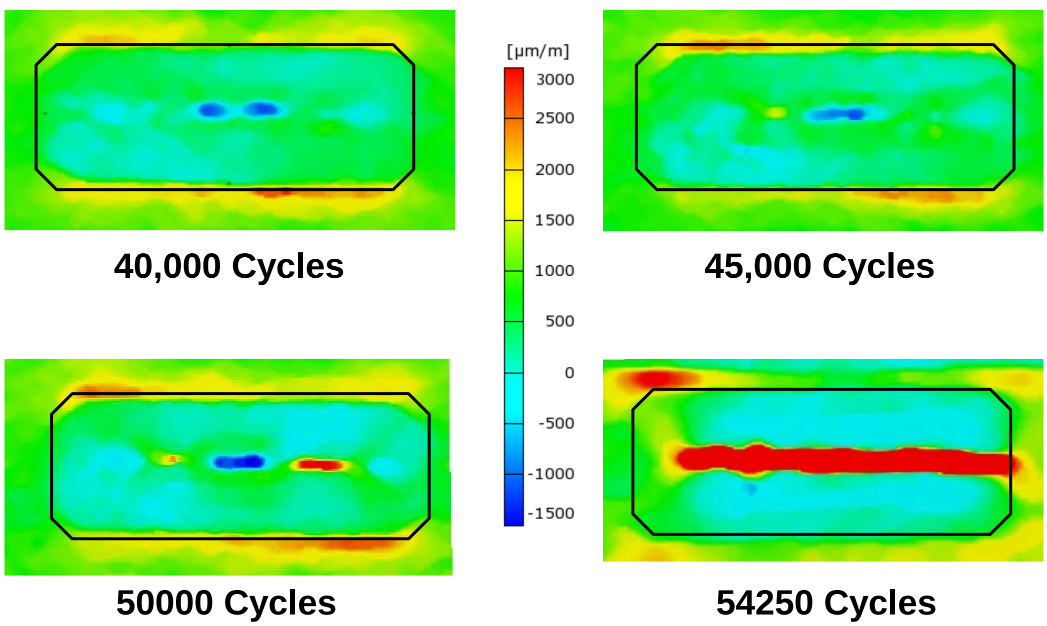


Figure 34. The DIC results showing the hoop strains in the vicinity of the U-A1 repair

To continue fatigue testing to the end of Phase 1 (60,000 cycles), temporary repairs were installed to mitigate further crack extension of the skin. Appendix I details the procedure and the materials used for these temporary repairs.

4.3 PHASE 2—PARTIAL DISBOND REPAIRS

The partially disbonded Phase 2 repairs, D-BE and D-A2, were fatigue-tested to 60,000 cycles using SL conditions. Similar to Phase 1 repairs, the global strain response remained relatively the same throughout the fatigue test. Figure 35 shows the DIC results for the D-BE repair, which are similar to the U-BE repair (i.e., compression at the center of the patch and tension at the patch boundary). Another similarity was that flash thermography and resonance ultrasonics revealed no indications of disbond growth. Figure 36 shows representative results for the D-BE repair, using flash thermography at 0 and 40,000 fatigue cycles. The images indicate temperature variations at two different sampling times, 0.5 and 2.5 sec. The plots show the relative temperature profile across the patch. The disbond inserts were easily detected and are exposed in the figures. As shown, there was a modest difference in the signatures in the data acquired throughout the fatigue test, and there was no clear indication of disbond growth from the inserts. Appendix J provides the thermography results of all the B/Ep patches.

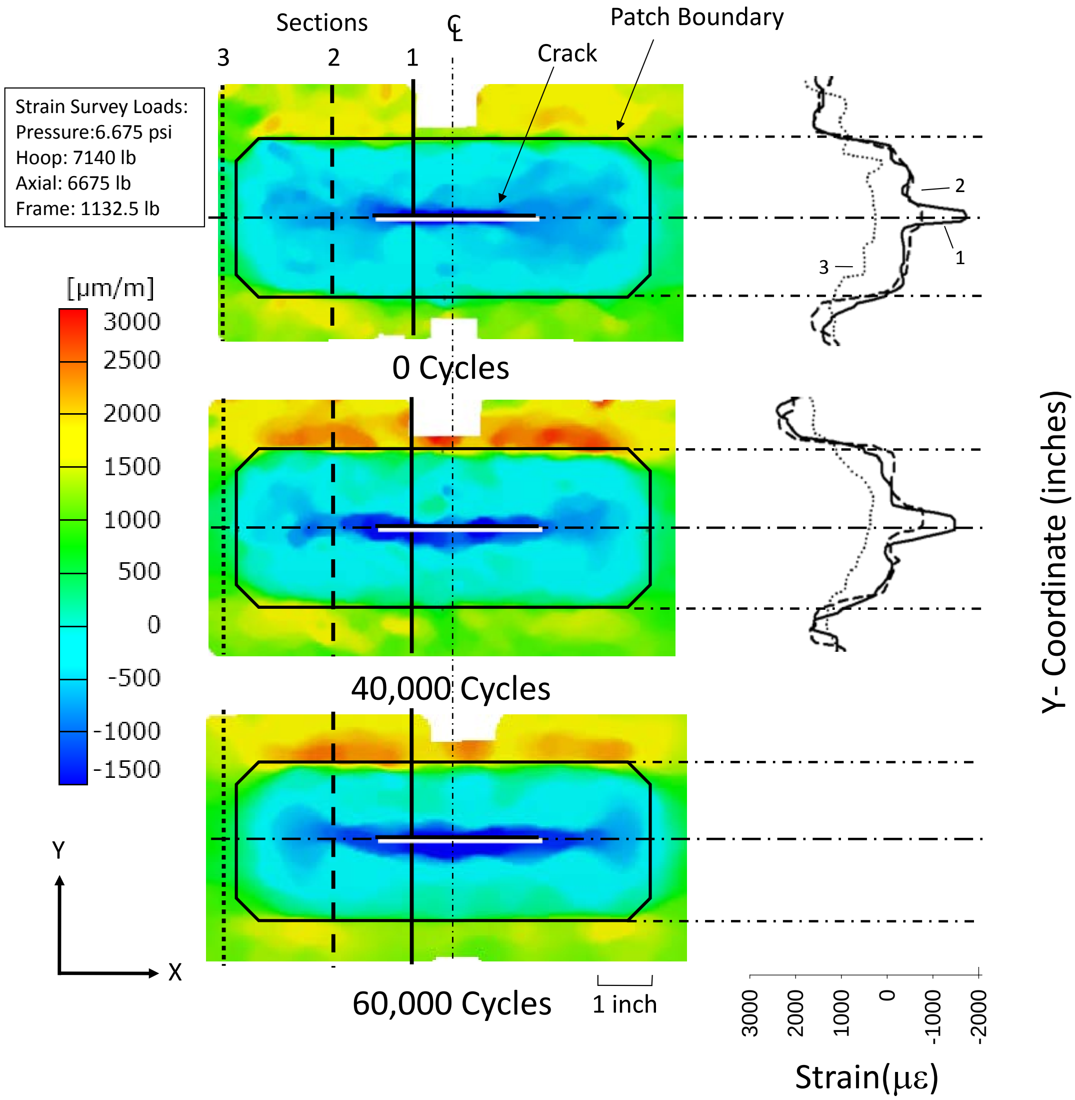


Figure 35. The DIC results for the D-BE repair

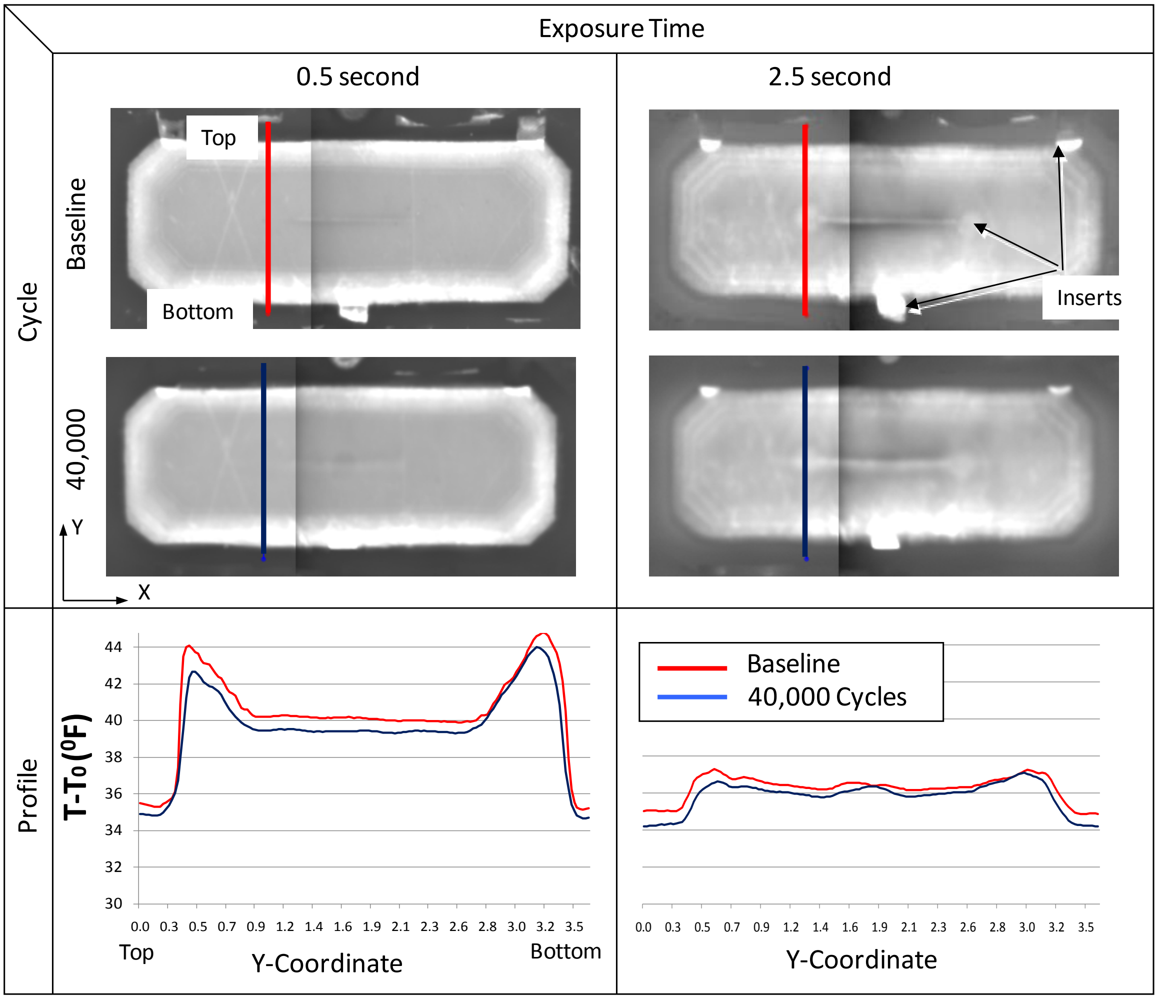


Figure 36. Flash thermography results for the D-BE repair

The measured crack growth during the fatigue test, using visual and eddy current inspections, was self-similar and collinear for the B/Ep patch, D-BE, and the two-layer aluminum patch, D-A2, respectively (see figures 37 and 38). For the D-BE repair, the crack lengths were measured visually and using external LFEC and internal HFEC inspections (see figure 37). For the D-A2 patch, only visual and internal HFEC inspections were used (see figure 38). As shown in the figures, the three inspection methods were in good agreement and the patches displayed nearly constant crack growth rates.

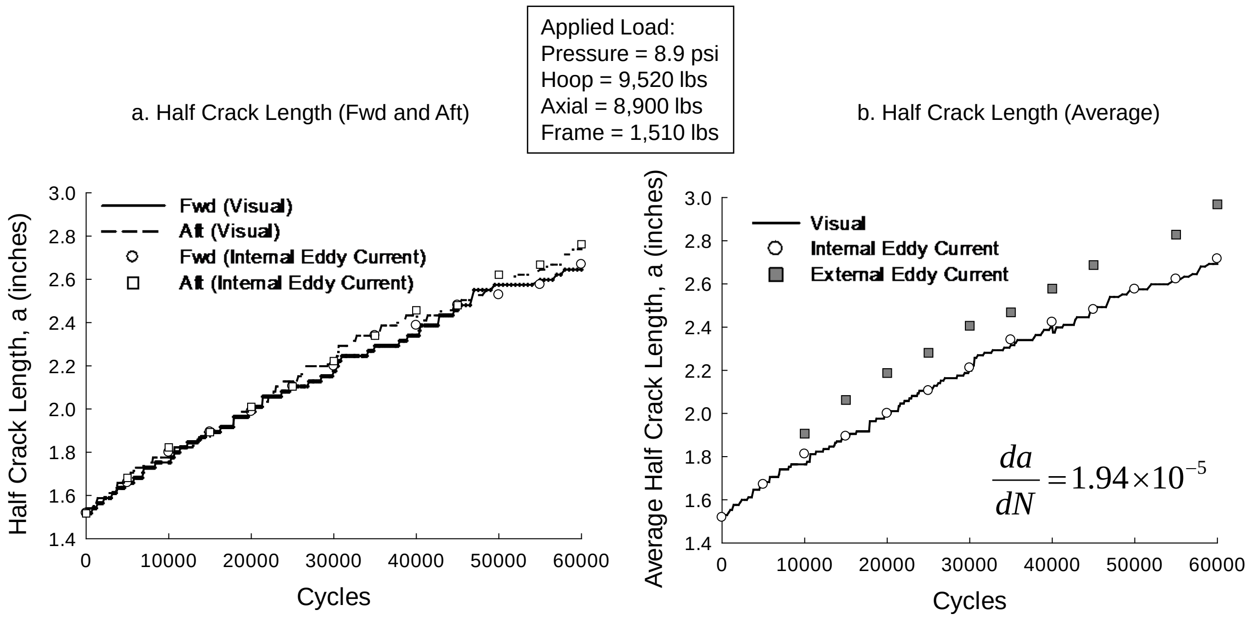


Figure 37. Crack growth for the D-BE repair: (a) fwd and aft half-crack length showing self-similar and collinear crack growth and (b) average half-crack length showing good agreement among the three measurements

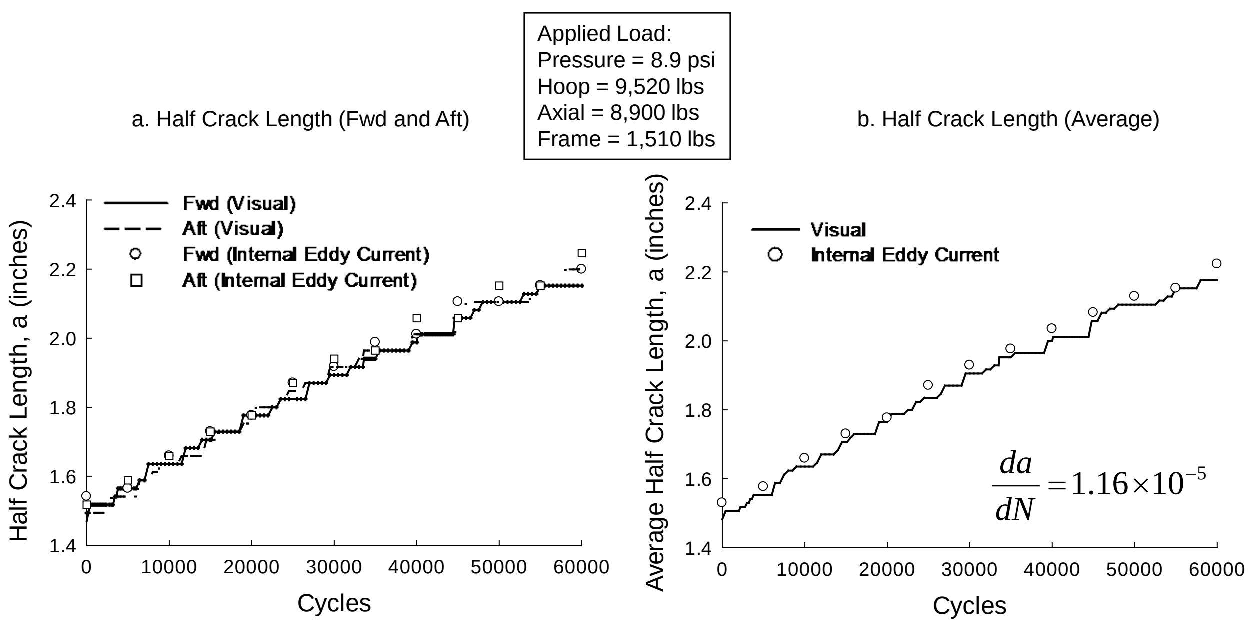


Figure 38. Crack growth for D-A2 patch: (a) fwd and aft half-crack length showing self-similar and collinear crack growth and (b) average half-crack length showing good agreement among the three measurements

4.4 PHASE 3—COMPLIANT REPAIRS

The compliant Phase 3 repairs, C-BE and CD-BE, were fatigue-tested to 20,000 cycles using SL conditions. Unlike the Phase 1 and Phase 2 repairs, there was a significant amount of strain redistribution during fatigue. Representative results of the full-field hoop strain in the vicinity of C-BE and CD-BE, measured after several fatigue cycles using the DIC equipment, are shown in figures 39 and 40, respectively. Total magnitudes of 75% of the SL conditions were applied during the strain survey. The patch boundary and initial defect are indicated in the figures. The white regions are areas where data could not be processed because of interference from strain gage wires. In general, for both patches, the strain increased in the panel skin along the edges of the repair patches and decreased slightly in the repair patch region.

For the C-BE patch, strains along the notch centerline were slightly in tension at the beginning (0 cycles) of the fatigue test and then increased substantially during the test, as indicated by the red fringe patterns after 20,000 cycles (see figure 39). Details of the hoop strain variation in the vicinity of the patch along three vertical sections are shown in the plots. As the figure shows, after 20,000 cycles, the strain gradient was high in a narrow band of approximately ±0.5″ around the crack (section 1). Over this short distance, the strain ranged from 2,000–12,000 $\mu\varepsilon$.

For the CD-BE patch, strains along the notch centerline were slightly in compression at the beginning (0 cycles) of the fatigue test, similar to the Phase 1 and Phase 2 B/Ep repairs (see figure 40). As the fatigue test continued, the strains in the notch region eventually redistributed in tension and increased substantially during the test, as indicated by the red fringe patterns after 20,000 cycles. As shown in the section plots, after 20,000 cycles, the strain gradient was high in a narrow band of approximately ±0.5″ around the crack (section 1). Over this short distance, the strain ranged from 1000–4000 $\mu\varepsilon$.

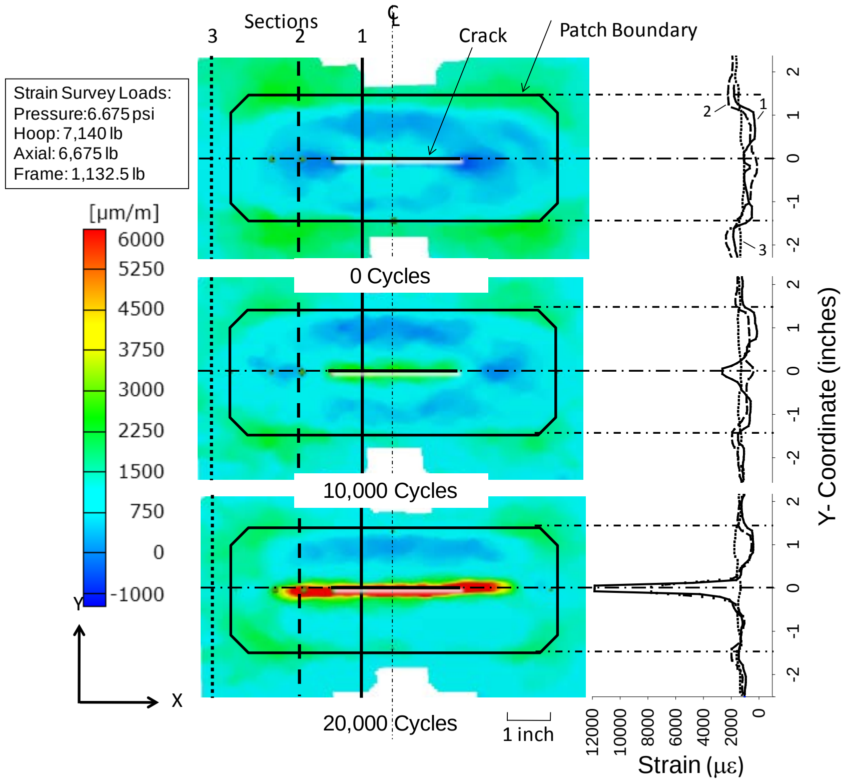


Figure 39. The DIC results for the C-BE repair

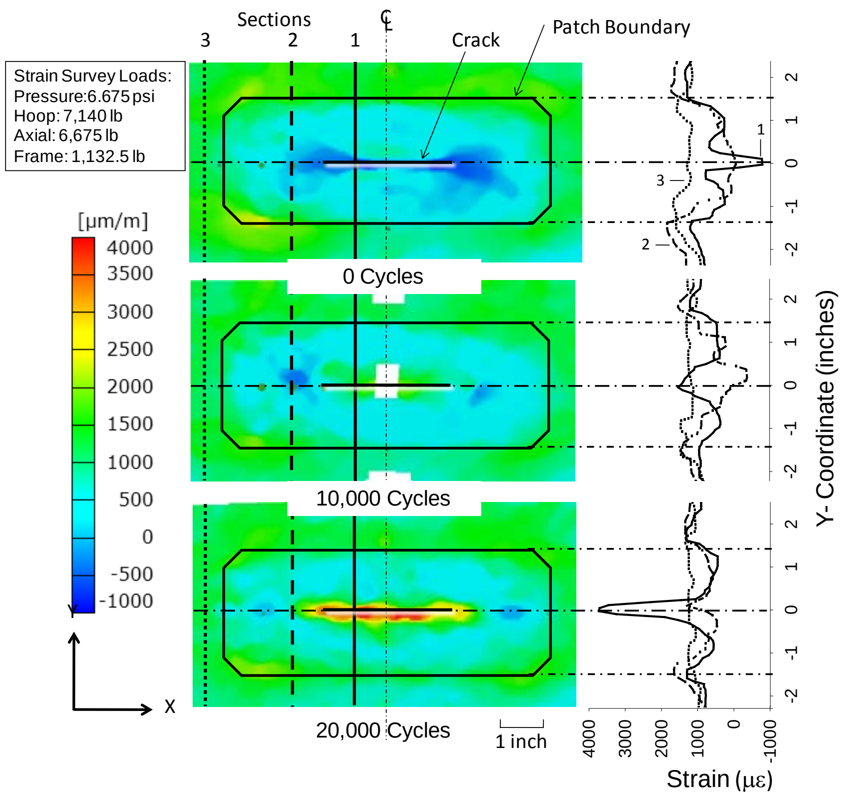


Figure 40. The DIC results for the CD-BE repair

Similar results were obtained from strain gages along the centerline of the patch (see figure 41). Strain gages SB1 and SB2 were mounted on the skin located 0.75″ from the patch boundary, and strain gage P1 was located on the center of the patch above the notch. For both patches, the strain measured on the patch at P1 continuously increased throughout the fatigue test.

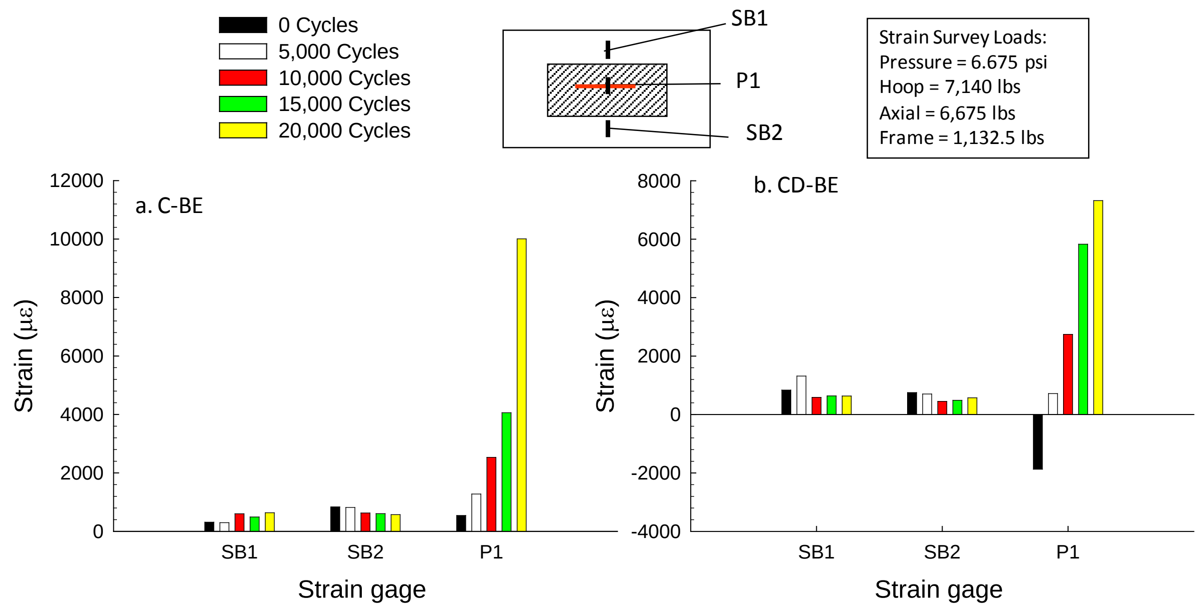


Figure 41. Strain gage results for phase 3 C-BE and CD-BE repairs

The observed crack growth was measured during the fatigue test using visual and eddy current inspections for the Phase 3 patches (see figures 42 and 43). For both patches, the crack length was measured visually and using external LFEC and internal HFEC inspections. As shown, there was good agreement between the visual and eddy current results. In addition, the crack growth rate was not constant, but appeared to increase with fatigue cycles. The increase in crack growth rate and observed strain redistributions of Phase 3 repairs show the ineffectiveness of the repair due to low stiffness.

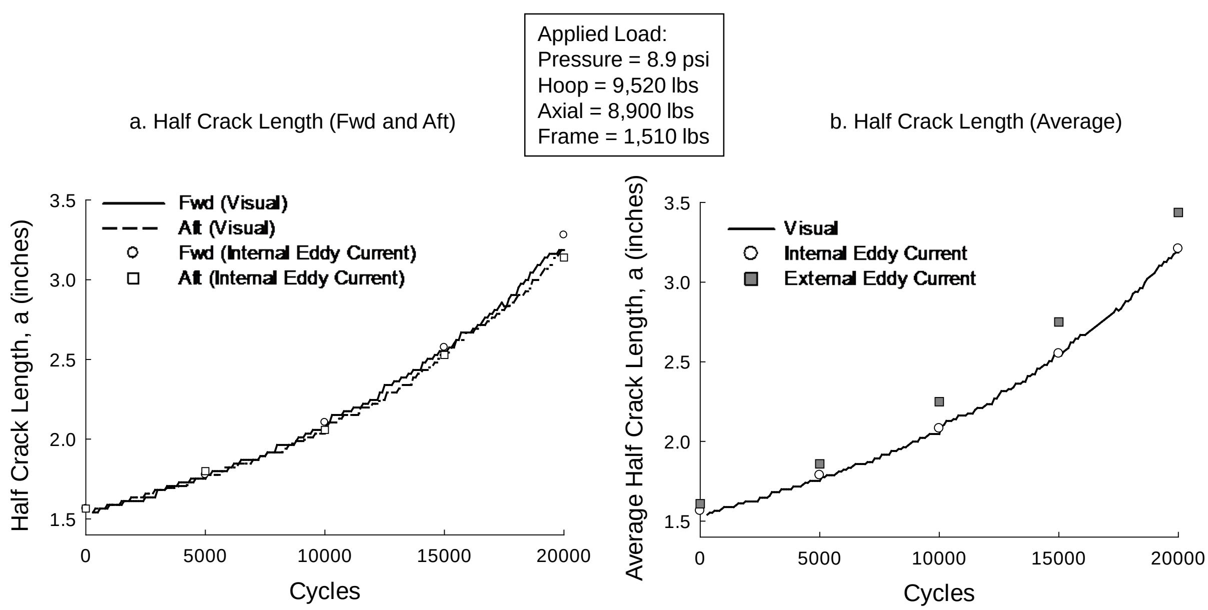


Figure 42. Crack growth for C-BE repairs: (a) fwd and aft half-crack length and (b) average half-crack length

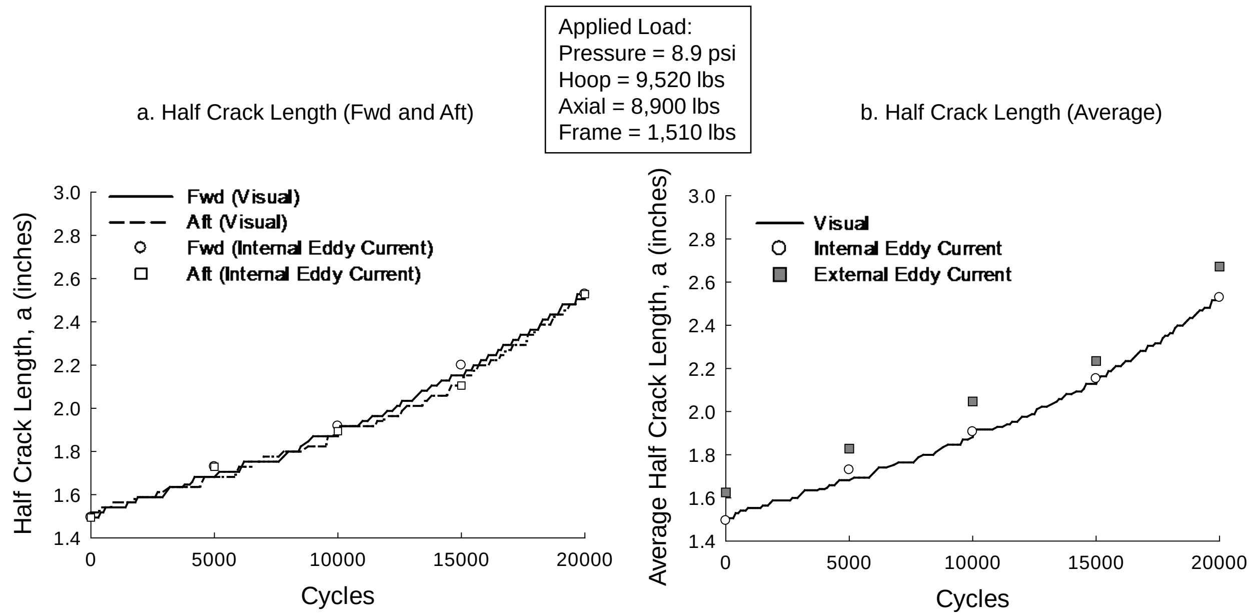


Figure 43. Crack growth for CD-BE repair: (a) fwd and aft half-crack length and (b) average half-crack length

After Phase 3 testing, both patches, C-BE and CD-BE, were removed and replaced with mechanically fastened repairs from the Structural Repair Manual (SRM), as outlined in appendix K, to finish the overall test program for panel 2.

4.5 PHASE 4—REPAIRS WITH IMPACT DAMAGE

Impacting R-BE, U-BE, and U-A2 patches caused both the crack extension and disbonding. After impact, the forward crack tip under the R-BE repair extended by 0.25″. Figure 44 shows the impact damage on the external surface of the patch and the crack extension on the internal surface of the panel. Similarly, figures 45 and 46 show the impact damage and crack extensions of the U-BE and U-A2 repairs, respectively. Appendix L provides the procedure and setup of impact.

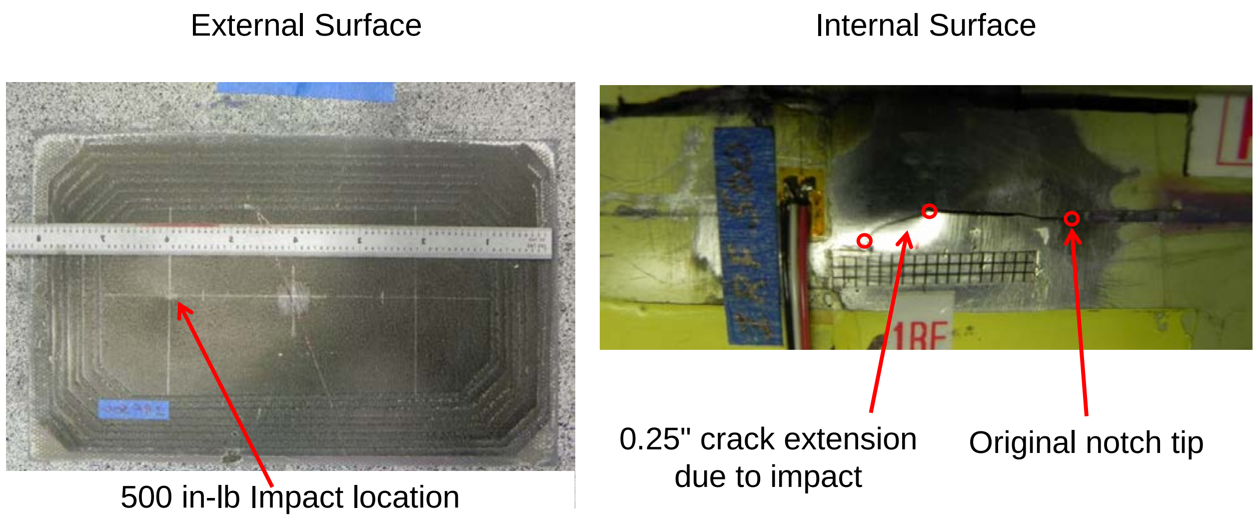


Figure 44. Locations of impact damage and crack extension for the R-BE repair after impact

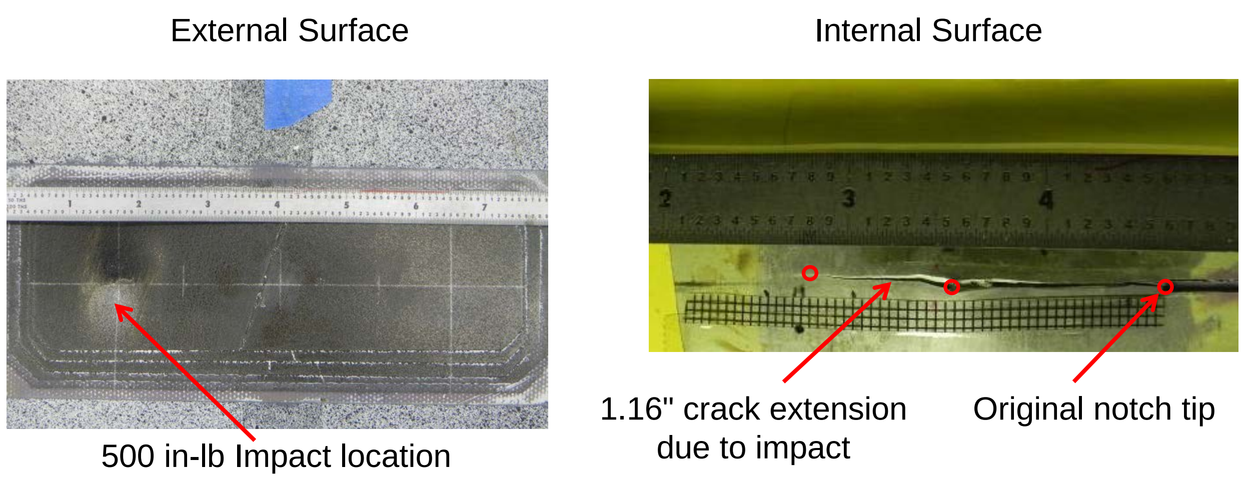


Figure 45. Locations of impact damage and crack extension for the U-BE repair after impact

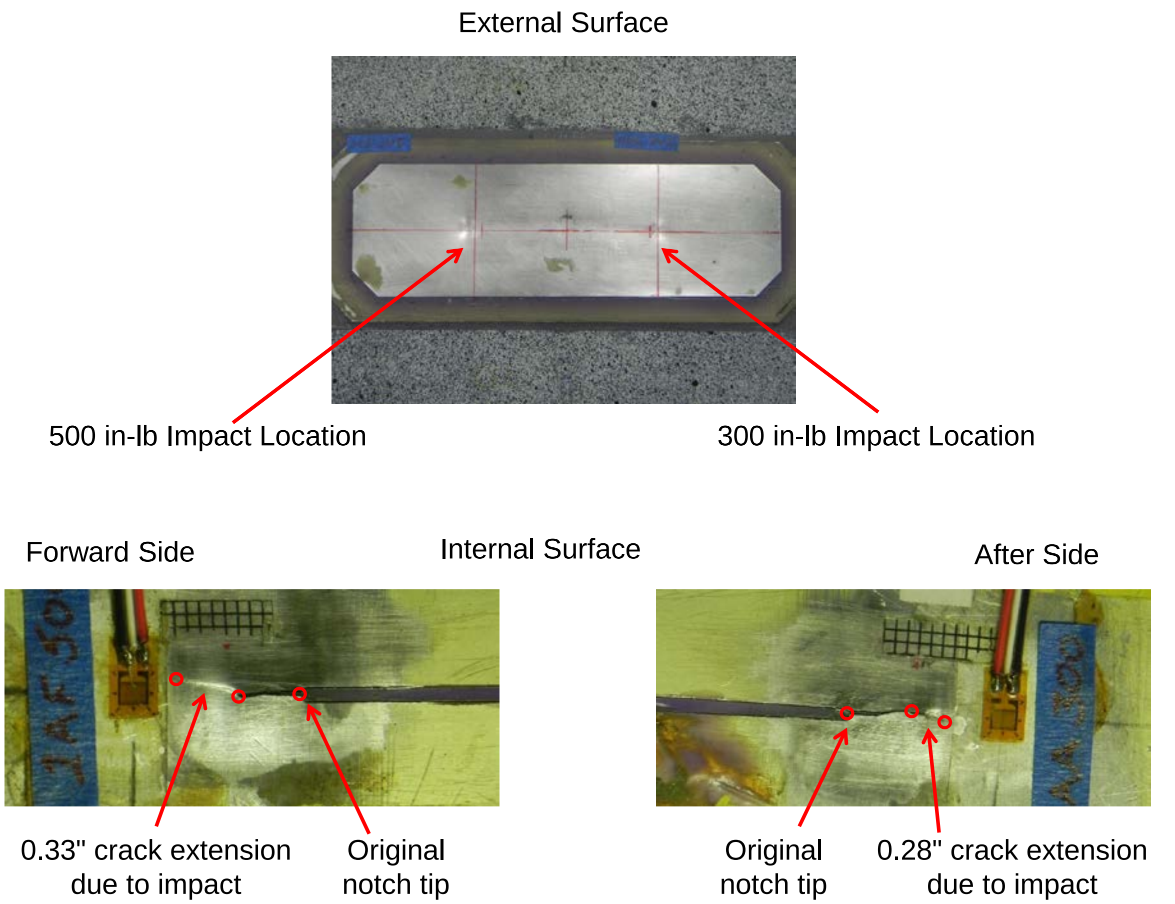


Figure 46. Locations of impact damage and crack extension for the U-A2 repair after impact

The panel was then subjected to 20,000 fatigue cycles after the introduction of the impact damage in the three repairs. During fatigue, these repairs were monitored for any crack extension and disbond growth. Using DIC and strain gages, the strain data were also collected during fatigue.

Figure 47 shows representative results of strains monitored using DIC for the U-BE repair. The figure shows the hoop strains before impact, after impact, and 20,000 fatigue cycles after impact. The results clearly show that, before impact, the center of the patch, along the notch centerline, was in compression but, after impact, the damaged region showed tension. The plots also show details of the hoop strain variation in the vicinity of the patch along three vertical sections. It is also shown that, before impact, both sections 1 and 2 indicated compression along the center of the patch. The same sections, after impact, showed tension at the center of the patch indicating load redistribution. Section 3 (outside the patch region) showed only slight variation in the strains before and after the impact. However, all three sections showed that, during fatigue, there was no significant load distribution due to disbonding or crack growth.

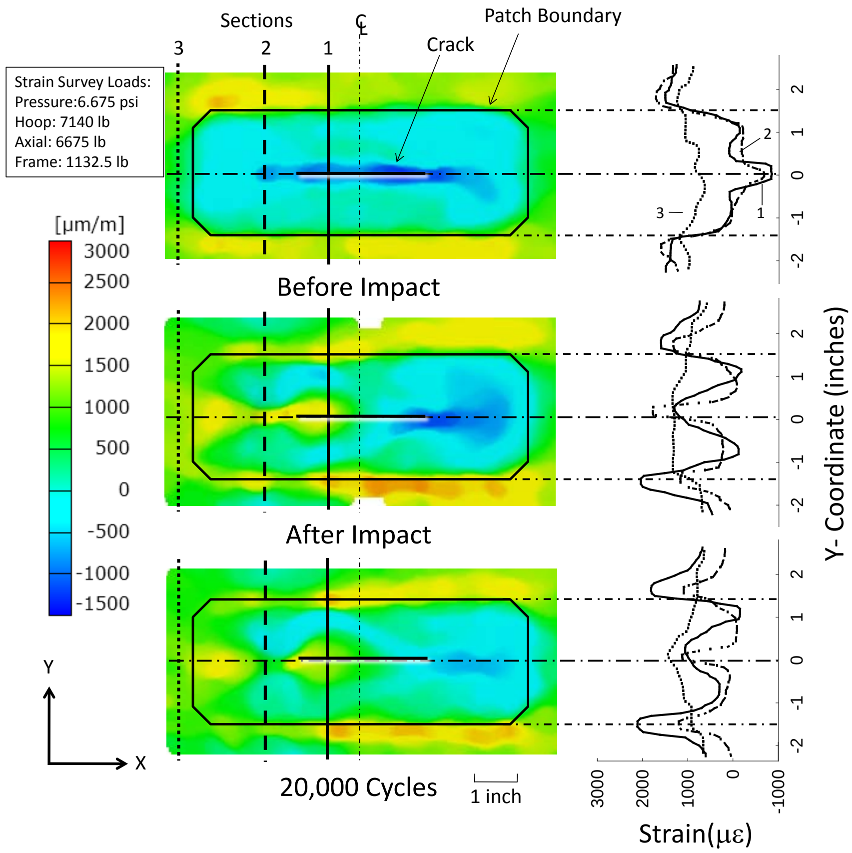


Figure 47. The DIC results for the U-BE repair after impact

Figures 48 and 49 show representative results, using flash thermography before impact, after impact, and after 20,000 fatigue cycles for the R-BE and U-BE repair patches, respectively. The images indicate temperature variations at two different sampling times: 1.5 seconds for the R-BE patch and 2.5 seconds for the U-BE patch. Thermography images for both of the patches show that the impact caused the disbond around the region of impact. The images also show that there was no indication of the disbond growth throughout fatigue.

Figures 50–52 show the observed crack growth for the three R-BE, U-BE, and U-A2 repairs due to impact and also during the fatigue test. Figure 50 shows the complete crack growth for the R-BE repair during Phase 1, on impact, and during Phase 4. For the R-BE repair, only the forward side of the notch was impacted. Figure 50 shows the visual measurements (solid line) and the internal HFEC current measurements (open circles) for the forward side of the notch. The visual and internal eddy current measurements for the after side are shown by the dashed line and open squares, respectively. During Phase 4, the forward side crack continued to grow at the same rate as that measured in Phase 1. However, no crack extension was observed in the aft side of the notch that was impacted during Phase 4. This was due to the plastic deformation at the crack tip after the impact that retarded crack growth. Similar trends were seen for U-BE repair (see figure 51). In the case of U-A2 repair, both the forward and after side of the notch showed crack extension due to impact and no fatigue crack growth during fatigue loading after impact (see figure 52).

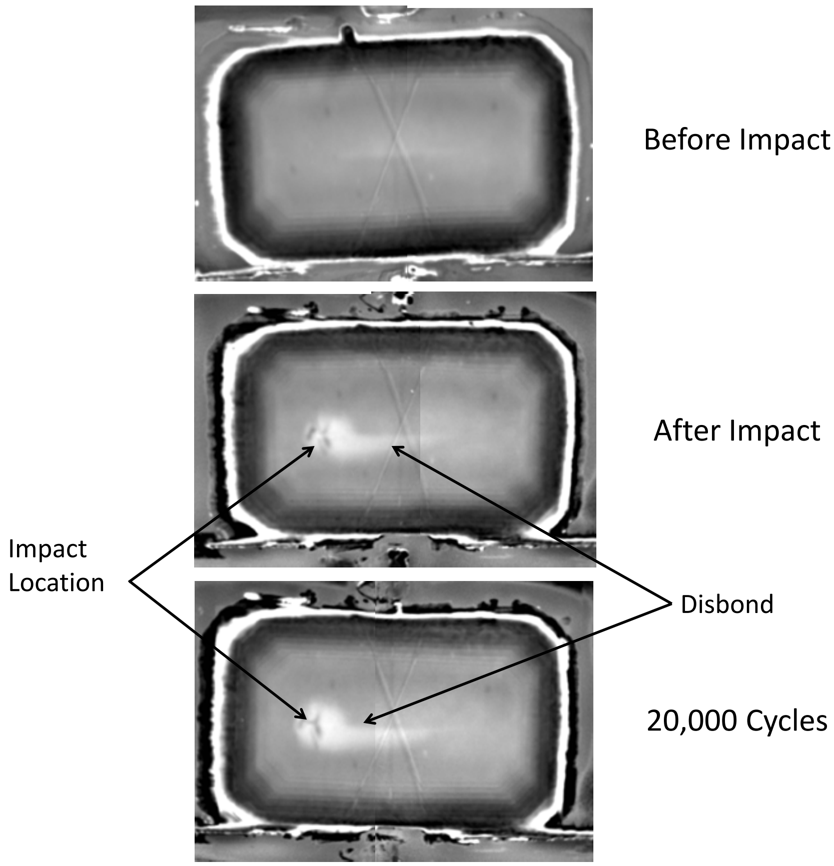


Figure 48. Thermography snapshots of the R-BE repair showing the impact damage and disbond created by the impact

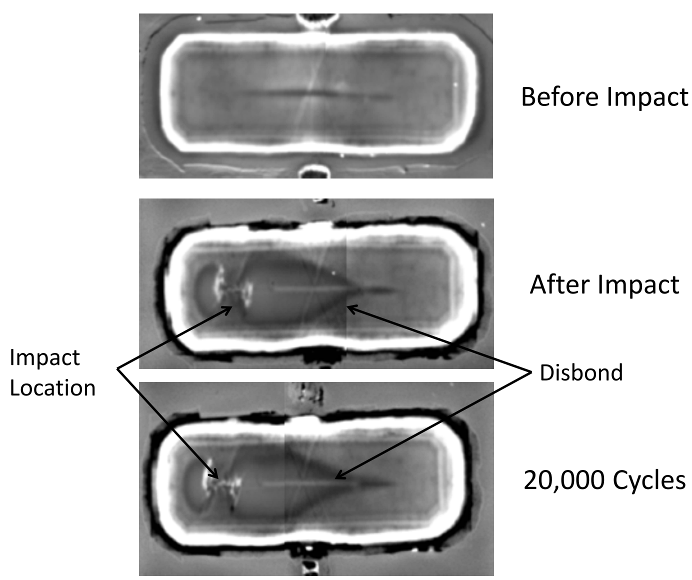


Figure 49. Thermography snapshots of the U-BE repair showing the impact damage and disbond created by the impact

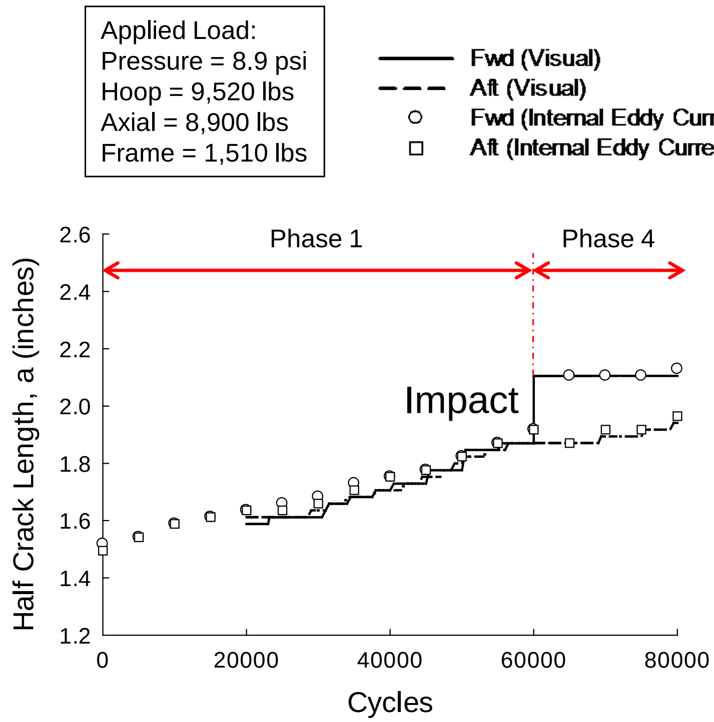


Figure 50. Crack growth for the R-BE repair during phase 1 and phase 4

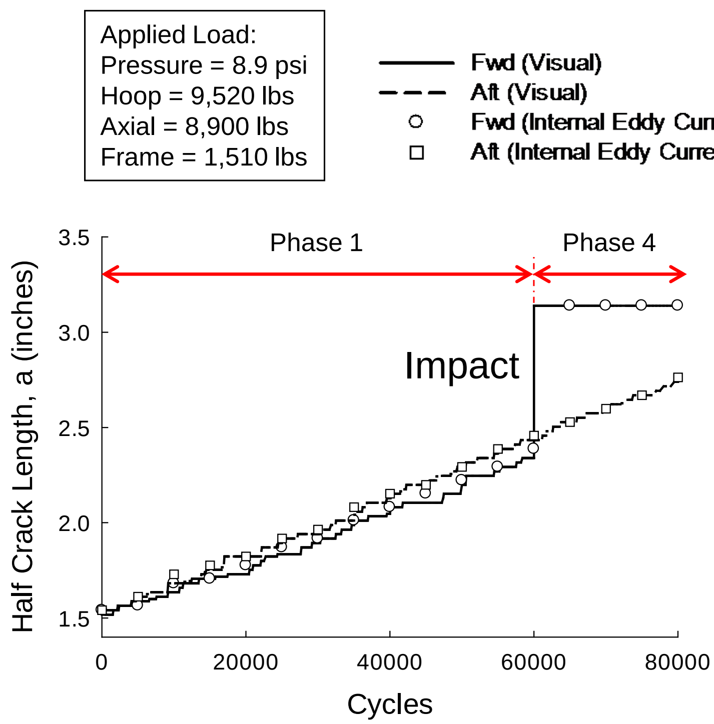


Figure 51. Crack growth for the U-BE repair during phase 1 and phase 4

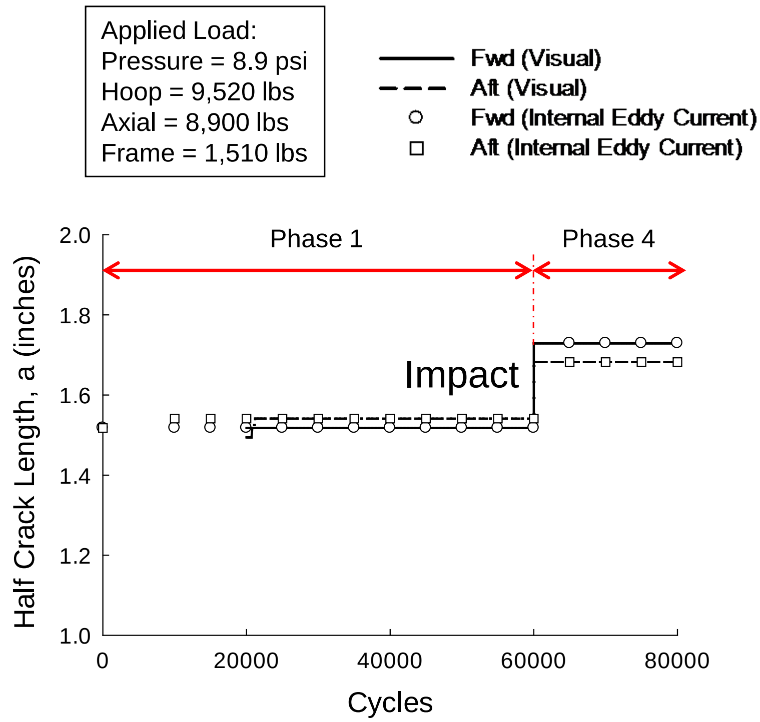


Figure 52. Crack growth for the U-A2 repair during phase 1 and phase 4

4.6 MONITORING DAMAGE USING NDI

Table 2 summarizes the NDI methods used to monitor and record damage formation and growth of cracks and disbonds. Crack growth was monitored visually and using eddy current equipment. For all the repairs, HFEC was used from the inner surface of the fuselage panel. For all the B/Ep repairs, LFEC was used from the outer surface of the repairs. The eddy current results were in good agreement with the visual inspections, as shown by the crack growth data provided for all the repairs (see figures 24, 29, 30, 33, 37, 38, 42, 43, 50, 51, and 52).

A flash thermography system and resonance ultrasonic equipment were used for disbond detection. The flash thermography system was able to detect the intentional disbonds during Phase 2 and the disbonds caused by impact during Phase 4 in the B/Ep repairs. For aluminium repairs, the thermography system was not able to provide satisfactory results because the heat dissipates very quickly through the repair and the fuselage skin. In addition, the thermography system should have a very high capture rate to capture temperature change due to heat transfer. The thermography system used in this test was limited in its capture rate. Unlike thermography, the resonance ultrasonic system was used for both B/Ep and aluminium repairs and it was effective in detecting the disbonds in all the repairs. The results, using both the thermography system and resonance ultrasonic equipment, show that there was no disbond growth during fatigue in any of the repairs. Overall, the NDI methods used during the tests were effective in detecting damage (both crack growth and disbonds).

4.7 MONITORING DAMAGE USING SHM

The prototype SHM system was used to detect crack length at each of the repair locations, where the aft crack length was monitored and used to correlate damage index values. Independently, the model constructed from the aft crack length was used to predict growth at the forward end of the crack. Representative results are discussed below.

Figures 53 and 54 show the results from the underdesigned B/Ep (U-BE) and single-layer aluminum patch (U-A1), respectively. As seen in the results for the B/Ep patch (U-BE), the SHM data correlate very well with the actual crack growth data. Figure 53 shows the model created from the aft crack, and figure 53(b) shows the application of that model to the forward crack. As seen in figure 53(b), the model applied to the forward crack predicts the growth very well. Between 15,000 and 40,000 cycles, the model slightly under-predicts the forward crack growth, but, overall, the trend is very good. The results for the U-A1 patch in figure 54 also correlate fairly well but are not quite as close as the U-BE patch. One reason for this may be that there were data for only 40,000 cycles for the U-A1 patch.

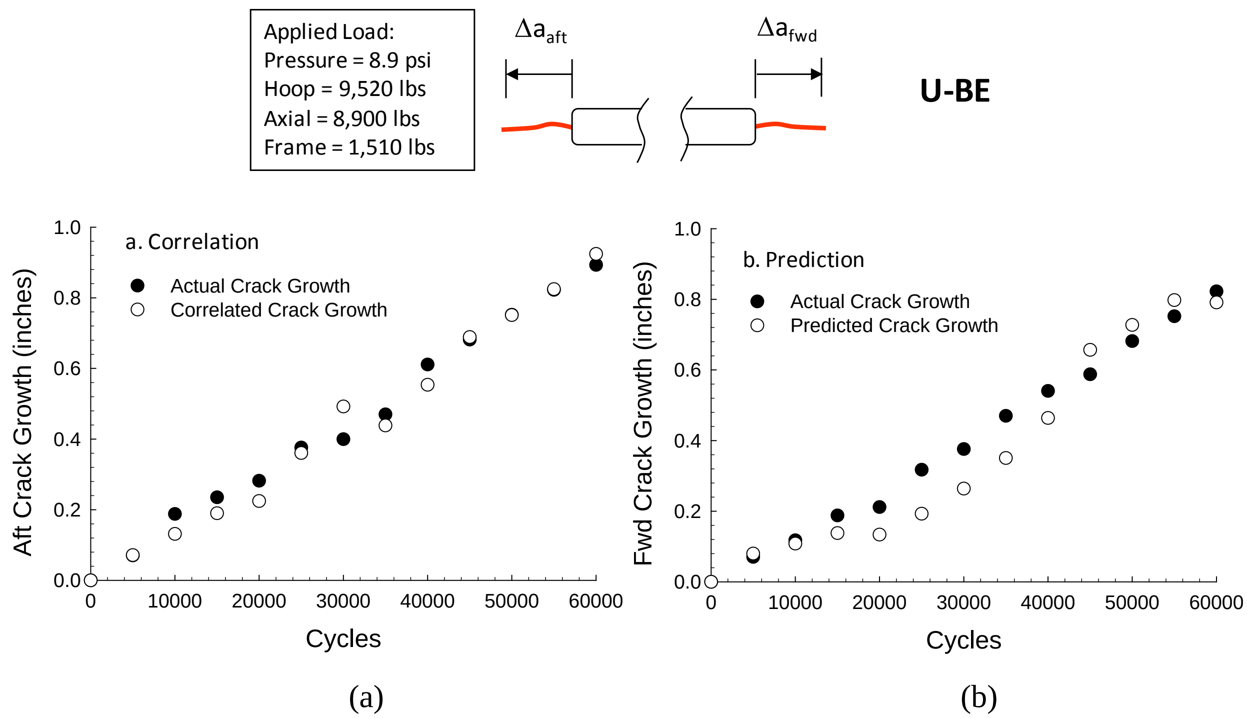


Figure 53. Application of SHM to monitor cracks (U-BE)

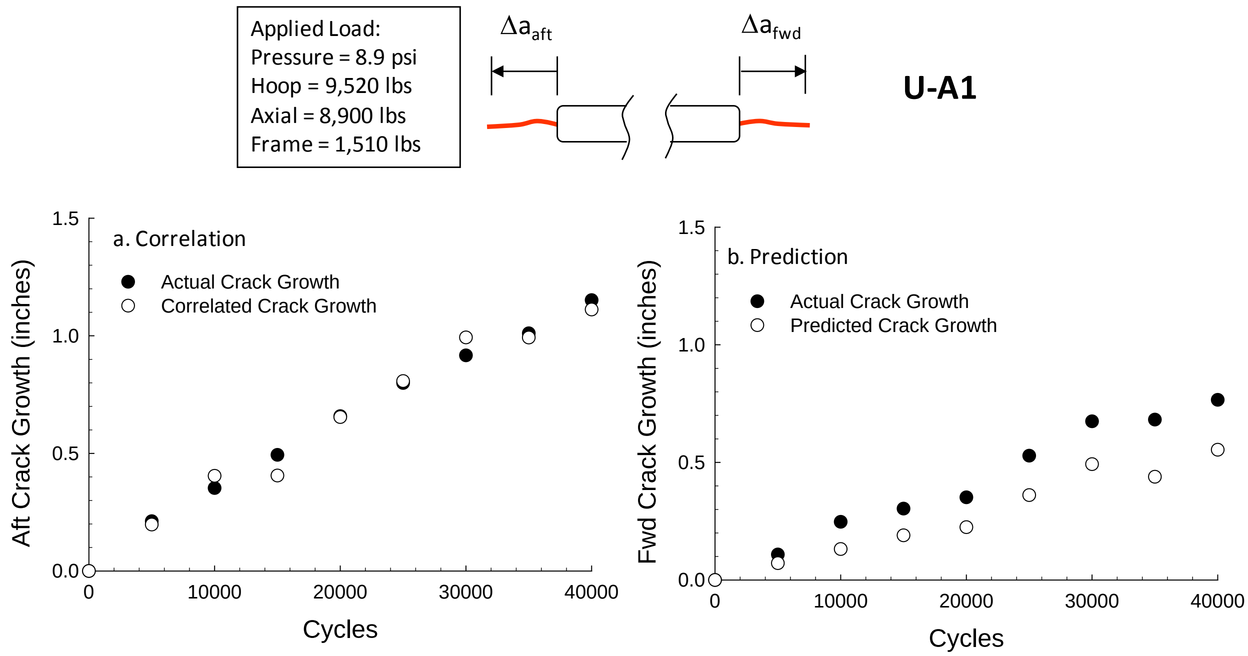


Figure 54. Application of SHM to monitor cracks (U-A1)

The results shown in figures 53 and 54 are very promising and show very good correlation to actual crack data. However, some improvements can be made to improve the accuracy. These improvements include considering the development of different algorithms (damage indices), different combinations of pitch-catch paths, and using a denser sensor grid. The required accuracy of the system is entirely dependent on the system-level requirements for bonded repair integrity. This prototype system only provides a demonstration of the capabilities of the system and can be designed according to the desired accuracy.

4.8 COMPARISONS AND DISCUSSION

In this section, a comparison of the observed strain and crack growth behaviors for the different repair types is outlined.

4.8.1 Thermal Strains

During the curing process of the repair installation, the strains in the vicinity of the patches were monitored. Figure 55 shows representative results for Phase 3 C-BE repair. During the first 50 minutes, the temperature was ramped up from room temperature to 250°F. As indicated, the strain in the outer skin increased along the patch boundary, as measured from strain gages S28 and S29. The corresponding inner surface gages, IS28 and IS29, decreased. The temperature was held constant at 250ºF for 90 minutes, during which the strains remained constant. Afterward, the temperature was decreased back to room temperature. At the end of the cure cycle, residual thermal strains existed in all the repairs.

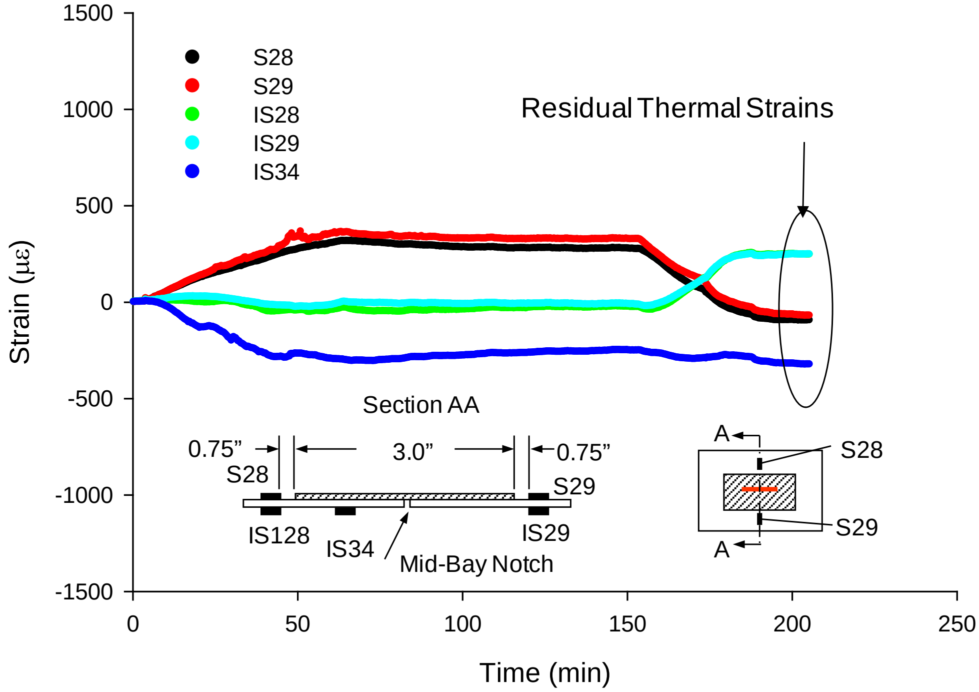


Figure 55. Strains during cure process for C-BE

A summary of the residual thermal strains at a point along the patch boundary is provided in figure 56 for all the B/Ep patches and in figure 57 for all the aluminium patches. In general, for both B/Ep and aluminium patches, the residual thermal strains on the inner skin surface along the patch boundary are in tension while the corresponding outer skin strains are in compression. The Phase 3 C-BE and CD-BE repairs had the lowest residual thermal strains among the B/Ep patches. Also, as expected, the thermal residual strains at the boundary of B/Ep patches were much larger than the aluminium patches because of the lower coefficient of thermal expansion of B/Ep.

4.8.2 Mechanical Strains

Figure 58 provides a summary of the mechanical strains at the end of the fatigue test for each B/Ep patch. As shown, the compliant repair patches, C-BE and CD-BE, displayed significantly high tensile strains in the patch above the notch (measured using gage P1).

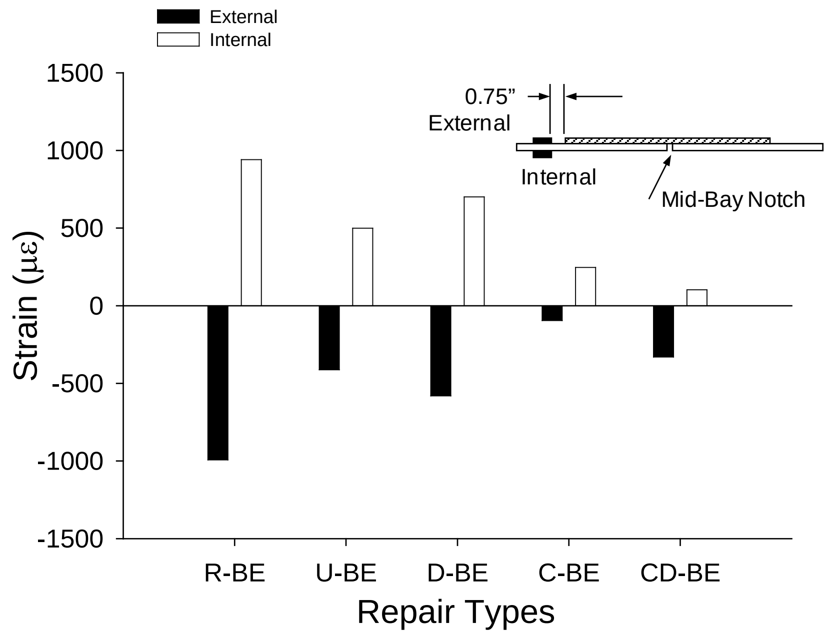


Figure 56. Final residual thermal strains in the B/Ep repairs

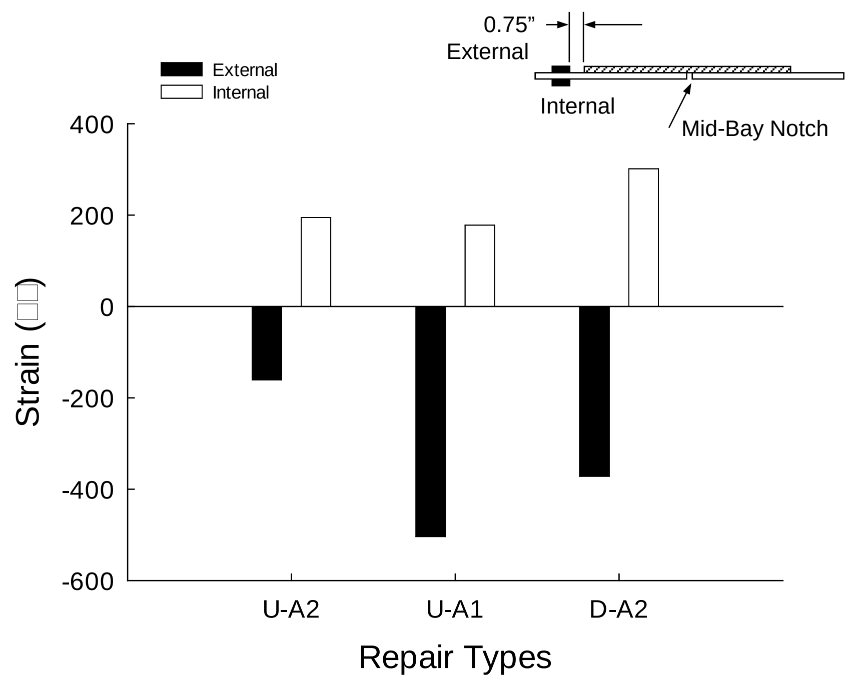


Figure 57. Final residual thermal strains in the aluminum repairs

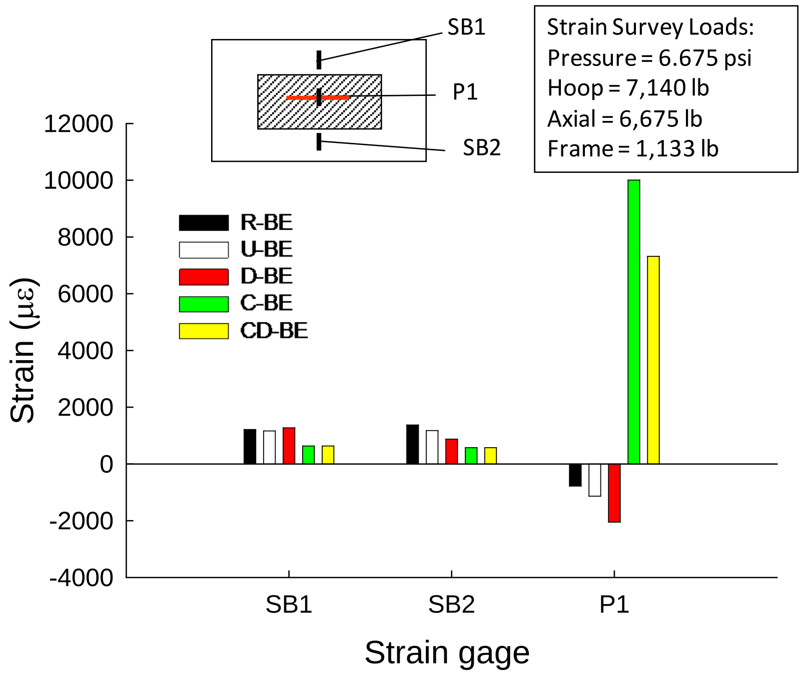


Figure 58. Final mechanical strains in the B/Ep repairs

4.8.3 Crack Growth

Figure 59 shows a summary of the crack growth measured in all repairs. The results for the B/Ep patches are shown in figure 59(a). The crack growth rate was nearly constant for the underdesigned U-BE repair, the partial disbond D-BE repair, and the R-BE reference repair. The R-BE reference repair displayed the least amount of crack growth. However, for the C-BE and CD-BE compliant patches, the crack growth rate continuously increased. As shown, the fatigue performance was considerably degraded because of the low stiffness of the patch.

Figure 59(b) shows the results for the aluminium patches. There was essentially no crack growth for the two-layer underdesigned U-A2 repair. However, for the same patch configuration (two-layer patch) with a partial disbond around the notch (see figure 8(b)), crack growth was displayed under the D-A2 repair. The most crack extension occurred for the single-layer aluminium U-A1 repair.

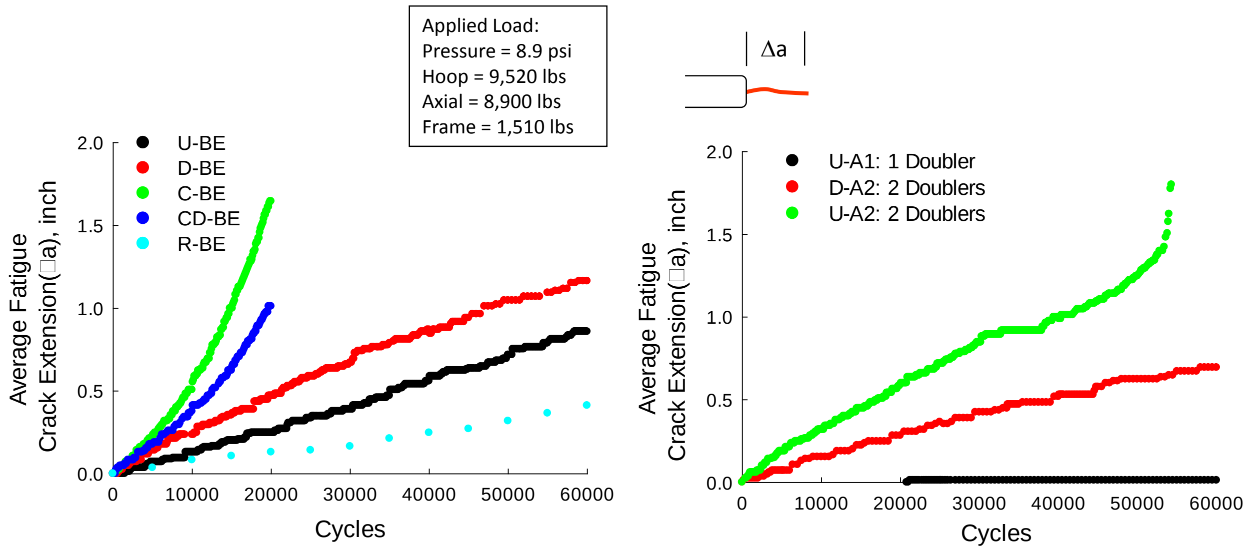


Figure 59. Fatigue crack growth summary: (a) B/Ep repairs and (b) aluminum repairs

4.8.4 Repair Effectiveness

Figure 60 shows a summary of the crack growth rates from the through-thickness mid-bay cracks and a comparison of the measurements made during fatigue pre-cracking before the patches were installed and during fatigue at SL conditions after the patches were installed. The results in figure 60(a) indicate that the Phase 1, Phase 2, and R-BE repair patches were quite effective in reducing the crack growth rate; their effectiveness diminished as the defect in the repair increased. Comparing the R-BE, U-BE, and D-BE repairs, R-BE was the most effective repair and D-BE was the least effective repair in reducing the fatigue crack growth rate. It should be noted that the pre-cracking loads were 75% of the SL used during fatigue.

In the case of the aluminum repairs, all three repairs were effective in reducing the crack growth rate, with the U-A1 patch having the highest crack growth rate (see figure 60(a)), as had been expected.

Load Component	Precracking (before Patch Installation)	Fatigue (after Patch Installation)
Pressure	6.7 psi	8.9 psi
Hoop	7,140 lb	9,520 lb
Axial	6,675 lb	8,900 lb
Frame	1,133 lb	1,510 lb

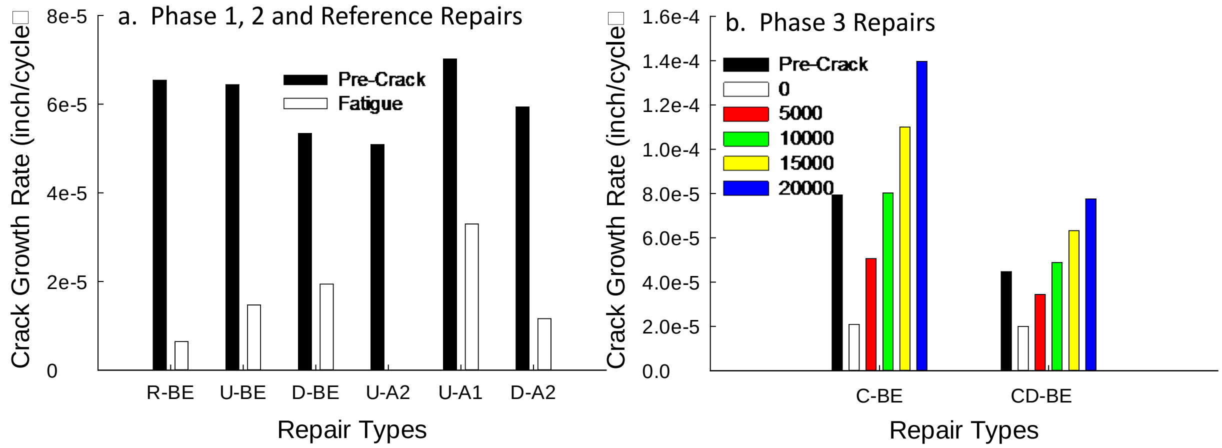


Figure 60. Effect of patches on reducing crack growth rates

The Phase 3 compliant repair patches reduced the crack growth rate in the beginning of fatigue. However, the effectiveness reduced continuously with increased cycles (see figure 60(b)). At 10,000 cycles, the crack growth rate in both C-BE and CD-BE was similar to the rate measured during fatigue pre-cracking and was approximately double the rate after 20,000 cycles.

5. TEST AND ANALYSIS CORRELATION

In this section, data obtained from the Panel 2 tests were used to validate and calibrate analytical predictions of bonded repair patches. Analytical predictions made using FE and CRAS closed-form methods were correlated with strain gage measurements and crack growth data collected from the test. Much emphasis was placed on the correlation and calibration with CRAS closed-form models to demonstrate its capability to efficiently design and analyze bonded repairs for fuselage structures. The following steps outlined the general approach for the test-analysis correlation:

- Determine stresses at the prospective patch locations using global FEA and compare with strain gage measurements for the baseline pristine configuration

- Verify CRAS predictions with FE results for a case of pressure loading for U-A2, U-BE, and R-BE patches

- Estimate the thermal effect due to the curing of adhesive in U-BE, D-BE, and R-BE boron patches

- Estimate the disbond effect in D-A2 and D-BE patches
- Adjust for the effect of thick patch or the patch transverse shear effect
- Use *da*/*dN* versus Δ*K* data from NASGRO for crack growth predictions

5.1 STRAIN GAGE MEASUREMENTS

The FEM strains for a baseline pristine configuration were compared to actual strain gage data measured on the test panel. The strains were compared at 75% of the fatigue load (8.9 psi pressure). Table 5 and figure 61 show the strain gage locations and comparisons. In general, good agreement was found between analytical predictions and strain gage measurements. Therefore, the developed FEM was a good representation of the test article.

Table 5. Strain gage comparison

	Gage (μ)	FE (μ)
S01	800	720
S02	750	730
S03	700	775
S04	600	500
S05	800	750
S06	800	700
S07	800	760
S08	600	540
S09	800	770

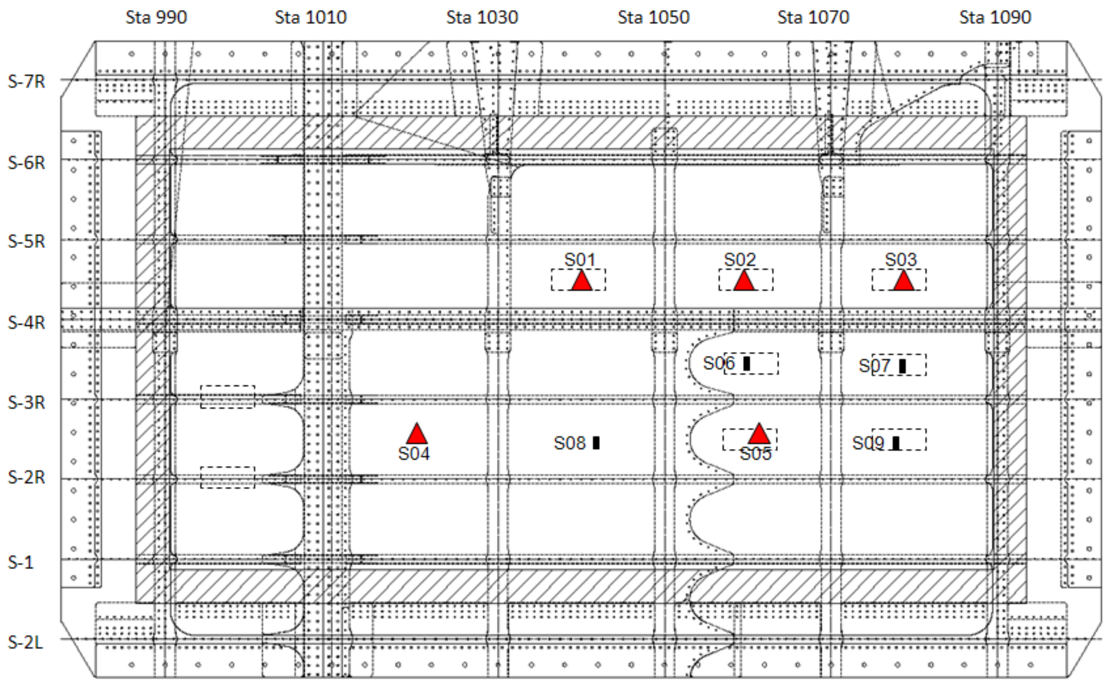


Figure 61. Strain gage locations

5.2 VERIFY CRAS PREDICTIONS WITH FE RESULTS

Following the analytical procedure discussed in section 3, the SIFs for mid-bay cracks, each with a length of 2a equal to 3.0″, were calculated by CRAS and global structural FEA. Table 6 shows the calculated SIFs for the underdesigned B/EP repair and the underdesigned aluminum patch (0.04″-thick). Similar predictions for the R-BE patch were presented in table 7.

Table 6. The SIF predictions for U-BE and U-A2

Patch U-BE				
Method	K_{mem} (ksi-in$^{1/2}$)	K_b (ksi-in$^{1/2}$)	K_{eff} (ksi-in$^{1/2}$)	K_{max} (ksi-in$^{1/2}$)
CRAS	7.69	3.81	9.74	11.50
FE Curved Panel	7.05	2.90	8.98	9.95
FE Flat Panel-3D Crack Tip Element	7.868	N/A	N/A	N/A

Patch U-A2				
Method	K_{mem} (ksi-in$^{1/2}$)	K_b (ksi-in$^{1/2}$)	K_{eff} (ksi-in$^{1/2}$)	K_{max} (ksi-in$^{1/2}$)
CRAS	7.0	2.63	8.31	9.63
FE Curved Panel	6.41	1.99	7.74	8.4
FE Flat Panel-3D Crack Tip Element	7.327	N/A	N/A	N/A

Comparing the CRAS predictions and the FE results from the full curved panel analysis, the SIFs showed good agreement within ±10% for the membrane component. For reference, results from 3D (solid modeling) NASTRAN® FE analyses with a usage of the specialized crack-tip element for a flat cracked panel were also obtained and reported in table 6. For U-BE and U-A2 patches, CRAS predictions were very close to the 3D NASTRAB® FE analysis results of a flat panel, as expected. However, there was a large discrepancy of approximately 18% between the two for the R-BE patch. This large discrepancy may be attributable to the effect of the R-BE patch thickness, as the effect of patch out-of-plane shear deformation became important.

Table 7. The SIF predictions for R-BE

Patch R-BE				
Method	K_{mem} (ksi-in$^{1/2}$)	K_b (ksi-in$^{1/2}$)	K_{eff} (ksi-in$^{1/2}$)	K_{max} (ksi-in$^{1/2}$)
CRAS	4.66	0.84	5.22	5.50
FE Curved Panel	5.09	1.52	6.10	6.61
FE Flat Panel-3D Crack Tip Element	5.53	N/A	N/A	N/A

5.3 ESTIMATION OF THE THERMAL EFFECT DUE TO CURING

From lessons learned on the panel 1 test-analysis correlation, the thermal effect due to curing had to be accounted for with boron patches. There were two proposed approaches:

1. Estimate the SIF due to curing alone using the CRAS analytical model ($K_{thermal}$), calculating the R-ratio (by $(K_{@\text{ minimum pressure}} + K_{therm})/(K_{@\text{ maximum pressure}} + K_{thermal})$), and using a maximum through thickness value of K in the analysis

2. Calculate the effective value of the SIF due to a combined maximum pressure load and thermal load, denoted as $K_{@\text{maximum pressure + thermal}}$, calculate the effective value of the SIF due to a combined minimum pressure load and thermal load, denoted as $K_{@\text{minimum pressure + thermal}}$, and predict crack growth using $K_{@\text{maximum pressure + thermal}}$ and $K_{@\text{minimum pressure + thermal}}$

Approach 1 was used in the panel 1 test-analysis correlation because it could be applied directly to the results of a curved panel FE analysis in which only pressure load could be simulated. It also showed excellent agreement with test data when the FE results of the curved panel (which was believed to be more accurate and with fewer assumptions) were used in the prediction. Nevertheless, approach 2 was the original approach used under the U.S. Air Force CRAS program to account for the thermal effects, and it was correlated with simple test flat specimen coupons under a uniform curing process. To illustrate the difference between the two approaches, figures 62 and 63 show the crack growth predictions for the panel 1 test based on approach 1 and approach 2, respectively, against test results. In these panel 1 predictions, the boron patch was a 6-ply laminate with a lay-up of [20/-20/0/0/-20/20].

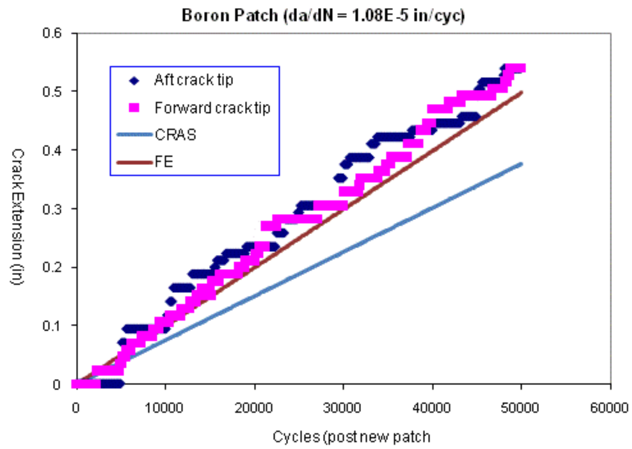


Figure 62. Panel 1 Results—Approach 1

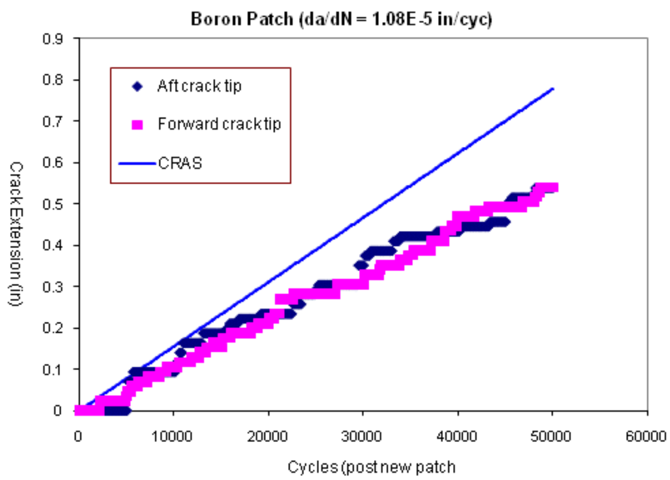


Figure 63. Panel 1 Results—Approach 2

In the present test-analysis correlation for panel 2, the thermal effect was also accounted for by using both approaches. Tables 8 and 9 show new predictions for the R-BE and the U-BE repairs based on approach 1 and 2, respectively. It should be noted that, in approach 2, the effective value of the SIF was used in the crack growth prediction. Because the thermal strains and stresses during curing were also captured in the test for R-BE and U-BE repairs (see figure 64), these thermal effects are shown in table 8 for comparison.

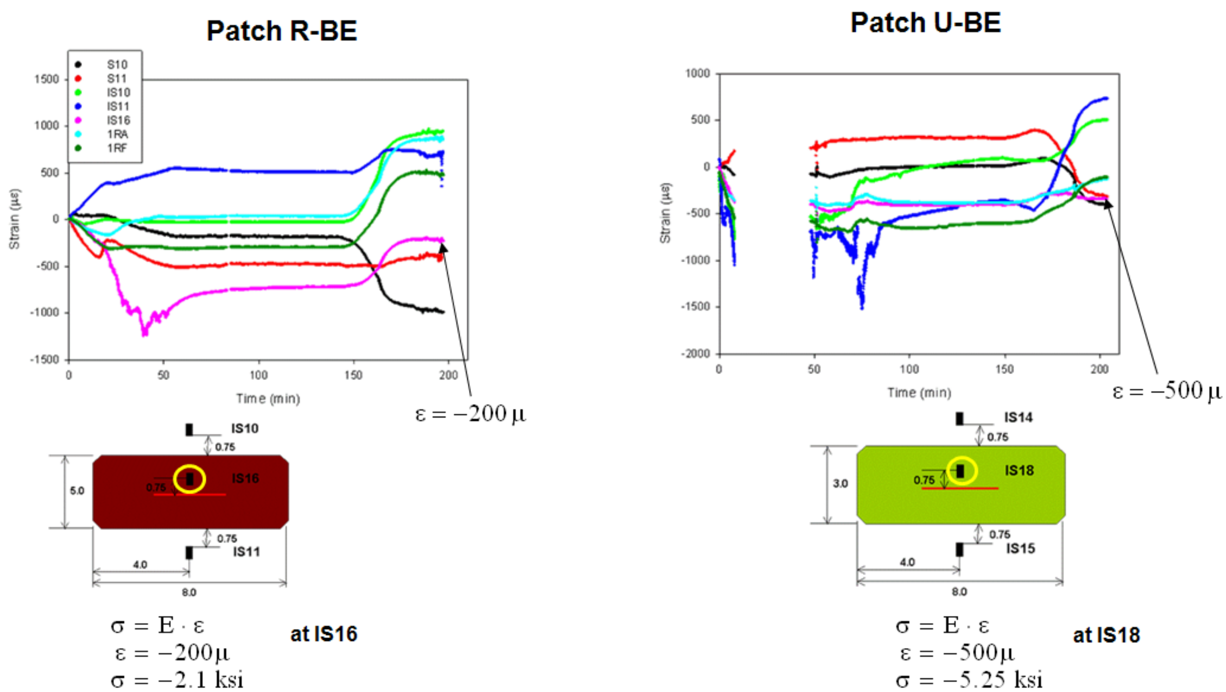


Figure 64. Thermal stresses from strain gages

Table 8. Thermal effect for panel 2 boron repairs using approach 1

	Top surface skin stress (ksi)	Bottom surface skin stress (ksi)	K_{eff} (ksi-in$^{1/2}$)	K_{max} (ksi-in$^{1/2}$)
Patch U-BE or D-BE	7.356	-5.023	1.47	1.85
Gage IS18	-	-5.25	-	-
Patch R-BE	5.439	-0.239	1.37	1.72
Gage IS16	-	-2.1	-	-

Table 9. Thermal effect for panel 2 boron repairs using approach 2

Patch	$K_{@min\ p+t}$	$K_{@max\ p+t}$	ΔK	*R*-ratio
U-BE or D-BE	3.11	14.99	11.88	0.207
R-BE	2.30	8.23	5.93	0.28

5.4 ESTIMATE THE DISBOND EFFECT

The effect of disbond on crack growth was estimated by using CRAS and a compounding technique. The beta factor associated with a disbond effect was derived based on a closed-form model for a cracked plate fully covered with a bonded patch under a plane stress condition (no out-of-plane bending). The CRAS disbond method was originally developed for an elliptical disbond surrounding the whole crack. However, it was recently expanded to address a square disbond at two crack tips.

The D-A2 aluminum patch had a square disbond surrounding the entire crack, whereas the D-BE patch had two circular disbonds around each crack tip. As figure 65 shows, the rectangular disbond in the D-A2 patch and the circular disbonds in the D-BE patch were idealized as elliptical and square disbonds in CRAS analyses because of the limitation of tool capability. The beta factors for repair D-A2 and D-BE patches were found to be 1.553 and 1.331, respectively. The effect of disbond on crack growth was accounted for by compounding the above beta factor in the SIF calculation. However, no disbond (delamination) growth rate was predicted because *da*/*dN* data for disbond growth and a 2D (planar) damage progression algorithm were not available.

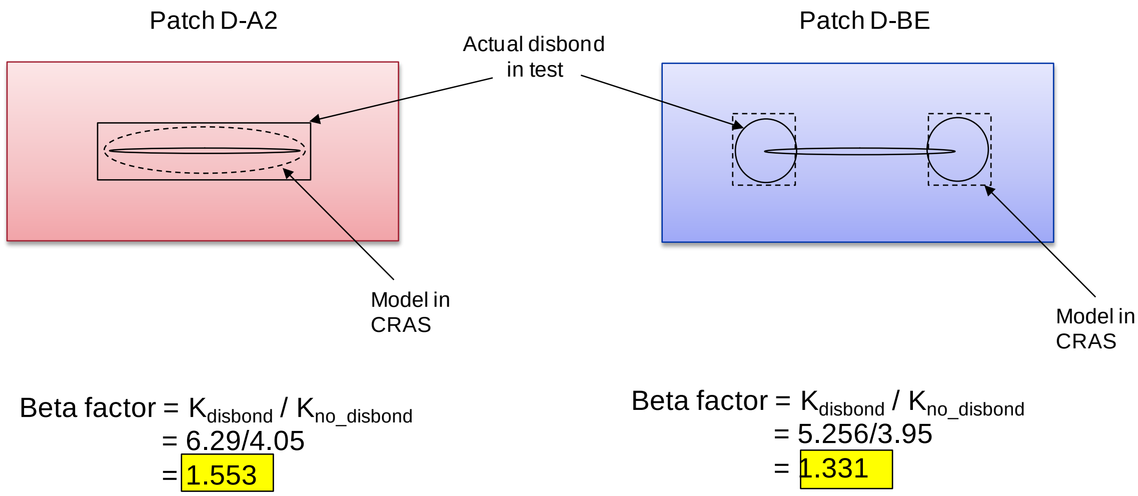


Figure 65. The CRAS modeling of disbond effect

5.5 ADJUST FOR THE EFFECT OF THICK PATCH OR THE PATCH TRANSVERSE SHEAR EFFECT

For the R-BE, the large difference between CRAS and 3D NASTRAN FE predictions indicates the influence effect of a thick patch or a patch transverse shear effect. Because the difference was about 18%, the shear correction factor was estimated at 1.18. Table 10 shows the comparison of predictions for a 5-ply patch and a 9-ply patch.

Table 10. Comparison between a 5- and 9-ply patch

Number of plies	Patch stiffness ratio	CRAS	3-D FE (Flat Panel)	FE (Curved Panel)
5	1.16	7.69	7.868	7.05
9	2.0	4.66	5.53	5.09

5.6 USE OF *DA/DN* VS. Δ*K* DATA FROM NASGRO FOR CRACK GROWTH PREDICTIONS

The fatigue crack growth data for Aluminum 2024-T3, from the Forman Equation in NASGRO, was given by:

$$\frac{da}{dN} = C\left[\left(\frac{1-f}{1-R}\right)\Delta K\right]^{n} \frac{\left(1-\frac{\Delta K_{th}}{\Delta K}\right)^{p}}{\left(1-\frac{K_{\max}}{K_{c}}\right)^{q}}$$

C=2.44E-8
n= 2.6
q=1.0
p=0.25
Kc=53.8
Delta Kth = 2.108
f=R

The above data were used in the analysis to predict crack growth for all repair patches considered in this section (i.e., U-BE, U-A2, R-BE, D-A2, and D-BE).

5.7 TEST AND ANALYSIS COMPARISON

Figures 66–70 show the comparisons of test and predicted crack growth. From these figures, the crack growth predictions using both CRAS and FE methods with *da*/*dN* from NASGRO compared well with test data, except for two cases (U-A2 and R-BE patches). In the first case, no crack growth was observed in the U-A2 patch from the test, while analytical predictions indicated otherwise (see figure 67).

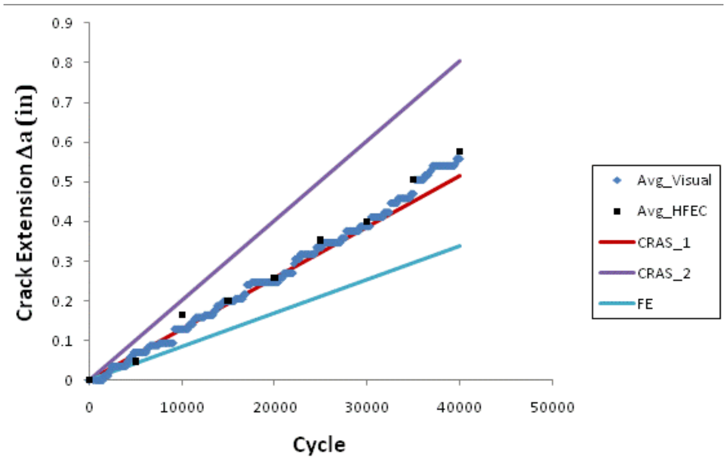


Figure 66. Comparison of crack growths for U-BE patch

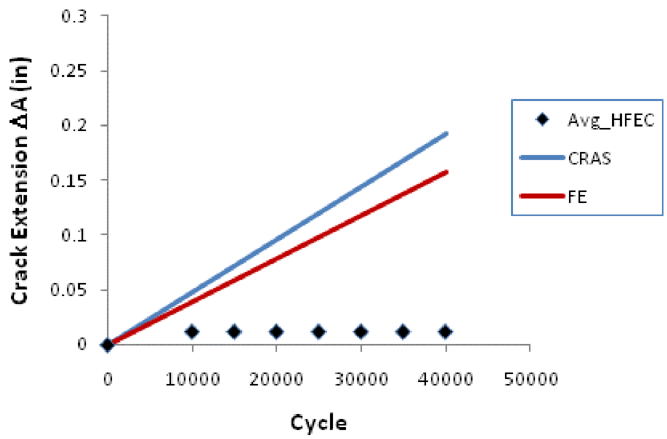


Figure 67. Comparison of crack growths for U-A2 patch

In the second case, the measured crack growth rate for the R-BE patch was significantly higher than the prediction indicated in figure 68. Such discrepancies could be attributable to a combination of various factors: crack growth data scattering; material and load variation; limitation of the analytical model; etc. For example, even though the effect of thermal stresses in the boron patch were accounted for in the analysis by CRAS, further investigation and improvement might be needed, especially for a thick patch. Nevertheless, the discrepancy in the first U-A2 case might seem unusual in light of the result of the aluminum patch in the panel 1 test. Table 11 summarizes a comparison of patch geometry, skin thickness, and loading of the current U-A2 patch with those of the aluminum patch in the panel 1 test.

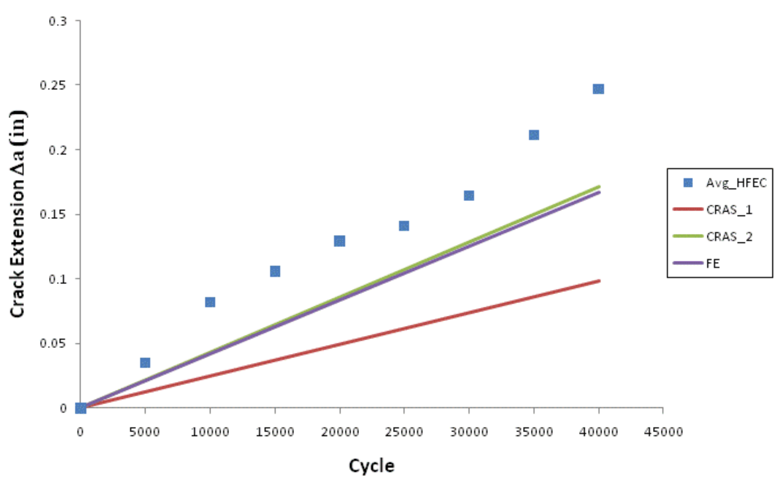


Figure 68. Comparison of crack growths for R-BE patch

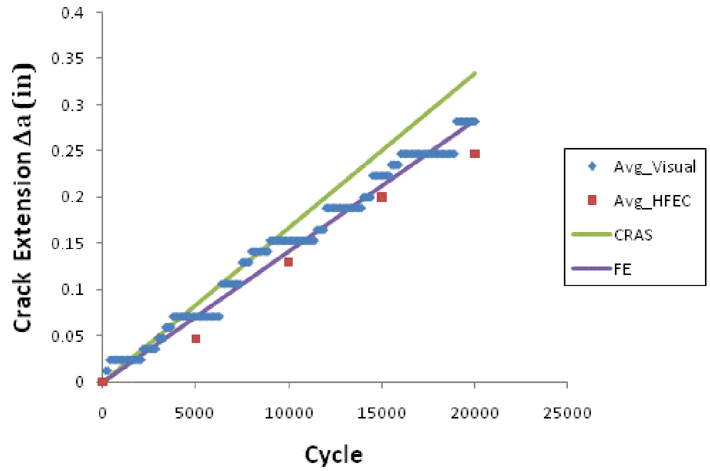


Figure 69. Comparison of crack growths for D-A2 patch

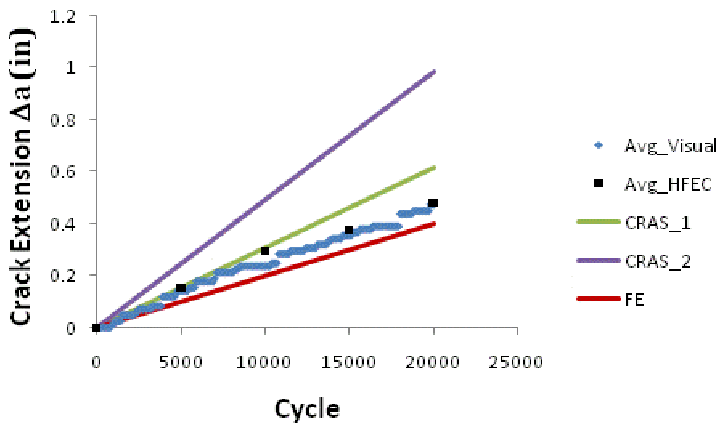


Figure 70. Comparison of crack growths for D-BE patch

Figure 71 shows the corresponding crack growth results for the panel 1 aluminum patch repair. Table 11 and figure 71 show that, even though the loading stress in the panel 1 aluminum patch repair was significantly lower than the U-A2 patch (at 84%) while its stiffness ratio was only 17% lower, the panel 1 aluminum patch repair showed significant crack growth in comparison to the lack of growth measured in the test for the U-A2 patch.

Table 11. Comparison of patch geometry, skin thickness, and loading between panel 1 aluminum patch repair and the current U-A2 repair

Patch Configuration	Skin Thickness (in)	Patch Geometry (in)	Patch Stiffness Ratio	Loading Stress (ksi)
Aluminum Patch Panel 1	0.072	6 x 3 x 0.060	0.83	7.86
U-A2	0.040	8 x 3 x 0.040	1.0	14.5

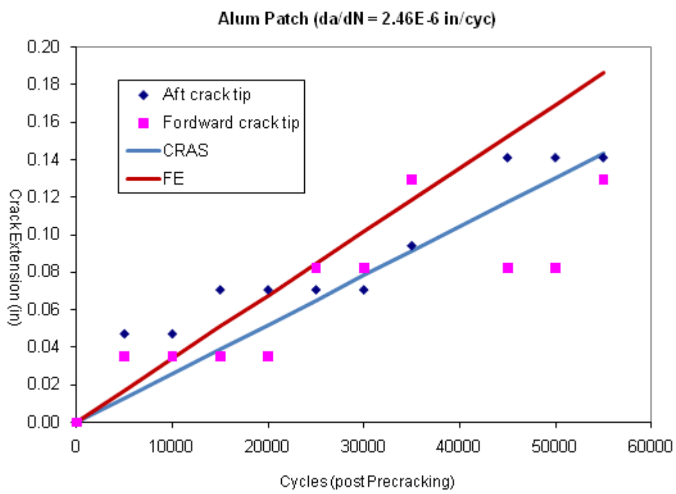


Figure 71. Crack growth results for aluminum patch in panel 1 test

In summary, analytical predictions by FE and CRAS closed-form analyses were found, in general, to be in good agreement with crack growth test results for different repair patch configurations with and without artificially induced disbond. However, whenever there was a large discrepancy between analytical predictions and test results, the analytical prediction tended to be conservative for the aluminum patch. In contrast, the large discrepancy for the boron patch may not be conservative, and it could be attributed to the underestimation of the analytical methods for the effects of the thermal stress and thickness of the large patch. Further investigation of these effects is therefore recommended.

6. SUMMARY

This program studied the fatigue performance of underdesigned, partially disbonded, compliant, and damaged repairs to mid-bay cracks in metallic fuselage. Both boron/epoxy (B/Ep) and aluminum patch repairs were made to be intentionally deficient to allow damage growth in the form of crack propagation and disbonding during fatigue cycling. Full-scale fatigue tests were performed using a Boeing 727 fuselage panel. For all phases, a digital image correlation method was used to obtain full-field displacement and strain measurements in the patch and surrounding regions. Several nondestructive inspection (NDI) methods were used, including flash thermography, resonance ultrasonics, and computer-aided tap techniques to scan for patch disbonds, and eddy current to monitor crack growth. In addition, a prototype piezoelectric-based structural health monitoring (SHM) system was used to assess and demonstrate its capabilities in determining the condition of damage and repair patches.

The goals were to collect experimental data on the performance of bonded repairs, assess the results of analytical tools to show correlation to test, and assess structure health management. To achieve these goals, the following types of repairs were used:

- Phase 1–Underdesigned Repairs: Repair patches were intentionally underdesigned to allow the cracks to grow by reducing the number of reinforcing plies or aluminum doublers. One B/Ep and two aluminum underdesigned repairs were installed to mid-bay through-cracks and were subjected to 60,000 fatigue cycles simulating the service load conditions. Slow, stable crack growth was measured for the mid-bay cracks with a B/Ep patch and one of the aluminum patches, but negligible crack growth was observed for the mid-bay crack with the other aluminum patch.

- Phase 2–Partial Disbond Repairs: Repairs with similar patch configurations to Phase 1 underdesigned repairs, but with intentional partial disbond, were fatigued to 60,000 cycles. Stable crack growth was measured for all of the mid-bay cracks with crack growth rates higher than the corresponding underdesigned repairs.

- Phase 3–Compliant Repairs: Similar B/Ep patch dimensions to Phase 1 and 2 repairs, but with fiber oriented in the axial direction, were fatigued to 20,000 cycles. The crack growth for both mid-bay cracks was nonlinear with very high crack growth rates.

- Phase 4–Repairs With Impact Damage: Several repairs were impacted and then subjected to 20,000 fatigue cycles under SL conditions to study the effectiveness of repairs after impact. Though crack extension and disbonding occurred during the impact event, there was no subsequent damage growth during fatigue. Extensive plastic deformation at the crack tips due to impact retarded crack growth.

In general, the results revealed that crack growth was readily detected in the patches and could be reconstructed by the SHM system. The NDI methods used were successful in detecting and monitoring damage. Overall, the fatigue performance was reduced as repair quality degraded. For the majority of repair patch configurations, predictions of fatigue crack growth were in good agreement with the test results. However, further work is needed to account for thermal residual stresses and thick patch configurations.

7. REFERENCES

1. Chadha, R., Bakuckas, J.G., Won, I.Y., et al., "Characterization of Adhesive-Bonded Repairs to Fuselage Structure," *Proceedings of the Joint DoD/NASA/FAA Conference on Aircraft Airworthiness and Sustainment*, Austin, Texas, May 10–13, 2010.

2. Steadman, D. and Bakuckas, J.G., “Destructive Evaluation and Extended Fatigue Testing of Retired Transport Aircraft, Volume 1: Program Overview,” FAA Report DOT/FAA/AR-07/22,V1, October 2007.

3. Ihn, J.-B. and Chang, F.-K., “Detection and Monitoring of Hidden Fatigue Crack Growth Using a Built-in Piezoelectric Sensor/Actuator Network: I. Diagnostics,” *Smart Materials and Structures*, Vol. 13, 2004, pp. 609–620.

4. Ihn, J.-B., Leonard, M.S., Olson S.E., and DeSimio, M.P., “Design Framework Validation for a Hot Spot on Complex Aircraft Structures,” *Proceedings of the Fifth European Workshop on Structural Health Monitoring*, Sorrento, Italy, 2010, pp. 1359–1366.

5. Duong, C.N. et al., “Composite Repair of Aircraft Structures (CRAS),” Vol. 1–3, Technical Report AFRL-VA-WP-TR-2006-3019.

6. Duong, C.N. and Wang, C.H, “On the Characterization of Fatigue Crack Growth in the One-Sided Repair,” *Journal of Engineering Materials and Technology*, Vol. 136, 2004, pp. 192–198.

7. NASGRO User’s Manual.

8. Viz, M.J., Poyondi, D.O., Zehnder, A.T., Rankin, C.C., and Riks, E., “Computation of Membrane and Bending Stress Intensity Factors for Thin, Cracked Plates,” *International Journal of Fracture*, Vol. 72, 1995, pp. 21–38.

9. 3M Scotch-Weld™ Epoxy Adhesive 2216 B/A Technical Data, available at http://multimedia.3m.com/mws/media/153955O/3mtm-scotch-weldtm-epoxy-adhesive-2216-b-a.pdf (accessed on 04/20/15).

APPENDIX A—PANEL ENGINEERING DRAWINGS

This appendix includes detailed engineering drawings for the panel tested. The panel is cross-referenced in the engineering drawings (numbered 53–1069). The selected panel configurations represent generic fuselage structure from a retired passenger service airplane, specifically, a Boeing 727-232 with serial number 20751, line number 1000, and registration number N474DA. The airplane was placed into service in 1974 and retired in 1998. While in service, the airplane accumulated 59,497 flight cycles and 66,412 flight hours and was near its design service goal of 60,000 flight cycles. The airplane was owned and operated exclusively by Delta Air Lines, was well-maintained and stored, and had a well-documented and accessible service history. Its use is representative of typical 14 Code of Federal Regulations part 121 revenue service passenger aircraft currently in the domestic fleet.

The panel was removed from the crown of the airplane having dimensions of 125″ x 73″ and a radius of 74″. The substructure included six stringers (S), S-1R–S-6R, in the longitudinal direction with 9.5″ spacing; and six frame stations (FS), FS-990–FS-1090, in the hoop direction with 20″ spacing. The Z-shaped frames, stringer clips, and hat-shaped stringers are made from 7075-T6 aluminum.

The panel skin was 2024-T3 aluminum with a thickness varying from 0.040″–0.080″ at various bays. The skin thickness between FS-1050 and FS-1090, as well as between FS-1030 and FS-1050 and S-4R and S-6R, was 0.04″. These locations, with the same skin thickness, were chosen as the test section. A longitudinal lap joint was located along stringer S-4R, and a circumferential butt joint was located along FS-1010. The longitudinal lap joint consisted of two skin layers and a 0.02″-thick 2024-T3 aluminum doubler layer sandwiched between the two skin layers, which were connected together by three rows of rivets. The doubler was bonded to the outer skin, and there was a sealant between the doubler and the inner skin of the lap joint.

The panel was reinforced along the four edges with aluminum doublers. In both longitudinal doublers, 28 half-inch-diameter holes were inserted, spaced 4″ apart. In both hoop doublers, 16 half-inch-diameter holes were inserted, spaced 3.5″ apart. These holes were used to attach the edges of the panel to the loading mechanisms of the Full-Scale Aircraft Structural Test, Evaluation and Research (FASTER) fixture, which has seven hoop loaders on each side and four longitudinal loaders on both ends. Each actuator is attached to the panel at four holes using a whiffle tree assembly. The two ends of each frame, where the frame load is applied, were also reinforced with aluminum doublers. An elastomeric seal was bonded along the perimeter of the inner surface of the curved panel to attach to the pressure box of the FASTER fixture.

SYMBOL	FASTENER
PH	HL20-() HI-LOK, HL86-() COLLAR
BJ	MS20470AD() RIVET
LZ	NAS1097AD() RIVET

TITLE PANEL ASSY- B727DE FT4		No. 53-1069 SH. 3 OF 22	REV. A
ENGINEERING AUTHORIZATION ER/A 373668-14	SCALE: 1/1 & NOTED TOLERANCES ANG +/- 1 Deg. DEC X.XX +/- 0.03 DEC X.XXX +/- 0.010	ORIG. ISSUE DATE: XXXXX XXX XXXXX XXXXXXXXXXX XXXX XXXXXXX XXXXXX XXXXXX, XXXXXXX	
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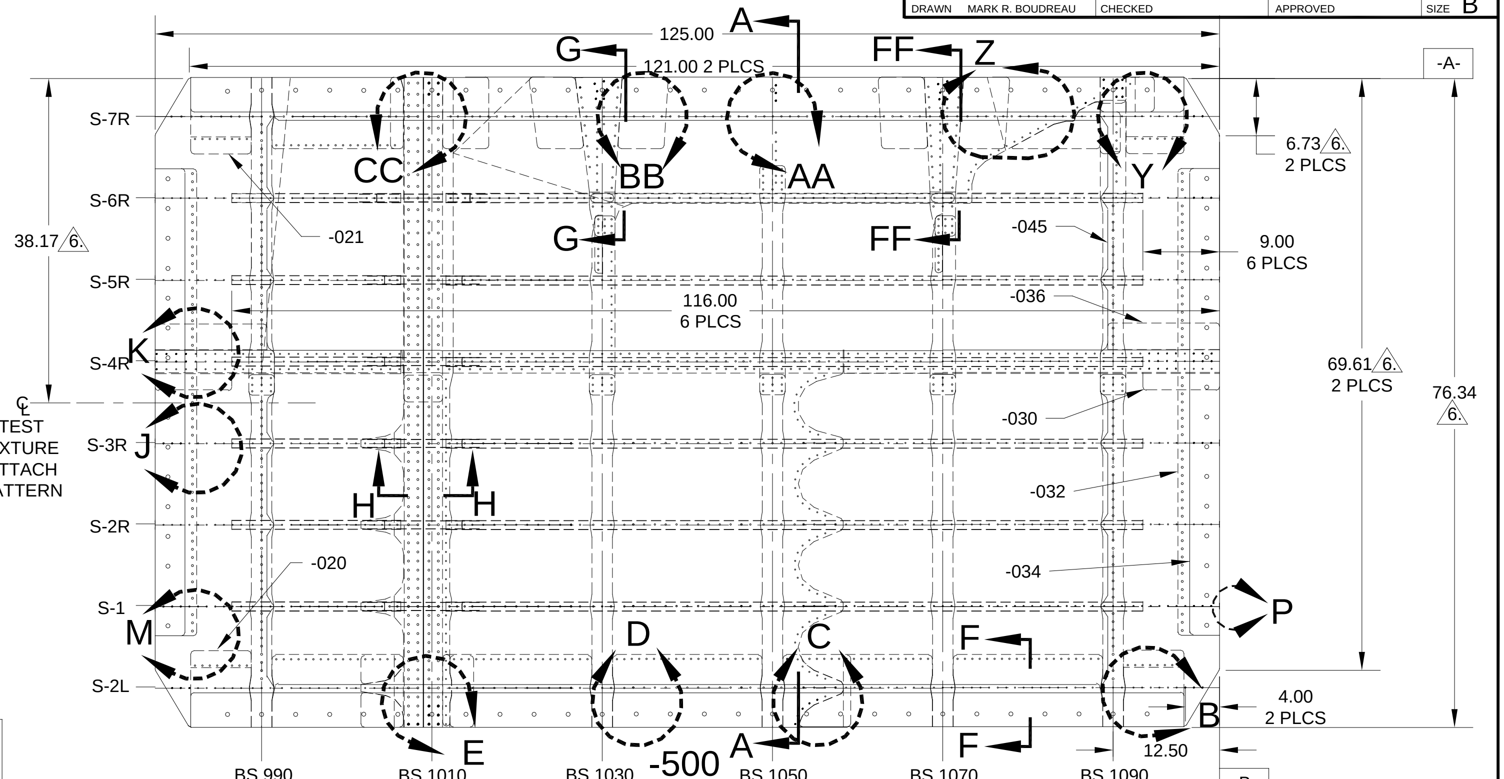

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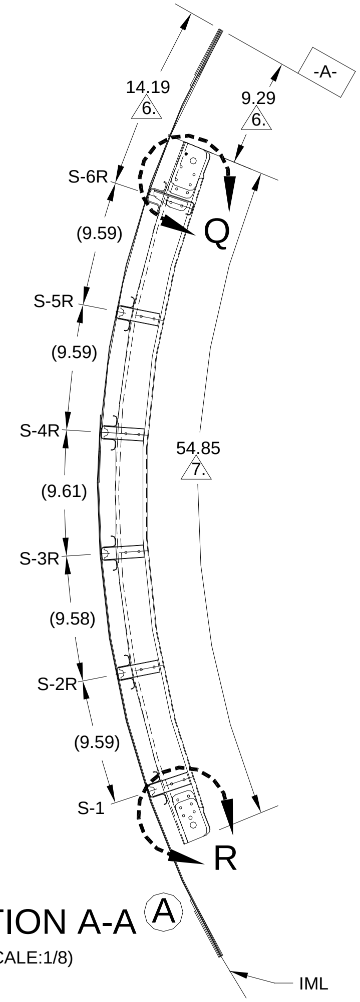

SECTION A-A (A)

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NOTES (CONTINUED):

4. THE IML IS THE INNER MOLD LINE OF THE FUSELAGE SKIN WHICH HAS A RADIUS OF 74 INCHES.

5. BREAK ALL SHARP EDGES 0.015/0.030 R.

6. NOTED DIMENSION IS IN PLANE OF THE IML.

7. NOTED DIMENSION IS IN PLANE OF INNER CHORD INNER SURFACE OF THE FUSELAGE FRAME.

8. 2024-T3 CLAD SHEET, QQ-A-250/5.

9. ALL FASTENERS ARE TO BE INSTALLED PER B727 SRM CHAPTER 51-30-2. EXISTING RIVETS REPLACED WITH SAME DIAMETER RIVET MAYBE OVERSIZED 1/32 TO MAINTAIN HOLE QUALITY.

10. DIMENSION WITHIN PARENTHESIS ARE FOR EXISTING BOEING MANUFACTURED PARTS WHICH ARE PART OF THE FT1 PANEL.

11. ALL OUTSIDE RADII TO BE 0.40 INCHES EXCEPT AS NOTED.

12. ● DOUBLE FLUSH PLUG IN EXISTING STACKUP (SKIN, TEAR STRAP, SPLICE AND SPLICE DOUBLER) ONLY USING 1/32 OVERSIZE AD, D OR DD RIVET MATERIAL AND A TOUCH COUNTERSINK OF 0.005 - 0.015 INCHES IN DEPTH. MICROSHAVE FLUSH ON BOTH SURFACES.

13. ○ REFERENCE FASTENER LOCATIONS.

14. INSTALL CONICAL WASHERS AT ALL EXISTING COUNTERSINKS.

15. APPLY CHEMICAL FILM TREATMENT TO ALL BARE ALUMINUM SURFACES PER P.S. 900-2-4-1, NO. 02.

16. ALL MODIFICATION PARTS ARE TO BE BONDED INTO PLACE USING EC2216B/A TWO PART EPOXY ADHESIVE PER P.S. 900-7-1-1, NO. 03.

17. AFTER ADHESIVE HAS CURED FOR A MINIMUM OF 48 HOURS, APPLY ONE COAT OF F.R. PRIMER (10-P4-3, YELLOW) TO ALL MODIFICATION PARTS AND CUT EDGES.

18. TI-6AL-4V SHEET, MIL-T-9046E, TYP III, COMP C.

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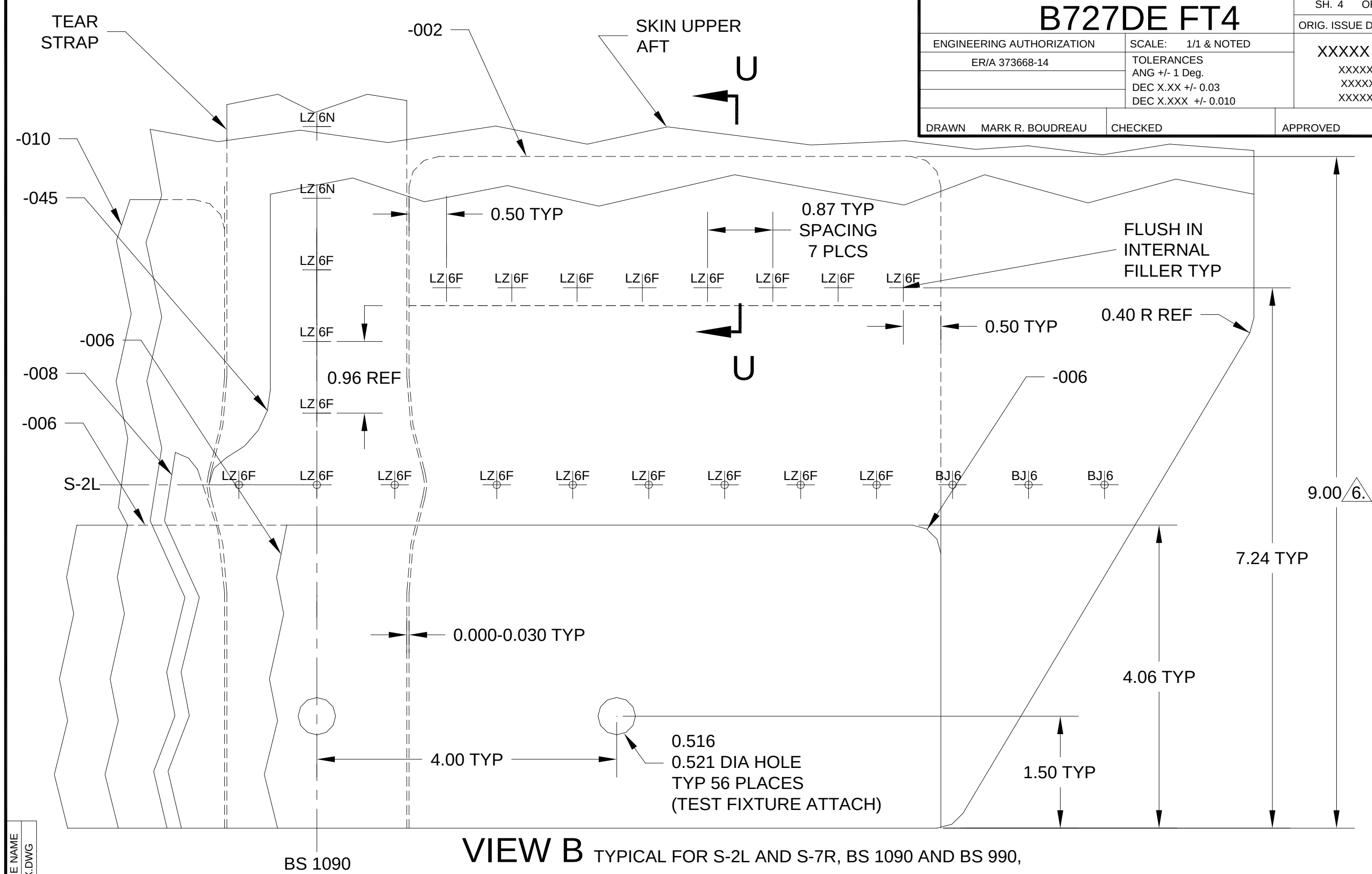
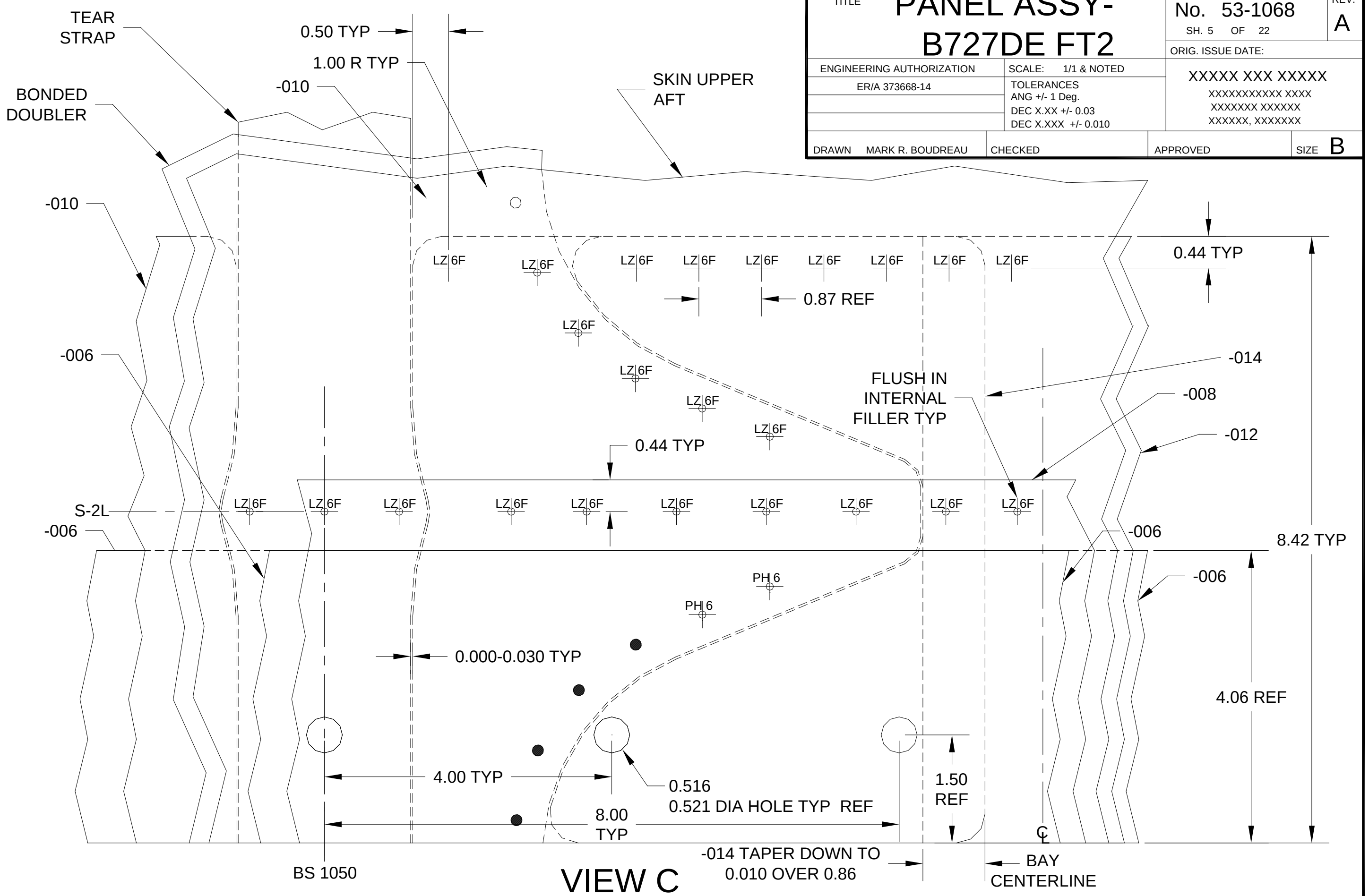


VIEW B TYPICAL FOR S-2L AND S-7R, BS 1090 AND BS 990,
S-2R AND BS 1090 SHOWN OTHER LOCATIONS OPPOSITE EXCEPT AS NOTED
(SCALE: 3/4)

DRAWING FILE NAME XXXXXXXX.DWG

REV. & DATE	CHANGE DESCRIPTION	EA AFFECTED	DWN.	CK'D	APPR.

TITLE PANEL ASSY-B727DE FT2		No. 53-1068 SH. 5 OF 22	REV. A
ENGINEERING AUTHORIZATION ER/A 373668-14	SCALE: 1/1 & NOTED TOLERANCES ANG +/- 1 Deg. DEC X.XX +/- 0.03 DEC X.XXX +/- 0.010	ORIG. ISSUE DATE: XXXXX XXX XXXXX XXXXXXXXXXXX XXXX XXXXXXX XXXXXX XXXXXX, XXXXXXX	
DRAWN MARK R. BOUDREAU	CHECKED	APPROVED	SIZE B

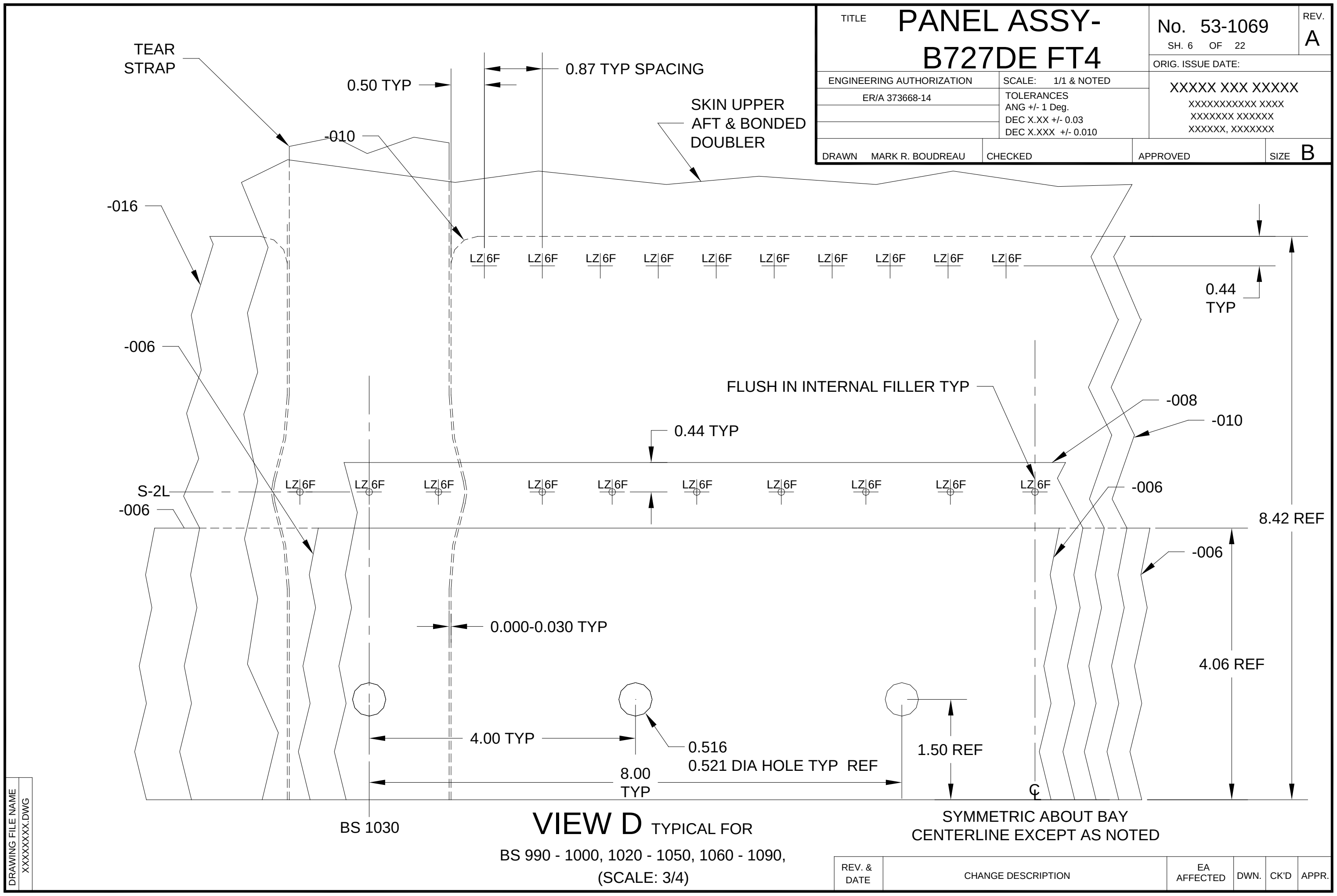


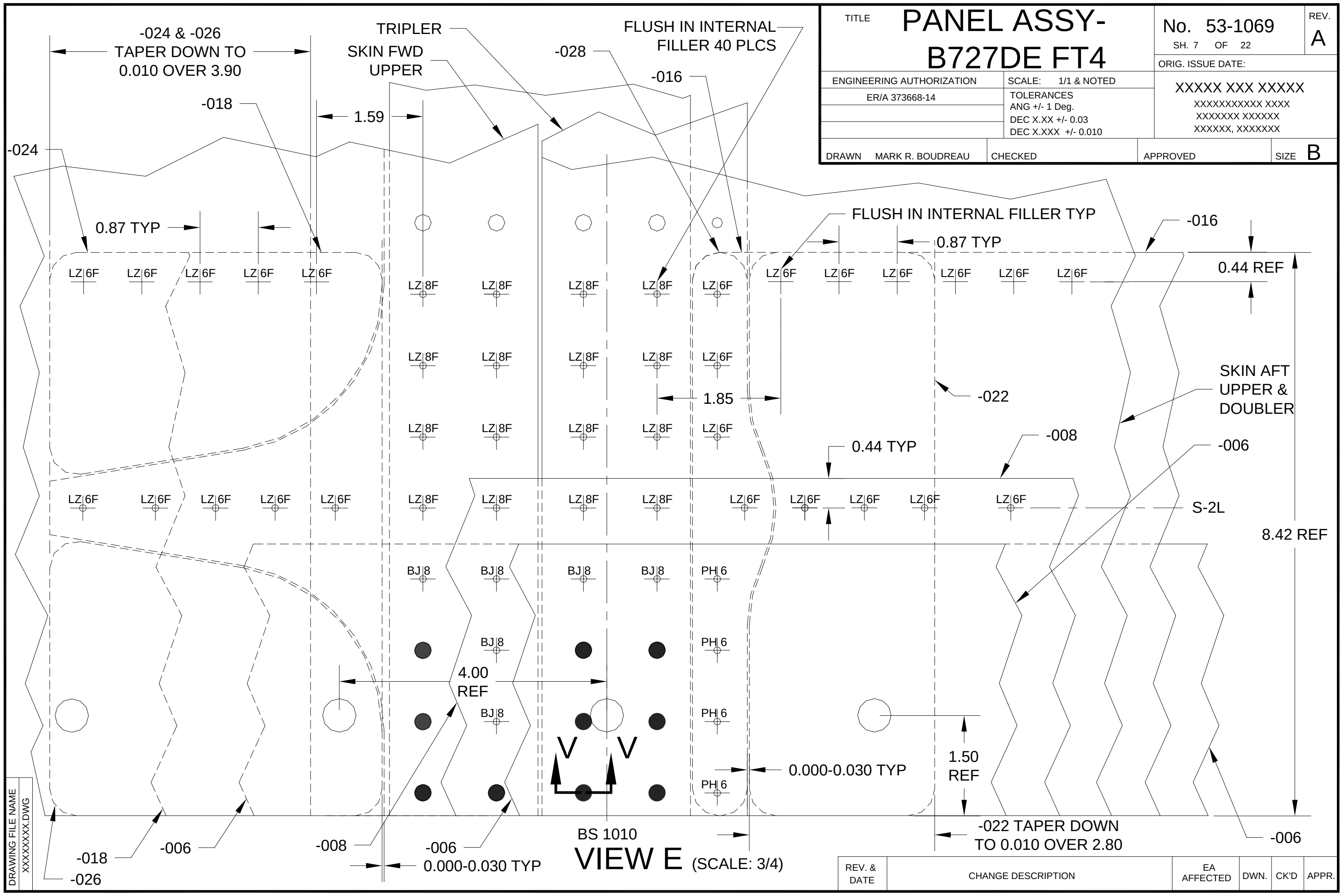
VIEW C

(SCALE: 3/4)

REV. & DATE	CHANGE DESCRIPTION	EA AFFECTED	DWN.	CK'D	APPR.

DRAWING FILE NAME XXXXXXXX.DWG


TITLE
PANEL ASSY-
B727DE FT4
No. 53-1069
SH. 6 OF 22
REV.
A
ORIG. ISSUE DATE:
ENGINEERING AUTHORIZATION
ER/A 373668-14
SCALE: 1/1 & NOTED
TOLERANCES
ANG +/- 1 Deg.
DEC X.XX +/- 0.03
DEC X.XXX +/- 0.010
XXXXX XXX XXXXX
XXXXXXXXXXXX XXXX
XXXXXXX XXXXXX
XXXXXX, XXXXXXX
DRAWN MARK R. BOUDREAU
CHECKED
APPROVED
SIZE B
TEAR STRAP
0.50 TYP
0.87 TYP SPACING
SKIN UPPER AFT & BONDED DOUBLER
-010
-016
LZ 6F
0.44 TYP
-006
FLUSH IN INTERNAL FILLER TYP
-008
-010
0.44 TYP
S-2L
-006
-006
8.42 REF
-006
0.000-0.030 TYP
4.06 REF
4.00 TYP
0.516
0.521 DIA HOLE TYP REF
1.50 REF
8.00 TYP
BS 1030
℄
SYMMETRIC ABOUT BAY CENTERLINE EXCEPT AS NOTED
VIEW D TYPICAL FOR
BS 990 - 1000, 1020 - 1050, 1060 - 1090,
(SCALE: 3/4)
REV. & DATE
CHANGE DESCRIPTION
EA AFFECTED
DWN.
CK'D
APPR.
DRAWING FILE NAME
XXXXXXXXX.DWG


TITLE
PANEL ASSY-
B727DE FT4
No. 53-1069
SH. 7 OF 22
REV.
A
ORIG. ISSUE DATE:
ENGINEERING AUTHORIZATION
ER/A 373668-14
SCALE: 1/1 & NOTED
TOLERANCES
ANG +/- 1 Deg.
DEC X.XX +/- 0.03
DEC X.XXX +/- 0.010
XXXXX XXX XXXXX
XXXXXXXXXXX XXXX
XXXXXXX XXXXXX
XXXXXX, XXXXXXX
DRAWN MARK R. BOUDREAU
CHECKED
APPROVED
SIZE B
-024 & -026
TAPER DOWN TO
0.010 OVER 3.90
TRIPLER
SKIN FWD
UPPER
-028
FLUSH IN INTERNAL
FILLER 40 PLCS
-016
-018
1.59
-024
0.87 TYP
FLUSH IN INTERNAL FILLER TYP
0.87 TYP
-016
0.44 REF
LZ 6F
LZ 8F
BJ 8
PH 6
1.85
-022
SKIN AFT
UPPER &
DOUBLER
0.44 TYP
-008
-006
S-2L
8.42 REF
4.00
REF
V
V
0.000-0.030 TYP
1.50
REF
-022 TAPER DOWN
TO 0.010 OVER 2.80
-018
-006
-008
-006
-026
0.000-0.030 TYP
BS 1010
VIEW E (SCALE: 3/4)
-006
DRAWING FILE NAME
XXXXXXXX.DWG
REV. &
DATE
CHANGE DESCRIPTION
EA
AFFECTED
DWN.
CK'D
APPR.

TITLE PANEL ASSY- B727DE FT4

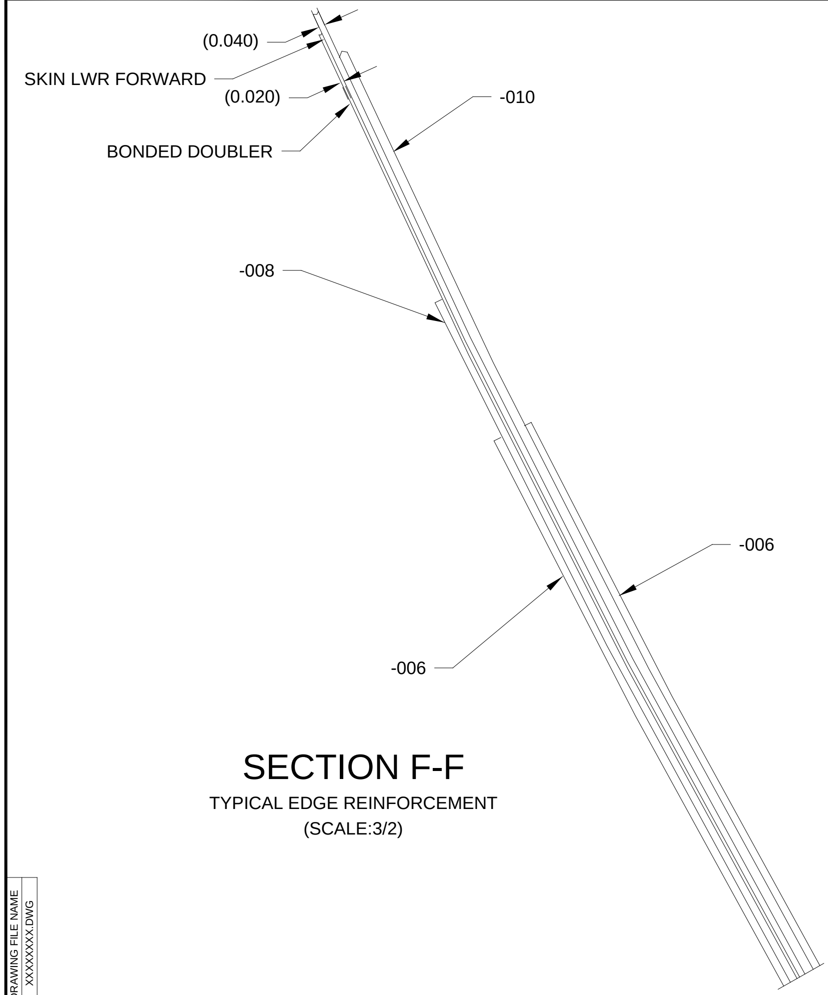
No. 53-1069 SH. 8 OF 22

REV. A

ORIG. ISSUE DATE:

ENGINEERING AUTHORIZATION	SCALE: 1/1 & NOTED	XXXXX XXX XXXXX
ER/A 373668-14	TOLERANCES ANG +/- 1 Deg. DEC X.XX +/- 0.03 DEC X.XXX +/- 0.010	XXXXXXXXXXX XXXX XXXXXXX XXXXXX XXXXXX, XXXXXXX

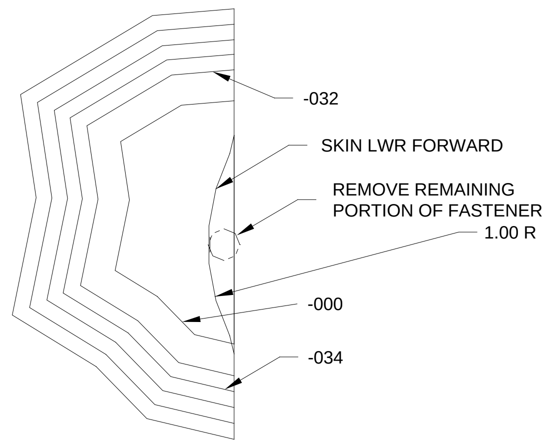
DRAWN MARK R. BOUDREAU | CHECKED | APPROVED | SIZE B



SECTION F-F

TYPICAL EDGE REINFORCEMENT

(SCALE:3/2)



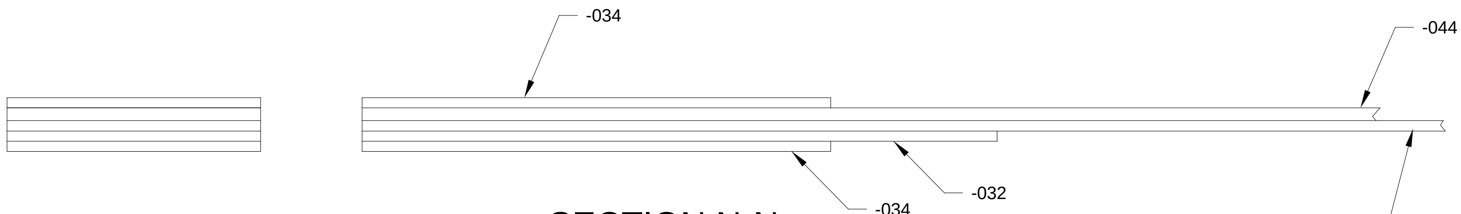
VIEW P

TYPICAL EXISTING FASTENER LOCATIONS
THAT FALL ON THE EDGE OF THE PANEL CUT
(SCALE: 2/1)

DRAWING FILE NAME XXXXXXXX.DWG

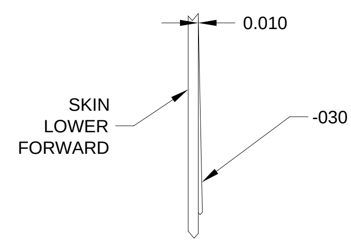
REV. & DATE	CHANGE DESCRIPTION	EA AFFECTED	DWN.	CK'D	APPR.

TITLE	PANEL ASSY- B727DE FT4	No. 53-1069 SH. 9 OF 22	REV. A
ENGINEERING AUTHORIZATION ER/A 373668-14	SCALE: 1/1 & NOTED TOLERANCES ANG +/- 1 Deg. DEC X.XX +/- 0.03 DEC X.XXX +/- 0.010	ORIG. ISSUE DATE: XXXXX XXX XXXXX XXXXXXXXXXX XXXX XXXXXXX XXXXXX XXXXXX, XXXXXXX	
DRAWN MARK R. BOUDREAU	CHECKED	APPROVED	SIZE B



SECTION N-N

TYPICAL 30 LOCATIONS
FORWARD END SHOWN AFT END OPPOSITE
(SCALE:2/1)

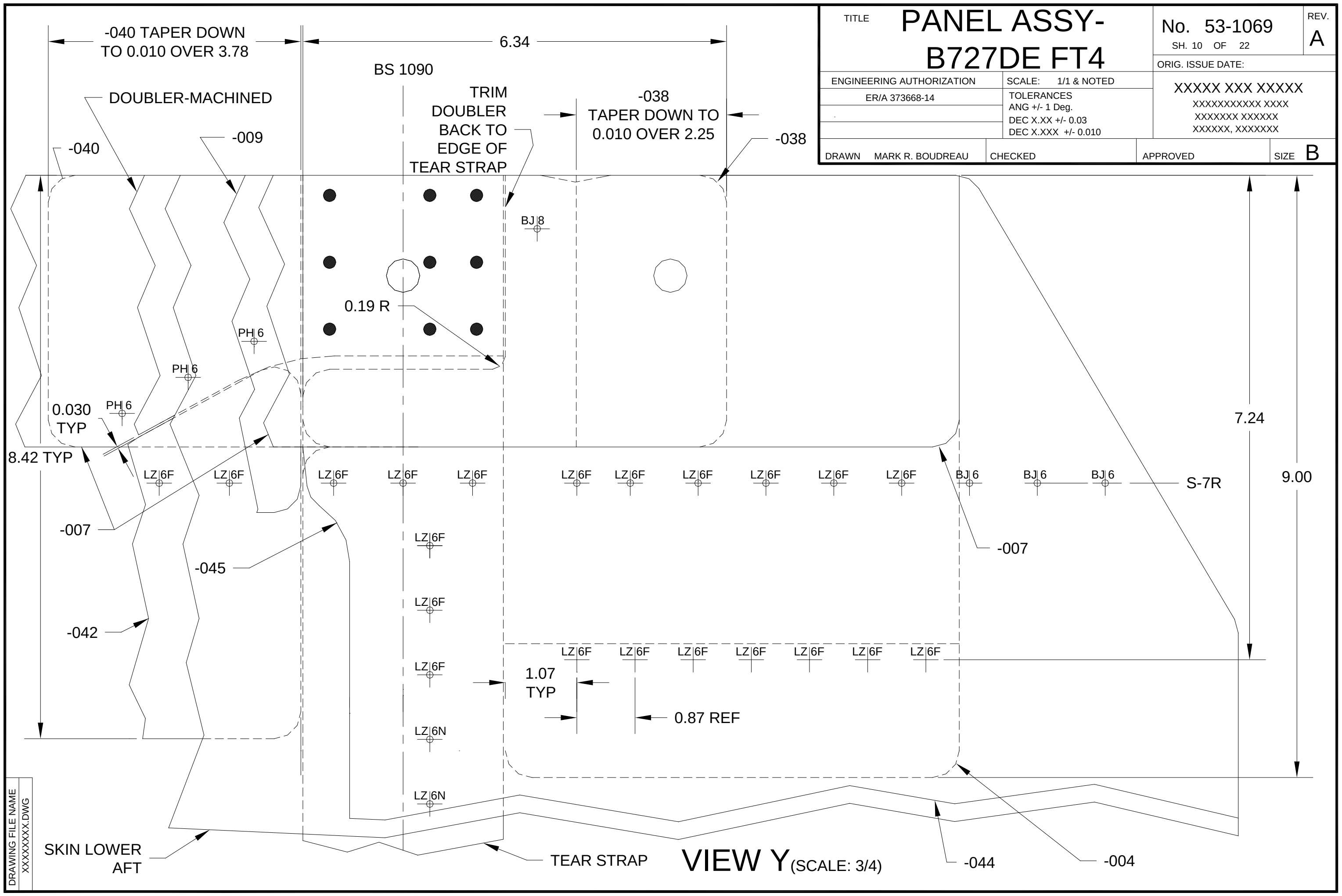


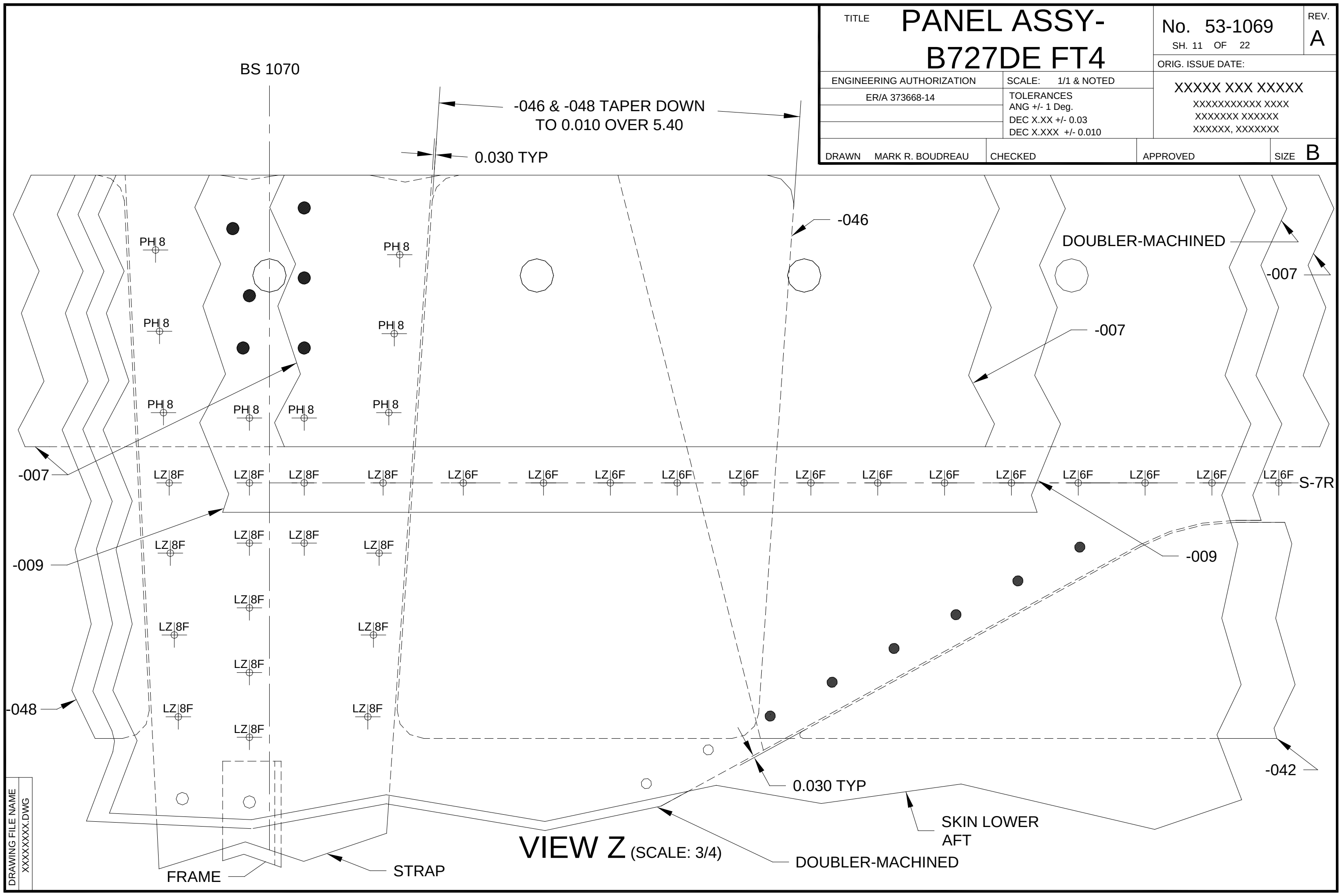
SECTION W-W

TYPICAL SECTION FOR -030
(SCALE: 2/1)

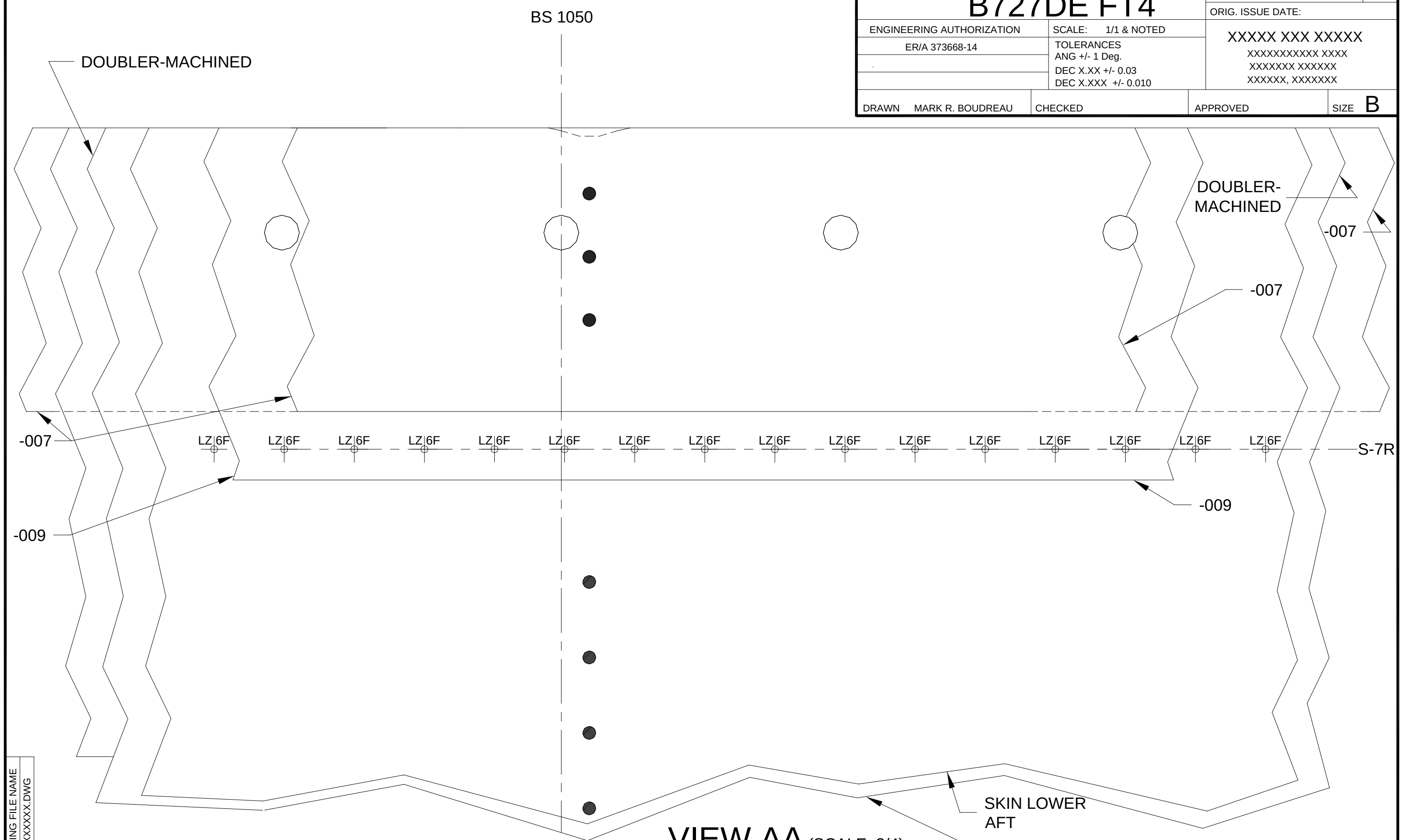
DRAWING FILE NAME XXXXXXXXX.DWG

REV. & DATE	CHANGE DESCRIPTION	EA AFFECTED	DWN.	CK'D	APPR.


TITLE
PANEL ASSY-
B727DE FT4
No. 53-1069
SH. 10 OF 22
REV.
A
ORIG. ISSUE DATE:
ENGINEERING AUTHORIZATION
ER/A 373668-14
SCALE: 1/1 & NOTED
TOLERANCES
ANG +/- 1 Deg.
DEC X.XX +/- 0.03
DEC X.XXX +/- 0.010
XXXXX XXX XXXXX
XXXXXXXXXXX XXXX
XXXXXXX XXXXXX
XXXXXX, XXXXXXX
DRAWN MARK R. BOUDREAU
CHECKED
APPROVED
SIZE B
DRAWING FILE NAME
XXXXXXXX.DWG
-040 TAPER DOWN
TO 0.010 OVER 3.78
6.34
BS 1090
DOUBLER-MACHINED
-009
-040
TRIM
DOUBLER
BACK TO
EDGE OF
TEAR STRAP
-038
TAPER DOWN TO
0.010 OVER 2.25
-038
BJ 8
0.19 R
PH 6
PH 6
PH 6
0.030
TYP
8.42 TYP
LZ 6F
BJ 6
S-7R
-007
-045
-042
1.07
TYP
0.87 REF
LZ 6N
7.24
9.00
SKIN LOWER
AFT
TEAR STRAP
VIEW Y(SCALE: 3/4)
-044
-004


TITLE
PANEL ASSY-
B727DE FT4
No. 53-1069
SH. 11 OF 22
REV.
A
ORIG. ISSUE DATE:
ENGINEERING AUTHORIZATION
ER/A 373668-14
SCALE: 1/1 & NOTED
TOLERANCES
ANG +/- 1 Deg.
DEC X.XX +/- 0.03
DEC X.XXX +/- 0.010
XXXXX XXX XXXXX
XXXXXXXXXXX XXXX
XXXXXXX XXXXXX
XXXXXX, XXXXXXX
DRAWN MARK R. BOUDREAU
CHECKED
APPROVED
SIZE B
BS 1070
-046 & -048 TAPER DOWN
TO 0.010 OVER 5.40
0.030 TYP
-046
DOUBLER-MACHINED
-007
-007
-007
PH 8
LZ 8F
LZ 6F
S-7R
-009
-009
-048
-042
0.030 TYP
SKIN LOWER
AFT
DOUBLER-MACHINED
STRAP
FRAME
VIEW Z (SCALE: 3/4)
DRAWING FILE NAME
XXXXXXXXX.DWG

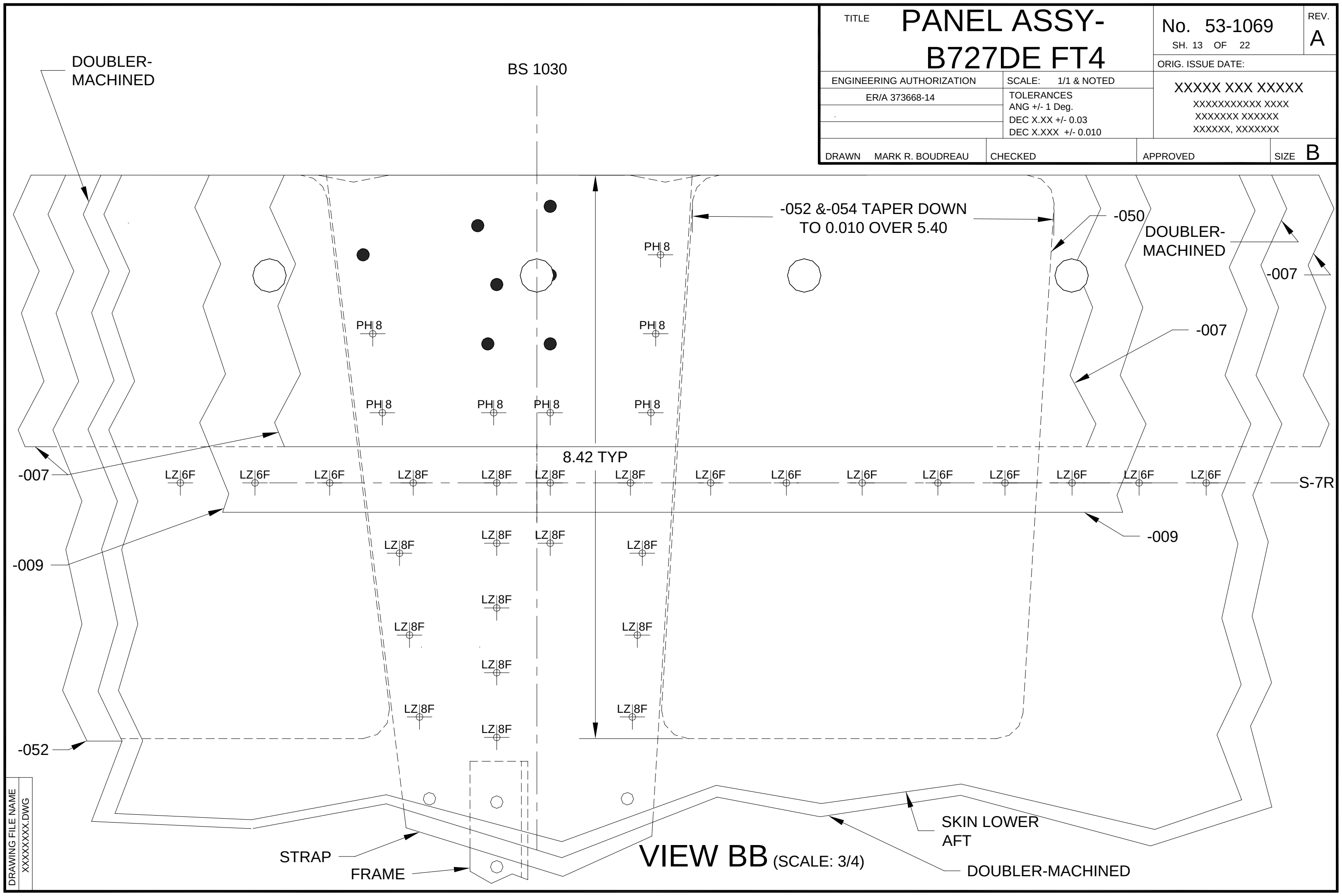
TITLE	PANEL ASSY- B727DE FT4	No. 53-1069 SH. 12 OF 22	REV. A
ENGINEERING AUTHORIZATION ER/A 373668-14	SCALE: 1/1 & NOTED TOLERANCES ANG +/- 1 Deg. DEC X.XX +/- 0.03 DEC X.XXX +/- 0.010	ORIG. ISSUE DATE: XXXXX XXX XXXXX XXXXXXXXXXX XXXX XXXXXXX XXXXXX XXXXXX, XXXXXXX	
DRAWN MARK R. BOUDREAU	CHECKED	APPROVED	SIZE B



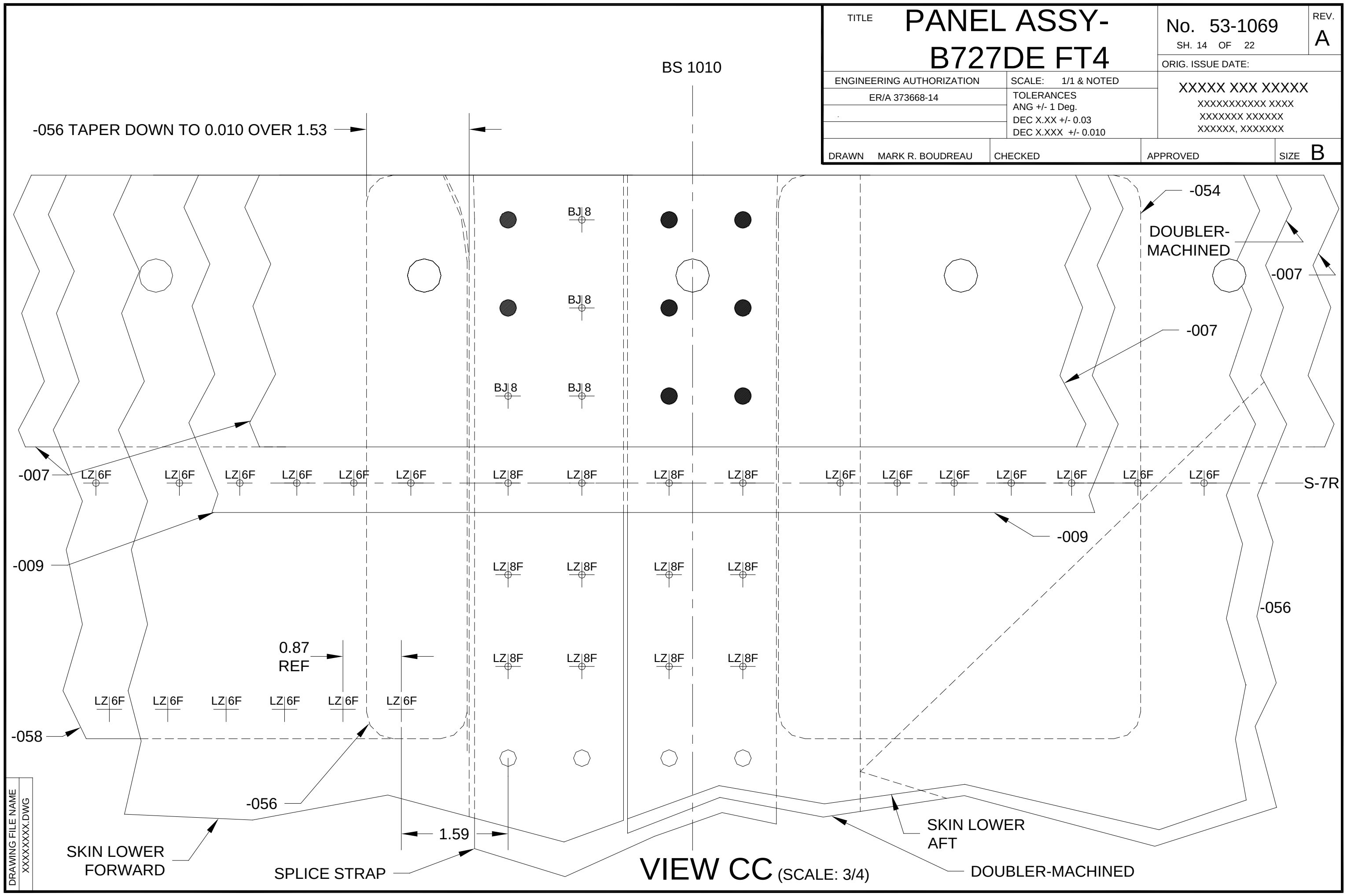
VIEW AA (SCALE: 3/4)

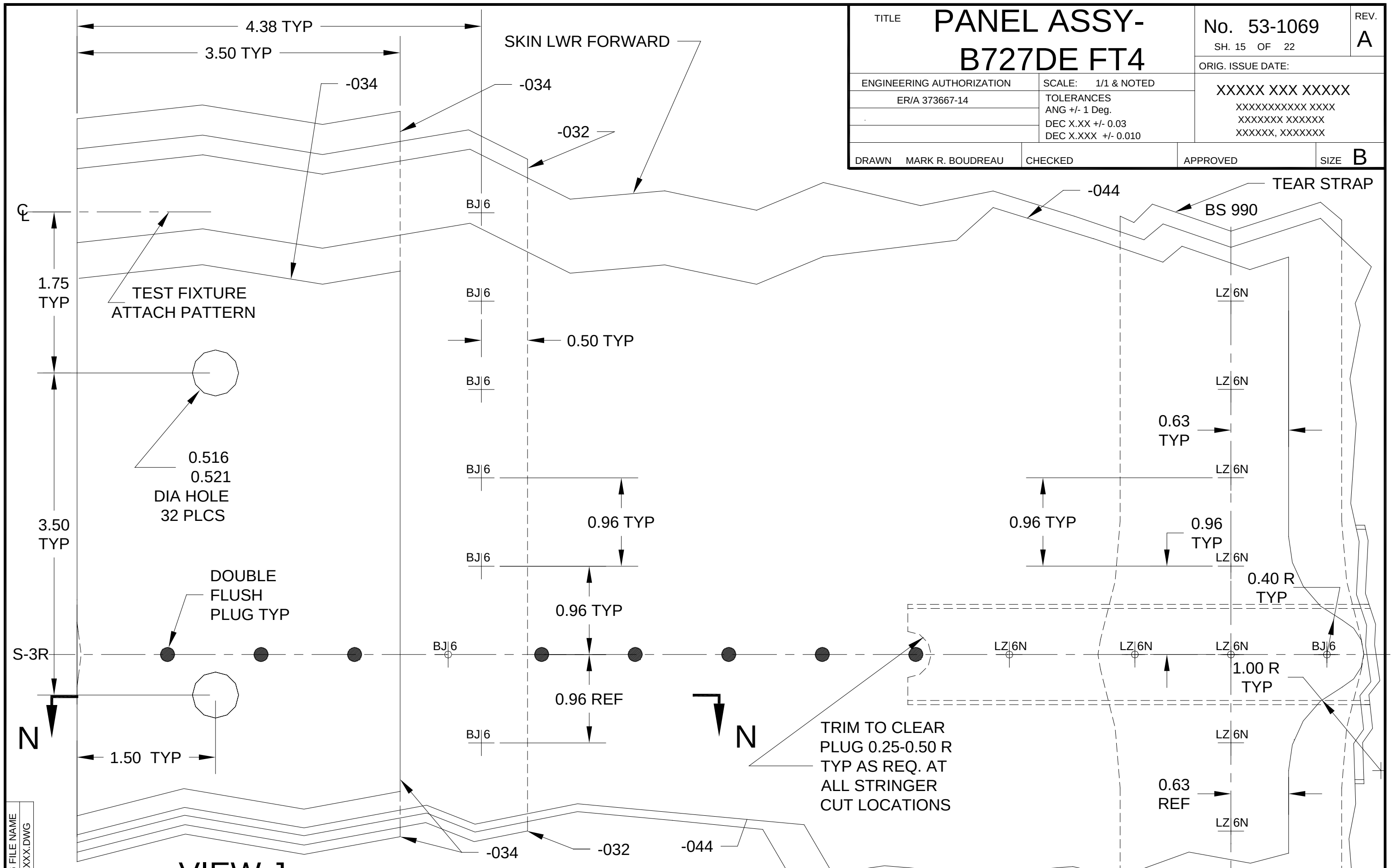
DRAWING FILE NAME XXXXXXXXX.DWG

TITLE PANEL ASSY- B727DE FT4		No. 53-1069 SH. 13 OF 22	REV. A
ENGINEERING AUTHORIZATION	SCALE: 1/1 & NOTED	ORIG. ISSUE DATE:	
ER/A 373668-14	TOLERANCES ANG +/- 1 Deg. DEC X.XX +/- 0.03 DEC X.XXX +/- 0.010	XXXXX XXX XXXXX XXXXXXXXXXX XXXX XXXXXXX XXXXXX XXXXXX, XXXXXXX	
DRAWN MARK R. BOUDREAU	CHECKED	APPROVED	SIZE B

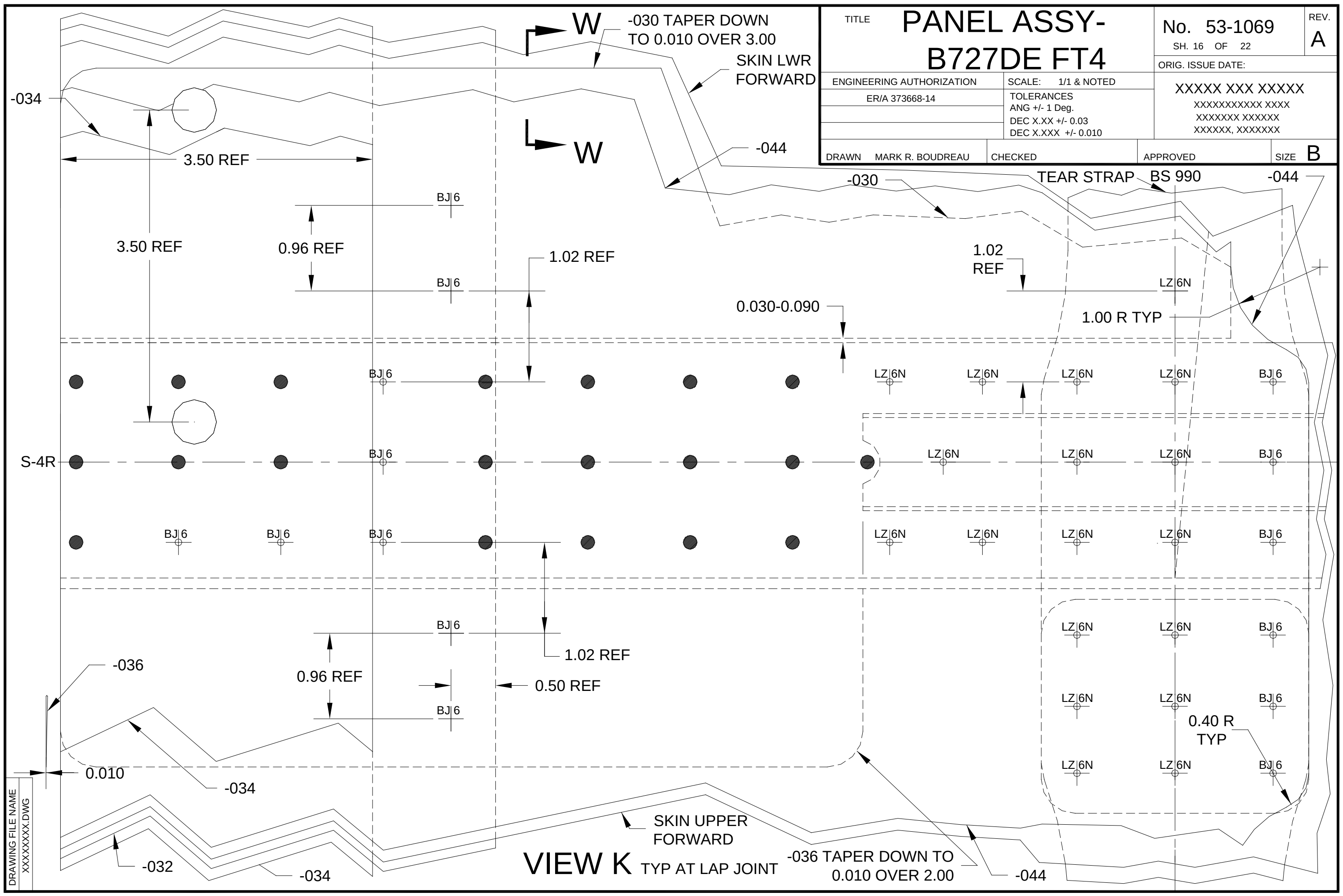


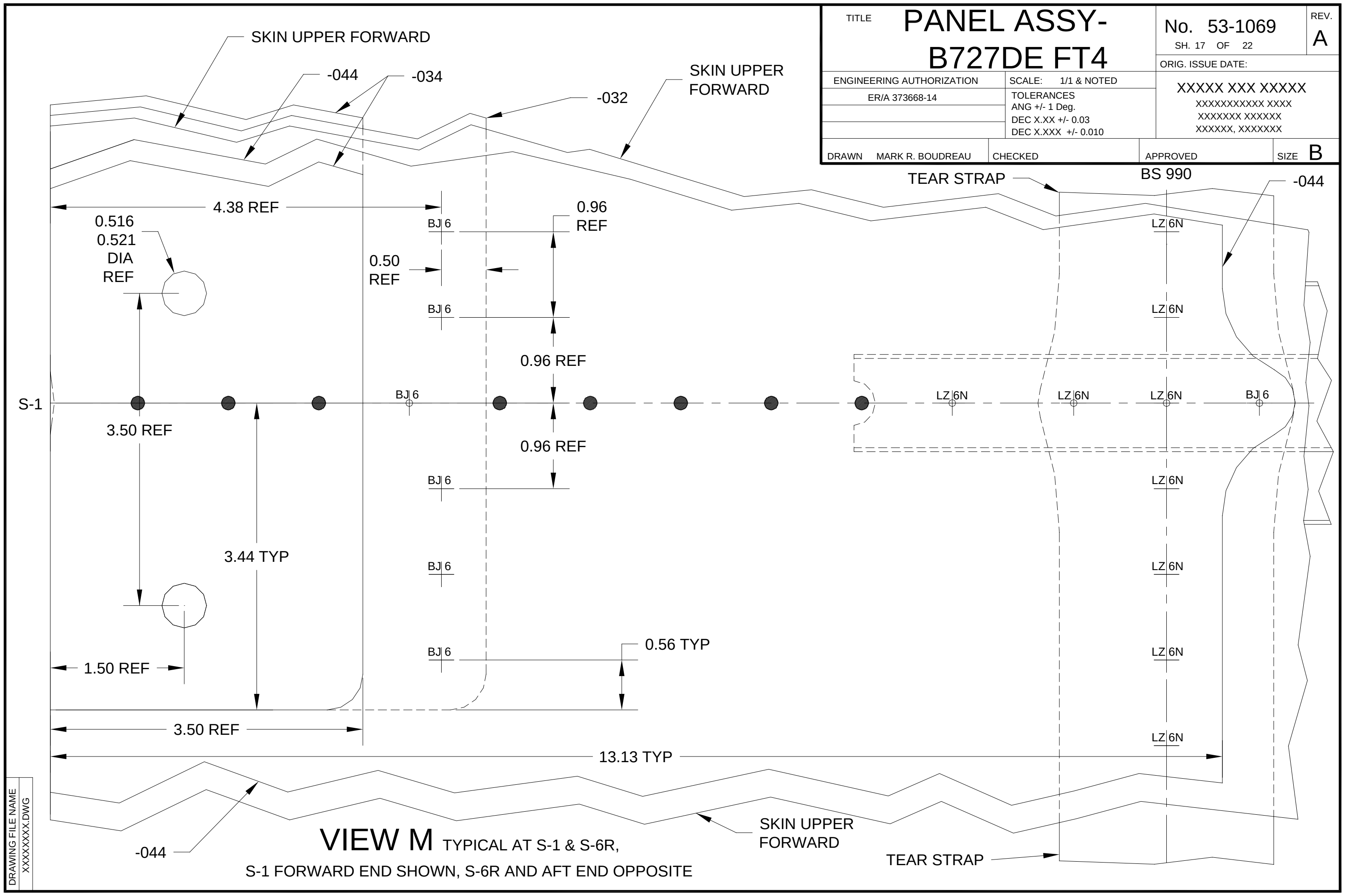
VIEW BB (SCALE: 3/4)


TITLE
PANEL ASSY-
B727DE FT4
No. 53-1069
SH. 14 OF 22
REV.
A
ORIG. ISSUE DATE:
ENGINEERING AUTHORIZATION
ER/A 373668-14
SCALE: 1/1 & NOTED
TOLERANCES
ANG +/- 1 Deg.
DEC X.XX +/- 0.03
DEC X.XXX +/- 0.010
XXXXX XXX XXXXX
XXXXXXXXXXX XXXX
XXXXXXX XXXXXX
XXXXXX, XXXXXXX
DRAWN MARK R. BOUDREAU
CHECKED
APPROVED
SIZE B
BS 1010
-056 TAPER DOWN TO 0.010 OVER 1.53
-054
DOUBLER-
MACHINED
-007
-007
-007
BJ 8
BJ 8
BJ 8
BJ 8
LZ 6F
LZ 8F
S-7R
-009
-009
-056
0.87
REF
-058
-056
1.59
SKIN LOWER
FORWARD
SPLICE STRAP
SKIN LOWER
AFT
DOUBLER-MACHINED
VIEW CC (SCALE: 3/4)
DRAWING FILE NAME
XXXXXXXX.DWG

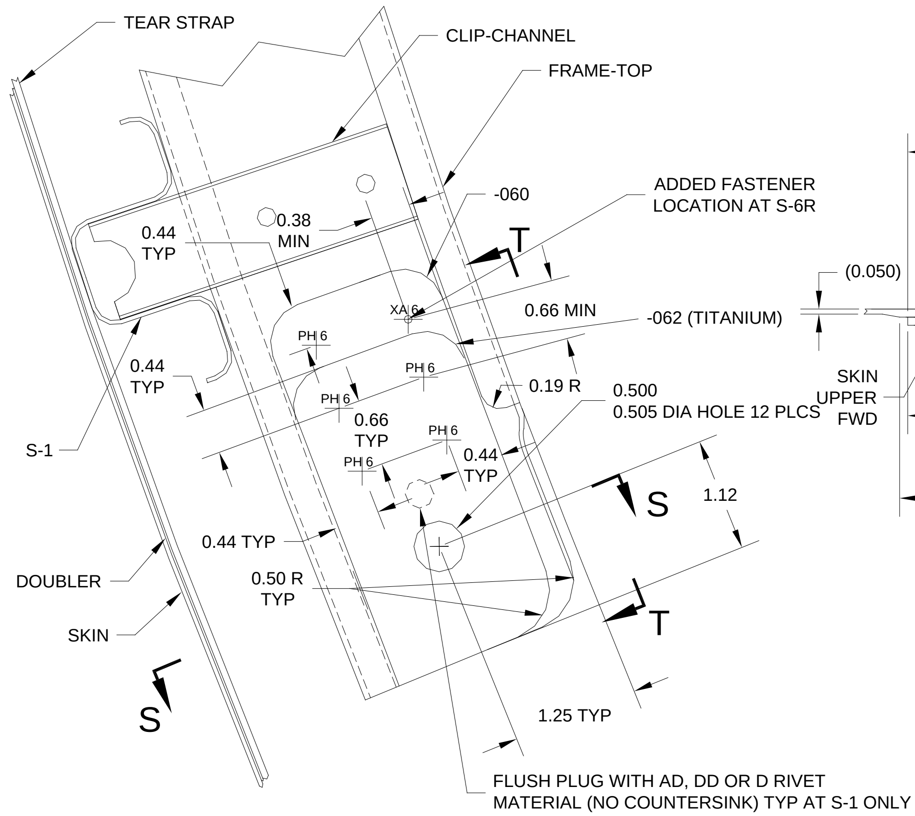


VIEW J TYPICAL AT ALL STRINGER AND FIXTURE ATTACHMENT
LOCATIONS EXCEPT AS NOTED, FORWARD END SHOWN AFT END OPPOSITE


TITLE PANEL ASSY- B727DE FT4
No. 53-1069
SH. 16 OF 22
REV. A
ORIG. ISSUE DATE:
ENGINEERING AUTHORIZATION
ER/A 373668-14
SCALE: 1/1 & NOTED
TOLERANCES
ANG +/- 1 Deg.
DEC X.XX +/- 0.03
DEC X.XXX +/- 0.010
XXXXX XXX XXXXX
XXXXXXXXXXX XXXX
XXXXXXX XXXXXX
XXXXXX, XXXXXXX
DRAWN MARK R. BOUDREAU
CHECKED
APPROVED
SIZE B
DRAWING FILE NAME
XXXXXXXX.DWG
W
-030 TAPER DOWN TO 0.010 OVER 3.00
SKIN LWR FORWARD
-034
-044
3.50 REF
3.50 REF
0.96 REF
1.02 REF
-030
TEAR STRAP
BS 990
-044
1.02 REF
0.030-0.090
1.00 R TYP
BJ 6
LZ 6N
S-4R
1.02 REF
0.96 REF
0.50 REF
-036
0.010
-034
0.40 R TYP
SKIN UPPER FORWARD
-032
-034
VIEW K TYP AT LAP JOINT
-036 TAPER DOWN TO 0.010 OVER 2.00
-044


TITLE
PANEL ASSY-
B727DE FT4
No. 53-1069
SH. 17 OF 22
REV.
A
ORIG. ISSUE DATE:
ENGINEERING AUTHORIZATION
ER/A 373668-14
SCALE: 1/1 & NOTED
TOLERANCES
ANG +/- 1 Deg.
DEC X.XX +/- 0.03
DEC X.XXX +/- 0.010
XXXXX XXX XXXXX
XXXXXXXXXXX XXXX
XXXXXXX XXXXXX
XXXXXX, XXXXXXX
DRAWN MARK R. BOUDREAU
CHECKED
APPROVED
SIZE B
SKIN UPPER FORWARD
-044
-034
-032
SKIN UPPER FORWARD
TEAR STRAP
BS 990
-044
4.38 REF
0.516
0.521
DIA
REF
0.50
REF
0.96
REF
BJ 6
LZ 6N
0.96 REF
S-1
3.50 REF
0.96 REF
3.44 TYP
0.56 TYP
1.50 REF
3.50 REF
13.13 TYP
-044
SKIN UPPER FORWARD
TEAR STRAP
VIEW M TYPICAL AT S-1 & S-6R,
S-1 FORWARD END SHOWN, S-6R AND AFT END OPPOSITE
DRAWING FILE NAME
XXXXXXXX.DWG

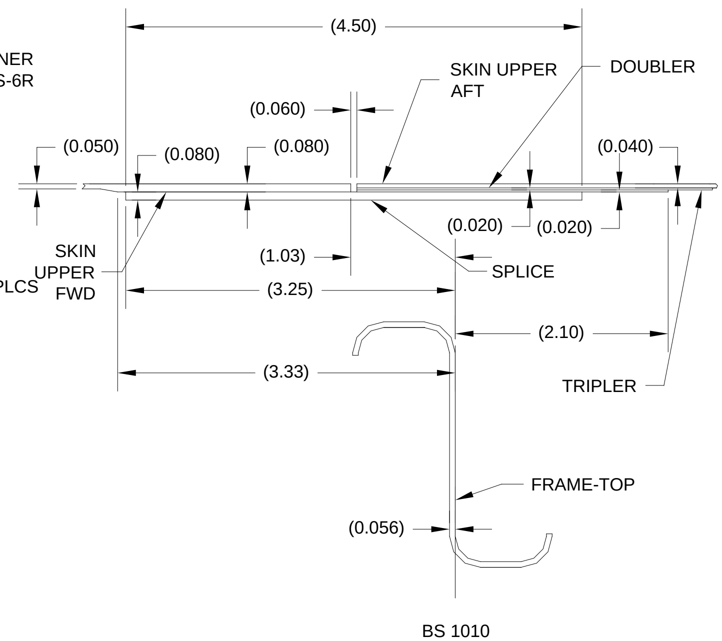
TITLE PANEL ASSY- B727DE FT4	No. 53-1069 SH. 18 OF 22	REV. A
ENGINEERING AUTHORIZATION: ER/A 373668-14	SCALE: 1/1 & NOTED; TOLERANCES ANG +/- 1 Deg. DEC X.XX +/- 0.03 DEC X.XXX +/- 0.010	ORIG. ISSUE DATE: XXXXX XXX XXXXX XXXXXXXXXXX XXXX XXXXXXX XXXXXX XXXXXX, XXXXXXX
DRAWN MARK R. BOUDREAU	CHECKED	APPROVED SIZE B



VIEW R (A)

TYPICAL BS 990 - 1090, S-1 FRAME RIENFORCEMENT AND FIXTURE ATTACHMENT

BS990, S-6R OPPOSITE



SECTION H-H

TYPICAL SECTION FOR BS 1009 BUTT SPLICE

DRAWING FILE NAME XXXXXXXXX.DWG

TITLE PANEL ASSY- B727DE FT4

No. 53-1069
SH. 19 OF 22
REV. A

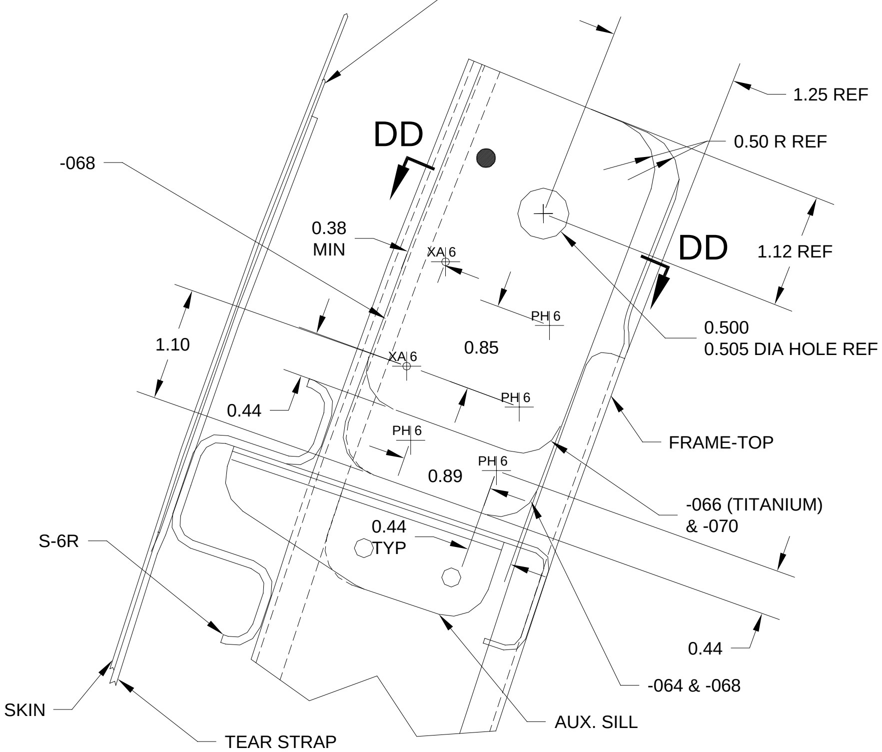
ORIG. ISSUE DATE:

XXXXX XXX XXXXX
XXXXXXXXXXX XXXX
XXXXXXX XXXXXX
XXXXXX, XXXXXXX

ENGINEERING AUTHORIZATION
ER/A 373668-14

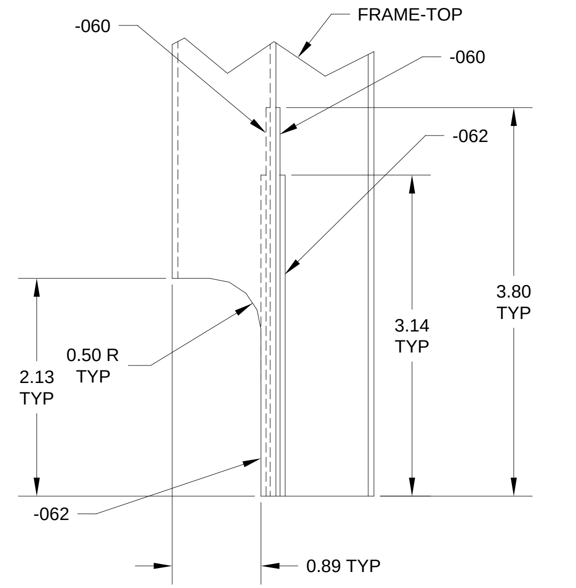
SCALE: 1/1 & NOTED
TOLERANCES
ANG +/- 1 Deg.
DEC X.XX +/- 0.03
DEC X.XXX +/- 0.010

DRAWN MARK R. BOUDREAU
CHECKED
APPROVED
SIZE B



VIEW Q (A)

TYPICAL BS 1010, BS 1050 AND BS 1090

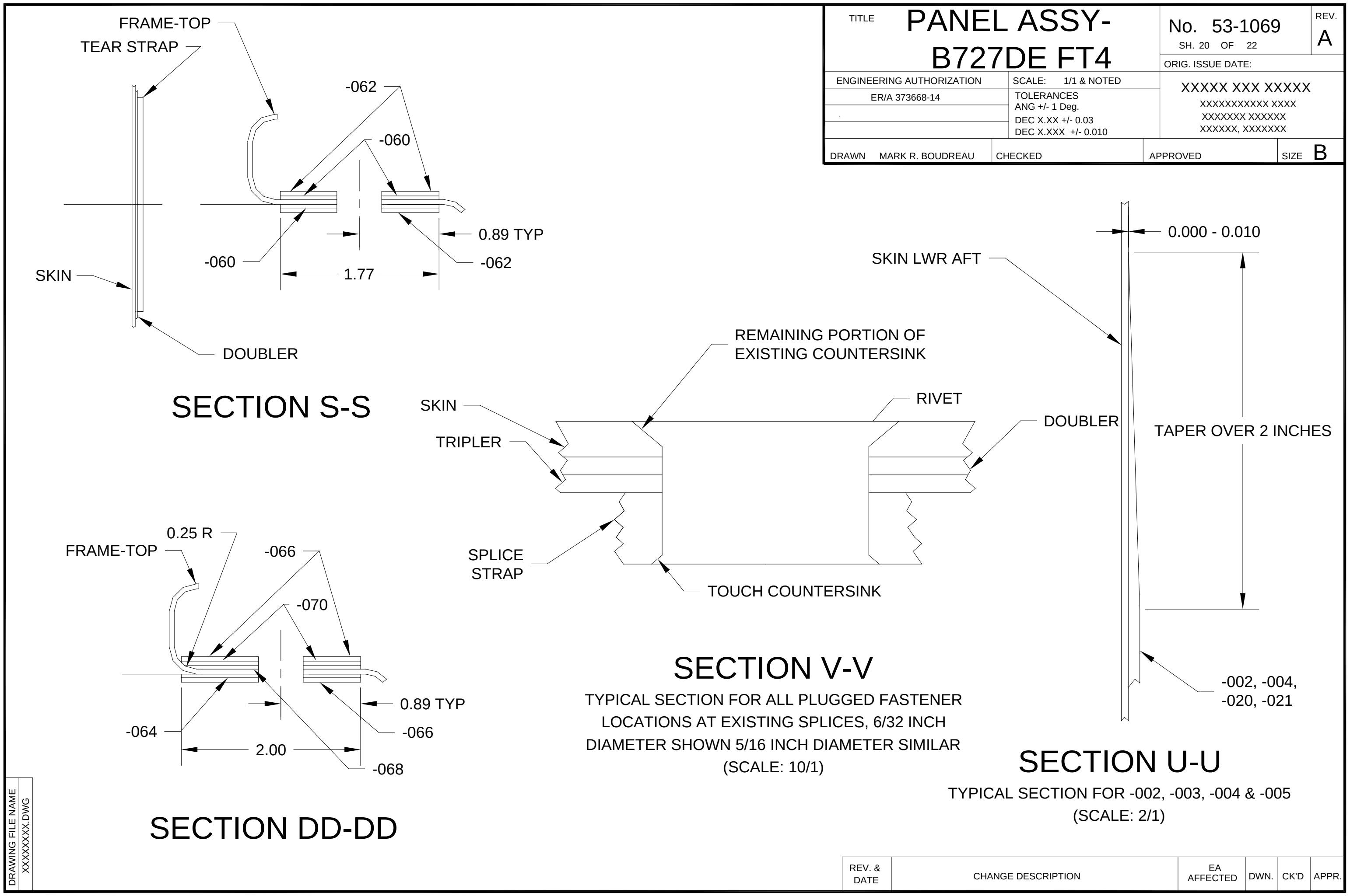


SECTION T-T (A)

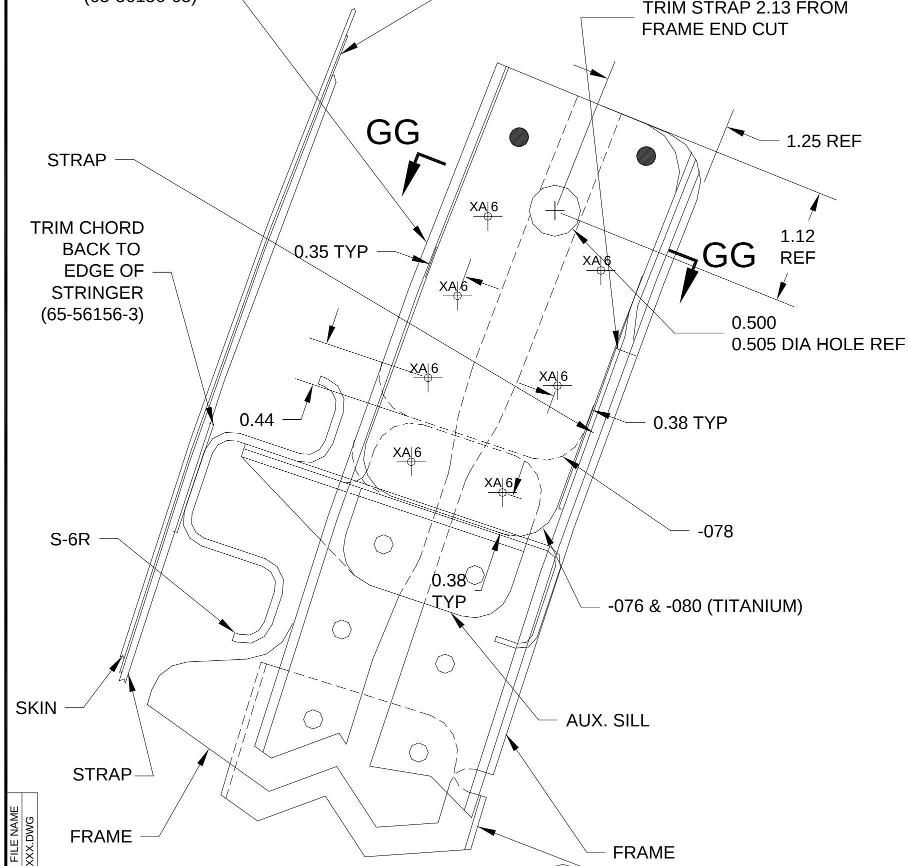
TYPICAL SECTION FOR ALL FRAMES

LEFT HAND SHOWN, RIGHT HAND OPPOSITE

DRAWING FILE NAME
XXXXXXXX.DWG

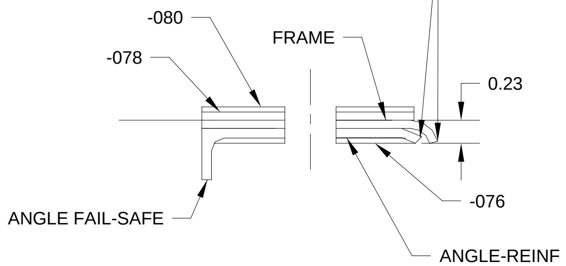

TITLE
PANEL ASSY-
B727DE FT4
No. 53-1069
SH. 20 OF 22
REV.
A
ORIG. ISSUE DATE:
ENGINEERING AUTHORIZATION
ER/A 373668-14
SCALE: 1/1 & NOTED
TOLERANCES
ANG +/- 1 Deg.
DEC X.XX +/- 0.03
DEC X.XXX +/- 0.010
XXXXX XXX XXXXX
XXXXXXXXXXX XXXX
XXXXXXX XXXXXX
XXXXXX, XXXXXXX
DRAWN MARK R. BOUDREAU
CHECKED
APPROVED
SIZE B
FRAME-TOP
TEAR STRAP
-062
-060
SKIN
-060
1.77
0.89 TYP
-062
DOUBLER
SECTION S-S
FRAME-TOP
0.25 R
-066
-070
-064
2.00
0.89 TYP
-066
-068
SECTION DD-DD
REMAINING PORTION OF
EXISTING COUNTERSINK
SKIN
RIVET
TRIPLER
DOUBLER
SPLICE
STRAP
TOUCH COUNTERSINK
SECTION V-V
TYPICAL SECTION FOR ALL PLUGGED FASTENER
LOCATIONS AT EXISTING SPLICES, 6/32 INCH
DIAMETER SHOWN 5/16 INCH DIAMETER SIMILAR
(SCALE: 10/1)
0.000 - 0.010
SKIN LWR AFT
TAPER OVER 2 INCHES
-002, -004,
-020, -021
SECTION U-U
TYPICAL SECTION FOR -002, -003, -004 & -005
(SCALE: 2/1)
DRAWING FILE NAME
XXXXXXXX.DWG
REV. &
DATE
CHANGE DESCRIPTION
EA
AFFECTED
DWN.
CK'D
APPR.

TITLE PANEL ASSY- B727DE FT4	No. 53-1069 SH. 22 OF 22	REV. A
ENGINEERING AUTHORIZATION ER/A 373668-14	SCALE: 1/1 & NOTED TOLERANCES ANG +/- 1 Deg. DEC X.XX +/- 0.03 DEC X.XXX +/- 0.010	ORIG. ISSUE DATE: XXXXX XXX XXXXX XXXXXXXXXXX XXXX XXXXXXX XXXXXX XXXXXX, XXXXXXX
DRAWN MARK R. BOUDREAU	CHECKED	APPROVED SIZE B



SECTION FF-FF (A)

TRIM OFF INBOARD/AFT FLANGE OF FRAME & ANGLE- REINF AS SHOWN IN SECTION T-T EXCEPT UTILIZE THE 0.23 DIMENSION SHOWN BELOW INSTEAD OF THE 0.89 DIMENSION



SECTION GG-GG

DRAWING FILE NAME XXXXXXXX.DWG

TITLE **PANEL ASSY- B727DE FT4**

No. 53-1069 SH. 1 OF 22

REV. A

ORIG. ISSUE DATE:

ENGINEERING AUTHORIZATION: ER/A 373668-14

SCALE: 1/1 & NOTED

TOLERANCES
ANG +/- 1 Deg.
DEC X.XX +/- 0.03
DEC X.XXX +/- 0.010

XXXXX XXX XXXXX
XXXXXXXXXXX XXXX
XXXXXXX XXXXXX
XXXXXX, XXXXXXX

DRAWN MARK R. BOUDREAU | CHECKED | APPROVED | SIZE B

USED ON	DASH NUMBER
	-500

QTY.	ITEM	PART NUMBER	KEYWORD	SUPERSEDES	MATERIAL	STATUS
1		-046	SHIM		0.090 X 6 X 9 8.	FS
1		-048	SHIM		0.090 X 6 X 9 8.	FS
1		-050	SHIM		0.090 X 6 X 9 8.	FS
1		-052	SHIM		0.090 X 6 X 9 8.	FS
1		-054	SHIM		0.090 X 6 X 9 8.	FS
1		-056	SHIM		0.025 X 2 X 9 8.	FS
1		-058	FILLER		0.063 X 9 X 18 8.	FS
14		-060	DOUBLER		0.040 X 2 X 5 8.	FS
14		-062	DOUBLER		0.050 X 2 X 4 18.	FS
3		-064	DOUBLER		0.040 X 2 X 5 8.	FS
6		-066	DOUBLER		0.050 X 2 X 5 18.	FS
3		-068	DOUBLER		0.040 X 2 X 5 8.	FS
3		-070	DOUBLER		0.050 X 2 X 5 18.	FS
1		-072	DOUBLER		0.080 X 2 X 5 8.	FS
1		-074	DOUBLER		0.050 X 2 X 5 18.	FS
1		-076	DOUBLER		0.050 X 3 X 5 18.	FS
1		-078	DOUBLER		0.080 X 3 X 5 8.	FS
1		-080	DOUBLER		0.050 X 3 X 5 18.	FS

USED ON	DASH NUMBER
	-500

QTY.	ITEM	PART NUMBER	KEYWORD	SUPERSEDES	MATERIAL	STATUS
1		-002	FILLER		0.063 X 8 X 9 8.	FS
1		-004	FILLER		0.063 X 8 X 9 8.	FS
2		-006	DOUBLER		0.050 X 5 X 117 8.	FS
2		-007	DOUBLER		0.050 X 5 X 117 8.	FS
1		-008	DOUBLER		0.050 X 6 X 117 8.	FS
1		-009	DOUBLER		0.050 X 6 X 117 8.	FS
3		-010	FILLER		0.063 X 9 X 18 8.	FS
1		-012	FILLER		0.063 X 9 X 17 8.	FS
1		-014	SHIM		0.020 X 7 X 9 8.	FS
1		-016	FILLER		0.063 X 9 X 17 8.	FS
1		-018	FILLER		0.063 X 9 X 17 8.	FS
1		-020	FILLER		0.063 X 8 X 9 8.	FS
1		-021	FILLER		0.063 X 8 X 9 8.	FS
1		-022	SHIM		0.040 X 3 X 9 8.	FS
1		-024	SHIM		0.040 X 5 X 5 8.	FS
1		-026	SHIM		0.040 X 5 X 5 8.	FS
1		-028	FILLER		0.020 X 2 X 9 8.	FS
2		-030	SHIM		0.063 X 3 X 15 8.	FS
2		-032	DOUBLER		0.050 X 5 X 63 8.	FS
4		-034	DOUBLER		0.050 X 5 X 63 8.	FS
2		-036	SHIM		0.063 X 2 X 9 8.	FS
1		-038	SHIM		0.040 X 5 X 7 8.	FS
1		-040	SHIM		0.063 X 4 X 5 8.	FS
1		-042	SHIM		0.050 X 7 X 13 8.	FS
1		-044	DOUBLER		0.063 X 14 X 77 8.	FS
1		-045	DOUBLER		0.063 X 14 X 77 8.	FS

NOTES:

1. ALL DIMENSIONS ARE IN INCHES EXCEPT AS NOTED.
2. EXISTING FASTENER LOCATION AND DIAMETER IS X SYMBOL WITH THE NUMBER IN THE RIGHT HAND UPPER QUADRANT INDICATING THE DIAMETER IN 1/32 INCREMENTS AND THE LETTERS IN THE UPPER LEFT HAND QUADRANT INDICATING THE FASTENER TYPE.
3. ADDED FASTENER LOCATION AND DIAMETER IS X SYMBOL WITH NUMBER IN THE RIGHT HAND UPPER QUADRANT INDICATING THE DIAMETER IN 1/32 INCREMENTS AND THE LETTERS IN THE UPPER LEFT HAND QUADRANT INDICATING THE FASTENTER TYPE.

DRAWING FILE NAME XXXXXXXX.DWG

REV. & DATE	CHANGE DESCRIPTION	EA AFFECTED	DWN.	CK'D	APPR.
REV. A 08/19/03	REVISED END DETAIL FOR FRAME AND MOVED THE FRAME ATTACHMENT LOCATION.	ER/A 373668-14	MRB		

APPENDIX B—RATIONALE BEHIND REPAIR TYPES

The repair types were decided based on the type of anomalies in the repair patches (design, repair installation, or in-service anomalies). The purpose of these defects was to reduce the effectiveness of the repairs in reducing the crack growth rate of the cracks, which were located at the mid-bay locations of the fuselage panel. For the four phases of the test, the rationale behind repair types is described below.

B.1 UNDERDESIGNED REPAIRS

A good design boron/epoxy (B/Ep) patch was considered as the basis for underdesigning the repairs. To achieve the underdesigned B/Ep repair configuration, the following procedure was followed:

1. Determine stresses at the prospective crack location using global finite element analysis

2. The stresses at the prospective crack location were used in the Composite Repair of Aircraft Structure (CRAS) software developed by the Boeing Company under U.S. Air Force funding to develop the patch sizing

Using CRAS, a good B/EP patch design for a 3″-long through-thickness crack on a 0.04″ skin has the following configuration:

- Ply layup:
  - 9 plies [20°/-20°/20°/-20°/0°/-20°/20°/-20°/20°]
  - 0° ply is perpendicular to the crack direction

- Dimensions and fiber directions (L x W, θ):
  - Ply 1: 8.00″ x 5.00″, 20°
  - Ply 2: 7.75″ x 4.75″, -20°
  - Ply 3: 7.50″ x 4.50″, 20°
  - Ply 4: 7.25″ x 4.25″, -20°
  - Ply 5: 7.00″ x 4.00″, 0°
  - Ply 6: 6.75″ x 3.75″, -20°
  - Ply 7: 6.50″ x 3.50″, 20°
  - Ply 8: 6.25″ x 3.25″, -20°
  - Ply 9: 6.00″ x 3.00″, 20°

- Patch stiffness ratio: 1.9

- Patch thickness: 0.051″

A well-designed boron/epoxy repair patch was installed on the panel and was referred to as Reference boron/epoxy repair (R-BE). Based on the configuration of a good B/Ep patch, the configuration of the under-designed B/Ep patch was decided by reducing the number of plies and the width of the patch. The underdesigned B/Ep patch configuration is as follows:

- Ply layup:

  - 5 plies [20°/-20°/0°/-20°/20°]
  - 0° ply is perpendicular to the crack direction

- Dimensions and fiber directions (L x W, θ):

  - Ply 1: 8.00″ x 3.00″, 20°
  - Ply 2: 7.75″ x 2.75″, -20°
  - Ply 3: 7.50″ x 2.50″, 0°
  - Ply 4: 7.25″ x 2.25″, -20°
  - Ply 5: 7.00″ x 2.00″, 20°

- Patch stiffness ratio: 1.16

- Patch thickness: 0.029″

For underdesigned aluminum repairs, an aluminum repair with three doublers was considered as reference. The configuration of the reference aluminum repair was as follows:

- Number of doublers: 3

- Dimensions (L x W x T):

  - Sheet 1: 6.00″ x 3.00″ x 0.020″
  - Sheet 2: 5.40″ x 2.40″ x 0.020″
  - Sheet 3: 4.80″ x 1.80″ x 0.020″

- Patch stiffness ratio: 1.5

Based on the reference aluminum patch, the configuration of the underdesigned aluminum patch was decided by reducing the number of doublers. The length of the patch was also increased from 6″ to 8″ to make sure that the crack did not grow beyond the patch boundary. Therefore, the configuration of the underdesigned aluminum patch was as follows:

- Number of doublers: 2

- Dimensions (L x W x T):

  - Sheet 1: 8.00″ x 3.00″ x 0.020″
  - Sheet 2: 7.20″ x 2.20″ x 0.020″

- Patch stiffness ratio: 1

The configuration of the underdesigned aluminum patch with one doubler is as follows:

- Number of doublers: 1
- Dimensions (L x W x T):
  - Sheet 1: 8.00″ x 3.00″ x 0.020″
- Patch stiffness ratio: 0.5

Therefore, Phase 1 comprised one underdesigned B/Ep patch and two underdesigned aluminum patches with one doubler and two doublers, respectively. The patch configuration of underdesigned repairs is shown in appendix C.

B.2 PARTIAL DISBOND REPAIRS

The repairs in Phase 2 had the same configuration as the B/Ep patch and aluminum patch with two doublers in Phase 1. To further reduce the effectiveness of the repair patches, intentional partial disbonds were introduced on the repairs at the patch edges and crack tips. The disbonds were located between the patches and the aluminum skin. The disbonds were typically of two types—one at the crack tip and one at the patch boundary.

1. Crack tip disbonds: The rationale behind the crack disbonds was based on a literature survey and CRAS predictions. According to the literature, disbonds at the crack tips have negligible effect on crack growth. However, in these studies, the crack tip was stop-drilled and, in addition, the disbond does not fully cover the crack length. Furthermore, CRAS predictions showed that, for the case in which the disbond surrounds the whole crack length, the stress intensity factor at the crack tips can increase by 10%–20% compared to the repair patch without any disbond surrounding the crack. For the aluminum patch, the disbond was 3.5″ x 0.5″ surrounding the crack; however, circular disbonds of 0.5″ in diameter were located only at the two tips of the crack for the B/Ep patch. This was to avoid any unpredictable results due to the underestimation of residual thermal stresses in the case of the B/EP repair patch.

2. Patch edge disbonds: Patch edge disbond locations were decided based on the literature survey, which showed that the edge disbonds can cause a total delamination of the substrate because of the high load transfer between skin and the patch. The disbonds were introduced at the patch corner as the load transfer is highest at this region. The disbond in the middle of the patch was introduced because, when the disbond grows, it may link up with the disbond around the crack.

B.3 COMPLIANT B/EP REPAIRS

For Phase 3, only B/Ep patches were installed. The dimensions of these patches were exactly the same as underdesigned B/Ep and partial-disbond B/Ep repairs, but the fibers were oriented in the axial direction, along the crack length (perpendicular to the fiber orientation of the B/Ep repairs in Phase 1 and Phase 2). The purpose of these repairs was to study the effect of repair stiffness and the capabilities of commercially available NDIs and structural health monitoring to monitor damage growth.

B.4 REPAIRS WITH IMPACT DAMAGE

After subjecting the R-BE, U-BE, and U-A2 repairs to 60,000 fatigue cycles, these repairs were impacted with 300 lb-in and 500 lb-in force at the crack tips. The purpose was to introduce the damage in the patch at the crack tip locations and observe if the repairs were still capable of reducing the fatigue crack growth.

APPENDIX C—DAMAGE SCENARIOS, PATCH CONFIGURATIONS, AND LOCATIONS OF STRAIN GAGES

The damage scenario, patch configurations, and strain gages locations for all repairs are provided in this appendix. Through-thickness notches were introduced on the fuselage panel. These damages were repaired using both boron/epoxy (B/EP) and aluminum repair patches.

Strain gages were placed on the fuselage panel skin, repair patches, and the substructure of the panel to monitor the strain distribution and ensure proper load introduction. The type and location of the strain gages used are provided in the tables and figures of this appendix. All strain gages were 350 ohms with a Constantan foil alloy. A three-conductor, Teflon®-coated twisted cable was used for connection to the strain gages. The strain gage, coating, cable, and adhesive types for each panel are listed in table C-1. The strain gages installed on the inner surface of the panel and on the substructure were exposed to water. To avoid ingression of water in the gages, these gages were covered using a Teflon® tape and then sealed with B-1/2 sealant.

The substructure strain gages were installed at the start of the testing irrespective of the test phases. Table C-2 and figure C-1 show the locations of these strain gages. A total of seven gages were installed at the flange of the stringers and 12 gages were installed at the outer and inner flanges of the frames. Figures C-2 and C-3 show the placement of the strain gages on the frames and stringers of the fuselage panel substructure. These strain gages were removed at the later stages of the testing because of channel limitations.

To collect the baseline strain data, the strain gages were also installed on the fuselage skin before any damage to the panel was introduced. Table C-3 lists the gages installed on the pristine panel and figure C-4 shows their locations. Figure C-5 shows the close-up view of these gages.

This appendix shows the locations and configurations of the entire repair patches installed during the four phases of the tests, as well as the locations of strain gages installed on the fuselage skin and repair patches for each repair. The subsequent paragraphs explain the details of the repair patch locations, patch configurations, and strain gage locations.

During the test, through-thickness mid-bay cracks were introduced on the panel; these cracks were repaired using different types of patches. Table C-4 explains the nomenclature used for each type of repair. Figure C-6 shows the locations of the repairs.

Table C-1. General strain gage information

Phase	Reference Repair	Phase 1: Underdesigned Repairs	Phase 2: Partial Disbond Repairs	Phase 3: Compliant Repairs	Phase 4: Repairs with Impact Damage
Gage No. Axial	R-BE Repair S10, S11, S16 IS10, IS11, IS16 1RF, 1RA	U-BE Repair S14, S15, S18 IS14, IS15, IS18 1BF, 1BA	D-BE Repair S21, S22, S26 IS21, IS22, IS26 2BF, 2BA	C-BE Repair S28, S29, S34 IS28, IS29, IS34 3BF, 3BA	U-BE Repair With Impact Damage S14, S15, IS14, IS15, IS18
		U-A1 Repair S23, S24, S27 IS23, IS24, IS27 1UAF, 1UAA	D-A2 Repair S19, S20, S25 IS19, IS20, IS25 2AF, 2AA	CD-BE Repair S30, S31, S35 IS30, IS31, IS35 3BDF, 3BDA	R-BE Repair With Impact Damage S10, S11, IS10, IS11, IS16
		U-A2 Repair S12, S13, S17 IS12, IS13, IS17 1AF, 1AA			U-A2 Repair With Impact Damage S12, S13, IS12, IS13, IS17
	Frames F01–F10	Frames F01–F10	Frames F01–F10	No Frame gages	No Frame gages
	Longerons L01–L05	Longerons L01–L05	Longerons L01–L05	No Longeron gages	No Longeron gages
Gage No. Rosette	R 01 – R 05	R 01 – R 05	R 04	No Rosette gages	No Rosette gages
Vishay Micro-Measurement Part No., Axial	CEA-13-062UW-350				
Vishay Micro-Measurement Part No., Rosette	CEA-13-062UR-350				
Vishay Micro-Measurement Part No., Coatings	M-Coat A				
Vishay Micro-Measurement Part No., Cable	330-FTE				
Vishay Micro-Measurement Part No., Adhesive	M-Bond 200/AE-10				

Table C-2. Substructure strain gage locations

Strain Gage No.	Location	
L01	Outside of Longeron Flange S5-R	Midway between Station 1050 and 1070 (10), Center of Flange (0.44)
L02	Outside of Longeron Flange S-4R	Midway between Station 1050 and 1070 (10), Center of Flange (0.44)
L03	Outside of Longeron Flange S-3R	Midway between Station 1050 and 1070 (10), Center of Flange (0.44)
L04	Outside of Longeron Flange S-2R	Midway between Station 1050 and 1070 (10), Center of Flange (0.44)
L05	Outside of Longeron Flange S-3R	Midway between Station 1010 and 1030 (10), Center of Flange (0.44)
F01	Outside of Frame Flange, Station 1050	Midway between S-4R and S-5R (4.8), Center of Flange (0.5)
F02	Inside of Frame Flange, Station 1050	Midway between S-4R and S-5R (4.8), Center of Flange (0.5)
F03	Outside of Frame Flange, Station 1050	Midway between S-3R and S-4R (4.8), Center of Flange (0.5)
F04	Inside of Frame Flange, Station 1050	Midway between S-3R and S-4R (4.8), Center of Flange (0.5)
F05	Outside of Frame Flange, Station 1070	Midway between S-4R and S-5R (4.8), Center of Flange (0.5)
F06	Inside of Frame Flange, Station 1070	Midway between S-4R and S-5R (4.8), Center of Flange (0.5)
F07	Outside of Frame Flange, Station 1070	Midway between S-3R and S-4R (4.8), Center of Flange (0.5)
F08	Inside of Frame Flange, Station 1070	Midway between S-3R and S-4R (4.8), Center of Flange (0.5)
F09	Outside of Frame Flange, Station 1030	Midway between S-2R and S-3R (4.8), Center of Flange (0.5)
F10	Inside of Frame Flange, Station 1030	Midway between S-2R and S-3R (4.8), Center of Flange (0.5)

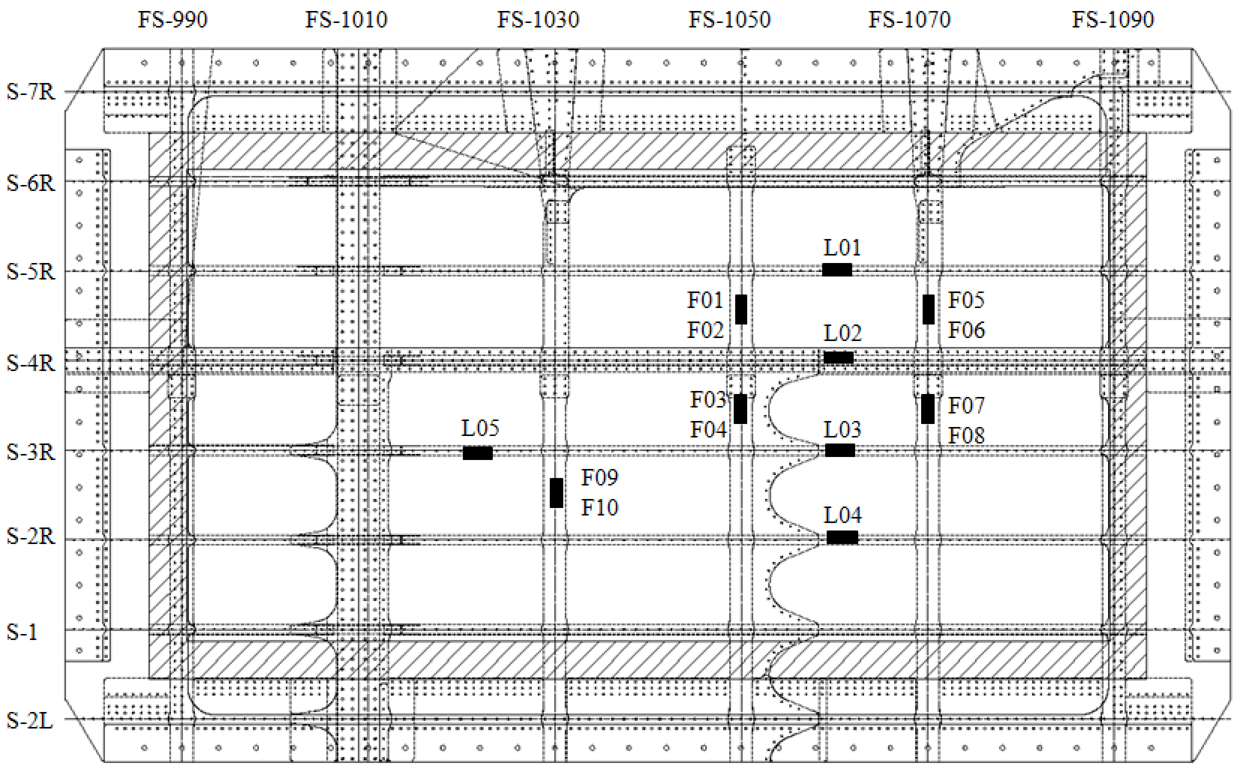


Figure C-1. Substructure strain gages

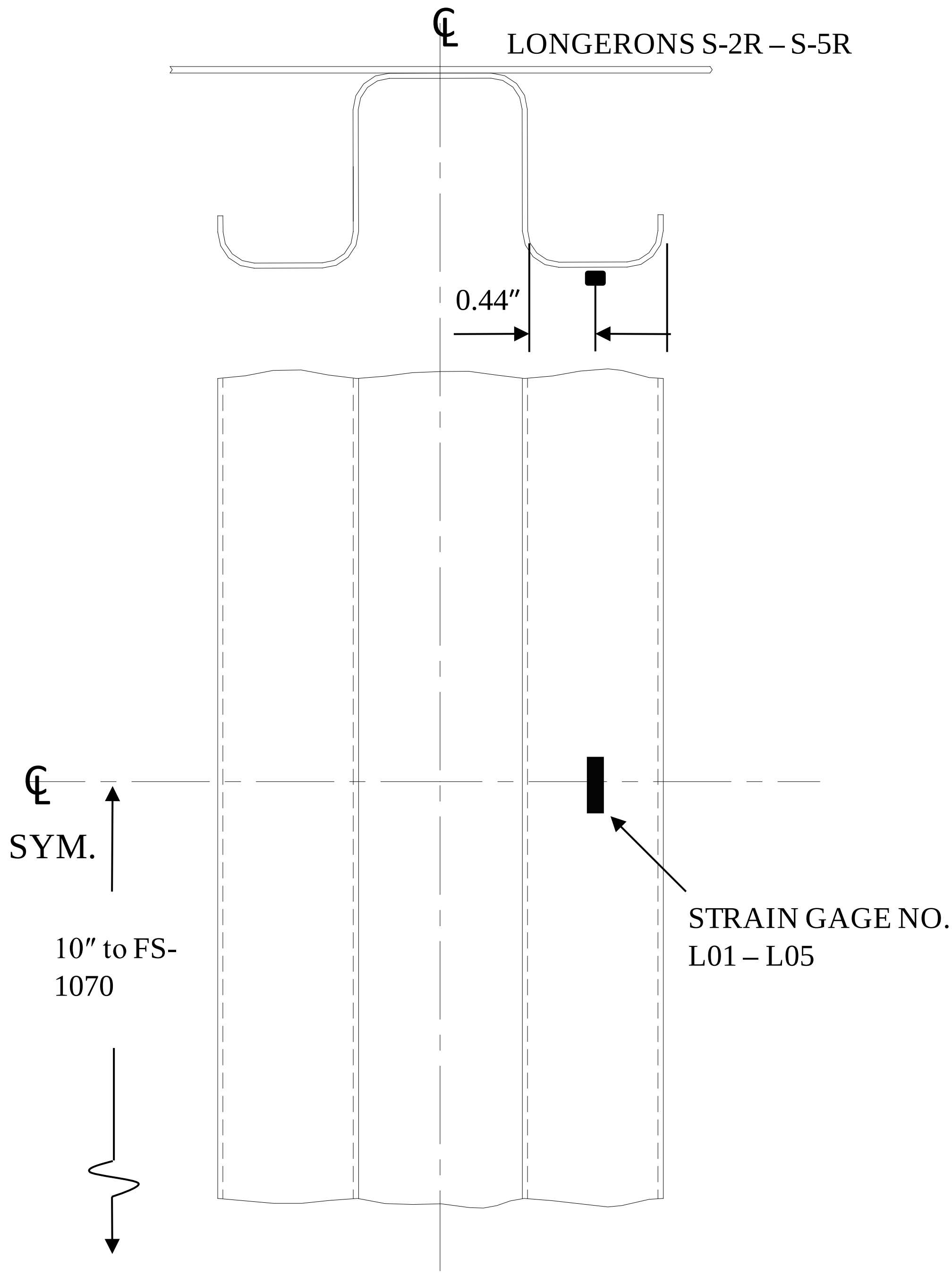


Figure C-2. Placement of axial strain gages at the cap of the stringers (longerons) of the panel

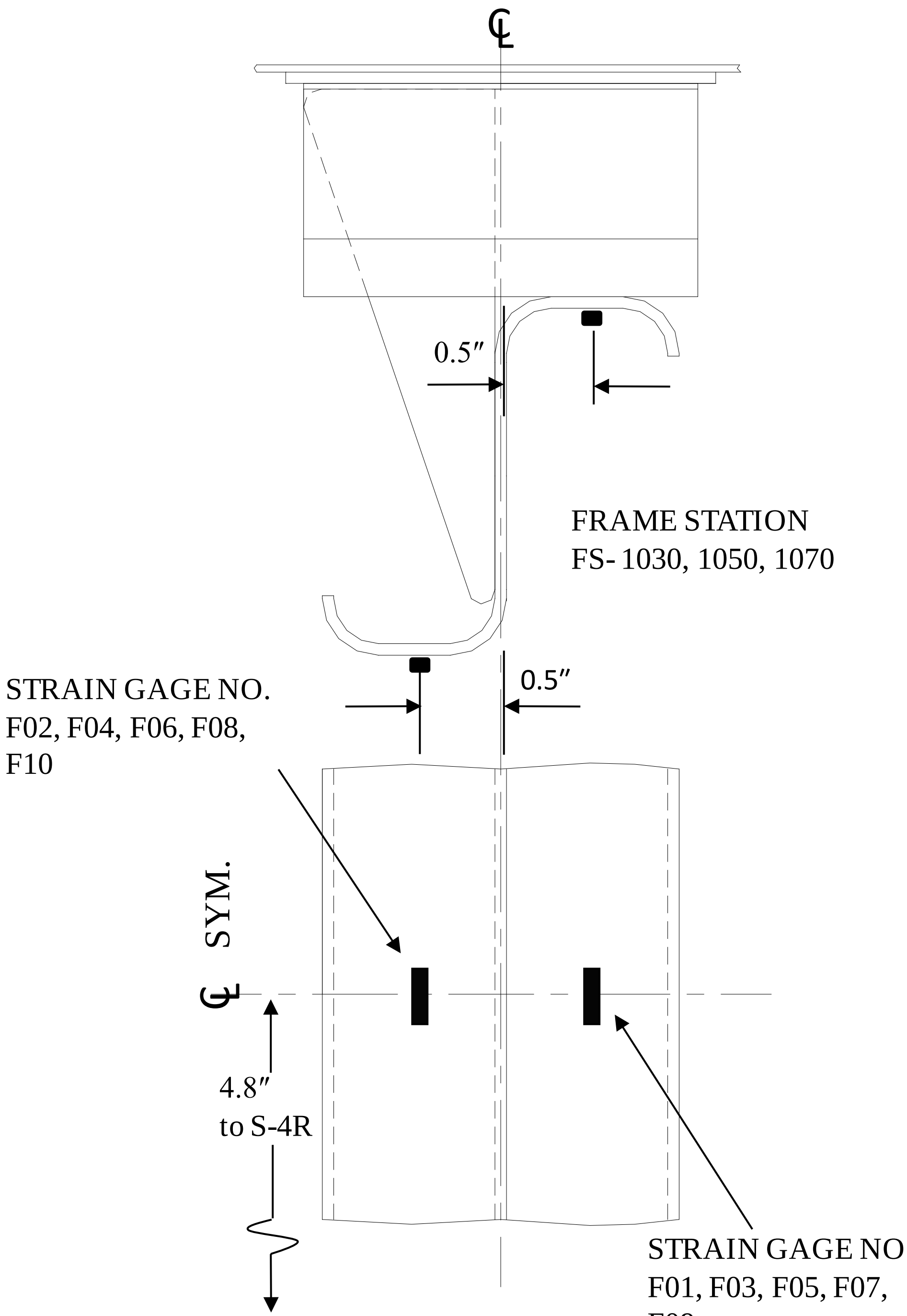


Figure C-3. Placement of axial strain gages at the inner and outer cap of the frames in the panel

Table C-3. Pristine panel strain gage locations

Strain Gage No.	Location	
R01-L R01-45 R01-T	Exterior surface of skin	Midway between Frame Stations 1030 and 1050 (10) and Longerons S-4R and S-5R (4.8)
R02-L R02-45 R02-T	Exterior surface of skin	Midway between Frame Stations 1050 and 1070 (10) and Longerons S-4R and S-5R (4.8)
R03-L R03-45 R03-T	Exterior surface of skin	Midway between Frame Stations 1070 and 1090 (10) and Longerons S-4R and S-5R (4.8)
R04-L R04-45 R04-T	Exterior surface of skin	Midway between Frame Stations 1010 and 1030 (10) and Longerons S-2R and S-3R (4.8)
R05-L R05-45 R05-T	Exterior surface of skin	Midway between Frame Stations 1050 and 1070 (10) and Longerons S-2R and S-3R (4.8)
S06	Exterior surface of skin	Midway between Frame Stations 1050 and 1070 (10) and Longerons S-3R and S-4R (4.8)
S07	Exterior surface of skin	Midway between Frame Stations 1070 and 1090 (10) and Longerons S-3R and S-4R (4.8)
S08	Exterior surface of skin	Midway between Frame Stations 1030 and 1050 (10) and Longerons S-2R and S-3R (4.8)
S09	Exterior surface of skin	Midway between Frame Stations 1070 and 1090 (10) and Longerons S-2R and S-3R (4.8)
IS01	Interior surface of skin	Midway between Frame Stations 1010 and 1030 (10) and Longerons S-2R and S-3R (4.8)
IS02	Interior surface of skin	Midway between Frame Stations 1030 and 1050 (10) and Longerons S-2R and S-3R (4.8)

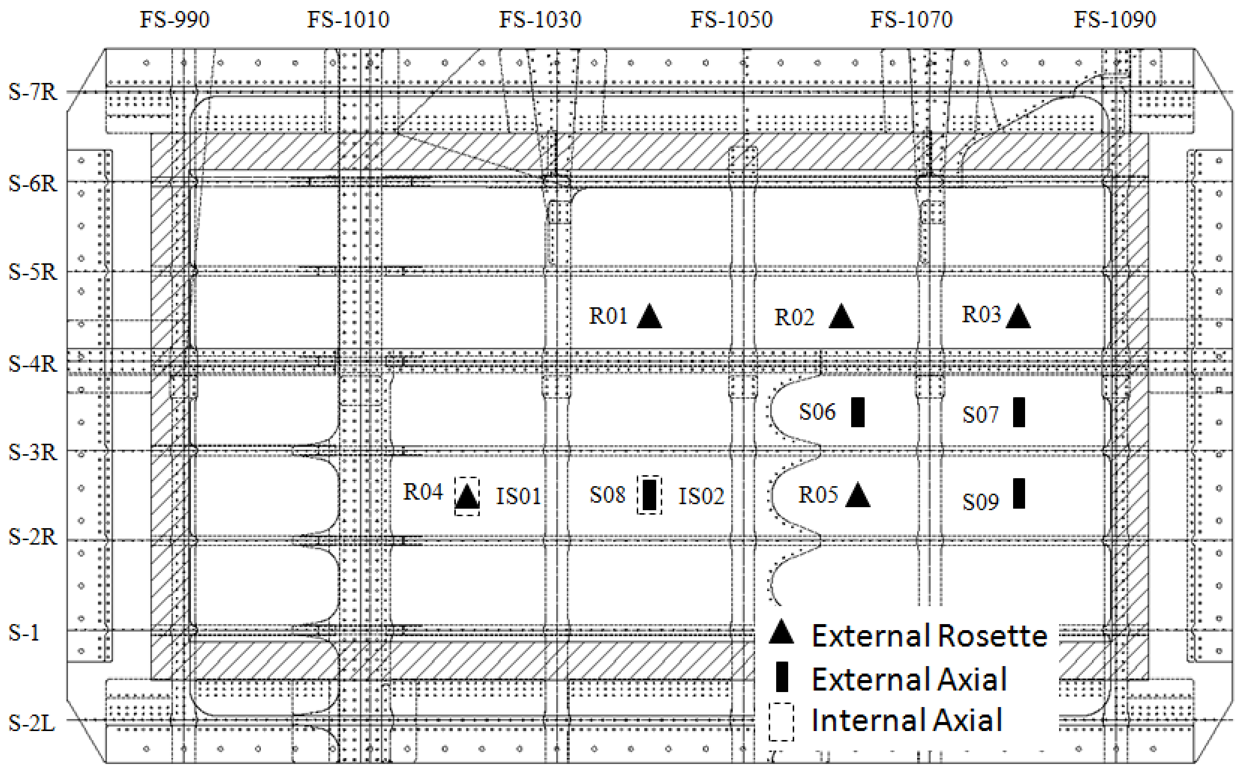


Figure C-4. Pristine panel strain gage locations

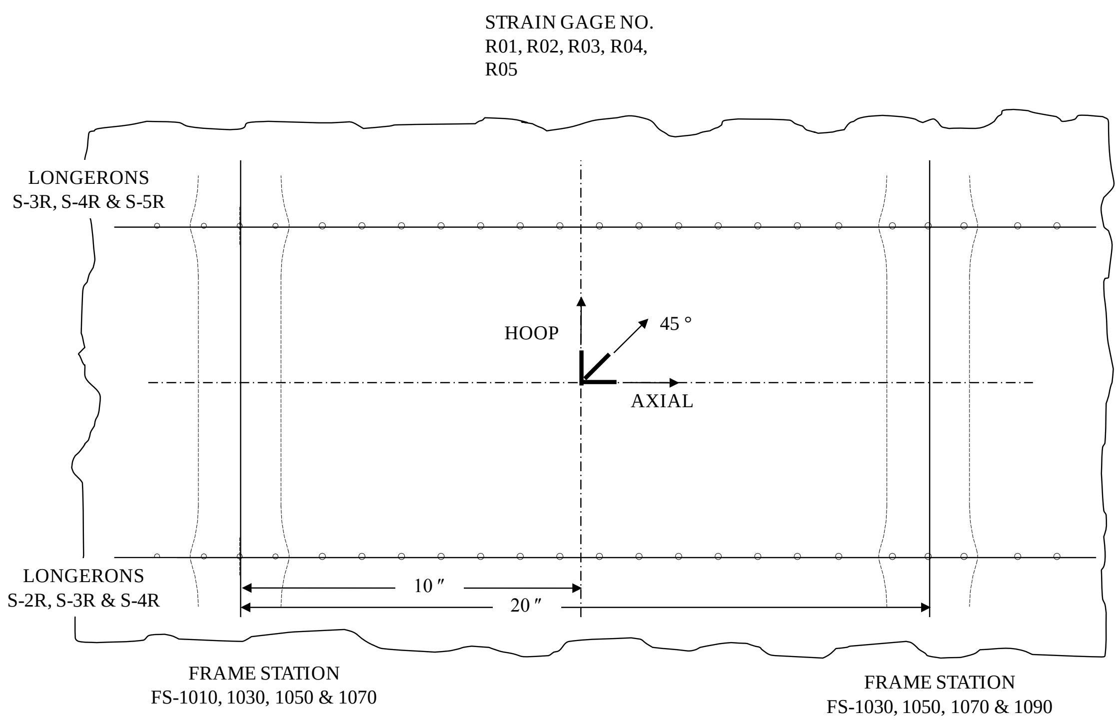


Figure C-5. Placement of rosette gages at the skin mid-bay location of the panel

Table C-4. Repair nomenclature

Test Phases	Repair Name	Repair Description
Reference Repair	R-BE	Reference B/Ep repair
Phase 1: Underdesigned Repairs	U-BE	Underdesigned B/Ep repair
	U-A1	Underdesigned aluminum repair having a single aluminum doubler, 0.02″ thick
	U-A2	Underdesigned aluminum repair having two aluminum doublers, each 0.02″ thick
Phase 2: Partial Disbond Repairs	D-BE	Partially disbonded and underdesigned B/Ep repair
	D-A2	Partially disbonded and underdesigned aluminum repair having two aluminum doublers, each 0.02″ thick
Phase 3: Compliant B/Ep Repairs	C-BE	Compliant B/Ep repair
	CD-BE	Compliant B/Ep repair with partial disbonds
Phase 4: Repairs With Impact Damage	U-BE	U-BE repair impacted after 60,000 fatigue cycles
	U-A2	U-A2 repair impacted after 60,000 fatigue cycles
	R-BE	R-BE repair impacted after 60,000 fatigue cycles

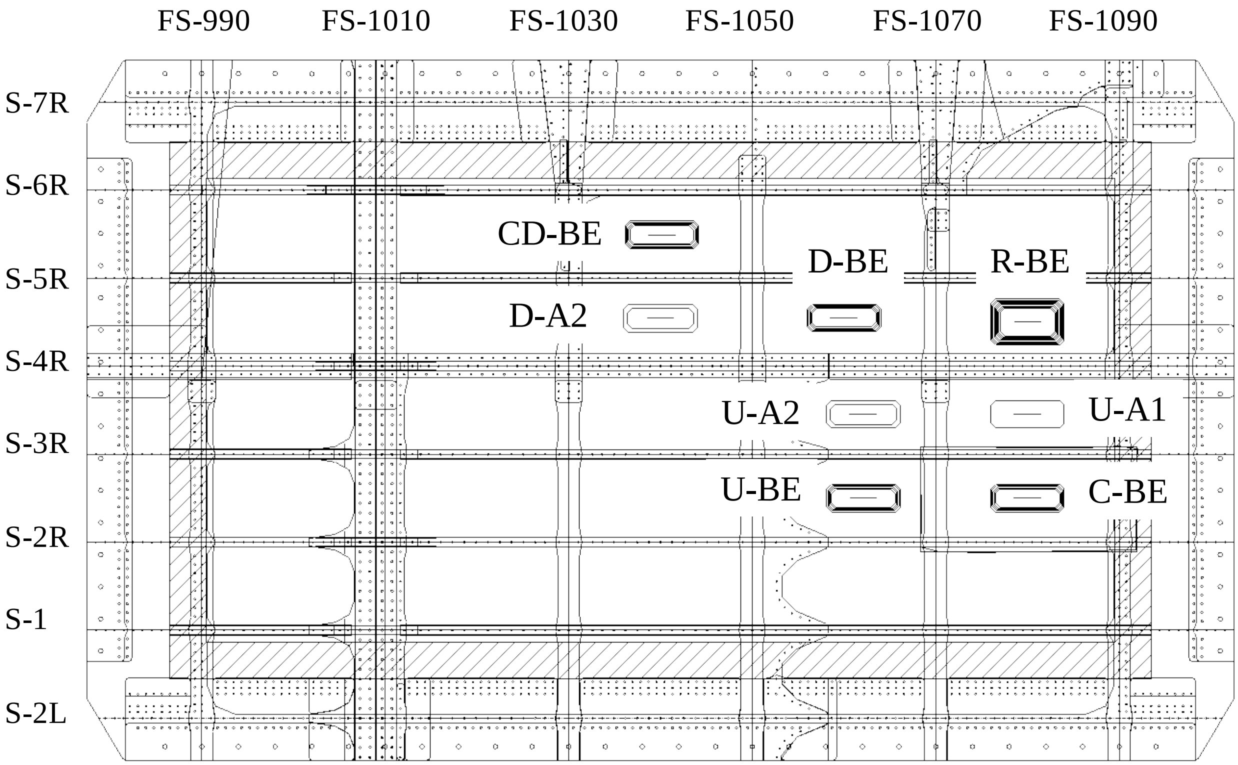


Figure C-6. Repair patch locations

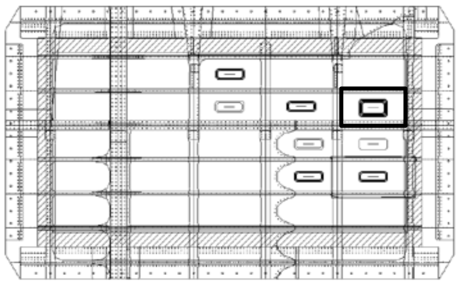
C.1 REFERENCE REPAIR

Reference boron/epoxy repair (R-BE): Table C-5 lists the strain gages used for the R-BE repair and figure C-7 shows the details of the R-BE repair and strain gages for this repair.

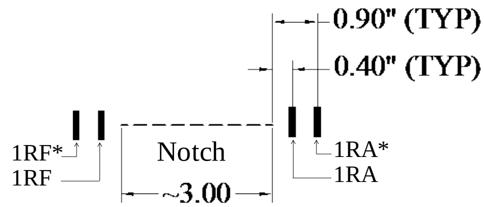
Table C-5. Strain gage locations for R-BE patch

Strain Gage No.	Location	
S10	Exterior Surface of Skin	0.75″ RIGHT of R-BE patch between Frame Stations 1070 and 1090 and Longerons S-4R and S-5R
S11	Exterior Surface of Skin	0.75″ LEFT of R-BE patch between Frame Stations 1070 and 1090 and Longerons S-4R and S-5R
S16	Exterior Surface of Patch	Center mid-bay R-BE patch between Frame Stations 1070 and 1090 and Longerons S-4R and S-5R
IS10	Interior Surface of Skin	0.75″ RIGHT of R-BE patch between Frame Stations 1070 and 1090 and Longerons S-4R and S-5R
IS11	Interior Surface of Skin	0.75″ LEFT of R-BE patch between Frame Stations 1070 and 1090 and Longerons S-4R and S-5R
IS16	Interior Surface of Skin	0.75″ RIGHT of mid-bay notch between Frame Stations 1070 and 1090 and Longerons S-4R and S-5R
1RF	Interior Surface of Skin	0.4″ FWD of notch tip between Frame Stations 1070 and 1090 and Longerons S-4R and S-5R (0–45,000 cycles)
1RF*	Interior Surface of Skin	0.9″ FWD of notch tip between Frame Stations 1070 and 1090 and Longerons S-4R and S-5R (45,000–60,000 cycles)
1RA	Interior Surface of Skin	0.4″ AFT of notch tip between Frame Stations 1070 and 1090 and Longerons S-4R and S-5R (0–45,000 cycles)
1RA*	Interior Surface of Skin	0.9″ AFT of notch tip between Frame Stations 1070 and 1090 and Longerons S-4R and S-5R (45,000–60,000 cycles)

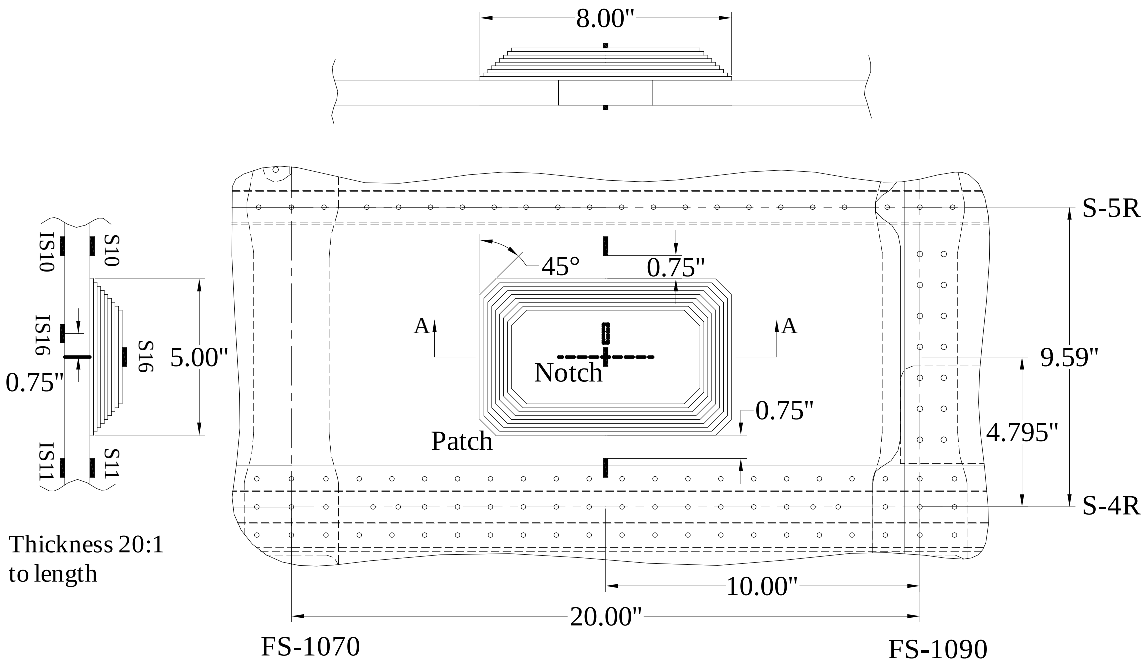
Note: * represents the progressive distance between the notch tip and the strain gage.



a) Repair Patch Location



b) Internal Notch Tip Gages



c) Repair patch, damages and strain gages locations and dimensions

MATERIAL	SHEETS/PLIES	LOCATION	FATIGUE CYCLES
Boron/Epoxy (9 Plies) 0º perpendicular to the crack	(Length × Width, Angle) Ply 1: 8.00″ × 5.00″ , +20° Ply 2: 7.75″ × 4.75″ , -20° Ply 3: 7.50″ × 4.50″ , +20° Ply 4: 7.25″ × 4.25″ , -20° Ply 5: 7.00″ × 4.00″ , 0° Ply 6: 6.75″ × 3.75″ , -20° Ply 7: 6.50″ × 3.50″ , +20° Ply 8: 6.25″ × 3.25″ , -20° Ply 9: 6.00″ × 3.00″ , +20° Patch Thickness: 0.051″ Patch Stiffness Ratio: 1.9 Taper ratio: 20:1	Midbay Between Frame Stations 1070 and 1090 and Longerons S-4R and S-5R	60,000

d) Repair patch details

Figure C-7. The R-BE repair patch: (a) repair patch location, (b) internal notch tip gages, (c) repair patch, damages, and strain gages locations and dimensions, and (d) repair patch details

C.2 PHASE 1: UNDERDESIGNED REPAIRS

1. Underdesigned B/Ep Repair (U-BE): Table C-6 lists the strain gages used for the U-BE repair and figure C-8 shows the details of the U-BE repair and strain gages for this repair.

2. Underdesigned Two-Layer Aluminum Repair (U-A2): Table C-7 lists the locations of the strain gages used for the U-A2 repair and figure C-9 shows the details and strain gages needed for this repair.

3. Underdesigned Single-Layer Aluminum Repair (U-A1): Table C-8 lists the strain gages used for the U-A1 repair and figure C-10 shows the details and strain gages needed for this repair.

C.3 PHASE 2: PARTIAL-DISBOND REPAIRS

1. Partial Disbond B/Ep Repair (D-BE): Table C-9 lists the strain gages used for the D-BE repair and figure C-11 shows the details and strain gages needed for this repair.

2. Partial Disbond Two-Layer Aluminum Repair (D-A2): Table C-10 lists the strain gages used for the D-A2 repair and figure C-12 shows the details and strain gages needed for this repair.

C.4 PHASE 3: COMPLIANT B/EP REPAIRS

1. Compliant B/Ep Repair (C-BE): Table C-11 lists the strain gages used for the C-BE repair and figure C-13 shows the details and strain gages needed for this repair.

2. Compliant B/Ep Repair with partial disbonds (CD-BE): Table C-12 lists the strain gages used for the CD-BE repair and figure C-14 shows the details and strain gages for this repair.

C.5 PHASE 4: REPAIRS WITH IMPACT DAMAGE

1. Reference B/Ep Repair with impact damage (R-BE): Table C-13 lists the strain gages used for the R-BE repair and figure C-15 shows the details and strain gages needed for this repair.

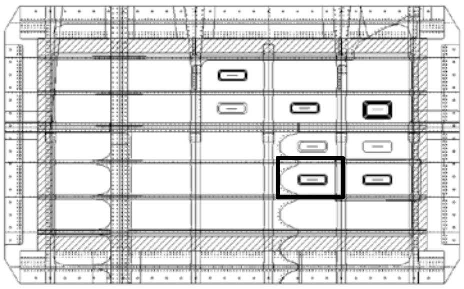
2. Underdesigned B/Ep Repair with impact damage (U-BE): Table C-14 lists the strain gages used for the U-BE repair and figure C-16 shows the details and strain gages needed for this repair.

3. Underdesigned Two-Layer Aluminum Repair with impact damage (U-A2): Table C-15 lists the strain gages used for the U-A2 repair and figure C-17 shows the details and strain gages needed for this repair.

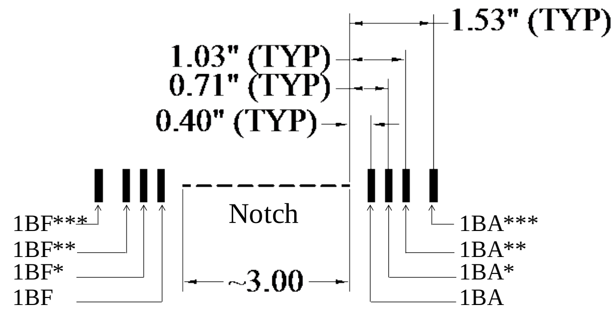
Table C-6. Strain gage locations for U-BE patch

Strain Gage No.	Location	
S14	Exterior Surface of Skin	0.75″ RIGHT of U-BE patch between Frame Stations 1050 and 1070 and Longerons S-2R and S-3R
S15	Exterior Surface of Skin	0.75″ LEFT of U-BE patch between Frame Stations 1050 and 1070 and Longerons S-2R and S-3R
S18	Exterior Surface of Patch	Center Mid-bay U-BE patch between Frame Stations 1050 and 1070 and Longerons S-2R and S-3R
IS14	Interior Surface of Skin	0.75″ RIGHT of U-BE patch between Frame Stations 1050 and 1070 and Longerons S-2R and S-3R
IS15	Interior Surface of Skin	0.75″ LEFT of U-BE patch between Frame Stations 1050 and 1070 and Longerons S-2R and S-3R
IS18	Interior Surface of Skin	0.75″ RIGHT of Mid-bay notch between Frame Stations 1050 and 1070 and Longerons S-2R and S-3R
1BF	Interior Surface of Skin	0.4″ FWD of notch tip between Frame Stations 1050 and 1070 and Longerons S-2R and S-3R (0–10,000 cycles)
1BF*	Interior Surface of Skin	0.71″ FWD of notch tip between Frame Stations 1050 and 1070 and Longerons S-2R and S-3R (10,000–30,000 cycles)
1BF**	Interior Surface of Skin	1.03″ FWD of notch tip between Frame Stations 1050 and 1070 and Longerons S-2R and S-3R (30,000–45,000 cycles)
1BF***	Interior Surface of Skin	1.53″ FWD of notch tip between Frame Stations 1050 and 1070 and Longerons S-2R and S-3R (45,000–60,000 cycles)
1BA	Interior Surface of Skin	0.4″ AFT of notch tip between Frame Stations 1050 and 1070 and Longerons S-2R and S-3R (0–10,000 cycles)
1BA*	Interior Surface of Skin	0.71″ AFT of notch tip between Frame Stations 1050 and 1070 and Longerons S-2R and S-3R (10,000–30,000 cycles)
1BA**	Interior Surface of Skin	1.03″ AFT of notch tip between Frame Stations 1050 and 1070 and Longerons S-2R and S-3R (30,000–45,000 cycles)
1BA***	Interior Surface of Skin	1.53″ AFT of notch tip between Frame Stations 1050 and 1070 and Longerons S-2R and S-3R (45,000–60,000 cycles)

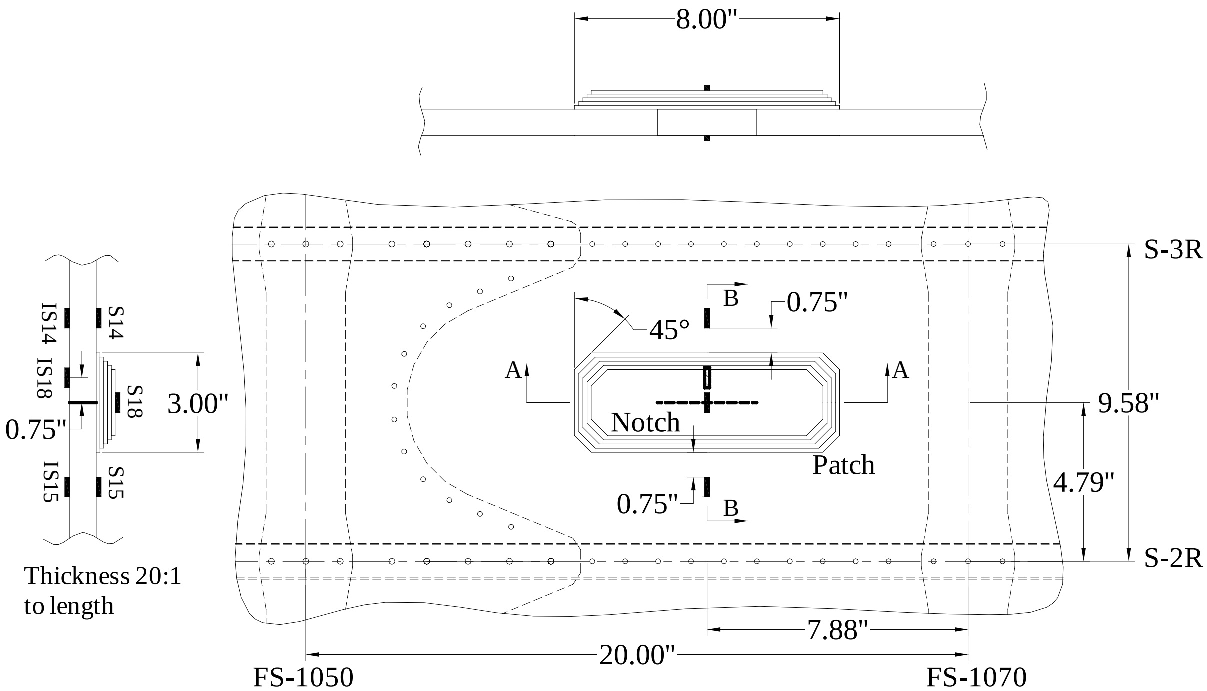
Note: *, **, and *** represent the progressive distance between the notch tip and strain gage.



a) Repair Patch Location



b) Internal Notch Tip Gages



c) Repair patch, damages and strain gages locations and dimensions

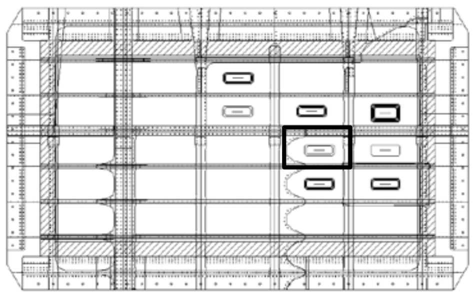
MATERIAL	SHEETS/PLIES	LOCATION	FATIGUE CYCLES
Boron/Epoxy (5 Plies) 0º perpendicular to the crack	(Length × Width, Angle) Ply 1: 8.00″ × 3.00″, +20º Ply 2: 7.75″ × 2.75″, -20º Ply 3: 7.50″ × 2.50″, 0º Ply 4: 7.25″ × 2.25″, -20º Ply 5: 7.00″ × 2.00″, +20º Patch Thickness: 0.029″ Patch Stiffness Ratio: 1.16 Taper ratio: 20:1	Midbay Between Frame Stations 1050 and 1070 and Longerons S-3R and S-4R	60,000

d) Repair patch details

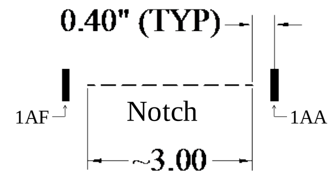
Figure C-8. The U-BE repair patch: (a) repair patch location, (b) internal notch tip gages, (c) repair patch, damages, and strain gage locations and dimensions, and (d) repair patch details

Table C-7. Strain gages locations for U-A2 patch

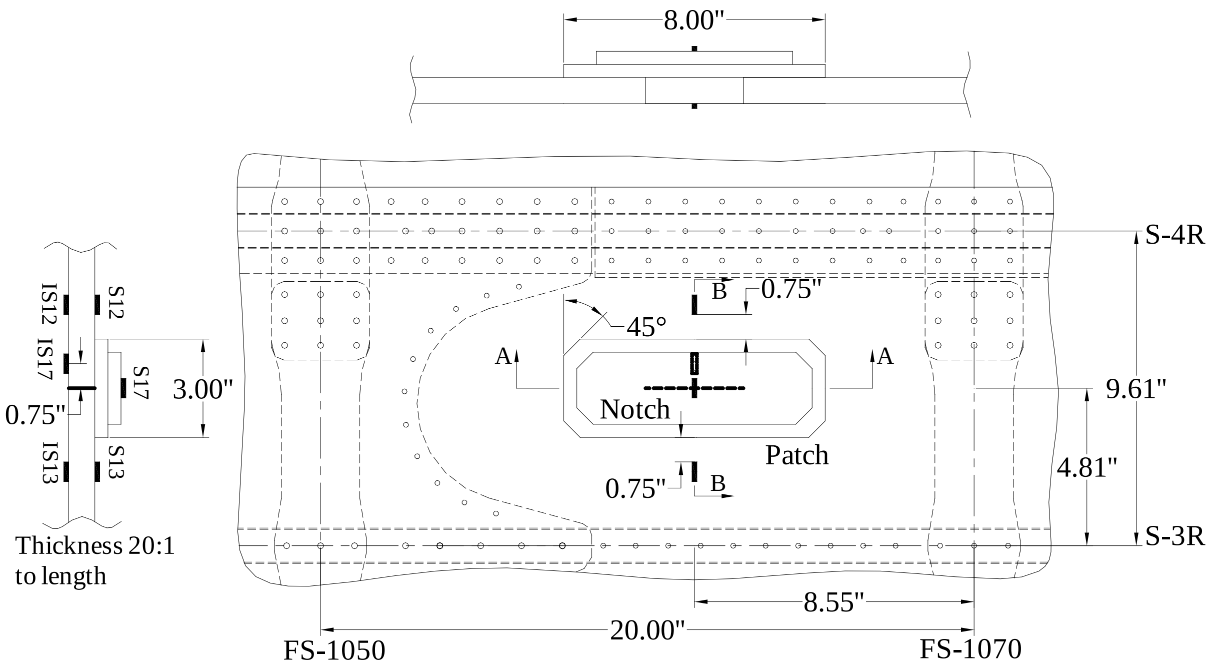
Strain Gage No.	Location	
S12	Exterior Surface of Skin	0.75″ RIGHT of U-A2 patch between Frame Stations 1050 and 1070 and Longerons S-3R and S-4R
S13	Exterior Surface of Skin	0.75″ LEFT of U-A2 patch between Frame Stations 1050 and 1070 and Longerons S-3R and S-4R
S17	Exterior Surface of Patch	Center Mid-bay U-A2 patch between Frame Stations 1050 and 1070 and Longerons S-3R and S-4R
IS12	Interior Surface of Skin	0.75″ RIGHT of U-A2 patch between Frame Stations 1050 and 1070 and Longerons S-3R and S-4R
IS13	Interior Surface of Skin	0.75″ LEFT of U-A2 patch between Frame Stations 1050 and 1070 and Longerons S-3R and S-4R
IS17	Interior Surface of Skin	0.75″ RIGHT of Mid-bay notch between Frame Stations 1050 and 1070 and Longerons S-3R and S-4R
1AF	Interior Surface of Skin	0.4″ FWD of notch tip between Frame Stations 1050 and 1070 and Longerons S-3R and S-4R (0–40,000 cycles)
1AA	Interior Surface of Skin	0.4″ AFT of notch tip between Frame Stations 1050 and 1070 and Longerons S-3R and S-4R (0–40,000 cycles)



a) Repair Patch Location



b) Internal Notch Tip Gages



c) Repair patch, damages and strain gages locations and dimensions

MATERIAL	SHEETS/PLIES	LOCATION	FATIGUE CYCLES
Aluminum (2 Layers)	(Length × Width × Thickness) Sheet 1: 8.00″ × 3.00″ × 0.020″ Sheet 2: 7.20″ × 2.20″ × 0.020″ Patch Thickness: 0.040″ Patch Stiffness Ratio: 1.0 Taper ratio: 20:1	Midbay Between Frame Stations 1050 and 1070 and Longerons S-3R and S-4R	60,000

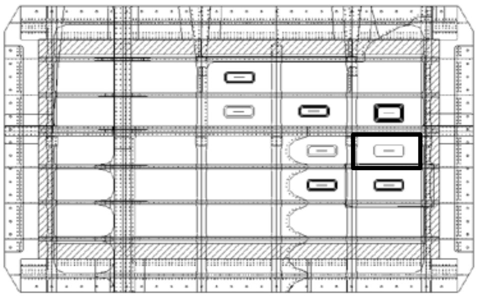
d) Repair patch details

Figure C-9. The U-A2 repair patch: (a) repair patch location, (b) internal notch tip gages, (c) repair patch, damages, and strain gage locations and dimensions, and (d) repair patch details

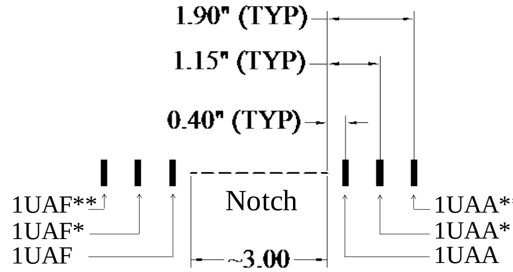
Table C-8. strain gage locations for U-A1 patch

Strain Gage No.	Location	
S23	Exterior Surface of Skin	0.75″ RIGHT of U-A1 patch between Frame Stations 1070 and 1090 and Longerons S-3R and S-4R
S24	Exterior Surface of Skin	0.75″ LEFT of U-A1 patch between Frame Stations 1070 and 1090 and Longerons S-3R and S-4R
S27	Exterior Surface of Patch	Center Mid-bay U-A1 patch between Frame Stations 1070 and 1090 and Longerons S-3R and S-4R
IS23	Interior Surface of Skin	0.75″ RIGHT of U-A1 patch between Frame Stations 1070 and 1090 and Longerons S-3R and S-4R
IS24	Interior Surface of Skin	0.75″ LEFT of U-A1 patch between Frame Stations 1070 and 1090 and Longerons S-3R and S-4R
IS27	Interior Surface of Skin	0.75″ RIGHT of mid-bay notch between Frame Stations 1070 and 1090 and Longerons S-3R and S-4R
1UAF	Interior Surface of Skin	0.4″ FWD of notch tip between Frame Stations 1070 and 1090 and Longerons S-3R and S-4R (0–5,000 cycles)
1UAF*	Interior Surface of Skin	1.15″ FWD of notch tip between Frame Stations 1070 and 1090 and Longerons S-3R and S-4R (5,000–25,000 cycles)
1UAF**	Interior Surface of Skin	1.9″ FWD of notch tip between Frame Stations 1070 and 1090 and Longerons S-3R and S-4R (25,000–40,000 cycles)
1UAA	Interior Surface of Skin	0.4″ AFT of notch tip between Frame Stations 1070 and 1090 and Longerons S-3R and S-4R (0–5,000 cycles)
1UAA*	Interior Surface of Skin	1.15″ AFT of notch tip between Frame Stations 1070 and 1090 and Longerons S-3R and S-4R (5,000–25,000 cycles)
1UAA**	Interior Surface of Skin	1.9″ AFT of notch tip between Frame Stations 1070 and 1090 and Longerons S-3R and S-4R (25,000–40,000 cycles)

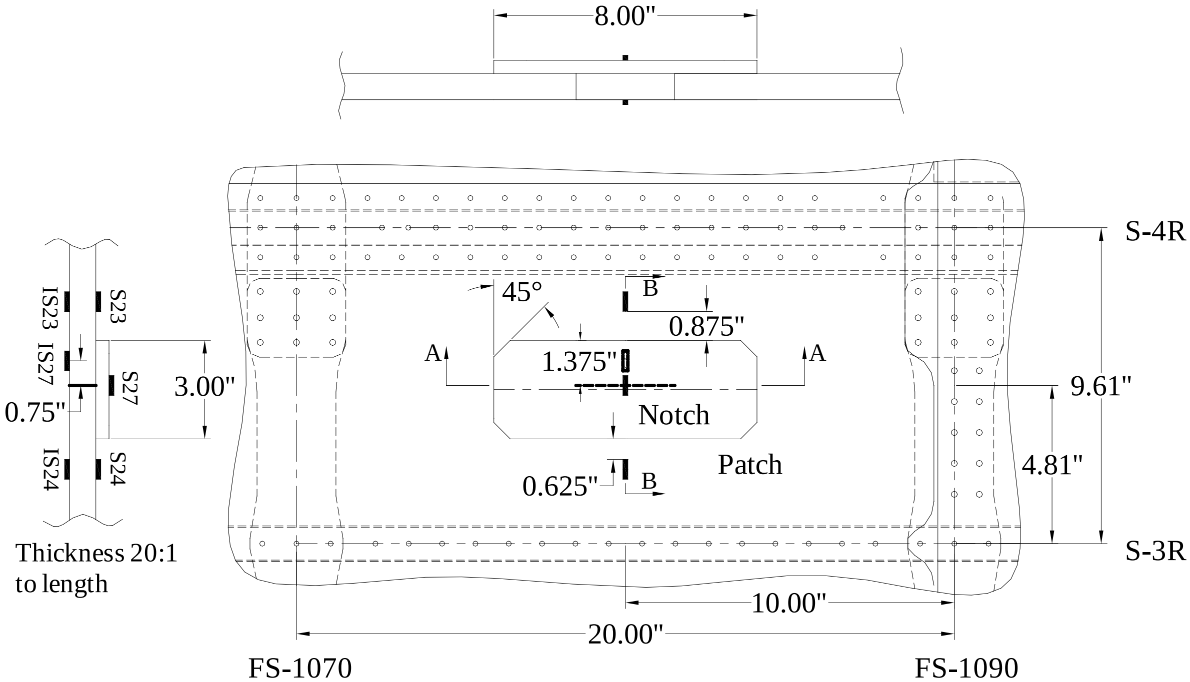
Note: * and ** represent the progressive distance between the notch tip and strain gage.



a) Repair Patch Location



b) Internal Notch Tip Gages



c) Repair patch, damages and strain gages locations and dimensions

MATERIAL	SHEETS/PLIES	LOCATION	FATIGUE CYCLES
Aluminum (1 Layer)	(Length × Width × Thickness) Sheet 1: 8.00″ × 3.00″ × 0.020″ Patch Thickness: 0.020″ Patch Stiffness Ratio: 0.5 Taper ratio: 20:1	Midbay Between Frame Stations 1070 and 1090 and Longerons S-3R and S-4R	40,000

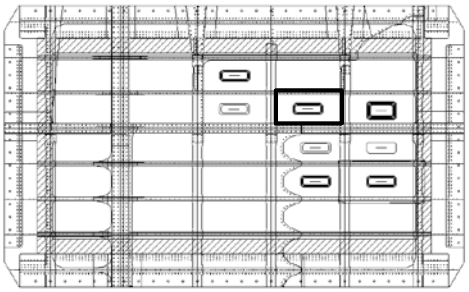
d) Repair patch details

Figure C-10. The U-A1 repair patch: (a) repair patch location, (b) internal notch tip gages, (c) repair patch, damages, and strain gage locations and dimensions, and (d) repair patch details

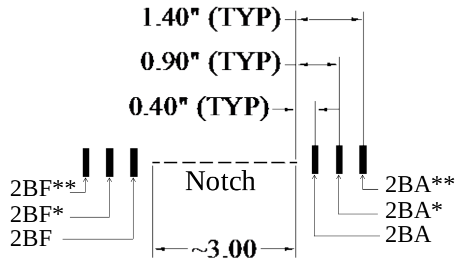
Table C-9. Strain gages locations for D-BE patch

Strain Gage No.	Location	
S21	Exterior surface of skin	0.75″ RIGHT of D-BE patch between Frame Stations 1050 and 1070 and Longerons S-4R and S-5R
S22	Exterior surface of skin	0.75″ LEFT of D-BE patch between Frame Stations 1050 and 1070 and Longerons S-4R and S-5R
S26	Exterior surface of patch	Center mid-bay D-BE patch between Frame Stations 1050 and 1070 and Longerons S-4R and S-5R
IS21	Interior surface of skin	0.75″ RIGHT of D-BE patch between Frame Stations 1050 and 1070 and Longerons S-4R and S-5R
IS22	Interior surface of skin	0.75″ LEFT of D-BE patch between Frame Stations 1050 and 1070 and Longerons S-4R and S-5R
IS26	Interior surface of skin	0.75″ RIGHT of mid-bay notch between Frame Stations 1050 and 1070 and Longerons S-4R and S-5R
2BF	Interior surface of skin	0.4″ FWD of notch tip between Frame Stations 1050 and 1070 and Longerons S-4R and S-5R (0–10,000 cycles)
2BF*	Interior surface of skin	0.9″ FWD of notch tip between Frame Stations 1050 and 1070 and Longerons S-4R and S-5R (10,000–25,000 cycles)
2BF**	Interior surface of skin	1.4″ FWD of notch tip between Frame Stations 1050 and 1070 and Longerons S-4R and S-5R (25,000–60,000 cycles)
2BA	Interior surface of skin	0.4″ AFT of notch tip between Frame Stations 1050 and 1070 and Longerons S-4R and S-5R (0–10,000 cycles)
2BA*	Interior surface of skin	0.9″ AFT of notch tip between Frame Stations 1050 and 1070 and Longerons S-4R and S-5R (10,000–25,000 cycles)
2BA**	Interior surface of skin	1.4″ AFT of notch tip between Frame Stations 1050 and 1070 and Longerons S-4R and S-5R (25,000–60,000 cycles)

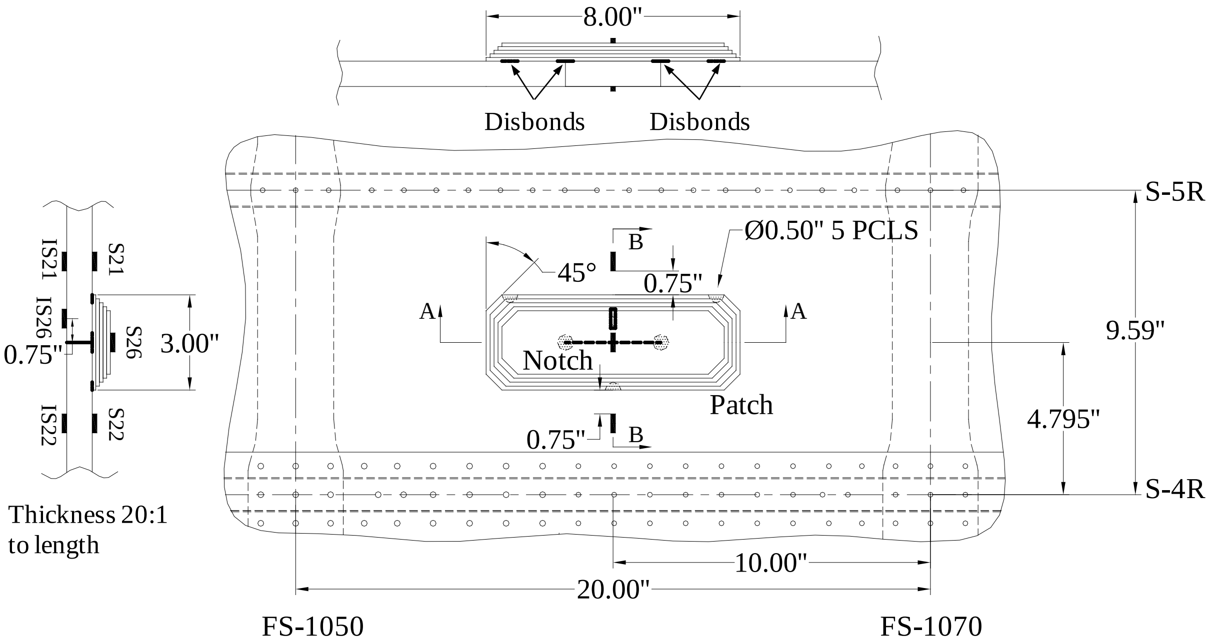
Note: * and ** represent the progressive distance between the notch tip and strain gage.



a) Repair Patch Location



b) Internal Notch Tip Gages



c) Repair patch, damages and strain gages locations and dimensions

MATERIAL	SHEETS/PLIES	LOCATION	FATIGUE CYCLES
Boron/Epoxy (5 Plies) 0º perpendicular to the crack	(Length × Width, Angle) Ply 1: 8.00″ × 3.00″, +20º Ply 2: 7.75″ × 2.75″, -20º Ply 3: 7.50″ × 2.50″, 0º Ply 4: 7.25″ × 2.25″, -20º Ply 5: 7.00″ × 2.00″, +20º Patch Thickness: 0.029″ Patch Stiffness Ratio: 1.16 Taper ratio: 20:1	Midbay Between Frame Stations 1050 and 1070 and Longerons S-4R and S-5R	40,000

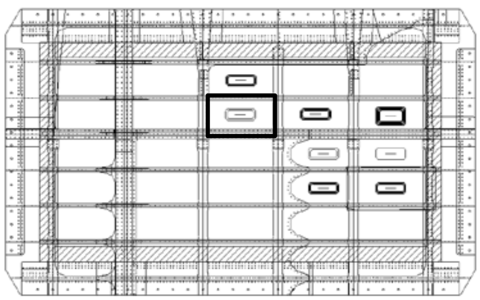
d) Repair patch details

Figure C-11. The D-BE repair patch: (a) repair patch location, (b) internal notch tip gages, (c) repair patch, damage, and strain gage locations and dimensions, and (d) repair patch details

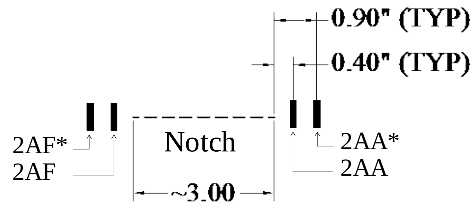
Table C-10. Strain gage locations for D-A2 patch

Strain Gage No.	Location	
S19	Exterior surface of skin	0.75″ RIGHT of D-A2 patch between Frame Stations 1030 and 1050 and Longerons S-4R and S-5R
S20	Exterior surface of skin	0.75″ LEFT of D-A2 patch between Frame Stations 1030 and 1050 and Longerons S-4R and S-5R
S25	Exterior surface of patch	Center mid-bay D-A2 patch between Frame Stations 1030 and 1050 and Longerons S-4R and S-5R
IS19	Interior surface of skin	0.75″ RIGHT of D-A2 patch between Frame Stations 1030 and 1050 and Longerons S-4R and S-5R
IS20	Interior surface of skin	0.75″ LEFT of D-A2 patch between Frame Stations 1030 and 1050 and Longerons S-4R and S-5R
IS25	Interior surface of skin	0.75″ RIGHT of mid-bay notch between Frame Stations 1030 and 1050 and Longerons S-4R and S-5R
2AF	Interior surface of skin	0.4″ FWD of notch tip between Frame Stations 1030 and 1050 and Longerons S-4R and S-5R (0–15,000 cycles)
2AF*	Interior surface of skin	0.9″ FWD of notch tip between Frame Stations 1030 and 1050 and Longerons S-4R and S-5R (15,000–60,000 cycles)
2AA	Interior surface of skin	0.4″ AFT of notch tip between Frame Stations 1030 and 1050 and Longerons S-4R and S-5R (0–15,000 cycles)
2AA*	Interior surface of skin	0.9″ AFT of notch tip between Frame Stations 1030 and 1050 and Longerons S-4R and S-5R (15,000–60,000 cycles)

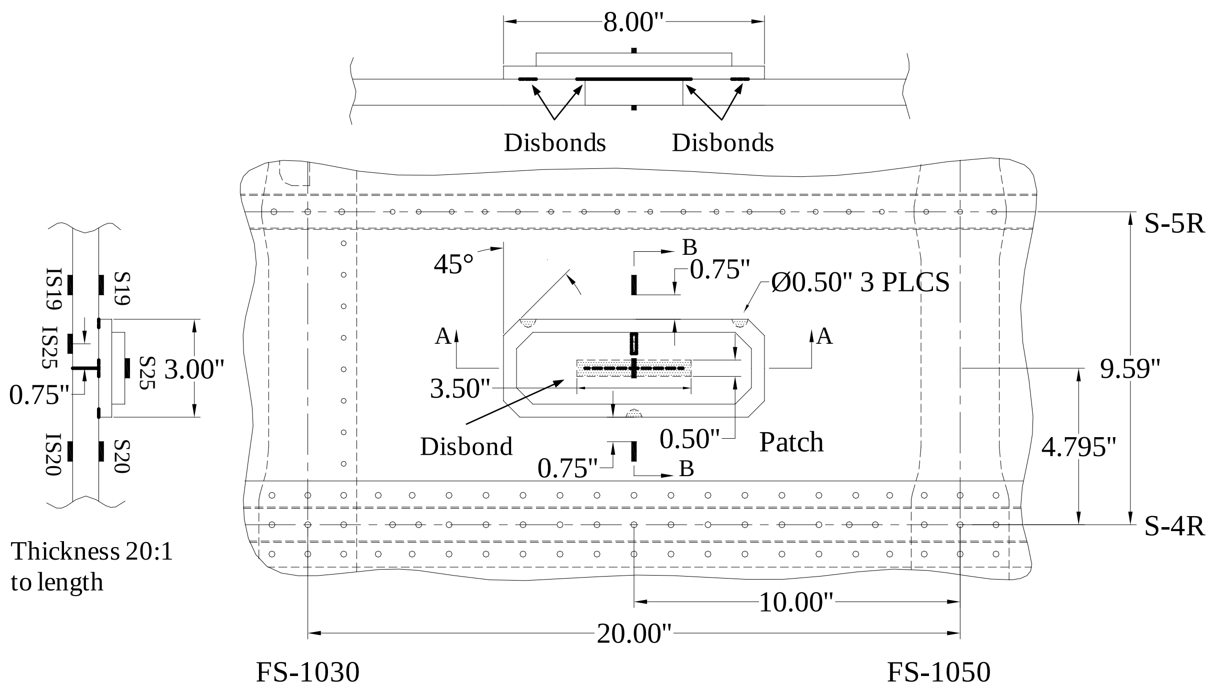
Note: * represents the progressive distance between the notch tip and the strain gage.



a) Repair Patch Location



b) Internal Notch Tip Gages



c) Repair patch, damages and strain gages locations and dimensions

MATERIAL	SHEETS/PLIES	LOCATION	FATIGUE CYCLES
Aluminum (2 Layers)	(Length × Width × Thickness) Sheet 1: 8.00″ × 3.00″ × 0.020″ Sheet 2: 7.20″ × 2.20″ × 0.020″ Patch Thickness: 0.040″ Patch Stiffness Ratio: 1.0 Taper ratio: 20:1	Midbay Between Frame Stations 1030 and 1050 and Longerons S-4R and S-5R	40,000

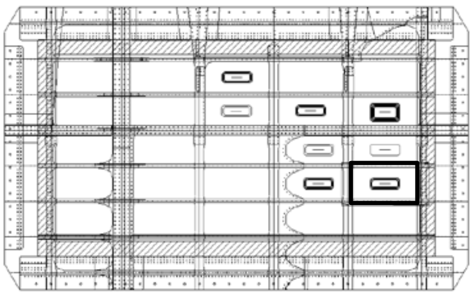
d) Repair patch details

Figure C-12. The D-A2 repair patch: (a) repair patch location, (b) internal notch tip gages, (c) repair patch, damage, and strain gage locations and dimensions, and (d) repair patch details

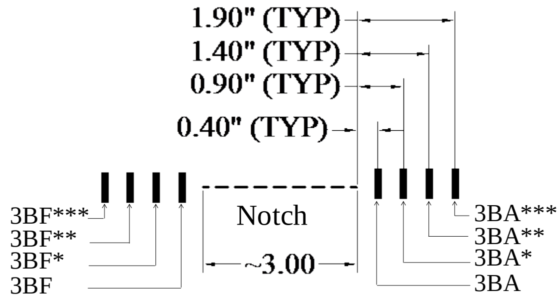
Table C-11. Strain gage locations for C-BE patch

Strain Gage No.	Location	
S28	Exterior surface of skin	0.75″ RIGHT of C-BE patch between Frame Stations 1070 and 1090 and Longerons S-2R and S-3R
S29	Exterior surface of skin	0.75″ LEFT of C-BE patch between Frame Stations 1070 and 1090 and Longerons S-2R and S-3R
S34	Exterior surface of patch	Center mid-bay C-BE patch between Frame Stations 1070 and 1090 and Longerons S-2R and S-3R
IS28	Interior surface of skin	0.75″ RIGHT of C-BE patch between Frame Stations 1070 and 1090 and Longerons S-2R and S-3R
IS29	Interior surface of skin	0.75″ LEFT of C-BE patch between Frame Stations 1070 and 1090 and Longerons S-2R and S-3R
IS34	Interior surface of skin	0.75″ RIGHT of mid-bay notch between Frame Stations 1070 and 1090 and Longerons S-2R and S-3R
3BF	Interior surface of skin	0.4″ FWD of notch tip between Frame Stations 1070 and 1090 and Longerons S-2R and S-3R (0–5,000 cycles)
3BF*	Interior surface of skin	0.9″ FWD of notch tip between Frame Stations 1070 and 1090 and Longerons S-2R and S-3R (5,000–10,000 cycles)
3BF**	Interior surface of skin	1.4″ FWD of notch tip between Frame Stations 1070 and 1090 and Longerons S-2R and S-3R (10,000–15,000 cycles)
3BF***	Interior surface of skin	1.9″ FWD of notch tip between Frame Stations 1070 and 1090 and Longerons S-2R and S-3R (15,000–20,000 cycles)
3BA	Interior surface of skin	0.4″ AFT of notch tip between Frame Stations 1070 and 1090 and Longerons S-2R and S-3R (0–5,000 cycles)
3BA*	Interior surface of skin	0.9″ AFT of notch tip between Frame Stations 1070 and 1090 and Longerons S-2R and S-3R (5,000–10,000 cycles)
3BA**	Interior surface of skin	1.4″ AFT of notch tip between Frame Stations 1070 and 1090 and Longerons S-2R and S-3R (10,000–15,000 cycles)
3BA***	Interior surface of skin	1.9″ AFT of notch tip between Frame Stations 1070 and 1090 and Longerons S-2R and S-3R (15,000–20,000 cycles)

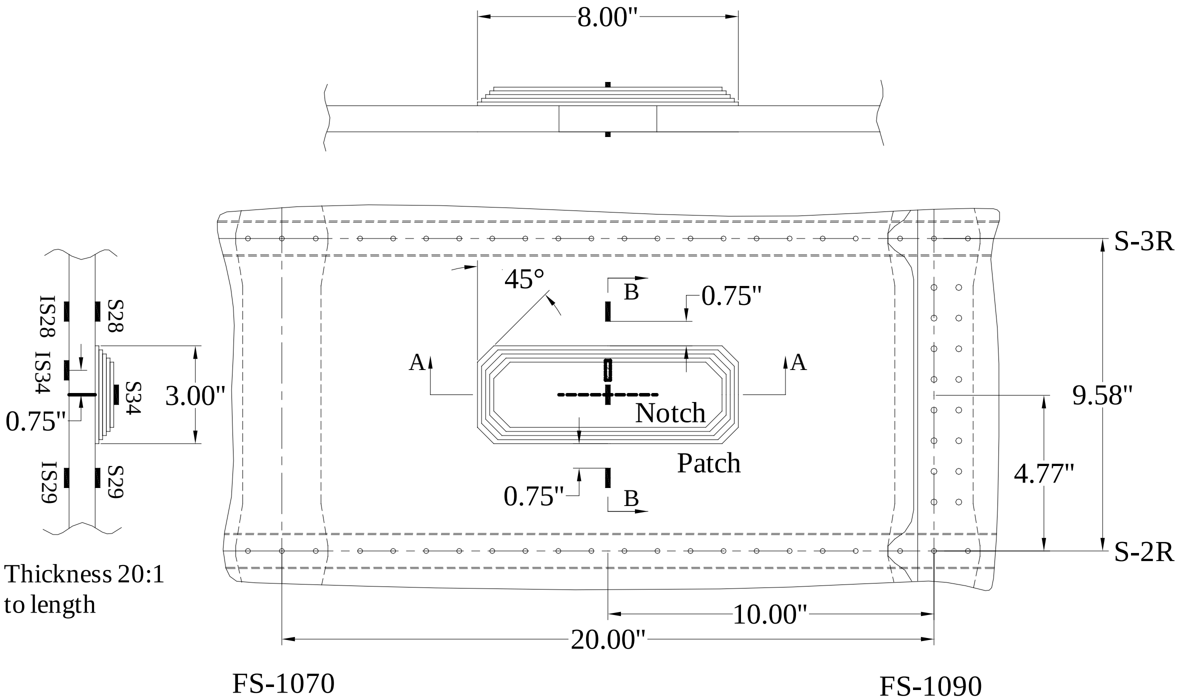
Note: *, **, and *** represent the progressive distance between the notch tip and strain gage.



a) Repair Patch Location



b) Internal Notch Tip Gages



c) Repair patch, damages and strain gages locations and dimensions

MATERIAL	SHEETS/PLIES	LOCATION	FATIGUE CYCLES
Boron/Epoxy (5 Plies) 0º parallel to the crack	(Length × Width, Angle) Ply 1: 8.00″ × 3.00″, +20º Ply 2: 7.75″ × 2.75″, -20º Ply 3: 7.50″ × 2.50″, 0º Ply 4: 7.25″ × 2.25″, -20º Ply 5: 7.00″ × 2.00″, +20º Patch Thickness: 0.029″ Patch Stiffness Ratio: 1.16 Taper ratio: 20:1	Midbay Between Frame Stations 1070 and 1090 and Longerons S-2R and S-3R	20,000

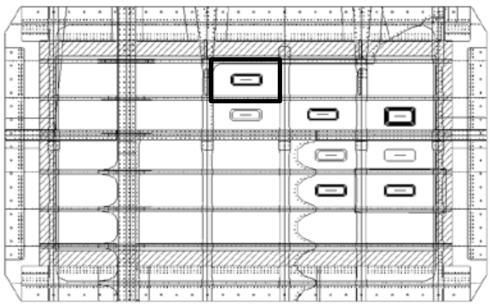
d) Repair patch details

Figure C-13. The C-BE repair patch: (a) repair patch location, (b) internal notch tip gages, (c) repair patch, damage, and strain gage locations and dimensions, and (d) repair patch details

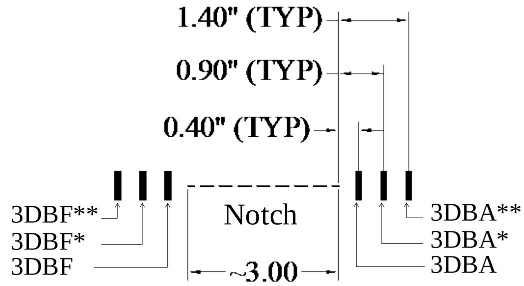
Table C-12. Strain gage locations for CD-BE patch

Strain Gage No.	Location	
S30	Exterior surface of skin	0.75″ RIGHT of C-BE patch between Frame Stations 1030 and 1050 and Longerons S-5R and S-6R
S31	Exterior surface of skin	0.75″ LEFT of C-BE patch between Frame Stations 1030 and 1050 and Longerons S-5R and S-6R
S35	Exterior surface of patch	Center mid-bay C-BE patch between Frame Stations 1030 and 1050 and Longerons S-5R and S-6R
IS30	Interior surface of skin	0.75″ RIGHT of C-BE patch between Frame Stations 1030 and 1050 and Longerons S-5R and S-6R
IS31	Interior surface of skin	0.75″ LEFT of C-BE patch between Frame Stations 1030 and 1050 and Longerons S-5R and S-6R
IS35	Interior surface of skin	0.75″ RIGHT of mid-bay notch between Frame Stations 1030 and 1050 and Longerons S-5R and S-6R
3DBF	Interior surface of skin	0.4″ FWD of notch tip between Frame Stations 1030 and 1050 and Longerons S-5R and S-6R (0–5,000 cycles)
3DBF*	Interior surface of skin	0.9″ FWD of notch tip between Frame Stations 1030 and 1050 and Longerons S-5R and S-6R (5,000–15,000 cycles)
3DBF**	Interior surface of skin	1.4″ FWD of notch tip between Frame Stations 1030 and 1050 and Longerons S-5R and S-6R (15,000–20,000 cycles)
3DBA	Interior surface of skin	0.4″ AFT of notch tip between Frame Stations 1030 and 1050 and Longerons S-5R and S-6R (0–5,000 cycles)
3DBA*	Interior surface of skin	0.9″ AFT of notch tip between Frame Stations 1030 and 1050 and Longerons S-5R and S-6R (5,000–15,000 cycles)
3DBA**	Interior surface of skin	1.4″ AFT of notch tip between Frame Stations 1030 and 1050 and Longerons S-5R and S-6R (15,000–20,000 cycles)

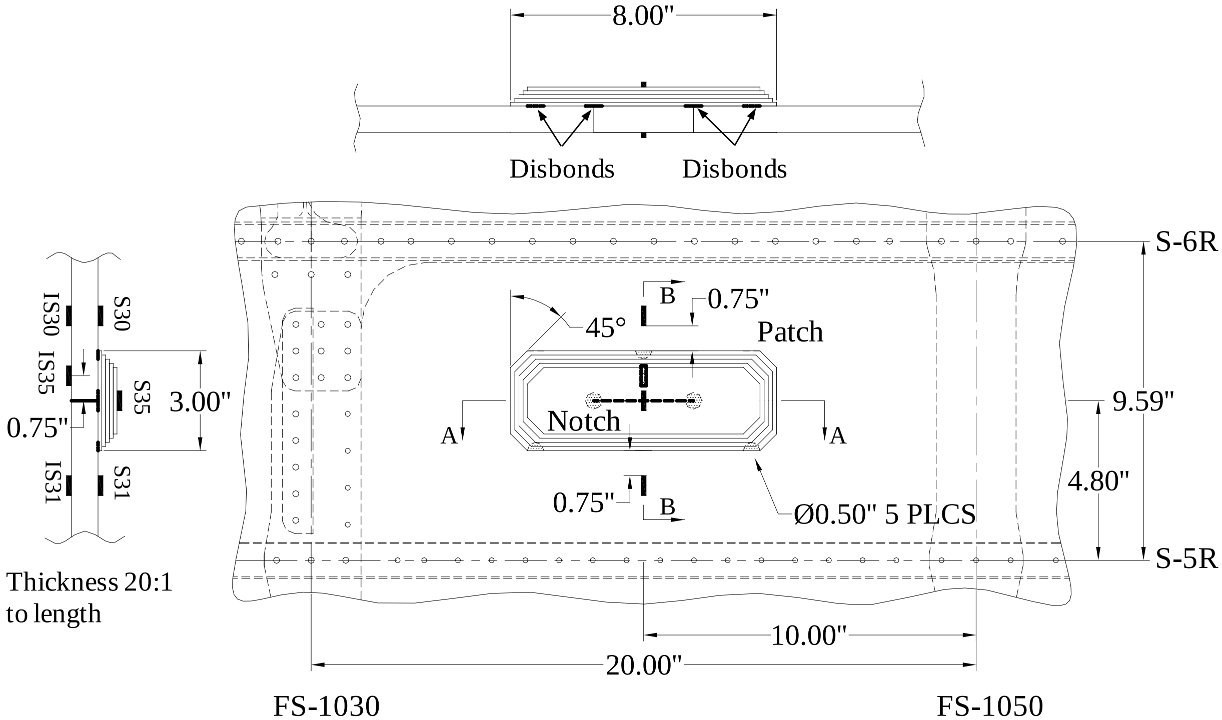
Note: * and ** represent the progressive distance between the notch tip and strain gage.



a) Repair Patch Location



b) Internal Notch Tip Gages



c) Repair patch, damages and strain gages locations and dimensions

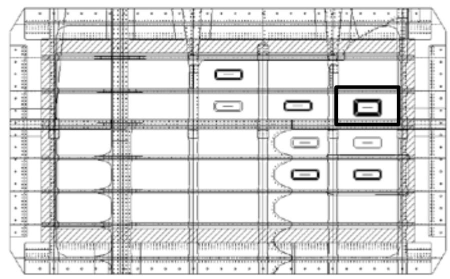
MATERIAL	SHEETS/PLIES	LOCATION	FATIGUE CYCLES
Boron/Epoxy (5 Plies) 0º parallel to the crack	(Length × Width, Angle) Ply 1: 8.00″ × 3.00″, +20º Ply 2: 7.75″ × 2.75″, -20º Ply 3: 7.50″ × 2.50″, 0º Ply 4: 7.25″ × 2.25″, -20º Ply 5: 7.00″ × 2.00″, +20º Patch Thickness: 0.029″ Patch Stiffness Ratio: 1.16 Taper ratio: 20:1	Midbay Between Frame Stations 1030 and 1050 and Longerons S-5R and S-6R	20,000

d) Repair patch details

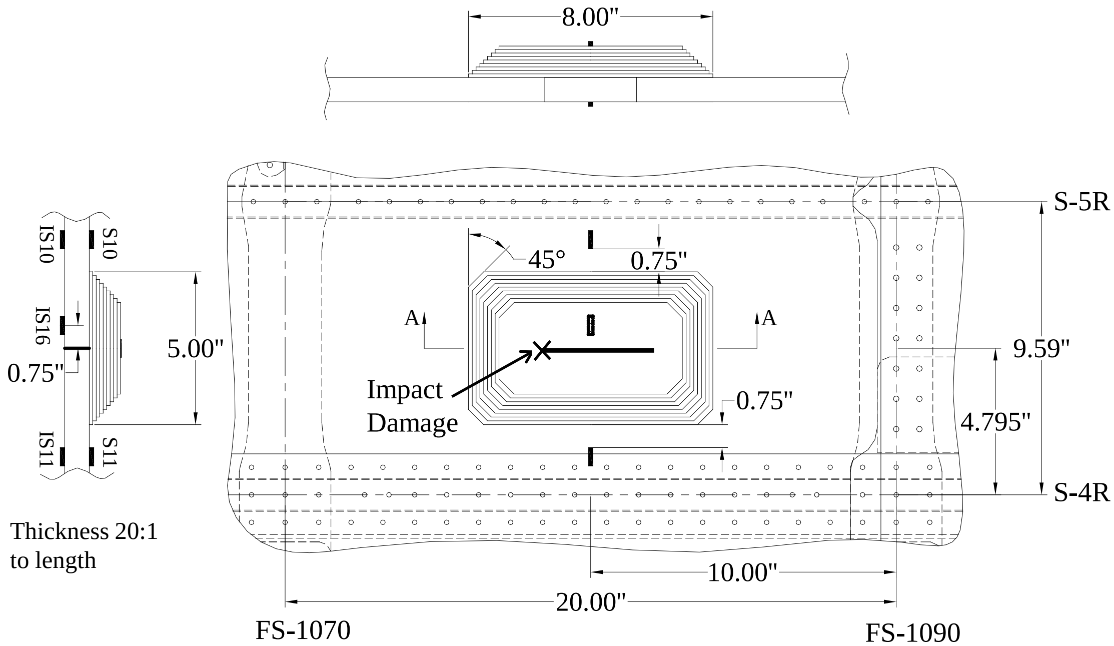
Figure C-14. Repair patch CD-BE: (a) repair patch location, (b) internal notch tip gages, (c) repair patch, damage, and strain gage locations and dimensions, and (d) repair patch details

Table C-13. Strain gage locations for R-BE patch after impact

Strain Gage No.	Location	
S10	Exterior surface of skin	0.75″ RIGHT of R-BE patch between Frame Stations 1070 and 1090 and Longerons S-4R and S-5R
S11	Exterior surface of skin	0.75″ LEFT of R-BE patch between Frame Stations 1070 and 1090 and Longerons S-4R and S-5R
IS10	Interior surface of skin	0.75″ RIGHT of R-BE patch between Frame Stations 1070 and 1090 and Longerons S-4R and S-5R
IS11	Interior surface of skin	0.75″ LEFT of R-BE patch between Frame Stations 1070 and 1090 and Longerons S-4R and S-5R
IS16	Interior surface of skin	0.75″ RIGHT of mid-bay notch between Frame Stations 1070 and 1090 and Longerons S-4R and S-5R



a) Repair Patch Location



b) Repair patch, damages and strain gages locations and dimensions

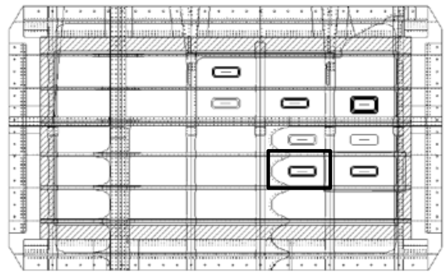
MATERIAL	SHEETS/PLIES	LOCATION	FATIGUE CYCLES
Boron/Epoxy (9 Plies) 0º perpendicular to the crack	(Length × Width, Angle) Ply 1: 8.00″ × 5.00″ , +20° Ply 2: 7.75″ × 4.75″ , -20° Ply 3: 7.50″ × 4.50″ , +20° Ply 4: 7.25″ × 4.25″ , -20° Ply 5: 7.00″ × 4.00″ , 0° Ply 6: 6.75″ × 3.75″ , -20° Ply 7: 6.50″ × 3.50″ , +20° Ply 8: 6.25″ × 3.25″ , -20° Ply 9: 6.00″ × 3.00″ , +20° Patch Thickness: 0.051″ Patch Stiffness Ratio: 1.9 Taper ratio: 20:1	Midbay Between Frame Stations 1070 and 1090 and Longerons S-4R and S-5R	20,000 cycles after impact

d) Repair patch details

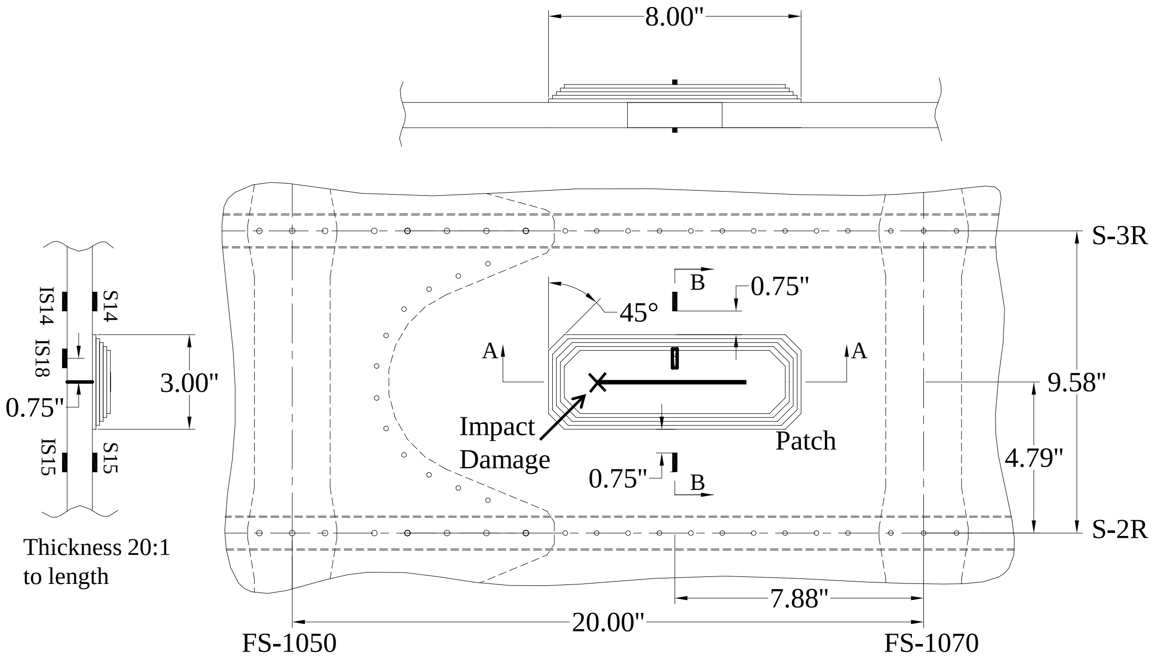
Figure C-15. Repair patch R-BE after impact: (a) repair patch location, (b) repair patch, damage, and strain gage locations and dimensions, and (c) repair patch details

Table C-14. Strain gage locations for U-BE patch after impact

Strain Gage No.	Location	
S14	Exterior surface of skin	0.75″ RIGHT of U-BE patch between Frame Stations 1050 and 1070 and Longerons S-2R and S-3R
S15	Exterior surface of skin	0.75″ LEFT of U-BE patch between Frame Stations 1050 and 1070 and Longerons S-2R and S-3R
IS14	Interior surface of skin	0.75″ RIGHT of U-BE patch between Frame Stations 1050 and 1070 and Longerons S-2R and S-3R
IS15	Interior surface of skin	0.75″ LEFT of U-BE patch between Frame Stations 1050 and 1070 and Longerons S-2R and S-3R
IS18	Interior surface of skin	0.75″ RIGHT of mid-bay notch between Frame Stations 1050 and 1070 and Longerons S-2R and S-3R



a) Repair Patch Location



b) Repair patch, damages and strain gages locations and dimensions

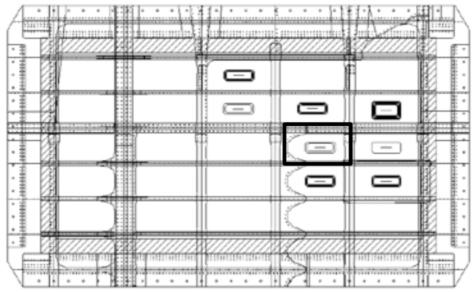
MATERIAL	SHEETS/PLIES	LOCATION	FATIGUE CYCLES
Boron/Epoxy (5 Plies) 0º perpendicular to the crack	(Length × Width, Angle) Ply 1: 8.00″ × 3.00″, +20º Ply 2: 7.75″ × 2.75″, -20º Ply 3: 7.50″ × 2.50″, 0º Ply 4: 7.25″ × 2.25″, -20º Ply 5: 7.00″ × 2.00″, +20º Patch Thickness: 0.029″ Patch Stiffness Ratio: 1.16 Taper ratio: 20:1	Midbay Between Frame Stations 1050 and 1070 and Longerons S-3R and S-4R	20,000 additional cycles after impact

c) Repair patch details

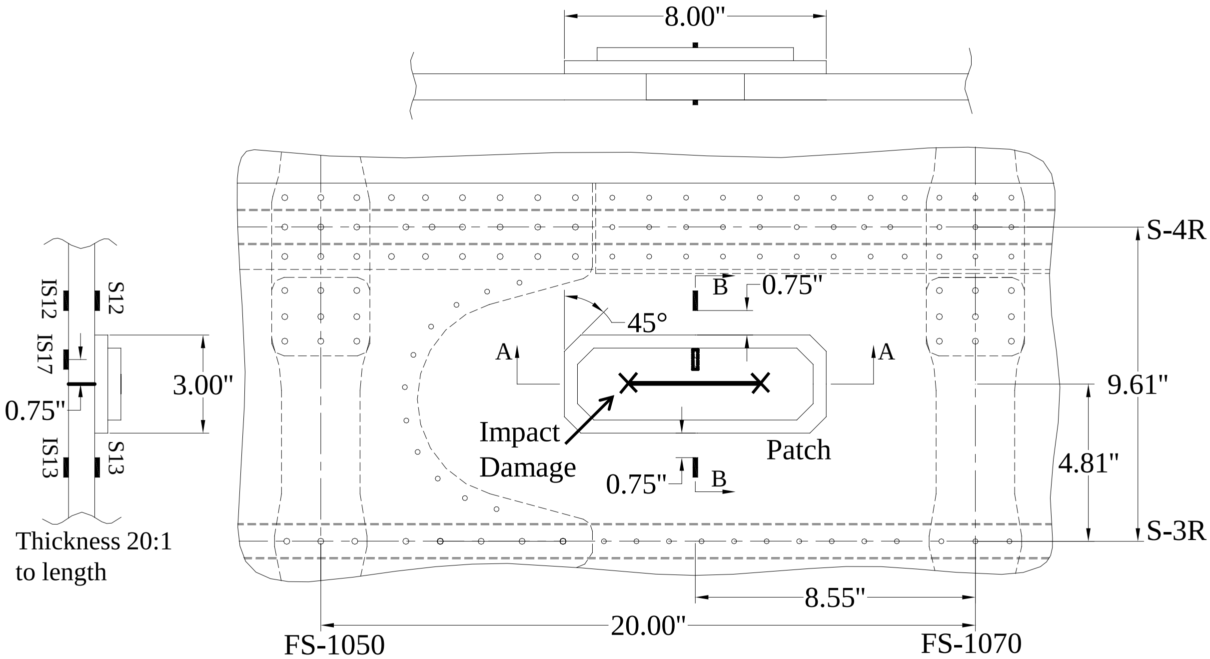
Figure C-16. Repair patch U-BE after impact: (a) repair patch location, (b) repair patch, damage and strain gage locations and dimensions, and (c) repair patch details

Table C-15. Strain gage locations for U-A2 patch after impact

Strain Gage No.	Location	
S12	Exterior surface of skin	0.75″ RIGHT of U-A2 patch between Frame Stations 1050 and 1070 and Longerons S-3R and S-4R
S13	Exterior surface of skin	0.75″ LEFT of U-A2 patch between Frame Stations 1050 and 1070 and Longerons S-3R and S-4R
IS12	Interior surface of skin	0.75″ RIGHT of U-A2 patch between Frame Stations 1050 and 1070 and Longerons S-3R and S-4R
IS13	Interior surface of skin	0.75″ LEFT of U-A2 patch between Frame Stations 1050 and 1070 and Longerons S-3R and S-4R
IS17	Interior surface of skin	0.75″ RIGHT of mid-bay notch between Frame Stations 1050 and 1070 and Longerons S-3R and S-4R



a) Repair Patch Location



b) Repair patch, damages and strain gages locations and dimensions

MATERIAL	SHEETS/PLIES	LOCATION	FATIGUE CYCLES
Aluminum (2 Layers)	(Length × Width × Thickness) Sheet 1: 8.00″ × 3.00″ × 0.020″ Sheet 2: 7.20″ × 2.20″ × 0.020″ Patch Thickness: 0.040″ Patch Stiffness Ratio: 1.0 Taper ratio: 20:1	Midbay Between Frame Stations 1050 and 1070 and Longerons S-3R and S-4R	20,000 cycles after impact

c) Repair patch details

Figure C-17. Repair patch U-A2 after impact: (a) repair patch location, (b) repair patch, damage, and strain gage locations and dimensions, and (c) repair patch details

APPENDIX D—PATCH INSTALLATION AND STRAINS MONITORED DURING CURING PROCESS

D.1 PATCH INSTALLATION

The patch installation procedure involves the five steps discussed in sections D.1.1–D.1.5.

D.1.1 CLEANING AND PREPARATION OF SURFACE

1. The part’s surface areas and adjacent surfaces were solvent-cleaned. All contaminants were removed.

2. All of the surface coatings and residual adhesive residues were removed down to bare metal.

3. The bare metal surface was solvent-cleaned. All contaminants were removed.

D.1.2 GRIT BLAST DEOXIDIZATION

1. A region slightly larger than the bond area was grit-blasted. Figure D-1 shows the grit-blast procedure.

2. Loose grit residue was removed with clean, dry compressed air or nitrogen.

Figure D-1. Grit-blasting the patch region

D.1.3 APPLICATION OF SOL-GEL COATING

1. Sol-gel solution was applied by brushing with a natural bristle brush, as shown in figure D-2. The surface was kept wet for a minimum of two minutes.

2. Sol-gel parts were left to dry under ambient conditions for a minimum of 60 minutes, as shown in figure D-3.

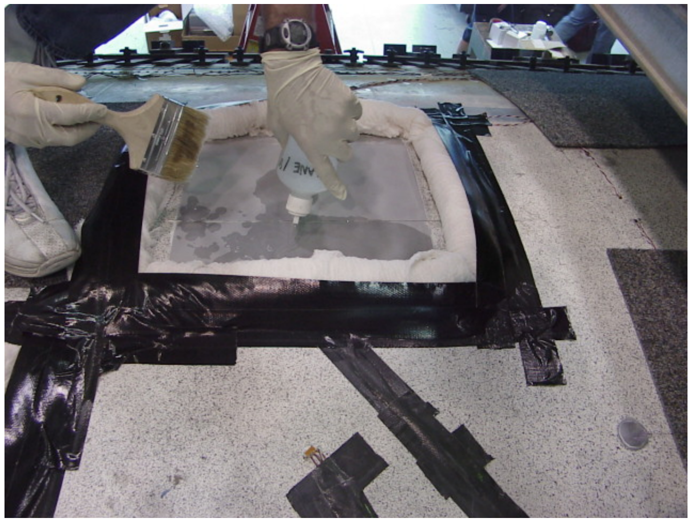


Figure D-2. Application of sol-gel solution

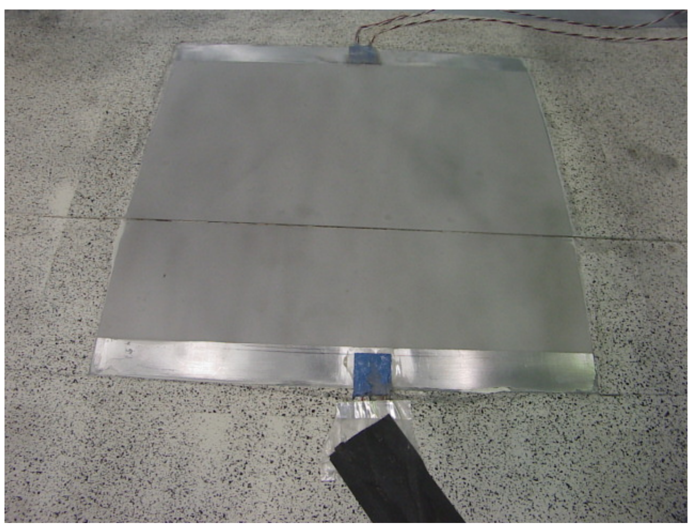


Figure D-3. Patch region after sol-gel application

D.1.4 APPLICATION OF BOND PRIMER

1. Cytec Fiberite, Inc. adhesive primer was thoroughly mixed by agitation in the original container.

2. The primer was transferred to a reservoir with continued agitation during application.

3. The adhesive primer was applied to the bond surface to obtain a cured film thickness of 0.00015″–0.00040″ (0.15–0.40 mil). Figure D-4 shows the patch region just after the application of bond primer.

4. Primed parts were allowed to dry at 135°F using a heat pump for 60 minutes before curing.

Figure D-4. Patch region just after application of bond-primer

D.1.5 CO-CURING

The primer and adhesive were cured simultaneously:

1. The Henkel EA9696 OST (one tacky side) mat carrier, grade 10 film adhesive and patch were applied to the sol-gel-treated and primed surface using standard bond procedures, as shown in figure D-5.

2. Both the adhesive and primer were co-cured for 90 minutes at 250° ±10°F, as shown in figure D-6.

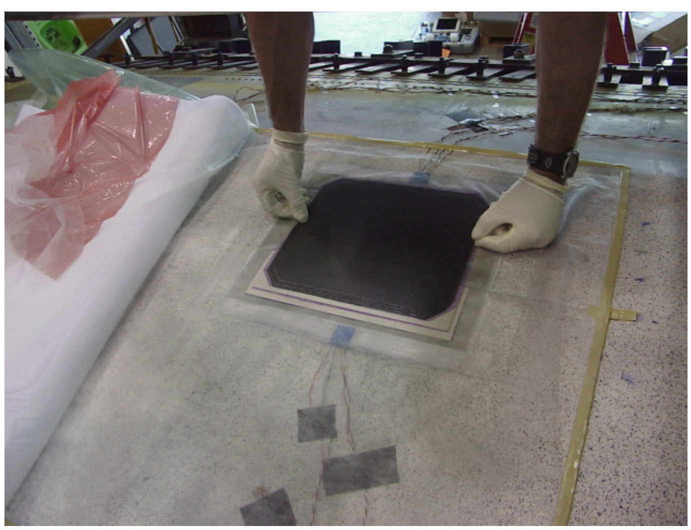


Figure D-5. Placement of boron/epoxy patch

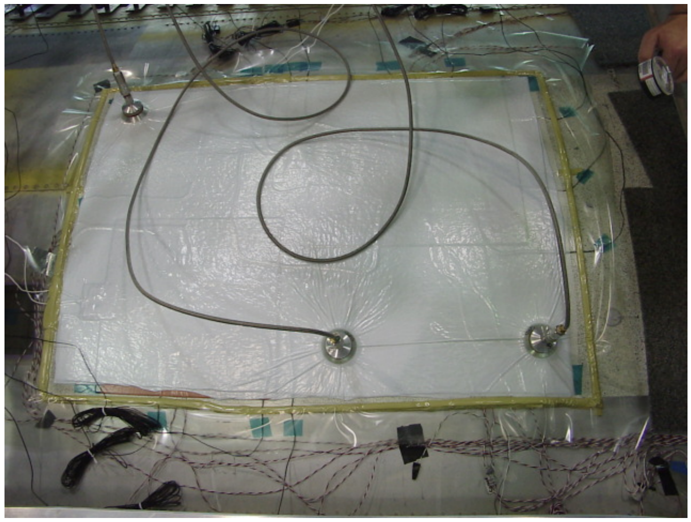


Figure D-6. Co-cure

D.2 MONITORING STRAINS

During the curing process, strain gages were installed on the exterior and interior surfaces of the aluminum fuselage skin. The strains, temperature, and locations of the strain gages for each repair type are provided in the figures below.

D.2.1 Reference Repair

Figure D-7 shows the strains during the curing process for R-BE repair. The figure also shows the location of the strain gages during the curing process both on the exterior and interior surfaces of the fuselage panel.

D.2.2 Phase 1 Repairs

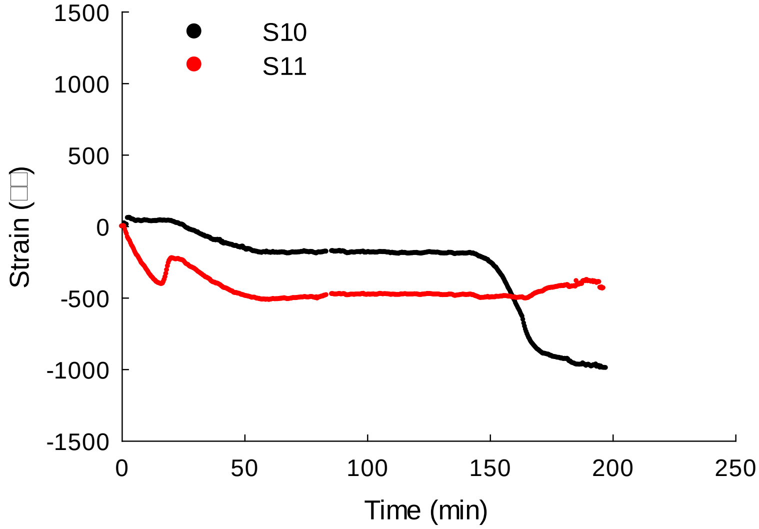
Figures D-8–D-10 show the strains during the curing process for the U-BE, U-A2, and U-A1 repairs. The figures also show the location of the strain gages during the curing process, both on the exterior and interior surfaces of the fuselage panel.

D.2.3 Phase 2 Repairs

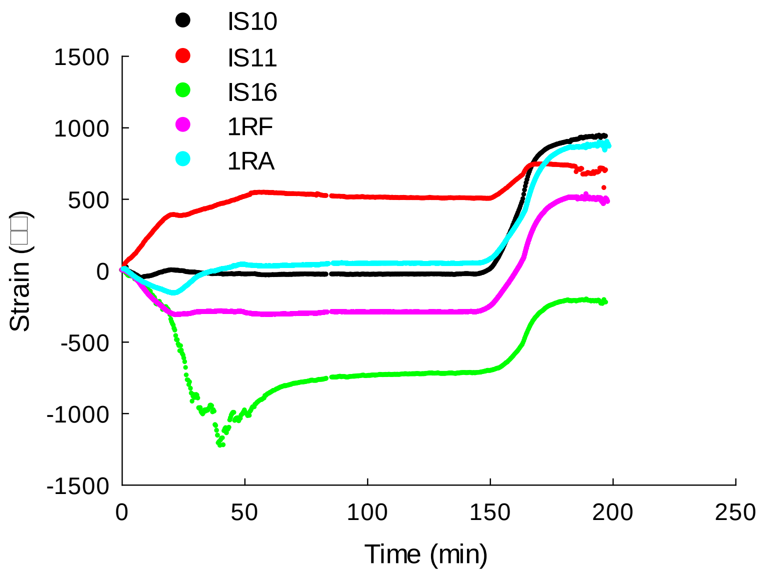
Figures D-11 and D-12 show the strains during the curing process for the D-BE and D-A2 repairs, respectively. The figures also show the location of the strain gages during the curing process, both on the exterior and interior surfaces of the fuselage panel.

D.2.4 Phase 3 Repairs

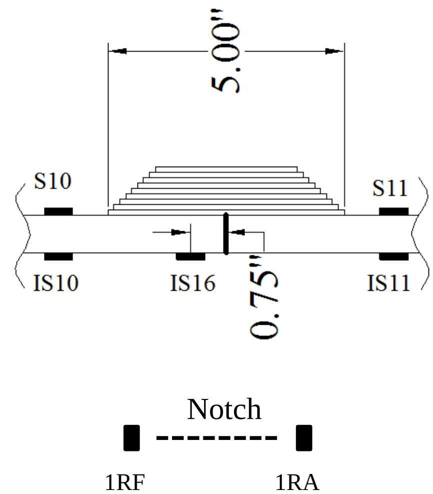
Figures D-13 and D-14 show the strains during the curing process for the C-BE and CD-BE repairs, respectively. The figures also show the location of the strain gages during the curing process, both on the exterior and interior surfaces of the fuselage panel.



a. External gages

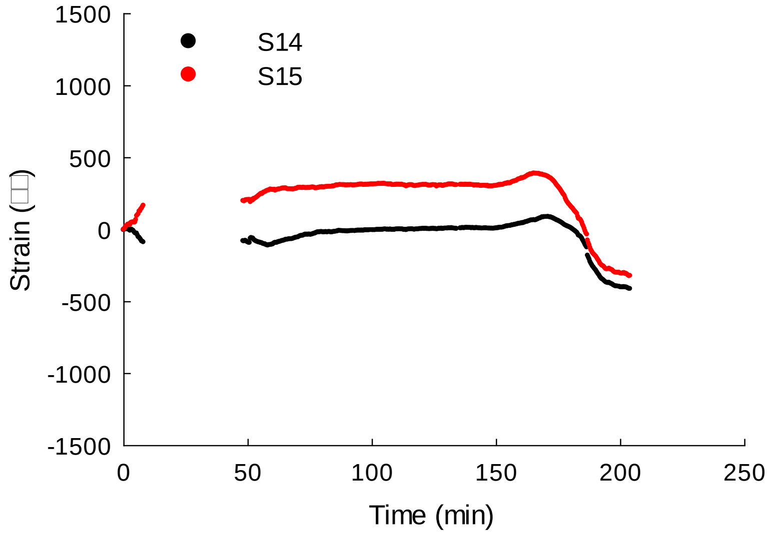


b. Internal gages

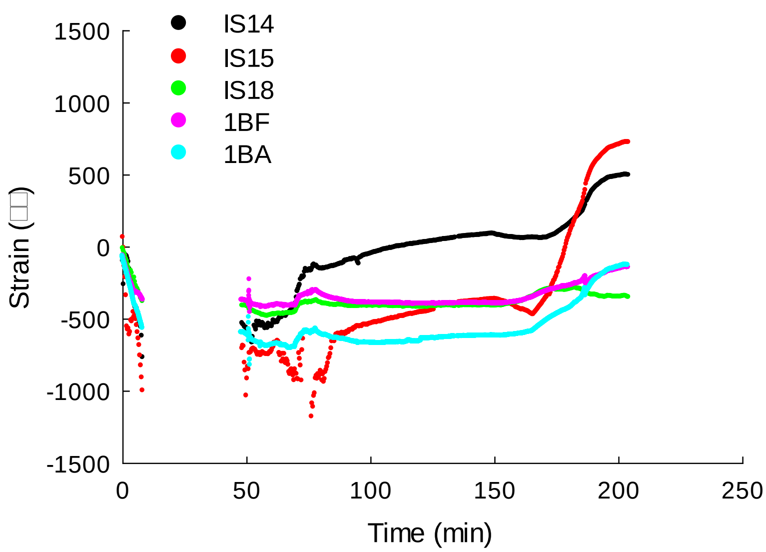


c. Gages locations

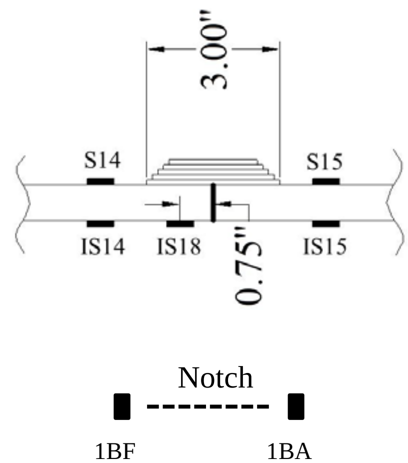
Figure D-7. Strains monitored during the R-BE repair curing



a. External gages

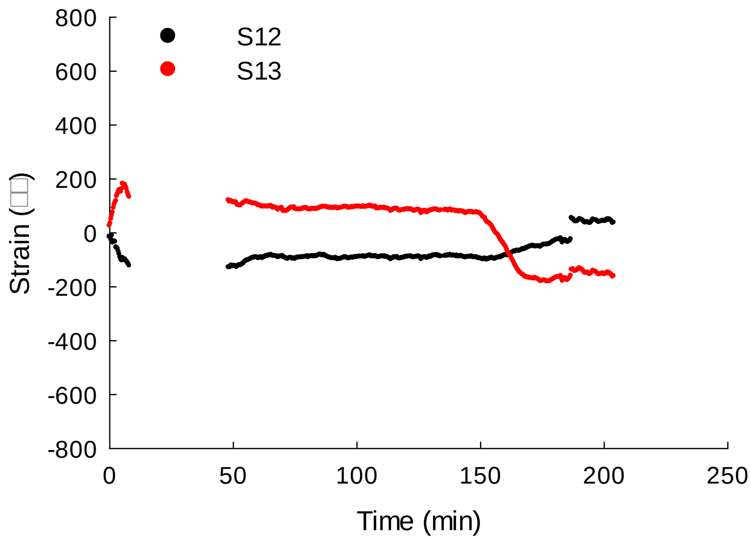


b. Internal gages

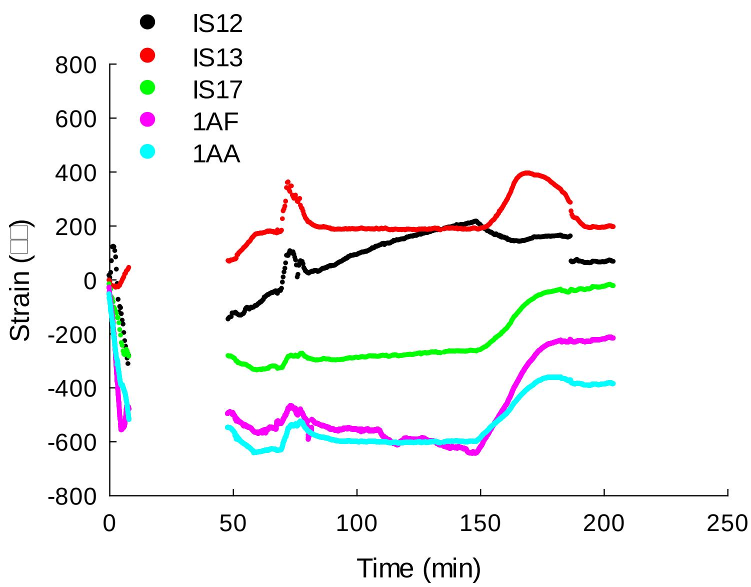


c. Gages locations

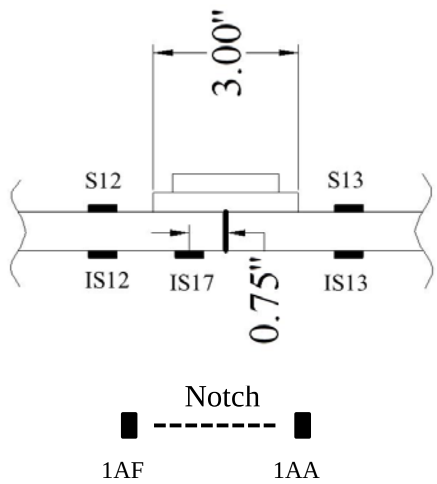
Figure D-8. Strains monitored during the U-BE repair curing



a. External gages

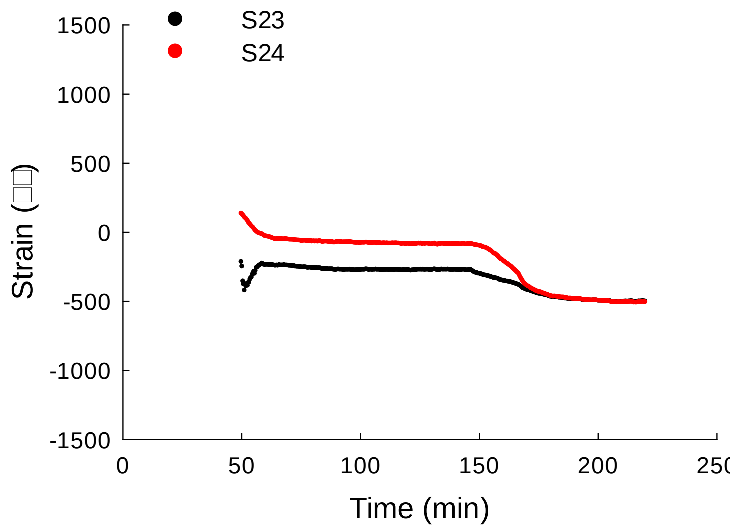


b. Internal gages

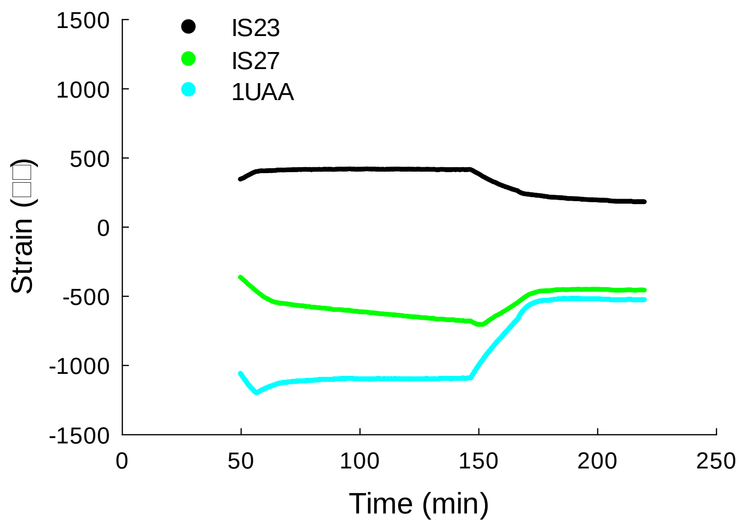


c. Gages locations

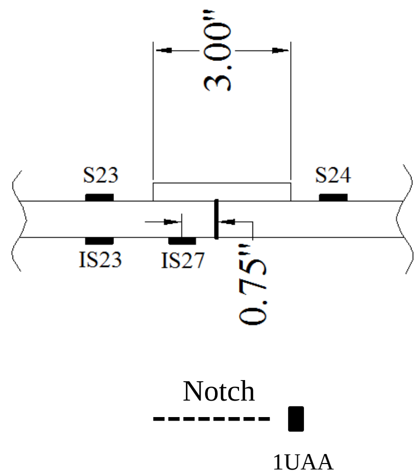
Figure D-9. Strains monitored during the U-A2 repair curing



a. External gages

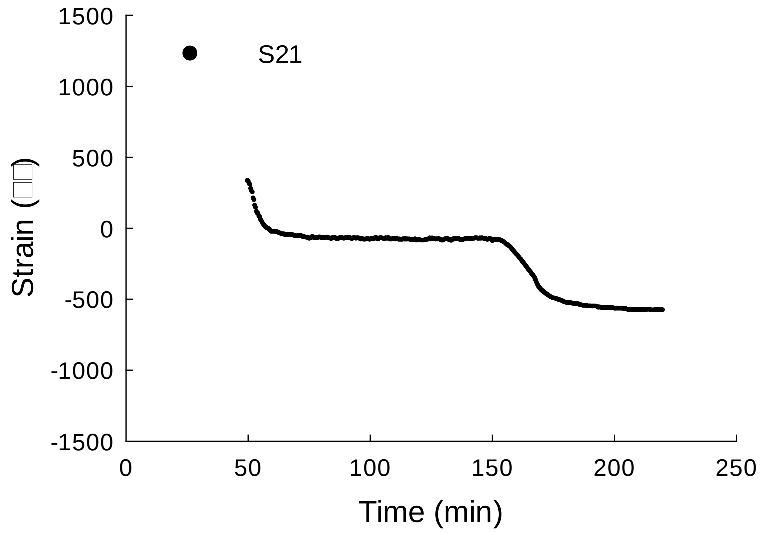


b. Internal gages

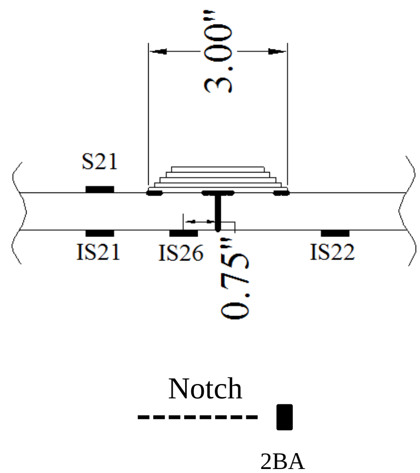


c. Gages locations

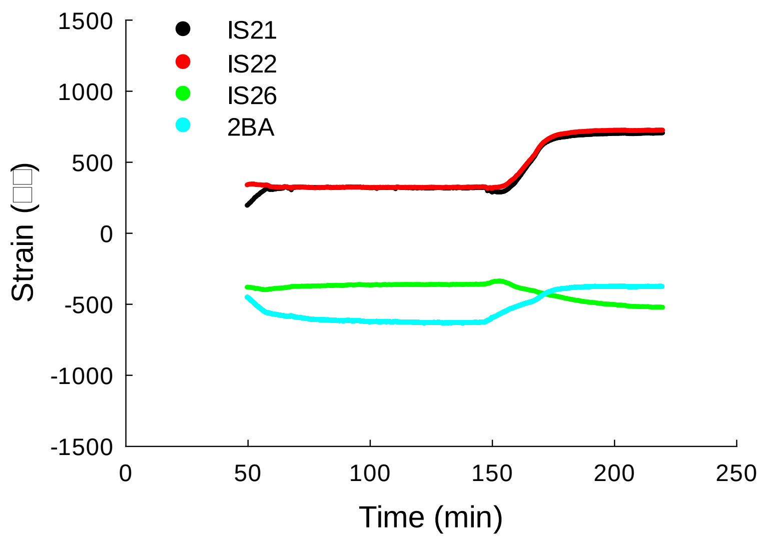
Figure D-10. Strains monitored during the U-A1 repair curing



a. External gages



c. Gages locations



b. Internal gages

Figure D-11. Strains monitored during the D-BE repair curing

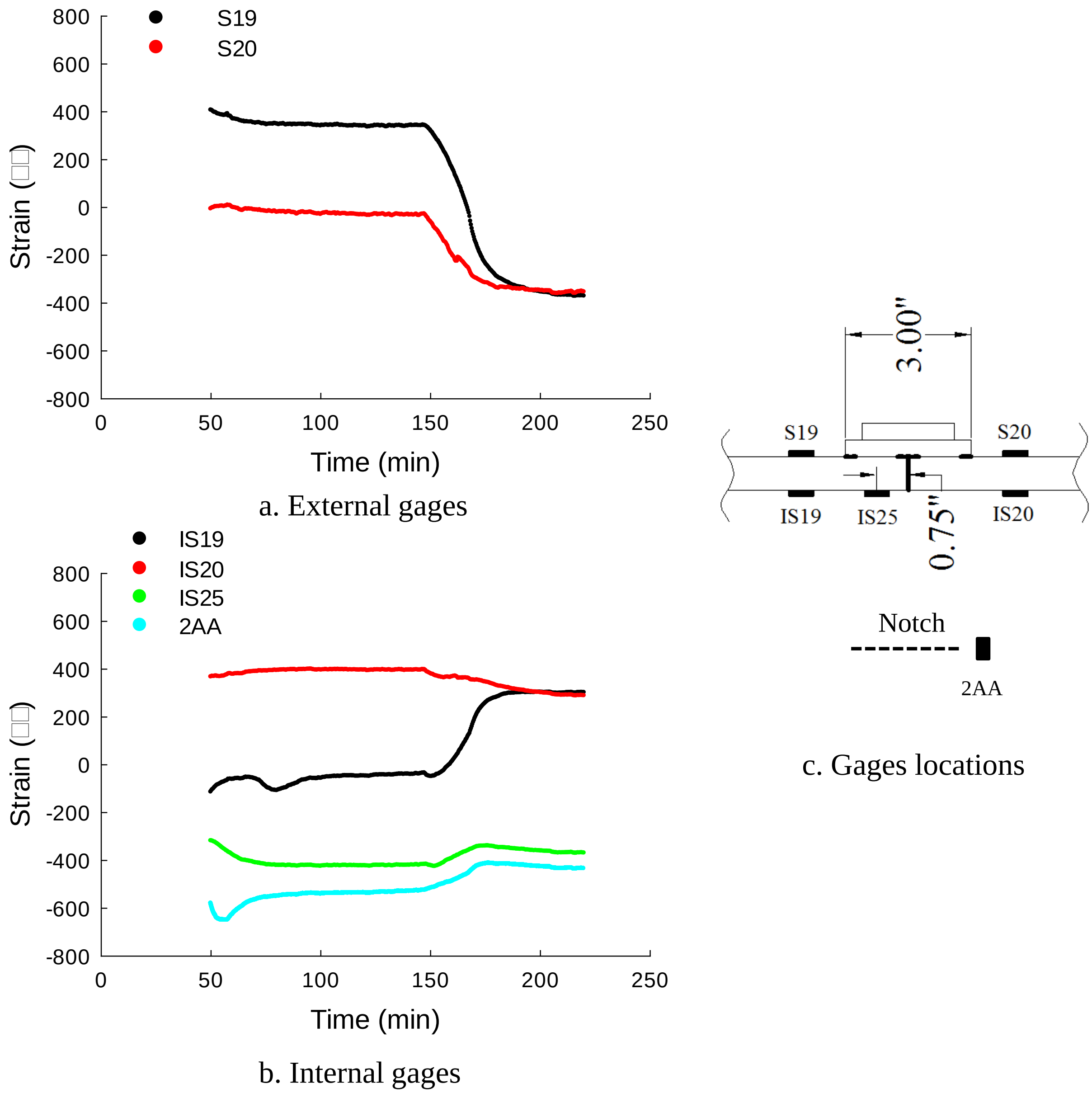
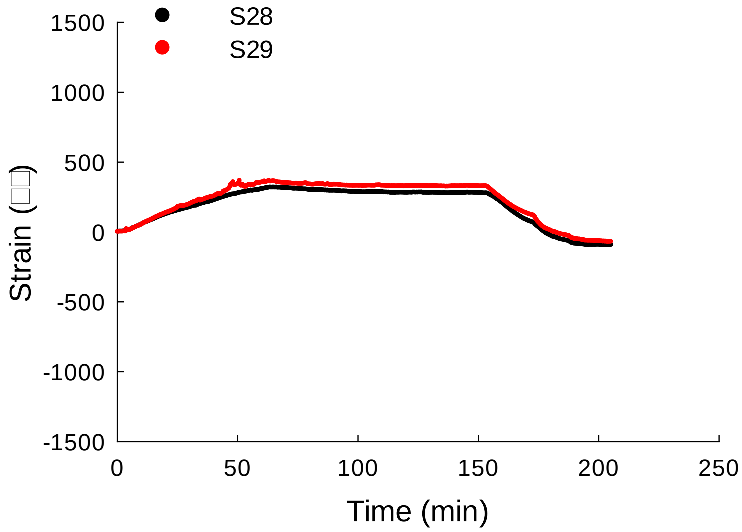
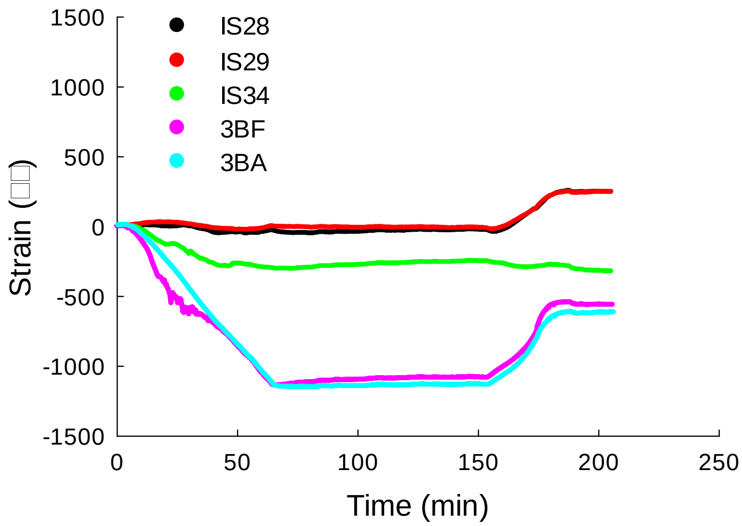


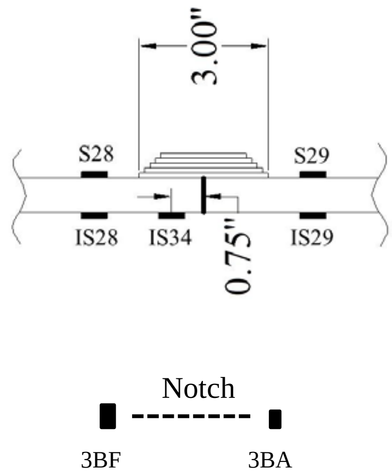
Figure D-12. Strains monitored during the D-A2 repair curing



a. External gages

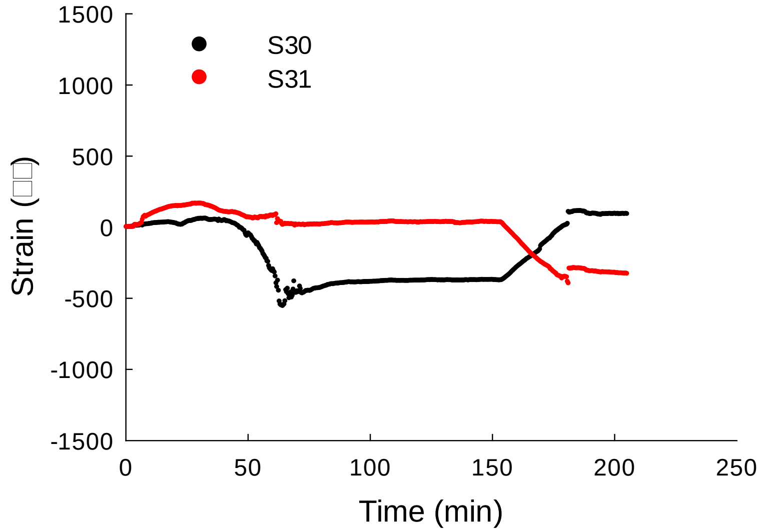


b. Internal gages

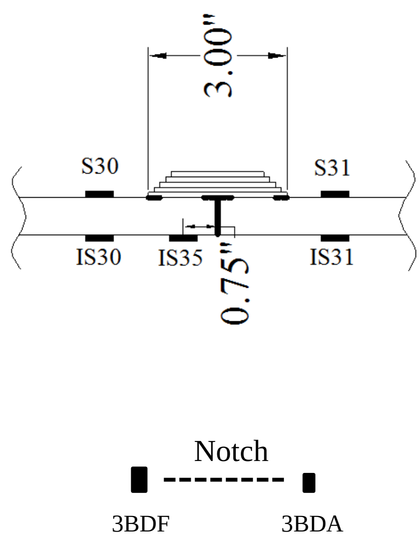


c. Gages locations

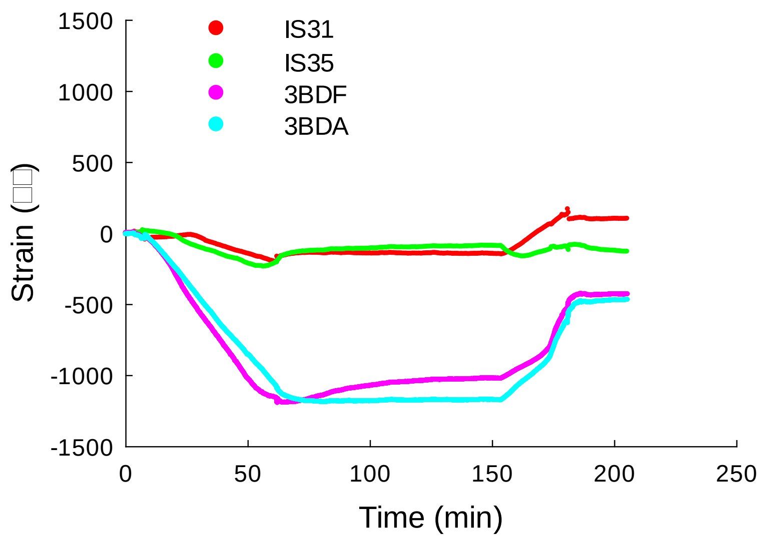
Figure D-13. Strains monitored during the C-BE repair curing



a. External gages



c. Gages locations



b. Internal gages

Figure D-14. Strains monitored during the CD-BE repair curing

APPENDIX E—RAW STRAIN GAGE DATA

The strain distribution was measured and predicted at ten equal load increments up to the maximum values for loads mentioned in table E-1 for each test phase. For the strain survey, the panel was subjected to 75% of the maximum fatigue loads.

The raw data from the strain survey for the strain gages for each repair are provided in the tables below, in which, for each load condition, applied loads and strains were measured at each gage at each of the ten equal load increments up to the maximum loads listed. For the applied loads, the pressure is in units of psi, 12-frame load assemblies (frames 1–12) are in units of lb, 14-hoop load assemblies (hoops 1–14) are in units of lb, and longitudinal load assemblies (longitudinals 1–8) are in units of lb. The strains measured at the gages are in units of $\mu\varepsilon$.

For the entire test, the applied loads were within ±2% of the prescribed values listed in table E-1. Valid strain readings were obtained for most of the gages, with the exception of a few gages (particularly substructure gages and internal skin gages), which short-circuited due to moisture absorption during panel pressurization using water. These gages show scattered readings or the values dropped as the test progressed with fatigue cycling.

Table E-1. Loading conditions of the test for the strain survey

Test Phase	Maximum Load			
	Pressure (psi)	Hoop (lb)	Frame (lb)	Longitudinal (lb)
Reference	6.7	7140	1133	6675
Phase 1	6.7	7140	1133	6675
Phase 2	6.7	7140	1133	6675
Phase 3	6.7	7140	1133	6675
Phase 4	6.7	7140	1133	6675

The strain survey was conducted every 5000 cycles and repeated three times to verify the repeatability of the results. To avoid overcrowding of data, in this appendix, the data is provided for every 20,000 cycles for reference, phase 1, and phase 2 repairs and every 10,000 cycles for phase 3 repairs. The raw strain gage data for phase 4 repairs are provided before impact, after impact, and after 20,000 fatigue cycles. In addition, the strain survey was also conducted for the pristine panel. The raw data is provided in tables E-2–E-4. The details of the data for each repair follow.

E.1 REFERENCE AND PHASE 1 REPAIRS

Tables E-5–E-16 provide the readings of pressure, hoop loads, axial loads, frame loads, and strain gages for reference and phase 1 repairs. Tables E-5–E-7 show the three runs of the baseline raw strain survey data for the R-BE, U-BE, and U-A2 repairs, respectively. Similarly, tables E-8–E-10, E-11–E-13, and E-14–E-16 consist of the raw strain survey data after 20,000 cycles, 40,000 cycles, and 60,000 cycles, respectively. For the U-A1 repair, tables E-8–E-10, E-11–E-13, and E-14–E-16 show the strain survey results at 0, 20,000, and 40,000 cycles, respectively. The strain gages for the U-A1 repair were removed after 40,000 cycles because of the limitations of strain gage channels.

E.2 PHASE 2 REPAIRS

Tables E-17–E-19 provide the baseline strain survey data for phase 2 repairs. Tables E-20–E-22, E-23–E-25, and E-26–E-28 provide the strain survey data after 20,000, 40,000, and 60,000 cycles, respectively.

E.3 PHASE 3 REPAIRS

Tables E-29–E-31 provide the baseline strain survey data for phase 3 repairs. Tables E-32–E-34 and E-35–E-37 provide the strain survey data after 10,000 and 20,000 cycles, respectively.

E.4 PHASE 4 REPAIRS

Tables E-38–E-40 provide the strain survey data before impact for phase 4 repairs. Tables E-41–E-43 and E-44–E-46 provide the strain survey data after impact and at 20,000 cycles, respectively.

Note that the missing strain gage values in the following tables are either due to removal of strain gages or faulty strain values.

Table E-2. Baseline strain survey raw data of pristine panel (run1)

Load Step	0	1	2	3	4	5	6	7	8	9	10
Pressure	0.03	0.67	1.35	2.03	2.68	3.35	4.01	4.66	5.59	5.99	6.66
Frame-1	-2.02	98.33	217.18	339.23	457.34	572.27	689.24	809.01	939.69	1041.13	1139.06
Frame-2	12.75	83.42	232.44	338.99	459.28	570.06	652.43	818.81	888.88	1027.42	1131.23
Frame-3	-32.18	130.33	281.56	369.73	444.14	508.34	683.33	811.12	843.44	977.25	1172.43
Frame-4	-18.46	86.90	228.94	369.10	392.93	500.34	664.68	776.97	898.25	1042.58	1160.84
Frame-5	-12.00	75.60	233.14	334.63	438.60	568.93	682.51	796.36	887.48	1024.31	1132.34
Frame-6	-0.86	94.89	214.23	333.01	452.86	559.44	685.73	800.94	888.04	1026.46	1124.83
Frame-7	-2.92	92.36	231.28	346.97	445.47	563.55	683.96	798.68	890.22	1015.36	1127.20
Frame-8	-5.84	99.92	230.66	337.92	434.33	563.17	684.56	804.69	883.40	1047.95	1137.75
Frame-9	24.11	131.95	248.06	347.96	462.84	571.69	686.74	801.89	890.26	1018.98	1130.11
Frame-10	4.80	115.48	225.14	334.76	460.36	553.67	679.44	810.18	885.23	1019.44	1136.78
Frame-11	12.86	110.90	221.76	321.32	464.71	565.19	694.66	808.77	883.40	1021.76	1127.43
Frame-12	-10.31	109.06	222.06	319.30	466.46	556.69	694.85	793.81	885.13	1015.59	1135.53
Hoop-1	36.48	586.84	1424.82	2131.03	2863.70	3578.03	4303.14	4992.62	5798.92	6418.25	7142.74
Hoop-2	124.58	740.62	1440.41	2156.63	2856.05	3594.56	4349.08	4988.06	5833.41	6403.15	7108.84
Hoop-3	53.00	698.70	1415.96	2172.09	2908.23	3582.89	4322.28	4992.19	5736.58	6431.37	7131.71
Hoop-4	65.50	723.76	1472.51	2143.57	2866.56	3569.39	4295.69	4988.13	5839.31	6410.68	7145.44
Hoop-5	2.67	743.82	1441.69	2139.89	2858.94	3563.42	4285.76	5003.29	5689.42	6147.23	6687.59
Hoop-6	-10.97	727.88	1422.78	2145.40	2852.73	3579.88	4270.51	4998.15	5652.03	6132.72	6695.22
Hoop-7	666.37	814.27	1233.15	2132.80	2842.40	3578.55	4284.28	4999.51	5772.79	6427.76	7134.70
Hoop-8	218.60	728.38	1523.13	2156.91	2862.86	3583.30	4282.46	5002.98	5696.49	6438.22	7129.39
Hoop-9	110.70	741.25	1433.57	2148.54	2737.37	3566.23	4279.20	5009.58	5804.80	6432.42	7121.39
Hoop-10	851.89	1054.02	1443.35	2135.34	2824.85	3546.23	4278.82	5023.32	5791.26	6430.46	7130.41
Hoop-11	169.74	714.10	1427.53	2145.74	2861.43	3575.25	4275.16	4990.86	5802.75	6416.50	7130.18
Hoop-12	192.88	757.52	1426.52	2143.91	2869.66	3580.82	4263.49	5003.77	5782.51	6442.25	7124.21
Hoop-13	158.75	640.52	1437.07	2138.06	2852.96	3538.58	4290.46	5019.95	5751.59	6436.63	7129.41
Hoop-14	-6.52	660.06	1430.04	2133.45	2858.13	3575.42	4300.59	4995.97	5744.76	6439.50	7120.01
Long-1	-93.44	577.32	1286.00	1900.28	2749.38	3519.46	3967.41	4521.48	5204.35	5927.43	6785.65
Long-2	127.99	867.09	1386.34	2126.02	2828.03	3470.39	3911.37	4752.21	5187.57	6070.06	6729.10
Long-3	-17.44	758.72	1491.38	2139.67	2528.32	3419.48	4047.50	4577.03	5410.39	6032.71	6573.67
Long-4	97.56	492.52	1399.54	2143.87	2756.65	3367.77	3836.55	4717.94	5495.47	5996.41	6575.62
Long-5	-46.99	547.20	1181.03	1912.75	2674.24	3313.13	4055.30	4709.98	5325.40	5983.32	6691.28
Long-6	-114.54	1014.30	1112.86	2168.98	2915.75	3115.68	3904.34	4587.79	5343.60	6060.61	6634.21
Long-7	16.87	519.62	1518.33	1898.34	2633.15	3176.95	4010.86	4760.41	5507.33	5734.02	6668.92
Long-8	-124.03	581.75	1519.08	2186.42	2937.84	3541.84	4124.37	4359.11	5039.06	5829.55	6850.95

Table E-2. Baseline strain survey raw data of pristine panel (run1) (continued)

R1-H	-691.77	100.45	201.60	286.21	368.08	449.49	530.86	609.41	699.78	758.19	833.50
R1-A	-207.30	-120.21	-69.58	-27.16	17.50	49.49	83.75	101.62	170.85	197.67	242.29
R2-H	139.14	94.95	161.36	228.78	302.11	376.38	455.03	530.74	617.92	672.39	750.60
R2-A	-86.24	-45.47	-6.78	36.66	79.50	118.20	155.19	177.32	249.02	279.00	325.05
R3-H	58.47	49.11	115.67	185.06	254.93	324.37	398.35	466.92	553.67	603.11	673.80
R3-A	-108.52	-28.97	15.56	70.57	127.69	181.44	230.16	270.48	343.97	394.78	456.18
R4-H	-21.95	64.17	143.66	213.69	278.29	342.68	405.20	462.31	530.53	572.77	628.07
R4-A	-125.76	-60.44	-33.00	5.21	42.67	68.22	103.05	125.41	180.47	206.95	248.29
R5-H	-830.09	81.21	216.66	316.32	407.74	493.02	577.27	654.01	743.81	802.49	880.47
R5-A	-16.84	-60.73	-15.53	40.44	87.58	133.12	177.46	210.09	292.92	324.02	375.31
S6	-750.54	111.62	227.92	321.30	407.69	489.54	571.45	647.67	748.44	802.43	875.54
S7	-802.54	87.19	198.64	290.40	377.72	458.50	540.42	615.93	721.06	773.25	850.90
S8	-52.84	68.00	150.13	217.32	280.02	342.32	404.99	462.17	525.28	569.46	624.86
S9	-627.33	111.98	253.57	353.78	445.57	526.46	608.18	681.85	770.64	826.07	903.12
IS01	-20.18	0.80	38.06	79.48	127.02	175.45	219.63	266.86	319.85	352.26	397.95
IS02	23.04	9.57	41.42	86.33	137.93	187.04	232.22	282.97	337.68	374.40	420.35
F01	1022.96	768.01	763.42	747.97	742.58	762.11	788.88	842.22	847.10	912.91	932.59
F02	-613.65	-396.94	-320.87	-269.19	-210.16	-155.26	-81.73	-34.59	44.79	77.16	164.97
F03	1213.75	909.43	899.24	867.99	850.60	864.44	879.49	927.83	917.68	982.98	996.13
F04	-843.67	-558.43	-465.90	-394.37	-320.34	-257.51	-168.87	-114.66	-17.73	18.48	124.31
F05	1024.90	743.93	747.46	757.46	773.55	800.45	820.00	872.77	889.19	958.95	965.25
F06	-587.15	-400.65	-340.73	-294.86	-222.82	-168.46	-105.73	-2.11	78.77	128.34	197.91
F07	1124.74	829.76	824.80	800.89	812.82	831.05	839.05	892.72	899.04	975.27	972.91
F08											
F09	1031.58	786.35	783.92	768.46	737.59	754.60	772.90	842.37	829.72	900.47	904.45
F10	-780.02	-542.00	-454.88	-375.91	-318.33	-259.85	-172.26	141.21	303.17	325.24	398.37
L01	-54.29	-22.33	-17.55	-9.19	4.95	15.03	20.86	49.77	48.32	63.19	80.31
L02	-135.54	-24.22	2.38	26.22	48.22	63.24	75.00	101.78	112.24	128.21	148.35
L03	-73.06	8.23	27.72	50.13	71.69	89.58	103.86	129.10	156.19	172.82	191.86
L04	-18.09	22.25	35.51	52.84	53.96	77.67	94.30	125.22	118.22	142.02	157.46
L05	-78.43	-37.93	-26.91	-0.72	22.22	32.69	43.71	76.23	860.14	839.28	840.19

Note: Strain gage F08 showed faulty readings.

Table E-3. Baseline strain survey raw data of pristine panel (run2)

Load Step	0	1	2	3	4	5	6	7	8	9	10
Pressure	0.05	0.66	1.37	2.01	2.67	3.34	4.03	4.67	5.32	6.01	6.65
Frame-1	5.69	71.76	229.66	324.64	464.94	540.67	680.48	795.75	915.03	996.08	1116.96
Frame-2	0.27	106.11	195.55	309.02	426.32	552.16	676.64	816.89	928.20	1026.47	1119.08
Frame-3	-21.15	138.33	255.65	292.91	554.14	558.43	709.18	720.80	962.08	969.41	1121.46
Frame-4	21.30	119.93	258.19	386.18	407.00	576.77	669.88	781.42	941.69	1053.11	1143.53
Frame-5	4.45	120.03	257.36	327.05	456.20	571.48	667.75	780.82	894.13	1016.55	1132.92
Frame-6	23.29	112.43	221.70	342.35	464.27	568.15	673.17	792.70	903.63	1020.44	1127.92
Frame-7	-2.52	112.81	226.46	343.40	448.68	565.23	675.31	782.34	905.12	1031.87	1102.73
Frame-8	-2.70	108.36	220.56	346.93	444.28	578.56	669.43	787.76	900.38	1025.05	1136.53
Frame-9	5.65	106.51	235.51	374.26	424.06	557.08	674.67	816.34	898.56	1031.65	1131.61
Frame-10	0.30	132.69	235.75	336.60	464.27	570.94	672.19	796.43	865.58	1024.83	1138.13
Frame-11	-0.82	116.69	218.48	336.15	456.57	565.42	662.33	784.45	895.13	1032.16	1150.11
Frame-12	-34.80	110.51	219.02	343.56	432.68	573.91	664.78	786.91	928.51	1014.81	1131.75
Hoop-1	58.21	713.71	1461.57	2482.61	2817.86	3566.42	4273.74	4991.80	5711.51	6436.46	7117.47
Hoop-2	131.73	821.14	1435.55	2103.33	2928.71	3565.26	4327.21	5008.70	5707.85	6421.13	7128.52
Hoop-3	44.25	681.33	1414.69	2077.83	2884.90	3569.95	4316.60	5061.46	5715.05	6426.29	7166.65
Hoop-4	81.83	716.65	1424.03	2113.06	2782.56	3599.48	4289.82	5119.74	5593.94	6407.15	7143.70
Hoop-5	0.88	722.43	1429.63	2133.02	2829.66	3580.64	4290.71	4961.20	5529.20	6089.82	6752.44
Hoop-6	-10.97	704.36	1416.05	2123.88	2846.71	3586.41	4288.29	5019.17	5595.17	6163.68	6770.13
Hoop-7	698.50	819.79	1146.38	2208.05	2904.29	3576.05	4294.56	4993.36	5734.80	6426.11	7115.09
Hoop-8	218.55	721.03	1427.54	2133.78	2839.87	3582.23	4296.60	5011.26	5716.64	6404.35	7137.38
Hoop-9	64.10	703.56	1427.34	2141.88	2831.21	3592.03	4287.73	4994.45	5724.26	6433.19	7125.68
Hoop-10	904.93	1107.13	1357.34	2139.38	2862.74	3562.91	4294.36	5013.68	5732.78	6447.21	7131.11
Hoop-11	151.62	712.22	1419.44	2129.99	2836.79	3575.99	4278.35	4991.85	5699.75	6424.49	7130.89
Hoop-12	191.02	719.32	1412.96	2157.15	2839.48	3572.49	4284.85	4997.50	5708.16	6423.01	7161.23
Hoop-13	151.41	706.15	1472.71	2136.79	2837.22	3595.90	4282.74	4984.45	5713.37	6424.59	7137.42
Hoop-14	-6.52	711.26	1370.59	2110.20	2871.64	3552.38	4292.84	4989.64	5713.75	6427.40	7128.05
Long-1	-119.13	840.51	1385.39	2124.90	2638.83	3230.84	3900.94	4635.19	5322.34	6120.03	6686.51
Long-2	-159.91	722.03	1290.86	1897.89	2571.38	3374.51	3890.96	4642.85	5400.30	6030.76	6666.67
Long-3	-14.57	543.76	1489.71	2031.95	2566.80	3471.17	4032.02	4644.53	5388.92	5997.54	6776.63
Long-4	14.39	671.52	1389.58	2088.56	2729.07	3500.49	3856.29	4948.58	5444.51	6060.77	6775.81
Long-5	-45.33	763.28	1122.01	1877.99	2777.08	3407.34	3986.21	4634.44	5329.71	6011.65	6750.63
Long-6	-117.56	813.46	1127.84	1759.90	2546.50	3541.06	4001.14	4686.79	5331.17	5962.66	6771.62
Long-7	-4.24	640.84	1607.34	2122.46	2508.75	3174.69	4191.11	4602.40	5246.37	6211.90	6551.93
Long-8	-84.13	517.17	1400.96	2005.22	3010.02	3225.19	3664.05	4723.03	5406.36	6153.32	6528.16

Table E-3. Baseline strain survey raw data of pristine panel (run2) (continued)

R1-H	-701.71	88.86	197.73	279.34	364.34	445.53	523.70	604.54	677.36	757.11	832.34
R1-A	-204.35	-152.96	-84.47	-45.02	-5.57	25.69	77.80	110.57	156.72	198.37	235.59
R2-H	56.34	90.96	160.71	224.77	302.00	376.30	447.93	526.20	597.50	673.64	749.49
R2-A	-138.07	-66.31	-15.07	26.24	67.59	102.84	159.38	197.90	244.70	290.54	326.32
R3-H	78.24	43.15	111.11	178.38	251.75	321.70	391.72	463.38	530.24	603.18	671.47
R3-A	-103.32	-47.74	6.89	58.96	111.87	161.44	226.32	278.56	340.10	400.85	453.66
R4-H	-26.67	51.57	137.33	205.78	274.43	336.64	398.43	459.30	513.84	572.22	625.93
R4-A	-128.76	-75.83	-40.65	-5.52	27.09	61.30	99.00	130.04	171.06	212.08	246.89
R5-H	-736.53	56.69	209.14	310.14	403.43	487.11	567.53	649.34	723.57	805.36	878.62
R5-A	-54.72	-86.29	-29.01	20.66	70.29	117.08	176.08	222.28	274.90	327.31	373.11
S6	-15.21	113.24	230.64	319.64	407.92	487.74	574.76	652.44	722.82	799.02	871.02
S7	-835.24	75.43	193.75	286.03	374.51	453.98	541.92	621.96	694.53	774.18	846.74
S8	-38.65	58.64	145.79	210.25	277.33	338.84	396.89	456.25	510.86	568.98	623.23
S9	-637.16	84.50	246.15	349.05	440.18	519.44	599.20	677.03	749.20	828.61	899.14
IS01	-13.49	3.88	40.05	82.19	130.65	172.63	220.92	268.15	308.67	354.00	396.68
IS02	3.43	10.57	41.51	87.36	136.77	183.63	233.46	283.99	325.29	375.04	421.03
F01	1039.49	896.39	822.82	810.90	808.74	827.78	859.73	882.75	913.09	902.62	940.71
F02	-615.97	-478.62	-361.01	-320.74	-239.34	-192.71	-126.89	-72.56	10.12	79.68	146.44
F03	1227.22	1059.90	968.00	939.32	933.01	936.71	967.19	981.72	1003.00	975.03	1003.71
F04	-844.43	-667.98	-519.72	-460.56	-363.42	-304.24	-230.64	-169.63	-67.40	17.71	100.45
F05	1022.83	883.06	806.65	819.46	816.57	853.28	882.34	917.62	939.82	941.97	975.72
F06	-535.17	-473.68	-379.72	-329.40	-262.06	-145.78	-93.15	-21.97	44.52	119.15	180.85
F07	1132.43	966.69	878.02	876.40	862.33	891.10	916.54	955.24	966.25	958.84	984.10
F08											
F09	1047.95	913.75	845.90	822.77	823.49	841.65	861.71	879.87	886.73	895.41	914.57
F10	-775.97	-638.72	-499.69	-423.25	-362.00	0.31	137.08	155.00	226.05	304.32	358.23
L01	-51.56	-20.83	-14.01	-4.60	3.86	23.95	27.77	37.77	53.00	68.95	78.04
L02	-101.26	-32.29	-0.37	21.45	38.69	54.46	77.94	93.72	113.17	132.58	147.07
L03	7.17	4.57	26.79	45.54	64.80	85.36	117.16	135.60	155.46	175.24	192.32
L04	-5.37	37.50	51.62	64.29	79.23	112.90	103.69	118.78	141.93	162.83	163.64
L05	-86.12	-46.64	-31.06	-10.47	5.24	26.56	921.56	1014.14	971.87	929.59	920.38

Note: Strain gage F08 showed faulty readings.

Table E-4. Baseline strain survey raw data of pristine panel (run3)

Load Step	0	1	2	3	4	5	6	7	8	9	10
Pressure	0.06	0.58	1.34	2.00	2.67	3.38	4.00	4.67	5.35	6.03	6.69
Frame-1	-8.96	133.67	258.18	333.15	465.57	580.18	662.59	797.29	902.20	1018.66	1136.95
Frame-2	-14.47	182.29	198.87	354.38	452.33	585.71	666.17	798.14	895.04	1041.65	1168.48
Frame-3	10.58	110.05	202.23	375.38	518.16	530.44	684.47	755.04	930.61	1049.40	1132.15
Frame-4	-6.29	100.86	239.84	356.52	419.12	512.25	664.46	790.63	895.57	1041.57	1138.33
Frame-5	11.71	105.20	241.97	333.46	452.82	559.94	671.46	791.92	887.20	1012.45	1130.14
Frame-6	4.83	121.45	233.87	335.74	487.61	598.94	677.95	781.62	902.15	1007.74	1132.82
Frame-7	-10.74	91.35	237.60	341.62	446.42	568.32	696.72	798.32	912.11	1011.66	1149.36
Frame-8	-29.83	119.66	211.86	365.92	453.16	567.70	671.89	796.07	923.58	1003.07	1111.96
Frame-9	-20.86	106.71	214.87	378.00	448.90	595.01	662.23	796.17	884.87	1039.82	1130.53
Frame-10	-9.06	123.02	234.11	343.64	456.27	556.53	669.43	797.68	908.14	1001.74	1131.09
Frame-11	-7.41	111.35	226.50	338.65	461.41	562.77	677.50	799.97	900.50	1006.90	1101.10
Frame-12	8.84	94.98	218.60	336.71	425.41	512.57	678.87	786.94	913.90	996.56	1138.56
Hoop-1	32.86	713.86	1427.17	2146.05	2928.32	3578.39	4276.93	4985.87	5726.56	6438.27	7124.63
Hoop-2	113.85	665.88	1419.48	2049.96	2853.70	3582.42	4273.20	4956.40	5758.43	6478.29	7189.22
Hoop-3	38.99	700.73	1442.69	2127.04	2863.89	3583.24	4300.42	5055.71	5710.36	6443.79	7152.71
Hoop-4	69.13	696.84	1434.91	2107.83	2867.81	3636.85	4282.14	5046.67	5728.73	6289.24	7141.81
Hoop-5	0.88	695.65	1433.22	2142.21	2858.38	3590.70	4284.90	4985.84	5517.19	6082.64	6754.00
Hoop-6	-7.33	684.47	1414.23	2140.48	2850.35	3562.04	4266.02	4974.99	5653.98	6241.96	6782.60
Hoop-7	680.58	805.67	1142.82	2154.73	2850.75	3593.18	4313.76	4994.65	5760.35	6451.09	7140.05
Hoop-8	211.27	735.81	1434.83	2148.13	2862.57	3561.80	4267.90	4996.69	5709.92	6401.80	7123.52
Hoop-9	28.28	693.02	1454.21	2148.83	2867.88	3586.29	4264.87	4969.37	5712.29	6416.30	7121.01
Hoop-10	922.67	1100.36	1364.44	2149.81	2847.63	3603.35	4312.52	5011.90	5713.84	6428.68	7144.24
Hoop-11	153.43	683.49	1395.93	2137.01	2859.34	3539.43	4262.50	4948.44	5703.93	6420.12	7135.21
Hoop-12	203.73	728.61	1371.20	2185.98	2869.38	3588.44	4227.18	4982.98	5715.99	6405.93	7132.89
Hoop-13	144.12	713.66	1392.41	2143.87	2852.67	3590.03	4275.87	4991.75	5721.24	6407.43	7130.83
Hoop-14	-28.49	682.17	1436.51	2131.96	2857.85	3575.77	4285.94	4989.64	5721.64	6439.50	7136.08
Long-1	-109.77	676.01	1392.02	2118.43	2776.19	3422.30	4122.74	4708.27	5309.56	6046.06	6809.41
Long-2	-256.25	572.69	1251.68	1977.42	2730.86	3237.96	3962.12	4551.90	5197.30	5908.04	6588.24
Long-3	-12.17	582.57	1512.30	2071.30	2851.37	3496.28	4039.61	4668.19	5295.65	6064.30	6704.21
Long-4	70.56	551.29	1269.35	1815.03	2770.53	3200.51	3705.17	4828.57	5291.76	5912.44	6695.27
Long-5	-57.60	604.50	1497.75	2111.84	2646.35	3315.92	4056.04	4739.25	5417.37	5971.29	6718.82
Long-6	91.46	756.64	1186.40	2033.84	2735.39	3444.02	4092.16	4578.42	5358.65	6033.36	6686.15
Long-7	3.05	509.52	1294.34	2091.68	2745.22	3527.96	4242.04	4574.17	5327.31	5743.71	6693.62
Long-8	-142.79	759.33	1312.45	1932.72	2653.38	3620.96	3871.54	4850.63	5320.14	6150.37	6804.99

Table E-4. Baseline strain survey raw data of pristine panel (run3) (continued)

R1-H	-718.14	63.54	190.77	274.54	361.21	446.65	519.93	600.46	682.67	761.56	837.06
R1-A	-187.93	-165.63	-94.15	-52.46	-7.06	28.67	70.36	112.03	151.48	191.69	232.57
R2-H	54.56	88.37	155.95	220.31	299.29	377.46	445.33	524.88	603.70	678.21	754.72
R2-A	-135.69	-76.46	-18.65	25.51	68.37	107.15	158.58	200.13	241.80	287.76	327.75
R3-H	75.70	37.56	107.76	173.53	247.11	323.24	386.26	459.51	534.74	606.26	675.53
R3-A	-101.43	-58.64	1.54	59.80	114.44	163.77	228.49	282.37	337.89	399.54	455.02
R4-H	-31.73	33.23	131.17	200.77	270.13	337.12	395.36	456.77	516.90	574.71	629.69
R4-A	-126.92	-88.07	-40.28	-4.86	30.32	61.49	96.16	130.67	171.49	211.50	246.98
R5-H	-741.02	26.45	201.16	302.71	399.30	490.80	563.47	645.24	728.30	808.56	883.18
R5-A	-45.00	-95.63	-33.21	19.73	70.90	115.40	171.95	225.88	275.03	325.95	373.79
S6	-13.58	96.61	225.95	316.38	404.70	491.54	569.75	647.97	726.66	801.63	873.19
S7	-849.50	58.07	187.80	279.15	369.11	457.24	536.18	616.77	698.01	775.89	850.00
S8	-42.76	41.02	139.75	207.36	274.47	338.66	393.67	453.63	513.84	571.39	626.72
S9	-641.37	41.28	238.04	341.99	434.62	523.42	596.54	672.55	754.47	831.95	904.02
IS01	-13.48	8.58	37.70	80.38	128.13	179.14	221.12	266.29	312.05	356.39	401.67
IS02	2.39	13.73	42.42	84.01	133.98	190.90	231.27	281.23	328.93	375.62	424.74
F01	1060.95	928.62	838.43	838.89	843.66	829.76	877.52	895.21	906.05	918.96	940.16
F02	-625.11	-511.18	-383.56	-325.12	-255.18	-192.66	-133.87	-73.95	10.16	86.56	150.57
F03	1248.26	1099.15	985.41	970.70	965.93	943.02	988.21	987.11	988.38	991.18	1000.62
F04	-853.82	-709.56	-548.65	-467.57	-378.76	-308.36	-240.17	-166.88	-64.36	29.80	107.86
F05	1025.52	961.29	833.07	840.39	847.51	859.78	891.81	922.67	928.80	941.71	972.09
F06	-579.78	-458.88	-384.54	-326.69	-218.58	-137.20	-92.84	-29.01	43.29	117.72	189.79
F07	1148.98	1032.83	906.62	898.05	897.96	910.40	935.58	954.87	950.18	956.59	983.54
F08											
F09	1121.83	1038.91	884.84	860.18	828.64	834.24	866.13	881.68	875.90	889.90	902.28
F10	-789.49	-678.15	-517.40	-430.33	-299.80	104.01	91.04	123.09	201.80	281.52	344.59
L01	-48.28	-18.47	-13.64	1.99	13.99	22.09	28.27	39.58	47.99	61.59	76.57
L02	-97.02	-35.77	-0.92	23.65	41.99	61.62	77.21	94.44	109.47	126.91	144.84
L03	15.31	6.70	28.78	49.75	71.61	100.03	116.99	136.31	151.68	170.54	190.39
L04	-15.92	40.62	52.57	65.47	87.76	91.78	100.81	115.55	130.17	143.99	147.87
L05	-81.09	-50.57	-33.23	-9.39	7.77	42.81	422.71	1089.97	1092.68	1036.07	996.58

Note: Strain gage F08 showed faulty readings.

Table E-5. Strain survey raw data (run1), reference, and phase 1 repairs (baseline for R-BE, U-BE, and U-A2 repairs)

Load Step	0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00
Pressure	-0.05	0.73	1.39	1.98	2.64	3.33	3.96	4.70	5.32	6.01	6.68
Frame-1	-10.24	117.50	227.94	342.52	468.19	582.55	669.33	791.22	892.13	1040.68	1138.75
Frame-2	33.50	114.28	221.78	338.40	424.46	566.44	694.46	795.91	903.88	1032.09	1132.21
Frame-3	39.04	117.06	280.94	304.04	484.33	526.20	718.88	779.73	912.97	1007.98	1138.16
Frame-4	6.26	98.78	236.07	318.76	449.80	547.74	692.93	801.14	942.76	1019.20	1156.72
Frame-5	-18.30	116.59	223.14	347.51	454.21	563.71	674.56	792.26	914.18	1037.39	1117.18
Frame-6	-0.28	125.48	219.98	346.39	458.67	569.74	685.96	797.01	908.46	1028.54	1133.36
Frame-7	6.60	123.58	230.64	342.44	465.54	572.81	670.18	788.60	918.00	1025.66	1142.84
Frame-8	23.92	132.38	232.81	333.62	463.09	565.08	693.51	797.85	904.37	1061.89	1127.82
Frame-9	-22.31	148.89	234.02	336.99	459.93	589.72	692.76	803.32	907.85	1011.06	1125.81
Frame-10	2.93	122.35	231.99	339.41	457.69	577.32	672.64	779.79	888.66	1029.37	1134.12
Frame-11	-6.02	121.51	239.43	323.98	468.74	576.99	696.77	769.41	921.71	1023.32	1158.11
Frame-12	15.27	129.46	199.25	329.57	458.38	563.73	660.09	766.41	890.40	1028.84	1133.97
Hoop-1	-13.31	674.59	1342.70	2175.72	2882.15	3560.84	4242.47	5018.38	5729.96	6443.34	7108.54
Hoop-2	-19.11	709.40	1457.68	2140.04	2881.48	3572.34	4282.19	5072.49	5727.92	6483.35	7185.93
Hoop-3	-23.13	731.01	1450.29	2138.21	2891.03	3596.02	4230.39	4968.08	5696.11	6387.39	7149.38
Hoop-4	-74.16	649.35	1432.81	2093.11	2840.60	3585.71	4261.22	5018.46	5738.47	6382.30	7139.29
Hoop-5	-102.71	695.81	1408.32	2129.94	2839.14	3607.00	4282.67	5010.48	5775.04	6428.32	7150.52
Hoop-6	-3.59	691.51	1390.39	2144.01	2848.63	3579.98	4248.77	4983.20	5722.12	6484.70	7153.35
Hoop-7	6.47	755.81	1417.87	2144.31	2854.82	3577.26	4258.00	4995.94	5732.94	6439.60	7141.62
Hoop-8	32.25	767.68	1437.58	2151.17	2886.89	3563.42	4270.08	5006.01	5690.54	6403.57	7140.42
Hoop-9	36.97	717.55	1417.83	2150.35	2865.25	3573.85	4410.61	5012.89	5729.36	6414.75	7132.57
Hoop-10	-18.35	774.39	1435.90	2154.15	2849.63	3569.02	4252.16	5001.05	5721.15	6419.33	7146.10
Hoop-11	99.68	694.57	1421.47	2119.44	2828.54	3571.07	4267.58	5029.34	5772.59	6430.20	7144.05
Hoop-12	-5.65	676.89	1550.03	2109.14	2893.62	3561.00	4367.33	5072.16	5384.41	6487.56	7186.05
Hoop-13	-16.47	691.48	1428.63	2114.68	2903.20	3559.41	4267.72	4998.06	5793.67	6457.25	7130.12
Hoop-14	-12.42	705.29	1415.68	2133.39	2829.41	3575.77	4264.54	5012.04	5766.44	6388.37	7114.82
Long-1	-53.49	455.97	1456.42	2134.78	2527.72	3344.50	4018.08	4635.44	5282.89	5972.03	6830.46
Long-2	73.88	706.45	1230.89	1982.66	2593.14	3336.69	4053.03	4733.22	5407.29	6008.97	6689.69
Long-3	43.07	587.92	1445.94	2021.50	2754.87	3376.09	4017.80	4732.31	5357.31	5978.13	6621.44
Long-4	1.16	614.05	1160.56	1854.22	2774.50	3258.23	4089.62	4822.97	5383.07	5881.90	6550.00
Long-5	18.13	513.92	1215.10	1867.47	2677.68	3372.52	4148.51	4655.18	5322.35	6042.53	6725.19
Long-6	-123.63	558.29	1343.72	1854.75	2623.51	3277.60	4071.49	4646.24	5330.62	6025.30	6646.65
Long-7	13.82	637.74	1398.06	2154.71	2534.10	3328.21	4198.03	4863.19	5188.55	5907.86	6853.23
Long-8	-416.08	621.15	1454.72	2177.32	2558.86	3190.98	3874.48	4677.49	5575.13	5662.94	6726.53

Table E-5. Strain survey raw data (run1), reference, and phase 1 repairs (baseline for R-BE, U-BE, and U-A2 repairs) (continued)

S10	-123.30	96.19	290.86	441.62	601.06	741.93	865.22	996.96	1102.50	1209.98	1308.91
S11											
S12	194.04	47.11	154.72	250.72	358.38	466.06	559.77	664.35	751.89	844.09	931.89
S13	-135.13	210.39	365.90	478.95	590.83	693.26	775.88	867.54	946.33	1028.22	1103.07
S14	-158.16	146.61	332.16	470.97	606.08	730.12	829.05	939.67	1033.78	1132.51	1220.48
S15	-124.24	227.46	455.53	610.94	754.72	884.81	988.45	1098.84	1189.95	1282.67	1368.60
S16	527.12	341.84	228.48	144.23	68.33	14.45	-40.89	-98.57	-146.31	-178.68	-211.94
S17	851.22	666.25	515.48	404.39	296.35	185.94	91.80	-5.56	-86.44	-165.48	-278.20
S18	797.20	201.65	-200.52	-515.64	-803.23	-1049.49	-1246.76	-1449.04	-1604.29	-1731.76	-1848.28
IS10	60.19	41.16	14.11	-0.70	-13.68	-24.28	-34.15	-39.08	-40.38	-41.28	-40.91
IS11	147.23	0.35	-144.08	-231.87	-299.68	-351.39	-381.32	-397.90	-400.84	-390.76	-377.54
IS12	-239.09	58.15	84.18	107.16	133.07	160.98	192.50	238.58	285.36	338.91	392.26
IS13	239.93	-46.32	-95.52	-110.59	-104.37	-87.12	-58.93	-14.73	29.42	79.62	132.89
IS14	166.00	-55.57	-139.82	-189.06	-219.35	-232.69	-231.37	-209.63	-183.26	-150.77	-114.82
IS15	1308.07	1091.25	1000.25	944.88	913.23	896.23	897.50	913.32	929.15	964.79	1002.60
IS16	-216.86	29.27	166.61	269.42	378.79	478.00	567.41	663.70	739.48	817.55	891.42
IS17	-47.76	48.75	128.51	192.96	260.69	326.07	381.70	445.31	498.47	553.88	605.09
IS18	-43.47	94.12	198.66	278.55	360.27	437.64	504.42	582.21	645.14	707.97	766.81
1AF	-57.47	84.40	215.17	327.31	444.02	559.67	656.56	767.80	861.50	956.70	1045.67
1AA	-97.10	72.07	219.96	343.01	472.64	597.88	703.30	819.47	920.53	1021.28	1118.12
1BF	-144.09	194.97	458.16	661.50	855.44	1039.99	1187.17	1351.71	1480.07	1598.84	1712.49
1BA	-297.25	135.80	428.92	652.66	866.79	1064.41	1224.91	1397.73	1533.55	1659.93	1781.52
1RF	-1369.31	-1199.95	-963.76	-824.00	-665.07	-413.34	-365.97	-8127.92	-134.49	-1030.02	-257.53
1RA	-234.16	48.17	253.94	366.55	477.20	611.08	714.84	819.65	896.69	979.91	1050.41
F01	979.95	751.26	771.09	808.50	851.53	852.34	892.04	894.95	933.91	965.80	989.35
F02	-613.31	-404.94	-332.31	-299.94	-233.18	-162.82	-100.40	-25.40	35.54	94.20	164.85
F03											
F04	-849.22	-586.49	-491.91	-442.66	-353.59	-260.74	-183.81	-89.55	-22.15	56.92	141.13
F05	916.44	725.02	720.39	755.23	779.04	783.47	819.17	823.53	860.46	895.42	915.53
F06	-434.75	-301.69	-254.15	-218.53	-181.31	-108.19	-52.08	27.64	73.51	137.33	199.35
F07	1156.26	881.50	859.68	881.86	879.05	873.88	903.04	902.68	927.86	955.74	969.85
F08											
F09	1005.15	794.38	787.38	799.07	812.03	799.96	825.73	811.24	849.30	864.91	885.60
F10	-737.35	-530.24	-467.24	-426.21	-350.69	-263.70	-184.44	-82.70	-19.71	68.39	148.16
L01	34.73	-29.78	-15.28	0.51	9.09	22.96	38.88	50.87	63.71	73.79	91.97
L02	-120.52	-22.92	-3.04	17.02	29.36	44.09	60.28	74.81	90.12	102.25	121.74
L03	-16.42	-1.74	-4.76	3.47	9.37	15.97	28.51	40.17	54.27	61.27	77.89
L04	184.44	144.93	150.51	164.30	178.44	184.62	199.26	209.00	223.76	230.24	242.51
L05	-35.08	-11.87	0.64	20.45	38.94	59.44	83.54	113.61	135.42	155.15	179.41

Note: Strain gages S11, F03, and F08 showed faulty readings.

Table E-6. Strain survey raw data (run2), reference, and phase 1 repairs (baseline for R-BE, U-BE, and U-A2 repairs)

Load Step	0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00
Pressure	0.03	0.79	1.36	2.06	2.68	3.34	3.95	4.70	5.34	6.03	6.70
Frame-1	16.86	117.18	208.18	339.81	469.91	550.14	674.93	773.88	888.90	1007.01	1136.82
Frame-2	39.40	77.28	234.81	315.53	426.27	549.03	672.16	778.43	914.62	1023.57	1130.32
Frame-3	-34.90	141.15	269.14	326.91	429.18	529.28	722.19	785.46	895.92	1012.41	1137.44
Frame-4	-41.42	78.14	196.87	328.91	502.65	591.48	680.71	793.77	906.33	1009.35	1084.63
Frame-5	4.22	67.75	227.56	342.09	425.07	564.09	700.79	785.80	908.05	1018.87	1125.98
Frame-6	21.86	106.24	222.89	338.64	457.88	561.24	662.53	784.67	929.21	1012.47	1133.96
Frame-7	-17.24	111.50	213.75	330.74	436.97	563.03	685.09	790.55	905.80	1078.12	1130.50
Frame-8	27.42	109.85	218.12	334.87	459.33	573.70	693.92	790.05	916.19	1016.68	1143.65
Frame-9	37.74	129.62	207.53	347.70	438.77	571.20	681.02	802.44	901.90	996.54	1139.94
Frame-10	31.81	129.38	209.17	338.22	444.66	593.51	647.34	772.89	911.36	1006.46	1128.64
Frame-11	24.28	80.21	239.92	319.62	417.04	563.27	660.59	802.27	907.04	998.28	1123.60
Frame-12	40.92	101.57	223.25	343.94	453.54	579.78	697.13	779.95	925.21	1009.49	1141.17
Hoop-1	6.60	853.80	1395.35	2110.33	2889.10	3573.51	4261.55	5005.21	5719.09	6456.01	7131.37
Hoop-2	93.40	691.54	1395.32	2209.47	2820.47	3543.76	4252.76	5043.42	5667.20	6410.13	7172.71
Hoop-3	-37.13	701.26	1483.68	2120.50	2876.74	3587.27	4287.30	5025.33	5668.11	6464.39	7215.17
Hoop-4	29.22	779.90	1467.41	2118.29	2833.06	3527.68	4365.56	4979.88	5656.86	6443.96	7087.80
Hoop-5	146.76	801.68	1451.53	2129.73	2903.47	3592.65	4281.82	5004.60	5687.10	6412.17	7110.32
Hoop-6	-23.61	726.09	1436.03	2147.43	2846.53	3594.54	4324.36	4975.43	5693.00	6444.66	7078.01
Hoop-7	-107.74	714.78	1451.92	2147.66	2827.77	3595.11	4260.73	4999.01	5747.22	6427.11	7144.48
Hoop-8	24.97	709.36	1430.30	2122.04	2879.32	3556.85	4299.64	4975.90	5733.10	6454.54	7133.13
Hoop-9	24.42	678.08	1417.83	2121.70	2836.31	3553.07	4303.58	5006.52	5744.34	6405.79	7123.62
Hoop-10	13.58	712.25	1437.67	2150.60	2851.12	3571.50	4305.79	4994.74	5714.69	6435.29	7144.32
Hoop-11	79.78	678.23	1434.13	2150.18	2781.24	3559.12	4349.39	4975.91	5719.01	6404.88	7145.86
Hoop-12	56.07	785.73	1375.77	2189.01	2755.37	3619.80	3953.84	5056.63	5681.01	6465.77	7229.62
Hoop-13	5.43	713.31	1435.92	2085.48	2859.12	3582.02	4384.93	4967.87	5646.56	6391.56	7152.02
Hoop-14	2.23	697.90	1444.97	2067.47	2858.42	3576.48	4389.48	5003.72	5714.04	6403.02	7151.45
Long-1	-6.33	828.54	1401.60	2108.63	2531.93	3520.75	3922.51	4858.16	5372.25	5959.90	6787.08
Long-2	-254.04	730.91	1440.90	1949.62	2756.10	3422.22	3953.12	4674.12	5264.33	6095.03	6667.84
Long-3	33.02	637.15	1314.38	2091.84	2556.02	3237.50	3985.42	4746.66	5344.09	5983.87	6758.88
Long-4	3.37	503.41	1305.45	2149.91	2785.78	3286.75	4071.12	4674.62	5323.71	5967.79	6538.08
Long-5	447.11	829.49	1397.60	1871.48	2684.05	3350.30	3918.25	4575.38	5282.63	6042.31	6601.11
Long-6	-416.01	655.43	1446.98	2118.39	2774.60	3334.41	3983.82	4650.98	5323.54	5945.91	6718.09
Long-7	7.29	627.37	1451.61	1926.08	2655.21	3285.91	3936.93	4694.58	5251.35	5894.21	6624.26
Long-8	55.43	684.41	1308.89	2207.93	2971.96	3261.44	4260.52	4566.86	5306.70	6354.65	6707.57

Table E-6. Strain survey raw data (run2), reference, and phase 1 repairs (baseline for R-BE, U-BE, and U-A2 repairs) (continued)

S10	-134.50	115.08	286.90	464.01	606.51	744.74	863.09	994.37	1102.91	1211.40	1312.26
S11											
S12	161.99	52.93	148.89	257.94	359.80	465.24	556.08	662.89	752.39	845.37	933.62
S13	-78.29	226.10	362.13	487.41	589.13	691.02	773.44	867.54	945.64	1028.16	1105.50
S14	-118.23	164.95	328.73	484.02	606.53	729.09	827.80	939.40	1031.47	1132.42	1221.59
S15	-71.70	255.33	454.10	625.37	757.28	885.00	985.81	1097.96	1188.02	1282.69	1370.54
S16	470.18	287.12	185.33	90.70	26.10	-35.43	-84.93	-144.61	-180.30	-220.50	-246.96
S17	465.62	305.93	182.24	73.48	-17.71	-97.30	-160.75	-284.72	-308.86	-347.63	-329.23
S18	641.61	60.11	-283.25	-622.97	-877.93	-1108.81	-1291.65	-1492.59	-1632.12	-1764.80	-1869.89
IS10	60.90	38.06	16.48	-3.99	-16.97	-28.48	-33.97	-39.81	-42.56	-44.38	-41.65
IS11	144.04	-21.87	-141.10	-243.68	-306.32	-353.17	-378.32	-398.83	-400.54	-392.17	-376.36
IS12	-207.80	59.76	86.00	106.23	130.32	161.32	195.21	239.13	284.55	340.30	396.02
IS13	189.93	-51.74	-93.60	-110.30	-103.22	-82.46	-54.24	-12.82	28.96	79.51	134.75
IS14	140.79	-57.96	-134.70	-195.95	-216.96	-225.35	-219.49	-202.70	-181.20	-146.00	-105.74
IS15	1238.25	1064.42	987.24	928.64	893.95	882.91	885.14	897.00	913.23	946.10	982.58
IS16	-206.70	46.61	165.51	287.74	385.12	484.09	568.08	664.42	743.26	822.12	895.33
IS17	-39.38	56.36	126.31	199.65	263.21	327.10	381.11	445.13	497.77	553.40	606.36
IS18	-26.64	109.68	199.83	289.54	366.87	444.46	509.59	585.35	645.99	710.19	771.27
1AF	-43.16	94.70	210.60	337.80	447.07	558.83	652.31	766.16	856.51	955.05	1045.07
1AA	-80.91	86.89	215.98	357.38	477.20	598.13	699.41	820.74	917.43	1022.89	1117.95
1BF	-107.75	226.96	455.21	681.69	867.70	1043.41	1187.05	1349.53	1473.09	1597.80	1710.10
1BA	-256.62	171.73	427.60	679.64	880.90	1071.11	1225.70	1398.82	1531.09	1664.87	1783.70
1RF	-732.65	-540.60	-453.29	-402.69	-415.10	-377.93	-319.19	-238.76	-140.89	-88.44	-32.15
1RA	-297.90	47.46	226.54	349.08	457.03	530.82	631.38	698.93	748.49	948.72	1038.76
F01	909.35	744.71	783.51	784.42	821.55	853.99	899.93	895.49	934.72	946.40	981.49
F02	-572.89	-385.24	-342.98	-269.54	-218.46	-165.24	-106.38	-22.36	41.97	110.28	170.57
F03											
F04	-798.26	-562.39	-506.04	-396.14	-335.66	-260.64	-198.69	-83.92	-5.46	77.62	149.85
F05	852.41	708.69	726.29	712.71	749.80	783.13	825.79	819.55	861.29	874.24	914.17
F06	-394.71	-298.53	-262.28	-197.47	-155.65	-96.93	-50.72	22.52	86.12	148.17	205.07
F07	1086.74	858.86	871.54	833.52	857.05	882.22	922.51	892.36	930.11	933.10	967.07
F08											
F09	924.32	754.45	774.07	748.68	799.43	808.14	841.98	809.61	829.46	840.08	868.81
F10	-676.74	-506.70	-482.21	-374.38	-309.32	-240.39	-207.43	-73.42	0.64	82.39	163.02
L01	13.01	-28.19	-16.97	-2.46	9.72	25.05	34.59	50.19	61.32	78.74	89.22
L02	-124.71	-22.37	-1.76	16.83	31.38	43.90	58.06	74.26	87.15	107.57	120.49
L03	-26.78	-4.76	-0.39	4.35	10.90	15.13	28.56	38.26	48.91	65.21	75.59
L04	174.06	141.52	156.48	166.26	176.43	183.50	202.68	207.19	218.44	232.91	241.13
L05	1.68	6.62	13.19	33.31	51.45	71.21	93.32	117.05	136.10	160.74	181.64

Note: Strain gages S11, F03, and F08 showed faulty readings.

Table E-7. Strain survey raw data (run3), reference, and phase 1 repairs (baseline for R-BE, U-BE, and U-A2 repairs)

Load Step	0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00
Pressure	0.12	0.74	1.39	2.04	2.65	3.33	4.01	4.68	5.33	6.03	6.70
Frame-1	28.87	120.51	223.74	338.50	452.75	579.98	681.28	792.85	903.84	1031.49	1117.97
Frame-2	39.00	135.09	171.88	323.06	450.80	561.31	677.41	797.50	957.56	1025.39	1118.94
Frame-3	-28.74	85.02	247.91	358.08	458.19	602.16	701.89	757.04	872.65	1029.29	1107.62
Frame-4	47.47	72.50	228.00	317.34	485.22	552.80	682.14	806.58	878.07	1035.42	1115.29
Frame-5	9.23	125.25	217.30	335.24	451.19	575.82	671.27	791.25	891.63	1019.45	1128.72
Frame-6	-1.42	119.67	235.97	328.49	448.25	563.37	687.85	787.27	907.57	1019.33	1136.53
Frame-7	27.11	118.29	221.49	333.25	468.10	568.35	653.21	787.42	909.64	1027.91	1133.32
Frame-8	10.32	130.11	219.96	349.68	479.31	563.60	688.40	795.35	900.54	1017.15	1139.43
Frame-9	0.91	99.53	213.39	347.34	473.09	545.16	675.67	780.66	909.50	1061.66	1123.70
Frame-10	8.30	125.24	210.86	340.32	467.18	562.58	670.64	809.28	906.04	1019.08	1143.22
Frame-11	6.83	120.59	226.32	347.40	471.22	550.15	664.80	793.61	900.92	1038.17	1154.48
Frame-12	14.30	97.19	211.93	350.13	438.44	567.56	677.54	792.82	926.06	1006.01	1137.17
Hoop-1	95.31	710.79	1440.75	2135.46	2745.79	3573.16	4277.84	4953.53	5667.83	6440.89	7161.05
Hoop-2	4.11	754.03	1434.75	2125.33	2838.05	3579.12	4161.68	5038.84	5809.49	6432.71	7134.13
Hoop-3	-31.88	741.50	1461.08	2141.28	2808.21	3609.66	4208.55	4973.59	5637.80	6414.75	7114.38
Hoop-4	-37.88	652.97	1384.13	2138.02	2879.93	3576.29	4351.06	4951.70	5705.26	6503.17	7115.71
Hoop-5	-52.45	667.10	1422.95	2138.49	2845.75	3568.96	4303.36	5003.61	5747.55	6424.09	7109.23
Hoop-6	-39.98	711.53	1421.61	2138.12	2864.44	3621.48	4293.42	4992.63	5752.49	6487.69	7184.29
Hoop-7	42.16	716.56	1416.37	2138.53	2873.88	3562.63	4326.75	5003.37	5741.29	6449.67	7114.85
Hoop-8	32.24	709.36	1437.72	2136.60	2850.76	3577.99	4248.24	4997.74	5726.39	6433.33	7154.27
Hoop-9	40.54	722.85	1434.09	2141.40	2899.57	3602.50	4260.16	5002.94	5723.42	6436.88	7140.82
Hoop-10	-16.57	710.48	1425.40	2127.55	2862.33	3579.66	4275.21	4992.97	5704.62	6434.15	7134.74
Hoop-11	202.72	699.93	1423.42	2104.97	2870.41	3592.77	4265.78	4988.56	5687.03	6427.22	7123.45
Hoop-12	10.69	753.06	1435.82	1978.44	2806.76	3437.57	4432.68	4962.24	5790.50	6430.11	7163.55
Hoop-13	-9.16	749.80	1406.87	2158.47	2932.69	3610.50	4223.93	4989.76	5661.72	6421.39	7129.41
Hoop-14	-12.41	734.51	1423.14	2184.65	2917.59	3561.13	4191.31	5011.05	5714.61	6425.63	7143.41
Long-1	-45.32	617.72	1288.00	1884.93	2583.29	3264.99	4063.15	4518.70	5505.17	5993.97	6650.20
Long-2	82.88	693.37	1240.02	2053.19	2549.09	3343.28	4067.30	4718.42	5394.91	5929.62	6786.57
Long-3	50.96	656.53	1268.79	1878.37	2789.80	3337.67	4081.93	4589.47	5365.04	6037.70	6678.39
Long-4	32.34	862.78	1455.26	2185.29	2512.19	3346.58	3862.92	4740.30	5210.32	6118.10	6666.12
Long-5	78.55	571.94	1316.26	1994.43	2743.78	3364.60	3994.82	4667.44	5345.07	5978.79	6693.56
Long-6	57.91	710.33	1163.31	1961.21	2657.50	3325.76	3922.16	4713.68	5338.84	5987.53	6684.17
Long-7	-57.78	795.46	1253.99	1887.57	2704.71	3441.35	3870.87	4678.00	5305.06	5962.13	6664.53
Long-8	-3.02	526.93	1207.17	1847.47	2386.06	3267.14	4078.59	4443.24	5611.50	5888.14	7019.95

Table E-7. Strain survey raw data (run3), reference, and phase 1 repairs (baseline for R-BE, U-BE, and U-A2 repairs) (continued)

S10	-146.56	98.41	293.24	456.93	605.64	740.19	868.37	990.40	1096.28	1212.14	1309.04
S11											
S12	143.84	42.75	149.62	253.58	359.73	462.14	564.02	660.05	749.63	846.83	930.53
S13	-87.10	195.18	352.30	476.53	585.23	685.51	776.32	862.25	941.50	1024.65	1098.58
S14	-126.64	137.33	325.00	473.58	604.59	725.54	833.87	935.20	1030.98	1128.04	1214.87
S15	-77.30	217.06	448.09	613.82	754.63	879.33	989.64	1090.45	1184.97	1278.62	1363.33
S16	244.00	115.63	14.63	-52.71	-103.48	-144.76	-186.83	-210.69	-249.69	-283.46	-307.33
S17	-775.49	-723.05	-738.27	-715.98	-824.38	-945.65	-822.39	-750.31	-816.83	-844.32	-953.00
S18	446.41	-47.33	-451.66	-761.61	-1017.13	-1239.73	-1430.89	-1597.28	-1727.57	-1866.43	-1971.15
IS10	70.42	46.64	19.96	3.51	-9.47	-17.33	-27.93	-36.52	-40.92	-40.36	-40.18
IS11	140.36	8.68	-141.66	-236.27	-299.96	-350.62	-384.39	-397.39	-402.84	-392.35	-379.61
IS12	-207.48	62.11	88.91	107.51	131.75	161.98	196.29	239.33	284.06	339.94	391.20
IS13	179.32	-28.52	-81.99	-103.34	-99.24	-79.93	-50.64	-11.69	31.33	83.65	133.31
IS14	145.74	-29.14	-120.11	-179.00	-203.79	-218.51	-214.18	-196.34	-168.66	-136.88	-102.44
IS15	1191.21	1034.24	944.69	883.59	855.04	847.19	850.00	866.18	888.04	891.14	931.51
IS16	-197.96	37.32	173.87	284.64	386.14	481.89	574.21	661.03	741.04	825.21	895.69
IS17	-44.16	49.39	129.59	196.92	261.88	325.69	386.90	444.81	498.23	556.32	605.33
IS18	-35.05	97.62	204.37	287.45	366.30	444.42	516.27	585.72	649.67	714.05	770.30
1AF	-56.37	79.45	212.60	328.52	440.43	553.14	660.25	760.78	854.67	954.50	1041.41
1AA	-91.63	68.06	218.21	347.18	468.68	592.47	707.99	815.68	915.56	1023.44	1115.50
1BF	-110.49	197.51	463.19	671.53	859.54	1039.36	1197.09	1340.23	1470.48	1597.07	1708.31
1BA	-249.84	137.12	436.34	667.63	870.54	1063.95	1234.13	1388.95	1527.39	1664.33	1780.61
1RF	-557.59	-292.11	-163.51	-30.30	81.75	185.11	280.64	365.86	459.79	534.91	599.18
1RA	-383.54	-16.36	171.80	305.21	415.61	534.05	636.03	729.27	808.30	832.16	952.44
F01	863.32	778.08	769.02	804.89	835.88	863.24	875.74	903.73	933.28	952.93	971.87
F02	-543.69	-419.37	-335.45	-275.84	-225.08	-155.46	-86.27	-26.71	34.58	115.36	180.57
F03	-513.95	-326.28	1284.60	-198.14	-1701.87	-2175.65	396.99	1286.91	-297.41	1309.94	392.68
F04	-756.80	-602.84	-488.86	-405.23	-339.77	-255.77	-161.51	-87.74	-18.73	84.17	162.86
F05	805.12	732.08	698.58	727.92	772.65	777.20	792.75	825.43	862.00	872.79	900.95
F06	-372.55	-320.57	-268.89	-218.84	-157.61	-106.86	-35.68	23.21	96.20	146.49	214.23
F07	1031.36	893.99	830.26	840.40	878.42	871.73	876.97	900.24	943.34	929.48	952.39
F08											
F09	864.28	750.31	725.46	748.13	800.36	803.83	804.35	810.42	841.06	840.44	869.00
F10	-628.68	-533.70	-450.95	-384.40	-317.90	-255.69	-157.25	-75.99	-15.17	89.11	176.61
L01	25.74	-32.48	-20.66	-5.70	7.99	22.67	39.05	47.27	66.35	74.64	94.13
L02	-107.25	-23.84	-3.41	16.83	29.35	47.37	63.03	73.34	92.14	105.18	125.80
L03	-9.82	1.38	-2.57	6.11	8.58	19.91	28.83	38.41	52.17	64.37	80.22
L04	178.44	152.31	154.30	169.88	175.31	191.21	197.59	210.29	220.84	233.99	245.07
L05	-34.31	-18.57	-1.85	19.35	34.76	57.59	79.35	123.41	168.22	176.14	193.75

Note: Strain gages S11 and F08 showed faulty readings.

Table E-8. Strain survey raw data (run1), reference, and phase 1 repairs (20,000 cycles for R-BE, U-BE, and U-A2 repairs and baseline for U-A1 repair)

Load Step	0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00
Pressure	-0.01	0.64	1.38	2.11	2.59	3.31	4.03	4.75	5.28	5.93	6.68
Frame-1	-0.60	114.16	212.09	334.38	454.96	566.92	674.18	813.33	912.12	1017.16	1184.56
Frame-2	-4.87	123.46	204.56	288.64	466.91	607.79	680.49	803.10	908.76	1047.59	1153.06
Frame-3	-44.22	144.68	176.98	303.42	466.00	589.45	676.60	791.35	922.30	1030.13	1127.82
Frame-4	6.61	109.99	223.26	333.15	474.04	573.43	678.26	784.79	927.93	1049.52	1147.74
Frame-5	3.08	108.85	242.72	324.36	453.53	621.33	685.45	789.20	900.52	1052.60	1148.92
Frame-6	-16.87	136.23	211.90	328.41	448.16	570.72	678.46	792.92	914.84	1030.42	1137.88
Frame-7	-4.56	127.70	228.99	365.77	465.47	569.79	667.37	790.12	914.13	1032.32	1149.78
Frame-8	-10.42	149.83	237.85	334.84	479.31	575.73	674.01	792.11	941.78	1021.08	1124.49
Frame-9	-19.01	154.19	273.07	319.87	486.96	561.49	671.51	788.78	934.04	1021.43	1123.01
Frame-10	-10.72	94.50	228.71	368.41	475.21	558.23	685.61	791.49	931.06	1035.41	1125.90
Frame-11	18.24	215.52	298.27	228.30	523.49	524.73	632.02	831.32	950.25	1025.51	1095.80
Frame-12	-50.75	39.18	319.89	360.28	526.73	527.30	689.39	787.81	912.10	1022.06	1143.22
Hoop-1	77.24	895.39	1359.65	2041.87	2888.45	3365.45	4272.71	5058.12	5795.78	6402.19	7203.91
Hoop-2	109.45	596.16	1524.65	2269.14	3045.08	3490.52	4321.02	5081.39	5470.86	6339.13	7146.01
Hoop-3	3.03	532.55	1300.40	2321.00	2718.48	3409.18	4366.77	4978.64	5637.29	6418.03	7147.36
Hoop-4	-14.23	770.73	1451.97	2237.08	2750.76	3491.96	4233.59	5056.63	5755.55	6406.56	7162.37
Hoop-5	17.66	584.08	1474.00	2265.33	2987.58	3332.75	4280.61	5096.88	5590.75	6285.32	7085.41
Hoop-6	88.16	675.33	1371.75	2279.96	2797.26	3732.50	4276.20	4917.99	5836.33	6427.65	6916.28
Hoop-7	591.61	849.24	1560.66	2057.85	2852.89	3671.57	4285.12	5014.50	5736.17	6471.48	7216.95
Hoop-8	50.24	809.19	1640.94	2268.23	2888.68	3581.87	4296.95	5070.41	5668.74	6419.67	7202.49
Hoop-9	-39.41	703.69	965.65	2071.02	2875.28	3521.39	4305.70	4958.99	5793.55	6395.96	7148.23
Hoop-10	-33.69	593.71	1553.32	2255.08	2891.54	3645.06	4368.37	4970.83	5779.45	6402.60	7163.52
Hoop-11	155.52	619.48	1471.05	2369.56	2782.93	3549.40	4279.64	5035.24	5705.67	6435.26	7042.51
Hoop-12	-1.63	620.55	1251.71	2081.00	3019.84	3325.44	4198.59	5100.85	5843.03	6235.33	7030.46
Hoop-13	36.82	695.13	1565.39	2252.66	2742.90	3605.92	4329.97	5024.78	5756.15	6406.43	7059.39
Hoop-14	-41.07	780.95	1529.44	2197.06	2799.07	3701.75	4288.86	4986.06	5697.93	6467.87	7108.41
Long-1	227.38	981.26	1348.26	2078.05	2571.58	3384.56	3994.76	4713.02	5255.04	6076.38	6683.73
Long-2	-195.03	384.51	1424.71	2213.90	2736.74	3401.72	3850.56	4546.59	5266.08	6054.84	6586.97
Long-3	80.06	870.87	1489.57	2039.47	2773.43	3333.34	4113.05	4665.51	5172.78	5859.14	6528.86
Long-4	54.44	535.03	1247.84	2059.46	2648.14	3189.17	3725.10	4618.64	5519.89	5919.20	6674.18
Long-5	-411.79	589.84	1335.09	2152.24	2445.03	3370.89	4047.49	4428.91	5375.02	6109.94	6532.04
Long-6	74.12	451.77	1213.14	1911.44	2702.31	3209.84	3930.27	4708.68	5363.36	6020.86	6577.13
Long-7	263.15	644.26	1568.08	2052.65	2462.47	3217.56	3932.14	4458.38	5414.71	5828.34	6557.10
Long-8	108.01	835.78	1482.45	2012.25	2732.77	3834.08	4102.20	4944.00	5003.52	6014.18	7290.40

Table E-8. Strain survey raw data (run1), reference, and phase 1 repairs (20,000 cycles for R-BE, U-BE, and U-A2 repairs and baseline for U-A1 repair) (continued)

S10	43.89	191.48	383.79	535.55	550.18	677.32	800.03	923.04	1012.27	1105.28	1205.67
S11	-55.80	141.82	369.08	542.55	529.88	666.02	801.18	930.14	1021.51	1122.76	1227.98
S12	740.42	795.24	931.30	1072.06	1115.35	1213.07	1309.08	1410.33	1473.44	1564.76	1635.28
S13	4.70	184.64	376.03	508.77	553.52	651.66	751.07	844.83	914.73	988.27	1065.53
S14	6.67	170.94	366.20	512.86	570.99	680.50	797.57	906.00	986.55	1072.74	1162.66
S15	15.05	216.90	431.24	584.30	639.28	747.36	861.11	963.77	1037.89	1120.83	1206.06
S16	-7.51	-97.00	-198.78	-277.42	-251.94	-316.08	-362.40	-406.12	-435.43	-467.06	-493.37
S17	-32.94	-213.68	-461.34	-643.99	-557.81	-720.29	-849.17	-982.99	-1072.98	-1181.34	-1283.59
S18	21.40	-292.55	-656.64	-896.97	-867.11	-1058.87	-1212.93	-1342.69	-1423.53	-1508.58	-1580.99
S23	-2.51	45.65	139.08	227.08	248.38	317.47	397.73	476.56	534.46	596.08	664.82
S24	-41.44	160.20	388.68	540.02	568.39	676.11	784.33	888.04	960.25	1039.37	1123.43
S27	273.65	-340.01	-1049.81	-1463.49	-2010.19	-2003.15	-2425.62	-2743.70	-3129.03	-3411.24	-3562.57
IS10	30.08	-24.10	-89.68	-128.45	-111.60	-139.35	-138.22	-136.97	-124.47	-109.24	-83.53
IS11	-309.06	-470.80	-636.70	-714.55	-639.70	-697.06	-702.17	-694.59	-674.30	-651.28	-603.50
IS12	-64.03	-41.64	-16.96	1.09	11.95	19.48	33.24	47.65	61.56	70.49	82.82
IS13	-88.92	-188.03	-257.03	-265.00	-224.42	-225.61	-189.53	-153.35	-118.74	-75.47	-23.62
IS14	-26.83	-106.38	-186.44	-212.71	-163.09	-185.02	-165.26	-147.22	-124.42	-92.49	-52.00
IS15	-28.24	-128.98	-217.08	-245.92	-217.04	-229.54	-207.93	-184.63	-160.95	-122.74	-76.71
IS16	-21.98	88.15	219.39	329.82	328.73	419.49	508.40	596.03	660.42	729.14	800.45
IS17	-28.49	31.61	103.34	165.84	176.72	221.01	276.48	328.58	373.92	417.39	461.18
IS18	11.81	81.27	162.83	233.09	274.83	324.01	392.29	450.72	493.69	543.84	596.71
IS23	-20.56	-23.55	-41.71	-40.76	-6.86	-12.51	9.86	31.20	52.26	81.00	117.81
IS24	36.56	-87.40	-202.07	-238.86	-217.72	-240.77	-232.81	-220.85	-206.33	-179.37	-146.37
IS27	-61.48	-25.86	13.41	47.58	63.03	83.76	115.54	141.73	160.81	181.51	206.09
1AF	-21.30	103.22	277.36	418.48	417.93	535.30	658.03	777.18	864.39	961.53	1062.42
1AA	-60.90	78.70	274.07	427.13	418.75	546.13	674.91	801.10	892.60	997.31	1105.97
1BF*	2.42	131.64	281.78	386.38	406.06	490.17	586.41	666.65	720.95	787.57	855.16
1BA*	-16.19	257.00	586.78	827.21	834.66	1019.31	1200.17	1362.94	1471.25	1597.57	1721.30
1UAF	18.41	237.08	511.54	733.79	716.54	897.79	1070.04	1238.87	1358.37	1494.07	1630.05
1UAA	136.93	354.57	636.33	872.89	834.20	1033.73	1210.09	1389.10	1514.68	1658.35	1798.15
1RF	-43.28	66.45	186.17	270.76	261.20	331.31	397.84	456.91	500.25	543.18	588.99
1RA	-38.97	114.63	291.78	444.26	426.83	551.47	663.66	774.46	854.15	938.10	1022.16
F01	87.60	69.48	-23.36	-64.70	693.68	665.89	704.85	711.99	800.65	801.11	798.01
F04	141.87	209.71	418.63	532.22	-15.06	137.38	176.20	280.63	310.31	407.91	498.73
F06	-91.54	-21.61	47.56	119.48	-87.14	42.44	48.55	138.42	173.23	241.68	324.77
F07	-421.62	-424.02	-534.17	-541.64	118.51	102.00	121.62	132.37	225.76	210.25	226.37
F10	-72.99	7.25	263.14	379.13	-181.07	-24.97	19.89	133.71	174.61	259.95	355.85
L02	76.03	91.14	119.30	136.24	115.43	151.00	173.24	204.38	226.85	255.73	282.86
L03	789.77	800.45	814.05	825.77	791.92	813.66	815.83	825.95	838.60	856.55	873.64

Note: Strain gages F02, F03, F05, F08, F09, L01, L04, and L05 were removed. Successive * signs on the gage number represent the progressive distances between the notch tip and strain gage (see appendix C for details).

Table E-9. Strain survey raw data (run2), reference, and phase 1 repairs (20,000 cycles for R-BE, U-BE, and U-A2 repairs and baseline for U-A1 repair)

Load Step	0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00
Pressure	0.01	0.62	1.39	1.96	2.59	3.25	3.98	4.75	5.35	6.07	6.62
Frame-1	-14.44	85.82	213.65	334.37	457.48	566.79	675.54	786.51	902.14	1035.71	1112.25
Frame-2	10.40	117.72	211.25	342.88	487.21	552.99	685.57	779.88	901.38	1020.88	1116.86
Frame-3	-37.42	123.63	208.53	373.98	494.50	559.44	676.71	789.58	900.68	1017.55	1135.38
Frame-4	2.82	86.35	215.95	311.18	449.79	573.20	683.38	797.17	892.41	1018.79	1127.94
Frame-5	27.45	102.73	232.28	361.81	442.73	573.77	690.84	765.83	892.68	1012.04	1131.97
Frame-6	-4.24	120.45	222.31	347.29	454.47	569.31	679.81	783.71	894.76	1009.93	1136.05
Frame-7	10.05	122.74	203.23	339.53	449.58	563.85	689.18	782.58	908.39	1030.42	1134.56
Frame-8	-2.03	131.32	232.64	363.67	471.07	567.33	680.99	787.70	903.21	1042.70	1126.57
Frame-9	-8.11	129.37	203.34	360.04	472.18	562.67	670.21	797.93	892.37	1031.87	1116.91
Frame-10	28.48	97.61	257.09	355.80	511.86	565.33	666.06	793.69	881.17	1018.18	1128.85
Frame-11	-92.83	74.19	342.21	302.78	426.42	597.79	688.41	770.51	901.03	1057.41	1124.67
Frame-12	-28.36	96.23	258.64	388.83	475.70	574.27	676.33	786.24	905.66	1064.97	1111.09
Hoop-1	17.40	668.57	1535.75	2251.85	3042.61	3334.28	4492.19	4954.73	5748.62	6481.35	7134.99
Hoop-2	12.86	735.65	1333.35	2229.33	2483.36	3508.06	4151.05	4997.30	5563.89	6449.41	7052.98
Hoop-3	32.83	681.52	1360.15	2036.55	2774.58	3512.26	4478.98	5075.07	5749.48	6266.63	7128.08
Hoop-4	20.28	761.56	1530.25	2263.88	2850.67	3586.07	4199.07	5078.43	5777.35	6413.19	7037.01
Hoop-5	66.21	776.40	1537.09	1986.22	2825.78	3425.90	4384.89	4909.89	5743.57	6500.43	7132.16
Hoop-6	59.00	660.68	1408.35	2235.75	2786.32	3389.42	4261.61	5023.74	5703.24	6501.75	7195.24
Hoop-7	446.93	743.68	1494.67	2153.97	2920.81	3605.08	4308.36	5041.32	5698.63	6433.30	7118.63
Hoop-8	42.95	692.29	1356.23	2180.90	2793.55	3457.83	4253.60	5040.72	5800.66	6449.49	7157.99
Hoop-9	0.07	662.27	1502.14	2153.78	2796.03	3564.46	4309.72	5064.38	5702.59	6393.00	7095.46
Hoop-10	101.37	682.44	1709.55	2141.57	2782.85	3415.80	4267.50	5021.87	5724.92	6394.35	7159.25
Hoop-11	90.31	775.17	1246.24	2192.22	3000.07	3460.62	4347.11	4993.06	5834.90	6492.08	7116.11
Hoop-12	51.13	671.36	1473.49	2226.73	2663.04	3580.11	4279.06	5049.41	5610.75	6512.45	7058.87
Hoop-13	-21.68	673.05	1389.72	2194.37	2815.75	3445.01	4286.52	4936.52	5778.66	6421.69	7073.32
Hoop-14	32.31	883.53	1375.19	2145.91	2813.47	3510.94	4267.27	5029.59	5727.85	6373.11	7203.12
Long-1	-74.36	500.06	1489.69	1952.68	2768.36	3242.83	4117.55	4562.62	5257.97	5940.34	6631.07
Long-2	22.89	833.06	1198.14	2106.32	2643.73	3373.39	4036.86	4567.65	5292.11	5924.58	6586.87
Long-3	41.70	443.42	1212.10	2073.51	2717.40	3203.67	4115.44	4781.77	5462.49	6096.35	6746.69
Long-4	-195.48	796.41	1394.88	1975.71	2532.33	3150.84	3814.83	4872.56	5250.93	5875.41	6903.07
Long-5	-461.65	577.24	1325.76	2154.37	2681.59	3274.64	3915.05	4840.44	5311.99	6003.61	6580.23
Long-6	-89.85	799.58	1580.11	1941.97	2566.35	3261.80	4021.33	4569.42	5312.35	6025.56	6760.94
Long-7	441.83	605.93	1282.76	2125.90	2818.17	3455.92	4291.31	4417.10	5512.55	6244.61	6765.68
Long-8	293.64	654.47	1474.00	2214.41	2684.52	2938.40	3687.00	4839.90	5459.31	6118.84	6979.76

Table E-9. Strain survey raw data (run2), reference, and phase 1 repairs (20,000 cycles for R-BE, U-BE, and U-A2 repairs and baseline for U-A1 repair) (continued)

S10	-75.29	84.60	281.09	405.08	531.12	661.19	789.29	912.11	1007.64	1109.17	1194.88
S11	-312.51	-15.65	239.52	378.07	521.99	662.83	803.41	930.32	1029.32	1135.47	1225.19
S12	651.05	701.47	807.63	942.58	1093.09	1207.79	1298.72	1406.51	1488.17	1543.84	1633.49
S13	-324.43	68.89	291.55	416.41	526.41	636.71	739.45	832.25	910.49	991.19	1058.94
S14	-179.94	76.63	292.73	425.73	551.66	675.21	791.61	896.63	985.53	1078.42	1155.66
S15	-160.16	115.56	358.13	497.73	620.11	742.88	855.33	954.84	1039.28	1126.06	1198.38
S16	-219.35	-180.82	-223.09	-267.96	-323.51	-360.03	-411.18	-452.72	-484.76	-510.01	-530.95
S17	-125.01	-285.07	-472.04	-612.03	-761.43	-942.60	-1100.79	-1234.23	-1344.25	-1429.29	-1519.95
S18	159.04	-170.11	-507.34	-703.98	-898.52	-1071.66	-1242.06	-1368.18	-1462.85	-1538.44	-1595.24
S23	-27.95	20.39	102.81	164.33	232.13	313.14	393.62	468.57	532.16	601.01	661.51
S24	-257.11	29.63	284.71	418.35	538.31	660.80	790.53	884.72	966.11	1051.54	1122.96
S27	-393.75	-385.15	-395.51	-384.73	-383.82	-346.01	-300.76	-268.40	-233.30	-174.44	-116.55
IS10	-4.16	18.84	-48.73	-84.61	-118.14	-137.50	-144.02	-141.13	-130.08	-111.05	-86.95
IS11	-13.95	-300.32	-496.32	-583.48	-651.07	-691.19	-698.18	-693.26	-674.96	-638.97	-598.39
IS12	-67.26	-38.07	-17.47	-4.10	7.89	17.10	31.96	44.37	55.13	70.27	79.34
IS13	242.62	-68.27	-189.68	-217.28	-229.91	-217.30	-188.11	-158.08	-118.24	-72.06	-26.76
IS14	165.44	15.68	-101.62	-139.01	-165.66	-174.20	-163.44	-150.32	-123.87	-90.12	-54.18
IS15	87.27	-55.92	-156.79	-192.57	-218.93	-221.26	-206.20	-186.37	-156.52	-118.17	-80.48
IS16	-187.51	6.14	146.41	233.04	321.43	410.13	504.44	590.30	659.69	732.78	796.11
IS17	-64.76	-0.58	68.61	117.27	163.58	219.13	282.30	331.31	373.92	417.03	479.11
IS18	-29.02	70.37	151.96	210.94	265.31	327.68	391.79	445.90	496.29	548.39	592.72
IS23	29.70	25.86	10.49	1.59	-4.42	1.64	24.05	41.18	63.56	94.83	126.87
IS24	281.18	30.38	-117.51	-173.22	-210.53	-224.10	-226.68	-218.54	-200.07	-172.29	-141.45
IS27	156.61	-81.30	-948.94	-1522.53	-1608.26	-1770.79	-2408.59	-2662.14	-2942.71	-3199.57	-3467.59
1AF	-96.50	30.96	189.42	296.12	408.14	530.22	658.21	772.26	871.68	972.45	1058.20
1AA	-156.76	-12.54	170.77	287.93	410.36	540.59	674.54	796.18	900.80	1008.61	1102.28
1BF*	-58.45	95.33	243.51	329.16	408.10	496.03	591.88	666.29	732.07	798.14	851.71
1BA*	-287.78	87.19	431.04	635.30	828.02	1016.10	1202.72	1358.39	1485.97	1611.92	1714.23
1UAF	-90.38	113.01	379.46	542.78	715.34	892.07	1059.51	1230.33	1365.09	1505.15	1623.19
1UAA	22.29	207.34	484.46	653.85	839.39	1026.12	1227.61	1402.24	1540.23	1683.17	1808.74
1RF	-167.63	3.55	134.44	204.71	268.48	330.21	401.61	458.77	503.61	549.88	589.41
1RA	-242.46	-3.93	188.85	304.85	426.51	541.14	664.75	774.10	859.96	946.27	1021.05
F01	712.35	654.21	593.24	694.40	733.09	730.95	746.00	764.57	788.68	825.76	871.08
F04	-473.29	-318.14	-144.11	-127.97	-35.06	43.07	110.89	230.04	282.58	375.36	432.31
F06	-388.29	-289.12	-191.10	-157.97	-87.06	-28.63	37.08	130.13	178.44	236.20	287.18
F07	187.76	129.04	52.25	135.90	164.36	160.34	182.30	192.78	229.20	249.55	287.28
F10	-660.15	-468.33	-300.12	-298.34	-201.24	-107.55	-33.85	94.78	143.39	239.60	297.89
L02	57.79	75.45	96.46	109.17	126.12	142.12	174.71	205.67	235.32	260.52	282.99
L03	746.56	770.76	773.33	787.09	800.00	798.54	813.23	825.77	841.20	853.76	872.72

Note: Strain gages F02, F03, F05, F08, F09, L01, L04, and L05 were removed. Successive * signs on the gage number represent the progressive distances between the notch tip and strain gage (see appendix C for details).

Table E-10. Strain survey raw data (run3), reference, and phase 1 repairs (20,000 cycles for R-BE, U-BE, and U-A2 repairs and baseline for U-A1 repair)

Load Step	0	1	2	3	4	5	6	7	8	9	10
Pressure	-0.01	0.69	1.40	1.97	2.67	3.41	3.97	4.70	5.29	6.05	6.67
Frame-1	-1.65	98.03	232.33	356.97	471.09	552.72	675.81	795.65	919.30	1030.05	1129.32
Frame-2	9.31	78.14	181.88	339.03	450.33	531.51	698.52	787.72	905.87	1008.81	1124.02
Frame-3	14.38	155.80	236.81	375.26	434.52	568.71	679.71	787.21	913.75	996.52	1137.50
Frame-4	31.08	138.41	257.87	323.89	415.23	550.28	690.03	788.48	912.25	1028.34	1118.54
Frame-5	30.34	103.84	198.31	322.58	416.99	563.10	658.70	782.27	919.06	1018.09	1126.10
Frame-6	7.33	101.15	227.16	335.86	444.16	550.20	675.03	785.28	905.63	1025.71	1132.99
Frame-7	4.56	117.83	219.21	333.83	437.66	556.44	676.86	784.28	894.99	1015.52	1131.23
Frame-8	6.53	112.85	214.76	351.35	445.93	574.04	680.29	782.43	891.85	1018.87	1131.66
Frame-9	-15.91	153.13	227.63	383.04	451.72	562.61	676.26	772.54	905.48	997.80	1128.66
Frame-10	-60.40	160.74	224.19	383.98	447.03	577.66	683.75	779.16	894.21	1000.71	1141.99
Frame-11	48.21	163.70	267.66	414.05	421.86	541.29	705.99	814.39	940.10	982.42	1143.93
Frame-12	-3.21	85.30	215.48	332.61	484.63	571.62	691.38	781.19	949.82	1034.47	1117.28
Hoop-1	24.65	813.68	1388.81	2110.59	2663.55	3515.63	4329.37	4981.93	5499.98	6442.09	7074.42
Hoop-2	41.49	775.01	1537.32	2115.05	2848.30	3629.70	4333.97	5061.71	5565.55	6609.28	7204.33
Hoop-3	66.15	567.56	1453.08	2224.35	2879.76	3549.07	4286.55	5059.29	5654.75	6375.95	7116.85
Hoop-4	22.10	658.00	1412.14	2111.49	2707.16	3629.67	4306.69	4945.80	5582.82	6341.15	7070.83
Hoop-5	-7.51	634.36	1567.65	2203.97	2716.12	3483.42	4284.63	5091.48	5766.86	6357.24	7136.84
Hoop-6	75.42	658.86	1446.65	2173.98	2933.99	3615.46	4358.68	4808.59	5637.48	6405.77	7192.70
Hoop-7	416.58	849.16	1412.43	2132.73	2842.16	3590.78	4190.79	5059.20	5657.42	6374.95	7108.98
Hoop-8	50.25	677.70	1465.52	2217.38	2771.93	3487.01	4348.03	4946.36	5632.26	6413.01	7113.50
Hoop-9	79.04	692.78	1430.21	2051.48	2837.59	3499.85	4257.24	5046.93	5705.61	6445.05	7089.37
Hoop-10	12.51	627.35	1455.29	2129.13	2868.43	3687.71	4279.51	4945.95	5687.03	6403.24	7211.85
Hoop-11	166.42	771.55	1452.64	2177.73	2808.30	3549.40	4352.12	5049.73	5707.48	6403.29	7189.69
Hoop-12	31.12	696.82	1342.39	2030.27	2706.96	3652.88	4351.40	5064.47	5377.35	6272.33	6868.98
Hoop-13	7.57	534.10	1484.64	2150.49	2830.66	3671.74	4249.52	5010.15	5697.64	6407.07	7270.08
Hoop-14	-19.06	626.70	1397.06	2278.01	2813.75	3584.33	4266.85	4934.68	5631.88	6380.44	7209.74
Long-1	249.36	444.40	1386.25	2100.56	2617.47	3383.73	4022.30	4658.76	5384.34	6149.13	6771.41
Long-2	22.39	749.56	1569.00	1975.77	2666.05	3405.07	3999.15	4800.64	5415.76	6091.70	6651.82
Long-3	-446.11	432.87	1192.69	1928.58	2778.54	3192.72	3940.14	4802.15	5245.62	5980.21	6537.18
Long-4	10.12	849.36	1432.04	1915.50	2522.36	3520.52	4235.10	4367.38	5273.39	6259.58	6446.85
Long-5	78.73	527.11	1483.00	2040.91	2525.00	3395.11	3900.07	4664.01	5308.74	5876.95	6707.47
Long-6	-294.96	753.92	1548.26	1967.81	2685.94	3200.82	4036.61	4577.04	5386.29	6148.52	6711.75
Long-7	196.69	568.68	1425.47	1777.92	2600.16	3029.34	4196.08	4422.44	5439.35	6007.83	6458.33
Long-8	111.26	726.26	1137.97	2156.58	2500.93	3636.95	4248.53	5118.70	4951.21	5966.08	6628.19

Table E-10. Strain survey raw data (run3), reference, and phase 1 repairs (20,000 cycles for R-BE, U-BE, and U-A2 repairs and baseline for U-A1 repair) (continued)

S10	-81.86	114.79	277.24	420.23	552.96	684.15	792.36	902.03	998.47	1109.54	1199.25
S11	-275.50	42.43	241.42	397.15	544.69	687.66	806.19	919.33	1018.86	1137.65	1230.22
S12	730.16	775.08	872.02	1006.03	1123.17	1225.98	1315.86	1405.82	1484.56	1570.21	1630.38
S13	-339.33	104.72	291.54	431.40	543.22	654.38	742.66	830.90	906.26	991.69	1066.24
S14	-171.88	106.20	289.40	441.96	569.78	694.09	793.07	895.00	980.25	1079.78	1166.60
S15	-158.17	151.10	358.29	513.58	638.22	759.62	856.13	954.24	1033.72	1127.91	1209.18
S16	82.60	-68.35	-156.75	-220.40	-284.34	-344.74	-393.48	-432.84	-463.05	-496.36	-520.08
S17	-143.23	-321.58	-540.56	-674.18	-833.03	-981.44	-1120.40	-1249.88	-1339.31	-1431.29	-1514.30
S18	237.70	-213.11	-525.44	-731.51	-932.66	-1106.61	-1239.75	-1354.93	-1442.32	-1536.26	-1592.49
S23	-68.71	17.68	92.52	173.89	244.78	326.67	395.21	464.47	527.24	603.72	665.59
S24	86.72	196.18	360.16	496.50	599.22	711.04	801.43	887.50	963.31	1056.04	1129.15
S27	279.84	-428.37	-970.07	-1164.67	-1248.40	-1896.94	-2344.24	-2614.48	-2948.80	-3255.75	-3482.46
IS10	3.08	9.42	-49.09	-87.49	-120.48	-138.04	-145.64	-142.75	-135.87	-113.40	-85.33
IS11	-6.30	-343.29	-491.90	-579.04	-653.34	-688.53	-708.09	-704.83	-691.86	-648.95	-601.44
IS12	-75.56	-38.21	-19.92	-4.10	7.71	20.98	31.23	41.95	47.74	67.71	85.50
IS13	268.90	-104.85	-190.92	-220.65	-231.21	-215.34	-192.83	-159.48	-127.47	-74.43	-22.84
IS14	161.80	-19.53	-98.86	-142.81	-170.57	-175.66	-171.27	-151.95	-132.80	-93.22	-50.17
IS15	89.28	-75.79	-156.63	-196.46	-219.77	-220.16	-209.83	-186.08	-164.22	-119.31	-75.97
IS16	-179.54	33.07	146.02	240.23	330.82	424.82	503.52	581.46	647.98	729.68	795.64
IS17	-49.97	18.17	83.71	139.55	192.38	250.80	299.20	348.39	389.90	441.79	485.72
IS18	-28.66	76.11	151.79	217.35	273.38	337.50	389.75	445.63	488.60	547.89	598.83
IS23	102.97	42.54	26.76	18.58	7.01	14.83	22.69	38.97	56.59	94.78	130.54
IS24	59.61	-73.77	-150.87	-196.54	-226.66	-231.90	-230.15	-218.52	-203.14	-169.57	-135.65
IS27	-62.20	-25.31	7.77	38.48	62.12	91.37	112.26	134.44	152.43	182.24	206.07
1AF	-99.41	40.34	180.46	298.42	419.75	545.33	654.87	764.35	857.93	970.27	1060.86
1AA	-156.58	4.36	160.76	290.47	422.44	557.17	672.29	786.81	887.05	1007.69	1104.40
1BF*	-61.55	111.21	242.73	337.65	423.55	514.07	588.54	663.12	717.78	795.95	855.26
1BA*	-300.05	130.10	423.32	641.35	844.83	1037.72	1197.14	1346.45	1467.65	1610.11	1715.67
1UAF	-134.01	124.24	348.92	531.82	716.00	905.15	1063.03	1216.95	1351.52	1507.33	1628.80
1UAA	21.74	269.80	496.04	685.84	870.70	1065.54	1234.06	1390.42	1525.48	1691.20	1809.65
1RF	-164.19	33.07	135.59	212.73	279.69	349.02	401.16	452.92	491.82	548.62	589.65
1RA	-217.77	39.64	193.90	318.94	439.00	561.65	664.32	762.22	844.26	942.64	1018.25
F01	697.12	576.92	594.93	684.66	670.65	736.21	737.04	755.43	787.15	794.40	863.19
F04	-496.43	-217.56	-158.76	-104.95	-1.29	63.62	138.10	212.88	312.51	406.13	442.22
F06	-390.97	-256.46	-189.62	-136.78	-47.94	-5.83	64.63	132.74	203.57	271.37	292.42
F07	204.56	38.75	59.57	134.92	124.67	167.72	180.97	200.24	224.06	220.39	282.60
F10	-665.09	-346.06	-309.45	-280.16	-155.38	-90.75	-10.73	71.06	183.29	294.92	315.70
L02	58.71	86.70	102.33	113.01	129.24	149.85	182.24	210.80	238.42	267.89	282.46
L03	737.44	770.17	775.41	778.75	788.02	797.05	814.26	823.27	837.77	853.94	863.70

Note: Strain gages F02, F03, F05, F08, F09, L01, L04, and L05 were removed. Successive * signs on the gage number represent the progressive distances between the notch tip and strain gage (see appendix C for details).

Table E-11. Strain survey raw data (run1), reference, and phase 1 repairs (40,000 cycles for R-BE, U-BE, and U-A2 repairs and 20,000 cycles for U-A1 repair)

Load Step	0	1	2	3	4	5	6	7	8	9	10
Pressure	-0.06	0.66	1.37	1.90	2.70	3.30	3.92	4.74	5.38	5.95	6.76
Frame-1	-13.41	70.40	214.33	337.43	457.00	576.32	667.94	800.75	899.51	1033.88	1114.27
Frame-2	-3.75	101.17	219.67	346.01	446.52	585.69	684.32	784.23	910.38	1018.97	1111.74
Frame-3	35.50	100.10	191.48	377.14	451.78	583.15	724.04	800.73	900.44	1057.52	1167.30
Frame-4	8.00	87.81	197.87	342.67	475.44	597.38	748.74	818.38	897.87	1017.15	1143.41
Frame-5	40.49	129.46	218.02	352.71	451.87	615.10	696.00	814.79	892.57	1020.53	1107.40
Frame-6	-2.08	82.16	239.27	347.68	452.65	580.01	708.66	791.55	900.84	1030.66	1138.00
Frame-7	1.46	95.02	232.90	355.26	446.18	583.32	712.31	797.99	891.19	1036.38	1129.82
Frame-8	6.86	80.97	248.46	353.77	422.77	574.40	728.40	784.46	909.24	1041.85	1143.45
Frame-9	-9.59	91.63	258.47	380.61	421.68	550.05	715.79	771.16	917.79	1049.11	1146.28
Frame-10	44.54	84.61	236.62	377.22	441.00	604.40	685.73	806.44	903.42	1075.57	1147.48
Frame-11	-36.28	119.51	284.77	359.84	365.46	504.69	756.11	697.85	822.34	1064.61	1138.67
Frame-12	-26.39	45.95	213.52	340.22	426.13	581.15	734.53	749.23	925.94	1053.71	1148.32
Hoop-1	19.90	730.87	1476.43	2196.76	2736.80	3561.27	4368.67	4926.89	5767.45	6551.62	7176.68
Hoop-2	-11.11	704.46	1421.96	2171.81	2715.21	3700.23	4255.05	5167.07	5640.11	6433.24	7087.35
Hoop-3	4.09	714.07	1413.67	2183.55	2851.02	3626.95	4335.41	5120.47	5836.44	6564.61	7296.72
Hoop-4	-26.35	751.19	1454.39	2106.86	2898.51	3575.38	4275.13	5066.82	5810.65	6597.93	7238.56
Hoop-5	-1.22	764.63	1393.99	2118.78	2898.59	3541.45	4352.55	5046.13	5758.84	6496.58	7218.63
Hoop-6	52.40	768.87	1405.27	2081.90	2918.28	3634.01	4471.10	5090.58	5550.80	6293.42	7238.97
Hoop-7	41.72	629.82	1355.69	2262.28	2799.87	3574.94	4336.71	5026.34	5731.41	6613.32	7131.05
Hoop-8	-12.59	738.83	1446.61	2081.58	2833.14	3613.53	4263.30	5022.16	5801.76	6430.44	7240.38
Hoop-9	-64.90	774.88	1273.85	2083.41	2932.33	3563.73	4217.38	4962.21	5696.92	6548.77	6984.90
Hoop-10	5.90	689.98	1416.84	2174.05	2744.53	3639.86	4477.27	5069.07	5709.50	6547.68	7420.28
Hoop-11	-0.09	559.70	1360.58	2161.62	2899.10	3636.21	4261.71	5049.93	5735.53	6488.65	7182.64
Hoop-12	3.83	744.04	1360.72	2073.93	2888.87	3696.16	4395.05	5108.13	5740.02	6359.64	7247.35
Hoop-13	22.69	614.99	1434.10	2275.32	2721.46	3635.31	4374.36	5076.47	5770.12	6575.78	7307.15
Hoop-14	6.31	659.34	1444.58	2200.63	2883.15	3668.05	4299.56	5055.46	5788.19	6479.20	7227.77
Long-1	24.71	528.26	1157.18	2187.41	2525.87	3232.20	3881.38	4834.54	5378.33	5904.57	6632.69
Long-2	12.89	622.71	1559.00	2209.38	2765.85	3285.90	4144.87	4800.92	5406.48	6113.05	6536.45
Long-3	12.22	768.67	1430.21	1955.52	2638.72	3200.55	3985.45	4761.16	5235.50	6114.70	6787.77
Long-4	-4.43	556.98	1418.60	1858.30	2658.62	3421.65	3926.73	4652.15	5273.16	5940.10	6608.01
Long-5	19.64	538.26	1059.01	2027.13	2356.15	3393.39	4001.57	4726.01	5351.05	6123.23	6627.90
Long-6	-3.93	451.89	1465.94	2140.63	2832.38	3313.17	4092.78	4695.25	5135.18	6103.02	6506.27
Long-7	4.81	821.07	1349.13	2053.80	2828.12	3374.30	3794.52	4624.24	5294.01	5831.54	6779.87
Long-8	56.23	812.27	1222.58	1920.92	2638.01	3324.59	4025.50	4608.74	5509.30	5996.79	6520.27

Table E-11. Strain survey raw data (run1), reference, and phase 1 repairs (40,000 cycles for R-BE, U-BE, and U-A2 repairs and 20,000 cycles for U-A1 repair) (continued)

S10	10.38	188.77	389.45	516.01	683.92	803.06	923.92	1055.22	1155.56	1251.81	1368.29
S11	-411.56	-92.67	126.47	262.61	437.07	561.42	685.49	820.37	919.70	1015.41	1132.98
S12	-3.89	24.65	141.70	229.32	339.52	431.54	523.31	621.38	700.19	778.01	869.84
S13	-591.74	92.37	302.51	427.11	549.27	647.27	737.56	830.59	904.79	977.68	1061.95
S14	-263.61	60.70	284.67	424.46	566.82	681.16	785.23	893.63	981.11	1066.69	1163.99
S15	-157.62	127.09	353.75	494.90	633.73	744.63	844.90	950.11	1032.55	1113.41	1205.39
S16	107.99	-41.72	-137.41	-205.55	-285.32	-338.22	-388.52	-440.23	-473.31	-502.65	-531.58
S17	204.72	36.68	-153.57	-289.55	-481.77	-604.49	-737.77	-880.16	-982.89	-1074.80	-1182.32
S18	444.45	-55.85	-383.26	-575.58	-804.07	-942.87	-1076.43	-1194.62	-1269.64	-1324.81	-1375.48
S23	55.08	35.07	102.50	151.73	217.00	279.17	340.14	410.64	467.88	524.59	598.51
S24	-261.44	113.27	371.31	506.89	645.81	753.23	850.52	954.05	1033.02	1107.36	1200.06
S27	314.40	-29.00	-379.64	-585.14	-898.59	-1090.40	-1290.46	-1505.13	-1637.28	-1747.92	-1852.89
IS10	31.34	1.64	-68.10	-109.93	-157.90	-177.31	-190.71	-198.48	-193.63	-178.42	-155.40
IS11	288.93	38.05	-83.39	-150.37	-225.11	-255.84	-280.16	-291.75	-288.36	-275.11	-247.67
IS12	-49.30	127.66	156.18	179.28	177.42	206.36	232.66	262.17	297.01	344.34	395.96
IS13	585.59	21.95	-80.16	-107.69	-119.32	-103.73	-77.60	-41.09	-2.99	44.35	101.20
IS14	254.77	53.98	-62.37	-106.68	-154.43	-161.39	-158.29	-145.51	-125.29	-92.83	-53.06
IS15	74.20	-74.92	-166.02	-206.87	-235.91	-235.09	-223.41	-197.39	-167.39	-127.11	-77.47
IS16	-145.36	34.62	159.45	246.99	356.95	442.67	527.23	619.91	691.32	761.74	843.54
IS17	-28.12	31.99	99.90	151.72	212.34	263.72	315.59	369.44	412.66	457.26	506.91
IS18											
IS23	-22.24	-4.48	-3.25	-3.57	-10.29	-0.13	13.00	37.25	60.50	92.31	139.20
IS24	336.18	-23.27	-162.61	-219.21	-269.71	-284.53	-288.51	-276.53	-261.77	-234.18	-194.66
IS27	26.23	28.23	51.32	62.04	71.30	84.77	95.68	110.39	122.78	139.14	162.58
1AF	-101.66	35.22	179.00	288.93	432.82	543.76	661.90	787.06	884.79	981.45	1090.94
1AA	-89.69	31.02	198.87	319.61	477.49	595.66	718.88	852.72	956.22	1059.91	1179.70
1BF**	37.58	299.80	440.99	595.71	800.33	952.52	1103.83	1255.74	1370.21	1478.61	1591.22
1BA**	-413.16	63.42	384.46	596.24	846.95	1026.05	1199.36	1376.34	1504.88	1626.79	1756.88
1UAF*	-108.14	61.95	255.57	392.71	568.51	698.41	829.48	972.38	1075.50	1176.61	1291.07
1UAA*	-109.41	44.64	264.12	419.60	634.56	782.20	934.07	1102.54	1222.67	1333.86	1465.98
1RF	-215.62	58.16	273.19	430.82	617.94	760.48	897.28	1041.96	1150.86	1256.83	1372.63
1RA	-257.08	41.72	243.62	385.92	565.17	695.44	823.25	962.93	1064.43	1162.29	1272.37
F01											
F04	-991.51	-744.37	-617.86	-612.30	-433.76	-405.81	-336.42	-182.49	-109.27	-70.82	69.60
F06	-536.47	-369.66	-295.79	-279.63	-145.40	-116.43	-69.13	50.93	115.06	139.80	247.61
F07	1263.50	1040.82	1036.32	1115.54	1028.94	1094.71	1103.76	1054.40	1081.42	1118.18	1101.23
F10	-827.24	-597.04	-472.31	-492.41	-316.14	-289.53	-215.85	-74.40	3.22	35.62	175.68
L02	60.64	101.69	121.04	145.52	171.07	191.91	216.58	250.25	272.57	296.69	315.07
L03	12.90	42.26	37.25	44.31	49.51	57.14	66.24	79.43	92.09	107.52	117.55

Note: Strain gages F02, F03, F05, F08, F09, L01, L04 and L05 were removed and IS18 and F01 showed faulty readings. Successive * signs on the gage number represent the progressive distances between the notch tip and strain gage (see appendix C for details).

Table E-12. Strain survey raw data (run2), reference, and phase 1 repairs (40,000 cycles for R-BE, U-BE, and U-A2 repairs and 20,000 cycles for U-A1 repair)

Load Step	0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00
Pressure	0.04	0.76	1.42	1.98	2.58	3.55	3.97	4.61	5.34	5.98	6.69
Frame-1	5.71	141.56	216.07	352.57	425.62	546.72	701.67	803.35	913.57	1006.18	1131.32
Frame-2	3.04	105.82	217.73	319.57	443.86	563.97	677.79	785.33	911.77	1005.10	1130.04
Frame-3	-32.12	83.14	202.87	339.17	469.54	522.75	665.37	803.52	926.44	1023.60	1117.80
Frame-4	-38.80	83.52	206.11	350.51	466.41	539.74	723.02	800.38	915.87	1045.30	1096.76
Frame-5	-17.11	104.71	211.92	343.50	459.81	513.69	706.63	806.47	904.85	1028.74	1116.05
Frame-6	22.16	105.55	219.58	360.37	464.07	530.22	683.15	797.90	914.92	1029.42	1128.56
Frame-7	-42.85	93.07	194.67	334.28	466.49	519.61	682.06	801.46	917.59	1007.37	1130.67
Frame-8	11.41	93.03	234.98	388.81	454.69	517.51	644.85	797.18	920.41	1020.07	1120.75
Frame-9	15.13	134.47	231.88	369.11	459.51	520.26	665.18	807.74	920.59	1009.00	1125.40
Frame-10	24.35	141.87	232.12	358.34	426.31	525.19	671.66	845.54	920.56	1025.83	1116.26
Frame-11	0.72	150.11	300.57	463.15	510.63	508.53	503.35	850.18	895.67	998.74	1136.63
Frame-12	5.52	129.53	264.95	336.90	517.88	474.97	639.50	787.38	910.32	1038.29	1141.11
Hoop-1	-1.86	632.99	1456.48	2124.19	2903.65	3628.40	4272.98	4904.14	5625.29	6487.61	7142.94
Hoop-2	3.20	586.45	1346.82	2161.08	3008.60	3714.48	4276.95	4935.27	5626.92	6629.57	6901.99
Hoop-3	18.11	736.93	1413.67	2232.64	2928.15	3551.53	4300.78	5093.15	5649.99	6471.22	7109.85
Hoop-4	-59.05	738.55	1332.66	2255.85	2956.64	3644.44	4406.36	5040.38	5637.37	6444.78	7142.99
Hoop-5	-29.98	690.99	1435.34	2142.15	2857.24	3510.93	4358.38	5012.77	5707.84	6492.48	7172.61
Hoop-6	-2.29	734.31	1489.14	2098.31	2867.23	3592.10	4216.31	5016.64	5500.85	6473.39	7157.65
Hoop-7	-36.93	608.43	1475.47	2162.16	2891.04	3603.54	4353.23	4991.38	5771.89	6561.00	7042.37
Hoop-8	-12.59	702.35	1432.16	2074.07	2869.34	3570.11	4307.08	5014.37	5708.63	6438.38	7079.14
Hoop-9	87.62	582.88	1426.53	2095.77	3077.40	3603.57	4240.71	5128.61	5752.47	6533.27	6942.93
Hoop-10	-1.21	665.10	1413.42	2191.61	2893.52	3396.75	4281.78	5070.34	5862.28	6447.03	7021.49
Hoop-11	52.45	701.01	1355.28	2108.86	2884.31	3584.03	4305.20	4986.01	5594.08	6462.11	7091.33
Hoop-12	-18.00	647.65	1448.17	2299.26	2917.68	3674.70	4460.54	4758.39	5719.90	6425.77	7122.94
Hoop-13	-13.87	717.36	1331.85	2004.51	2947.89	3533.28	4250.02	5010.15	5808.42	6481.35	7050.47
Hoop-14	-8.37	791.41	1452.07	2185.74	2882.86	3558.33	4306.89	5032.94	5606.44	6377.10	7080.29
Long-1	23.54	813.22	1307.46	2070.24	2590.66	3195.10	3930.27	4590.59	5204.83	5865.27	6628.40
Long-2	6.37	658.13	1217.60	2186.84	2526.13	3440.20	4147.38	4455.08	5353.60	5907.14	6855.73
Long-3	12.94	566.19	1173.15	2097.48	2606.12	3455.92	4080.85	4613.73	5469.26	5932.98	6594.71
Long-4	23.27	606.89	1420.29	1949.41	2522.81	3196.20	3803.09	4787.77	5236.46	5845.92	6479.04
Long-5	15.62	492.90	1422.64	2151.09	2730.75	3237.63	4128.58	4773.55	5212.75	5739.09	6782.01
Long-6	-2.42	505.92	1473.90	1893.19	2779.66	3392.21	3994.39	4535.52	5209.86	5931.45	6626.89
Long-7	8.34	514.80	1451.47	1936.54	2710.57	3112.60	3983.06	4558.50	5510.77	6163.35	6806.65
Long-8	73.43	711.50	1323.55	2054.11	2758.83	3401.83	3874.46	4766.75	5388.09	6040.48	6481.14

Table E-12. Strain survey raw data (run2), reference, and phase 1 repairs (40,000 cycles for R-BE, U-BE, and U-A2 repairs and 20,000 cycles for U-A1 repair) (continued)

S10	-8.87	218.40	396.12	537.53	672.21	834.07	924.56	1035.44	1151.82	1248.48	1351.58
S11	-369.06	-65.26	136.59	286.88	420.55	597.95	685.83	798.56	913.52	1013.59	1116.38
S12	-9.94	44.69	147.80	244.89	335.91	451.95	523.25	608.23	696.91	777.42	855.92
S13	-321.79	140.94	319.68	449.80	555.39	669.44	743.45	823.83	905.20	982.05	1053.31
S14	-198.83	107.17	300.15	448.23	572.10	703.88	790.69	885.42	980.50	1071.54	1153.62
S15	-113.94	170.00	366.33	516.35	638.53	766.14	849.29	939.67	1029.57	1116.46	1194.09
S16	88.30	-52.61	-145.38	-216.14	-277.17	-356.77	-394.49	-435.40	-474.49	-504.29	-535.09
S17	227.79	29.71	-161.00	-305.44	-446.75	-645.85	-738.33	-855.41	-974.99	-1069.32	-1179.59
S18	372.41	-87.07	-394.15	-603.22	-778.82	-987.05	-1073.42	-1175.26	-1259.22	-1321.18	-1369.81
S23	33.26	59.94	108.46	164.87	219.32	293.98	340.50	402.12	467.48	527.17	587.45
S24	-110.15	200.23	402.46	541.19	654.22	782.35	854.31	942.77	1033.15	1110.89	1188.40
S27	339.04	-68.68	-393.77	-624.66	-837.29	-1166.76	-1295.40	-1463.39	-1628.44	-1728.30	-1843.66
IS10	24.28	-11.95	-72.81	-116.47	-147.97	-186.35	-192.33	-197.26	-193.41	-177.69	-162.66
IS11	243.55	27.17	-92.11	-160.73	-213.72	-270.15	-282.67	-291.26	-289.75	-275.11	-257.50
IS12	-12.15	122.20	142.59	164.25	183.74	182.95	216.68	247.32	280.45	335.04	371.24
IS13	358.67	-3.95	-89.35	-113.62	-114.75	-108.68	-83.42	-51.16	-11.32	41.85	86.33
IS14	203.34	26.45	-74.59	-118.54	-145.16	-173.77	-164.65	-152.65	-134.56	-94.83	-67.48
IS15	36.20	-91.88	-174.52	-212.75	-228.95	-238.93	-226.02	-205.02	-174.90	-127.89	-89.48
IS16	-141.68	46.27	163.09	257.84	346.74	461.59	527.63	605.12	686.63	758.28	830.88
IS17	-36.72	37.55	101.68	156.88	209.29	271.52	313.56	360.05	407.30	455.98	497.13
IS18											
IS23	-10.93	2.25	0.83	1.10	1.88	2.79	15.29	35.33	60.99	99.04	134.64
IS24	190.15	-61.86	-173.03	-227.79	-262.56	-288.21	-288.80	-281.25	-265.66	-231.65	-202.61
IS27	14.59	33.86	49.69	63.14	73.32	82.22	91.49	104.05	118.94	137.32	152.23
1AF	-103.75	43.92	182.64	302.06	419.08	568.46	658.38	764.82	874.60	977.09	1076.66
1AA	-121.53	44.37	203.47	333.90	459.82	622.79	715.71	828.11	944.92	1054.63	1163.60
1BF**	-52.26	299.28	489.01	638.33	793.94	985.89	1100.08	1228.35	1353.94	1471.34	1573.19
1BA**	-357.39	90.50	392.64	622.65	826.77	1067.55	1197.24	1346.09	1489.87	1621.70	1739.07
1UAF*	-109.69	83.54	264.13	411.92	548.41	734.04	830.85	949.07	1067.45	1173.33	1278.08
1UAA*	-131.21	64.99	272.84	443.62	601.99	830.07	939.06	1076.60	1215.16	1331.68	1454.50
1RF	-204.73	72.68	279.36	447.38	599.74	789.80	898.46	1018.76	1142.65	1250.11	1354.63
1RA	-231.12	58.61	249.61	402.85	542.23	728.41	824.98	939.34	1057.14	1155.94	1257.25
F01											
F04	-894.54	-707.82	-609.82	-579.05	-539.68	-290.95	-316.49	-232.25	-97.39	-78.00	85.15
F06	-463.71	-348.72	-284.23	-264.57	-218.69	-46.11	-52.41	8.44	116.16	136.31	260.23
F07	1187.07	1066.09	1043.92	1085.58	1126.95	981.78	1087.36	1104.60	1091.88	1120.00	1080.87
F10	-714.05	-536.26	-451.96	-455.51	-428.80	-166.45	-205.75	-127.36	7.96	26.73	190.31
L02	62.85	93.41	116.62	136.69	155.83	193.00	215.45	241.09	267.92	285.09	323.02
L03	20.52	28.70	33.35	36.88	43.75	56.94	68.47	80.01	90.21	101.02	126.11

Note: Strain gages F02, F03, F05, F08, F09, L01, L04 and L05 were removed and IS18 and F01 showed faulty readings. Successive * signs on the gage number represent the progressive distances between the notch tip and strain gage (see appendix C for details).

Table E-13. Strain survey raw data (run3), reference, and phase 1 repairs (40,000 cycles for R-BE, U-BE, and U-A2 repairs and 20,000 cycles for U-A1 repair)

Load Step	0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00
Pressure	-0.05	0.77	1.30	2.13	2.62	3.42	3.96	4.65	5.22	6.12	6.63
Frame-1	-17.17	111.27	232.01	335.18	432.66	575.57	674.59	811.83	916.94	1034.50	1146.54
Frame-2	-10.05	107.04	220.85	346.77	445.94	566.14	678.42	800.30	903.53	1013.61	1145.27
Frame-3	24.66	121.07	234.97	316.37	471.69	567.42	697.27	751.58	913.79	1025.63	1123.36
Frame-4	-30.25	114.10	242.46	320.39	481.25	540.69	690.47	820.53	942.07	990.02	1152.92
Frame-5	10.81	100.61	212.51	304.95	433.66	547.04	676.22	789.99	925.76	1009.47	1153.87
Frame-6	10.56	90.34	232.99	308.90	454.73	547.74	693.88	793.79	923.32	1004.83	1137.50
Frame-7	-8.97	74.98	238.18	308.63	443.06	556.48	688.31	781.37	919.59	999.95	1140.10
Frame-8	-16.24	86.52	265.56	313.52	442.02	561.47	680.77	762.69	931.82	1034.16	1130.54
Frame-9	-33.51	85.01	258.97	291.63	464.67	544.25	698.92	763.30	907.40	1010.75	1124.14
Frame-10	-18.62	109.26	216.24	324.93	451.78	526.04	729.09	810.20	930.45	1003.17	1137.01
Frame-11	-58.46	49.17	272.68	283.56	470.97	554.82	641.35	722.09	938.29	1032.81	1133.96
Frame-12	-39.16	140.37	237.56	299.59	492.78	601.72	698.50	740.26	935.46	1016.45	1088.80
Hoop-1	59.82	732.68	1374.72	2163.67	2825.67	3598.65	4315.56	5006.71	5848.42	6482.17	7228.19
Hoop-2	-18.27	695.52	1586.40	2096.25	2903.05	3534.89	4302.85	4964.88	5651.97	6488.21	7274.12
Hoop-3	-27.47	693.03	1462.61	2107.73	2921.14	3645.51	4275.34	5083.65	5646.48	6380.04	7083.56
Hoop-4	171.70	716.67	1394.30	2088.27	2878.53	3480.20	4214.63	5099.53	5702.79	6557.45	7024.90
Hoop-5	31.15	737.67	1411.83	2127.34	2875.22	3612.66	4231.58	5038.94	5722.23	6438.53	7194.18
Hoop-6	-7.76	644.90	1441.59	2156.23	2861.76	3636.93	4426.85	5048.64	5473.50	6467.92	7030.02
Hoop-7	-36.93	733.50	1461.02	2025.88	2815.96	3533.11	4300.46	5020.98	5734.34	6421.53	7224.72
Hoop-8	16.59	636.82	1315.42	2088.66	2906.40	3636.51	4328.97	5058.65	5678.31	6466.92	7109.03
Hoop-9	137.88	649.40	1218.34	2146.02	2882.37	3729.95	4393.27	5012.46	5722.61	6466.21	7141.04
Hoop-10	2.35	782.53	1463.18	2092.10	2924.31	3530.74	4290.67	5029.98	5724.28	6501.48	7063.06
Hoop-11	-3.71	572.50	1464.00	2125.16	2828.71	3579.31	4274.40	5028.18	5699.86	6490.46	7099.29
Hoop-12	29.29	713.27	1571.86	2053.71	2940.09	3595.38	4227.70	5028.09	5733.31	6672.52	7167.31
Hoop-13	22.70	710.19	1375.73	2084.96	2948.48	3563.24	4454.81	4944.82	5756.07	6400.25	7131.62
Hoop-14	6.31	659.47	1386.02	2053.65	2824.72	3595.74	4380.28	5048.12	5744.74	6405.82	7073.65
Long-1	22.14	766.90	1326.54	2082.89	2807.28	3386.20	4143.36	4788.23	5427.82	5863.17	6551.68
Long-2	14.64	522.46	1242.55	1880.71	2585.82	3491.11	4002.44	4596.56	5235.51	6156.21	6498.63
Long-3	13.42	824.13	1357.38	1927.57	2497.31	3249.05	4043.22	4777.70	5306.31	5895.84	6682.93
Long-4	13.29	658.74	1514.39	1883.86	2554.08	3204.18	3823.04	4629.33	5526.16	5955.98	6643.01
Long-5	21.06	775.06	1363.88	1824.76	2516.51	3174.72	3919.50	4508.91	5343.37	5997.85	6513.81
Long-6	2.13	498.10	1475.56	2098.33	2721.91	3187.11	3898.27	4684.15	5424.83	5850.56	6748.99
Long-7	8.33	829.46	1408.06	2158.35	2580.45	3224.86	4163.54	4856.56	5243.96	6163.13	6680.03
Long-8	62.27	525.38	1366.21	2075.98	2595.75	3274.49	4095.21	4667.29	5378.87	6024.40	6630.55

Table E-13. Strain survey raw data (run3), reference, and phase 1 repairs (40,000 cycles for R-BE, U-BE, and U-A2 repairs and 20,000 cycles for U-A1 repair) (continued)

S10	10.38	214.75	379.79	554.50	670.73	821.28	916.98	1035.33	1136.87	1267.05	1341.64
S11	-405.34	-58.42	115.02	307.91	419.96	584.45	677.02	798.67	899.72	1032.56	1108.10
S12	-4.94	40.29	139.42	251.73	335.04	447.45	519.91	609.35	689.23	789.16	859.15
S13	-515.03	139.33	312.68	458.18	557.12	668.84	744.42	828.80	903.47	996.90	1054.66
S14	-243.90	105.29	293.22	460.25	574.25	703.93	793.14	891.91	980.65	1085.08	1150.80
S15	-140.70	169.25	362.31	525.41	639.82	765.51	850.11	945.44	1027.51	1136.00	1194.29
S16	98.19	-61.69	-137.85	-234.35	-280.64	-351.93	-393.30	-442.64	-476.59	-515.17	-537.23
S17	226.61	22.42	-125.09	-341.89	-441.90	-624.59	-721.85	-857.04	-956.56	-1079.86	-1158.44
S18	434.83	-95.80	-359.27	-638.00	-777.37	-968.37	-1062.02	-1175.87	-1248.58	-1329.03	-1369.68
S23	44.62	47.15	109.00	164.51	220.44	294.04	342.49	403.07	462.34	539.19	585.53
S24	-192.40	190.44	391.82	548.81	656.16	783.58	856.29	945.21	1025.55	1125.39	1184.37
S27	352.63	-72.50	-337.96	-683.76	-832.54	-1123.22	-1260.69	-1461.48	-1591.25	-1755.81	-1821.32
IS10	28.99	-9.23	-62.84	-127.86	-148.15	-181.68	-188.74	-195.42	-188.92	-172.42	-155.58
IS11	279.31	12.83	-74.49	-182.50	-214.99	-266.57	-280.73	-294.50	-291.08	-273.81	-255.47
IS12	-52.59	105.95	154.93	133.10	174.85	182.08	211.94	241.23	277.82	327.57	384.92
IS13	525.14	-9.55	-77.33	-128.58	-117.70	-108.11	-85.85	-52.20	-15.38	50.27	86.18
IS14	234.89	20.44	-58.71	-142.78	-149.17	-172.16	-166.87	-155.19	-137.87	-100.84	-70.20
IS15	65.33	-94.44	-167.28	-223.32	-231.64	-238.52	-227.66	-204.41	-176.48	-121.56	-87.06
IS16	-146.41	47.96	151.47	268.55	343.65	450.13	519.46	605.28	676.40	767.48	823.70
IS17	-36.27	36.83	96.93	157.78	207.83	267.93	309.98	360.56	403.01	456.85	493.25
IS18											
IS23	-6.77	8.06	14.01	-4.39	8.97	12.41	22.75	41.19	66.31	111.75	143.00
IS24	283.82	-61.33	-158.70	-241.00	-260.29	-285.78	-287.14	-279.54	-264.85	-228.00	-199.83
IS27	16.59	27.14	49.68	55.32	71.13	82.41	90.78	101.31	115.14	138.58	152.58
1AF	-112.62	43.29	166.79	312.96	413.98	557.65	648.13	765.66	860.58	978.26	1061.81
1AA	-112.79	43.93	182.67	348.94	454.26	609.34	704.19	828.94	929.07	1064.72	1143.44
1BF**	-61.17	327.35	518.60	673.91	801.94	980.99	1095.94	1238.41	1344.02	1475.55	1563.57
1BA**	-411.80	97.06	360.63	650.01	818.96	1047.96	1182.58	1347.78	1472.72	1626.08	1722.73
1UAF*	-116.61	85.65	244.20	433.24	547.22	717.07	819.36	951.71	1054.37	1189.06	1268.30
1UAA*	-126.85	69.36	244.47	479.18	603.44	810.62	926.17	1083.03	1200.87	1359.16	1447.08
1RF	-217.43	76.50	258.46	465.48	594.47	768.36	883.95	1019.75	1127.27	1261.42	1344.69
1RA	-261.44	61.71	225.26	425.68	537.32	706.59	810.07	939.25	1039.20	1167.98	1243.14
F01											
F04	-996.24	-698.19	-689.19	-463.34	-525.37	-338.55	-342.14	-232.50	-152.35	-6.47	15.34
F06	-528.72	-347.70	-345.82	-175.15	-219.59	-78.20	-74.35	26.74	83.84	193.42	216.53
F07	1265.31	1028.45	1106.48	981.52	1118.07	1046.46	1124.16	1101.23	1139.38	1090.18	1125.14
F10	-837.51	-549.80	-553.64	-330.62	-399.76	-207.97	-226.14	-108.39	-21.47	127.28	129.85
L02	50.33	91.22	106.49	138.52	151.22	179.41	206.11	238.12	260.79	286.17	301.82
L03	14.01	35.40	32.60	42.27	41.15	48.96	62.91	79.63	91.72	112.16	120.15

Note: Strain gages F02, F03, F05, F08, F09, L01, L04 and L05 were removed and IS18 and F01 showed faulty readings. Successive * signs on the gage number represent the progressive distances between the notch tip and strain gage (see appendix C for details).

Table E-14. Strain survey raw data (run1), reference, and phase 1 repairs (60,000 cycles for R-BE, U-BE, and U-A2 repairs and 40,000 cycles for U-A1 repair)

Load Step	0	1	2	3	4	5	6	7	8	9	10
Pressure	0.03	0.62	1.35	1.96	2.56	3.39	4.00	4.62	5.42	6.03	6.65
Frame-1	-15.80	121.72	228.54	380.77	432.06	597.15	674.54	739.06	895.37	1021.59	1114.75
Frame-2	12.74	135.96	274.22	329.85	467.73	614.14	656.52	791.30	886.93	987.39	1129.44
Frame-3	29.86	117.05	183.36	343.43	448.97	564.53	687.35	830.24	896.98	977.41	1109.09
Frame-4	27.11	149.61	262.94	368.50	459.80	588.97	608.47	766.82	887.04	954.74	1130.62
Frame-5	53.19	98.10	205.01	306.32	495.20	520.30	676.40	809.29	897.85	1013.12	1171.32
Frame-6	50.76	48.68	145.88	277.22	462.61	586.70	641.75	786.14	911.52	990.26	1091.42
Frame-7	-12.52	134.40	240.59	404.00	427.95	596.54	719.10	801.17	884.94	1036.57	1110.39
Frame-8	60.53	139.81	204.88	320.07	477.12	588.35	643.71	794.20	923.65	965.13	1110.55
Frame-9	18.70	146.17	211.28	322.19	479.72	564.37	639.61	798.07	894.85	1037.24	1118.44
Frame-10	-11.49	164.51	282.95	318.24	494.66	597.95	669.28	817.26	859.49	1050.26	1157.52
Frame-11	48.22	116.15	262.36	331.25	458.72	545.04	648.45	837.39	908.25	1117.00	1135.15
Frame-12	-17.20	150.04	323.48	372.48	461.57	592.47	612.04	848.70	906.27	1008.14	1134.33
Hoop-1	16.98	805.77	1444.49	2058.98	2929.46	3676.62	4306.33	5063.95	5566.84	6474.33	7021.41
Hoop-2	27.26	665.77	1524.74	2154.07	2833.80	3588.65	4315.31	4908.74	5692.78	6498.45	7177.59
Hoop-3	20.94	743.04	1448.05	2091.07	2844.80	3570.48	4228.23	5070.93	5737.59	6430.68	7069.90
Hoop-4	201.26	633.49	1536.66	2068.59	2844.23	3501.81	4167.06	5089.43	5747.58	6365.88	7048.32
Hoop-5	19.86	783.76	1488.79	2234.49	3002.06	3456.86	4219.46	4999.19	5616.32	6256.95	7061.73
Hoop-6	68.51	618.95	1461.48	2255.98	2766.39	3663.25	4237.89	4848.13	5807.55	6333.23	6883.17
Hoop-7	-29.18	751.82	1488.58	2233.61	3016.46	3650.97	4307.36	5030.80	5683.75	6372.58	7312.19
Hoop-8	53.30	753.93	1505.34	2169.56	2862.82	3746.19	4190.96	5080.75	5642.60	6474.43	7146.44
Hoop-9	78.36	724.61	1526.72	2248.44	2991.54	3501.66	4352.11	4940.35	5708.51	6281.04	7067.85
Hoop-10	20.12	756.02	1573.37	2080.07	2870.99	3580.51	4175.57	4978.44	5771.06	6384.18	7154.41
Hoop-11	19.95	777.51	1455.04	2143.81	2845.12	3664.59	4340.16	4973.93	5579.13	6470.63	7165.34
Hoop-12	34.05	698.15	1363.78	2138.92	2822.96	3390.90	4372.95	4983.72	5609.48	6293.45	7152.76
Hoop-13	72.99	599.69	1367.51	2230.75	3028.02	3657.43	4286.10	4943.91	5770.36	6487.10	7072.91
Hoop-14	8.66	691.31	1439.74	2107.79	2790.37	3634.79	4295.00	5065.15	5556.86	6452.20	7179.46
Long-1	11.09	530.65	1309.43	2088.63	2549.01	3248.32	4129.68	4652.28	5499.66	5873.29	6762.31
Long-2	8.11	508.70	1216.95	2084.97	2529.63	3109.03	4073.29	4688.50	5499.12	6181.61	6665.45
Long-3	6.43	708.38	1357.62	1841.37	2489.86	3339.82	3917.97	4518.26	5413.26	5858.49	6499.61
Long-4	23.56	865.19	1573.50	2068.01	2728.36	3430.50	4189.57	4594.87	5357.03	6046.70	6838.54
Long-5	15.05	609.23	1345.13	2235.89	2609.14	3019.36	4032.62	4545.43	5509.39	5923.84	6606.32
Long-6	25.59	519.35	1147.55	1876.98	2952.79	3280.60	3763.18	4468.36	5259.09	6283.54	6724.86
Long-7	32.49	617.05	1369.05	1922.88	2591.52	3100.11	3818.55	4927.75	5543.83	5862.33	6495.29
Long-8	1.53	773.06	1660.18	1913.85	2205.50	3347.33	3931.92	4761.31	5081.12	6178.80	6659.20

Table E-14. Strain survey raw data (run1), reference, and phase 1 repairs (60,000 cycles for R-BE, U-BE, and U-A2 repairs and 40,000 cycles for U-A1 repair) (continued)

S10	18.71	187.38	370.87	504.74	638.31	746.96	820.76	940.44	1052.84	1157.77	1266.60
S11	-56.69	163.76	394.93	551.83	701.24	812.57	889.97	1021.54	1145.23	1253.28	1369.52
S12	27.41	98.43	196.08	272.62	357.11	435.64	494.84	576.06	655.97	729.03	805.42
S13	50.62	216.82	360.59	462.96	559.72	642.21	709.07	791.85	866.90	938.05	1010.54
S14	14.32	193.35	363.14	481.90	593.97	692.62	771.41	867.85	954.71	1034.39	1112.97
S15	20.11	259.36	468.54	609.45	732.81	841.61	922.61	1025.40	1118.73	1200.21	1284.38
S16	56.33	-78.58	-220.48	-325.94	-416.60	-486.09	-539.56	-610.28	-675.28	-732.76	-787.76
S17	-1.71	-205.45	-444.30	-625.74	-772.51	-891.15	-965.79	-1117.21	-1262.40	-1383.31	-1520.47
S18	35.67	-214.13	-460.35	-625.45	-755.23	-843.36	-899.32	-983.71	-1046.13	-1092.75	-1131.84
S23	136.96	158.70	212.81	261.16	322.87	391.44	438.46	510.81	576.94	637.39	698.18
S24	144.45	366.67	555.35	670.11	773.99	872.54	936.84	1023.84	1101.21	1164.68	1229.54
S27	-265.52	-639.38	-1050.41	-1335.50	-1603.20	-1816.65	-1968.28	-2234.42	-2425.76	-2567.02	-2655.77
IS10	-34.60	-99.65	-166.71	-210.06	-229.77	-243.18	-244.76	-246.78	-243.73	-223.45	-209.25
IS11	56.29	-67.84	-182.36	-244.20	-274.14	-281.60	-283.36	-289.93	-281.05	-261.99	-231.75
IS12	-7.76	9.95	15.90	30.66	65.03	102.59	138.48	175.91	219.70	263.59	314.50
IS13	-15.98	-111.30	-163.10	-179.42	-168.50	-140.47	-115.37	-82.87	-41.29	-2.88	44.51
IS14	6.84	-96.31	-173.06	-205.30	-209.27	-191.82	-171.61	-147.54	-112.99	-80.20	-36.51
IS15	-14.59	-170.01	-277.75	-328.13	-344.98	-339.11	-323.36	-299.42	-268.29	-232.51	-187.50
IS23	-152.19	-147.25	-153.67	-153.84	-141.58	-132.43	-120.00	-113.28	-82.34	-54.74	-7.03
IS24	-147.92	-297.34	-409.15	-460.32	-488.01	-503.79	-503.14	-511.62	-492.55	-472.15	-432.67
IS27	42.98	43.89	41.53	41.00	50.81	67.73	83.72	102.09	125.57	148.68	179.56
1BF***	25.49	237.46	466.73	633.26	781.91	909.25	997.70	1131.84	1250.94	1347.36	1447.75
1BA***	-4.72	272.16	559.42	761.25	941.10	1089.10	1189.95	1341.51	1478.55	1590.35	1704.58
1UAF**	105.21	244.60	397.88	513.03	628.41	722.14	797.74	909.53	1008.16	1096.27	1184.64
1UAA**	97.87	230.65	380.79	490.91	602.30	688.29	758.09	867.46	963.73	1049.09	1133.28
1RF*	44.71	212.48	388.20	522.44	652.62	753.43	833.92	939.34	1039.52	1134.45	1227.46
1RA*	68.46	217.28	378.30	498.83	615.52	702.77	767.42	864.73	958.61	1045.06	1133.25

Note: Strain gages IS16-IS18, 1AF, 1AA, F01-F10 and L01-L05 were removed. Successive * signs on the gage number represent the progressive distances between the notch tip and strain gage (see appendix C for details).

Table E-15. Strain survey raw data (run2), reference, and phase 1 repairs (60,000 cycles for R-BE, U-BE, and U-A2 repairs and 40,000 cycles for U-A1 repair)

Load Step	0	1	2	3	4	5	6	7	8	9	10
Pressure	-0.03	0.72	1.44	1.96	2.72	3.34	4.00	4.66	5.31	5.98	6.71
Frame-1	-16.83	146.81	169.12	373.08	446.34	606.60	667.47	752.96	974.51	1037.19	1112.37
Frame-2	1.41	92.94	179.00	347.48	435.50	579.17	679.86	788.88	904.29	1047.42	1160.15
Frame-3	61.32	107.45	210.27	321.56	448.08	588.29	723.17	801.78	949.70	1087.89	1167.61
Frame-4	-36.59	129.28	192.68	331.36	428.62	558.91	658.74	787.35	873.90	1058.52	1202.32
Frame-5	-10.24	96.91	226.60	341.31	393.38	584.38	699.90	802.67	904.14	1020.28	1121.62
Frame-6	0.48	107.95	230.25	283.39	484.56	574.71	652.33	816.49	882.26	1004.63	1171.10
Frame-7	8.01	98.88	161.42	285.24	440.61	533.58	690.54	831.09	887.70	1031.35	1135.38
Frame-8	-4.20	124.65	196.85	324.66	409.26	625.02	673.26	808.44	877.84	1038.81	1156.32
Frame-9	-3.85	119.31	209.60	337.05	408.76	617.13	657.80	778.42	907.94	1077.08	1137.61
Frame-10	43.68	112.21	180.21	354.90	437.87	626.18	724.82	788.51	927.38	1064.33	1084.62
Frame-11	27.53	121.77	187.34	366.48	487.18	612.86	678.70	743.64	909.35	1082.68	1073.50
Frame-12	4.08	92.52	183.05	241.57	459.41	607.09	692.57	828.30	938.62	1004.95	1209.29
Hoop-1	-2.97	595.48	1476.70	2145.81	2929.46	3680.98	4333.11	5124.30	5653.90	6263.29	7273.51
Hoop-2	2.21	728.44	1456.32	2053.70	2789.08	3582.21	4372.12	4957.53	5712.46	6531.79	7125.71
Hoop-3	-10.62	653.72	1359.99	2076.84	2767.67	3586.97	4294.41	5092.47	5706.04	6437.05	7050.61
Hoop-4	-49.46	737.09	1508.95	2124.69	2853.32	3566.10	4359.20	4922.80	5636.76	6447.00	7208.19
Hoop-5	-8.91	631.04	1434.42	1970.05	2683.89	3479.12	4253.19	5066.21	5729.58	6486.45	7228.93
Hoop-6	39.34	803.13	1391.78	2020.62	2908.57	3578.29	4386.94	5211.41	5712.75	6555.02	7264.19
Hoop-7	58.42	805.52	1582.86	2113.64	2835.94	3710.69	4308.72	4945.50	5742.74	6504.22	7281.80
Hoop-8	-5.09	739.26	1432.95	2045.71	2877.70	3527.24	4424.48	4971.79	5745.33	6519.51	7183.64
Hoop-9	-11.39	633.00	1378.31	2112.23	2995.43	3408.31	4486.73	4872.64	5814.98	6447.44	7255.24
Hoop-10	-13.65	670.63	1449.55	2082.06	2828.62	3491.64	4363.97	4913.17	5682.77	6501.00	7132.02
Hoop-11	1.83	695.89	1452.00	2078.78	2847.22	3573.97	4235.06	4997.98	5693.86	6529.92	7137.06
Hoop-12	-0.52	725.36	1333.39	2139.13	2670.41	3558.29	4161.92	5064.27	5791.97	6418.43	7269.92
Hoop-13	-14.79	723.97	1477.80	2143.19	2633.30	3730.58	4395.82	5215.04	5683.16	6466.45	7183.34
Hoop-14	-6.02	852.71	1396.26	2210.76	2952.14	3642.13	4265.64	4999.60	5660.16	6497.53	7136.14
Long-1	5.71	695.10	1432.40	2188.79	2749.49	3217.38	3994.94	4654.15	5237.87	6099.15	6667.80
Long-2	9.36	477.35	1260.34	1993.78	2635.97	3487.72	4193.42	4733.89	5504.39	5948.26	6614.78
Long-3	8.35	874.52	1544.27	1817.52	2522.22	3446.96	4139.48	4637.89	5403.19	5985.45	6720.19
Long-4	1.18	898.42	1223.04	1855.35	2532.92	3374.00	3870.47	4774.80	5287.88	6152.25	6596.32
Long-5	8.43	608.05	1554.83	1884.73	2409.03	3170.92	3679.71	4620.65	5346.88	6206.62	6584.79
Long-6	-5.95	678.04	1191.99	2104.89	2755.74	3379.68	3870.16	4804.17	5517.73	5793.19	6849.25
Long-7	13.61	819.96	1233.34	1750.33	2757.17	3514.73	3929.82	4398.07	5062.94	6188.26	6446.69
Long-8	5.25	944.10	1465.98	2234.57	2765.56	2941.43	4350.91	4958.15	5589.87	5636.02	6080.96

Table E-15. Strain survey raw data (run2), reference, and phase 1 repairs (60,000 cycles for R-BE, U-BE, and U-A2 repairs and 40,000 cycles for U-A1 repair) (continued)

S10	-13.29	217.04	386.63	504.50	655.84	742.91	824.84	948.38	1036.95	1150.90	1276.35
S11	-114.05	194.04	422.05	544.40	719.69	806.92	893.87	1027.64	1121.70	1244.61	1380.69
S12	6.26	103.75	198.92	267.99	363.38	427.09	496.72	581.39	646.60	727.68	815.36
S13	28.57	235.56	374.55	467.33	571.20	642.34	717.21	797.72	864.40	940.74	1021.64
S14	-5.79	220.65	381.53	488.49	608.98	690.48	779.33	871.07	948.34	1035.29	1125.38
S15	-28.81	272.55	477.54	603.82	744.89	832.51	926.16	1026.01	1105.83	1197.46	1291.81
S16	76.15	-105.46	-245.70	-329.17	-439.47	-493.79	-548.57	-620.73	-674.68	-737.66	-794.25
S17	47.40	-240.69	-477.81	-609.95	-814.82	-889.92	-972.25	-1122.81	-1230.88	-1372.43	-1523.49
S18	81.46	-250.75	-487.01	-618.36	-781.03	-847.34	-908.13	-990.16	-1042.13	-1094.64	-1138.24
S23	181.08	213.33	257.00	298.33	355.41	399.55	449.64	519.66	573.03	636.48	708.76
S24	122.87	419.61	594.18	692.72	803.28	868.94	940.45	1026.83	1088.51	1158.06	1234.35
S27	-372.07	-896.03	-1276.43	-1470.70	-1764.73	-1873.08	-2011.10	-2237.18	-2406.91	-2553.54	-2639.81
IS10	-21.73	-112.38	-172.85	-208.55	-242.82	-240.15	-242.84	-241.01	-236.84	-221.62	-196.25
IS11	84.64	-91.87	-204.69	-242.86	-295.41	-290.74	-287.99	-289.05	-281.96	-261.42	-226.70
IS12	-16.30	-9.04	3.45	21.25	42.87	93.02	138.66	180.56	217.29	268.65	328.37
IS13	-7.32	-134.34	-175.42	-187.89	-183.78	-151.11	-114.36	-78.66	-47.64	-0.11	56.63
IS14	11.90	-131.65	-193.22	-216.08	-231.49	-201.70	-170.30	-143.91	-117.91	-75.37	-24.17
IS15	26.58	-177.81	-280.18	-323.34	-354.08	-338.55	-315.04	-295.35	-268.47	-225.75	-174.53
IS23	-247.13	-238.16	-224.88	-211.61	-194.42	-162.49	-138.67	-114.07	-98.55	-56.20	0.66
IS24	-189.07	-388.19	-472.87	-501.79	-530.39	-521.61	-512.22	-506.19	-499.71	-467.89	-421.88
IS27	53.53	49.01	45.35	45.89	44.26	61.37	80.29	101.01	118.29	146.49	184.50
1BF***	-24.46	261.54	484.49	617.63	799.53	904.71	1007.99	1137.77	1232.23	1347.77	1462.39
1BA***	-69.26	302.10	581.00	744.12	958.92	1074.59	1192.49	1340.37	1448.74	1579.28	1711.46
1UAF**	137.52	317.44	461.15	543.64	661.19	731.60	808.58	914.31	996.76	1094.70	1192.52
1UAA**	140.13	311.65	449.24	533.03	643.84	703.73	772.16	875.56	954.26	1049.71	1145.17
1RF*	14.42	229.87	402.96	514.20	655.89	745.95	831.44	940.53	1023.90	1125.26	1226.07
1RA*	40.07	240.36	397.26	495.09	625.02	696.77	766.28	865.36	938.98	1034.78	1130.75

Note: Strain gages IS16-IS18, 1AF, 1AA, F01-F10 and L01-L05 were removed. Successive * signs on the gage number represent the progressive distances between the notch tip and strain gage (see appendix C for details).

Table E-16. Strain survey raw data (run3), reference, and phase 1 repairs (60,000 cycles for R-BE, U-BE, and U-A2 repairs and 40,000 cycles for U-A1 repair)

Load Step	0	1	2	3	4	5	6	7	8	9	10
Pressure	0.02	0.72	1.29	2.02	2.69	3.45	4.05	4.81	5.31	5.98	6.74
Frame-1	35.91	123.86	221.48	309.14	444.43	579.58	639.85	745.91	920.84	1071.91	1100.40
Frame-2	36.91	128.18	242.90	321.23	437.31	564.83	664.82	770.66	890.80	1017.70	1098.67
Frame-3	35.37	132.93	276.20	368.01	454.16	534.73	663.54	764.33	874.20	1014.01	1047.47
Frame-4	-41.74	75.40	208.49	301.11	427.90	545.74	665.29	793.23	876.93	1045.21	1065.19
Frame-5	7.31	104.71	201.37	360.65	475.01	554.28	644.72	745.49	926.26	1025.11	1122.36
Frame-6	19.28	140.48	199.39	403.60	485.15	566.58	653.70	796.85	868.85	1005.35	1084.63
Frame-7	62.98	90.67	248.39	331.36	443.27	544.10	645.92	776.57	895.24	1047.08	1094.90
Frame-8	25.56	52.92	227.69	356.34	474.01	574.75	667.32	806.45	891.31	1037.59	1083.22
Frame-9	40.16	38.06	277.32	359.86	446.07	544.24	645.82	775.43	929.33	1071.96	1086.14
Frame-10	-9.14	120.37	237.75	342.68	444.78	526.07	685.95	770.11	929.67	1084.11	1174.74
Frame-11	21.39	65.02	308.87	307.23	416.42	487.37	698.52	771.34	859.93	1102.65	1115.40
Frame-12	20.68	93.41	301.23	373.75	506.15	549.34	694.04	831.96	947.62	1049.74	1100.33
Hoop-1	27.86	742.38	1344.59	2129.71	2828.75	3687.13	4079.22	4915.73	5780.86	6515.40	7083.78
Hoop-2	9.37	635.43	1683.80	1964.47	2702.24	3507.81	4252.27	5086.34	5671.31	6442.34	7103.16
Hoop-3	48.98	662.48	1570.62	2168.19	2829.87	3524.56	4262.86	5146.82	5585.08	6500.16	7040.80
Hoop-4	35.92	660.80	1567.39	2124.90	2897.78	3555.95	4301.07	5138.99	5733.04	6510.58	7138.05
Hoop-5	210.38	661.60	1533.58	2191.35	2981.38	3611.09	4114.77	4976.32	5729.58	6457.68	7080.42
Hoop-6	97.66	739.33	1526.97	2095.56	2776.33	3639.19	4430.69	4819.45	5543.21	6438.34	7108.12
Hoop-7	72.70	614.27	1338.28	2070.96	2833.21	3402.19	4160.37	5079.57	5696.26	6479.20	7057.27
Hoop-8	75.18	680.81	1447.26	2125.35	2826.05	3592.57	4147.59	5016.08	5694.24	6431.93	7064.76
Hoop-9	20.92	693.95	1455.22	2109.81	2836.90	3547.97	4243.04	5135.21	5635.49	6503.09	7093.36
Hoop-10	55.66	750.54	1531.02	2159.62	2838.72	3530.39	4327.08	5068.31	5673.88	6572.10	7167.20
Hoop-11	41.69	741.12	1471.65	2076.35	2795.92	3580.87	4220.98	4965.86	5730.10	6551.67	7093.25
Hoop-12	43.14	779.86	1365.88	1992.98	2669.87	3674.36	3936.73	4846.44	5741.03	6382.04	7078.58
Hoop-13	72.98	723.90	1418.99	2186.42	2910.70	3408.37	4110.97	4930.27	5741.68	6532.29	7078.81
Hoop-14	-6.02	771.90	1542.79	2100.03	2790.10	3678.47	4244.04	5000.10	5689.52	6446.15	7075.30
Long-1	69.81	531.12	1364.05	1899.61	2820.88	3469.64	3929.36	4569.03	5374.83	5964.29	6785.97
Long-2	7.86	504.19	1231.12	1881.57	2456.14	3179.26	4092.51	4509.78	5067.70	6107.12	6542.90
Long-3	40.72	926.30	1166.15	2052.82	2524.87	3280.35	4136.30	4568.42	5528.44	5970.70	6833.39
Long-4	37.31	699.43	1180.86	1866.13	2843.66	3470.84	3829.41	4630.29	5207.73	5770.12	6686.51
Long-5	5.35	673.10	1068.45	2108.40	2395.08	2963.53	3969.86	4432.90	5195.86	6139.11	6670.24
Long-6	6.67	499.41	1320.53	2042.23	2567.02	3429.22	4144.82	4842.82	5531.51	5845.50	6726.20
Long-7	75.80	807.12	1493.29	1987.07	2593.79	3478.53	4018.84	4791.11	5101.71	6270.96	6627.31
Long-8	4.08	618.05	1259.34	1906.42	2877.16	3649.23	3723.37	4316.36	5588.99	5687.95	6476.57

Table E-16. Strain survey raw data (run3), reference, and phase 1 repairs (60,000 cycles for R-BE, U-BE, and U-A2 repairs and 40,000 cycles for U-A1 repair) (continued)

S10	16.06	218.42	358.18	519.70	656.32	760.92	826.42	966.01	1038.02	1152.54	1273.01
S11	-73.64	190.75	376.08	567.06	724.56	831.50	899.51	1051.27	1123.39	1246.07	1376.65
S12	15.91	104.98	189.44	273.63	361.03	432.64	490.07	588.13	643.79	728.18	804.84
S13	51.18	237.19	369.75	473.80	569.78	645.92	711.44	806.69	865.09	944.34	1014.72
S14	17.10	223.06	372.38	494.09	604.37	693.28	770.09	880.81	946.74	1038.52	1116.85
S15	8.48	273.92	467.95	612.22	741.23	839.79	919.75	1039.51	1104.20	1199.09	1284.40
S16	48.27	-108.83	-222.99	-347.76	-441.52	-518.26	-560.29	-636.88	-686.58	-747.91	-805.77
S17	17.48	-228.76	-405.98	-635.30	-810.34	-932.33	-998.66	-1153.36	-1239.48	-1375.65	-1532.99
S18	37.50	-246.19	-447.45	-640.52	-780.59	-871.97	-924.57	-1008.07	-1051.37	-1103.90	-1147.81
S23	187.34	217.81	249.96	296.67	358.00	406.23	449.73	533.14	574.43	639.91	704.67
S24	170.08	423.53	578.19	691.25	799.88	872.46	934.23	1037.22	1085.26	1158.24	1224.97
S27	-425.08	-865.92	-1118.96	-1490.86	-1755.58	-1959.80	-2052.44	-2291.96	-2420.93	-2558.79	-2667.81
IS10	-25.73	-107.40	-148.22	-206.74	-238.63	-249.55	-245.13	-241.76	-231.90	-213.82	-195.72
IS11	56.66	-94.16	-177.08	-257.94	-294.11	-302.71	-301.89	-295.62	-286.26	-265.78	-234.91
IS12	-9.58	-15.16	25.30	19.34	46.13	82.48	124.81	175.99	214.48	268.84	312.46
IS13	-18.57	-136.41	-157.93	-190.02	-181.41	-156.90	-126.89	-81.02	-49.99	-0.97	40.26
IS14	2.01	-134.60	-162.77	-219.45	-225.78	-210.97	-183.22	-146.98	-120.61	-76.78	-41.62
IS15	0.79	-178.04	-254.91	-328.48	-351.27	-346.06	-324.27	-293.97	-267.69	-222.39	-185.42
IS23	-242.37	-239.16	-202.06	-210.88	-192.15	-173.92	-154.33	-120.86	-102.97	-60.41	-10.24
IS24	-215.22	-386.97	-436.16	-506.18	-527.30	-532.21	-525.53	-510.14	-501.78	-468.48	-430.26
IS27	53.00	45.15	52.08	37.35	43.71	52.82	70.26	98.48	114.27	144.49	175.97
1BF***	25.31	258.79	464.92	640.88	799.63	921.87	1012.41	1156.42	1236.71	1352.31	1451.27
1BA***	-30.36	280.91	527.33	756.12	950.10	1092.85	1189.59	1354.87	1444.81	1576.19	1698.18
1UAF**	159.32	305.19	424.47	549.05	659.66	748.30	810.29	929.26	998.28	1096.70	1189.18
1UAA**	164.93	309.22	421.59	539.58	644.50	727.71	781.40	900.42	962.08	1058.46	1152.57
1RF*	29.55	215.98	362.99	520.92	650.38	758.96	823.38	943.35	1019.52	1119.81	1218.56
1RA*	54.84	229.23	355.04	502.18	620.68	713.75	764.69	873.27	936.43	1026.60	1126.14

Note: Strain gages IS16-IS18, 1AF, 1AA, F01-F10 and L01-L05 were removed. Successive * signs on the gage number represent the progressive distances between the notch tip and strain gage (see appendix C for details).

Table E-17. Strain survey raw data (run1) and phase 2 repairs (baseline for D-BE and D-A2 repairs)

Load Step	0	1	2	3	4	5	6	7	8	9	10
Pressure	-0.01	0.64	1.38	2.11	2.59	3.31	4.03	4.75	5.28	5.93	6.68
Frame-1	-0.60	114.16	212.09	334.38	454.96	566.92	674.18	813.33	912.12	1017.16	1184.56
Frame-2	-4.87	123.46	204.56	288.64	466.91	607.79	680.49	803.10	908.76	1047.59	1153.06
Frame-3	-44.22	144.68	176.98	303.42	466.00	589.45	676.60	791.35	922.30	1030.13	1127.82
Frame-4	6.61	109.99	223.26	333.15	474.04	573.43	678.26	784.79	927.93	1049.52	1147.74
Frame-5	3.08	108.85	242.72	324.36	453.53	621.33	685.45	789.20	900.52	1052.60	1148.92
Frame-6	-16.87	136.23	211.90	328.41	448.16	570.72	678.46	792.92	914.84	1030.42	1137.88
Frame-7	-4.56	127.70	228.99	365.77	465.47	569.79	667.37	790.12	914.13	1032.32	1149.78
Frame-8	-10.42	149.83	237.85	334.84	479.31	575.73	674.01	792.11	941.78	1021.08	1124.49
Frame-9	-19.01	154.19	273.07	319.87	486.96	561.49	671.51	788.78	934.04	1021.43	1123.01
Frame-10	-10.72	94.50	228.71	368.41	475.21	558.23	685.61	791.49	931.06	1035.41	1125.90
Frame-11	18.24	215.52	298.27	228.30	523.49	524.73	632.02	831.32	950.25	1025.51	1095.80
Frame-12	-50.75	39.18	319.89	360.28	526.73	527.30	689.39	787.81	912.10	1022.06	1143.22
Hoop-1	77.24	895.39	1359.65	2041.87	2888.45	3365.45	4272.71	5058.12	5795.78	6402.19	7203.91
Hoop-2	109.45	596.16	1524.65	2269.14	3045.08	3490.52	4321.02	5081.39	5470.86	6339.13	7146.01
Hoop-3	3.03	532.55	1300.40	2321.00	2718.48	3409.18	4366.77	4978.64	5637.29	6418.03	7147.36
Hoop-4	-14.23	770.73	1451.97	2237.08	2750.76	3491.96	4233.59	5056.63	5755.55	6406.56	7162.37
Hoop-5	17.66	584.08	1474.00	2265.33	2987.58	3332.75	4280.61	5096.88	5590.75	6285.32	7085.41
Hoop-6	88.16	675.33	1371.75	2279.96	2797.26	3732.50	4276.20	4917.99	5836.33	6427.65	6916.28
Hoop-7	591.61	849.24	1560.66	2057.85	2852.89	3671.57	4285.12	5014.50	5736.17	6471.48	7216.95
Hoop-8	50.24	809.19	1640.94	2268.23	2888.68	3581.87	4296.95	5070.41	5668.74	6419.67	7202.49
Hoop-9	-39.41	703.69	965.65	2071.02	2875.28	3521.39	4305.70	4958.99	5793.55	6395.96	7148.23
Hoop-10	-33.69	593.71	1553.32	2255.08	2891.54	3645.06	4368.37	4970.83	5779.45	6402.60	7163.52
Hoop-11	155.52	619.48	1471.05	2369.56	2782.93	3549.40	4279.64	5035.24	5705.67	6435.26	7042.51
Hoop-12	-1.63	620.55	1251.71	2081.00	3019.84	3325.44	4198.59	5100.85	5843.03	6235.33	7030.46
Hoop-13	36.82	695.13	1565.39	2252.66	2742.90	3605.92	4329.97	5024.78	5756.15	6406.43	7059.39
Hoop-14	-41.07	780.95	1529.44	2197.06	2799.07	3701.75	4288.86	4986.06	5697.93	6467.87	7108.41
Long-1	227.38	981.26	1348.26	2078.05	2571.58	3384.56	3994.76	4713.02	5255.04	6076.38	6683.73
Long-2	-195.03	384.51	1424.71	2213.90	2736.74	3401.72	3850.56	4546.59	5266.08	6054.84	6586.97
Long-3	80.06	870.87	1489.57	2039.47	2773.43	3333.34	4113.05	4665.51	5172.78	5859.14	6528.86
Long-4	54.44	535.03	1247.84	2059.46	2648.14	3189.17	3725.10	4618.64	5519.89	5919.20	6674.18
Long-5	-411.79	589.84	1335.09	2152.24	2445.03	3370.89	4047.49	4428.91	5375.02	6109.94	6532.04
Long-6	74.12	451.77	1213.14	1911.44	2702.31	3209.84	3930.27	4708.68	5363.36	6020.86	6577.13
Long-7	263.15	644.26	1568.08	2052.65	2462.47	3217.56	3932.14	4458.38	5414.71	5828.34	6557.10
Long-8	108.01	835.78	1482.45	2012.25	2732.77	3834.08	4102.20	4944.00	5003.52	6014.18	7290.40

Table E-17. Strain survey raw data (run1) and phase 2 repairs (baseline for D-BE and D-A2 repairs) (continued)

S19	3.48	212.60	415.85	552.03	580.16	687.87	786.01	882.80	955.43	1029.59	1108.41
S20	38.13	175.46	342.70	469.33	498.09	596.54	695.61	791.02	863.14	938.38	1018.89
S21	-0.60	235.88	481.61	649.70	709.09	829.36	945.09	1055.17	1136.51	1216.62	1302.50
S22	14.78	144.84	315.00	444.88	495.77	591.31	698.06	796.21	869.82	943.35	1021.91
S25	-59.67	-203.15	-379.92	-492.73	-443.80	-542.78	-613.61	-680.42	-721.48	-763.00	-799.99
S26	-272.87	-633.05	-1124.49	-1494.26	-1422.79	-1711.75	-1966.13	-2228.11	-2404.20	-2601.58	-2790.89
IS19	-26.16	-140.80	-201.53	-203.16	-156.73	-146.97	-105.94	-62.97	-14.91	30.06	87.20
IS20	-78.90	-106.97	-116.36	-95.72	-52.46	-25.86	31.15	83.46	144.28	200.19	271.19
IS21	-100.06	-266.13	-405.28	-473.80	-466.73	-505.07	-506.55	-506.42	-493.37	-478.28	-452.63
IS22	-91.73	-142.74	-205.86	-219.83	-198.60	-217.15	-208.01	-201.50	-188.44	-172.81	-147.62
IS25	-26.28	25.71	90.51	143.00	170.27	211.86	255.85	294.95	329.43	356.62	387.61
IS26	-24.05	45.91	144.62	223.31	254.82	315.73	389.76	457.37	512.02	564.79	622.46
2AF	35.35	189.96	393.86	557.47	569.41	706.41	838.70	966.78	1065.50	1165.72	1271.91
2AA	55.98	146.52	272.79	363.89	367.75	454.27	540.46	623.31	688.89	752.04	824.63
2BF	126.70	372.04	701.17	938.99	916.28	1116.90	1303.50	1486.77	1617.94	1755.48	1894.65
2BA	86.12	333.53	662.87	895.08	863.99	1061.32	1243.00	1417.15	1542.81	1675.20	1807.75
F01	87.60	69.48	-23.36	-64.70	693.68	665.89	704.85	711.99	800.65	801.11	798.01
F04	141.87	209.71	418.63	532.22	-15.06	137.38	176.20	280.63	310.31	407.91	498.73
F06	-91.54	-21.61	47.56	119.48	-87.14	42.44	48.55	138.42	173.23	241.68	324.77
F07	-421.62	-424.02	-534.17	-541.64	118.51	102.00	121.62	132.37	225.76	210.25	226.37
F10	-72.99	7.25	263.14	379.13	-181.07	-24.97	19.89	133.71	174.61	259.95	355.85
L02	76.03	91.14	119.30	136.24	115.43	151.00	173.24	204.38	226.85	255.73	282.86
L03	789.77	800.45	814.05	825.77	791.92	813.66	815.83	825.95	838.60	856.55	873.64

Note: Strain gages F02, F03, F05, F08, F09, L01, L04, and L05 were removed.

Table E-18. Strain survey raw data (run2) and phase 2 repairs (baseline for D-BE and D-A2 repairs)

Load Step	0	1	2	3	4	5	6	7	8	9	10
Pressure	0.01	0.62	1.39	1.96	2.59	3.25	3.98	4.75	5.35	6.07	6.62
Frame-1	-14.44	85.82	213.65	334.37	457.48	566.79	675.54	786.51	902.14	1035.71	1112.25
Frame-2	10.40	117.72	211.25	342.88	487.21	552.99	685.57	779.88	901.38	1020.88	1116.86
Frame-3	-37.42	123.63	208.53	373.98	494.50	559.44	676.71	789.58	900.68	1017.55	1135.38
Frame-4	2.82	86.35	215.95	311.18	449.79	573.20	683.38	797.17	892.41	1018.79	1127.94
Frame-5	27.45	102.73	232.28	361.81	442.73	573.77	690.84	765.83	892.68	1012.04	1131.97
Frame-6	-4.24	120.45	222.31	347.29	454.47	569.31	679.81	783.71	894.76	1009.93	1136.05
Frame-7	10.05	122.74	203.23	339.53	449.58	563.85	689.18	782.58	908.39	1030.42	1134.56
Frame-8	-2.03	131.32	232.64	363.67	471.07	567.33	680.99	787.70	903.21	1042.70	1126.57
Frame-9	-8.11	129.37	203.34	360.04	472.18	562.67	670.21	797.93	892.37	1031.87	1116.91
Frame-10	28.48	97.61	257.09	355.80	511.86	565.33	666.06	793.69	881.17	1018.18	1128.85
Frame-11	-92.83	74.19	342.21	302.78	426.42	597.79	688.41	770.51	901.03	1057.41	1124.67
Frame-12	-28.36	96.23	258.64	388.83	475.70	574.27	676.33	786.24	905.66	1064.97	1111.09
Hoop-1	17.40	668.57	1535.75	2251.85	3042.61	3334.28	4492.19	4954.73	5748.62	6481.35	7134.99
Hoop-2	12.86	735.65	1333.35	2229.33	2483.36	3508.06	4151.05	4997.30	5563.89	6449.41	7052.98
Hoop-3	32.83	681.52	1360.15	2036.55	2774.58	3512.26	4478.98	5075.07	5749.48	6266.63	7128.08
Hoop-4	20.28	761.56	1530.25	2263.88	2850.67	3586.07	4199.07	5078.43	5777.35	6413.19	7037.01
Hoop-5	66.21	776.40	1537.09	1986.22	2825.78	3425.90	4384.89	4909.89	5743.57	6500.43	7132.16
Hoop-6	59.00	660.68	1408.35	2235.75	2786.32	3389.42	4261.61	5023.74	5703.24	6501.75	7195.24
Hoop-7	446.93	743.68	1494.67	2153.97	2920.81	3605.08	4308.36	5041.32	5698.63	6433.30	7118.63
Hoop-8	42.95	692.29	1356.23	2180.90	2793.55	3457.83	4253.60	5040.72	5800.66	6449.49	7157.99
Hoop-9	0.07	662.27	1502.14	2153.78	2796.03	3564.46	4309.72	5064.38	5702.59	6393.00	7095.46
Hoop-10	101.37	682.44	1709.55	2141.57	2782.85	3415.80	4267.50	5021.87	5724.92	6394.35	7159.25
Hoop-11	90.31	775.17	1246.24	2192.22	3000.07	3460.62	4347.11	4993.06	5834.90	6492.08	7116.11
Hoop-12	51.13	671.36	1473.49	2226.73	2663.04	3580.11	4279.06	5049.41	5610.75	6512.45	7058.87
Hoop-13	-21.68	673.05	1389.72	2194.37	2815.75	3445.01	4286.52	4936.52	5778.66	6421.69	7073.32
Hoop-14	32.31	883.53	1375.19	2145.91	2813.47	3510.94	4267.27	5029.59	5727.85	6373.11	7203.12
Long-1	-74.36	500.06	1489.69	1952.68	2768.36	3242.83	4117.55	4562.62	5257.97	5940.34	6631.07
Long-2	22.89	833.06	1198.14	2106.32	2643.73	3373.39	4036.86	4567.65	5292.11	5924.58	6586.87
Long-3	41.70	443.42	1212.10	2073.51	2717.40	3203.67	4115.44	4781.77	5462.49	6096.35	6746.69
Long-4	-195.48	796.41	1394.88	1975.71	2532.33	3150.84	3814.83	4872.56	5250.93	5875.41	6903.07
Long-5	-461.65	577.24	1325.76	2154.37	2681.59	3274.64	3915.05	4840.44	5311.99	6003.61	6580.23
Long-6	-89.85	799.58	1580.11	1941.97	2566.35	3261.80	4021.33	4569.42	5312.35	6025.56	6760.94
Long-7	441.83	605.93	1282.76	2125.90	2818.17	3455.92	4291.31	4417.10	5512.55	6244.61	6765.68
Long-8	293.64	654.47	1474.00	2214.41	2684.52	2938.40	3687.00	4839.90	5459.31	6118.84	6979.76

Table E-18. Strain survey raw data (run2) and phase 2 repairs (baseline for D-BE and D-A2 repairs) (continued)

S19	-557.38	35.46	300.90	433.40	557.99	670.23	776.81	874.68	952.89	1035.62	1105.27
S20	-99.65	81.74	270.56	379.50	487.49	591.70	694.66	788.49	864.91	946.10	1015.24
S21	-292.02	110.83	397.20	555.72	695.71	825.27	942.87	1050.82	1135.38	1224.07	1298.27
S22	-74.99	94.07	266.44	378.22	488.64	596.91	700.05	794.41	870.19	951.56	1019.12
S25	-57.88	-206.92	-383.16	-471.33	-560.39	-636.77	-718.31	-779.94	-824.19	-860.18	-885.99
S26	-6.05	-458.66	-949.32	-1246.30	-1545.47	-1828.16	-2094.78	-2347.78	-2553.78	-2751.96	-2917.80
IS19	465.86	-6.75	-129.71	-150.93	-160.37	-140.76	-102.68	-61.88	-15.64	39.49	89.18
IS20	5.82	-46.30	-86.67	-74.73	-58.26	-18.25	34.59	91.43	146.45	205.26	264.62
IS21	131.41	-173.97	-357.07	-432.65	-488.71	-515.79	-522.68	-522.19	-508.96	-486.07	-461.79
IS22	-53.07	-120.19	-188.07	-218.74	-227.11	-232.69	-227.24	-218.38	-203.68	-181.70	-159.03
IS25	-41.46	4.32	74.19	121.39	164.68	210.38	255.94	294.41	327.65	360.77	387.85
IS26	-54.47	30.59	125.68	190.71	253.03	320.91	393.22	457.56	513.11	572.25	621.79
2AF	-107.48	92.28	302.02	435.80	566.75	704.75	846.65	973.65	1078.88	1185.78	1274.36
2AA	12.37	99.10	223.65	298.27	370.24	453.82	547.09	627.90	695.70	767.07	823.24
2BF	-123.49	204.41	537.48	734.24	930.00	1128.56	1325.12	1498.94	1643.74	1788.18	1907.35
2BA	-183.97	145.04	482.89	678.14	872.44	1066.27	1256.46	1423.34	1561.17	1698.66	1814.12
F01	712.35	654.21	593.24	694.40	733.09	730.95	746.00	764.57	788.68	825.76	871.08
F04	-473.29	-318.14	-144.11	-127.97	-35.06	43.07	110.89	230.04	282.58	375.36	432.31
F06	-388.29	-289.12	-191.10	-157.97	-87.06	-28.63	37.08	130.13	178.44	236.20	287.18
F07	187.76	129.04	52.25	135.90	164.36	160.34	182.30	192.78	229.20	249.55	287.28
F10	-660.15	-468.33	-300.12	-298.34	-201.24	-107.55	-33.85	94.78	143.39	239.60	297.89
L02	57.79	75.45	96.46	109.17	126.12	142.12	174.71	205.67	235.32	260.52	282.99
L03	746.56	770.76	773.33	787.09	800.00	798.54	813.23	825.77	841.20	853.76	872.72

Note: Strain gages F02, F03, F05, F08, F09, L01, L04, and L05 were removed.

Table E-19. Strain survey raw data (run3) and phase 2 repairs (baseline for D-BE and D-A2 repairs)

Load Step	0	1	2	3	4	5	6	7	8	9	10
Pressure	-0.01	0.69	1.40	1.97	2.67	3.41	3.97	4.70	5.29	6.05	6.67
Frame-1	-1.65	98.03	232.33	356.97	471.09	552.72	675.81	795.65	919.30	1030.05	1129.32
Frame-2	9.31	78.14	181.88	339.03	450.33	531.51	698.52	787.72	905.87	1008.81	1124.02
Frame-3	14.38	155.80	236.81	375.26	434.52	568.71	679.71	787.21	913.75	996.52	1137.50
Frame-4	31.08	138.41	257.87	323.89	415.23	550.28	690.03	788.48	912.25	1028.34	1118.54
Frame-5	30.34	103.84	198.31	322.58	416.99	563.10	658.70	782.27	919.06	1018.09	1126.10
Frame-6	7.33	101.15	227.16	335.86	444.16	550.20	675.03	785.28	905.63	1025.71	1132.99
Frame-7	4.56	117.83	219.21	333.83	437.66	556.44	676.86	784.28	894.99	1015.52	1131.23
Frame-8	6.53	112.85	214.76	351.35	445.93	574.04	680.29	782.43	891.85	1018.87	1131.66
Frame-9	-15.91	153.13	227.63	383.04	451.72	562.61	676.26	772.54	905.48	997.80	1128.66
Frame-10	-60.40	160.74	224.19	383.98	447.03	577.66	683.75	779.16	894.21	1000.71	1141.99
Frame-11	48.21	163.70	267.66	414.05	421.86	541.29	705.99	814.39	940.10	982.42	1143.93
Frame-12	-3.21	85.30	215.48	332.61	484.63	571.62	691.38	781.19	949.82	1034.47	1117.28
Hoop-1	24.65	813.68	1388.81	2110.59	2663.55	3515.63	4329.37	4981.93	5499.98	6442.09	7074.42
Hoop-2	41.49	775.01	1537.32	2115.05	2848.30	3629.70	4333.97	5061.71	5565.55	6609.28	7204.33
Hoop-3	66.15	567.56	1453.08	2224.35	2879.76	3549.07	4286.55	5059.29	5654.75	6375.95	7116.85
Hoop-4	22.10	658.00	1412.14	2111.49	2707.16	3629.67	4306.69	4945.80	5582.82	6341.15	7070.83
Hoop-5	-7.51	634.36	1567.65	2203.97	2716.12	3483.42	4284.63	5091.48	5766.86	6357.24	7136.84
Hoop-6	75.42	658.86	1446.65	2173.98	2933.99	3615.46	4358.68	4808.59	5637.48	6405.77	7192.70
Hoop-7	416.58	849.16	1412.43	2132.73	2842.16	3590.78	4190.79	5059.20	5657.42	6374.95	7108.98
Hoop-8	50.25	677.70	1465.52	2217.38	2771.93	3487.01	4348.03	4946.36	5632.26	6413.01	7113.50
Hoop-9	79.04	692.78	1430.21	2051.48	2837.59	3499.85	4257.24	5046.93	5705.61	6445.05	7089.37
Hoop-10	12.51	627.35	1455.29	2129.13	2868.43	3687.71	4279.51	4945.95	5687.03	6403.24	7211.85
Hoop-11	166.42	771.55	1452.64	2177.73	2808.30	3549.40	4352.12	5049.73	5707.48	6403.29	7189.69
Hoop-12	31.12	696.82	1342.39	2030.27	2706.96	3652.88	4351.40	5064.47	5377.35	6272.33	6868.98
Hoop-13	7.57	534.10	1484.64	2150.49	2830.66	3671.74	4249.52	5010.15	5697.64	6407.07	7270.08
Hoop-14	-19.06	626.70	1397.06	2278.01	2813.75	3584.33	4266.85	4934.68	5631.88	6380.44	7209.74
Long-1	249.36	444.40	1386.25	2100.56	2617.47	3383.73	4022.30	4658.76	5384.34	6149.13	6771.41
Long-2	22.39	749.56	1569.00	1975.77	2666.05	3405.07	3999.15	4800.64	5415.76	6091.70	6651.82
Long-3	-446.11	432.87	1192.69	1928.58	2778.54	3192.72	3940.14	4802.15	5245.62	5980.21	6537.18
Long-4	10.12	849.36	1432.04	1915.50	2522.36	3520.52	4235.10	4367.38	5273.39	6259.58	6446.85
Long-5	78.73	527.11	1483.00	2040.91	2525.00	3395.11	3900.07	4664.01	5308.74	5876.95	6707.47
Long-6	-294.96	753.92	1548.26	1967.81	2685.94	3200.82	4036.61	4577.04	5386.29	6148.52	6711.75
Long-7	196.69	568.68	1425.47	1777.92	2600.16	3029.34	4196.08	4422.44	5439.35	6007.83	6458.33
Long-8	111.26	726.26	1137.97	2156.58	2500.93	3636.95	4248.53	5118.70	4951.21	5966.08	6628.19

Table E-19. Strain survey raw data (run3) and phase 2 repairs (baseline for D-BE and D-A2 repairs) (continued)

S19	-534.92	102.57	309.86	455.00	577.62	692.99	782.84	872.43	951.00	1037.17	1110.50
S20	-114.43	114.03	267.21	392.48	504.92	610.01	696.76	784.39	859.53	946.78	1020.80
S21	-281.12	177.49	408.82	583.36	722.47	852.16	951.85	1048.76	1131.68	1223.65	1301.90
S22	-62.17	127.67	274.15	399.82	511.58	620.64	706.08	793.06	867.57	953.46	1025.44
S25	18.35	-179.16	-331.75	-433.62	-536.11	-623.21	-694.82	-752.73	-796.99	-841.48	-866.09
S26	44.46	-520.35	-936.40	-1260.64	-1583.46	-1876.71	-2135.07	-2364.77	-2582.85	-2792.33	-2962.47
IS19	451.36	-56.26	-139.47	-161.60	-162.54	-138.40	-110.83	-67.14	-27.42	31.15	91.36
IS20	16.86	-77.62	-96.06	-86.47	-59.34	-22.78	15.59	73.68	119.83	188.42	256.32
IS21	116.00	-241.61	-379.65	-459.02	-509.50	-529.93	-540.75	-534.46	-525.94	-498.21	-464.91
IS22	-50.17	-159.59	-207.81	-239.38	-247.95	-245.93	-244.46	-230.51	-221.26	-193.50	-161.94
IS25	-36.27	13.08	73.49	126.24	172.42	219.05	255.18	294.06	323.74	358.58	391.09
IS26	-44.08	47.36	128.39	200.87	266.48	337.49	393.00	454.41	505.23	570.61	626.77
2AF	-95.18	125.93	300.51	448.01	591.82	731.68	850.73	971.21	1071.17	1187.77	1282.81
2AA	26.45	125.78	228.15	312.24	396.23	479.52	551.85	627.56	689.50	770.20	832.50
2BF	-91.33	282.76	553.72	764.97	974.97	1172.70	1340.06	1503.33	1647.39	1801.99	1927.89
2BA	-166.02	218.99	492.29	702.73	908.54	1103.73	1265.97	1422.83	1560.65	1711.39	1831.21
F01	697.12	576.92	594.93	684.66	670.65	736.21	737.04	755.43	787.15	794.40	863.19
F04	-496.43	-217.56	-158.76	-104.95	-1.29	63.62	138.10	212.88	312.51	406.13	442.22
F06	-390.97	-256.46	-189.62	-136.78	-47.94	-5.83	64.63	132.74	203.57	271.37	292.42
F07	204.56	38.75	59.57	134.92	124.67	167.72	180.97	200.24	224.06	220.39	282.60
F10	-665.09	-346.06	-309.45	-280.16	-155.38	-90.75	-10.73	71.06	183.29	294.92	315.70
L02	58.71	86.70	102.33	113.01	129.24	149.85	182.24	210.80	238.42	267.89	282.46
L03	737.44	770.17	775.41	778.75	788.02	797.05	814.26	823.27	837.77	853.94	863.70

Note: Strain gages F02, F03, F05, F08, F09, L01, L04, and L05 were removed.

Table E-20. Strain survey raw data (run1) and phase 2 repairs (20,000 cycles for D-BE and D-A2 repairs)

Load Step	0	1	2	3	4	5	6	7	8	9	10
Pressure	-0.06	0.66	1.37	1.90	2.70	3.30	3.92	4.74	5.38	5.95	6.76
Frame-1	-13.41	70.40	214.33	337.43	457.00	576.32	667.94	800.75	899.51	1033.88	1114.27
Frame-2	-3.75	101.17	219.67	346.01	446.52	585.69	684.32	784.23	910.38	1018.97	1111.74
Frame-3	35.50	100.10	191.48	377.14	451.78	583.15	724.04	800.73	900.44	1057.52	1167.30
Frame-4	8.00	87.81	197.87	342.67	475.44	597.38	748.74	818.38	897.87	1017.15	1143.41
Frame-5	40.49	129.46	218.02	352.71	451.87	615.10	696.00	814.79	892.57	1020.53	1107.40
Frame-6	-2.08	82.16	239.27	347.68	452.65	580.01	708.66	791.55	900.84	1030.66	1138.00
Frame-7	1.46	95.02	232.90	355.26	446.18	583.32	712.31	797.99	891.19	1036.38	1129.82
Frame-8	6.86	80.97	248.46	353.77	422.77	574.40	728.40	784.46	909.24	1041.85	1143.45
Frame-9	-9.59	91.63	258.47	380.61	421.68	550.05	715.79	771.16	917.79	1049.11	1146.28
Frame-10	44.54	84.61	236.62	377.22	441.00	604.40	685.73	806.44	903.42	1075.57	1147.48
Frame-11	-36.28	119.51	284.77	359.84	365.46	504.69	756.11	697.85	822.34	1064.61	1138.67
Frame-12	-26.39	45.95	213.52	340.22	426.13	581.15	734.53	749.23	925.94	1053.71	1148.32
Hoop-1	19.90	730.87	1476.43	2196.76	2736.80	3561.27	4368.67	4926.89	5767.45	6551.62	7176.68
Hoop-2	-11.11	704.46	1421.96	2171.81	2715.21	3700.23	4255.05	5167.07	5640.11	6433.24	7087.35
Hoop-3	4.09	714.07	1413.67	2183.55	2851.02	3626.95	4335.41	5120.47	5836.44	6564.61	7296.72
Hoop-4	-26.35	751.19	1454.39	2106.86	2898.51	3575.38	4275.13	5066.82	5810.65	6597.93	7238.56
Hoop-5	-1.22	764.63	1393.99	2118.78	2898.59	3541.45	4352.55	5046.13	5758.84	6496.58	7218.63
Hoop-6	52.40	768.87	1405.27	2081.90	2918.28	3634.01	4471.10	5090.58	5550.80	6293.42	7238.97
Hoop-7	41.72	629.82	1355.69	2262.28	2799.87	3574.94	4336.71	5026.34	5731.41	6613.32	7131.05
Hoop-8	-12.59	738.83	1446.61	2081.58	2833.14	3613.53	4263.30	5022.16	5801.76	6430.44	7240.38
Hoop-9	-64.90	774.88	1273.85	2083.41	2932.33	3563.73	4217.38	4962.21	5696.92	6548.77	6984.90
Hoop-10	5.90	689.98	1416.84	2174.05	2744.53	3639.86	4477.27	5069.07	5709.50	6547.68	7420.28
Hoop-11	-0.09	559.70	1360.58	2161.62	2899.10	3636.21	4261.71	5049.93	5735.53	6488.65	7182.64
Hoop-12	3.83	744.04	1360.72	2073.93	2888.87	3696.16	4395.05	5108.13	5740.02	6359.64	7247.35
Hoop-13	22.69	614.99	1434.10	2275.32	2721.46	3635.31	4374.36	5076.47	5770.12	6575.78	7307.15
Hoop-14	6.31	659.34	1444.58	2200.63	2883.15	3668.05	4299.56	5055.46	5788.19	6479.20	7227.77
Long-1	24.71	528.26	1157.18	2187.41	2525.87	3232.20	3881.38	4834.54	5378.33	5904.57	6632.69
Long-2	12.89	622.71	1559.00	2209.38	2765.85	3285.90	4144.87	4800.92	5406.48	6113.05	6536.45
Long-3	12.22	768.67	1430.21	1955.52	2638.72	3200.55	3985.45	4761.16	5235.50	6114.70	6787.77
Long-4	-4.43	556.98	1418.60	1858.30	2658.62	3421.65	3926.73	4652.15	5273.16	5940.10	6608.01
Long-5	19.64	538.26	1059.01	2027.13	2356.15	3393.39	4001.57	4726.01	5351.05	6123.23	6627.90
Long-6	-3.93	451.89	1465.94	2140.63	2832.38	3313.17	4092.78	4695.25	5135.18	6103.02	6506.27
Long-7	4.81	821.07	1349.13	2053.80	2828.12	3374.30	3794.52	4624.24	5294.01	5831.54	6779.87
Long-8	56.23	812.27	1222.58	1920.92	2638.01	3324.59	4025.50	4608.74	5509.30	5996.79	6520.27

Table E-20. Strain survey raw data (run1) and phase 2 repairs (20,000 cycles for D-BE and D-A2 repairs) (continued)

S19	-1019.29	41.94	300.49	436.34	588.03	694.48	797.40	902.87	983.34	1062.03	1152.82
S20	-226.23	37.74	208.35	318.76	452.37	549.79	646.01	744.46	820.72	895.71	982.87
S21	-516.48	112.94	446.95	636.36	831.55	967.15	1089.15	1211.38	1305.07	1393.90	1498.65
S22	-61.84	52.69	200.77	303.09	417.92	511.16	598.34	687.01	757.17	826.96	907.14
S25	186.81	18.38	-145.67	-251.46	-380.16	-466.79	-543.37	-619.20	-670.33	-708.21	-745.58
S26	669.68	25.49	-402.73	-675.86	-1032.86	-1266.86	-1499.92	-1748.77	-1930.65	-2093.67	-2268.80
IS19	871.16	20.86	-100.28	-124.90	-145.51	-124.71	-100.63	-64.23	-24.59	27.38	87.13
IS20	124.37	29.79	8.41	18.91	29.23	67.33	110.67	165.45	220.84	286.53	360.99
IS21	453.75	-55.19	-305.35	-423.22	-537.56	-585.19	-619.29	-642.44	-648.73	-639.30	-622.55
IS22	28.46	-0.57	-68.07	-103.63	-151.50	-169.67	-180.56	-187.80	-183.48	-166.79	-144.27
IS25	-17.27	21.80	62.43	90.66	119.24	144.87	167.90	190.68	208.76	228.57	247.27
IS26	-30.48	41.11	101.08	151.95	210.42	266.97	322.39	381.59	432.73	487.79	552.98
2AF*	-208.08	30.76	190.92	311.69	458.50	582.10	698.71	821.59	919.88	1014.92	1118.01
2AA*	-7.20	23.51	189.19	316.89	471.07	596.72	716.85	841.42	939.87	1035.45	1139.58
2BF*	-380.09	65.85	381.83	596.96	864.61	1057.98	1248.99	1444.95	1594.15	1730.70	1888.14
2BA*	-383.09	64.91	408.15	641.19	927.21	1132.07	1335.10	1543.46	1698.07	1843.02	2007.20
F01											
F04	-991.51	-744.37	-617.86	-612.30	-433.76	-405.81	-336.42	-182.49	-109.27	-70.82	69.60
F06	-536.47	-369.66	-295.79	-279.63	-145.40	-116.43	-69.13	50.93	115.06	139.80	247.61
F07	1263.50	1040.82	1036.32	1115.54	1028.94	1094.71	1103.76	1054.40	1081.42	1118.18	1101.23
F10	-827.24	-597.04	-472.31	-492.41	-316.14	-289.53	-215.85	-74.40	3.22	35.62	175.68
L02	60.64	101.69	121.04	145.52	171.07	191.91	216.58	250.25	272.57	296.69	315.07
L03	12.90	42.26	37.25	44.31	49.51	57.14	66.24	79.43	92.09	107.52	117.55

Note: Strain gages F02, F03, F05, F08, F09, L01, L04 and L05 were removed and F01 showed faulty readings. Successive * signs on the gage number represent the progressive distances between the notch tip and strain gage (see appendix C for details).

Table E-21. Strain survey raw data (run2) and phase 2 repairs (20,000 cycles for D-BE and D-A2 repairs)

Load Step	0	1	2	3	4	5	6	7	8	9	10
Pressure	0.04	0.76	1.42	1.98	2.58	3.55	3.97	4.61	5.34	5.98	6.69
Frame-1	5.71	141.56	216.07	352.57	425.62	546.72	701.67	803.35	913.57	1006.18	1131.32
Frame-2	3.04	105.82	217.73	319.57	443.86	563.97	677.79	785.33	911.77	1005.10	1130.04
Frame-3	-32.12	83.14	202.87	339.17	469.54	522.75	665.37	803.52	926.44	1023.60	1117.80
Frame-4	-38.80	83.52	206.11	350.51	466.41	539.74	723.02	800.38	915.87	1045.30	1096.76
Frame-5	-17.11	104.71	211.92	343.50	459.81	513.69	706.63	806.47	904.85	1028.74	1116.05
Frame-6	22.16	105.55	219.58	360.37	464.07	530.22	683.15	797.90	914.92	1029.42	1128.56
Frame-7	-42.85	93.07	194.67	334.28	466.49	519.61	682.06	801.46	917.59	1007.37	1130.67
Frame-8	11.41	93.03	234.98	388.81	454.69	517.51	644.85	797.18	920.41	1020.07	1120.75
Frame-9	15.13	134.47	231.88	369.11	459.51	520.26	665.18	807.74	920.59	1009.00	1125.40
Frame-10	24.35	141.87	232.12	358.34	426.31	525.19	671.66	845.54	920.56	1025.83	1116.26
Frame-11	0.72	150.11	300.57	463.15	510.63	508.53	503.35	850.18	895.67	998.74	1136.63
Frame-12	5.52	129.53	264.95	336.90	517.88	474.97	639.50	787.38	910.32	1038.29	1141.11
Hoop-1	-1.86	632.99	1456.48	2124.19	2903.65	3628.40	4272.98	4904.14	5625.29	6487.61	7142.94
Hoop-2	3.20	586.45	1346.82	2161.08	3008.60	3714.48	4276.95	4935.27	5626.92	6629.57	6901.99
Hoop-3	18.11	736.93	1413.67	2232.64	2928.15	3551.53	4300.78	5093.15	5649.99	6471.22	7109.85
Hoop-4	-59.05	738.55	1332.66	2255.85	2956.64	3644.44	4406.36	5040.38	5637.37	6444.78	7142.99
Hoop-5	-29.98	690.99	1435.34	2142.15	2857.24	3510.93	4358.38	5012.77	5707.84	6492.48	7172.61
Hoop-6	-2.29	734.31	1489.14	2098.31	2867.23	3592.10	4216.31	5016.64	5500.85	6473.39	7157.65
Hoop-7	-36.93	608.43	1475.47	2162.16	2891.04	3603.54	4353.23	4991.38	5771.89	6561.00	7042.37
Hoop-8	-12.59	702.35	1432.16	2074.07	2869.34	3570.11	4307.08	5014.37	5708.63	6438.38	7079.14
Hoop-9	87.62	582.88	1426.53	2095.77	3077.40	3603.57	4240.71	5128.61	5752.47	6533.27	6942.93
Hoop-10	-1.21	665.10	1413.42	2191.61	2893.52	3396.75	4281.78	5070.34	5862.28	6447.03	7021.49
Hoop-11	52.45	701.01	1355.28	2108.86	2884.31	3584.03	4305.20	4986.01	5594.08	6462.11	7091.33
Hoop-12	-18.00	647.65	1448.17	2299.26	2917.68	3674.70	4460.54	4758.39	5719.90	6425.77	7122.94
Hoop-13	-13.87	717.36	1331.85	2004.51	2947.89	3533.28	4250.02	5010.15	5808.42	6481.35	7050.47
Hoop-14	-8.37	791.41	1452.07	2185.74	2882.86	3558.33	4306.89	5032.94	5606.44	6377.10	7080.29
Long-1	23.54	813.22	1307.46	2070.24	2590.66	3195.10	3930.27	4590.59	5204.83	5865.27	6628.40
Long-2	6.37	658.13	1217.60	2186.84	2526.13	3440.20	4147.38	4455.08	5353.60	5907.14	6855.73
Long-3	12.94	566.19	1173.15	2097.48	2606.12	3455.92	4080.85	4613.73	5469.26	5932.98	6594.71
Long-4	23.27	606.89	1420.29	1949.41	2522.81	3196.20	3803.09	4787.77	5236.46	5845.92	6479.04
Long-5	15.62	492.90	1422.64	2151.09	2730.75	3237.63	4128.58	4773.55	5212.75	5739.09	6782.01
Long-6	-2.42	505.92	1473.90	1893.19	2779.66	3392.21	3994.39	4535.52	5209.86	5931.45	6626.89
Long-7	8.34	514.80	1451.47	1936.54	2710.57	3112.60	3983.06	4558.50	5510.77	6163.35	6806.65
Long-8	73.43	711.50	1323.55	2054.11	2758.83	3401.83	3874.46	4766.75	5388.09	6040.48	6481.14

Table E-21. Strain survey raw data (run2) and phase 2 repairs (20,000 cycles for D-BE and D-A2 repairs) (continued)

S19	-640.20	106.05	325.91	468.37	585.42	729.19	806.06	895.20	986.14	1065.46	1146.73
S20	-144.87	68.98	226.45	346.49	452.37	579.51	651.08	735.26	819.08	895.99	972.21
S21	-393.05	179.26	474.61	674.72	833.05	1004.54	1099.60	1204.74	1310.51	1402.81	1491.14
S22	-65.63	83.72	215.22	326.87	424.41	533.94	603.57	681.13	758.69	831.83	897.22
S25	134.35	-12.67	-167.27	-280.89	-385.42	-503.05	-560.12	-624.52	-684.24	-721.18	-759.92
S26	550.06	-83.41	-488.77	-779.76	-1043.24	-1390.15	-1558.57	-1764.37	-1975.28	-2133.24	-2308.96
IS19	576.38	-26.58	-121.29	-145.37	-146.99	-146.07	-114.74	-82.53	-37.98	16.70	66.32
IS20	79.71	9.34	-9.42	1.27	25.11	51.18	96.03	146.72	208.60	276.58	340.39
IS21	308.83	-123.03	-344.71	-465.52	-545.83	-626.84	-644.80	-665.06	-672.73	-658.71	-648.19
IS22	5.24	-34.68	-93.48	-132.67	-161.69	-203.04	-204.49	-208.16	-205.22	-182.76	-166.06
IS25	1.54	27.79	65.28	95.11	121.17	146.17	165.48	185.10	204.73	225.40	239.36
IS26	-30.66	54.01	108.54	164.87	218.46	279.85	326.90	378.03	434.83	493.61	547.40
2AF*	-123.03	55.25	206.16	335.84	463.31	610.15	705.71	813.77	922.78	1018.91	1112.14
2AA*	-12.08	43.74	202.20	339.69	472.07	623.39	720.94	828.22	940.41	1036.35	1133.73
2BF*	-319.26	132.31	428.87	657.31	869.87	1132.67	1277.19	1443.06	1611.26	1752.49	1896.32
2BA*	-317.86	130.33	455.25	702.64	929.60	1209.28	1361.71	1536.26	1712.75	1862.45	2014.18
F01											
F04	-894.54	-707.82	-609.82	-579.05	-539.68	-290.95	-316.49	-232.25	-97.39	-78.00	85.15
F06	-463.71	-348.72	-284.23	-264.57	-218.69	-46.11	-52.41	8.44	116.16	136.31	260.23
F07	1187.07	1066.09	1043.92	1085.58	1126.95	981.78	1087.36	1104.60	1091.88	1120.00	1080.87
F10	-714.05	-536.26	-451.96	-455.51	-428.80	-166.45	-205.75	-127.36	7.96	26.73	190.31
L02	62.85	93.41	116.62	136.69	155.83	193.00	215.45	241.09	267.92	285.09	323.02
L03	20.52	28.70	33.35	36.88	43.75	56.94	68.47	80.01	90.21	101.02	126.11

Note: Strain gages F02, F03, F05, F08, F09, L01, L04 and L05 were removed and F01 showed faulty readings. Successive * signs on the gage number represent the progressive distances between the notch tip and strain gage (see appendix C for details).

Table E-22. Strain survey raw data (run3) and phase 2 repairs (20,000 cycles for D-BE and D-A2 repairs)

Load Step	0	1	2	3	4	5	6	7	8	9	10
Pressure	-0.05	0.77	1.30	2.13	2.62	3.42	3.96	4.65	5.22	6.12	6.63
Frame-1	-17.17	111.27	232.01	335.18	432.66	575.57	674.59	811.83	916.94	1034.50	1146.54
Frame-2	-10.05	107.04	220.85	346.77	445.94	566.14	678.42	800.30	903.53	1013.61	1145.27
Frame-3	24.66	121.07	234.97	316.37	471.69	567.42	697.27	751.58	913.79	1025.63	1123.36
Frame-4	-30.25	114.10	242.46	320.39	481.25	540.69	690.47	820.53	942.07	990.02	1152.92
Frame-5	10.81	100.61	212.51	304.95	433.66	547.04	676.22	789.99	925.76	1009.47	1153.87
Frame-6	10.56	90.34	232.99	308.90	454.73	547.74	693.88	793.79	923.32	1004.83	1137.50
Frame-7	-8.97	74.98	238.18	308.63	443.06	556.48	688.31	781.37	919.59	999.95	1140.10
Frame-8	-16.24	86.52	265.56	313.52	442.02	561.47	680.77	762.69	931.82	1034.16	1130.54
Frame-9	-33.51	85.01	258.97	291.63	464.67	544.25	698.92	763.30	907.40	1010.75	1124.14
Frame-10	-18.62	109.26	216.24	324.93	451.78	526.04	729.09	810.20	930.45	1003.17	1137.01
Frame-11	-58.46	49.17	272.68	283.56	470.97	554.82	641.35	722.09	938.29	1032.81	1133.96
Frame-12	-39.16	140.37	237.56	299.59	492.78	601.72	698.50	740.26	935.46	1016.45	1088.80
Hoop-1	59.82	732.68	1374.72	2163.67	2825.67	3598.65	4315.56	5006.71	5848.42	6482.17	7228.19
Hoop-2	-18.27	695.52	1586.40	2096.25	2903.05	3534.89	4302.85	4964.88	5651.97	6488.21	7274.12
Hoop-3	-27.47	693.03	1462.61	2107.73	2921.14	3645.51	4275.34	5083.65	5646.48	6380.04	7083.56
Hoop-4	171.70	716.67	1394.30	2088.27	2878.53	3480.20	4214.63	5099.53	5702.79	6557.45	7024.90
Hoop-5	31.15	737.67	1411.83	2127.34	2875.22	3612.66	4231.58	5038.94	5722.23	6438.53	7194.18
Hoop-6	-7.76	644.90	1441.59	2156.23	2861.76	3636.93	4426.85	5048.64	5473.50	6467.92	7030.02
Hoop-7	-36.93	733.50	1461.02	2025.88	2815.96	3533.11	4300.46	5020.98	5734.34	6421.53	7224.72
Hoop-8	16.59	636.82	1315.42	2088.66	2906.40	3636.51	4328.97	5058.65	5678.31	6466.92	7109.03
Hoop-9	137.88	649.40	1218.34	2146.02	2882.37	3729.95	4393.27	5012.46	5722.61	6466.21	7141.04
Hoop-10	2.35	782.53	1463.18	2092.10	2924.31	3530.74	4290.67	5029.98	5724.28	6501.48	7063.06
Hoop-11	-3.71	572.50	1464.00	2125.16	2828.71	3579.31	4274.40	5028.18	5699.86	6490.46	7099.29
Hoop-12	29.29	713.27	1571.86	2053.71	2940.09	3595.38	4227.70	5028.09	5733.31	6672.52	7167.31
Hoop-13	22.70	710.19	1375.73	2084.96	2948.48	3563.24	4454.81	4944.82	5756.07	6400.25	7131.62
Hoop-14	6.31	659.47	1386.02	2053.65	2824.72	3595.74	4380.28	5048.12	5744.74	6405.82	7073.65
Long-1	22.14	766.90	1326.54	2082.89	2807.28	3386.20	4143.36	4788.23	5427.82	5863.17	6551.68
Long-2	14.64	522.46	1242.55	1880.71	2585.82	3491.11	4002.44	4596.56	5235.51	6156.21	6498.63
Long-3	13.42	824.13	1357.38	1927.57	2497.31	3249.05	4043.22	4777.70	5306.31	5895.84	6682.93
Long-4	13.29	658.74	1514.39	1883.86	2554.08	3204.18	3823.04	4629.33	5526.16	5955.98	6643.01
Long-5	21.06	775.06	1363.88	1824.76	2516.51	3174.72	3919.50	4508.91	5343.37	5997.85	6513.81
Long-6	2.13	498.10	1475.56	2098.33	2721.91	3187.11	3898.27	4684.15	5424.83	5850.56	6748.99
Long-7	8.33	829.46	1408.06	2158.35	2580.45	3224.86	4163.54	4856.56	5243.96	6163.13	6680.03
Long-8	62.27	525.38	1366.21	2075.98	2595.75	3274.49	4095.21	4667.29	5378.87	6024.40	6630.55

Table E-22. Strain survey raw data (run3) and phase 2 repairs (20,000 cycles for D-BE and D-A2 repairs) (continued)

S19	-854.03	119.09	315.66	495.75	593.14	727.03	805.88	902.33	982.27	1082.03	1142.76
S20	-206.34	76.98	220.69	368.15	457.30	577.97	649.40	737.67	810.84	907.11	967.51
S21	-461.44	191.52	465.25	706.76	844.17	1005.36	1102.50	1212.47	1305.24	1417.42	1480.97
S22	-47.05	90.40	218.30	336.58	429.68	534.48	605.01	685.39	754.98	843.93	902.99
S25	100.03	-34.27	-164.37	-318.55	-398.65	-514.00	-571.71	-641.70	-693.24	-745.98	-771.03
S26	595.62	-135.71	-477.65	-905.83	-1115.48	-1399.14	-1571.95	-1836.62	-2008.35	-2212.16	-2331.96
IS19	757.63	-48.50	-121.82	-178.31	-163.10	-154.24	-127.81	-92.67	-50.84	12.72	58.16
IS20	124.00	-9.42	-16.18	-27.44	8.22	43.50	84.97	139.19	196.07	278.43	333.60
IS21	369.05	-153.35	-345.22	-518.80	-569.77	-641.30	-661.98	-682.04	-686.46	-673.52	-645.22
IS22	-28.88	-60.10	-102.18	-166.05	-179.11	-211.06	-216.15	-220.48	-216.87	-192.90	-167.50
IS25	3.31	27.88	64.82	93.83	120.03	146.65	163.11	183.72	200.87	225.83	240.02
IS26	-27.03	56.93	113.98	165.76	221.73	282.08	329.15	384.35	436.91	505.37	556.61
2AF*	-138.99	65.42	202.69	354.13	467.30	614.98	708.94	822.21	920.60	1041.30	1115.11
2AA*	63.25	53.33	195.85	359.34	474.60	626.41	719.09	835.36	933.55	1055.76	1131.09
2BF*	-345.96	164.85	419.93	710.99	885.85	1133.63	1281.08	1468.34	1615.21	1789.36	1896.85
2BA*	-352.13	164.26	443.11	758.27	944.81	1207.69	1364.92	1558.28	1714.01	1900.01	1983.93
F01											
F04	-996.24	-698.19	-689.19	-463.34	-525.37	-338.55	-342.14	-232.50	-152.35	-6.47	15.34
F06	-528.72	-347.70	-345.82	-175.15	-219.59	-78.20	-74.35	26.74	83.84	193.42	216.53
F07	1265.31	1028.45	1106.48	981.52	1118.07	1046.46	1124.16	1101.23	1139.38	1090.18	1125.14
F10	-837.51	-549.80	-553.64	-330.62	-399.76	-207.97	-226.14	-108.39	-21.47	127.28	129.85
L02	50.33	91.22	106.49	138.52	151.22	179.41	206.11	238.12	260.79	286.17	301.82
L03	14.01	35.40	32.60	42.27	41.15	48.96	62.91	79.63	91.72	112.16	120.15

Note: Strain gages F02, F03, F05, F08, F09, L01, L04 and L05 were removed and F01 showed faulty readings. Successive * signs on the gage number represent the progressive distances between the notch tip and strain gage (see appendix C for details).

Table E-23. Strain survey raw data (run1) and phase 2 repairs (40,000 cycles for D-BE and D-A2 repairs)

Load Step	0	1	2	3	4	5	6	7	8	9	10
Pressure	0.03	0.62	1.35	1.96	2.56	3.39	4.00	4.62	5.42	6.03	6.65
Frame-1	-15.80	121.72	228.54	380.77	432.06	597.15	674.54	739.06	895.37	1021.59	1114.75
Frame-2	12.74	135.96	274.22	329.85	467.73	614.14	656.52	791.30	886.93	987.39	1129.44
Frame-3	29.86	117.05	183.36	343.43	448.97	564.53	687.35	830.24	896.98	977.41	1109.09
Frame-4	27.11	149.61	262.94	368.50	459.80	588.97	608.47	766.82	887.04	954.74	1130.62
Frame-5	53.19	98.10	205.01	306.32	495.20	520.30	676.40	809.29	897.85	1013.12	1171.32
Frame-6	50.76	48.68	145.88	277.22	462.61	586.70	641.75	786.14	911.52	990.26	1091.42
Frame-7	-12.52	134.40	240.59	404.00	427.95	596.54	719.10	801.17	884.94	1036.57	1110.39
Frame-8	60.53	139.81	204.88	320.07	477.12	588.35	643.71	794.20	923.65	965.13	1110.55
Frame-9	18.70	146.17	211.28	322.19	479.72	564.37	639.61	798.07	894.85	1037.24	1118.44
Frame-10	-11.49	164.51	282.95	318.24	494.66	597.95	669.28	817.26	859.49	1050.26	1157.52
Frame-11	48.22	116.15	262.36	331.25	458.72	545.04	648.45	837.39	908.25	1117.00	1135.15
Frame-12	-17.20	150.04	323.48	372.48	461.57	592.47	612.04	848.70	906.27	1008.14	1134.33
Hoop-1	16.98	805.77	1444.49	2058.98	2929.46	3676.62	4306.33	5063.95	5566.84	6474.33	7021.41
Hoop-2	27.26	665.77	1524.74	2154.07	2833.80	3588.65	4315.31	4908.74	5692.78	6498.45	7177.59
Hoop-3	20.94	743.04	1448.05	2091.07	2844.80	3570.48	4228.23	5070.93	5737.59	6430.68	7069.90
Hoop-4	201.26	633.49	1536.66	2068.59	2844.23	3501.81	4167.06	5089.43	5747.58	6365.88	7048.32
Hoop-5	19.86	783.76	1488.79	2234.49	3002.06	3456.86	4219.46	4999.19	5616.32	6256.95	7061.73
Hoop-6	68.51	618.95	1461.48	2255.98	2766.39	3663.25	4237.89	4848.13	5807.55	6333.23	6883.17
Hoop-7	-29.18	751.82	1488.58	2233.61	3016.46	3650.97	4307.36	5030.80	5683.75	6372.58	7312.19
Hoop-8	53.30	753.93	1505.34	2169.56	2862.82	3746.19	4190.96	5080.75	5642.60	6474.43	7146.44
Hoop-9	78.36	724.61	1526.72	2248.44	2991.54	3501.66	4352.11	4940.35	5708.51	6281.04	7067.85
Hoop-10	20.12	756.02	1573.37	2080.07	2870.99	3580.51	4175.57	4978.44	5771.06	6384.18	7154.41
Hoop-11	19.95	777.51	1455.04	2143.81	2845.12	3664.59	4340.16	4973.93	5579.13	6470.63	7165.34
Hoop-12	34.05	698.15	1363.78	2138.92	2822.96	3390.90	4372.95	4983.72	5609.48	6293.45	7152.76
Hoop-13	72.99	599.69	1367.51	2230.75	3028.02	3657.43	4286.10	4943.91	5770.36	6487.10	7072.91
Hoop-14	8.66	691.31	1439.74	2107.79	2790.37	3634.79	4295.00	5065.15	5556.86	6452.20	7179.46
Long-1	11.09	530.65	1309.43	2088.63	2549.01	3248.32	4129.68	4652.28	5499.66	5873.29	6762.31
Long-2	8.11	508.70	1216.95	2084.97	2529.63	3109.03	4073.29	4688.50	5499.12	6181.61	6665.45
Long-3	6.43	708.38	1357.62	1841.37	2489.86	3339.82	3917.97	4518.26	5413.26	5858.49	6499.61
Long-4	23.56	865.19	1573.50	2068.01	2728.36	3430.50	4189.57	4594.87	5357.03	6046.70	6838.54
Long-5	15.05	609.23	1345.13	2235.89	2609.14	3019.36	4032.62	4545.43	5509.39	5923.84	6606.32
Long-6	25.59	519.35	1147.55	1876.98	2952.79	3280.60	3763.18	4468.36	5259.09	6283.54	6724.86
Long-7	32.49	617.05	1369.05	1922.88	2591.52	3100.11	3818.55	4927.75	5543.83	5862.33	6495.29
Long-8	1.53	773.06	1660.18	1913.85	2205.50	3347.33	3931.92	4761.31	5081.12	6178.80	6659.20

Table E-23. Strain survey raw data (run1) and phase 2 repairs (40,000 cycles for D-BE and D-A2 repairs) (continued)

S19	29.97	244.77	433.84	556.46	667.17	757.84	821.64	915.12	1002.20	1075.47	1156.14
S20	1.90	140.04	285.65	386.24	484.27	569.42	630.50	720.52	806.87	880.76	962.57
S21	27.63	349.93	628.44	794.33	939.22	1050.97	1129.63	1238.92	1337.51	1422.97	1511.50
S22	25.69	141.88	270.36	365.13	467.67	552.84	618.56	703.66	784.69	856.26	931.07
S25	16.03	-139.41	-323.27	-450.25	-548.33	-621.96	-669.17	-744.09	-809.06	-856.80	-900.22
S26	42.62	-337.04	-745.22	-1026.41	-1255.36	-1438.94	-1547.90	-1735.20	-1901.00	-2024.42	-2144.50
IS19	-21.54	-136.01	-212.80	-239.63	-236.14	-224.62	-201.47	-180.92	-147.26	-112.33	-67.39
IS20	-22.51	-44.10	-49.92	-32.32	2.72	40.30	81.67	130.32	188.60	241.99	303.08
IS21	-24.14	-287.61	-493.43	-591.17	-643.86	-674.53	-680.57	-692.97	-687.42	-671.51	-643.19
IS22	-9.72	-65.46	-131.90	-171.41	-189.11	-194.63	-189.11	-187.53	-173.66	-154.94	-125.39
2AF*	-95.85	50.75	241.27	397.22	543.39	663.33	758.07	888.05	1015.34	1124.32	1238.82
2AA*	-29.54	135.53	356.51	527.88	684.52	815.32	913.83	1057.77	1194.67	1309.64	1432.58
2BF**	72.03	288.09	525.28	700.25	856.39	985.42	1073.53	1212.47	1343.07	1450.80	1564.65
2BA**	2.07	239.44	492.74	675.49	840.99	974.29	1066.05	1210.19	1344.17	1459.05	1577.87

Note: Strain gages IS25, IS26, F01-F10 and L01-L05 were removed. Successive * signs on the gage number represent the progressive distances between the notch tip and strain gage (see appendix C for details).

Table E-24. Strain survey raw data (run2) and phase 2 repairs (40,000 cycles for D-BE and D-A2 repairs)

Load Step	0	1	2	3	4	5	6	7	8	9	10
Pressure	-0.03	0.72	1.44	1.96	2.72	3.34	4.00	4.66	5.31	5.98	6.71
Frame-1	-16.83	146.81	169.12	373.08	446.34	606.60	667.47	752.96	974.51	1037.19	1112.37
Frame-2	1.41	92.94	179.00	347.48	435.50	579.17	679.86	788.88	904.29	1047.42	1160.15
Frame-3	61.32	107.45	210.27	321.56	448.08	588.29	723.17	801.78	949.70	1087.89	1167.61
Frame-4	-36.59	129.28	192.68	331.36	428.62	558.91	658.74	787.35	873.90	1058.52	1202.32
Frame-5	-10.24	96.91	226.60	341.31	393.38	584.38	699.90	802.67	904.14	1020.28	1121.62
Frame-6	0.48	107.95	230.25	283.39	484.56	574.71	652.33	816.49	882.26	1004.63	1171.10
Frame-7	8.01	98.88	161.42	285.24	440.61	533.58	690.54	831.09	887.70	1031.35	1135.38
Frame-8	-4.20	124.65	196.85	324.66	409.26	625.02	673.26	808.44	877.84	1038.81	1156.32
Frame-9	-3.85	119.31	209.60	337.05	408.76	617.13	657.80	778.42	907.94	1077.08	1137.61
Frame-10	43.68	112.21	180.21	354.90	437.87	626.18	724.82	788.51	927.38	1064.33	1084.62
Frame-11	27.53	121.77	187.34	366.48	487.18	612.86	678.70	743.64	909.35	1082.68	1073.50
Frame-12	4.08	92.52	183.05	241.57	459.41	607.09	692.57	828.30	938.62	1004.95	1209.29
Hoop-1	-2.97	595.48	1476.70	2145.81	2929.46	3680.98	4333.11	5124.30	5653.90	6263.29	7273.51
Hoop-2	2.21	728.44	1456.32	2053.70	2789.08	3582.21	4372.12	4957.53	5712.46	6531.79	7125.71
Hoop-3	-10.62	653.72	1359.99	2076.84	2767.67	3586.97	4294.41	5092.47	5706.04	6437.05	7050.61
Hoop-4	-49.46	737.09	1508.95	2124.69	2853.32	3566.10	4359.20	4922.80	5636.76	6447.00	7208.19
Hoop-5	-8.91	631.04	1434.42	1970.05	2683.89	3479.12	4253.19	5066.21	5729.58	6486.45	7228.93
Hoop-6	39.34	803.13	1391.78	2020.62	2908.57	3578.29	4386.94	5211.41	5712.75	6555.02	7264.19
Hoop-7	58.42	805.52	1582.86	2113.64	2835.94	3710.69	4308.72	4945.50	5742.74	6504.22	7281.80
Hoop-8	-5.09	739.26	1432.95	2045.71	2877.70	3527.24	4424.48	4971.79	5745.33	6519.51	7183.64
Hoop-9	-11.39	633.00	1378.31	2112.23	2995.43	3408.31	4486.73	4872.64	5814.98	6447.44	7255.24
Hoop-10	-13.65	670.63	1449.55	2082.06	2828.62	3491.64	4363.97	4913.17	5682.77	6501.00	7132.02
Hoop-11	1.83	695.89	1452.00	2078.78	2847.22	3573.97	4235.06	4997.98	5693.86	6529.92	7137.06
Hoop-12	-0.52	725.36	1333.39	2139.13	2670.41	3558.29	4161.92	5064.27	5791.97	6418.43	7269.92
Hoop-13	-14.79	723.97	1477.80	2143.19	2633.30	3730.58	4395.82	5215.04	5683.16	6466.45	7183.34
Hoop-14	-6.02	852.71	1396.26	2210.76	2952.14	3642.13	4265.64	4999.60	5660.16	6497.53	7136.14
Long-1	5.71	695.10	1432.40	2188.79	2749.49	3217.38	3994.94	4654.15	5237.87	6099.15	6667.80
Long-2	9.36	477.35	1260.34	1993.78	2635.97	3487.72	4193.42	4733.89	5504.39	5948.26	6614.78
Long-3	8.35	874.52	1544.27	1817.52	2522.22	3446.96	4139.48	4637.89	5403.19	5985.45	6720.19
Long-4	1.18	898.42	1223.04	1855.35	2532.92	3374.00	3870.47	4774.80	5287.88	6152.25	6596.32
Long-5	8.43	608.05	1554.83	1884.73	2409.03	3170.92	3679.71	4620.65	5346.88	6206.62	6584.79
Long-6	-5.95	678.04	1191.99	2104.89	2755.74	3379.68	3870.16	4804.17	5517.73	5793.19	6849.25
Long-7	13.61	819.96	1233.34	1750.33	2757.17	3514.73	3929.82	4398.07	5062.94	6188.26	6446.69
Long-8	5.25	944.10	1465.98	2234.57	2765.56	2941.43	4350.91	4958.15	5589.87	5636.02	6080.96

Table E-24. Strain survey raw data (run2) and phase 2 repairs (40,000 cycles for D-BE and D-A2 repairs) (continued)

S19	-14.73	276.35	455.13	554.41	686.12	751.85	824.17	917.64	989.75	1074.64	1165.17
S20	-29.07	153.88	297.20	378.43	494.03	556.15	631.35	720.52	790.59	876.47	969.76
S21	-18.43	408.82	662.87	804.83	967.40	1054.61	1140.10	1249.58	1329.20	1423.37	1524.51
S22	16.98	159.59	283.94	369.39	474.72	549.69	624.34	710.53	777.28	857.07	943.36
S25	48.55	-169.37	-340.42	-443.40	-571.34	-622.08	-671.00	-746.64	-794.52	-848.07	-897.79
S26	78.93	-454.79	-847.36	-1058.32	-1359.58	-1481.78	-1601.14	-1787.10	-1906.77	-2048.67	-2180.11
IS19	5.87	-165.98	-226.32	-247.03	-258.52	-230.43	-201.98	-175.54	-146.13	-105.34	-54.63
IS20	-17.24	-57.01	-56.08	-41.74	-14.52	31.59	77.70	130.69	178.25	242.33	314.39
IS21	-5.27	-359.61	-540.01	-616.76	-695.58	-691.73	-698.92	-697.40	-694.49	-673.99	-638.06
IS22	-27.63	-104.24	-163.50	-193.52	-228.54	-213.87	-203.98	-193.95	-183.17	-157.03	-119.93
2AF*	-120.12	70.01	257.03	386.21	556.45	656.38	760.84	892.68	996.10	1118.58	1246.69
2AA*	-60.02	161.36	375.16	513.39	698.31	805.51	915.74	1061.14	1170.54	1303.16	1442.30
2BF**	48.41	344.92	575.02	706.39	894.38	996.16	1092.75	1234.39	1333.62	1458.11	1588.23
2BA**	-20.42	303.43	547.36	687.71	883.05	990.88	1090.05	1236.54	1339.43	1468.74	1603.14

Note: Strain gages IS25, IS26, F01-F10 and L01-L05 were removed. Successive * signs on the gage number represent the progressive distances between the notch tip and strain gage (see appendix C for details).

Table E-25. Strain survey raw data (run3) and phase 2 repairs (40,000 cycles for D-BE and D-A2 repairs)

Load Step	0	1	2	3	4	5	6	7	8	9	10
Pressure	0.02	0.72	1.29	2.02	2.69	3.45	4.05	4.81	5.31	5.98	6.74
Frame-1	35.91	123.86	221.48	309.14	444.43	579.58	639.85	745.91	920.84	1071.91	1100.40
Frame-2	36.91	128.18	242.90	321.23	437.31	564.83	664.82	770.66	890.80	1017.70	1098.67
Frame-3	35.37	132.93	276.20	368.01	454.16	534.73	663.54	764.33	874.20	1014.01	1047.47
Frame-4	-41.74	75.40	208.49	301.11	427.90	545.74	665.29	793.23	876.93	1045.21	1065.19
Frame-5	7.31	104.71	201.37	360.65	475.01	554.28	644.72	745.49	926.26	1025.11	1122.36
Frame-6	19.28	140.48	199.39	403.60	485.15	566.58	653.70	796.85	868.85	1005.35	1084.63
Frame-7	62.98	90.67	248.39	331.36	443.27	544.10	645.92	776.57	895.24	1047.08	1094.90
Frame-8	25.56	52.92	227.69	356.34	474.01	574.75	667.32	806.45	891.31	1037.59	1083.22
Frame-9	40.16	38.06	277.32	359.86	446.07	544.24	645.82	775.43	929.33	1071.96	1086.14
Frame-10	-9.14	120.37	237.75	342.68	444.78	526.07	685.95	770.11	929.67	1084.11	1174.74
Frame-11	21.39	65.02	308.87	307.23	416.42	487.37	698.52	771.34	859.93	1102.65	1115.40
Frame-12	20.68	93.41	301.23	373.75	506.15	549.34	694.04	831.96	947.62	1049.74	1100.33
Hoop-1	27.86	742.38	1344.59	2129.71	2828.75	3687.13	4079.22	4915.73	5780.86	6515.40	7083.78
Hoop-2	9.37	635.43	1683.80	1964.47	2702.24	3507.81	4252.27	5086.34	5671.31	6442.34	7103.16
Hoop-3	48.98	662.48	1570.62	2168.19	2829.87	3524.56	4262.86	5146.82	5585.08	6500.16	7040.80
Hoop-4	35.92	660.80	1567.39	2124.90	2897.78	3555.95	4301.07	5138.99	5733.04	6510.58	7138.05
Hoop-5	210.38	661.60	1533.58	2191.35	2981.38	3611.09	4114.77	4976.32	5729.58	6457.68	7080.42
Hoop-6	97.66	739.33	1526.97	2095.56	2776.33	3639.19	4430.69	4819.45	5543.21	6438.34	7108.12
Hoop-7	72.70	614.27	1338.28	2070.96	2833.21	3402.19	4160.37	5079.57	5696.26	6479.20	7057.27
Hoop-8	75.18	680.81	1447.26	2125.35	2826.05	3592.57	4147.59	5016.08	5694.24	6431.93	7064.76
Hoop-9	20.92	693.95	1455.22	2109.81	2836.90	3547.97	4243.04	5135.21	5635.49	6503.09	7093.36
Hoop-10	55.66	750.54	1531.02	2159.62	2838.72	3530.39	4327.08	5068.31	5673.88	6572.10	7167.20
Hoop-11	41.69	741.12	1471.65	2076.35	2795.92	3580.87	4220.98	4965.86	5730.10	6551.67	7093.25
Hoop-12	43.14	779.86	1365.88	1992.98	2669.87	3674.36	3936.73	4846.44	5741.03	6382.04	7078.58
Hoop-13	72.98	723.90	1418.99	2186.42	2910.70	3408.37	4110.97	4930.27	5741.68	6532.29	7078.81
Hoop-14	-6.02	771.90	1542.79	2100.03	2790.10	3678.47	4244.04	5000.10	5689.52	6446.15	7075.30
Long-1	69.81	531.12	1364.05	1899.61	2820.88	3469.64	3929.36	4569.03	5374.83	5964.29	6785.97
Long-2	7.86	504.19	1231.12	1881.57	2456.14	3179.26	4092.51	4509.78	5067.70	6107.12	6542.90
Long-3	40.72	926.30	1166.15	2052.82	2524.87	3280.35	4136.30	4568.42	5528.44	5970.70	6833.39
Long-4	37.31	699.43	1180.86	1866.13	2843.66	3470.84	3829.41	4630.29	5207.73	5770.12	6686.51
Long-5	5.35	673.10	1068.45	2108.40	2395.08	2963.53	3969.86	4432.90	5195.86	6139.11	6670.24
Long-6	6.67	499.41	1320.53	2042.23	2567.02	3429.22	4144.82	4842.82	5531.51	5845.50	6726.20
Long-7	75.80	807.12	1493.29	1987.07	2593.79	3478.53	4018.84	4791.11	5101.71	6270.96	6627.31
Long-8	4.08	618.05	1259.34	1906.42	2877.16	3649.23	3723.37	4316.36	5588.99	5687.95	6476.57

Table E-25. Strain survey raw data (run3) and phase 2 repairs (40,000 cycles for D-BE and D-A2 repairs) (continued)

S19	27.50	274.36	424.05	570.36	684.56	766.68	827.50	932.62	989.19	1075.65	1159.28
S20	-10.35	149.17	269.61	388.41	489.56	566.30	626.53	728.74	785.87	874.16	958.54
S21	51.31	426.88	640.48	829.56	973.82	1074.09	1144.73	1266.13	1331.65	1428.03	1521.28
S22	47.11	166.36	282.71	381.39	480.55	556.27	619.70	719.78	776.23	859.69	934.59
S25	25.13	-170.99	-297.21	-451.19	-564.84	-638.65	-677.12	-754.97	-794.92	-847.71	-900.35
S26	-29.87	-481.09	-793.49	-1135.99	-1389.67	-1564.00	-1661.45	-1851.50	-1947.33	-2082.03	-2214.92
IS19	-18.74	-163.63	-202.46	-249.03	-255.60	-239.70	-211.30	-178.69	-148.59	-105.11	-67.23
IS20	-18.88	-51.16	-41.57	-39.20	-11.62	25.60	70.78	130.89	176.76	243.24	303.71
IS21	-73.33	-387.62	-519.92	-645.25	-702.23	-722.69	-718.67	-718.16	-704.33	-681.07	-658.08
IS22	-56.51	-122.11	-157.67	-212.75	-235.41	-238.34	-225.39	-210.79	-194.05	-165.62	-141.05
2AF*	-99.59	72.85	222.95	397.64	551.13	670.29	757.89	904.20	993.36	1119.31	1238.83
2AA*	-40.25	157.96	333.11	524.64	692.07	820.30	914.01	1073.22	1167.58	1302.43	1430.29
2BF**	100.40	349.01	540.36	741.65	905.55	1028.05	1111.87	1260.33	1345.53	1467.74	1586.75
2BA**	37.95	308.92	511.81	724.68	896.08	1023.75	1108.84	1263.07	1351.91	1479.48	1603.30

Note: Strain gages IS25, IS26, F01-F10 and L01-L05 were removed. Successive * signs on the gage number represent the progressive distances between the notch tip and strain gage (see appendix C for details).

Table E-26. Strain survey raw data (run1) and phase 2 repairs (60,000 cycles for D-BE and D-A2 repairs)

Load Step	0	1	2	3	4	5	6	7	8	9	10
Pressure	-0.08	0.80	1.41	2.02	2.77	3.48	4.08	4.77	5.22	5.99	6.81
Frame-1	24.48	72.90	223.64	375.63	500.06	565.18	631.47	789.95	914.44	1007.85	1099.00
Frame-2	97.68	209.16	238.85	365.35	479.33	420.77	849.87	937.98	927.57	1036.24	1149.28
Frame-3	-0.16	131.71	221.91	356.54	531.11	654.20	640.76	776.35	918.98	1038.64	1113.98
Frame-4	-8.27	106.31	253.58	350.13	431.06	591.89	660.46	822.86	896.44	1026.04	1136.47
Frame-5	24.87	86.00	199.92	377.81	485.60	591.13	694.13	791.54	886.96	1037.78	1069.30
Frame-6	1.54	99.94	245.28	336.85	456.07	579.77	669.44	799.04	898.37	1055.01	1119.43
Frame-7	16.61	81.53	230.44	339.31	457.78	584.73	675.59	799.29	906.42	1042.50	1137.26
Frame-8	-9.16	95.25	377.72	265.47	585.07	519.71	735.24	799.95	837.44	954.46	1070.56
Frame-9	58.94	94.64	369.39	352.72	514.19	603.16	599.38	857.86	993.12	919.64	975.78
Frame-10	167.60	143.96	229.15	361.41	421.77	540.31	670.57	767.13	900.93	1018.27	1107.59
Frame-11	-36.20	35.16	222.40	304.90	415.92	545.69	772.80	863.69	899.13	1078.90	1087.82
Frame-12	-4.08	127.59	202.05	291.04	512.18	553.14	663.24	856.62	851.92	1094.06	1102.99
Hoop-1	-36.23	631.49	1324.74	2110.68	2797.93	3663.79	4457.70	4674.06	5881.84	6388.71	7335.85
Hoop-2	62.86	693.69	1346.17	2165.49	2880.13	3500.57	4119.90	5034.31	5599.96	6394.56	7046.91
Hoop-3	-25.02	689.11	1456.85	2112.60	2872.87	3656.35	4397.27	4975.56	5723.60	6441.76	7214.53
Hoop-4	-29.76	833.10	1361.44	2190.22	2772.25	3514.26	4334.72	4955.61	5705.63	6415.40	7269.21
Hoop-5	89.20	557.90	1482.91	2082.99	2858.39	3478.30	4219.23	5045.74	5693.38	6478.83	7277.99
Hoop-6	-15.36	577.29	1371.23	2179.84	2976.85	3526.34	4306.69	4910.63	5624.01	6327.89	7101.77
Hoop-7	-33.67	688.97	1433.20	2150.75	2821.08	3640.66	4344.61	4983.60	5857.65	6423.50	7219.46
Hoop-8	-1.12	578.68	1463.01	2129.84	2876.11	3637.82	4290.22	4971.61	5711.00	6414.14	7131.78
Hoop-9	-12.46	705.09	1336.88	2165.45	2804.04	3629.68	4492.33	5004.20	5741.58	6563.07	7119.68
Hoop-10	15.71	779.01	1328.66	2157.42	2848.07	3569.68	4313.70	4827.97	5729.27	6526.31	7360.46
Hoop-11	-40.56	788.73	1384.30	2107.53	2841.27	3649.70	4461.16	4901.98	5783.61	6535.70	6996.31
Hoop-12	66.91	643.68	1485.41	2180.15	2927.20	3638.91	4248.45	4937.82	5757.80	6396.37	7310.68
Hoop-13	-7.43	675.65	1215.04	2077.96	2811.17	3624.39	3919.25	4954.86	5594.92	6393.21	7141.14
Hoop-14	193.20	719.43	1377.37	2239.91	2941.35	3460.98	4396.71	5222.79	5654.10	6436.32	7057.70
Long-1	23.54	474.78	1334.64	2043.82	2753.78	3358.48	3909.91	4650.51	5292.88	6128.54	6738.78
Long-2	6.85	738.06	1253.48	2220.21	2917.40	3240.82	3841.98	4923.76	5445.19	6076.22	6866.15
Long-3	6.49	526.60	1220.80	1902.96	2725.51	3271.51	4132.06	4863.50	5157.25	6116.68	6642.41
Long-4	76.86	621.98	1449.34	1912.21	2300.53	3377.39	3863.63	4386.08	5526.65	5931.71	6896.93
Long-5	13.05	695.84	1282.71	1895.98	2724.59	3367.69	3861.14	4520.86	5517.64	5861.14	6601.96
Long-6	1.01	651.22	1175.47	2172.28	2782.47	3094.35	4154.09	4773.15	5284.80	6119.38	6572.92
Long-7	1.66	722.92	1415.28	2107.35	2846.50	3372.99	3731.23	4926.10	5243.25	6202.48	6886.69
Long-8	413.49	514.67	1377.25	1973.15	2735.04	3550.97	3817.06	4509.16	5187.24	6010.17	6860.85
S19	4.74	376.55	499.10	637.64	742.57	823.84	940.51	975.35	1040.16	1108.44	1206.03
S20	-169.53	57.97	160.53	256.61	351.20	401.03	499.30	533.92	602.53	664.78	750.74
S21	46.21	492.05	660.03	831.90	967.58	1072.02	1207.00	1258.29	1327.80	1412.61	1521.61
S22	-16.45	185.83	294.55	410.44	509.98	594.04	697.71	743.87	814.58	885.84	981.06
IS19	18.06	-197.48	-223.38	-231.33	-204.68	-170.79	-113.84	-77.09	-6.45	52.66	134.85
IS20	4.15	-63.34	-61.88	-53.23	-20.03	19.49	79.57	121.26	188.93	252.25	335.31
IS21	112.14	-246.83	-370.62	-406.12	-418.58	-420.88	-401.62	-368.71	-327.13	-298.65	-264.32
IS22	36.31	-115.52	-156.70	-210.21	-226.13	-221.77	-216.71	-189.99	-147.33	-110.45	-58.41
IS25	-1.45	82.77	128.82	179.94	226.75	262.71	308.78	331.13	370.00	402.35	441.31
IS26	-3.72	46.78	89.48	136.19	186.34	232.65	291.11	324.08	375.67	425.58	493.37
2AF*	-5.92	254.55	410.50	607.50	772.79	896.99	1086.19	1146.91	1257.12	1368.28	1507.64
2AA*											
2BF**	-31.74	333.59	500.99	720.51	881.58	997.73	1178.93	1230.31	1322.72	1415.72	1534.42
2BA**	-34.87	375.20	561.38	804.91	983.14	1114.10	1312.87	1366.23	1467.79	1569.20	1700.24

Note: Strain gages S25 and S26 were removed and 2AA* showed faulty readings. Successive * signs on the gage number represent the progressive distances between the notch tip and strain gage (see appendix C for details).

Table E-27. Strain survey raw data (run2) and phase 2 repairs (60,000 cycles for D-BE and D-A2 repairs)

Load Step	0	1	2	3	4	5	6	7	8	9	10
Pressure	-0.11	0.68	1.35	1.88	2.78	3.33	3.94	4.67	5.30	6.12	6.68
Frame-1	-1.17	81.35	226.55	365.43	427.72	573.33	679.18	818.01	899.18	1035.53	1175.77
Frame-2	17.37	15.18	118.19	488.23	371.80	571.97	755.43	754.94	876.92	1047.45	1114.70
Frame-3	76.32	81.90	303.85	303.52	437.06	460.10	702.90	812.03	981.01	1006.23	1210.43
Frame-4	-13.61	62.81	197.91	331.87	490.99	539.73	670.52	774.55	930.13	1017.55	1129.88
Frame-5	22.63	20.17	160.30	365.59	545.40	561.58	738.17	772.42	941.97	978.53	1200.70
Frame-6	41.48	94.97	229.07	333.85	468.23	554.55	692.81	804.68	927.34	976.53	1161.07
Frame-7	-1.85	97.75	242.20	352.73	468.47	551.15	682.84	804.47	908.51	1016.45	1139.76
Frame-8	74.55	133.98	194.40	260.81	464.08	474.49	757.03	746.82	1014.34	1039.67	1175.95
Frame-9	113.94	122.16	178.31	379.62	517.34	474.84	752.42	711.19	812.65	954.71	1158.94
Frame-10	6.31	132.74	234.20	358.22	462.75	543.54	690.33	800.78	930.40	1015.33	1101.40
Frame-11	49.29	140.31	187.22	317.89	461.47	601.70	691.29	784.88	875.70	1053.74	1103.90
Frame-12	-38.96	-19.48	279.65	325.25	442.90	523.14	715.06	756.55	929.15	1059.89	1140.49
Hoop-1	85.34	669.59	1322.66	2170.14	2812.17	3545.48	4380.13	4947.55	5740.96	6518.70	7069.13
Hoop-2	121.99	725.95	1331.57	2159.68	3028.58	3711.70	4184.83	4942.42	5620.35	6499.65	7123.97
Hoop-3	-0.87	733.96	1347.90	2176.00	2820.84	3576.64	4209.69	4956.10	5739.71	6530.80	7130.00
Hoop-4	19.09	708.28	1346.70	2131.90	3019.77	3714.69	4255.56	4938.84	5579.68	6389.44	7166.10
Hoop-5	385.50	532.76	1491.59	2213.68	2885.04	3508.49	4284.30	5027.28	5665.31	6384.81	7198.97
Hoop-6	107.88	734.96	1338.34	2190.28	2900.44	3547.74	4404.98	5089.55	5738.88	6519.35	7029.28
Hoop-7	130.90	692.55	1429.34	2273.74	2901.28	3599.16	4337.89	4975.95	5704.44	6499.76	7176.53
Hoop-8	56.88	723.77	1434.30	2166.30	2869.44	3435.19	4239.48	5015.61	5748.39	6399.64	7124.53
Hoop-9	32.29	674.81	1469.60	2137.03	2965.68	3225.51	4320.52	5060.19	5660.37	6108.47	7173.37
Hoop-10	42.23	669.60	1406.69	2194.75	2937.00	3653.10	4453.31	4999.89	5714.51	6669.46	7212.01
Hoop-11	-8.18	666.54	1406.17	2131.13	2831.04	3662.66	4328.02	4817.89	5800.96	6337.78	7111.46
Hoop-12	134.06	720.00	1420.39	2122.31	2891.50	3668.30	4117.84	4981.85	5555.72	6396.37	7194.58
Hoop-13	28.53	618.25	1733.14	2142.90	2898.03	3538.44	4343.56	4804.31	5725.51	6501.08	7054.84
Hoop-14	449.13	756.12	1494.62	2101.24	2824.97	3673.34	4221.26	5077.08	5816.09	6443.63	7072.32
Long-1	34.37	592.47	1268.50	1982.89	2709.76	3342.24	4003.60	4611.44	5231.45	5983.03	6782.64
Long-2	10.86	513.01	1305.30	1792.43	2390.96	3478.63	4021.73	4846.16	5542.56	6044.22	6757.65
Long-3	12.96	633.55	1226.32	1902.30	2694.09	3264.80	3986.02	4687.73	5266.59	6064.87	6750.19
Long-4	24.73	834.72	1296.74	1819.35	2625.10	3164.20	4162.61	4793.97	5263.56	6199.85	6662.77
Long-5	4.31	574.64	1398.00	1922.97	2809.41	3292.56	3821.21	4839.10	5180.97	5949.99	6529.06
Long-6	2.77	721.25	1306.97	2004.54	2534.33	3482.56	4073.72	4495.28	5496.67	5797.46	6644.17
Long-7	18.74	480.15	1195.13	1731.68	2849.01	3325.50	4009.46	4750.43	5415.65	5972.30	6765.44
Long-8	219.00	840.25	1484.23	2133.07	2851.07	3166.91	3846.07	4623.80	5152.20	5862.08	6736.49
S19	-16.44	320.43	481.72	634.68	754.15	864.75	903.94	977.53	1055.00	1138.27	1195.65
S20	-701.75	-516.93	-389.09	-247.54	-150.76	-47.48	-2.70	63.75	138.14	222.64	281.14
S21	29.74	427.61	636.68	823.67	972.65	1100.26	1158.67	1250.87	1345.54	1444.92	1505.37
S22	4.20	165.00	289.80	414.05	517.66	618.70	671.03	742.23	822.08	909.78	965.88
IS19	46.18	-183.06	-227.01	-237.82	-220.52	-174.39	-131.88	-82.84	-17.98	57.70	118.97
IS20	10.65	-60.45	-64.05	-59.00	-35.00	15.16	60.99	113.12	180.45	258.38	317.38
IS21	-1008.12	-867.75	-836.52	-839.76	-783.60	-832.02	-725.53	-807.82	-754.51	-689.99	-714.83
IS22	42.09	-92.38	-150.21	-208.04	-231.17	-236.96	-211.68	-192.12	-156.73	-106.83	-67.07
IS25	15.11	77.02	132.43	187.86	231.76	277.83	304.49	335.38	372.88	413.15	438.34
IS26	13.66	41.90	90.76	139.26	187.40	242.42	277.20	320.40	376.57	439.15	480.60
2AF*	101.23	310.83	501.27	691.91	869.21	1046.87	1116.06	1237.93	1361.74	1484.43	1572.99
2AA*											
2BF**	-32.46	258.50	483.72	698.85	886.55	1062.70	1111.90	1221.40	1334.28	1441.71	1514.62
2BA**	-35.95	297.89	548.22	785.18	997.16	1189.41	1242.21	1365.23	1486.98	1604.32	1684.52

Note: Strain gages S25 and S26 were removed and 2AA* showed faulty readings. Successive * signs on the gage number represent the progressive distances between the notch tip and strain gage (see appendix C for details).

Table E-28. Strain survey raw data (run3) and phase 2 repairs (60,000 cycles for D-BE and D-A2 repairs)

Load Step	0	1	2	3	4	5	6	7	8	9	10
Pressure	-0.20	0.77	1.31	2.09	2.70	3.45	4.27	4.74	5.49	5.86	6.58
Frame-1	48.44	113.09	260.80	324.48	446.71	579.52	624.37	798.23	857.41	1039.61	1148.37
Frame-2	30.83	217.66	157.00	320.60	346.78	647.39	730.79	655.92	989.37	951.74	1228.31
Frame-3	-21.89	90.86	170.35	315.25	486.16	591.16	586.23	780.51	914.32	1072.22	1134.86
Frame-4	-21.76	101.85	215.02	322.00	465.96	566.78	682.37	793.08	886.22	1027.57	1109.87
Frame-5	-15.16	143.62	217.55	327.65	532.11	583.72	609.03	840.40	852.30	1036.67	1146.80
Frame-6	-7.94	119.52	263.83	354.52	453.88	576.60	669.04	805.23	870.37	1029.84	1139.17
Frame-7	-13.16	103.93	244.14	353.31	469.55	574.79	654.08	794.76	898.21	1024.06	1133.54
Frame-8	61.88	168.70	367.95	458.83	516.61	488.98	768.85	820.42	873.78	949.11	1057.47
Frame-9	27.41	136.49	270.04	333.73	368.53	673.84	529.83	859.31	795.03	1050.27	1134.90
Frame-10	-3.48	119.82	231.26	355.60	439.12	555.49	694.74	800.41	950.56	1090.62	1151.16
Frame-11	34.85	85.78	201.49	383.28	428.39	502.17	725.58	797.81	906.34	1064.23	1212.14
Frame-12	30.83	101.03	237.91	342.91	503.34	560.05	658.72	785.74	964.27	1001.06	1159.21
Hoop-1	-59.81	722.28	1422.59	2354.98	2908.61	3757.40	4455.45	5064.17	5499.64	6573.13	7354.73
Hoop-2	27.01	607.73	1614.86	2146.92	2756.47	3553.63	4350.63	4649.00	5738.63	6397.51	7113.93
Hoop-3	21.56	680.55	1482.58	2086.09	2902.19	3540.07	4231.28	5158.41	5665.54	6496.31	7177.29
Hoop-4	-8.04	657.70	1598.27	2147.96	2754.16	3587.71	4283.65	5062.33	5780.47	6456.36	7228.32
Hoop-5	89.18	507.66	1344.48	2096.74	2928.43	3549.44	4288.83	4979.29	5704.82	6445.87	7206.87
Hoop-6	15.45	615.41	1365.66	2123.01	2826.42	3668.80	4219.28	4984.94	5706.26	6541.10	7236.61
Hoop-7	-28.29	662.20	1535.02	2146.53	2853.28	3563.03	4342.39	4912.06	5774.20	6396.03	7112.85
Hoop-8	20.63	876.08	1397.92	2122.59	2891.47	3587.08	4218.99	4971.61	5631.26	6501.13	7146.28
Hoop-9	-119.84	690.98	1396.07	2271.03	2826.36	3586.72	4237.66	4818.07	5659.25	6507.59	7320.13
Hoop-10	-14.33	634.32	1429.52	2198.06	2833.01	3709.29	4253.11	5108.96	5893.63	6416.74	7353.39
Hoop-11	-44.16	677.40	1463.61	2139.91	2879.91	3669.49	4305.91	4928.97	5648.67	6631.06	6915.34
Hoop-12	23.38	767.24	1516.40	2071.31	2913.56	3464.76	4344.09	5068.43	5794.08	6323.80	7078.47
Hoop-13	-0.24	776.54	1545.98	2092.34	2804.81	3574.05	4258.53	5026.78	5767.52	6501.08	6932.58
Hoop-14	280.94	631.91	1340.95	2130.27	2810.63	3870.36	4288.33	5032.72	5646.79	6545.97	7240.46
Long-1	20.48	832.80	1456.10	2172.61	2709.76	3396.51	4016.86	4592.14	5441.95	5990.92	6775.37
Long-2	11.61	538.30	1218.43	1972.41	2460.80	3385.92	3866.38	4783.83	5281.25	5996.00	6711.17
Long-3	5.29	633.55	1221.52	2125.30	2557.65	3459.89	3890.18	4629.70	5440.99	6161.64	6764.63
Long-4	-7.79	808.88	942.76	2103.38	2768.79	3259.00	3697.06	4695.06	5288.15	6115.14	6509.30
Long-5	17.54	505.18	1178.75	1860.12	2554.01	3327.90	3942.98	4821.39	5284.27	6088.57	6602.59
Long-6	-22.67	563.80	1404.71	1814.34	2444.90	3114.70	4139.07	4746.45	5391.40	6156.31	6806.48
Long-7	2.41	617.87	1057.67	2113.17	2821.87	3586.50	3726.34	4679.56	5365.92	6228.00	6894.68
Long-8	247.08	821.69	1432.24	2186.68	2768.00	3570.58	4321.42	4610.34	5363.45	6003.08	6754.62
S19	-88.29	338.90	533.85	682.47	745.82	826.48	944.58	996.53	1065.06	1116.48	1200.42
S20	-823.08	-589.88	-420.15	-289.43	-225.15	-142.80	-33.03	20.41	89.76	147.54	235.62
S21	-56.24	440.64	692.80	870.56	965.41	1067.21	1207.79	1276.03	1358.34	1418.99	1513.73
S22	-37.46	154.95	317.39	429.40	506.69	589.59	696.18	757.21	828.55	887.58	969.99
IS19	87.25	-200.32	-239.98	-255.17	-221.24	-180.19	-124.63	-74.93	-10.77	44.73	123.30
IS20	5.05	-72.71	-79.21	-77.78	-37.17	7.22	66.57	118.20	186.21	242.68	320.27
IS21	-269.82	-470.87	-580.01	-640.44	-651.47	-604.61	-598.07	-812.30	-742.19	-819.42	-691.43
IS22	57.26	-94.53	-172.62	-240.62	-226.83	-220.37	-216.67	-187.82	-150.93	-110.45	-63.46
IS25	3.59	84.20	151.15	198.69	233.20	269.97	315.92	346.24	380.04	408.83	444.10
IS26	-2.27	35.92	98.18	137.84	183.60	228.90	289.06	330.23	380.88	423.95	481.32
2AF*	83.54	339.63	573.77	786.58	873.72	996.57	1175.78	1258.92	1379.10	1460.62	1591.21
2AA*											
2BF**	-85.87	264.95	538.58	776.97	861.28	985.65	1164.98	1228.14	1331.98	1399.84	1506.68
2BA**	-87.53	313.22	613.93	885.83	979.78	1115.96	1314.60	1384.51	1496.43	1572.46	1689.95

Note: Strain gages S25 and S26 were removed and 2AA* showed faulty readings. Successive * signs on the gage number represent the progressive distances between the notch tip and strain gage (see appendix C for details).

Table E-29. Strain survey raw data (run1) and phase 3 repairs (baseline for C-BE and CD-BE repairs)

Load Step	0	1	2	3	4	5	6	7	8	9	10
Pressure	0.05	0.61	1.40	1.98	2.74	3.39	4.08	4.62	5.35	5.95	6.58
Frame-1	-16.36	77.54	218.68	313.47	431.21	587.68	691.26	808.71	919.10	1031.23	1126.46
Frame-2	-23.32	78.74	185.71	359.77	429.16	613.49	711.61	784.07	915.78	1018.51	1122.07
Frame-3	2.11	111.50	231.11	342.82	450.78	586.91	759.68	739.72	914.40	1001.37	1089.13
Frame-4	30.40	79.30	203.27	375.62	420.96	616.39	739.13	777.42	968.39	978.41	1128.32
Frame-5	-7.34	104.21	233.21	366.03	429.34	600.16	749.42	771.36	901.01	1093.00	1131.85
Frame-6	24.96	82.65	219.33	351.13	445.41	625.18	715.34	794.11	911.30	996.12	1135.95
Frame-7	-8.77	101.55	199.00	341.26	457.81	623.30	660.60	779.85	944.48	977.07	1194.29
Frame-8	-16.12	115.11	245.88	320.59	471.63	613.13	695.40	783.86	915.44	1003.67	1161.12
Frame-9	-19.76	102.67	236.98	338.83	474.97	603.90	674.84	770.03	925.22	987.90	1155.25
Frame-10	-21.91	83.57	231.83	338.22	441.72	611.81	718.39	794.28	886.94	1068.93	1154.17
Frame-11	-55.32	94.63	183.61	347.22	404.35	549.74	728.81	823.56	925.96	1020.50	1106.11
Frame-12	-25.78	81.56	273.82	346.75	511.99	581.14	719.64	808.34	947.57	987.66	1206.77
Hoop-1	-62.63	715.53	1428.37	2208.77	2888.24	3529.53	4321.05	4896.96	5657.05	6362.71	7140.93
Hoop-2	49.83	752.94	1320.09	2247.29	2761.83	3711.07	4314.61	5054.45	5757.64	6387.46	7244.53
Hoop-3	6.23	718.04	1354.45	2149.08	2900.50	3662.41	4325.71	5089.30	5711.75	6488.50	7203.88
Hoop-4	-36.45	724.82	1324.39	2118.78	2777.60	3621.62	4396.27	5113.06	5765.38	6457.67	7155.42
Hoop-5	-26.59	746.53	1451.33	2172.74	2871.42	3559.24	4259.30	5029.75	5795.76	6486.24	7171.33
Hoop-6	12.91	709.40	1431.41	2223.15	2809.51	3517.92	4293.50	4879.68	5778.63	6342.08	7113.39
Hoop-7	-1.97	800.71	1399.59	2149.07	2747.25	3751.17	4282.73	4948.67	5721.04	6511.28	7149.56
Hoop-8	21.77	693.21	1320.85	2247.95	2699.68	3648.98	4363.33	5027.84	5721.67	6414.36	7092.32
Hoop-9	-25.07	709.13	1288.96	2123.90	2812.45	3536.44	4294.92	5006.15	5710.33	6469.02	7116.28
Hoop-10	10.25	708.82	1313.18	2230.61	2789.75	3696.84	4401.65	5004.61	5696.57	6431.82	7078.07
Hoop-11	165.34	631.12	1368.74	2015.96	2968.46	3742.92	4392.68	4987.51	5680.33	6437.25	7203.08
Hoop-12	-34.57	673.19	1457.37	2267.24	2921.42	3722.55	4493.09	5010.21	5840.37	6523.82	7301.73
Hoop-13	-31.34	714.81	1446.32	2163.43	2799.07	3633.56	4466.60	5022.94	5784.22	6324.91	7209.24
Hoop-14	-19.28	648.70	1500.18	2227.09	2864.91	3570.16	4332.69	5052.40	5750.24	6490.97	7393.00
Long-1	98.94	817.67	1301.93	2113.31	2862.28	3208.22	4147.37	4777.34	5311.17	5885.24	6522.88
Long-2	25.83	590.44	1418.62	2077.82	2540.08	3379.08	4153.21	4453.92	5174.96	6148.56	6689.70
Long-3	18.43	825.95	1267.57	1873.94	2822.30	3405.28	3933.80	4777.43	5461.88	6039.88	6657.86
Long-4	16.92	671.59	1281.89	2031.88	2824.65	3493.01	4019.84	4522.64	5200.50	5927.34	6665.25
Long-5	12.48	565.80	1501.81	2070.56	2835.69	3499.14	3848.63	4605.55	5352.53	5788.70	6613.93
Long-6	15.23	847.91	1490.04	2043.94	2779.39	3251.82	3947.85	4816.27	5200.52	6057.34	6604.73
Long-7	60.35	793.28	1358.49	1866.34	2849.68	3433.89	4241.41	4561.38	5222.47	6195.23	6534.49
Long-8	75.28	577.77	1295.20	1867.42	2611.99	3433.42	4125.82	4651.49	5270.11	6000.04	6804.32
S28	-212.54	120.49	304.06	390.65	465.92	538.70	607.81	658.72	724.21	778.74	845.01
S29	-154.16	176.42	365.26	458.37	538.91	616.58	690.23	745.14	814.77	874.43	944.49
S30	33.22	162.46	304.83	389.80	472.59	571.30	627.21	678.77	758.49	821.18	875.64
S31	-42.52	54.55	183.94	256.75	342.76	417.34	483.38	536.36	604.46	659.98	722.54
S34	-9.42	59.48	112.95	141.68	186.59	224.03	264.21	308.21	393.94	468.43	581.35
S35	173.45	-15.01	-168.77	-329.55	-567.67	-792.62	-998.88	-1174.33	-1344.58	-1490.99	-1579.64
IS28	142.45	15.22	-56.33	-80.43	-120.59	-132.25	-138.83	-138.28	-130.04	-118.76	-93.75
IS29	87.20	-29.61	-86.20	-96.94	-123.32	-121.49	-116.76	-106.02	-89.45	-70.19	-38.35
IS30	27.40	-31.18	-73.50	-82.27	-93.81	-83.53	-77.44	-64.85	-39.99	-13.96	21.54
IS31	203.42	78.50	17.52	13.89	-2.82	8.08	20.42	30.59	55.99	78.52	120.64
IS34	-36.68	11.35	36.70	59.33	79.33	104.40	127.85	147.44	170.17	191.17	215.89
IS35	-5.14	19.25	48.84	76.85	101.55	129.05	150.63	168.00	189.54	208.29	228.92
3BF	-311.58	58.98	323.08	499.09	687.46	869.02	1037.91	1181.68	1345.02	1489.94	1639.19
3BA	-280.56	52.00	310.21	485.71	680.68	865.74	1041.82	1187.45	1355.28	1503.88	1652.61
3DBF	-119.91	121.05	364.64	541.59	729.44	907.94	1070.72	1201.92	1360.99	1500.42	1646.89
3DBA	-97.64	101.85	326.27	507.27	699.77	884.81	1053.09	1188.98	1353.36	1496.55	1647.65

Table E-30. Strain survey raw data (run2) and phase 3 repairs (baseline for C-BE and CD-BE repairs)

Load Step	0	1	2	3	4	5	6	7	8	9	10
Pressure	-0.05	0.72	1.27	2.07	2.56	3.18	3.92	4.61	5.33	6.11	6.75
Frame-1	-53.36	165.36	232.48	341.44	431.24	612.62	714.53	788.28	916.32	1024.34	1175.49
Frame-2	-62.07	166.17	223.47	318.35	482.12	589.98	685.25	797.70	900.23	994.13	1117.24
Frame-3	-40.50	104.36	239.18	332.25	442.65	568.98	701.95	790.99	895.11	958.66	1114.84
Frame-4	-20.04	131.47	273.18	316.07	452.59	611.94	716.49	807.72	917.03	971.70	1118.32
Frame-5	-37.83	140.59	303.10	304.40	504.61	614.24	683.48	829.10	911.47	998.18	1136.21
Frame-6	-34.88	117.70	243.22	319.87	469.36	578.16	671.71	825.37	912.29	991.79	1156.12
Frame-7	-35.59	110.63	337.70	318.67	484.39	649.47	713.82	839.60	899.36	1022.67	1147.60
Frame-8	21.18	124.06	229.03	356.02	449.20	564.52	693.08	798.60	881.72	990.90	1128.93
Frame-9	-5.56	152.46	236.72	369.04	449.52	580.75	729.23	801.97	907.36	998.23	1121.38
Frame-10	0.61	152.01	257.08	329.08	474.60	617.44	690.59	863.49	876.82	993.03	1112.68
Frame-11	20.14	97.30	294.63	318.18	456.72	584.85	688.67	728.88	903.11	1055.07	1118.43
Frame-12	-30.32	67.13	179.26	402.33	489.83	548.12	737.12	881.29	931.51	961.06	1084.83
Hoop-1	-0.95	728.37	1531.92	2165.02	2856.45	3558.20	4280.19	5043.90	5777.44	6561.09	7153.63
Hoop-2	-116.55	683.30	1479.46	2050.24	2666.02	3563.98	4358.42	4963.19	5627.69	6572.41	7206.95
Hoop-3	44.80	783.06	1440.50	2029.64	2741.79	3604.18	4224.88	5012.15	5796.51	6461.09	7207.39
Hoop-4	-29.17	770.40	1377.21	2038.62	2840.22	3635.80	4206.35	5064.00	5827.81	6458.31	7206.29
Hoop-5	-26.58	701.72	1422.70	2138.36	2877.68	3555.29	4306.90	5022.56	5688.53	6467.10	7058.04
Hoop-6	-19.90	729.60	1480.78	2049.70	2784.82	3435.51	4442.05	5032.85	5790.24	6525.07	7098.80
Hoop-7	-30.57	740.08	1499.85	2120.25	2769.52	3425.40	4374.77	5059.52	5764.59	6404.65	7115.59
Hoop-8	-14.72	766.04	1496.01	2094.46	2896.98	3597.18	4291.65	5021.04	5764.88	6444.19	7071.13
Hoop-9	-41.22	665.92	1542.07	2053.68	2839.65	3621.89	4333.91	5195.13	5731.30	6336.83	7160.07
Hoop-10	6.69	730.00	1549.59	2098.85	2891.34	3568.15	4434.96	5140.20	5722.66	6334.70	7091.22
Hoop-11	315.74	815.81	1497.42	2124.50	2874.52	3553.73	4334.18	4988.01	5786.68	6430.64	7214.67
Hoop-12	-90.96	674.88	1610.20	1874.01	2645.19	3416.21	4159.63	4843.32	5992.60	6648.19	6807.62
Hoop-13	-24.02	860.94	1563.37	2090.06	2952.95	3596.27	4380.14	5250.21	5871.42	6369.43	7253.84
Hoop-14	2.75	670.58	1507.52	2072.72	3004.65	3708.88	4539.53	5060.25	5757.01	6425.55	7276.31
Long-1	21.99	778.14	1222.52	2154.72	2595.44	3304.04	3889.26	4543.63	5292.63	5967.24	6508.85
Long-2	22.82	604.80	1323.70	2110.17	2762.01	3176.61	4160.65	4584.29	5139.84	5898.35	6811.35
Long-3	-0.99	493.49	1227.66	2100.99	2839.12	3384.08	3995.81	4467.90	5127.65	5881.76	6665.77
Long-4	10.50	744.94	1170.99	1906.00	2688.66	3545.84	4002.95	4748.25	5340.68	5824.21	6548.46
Long-5	9.17	788.40	1138.17	1929.10	2622.40	3335.11	4216.87	4496.95	5101.77	6094.91	6770.77
Long-6	10.94	662.76	1285.31	1847.63	2548.33	3372.10	4006.03	4689.83	5413.94	5966.09	6656.21
Long-7	2.96	781.72	1226.97	2165.45	2727.87	3341.91	4145.91	4447.78	5068.91	5810.89	6665.41
Long-8	84.81	521.60	1354.09	2181.88	2562.52	3511.39	3451.78	4773.27	5537.96	5987.85	6497.07
S28	-346.03	169.17	300.77	392.73	453.56	519.87	600.72	660.67	728.51	795.16	854.66
S29	-241.96	224.39	365.90	465.12	529.50	599.71	684.58	749.09	821.01	894.56	957.91
S30	-20.52	192.99	291.73	399.93	455.75	547.34	633.81	702.01	775.35	857.57	912.50
S31	-79.13	83.82	168.50	265.57	323.11	390.30	474.40	536.95	604.31	673.71	731.74
S34	-33.61	78.22	122.21	165.66	192.90	230.21	280.24	338.75	414.75	512.31	621.41
S35	310.47	-1.97	-101.18	-326.96	-478.06	-691.17	-929.08	-1137.22	-1299.12	-1480.66	-1581.37
IS28	217.11	7.92	-36.61	-91.92	-111.97	-126.78	-133.91	-137.37	-124.41	-111.29	-89.72
IS29	148.33	-37.80	-69.27	-109.12	-117.46	-118.76	-113.86	-107.48	-85.65	-62.74	-35.43
IS30	52.39	-39.27	-60.54	-98.48	-93.19	-91.67	-78.27	-67.22	-36.54	-12.82	14.72
IS31	164.93	118.46	76.33	18.24	21.87	18.97	30.59	43.66	62.31	87.97	115.53
IS34	-63.57	14.84	34.30	55.02	71.01	93.47	122.37	143.72	168.66	194.59	218.02
IS35	-4.64	22.06	51.51	69.74	96.09	119.05	145.80	165.06	189.04	207.99	224.80
3BF	-405.50	91.75	298.85	506.68	643.59	815.70	1009.26	1175.68	1340.01	1517.76	1664.15
3BA	-390.34	80.23	280.88	495.04	631.58	806.15	1007.50	1176.95	1347.59	1531.39	1680.72
3DBF	-165.96	156.74	358.61	543.17	696.92	857.12	1047.41	1201.38	1364.34	1520.17	1655.63
3DBA	-134.28	131.14	325.78	508.63	666.68	832.52	1027.68	1188.25	1356.89	1518.24	1656.91

Table E-31. Strain survey raw data (run3) and phase 3 repairs (baseline for C-BE and CD-BE repairs)

Load Step	0	1	2	3	4	5	6	7	8	9	10
Pressure	0.04	0.66	1.38	2.00	2.61	3.21	3.91	4.58	5.25	5.97	6.84
Frame-1	52.10	97.91	248.61	263.20	496.96	603.74	675.35	827.91	930.87	1044.55	1137.46
Frame-2	-3.85	129.82	220.91	332.01	453.28	572.21	681.28	802.07	927.44	1021.83	1128.58
Frame-3	21.61	85.95	158.85	283.21	418.49	582.49	674.65	786.20	893.15	983.15	1147.16
Frame-4	-4.89	135.76	178.69	326.00	446.53	623.41	703.58	764.90	923.99	985.56	1193.51
Frame-5	-0.12	119.44	178.81	371.62	442.83	572.36	700.87	798.61	951.22	1015.47	1109.14
Frame-6	27.95	123.28	207.67	290.66	468.36	608.40	686.71	779.26	944.52	999.37	1126.86
Frame-7	-11.29	129.96	227.92	307.57	501.47	576.67	693.72	789.53	892.43	990.45	1136.69
Frame-8	-9.51	124.85	213.66	310.23	455.38	586.98	665.75	770.62	891.56	981.96	1157.64
Frame-9	0.92	176.01	240.66	286.54	459.09	589.96	700.90	771.70	907.97	988.83	1155.04
Frame-10	-14.17	135.46	213.17	315.28	436.94	630.70	703.97	756.69	920.02	1002.66	1113.99
Frame-11	-4.14	137.44	188.88	367.15	511.71	505.78	737.89	777.50	971.36	1079.15	1154.93
Frame-12	20.51	71.68	240.73	333.90	521.40	566.25	667.68	771.99	900.66	992.50	1129.35
Hoop-1	-60.81	788.24	1334.32	2217.40	2842.22	3646.72	4157.82	5083.81	5685.50	6440.71	7221.47
Hoop-2	-52.16	710.14	1338.24	2209.27	2841.67	3694.23	4173.29	5041.92	5694.44	6453.67	7316.83
Hoop-3	-16.56	707.66	1498.51	2204.76	2831.50	3610.83	4220.53	4887.66	5863.71	6300.89	7115.17
Hoop-4	-31.00	728.60	1484.57	2263.71	2887.75	3499.17	4230.95	4911.36	5626.72	6303.22	7097.98
Hoop-5	-1.42	699.93	1471.40	2170.51	2811.42	3605.27	4208.97	5020.76	5809.56	6371.16	7206.21
Hoop-6	12.91	731.42	1402.52	2133.36	2843.46	3522.69	4125.77	4901.56	5708.77	6309.25	7274.58
Hoop-7	-23.42	777.63	1399.87	2196.91	2803.78	3510.87	4173.69	5018.40	5759.80	6445.13	7103.78
Hoop-8	14.48	737.00	1357.34	2152.85	2795.09	3503.36	4232.84	5027.84	5700.34	6275.71	7174.01
Hoop-9	7.24	714.52	1518.73	2202.67	3001.50	3723.51	4227.56	4867.93	5662.43	6285.94	7126.68
Hoop-10	-11.08	817.25	1304.29	2134.40	3040.94	3681.21	4249.66	5018.83	5777.13	6229.20	6999.49
Hoop-11	149.03	776.11	1254.57	1988.57	2914.68	3654.48	4328.31	4951.27	5619.27	6372.01	7079.46
Hoop-12	-7.27	727.77	1348.20	2077.79	2645.45	3417.23	4006.38	4981.10	5688.10	6363.73	7201.30
Hoop-13	-60.60	780.64	1321.97	2170.53	2741.11	3802.19	4365.08	4876.65	5623.85	6317.60	7049.74
Hoop-14	-11.94	780.82	1448.79	2028.68	2770.06	3673.29	4282.17	5045.06	5684.74	6256.10	7255.01
Long-1	18.01	832.18	1159.13	2068.94	2784.80	3434.58	3875.00	4564.23	5320.76	6074.02	6777.43
Long-2	28.34	719.61	1221.89	2175.99	2600.29	3214.48	4078.66	4519.13	5486.20	6185.18	6808.84
Long-3	16.75	678.49	1444.62	1977.88	2802.08	3360.35	3844.33	4760.65	5382.04	5862.95	6779.18
Long-4	8.95	520.89	1293.98	2111.25	2664.20	3279.48	4140.00	4773.48	5284.71	5882.35	6483.52
Long-5	6.34	758.83	1138.40	1807.20	2464.20	3492.88	3935.13	4909.26	5537.26	6103.53	6770.29
Long-6	14.98	827.22	1526.01	2162.39	2805.23	3254.78	3899.64	4567.50	5239.38	6132.52	6578.24
Long-7	4.98	784.22	1417.04	2292.92	2625.45	3339.90	4140.89	4427.95	5152.24	6049.97	6566.71
Long-8	43.45	582.65	1316.48	2003.48	2706.70	3217.18	3795.08	4289.89	4951.04	5878.27	6760.62
S28	-204.86	167.98	307.80	392.69	459.04	539.66	590.93	655.67	719.78	779.15	858.99
S29	-150.49	223.15	371.49	462.99	535.37	618.93	674.04	744.03	812.17	877.51	963.04
S30	41.23	195.15	309.13	381.05	476.17	550.35	609.78	697.58	767.36	824.81	929.38
S31	-39.67	72.56	184.26	256.18	325.48	402.99	463.47	532.59	597.64	658.12	736.01
S34	-5.24	68.21	140.01	158.94	203.66	236.26	283.84	346.17	411.48	495.53	617.17
S35	211.49	-6.58	-138.78	-312.65	-488.05	-700.48	-915.72	-1120.42	-1298.16	-1470.48	-1606.72
IS28	138.85	4.64	-57.05	-84.43	-114.19	-121.69	-141.20	-139.72	-130.43	-121.13	-91.93
IS29	83.58	-37.25	-84.73	-99.11	-116.21	-111.50	-122.58	-108.92	-89.65	-73.46	-35.98
IS30	23.50	-39.95	-77.02	-88.71	-93.85	-88.18	-86.39	-64.48	-42.54	-23.00	13.67
IS31	161.35	164.92	47.28	17.52	8.08	10.98	8.80	33.49	61.81	74.16	106.84
IS34	-41.36	15.39	33.34	56.11	72.66	100.66	116.51	140.48	164.58	187.45	220.56
IS35	-5.05	23.46	44.53	72.86	96.11	122.60	140.63	164.10	185.24	202.50	226.34
3BF	-329.88	84.46	318.11	497.94	654.46	837.89	990.59	1162.64	1326.91	1490.85	1679.96
3BA	-300.21	72.70	299.82	482.22	639.86	828.96	988.92	1165.06	1333.09	1504.61	1698.27
3DBF	-120.40	153.86	360.03	537.91	702.69	879.08	1025.17	1190.92	1345.65	1492.43	1666.85
3DBA	-97.53	129.86	325.34	505.37	674.23	853.50	1004.41	1177.10	1337.35	1489.49	1669.91

Table E-32. Strain survey raw data (run1) and phase 3 repairs (10,000 cycles for C-BE and CD-BE repairs)

Load Step	0	1	2	3	4	5	6	7	8	9	10
Pressure	-0.04	0.65	1.43	2.07	2.57	3.43	4.11	4.63	5.45	5.88	6.56
Frame-1	21.52	190.04	218.99	303.65	445.87	544.64	716.80	784.64	899.65	1014.77	1114.05
Frame-2	-3.10	104.62	224.16	343.72	449.93	563.84	673.95	790.29	905.25	1024.63	1143.78
Frame-3	26.64	113.32	247.74	343.10	477.43	558.15	690.83	769.42	892.09	1017.56	1130.05
Frame-4	49.48	121.91	203.65	350.52	434.24	558.79	665.52	787.50	881.21	1048.38	1125.92
Frame-5	16.04	122.83	177.41	352.19	431.67	578.89	670.67	777.15	879.53	1048.67	1135.22
Frame-6	-27.98	190.39	242.37	297.14	462.58	575.73	684.14	787.66	905.72	1056.59	1123.51
Frame-7	22.01	91.31	188.28	310.76	488.01	559.34	691.83	796.53	891.17	1043.11	1152.47
Frame-8	-4.09	156.60	215.66	298.22	493.68	601.84	709.41	795.71	899.46	1077.62	1117.00
Frame-9	2.99	171.89	198.03	279.96	479.62	558.88	714.25	799.42	897.62	1045.50	1142.96
Frame-10	37.67	104.84	236.86	328.93	503.11	560.06	657.70	794.08	869.36	1023.39	1135.70
Frame-11	-15.99	119.07	192.14	336.29	457.21	591.34	677.07	793.75	933.64	921.69	1125.67
Frame-12	-20.70	207.79	182.27	351.09	406.47	521.66	727.83	795.02	853.97	1050.19	1065.18
Hoop-1	106.88	756.16	1503.40	2060.20	2862.42	3607.27	4324.10	4750.36	5732.90	6321.79	7141.74
Hoop-2	38.20	599.92	1505.11	2077.57	2949.36	3489.03	4244.38	4938.55	5648.27	6533.30	7061.13
Hoop-3	29.51	713.19	1395.13	2117.38	2926.11	3628.49	4335.40	4929.74	5556.83	6445.16	7069.36
Hoop-4	-35.53	667.53	1312.45	2197.17	2911.71	3570.59	4259.53	4886.35	5710.64	6267.79	7167.23
Hoop-5	49.83	727.59	1387.37	2119.06	2898.07	3611.21	4379.30	4918.68	5737.98	6427.80	7238.76
Hoop-6	24.66	823.17	1413.85	2128.49	2914.82	3632.53	4486.18	4883.65	5812.93	6202.48	7179.85
Hoop-7	113.54	726.65	1464.90	2120.92	2954.50	3574.18	4320.01	5081.57	5790.71	6680.44	7038.02
Hoop-8	48.34	807.27	1486.08	2164.60	3025.40	3573.72	4303.19	4967.32	5718.47	6419.03	7162.65
Hoop-9	39.56	753.95	1418.21	2087.58	2812.46	3339.32	4218.60	5012.04	5618.23	6393.64	7209.62
Hoop-10	53.60	769.87	1470.29	2161.53	2877.52	3703.24	4307.23	4956.03	5668.25	6437.84	7128.52
Hoop-11	36.37	757.61	1384.76	2120.36	2830.45	3568.99	4328.01	4933.34	5677.65	6406.14	7110.37
Hoop-12	35.17	655.53	1228.71	2138.21	3018.43	3477.87	4365.40	4911.23	5609.33	6453.46	7122.24
Hoop-13	0.05	651.04	1367.99	2033.46	2954.79	3694.58	4352.57	4871.95	5771.14	6341.67	7079.72
Hoop-14	-16.93	724.37	1590.60	2089.54	2889.27	3631.58	4409.30	4901.10	5832.75	6471.29	7211.87
Long-1	-6.99	792.51	1354.36	1907.97	2753.44	3472.50	4095.00	4577.37	5232.84	6064.46	6577.94
Long-2	18.98	710.36	1290.65	2035.40	2598.19	3365.88	4100.21	4622.92	5474.34	6093.56	6767.70
Long-3	43.04	626.51	1183.84	1904.60	2640.61	3333.19	3882.90	4625.38	5418.65	6063.54	6681.58
Long-4	8.92	622.90	1439.18	1995.53	2500.35	3142.29	4170.94	4860.28	5141.97	5842.66	6773.58
Long-5	10.93	437.13	1160.15	2030.01	2509.01	3125.41	3941.93	4704.77	5341.04	5975.91	6793.85
Long-6	-0.45	782.36	1052.30	1758.84	2611.63	3247.42	3951.59	4664.13	5405.60	6143.58	6611.85
Long-7	0.41	848.46	1551.03	1825.59	2548.11	3295.30	4032.67	4390.72	5356.62	5730.97	6885.74
Long-8	12.36	688.31	1488.81	2044.13	3040.92	3326.22	4272.04	4669.43	5115.15	5990.32	6591.05
S28	-25.02	172.04	272.67	337.01	381.90	453.97	517.25	546.08	619.25	664.18	731.97
S29	-24.07	184.62	292.07	358.84	403.73	471.27	538.53	568.10	648.12	693.45	763.23
S30	-1.53	132.07	248.99	331.98	367.54	436.02	522.29	558.91	646.88	699.56	785.86
S31	418.46	503.39	595.58	662.30	695.75	760.28	832.14	862.62	939.65	985.29	1054.75
S34	337.29	1063.40	1316.01	1409.50	1555.44	1854.20	2003.25	2275.55	2709.66	3197.43	3797.23
S35	265.60	298.37	430.57	601.12	705.70	949.42	1269.68	1553.52	2039.85	2512.11	3107.22
IS28	-13.62	-106.36	-170.07	-206.57	-203.12	-199.26	-220.76	-226.55	-226.76	-229.89	-227.19
IS29	-3.07	-75.68	-118.08	-140.81	-128.81	-116.79	-126.80	-123.52	-110.98	-98.42	-84.39
IS30	7.79	-59.20	-108.38	-117.92	-105.16	-97.06	-95.46	-78.60	-64.75	-39.47	-16.88
IS31	937.65	925.34	895.66	898.20	920.85	940.77	935.78	950.12	953.76	970.41	980.43
IS34	22.59	20.09	26.72	33.97	44.72	60.45	72.88	77.14	98.15	113.88	146.00
IS35	4.06	13.02	21.61	37.18	53.97	65.77	76.18	85.41	95.60	106.90	120.49
3BF**	-60.87	152.06	337.92	478.91	575.54	686.14	853.50	934.72	1103.29	1220.42	1390.25
3BA**	-49.42	151.26	341.37	479.78	564.83	668.61	833.33	907.27	1077.54	1187.43	1351.88
3DBF*	-38.27	184.33	379.49	548.97	668.41	805.71	989.58	1092.78	1274.43	1406.03	1580.86
3DBA*	-23.40	171.46	362.70	533.10	655.04	788.61	978.20	1083.22	1269.14	1403.19	1581.78

Note: Successive * signs on the gage number represent the progressive distances between the notch tip and strain gage (see appendix C for details).

Table E-33. Strain survey raw data (run2) and phase 3 repairs (10,000 cycles for C-BE and CD-BE repairs)

Load Step	0	1	2	3	4	5	6	7	8	9	10
Pressure	0.05	0.65	1.27	2.14	2.67	3.20	4.21	4.79	5.42	5.94	6.56
Frame-1	19.64	78.77	288.55	364.25	481.39	588.44	613.52	772.92	879.04	1033.52	1196.99
Frame-2	1.52	115.58	217.79	332.59	460.55	574.53	669.05	778.80	922.49	1030.96	1132.19
Frame-3	-51.40	145.40	245.33	348.71	449.21	546.99	646.03	797.52	886.15	1043.21	1114.94
Frame-4	26.02	116.34	210.04	294.65	483.18	584.91	655.47	793.76	921.52	1067.49	1127.03
Frame-5	-7.40	85.87	244.88	302.53	476.78	559.13	665.48	783.87	923.56	1023.00	1136.39
Frame-6	29.48	85.16	176.98	337.71	454.03	579.18	650.08	762.07	922.92	1035.02	1147.32
Frame-7	16.62	226.26	270.56	318.43	429.73	566.92	651.65	759.02	890.40	1028.92	1181.12
Frame-8	25.50	86.06	229.75	343.67	460.70	554.67	669.96	746.77	927.50	984.88	1160.31
Frame-9	9.13	59.37	250.84	355.42	445.01	555.85	664.45	734.49	903.67	1026.43	1166.64
Frame-10	0.61	128.61	250.34	329.03	454.77	553.38	674.93	761.06	908.99	1034.26	1132.74
Frame-11	-19.49	108.47	191.16	330.63	458.95	546.15	620.73	790.52	901.98	1077.64	1151.80
Frame-12	66.48	102.33	280.72	318.39	400.34	622.12	730.51	690.02	862.46	1005.47	1110.46
Hoop-1	18.00	810.73	1523.65	2101.91	2798.65	3502.07	4298.71	4998.36	5658.54	6451.76	7064.85
Hoop-2	61.46	660.87	1376.59	2040.00	2959.81	3623.20	4035.06	4916.59	5782.43	6439.61	7241.13
Hoop-3	57.56	648.46	1532.17	2147.18	2946.86	3591.68	4335.40	4922.24	5730.39	6455.03	7130.02
Hoop-4	44.41	673.11	1547.11	2244.41	2909.60	3601.47	4206.84	4904.03	5647.05	6334.39	7291.88
Hoop-5	21.06	689.97	1477.55	2185.58	2770.13	3532.11	4203.10	5029.65	5694.83	6410.98	7113.98
Hoop-6	77.54	770.45	1428.72	2256.11	2706.68	3391.89	4194.46	4946.97	5521.24	6396.95	7277.59
Hoop-7	33.10	671.37	1511.68	2260.35	2802.25	3609.93	4412.97	5022.07	5715.63	6268.60	7214.30
Hoop-8	41.04	719.77	1369.04	2296.18	2704.61	3485.44	4135.33	4967.32	5674.68	6433.62	7208.59
Hoop-9	77.26	710.94	1419.73	2046.50	2906.08	3518.15	4285.02	4906.13	5691.82	6343.38	7227.93
Hoop-10	5.61	764.61	1356.26	2126.20	2881.36	3581.64	4200.58	4948.92	5696.69	6366.75	7121.77
Hoop-11	50.86	757.68	1417.09	2126.01	2859.72	3599.09	4255.52	4969.59	5655.90	6426.08	7272.00
Hoop-12	6.06	766.58	1521.34	2160.26	3047.84	3549.95	4358.13	4940.34	5565.67	6533.51	7211.71
Hoop-13	7.37	709.62	1396.97	2136.08	2838.05	3657.27	4038.02	4959.73	5580.97	6400.18	7250.10
Hoop-14	-16.93	687.74	1524.24	2119.11	2838.18	3498.75	4167.07	5047.91	5612.56	6427.25	7404.90
Long-1	21.32	579.95	1478.54	2059.12	2682.99	3412.75	4034.58	4579.00	5415.70	5914.98	6783.80
Long-2	13.97	881.98	1379.58	2075.07	2571.10	3269.25	4039.17	4619.37	5189.41	5882.13	6764.69
Long-3	54.33	686.74	1221.12	2102.41	2551.41	3305.77	3916.38	4642.15	5296.10	5965.25	6602.23
Long-4	0.06	562.69	1237.25	2175.25	2572.56	3478.54	4163.15	4691.02	5567.99	6227.79	6520.52
Long-5	2.90	784.17	1369.16	2209.79	2824.54	3320.93	4002.41	4605.89	5301.49	5901.87	6589.48
Long-6	-9.28	555.62	1086.93	1989.50	2621.46	3352.80	4027.68	4652.74	5359.40	6012.89	6757.43
Long-7	59.57	788.13	1520.27	2247.30	2394.79	3140.16	3936.64	4879.05	5071.39	6268.20	6891.79
Long-8	9.34	659.56	1299.35	1891.96	2765.93	3126.75	3924.32	4387.07	5665.11	6078.63	6341.23
S28	63.35	191.44	283.23	356.11	407.12	449.22	520.78	574.52	631.28	675.61	738.45
S29	34.26	180.02	279.11	358.11	407.64	445.24	524.42	582.80	645.56	694.06	764.56
S30	31.10	131.33	223.59	339.95	376.75	407.74	513.41	575.82	650.13	705.25	780.27
S31	446.82	509.15	584.63	673.18	705.12	740.69	827.78	883.03	947.35	992.64	1059.64
S34	124.31	690.42	957.81	828.07	1146.79	1502.36	1553.01	1862.47	2293.81	2897.44	3619.55
S35	256.52	265.93	354.78	491.34	641.54	858.02	1185.02	1495.41	1953.50	2414.58	2980.74
IS28	-101.81	-163.49	-194.38	-259.59	-247.09	-237.87	-261.42	-257.66	-256.94	-252.91	-230.46
IS29	-40.75	-92.59	-113.70	-162.64	-142.26	-125.89	-140.45	-128.27	-119.32	-107.16	-76.60
IS30	-18.39	-64.20	-94.87	-130.87	-109.74	-90.19	-100.65	-86.11	-72.91	-46.30	-12.98
IS31	936.74	934.51	930.11	904.83	934.37	966.92	948.90	957.66	964.41	974.78	998.99
IS34	44.86	39.28	48.75	51.52	63.54	70.98	84.45	97.56	111.77	125.18	154.33
IS35	5.14	19.48	32.97	42.79	60.75	73.96	81.24	91.62	99.69	111.93	127.12
3BF**	6.82	172.72	331.48	514.02	597.25	661.82	852.04	982.19	1124.72	1250.18	1393.87
3BA**	15.11	175.70	331.55	514.03	587.97	639.25	831.34	959.92	1097.87	1210.56	1353.28
3DBF*	-0.29	185.58	359.10	565.32	680.88	774.46	974.14	1121.06	1278.77	1419.61	1586.93
3DBA*	4.45	173.93	343.56	550.49	666.38	757.64	962.44	1111.58	1273.10	1417.09	1587.28

Successive * signs on the gage number represent the progressive distances between the notch tip and strain gage (see appendix C for details).

Table E-34. Strain survey raw data (run3) and phase 3 repairs (10,000 cycles for C-BE and CD-BE repairs)

Load Step	0	1	2	3	4	5	6	7	8	9	10
Pressure	-0.03	0.71	1.42	1.95	2.80	3.25	3.94	4.64	5.46	6.07	6.68
Frame-1	44.42	168.51	208.52	373.92	403.10	562.23	654.12	806.86	854.93	988.21	1110.33
Frame-2	3.51	113.51	221.19	348.29	445.37	558.38	715.78	779.70	905.89	990.63	1109.81
Frame-3	28.26	102.33	236.45	344.18	469.35	558.11	677.56	783.87	877.81	987.59	1085.32
Frame-4	-49.80	157.62	168.76	379.40	457.66	555.90	722.95	817.68	904.82	1000.10	1101.93
Frame-5	20.37	120.16	191.80	366.48	468.75	568.97	693.54	815.86	862.66	999.01	1119.34
Frame-6	-42.89	167.56	297.51	353.65	419.78	574.38	676.81	813.72	884.88	953.03	1181.66
Frame-7	105.43	118.79	183.24	398.33	435.29	559.28	682.82	783.53	890.21	957.60	1120.17
Frame-8	-3.99	122.99	210.71	399.39	431.33	618.42	652.01	822.34	901.56	945.16	1161.08
Frame-9	-26.55	127.25	204.39	379.20	413.61	604.46	667.16	784.03	868.52	985.84	1121.61
Frame-10	37.76	112.08	235.28	356.46	354.45	580.41	749.11	744.74	933.33	1006.17	1094.51
Frame-11	43.21	137.11	248.05	326.09	482.33	584.23	678.69	803.00	886.33	1022.46	1122.96
Frame-12	-76.92	55.71	251.31	350.63	437.94	626.18	657.14	819.34	798.17	950.32	1201.59
Hoop-1	-50.93	607.44	1425.27	2104.15	2941.94	3670.75	4338.18	4969.34	5683.93	6447.49	7256.02
Hoop-2	-65.57	650.01	1411.95	2196.08	2791.63	3682.24	4276.16	4884.39	5703.72	6367.41	7087.97
Hoop-3	-37.11	814.87	1351.17	2184.43	2789.07	3588.18	4247.32	4873.15	5572.61	6349.21	7186.84
Hoop-4	129.80	851.01	1408.59	2208.51	2907.79	3528.80	4171.91	5120.22	5745.16	6491.81	7243.55
Hoop-5	-2.31	741.97	1345.88	2203.99	2906.77	3577.05	4177.51	4993.70	5637.30	6356.41	7157.84
Hoop-6	24.66	721.08	1271.52	2081.51	2910.88	3579.66	4132.05	5114.69	5734.54	6436.42	7218.14
Hoop-7	-86.68	817.82	1441.52	2267.95	2814.76	3611.72	4253.44	4950.57	5654.86	6434.22	7057.68
Hoop-8	33.73	675.98	1405.66	2164.17	2777.31	3551.47	4266.27	4989.22	5703.87	6383.81	7199.14
Hoop-9	52.12	703.76	1419.87	2153.57	2965.01	3602.87	4322.28	5071.28	5356.17	6527.77	7268.85
Hoop-10	-24.61	778.83	1331.51	2185.98	2895.29	3644.21	4225.04	5080.45	5702.02	6483.57	7178.29
Hoop-11	-36.12	734.12	1380.99	2056.52	2826.82	3565.01	4229.73	5042.08	5710.27	6436.42	7133.92
Hoop-12	-63.07	728.37	1385.04	1968.63	2705.55	3746.80	4132.11	5165.95	5507.46	6338.30	6889.40
Hoop-13	-21.89	694.99	1367.85	2172.01	2757.32	3621.06	4169.28	5069.46	5851.60	6438.04	7335.70
Hoop-14	-9.59	812.53	1406.96	2103.80	2992.02	3616.54	4203.35	4952.48	5671.27	6501.95	7226.55
Long-1	19.45	582.81	1390.15	2052.75	2566.51	3410.51	3961.89	4615.26	5462.56	6161.83	6531.15
Long-2	13.21	584.84	1249.52	2106.08	2771.26	3427.32	3959.52	4522.81	5244.10	5949.28	6581.61
Long-3	-3.94	516.58	1601.18	1868.83	2685.93	3403.19	3955.06	4664.20	5390.60	6047.96	6684.94
Long-4	-13.46	826.69	1225.80	2190.09	2758.09	3337.07	4053.93	4492.03	5420.52	6046.84	6699.13
Long-5	20.64	820.45	1361.42	1866.99	2649.76	3319.13	4041.99	4710.44	5234.84	5892.40	6612.66
Long-6	-3.48	627.34	1299.78	2201.85	2640.65	3338.25	3924.34	4662.58	5459.09	6076.17	6766.77
Long-7	0.16	488.35	1532.65	1830.05	2769.17	3590.35	3819.19	4950.04	5154.72	5966.79	6517.94
Long-8	18.87	618.49	1405.39	2025.05	2757.14	3275.33	4164.91	4567.41	5468.61	5849.97	6832.97
S28	41.08	234.10	297.93	358.09	415.01	466.15	519.01	575.47	639.55	692.40	747.54
S29	-11.37	205.48	284.36	346.86	406.03	454.62	512.36	572.19	647.64	707.44	769.58
S30	5.54	157.26	248.63	316.78	386.74	421.20	495.47	562.04	653.88	724.82	792.26
S31	435.89	538.24	606.47	663.09	720.07	758.91	819.80	877.95	956.25	1015.15	1075.39
S34	-16.00	483.77	600.71	721.56	792.72	1192.48	1343.81	1676.93	2101.15	2742.74	3434.36
S35	232.46	196.40	269.60	428.20	562.66	773.07	1058.30	1378.87	1850.84	2386.91	2897.29
IS28	-119.51	-190.98	-253.96	-260.72	-278.33	-262.08	-277.21	-273.59	-268.22	-261.63	-245.97
IS29	-36.37	-102.79	-150.10	-151.20	-160.03	-135.00	-141.54	-130.63	-122.98	-108.98	-84.60
IS30	-18.16	-75.84	-122.25	-130.02	-133.00	-100.93	-106.83	-80.38	-77.20	-51.61	-27.43
IS31	937.51	947.95	914.00	924.98	932.14	968.10	957.43	978.04	967.42	982.72	999.06
IS34	55.97	54.70	51.39	62.91	70.49	81.82	90.30	102.69	120.68	138.38	165.28
IS35	8.90	24.87	33.02	47.09	60.14	78.85	84.59	99.58	104.86	117.32	130.94
3BF**	-14.40	205.48	361.15	499.44	624.62	699.75	843.26	968.47	1140.67	1286.03	1421.40
3BA**	-4.56	206.89	363.12	497.41	616.90	678.64	822.64	941.07	1117.66	1250.98	1380.92
3DBF*	-35.36	217.04	388.39	537.76	691.87	805.24	955.97	1120.15	1290.11	1451.96	1609.14
3DBA*	-23.94	202.11	371.71	522.65	676.25	790.32	942.89	1109.95	1284.40	1449.87	1610.50

Successive * signs on the gage number represent the progressive distances between the notch tip and strain gage (see appendix C for details).

Table E-35. Strain survey raw data (run1) and phase 3 repairs (20,000 cycles for C-BE and CD-BE repairs)

Load Step	0	1	2	3	4	5	6	7	8	9	10
Pressure	0.03	0.62	1.35	1.96	2.56	3.39	4.00	4.62	5.42	6.03	6.65
Frame-1	-15.80	121.72	228.54	380.77	432.06	597.15	674.54	739.06	895.37	1021.59	1114.75
Frame-2	12.74	135.96	274.22	329.85	467.73	614.14	656.52	791.30	886.93	987.39	1129.44
Frame-3	29.86	117.05	183.36	343.43	448.97	564.53	687.35	830.24	896.98	977.41	1109.09
Frame-4	27.11	149.61	262.94	368.50	459.80	588.97	608.47	766.82	887.04	954.74	1130.62
Frame-5	53.19	98.10	205.01	306.32	495.20	520.30	676.40	809.29	897.85	1013.12	1171.32
Frame-6	50.76	48.68	145.88	277.22	462.61	586.70	641.75	786.14	911.52	990.26	1091.42
Frame-7	-12.52	134.40	240.59	404.00	427.95	596.54	719.10	801.17	884.94	1036.57	1110.39
Frame-8	60.53	139.81	204.88	320.07	477.12	588.35	643.71	794.20	923.65	965.13	1110.55
Frame-9	18.70	146.17	211.28	322.19	479.72	564.37	639.61	798.07	894.85	1037.24	1118.44
Frame-10	-11.49	164.51	282.95	318.24	494.66	597.95	669.28	817.26	859.49	1050.26	1157.52
Frame-11	48.22	116.15	262.36	331.25	458.72	545.04	648.45	837.39	908.25	1117.00	1135.15
Frame-12	-17.20	150.04	323.48	372.48	461.57	592.47	612.04	848.70	906.27	1008.14	1134.33
Hoop-1	16.98	805.77	1444.49	2058.98	2929.46	3676.62	4306.33	5063.95	5566.84	6474.33	7021.41
Hoop-2	27.26	665.77	1524.74	2154.07	2833.80	3588.65	4315.31	4908.74	5692.78	6498.45	7177.59
Hoop-3	20.94	743.04	1448.05	2091.07	2844.80	3570.48	4228.23	5070.93	5737.59	6430.68	7069.90
Hoop-4	201.26	633.49	1536.66	2068.59	2844.23	3501.81	4167.06	5089.43	5747.58	6365.88	7048.32
Hoop-5	19.86	783.76	1488.79	2234.49	3002.06	3456.86	4219.46	4999.19	5616.32	6256.95	7061.73
Hoop-6	68.51	618.95	1461.48	2255.98	2766.39	3663.25	4237.89	4848.13	5807.55	6333.23	6883.17
Hoop-7	-29.18	751.82	1488.58	2233.61	3016.46	3650.97	4307.36	5030.80	5683.75	6372.58	7312.19
Hoop-8	53.30	753.93	1505.34	2169.56	2862.82	3746.19	4190.96	5080.75	5642.60	6474.43	7146.44
Hoop-9	78.36	724.61	1526.72	2248.44	2991.54	3501.66	4352.11	4940.35	5708.51	6281.04	7067.85
Hoop-10	20.12	756.02	1573.37	2080.07	2870.99	3580.51	4175.57	4978.44	5771.06	6384.18	7154.41
Hoop-11	19.95	777.51	1455.04	2143.81	2845.12	3664.59	4340.16	4973.93	5579.13	6470.63	7165.34
Hoop-12	34.05	698.15	1363.78	2138.92	2822.96	3390.90	4372.95	4983.72	5609.48	6293.45	7152.76
Hoop-13	72.99	599.69	1367.51	2230.75	3028.02	3657.43	4286.10	4943.91	5770.36	6487.10	7072.91
Hoop-14	8.66	691.31	1439.74	2107.79	2790.37	3634.79	4295.00	5065.15	5556.86	6452.20	7179.46
Long-1	11.09	530.65	1309.43	2088.63	2549.01	3248.32	4129.68	4652.28	5499.66	5873.29	6762.31
Long-2	8.11	508.70	1216.95	2084.97	2529.63	3109.03	4073.29	4688.50	5499.12	6181.61	6665.45
Long-3	6.43	708.38	1357.62	1841.37	2489.86	3339.82	3917.97	4518.26	5413.26	5858.49	6499.61
Long-4	23.56	865.19	1573.50	2068.01	2728.36	3430.50	4189.57	4594.87	5357.03	6046.70	6838.54
Long-5	15.05	609.23	1345.13	2235.89	2609.14	3019.36	4032.62	4545.43	5509.39	5923.84	6606.32
Long-6	25.59	519.35	1147.55	1876.98	2952.79	3280.60	3763.18	4468.36	5259.09	6283.54	6724.86
Long-7	32.49	617.05	1369.05	1922.88	2591.52	3100.11	3818.55	4927.75	5543.83	5862.33	6495.29
Long-8	1.53	773.06	1660.18	1913.85	2205.50	3347.33	3931.92	4761.31	5081.12	6178.80	6659.20
S28	80.85	194.31	297.65	374.26	442.85	508.34	553.94	605.63	647.19	678.40	706.07
S29	50.02	177.29	274.67	339.95	394.93	452.66	490.20	542.08	593.01	636.07	682.75
S30	100.01	197.55	305.86	388.94	474.04	542.10	582.35	658.29	725.60	785.30	848.30
S31	41.90	85.98	153.44	207.14	267.43	317.91	350.41	404.19	454.94	495.63	541.97
S34	1835.40	2977.61	3838.70	4630.95	5469.54	6280.68	7132.59	8356.08	9578.36	11250.52	13237.86
S35	575.59	1061.64	1611.51	2108.98	2647.74	3205.73	3777.18	4676.67	5593.12	6709.03	8119.02
IS28	-94.78	-173.44	-257.83	-317.80	-360.04	-379.43	-387.43	-404.12	-396.13	-388.32	-365.26
IS29	-61.16	-120.47	-170.87	-198.20	-209.26	-207.26	-197.03	-198.51	-191.25	-184.72	-175.39
IS30	-106.33	-156.36	-221.04	-263.67	-296.75	-313.97	-306.64	-322.48	-319.01	-310.87	-290.69
IS31	-52.35	-35.84	-33.52	-30.49	-19.68	16.17	26.51	49.29	66.23	71.23	89.99
IS34	-23.67	-30.74	-25.85	-16.01	-3.08	13.52	27.93	48.65	75.82	99.32	129.17
IS35	-18.77	-10.22	1.81	20.46	43.66	60.09	78.66	97.81	118.72	140.99	166.91
3BF***	-71.57	313.33	941.53	1516.69	2024.04	2406.05	2694.77	3136.17	3552.11	3925.75	4316.74
3BA***	-42.97	249.82	642.69	989.16	1342.12	1617.36	1835.52	2185.57	2514.85	2826.80	3157.11
3DBF**	11.82	240.94	511.17	744.27	982.16	1176.41	1344.05	1567.12	1779.34	1978.87	2187.02
3DBA**	6.98	205.20	447.97	661.05	881.89	1066.77	1219.30	1429.32	1630.51	1815.62	2010.29

Successive * signs on the gage number represent the progressive distances between the notch tip and strain gage (see appendix C for details).

Table E-36. Strain survey raw data (run2) and phase 3 repairs (20,000 cycles for C-BE and CD-BE repairs)

Load Step	0	1	2	3	4	5	6	7	8	9	10
Pressure	-0.03	0.72	1.44	1.96	2.72	3.34	4.00	4.66	5.31	5.98	6.71
Frame-1	-16.83	146.81	169.12	373.08	446.34	606.60	667.47	752.96	974.51	1037.19	1112.37
Frame-2	1.41	92.94	179.00	347.48	435.50	579.17	679.86	788.88	904.29	1047.42	1160.15
Frame-3	61.32	107.45	210.27	321.56	448.08	588.29	723.17	801.78	949.70	1087.89	1167.61
Frame-4	-36.59	129.28	192.68	331.36	428.62	558.91	658.74	787.35	873.90	1058.52	1202.32
Frame-5	-10.24	96.91	226.60	341.31	393.38	584.38	699.90	802.67	904.14	1020.28	1121.62
Frame-6	0.48	107.95	230.25	283.39	484.56	574.71	652.33	816.49	882.26	1004.63	1171.10
Frame-7	8.01	98.88	161.42	285.24	440.61	533.58	690.54	831.09	887.70	1031.35	1135.38
Frame-8	-4.20	124.65	196.85	324.66	409.26	625.02	673.26	808.44	877.84	1038.81	1156.32
Frame-9	-3.85	119.31	209.60	337.05	408.76	617.13	657.80	778.42	907.94	1077.08	1137.61
Frame-10	43.68	112.21	180.21	354.90	437.87	626.18	724.82	788.51	927.38	1064.33	1084.62
Frame-11	27.53	121.77	187.34	366.48	487.18	612.86	678.70	743.64	909.35	1082.68	1073.50
Frame-12	4.08	92.52	183.05	241.57	459.41	607.09	692.57	828.30	938.62	1004.95	1209.29
Hoop-1	-2.97	595.48	1476.70	2145.81	2929.46	3680.98	4333.11	5124.30	5653.90	6263.29	7273.51
Hoop-2	2.21	728.44	1456.32	2053.70	2789.08	3582.21	4372.12	4957.53	5712.46	6531.79	7125.71
Hoop-3	-10.62	653.72	1359.99	2076.84	2767.67	3586.97	4294.41	5092.47	5706.04	6437.05	7050.61
Hoop-4	-49.46	737.09	1508.95	2124.69	2853.32	3566.10	4359.20	4922.80	5636.76	6447.00	7208.19
Hoop-5	-8.91	631.04	1434.42	1970.05	2683.89	3479.12	4253.19	5066.21	5729.58	6486.45	7228.93
Hoop-6	39.34	803.13	1391.78	2020.62	2908.57	3578.29	4386.94	5211.41	5712.75	6555.02	7264.19
Hoop-7	58.42	805.52	1582.86	2113.64	2835.94	3710.69	4308.72	4945.50	5742.74	6504.22	7281.80
Hoop-8	-5.09	739.26	1432.95	2045.71	2877.70	3527.24	4424.48	4971.79	5745.33	6519.51	7183.64
Hoop-9	-11.39	633.00	1378.31	2112.23	2995.43	3408.31	4486.73	4872.64	5814.98	6447.44	7255.24
Hoop-10	-13.65	670.63	1449.55	2082.06	2828.62	3491.64	4363.97	4913.17	5682.77	6501.00	7132.02
Hoop-11	1.83	695.89	1452.00	2078.78	2847.22	3573.97	4235.06	4997.98	5693.86	6529.92	7137.06
Hoop-12	-0.52	725.36	1333.39	2139.13	2670.41	3558.29	4161.92	5064.27	5791.97	6418.43	7269.92
Hoop-13	-14.79	723.97	1477.80	2143.19	2633.30	3730.58	4395.82	5215.04	5683.16	6466.45	7183.34
Hoop-14	-6.02	852.71	1396.26	2210.76	2952.14	3642.13	4265.64	4999.60	5660.16	6497.53	7136.14
Long-1	5.71	695.10	1432.40	2188.79	2749.49	3217.38	3994.94	4654.15	5237.87	6099.15	6667.80
Long-2	9.36	477.35	1260.34	1993.78	2635.97	3487.72	4193.42	4733.89	5504.39	5948.26	6614.78
Long-3	8.35	874.52	1544.27	1817.52	2522.22	3446.96	4139.48	4637.89	5403.19	5985.45	6720.19
Long-4	1.18	898.42	1223.04	1855.35	2532.92	3374.00	3870.47	4774.80	5287.88	6152.25	6596.32
Long-5	8.43	608.05	1554.83	1884.73	2409.03	3170.92	3679.71	4620.65	5346.88	6206.62	6584.79
Long-6	-5.95	678.04	1191.99	2104.89	2755.74	3379.68	3870.16	4804.17	5517.73	5793.19	6849.25
Long-7	13.61	819.96	1233.34	1750.33	2757.17	3514.73	3929.82	4398.07	5062.94	6188.26	6446.69
Long-8	5.25	944.10	1465.98	2234.57	2765.56	2941.43	4350.91	4958.15	5589.87	5636.02	6080.96
S28	134.25	255.87	342.74	405.19	471.63	514.23	562.16	608.95	641.72	676.20	711.19
S29	27.80	189.66	286.30	344.93	410.62	447.72	493.34	544.63	582.67	630.79	687.83
S30	143.95	265.93	363.68	415.73	515.55	552.54	594.76	666.74	719.80	786.17	858.76
S31	77.28	127.08	187.76	222.09	288.25	318.97	354.69	407.72	446.91	496.40	551.10
S34	1797.75	3066.68	3990.53	4798.68	5659.41	6340.88	7244.60	8434.03	9628.56	11124.99	13105.93
S35	80.43	697.38	1458.46	2012.01	2692.08	3222.43	3829.42	4745.75	5614.29	6749.96	8179.77
IS28	-199.44	-272.88	-321.81	-356.90	-403.07	-406.02	-401.97	-405.03	-406.40	-388.88	-355.70
IS29	-77.54	-159.83	-192.69	-206.51	-230.18	-218.22	-201.46	-199.80	-196.16	-184.52	-167.05
IS30	-186.03	-249.06	-282.22	-301.85	-344.60	-331.35	-324.23	-322.69	-316.24	-300.43	-282.52
IS31	16.80	40.01	52.56	54.92	67.41	89.57	100.09	107.62	115.83	131.80	146.01
IS34	-14.46	-33.02	-23.85	-13.24	0.27	12.75	30.57	51.70	69.88	98.63	136.00
IS35	6.16	5.80	12.08	24.16	43.84	63.36	80.14	102.12	121.39	145.64	173.28
3BF***	-97.87	390.17	1041.50	1522.07	2111.69	2402.88	2716.76	3145.98	3481.98	3895.41	4332.94
3BA***	-79.93	293.60	691.72	991.76	1411.70	1621.13	1853.29	2194.49	2467.01	2802.60	3161.37
3DBF**	19.81	302.65	555.08	744.95	1010.15	1178.10	1348.63	1574.18	1760.80	1976.49	2200.73
3DBA**	21.28	259.54	487.36	659.77	910.42	1064.22	1226.01	1436.17	1610.95	1811.82	2023.91

Successive * signs on the gage number represent the progressive distances between the notch tip and strain gage (see appendix C for details).

Table E-37. Strain survey raw data (run3) and phase 3 repairs (20,000 cycles for C-BE and CD-BE repairs)

Load Step	0	1	2	3	4	5	6	7	8	9	10
Pressure	0.02	0.72	1.29	2.02	2.69	3.45	4.05	4.81	5.31	5.98	6.74
Frame-1	35.91	123.86	221.48	309.14	444.43	579.58	639.85	745.91	920.84	1071.91	1100.40
Frame-2	36.91	128.18	242.90	321.23	437.31	564.83	664.82	770.66	890.80	1017.70	1098.67
Frame-3	35.37	132.93	276.20	368.01	454.16	534.73	663.54	764.33	874.20	1014.01	1047.47
Frame-4	-41.74	75.40	208.49	301.11	427.90	545.74	665.29	793.23	876.93	1045.21	1065.19
Frame-5	7.31	104.71	201.37	360.65	475.01	554.28	644.72	745.49	926.26	1025.11	1122.36
Frame-6	19.28	140.48	199.39	403.60	485.15	566.58	653.70	796.85	868.85	1005.35	1084.63
Frame-7	62.98	90.67	248.39	331.36	443.27	544.10	645.92	776.57	895.24	1047.08	1094.90
Frame-8	25.56	52.92	227.69	356.34	474.01	574.75	667.32	806.45	891.31	1037.59	1083.22
Frame-9	40.16	38.06	277.32	359.86	446.07	544.24	645.82	775.43	929.33	1071.96	1086.14
Frame-10	-9.14	120.37	237.75	342.68	444.78	526.07	685.95	770.11	929.67	1084.11	1174.74
Frame-11	21.39	65.02	308.87	307.23	416.42	487.37	698.52	771.34	859.93	1102.65	1115.40
Frame-12	20.68	93.41	301.23	373.75	506.15	549.34	694.04	831.96	947.62	1049.74	1100.33
Hoop-1	27.86	742.38	1344.59	2129.71	2828.75	3687.13	4079.22	4915.73	5780.86	6515.40	7083.78
Hoop-2	9.37	635.43	1683.80	1964.47	2702.24	3507.81	4252.27	5086.34	5671.31	6442.34	7103.16
Hoop-3	48.98	662.48	1570.62	2168.19	2829.87	3524.56	4262.86	5146.82	5585.08	6500.16	7040.80
Hoop-4	35.92	660.80	1567.39	2124.90	2897.78	3555.95	4301.07	5138.99	5733.04	6510.58	7138.05
Hoop-5	210.38	661.60	1533.58	2191.35	2981.38	3611.09	4114.77	4976.32	5729.58	6457.68	7080.42
Hoop-6	97.66	739.33	1526.97	2095.56	2776.33	3639.19	4430.69	4819.45	5543.21	6438.34	7108.12
Hoop-7	72.70	614.27	1338.28	2070.96	2833.21	3402.19	4160.37	5079.57	5696.26	6479.20	7057.27
Hoop-8	75.18	680.81	1447.26	2125.35	2826.05	3592.57	4147.59	5016.08	5694.24	6431.93	7064.76
Hoop-9	20.92	693.95	1455.22	2109.81	2836.90	3547.97	4243.04	5135.21	5635.49	6503.09	7093.36
Hoop-10	55.66	750.54	1531.02	2159.62	2838.72	3530.39	4327.08	5068.31	5673.88	6572.10	7167.20
Hoop-11	41.69	741.12	1471.65	2076.35	2795.92	3580.87	4220.98	4965.86	5730.10	6551.67	7093.25
Hoop-12	43.14	779.86	1365.88	1992.98	2669.87	3674.36	3936.73	4846.44	5741.03	6382.04	7078.58
Hoop-13	72.98	723.90	1418.99	2186.42	2910.70	3408.37	4110.97	4930.27	5741.68	6532.29	7078.81
Hoop-14	-6.02	771.90	1542.79	2100.03	2790.10	3678.47	4244.04	5000.10	5689.52	6446.15	7075.30
Long-1	69.81	531.12	1364.05	1899.61	2820.88	3469.64	3929.36	4569.03	5374.83	5964.29	6785.97
Long-2	7.86	504.19	1231.12	1881.57	2456.14	3179.26	4092.51	4509.78	5067.70	6107.12	6542.90
Long-3	40.72	926.30	1166.15	2052.82	2524.87	3280.35	4136.30	4568.42	5528.44	5970.70	6833.39
Long-4	37.31	699.43	1180.86	1866.13	2843.66	3470.84	3829.41	4630.29	5207.73	5770.12	6686.51
Long-5	5.35	673.10	1068.45	2108.40	2395.08	2963.53	3969.86	4432.90	5195.86	6139.11	6670.24
Long-6	6.67	499.41	1320.53	2042.23	2567.02	3429.22	4144.82	4842.82	5531.51	5845.50	6726.20
Long-7	75.80	807.12	1493.29	1987.07	2593.79	3478.53	4018.84	4791.11	5101.71	6270.96	6627.31
Long-8	4.08	618.05	1259.34	1906.42	2877.16	3649.23	3723.37	4316.36	5588.99	5687.95	6476.57
S28	136.50	248.42	342.64	398.41	466.02	510.61	554.30	616.12	640.64	679.28	703.75
S29	58.42	192.81	292.22	343.29	404.14	447.22	485.99	552.39	581.83	634.28	683.14
S30	161.16	261.64	337.53	434.54	514.18	570.29	609.76	689.51	724.36	790.93	861.97
S31	75.66	117.23	170.04	232.71	285.68	326.34	359.66	421.01	447.37	497.63	547.71
S34	1955.45	3149.83	4102.42	4738.85	5567.92	6327.15	7109.32	8475.62	9524.08	11114.08	12928.99
S35	181.54	790.02	1458.79	2098.13	2695.28	3287.07	3847.24	4828.71	5581.05	6760.91	8062.34
IS28	-182.10	-262.17	-289.54	-366.89	-401.25	-419.17	-420.87	-411.73	-411.88	-391.80	-365.73
IS29	-85.38	-158.06	-165.96	-217.25	-231.25	-230.93	-218.13	-203.82	-198.67	-181.24	-175.99
IS30	-186.52	-235.73	-258.94	-308.99	-339.84	-344.00	-338.76	-335.95	-320.68	-303.20	-295.96
IS31	74.22	94.86	112.61	112.28	117.54	128.73	142.94	154.69	160.95	174.28	175.34
IS34	-16.05	-31.00	-14.83	-13.83	0.46	14.24	28.16	58.19	71.95	102.35	136.06
IS35	6.38	5.57	13.89	26.88	45.78	65.39	81.56	105.79	124.30	149.35	173.89
3BF***	-56.25	387.67	913.04	1580.50	2101.98	2482.27	2736.39	3211.32	3489.32	3910.75	4334.84
3BA***	-43.52	291.01	622.03	1023.47	1401.96	1695.81	1876.65	2255.60	2475.21	2816.37	3177.64
3DBF**	48.17	299.87	511.53	765.85	1004.41	1204.70	1352.95	1599.42	1763.54	1985.76	2197.49
3DBA**	43.98	254.99	445.11	680.64	903.58	1093.37	1228.18	1460.41	1612.44	1818.34	2019.04

Successive * signs on the gage number represent the progressive distances between the notch tip and strain gage (see appendix C for details).

Table E-38. Strain survey raw data (run1) and phase 4 repairs (before impact for R-BE, U-BE, and U-A2 repairs)

Load Step	0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00
Pressure	0.00	0.73	1.45	2.05	2.66	3.32	4.06	4.62	5.38	5.98	6.64
Frame-1	-12.35	71.36	230.41	307.06	450.09	570.89	677.57	811.28	893.89	1006.92	1143.95
Frame-2	-0.59	95.21	199.96	323.16	449.46	578.98	707.64	791.09	885.45	1023.87	1139.42
Frame-3	36.84	152.01	273.47	330.46	503.25	608.63	665.30	787.28	897.55	1017.79	1138.48
Frame-4	34.83	118.10	226.26	322.65	441.21	601.42	644.09	810.28	896.38	1007.07	1148.63
Frame-5	-18.14	112.94	224.02	341.48	448.45	572.34	675.60	803.40	909.73	1013.47	1131.97
Frame-6	24.27	121.82	239.38	344.99	445.10	556.87	686.28	800.14	897.72	1011.00	1133.33
Frame-7	-10.37	124.08	213.49	341.96	454.20	558.71	676.23	781.40	896.08	1020.35	1145.10
Frame-8	-22.49	86.99	205.00	302.43	454.63	522.17	687.94	795.88	909.50	1015.93	1133.55
Frame-9	5.10	129.24	250.52	326.10	458.00	604.13	686.05	787.44	905.89	1021.88	1172.91
Frame-10	-27.78	95.13	233.93	347.72	472.51	569.46	675.54	793.91	901.92	1007.54	1171.63
Frame-11	29.49	162.32	263.30	309.16	461.20	624.59	635.65	794.85	900.61	1033.65	1145.20
Frame-12	136.94	163.11	217.55	355.55	419.92	635.65	734.47	806.36	858.16	1010.81	1095.69
Hoop-1	49.16	678.96	1412.22	2143.65	3164.86	3519.41	4344.80	4974.53	5774.19	6376.74	7215.43
Hoop-2	-17.89	704.57	1384.00	2174.58	2860.61	3520.89	4336.14	4942.01	5697.80	6393.32	7196.64
Hoop-3	5.46	783.64	1347.86	2241.64	2800.13	3627.18	4284.15	4879.37	5793.19	6483.23	7049.44
Hoop-4	1.30	721.46	1561.05	2029.70	2745.69	3547.83	4415.92	5047.36	5694.40	6349.40	7227.16
Hoop-5	-8.10	656.56	1522.42	2034.39	2924.82	3539.77	4218.39	5067.99	5717.57	6423.50	7167.40
Hoop-6	-37.92	712.62	1376.14	2128.49	2802.33	3622.32	4254.60	4896.30	5727.66	6356.72	7196.26
Hoop-7	-9.13	685.09	1425.82	2102.15	2888.83	3608.67	4370.44	4957.25	5774.20	6386.06	7134.15
Hoop-8	-54.88	677.25	1416.50	2235.54	2873.66	3584.05	4272.70	5004.83	5715.79	6417.73	7164.29
Hoop-9	-19.04	632.43	1364.30	2105.18	2794.44	3569.40	4317.51	4929.61	5719.46	6346.46	7121.34
Hoop-10	-4.75	691.56	1451.33	2121.06	2872.36	3572.19	4307.38	5007.21	5774.78	6397.41	7169.63
Hoop-11	11.90	636.24	1416.98	2115.02	2834.93	3615.80	4272.53	5019.22	5737.69	6389.61	7161.42
Hoop-12	-64.81	762.43	1448.02	2130.06	2841.41	3378.38	4154.83	4982.06	5744.56	6396.44	7194.57
Hoop-13	-7.63	682.77	1409.00	2120.91	2804.33	3631.38	4278.63	4969.04	5782.28	6370.79	7140.23
Hoop-14	11.67	611.13	1407.82	1999.91	2943.15	3506.05	4361.37	4968.14	5743.61	6371.10	7175.17
Long-1	79.79	711.79	1320.96	1923.55	2631.09	3285.49	3878.90	4629.99	5411.73	6009.71	6717.88
Long-2	57.88	813.36	1258.19	2025.44	2749.86	3352.42	4023.29	4731.41	5409.35	6069.10	6546.83
Long-3	45.12	756.58	1419.61	1911.43	2550.22	3362.66	4016.09	4779.83	5324.65	6015.37	6715.69
Long-4	33.29	521.81	1220.63	2132.20	2528.03	3339.38	3768.43	4641.71	5191.02	5908.19	6636.56
Long-5	25.71	714.64	1480.59	1787.73	2523.66	3485.01	4018.95	4781.84	5294.99	6015.92	6697.65
Long-6	31.17	673.56	1117.20	2356.40	2594.96	3506.67	3757.33	4766.21	5158.01	5886.48	6681.12
Long-7	82.60	534.70	1404.23	2021.96	2574.58	3132.25	3806.01	4521.64	5537.04	6169.48	6629.99
Long-8	19.07	798.33	1319.78	2080.01	2606.77	3204.59	4346.80	4746.89	5217.96	5707.50	6718.70
S10	-99.26	103.94	315.69	471.65	633.66	779.73	922.40	1061.84	1182.62	1266.94	1361.90
S11	-227.11	114.00	356.97	534.78	713.06	871.05	1024.59	1144.17	1282.14	1376.85	1478.75
S12	62.69	106.84	229.82	334.69	448.94	550.81	654.12	738.47	834.90	908.60	992.43
S13	-262.16	332.60	545.42	679.58	806.43	912.35	1012.92	1091.19	1181.94	1248.32	1324.81
S14	-90.01	229.93	450.68	596.31	731.91	837.75	944.01	1024.37	1119.58	1187.70	1268.46
S15	190.97	510.00	728.50	867.44	1006.20	1109.21	1229.90	1310.11	1407.24	1487.32	1576.96
IS10	51.68	-3.32	-81.50	-137.22	-180.66	-210.30	-228.41	-231.33	-219.73	-202.36	-172.70
IS11	327.02	61.98	-69.55	-155.72	-218.52	-263.10	-286.89	-290.37	-275.82	-254.78	-217.06
IS12	58.93	96.28	87.16	79.33	88.16	98.00	125.33	157.50	208.59	255.04	318.66
IS13	485.14	17.55	-86.56	-122.22	-133.64	-132.71	-103.75	-74.79	-24.82	18.27	78.21
IS14	783.74	590.79	483.56	422.99	401.34	394.04	400.76	429.71	479.90	511.34	570.85
IS15	1082.54	939.52	871.60	839.56	819.74	829.07	851.64	880.51	926.99	965.54	1026.10
IS16	-163.59	29.63	170.41	277.69	390.46	495.85	604.46	693.37	793.36	863.75	942.00
IS17	-52.95	39.53	115.92	176.35	242.26	301.20	363.49	412.40	470.64	512.81	562.82
IS18	133.47	228.81	298.30	353.60	416.39	462.05	523.40	567.22	624.66	695.19	762.17

Table E-39. Strain survey raw data (run2) and phase 4 repairs (before impact for R-BE, U-BE, and U-A2 repairs)

Load Step	0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00
Pressure	0.09	0.63	1.24	1.99	2.73	3.35	4.02	4.69	5.32	6.02	6.71
Frame-1	45.41	126.01	214.95	319.53	456.71	546.28	671.26	796.72	902.62	1019.87	1113.12
Frame-2	5.91	102.08	254.45	352.58	458.07	592.24	661.39	815.99	880.75	1026.11	1122.64
Frame-3	-51.19	120.86	276.21	331.82	469.90	538.58	692.84	783.63	924.35	1039.36	1130.53
Frame-4	16.38	81.75	272.93	330.94	439.82	567.19	662.40	789.83	930.33	1029.88	1123.38
Frame-5	-4.40	114.73	240.39	323.75	442.56	599.67	651.13	789.40	893.96	1018.92	1119.76
Frame-6	9.34	142.63	222.61	330.94	454.90	572.59	691.06	791.69	924.34	1030.21	1127.03
Frame-7	-5.14	113.36	229.93	339.73	448.32	565.67	679.04	800.86	909.67	1021.99	1124.83
Frame-8	21.13	130.76	218.16	339.06	525.53	573.86	695.93	802.22	893.14	1020.69	1121.10
Frame-9	-25.74	114.97	176.34	360.54	468.95	557.42	667.33	791.48	898.66	1030.77	1112.98
Frame-10	-17.09	124.11	205.51	346.45	452.83	588.03	673.53	779.14	902.77	1029.07	1125.52
Frame-11	41.15	113.08	228.17	316.56	418.32	578.22	644.72	894.89	908.91	1032.95	1123.71
Frame-12	86.14	98.13	291.17	302.68	439.22	573.83	647.27	872.07	966.17	1035.91	1169.82
Hoop-1	38.27	755.04	1410.12	2157.96	2820.92	3688.20	4223.62	4945.99	5718.60	6517.76	7162.08
Hoop-2	5.41	799.42	1417.78	2090.11	2775.41	3529.86	4307.89	4985.53	5721.76	6564.90	7165.45
Hoop-3	53.77	642.03	1508.03	2099.95	2776.81	3571.96	4253.51	4974.75	5805.84	6403.42	7259.24
Hoop-4	-25.84	835.29	1450.38	2170.62	2938.33	3576.78	4360.27	5089.48	5743.93	6404.95	7052.73
Hoop-5	-42.23	681.57	1426.93	2109.63	2774.78	3645.76	4184.67	5077.48	5707.45	6430.16	7111.00
Hoop-6	-21.60	670.79	1355.93	2162.72	2843.06	3656.76	4273.15	5025.50	5719.27	6432.31	7177.41
Hoop-7	-18.08	620.55	1463.11	2057.21	2878.96	3549.63	4209.85	4916.59	5681.81	6512.58	7149.54
Hoop-8	17.60	727.92	1452.74	2134.28	2852.49	3613.05	4286.77	4976.33	5722.47	6448.65	7150.50
Hoop-9	-4.72	720.05	1432.30	2162.66	2816.48	3565.82	4256.24	5032.12	5709.94	6452.18	7157.84
Hoop-10	-40.09	709.16	1511.42	2128.34	2796.92	3586.33	4326.39	5005.94	5685.84	6427.60	7154.44
Hoop-11	-31.28	715.34	1431.37	2154.81	2803.10	3509.65	4281.10	4960.34	5717.33	6458.11	7145.93
Hoop-12	31.34	715.19	1431.70	1934.35	2878.26	3516.26	4031.07	4982.56	5693.20	6405.60	7057.41
Hoop-13	-14.82	632.37	1473.71	2113.92	2682.60	3386.86	4335.74	4933.57	5709.79	6451.82	7184.09
Hoop-14	26.29	830.36	1334.73	2270.59	2812.12	3739.99	4119.72	5056.36	5721.11	6490.00	7110.09
Long-1	3.98	547.20	1375.77	2049.98	2620.97	3265.66	3986.54	4745.35	5343.23	6114.35	6609.37
Long-2	35.10	816.03	1389.09	1967.17	2628.72	3453.49	3866.45	4812.61	5228.11	5945.05	6588.38
Long-3	54.71	749.32	1283.63	1962.07	2676.58	3236.93	3940.65	4622.57	5279.56	6047.14	6638.47
Long-4	43.31	781.26	1351.13	1967.60	2593.07	3270.97	3959.61	4535.63	5272.55	5818.33	6661.51
Long-5	34.22	576.37	1510.77	1797.00	2503.58	3368.26	4053.99	4683.09	5266.40	6055.74	6719.86
Long-6	30.91	683.32	1390.25	2087.14	2848.11	3454.70	3898.27	4456.03	5502.89	5799.40	6690.70
Long-7	20.52	519.57	1386.37	1801.38	2589.91	3373.17	4118.74	4852.01	5127.91	5726.53	6429.20
Long-8	43.67	766.23	1483.55	2248.03	2643.43	3197.56	3886.69	4731.08	5201.02	6217.68	6736.57
S10	-108.15	97.96	298.17	475.67	650.36	798.37	926.30	1048.53	1162.35	1273.45	1361.72
S11	-161.87	83.10	299.70	528.87	722.32	884.06	1024.15	1153.09	1275.27	1393.12	1485.62
S12	34.98	98.63	209.23	332.54	445.93	557.01	647.61	742.78	829.24	917.17	992.25
S13	-24.83	309.21	514.28	678.55	803.00	919.42	1006.12	1097.61	1176.32	1257.21	1324.99
S14	-55.43	199.13	415.39	593.65	722.89	845.18	934.13	1029.53	1111.97	1196.94	1267.73
S15	259.91	477.47	710.31	880.91	999.13	1135.42	1230.20	1328.78	1410.31	1491.30	1571.17
IS10	51.70	13.32	-52.55	-124.93	-179.18	-207.40	-222.65	-223.35	-213.21	-192.95	-166.91
IS11	277.94	94.27	-31.63	-148.66	-229.90	-264.91	-288.55	-290.70	-277.09	-252.78	-219.24
IS12	69.08	103.56	101.33	83.95	77.88	99.31	118.37	159.65	205.33	260.24	317.16
IS13	276.86	40.72	-59.41	-119.88	-142.48	-130.71	-113.54	-74.78	-30.43	20.63	72.96
IS14	760.48	622.22	523.91	445.25	404.88	411.02	443.09	529.95	624.09	748.59	969.85
IS15	818.50	657.59	602.76	585.23	756.82	635.38	642.65	666.39	693.18	744.76	791.41
IS16	-146.45	18.77	140.93	272.83	393.63	500.38	598.37	693.12	782.87	871.71	942.73
IS17	-48.98	30.66	100.72	172.93	239.49	304.28	356.83	413.99	465.39	517.69	562.82
IS18	188.13	262.62	355.48	466.30	555.89	636.72	742.28	837.68	1016.16	1126.83	1140.14

Table E-40. Strain survey raw data (run3) and phase 4 repairs (before impact for R-BE, U-BE, and U-A2 repairs)

Load Step	0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00
Pressure	0.06	0.73	1.40	1.97	2.65	3.42	3.98	4.70	5.36	6.07	6.71
Frame-1	-3.03	98.21	219.66	364.47	453.76	572.44	678.37	786.07	909.58	1041.52	1115.31
Frame-2	-8.93	109.73	215.22	323.37	480.58	548.80	661.88	802.10	897.12	1063.09	1099.16
Frame-3	-35.37	100.24	256.78	293.70	445.76	589.41	661.25	811.33	913.52	1006.50	1110.78
Frame-4	-15.50	79.50	226.76	343.31	521.34	549.88	691.67	801.55	899.06	1031.74	1123.31
Frame-5	-7.00	106.94	233.88	334.38	449.95	554.09	666.82	804.21	889.57	1040.64	1140.98
Frame-6	-15.00	110.36	227.20	339.48	463.93	558.86	702.87	802.35	889.16	1026.38	1128.37
Frame-7	1.54	97.40	236.07	343.15	449.85	560.16	675.87	796.98	896.09	1024.91	1122.39
Frame-8	-25.35	156.75	222.84	347.63	438.74	549.36	685.43	787.85	897.68	992.22	1127.42
Frame-9	-9.52	174.46	222.37	367.36	491.35	549.53	692.42	808.88	903.14	1015.02	1155.49
Frame-10	-1.39	107.25	227.16	353.76	493.70	520.76	693.46	805.79	894.52	1013.81	1101.99
Frame-11	18.91	149.92	260.35	382.49	518.89	587.05	693.89	791.82	906.74	979.85	1096.69
Frame-12	-26.37	129.38	167.94	373.56	409.89	499.38	668.20	836.79	944.57	1043.09	1092.27
Hoop-1	21.94	662.63	1628.20	2194.47	2920.47	3558.99	4318.53	4990.86	5682.87	6431.82	7134.86
Hoop-2	-17.89	672.30	1475.43	2203.26	2873.73	3628.10	4220.58	4985.03	5704.40	6453.11	7136.77
Hoop-3	19.27	797.44	1444.49	2100.16	3092.29	3638.89	4388.51	4984.61	5766.73	6357.93	7121.21
Hoop-4	-29.46	565.85	1389.15	2103.88	2824.04	3520.33	4382.48	5101.64	5742.69	6534.58	7139.59
Hoop-5	-0.92	708.66	1736.19	2199.66	2923.61	3562.77	4258.85	5075.18	5679.27	6370.25	7098.42
Hoop-6	18.28	665.48	1358.01	2226.39	2931.61	3638.27	4273.69	5057.63	5607.44	6471.55	7072.27
Hoop-7	-14.50	715.50	1415.09	2118.25	2932.35	3475.92	4185.34	4941.15	5659.12	6468.99	7174.59
Hoop-8	39.35	684.50	1373.15	2206.77	2946.45	3577.16	4280.37	4997.59	5701.86	6440.11	7122.22
Hoop-9	11.39	736.23	1505.82	2103.60	2878.85	3582.29	4253.51	5067.42	5736.14	6458.05	7167.50
Hoop-10	-15.35	746.34	1552.21	2151.31	2999.90	3645.02	4350.22	5024.88	5745.30	6433.39	7156.92
Hoop-11	-4.29	711.81	1483.69	2108.03	2975.57	3524.39	4269.36	5001.23	5693.27	6453.22	7108.86
Hoop-12	-64.81	657.21	1431.84	2028.68	2936.03	3523.86	4358.44	5032.86	5701.59	6542.20	7166.97
Hoop-13	-0.44	661.20	1351.60	2070.77	2905.30	3653.32	4243.10	4969.04	5689.34	6414.58	7148.84
Hoop-14	-32.19	625.75	1554.17	2190.18	3016.55	3484.47	4420.29	5092.41	5729.56	6525.26	7088.86
Long-1	13.17	590.15	1457.96	1919.31	2642.47	3327.15	4174.78	4725.58	5247.72	5997.49	6712.23
Long-2	72.41	593.64	1207.63	1996.15	2770.71	3255.04	3916.90	4511.18	5335.78	5921.35	6578.37
Long-3	40.57	656.18	1490.59	2063.70	2550.75	3324.77	3968.14	4628.53	5387.05	6061.41	6601.54
Long-4	26.16	653.09	1204.82	2119.72	2642.64	3194.13	3928.15	4821.45	5462.00	5958.38	6917.69
Long-5	20.52	844.20	1384.43	1825.06	2702.82	3145.51	4105.90	4585.97	5308.27	6103.36	6639.53
Long-6	6.98	973.19	1536.90	1833.91	2476.30	3249.96	4002.70	4940.35	5247.46	5984.40	6704.30
Long-7	14.74	730.54	1365.28	2259.19	2849.09	3365.47	4158.35	4425.24	5530.81	6269.48	6914.23
Long-8	4.91	651.73	1397.75	1976.28	2543.48	3602.11	3978.75	4649.64	5304.35	5790.57	6676.47
S10	-93.67	126.75	314.58	466.40	638.49	793.02	912.99	1045.99	1154.68	1264.28	1350.81
S11	-164.39	135.71	364.88	533.88	732.87	894.82	1022.44	1166.11	1280.46	1397.31	1487.35
S12	39.72	113.96	234.36	335.24	460.75	557.62	648.96	745.69	829.33	917.08	990.49
S13	-31.90	350.95	551.90	681.03	820.67	918.79	1008.40	1099.24	1176.80	1256.72	1322.96
S14	-52.34	236.29	456.07	594.50	750.86	844.17	938.03	1030.79	1111.53	1194.83	1264.63
S15	274.53	546.21	759.34	893.11	1044.96	1148.37	1249.13	1346.50	1429.79	1518.26	1592.57
IS10	43.73	-2.60	-70.63	-122.74	-171.96	-207.42	-217.60	-219.73	-210.34	-190.03	-167.58
IS11	284.81	59.63	-64.28	-144.83	-211.42	-271.83	-284.95	-288.52	-278.21	-252.39	-220.99
IS12	71.88	85.53	91.27	86.43	100.45	91.27	124.40	160.65	202.50	259.13	312.19
IS13	282.81	-6.71	-88.00	-125.66	-129.10	-138.15	-110.83	-77.14	-35.32	17.37	67.69
IS14	783.72	607.11	507.19	471.05	418.83	567.72	727.23	1036.79	1530.40	1600.92	1332.49
IS15	654.33	541.77	489.65	456.75	764.13	663.95	564.47	591.32	639.12	684.29	740.41
IS16	-146.44	38.31	168.23	269.91	395.12	503.32	595.54	697.47	783.13	870.90	939.91
IS17	-47.89	39.17	116.63	175.09	248.02	301.60	357.59	414.89	464.35	517.28	560.11
IS18	633.41	765.71	906.39	1033.34	1252.14	1379.81	1490.23	1615.79	1752.49	1818.13	1916.48

Table E-41. Strain survey raw data (run1) and phase 4 repairs (after impact for R-BE, U-BE, and U-A2 repairs)

Load Step	0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00
Pressure	-0.09	0.82	1.40	1.97	2.76	3.31	4.00	4.64	5.32	6.07	6.64
Frame-1	-11.32	132.04	218.90	363.17	461.15	565.92	647.56	822.71	907.84	1024.05	1120.01
Frame-2	30.27	130.88	230.99	335.70	402.01	570.88	649.55	757.94	909.97	983.94	1131.07
Frame-3	-30.88	149.69	177.25	394.47	387.47	597.08	695.22	819.56	863.68	1013.24	1138.14
Frame-4	-16.25	130.79	186.01	356.91	431.64	578.87	637.53	813.38	918.92	992.54	1116.63
Frame-5	-7.05	113.92	224.34	333.74	464.58	585.53	695.43	781.92	923.84	1024.16	1124.04
Frame-6	7.17	129.10	206.44	350.67	442.15	577.60	681.03	786.29	912.56	983.08	1127.26
Frame-7	1.81	134.15	246.41	344.91	404.12	560.15	678.42	790.26	922.73	1011.76	1138.18
Frame-8	-14.80	134.15	165.67	386.18	435.89	570.44	681.62	785.74	900.48	1003.73	1135.39
Frame-9	-31.54	53.04	171.14	406.31	421.32	573.78	674.39	803.07	921.99	998.76	1137.88
Frame-10	-12.19	164.20	250.80	311.63	465.05	562.65	663.28	802.48	908.40	995.16	1174.39
Frame-11	-18.04	133.34	248.75	337.36	471.06	526.58	670.36	752.35	881.86	1009.31	1171.49
Frame-12	-31.57	152.36	209.00	318.59	508.25	616.42	639.92	763.23	975.44	1039.80	1091.63
Hoop-1	-24.83	679.38	1454.23	2107.35	2820.21	3498.81	4270.80	4806.17	5637.35	6366.26	7200.99
Hoop-2	109.47	683.15	1426.98	2193.96	2824.59	3548.62	4226.90	4922.40	5836.58	6492.00	7069.13
Hoop-3	45.72	689.32	1484.60	2215.90	2805.61	3645.65	4333.03	4973.11	5752.93	6426.88	7220.43
Hoop-4	-20.20	631.19	1488.73	2029.50	2912.04	3452.91	4347.38	4902.82	5698.90	6418.35	7060.58
Hoop-5	98.36	755.86	1296.45	2183.56	3036.37	3514.07	4206.31	4786.49	5801.35	6409.63	7023.87
Hoop-6	3.37	594.38	1245.08	2167.54	2772.65	3497.59	4210.69	4836.08	5726.12	6503.13	7046.89
Hoop-7	144.32	656.07	1480.75	2022.63	2796.93	3499.88	4277.02	5049.89	5772.66	6419.66	7033.24
Hoop-8	6.84	775.29	1391.51	2159.54	2833.90	3573.28	4290.92	4971.82	5740.70	6415.48	7140.44
Hoop-9	25.35	698.36	1383.90	2153.14	2797.66	3490.30	4263.47	4876.86	5677.37	6431.49	7091.97
Hoop-10	86.58	722.86	1435.14	2175.26	2742.77	3495.63	4239.64	4947.82	5704.70	6459.97	7099.78
Hoop-11	-6.29	690.09	1442.25	2147.20	2733.97	3520.25	4310.12	4955.56	5717.13	6437.47	7126.65
Hoop-12	-62.09	656.37	1509.09	2043.90	2827.80	3596.99	4133.97	5026.01	5650.57	6442.16	7167.88
Hoop-13	28.53	632.70	1481.40	2178.64	2898.03	3552.47	4286.03	4846.50	5702.80	6523.31	7120.28
Hoop-14	14.01	876.72	1381.19	2148.44	2843.14	3413.35	4385.64	4948.05	5738.06	6330.84	7091.20
Long-1	10.05	627.87	1238.99	1953.62	2651.78	3285.76	3986.41	4757.77	5456.07	6084.30	6718.53
Long-2	21.12	718.96	1197.91	2114.10	2555.43	3376.83	4119.21	4576.76	5403.21	6051.83	6712.84
Long-3	42.53	680.79	1417.75	2063.99	2748.12	3398.78	3976.82	4688.99	5295.06	5898.39	6683.37
Long-4	102.77	769.66	1412.20	1991.18	2533.17	3444.85	3945.74	4692.70	5251.98	6186.95	6571.28
Long-5	0.80	569.41	1162.71	2169.18	2761.71	3483.12	4027.82	4765.19	5387.62	6066.39	6547.52
Long-6	13.22	679.23	1265.52	1899.85	2647.55	3306.41	4027.58	4609.72	5311.42	6041.28	6608.51
Long-7	51.21	935.23	1443.97	2245.65	2634.93	3260.02	3858.82	4494.08	5434.87	6126.50	6775.28
Long-8	-1.60	826.09	1426.05	2080.47	2750.20	3239.01	3970.15	4597.64	5224.09	5884.55	6616.59
S10	15.25	296.09	440.18	527.59	655.72	739.97	850.63	936.67	1031.60	1119.26	1204.73
S11	86.42	470.09	644.18	747.02	893.96	984.41	1102.31	1196.57	1296.09	1388.31	1477.25
S12	15.89	-26.25	-6.37	27.57	70.08	106.19	151.60	201.05	260.73	319.44	377.60
S13	50.25	-61.83	-62.02	-37.35	-15.22	8.72	36.46	72.38	115.92	159.43	205.11
S14	96.22	340.84	452.85	539.83	635.87	716.61	801.33	871.53	947.36	1015.75	1082.32
S15	85.65	220.34	312.02	384.52	458.10	519.52	585.62	642.44	706.15	763.20	820.06
IS10	19.63	-108.47	-142.50	-146.85	-155.53	-146.83	-130.17	-113.54	-81.70	-48.40	-9.32
IS11	79.03	-244.08	-308.52	-323.21	-333.92	-325.18	-306.28	-278.37	-240.84	-194.01	-143.56
IS12	21.88	164.25	281.15	370.66	473.06	560.84	665.21	744.74	846.35	934.37	1018.71
IS13	1.42	195.50	317.92	409.54	518.72	608.11	718.84	801.29	905.84	998.81	1086.14
IS14	-68.06	-149.02	-90.48	-78.92	-48.38	-27.77	-54.69	-86.86	-100.06	67.81	78.46
IS15											
IS16	-1100.22	-917.22	-849.99	-841.31	-795.71	-805.76	-813.64	-792.73	-768.93	-784.77	-807.85
IS17	-4.01	-13.97	6.30	28.93	55.53	71.46	94.97	121.05	156.90	186.38	215.86
IS18	6.01	-2.63	34.67	82.05	111.53	136.11	161.95	181.86	210.63	230.14	246.94

Note: Strain gage IS15 showed faulty readings.

Table E-42. Strain survey raw data (run2) and phase 4 repairs (after impact for R-BE, U-BE, and U-A2 repairs)

Load Step	0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00
Pressure	0.00	0.54	1.18	1.90	2.65	3.26	4.06	4.63	5.27	5.98	6.53
Frame-1	-11.68	80.63	198.32	353.50	436.64	586.12	655.28	830.47	892.36	1045.79	1134.56
Frame-2	9.30	98.96	196.83	295.27	462.28	586.98	640.59	810.52	938.10	1038.66	1157.37
Frame-3	35.18	33.03	235.89	295.27	535.32	579.85	713.53	770.23	875.01	1050.61	1156.54
Frame-4	12.35	45.31	304.77	349.06	468.78	518.26	675.97	760.99	887.49	1009.37	1134.25
Frame-5	8.13	106.49	225.85	324.58	464.55	565.32	675.31	799.53	912.16	1018.49	1123.77
Frame-6	-0.35	69.70	210.16	354.03	456.54	563.39	679.46	797.50	911.42	1017.63	1138.52
Frame-7	0.53	110.68	262.25	344.33	450.15	564.58	694.38	783.07	906.71	1019.16	1125.84
Frame-8	-4.20	87.62	180.45	300.85	454.09	584.23	707.21	803.73	901.66	1041.77	1087.41
Frame-9	-4.09	121.09	240.77	324.35	451.43	558.39	734.80	784.84	928.97	1019.90	1143.69
Frame-10	-3.53	68.43	262.35	363.78	434.01	578.36	687.83	787.40	918.27	1025.04	1104.38
Frame-11	40.47	99.88	195.88	353.84	554.06	589.92	651.86	766.72	907.63	996.38	1140.07
Frame-12	-27.75	41.95	243.25	316.58	461.64	536.20	705.58	851.91	940.69	993.82	1124.14
Hoop-1	16.90	584.88	1296.47	2060.58	2823.56	3569.93	4402.84	5054.80	5609.01	6408.00	7061.26
Hoop-2	41.36	620.29	1294.46	2135.24	2895.98	3602.74	4267.70	5047.87	5738.64	6377.29	7058.38
Hoop-3	-0.86	713.33	1388.13	2185.28	2931.23	3644.29	4303.27	4992.09	5756.96	6337.17	7158.32
Hoop-4	34.07	612.98	1514.21	1993.71	2879.20	3632.35	4431.97	4926.34	5724.90	6427.40	6995.45
Hoop-5	10.36	691.06	1393.58	2149.86	2737.99	3568.30	4329.82	4980.48	5789.42	6520.98	7079.55
Hoop-6	1.56	764.64	1413.81	2084.58	2752.44	3588.57	4395.15	4923.09	5674.23	6472.32	7063.20
Hoop-7	101.38	582.59	1271.56	2173.33	2880.71	3591.46	4213.99	5055.26	5689.23	6478.69	7076.17
Hoop-8	-29.42	731.72	1369.76	2152.29	2870.71	3616.78	4291.35	5008.56	5697.21	6422.09	7124.53
Hoop-9	-46.25	750.20	1299.78	2222.94	2898.47	3590.52	4331.91	4975.79	5725.69	6477.38	7029.71
Hoop-10	17.66	652.10	1396.26	2164.66	2937.76	3615.80	4248.90	4973.06	5764.79	6443.42	7091.30
Hoop-11	-8.09	779.99	1476.44	2111.22	2905.48	3617.41	4285.35	5035.22	5697.34	6386.45	7098.25
Hoop-12	44.96	777.85	1607.07	2036.65	2879.17	3596.99	4294.04	4975.72	5802.95	6485.06	7115.66
Hoop-13	-0.24	675.78	1524.56	2070.77	2819.48	3581.24	4286.46	5033.97	5875.40	6443.55	7054.14
Hoop-14	-22.55	628.08	1483.55	2228.84	2916.82	3661.91	4393.38	5050.89	5708.82	6512.97	7104.41
Long-1	16.87	716.51	1238.29	2108.98	2735.07	3429.38	3938.39	4809.10	5446.37	6126.16	6805.15
Long-2	24.88	535.10	1457.24	1969.91	2687.08	3303.32	4108.70	4770.01	5309.21	6095.93	6802.46
Long-3	10.88	692.92	1295.45	2046.72	2748.09	3328.09	3977.30	4708.41	5328.19	6002.71	6757.22
Long-4	101.44	698.08	1469.23	1934.37	2588.83	3225.21	3968.91	4701.63	5238.75	6103.97	6716.97
Long-5	18.75	549.21	1252.49	1863.22	2524.49	3138.47	3896.23	4772.04	5385.71	6016.52	6765.59
Long-6	56.29	876.39	1449.67	1845.94	2616.81	3381.57	3990.04	4630.34	5365.22	5946.37	6695.93
Long-7	38.14	625.01	1181.10	1837.27	2742.72	3252.33	4072.94	4859.00	5546.77	6077.04	6890.38
Long-8	72.90	666.11	1335.55	2067.01	2691.68	3449.29	4090.36	4696.51	5227.58	6091.75	6866.98
S10	105.71	248.12	380.92	512.33	648.17	741.32	858.50	946.55	1019.29	1120.34	1190.61
S11	199.70	402.64	566.72	718.39	869.39	970.95	1096.27	1192.23	1272.96	1377.29	1447.26
S12	-14.57	-34.09	-2.90	19.54	71.16	107.48	159.64	204.76	253.79	313.79	357.72
S13	-27.55	-58.92	-32.99	-34.44	-5.06	15.98	46.08	75.66	116.82	158.71	192.24
S14	200.92	318.16	439.72	539.23	650.05	723.21	807.93	874.33	943.37	1013.76	1069.10
S15	111.31	209.11	311.41	386.47	469.94	528.07	593.63	646.07	702.89	761.39	808.13
IS10	-29.58	-83.86	-104.84	-138.15	-143.92	-138.89	-128.74	-109.95	-79.53	-49.12	-15.11
IS11	-71.89	-207.59	-255.67	-307.03	-321.70	-317.23	-302.86	-277.73	-239.75	-194.01	-153.17
IS12	50.82	160.80	271.14	374.24	475.00	568.27	669.48	755.50	838.08	931.97	1010.66
IS13	73.10	186.07	291.79	408.23	517.90	615.23	723.80	814.02	896.79	995.55	1075.28
IS14	165.17	-36.44	8.91	-8.26	6.38	56.61	83.53	135.25	15.96	15.41	-47.10
IS15											
IS16	-1713.00	-1687.84	-1659.61	-1614.91	-1620.54	-1604.21	-1826.24	-1784.08	-1685.28	-1652.54	-1678.43
IS17	-35.50	-26.64	-1.30	18.25	45.21	70.20	98.60	123.44	148.03	179.32	197.58
IS18	-12.53	13.15	65.40	91.09	118.38	144.44	166.31	182.64	210.82	226.71	239.88

Note: Strain gage IS15 showed faulty readings.

Table E-43. Strain survey raw data (run3) and phase 4 repairs (after impact for R-BE, U-BE, and U-A2 repairs)

Load Step	0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00
Pressure	0.01	0.64	1.34	2.08	2.59	3.28	4.08	4.64	5.37	6.14	6.64
Frame-1	21.49	87.61	261.14	312.32	465.49	561.53	680.71	823.00	866.97	1002.30	1129.78
Frame-2	-11.86	124.17	202.62	317.71	442.81	573.94	650.33	771.49	878.63	965.82	1184.82
Frame-3	7.55	139.12	265.38	283.37	415.60	559.05	702.03	795.26	923.48	974.64	1199.30
Frame-4	22.73	77.40	254.14	325.09	439.40	547.31	667.29	777.98	857.96	981.13	1147.84
Frame-5	1.69	105.76	222.59	334.81	469.99	592.67	680.86	785.76	912.83	1006.11	1126.05
Frame-6	11.78	139.56	232.85	326.18	447.58	550.76	676.14	785.22	896.40	1006.69	1143.87
Frame-7	-1.32	115.56	220.81	346.76	455.40	557.98	689.51	800.37	898.98	1004.19	1127.72
Frame-8	-1.63	121.14	225.55	314.89	461.13	564.13	680.14	831.65	896.60	995.60	1112.77
Frame-9	11.60	107.74	229.97	293.01	441.14	565.66	665.70	839.92	895.06	996.65	1147.41
Frame-10	-9.19	124.29	247.96	354.44	476.42	578.73	660.53	805.90	911.46	988.42	1117.67
Frame-11	45.83	95.29	166.62	386.97	483.88	587.81	696.79	766.73	887.23	965.86	1128.64
Frame-12	-28.53	99.12	225.42	343.99	414.57	606.23	722.08	757.78	957.95	1022.36	1188.27
Hoop-1	-48.43	704.51	1566.28	2365.02	2922.40	3592.07	4335.70	5047.54	5768.01	6403.19	7083.04
Hoop-2	48.53	774.27	1431.93	2249.53	2930.91	3592.35	4334.02	4979.76	5789.98	6433.49	7096.02
Hoop-3	66.43	614.88	1396.20	2196.92	2873.45	3594.61	4332.60	5038.67	5732.23	6391.29	7051.37
Hoop-4	-52.77	706.91	1513.60	2089.20	2887.29	3469.88	4270.96	4951.67	5711.57	6413.56	7131.13
Hoop-5	22.93	568.81	1202.69	2020.12	2706.48	3586.62	4328.03	5145.73	5743.87	6430.03	7153.19
Hoop-6	41.44	699.25	1360.69	2187.48	2925.47	3616.12	4335.33	4988.34	5785.94	6443.96	7103.08
Hoop-7	62.04	820.35	1525.02	2087.03	2901.25	3556.04	4349.94	5064.20	5804.86	6393.46	7103.00
Hoop-8	-7.66	688.16	1427.47	2188.97	2863.46	3566.39	4298.60	5008.06	5718.95	6400.35	7132.48
Hoop-9	-96.35	712.54	1507.11	2182.21	2905.63	3601.62	4331.91	4925.18	5777.59	6436.22	7055.47
Hoop-10	-28.30	719.18	1388.91	2186.30	2815.79	3526.02	4331.97	5060.92	5763.02	6439.89	7106.14
Hoop-11	-13.48	677.36	1427.57	2136.83	2869.49	3590.77	4297.95	5031.12	5765.71	6399.05	7075.57
Hoop-12	-65.71	756.01	1447.12	2138.65	2893.69	3568.32	4337.58	4982.48	5795.70	6412.50	7116.37
Hoop-13	-14.62	718.86	1445.15	2042.41	2956.15	3581.60	4344.00	4954.37	5753.14	6450.74	7054.84
Hoop-14	-7.92	613.40	1351.68	2170.80	2741.34	3618.40	4334.90	4969.98	5789.24	6315.59	7061.25
Long-1	162.56	682.31	1427.63	2031.07	2590.58	3288.12	3923.72	4757.30	5408.91	5935.64	6678.24
Long-2	-13.92	633.67	1380.26	1953.89	2803.75	3429.91	4043.77	4652.91	5252.46	5947.02	6726.53
Long-3	8.00	559.29	1232.26	2036.41	2578.83	3358.73	4065.23	4661.67	5303.16	5975.01	6664.85
Long-4	274.06	789.34	1457.72	2096.54	2802.72	3382.47	3883.97	4575.28	5440.60	6038.95	6524.92
Long-5	-6.06	668.23	1170.40	2093.34	2834.24	3425.23	4083.04	4697.14	5349.04	6072.67	6632.52
Long-6	-10.97	718.34	1311.74	1950.74	2654.86	3426.58	3987.67	4685.34	5393.02	6041.63	6662.33
Long-7	53.46	780.26	1328.99	2073.25	2712.09	3119.02	3996.18	4876.88	5414.97	5919.49	6658.33
Long-8	-8.33	503.60	1522.67	2138.25	2662.48	3361.09	3883.74	4639.65	5297.14	5902.55	6501.20
S10	47.64	272.29	434.30	573.32	661.74	759.88	872.33	954.68	1047.26	1129.32	1203.40
S11	99.97	407.68	606.29	765.38	864.15	969.23	1091.36	1183.68	1282.12	1369.11	1448.13
S12	-15.49	-47.24	-29.71	0.93	44.53	87.40	144.54	193.41	247.43	302.87	355.74
S13	16.70	-69.47	-78.87	-71.08	-37.70	-7.42	31.22	65.13	107.40	148.93	190.81
S14	144.05	337.68	459.29	558.62	640.09	722.23	808.90	874.52	948.90	1013.14	1073.01
S15	118.91	214.43	316.11	391.35	457.65	522.23	592.37	645.58	707.12	762.01	813.64
IS10	16.74	-91.13	-137.41	-159.86	-153.33	-143.94	-128.05	-111.38	-75.92	-46.23	-11.49
IS11	75.95	-213.48	-302.29	-340.42	-338.57	-326.27	-303.50	-277.13	-236.14	-193.66	-148.65
IS12	103.82	190.36	302.44	408.16	495.62	586.94	687.68	770.27	863.99	948.08	1027.90
IS13	68.04	208.60	337.41	453.68	538.90	633.27	742.31	828.71	924.04	1011.22	1092.05
IS14	-4.64	-290.04	-386.76	-234.30	-71.85	-80.35	-18.74	90.77	63.67	49.75	94.19
IS15											
IS16	-2315.99	-2068.59	-1952.70	-1872.56	-1798.56	-1724.19	-1676.93	-1649.81	-1621.02	-1611.45	-1612.74
IS17	-46.00	-35.34	-14.33	5.94	32.18	54.26	86.32	113.46	139.72	167.58	193.62
IS18	32.49	29.25	50.57	68.84	104.46	133.22	160.57	180.61	205.23	223.29	242.08

Note: Strain gage IS15 showed faulty readings.

Table E-44. Strain survey raw data (run1) and phase 4 repairs (20,000 cycles for R-BE, U-BE, and U-A2 repairs)

Load Step	0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00
Pressure	-0.08	0.80	1.41	2.02	2.77	3.48	4.08	4.77	5.22	5.99	6.81
Frame-1	24.48	72.90	223.64	375.63	500.06	565.18	631.47	789.95	914.44	1007.85	1099.00
Frame-2	97.68	209.16	238.85	365.35	479.33	420.77	849.87	937.98	927.57	1036.24	1149.28
Frame-3	-0.16	131.71	221.91	356.54	531.11	654.20	640.76	776.35	918.98	1038.64	1113.98
Frame-4	-8.27	106.31	253.58	350.13	431.06	591.89	660.46	822.86	896.44	1026.04	1136.47
Frame-5	24.87	86.00	199.92	377.81	485.60	591.13	694.13	791.54	886.96	1037.78	1069.30
Frame-6	1.54	99.94	245.28	336.85	456.07	579.77	669.44	799.04	898.37	1055.01	1119.43
Frame-7	16.61	81.53	230.44	339.31	457.78	584.73	675.59	799.29	906.42	1042.50	1137.26
Frame-8	-9.16	95.25	377.72	265.47	585.07	519.71	735.24	799.95	837.44	954.46	1070.56
Frame-9	58.94	94.64	369.39	352.72	514.19	603.16	599.38	857.86	993.12	919.64	975.78
Frame-10	167.60	143.96	229.15	361.41	421.77	540.31	670.57	767.13	900.93	1018.27	1107.59
Frame-11	-36.20	35.16	222.40	304.90	415.92	545.69	772.80	863.69	899.13	1078.90	1087.82
Frame-12	-4.08	127.59	202.05	291.04	512.18	553.14	663.24	856.62	851.92	1094.06	1102.99
Hoop-1	-36.23	631.49	1324.74	2110.68	2797.93	3663.79	4457.70	4674.06	5881.84	6388.71	7335.85
Hoop-2	62.86	693.69	1346.17	2165.49	2880.13	3500.57	4119.90	5034.31	5599.96	6394.56	7046.91
Hoop-3	-25.02	689.11	1456.85	2112.60	2872.87	3656.35	4397.27	4975.56	5723.60	6441.76	7214.53
Hoop-4	-29.76	833.10	1361.44	2190.22	2772.25	3514.26	4334.72	4955.61	5705.63	6415.40	7269.21
Hoop-5	89.20	557.90	1482.91	2082.99	2858.39	3478.30	4219.23	5045.74	5693.38	6478.83	7277.99
Hoop-6	-15.36	577.29	1371.23	2179.84	2976.85	3526.34	4306.69	4910.63	5624.01	6327.89	7101.77
Hoop-7	-33.67	688.97	1433.20	2150.75	2821.08	3640.66	4344.61	4983.60	5857.65	6423.50	7219.46
Hoop-8	-1.12	578.68	1463.01	2129.84	2876.11	3637.82	4290.22	4971.61	5711.00	6414.14	7131.78
Hoop-9	-12.46	705.09	1336.88	2165.45	2804.04	3629.68	4492.33	5004.20	5741.58	6563.07	7119.68
Hoop-10	15.71	779.01	1328.66	2157.42	2848.07	3569.68	4313.70	4827.97	5729.27	6526.31	7360.46
Hoop-11	-40.56	788.73	1384.30	2107.53	2841.27	3649.70	4461.16	4901.98	5783.61	6535.70	6996.31
Hoop-12	66.91	643.68	1485.41	2180.15	2927.20	3638.91	4248.45	4937.82	5757.80	6396.37	7310.68
Hoop-13	-7.43	675.65	1215.04	2077.96	2811.17	3624.39	3919.25	4954.86	5594.92	6393.21	7141.14
Hoop-14	193.20	719.43	1377.37	2239.91	2941.35	3460.98	4396.71	5222.79	5654.10	6436.32	7057.70
Long-1	23.54	474.78	1334.64	2043.82	2753.78	3358.48	3909.91	4650.51	5292.88	6128.54	6738.78
Long-2	6.85	738.06	1253.48	2220.21	2917.40	3240.82	3841.98	4923.76	5445.19	6076.22	6866.15
Long-3	6.49	526.60	1220.80	1902.96	2725.51	3271.51	4132.06	4863.50	5157.25	6116.68	6642.41
Long-4	76.86	621.98	1449.34	1912.21	2300.53	3377.39	3863.63	4386.08	5526.65	5931.71	6896.93
Long-5	13.05	695.84	1282.71	1895.98	2724.59	3367.69	3861.14	4520.86	5517.64	5861.14	6601.96
Long-6	1.01	651.22	1175.47	2172.28	2782.47	3094.35	4154.09	4773.15	5284.80	6119.38	6572.92
Long-7	1.66	722.92	1415.28	2107.35	2846.50	3372.99	3731.23	4926.10	5243.25	6202.48	6886.69
Long-8	413.49	514.67	1377.25	1973.15	2735.04	3550.97	3817.06	4509.16	5187.24	6010.17	6860.85
S10	22.05	250.93	365.38	508.16	626.72	723.99	869.99	910.79	984.79	1070.44	1189.72
S11	-12.67	319.43	464.94	646.45	787.39	901.83	1072.10	1108.47	1196.35	1290.23	1423.84
S12	6.85	-1.53	28.72	49.14	94.90	141.37	202.62	239.46	293.06	351.54	430.37
S13	-14.10	-72.63	-61.20	-77.16	-53.42	-24.79	8.20	42.63	83.23	130.70	191.81
S14	63.75	245.27	343.73	421.50	507.42	581.12	659.40	710.27	772.28	837.28	913.02
S15	-21.59	94.02	165.16	212.87	270.15	315.64	372.72	404.92	446.83	496.45	558.34
IS10	-414.24	-638.18	-705.01	-713.72	-786.52	-798.68	-803.00	-807.40	-924.05	-986.60	-1018.48
IS11	-3.49	-242.30	-299.82	-376.02	-405.12	-408.87	-406.34	-396.09	-367.39	-338.30	-285.83
IS12	219.51	273.54	363.95	458.39	551.91	634.11	733.08	790.30	879.11	942.53	1057.79
IS13	1017.14	1335.07	1471.55	1644.11	1801.42	1977.29	2162.79	2240.13	2380.54	2524.34	2673.28
IS14	19.01	13.26	59.27	95.37	155.66	211.44	291.05	335.69	415.04	487.10	583.04
IS15	-21.40	-9.82	27.25	51.67	97.44	139.21	197.27	241.60	302.74	366.37	447.85
IS16	-41.45	116.05	197.82	295.60	378.63	443.63	539.07	554.57	603.30	650.51	724.28
IS17	-21.15	-13.20	9.95	30.57	60.23	88.62	124.42	149.21	186.65	221.54	265.71
IS18	18.05	29.79	64.40	66.39	80.84	91.49	78.08	101.47	114.34	119.34	111.69

Table E-45. Strain survey raw data (run2) and phase 4 repairs (20,000 cycles for R-BE, U-BE, and U-A2 repairs)

Load Step	0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00
Pressure	-0.11	0.68	1.35	1.88	2.78	3.33	3.94	4.67	5.30	6.12	6.68
Frame-1	-1.17	81.35	226.55	365.43	427.72	573.33	679.18	818.01	899.18	1035.53	1175.77
Frame-2	17.37	15.18	118.19	488.23	371.80	571.97	755.43	754.94	876.92	1047.45	1114.70
Frame-3	76.32	81.90	303.85	303.52	437.06	460.10	702.90	812.03	981.01	1006.23	1210.43
Frame-4	-13.61	62.81	197.91	331.87	490.99	539.73	670.52	774.55	930.13	1017.55	1129.88
Frame-5	22.63	20.17	160.30	365.59	545.40	561.58	738.17	772.42	941.97	978.53	1200.70
Frame-6	41.48	94.97	229.07	333.85	468.23	554.55	692.81	804.68	927.34	976.53	1161.07
Frame-7	-1.85	97.75	242.20	352.73	468.47	551.15	682.84	804.47	908.51	1016.45	1139.76
Frame-8	74.55	133.98	194.40	260.81	464.08	474.49	757.03	746.82	1014.34	1039.67	1175.95
Frame-9	113.94	122.16	178.31	379.62	517.34	474.84	752.42	711.19	812.65	954.71	1158.94
Frame-10	6.31	132.74	234.20	358.22	462.75	543.54	690.33	800.78	930.40	1015.33	1101.40
Frame-11	49.29	140.31	187.22	317.89	461.47	601.70	691.29	784.88	875.70	1053.74	1103.90
Frame-12	-38.96	-19.48	279.65	325.25	442.90	523.14	715.06	756.55	929.15	1059.89	1140.49
Hoop-1	85.34	669.59	1322.66	2170.14	2812.17	3545.48	4380.13	4947.55	5740.96	6518.70	7069.13
Hoop-2	121.99	725.95	1331.57	2159.68	3028.58	3711.70	4184.83	4942.42	5620.35	6499.65	7123.97
Hoop-3	-0.87	733.96	1347.90	2176.00	2820.84	3576.64	4209.69	4956.10	5739.71	6530.80	7130.00
Hoop-4	19.09	708.28	1346.70	2131.90	3019.77	3714.69	4255.56	4938.84	5579.68	6389.44	7166.10
Hoop-5	385.50	532.76	1491.59	2213.68	2885.04	3508.49	4284.30	5027.28	5665.31	6384.81	7198.97
Hoop-6	107.88	734.96	1338.34	2190.28	2900.44	3547.74	4404.98	5089.55	5738.88	6519.35	7029.28
Hoop-7	130.90	692.55	1429.34	2273.74	2901.28	3599.16	4337.89	4975.95	5704.44	6499.76	7176.53
Hoop-8	56.88	723.77	1434.30	2166.30	2869.44	3435.19	4239.48	5015.61	5748.39	6399.64	7124.53
Hoop-9	32.29	674.81	1469.60	2137.03	2965.68	3225.51	4320.52	5060.19	5660.37	6108.47	7173.37
Hoop-10	42.23	669.60	1406.69	2194.75	2937.00	3653.10	4453.31	4999.89	5714.51	6669.46	7212.01
Hoop-11	-8.18	666.54	1406.17	2131.13	2831.04	3662.66	4328.02	4817.89	5800.96	6337.78	7111.46
Hoop-12	134.06	720.00	1420.39	2122.31	2891.50	3668.30	4117.84	4981.85	5555.72	6396.37	7194.58
Hoop-13	28.53	618.25	1733.14	2142.90	2898.03	3538.44	4343.56	4804.31	5725.51	6501.08	7054.84
Hoop-14	449.13	756.12	1494.62	2101.24	2824.97	3673.34	4221.26	5077.08	5816.09	6443.63	7072.32
Long-1	34.37	592.47	1268.50	1982.89	2709.76	3342.24	4003.60	4611.44	5231.45	5983.03	6782.64
Long-2	10.86	513.01	1305.30	1792.43	2390.96	3478.63	4021.73	4846.16	5542.56	6044.22	6757.65
Long-3	12.96	633.55	1226.32	1902.30	2694.09	3264.80	3986.02	4687.73	5266.59	6064.87	6750.19
Long-4	24.73	834.72	1296.74	1819.35	2625.10	3164.20	4162.61	4793.97	5263.56	6199.85	6662.77
Long-5	4.31	574.64	1398.00	1922.97	2809.41	3292.56	3821.21	4839.10	5180.97	5949.99	6529.06
Long-6	2.77	721.25	1306.97	2004.54	2534.33	3482.56	4073.72	4495.28	5496.67	5797.46	6644.17
Long-7	18.74	480.15	1195.13	1731.68	2849.01	3325.50	4009.46	4750.43	5415.65	5972.30	6765.44
Long-8	219.00	840.25	1484.23	2133.07	2851.07	3166.91	3846.07	4623.80	5152.20	5862.08	6736.49
S10	-0.21	193.03	333.22	481.21	621.78	762.53	802.23	896.86	997.27	1101.56	1166.51
S11	-48.26	224.97	414.38	605.36	769.36	930.47	975.67	1079.75	1188.95	1307.00	1372.32
S12	22.17	14.87	28.00	52.79	93.07	146.84	186.23	233.77	295.79	366.30	414.79
S13	39.37	-42.19	-61.21	-69.18	-59.58	-32.22	3.30	33.56	81.96	137.58	176.73
S14	54.76	232.16	322.34	412.46	501.58	585.10	638.31	700.72	774.08	847.58	901.63
S15	38.02	107.03	163.73	222.98	274.10	330.46	362.10	400.14	453.69	509.28	547.03
IS10	-1256.00	-1188.32	-1214.84	-1269.56	-1384.04	-1420.04	-1414.42	-1521.40	-1502.99	-1505.00	-1489.16
IS11	26.83	-194.29	-290.65	-370.24	-408.33	-420.60	-408.55	-398.18	-371.36	-328.91	-299.31
IS12	40.25	103.14	166.55	272.79	413.67	515.35	571.20	614.58	717.16	820.39	898.00
IS13	978.58	1161.92	1313.84	1478.25	1653.57	1843.44	1929.47	2051.28	2173.92	2323.56	2395.58
IS14	55.34	21.10	53.43	93.19	149.03	215.83	269.02	329.38	408.34	496.11	557.39
IS15	-15.61	7.54	33.95	65.06	99.60	147.35	195.48	240.65	305.63	378.13	434.02
IS16	502.21	534.03	600.88	678.87	757.04	831.21	858.20	898.56	942.92	1010.09	1044.09
IS17	-1.44	-6.87	12.85	35.09	60.41	92.05	119.19	147.38	184.84	227.14	256.98
IS18	36.11	40.80	64.99	76.73	78.89	73.66	101.29	98.56	104.00	107.38	110.13

Table E-46. Strain survey raw data (run3) and phase 4 repairs (20,000 cycles for R-BE, U-BE, and U-A2 repairs)

Load Step	0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00
Pressure	-0.20	0.77	1.31	2.09	2.70	3.45	4.27	4.74	5.49	5.86	6.58
Frame-1	48.44	113.09	260.80	324.48	446.71	579.52	624.37	798.23	857.41	1039.61	1148.37
Frame-2	30.83	217.66	157.00	320.60	346.78	647.39	730.79	655.92	989.37	951.74	1228.31
Frame-3	-21.89	90.86	170.35	315.25	486.16	591.16	586.23	780.51	914.32	1072.22	1134.86
Frame-4	-21.76	101.85	215.02	322.00	465.96	566.78	682.37	793.08	886.22	1027.57	1109.87
Frame-5	-15.16	143.62	217.55	327.65	532.11	583.72	609.03	840.40	852.30	1036.67	1146.80
Frame-6	-7.94	119.52	263.83	354.52	453.88	576.60	669.04	805.23	870.37	1029.84	1139.17
Frame-7	-13.16	103.93	244.14	353.31	469.55	574.79	654.08	794.76	898.21	1024.06	1133.54
Frame-8	61.88	168.70	367.95	458.83	516.61	488.98	768.85	820.42	873.78	949.11	1057.47
Frame-9	27.41	136.49	270.04	333.73	368.53	673.84	529.83	859.31	795.03	1050.27	1134.90
Frame-10	-3.48	119.82	231.26	355.60	439.12	555.49	694.74	800.41	950.56	1090.62	1151.16
Frame-11	34.85	85.78	201.49	383.28	428.39	502.17	725.58	797.81	906.34	1064.23	1212.14
Frame-12	30.83	101.03	237.91	342.91	503.34	560.05	658.72	785.74	964.27	1001.06	1159.21
Hoop-1	-59.81	722.28	1422.59	2354.98	2908.61	3757.40	4455.45	5064.17	5499.64	6573.13	7354.73
Hoop-2	27.01	607.73	1614.86	2146.92	2756.47	3553.63	4350.63	4649.00	5738.63	6397.51	7113.93
Hoop-3	21.56	680.55	1482.58	2086.09	2902.19	3540.07	4231.28	5158.41	5665.54	6496.31	7177.29
Hoop-4	-8.04	657.70	1598.27	2147.96	2754.16	3587.71	4283.65	5062.33	5780.47	6456.36	7228.32
Hoop-5	89.18	507.66	1344.48	2096.74	2928.43	3549.44	4288.83	4979.29	5704.82	6445.87	7206.87
Hoop-6	15.45	615.41	1365.66	2123.01	2826.42	3668.80	4219.28	4984.94	5706.26	6541.10	7236.61
Hoop-7	-28.29	662.20	1535.02	2146.53	2853.28	3563.03	4342.39	4912.06	5774.20	6396.03	7112.85
Hoop-8	20.63	876.08	1397.92	2122.59	2891.47	3587.08	4218.99	4971.61	5631.26	6501.13	7146.28
Hoop-9	-119.84	690.98	1396.07	2271.03	2826.36	3586.72	4237.66	4818.07	5659.25	6507.59	7320.13
Hoop-10	-14.33	634.32	1429.52	2198.06	2833.01	3709.29	4253.11	5108.96	5893.63	6416.74	7353.39
Hoop-11	-44.16	677.40	1463.61	2139.91	2879.91	3669.49	4305.91	4928.97	5648.67	6631.06	6915.34
Hoop-12	23.38	767.24	1516.40	2071.31	2913.56	3464.76	4344.09	5068.43	5794.08	6323.80	7078.47
Hoop-13	-0.24	776.54	1545.98	2092.34	2804.81	3574.05	4258.53	5026.78	5767.52	6501.08	6932.58
Hoop-14	280.94	631.91	1340.95	2130.27	2810.63	3870.36	4288.33	5032.72	5646.79	6545.97	7240.46
Long-1	20.48	832.80	1456.10	2172.61	2709.76	3396.51	4016.86	4592.14	5441.95	5990.92	6775.37
Long-2	11.61	538.30	1218.43	1972.41	2460.80	3385.92	3866.38	4783.83	5281.25	5996.00	6711.17
Long-3	5.29	633.55	1221.52	2125.30	2557.65	3459.89	3890.18	4629.70	5440.99	6161.64	6764.63
Long-4	-7.79	808.88	942.76	2103.38	2768.79	3259.00	3697.06	4695.06	5288.15	6115.14	6509.30
Long-5	17.54	505.18	1178.75	1860.12	2554.01	3327.90	3942.98	4821.39	5284.27	6088.57	6602.59
Long-6	-22.67	563.80	1404.71	1814.34	2444.90	3114.70	4139.07	4746.45	5391.40	6156.31	6806.48
Long-7	2.41	617.87	1057.67	2113.17	2821.87	3586.50	3726.34	4679.56	5365.92	6228.00	6894.68
Long-8	247.08	821.69	1432.24	2186.68	2768.00	3570.58	4321.42	4610.34	5363.45	6003.08	6754.62
S10	3.59	238.94	416.08	571.60	639.69	743.32	894.24	954.75	1036.43	1093.60	1201.61
S11	-88.79	241.20	487.50	689.70	770.39	878.05	1049.16	1113.89	1207.77	1272.91	1390.72
S12	6.12	-1.17	23.62	39.85	88.15	134.47	198.39	246.94	300.68	348.99	418.98
S13	14.36	-67.55	-72.81	-103.82	-60.12	-30.23	3.85	46.80	87.93	128.34	182.16
S14	14.40	234.33	354.79	430.08	503.39	576.90	659.63	719.12	780.33	837.10	906.70
S15	-25.38	75.58	168.43	206.77	257.12	305.05	362.35	401.66	445.88	485.26	540.53
IS10	-1328.46	-1278.79	-1376.12	-1453.45	-1542.44	-1438.32	-1636.43	-1659.96	-1543.16	-1476.20	-1452.44
IS11	48.66	-208.15	-323.86	-408.41	-408.87	-412.38	-411.49	-393.21	-368.80	-339.92	-295.70
IS12	23.98	145.03	299.35	424.19	500.18	601.03	694.50	771.78	855.22	955.86	1052.07
IS13	1262.07	1427.18	1652.84	1785.59	1857.26	1963.86	2128.18	2211.75	2335.20	2410.13	2483.60
IS14	57.36	9.18	71.77	91.53	153.42	216.87	290.22	346.02	421.21	491.76	575.46
IS15	-26.10	-7.29	37.56	39.74	96.16	145.21	195.60	245.94	303.98	362.58	437.09
IS16	321.93	477.07	579.97	724.09	763.76	796.46	877.57	900.20	909.38	922.65	958.46
IS17	-14.28	-15.91	12.85	26.05	58.42	88.64	123.31	152.65	187.18	220.63	258.79
IS18	26.89	32.72	67.84	44.73	82.05	97.19	79.65	100.61	103.76	119.07	109.77

APPENDIX F—STRAIN GAGE DATA REDUCTION PROCEDURE

The raw strain gage data in appendix E was reduced to remove the strain gage offset due to preloading after the panel was installed in the fixture. In the strain gage data reduction, the first data point was removed to minimize the effects of preloading and free play. A second order regression using a least squares method was used to curve-fit the remaining data set to a second order polynomial:

$$\varepsilon = Ax^2 + Bx + C \tag{F-1}$$

where ε is the dependent strain value, x is the independent load increment variable, A is the quadratic coefficient, B is the linear coefficient, and C is the constant term or ordinate intercept. Parameter C was used to define the zero load offset, which was used to shift all data in the set and finally obtain the shifted values.

Table F-1(a) shows all the raw readings of strain gage S10 and table F-1(b) shows the raw readings of strain gage S10 with the first data point removed. The data in table F-1(b) is plotted with strain readings as ordinate and pressure as abscissa, as shown in figure F-1. The data after shifting to zero load offset is shown in figure F-2. Following the procedure defined above, the raw strain gage data documented in appendix E can be reduced. As an example, tables F-2–F-9 show the reduced strain gage data for all the patches at their respective 20,000 cycles in terms of the 10 equal load increments up to the maximum loads for each load sequence. These values were obtained by following the data reduction procedure explained above. The hoop strain values shown in table F-2–F-9 are plotted with respect to increasing pressure in figures F-3–F-10 for all the patches. These figures show the reduced results from the strain gages on the exterior surface of the patches and exterior and interior surface of the fuselage panel skin. The figures also include the locations of these strain gages and the maximum load applied for these strain surveys.

Table F-1. Raw data for strain gage S10 with the increasing pressure (a) readings of all the data points and (b) readings with the first data point removed

Run	Pressure	S10
RUN 1	-0.04	-92.22
	0.74	87.49
	1.29	232.87
	1.94	397.47
	2.63	547.47
	3.17	651.86
	3.95	790.03
	4.63	910.41
	5.34	1020.99
	5.98	1121.40
	6.79	1228.75
RUN 2	-0.03	-111.75
	0.60	40.09
	1.27	238.52
	2.00	409.56
	2.70	566.40
	3.36	688.07
	4.10	823.80
	4.66	910.60
	5.34	1027.92
	6.02	1124.92
	6.71	1226.90
RUN 3	0.03	-105.70
	0.70	76.08
	1.30	242.31
	2.05	415.66
	2.71	556.40
	3.37	702.43
	4.14	825.85
	4.70	923.37
	5.46	1033.10
	6.03	1126.29
	6.63	1215.79

(a)

Run	Pressure	S10
RUN 1	0.74	187.52
	1.29	332.90
	1.94	497.50
	2.63	647.50
	3.17	751.89
	3.95	890.07
	4.63	1010.44
	5.34	1121.02
	5.98	1221.43
	6.79	1328.78
RUN 2	0.60	140.12
	1.27	338.55
	2.00	509.59
	2.70	666.43
	3.36	788.10
	4.10	923.83
	4.66	1010.63
	5.34	1127.95
	6.02	1224.95
	6.71	1326.93
RUN 3	0.70	176.11
	1.30	342.34
	2.05	515.69
	2.71	656.43
	3.37	802.46
	4.14	925.88
	4.70	1023.40
	5.46	1133.13
	6.03	1226.32
	6.63	1315.82

(b)

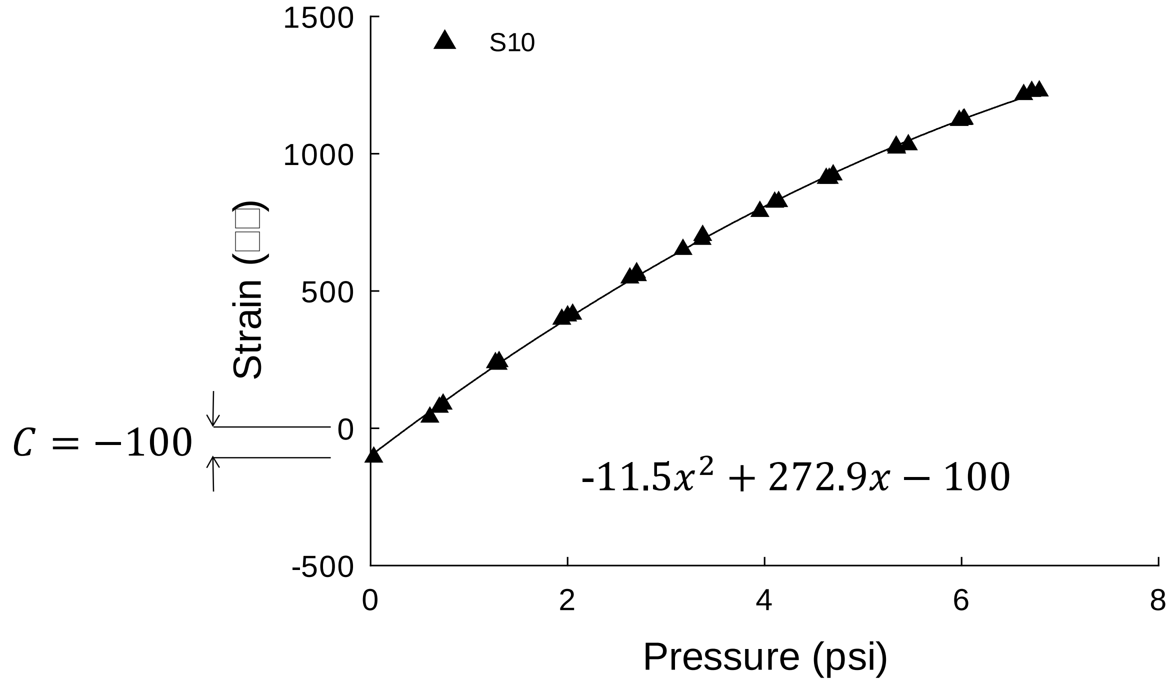


Figure F-1. Raw strain gage reading with increasing pressure showing Y-intercept

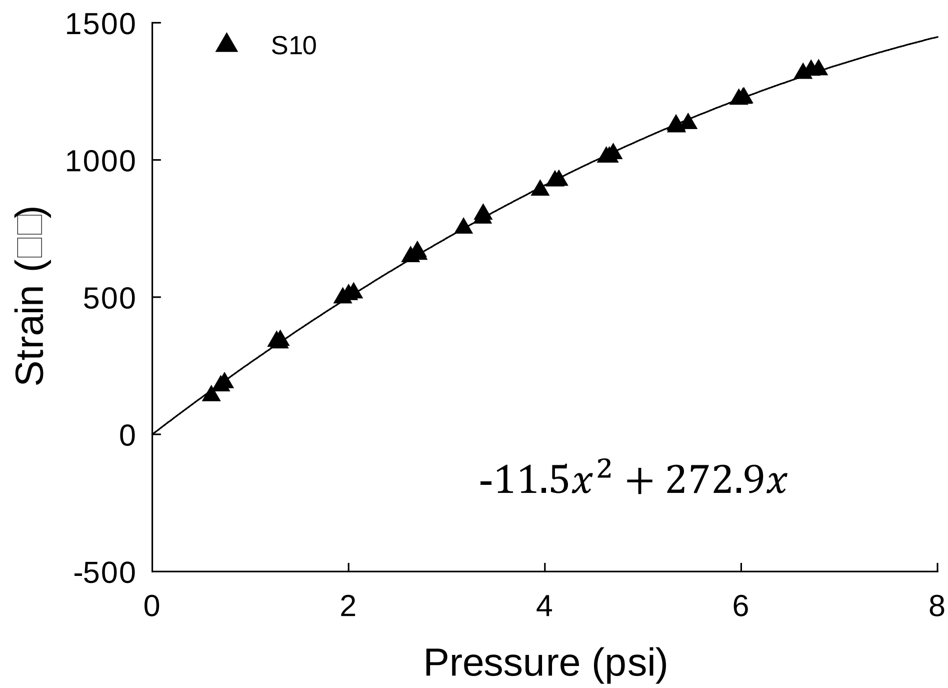


Figure F-2. Strain gage reading with increasing pressure after shifting to 0 loads offset

S10			
Load Step	Run1	Run 2	Run 3
0			
1	187.52	140.12	176.11
2	332.90	338.55	342.34
3	497.50	509.59	515.69
4	647.50	666.43	656.43
5	751.89	788.10	802.46
6	890.07	923.83	925.88
7	1010.44	1010.63	1023.40
8	1121.02	1127.95	1133.13
9	1221.43	1224.95	1226.32
10	1328.78	1326.93	1315.82

S11			
Load Step	Run1	Run 2	Run 3
0			
1	245.65	159.09	210.80
2	435.41	441.94	441.03
3	643.54	662.06	670.41
4	815.53	842.43	834.14
5	941.30	985.12	1002.38
6	1102.46	1139.01	1142.63
7	1232.65	1234.23	1247.84
8	1353.08	1360.41	1369.30
9	1461.25	1467.06	1468.93
10	1578.19	1575.65	1564.57

S16			
Load Step	Run1	Run 2	Run 3
0			
1	-250.61	-174.55	-213.45
2	-438.72	-434.48	-437.26
3	-632.87	-654.06	-660.12
4	-805.85	-821.58	-823.52
5	-934.38	-965.83	-984.71
6	-1088.29	-1113.71	-1114.25
7	-1201.02	-1206.44	-1214.83
8	-1312.96	-1311.76	-1327.06
9	-1403.28	-1405.29	-1403.89
10	-1490.75	-1486.02	-1484.38

IS10			
Load Step	Run1	Run 2	Run 3
0			
1	-88.48	-65.27	-48.23
2	-150.49	-147.23	-132.00
3	-190.58	-207.78	-196.18
4	-231.72	-241.71	-237.34
5	-254.58	-263.99	-263.07
6	-269.79	-275.62	-269.96
7	-266.77	-270.14	-269.05
8	-260.55	-258.72	-263.79
9	-241.16	-240.07	-238.97
10	-210.70	-214.33	-215.41

IS11			
Load Step	Run1	Run 2	Run 3
0			
1	-106.10	-61.44	-84.31
2	-192.13	-192.50	-192.86
3	-265.49	-275.99	-281.98
4	-317.38	-318.85	-327.36
5	-343.17	-346.78	-351.29
6	-354.77	-354.97	-355.29
7	-349.39	-350.21	-352.75
8	-335.89	-331.15	-336.23
9	-307.96	-308.32	-309.21
10	-274.74	-273.83	-281.27

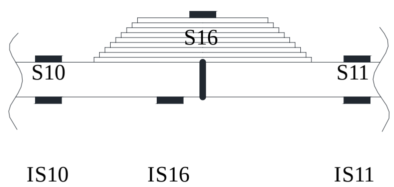
IS16			
Load Step	Run1	Run 2	Run 3
0			
1	134.00	94.04	113.91
2	233.39	234.12	230.84
3	343.92	352.01	351.10
4	444.65	454.74	444.47
5	519.56	540.98	546.16
6	618.71	635.59	633.61
7	703.27	700.69	703.01
8	778.66	781.68	782.04
9	851.15	850.24	847.79
10	924.47	921.56	911.55

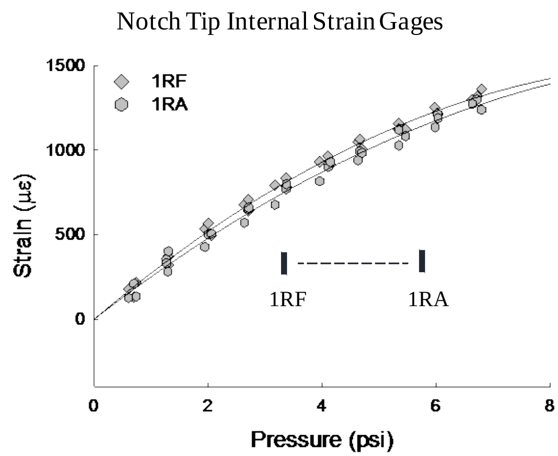
1RF			
Load Step	Run1	Run 2	Run 3
0			
1	217.23	178.09	131.14
2	369.36	356.81	319.86
3	531.93	565.91	496.21
4	677.47	707.73	640.35
5	792.00	834.71	784.07
6	930.44	963.99	914.18
7	1046.05	1064.67	1005.71
8	1156.11	1123.44	1123.26
9	1251.75	1218.44	1209.79
10	1361.14	1316.18	1296.70

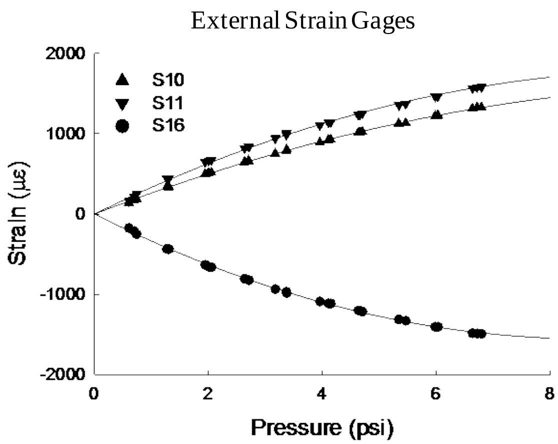
1RA			
Load Step	Run1	Run 2	Run 3
0			
1	133.65	125.66	210.30
2	281.16	331.36	401.49
3	427.27	501.35	507.51
4	571.13	651.27	659.57
5	676.83	769.57	798.69
6	815.79	900.85	930.07
7	938.70	993.50	983.35
8	1027.46	1119.62	1082.47
9	1135.21	1214.59	1188.40
10	1238.52	1298.69	1273.50

Figure F-3. Strain gages reading for R-BE repair after data reduction

Load Condition	Max. Load
Pressure	6.675 psi
Hoop	7140 lb
Axial	6675 lb
Frame	1132.5 lb







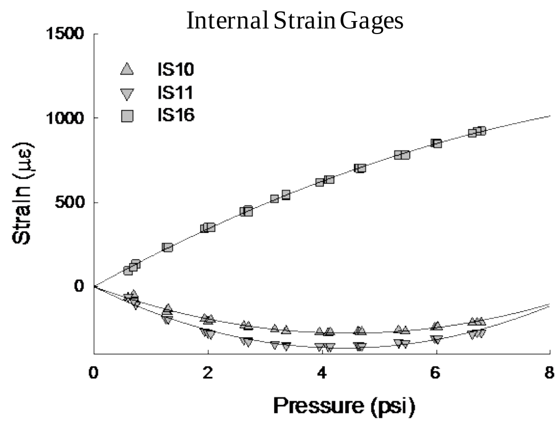


Figure F-4. Strain vs. pressure for R-BE repair gages after data reduction

S14			
Load Step	Run1	Run 2	Run 3
0			
1	158.31	125.95	159.03
2	323.44	332.24	336.39
3	481.69	491.06	496.70
4	615.99	632.50	620.23
5	708.79	740.93	744.77
6	832.12	853.64	857.35
7	935.57	938.10	941.31
8	1026.07	1037.53	1038.42
9	1121.48	1125.54	1126.03
10	1212.78	1213.57	1202.99

S15			
Load Step	Run1	Run 2	Run 3
0			
1	158.83	120.35	155.30
2	340.52	349.16	348.56
3	499.58	508.68	511.36
4	632.84	644.88	630.85
5	720.37	749.47	753.18
6	838.59	856.10	858.88
7	935.06	935.70	937.18
8	1018.54	1027.26	1029.16
9	1107.44	1109.39	1109.92
10	1192.04	1191.40	1180.90

S18			
Load Step	Run1	Run 2	Run 3
0			
1	-335.34	-242.46	-307.05
2	-595.92	-607.53	-603.18
3	-864.59	-889.14	-902.93
4	-1090.91	-1115.68	-1109.06
5	-1245.61	-1297.76	-1307.82
6	-1432.76	-1469.90	-1460.95
7	-1561.63	-1560.37	-1571.26
8	-1666.47	-1666.32	-1688.82
9	-1748.64	-1752.27	-1755.74
10	-1827.76	-1821.95	-1819.04

IS14			
Load Step	Run1	Run 2	Run 3
0			
1	-76.87	-42.77	-59.00
2	-144.34	-144.34	-149.44
3	-197.06	-206.52	-213.45
4	-230.59	-234.43	-244.81
5	-241.36	-242.26	-249.35
6	-234.05	-237.53	-236.41
7	-214.94	-217.26	-226.01
8	-196.31	-189.55	-195.38
9	-154.92	-157.47	-158.93
10	-116.44	-116.62	-126.65

IS15			
Load Step	Run1	Run 2	Run 3
0			
1	-50.90	-34.99	-42.57
2	-106.98	-104.61	-108.49
3	-144.37	-149.32	-150.23
4	-161.54	-161.97	-170.35
5	-165.66	-161.09	-166.77
6	-148.18	-148.10	-147.07
7	-123.35	-123.62	-130.10
8	-98.31	-91.87	-93.33
9	-53.20	-54.21	-54.52
10	-8.95	-9.13	-18.03

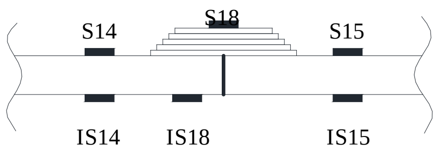
IS18			
Load Step	Run1	Run 2	Run 3
0			
1	64.66	55.40	64.13
2	131.91	134.86	127.36
3	196.90	195.50	194.63
4	254.14	261.89	247.64
5	296.99	314.14	310.29
6	363.18	370.68	371.73
7	419.09	419.69	414.69
8	465.73	474.14	470.95
9	523.33	523.38	521.46
10	574.47	574.66	563.34

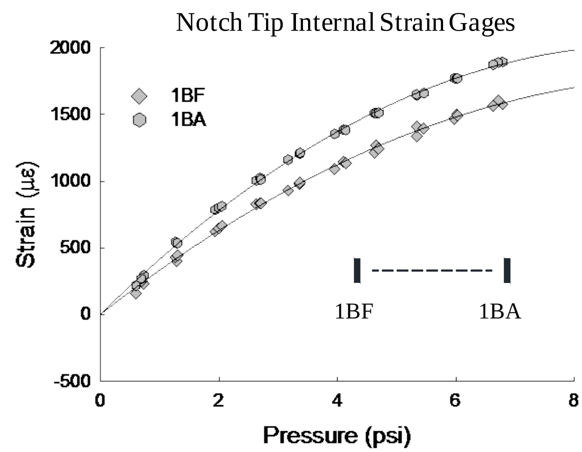
1BF			
Load Step	Run1	Run 2	Run 3
0			
1	230.16	157.68	254.59
2	399.77	430.19	442.94
3	623.38	644.41	665.54
4	825.29	833.74	833.13
5	929.93	978.67	988.60
6	1092.70	1143.44	1133.04
7	1215.26	1268.01	1244.87
8	1339.34	1408.44	1395.32
9	1467.72	1501.24	1493.82
10	1575.57	1603.99	1566.09

1BA			
Load Step	Run1	Run 2	Run 3
0			
1	293.52	216.52	268.66
2	533.87	544.41	535.87
3	785.04	801.09	811.99
4	1004.18	1024.61	1010.90
5	1161.41	1205.27	1212.61
6	1354.95	1385.23	1384.98
7	1509.40	1508.50	1512.31
8	1644.69	1650.72	1660.53
9	1772.01	1772.55	1770.94
10	1894.27	1889.73	1874.11

Figure F-5. Strain gages reading for U-BE repair after data reduction

Load Condition	Max. Load
Pressure	6.675 psi
Hoop	7140 lb
Axial	6675 lb
Frame	1132.5 lb





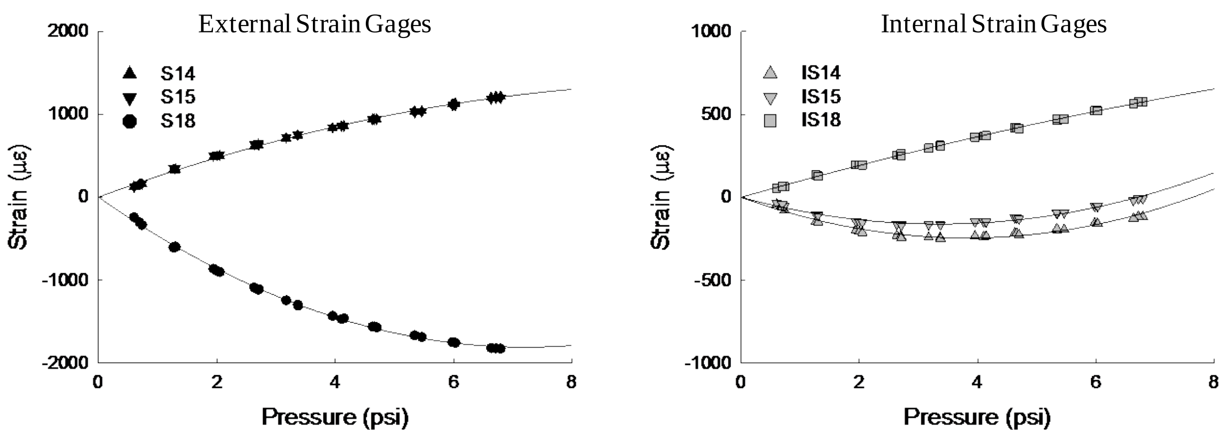


Figure F-6. Strain vs. pressure for U-BE repair gages after data reduction

S12			
Load Step	Run1	Run 2	Run 3
0			
1	133.96	94.89	136.52
2	219.23	197.78	227.41
3	332.73	328.49	337.58
4	440.47	453.60	443.56
5	520.33	546.82	554.04
6	626.08	651.05	654.56
7	724.27	725.46	732.73
8	813.33	821.61	824.16
9	901.40	905.58	906.04
10	992.30	991.39	981.58

S13			
Load Step	Run1	Run 2	Run 3
0			
1	135.12	109.42	135.38
2	285.37	296.90	298.08
3	422.97	435.82	437.37
4	539.22	554.03	544.78
5	619.72	647.26	651.75
6	722.01	742.86	745.85
7	809.48	812.66	817.35
8	887.44	896.74	897.83
9	966.57	970.81	971.66
10	1044.47	1045.01	1036.81

S17			
Load Step	Run1	Run 2	Run 3
0			
1	-320.99	-224.73	-277.81
2	-525.63	-529.03	-528.71
3	-773.32	-802.63	-813.78
4	-1002.05	-1027.23	-1032.14
5	-1175.59	-1222.50	-1250.23
6	-1388.56	-1436.85	-1429.19
7	-1555.59	-1553.63	-1571.39
8	-1721.40	-1715.64	-1742.51
9	-1852.86	-1855.39	-1852.11
10	-1998.04	-1989.11	-1976.82

IS12			
Load Step	Run1	Run 2	Run 3
0			
1	45.14	41.34	62.22
2	143.04	138.52	138.71
3	211.93	200.56	200.15
4	264.93	256.99	247.47
5	305.81	303.76	302.49
6	360.01	357.10	357.23
7	415.83	406.37	397.98
8	459.71	459.78	451.72
9	515.97	509.13	505.15
10	565.94	561.24	549.94

IS13			
Load Step	Run1	Run 2	Run 3
0			
1	-40.88	-12.66	-25.54
2	-100.64	-101.28	-103.51
3	-128.06	-138.01	-141.38
4	-133.92	-136.61	-147.52
5	-127.42	-122.72	-127.08
6	-96.14	-94.10	-92.44
7	-58.73	-61.81	-65.86
8	-21.26	-15.03	-19.12
9	33.45	31.45	29.94
10	86.35	84.76	74.51

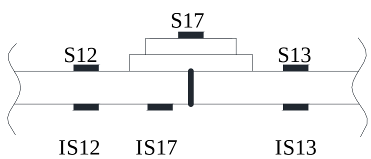
IS17			
Load Step	Run1	Run 2	Run 3
0			
1	73.94	57.43	70.53
2	132.23	134.74	134.24
3	200.16	202.13	203.04
4	260.92	266.22	260.01
5	306.99	320.07	322.95
6	369.03	379.26	380.64
7	422.66	421.77	423.05
8	470.59	475.28	474.91
9	521.60	521.42	521.01
10	569.29	568.57	561.29

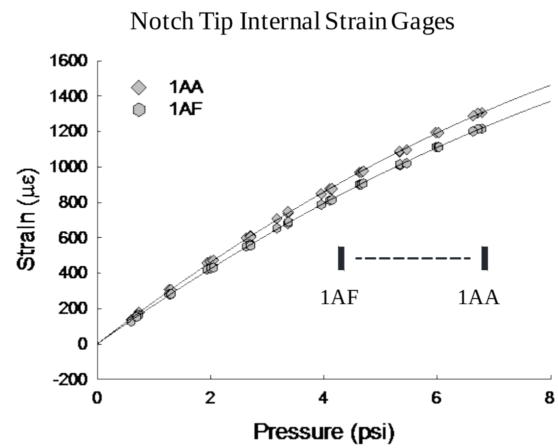
1AF			
Load Step	Run1	Run 2	Run 3
0			
1	162.69	126.81	153.11
2	278.74	281.65	282.02
3	419.86	426.71	430.90
4	550.66	561.99	555.21
5	653.00	679.89	689.65
6	786.91	810.82	813.59
7	900.72	900.76	907.31
8	1008.59	1015.60	1020.33
9	1112.80	1113.71	1112.52
10	1216.01	1213.65	1201.09

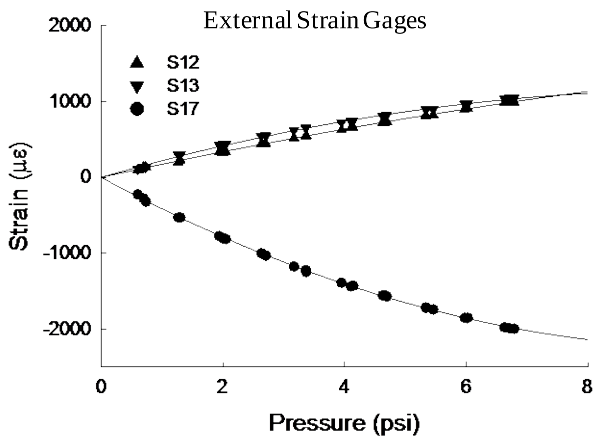
1AA			
Load Step	Run1	Run 2	Run 3
0			
1	177.97	134.16	161.17
2	304.56	307.43	305.65
3	458.13	466.72	471.27
4	599.76	612.57	605.23
5	707.32	737.14	747.46
6	849.01	875.50	876.26
7	968.97	968.81	975.73
8	1084.22	1089.22	1096.15
9	1194.19	1195.10	1193.90
10	1306.80	1302.98	1289.86

Figure F-7. Strain gage reading for U-A2 repair after data reduction

Load Condition	Max. Load
Pressure	6.675 psi
Hoop	7140 lb
Axial	6675 lb
Frame	1132.5 lb







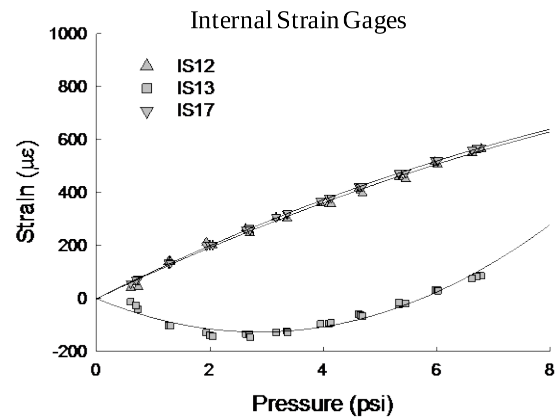


Figure F-8. Strain vs. pressure for U-A2 repair gages after data reduction

S23			
Load Step	Run1	Run 2	Run 3
0			
1	53.10	77.98	65.19
2	120.53	126.49	127.03
3	169.76	182.91	182.55
4	235.03	237.36	238.48
5	297.21	312.02	312.08
6	358.18	358.54	360.52
7	428.68	420.16	421.10
8	485.92	485.52	480.38
9	542.63	545.20	557.23
10	616.55	605.49	603.57

S24			
Load Step	Run1	Run 2	Run 3
0			
1	99.58	186.54	176.75
2	357.62	388.77	378.13
3	493.20	527.50	535.12
4	632.12	640.53	642.47
5	739.54	768.65	769.89
6	836.83	840.62	842.60
7	940.36	929.08	931.52
8	1019.33	1019.46	1011.86
9	1093.67	1097.20	1111.70
10	1186.37	1174.71	1170.68

S27			
Load Step	Run1	Run 2	Run 3
0			
1	-324.68	-364.36	-368.18
2	-675.32	-689.45	-633.65
3	-880.82	-920.34	-979.44
4	-1194.27	-1132.97	-1128.22
5	-1386.08	-1462.44	-1418.90
6	-1586.14	-1591.08	-1556.37
7	-1800.81	-1759.07	-1757.16
8	-1932.96	-1924.12	-1886.93
9	-2043.60	-2023.98	-2051.49
10	-2148.57	-2139.34	-2117.00

IS23			
Load Step	Run1	Run 2	Run 3
0			
1	-29.24	-22.52	-16.70
2	-28.01	-23.93	-10.76
3	-28.33	-23.66	-29.15
4	-35.05	-22.88	-15.79
5	-24.90	-21.97	-12.36
6	-11.76	-9.48	-2.01
7	12.49	10.57	16.42
8	35.74	36.23	41.55
9	67.55	74.27	86.98
10	114.44	109.88	118.24

IS24			
Load Step	Run1	Run 2	Run 3
0			
1	-181.81	-192.22	
2	-238.41	-246.99	
3	-288.90	-281.75	
4	-303.72	-307.41	
5	-307.71	-307.99	
6	-295.72	-300.44	
7	-280.96	-284.85	
8	-253.38	-250.84	
9	-213.86	-221.80	
10	-81.06	-80.52	

IS27			
Load Step	Run1	Run 2	Run 3
0			
1	3.85	9.49	2.76
2	26.94	25.31	25.30
3	37.66	38.76	30.94
4	46.92	48.94	46.75
5	60.39	57.84	58.03
6	71.30	67.11	66.40
7	86.01	79.67	76.93
8	98.40	94.56	90.76
9	114.76	112.95	114.20
10	138.20	127.85	128.20

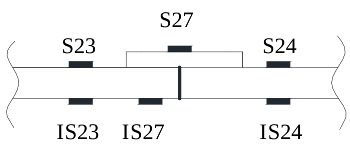
1UAF			
Load Step	Run1	Run 2	Run 3
0			
1	177.17	198.76	200.88
2	370.79	379.36	359.43
3	507.93	527.15	548.46
4	683.74	663.63	662.45
5	813.64	849.27	832.29
6	944.70	946.08	934.59
7	1087.60	1064.30	1066.93
8	1190.73	1182.68	1169.59
9	1291.83	1288.56	1304.29
10	1406.29	1393.31	1383.52

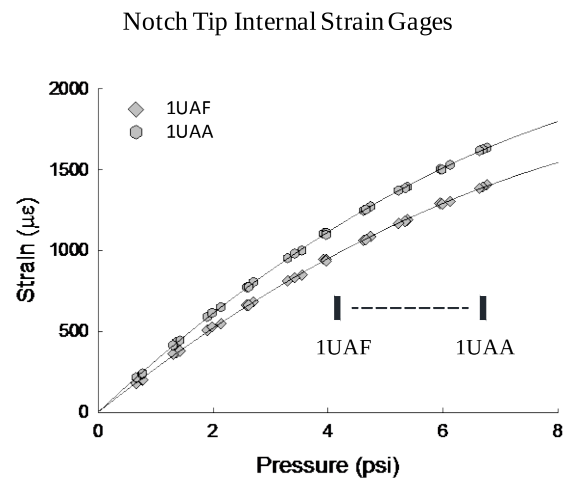
1UAA			
Load Step	Run1	Run 2	Run 3
0			
1	215.78	236.14	240.51
2	435.26	443.99	415.62
3	590.74	614.77	650.33
4	805.70	773.13	774.59
5	953.34	1001.22	981.76
6	1105.21	1110.20	1097.31
7	1273.69	1247.74	1254.18
8	1393.82	1386.31	1372.01
9	1505.01	1502.83	1530.30
10	1637.12	1625.64	1618.23

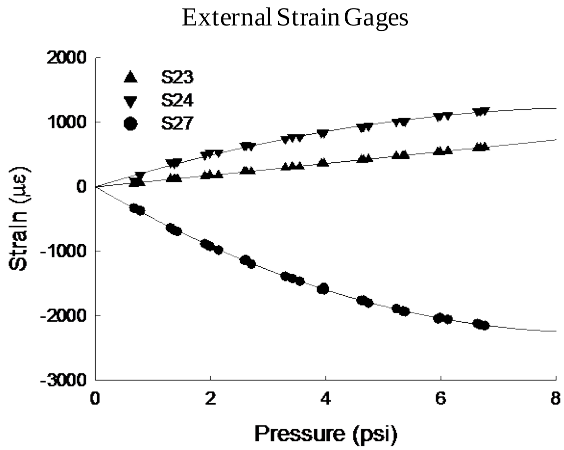
Note: Run 3 of IS24 showed faulty data

Figure F-9. Strain gage readings for repair U-A1 after data reduction

Load Condition	Max. Load
Pressure	6.675 psi
Hoop	7140 lb
Axial	6675 lb
Frame	1132.5 lb







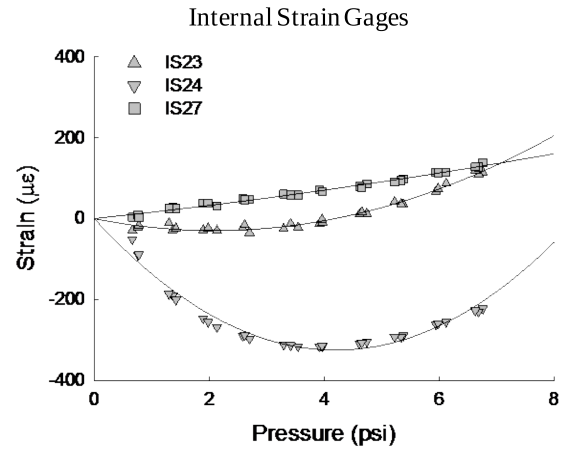


Figure F-10. Strain vs. pressure for U-A1 repair gages after data reduction

S21			
Load Step	Run1	Run 2	Run 3
0			
1	174.64	240.96	253.22
2	508.65	536.31	526.95
3	698.06	736.42	768.46
4	893.25	894.75	905.87
5	1028.85	1066.24	1067.06
6	1150.85	1161.30	1164.20
7	1273.08	1266.44	1274.17
8	1366.77	1372.22	1366.94
9	1455.60	1464.51	1479.12
10	1560.35	1552.84	1542.67

S22			
Load Step	Run1	Run 2	Run 3
0			
1	106.73	137.76	144.43
2	254.80	269.25	272.34
3	357.12	380.90	390.61
4	471.95	478.44	483.72
5	565.20	587.98	588.52
6	652.37	657.60	659.04
7	741.05	735.16	739.42
8	811.21	812.72	809.01
9	880.99	885.86	897.96
10	961.17	951.25	957.03

S26			
Load Step	Run1	Run 2	Run 3
0			
1	-301.82	-410.73	-463.03
2	-730.05	-816.09	-804.97
3	-1003.18	-1107.08	-1233.15
4	-1360.18	-1370.56	-1442.80
5	-1594.18	-1717.46	-1726.46
6	-1827.24	-1885.89	-1899.27
7	-2076.09	-2091.69	-2163.94
8	-2257.97	-2302.60	-2335.67
9	-2420.99	-2460.56	-2539.48
10	-2596.11	-2636.28	-2659.28

IS21			
Load Step	Run1	Run 2	Run 3
0			
1	-94.86	-162.71	-193.03
2	-345.02	-384.38	-384.89
3	-462.89	-505.20	-558.47
4	-577.23	-585.50	-609.44
5	-624.86	-666.51	-680.97
6	-658.96	-684.47	-701.65
7	-682.11	-704.73	-721.72
8	-688.41	-712.40	-726.14
9	-678.97	-698.38	-713.19
10	-662.22	-687.86	-684.90

IS22			
Load Step	Run1	Run 2	Run 3
0			
1	-39.03	-73.14	-98.55
2	-106.53	-131.93	-140.63
3	-142.09	-171.13	-204.50
4	-189.96	-200.15	-217.57
5	-208.13	-241.50	-249.52
6	-219.02	-242.95	-254.60
7	-226.26	-246.62	-258.93
8	-221.94	-243.67	-255.33
9	-205.24	-221.21	-231.36
10	-182.73	-204.52	-205.95

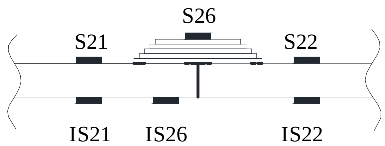
IS26			
Load Step	Run1	Run 2	Run 3
0			
1	50.21	63.11	66.03
2	110.19	117.64	123.08
3	161.05	173.97	174.86
4	219.52	227.56	230.83
5	276.07	288.95	291.18
6	331.49	336.00	338.25
7	390.69	387.13	393.46
8	441.83	443.93	446.01
9	496.90	502.71	514.47
10	562.08	556.50	565.71

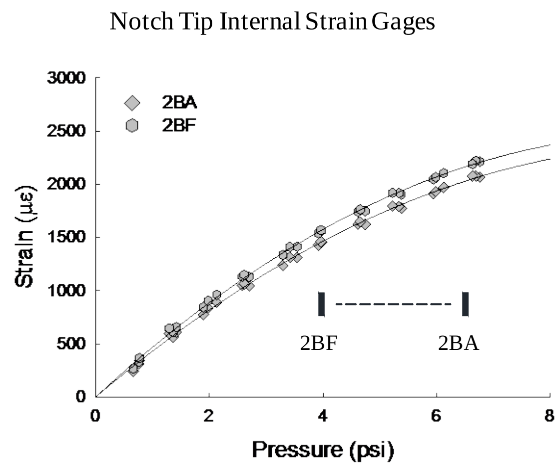
2BF			
Load Step	Run1	Run 2	Run 3
0			
1	244.85	311.31	343.84
2	560.83	607.86	598.92
3	775.96	836.31	889.99
4	1043.61	1048.86	1064.84
5	1236.97	1311.67	1312.62
6	1427.99	1456.19	1460.08
7	1623.95	1622.06	1647.33
8	1773.14	1790.25	1794.21
9	1909.70	1931.49	1968.36
10	2067.13	2075.31	2075.85

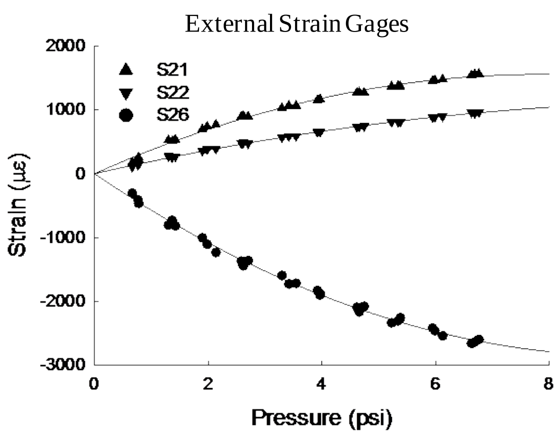
2BA			
Load Step	Run1	Run 2	Run 3
0			
1	27.15	92.57	126.50
2	370.40	417.49	405.35
3	603.43	664.88	720.52
4	889.46	891.84	907.05
5	1094.31	1171.52	1169.93
6	1297.34	1323.95	1327.16
7	1505.70	1498.50	1520.52
8	1660.31	1675.00	1676.26
9	1805.27	1824.69	1862.25
10	1969.44	1976.42	1946.17

Figure F-11. Strain gage reading for D-BE repair after data reduction

Load Condition	Max. Load
Pressure	6.675 psi
Hoop	7140 lb
Axial	6675 lb
Frame	1132.5 lb







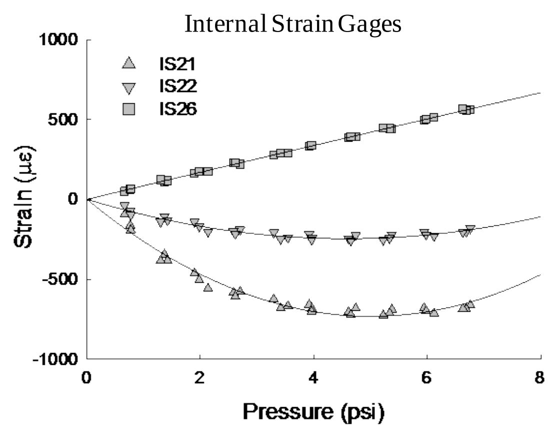


Figure F-12. Strain vs. pressure for D-BE repair gages after data reduction

S19			
Load Step	Run1	Run 2	Run 3
0			
1	117.60	181.70	194.74
2	376.14	401.57	391.31
3	511.99	544.02	571.40
4	663.69	661.07	668.80
5	770.14	804.85	802.68
6	873.06	881.72	881.54
7	978.52	970.85	977.98
8	1058.99	1061.79	1057.92
9	1137.68	1141.11	1157.68
10	1228.47	1222.39	1218.42

S20			
Load Step	Run1	Run 2	Run 3
0			
1	120.23	151.48	159.48
2	290.84	308.95	303.18
3	401.26	428.98	450.65
4	534.87	534.87	539.80
5	632.29	662.00	660.47
6	728.51	733.57	731.90
7	826.95	817.76	820.17
8	903.21	901.58	893.34
9	978.21	978.48	989.60
10	1065.36	1054.71	1050.01

S25			
Load Step	Run1	Run 2	Run 3
0			
1	-132.73	-163.78	-185.38
2	-296.78	-318.38	-315.49
3	-402.57	-432.01	-469.66
4	-531.27	-536.54	-549.77
5	-617.91	-654.16	-665.11
6	-694.49	-711.24	-722.82
7	-770.31	-775.63	-792.82
8	-821.45	-835.35	-844.36
9	-859.32	-872.29	-897.09
10	-896.69	-911.03	-922.15

IS19			
Load Step	Run1	Run 2	Run 3
0			
1	3.52	-43.92	-65.84
2	-117.62	-138.63	-139.16
3	-142.24	-162.71	-195.65
4	-162.85	-164.33	-180.44
5	-142.06	-163.41	-171.59
6	-117.97	-132.09	-145.15
7	-81.57	-99.88	-110.01
8	-41.93	-55.32	-68.19
9	10.04	-0.64	-4.63
10	69.79	48.98	40.82

IS20			
Load Step	Run1	Run 2	Run 3
0			
1	17.99	-2.46	-21.23
2	-3.40	-21.23	-27.98
3	7.11	-10.53	-39.24
4	17.42	13.30	-3.59
5	55.52	39.38	31.69
6	98.87	84.22	73.17
7	153.64	134.91	127.39
8	209.04	196.80	184.27
9	274.72	264.78	266.62
10	349.19	328.58	321.79

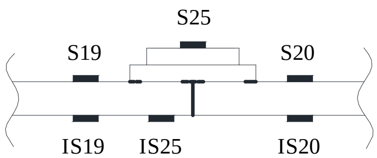
IS25			
Load Step	Run1	Run 2	Run 3
0			
1	29.16	35.15	35.24
2	69.79	72.64	72.18
3	98.02	102.47	101.19
4	126.60	128.53	127.39
5	152.23	153.53	154.02
6	175.26	172.84	170.47
7	198.04	192.46	191.08
8	216.12	212.09	208.23
9	235.93	232.76	233.19
10	254.63	246.72	247.38

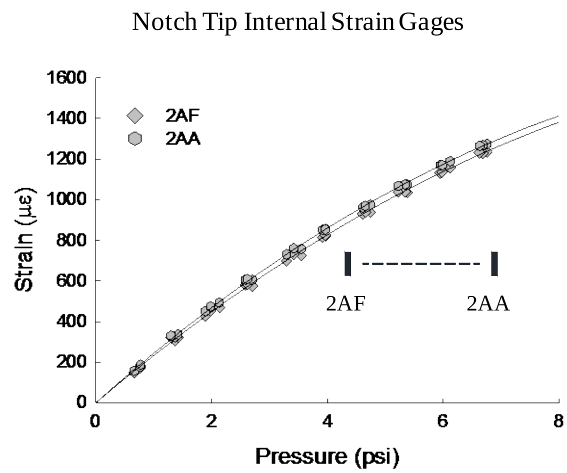
2AF			
Load Step	Run1	Run 2	Run 3
0			
1	147.29	171.77	181.94
2	307.45	322.68	319.22
3	428.21	452.37	470.65
4	575.02	579.83	583.82
5	698.62	726.67	731.51
6	815.23	822.24	825.46
7	938.11	930.30	938.74
8	1036.40	1039.30	1037.13
9	1131.44	1135.43	1157.82
10	1234.54	1228.66	1231.63

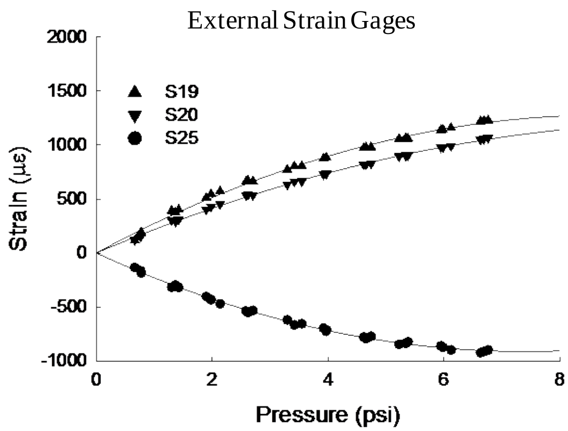
2AA			
Load Step	Run1	Run 2	Run 3
0			
1	158.00	178.23	187.82
2	323.68	336.69	330.34
3	451.38	474.18	493.83
4	605.56	606.56	609.09
5	731.21	757.89	760.90
6	851.35	855.43	853.58
7	975.91	962.71	969.85
8	1074.36	1074.90	1068.04
9	1169.94	1170.84	1190.25
10	1274.07	1268.22	1265.58

Figure F-13. Strain gage readings for D-A2 repair after data reduction

Load Condition	Max. Load
Pressure	6.675 psi
Hoop	7140 lb
Axial	6675 lb
Frame	1132.5 lb







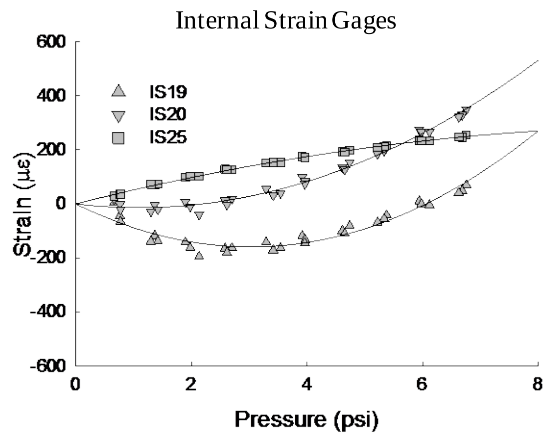


Figure F-14. Strain vs. pressure for D-A2 repair gages after data reduction

S28			
Load Step	Run1	Run 2	Run 3
0			
1	39.24	100.80	93.35
2	142.59	187.68	187.57
3	219.20	250.13	243.34
4	287.78	316.56	310.95
5	353.27	359.17	355.54
6	398.87	407.09	399.23
7	450.56	453.88	461.05
8	492.13	486.65	485.57
9	523.33	521.14	524.21
10	551.00	556.12	548.68

S29			
Load Step	Run1	Run 2	Run 3
0			
1	43.69	56.06	59.21
2	141.07	152.70	158.62
3	206.35	211.33	209.69
4	261.33	277.02	270.54
5	319.06	314.12	313.62
6	356.60	359.74	352.38
7	408.48	411.03	418.79
8	459.41	449.07	448.23
9	502.46	497.19	500.68
10	549.15	554.23	549.54

S34			
Load Step	Run1	Run 2	Run 3
0			
1	54.73	143.80	226.96
2	915.83	1067.65	1179.54
3	1708.08	1875.80	1815.98
4	2546.66	2736.53	2645.04
5	3357.81	3418.00	3404.27
6	4209.71	4321.72	4186.44
7	5433.20	5511.16	5552.75
8	6655.49	6705.68	6601.20
9	8327.64	8202.12	8191.20
10	10314.98	10183.05	10006.12

IS28			
Load Step	Run1	Run 2	Run 3
0			
1	-4.08	-103.52	-92.81
2	-88.47	-152.46	-120.18
3	-148.45	-187.55	-197.54
4	-190.68	-233.71	-231.89
5	-210.08	-236.67	-249.82
6	-218.08	-232.61	-251.52
7	-234.77	-235.68	-242.38
8	-226.78	-237.04	-242.53
9	-218.97	-219.52	-222.44
10	-195.90	-186.35	-196.38

IS29			
Load Step	Run1	Run 2	Run 3
0			
1	4.54	-34.81	-33.05
2	-45.86	-67.68	-40.95
3	-73.19	-81.50	-92.23
4	-84.25	-105.17	-106.24
5	-82.25	-93.21	-105.92
6	-72.02	-76.45	-93.12
7	-73.50	-74.79	-78.81
8	-66.24	-71.15	-73.66
9	-59.71	-59.51	-56.23
10	-50.38	-42.04	-50.98

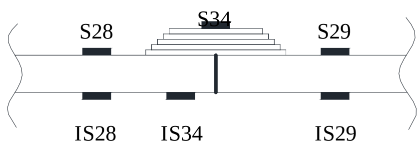
IS34			
Load Step	Run1	Run 2	Run 3
0			
1	1.77	-0.51	1.51
2	6.66	8.66	17.68
3	16.50	19.27	18.68
4	29.43	32.78	32.96
5	46.02	45.25	46.75
6	60.44	63.08	60.66
7	81.16	84.20	90.69
8	108.33	102.39	104.46
9	131.83	131.14	134.86
10	161.68	168.50	168.56

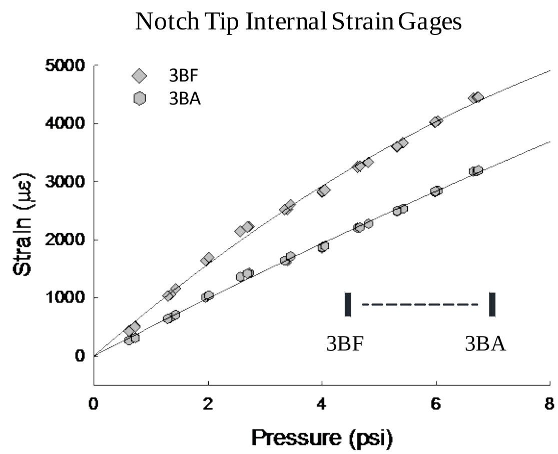
3BF			
Load Step	Run1	Run 2	Run 3
0			
1	431.26	508.11	505.61
2	1059.47	1159.44	1030.98
3	1634.63	1640.01	1698.44
4	2141.97	2229.63	2219.92
5	2523.99	2520.82	2600.21
6	2812.70	2834.70	2854.33
7	3254.11	3263.92	3329.25
8	3670.04	3599.92	3607.26
9	4043.69	4013.35	4028.69
10	4434.68	4450.88	4452.78

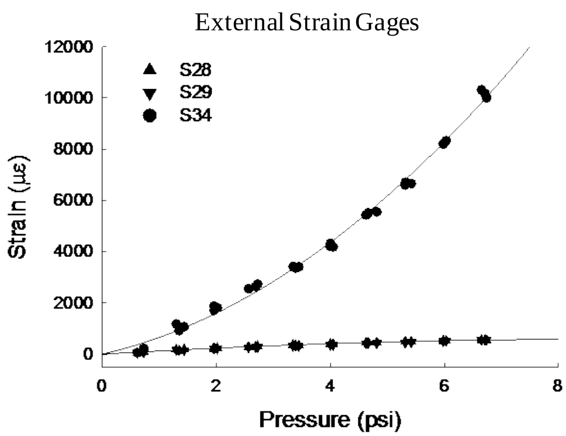
3BA			
Load Step	Run1	Run 2	Run 3
0			
1	269.40	313.18	310.59
2	662.26	711.30	641.61
3	1008.74	1011.34	1043.04
4	1361.70	1431.28	1421.53
5	1636.94	1640.71	1715.39
6	1855.10	1872.87	1896.22
7	2205.15	2214.06	2275.17
8	2534.43	2486.59	2494.79
9	2846.37	2822.17	2835.94
10	3176.69	3180.95	3197.21

Figure F-15. Strain gage readings for repair C-BE after data reduction

Load Condition	Max. Load
Pressure	6.675 psi
Hoop	7140 lb
Axial	6675 lb
Frame	1132.5 lb







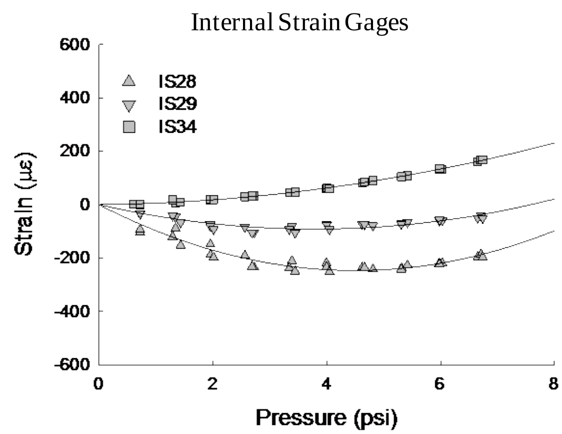


Figure F-16. Strain vs. pressure for C-BE repair gages after data reduction

S30			
Load Step	Run1	Run 2	Run 3
0			
1	27.09	95.47	91.18
2	135.40	193.22	167.07
3	218.48	245.27	264.07
4	303.58	345.09	343.72
5	371.64	382.08	399.83
6	411.89	424.30	439.30
7	487.83	496.28	519.05
8	555.14	549.34	553.90
9	614.84	615.71	620.47
10	677.84	688.30	691.51

S31			
Load Step	Run1	Run 2	Run 3
0			
1	25.19	66.28	56.43
2	92.64	126.96	109.25
3	146.35	161.30	171.91
4	206.63	227.45	224.88
5	257.12	258.18	265.54
6	289.61	293.89	298.86
7	343.39	346.93	360.21
8	394.15	386.12	386.57
9	434.84	435.60	436.83
10	481.17	490.31	486.91

S35			
Load Step	Run1	Run 2	Run 3
0			
1	317.56	-46.69	45.94
2	867.44	714.38	714.71
3	1364.90	1267.93	1354.05
4	1903.67	1948.01	1951.20
5	2461.65	2478.35	2543.00
6	3033.11	3085.34	3103.16
7	3932.59	4001.67	4084.63
8	4849.05	4870.21	4836.98
9	5964.96	6005.89	6016.83
10	7374.95	7435.70	7318.27

IS30			
Load Step	Run1	Run 2	Run 3
0			
1	12.61	-80.10	-66.77
2	-52.08	-113.26	-89.97
3	-94.71	-132.89	-140.02
4	-127.78	-175.64	-170.87
5	-145.01	-162.39	-175.03
6	-137.67	-155.26	-169.80
7	-153.52	-153.73	-166.99
8	-150.05	-147.28	-151.71
9	-141.90	-131.46	-134.24
10	-121.73	-113.56	-127.00

IS31			
Load Step	Run1	Run 2	Run 3
0			
1	-52.79	23.05	77.91
2	-50.48	35.61	95.65
3	-47.44	37.97	95.32
4	-36.64	50.45	100.59
5	-0.78	72.62	111.78
6	9.56	83.14	125.99
7	32.34	90.66	137.74
8	49.27	98.88	144.00
9	54.27	114.85	157.33
10	73.03	129.06	158.39

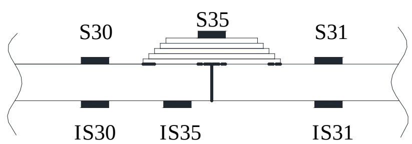
IS35			
Load Step	Run1	Run 2	Run 3
0			
1	4.43	20.45	20.21
2	16.46	26.73	28.54
3	35.11	38.81	41.52
4	58.31	58.49	60.43
5	74.73	78.00	80.03
6	93.31	94.78	96.21
7	112.46	116.76	120.44
8	133.37	136.04	138.95
9	155.64	160.29	163.99
10	181.56	187.93	188.53

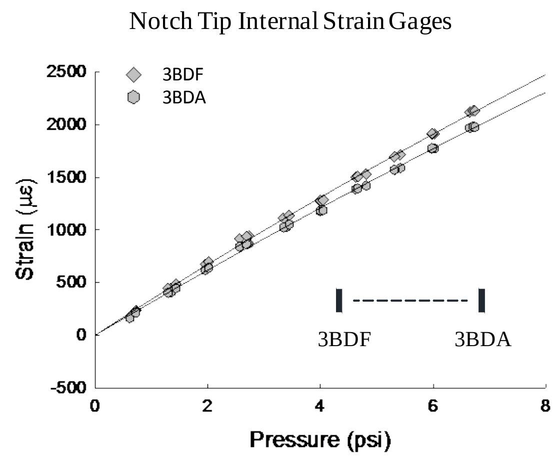
3BDF			
Load Step	Run1	Run 2	Run 3
0			
1	173.42	235.14	232.35
2	443.65	487.57	444.02
3	676.76	677.44	698.34
4	914.65	942.64	936.90
5	1108.90	1110.59	1137.19
6	1276.54	1281.12	1285.44
7	1499.61	1506.67	1531.91
8	1711.82	1693.29	1696.03
9	1911.36	1908.98	1918.25
10	2119.51	2133.22	2129.98

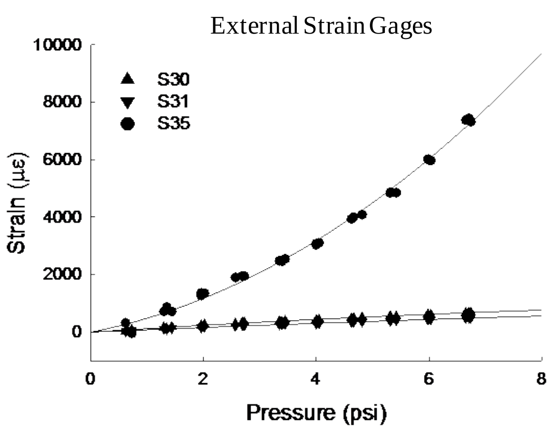
3BDA			
Load Step	Run1	Run 2	Run 3
0			
1	164.13	218.48	213.92
2	406.90	446.29	404.05
3	619.99	618.70	639.58
4	840.83	869.35	862.52
5	1025.71	1023.16	1052.31
6	1178.24	1184.95	1187.11
7	1388.26	1395.11	1419.34
8	1589.45	1569.89	1571.38
9	1774.56	1770.76	1777.28
10	1969.22	1982.85	1977.98

Figure F-17. Strain gage readings for CD-BE repair after data reduction

Load Condition	Max. Load
Pressure	6.675 psi
Hoop	7140 lb
Axial	6675 lb
Frame	1132.5 lb







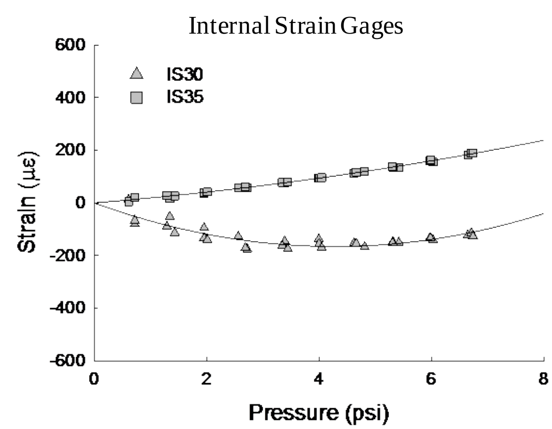


Figure F-18. Strain vs. pressure for repair CD-BE gages after data reduction

APPENDIX G—DIGITAL IMAGE CORRELATION STRAIN SURVEY RESULTS

During the strain survey, the digital image correlation (DIC) snapshots were also captured for all the repairs during all the test phases. The colored fringe pattern in all the figures of this appendix shows the hoop strain distribution. The accompanying plots show the value of hoop strains along the vertical sections drawn in the figures. All of the results are obtained at the maximum strain survey load of each phase, as listed in table G-1. Figure G-1 shows the DIC results for R-BE, phase 1, and phase 2 repairs are provided for every 20,000 fatigue cycles. The DIC snapshots and hoop strains along the three vertical sections for the R-BE repair are shown in figure G-1. Similarly, figures G-2, G-3, and G-4 show the results for the U-BE, U-A2, and U-A1 repairs, respectively. Figures G-5 and G-6 show the results of the phase 2 repairs, D-BE and D-A2. For the phase 3 repairs, C-BE and CD-BE results are provided for every 10,000 cycles because these repairs were subjected to only 20,000 fatigue cycles (see figures G-7 and G-8). For the phase 4 repairs, DIC results are shown before and after impact and also after 20,000 fatigue cycles after impact to show the effect of impact on the hoop strains. Figures G-9, G-10, and G-11 show these results for impacted R-BE, U-BE, and U-A2 repairs, respectively. The white regions at the center of the repairs in a few of the images are the regions where data could not be processed because of interference from strain gage wires.

Table G-1. Loading conditions during the strain survey

Phases	Maximum Load			
	Pressure (psi)	Hoop (lb)	Frame (lb)	Long. (lb)
Phase 1	6.7	7140	1133	6675
Phase 2	6.7	7140	1133	6675
Phase 3	6.7	7140	1133	6675
Phase 4	6.7	7140	1133	6675

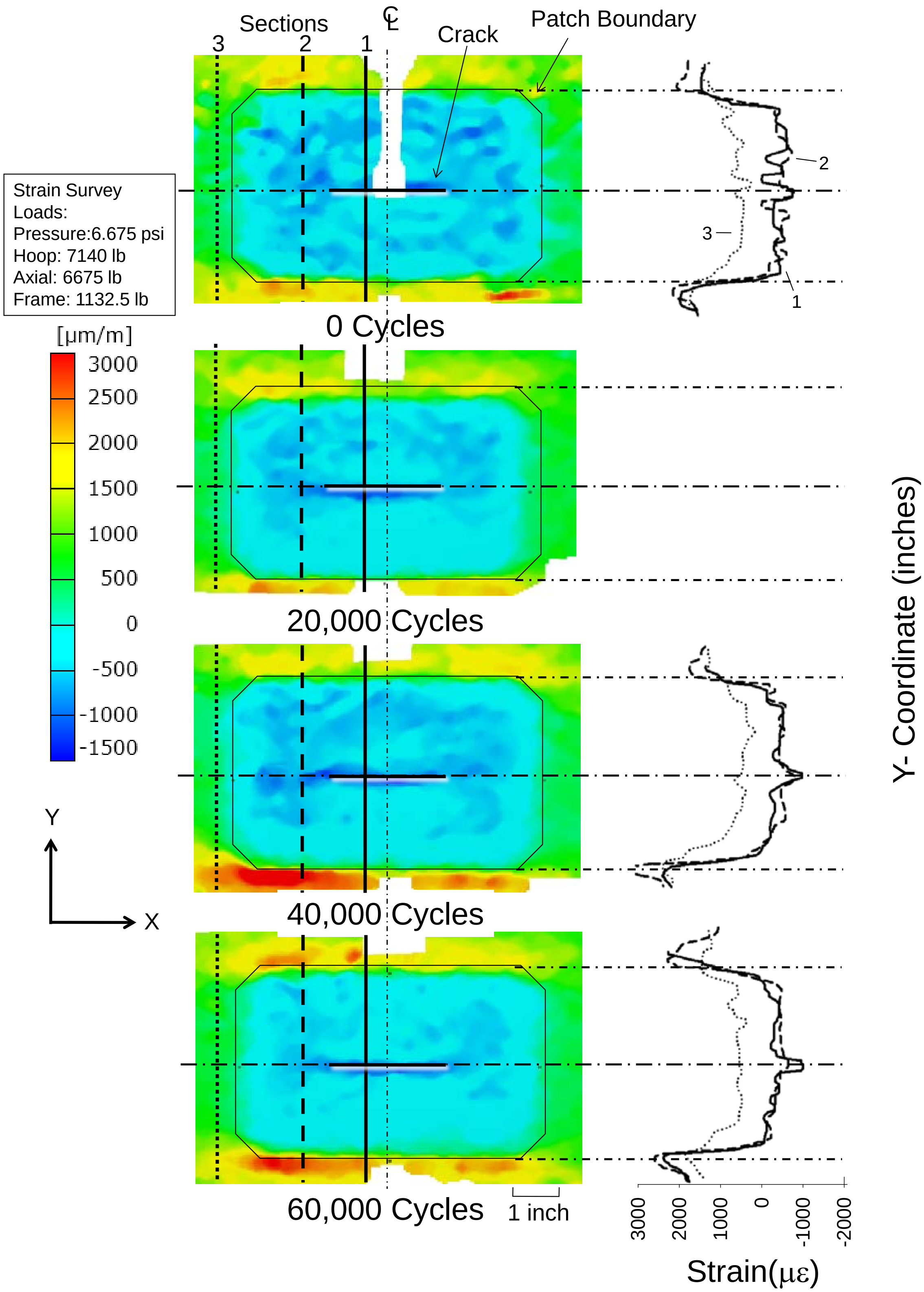


Figure G-1. The DIC results for the R-BE repair at 0, 20,000, 40,000, and 60,000 cycles

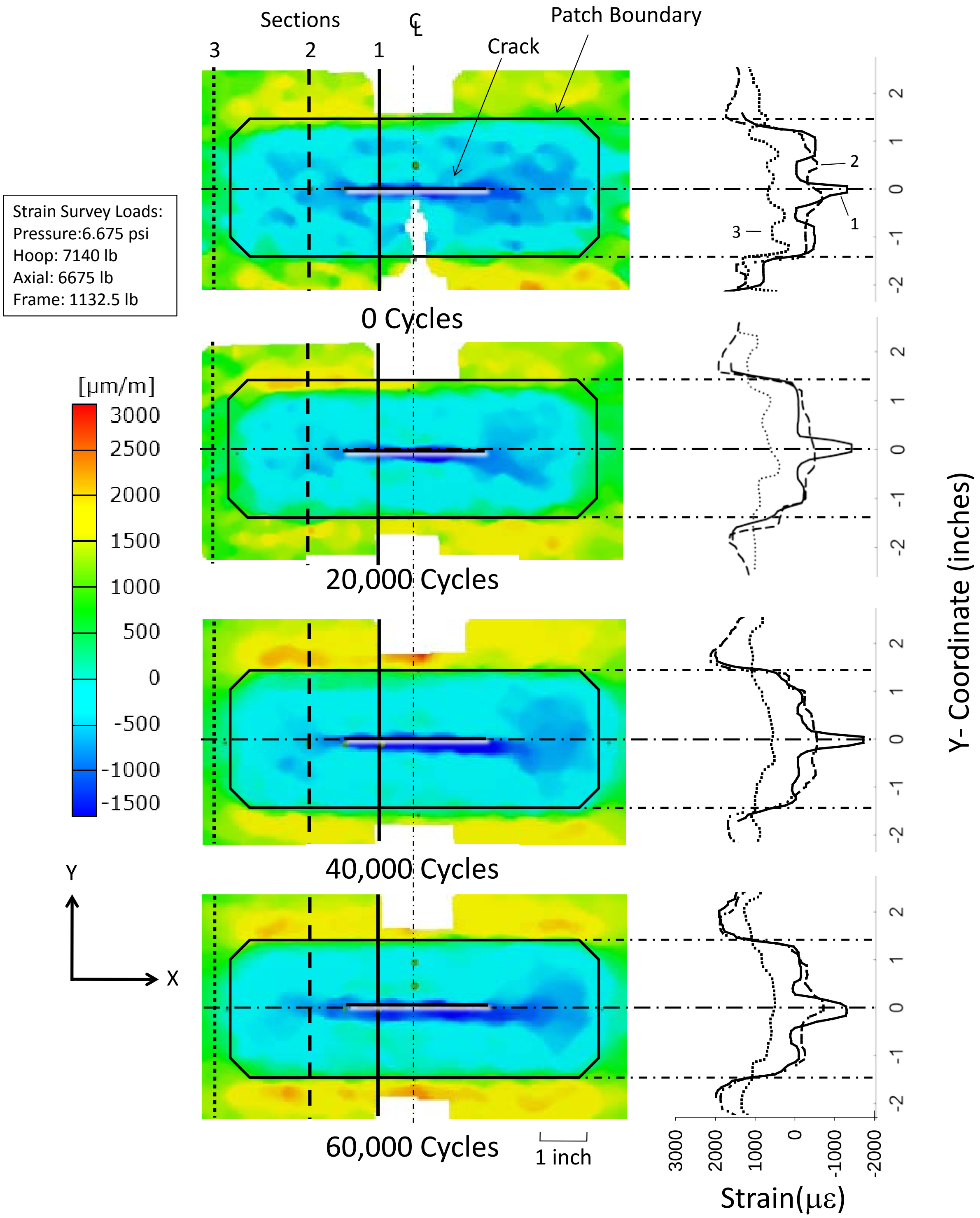


Figure G-2. The DIC results for the U-BE repair at 0, 20,000, 40,000, and 60,000 cycles

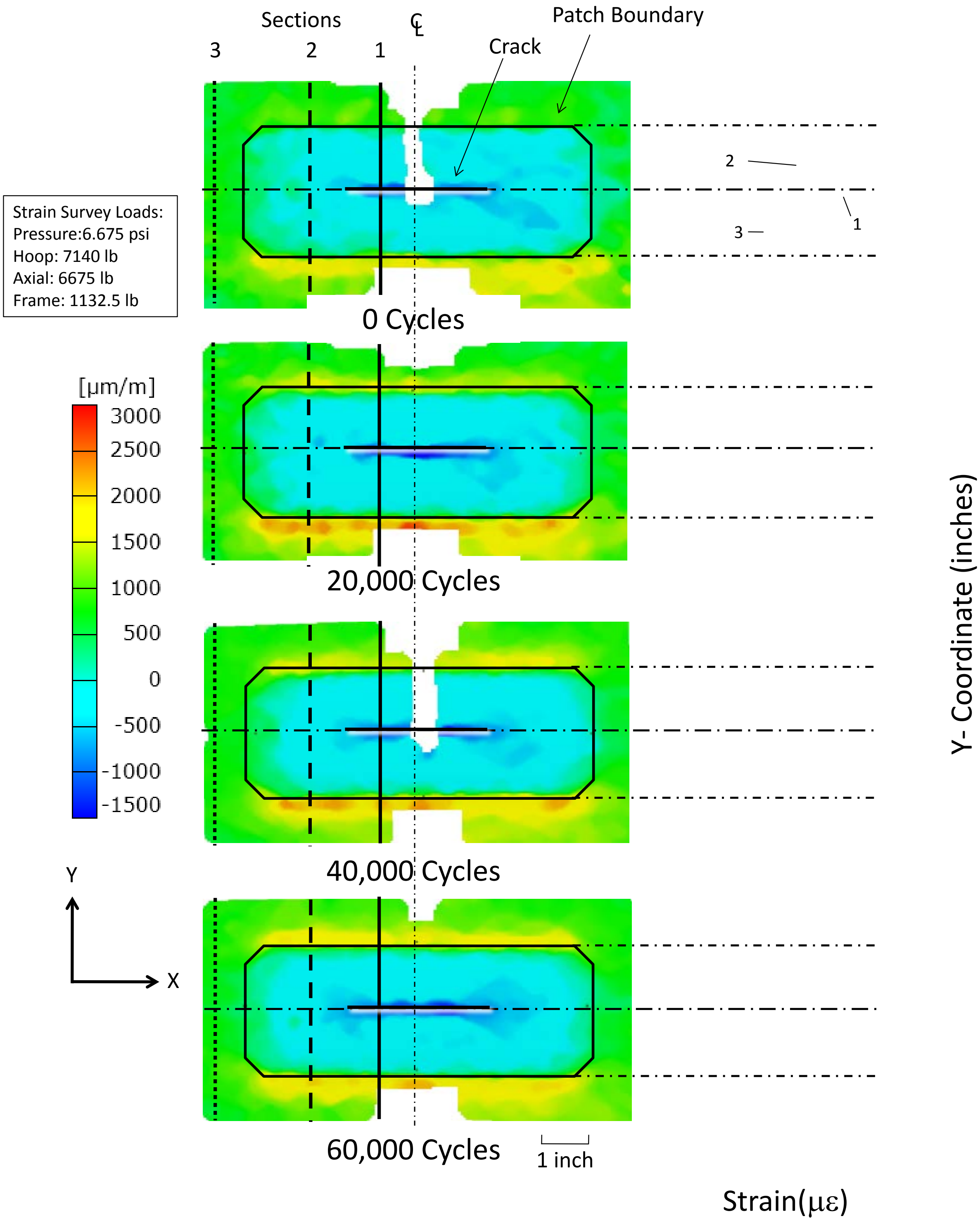


Figure G-3. The DIC results for the U-A2 repair at 0, 20,000, 40,000, and 60,000 cycles

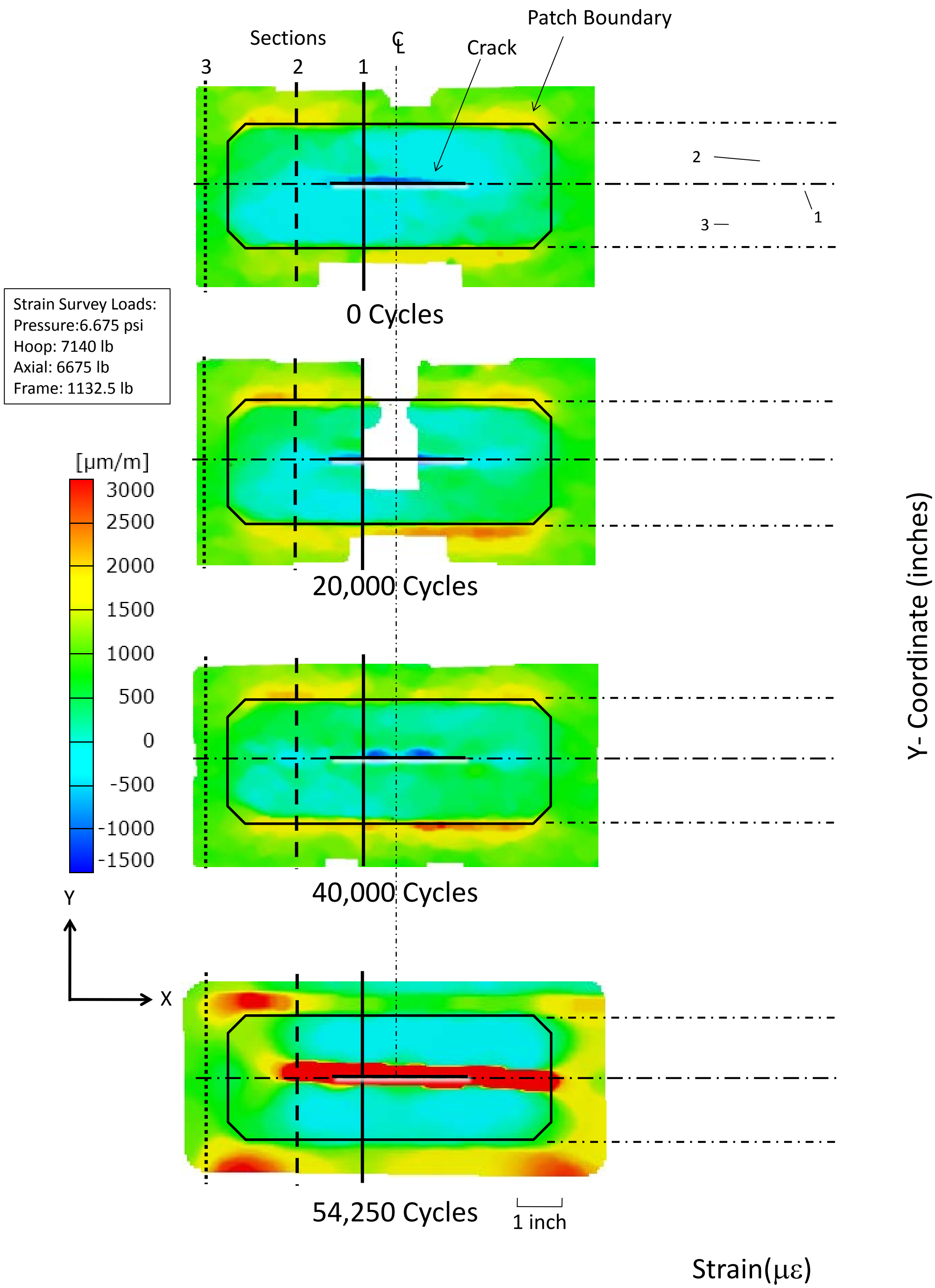


Figure G-4. The DIC results for the U-A1 repair at 0, 20,000, 40,000, and 54,250 cycles

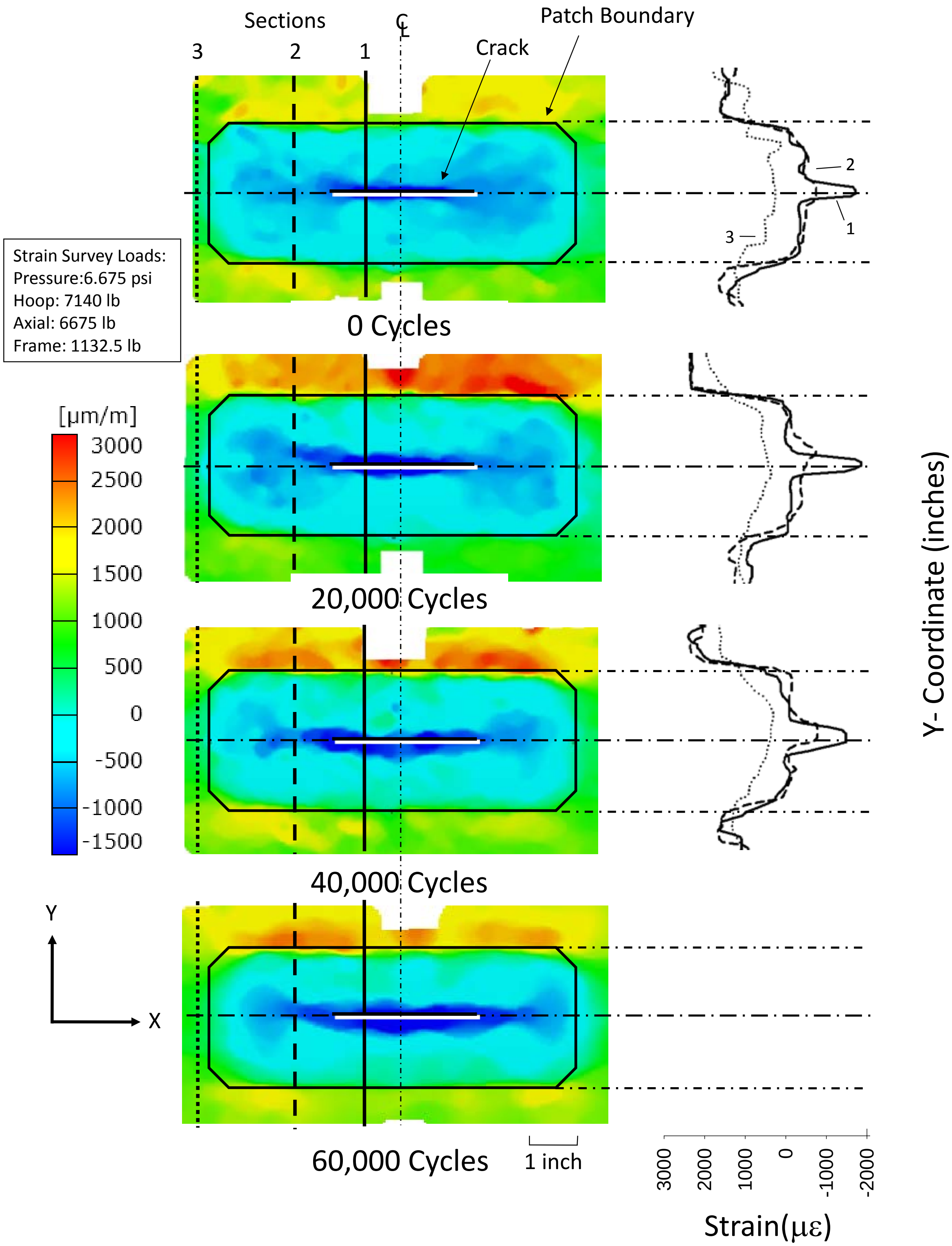


Figure G-5. The DIC results for the D-BE repair at 0, 20,000, 40,000, and 60,000 cycles

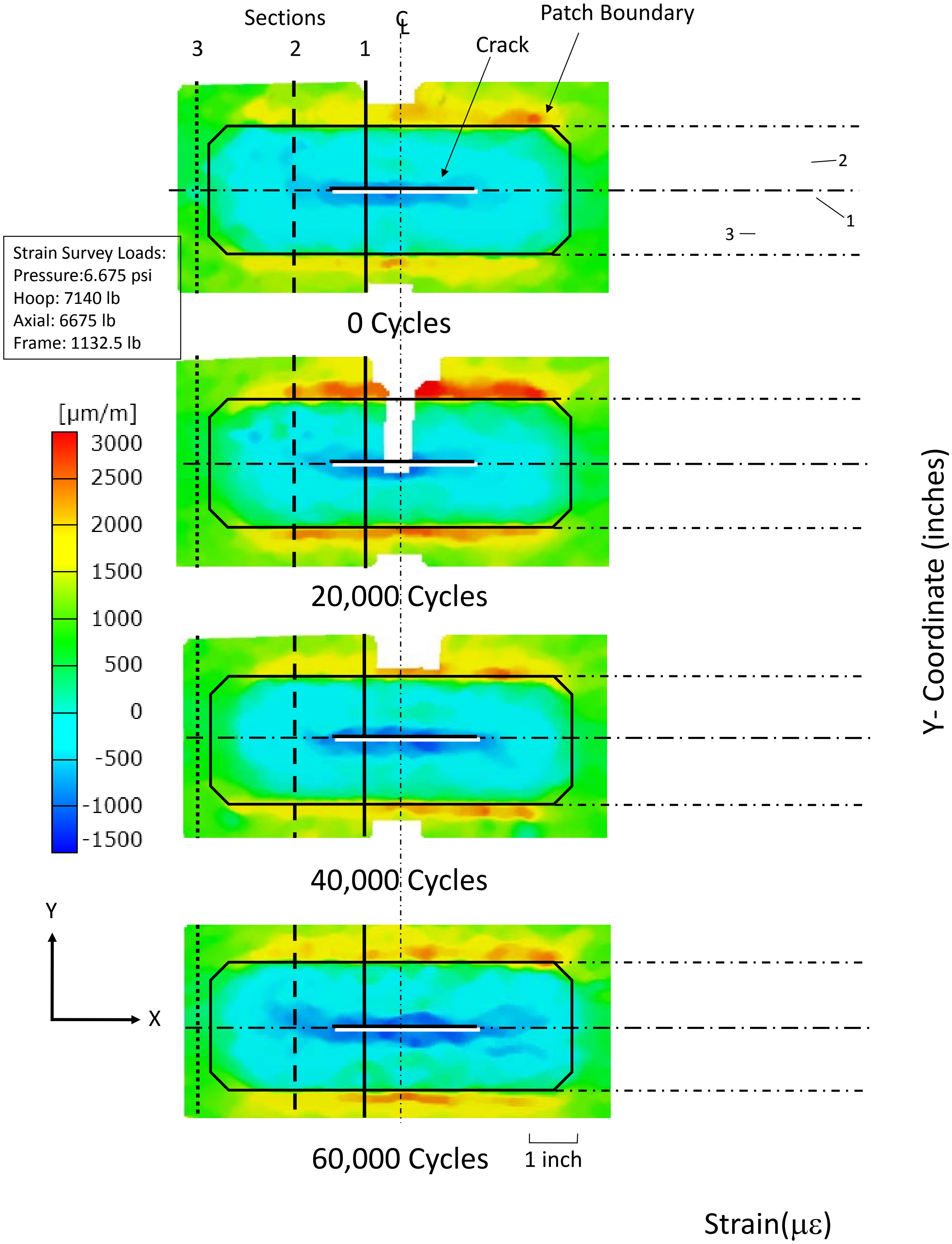


Figure G-6. The DIC results for the D-A2 repair at 0, 20,000, 40,000, and 60,000 cycles

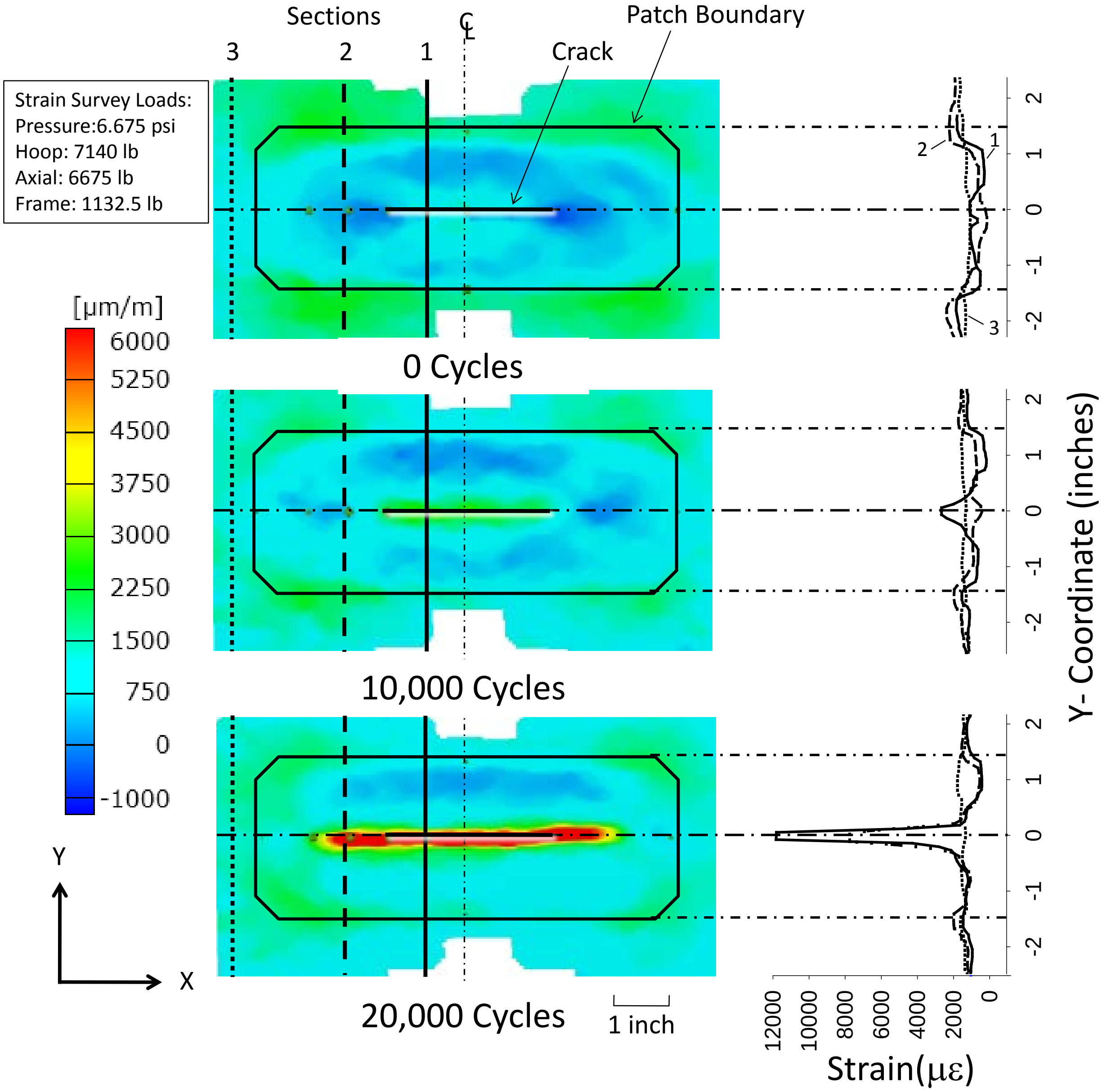


Figure G-7. The DIC results for the C-BE repair at 0, 10,000, and 20,000 cycles

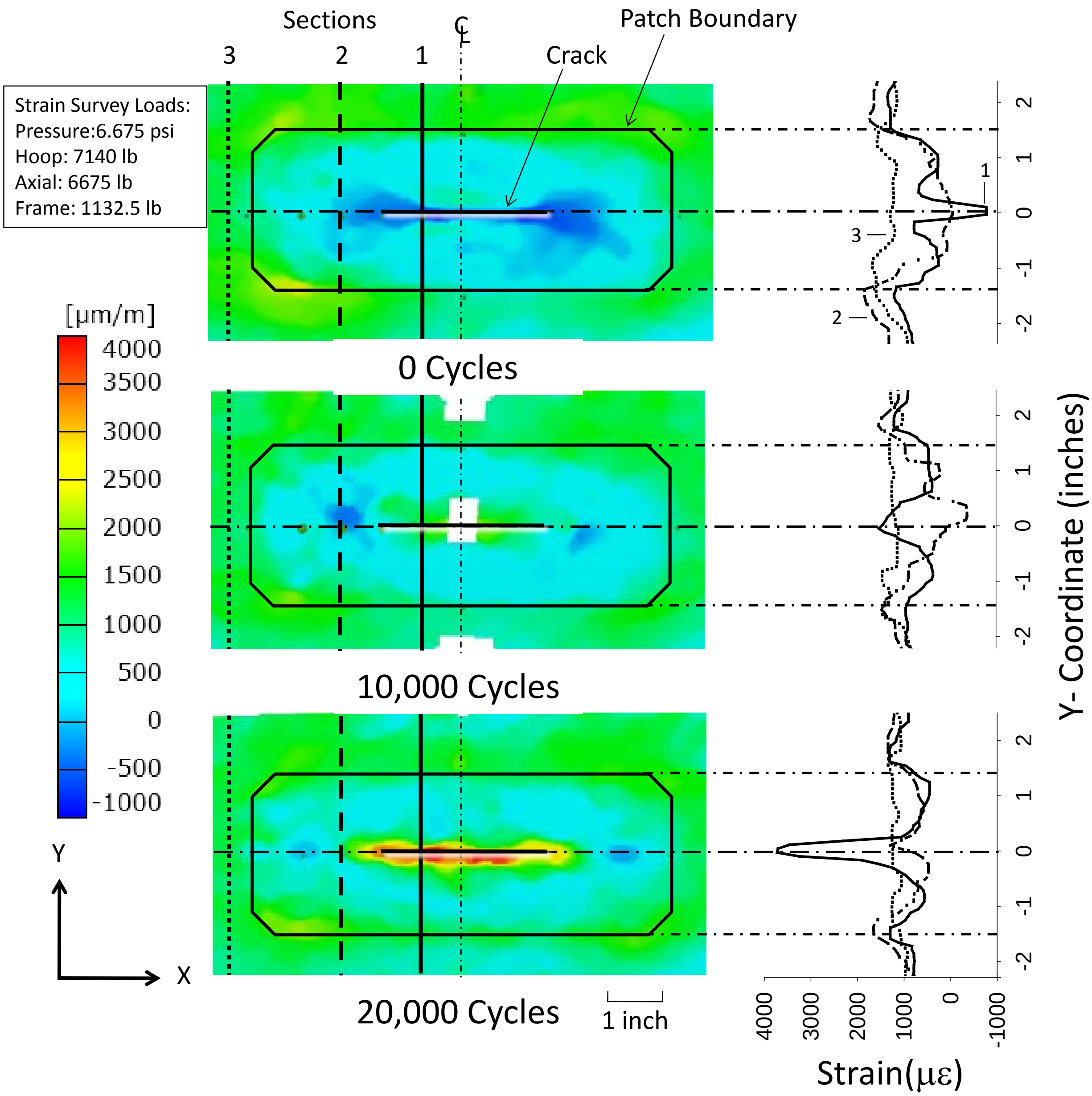


Figure G-8. The DIC results for the CD-BE repair at 0, 10,000, and 20,000 cycles

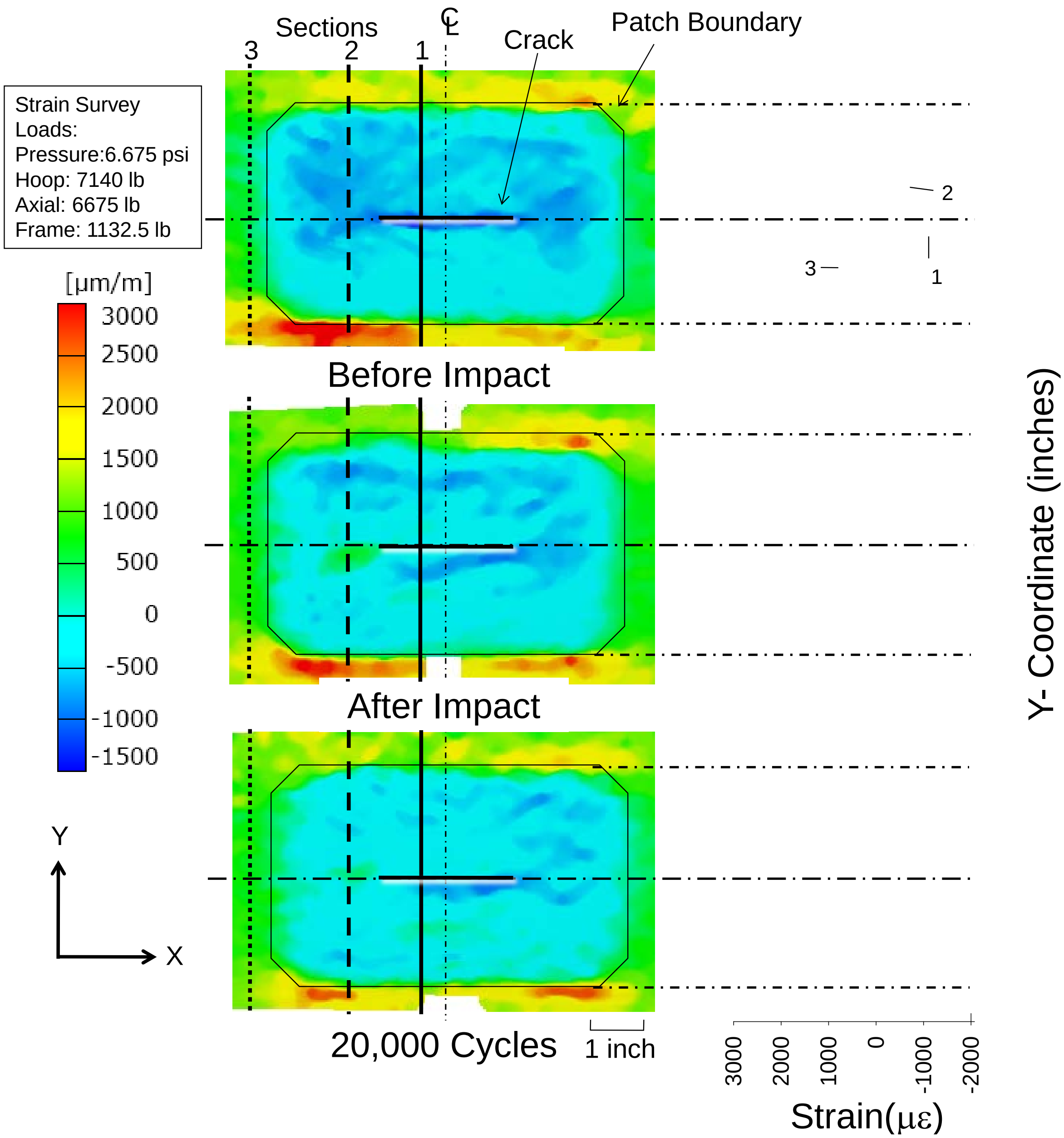


Figure G-9. The DIC results for the R-BE repair during phase 4 before impact, after impact, and 20,000 cycles after impact

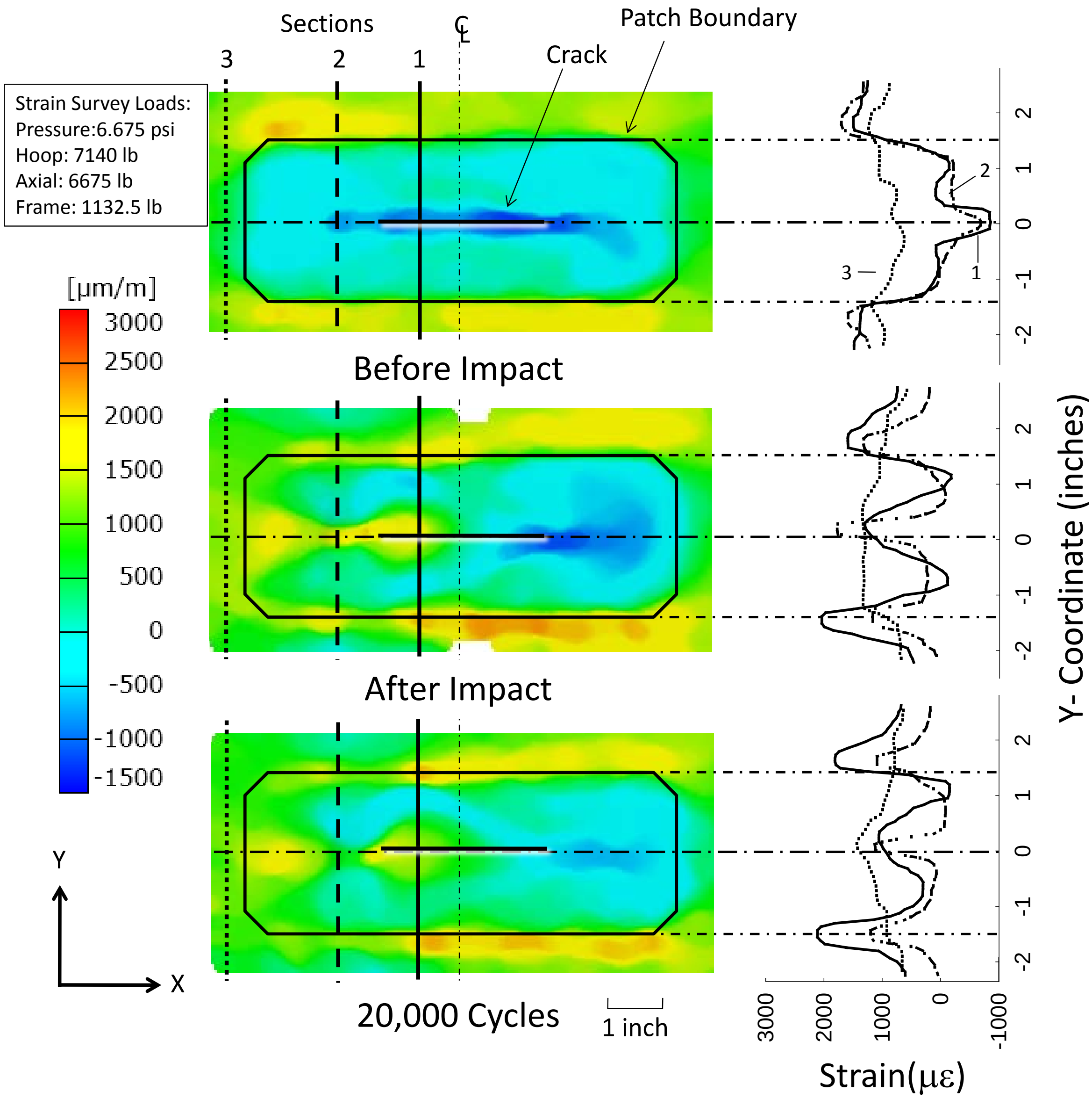


Figure G-10. The DIC results for the U-BE repair during phase 4 before impact, after impact, and 20,000 cycles after impact

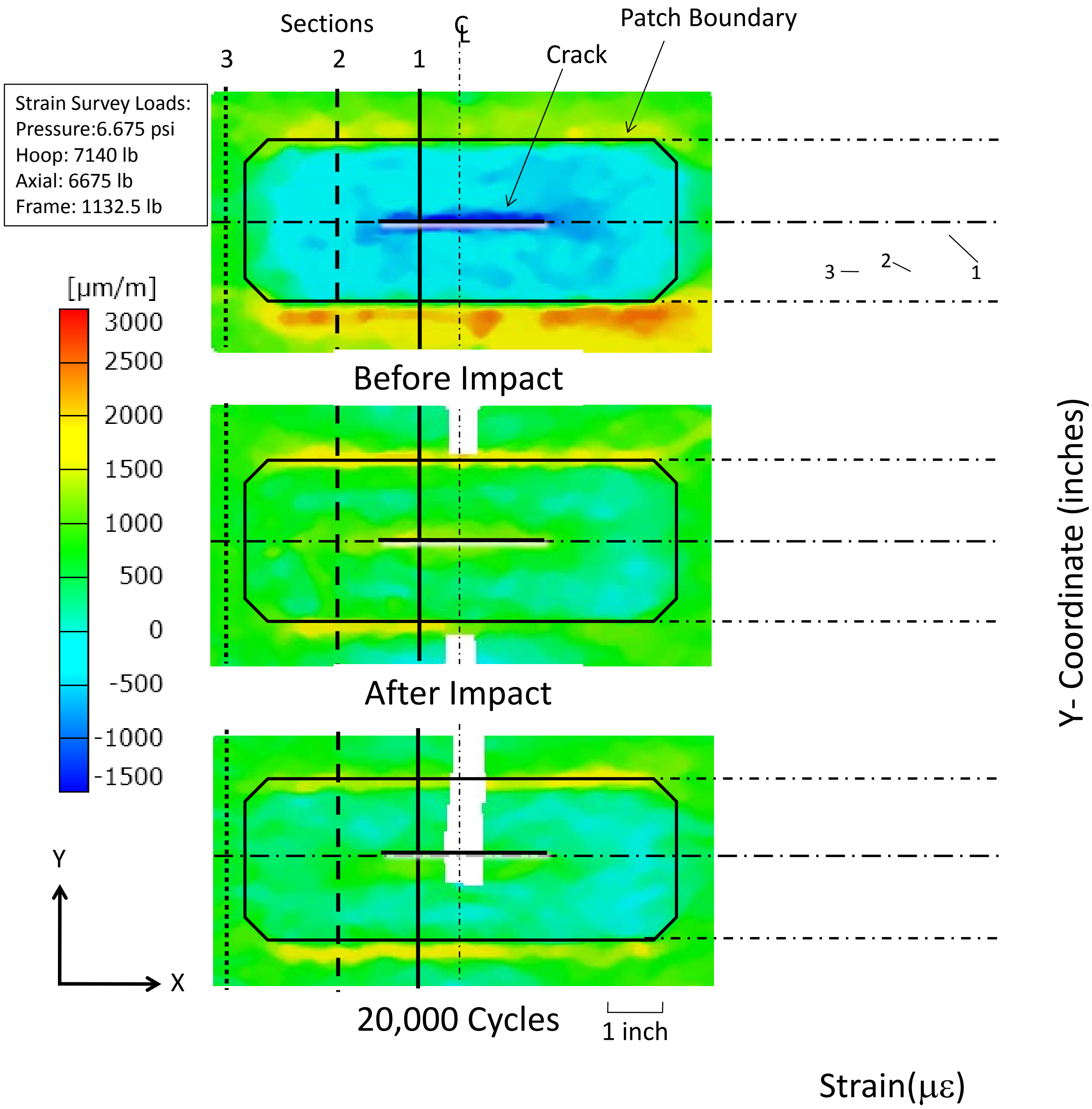


Figure G-11. The DIC results for the U-A2 repair during phase 4 before impact, after impact, and 20,000 cycles after impact

APPENDIX H—CRACK GROWTH DATA

The initial notches introduced at various mid-bay locations of the panel were 2.8″ in length (2a = 2.8″). These notches were fatigue-presharpened using cyclic loads that were 75% of applied fatigue loads to extend the total crack length to approximately 3″. This appendix sums up the crack growth data for all the notches during pre-cracking and also during the fatigue tests after patch installations. The pre-cracking crack extension data was collected from the external surface of the panel using a remote-controlled crack monitoring system. During fatigue cycling, crack extension data was collected at intervals of 100, 200, or 500 cycles using the underwater camera system, which is reported as visual measurements in this appendix. The eddy current system was used every 5000 cycles to measure crack extension from the external surface of the patch and internal surface of the panel for composite repairs, and from the internal surface of the skin for the aluminum repairs. In this appendix, crack growth data for all of the repairs during pre-cracking and fatigue tests are provided. These data are provided for forward (fwd) and aft half-crack lengths for pre-cracking and average half-crack length for fatigue stages.

In the figures representing pre-cracking crack growth data, the closed and open circles represent visual measurements of the fwd and aft side of the notch, respectively. During fatigue, a solid line shows the visual measurements, the open circle shows the internal high frequency eddy current results, and the open square shows the external low frequency eddy current results.

H.1 REFERENCE REPAIR

The R-BE repair was subjected to a total of 60,000 fatigue cycles. Table H-1 provides the half-crack length data for the R-BE repair during pre-cracking. Figure H-1 shows the corresponding half-crack length plot. Table H-2 provides the half-crack length data for the R-BE repair during fatigue tests and figure H-2 shows the increase in average half-crack length with increasing fatigue cycles. The crack growth data of reference repair is up to 60,000 fatigue cycles.

H.2 PHASE 1 REPAIRS

Phase 1 repairs (U-BE, U-A2, and U-A1) were subjected to 60,000 fatigue cycles. Table H-4 provides the half-crack length data for the U-BE repair during pre-cracking. The corresponding half-crack length plot is shown in figure H-4. Table H-5 provides the half-crack length data for repair U-BE during fatigue tests and figure H-5 shows the increase in average half-crack length with increasing fatigue cycles. Similar data and plots are provided in tables H-7 and H-8 and figures H-7 and H-8 for the U-A2 repair, and tables H-10 and H-11 and figures H-10 and H-11 for the U-A1 repair. The crack growth data of phase 1 repairs is up to 60,000 fatigue cycles.

H.3 PHASE 2 REPAIRS

Phase 2 repairs (D-BE and D-A2) were subjected to 60,000 fatigue cycles. Table H-12 provides the half-crack length data for the D-BE repair during pre-cracking. Figure H-12 shows the corresponding half-crack length plot. The half-crack length data for the D-BE repair during fatigue tests is provided in table H-13 and figure H-13 shows the increase in average half-crack length with increasing fatigue cycles. Similar data and plots are given in tables H-14 and H-15 and figures H-14 and H-15 for the D-A2 repair.

H.4 PHASE 3 REPAIRS

Phase 3 repairs (C-BE and CD-BE) were subjected to 20,000 fatigue cycles. Table H-16 provides the half-crack length data for the C-BE repair during pre-cracking. Figure H-16 shows the corresponding half-crack length plot. Table H-17 provides the average half-crack length data for repair C-BE during fatigue tests and figure H-17 shows the increase in half-crack length with increasing fatigue cycles. Similar data and plots are given in tables H-18 and H-19 and figures H-18 and H-19 for the CD-BE repair.

H.5 PHASE 4 REPAIRS

Tables H-3, H-6, and H-9 provide the half-crack length data of R-BE, U-BE, and U-A2 repairs after impact. The tables show the crack growth due to impact after 60,000 cycles and the half-crack length data from 60,000–80,000 fatigue cycles. Figures H-3, H-6, and H-9 show the corresponding half-crack length plots. These figures show the complete crack growth before impact, at impact, and after impact.

Table H-1. Half-crack length data during pre-cracking for the R-BE repair (tabular)

CYCLES	VISUAL	
	a_{AFT} (in.)	a_{FWD} (in.)
1221	1.454	1.444
1345	1.464	1.457
1500	1.473	1.461
1590	1.481	1.467
1612	1.482	1.470

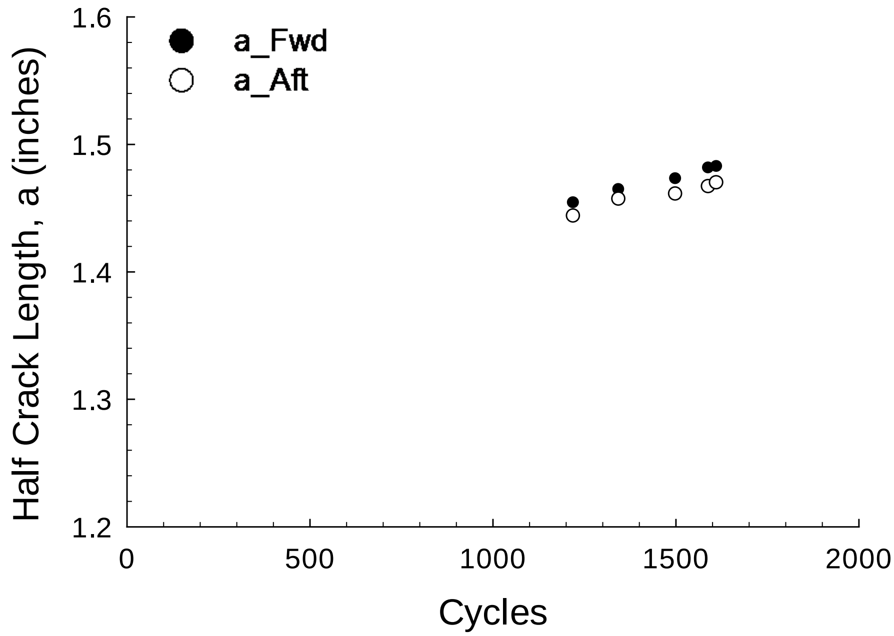


Figure H-1. Half-crack length data during pre-cracking for the R-BE repair

Table H-2. Half-crack length data during fatigue for the R-BE repair (tabular)

CYCLES	VISUAL			INTERNAL HFEC			EXTERNAL LFEC		
	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)
0				1.518	1.494	1.506	1.750	1.781	1.766
100									
200									
300									
400									
500									
600									
700									
800									
900									
1000									
1100									
1200									
1300									
1400									
1500									
1600									
1700									
1800									
1900									
2000									
2100									
2200									
2300									
2400									
2500									
2600									
2700									
2800									
2900									
3000									
3100									
3200									
3300									
3400									
3500									
3600									
3700									
3800									
3900									
4000									
4100									
4200									
4300									
4400									
4500									
4600									
4700									
4800									
4900									
5000				1.541	1.541	1.541			

Table H-2. Half-crack length data during fatigue for the R-BE repair (tabular) (continued)

CYCLES	VISUAL			INTERNAL EDDY CURRENT			EXTERNAL EDDY CURRENT		
	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)
5100									
5200									
5300									
5400									
5500									
5600									
5700									
5800									
5900									
6000									
6100									
6200									
6300									
6400									
6500									
6600									
6700									
6800									
6900									
7000									
7100									
7200									
7300									
7400									
7500									
7600									
7700									
7800									
7900									
8000									
8100									
8200									
8300									
8400									
8500									
8600									
8700									
8800									
8900									
9000									
9100									
9200									
9300									
9400									
9500									
9600									
9700									
9800									
9900									
10000				1.588	1.588	1.588	1.813	1.750	1.781

Table H-2. Half-crack length data during fatigue for the R-BE repair (tabular) (continued)

CYCLES	VISUAL			INTERNAL EDDY CURRENT			EXTERNAL EDDY CURRENT		
	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)
10100									
10200									
10300									
10400									
10500									
10600									
10700									
10800									
10900									
11000									
11100									
11200									
11300									
11400									
11500									
11600									
11700									
11800									
11900									
12000									
12100									
12200									
12300									
12400									
12500									
12600									
12700									
12800									
12900									
13000									
13100									
13200									
13300									
13400									
13500									
13600									
13700									
13800									
13900									
14000									
14100									
14200									
14300									
14400									
14500									
14600									
14700									
14800									
14900									
15000				1.612	1.612	1.612	1.781	1.781	1.781

Table H-2. Half-crack length data during fatigue for the R-BE repair (tabular) (continued)

CYCLES	VISUAL			INTERNAL EDDY CURRENT			EXTERNAL EDDY CURRENT		
	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	Δa_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)
15100									
15200									
15300									
15400									
15500									
15600									
15700									
15800									
15900									
16000									
16100									
16200									
16300									
16400									
16500									
16600									
16700									
16800									
16900									
17000									
17100									
17200									
17300									
17400									
17500									
17600									
17700									
17800									
17900									
18000									
18100									
18200									
18300									
18400									
18500									
18600									
18700									
18800									
18900									
19000									
19100									
19200									
19300									
19400									
19500									
19600									
19700									
19800									
19900									
20000	1.588	1.612	1.600	1.635	1.635	1.635	1.781	1.781	1.781

Table H-2. Half-crack length data during fatigue for the R-BE repair (tabular) (continued)

CYCLES	VISUAL			INTERNAL EDDY CURRENT			EXTERNAL EDDY CURRENT		
	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)
20100	1.588	1.612	1.600						
20200	1.588	1.612	1.600						
20300									
20400	1.588	1.612	1.600						
20500									
20600	1.588	1.612	1.600						
20700									
20800	1.588	1.612	1.600						
20900									
21000	1.588	1.612	1.600						
21100									
21200	1.588	1.612	1.600						
21300									
21400	1.588	1.612	1.600						
21500									
21600	1.588	1.612	1.600						
21700									
21800	1.588	1.612	1.600						
21900									
22000	0.188	0.212	0.200						
22100									
22200	1.588	1.612	1.600						
22300									
22400	1.588	1.612	1.600						
22500									
22600									
22700									
22800	1.588	1.612	1.600						
22900									
23000	1.588	1.612	1.600						
23100									
23200	1.612	1.612	1.612						
23300									
23400	1.612	1.612	1.612						
23500									
23600	1.612	1.612	1.612						
23700									
23800	1.612	1.612	1.612						
23900									
24000	1.612	1.612	1.612						
24100									
24200	1.612	1.612	1.612						
24300									
24400	1.612	1.612	1.612						
24500									
24600	1.612	1.612	1.612						
24700									
24800	1.612	1.612	1.612						
24900									
25000	1.612	1.612	1.612	1.659	1.635	1.647			

Table H-2. Half-crack length data during fatigue for the R-BE repair (tabular) (continued)

CYCLES	VISUAL			INTERNAL EDDY CURRENT			EXTERNAL EDDY CURRENT		
	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)
25100	1.612	1.612	1.612						
25200	1.612	1.612	1.612						
25300									
25400	1.612	1.612	1.612						
25500									
25600									
25700	1.612	1.612	1.612						
25800									
25900									
26000	1.612	1.612	1.612						
26100									
26200									
26300									
26400	1.612	1.612	1.612						
26500									
26600	1.612	1.612	1.612						
26700									
26800									
26900									
27000	1.612	1.612	1.612						
27100									
27200									
27300									
27400									
27500	1.612	1.612	1.612						
27600									
27700									
27800									
27900									
28000	1.612	1.612	1.612						
28100									
28200									
28300									
28400									
28500	1.612	1.612	1.612						
28600									
28700									
28800									
28900									
29000	1.612	1.635	1.623						
29100									
29200									
29300									
29400									
29500	1.612	1.635	1.623						
29600									
29700									
29800									
29900									
30000	1.612	1.635	1.623	1.682	1.659	1.670	1.844	1.813	1.828

Table H-2. Half-crack length data during fatigue for the R-BE repair (tabular) (continued)

CYCLES	VISUAL			INTERNAL EDDY CURRENT			EXTERNAL EDDY CURRENT		
	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)
30100									
30200									
30300									
30400									
30500	1.612	1.635	1.623						
30600									
30700									
30800									
30900									
31000	1.635	1.635	1.635						
31100									
31200									
31300									
31400									
31500	1.659	1.659	1.659						
31600									
31700									
31800									
31900									
32000	1.659	1.659	1.659						
32100									
32200									
32300									
32400									
32500	1.659	1.659	1.659						
32600									
32700									
32800									
32900									
33000	1.659	1.659	1.659						
33100									
33200									
33300									
33400									
33500	1.659	1.659	1.659						
33600									
33700									
33800									
33900									
34000	1.659	1.682	1.670						
34100									
34200									
34300									
34400									
34500	1.682	1.682	1.682						
34600									
34700									
34800									
34900									
35000	1.682	1.682	1.682	1.729	1.706	1.717	1.906	1.844	1.875

Table H-2. Half-crack length data during fatigue for the R-BE repair (tabular) (continued)

CYCLES	VISUAL			INTERNAL EDDY CURRENT			EXTERNAL EDDY CURRENT		
	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)
35100									
35200									
35300									
35400									
35500	1.682	1.682	1.682						
35600									
35700									
35800									
35900									
36000	1.682	1.682	1.682						
36100									
36200									
36300									
36400									
36500	1.682	1.682	1.682						
36600									
36700									
36800									
36900									
37000	1.682	1.682	1.682						
37100									
37200									
37300									
37400									
37500	1.682	1.682	1.682						
37600									
37700									
37800									
37900									
38000	1.706	1.706	1.706						
38100									
38200									
38300									
38400									
38500	1.706	1.706	1.706						
38600									
38700									
38800									
38900									
39000	1.706	1.706	1.706						
39100									
39200									
39300									
39400									
39500	1.706	1.706	1.706						
39600									
39700									
39800									
39900									
40000	1.706	1.706	1.706	1.753	1.753	1.753	2.000	1.906	1.953

Table H-2. Half-crack length data during fatigue for the R-BE repair (tabular) (continued)

CYCLES	VISUAL			INTERNAL EDDY CURRENT			EXTERNAL EDDY CURRENT		
	Δa_{AFT} (inches)	Δa_{FWD} (inches)	Δa_{AVG} (inches)	Δa_{AFT} (inches)	Δa_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)
40100									
40200									
40300									
40400									
40500	1.729	1.706	1.717						
40600									
40700									
40800									
40900									
41000	1.729	1.706	1.717						
41100									
41200									
41300									
41400									
41500	1.729	1.706	1.717						
41600									
41700									
41800									
41900									
42000	1.729	1.729	1.729						
42100									
42200									
42300									
42400									
42500	1.729	1.729	1.729						
42600									
42700									
42800									
42900									
43000	1.729	1.729	1.729						
43100									
43200									
43300									
43400									
43500	1.729	1.729	1.729						
43600									
43700									
43800									
43900									
44000	1.729	1.729	1.729						
44100									
44200									
44300									
44400									
44500	1.729	1.753	1.741						
44600									
44700									
44800									
44900									
45000	1.729	1.753	1.741	1.776	1.776	1.776	1.875	1.969	1.922

Table H-2. Half-crack length data during fatigue for the R-BE repair (tabular) (continued)

CYCLES	VISUAL			INTERNAL EDDY CURRENT			EXTERNAL EDDY CURRENT		
	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	Δa_{AVG} (inches)	Δa_{AFT} (inches)	Δa_{FWD} (inches)	Δa_{AVG} (inches)
45100									
45200									
45300									
45400									
45500	1.776	1.753	1.764						
45600									
45700	1.776	1.753	1.764						
45800									
45900									
46000	1.776	1.753	1.764						
46100									
46200									
46300									
46400									
46500	1.776	1.753	1.764						
46600									
46700									
46800									
46900									
47000	1.776	1.753	1.764						
47100									
47200									
47300									
47400									
47500	1.776	1.776	1.776						
47600									
47700									
47800									
47900									
48000	1.776	1.776	1.776						
48100									
48200									
48300									
48400									
48500	1.776	1.776	1.776						
48600									
48700									
48800									
48900									
49000	1.776	1.800	1.788						
49100									
49200									
49300									
49400									
49500	1.776	1.800	1.788						
49600									
49700									
49800									
49900									
50000	1.776	1.800	1.788	1.823	1.823	1.823	2.031	2.000	2.016

Table H-2. Half-crack length data during fatigue for the R-BE repair (tabular) (continued)

CYCLES	VISUAL			INTERNAL EDDY CURRENT			EXTERNAL EDDY CURRENT		
	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)
50100									
50200									
50300									
50400									
50500	1.847	1.823	1.835						
50600									
50700									
50800									
50900									
51000	1.847	1.823	1.835						
51100									
51200									
51300									
51400									
51500	1.847	1.823	1.835						
51600									
51700									
51800									
51900									
52000	1.847	1.823	1.835						
52100									
52200									
52300									
52400									
52500	1.847	1.823	1.835						
52600									
52700									
52800									
52900									
53000	1.847	1.823	1.835						
53100									
53200									
53300									
53400									
53500	1.847	1.847	1.847						
53600									
53700									
53800									
53900									
54000	1.847	1.847	1.847						
54100									
54200									
54300									
54400									
54500	1.847	1.847	1.847						
54600									
54700									
54800									
54900									
55000	1.847	1.847	1.847	1.870	1.870	1.870	2.031	2.000	2.016

Table H-2. Half-crack length data during fatigue for the R-BE repair (tabular) (continued)

CYCLES	VISUAL			INTERNAL EDDY CURRENT			EXTERNAL EDDY CURRENT		
	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)
55100									
55200									
55300									
55400									
55500	1.870	1.847	1.858						
55600									
55700									
55800									
55900									
56000	1.870	1.847	1.858						
56100									
56200									
56300									
56400									
56500	1.870	1.870	1.870						
56600									
56700									
56800									
56900									
57000	1.870	1.870	1.870						
57100									
57200									
57300									
57400									
57500	1.870	1.870	1.870						
57600									
57700									
57800									
57900									
58000	1.870	1.870	1.870						
58100									
58200									
58300									
58400									
58500	1.870	1.870	1.870						
58600									
58700									
58800									
58900									
59000	1.870	1.870	1.870						
59100									
59200									
59300									
59400									
59500	1.870	1.870	1.870						
59600									
59700									
59800									
59900									
60000	1.870	1.870	1.870	1.917	1.917	1.917	2.094	2.000	2.047

Table H-3. Half-crack length data during fatigue for the R-BE repair after impact (tabular)

CYCLES	VISUAL			INTERNAL EDDY CURRENT			EXTERNAL EDDY CURRENT		
	aAFT (inches)	aFWD (inches)	aAVG (inches)	aAFT (inches)	aFWD (inches)	aAVG (inches)	aAFT (inches)	aFWD (inches)	aAVG (inches)
Impact	2.105	1.870	1.988						
60100	2.105	1.870	1.988						
60200	2.105	1.870	1.988						
60300	2.105	1.870	1.988						
60400	2.105	1.870	1.988						
60500	2.105	1.870	1.988						
60600	2.105	1.870	1.988						
60700	2.105	1.870	1.988						
60800	2.105	1.870	1.988						
60900	2.105	1.870	1.988						
61000	2.105	1.870	1.988						
61100	2.105	1.870	1.988						
61200	2.105	1.870	1.988						
61300	2.105	1.870	1.988						
61400	2.105	1.870	1.988						
61500	2.105	1.870	1.988						
61600	2.105	1.870	1.988						
61700	2.105	1.870	1.988						
61800	2.105	1.870	1.988						
61900	2.105	1.870	1.988						
62000	2.105	1.870	1.988						
62100	2.105	1.870	1.988						
62200	2.105	1.870	1.988						
62300	2.105	1.870	1.988						
62400	2.105	1.870	1.988						
62500	2.105	1.870	1.988						
62600	2.105	1.870	1.988						
62700	2.105	1.870	1.988						
62800	2.105	1.870	1.988						
62900	2.105	1.870	1.988						
63000	2.105	1.870	1.988						
63100	2.105	1.870	1.988						
63200	2.105	1.870	1.988						
63300	2.105	1.870	1.988						
63400	2.105	1.870	1.988						
63500	2.105	1.870	1.988						
63600	2.105	1.870	1.988						
63700	2.105	1.870	1.988						
63800	2.105	1.870	1.988						
63900	2.105	1.870	1.988						
64000	2.105	1.870	1.988						
64100	2.105	1.870	1.988						
64200	2.105	1.870	1.988						
64300	2.105	1.870	1.988						
64400	2.105	1.870	1.988						
64500	2.105	1.870	1.988						
64600	2.105	1.870	1.988						
64700	2.105	1.870	1.988						
64800	2.105	1.870	1.988						
64900	2.105	1.870	1.988						
65000	2.105	1.870	1.988	2.105	1.870	1.988			

Table H-3. Half-crack length data during fatigue for the R-BE repair after impact (tabular) (continued)

CYCLES	VISUAL			INTERNAL EDDY CURRENT			EXTERNAL EDDY CURRENT		
	aAFT (inches)	aFWD (inches)	aAVG (inches)	aAFT (inches)	aFWD (inches)	aAVG (inches)	aAFT (inches)	aFWD (inches)	aAVG (inches)
65100	2.105	1.870	1.988						
65200	2.105	1.870	1.988						
65300	2.105	1.870	1.988						
65400	2.105	1.870	1.988						
65500	2.105	1.870	1.988						
65600	2.105	1.870	1.988						
65700	2.105	1.870	1.988						
65800	2.105	1.870	1.988						
65900	2.105	1.870	1.988						
66000	2.105	1.870	1.988						
66100	2.105	1.870	1.988						
66200	2.105	1.870	1.988						
66300	2.105	1.870	1.988						
66400	2.105	1.870	1.988						
66500	2.105	1.870	1.988						
66600	2.105	1.870	1.988						
66700	2.105	1.870	1.988						
66800	2.105	1.870	1.988						
66900	2.105	1.870	1.988						
67000	2.105	1.870	1.988						
67100	2.105	1.870	1.988						
67200	2.105	1.870	1.988						
67300	2.105	1.870	1.988						
67400	2.105	1.870	1.988						
67500	2.105	1.870	1.988						
67600	2.105	1.870	1.988						
67700	2.105	1.870	1.988						
67800	2.105	1.870	1.988						
67900									
68000	2.105	1.870	1.988						
68100									
68200									
68300									
68400									
68500	2.105	1.870	1.988						
68600									
68700									
68800									
68900									
69000	2.105	1.870	1.988						
69100									
69200									
69300									
69400	2.105	1.894	1.999						
69500	2.105	1.894	1.999						
69600									
69700									
69800									
69900									
70000				2.105	1.917	2.011			

Table H-3. Half-crack length data during fatigue for the R-BE repair after impact (tabular) (continued)

CYCLES	VISUAL			INTERNAL EDDY CURRENT			EXTERNAL EDDY CURRENT		
	aAFT (inches)	aFWD (inches)	aAVG (inches)	aAFT (inches)	aFWD (inches)	aAVG (inches)	aAFT (inches)	aFWD (inches)	aAVG (inches)
70100									
70200									
70300									
70400									
70500	2.105	1.894	1.999						
70600									
70700									
70800									
70900									
71000	2.105	1.894	1.999						
71100									
71200									
71300									
71400									
71500	2.105	1.894	1.999						
71600									
71700									
71800									
71900									
72000									
72100									
72200									
72300									
72400									
72500	2.105	1.894	1.999						
72600									
72700									
72800									
72900									
73000	2.105	1.894	1.999						
73100									
73200									
73300									
73400									
73500	2.105	1.894	1.999						
73600									
73700									
73800									
73900									
74000	2.105	1.894	1.999						
74100									
74200									
74300									
74400									
74500	2.105	1.894	1.999						
74600									
74700									
74800									
74900									
75000	2.105	1.894	1.999	2.105	1.917	2.011			

Table H-3. Half-crack length data during fatigue for the R-BE repair after impact (tabular) (continued)

CYCLES	VISUAL			INTERNAL EDDY CURRENT			EXTERNAL EDDY CURRENT		
	aAFT (inches)	aFWD (inches)	aAVG (inches)	aAFT (inches)	aFWD (inches)	aAVG (inches)	aAFT (inches)	aFWD (inches)	aAVG (inches)
75100									
75200									
75300									
75400									
75500	2.105	1.917	2.011						
75600									
75700									
75800									
75900									
76000	2.105	1.917	2.011						
76100									
76200									
76300									
76400									
76500	2.105	1.917	2.011						
76600									
76700									
76800									
76900									
77000	2.105	1.917	2.011						
77100									
77200									
77300									
77400									
77500	2.105	1.917	2.011						
77600									
77700									
77800									
77900									
78000	2.105	1.917	2.011						
78100									
78200									
78300									
78400									
78500	2.105	1.917	2.011						
78600									
78700									
78800									
78900									
79000	2.105	1.917	2.011						
79100									
79200									
79300									
79400									
79500	2.105	1.941	2.023						
79600									
79700									
79800									
79900									
80000	2.105	1.941	2.023	2.129	1.964	2.046			

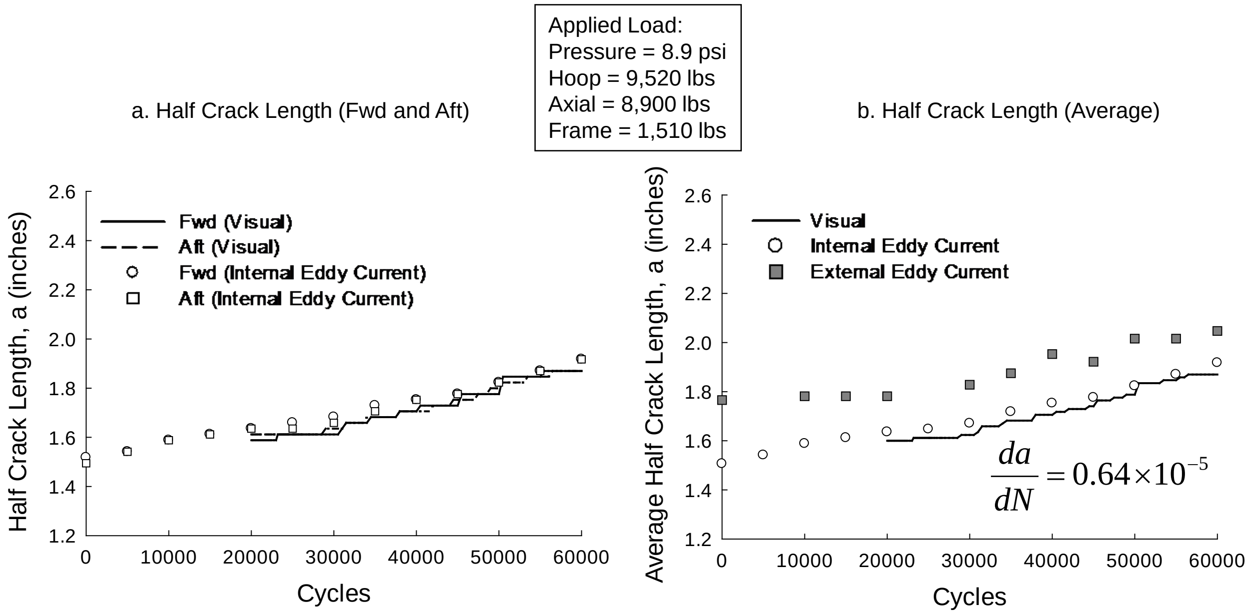


Figure H-2. The R-BE repair crack growth data during fatigue (60,000 cycles): (a) fwd and aft half-crack length and (b) average half-crack length

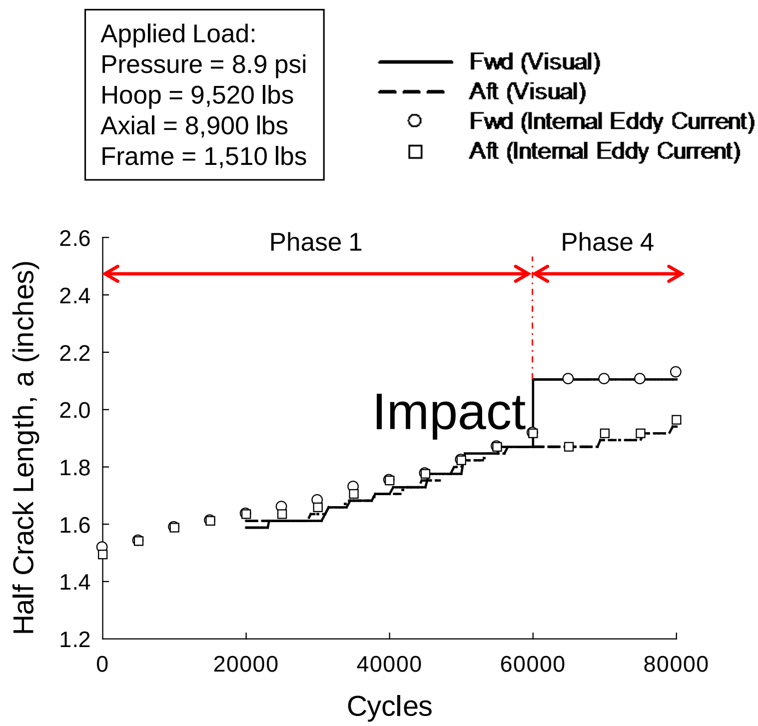


Figure H-3. Half-crack length data during fatigue before and after impact for the R-BE repair

Table H-4. Half-crack length data during pre-cracking for the U-BE repair (tabular)

CYCLES	VISUAL	
	a_{AFT} (inches)	a_{FWD} (inches)
350		1.411
630	1.437	
710		1.426
768	1.445	
780		1.432
864		1.441
902	1.453	
1021	1.468	
1035		1.461
1165	1.475	
1172		1.465
1230	1.478	
1235		1.467
1260	1.482	1.400
1270		1.473
1327		1.469
1330	1.491	
1377	1.489	1.470
1510	1.499	1.480
1555	1.502	1.478
1590	1.510	1.479
1610	1.511	1.478

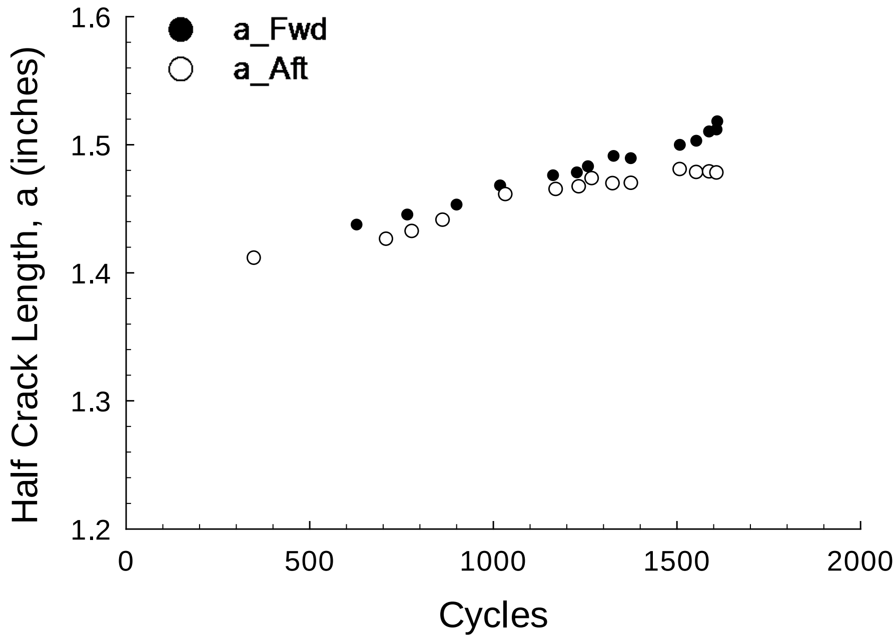


Figure H-4. Half-crack length data during pre-cracking for the U-BE repair

Table H-5. Half-crack length data during fatigue for the U-BE repair (tabular)

CYCLES	VISUAL			INTERNAL HFEC			EXTERNAL LFEC		
	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)
0	1.518	1.541	1.529	1.541	1.541	1.541	1.813	1.750	1.781
100									
200									
300									
400									
500	1.518	1.541	1.529						
600									
700	1.518	1.541	1.529						
800									
900	1.518	1.541	1.529						
1000	1.518	1.541	1.529						
1100	1.518	1.541	1.529						
1200	1.518	1.541	1.529						
1300	1.518	1.541	1.529						
1400	1.518	1.541	1.529						
1500	1.518	1.541	1.529						
1600	1.541	1.541	1.541						
1700	1.541	1.541	1.541						
1800	1.541	1.541	1.541						
1900	1.541	1.541	1.541						
2000	1.541	1.541	1.541						
2100	1.541	1.541	1.541						
2200	1.565	1.541	1.553						
2300	1.565	1.541	1.553						
2400	1.565	1.565	1.565						
2500	1.565	1.565	1.565						
2600	1.565	1.565	1.565						
2700	1.565	1.565	1.565						
2800	1.565	1.565	1.565						
2900	1.565	1.565	1.565						
3000	1.565	1.565	1.565						
3100	1.565	1.565	1.565						
3200	1.565	1.565	1.565						
3300	1.565	1.565	1.565						
3400	1.565	1.565	1.565						
3500	1.565	1.565	1.565						
3600	1.565	1.565	1.565						
3700	1.565	1.565	1.565						
3800	1.565	1.565	1.565						
3900	1.565	1.565	1.565						
4000	1.565	1.565	1.565						
4100	1.565	1.588	1.576						
4200	1.565	1.588	1.576						
4300	1.565	1.588	1.576						
4400	1.588	1.588	1.588						
4500	1.588	1.588	1.588						
4600	1.588	1.588	1.588						
4700	1.588	1.588	1.588						
4800	1.588	1.612	1.600						
4900	1.588	1.612	1.600						
5000	1.588	1.612	1.600	1.565	1.612	1.588			

Table H-5. Half-crack length data during fatigue for the U-BE repair (tabular) (continued)

CYCLES	VISUAL			INTERNAL EDDY CURRENT			EXTERNAL EDDY CURRENT		
	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)
5100	1.588	1.612	1.600						
5200	1.588	1.612	1.600						
5300	1.588	1.612	1.600						
5400	1.588	1.612	1.600						
5500	1.588	1.612	1.600						
5600	1.588	1.612	1.600						
5700	1.588	1.612	1.600						
5800	1.588	1.612	1.600						
5900	1.588	1.612	1.600						
6000	1.588	1.612	1.600						
6100	1.588	1.612	1.600						
6200	1.588	1.612	1.600						
6300	1.588	1.635	1.612						
6400	1.588	1.635	1.612						
6500	1.588	1.635	1.612						
6600	1.600	1.635	1.617						
6700	1.600	1.635	1.617						
6800	1.600	1.635	1.617						
6900	1.600	1.635	1.617						
7000	1.600	1.635	1.617						
7100	1.600	1.635	1.617						
7200	1.600	1.635	1.617						
7300	1.600	1.635	1.617						
7400	1.600	1.635	1.617						
7500	1.600	1.635	1.617						
7600	1.612	1.635	1.623						
7700	1.612	1.635	1.623						
7800	1.612	1.635	1.623						
7900	1.612	1.635	1.623						
8000	1.612	1.635	1.623						
8100	1.612	1.635	1.623						
8200	1.612	1.635	1.623						
8300	1.612	1.635	1.623						
8400	1.612	1.635	1.623						
8500	1.612	1.635	1.623						
8600	1.612	1.635	1.623						
8700	1.612	1.635	1.623						
8800	1.612	1.635	1.623						
8900	1.612	1.635	1.623						
9000	1.612	1.635	1.623						
9100	1.612	1.635	1.623						
9200	1.635	1.682	1.659						
9300	1.635	1.682	1.659						
9400	1.635	1.682	1.659						
9500	1.635	1.682	1.659						
9600	1.635	1.682	1.659						
9700	1.635	1.682	1.659						
9800	1.635	1.682	1.659						
9900	1.635	1.682	1.659						
10000	1.635	1.682	1.659	1.682	1.729	1.706	1.844	1.875	1.859

Table H-5. Half-crack length data during fatigue for the U-BE repair (tabular) (continued)

CYCLES	VISUAL			INTERNAL EDDY CURRENT			EXTERNAL EDDY CURRENT		
	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)
10100	1.635	1.682	1.659						
10200	1.635	1.682	1.659						
10300	1.635	1.682	1.659						
10400	1.635	1.682	1.659						
10500	1.635	1.682	1.659						
10600	1.635	1.682	1.659						
10700	1.635	1.682	1.659						
10800	1.659	1.682	1.670						
10900	1.659	1.682	1.670						
11000	1.659	1.682	1.670						
11100	1.659	1.682	1.670						
11200	1.659	1.682	1.670						
11300	1.682	1.682	1.682						
11400	1.682	1.682	1.682						
11500	1.682	1.694	1.688						
11600	1.682	1.694	1.688						
11700	1.682	1.694	1.688						
11800	1.682	1.694	1.688						
11900	1.682	1.694	1.688						
12000	1.682	1.694	1.688						
12100	1.682	1.694	1.688						
12200	1.682	1.694	1.688						
12300	1.682	1.694	1.688						
12400	1.682	1.694	1.688						
12500	1.682	1.706	1.694						
12600	1.682	1.706	1.694						
12700	1.682	1.706	1.694						
12800	1.682	1.706	1.694						
12900	1.682	1.706	1.694						
13000	1.682	1.706	1.694						
13100	1.682	1.706	1.694						
13200	1.682	1.706	1.694						
13300	1.682	1.706	1.694						
13400	1.682	1.706	1.694						
13500	1.706	1.706	1.706						
13600	1.706	1.706	1.706						
13700	1.706	1.706	1.706						
13800	1.706	1.729	1.717						
13900	1.706	1.729	1.717						
14000	1.706	1.729	1.717						
14100	1.706	1.729	1.717						
14200	1.706	1.729	1.717						
14300	1.706	1.741	1.723						
14400	1.706	1.741	1.723						
14500	1.706	1.753	1.729						
14600	1.706	1.753	1.729						
14700	1.706	1.753	1.729						
14800	1.706	1.753	1.729						
14900	1.706	1.753	1.729						
15000	1.706	1.753	1.729	1.706	1.776	1.741	1.906	1.906	1.906

Table H-5. Half-crack length data during fatigue for the U-BE repair (tabular) (continued)

CYCLES	VISUAL			INTERNAL EDDY CURRENT			EXTERNAL EDDY CURRENT		
	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	Δa_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)
15100	1.706	1.753	1.729						
15200	1.706	1.753	1.729						
15300	1.706	1.753	1.729						
15400	1.706	1.753	1.729						
15500	1.706	1.753	1.729						
15600	1.706	1.753	1.729						
15700	1.706	1.753	1.729						
15800	1.717	1.753	1.735						
15900	1.717	1.753	1.735						
16000	1.717	1.753	1.735						
16100	1.717	1.753	1.735						
16200	1.717	1.753	1.735						
16300	1.717	1.753	1.735						
16400	1.717	1.753	1.735						
16500	1.717	1.753	1.735						
16600	1.717	1.753	1.735						
16700	1.717	1.776	1.747						
16800	1.717	1.776	1.747						
16900	1.717	1.776	1.747						
17000	1.717	1.823	1.770						
17100	1.717	1.823	1.770						
17200	1.717	1.823	1.770						
17300	1.717	1.823	1.770						
17400	1.717	1.823	1.770						
17500	1.729	1.823	1.776						
17600	1.729	1.823	1.776						
17700	1.729	1.823	1.776						
17800	1.729	1.823	1.776						
17900	1.729	1.823	1.776						
18000	1.729	1.823	1.776						
18100	1.729	1.823	1.776						
18200	1.729	1.823	1.776						
18300	1.729	1.823	1.776						
18400	1.729	1.823	1.776						
18500	1.729	1.823	1.776						
18600	1.729	1.823	1.776						
18700	1.729	1.823	1.776						
18800	1.729	1.823	1.776						
18900	1.729	1.823	1.776						
19000	1.729	1.823	1.776						
19100	1.729	1.823	1.776						
19200	1.729	1.823	1.776						
19300	1.729	1.823	1.776						
19400	1.729	1.823	1.776						
19500	1.729	1.823	1.776						
19600	1.729	1.823	1.776						
19700	1.729	1.823	1.776						
19800	1.729	1.823	1.776						
19900	1.729	1.823	1.776						
20000	1.729	1.823	1.776	1.776	1.823	1.800	1.938	1.906	1.922

Table H-5. Half-crack length data during fatigue for the U-BE repair (tabular) (continued)

CYCLES	VISUAL			INTERNAL EDDY CURRENT			EXTERNAL EDDY CURRENT		
	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)
20100	1.729	1.823	1.776						
20200	1.729	1.823	1.776						
20300	1.729	1.823	1.776						
20400	1.729	1.823	1.776						
20500	1.753	1.823	1.788						
20600	1.753	1.823	1.788						
20700	1.753	1.823	1.788						
20800	1.753	1.823	1.788						
20900	1.753	1.823	1.788						
21000	1.776	1.823	1.800						
21100	1.776	1.823	1.800						
21200	1.776	1.823	1.800						
21300	1.776	1.823	1.800						
21400	1.776	1.823	1.800						
21500	1.776	1.823	1.800						
21600	1.776	1.823	1.800						
21700	1.776	1.823	1.800						
21800	1.776	1.823	1.800						
21900	1.776	1.823	1.800						
22000	1.776	1.823	1.800						
22100	1.800	1.847	1.823						
22200	1.800	1.870	1.835						
22300	1.800	1.870	1.835						
22400	1.800	1.870	1.835						
22500	1.800	1.870	1.835						
22600									
22700									
22800	1.823	1.870	1.847						
22900	1.823	1.870	1.847						
23000	1.823	1.870	1.847						
23100	1.823	1.870	1.847						
23200	1.823	1.870	1.847						
23300	1.823	1.870	1.847						
23400	1.823	1.870	1.847						
23500	1.823	1.870	1.847						
23600	1.823	1.870	1.847						
23700	1.823	1.870	1.847						
23800	1.823	1.870	1.847						
23900	1.823	1.870	1.847						
24000	1.823	1.870	1.847						
24100	1.823	1.870	1.847						
24200	1.823	1.870	1.847						
24300	1.823	1.870	1.847						
24400	1.835	1.870	1.852						
24500	1.835	1.894	1.864						
24600	1.835	1.894	1.864						
24700	1.835	1.894	1.864						
24800	1.835	1.894	1.864						
24900	1.835	1.894	1.864						
25000	1.835	1.894	1.864	1.870	1.917	1.894			

Table H-5. Half-crack length data during fatigue for the U-BE repair (tabular) (continued)

CYCLES	VISUAL			INTERNAL EDDY CURRENT			EXTERNAL EDDY CURRENT		
	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)
25100	1.835	1.894	1.864						
25200	1.835	1.917	1.876						
25300	1.835	1.917	1.876						
25400	1.835	1.917	1.876						
25500	1.835	1.917	1.876						
25600									
25700	1.835	1.917	1.876						
25800	1.835	1.917	1.876						
25900									
26000	1.835	1.917	1.876						
26100									
26200	1.835	1.917	1.876						
26300	1.835	1.917	1.876						
26400	1.835	1.917	1.876						
26500	1.835	1.917	1.876						
26600	1.835	1.917	1.876						
26700	1.835	1.917	1.876						
26800	1.835	1.917	1.876						
26900	1.835	1.917	1.876						
27000	1.835	1.917	1.876						
27100	1.835	1.917	1.876						
27200	1.835	1.941	1.888						
27300	1.835	1.941	1.888						
27400	1.835	1.941	1.888						
27500	1.835	1.941	1.888						
27600	1.835	1.941	1.888						
27700	1.870	1.941	1.905						
27800	1.870	1.941	1.905						
27900	1.870	1.941	1.905						
28000	1.870	1.941	1.905						
28100	1.870	1.941	1.905						
28200	1.870	1.941	1.905						
28300	1.870	1.941	1.905						
28400	1.870	1.941	1.905						
28500	1.870	1.941	1.905						
28600	1.870	1.941	1.905						
28700	1.870	1.941	1.905						
28800	1.870	1.941	1.905						
28900	1.870	1.941	1.905						
29000	1.870	1.941	1.905						
29100	1.870	1.941	1.905						
29200	1.894	1.941	1.917						
29300	1.894	1.941	1.917						
29400	1.894	1.941	1.917						
29500	1.894	1.941	1.917						
29600	1.894	1.941	1.917						
29700	1.894	1.941	1.917						
29800	1.894	1.941	1.917						
29900	1.894	1.941	1.917						
30000	1.894	1.941	1.917	1.917	1.964	1.941	2.063	2.250	2.156

Table H-5. Half-crack length data during fatigue for the U-BE repair (tabular) (continued)

CYCLES	VISUAL			INTERNAL EDDY CURRENT			EXTERNAL EDDY CURRENT		
	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)
30100	1.894	1.941	1.917						
30200	1.894	1.941	1.917						
30300	1.894	1.941	1.917						
30400	1.917	1.964	1.941						
30500	1.917	1.964	1.941						
30600	1.917	1.964	1.941						
30700	1.917	1.964	1.941						
30800	1.917	1.964	1.941						
30900	1.917	1.964	1.941						
31000	1.917	1.964	1.941						
31100	1.917	1.964	1.941						
31200	1.917	1.964	1.941						
31300	1.917	1.964	1.941						
31400	1.917	1.964	1.941						
31500	1.917	1.964	1.941						
31600	1.917	1.964	1.941						
31700									
31800	1.917	1.988	1.952						
31900	1.917	1.988	1.952						
32000	1.917	1.988	1.952						
32100	1.917	1.988	1.952						
32200	1.917	1.988	1.952						
32300	1.917	1.988	1.952						
32400	1.917	1.988	1.952						
32500	1.941	2.011	1.976						
32600	1.941	2.011	1.976						
32700	1.941	2.011	1.976						
32800	1.941	2.011	1.976						
32900	1.941	2.011	1.976						
33000	1.941	2.011	1.976						
33100	1.941	2.011	1.976						
33200	1.941	2.011	1.976						
33300	1.964	2.011	1.988						
33400	1.964	2.011	1.988						
33500	1.964	2.011	1.988						
33600	1.964	2.011	1.988						
33700	1.964	2.011	1.988						
33800	1.964	2.011	1.988						
33900	1.964	2.011	1.988						
34000	1.964	2.011	1.988						
34100	1.964	2.011	1.988						
34200	1.964	2.011	1.988						
34300	1.964	2.011	1.988						
34400	1.964	2.011	1.988						
34500	1.964	2.011	1.988						
34600	1.964	2.011	1.988						
34700	1.988	2.011	1.999						
34800	1.988	2.011	1.999						
34900									
35000	1.988	2.011	1.999	2.011	2.082	2.046	2.188	2.281	2.234

Table H-5. Half-crack length data during fatigue for the U-BE repair (tabular) (continued)

CYCLES	VISUAL			INTERNAL EDDY CURRENT			EXTERNAL EDDY CURRENT		
	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)
35100	2.011	2.058	2.035						
35200	2.011	2.058	2.035						
35300	2.011	2.058	2.035						
35400	2.011	2.058	2.035						
35500	2.011	2.058	2.035						
35600	2.011	2.058	2.035						
35700	2.011	2.058	2.035						
35800	2.011	2.058	2.035						
35900	2.011	2.058	2.035						
36000	2.011	2.058	2.035						
36100	2.011	2.058	2.035						
36200	2.011	2.082	2.046						
36300	2.011	2.082	2.046						
36400	2.011	2.082	2.046						
36500	2.011	2.082	2.046						
36600	2.011	2.082	2.046						
36700	2.011	2.093	2.052						
36800	2.011	2.105	2.058						
36900	2.011	2.105	2.058						
37000	2.035	2.105	2.070						
37100	2.035	2.105	2.070						
37200	2.035	2.105	2.070						
37300	2.035	2.105	2.070						
37400	2.035	2.105	2.070						
37500	2.035	2.105	2.070						
37600	2.035	2.105	2.070						
37700	2.035	2.105	2.070						
37800	2.035	2.105	2.070						
37900	2.035	2.105	2.070						
38000	2.035	2.105	2.070						
38100	2.035	2.105	2.070						
38200	2.035	2.105	2.070						
38300	2.035	2.105	2.070						
38400	2.035	2.105	2.070						
38500	2.035	2.105	2.070						
38600	2.035	2.105	2.070						
38700	2.035	2.105	2.070						
38800	2.035	2.105	2.070						
38900	2.035	2.105	2.070						
39000	2.035	2.105	2.070						
39100	2.035	2.105	2.070						
39200	2.035	2.105	2.070						
39300	2.035	2.105	2.070						
39400	2.035	2.105	2.070						
39500	2.035	2.117	2.076						
39600	2.046	2.129	2.087						
39700	2.046	2.129	2.087						
39800	2.046	2.129	2.087						
39900	2.046	2.129	2.087						
40000	2.046	2.129	2.087	2.082	2.152	2.117	2.250	2.375	2.313

Table H-5. Half-crack length data during fatigue for the U-BE repair (tabular) (continued)

CYCLES	VISUAL			INTERNAL EDDY CURRENT			EXTERNAL EDDY CURRENT		
	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)
40100	2.082	2.152	2.117						
40200	2.082	2.152	2.117						
40300	2.082	2.152	2.117						
40400	2.082	2.152	2.117						
40500	2.082	2.152	2.117						
40600	2.082	2.152	2.117						
40700	2.082	2.152	2.117						
40800	2.082	2.152	2.117						
40900	2.082	2.152	2.117						
41000	2.082	2.152	2.117						
41100	2.082	2.152	2.117						
41200	2.082	2.152	2.117						
41300	2.082	2.152	2.117						
41400	2.082	2.152	2.117						
41500	2.082	2.176	2.129						
41600	2.082	2.176	2.129						
41700	2.082	2.176	2.129						
41800	2.105	2.176	2.140						
41900	2.105	2.176	2.140						
42000	2.105	2.176	2.140						
42100	2.105	2.176	2.140						
42200	2.105	2.176	2.140						
42300	2.105	2.199	2.152						
42400	2.105	2.199	2.152						
42500	2.105	2.199	2.152						
42600	2.105	2.199	2.152						
42700	2.105	2.199	2.152						
42800	2.105	2.199	2.152						
42900	2.105	2.199	2.152						
43000	2.105	2.199	2.152						
43100	2.105	2.199	2.152						
43200	2.105	2.199	2.152						
43300	2.105	2.199	2.152						
43400	2.105	2.199	2.152						
43500	2.105	2.199	2.152						
43600	2.105	2.199	2.152						
43700	2.105	2.199	2.152						
43800	2.105	2.199	2.152						
43900	2.105	2.199	2.152						
44000	2.105	2.199	2.152						
44100	2.105	2.199	2.152						
44200	2.105	2.199	2.152						
44300	2.105	2.199	2.152						
44400	2.105	2.199	2.152						
44500	2.105	2.199	2.152						
44600	2.105	2.199	2.152						
44700	2.105	2.211	2.158						
44800	2.105	2.211	2.158						
44900	2.105	2.211	2.158						
45000	2.105	2.223	2.164	2.152	2.199	2.176	2.406	2.344	2.375

Table H-5. Half-crack length data during fatigue for the U-BE repair (tabular) (continued)

CYCLES	VISUAL			INTERNAL EDDY CURRENT			EXTERNAL EDDY CURRENT		
	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)
45100									
45200	2.105	2.223	2.164						
45300									
45400	2.105	2.223	2.164						
45500	2.105	2.223	2.164						
45600									
45700	2.105	2.223	2.164						
45800									
45900									
46000	2.105	2.223	2.164						
46100									
46200	2.105	2.223	2.164						
46300									
46400	2.105	2.223	2.164						
46500	2.105	2.246	2.176						
46600	2.105	2.246	2.176						
46700									
46800	2.105	2.246	2.176						
46900									
47000	2.105	2.246	2.176						
47100									
47200	2.105	2.246	2.176						
47300									
47400	2.129	2.246	2.187						
47500	2.152	2.246	2.199						
47600	2.152	2.246	2.199						
47700									
47800	2.152	2.246	2.199						
47900									
48000	2.152	2.246	2.199						
48100									
48200	2.152	2.246	2.199						
48300									
48400	2.152	2.246	2.199						
48500	2.152	2.270	2.211						
48600	2.152	2.270	2.211						
48700									
48800	2.152	2.270	2.211						
48900									
49000	2.152	2.270	2.211						
49100									
49200	2.152	2.270	2.211						
49300									
49400	2.152	2.293	2.223						
49500	2.152	2.293	2.223						
49600	2.152	2.293	2.223						
49700									
49800	2.152	2.293	2.223						
49900									
50000	2.199	2.293	2.246	2.223	2.293	2.258	2.500	2.375	2.438

Table H-5. Half-crack length data during fatigue for the U-BE repair (tabular) (continued)

CYCLES	VISUAL			INTERNAL EDDY CURRENT			EXTERNAL EDDY CURRENT		
	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)
50100									
50200	2.199	2.293	2.246						
50300									
50400	2.199	2.293	2.246						
50500	2.199	2.293	2.246						
50600	2.246	2.317	2.281						
50700									
50800	2.246	2.317	2.281						
50900									
51000	2.246	2.317	2.281						
51100									
51200	2.246	2.317	2.281						
51300									
51400	2.246	2.317	2.281						
51500	2.246	2.317	2.281						
51600	2.246	2.317	2.281						
51700									
51800	2.246	2.317	2.281						
51900									
52000	2.246	2.317	2.281						
52100									
52200	2.246	2.340	2.293						
52300									
52400	2.246	2.340	2.293						
52500	2.246	2.340	2.293						
52600	2.246	2.340	2.293						
52700	2.246	2.340	2.293						
52800	2.246	2.340	2.293						
52900	2.246	2.340	2.293						
53000	2.246	2.340	2.293						
53100	2.246	2.340	2.293						
53200	2.246	2.340	2.293						
53300	2.246	2.340	2.293						
53400	2.246	2.340	2.293						
53500	2.246	2.340	2.293						
53600	2.246	2.340	2.293						
53700	2.246	2.340	2.293						
53800	2.246	2.340	2.293						
53900	2.246	2.340	2.293						
54000	2.246	2.340	2.293						
54100	2.246	2.340	2.293						
54200	2.246	2.340	2.293						
54300	2.246	2.340	2.293						
54400	2.246	2.340	2.293						
54500	2.270	2.364	2.317						
54600	2.270	2.364	2.317						
54700	2.270	2.364	2.317						
54800	2.270	2.364	2.317						
54900	2.270	2.364	2.317						
55000	2.270	2.364	2.317	2.293	2.387	2.340	2.594	2.438	2.516

Table H-5. Half-crack length data during fatigue for the U-BE repair (tabular) (continued)

CYCLES	VISUAL			INTERNAL EDDY CURRENT			EXTERNAL EDDY CURRENT		
	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)
55100									
55200	2.270	2.387	2.328						
55300									
55400	2.293	2.387	2.340						
55500	2.293	2.387	2.340						
55600	2.293	2.387	2.340						
55700	2.293	2.387	2.340						
55800	2.293	2.387	2.340						
55900	2.293	2.387	2.340						
56000	2.293	2.387	2.340						
56100	2.293	2.387	2.340						
56200	2.293	2.387	2.340						
56300	2.293	2.387	2.340						
56400	2.293	2.387	2.340						
56500	2.293	2.387	2.340						
56600	2.293	2.387	2.340						
56700	2.293	2.387	2.340						
56800	2.293	2.387	2.340						
56900	2.293	2.387	2.340						
57000	2.293	2.387	2.340						
57100	2.293	2.387	2.340						
57200	2.293	2.387	2.340						
57300									
57400	2.293	2.411	2.352						
57500	2.293	2.411	2.352						
57600	2.317	2.411	2.364						
57700									
57800	2.317	2.411	2.364						
57900									
58000	2.317	2.411	2.364						
58100									
58200	2.317	2.434	2.375						
58300									
58400	2.340	2.434	2.387						
58500	2.340	2.434	2.387						
58600	2.340	2.434	2.387						
58700	2.340	2.434	2.387						
58800	2.340	2.434	2.387						
58900	2.340	2.434	2.387						
59000	2.340	2.434	2.387						
59100	2.340	2.434	2.387						
59200	2.340	2.434	2.387						
59300	2.340	2.434	2.387						
59400	2.340	2.434	2.387						
59500	2.340	2.434	2.387						
59600	2.340	2.434	2.387						
59700	2.340	2.434	2.387						
59800	2.340	2.434	2.387						
59900	2.340	2.434	2.387						
60000	2.340	2.434	2.387	2.387	2.458	2.422	2.500	2.750	2.625

Table H-6. Half-crack length data during fatigue for the U-BE repair after impact (tabular)

CYCLES	VISUAL			INTERNAL EDDY CURRENT			EXTERNAL EDDY CURRENT		
	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)
Impact	3.139	2.434	2.787						
60100	3.139	2.434	2.787						
60200	3.139	2.434	2.787						
60300	3.139	2.434	2.787						
60400	3.139	2.434	2.787						
60500	3.139	2.434	2.787						
60600	3.139	2.434	2.787						
60700	3.139	2.434	2.787						
60800	3.139	2.434	2.787						
60900	3.139	2.434	2.787						
61000	3.139	2.434	2.787						
61100	3.139	2.434	2.787						
61200	3.139	2.458	2.798						
61300	3.139	2.458	2.798						
61400	3.139	2.458	2.798						
61500	3.139	2.458	2.798						
61600	3.139	2.458	2.798						
61700	3.139	2.458	2.798						
61800	3.139	2.481	2.810						
61900	3.139	2.481	2.810						
62000	3.139	2.481	2.810						
62100	3.139	2.481	2.810						
62200	3.139	2.481	2.810						
62300	3.139	2.481	2.810						
62400	3.139	2.481	2.810						
62500	3.139	2.481	2.810						
62600	3.139	2.481	2.810						
62700	3.139	2.505	2.822						
62800	3.139	2.505	2.822						
62900	3.139	2.505	2.822						
63000	3.139	2.505	2.822						
63100	3.139	2.505	2.822						
63200	3.139	2.505	2.822						
63300	3.139	2.505	2.822						
63400	3.139	2.505	2.822						
63500	3.139	2.505	2.822						
63600	3.139	2.528	2.834						
63700	3.139	2.528	2.834						
63800	3.139	2.528	2.834						
63900	3.139	2.528	2.834						
64000	3.139	2.528	2.834						
64100	3.139	2.528	2.834						
64200	3.139	2.528	2.834						
64300	3.139	2.528	2.834						
64400	3.139	2.528	2.834						
64500	3.139	2.528	2.834						
64600	3.139	2.528	2.834						
64700	3.139	2.528	2.834						
64800	3.139	2.528	2.834						
64900	3.139	2.528	2.834						
65000	3.139	2.528	2.834	3.139	2.528	2.834	3.469	2.719	3.094

Table H-6. Half-crack length data during fatigue for the U-BE repair after impact (tabular) (continued)

CYCLES	VISUAL			INTERNAL EDDY CURRENT			EXTERNAL EDDY CURRENT		
	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)
65100	3.139	2.528	2.834						
65200	3.139	2.528	2.834						
65300	3.139	2.528	2.834						
65400	3.139	2.528	2.834						
65500	3.139	2.528	2.834						
65600	3.139	2.528	2.834						
65700	3.139	2.528	2.834						
65800	3.139	2.528	2.834						
65900	3.139	2.528	2.834						
66000	3.139	2.552	2.845						
66100	3.139	2.552	2.845						
66200	3.139	2.552	2.845						
66300	3.139	2.552	2.845						
66400	3.139	2.552	2.845						
66500	3.139	2.552	2.845						
66600	3.139	2.552	2.845						
66700	3.139	2.552	2.845						
66800	3.139	2.552	2.845						
66900	3.139	2.552	2.845						
67000	3.139	2.552	2.845						
67100									
67200	3.139	2.575	2.857						
67300									
67400	3.139	2.575	2.857						
67500	3.139	2.575	2.857						
67600	3.139	2.575	2.857						
67700									
67800	3.139	2.575	2.857						
67900									
68000	3.139	2.575	2.857						
68100									
68200	3.139	2.575	2.857						
68300									
68400	3.139	2.575	2.857						
68500	3.139	2.575	2.857						
68600	3.139	2.575	2.857						
68700									
68800	3.139	2.575	2.857						
68900									
69000	3.139	2.575	2.857						
69100									
69200	3.139	2.575	2.857						
69300									
69400	3.139	2.575	2.857						
69500	3.139	2.575	2.857						
69600	3.139	2.599	2.869						
69700	3.139	2.599	2.869						
69800	3.139	2.599	2.869						
69900	3.139	2.599	2.869						
70000	3.139	2.599	2.869	3.139	2.599	2.869			

Table H-6. Half-crack length data during fatigue for the U-BE repair after impact (tabular) (continued)

CYCLES	VISUAL			INTERNAL EDDY CURRENT			EXTERNAL EDDY CURRENT		
	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)
70100									
70200	3.139	2.599	2.869						
70300									
70400	3.139	2.599	2.869						
70500	3.139	2.622	2.881						
70600	3.139	2.622	2.881						
70700									
70800	3.139	2.622	2.881						
70900									
71000	3.139	2.622	2.881						
71100									
71200									
71300									
71400									
71500	3.139	2.622	2.881						
71600									
71700									
71800									
71900									
72000	3.139	2.622	2.881						
72100									
72200									
72300									
72400									
72500									
72600									
72700									
72800	3.139	2.646	2.892						
72900									
73000	3.139	2.646	2.892						
73100									
73200	3.139	2.646	2.892						
73300									
73400	3.139	2.646	2.892						
73500	3.139	2.646	2.892						
73600	3.139	2.646	2.892						
73700									
73800	3.139	2.669	2.904						
73900									
74000	3.139	2.669	2.904						
74100									
74200									
74300									
74400									
74500	3.139	2.669	2.904						
74600									
74700									
74800									
74900									
75000	3.139	2.669	2.904	3.139	2.669	2.904	3.469	2.906	3.188

Table H-6. Half-crack length data during fatigue for the U-BE repair after impact (tabular) (continued)

CYCLES	VISUAL			INTERNAL EDDY CURRENT			EXTERNAL EDDY CURRENT		
	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)
75100									
75200									
75300									
75400									
75500	3.139	2.669	2.904						
75600									
75700									
75800									
75900									
76000	3.139	2.669	2.904						
76100									
76200									
76300									
76400									
76500	3.139	2.669	2.904						
76600									
76700									
76800									
76900									
77000	3.139	2.693	2.916						
77100									
77200									
77300									
77400									
77500	3.139	2.693	2.916						
77600									
77700									
77800									
77900									
78000	3.139	2.716	2.928						
78100									
78200									
78300									
78400									
78500	3.139	2.716	2.928						
78600									
78700									
78800									
78900									
79000	3.139	2.716	2.928						
79100									
79200									
79300									
79400									
79500	3.139	2.740	2.939						
79600									
79700									
79800									
79900									
80000	3.139	2.740	2.939	3.139	2.763	2.951	3.469	2.969	3.219

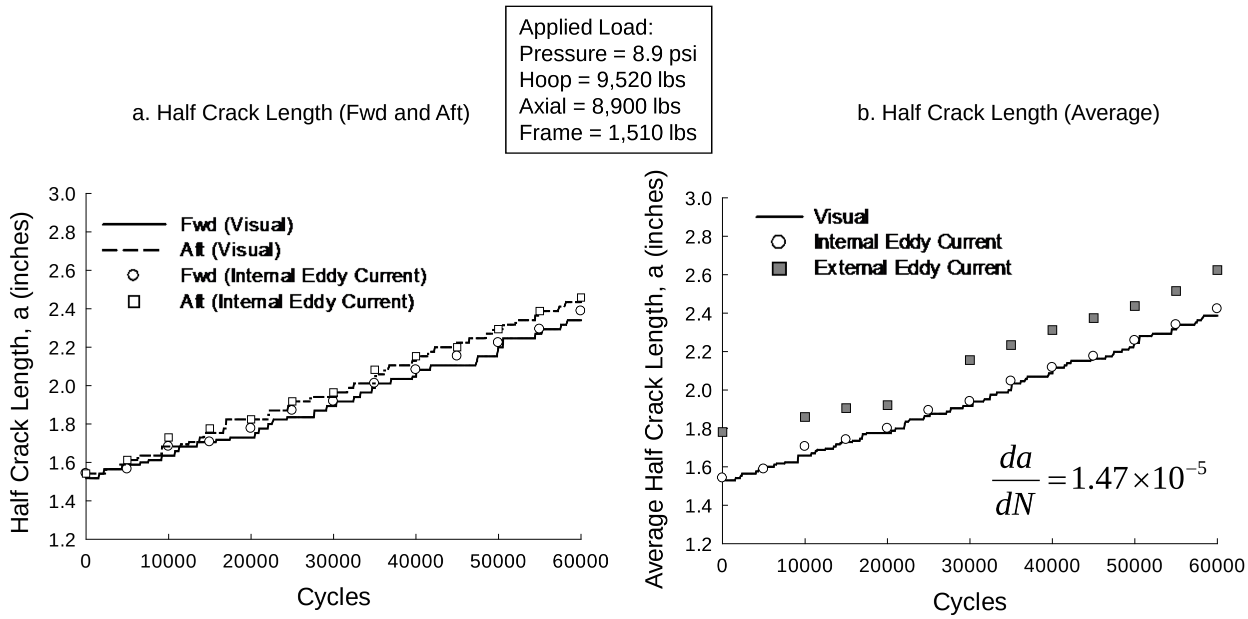


Figure H-5. The U-BE repair crack growth data during fatigue (60,000 cycles): (a) fwd and aft half-crack length and (b) average half-crack length

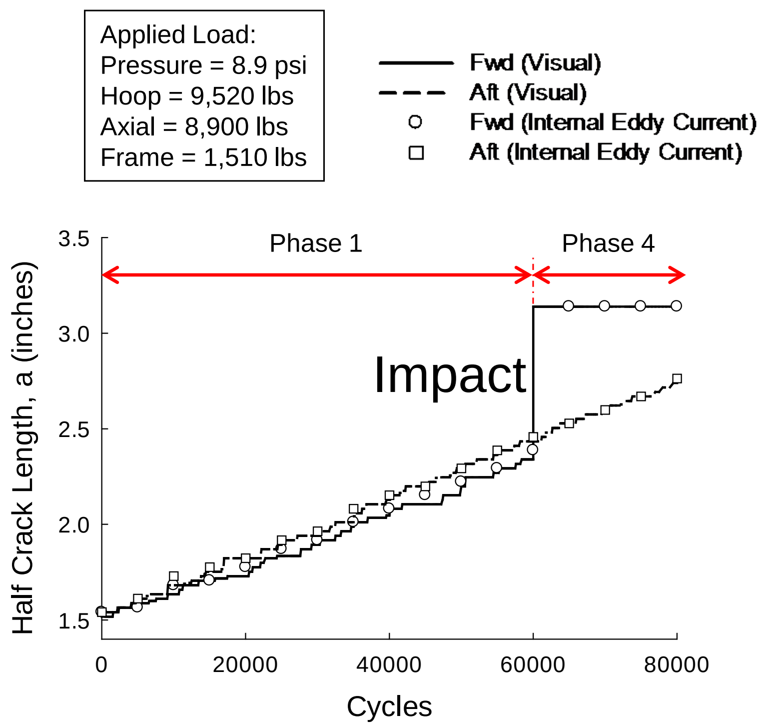


Figure H-6. Half-crack length data during fatigue before and after impact for the U-BE repair

Table H-7. Half-crack length data during pre-cracking for the U-A2 repair (tabular)

CYCLES	VISUAL	
	a_{AFT} (inches)	a_{FWD} (inches)
630	1.408	1.421
750	-	1.428
753	1.420	-
945	1.429	-
968	-	1.437
1122	1.438	-
1125	-	1.444
1295	-	1.450
1297	1.446	-
1470	1.455	1.462
1580	1.459	1.471
1611	1.462	1.472

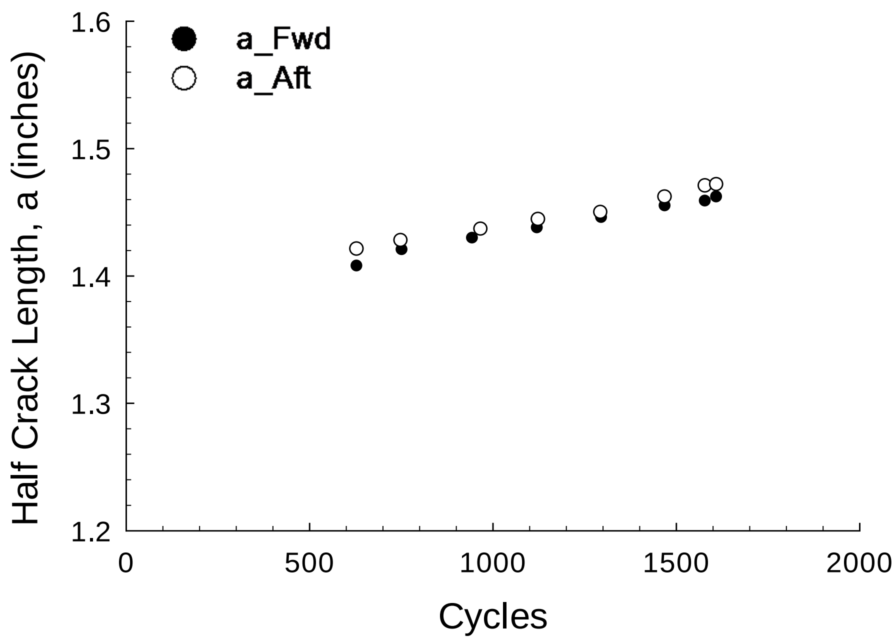


Figure H-7. Half-crack length data during pre-cracking for the U-A2 repair

Table H-8. Half-crack length data during fatigue for the U-A2 repair (tabular)

CYCLES	VISUAL			INTERNAL HFEC		
	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)
0				1.518	1.518	1.518
100						
200						
300						
400						
500						
600						
700						
800						
900						
1000						
1100						
1200						
1300						
1400						
1500						
1600						
1700						
1800						
1900						
2000						
2100						
2200						
2300						
2400						
2500						
2600						
2700						
2800						
2900						
3000						
3100						
3200						
3300						
3400						
3500						
3600						
3700						
3800						
3900						
4000						
4100						
4200						
4300						
4400						
4500						
4600						
4700						
4800						
4900						
5000						

Table H-8. Half-crack length data during fatigue for the U-A2 repair (tabular) (continued)

CYCLES	VISUAL			INTERNAL EDDY CURRENT		
	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)
5100						
5200						
5300						
5400						
5500						
5600						
5700						
5800						
5900						
6000						
6100						
6200						
6300						
6400						
6500						
6600						
6700						
6800						
6900						
7000						
7100						
7200						
7300						
7400						
7500						
7600						
7700						
7800						
7900						
8000						
8100						
8200						
8300						
8400						
8500						
8600						
8700						
8800						
8900						
9000						
9100						
9200						
9300						
9400						
9500						
9600						
9700						
9800						
9900						
10000				1.518	1.541	1.529

Table H-8. Half-crack length data during fatigue for the U-A2 repair (tabular) (continued)

CYCLES	VISUAL			INTERNAL EDDY CURRENT		
	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)
10100						
10200						
10300						
10400						
10500						
10600						
10700						
10800						
10900						
11000						
11100						
11200						
11300						
11400						
11500						
11600						
11700						
11800						
11900						
12000						
12100						
12200						
12300						
12400						
12500						
12600						
12700						
12800						
12900						
13000						
13100						
13200						
13300						
13400						
13500						
13600						
13700						
13800						
13900						
14000						
14100						
14200						
14300						
14400						
14500						
14600						
14700						
14800						
14900						
15000				1.518	1.541	1.529

Table H-8. Half-crack length data during fatigue for the U-A2 repair (tabular) (continued)

CYCLES	VISUAL			INTERNAL EDDY CURRENT		
	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)
15100						
15200						
15300						
15400						
15500						
15600						
15700						
15800						
15900						
16000						
16100						
16200						
16300						
16400						
16500						
16600						
16700						
16800						
16900						
17000						
17100						
17200						
17300						
17400						
17500						
17600						
17700						
17800						
17900						
18000						
18100						
18200						
18300						
18400						
18500						
18600						
18700						
18800						
18900						
19000						
19100						
19200						
19300						
19400						
19500						
19600						
19700						
19800						
19900						
20000	1.494	1.518	1.506	1.518	1.541	1.529

Table H-8. Half-crack length data during fatigue for the U-A2 repair (tabular) (continued)

CYCLES	VISUAL			INTERNAL EDDY CURRENT		
	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)
20100	1.494	1.518	1.506			
20200	1.494	1.518	1.506			
20300						
20400	1.494	1.518	1.506			
20500						
20600	1.494	1.518	1.506			
20700						
20800	1.518	1.518	1.518			
20900						
21000	1.518	1.518	1.518			
21100						
21200	1.518	1.541	1.529			
21300						
21400	1.518	1.541	1.529			
21500						
21600	1.518	1.541	1.529			
21700						
21800	1.518	1.541	1.529			
21900						
22000	1.518	1.541	1.529			
22100						
22200	1.518	1.541	1.529			
22300						
22400	1.518	1.541	1.529			
22500						
22600						
22700						
22800	1.518	1.541	1.529			
22900						
23000	1.518	1.541	1.529			
23100						
23200	1.518	1.541	1.529			
23300						
23400	1.518	1.541	1.529			
23500						
23600	1.518	1.541	1.529			
23700						
23800	1.518	1.541	1.529			
23900						
24000	1.518	1.541	1.529			
24100						
24200	1.518	1.541	1.529			
24300						
24400	1.518	1.541	1.529			
24500						
24600	1.518	1.541	1.529			
24700						
24800	1.518	1.541	1.529			
24900						
25000	1.518	1.541	1.529	1.518	1.541	1.529

Table H-8. Half-crack length data during fatigue for the U-A2 repair (tabular) (continued)

CYCLES	VISUAL			INTERNAL EDDY CURRENT		
	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)
25100	1.518	1.541	1.529			
25200	1.518	1.541	1.529			
25300						
25400	1.518	1.541	1.529			
25500						
25600						
25700	1.518	1.541	1.529			
25800						
25900						
26000	1.518	1.541	1.529			
26100						
26200						
26300						
26400	1.518	1.541	1.529			
26500						
26600						
26700						
26800						
26900						
27000	1.518	1.541	1.529			
27100						
27200						
27300						
27400						
27500	1.518	1.541	1.529			
27600						
27700						
27800						
27900						
28000	1.518	1.541	1.529			
28100						
28200						
28300						
28400						
28500	1.518	1.541	1.529			
28600						
28700						
28800						
28900						
29000	1.518	1.541	1.529			
29100						
29200						
29300						
29400						
29500	1.518	1.541	1.529			
29600						
29700						
29800						
29900						
30000	1.518	1.541	1.529	1.518	1.541	1.529

Table H-8. Half-crack length data during fatigue for the U-A2 repair (tabular) (continued)

CYCLES	VISUAL			INTERNAL EDDY CURRENT		
	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)
30100						
30200						
30300						
30400						
30500	1.518	1.541	1.529			
30600						
30700						
30800						
30900						
31000	1.518	1.541	1.529			
31100						
31200						
31300						
31400						
31500	1.518	1.541	1.529			
31600						
31700						
31800						
31900						
32000	1.518	1.541	1.529			
32100						
32200						
32300						
32400						
32500	1.518	1.541	1.529			
32600						
32700						
32800						
32900						
33000	1.518	1.541	1.529			
33100						
33200						
33300						
33400						
33500	1.518	1.541	1.529			
33600						
33700						
33800						
33900						
34000	1.518	1.541	1.529			
34100						
34200						
34300						
34400						
34500	1.518	1.541	1.529			
34600						
34700						
34800						
34900						
35000	1.518	1.541	1.529	1.518	1.541	1.529

Table H-8. Half-crack length data during fatigue for the U-A2 repair (tabular) (continued)

CYCLES	VISUAL			INTERNAL EDDY CURRENT		
	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)
35100						
35200						
35300						
35400						
35500	1.518	1.541	1.529			
35600						
35700						
35800						
35900						
36000	1.518	1.541	1.529			
36100						
36200						
36300						
36400						
36500	1.518	1.541	1.529			
36600						
36700						
36800						
36900						
37000	1.518	1.541	1.529			
37100						
37200						
37300						
37400						
37500	1.518	1.541	1.529			
37600						
37700						
37800						
37900						
38000	1.518	1.541	1.529			
38100						
38200						
38300						
38400						
38500	1.518	1.541	1.529			
38600						
38700						
38800						
38900						
39000	1.518	1.541	1.529			
39100						
39200						
39300						
39400						
39500	1.518	1.541	1.529			
39600						
39700						
39800						
39900						
40000	1.518	1.541	1.529	1.518	1.541	1.529

Table H-8. Half-crack length data during fatigue for the U-A2 repair (tabular) (continued)

CYCLES	VISUAL			INTERNAL EDDY CURRENT		
	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)
40100						
40200						
40300						
40400						
40500	1.518	1.541	1.529			
40600						
40700						
40800						
40900						
41000	1.518	1.541	1.529			
41100						
41200						
41300						
41400						
41500	1.518	1.541	1.529			
41600						
41700						
41800						
41900						
42000	1.518	1.541	1.529			
42100						
42200						
42300						
42400						
42500	1.518	1.541	1.529			
42600						
42700						
42800						
42900						
43000	1.518	1.541	1.529			
43100						
43200						
43300						
43400						
43500	1.518	1.541	1.529			
43600						
43700						
43800						
43900						
44000	1.518	1.541	1.529			
44100						
44200						
44300						
44400						
44500	1.518	1.541	1.529			
44600						
44700						
44800						
44900						
45000	1.518	1.541	1.529	1.518	1.541	1.529

Table H-8. Half-crack length data during fatigue for the U-A2 repair (tabular) (continued)

CYCLES	VISUAL			INTERNAL EDDY CURRENT		
	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)
45100						
45200						
45300						
45400						
45500	1.518	1.541	1.529			
45600						
45700						
45800						
45900						
46000	1.518	1.541	1.529			
46100						
46200						
46300						
46400						
46500	1.518	1.541	1.529			
46600						
46700						
46800						
46900						
47000	1.518	1.541	1.529			
47100						
47200						
47300						
47400						
47500	1.518	1.541	1.529			
47600						
47700						
47800						
47900						
48000	1.518	1.541	1.529			
48100						
48200						
48300						
48400						
48500	1.518	1.541	1.529			
48600						
48700						
48800						
48900						
49000	1.518	1.541	1.529			
49100						
49200						
49300						
49400						
49500	1.518	1.541	1.529			
49600						
49700						
49800						
49900						
50000	1.518	1.541	1.529	1.518	1.541	1.529

Table H-8. Half-crack length data during fatigue for the U-A2 repair (tabular) (continued)

CYCLES	VISUAL			INTERNAL EDDY CURRENT		
	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)
50100						
50200						
50300						
50400						
50500	1.518	1.541	1.529			
50600						
50700						
50800						
50900						
51000	1.518	1.541	1.529			
51100						
51200						
51300						
51400						
51500	1.518	1.541	1.529			
51600						
51700						
51800						
51900						
52000	1.518	1.541	1.529			
52100						
52200						
52300						
52400						
52500	1.518	1.541	1.529			
52600						
52700						
52800						
52900						
53000	1.518	1.541	1.529			
53100						
53200						
53300						
53400						
53500	1.518	1.541	1.529			
53600						
53700						
53800						
53900						
54000	1.518	1.541	1.529			
54100						
54200						
54300						
54400						
54500	1.518	1.541	1.529			
54600						
54700						
54800						
54900						
55000	1.518	1.541	1.529	1.518	1.541	1.529

Table H-8. Half-crack length data during fatigue for the U-A2 repair (tabular) (continued)

CYCLES	VISUAL			INTERNAL EDDY CURRENT		
	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)
55100						
55200						
55300						
55400						
55500	1.518	1.541	1.529			
55600						
55700						
55800						
55900						
56000	1.518	1.541	1.529			
56100						
56200						
56300						
56400						
56500	1.518	1.541	1.529			
56600						
56700						
56800						
56900						
57000	1.518	1.541	1.529			
57100						
57200						
57300						
57400						
57500	1.518	1.541	1.529			
57600						
57700						
57800						
57900						
58000	1.518	1.541	1.529			
58100						
58200						
58300						
58400						
58500	1.518	1.541	1.529			
58600						
58700						
58800						
58900						
59000	1.518	1.541	1.529			
59100						
59200						
59300						
59400						
59500	1.518	1.541	1.529			
59600						
59700						
59800						
59900						
60000	1.518	1.541	1.529	1.518	1.541	1.529

Table H-9. Half-crack length data during fatigue for the U-A2 repair after impact (tabular)

CYCLES	VISUAL			INTERNAL EDDY CURRENT		
	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)
Impact	1.729	1.682	1.706			
60100	1.729	1.682	1.706			
60200	1.729	1.682	1.706			
60300	1.729	1.682	1.706			
60400	1.729	1.682	1.706			
60500	1.729	1.682	1.706			
60600	1.729	1.682	1.706			
60700	1.729	1.682	1.706			
60800	1.729	1.682	1.706			
60900	1.729	1.682	1.706			
61000	1.729	1.682	1.706			
61100	1.729	1.682	1.706			
61200	1.729	1.682	1.706			
61300	1.729	1.682	1.706			
61400	1.729	1.682	1.706			
61500	1.729	1.682	1.706			
61600	1.729	1.682	1.706			
61700	1.729	1.682	1.706			
61800	1.729	1.682	1.706			
61900	1.729	1.682	1.706			
62000	1.729	1.682	1.706			
62100	1.729	1.682	1.706			
62200	1.729	1.682	1.706			
62300	1.729	1.682	1.706			
62400	1.729	1.682	1.706			
62500	1.729	1.682	1.706			
62600	1.729	1.682	1.706			
62700	1.729	1.682	1.706			
62800	1.729	1.682	1.706			
62900	1.729	1.682	1.706			
63000	1.729	1.682	1.706			
63100	1.729	1.682	1.706			
63200	1.729	1.682	1.706			
63300	1.729	1.682	1.706			
63400	1.729	1.682	1.706			
63500	1.729	1.682	1.706			
63600	1.729	1.682	1.706			
63700	1.729	1.682	1.706			
63800	1.729	1.682	1.706			
63900	1.729	1.682	1.706			
64000	1.729	1.682	1.706			
64100	1.729	1.682	1.706			
64200	1.729	1.682	1.706			
64300	1.729	1.682	1.706			
64400	1.729	1.682	1.706			
64500	1.729	1.682	1.706			
64600	1.729	1.682	1.706			
64700	1.729	1.682	1.706			
64800	1.729	1.682	1.706			
64900	1.729	1.682	1.706			
65000	1.729	1.682	1.706	1.729	1.682	1.706

Table H-9. Half-crack length data during fatigue for the U-A2 repair after impact (tabular) (continued)

CYCLES	VISUAL			INTERNAL EDDY CURRENT		
	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)
65100	1.729	1.682	1.706			
65200	1.729	1.682	1.706			
65300	1.729	1.682	1.706			
65400	1.729	1.682	1.706			
65500	1.729	1.682	1.706			
65600	1.729	1.682	1.706			
65700	1.729	1.682	1.706			
65800	1.729	1.682	1.706			
65900	1.729	1.682	1.706			
66000	1.729	1.682	1.706			
66100	1.729	1.682	1.706			
66200	1.729	1.682	1.706			
66300	1.729	1.682	1.706			
66400	1.729	1.682	1.706			
66500	1.729	1.682	1.706			
66600	1.729	1.682	1.706			
66700	1.729	1.682	1.706			
66800	1.729	1.682	1.706			
66900	1.729	1.682	1.706			
67000	1.729	1.682	1.706			
67100	1.729	1.682	1.706			
67200	1.729	1.682	1.706			
67300	1.729	1.682	1.706			
67400	1.729	1.682	1.706			
67500	1.729	1.682	1.706			
67600	1.729	1.682	1.706			
67700	1.729	1.682	1.706			
67800	1.729	1.682	1.706			
67900	1.729	1.682	1.706			
68000	1.729	1.682	1.706			
68100	1.729	1.682	1.706			
68200	1.729	1.682	1.706			
68300	1.729	1.682	1.706			
68400	1.729	1.682	1.706			
68500	1.729	1.682	1.706			
68600	1.729	1.682	1.706			
68700	1.729	1.682	1.706			
68800	1.729	1.682	1.706			
68900	1.729	1.682	1.706			
69000	1.729	1.682	1.706			
69100	1.729	1.682	1.706			
69200	1.729	1.682	1.706			
69300	1.729	1.682	1.706			
69400	1.729	1.682	1.706			
69500	1.729	1.682	1.706			
69600	1.729	1.682	1.706			
69700	1.729	1.682	1.706			
69800	1.729	1.682	1.706			
69900	1.729	1.682	1.706			
70000	1.729	1.682	1.706	1.729	1.682	1.706

Table H-9. Half-crack length data during fatigue for the U-A2 repair after impact (tabular) (continued)

CYCLES	VISUAL			INTERNAL EDDY CURRENT		
	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)
70100	1.729	1.682	1.706			
70200	1.729	1.682	1.706			
70300	1.729	1.682	1.706			
70400	1.729	1.682	1.706			
70500	1.729	1.682	1.706			
70600	1.729	1.682	1.706			
70700	1.729	1.682	1.706			
70800	1.729	1.682	1.706			
70900	1.729	1.682	1.706			
71000	1.729	1.682	1.706			
71100	1.729	1.682	1.706			
71200	1.729	1.682	1.706			
71300	1.729	1.682	1.706			
71400	1.729	1.682	1.706			
71500	1.729	1.682	1.706			
71600	1.729	1.682	1.706			
71700	1.729	1.682	1.706			
71800	1.729	1.682	1.706			
71900	1.729	1.682	1.706			
72000	1.729	1.682	1.706			
72100	1.729	1.682	1.706			
72200	1.729	1.682	1.706			
72300	1.729	1.682	1.706			
72400	1.729	1.682	1.706			
72500	1.729	1.682	1.706			
72600	1.729	1.682	1.706			
72700	1.729	1.682	1.706			
72800	1.729	1.682	1.706			
72900	1.729	1.682	1.706			
73000	1.729	1.682	1.706			
73100	1.729	1.682	1.706			
73200	1.729	1.682	1.706			
73300	1.729	1.682	1.706			
73400	1.729	1.682	1.706			
73500	1.729	1.682	1.706			
73600	1.729	1.682	1.706			
73700	1.729	1.682	1.706			
73800	1.729	1.682	1.706			
73900	1.729	1.682	1.706			
74000	1.729	1.682	1.706			
74100	1.729	1.682	1.706			
74200	1.729	1.682	1.706			
74300	1.729	1.682	1.706			
74400	1.729	1.682	1.706			
74500	1.729	1.682	1.706			
74600	1.729	1.682	1.706			
74700	1.729	1.682	1.706			
74800	1.729	1.682	1.706			
74900	1.729	1.682	1.706			
75000	1.729	1.682	1.706	1.729	1.682	1.706

Table H-9. Half-crack length data during fatigue for the U-A2 repair after impact (tabular) (continued)

CYCLES	VISUAL			INTERNAL EDDY CURRENT		
	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)
75100	1.729	1.682	1.706			
75200	1.729	1.682	1.706			
75300	1.729	1.682	1.706			
75400	1.729	1.682	1.706			
75500	1.729	1.682	1.706			
75600	1.729	1.682	1.706			
75700	1.729	1.682	1.706			
75800	1.729	1.682	1.706			
75900	1.729	1.682	1.706			
76000	1.729	1.682	1.706			
76100	1.729	1.682	1.706			
76200	1.729	1.682	1.706			
76300	1.729	1.682	1.706			
76400	1.729	1.682	1.706			
76500	1.729	1.682	1.706			
76600	1.729	1.682	1.706			
76700	1.729	1.682	1.706			
76800	1.729	1.682	1.706			
76900	1.729	1.682	1.706			
77000	1.729	1.682	1.706			
77100	1.729	1.682	1.706			
77200	1.729	1.682	1.706			
77300	1.729	1.682	1.706			
77400	1.729	1.682	1.706			
77500	1.729	1.682	1.706			
77600	1.729	1.682	1.706			
77700	1.729	1.682	1.706			
77800	1.729	1.682	1.706			
77900	1.729	1.682	1.706			
78000	1.729	1.682	1.706			
78100	1.729	1.682	1.706			
78200	1.729	1.682	1.706			
78300	1.729	1.682	1.706			
78400	1.729	1.682	1.706			
78500	1.729	1.682	1.706			
78600	1.729	1.682	1.706			
78700	1.729	1.682	1.706			
78800	1.729	1.682	1.706			
78900	1.729	1.682	1.706			
79000	1.729	1.682	1.706			
79100	1.729	1.682	1.706			
79200	1.729	1.682	1.706			
79300	1.729	1.682	1.706			
79400	1.729	1.682	1.706			
79500	1.729	1.682	1.706			
79600	1.729	1.682	1.706			
79700	1.729	1.682	1.706			
79800	1.729	1.682	1.706			
79900	1.729	1.682	1.706			
80000	1.729	1.682	1.706	1.729	1.682	1.706

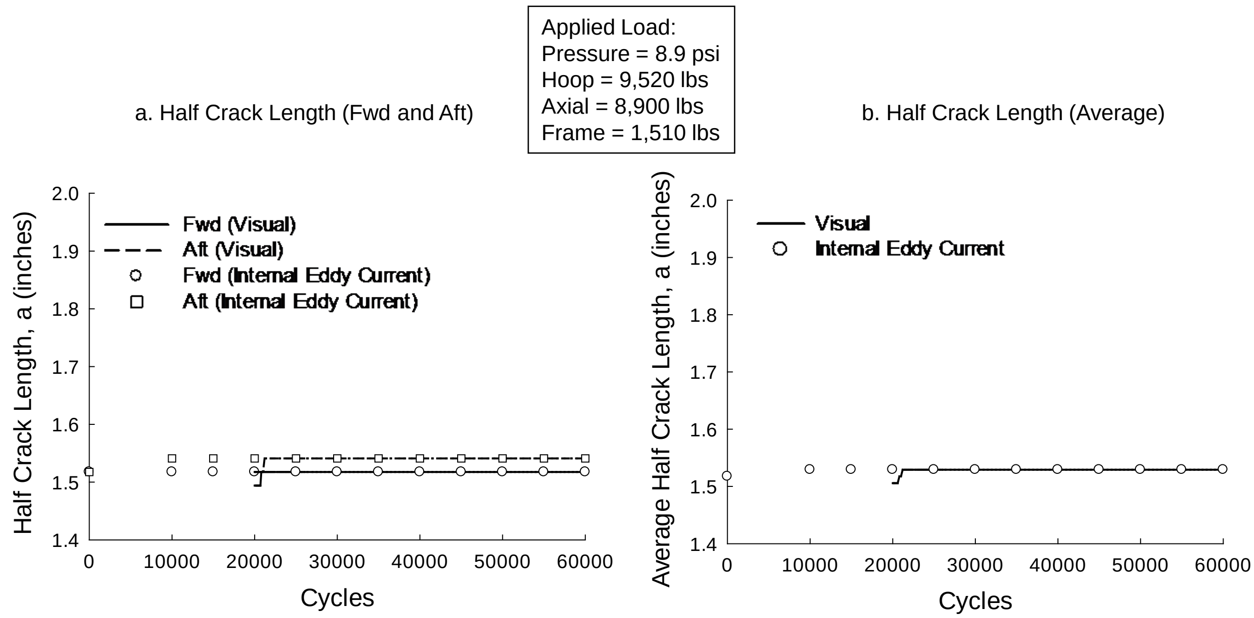


Figure H-8. The U-A2 repair crack growth data during fatigue (60,000 cycles): (a) fwd and aft half-crack length and (b) average half-crack length

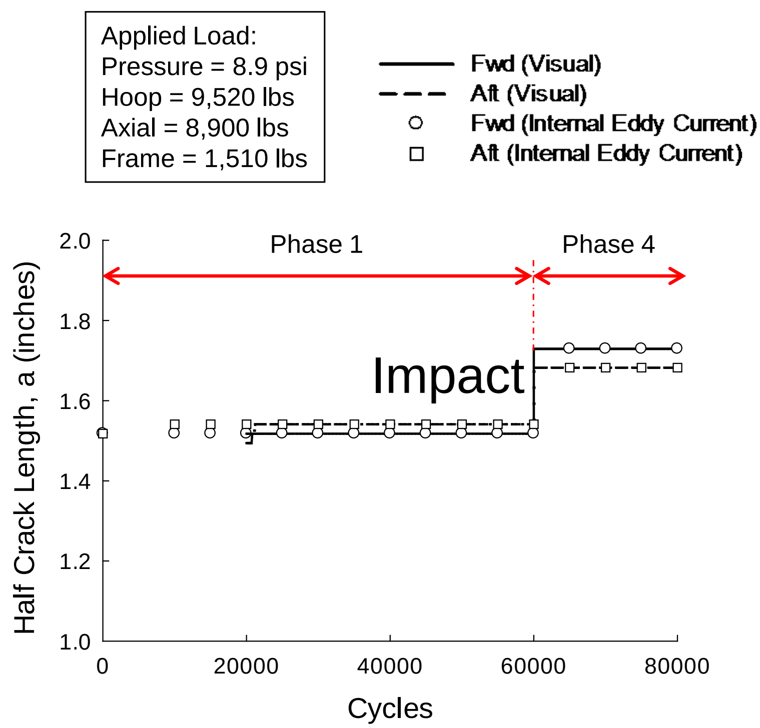


Figure H-9. Half-crack length data during fatigue before and after fatigue for the U-A2 repair

Table H-10. Half-crack length data during pre-cracking for the U-A1 repair (tabular)

CYCLES	VISUAL	
	a_{AFT} (inches)	a_{FWD} (inches)
225	1.409	
353	1.419	
420		1.404
530	1.431	
550		1.415
610	1.437	1.420
670	1.444	1.426
690	1.444	1.429
850	1.457	1.435
950	1.464	1.443
1040	1.473	1.448
1125	1.477	1.454
1225	1.485	1.459
1290	1.490	1.464
1372	1.496	1.470
1450	1.504	1.473
1512	1.507	1.478
1530	1.510	1.481
1570	1.511	1.482

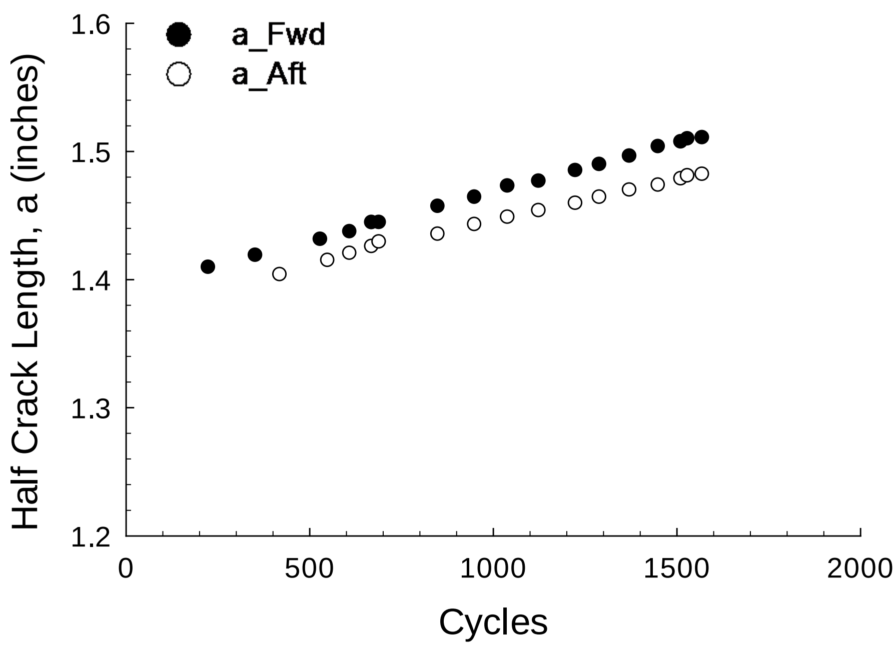


Figure H-10. Half-crack length data during pre-cracking for the U-A1 repair

Table H-11. Half-crack length data during fatigue for the U-A1 repair (tabular)

CYCLES	VISUAL			INTERNAL HFEC		
	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)
0	1.518	1.471	1.494	1.541	1.541	1.541
100						
200	1.518	1.471	1.494			
300	1.518	1.471	1.494			
400	1.541	1.494	1.518			
500	1.541	1.494	1.518			
600						
700	1.541	1.518	1.529			
800	1.541	1.518	1.529			
900	1.541	1.541	1.541			
1000	1.565	1.541	1.553			
1100	1.565	1.541	1.553			
1200	1.565	1.541	1.553			
1300	1.565	1.541	1.553			
1400	1.565	1.541	1.553			
1500	1.565	1.541	1.553			
1600	1.565	1.541	1.553			
1700	1.565	1.541	1.553			
1800	1.565	1.541	1.553			
1900	1.588	1.541	1.565			
2000	1.588	1.541	1.565			
2100	1.588	1.541	1.565			
2200	1.588	1.541	1.565			
2300	1.588	1.541	1.565			
2400	1.588	1.565	1.576			
2500	1.600	1.588	1.594			
2600	1.600	1.588	1.594			
2700						
2800	1.600	1.588	1.594			
2900	1.612	1.612	1.612			
3000	1.612	1.612	1.612			
3100	1.612	1.612	1.612			
3200	1.612	1.635	1.623			
3300	1.635	1.635	1.635			
3400	1.635	1.635	1.635			
3500	1.635	1.635	1.635			
3600	1.635	1.635	1.635			
3700	1.635	1.635	1.635			
3800	1.647	1.635	1.641			
3900	1.647	1.635	1.641			
4000	1.647	1.635	1.641			
4100	1.647	1.635	1.641			
4200	1.659	1.647	1.653			
4300	1.659	1.647	1.653			
4400	1.670	1.659	1.664			
4500	1.682	1.659	1.670			
4600	1.682	1.659	1.670			
4700	1.682	1.682	1.682			
4800	1.682	1.682	1.682			
4900	1.682	1.682	1.682			
5000	1.682	1.682	1.682	1.682	1.729	1.706

Table H-11. Half-crack length data during fatigue for the U-A1 repair (tabular) (continued)

CYCLES	VISUAL			INTERNAL EDDY CURRENT		
	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)
5100	1.682	1.682	1.682			
5200	1.682	1.682	1.682			
5300	1.682	1.682	1.682			
5400	1.682	1.682	1.682			
5500	1.706	1.706	1.706			
5600	1.706	1.706	1.706			
5700	1.706	1.706	1.706			
5800	1.706	1.706	1.706			
5900	1.706	1.706	1.706			
6000	1.706	1.706	1.706			
6100						
6200	1.729	1.729	1.729			
6300	1.729	1.729	1.729			
6400	1.729	1.729	1.729			
6500	1.729	1.729	1.729			
6600	1.729	1.729	1.729			
6700	1.753	1.729	1.741			
6800	1.753	1.729	1.741			
6900	1.753	1.729	1.741			
7000	1.753	1.729	1.741			
7100	1.753	1.729	1.741			
7200	1.753	1.729	1.741			
7300	1.753	1.729	1.741			
7400	1.753	1.729	1.741			
7500	1.753	1.753	1.753			
7600	1.753	1.753	1.753			
7700	1.753	1.753	1.753			
7800	1.753	1.753	1.753			
7900	1.753	1.764	1.758			
8000	1.753	1.764	1.758			
8100	1.753	1.764	1.758			
8200	1.753	1.764	1.758			
8300	1.753	1.764	1.758			
8400	1.753	1.764	1.758			
8500	1.753	1.776	1.764			
8600	1.776	1.776	1.776			
8700	1.776	1.776	1.776			
8800	1.776	1.776	1.776			
8900	1.776	1.776	1.776			
9000	1.776	1.800	1.788			
9100	1.776	1.800	1.788			
9200	1.776	1.800	1.788			
9300	1.800	1.800	1.800			
9400						
9500	1.800	1.800	1.800			
9600	1.800	1.823	1.811			
9700	1.800	1.823	1.811			
9800	1.800	1.823	1.811			
9900	1.800	1.823	1.811			
10000	1.800	1.823	1.811	1.847	1.847	1.847

Table H-11. Half-crack length data during fatigue for the U-A1 repair (tabular) (continued)

CYCLES	VISUAL			INTERNAL EDDY CURRENT		
	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)
10100	1.800	1.823	1.811			
10200	1.800	1.823	1.811			
10300	1.800	1.823	1.811			
10400	1.823	1.835	1.829			
10500	1.823	1.847	1.835			
10600	1.823	1.847	1.835			
10700	1.823	1.847	1.835			
10800	1.823	1.847	1.835			
10900	1.823	1.847	1.835			
11000	1.823	1.847	1.835			
11100	1.823	1.847	1.835			
11200	1.823	1.870	1.847			
11300	1.823	1.870	1.847			
11400	1.823	1.870	1.847			
11500	1.823	1.870	1.847			
11600	1.823	1.870	1.847			
11700						
11800	1.847	1.894	1.870			
11900	1.847	1.894	1.870			
12000	1.847	1.894	1.870			
12100	1.847	1.894	1.870			
12200						
12300	1.847	1.894	1.870			
12400						
12500	1.847	1.917	1.882			
12600	1.847	1.917	1.882			
12700	1.847	1.917	1.882			
12800	1.870	1.917	1.894			
12900	1.870	1.917	1.894			
13000	1.870	1.917	1.894			
13100	1.870	1.917	1.894			
13200	1.870	1.917	1.894			
13300	1.870	1.917	1.894			
13400	1.870	1.917	1.894			
13500	1.870	1.917	1.894			
13600	1.894	1.917	1.905			
13700	1.894	1.917	1.905			
13800	1.894	1.917	1.905			
13900	1.894	1.941	1.917			
14000	1.894	1.941	1.917			
14100	1.894	1.941	1.917			
14200	1.894	1.941	1.917			
14300	1.894	1.941	1.917			
14400	1.894	1.941	1.917			
14500	1.917	1.964	1.941			
14600	1.917	1.964	1.941			
14700	1.917	1.964	1.941			
14800	1.917	1.964	1.941			
14900	1.917	1.964	1.941			
15000	1.917	1.964	1.941	1.964	1.988	1.976

Table H-11. Half-crack length data during fatigue for the U-A1 repair (tabular) (continued)

CYCLES	VISUAL			INTERNAL EDDY CURRENT		
	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	Δa_{AVG} (inches)
15100	1.917	1.964	1.941			
15200	1.917	1.964	1.941			
15300	1.917	1.964	1.941			
15400	1.917	1.964	1.941			
15500	1.917	1.988	1.952			
15600	1.917	1.988	1.952			
15700	1.917	1.988	1.952			
15800	1.917	1.988	1.952			
15900	1.917	1.988	1.952			
16000	1.917	2.011	1.964			
16100	1.917	2.011	1.964			
16200	1.941	2.011	1.976			
16300	1.941	2.011	1.976			
16400	1.941	2.011	1.976			
16500	1.941	2.011	1.976			
16600	1.941	2.011	1.976			
16700	1.941	2.011	1.976			
16800	1.964	2.011	1.988			
16900	1.964	2.011	1.988			
17000	1.964	2.011	1.988			
17100	1.964	2.011	1.988			
17200	1.964	2.035	1.999			
17300	1.964	2.035	1.999			
17400	1.964	2.035	1.999			
17500	1.964	2.035	1.999			
17600	1.964	2.035	1.999			
17700	1.964	2.035	1.999			
17800	1.964	2.035	1.999			
17900	1.964	2.058	2.011			
18000	1.964	2.058	2.011			
18100	1.964	2.058	2.011			
18200	1.964	2.058	2.011			
18300	1.988	2.082	2.035			
18400	1.988	2.082	2.035			
18500	1.988	2.082	2.035			
18600	1.988	2.082	2.035			
18700	1.988	2.082	2.035			
18800	1.988	2.082	2.035			
18900	1.988	2.082	2.035			
19000	2.011	2.105	2.058			
19100	2.011	2.105	2.058			
19200	2.011	2.105	2.058			
19300	2.011	2.105	2.058			
19400	2.011	2.105	2.058			
19500	2.011	2.105	2.058			
19600	2.011	2.105	2.058			
19700	2.035	2.105	2.070			
19800	2.035	2.117	2.076			
19900	2.035	2.117	2.076			
20000	2.035	2.129	2.082	2.058	2.129	2.093

Table H-11. Half-crack length data during fatigue for the U-A1 repair (tabular) (continued)

CYCLES	VISUAL			INTERNAL EDDY CURRENT		
	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)
20100	2.035	2.152	2.093			
20200	2.035	2.152	2.093			
20300	2.035	2.152	2.093			
20400	2.035	2.152	2.093			
20500	2.035	2.152	2.093			
20600	2.035	2.152	2.093			
20700	2.035	2.152	2.093			
20800	2.035	2.152	2.093			
20900	2.058	2.199	2.129			
21000	2.058	2.199	2.129			
21100	2.058	2.199	2.129			
21200	2.058	2.199	2.129			
21300	2.058	2.199	2.129			
21400	2.058	2.199	2.129			
21500	2.058	2.199	2.129			
21600	2.058	2.199	2.129			
21700	2.058	2.199	2.129			
21800	2.058	2.199	2.129			
21900	2.058	2.199	2.129			
22000	2.082	2.199	2.140			
22100	2.082	2.199	2.140			
22200	2.082	2.199	2.140			
22300	2.082	2.199	2.140			
22400	2.082	2.199	2.140			
22500	2.105	2.199	2.152			
22600	2.105	2.199	2.152			
22700	2.105	2.199	2.152			
22800	2.105	2.199	2.152			
22900	2.105	2.199	2.152			
23000	2.105	2.199	2.152			
23100	2.105	2.199	2.152			
23200	2.105	2.199	2.152			
23300	2.105	2.199	2.152			
23400	2.105	2.223	2.164			
23500	2.105	2.246	2.176			
23600	2.105	2.246	2.176			
23700	2.105	2.246	2.176			
23800	2.105	2.246	2.176			
23900	2.105	2.246	2.176			
24000	2.105	2.246	2.176			
24100	2.105	2.246	2.176			
24200	2.105	2.246	2.176			
24300	2.105	2.246	2.176			
24400	2.129	2.246	2.187			
24500	2.129	2.246	2.187			
24600	2.129	2.246	2.187			
24700	2.152	2.270	2.211			
24800	2.152	2.270	2.211			
24900	2.152	2.270	2.211			
25000	2.152	2.270	2.211	2.176	2.270	2.223

Table H-11. Half-crack length data during fatigue for the U-A1 repair (tabular) (continued)

CYCLES	VISUAL			INTERNAL EDDY CURRENT		
	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)
25100	2.152	2.270	2.211			
25200	2.152	2.270	2.211			
25300	2.152	2.270	2.211			
25400	2.152	2.270	2.211			
25500	2.152	2.293	2.223			
25600	2.152	2.293	2.223			
25700	2.164	2.293	2.228			
25800	2.176	2.293	2.234			
25900	2.176	2.293	2.234			
26000	2.176	2.293	2.234			
26100	2.176	2.293	2.234			
26200	2.176	2.293	2.234			
26300	2.176	2.293	2.234			
26400	2.199	2.293	2.246			
26500	2.199	2.293	2.246			
26600	2.199	2.293	2.246			
26700	2.199	2.293	2.246			
26800	2.223	2.293	2.258			
26900	2.223	2.293	2.258			
27000	2.223	2.317	2.270			
27100	2.223	2.317	2.270			
27200	2.223	2.317	2.270			
27300	2.223	2.317	2.270			
27400	2.223	2.317	2.270			
27500	2.223	2.317	2.270			
27600	2.223	2.340	2.281			
27700	2.223	2.340	2.281			
27800	2.223	2.340	2.281			
27900	2.223	2.340	2.281			
28000	2.223	2.340	2.281			
28100	2.223	2.340	2.281			
28200	2.223	2.340	2.281			
28300	2.246	2.340	2.293			
28400	2.246	2.340	2.293			
28500	2.246	2.340	2.293			
28600	2.246	2.340	2.293			
28700	2.246	2.340	2.293			
28800	2.246	2.364	2.305			
28900	2.246	2.364	2.305			
29000	2.246	2.364	2.305			
29100	2.246	2.364	2.305			
29200	2.270	2.364	2.317			
29300	2.270	2.364	2.317			
29400	2.270	2.364	2.317			
29500	2.270	2.387	2.328			
29600	2.270	2.387	2.328			
29700	2.293	2.387	2.340			
29800	2.293	2.387	2.340			
29900	2.293	2.387	2.340			
30000	2.293	2.387	2.340	2.293	2.387	2.340

Table H-11. Half-crack length data during fatigue for the U-A1 repair (tabular) (continued)

CYCLES	VISUAL			INTERNAL EDDY CURRENT		
	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)
30100	2.293	2.387	2.340			
30200	2.293	2.387	2.340			
30300	2.340	2.411	2.375			
30400	2.340	2.411	2.375			
30500	2.340	2.411	2.375			
30600	2.340	2.411	2.375			
30700	2.340	2.411	2.375			
30800	2.340	2.434	2.387			
30900	2.340	2.434	2.387			
31000	2.340	2.434	2.387			
31100	2.340	2.434	2.387			
31200	2.340	2.434	2.387			
31300	2.340	2.434	2.387			
31400	2.340	2.434	2.387			
31500	2.340	2.434	2.387			
31600	2.340	2.434	2.387			
31700	2.340	2.434	2.387			
31800	2.340	2.434	2.387			
31900	2.340	2.434	2.387			
32000	2.340	2.434	2.387			
32100	2.340	2.434	2.387			
32200	2.340	2.434	2.387			
32300	2.340	2.434	2.387			
32400	2.340	2.434	2.387			
32500	2.340	2.434	2.387			
32600	2.340	2.434	2.387			
32700	2.340	2.434	2.387			
32800	2.340	2.481	2.411			
32900	2.340	2.481	2.411			
33000	2.340	2.481	2.411			
33100	2.340	2.481	2.411			
33200	2.340	2.481	2.411			
33300	2.340	2.481	2.411			
33400	2.340	2.481	2.411			
33500	2.340	2.481	2.411			
33600	2.340	2.481	2.411			
33700	2.340	2.481	2.411			
33800	2.340	2.481	2.411			
33900	2.340	2.481	2.411			
34000	2.340	2.481	2.411			
34100	2.340	2.481	2.411			
34200	2.340	2.481	2.411			
34300	2.340	2.481	2.411			
34400	2.340	2.481	2.411			
34500	2.340	2.481	2.411			
34600	2.340	2.481	2.411			
34700	2.340	2.481	2.411			
34800	2.340	2.481	2.411			
34900	2.340	2.481	2.411			
35000	2.340	2.481	2.411	2.387	2.528	2.458

Table H-11. Half-crack length data during fatigue for the U-A1 repair (tabular) (continued)

CYCLES	VISUAL			INTERNAL EDDY CURRENT		
	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)
35100	2.340	2.481	2.411			
35200	2.340	2.481	2.411			
35300	2.340	2.481	2.411			
35400	2.340	2.481	2.411			
35500	2.340	2.481	2.411			
35600	2.340	2.481	2.411			
35700	2.340	2.481	2.411			
35800	2.340	2.481	2.411			
35900	2.340	2.481	2.411			
36000	2.340	2.481	2.411			
36100	2.340	2.481	2.411			
36200	2.340	2.481	2.411			
36300	2.340	2.481	2.411			
36400	2.340	2.481	2.411			
36500	2.340	2.481	2.411			
36600	2.340	2.481	2.411			
36700	2.340	2.481	2.411			
36800	2.340	2.481	2.411			
36900	2.340	2.481	2.411			
37000	2.340	2.481	2.411			
37100	2.340	2.481	2.411			
37200	2.340	2.481	2.411			
37300	2.340	2.481	2.411			
37400	2.340	2.481	2.411			
37500	2.340	2.481	2.411			
37600	2.340	2.481	2.411			
37700	2.340	2.481	2.411			
37800	2.340	2.481	2.411			
37900	2.340	2.481	2.411			
38000	2.387	2.481	2.434			
38100						
38200	2.387	2.481	2.434			
38300						
38400	2.387	2.528	2.458			
38500	2.387	2.528	2.458			
38600	2.387	2.528	2.458			
38700						
38800	2.411	2.528	2.469			
38900						
39000	2.411	2.528	2.469			
39100						
39200	2.411	2.528	2.469			
39300						
39400	2.434	2.552	2.493			
39500	2.434	2.552	2.493			
39600	2.434	2.552	2.493			
39700						
39800	2.434	2.552	2.493			
39900						
40000	2.434	2.552	2.493	2.434	2.575	2.505

Table H-11. Half-crack length data during fatigue for the U-A1 repair (tabular) (continued)

CYCLES	VISUAL			INTERNAL EDDY CURRENT		
	Δa_{AFT} (inches)	Δa_{FWD} (inches)	Δa_{AVG} (inches)	Δa_{AFT} (inches)	Δa_{FWD} (inches)	a_{AVG} (inches)
40100	2.434	2.528	2.481			
40200	2.434	2.528	2.481			
40300	2.434	2.528	2.481			
40400	2.434	2.575	2.505			
40500	2.434	2.575	2.505			
40600	2.434	2.575	2.505			
40700	2.434	2.575	2.505			
40800						
40900						
41000	2.434	2.575	2.505			
41100						
41200	2.434	2.575	2.505			
41300						
41400	2.434	2.575	2.505			
41500						
41600	2.434	2.575	2.505			
41700						
41800	2.434	2.575	2.505			
41900						
42000	2.434	2.599	2.516			
42100						
42200	2.458	2.599	2.528			
42300						
42400	2.458	2.622	2.540			
42500						
42600	2.458	2.622	2.540			
42700						
42800	2.458	2.622	2.540			
42900						
43000	2.458	2.622	2.540			
43100						
43200	2.458	2.622	2.540			
43300						
43400	2.481	2.622	2.552			
43500						
43600	2.481	2.622	2.552			
43700						
43800	2.481	2.646	2.563			
43900						
44000	2.481	2.669	2.575			
44100						
44200	2.481	2.669	2.575			
44300						
44400	2.481	2.669	2.575			
44500						
44600	2.481	2.669	2.575			
44700						
44800	2.505	2.669	2.587			
44900						
45000	2.505	2.669	2.587	2.528	2.693	2.610

Table H-11. Half-crack length data during fatigue for the U-A1 repair (tabular) (continued)

CYCLES	VISUAL			INTERNAL EDDY CURRENT		
	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	Δa_{AVG} (inches)
45100						
45200	2.528	2.669	2.599			
45300						
45400	2.528	2.669	2.599			
45500	2.528	2.669	2.599			
45600	2.528	2.669	2.599			
45700						
45800	2.528	2.669	2.599			
45900						
46000	2.528	2.716	2.622			
46100						
46200	2.528	2.716	2.622			
46300						
46400	2.552	2.716	2.634			
46500	2.552	2.716	2.634			
46600						
46700						
46800	2.552	2.716	2.634			
46900						
47000	2.552	2.716	2.634			
47100						
47200	2.552	2.716	2.634			
47300						
47400	2.552	2.740	2.646			
47500	2.552	2.740	2.646			
47600	2.575	2.740	2.657			
47700						
47800	2.575	2.740	2.657			
47900						
48000	2.575	2.740	2.657			
48100						
48200	2.599	2.763	2.681			
48300						
48400	2.599	2.763	2.681			
48500	2.622	2.763	2.693			
48600	2.622	2.763	2.693			
48700						
48800	2.622	2.787	2.704			
48900						
49000	2.622	2.810	2.716			
49100						
49200	2.622	2.810	2.716			
49300						
49400	2.622	2.810	2.716			
49500	2.646	2.810	2.728			
49600	2.646	2.810	2.728			
49700						
49800	2.646	2.834	2.740			
49900						
50000	2.646	2.834	2.740	2.669	2.857	2.763

Table H-11. Half-crack length data during fatigue for the U-A1 repair (tabular) (continued)

CYCLES	VISUAL			INTERNAL EDDY CURRENT		
	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)
50100						
50200	2.646	2.857	2.751			
50300						
50400	2.669	2.857	2.763			
50500	2.669	2.881	2.775			
50600	2.669	2.881	2.775			
50700						
50800	2.669	2.904	2.787			
50900						
51000	2.669	2.904	2.787			
51100						
51200	2.693	2.904	2.798			
51300						
51400	2.693	2.928	2.810			
51500	2.693	2.928	2.810			
51600	2.693	2.951	2.822			
51700						
51800	2.693	2.951	2.822			
51900						
52000	2.716	2.951	2.834			
52100						
52200	2.716	2.951	2.834			
52300						
52400	2.740	2.975	2.857			
52500	2.740	2.998	2.869			
52600	2.740	2.998	2.869			
52700						
52800	2.763	3.022	2.892			
52900						
53000	2.763	3.022	2.892			
53100						
53200	2.763	3.022	2.892			
53300						
53400	2.787	3.045	2.916			
53500						
53600	2.810	3.139	2.975			
53700						
53800	2.810	3.186	2.998			
53900	2.857	3.280	3.069			
54000	2.904	3.327	3.116			
54100						
54200	2.998	3.539	3.268			
54300	3.022	3.562	3.292			
54400						
54500						
54600						
54700						
54800						
54900						
55000						

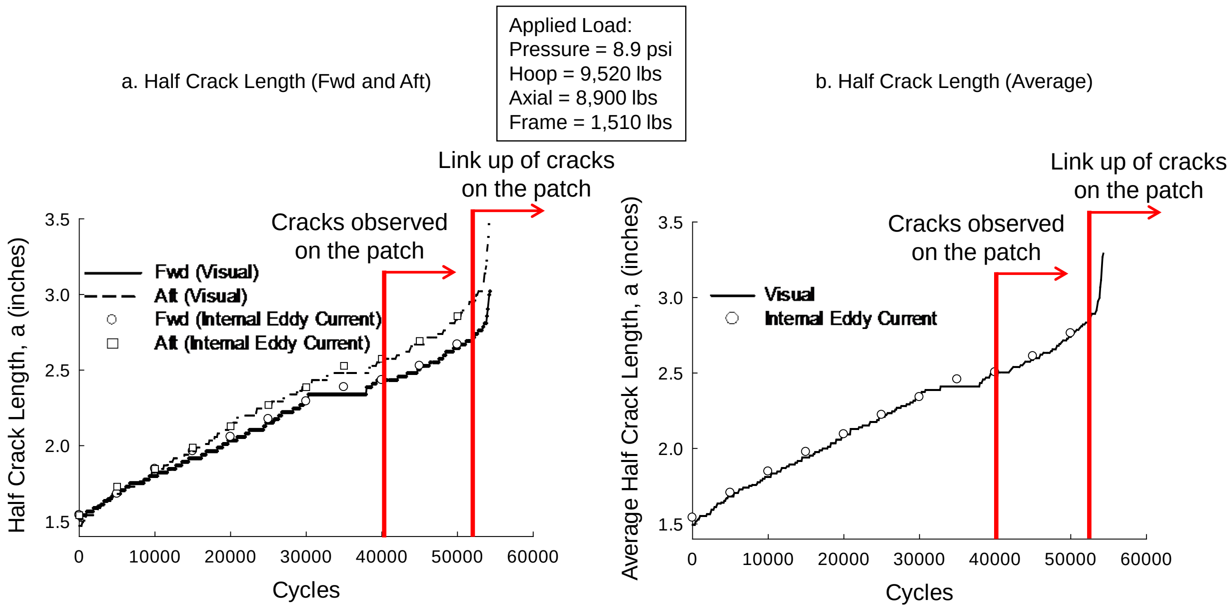


Figure H-11. The U-A1 repair crack growth data during fatigue (60,000 cycles): (a) fwd and aft half-crack length and (b) average half-crack length

Table H-12. Half-crack length data during pre-cracking for the D-BE repair (tabular)

CYCLES	VISUAL	
	a_{AFT} (inches)	a_{FWD} (inches)
300	1.408	
515	1.419	
618		1.417
622	1.426	
670		1.418
690	1.428	
710		1.419
730	1.432	
840	1.435	1.429
950	1.443	1.437
1040	1.448	1.441
1125	1.454	1.444
1205	1.457	1.446
1290	1.466	1.457
1372	1.463	1.459
1450	1.464	1.463
1571	1.472	1.470

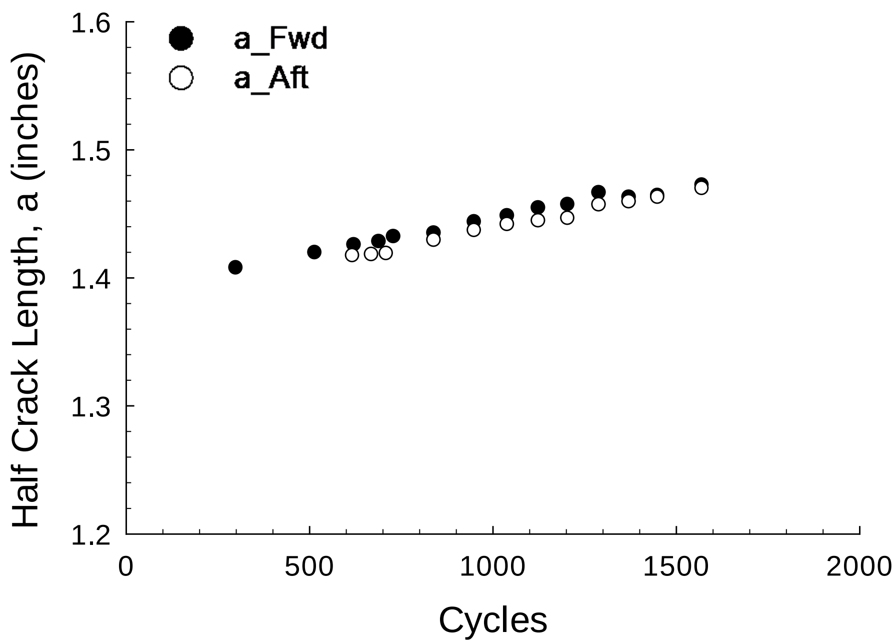


Figure H-12. Half-crack length data during pre-cracking for the D-BE repair

Table H-13. Half-crack length data during fatigue for the D-BE repair (tabular)

CYCLES	VISUAL			INTERNAL HFEC			EXTERNAL LFEC		
	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)
0	1.518	1.541	1.529	1.518	1.518	1.518			
100									
200	1.518	1.541	1.529						
300									
400	1.518	1.541	1.529						
500									
600	1.518	1.541	1.529						
700									
800	1.541	1.541	1.541						
900									
1000	1.541	1.565	1.553						
1100									
1200	1.541	1.565	1.553						
1300									
1400	1.565	1.588	1.576						
1500									
1600	1.565	1.588	1.576						
1700									
1800	1.565	1.588	1.576						
1900									
2000	1.565	1.588	1.576						
2100									
2200	1.588	1.588	1.588						
2300									
2400	1.588	1.612	1.600						
2500									
2600									
2700									
2800	1.588	1.612	1.600						
2900									
3000	1.588	1.612	1.600						
3100									
3200	1.612	1.612	1.612						
3300									
3400	1.612	1.612	1.612						
3500									
3600	1.612	1.612	1.612						
3700									
3800	1.635	1.659	1.647						
3900									
4000	1.635	1.659	1.647						
4100									
4200	1.635	1.659	1.647						
4300	1.635	1.659	1.647						
4400	1.635	1.659	1.647						
4500	1.635	1.659	1.647						
4600	1.635	1.682	1.659						
4700	1.659	1.682	1.670						
4800	1.659	1.682	1.670						
4900	1.659	1.682	1.670						
5000	1.659	1.682	1.670	1.659	1.682	1.670			

Table H-13. Half-crack length data during fatigue for the D-BE repair (tabular) (continued)

CYCLES	VISUAL			INTERNAL EDDY CURRENT			EXTERNAL EDDY CURRENT		
	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)
5100	1.659	1.682	1.670						
5200	1.659	1.682	1.670						
5300	1.659	1.682	1.670						
5400	1.659	1.706	1.682						
5500	1.659	1.706	1.682						
5600									
5700	1.659	1.706	1.682						
5800	1.682	1.729	1.706						
5900									
6000	1.682	1.729	1.706						
6100	1.682	1.729	1.706						
6200	1.682	1.729	1.706						
6300	1.682	1.729	1.706						
6400	1.682	1.729	1.706						
6500	1.682	1.729	1.706						
6600	1.682	1.729	1.706						
6700	1.682	1.729	1.706						
6800	1.682	1.729	1.706						
6900	1.706	1.729	1.717						
7000	1.729	1.753	1.741						
7100	1.729	1.753	1.741						
7200	1.729	1.753	1.741						
7300	1.729	1.753	1.741						
7400	1.729	1.753	1.741						
7500	1.729	1.753	1.741						
7600	1.729	1.753	1.741						
7700	1.729	1.753	1.741						
7800	1.729	1.753	1.741						
7900	1.729	1.753	1.741						
8000	1.729	1.753	1.741						
8100	1.729	1.776	1.753						
8200	1.729	1.776	1.753						
8300	1.729	1.776	1.753						
8400	1.753	1.776	1.764						
8500	1.753	1.776	1.764						
8600	1.753	1.776	1.764						
8700	1.753	1.776	1.764						
8800	1.753	1.776	1.764						
8900	1.753	1.776	1.764						
9000	1.753	1.776	1.764						
9100	1.753	1.776	1.764						
9200									
9300									
9400									
9500									
9600									
9700									
9800									
9900									
10000	1.753	1.776	1.764	1.800	1.823	1.811	1.906	1.906	1.906

Table H-13. Half-crack length data during fatigue for the D-BE repair (tabular) (continued)

CYCLES	VISUAL			INTERNAL EDDY CURRENT			EXTERNAL EDDY CURRENT		
	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)
10100	1.753	1.776	1.764						
10200	1.753	1.776	1.764						
10300	1.776	1.776	1.776						
10400	1.776	1.776	1.776						
10500	1.776	1.776	1.776						
10600	1.776	1.776	1.776						
10700	1.800	1.823	1.811						
10800	1.800	1.823	1.811						
10900	1.800	1.823	1.811						
11000	1.800	1.823	1.811						
11100	1.800	1.823	1.811						
11200	1.800	1.823	1.811						
11300	1.800	1.823	1.811						
11400	1.823	1.823	1.823						
11500	1.823	1.823	1.823						
11600	1.823	1.823	1.823						
11700									
11800	1.823	1.823	1.823						
11900	1.823	1.823	1.823						
12000	1.823	1.823	1.823						
12100	1.823	1.823	1.823						
12200	1.823	1.823	1.823						
12300	1.847	1.823	1.835						
12400	1.847	1.823	1.835						
12500	1.847	1.823	1.835						
12600	1.847	1.823	1.835						
12700	1.847	1.823	1.835						
12800	1.847	1.823	1.835						
12900	1.847	1.823	1.835						
13000	1.847	1.847	1.847						
13100	1.847	1.847	1.847						
13200	1.847	1.847	1.847						
13300	1.847	1.847	1.847						
13400	1.847	1.847	1.847						
13500	1.847	1.847	1.847						
13600	1.858	1.847	1.852						
13700	1.858	1.870	1.864						
13800	1.858	1.870	1.864						
13900	1.870	1.870	1.870						
14000	1.870	1.870	1.870						
14100	1.870	1.870	1.870						
14200	1.870	1.870	1.870						
14300	1.870	1.870	1.870						
14400	1.870	1.870	1.870						
14500	1.894	1.870	1.882						
14600	1.894	1.870	1.882						
14700	1.894	1.870	1.882						
14800	1.894	1.870	1.882						
14900	1.894	1.870	1.882						
15000	1.894	1.870	1.882	1.894	1.894	1.894	2.063	2.063	2.063

Table H-13. Half-crack length data during fatigue for the D-BE repair (tabular) (continued)

CYCLES	VISUAL			INTERNAL EDDY CURRENT			EXTERNAL EDDY CURRENT		
	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	Δa_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)
15100	1.894	1.894	1.894						
15200	1.894	1.894	1.894						
15300	1.894	1.894	1.894						
15400	1.894	1.894	1.894						
15500	1.894	1.917	1.905						
15600	1.894	1.917	1.905						
15700	1.894	1.917	1.905						
15800	1.894	1.917	1.905						
15900	1.894	1.917	1.905						
16000	1.894	1.917	1.905						
16100	1.894	1.917	1.905						
16200	1.894	1.917	1.905						
16300	1.917	1.917	1.917						
16400	1.917	1.917	1.917						
16500	1.917	1.917	1.917						
16600	1.917	1.917	1.917						
16700	1.917	1.917	1.917						
16800	1.917	1.917	1.917						
16900	1.917	1.917	1.917						
17000	1.917	1.917	1.917						
17100	1.917	1.917	1.917						
17200	1.917	1.917	1.917						
17300	1.917	1.917	1.917						
17400	1.917	1.917	1.917						
17500	1.917	1.917	1.917						
17600	1.917	1.917	1.917						
17700	1.917	1.917	1.917						
17800	1.917	1.917	1.917						
17900	1.964	1.964	1.964						
18000	1.964	1.964	1.964						
18100	1.964	1.964	1.964						
18200	1.964	1.964	1.964						
18300	1.964	1.964	1.964						
18400	1.964	1.964	1.964						
18500	1.964	1.964	1.964						
18600	1.964	1.964	1.964						
18700	1.964	1.988	1.976						
18800	1.964	1.988	1.976						
18900	1.964	1.988	1.976						
19000	1.964	1.988	1.976						
19100	1.964	1.988	1.976						
19200	1.964	1.988	1.976						
19300	1.964	1.988	1.976						
19400	1.964	1.988	1.976						
19500	1.964	1.988	1.976						
19600	1.964	1.988	1.976						
19700	1.988	2.011	1.999						
19800	1.988	2.011	1.999						
19900	1.988	2.011	1.999						
20000	1.988	2.011	1.999	1.988	2.011	1.999	2.188	2.188	2.188

Table H-13. Half-crack length data during fatigue for the D-BE repair (tabular) (continued)

CYCLES	VISUAL			INTERNAL EDDY CURRENT			EXTERNAL EDDY CURRENT		
	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)
20100	1.988	2.011	1.999						
20200	1.988	2.011	1.999						
20300	1.988	2.011	1.999						
20400	1.988	2.011	1.999						
20500	2.011	2.011	2.011						
20600	2.011	2.011	2.011						
20700	2.011	2.011	2.011						
20800	2.011	2.011	2.011						
20900	2.011	2.011	2.011						
21000	2.011	2.011	2.011						
21100	2.011	2.011	2.011						
21200	2.011	2.011	2.011						
21300	2.011	2.011	2.011						
21400	2.058	2.011	2.035						
21500	2.058	2.011	2.035						
21600	2.058	2.035	2.046						
21700	2.058	2.035	2.046						
21800	2.058	2.035	2.046						
21900	2.058	2.035	2.046						
22000	2.058	2.035	2.046						
22100	2.058	2.058	2.058						
22200	2.058	2.058	2.058						
22300	2.058	2.058	2.058						
22400	2.058	2.058	2.058						
22500	2.058	2.058	2.058						
22600	2.058	2.058	2.058						
22700	2.058	2.082	2.070						
22800	2.058	2.082	2.070						
22900	2.058	2.082	2.070						
23000	2.058	2.105	2.082						
23100	2.058	2.105	2.082						
23200	2.058	2.105	2.082						
23300	2.058	2.105	2.082						
23400	2.058	2.105	2.082						
23500	2.058	2.105	2.082						
23600	2.058	2.105	2.082						
23700	2.082	2.105	2.093						
23800	2.082	2.105	2.093						
23900	2.082	2.129	2.105						
24000	2.082	2.129	2.105						
24100	2.082	2.129	2.105						
24200	2.082	2.129	2.105						
24300									
24400	2.082	2.129	2.105						
24500	2.082	2.129	2.105						
24600	2.082	2.129	2.105						
24700	2.105	2.129	2.117						
24800	2.105	2.129	2.117						
24900									
25000	2.105	2.129	2.117	2.105	2.105	2.105	2.281	2.281	2.281

Table H-13. Half-crack length data during fatigue for the D-BE repair (tabular) (continued)

CYCLES	VISUAL			INTERNAL EDDY CURRENT			EXTERNAL EDDY CURRENT		
	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)
25100									
25200	2.105	2.129	2.117						
25300									
25400	2.105	2.129	2.117						
25500	2.105	2.129	2.117						
25600									
25700	2.105	2.152	2.129						
25800									
25900									
26000	2.105	2.152	2.129						
26100									
26200	2.105	2.176	2.140						
26300									
26400	2.105	2.176	2.140						
26500	2.105	2.199	2.152						
26600									
26700									
26800	2.105	2.199	2.152						
26900									
27000	2.129	2.199	2.164						
27100									
27200	2.129	2.199	2.164						
27300									
27400	2.129	2.199	2.164						
27500	2.129	2.199	2.164						
27600	2.129	2.199	2.164						
27700									
27800	2.129	2.199	2.164						
27900									
28000	2.129	2.199	2.164						
28100									
28200	2.129	2.199	2.164						
28300									
28400	2.129	2.199	2.164						
28500	2.152	2.199	2.176						
28600	2.152	2.199	2.176						
28700									
28800	2.152	2.199	2.176						
28900									
29000	2.152	2.199	2.176						
29100									
29200	2.152	2.199	2.176						
29300									
29400	2.152	2.223	2.187						
29500	2.152	2.223	2.187						
29600	2.152	2.223	2.187						
29700									
29800	2.152	2.223	2.187						
29900									
30000	2.176	2.223	2.199	2.199	2.223	2.211	2.375	2.438	2.406

Table H-13. Half-crack length data during fatigue for the D-BE repair (tabular) (continued)

CYCLES	VISUAL			INTERNAL EDDY CURRENT			EXTERNAL EDDY CURRENT		
	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)
30100									
30200	2.176	2.223	2.199						
30300									
30400	2.199	2.246	2.223						
30500	2.199	2.246	2.223						
30600	2.223	2.293	2.258						
30700									
30800	2.223	2.293	2.258						
30900									
31000	2.246	2.293	2.270						
31100									
31200	2.246	2.293	2.270						
31300									
31400	2.246	2.293	2.270						
31500	2.246	2.293	2.270						
31600	2.246	2.293	2.270						
31700									
31800	2.246	2.317	2.281						
31900									
32000	2.246	2.317	2.281						
32100									
32200	2.246	2.317	2.281						
32300									
32400	2.246	2.317	2.281						
32500	2.246	2.317	2.281						
32600	2.246	2.317	2.281						
32700									
32800	2.246	2.340	2.293						
32900									
33000	2.246	2.340	2.293						
33100									
33200									
33300									
33400	2.246	2.340	2.293						
33500	2.246	2.340	2.293						
33600	2.246	2.340	2.293						
33700									
33800	2.246	2.340	2.293						
33900									
34000	2.246	2.340	2.293						
34100									
34200	2.270	2.340	2.305						
34300									
34400	2.270	2.340	2.305						
34500	2.270	2.340	2.305						
34600	2.270	2.340	2.305						
34700									
34800	2.270	2.340	2.305						
34900									
35000	2.293	2.340	2.317	2.340	2.340	2.340	2.438	2.500	2.469

Table H-13. Half-crack length data during fatigue for the D-BE repair (tabular) (continued)

CYCLES	VISUAL			INTERNAL EDDY CURRENT			EXTERNAL EDDY CURRENT		
	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)
35100									
35200	2.293	2.340	2.317						
35300									
35400	2.293	2.340	2.317						
35500	2.293	2.364	2.328						
35600	2.293	2.364	2.328						
35700									
35800	2.293	2.387	2.340						
35900									
36000	2.293	2.387	2.340						
36100									
36200	2.293	2.387	2.340						
36300									
36400	2.293	2.387	2.340						
36500									
36600	2.293	2.387	2.340						
36700									
36800	2.293	2.387	2.340						
36900									
37000	2.293	2.387	2.340						
37100									
37200	2.293	2.387	2.340						
37300									
37400	2.293	2.387	2.340						
37500	2.293	2.387	2.340						
37600	2.293	2.387	2.340						
37700									
37800	2.293	2.411	2.352						
37900									
38000	2.317	2.411	2.364						
38100									
38200	2.317	2.411	2.364						
38300									
38400	2.317	2.411	2.364						
38500	2.317	2.411	2.364						
38600	2.317	2.411	2.364						
38700									
38800	2.317	2.434	2.375						
38900									
39000	2.340	2.434	2.387						
39100									
39200	2.340	2.434	2.387						
39300									
39400	2.340	2.434	2.387						
39500	2.340	2.434	2.387						
39600	2.340	2.434	2.387						
39700									
39800	2.340	2.458	2.399						
39900									
40000	2.340	2.458	2.399	2.387	2.458	2.422	2.500	2.656	2.578

Table H-13. Half-crack length data during fatigue for the D-BE repair (tabular) (continued)

CYCLES	VISUAL			INTERNAL EDDY CURRENT			EXTERNAL EDDY CURRENT		
	Δa_{AFT} (inches)	Δa_{FWD} (inches)	Δa_{AVG} (inches)	Δa_{AFT} (inches)	Δa_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)
40100	2.340	2.411	2.375						
40200	2.340	2.411	2.375						
40300	2.340	2.411	2.375						
40400	2.364	2.411	2.387						
40500	2.387	2.411	2.399						
40600	2.387	2.411	2.399						
40700	2.387	2.411	2.399						
40800									
40900									
41000	2.387	2.411	2.399						
41100									
41200	2.387	2.411	2.399						
41300									
41400	2.387	2.434	2.411						
41500									
41600	2.387	2.434	2.411						
41700									
41800	2.387	2.434	2.411						
41900									
42000	2.387	2.434	2.411						
42100									
42200	2.387	2.434	2.411						
42300									
42400	2.387	2.434	2.411						
42500									
42600	2.387	2.434	2.411						
42700									
42800	2.434	2.434	2.434						
42900									
43000	2.434	2.458	2.446						
43100									
43200	2.434	2.458	2.446						
43300									
43400	2.434	2.458	2.446						
43500									
43600	2.434	2.458	2.446						
43700									
43800	2.434	2.458	2.446						
43900									
44000	2.434	2.458	2.446						
44100									
44200	2.434	2.458	2.446						
44300									
44400	2.434	2.458	2.446						
44500									
44600	2.458	2.481	2.469						
44700									
44800	2.458	2.481	2.469						
44900									
45000	2.458	2.481	2.469	2.481	2.481	2.481	2.719	2.656	2.688

Table H-13. Half-crack length data during fatigue for the D-BE repair (tabular) (continued)

CYCLES	VISUAL			INTERNAL EDDY CURRENT			EXTERNAL EDDY CURRENT		
	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	Δa_{AVG} (inches)	Δa_{AFT} (inches)	Δa_{FWD} (inches)	Δa_{AVG} (inches)
45100									
45200									
45300									
45400									
45500	2.481	2.505	2.493						
45600									
45700									
45800									
45900									
46000	2.481	2.505	2.493						
46100									
46200									
46300									
46400									
46500	2.481	2.505	2.493						
46600									
46700									
46800									
46900									
47000	2.552	2.528	2.540						
47100									
47200									
47300									
47400									
47500	2.552	2.528	2.540						
47600									
47700									
47800									
47900									
48000	2.552	2.528	2.540						
48100									
48200									
48300									
48400									
48500	2.552	2.552	2.552						
48600									
48700									
48800									
48900									
49000	2.552	2.552	2.552						
49100									
49200									
49300									
49400									
49500	2.575	2.575	2.575						
49600									
49700									
49800									
49900									
50000	2.575	2.575	2.575	2.528	2.622	2.575			

Table H-13. Half-crack length data during fatigue for the D-BE repair (tabular) (continued)

CYCLES	VISUAL			INTERNAL EDDY CURRENT			EXTERNAL EDDY CURRENT		
	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)
50100									
50200									
50300									
50400									
50500	2.575	2.575	2.575						
50600									
50700									
50800									
50900									
51000	2.575	2.575	2.575						
51100									
51200									
51300									
51400									
51500	2.575	2.575	2.575						
51600									
51700									
51800									
51900									
52000	2.575	2.622	2.599						
52100									
52200									
52300									
52400									
52500	2.575	2.622	2.599						
52600									
52700									
52800									
52900									
53000	2.575	2.622	2.599						
53100									
53200									
53300									
53400									
53500	2.575	2.622	2.599						
53600									
53700									
53800									
53900									
54000	2.575	2.622	2.599						
54100									
54200									
54300									
54400									
54500									
54600									
54700									
54800									
54900									
55000	2.599	2.646	2.622	2.575	2.669	2.622	2.813	2.844	2.828

Table H-13. Half-crack length data during fatigue for the D-BE repair (tabular) (continued)

CYCLES	VISUAL			INTERNAL EDDY CURRENT			EXTERNAL EDDY CURRENT		
	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)
55100									
55200									
55300									
55400									
55500	2.599	2.646	2.622						
55600									
55700									
55800									
55900									
56000	2.599	2.669	2.634						
56100									
56200									
56300									
56400									
56500	2.599	2.669	2.634						
56600									
56700									
56800									
56900									
57000	2.622	2.669	2.646						
57100									
57200									
57300									
57400									
57500	2.622	2.669	2.646						
57600									
57700									
57800									
57900									
58000	2.646	2.716	2.681						
58100									
58200									
58300									
58400									
58500	2.646	2.716	2.681						
58600									
58700									
58800									
58900									
59000	2.646	2.740	2.693						
59100									
59200									
59300									
59400									
59500	2.646	2.740	2.693						
59600									
59700									
59800									
59900									
60000	2.646	2.740	2.693	2.669	2.763	2.716	2.906	3.031	2.969

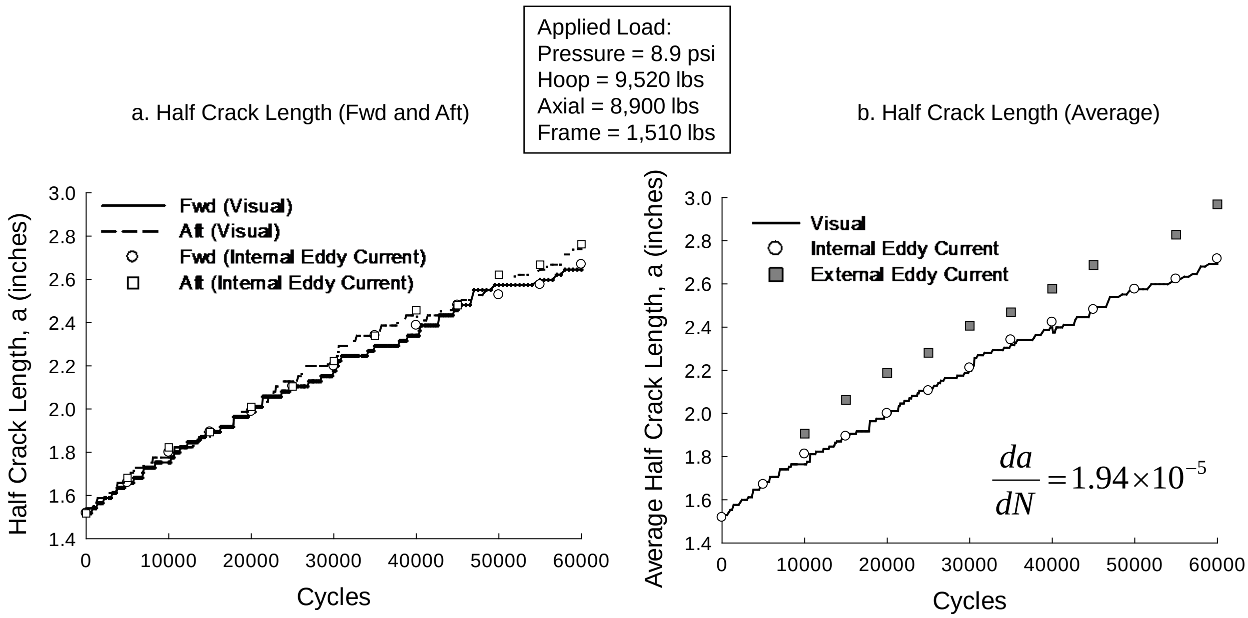


Figure H-13. The D-BE repair crack growth data during fatigue (60,000 cycles): (a) fwd and aft half-crack length and (b) average half-crack length

Table H-14. Half-crack length data during pre-cracking for the D-A2 repair (tabular)

CYCLES	VISUAL	
	a_{AFT} (inches)	a_{FWD} (inches)
180		1.415
300	1.410	
460	1.417	
482		1.417
631	1.424	1.423
670	1.427	1.432
750	1.435	1.435
830	1.439	1.438
965	1.447	1.448
1040	1.451	1.452
1140	1.457	1.455
1210	1.462	1.460
1290	1.465	1.468
1372	1.469	1.474
1450	1.479	1.472
1571	1.485	1.477

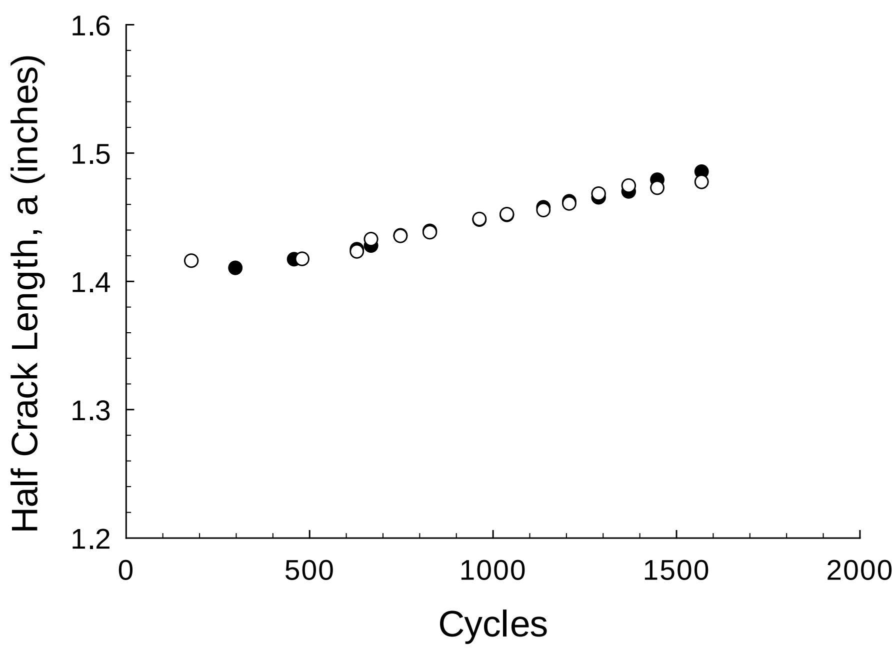


Figure H-14. Half-crack length data during pre-cracking for the D-A2 repair

Table H-15. Half-crack length data during fatigue for the D-A2 repair (tabular)

CYCLES	VISUAL			INTERNAL HFEC		
	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)
0	1.494	1.471	1.482	1.541	1.518	1.529
100						
200	1.494	1.494	1.494			
300						
400	1.518	1.494	1.506			
500						
600	1.518	1.494	1.506			
700						
800	1.518	1.494	1.506			
900						
1000	1.518	1.494	1.506			
1100						
1200	1.518	1.494	1.506			
1300						
1400	1.518	1.494	1.506			
1500						
1600	1.518	1.494	1.506			
1700						
1800	1.518	1.494	1.506			
1900						
2000	1.518	1.494	1.506			
2100						
2200	1.518	1.518	1.518			
2300						
2400	1.518	1.518	1.518			
2500						
2600						
2700						
2800	1.518	1.518	1.518			
2900						
3000	1.518	1.541	1.529			
3100						
3200	1.518	1.541	1.529			
3300						
3400	1.541	1.541	1.541			
3500						
3600	1.541	1.541	1.541			
3700						
3800	1.565	1.541	1.553			
3900						
4000	1.565	1.541	1.553			
4100						
4200	1.565	1.541	1.553			
4300						
4400	1.565	1.541	1.553			
4500						
4600	1.565	1.541	1.553			
4700						
4800	1.565	1.541	1.553			
4900						
5000	1.565	1.541	1.553	1.565	1.588	1.576

Table H-15. Half-crack length data during fatigue for the D-A2 repair (tabular) (continued)

CYCLES	VISUAL			INTERNAL EDDY CURRENT		
	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)
5100	1.565	1.541	1.553			
5200	1.565	1.541	1.553			
5300						
5400	1.565	1.541	1.553			
5500						
5600						
5700	1.565	1.541	1.553			
5800						
5900						
6000	1.565	1.541	1.553			
6100						
6200						
6300						
6400	1.588	1.588	1.588			
6500						
6600						
6700						
6800						
6900						
7000	1.588	1.588	1.588			
7100						
7200						
7300						
7400						
7500	1.635	1.588	1.612			
7600						
7700						
7800						
7900						
8000	1.635	1.612	1.623			
8100						
8200						
8300						
8400						
8500	1.635	1.612	1.623			
8600						
8700						
8800						
8900						
9000	1.635	1.635	1.635			
9100						
9200						
9300						
9400						
9500	1.635	1.635	1.635			
9600						
9700						
9800						
9900						
10000	1.635	1.635	1.635	1.659	1.659	1.659

Table H-15. Half-crack length data during fatigue for the D-A2 repair (tabular) (continued)

CYCLES	VISUAL			INTERNAL EDDY CURRENT		
	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)
10100						
10200						
10300						
10400						
10500	1.635	1.635	1.635			
10600						
10700						
10800						
10900						
11000	1.635	1.635	1.635			
11100						
11200						
11300						
11400						
11500	1.635	1.659	1.647			
11600						
11700						
11800						
11900						
12000	1.682	1.659	1.670			
12100						
12200						
12300						
12400						
12500	1.682	1.659	1.670			
12600						
12700						
12800						
12900						
13000	1.682	1.659	1.670			
13100						
13200						
13300						
13400						
13500	1.682	1.659	1.670			
13600						
13700						
13800						
13900						
14000	1.706	1.659	1.682			
14100						
14200						
14300						
14400						
14500	1.706	1.706	1.706			
14600						
14700						
14800						
14900	1.706	1.706	1.706			
15000	1.706	1.706	1.706	1.729	1.729	1.729

Table H-15. Half-crack length data during fatigue for the D-A2 repair (tabular) (continued)

CYCLES	VISUAL			INTERNAL EDDY CURRENT		
	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	Δa_{AVG} (inches)
15100	1.706	1.706	1.706			
15200						
15300						
15400						
15500	1.729	1.706	1.717			
15600						
15700						
15800						
15900						
16000	1.729	1.729	1.729			
16100						
16200						
16300						
16400						
16500	1.729	1.729	1.729			
16600						
16700						
16800						
16900						
17000	1.729	1.729	1.729			
17100						
17200						
17300						
17400						
17500	1.729	1.729	1.729			
17600						
17700						
17800						
17900						
18000	1.729	1.729	1.729			
18100						
18200						
18300						
18400						
18500	1.729	1.729	1.729			
18600						
18700						
18800						
18900						
19000	1.776	1.753	1.764			
19100						
19200						
19300						
19400						
19500	1.776	1.753	1.764			
19600						
19700						
19800						
19900						
20000	1.776	1.753	1.764	1.776	1.776	1.776

Table H-15. Half-crack length data during fatigue for the D-A2 repair (tabular) (continued)

CYCLES	VISUAL			INTERNAL EDDY CURRENT		
	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)
20100						
20200						
20300						
20400						
20500	1.776	1.800	1.788			
20600						
20700						
20800						
20900						
21000	1.776	1.800	1.788			
21100						
21200						
21300						
21400						
21500	1.776	1.800	1.788			
21600						
21700						
21800						
21900						
22000	1.776	1.800	1.788			
22100						
22200						
22300						
22400						
22500	1.800	1.800	1.800			
22600						
22700						
22800						
22900						
23000	1.800	1.800	1.800			
23100						
23200						
23300						
23400						
23500	1.823	1.823	1.823			
23600						
23700						
23800						
23900						
24000	1.823	1.823	1.823			
24100						
24200						
24300						
24400						
24500	1.823	1.847	1.835			
24600						
24700						
24800						
24900						
25000				1.870	1.870	1.870

Table H-15. Half-crack length data during fatigue for the D-A2 repair (tabular) (continued)

CYCLES	VISUAL			INTERNAL EDDY CURRENT		
	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)
25100						
25200						
25300						
25400						
25500	1.823	1.847	1.835			
25600						
25700						
25800						
25900						
26000	1.823	1.847	1.835			
26100						
26200						
26300						
26400						
26500	1.823	1.870	1.847			
26600						
26700						
26800						
26900						
27000	1.870	1.870	1.870			
27100						
27200						
27300						
27400						
27500	1.870	1.870	1.870			
27600						
27700						
27800						
27900						
28000	1.870	1.870	1.870			
28100						
28200						
28300						
28400						
28500	1.870	1.870	1.870			
28600						
28700						
28800						
28900						
29000	1.870	1.870	1.870			
29100						
29200						
29300						
29400						
29500	1.894	1.917	1.905			
29600						
29700						
29800						
29900						
30000	1.894	1.917	1.905	1.917	1.941	1.929

Table H-15. Half-crack length data during fatigue for the D-A2 repair (tabular) (continued)

CYCLES	VISUAL			INTERNAL EDDY CURRENT		
	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)
30100						
30200						
30300						
30400						
30500	1.894	1.917	1.905			
30600						
30700						
30800						
30900						
31000	1.894	1.917	1.905			
31100						
31200						
31300						
31400						
31500	1.894	1.917	1.905			
31600						
31700						
31800						
31900						
32000	1.917	1.917	1.917			
32100						
32200						
32300						
32400						
32500	1.917	1.917	1.917			
32600						
32700						
32800						
32900						
33000	1.917	1.941	1.929			
33100						
33200						
33300						
33400						
33500	1.917	1.941	1.929			
33600	1.941	1.964	1.952			
33700						
33800	1.941	1.964	1.952			
33900						
34000	1.941	1.964	1.952			
34100						
34200	1.941	1.964	1.952			
34300						
34400	1.941	1.964	1.952			
34500						
34600	1.941	1.964	1.952			
34700						
34800	1.941	1.964	1.952			
34900						
35000	1.941	1.964	1.952	1.988	1.964	1.976

Table H-15. Half-crack length data during fatigue for the D-A2 repair (tabular) (continued)

CYCLES	VISUAL			INTERNAL EDDY CURRENT		
	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)
35100						
35200						
35300						
35400						
35500	1.964	1.964	1.964			
35600						
35700						
35800						
35900						
36000	1.964	1.964	1.964			
36100						
36200						
36300						
36400						
36500	1.964	1.964	1.964			
36600						
36700						
36800						
36900						
37000	1.964	1.964	1.964			
37100						
37200						
37300						
37400						
37500	1.964	1.964	1.964			
37600						
37700						
37800						
37900						
38000	1.964	1.964	1.964			
38100						
38200						
38300						
38400						
38500	1.964	1.964	1.964			
38600						
38700						
38800						
38900						
39000	1.964	1.964	1.964			
39100						
39200						
39300						
39400						
39500	1.988	2.011	1.999			
39600						
39700						
39800						
39900						
40000	1.988	2.011	1.999	2.011	2.058	2.035

Table H-15. Half-crack length data during fatigue for the D-A2 repair (tabular) (continued)

CYCLES	VISUAL			INTERNAL EDDY CURRENT		
	Δa_{AFT} (inches)	Δa_{FWD} (inches)	Δa_{AVG} (inches)	Δa_{AFT} (inches)	Δa_{FWD} (inches)	a_{AVG} (inches)
40100	2.011	2.011	2.011			
40200	2.011	2.011	2.011			
40300	2.011	2.011	2.011			
40400	2.011	2.011	2.011			
40500	2.011	2.011	2.011			
40600	2.011	2.011	2.011			
40700	2.011	2.011	2.011			
40800						
40900						
41000	2.011	2.011	2.011			
41100						
41200	2.011	2.011	2.011			
41300						
41400	2.011	2.011	2.011			
41500						
41600	2.011	2.011	2.011			
41700						
41800	2.011	2.011	2.011			
41900						
42000	2.011	2.011	2.011			
42100						
42200	2.011	2.011	2.011			
42300						
42400	2.011	2.011	2.011			
42500						
42600	2.011	2.011	2.011			
42700						
42800	2.011	2.011	2.011			
42900						
43000	2.011	2.011	2.011			
43100						
43200	2.011	2.011	2.011			
43300						
43400	2.011	2.011	2.011			
43500						
43600	2.011	2.011	2.011			
43700						
43800	2.011	2.011	2.011			
43900						
44000	2.011	2.011	2.011			
44100						
44200	2.011	2.011	2.011			
44300						
44400	2.011	2.011	2.011			
44500						
44600	2.058	2.011	2.035			
44700						
44800	2.058	2.058	2.058			
44900						
45000	2.058	2.058	2.058	2.105	2.058	2.082

Table H-15. Half-crack length data during fatigue for the D-A2 repair (tabular) (continued)

CYCLES	VISUAL			INTERNAL EDDY CURRENT		
	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	Δa_{AVG} (inches)
45100						
45200						
45300						
45400						
45500	2.058	2.058	2.058			
45600						
45700						
45800						
45900						
46000	2.058	2.105	2.082			
46100						
46200						
46300						
46400						
46500	2.058	2.105	2.082			
46600						
46700						
46800						
46900						
47000	2.082	2.105	2.093			
47100						
47200						
47300						
47400						
47500	2.082	2.105	2.093			
47600						
47700						
47800						
47900						
48000	2.105	2.105	2.105			
48100						
48200						
48300						
48400						
48500	2.105	2.105	2.105			
48600						
48700						
48800						
48900						
49000	2.105	2.105	2.105			
49100						
49200						
49300						
49400						
49500	2.105	2.105	2.105			
49600						
49700						
49800						
49900						
50000	2.105	2.105	2.105	2.105	2.152	2.129

Table H-15. Half-crack length data during fatigue for the D-A2 repair (tabular) (continued)

CYCLES	VISUAL			INTERNAL EDDY CURRENT		
	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)
50100						
50200						
50300						
50400						
50500	2.105	2.105	2.105			
50600						
50700						
50800						
50900						
51000	2.105	2.105	2.105			
51100						
51200						
51300						
51400						
51500	2.105	2.105	2.105			
51600						
51700						
51800						
51900						
52000	2.105	2.105	2.105			
52100						
52200						
52300						
52400						
52500	2.105	2.105	2.105			
52600						
52700						
52800						
52900						
53000	2.129	2.105	2.117			
53100						
53200						
53300						
53400						
53500	2.129	2.105	2.117			
53600						
53700						
53800						
53900						
54000	2.129	2.129	2.129			
54100						
54200						
54300						
54400						
54500	2.129	2.129	2.129			
54600						
54700						
54800						
54900						
55000	2.152	2.152	2.152	2.152	2.152	2.152

Table H-15. Half-crack length data during fatigue for the D-A2 repair (tabular) (continued)

CYCLES	VISUAL			INTERNAL EDDY CURRENT		
	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)
55100						
55200						
55300						
55400						
55500	2.152	2.152	2.152			
55600						
55700						
55800						
55900						
56000	2.152	2.152	2.152			
56100						
56200						
56300						
56400						
56500	2.152	2.152	2.152			
56600						
56700						
56800						
56900						
57000	2.152	2.152	2.152			
57100						
57200						
57300						
57400						
57500	2.152	2.152	2.152			
57600						
57700						
57800						
57900						
58000	2.152	2.199	2.176			
58100						
58200						
58300						
58400						
58500	2.152	2.199	2.176			
58600						
58700						
58800						
58900						
59000	2.152	2.199	2.176			
59100						
59200						
59300						
59400						
59500	2.152	2.199	2.176			
59600						
59700						
59800						
59900						
60000	2.152	2.199	2.176	2.199	2.246	2.223

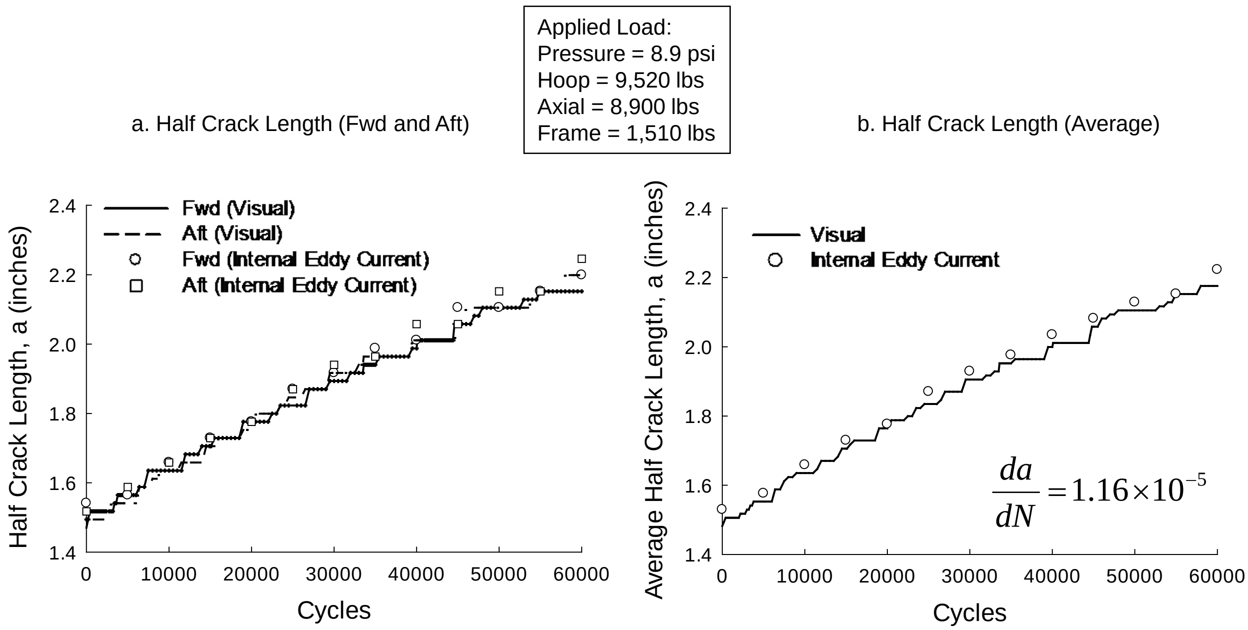


Figure H-15. The D-A2 repair crack growth data during fatigue (60,000 cycles): (a) fwd and aft half-crack length and (b) average half-crack length

Table H-16. Half-crack length data during pre-cracking for the C-BE repair (tabular)

CYCLES	VISUAL	
	a_{AFT} (inches)	a_{FWD} (inches)
0	1.400	1.400
295		1.413
450		1.416
580		1.431
710		1.436
810		
825	1.438	1.440
980	1.448	1.450
1100	1.460	1.464
1230	1.466	1.470
1350	1.476	1.477
1500	1.493	1.490
1625	1.505	1.499
1654	1.510	1.500

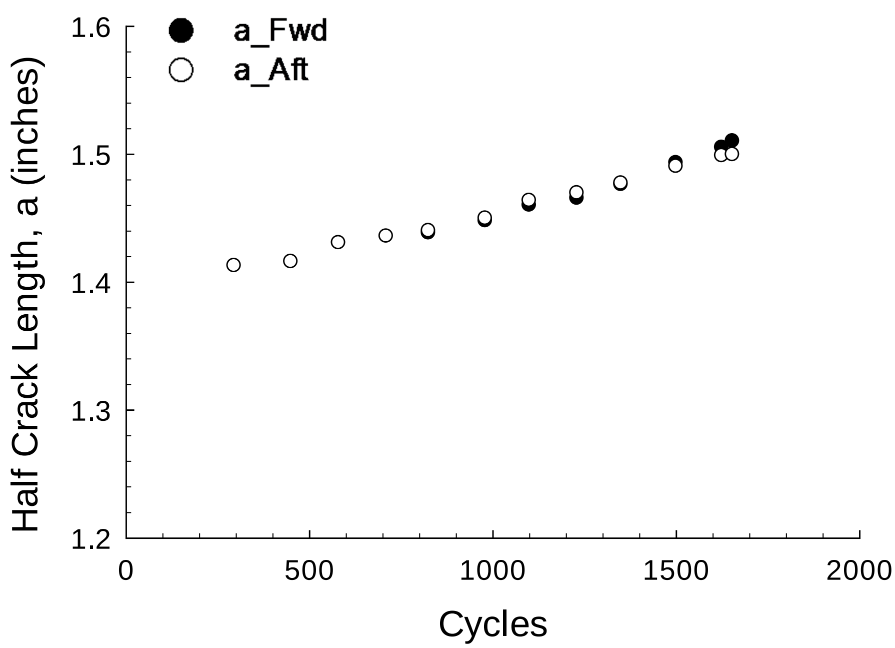


Figure H-16. Half-crack length data during pre-cracking for the C-BE repair

Table H-17. Half-crack length data during fatigue for the C-BE repair (tabular)

CYCLES	VISUAL			INTERNAL HFEC			EXTERNAL LFEC		
	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)
0	1.541	1.541	1.541	1.565	1.565	1.565	1.813	1.406	1.609
100									
200									
300	1.541	1.541	1.541						
400	1.541	1.565	1.553						
500	1.541	1.565	1.553						
600	1.565	1.565	1.565						
700	1.565	1.565	1.565						
800	1.565	1.565	1.565						
900	1.565	1.588	1.576						
1000	1.588	1.588	1.588						
1100	1.588	1.588	1.588						
1200	1.588	1.588	1.588						
1300	1.588	1.588	1.588						
1400	1.588	1.588	1.588						
1500	1.612	1.588	1.600						
1600	1.612	1.612	1.612						
1700	1.612	1.612	1.612						
1800	1.612	1.612	1.612						
1900	1.612	1.635	1.623						
2000	1.612	1.635	1.623						
2100	1.612	1.635	1.623						
2200	1.612	1.635	1.623						
2300	1.612	1.635	1.623						
2400	1.612	1.635	1.623						
2500	1.635	1.659	1.647						
2600	1.635	1.659	1.647						
2700	1.635	1.659	1.647						
2800	1.635	1.659	1.647						
2900	1.635	1.682	1.659						
3000	1.682	1.682	1.682						
3100	1.682	1.682	1.682						
3200	1.682	1.682	1.682						
3300	1.682	1.682	1.682						
3400	1.706	1.694	1.700						
3500	1.706	1.694	1.700						
3600	1.706	1.694	1.700						
3700	1.706	1.694	1.700						
3800	1.706	1.694	1.700						
3900	1.729	1.706	1.717						
4000	1.729	1.706	1.717						
4100	1.729	1.706	1.717						
4200	1.729	1.706	1.717						
4300	1.729	1.729	1.729						
4400	1.753	1.729	1.741						
4500	1.753	1.729	1.741						
4600	1.753	1.753	1.753						
4700	1.753	1.753	1.753						
4800	1.753	1.753	1.753						
4900	1.753	1.753	1.753						
5000	1.753	1.753	1.753	1.776	1.800	1.788	2.031	1.688	1.859

Table H-17. Half-crack length data during fatigue for the C-BE repair (tabular) (continued)

CYCLES	VISUAL			INTERNAL EDDY CURRENT			EXTERNAL EDDY CURRENT		
	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)
5100	1.776	1.776	1.776						
5200	1.776	1.776	1.776						
5300	1.800	1.776	1.788						
5400	1.800	1.776	1.788						
5500	1.800	1.776	1.788						
5600	1.800	1.776	1.788						
5700	1.800	1.800	1.800						
5800	1.800	1.823	1.811						
5900	1.800	1.823	1.811						
6000	1.823	1.823	1.823						
6100	1.823	1.823	1.823						
6200	1.847	1.823	1.835						
6300	1.847	1.823	1.835						
6400	1.847	1.847	1.847						
6500	1.870	1.847	1.858						
6600	1.870	1.847	1.858						
6700	1.870	1.847	1.858						
6800	1.870	1.847	1.858						
6900	1.870	1.847	1.858						
7000	1.870	1.870	1.870						
7100	1.870	1.870	1.870						
7200	1.870	1.870	1.870						
7300	1.894	1.894	1.894						
7400	1.894	1.894	1.894						
7500	1.894	1.894	1.894						
7600	1.917	1.917	1.917						
7700	1.917	1.917	1.917						
7800	1.917	1.917	1.917						
7900	1.917	1.917	1.917						
8000	1.964	1.917	1.941						
8100	1.964	1.917	1.941						
8200	1.964	1.917	1.941						
8300	1.964	1.941	1.952						
8400	1.964	1.941	1.952						
8500	1.964	1.964	1.964						
8600	1.964	1.964	1.964						
8700	1.964	1.988	1.976						
8800	1.988	1.988	1.988						
8900	2.011	1.988	1.999						
9000	2.011	1.988	1.999						
9100	2.011	1.988	1.999						
9200	2.035	2.011	2.023						
9300	2.035	2.011	2.023						
9400	2.035	2.011	2.023						
9500	2.058	2.011	2.035						
9600	2.058	2.035	2.046						
9700	2.058	2.035	2.046						
9800	2.058	2.035	2.046						
9900	2.058	2.035	2.046						
10000	2.058	2.035	2.046	2.105	2.058	2.082	2.438	2.063	2.250

Table H-17. Half-crack length data during fatigue for the C-BE repair (tabular) (continued)

CYCLES	VISUAL			INTERNAL EDDY CURRENT			EXTERNAL EDDY CURRENT		
	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)
10100	2.105	2.082	2.093						
10200	2.105	2.105	2.105						
10300	2.152	2.105	2.129						
10400	2.152	2.105	2.129						
10500	2.152	2.105	2.129						
10600	2.152	2.129	2.140						
10700	2.152	2.129	2.140						
10800	2.176	2.152	2.164						
10900	2.176	2.152	2.164						
11000	2.176	2.152	2.164						
11100	2.176	2.152	2.164						
11200	2.199	2.152	2.176						
11300	2.199	2.152	2.176						
11400	2.199	2.152	2.176						
11500	2.199	2.199	2.199						
11600	2.223	2.199	2.211						
11700	2.223	2.199	2.211						
11800	2.223	2.199	2.211						
11900	2.246	2.199	2.223						
12000	2.246	2.223	2.234						
12100	2.246	2.223	2.234						
12200	2.246	2.223	2.234						
12300	2.293	2.246	2.270						
12400	2.293	2.246	2.270						
12500	2.340	2.246	2.293						
12600	2.340	2.293	2.317						
12700	2.340	2.293	2.317						
12800	2.340	2.293	2.317						
12900	2.364	2.293	2.328						
13000	2.364	2.293	2.328						
13100	2.364	2.317	2.340						
13200	2.387	2.340	2.364						
13300	2.387	2.340	2.364						
13400	2.387	2.340	2.364						
13500	2.411	2.340	2.375						
13600	2.411	2.340	2.375						
13700	2.434	2.387	2.411						
13800	2.434	2.387	2.411						
13900	2.434	2.411	2.422						
14000	2.434	2.411	2.422						
14100	2.481	2.434	2.458						
14200	2.481	2.434	2.458						
14300	2.505	2.434	2.469						
14400	2.505	2.458	2.481						
14500	2.505	2.458	2.481						
14600	2.528	2.481	2.505						
14700	2.528	2.481	2.505						
14800	2.552	2.528	2.540						
14900	2.552	2.528	2.540						
15000	2.552	2.528	2.540	2.575	2.528	2.552	2.875	2.625	2.750

Table H-17. Half-crack length data during fatigue for the C-BE repair (tabular) (continued)

CYCLES	VISUAL			INTERNAL EDDY CURRENT			EXTERNAL EDDY CURRENT		
	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	Δa_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)
15100	2.552	2.528	2.540						
15200	2.575	2.552	2.563						
15300	2.575	2.575	2.575						
15400	2.575	2.599	2.587						
15500	2.622	2.622	2.622						
15600	2.622	2.622	2.622						
15700	2.669	2.622	2.646						
15800	2.669	2.622	2.646						
15900	2.669	2.669	2.669						
16000	2.669	2.669	2.669						
16100	2.669	2.669	2.669						
16200	2.693	2.669	2.681						
16300	2.693	2.693	2.693						
16400	2.716	2.693	2.704						
16500	2.716	2.716	2.716						
16600	2.740	2.716	2.728						
16700	2.763	2.716	2.740						
16800	2.763	2.740	2.751						
16900	2.787	2.740	2.763						
17000	2.787	2.763	2.775						
17100	2.810	2.763	2.787						
17200	2.810	2.787	2.798						
17300	2.834	2.787	2.810						
17400	2.857	2.810	2.834						
17500	2.834	2.810	2.822						
17600	2.834	2.834	2.834						
17700	2.881	2.834	2.857						
17800	2.904	2.857	2.881						
17900	2.904	2.857	2.881						
18000	2.904	2.881	2.892						
18100	2.951	2.904	2.928						
18200	2.975	2.904	2.939						
18300	2.975	2.904	2.939						
18400	2.998	2.928	2.963						
18500	2.998	2.928	2.963						
18600	3.045	2.951	2.998						
18700	3.045	2.998	3.022						
18800	3.069	2.998	3.033						
18900	3.092	2.998	3.045						
19000	3.092	3.022	3.057						
19100	3.116	3.045	3.080						
19200	3.139	3.069	3.104						
19300	3.139	3.069	3.104						
19400	3.163	3.092	3.127						
19500	3.163	3.092	3.127						
19600	3.163	3.139	3.151						
19700	3.163	3.139	3.151						
19800	3.186	3.163	3.174						
19900	3.186	3.186	3.186						
20000	3.186	3.186	3.186	3.280	3.139	3.210	3.563	3.313	3.438

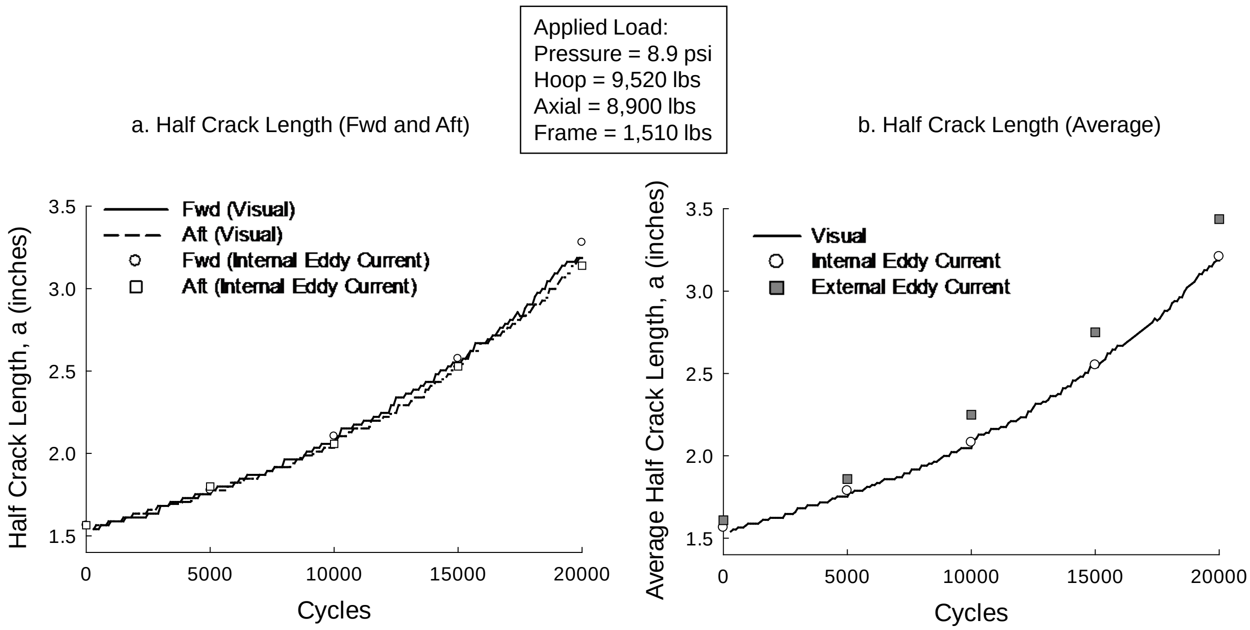


Figure H-17. The C-BE repair crack growth data during fatigue (20,000 cycles): (a) fwd and aft half-crack length and (b) average half-crack length

Table H-18. Half-crack length data during pre-cracking for the CD-BE repair (tabular)

CYCLES	VISUAL	
	a_{AFT} (inches)	a_{FWD} (inches)
530	1.414	
630	1.425	
810		1.415
980		1.434
1025	1.432	1.437
1080	1.439	1.441
1250	1.447	1.441
1350	1.451	1.447
1450	1.457	1.456
1650	1.462	1.465

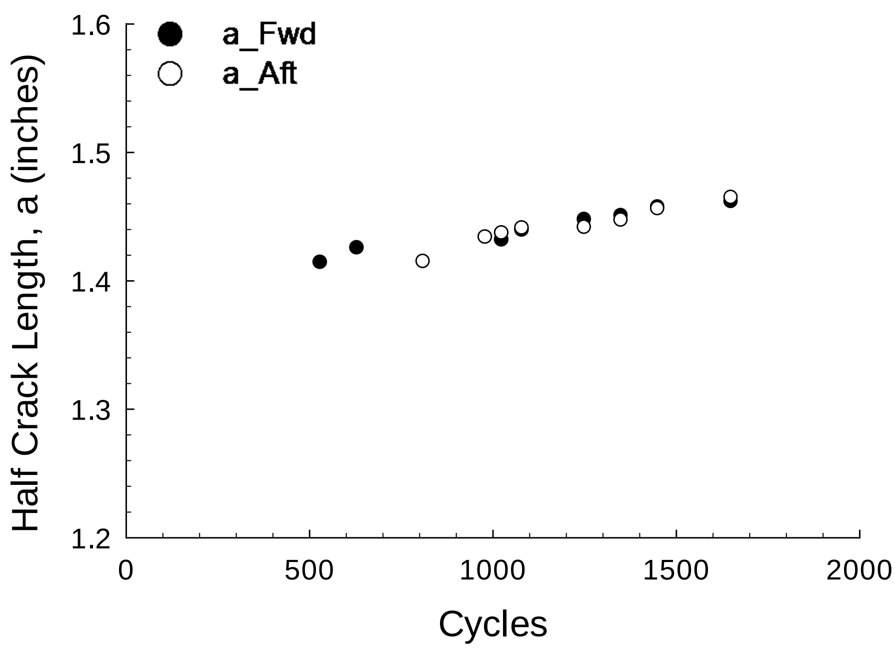


Figure H-18. Half crack length data during pre-cracking for the CD-BE repair

Table H-19. Half-crack length data during fatigue for the CD-BE repair (tabular)

CYCLES	VISUAL			INTERNAL HFEC			EXTERNAL LFEC		
	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)
0	1.494	1.518	1.506	1.494	1.494	1.494	1.563	1.688	1.625
100									
200									
300	1.494	1.518	1.506						
400	1.518	1.541	1.529						
500	1.518	1.541	1.529						
600	1.541	1.541	1.541						
700	1.541	1.541	1.541						
800	1.541	1.541	1.541						
900	1.541	1.565	1.553						
1000	1.541	1.565	1.553						
1100	1.541	1.565	1.553						
1200	1.541	1.565	1.553						
1300	1.541	1.565	1.553						
1400	1.541	1.565	1.553						
1500	1.565	1.565	1.565						
1600	1.565	1.565	1.565						
1700	1.565	1.565	1.565						
1800	1.565	1.588	1.576						
1900	1.588	1.588	1.588						
2000	1.588	1.588	1.588						
2100	1.588	1.588	1.588						
2200	1.588	1.588	1.588						
2300	1.588	1.588	1.588						
2400	1.588	1.588	1.588						
2500	1.588	1.588	1.588						
2600	1.588	1.588	1.588						
2700	1.588	1.612	1.600						
2800	1.588	1.612	1.600						
2900	1.588	1.612	1.600						
3000									
3100									
3200	1.635	1.635	1.635						
3300	1.635	1.635	1.635						
3400	1.635	1.635	1.635						
3500	1.635	1.635	1.635						
3600	1.635	1.635	1.635						
3700	1.635	1.635	1.635						
3800	1.647	1.635	1.641						
3900	1.647	1.635	1.641						
4000	1.647	1.635	1.641						
4100	1.659	1.635	1.647						
4200	1.682	1.635	1.659						
4300	1.682	1.635	1.659						
4400	1.682	1.635	1.659						
4500	1.682	1.659	1.670						
4600	1.682	1.682	1.682						
4700	1.682	1.682	1.682						
4800	1.682	1.682	1.682						
4900	1.682	1.682	1.682						
5000	1.682	1.682	1.682	1.729	1.729	1.729	1.781	1.875	1.828

Table H-19. Half-crack length data during fatigue for the CD-BE repair (tabular) (continued)

CYCLES	VISUAL			INTERNAL EDDY CURRENT			EXTERNAL EDDY CURRENT		
	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)
5100									
5200	1.706	1.682	1.694						
5300									
5400	1.706	1.682	1.694						
5500									
5600	1.706	1.682	1.694						
5700									
5800	1.706	1.682	1.694						
5900									
6000	1.706	1.729	1.717						
6100									
6200	1.753	1.729	1.741						
6300									
6400	1.753	1.729	1.741						
6500	1.753	1.729	1.741						
6600									
6700									
6800	1.753	1.753	1.753						
6900									
7000	1.753	1.776	1.764						
7100									
7200	1.753	1.776	1.764						
7300									
7400	1.753	1.776	1.764						
7500	1.753	1.776	1.764						
7600	1.753	1.776	1.764						
7700									
7800	1.776	1.800	1.788						
7900									
8000	1.800	1.800	1.800						
8100									
8200	1.800	1.800	1.800						
8300									
8400	1.800	1.800	1.800						
8500	1.823	1.800	1.811						
8600									
8700									
8800	1.847	1.823	1.835						
8900									
9000	1.870	1.823	1.847						
9100									
9200	1.870	1.823	1.847						
9300									
9400	1.870	1.823	1.847						
9500	1.870	1.823	1.847						
9600	1.870	1.870	1.870						
9700									
9800	1.870	1.870	1.870						
9900									
10000	1.870	1.894	1.882	1.917	1.894	1.905	2.094	2.000	2.047

Table H-19. Half-crack length data during fatigue for the CD-BE repair (tabular) (continued)

CYCLES	VISUAL			INTERNAL EDDY CURRENT			EXTERNAL EDDY CURRENT		
	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)
10100	1.917	1.917	1.917						
10200	1.917	1.917	1.917						
10300	1.917	1.917	1.917						
10400	1.917	1.917	1.917						
10500	1.917	1.917	1.917						
10600	1.917	1.917	1.917						
10700	1.917	1.917	1.917						
10800	1.917	1.917	1.917						
10900									
11000	1.941	1.917	1.929						
11100									
11200	1.941	1.917	1.929						
11300									
11400	1.964	1.917	1.941						
11500	1.964	1.917	1.941						
11600	1.964	1.941	1.952						
11700									
11800	1.964	1.941	1.952						
11900									
12000	1.988	1.964	1.976						
12100									
12200	1.988	1.964	1.976						
12300									
12400	2.011	1.964	1.988						
12500	2.011	1.964	1.988						
12600	2.035	1.988	2.011						
12700									
12800	2.035	2.011	2.023						
12900									
13000	2.035	2.011	2.023						
13100									
13200									
13300									
13400	2.082	2.011	2.046						
13500	2.082	2.035	2.058						
13600	2.082	2.035	2.058						
13700									
13800	2.105	2.058	2.082						
13900									
14000	2.105	2.058	2.082						
14100									
14200	2.129	2.058	2.093						
14300									
14400	2.129	2.058	2.093						
14500	2.129	2.082	2.105						
14600	2.152	2.105	2.129						
14700									
14800	2.152	2.105	2.129						
14900									
15000	2.152	2.105	2.129	2.199	2.105	2.152	2.219	2.250	2.234

Table H-19. Half-crack length data during fatigue for the CD-BE repair (tabular) (continued)

CYCLES	VISUAL			INTERNAL EDDY CURRENT			EXTERNAL EDDY CURRENT		
	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	Δa_{AVG} (inches)	a_{AFT} (inches)	a_{FWD} (inches)	a_{AVG} (inches)
15100	2.152	2.152	2.152						
15200	2.176	2.152	2.164						
15300	2.176	2.152	2.164						
15400	2.176	2.152	2.164						
15500	2.199	2.176	2.187						
15600	2.199	2.176	2.187						
15700	2.199	2.199	2.199						
15800	2.223	2.199	2.211						
15900	2.223	2.199	2.211						
16000	2.223	2.199	2.211						
16100	2.246	2.199	2.223						
16200	2.246	2.223	2.234						
16300	2.246	2.223	2.234						
16400	2.246	2.223	2.234						
16500	2.270	2.223	2.246						
16600	2.270	2.246	2.258						
16700	2.293	2.246	2.270						
16800	2.293	2.270	2.281						
16900	2.293	2.270	2.281						
17000	2.293	2.270	2.281						
17100	2.317	2.293	2.305						
17200	2.317	2.293	2.305						
17300	2.317	2.293	2.305						
17400	2.340	2.293	2.317						
17500	2.340	2.293	2.317						
17600	2.340	2.293	2.317						
17700	2.340	2.340	2.340						
17800	2.364	2.340	2.352						
17900	2.364	2.340	2.352						
18000	2.364	2.364	2.364						
18100	2.364	2.364	2.364						
18200	2.387	2.387	2.387						
18300	2.411	2.387	2.399						
18400	2.411	2.387	2.399						
18500	2.411	2.387	2.399						
18600	2.434	2.387	2.411						
18700	2.434	2.411	2.422						
18800	2.434	2.434	2.434						
18900	2.434	2.434	2.434						
19000	2.458	2.434	2.446						
19100	2.481	2.434	2.458						
19200	2.481	2.458	2.469						
19300	2.481	2.458	2.469						
19400	2.481	2.481	2.481						
19500	2.481	2.481	2.481						
19600	2.481	2.481	2.481						
19700	2.528	2.505	2.516						
19800	2.528	2.505	2.516						
19900	2.528	2.505	2.516						
20000	2.528	2.505	2.516	2.528	2.528	2.528	2.625	2.719	2.672

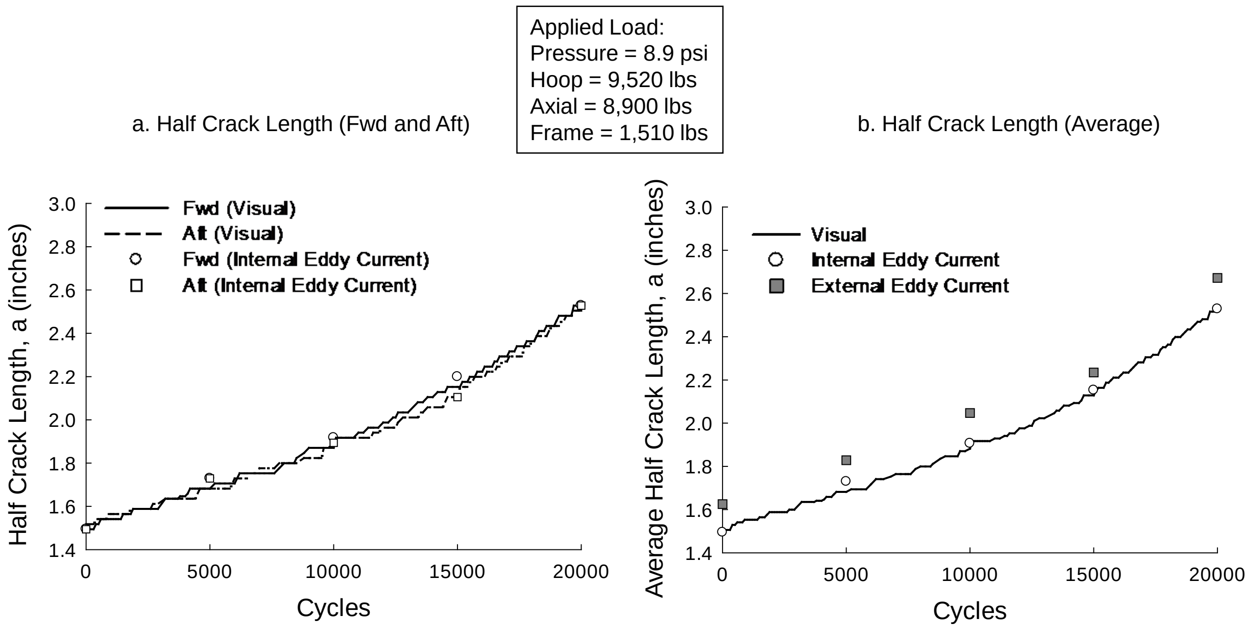
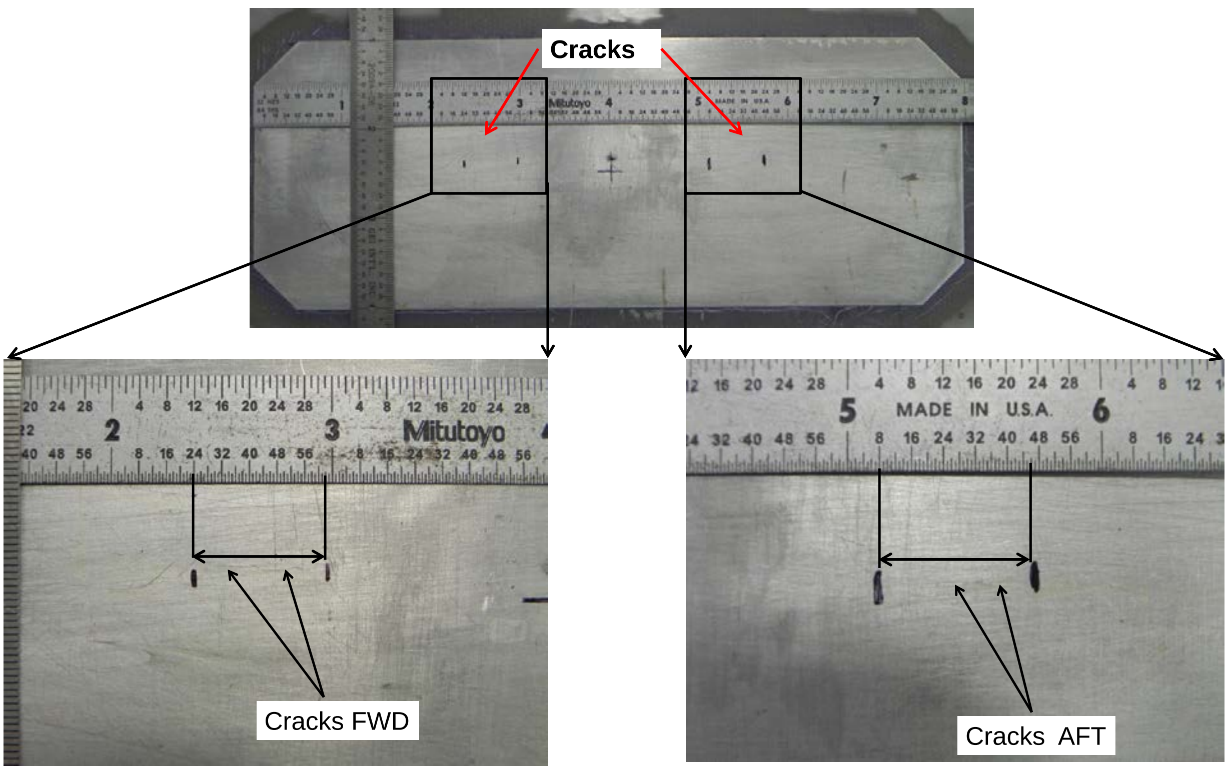


Figure H-19. The CD-BE repair crack growth data during fatigue (20,000 cycles): (a) fwd and aft half-crack length and (b) average half-crack length

APPENDIX I—TEMPORARY REPAIR FOR U-A1 PATCH

For the single-layer aluminum repair, U-A1, crack growth in the skin was slow and stable up to 40,000 fatigue cycles. At this point, two cracks of approximately 0.625″ were observed on the external surface of the single aluminum patch. Figure I-1 shows the location of the two external cracks. At 45,000 cycles, a third crack appeared on the patch. Figures I-2(a) and I-2(b) show the three crack lengths and locations. In this figure, the abscissa shows the length of the patch and the ordinate shows the crack extension. As shown in the figure, the two cracks link up at 50,000 cycles and then they link up with the third crack at 53,600 cycles resulting in a 6.7″-long crack on the patch, illustrated in figure I-2(c). At this stage, crack growth rate of the skin underneath the patch was substantial, highly non-linear, and fast approaching unstable. The test was stopped after 54,250 cycles. To continue fatigue testing to 60,000 cycles, temporary repairs were installed to mitigate further crack extension of the skin. This appendix details the procedure and materials used for these temporary repairs.

a. U-A1 Repair after 40,000 Cycles



b. Fwd Crack

c. Aft Crack

Figure I-1. Cracks developed on the U-A1 patch at 40,000 cycles

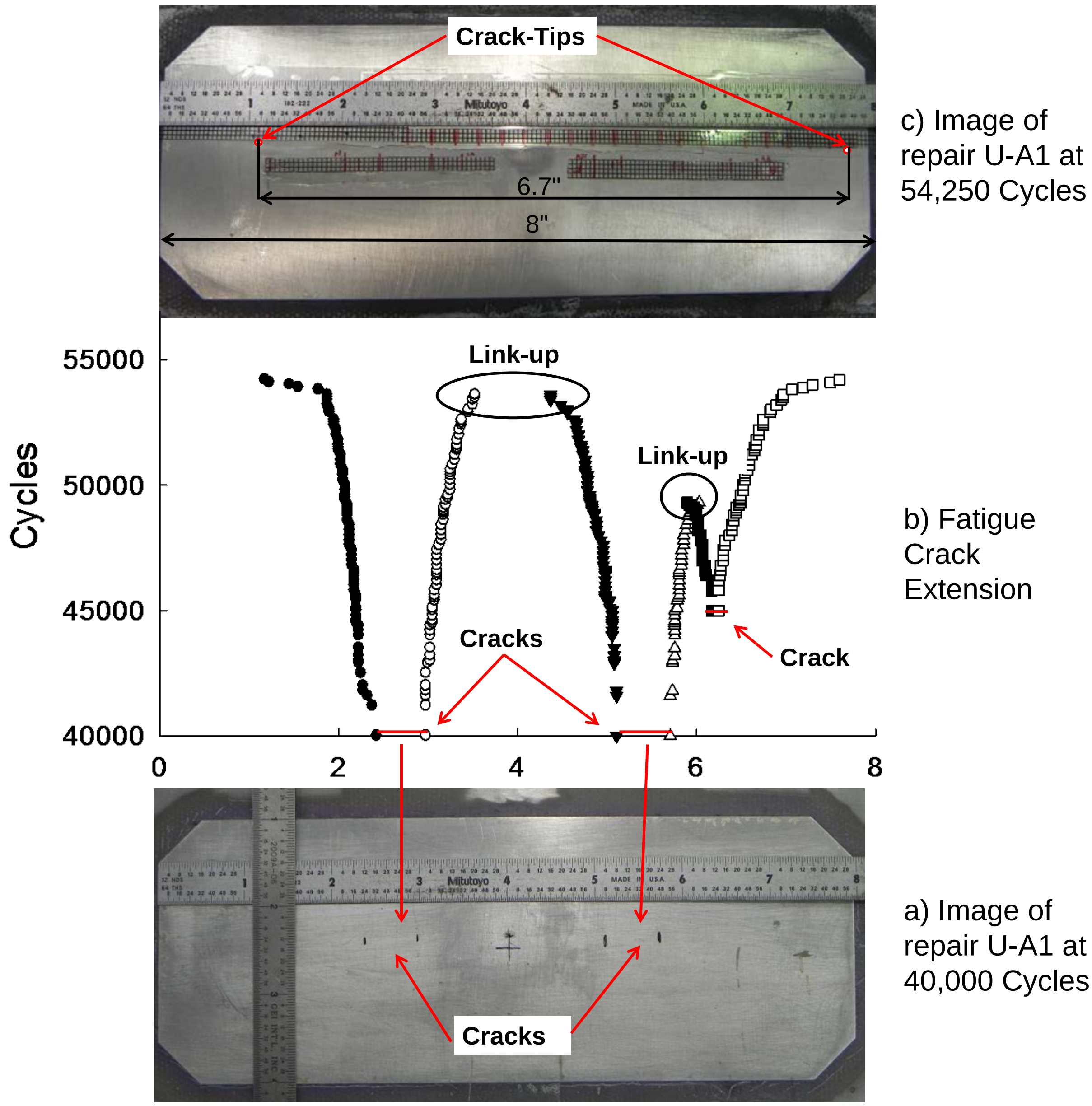


Figure I-2. Link up of external cracks on the U-A1 patch: (a) image of repair U-A1 at 40,000 cycles, (b) fatigue crack extension showing link up of cracks, and (c) image of repair U-A1 at 54,250 cycles showing 6.7″-long crack

Two repairs were used to extend the overall fatigue test by 5750 cycles to a total of 60,000 cycles. The first repair was installed at 54,250 cycles. The repair consisted of a 0.040″-thick 2024-T3 aluminum doubler with the same footprint as the original doubler (figure I-3). It was bonded directly over the original cracked doubler using a 3M™ 2216 B/A gray two-part epoxy adhesive, applying the procedures outlined in the technical data sheets shown in figure I-4.

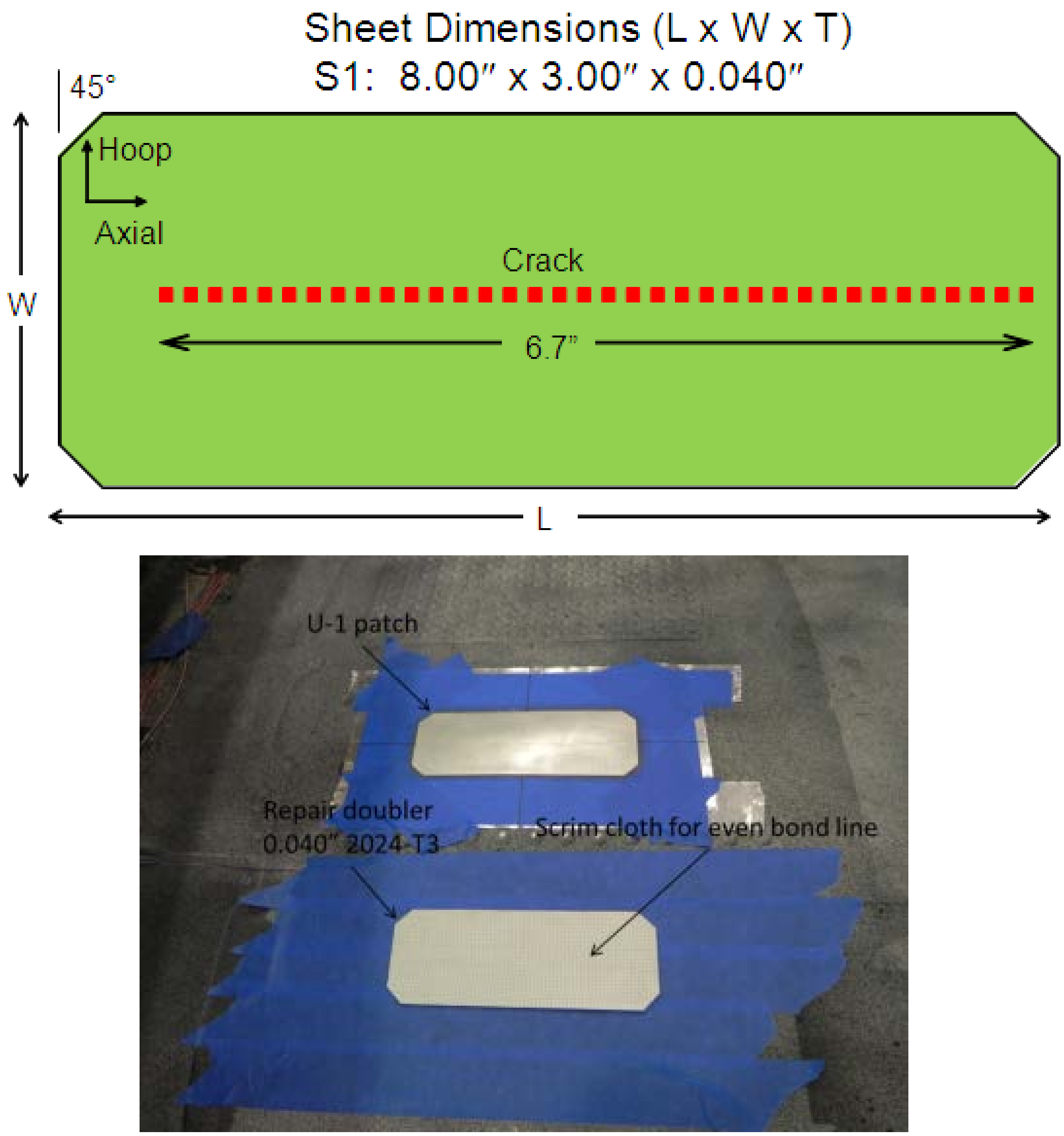


Figure I-3. Repair doubler installed at 54,250 cycles

3M

Scotch-Weld™
Epoxy Adhesive
2216 B/A

Technical Data | **December, 2009**

Product Description

3M™ Scotch-Weld™ Epoxy Adhesive 2216 B/A is a flexible, two-part, room temperature curing epoxy with high peel and shear strength. Scotch-Weld epoxy adhesive 2216 B/A is identical to 3M™ Scotch-Weld™ Epoxy Adhesive EC-2216 B/A in chemical composition. Scotch-Weld epoxy adhesive EC-2216 B/A has been labeled, packaged, tested, and certified for aircraft and aerospace applications. Scotch-Weld epoxy adhesive 2216 B/A may be used for aircraft and aerospace applications if proper Certificates of Test have been issued and material meets all aircraft manufacturer's specification requirements.

Typical Uncured Physical Properties

Note: The following technical information and data should be considered representative or typical only and should not be used for specification purposes.

Product	3M™ Scotch-Weld™ Epoxy Adhesive					
	2216 B/A Gray		2216 B/A Tan NS		2216 B/A Translucent	
	Base	Accelerator	Base	Accelerator	Base	Accelerator
Color:	White	Gray	White	Tan	Translucent	Amber
Base:	Modified Epoxy	Modified Amine	Modified Epoxy	Modified Amine	Modified Epoxy	Modified Amine
Net Wt.: (lb/gal)	11.1-11.6	10.5-11.0	11.1-11.6	10.5-11.0	9.4-9.8	8.0-8.5
Viscosity: (cps) (Approx.) Brookfield RVF #7 sp. @ 20 rpm	75,000 - 150,000	40,000 - 80,000	75,000 - 150,000	550,000 - 900,000	11,000 - 15,000	5,000 - 9,000
Mix Ratio: (by weight)	5 parts	7 parts	5 parts	7 parts	1 part	1 part
Mix Ratio: (by volume)	2 parts	3 parts	2 parts	3 parts	1 part	1 part
Work Life: 100 g Mass @ 75°F (24°C)	90 minutes	90 minutes	120 minutes	120 minutes	120 minutes	120 minutes

Features

- Excellent for bonding many metals, woods, plastics, rubbers, and masonry products.
- Base and Accelerator are contrasting colors.
- Good retention of strength after environmental aging.
- Resistant to extreme shock, vibration, and flexing.
- Excellent for cryogenic bonding applications.
- The tan NS Adhesive is non-sag for greater bondline control.
- The translucent can be injected.
- Meets DOD-A-82720.

Figure I-4. Technical data [9] for 2216 B/A epoxy adhesive (1 of 8)

3M™ Scotch-Weld™
Epoxy Adhesive
2216 B/A

Typical Cured Physical Properties

Product	3M™ Scotch-Weld™ Epoxy Adhesive		
	2216 Gray	2216 Tan NS	2216 Translucent
Color	Gray	Tan	Translucent
Shore D Hardness ASTM D 2240	50-65	65-70	35-50
Time to Handling Strength	8-12 hrs.	8-12 hrs.	12-16 hrs.

Typical Cured Electrical Properties

Product	3M™ Scotch-Weld™ Epoxy Adhesive	
	2216 Gray	2216 Translucent
Arc Resistance	130 seconds	
Dielectric Strength	408 volts/mil	630 volts/mil
Dielectric Constant @ 73°F (23°C)	5.51–Measured @ 1.00 KHz	6.3 @ 1 KHz
Dielectric Constant @ 140°F (60°C)	14.17–Measured @ 1.00 KHz	—
Dissipation Factor 73°F (23°C)	0.112 Measured @ 1.00 KHz	0.119 @ 1 KHz
Dissipation Factor 140°F (60°C)	0.422–Measured @ 1.00 KHz	—
Surface Resistivity @ 73°F (23°C)	5.5 x 10^{16} ohm–@ 500 volts DC	—
Volume Resistivity @ 73°F (23°C)	1.9 x 10^{12} ohm-cm–@ 500 volts DC	3.0 x 10^{12} ohm-cm @ 500 volts DC

Typical Cured Thermal Properties

Product	3M™ Scotch-Weld™ Epoxy Adhesive	
	2216 Gray	2216 Translucent
Thermal Conductivity	0.228 Btu-ft/ft²h°F	0.114 Btu-ft/ft²h°F
Coefficient of Thermal Expansion	102 x 10^{-6} in/in/°C between 0-40°C 134 x 10^{-6} in/in/°C between 40-80°C	81 x 10^{-6} in/in/°C between -50-0°C 207 x 10^{-6} in/in/°C between 60-150°C

Typical Cured Outgassing Properties

Outgassing Data
NASA 1124 Revision 4

	% TML	% CVCM	% Wtr
3M™ Scotch-Weld™ Epoxy Adhesive 2216 Gray	.77	.04	.23

Cured in air for 7 days @ 77°F (25°C).

Handling/Curing Information

Directions for Use

1. For high strength structural bonds, paint, oxide films, oils, dust, mold release agents and all other surface contaminants must be completely removed. However, the amount of surface preparation directly depends on the required bond strength and the environmental aging resistance desired by user. For suggested surface preparations of common substrates, see the following section on surface preparation.
2. These products consist of two parts. Mix thoroughly by weight or volume in the proportions specified on the product label and in the uncured properties section. Mix approximately 15 seconds after a uniform color is obtained.

Figure I-4. Technical data [9] for 2216 B/A epoxy adhesive (continued) (2 of 8)

Handling/Curing Information *(continued)*

3. For maximum bond strength, apply product evenly to both surfaces to be joined.
4. Application to the substrates should be made within 90 minutes. Larger quantities and/or higher temperatures will reduce this working time.
5. Join the adhesive coated surfaces and allow to cure at 60°F (16°C) or above until firm. Heat, up to 200°F (93°C), will speed curing.
6. The following times and temperatures will result in a full cure:

Product	3M™ Scotch-Weld™ Epoxy Adhesive		
	2216 Gray	2216 Tan NS	2216 Translucent
Cure Temperature	Time	Time	Time
75°F (24°C)	7 days	7 days	30 days
150°F (66°C)	120 minutes	120 minutes	240 minutes
200°F (93°C)	30 minutes	30 minutes	60 minutes

7. Keep parts from moving until handling strength is reached. Contact pressure is necessary. Maximum shear strength is obtained with a 3-5 mil bond line. Maximum peel strength is obtained with a 17-25 mil bond line.
8. Excess uncured adhesive can be cleaned up with ketone type solvents.*

Adhesive Coverage: A 0.005 in. thick bondline will typically yield a coverage of 320 sq. ft/gallon

Application and Equipment Suggestions

These products may be applied by spatula, trowel or flow equipment.

Two-part mixing/proportioning/dispensing equipment is available for intermittent or production line use. These systems are ideal because of their variable shot size and flow rate characteristics and are adaptable to many applications.

Surface Preparation

For high strength structural bonds, paint, oxide films, oils, dust, mold release agents and all other surface contaminants must be completely removed. However, the amount of surface preparation directly depends on the required bond strength and the environmental aging resistance desired by user.

The following cleaning methods are suggested for common surfaces.

Steel or Aluminum (Mechanical Abrasion)

1. Wipe free of dust with oil-free solvent such as acetone or alcohol solvents.*
2. Sandblast or abrade using clean fine grit abrasives (180 grit or finer).
3. Wipe again with solvents to remove loose particles.
4. If a primer is used, it should be applied within 4 hours after surface preparation.

*When using solvents, extinguish all ignition sources, including pilot lights, and follow the manufacturer's precautions and directions for use. Use solvents in accordance with local regulations.

Figure I-4. Technical data [9] for 2216 B/A epoxy adhesive (continued) (3 of 8)

3M™ Scotch-Weld™
Epoxy Adhesive
2216 B/A

Surface Preparation ***(continued)***

Aluminum (Chemical Etch)

Aluminum alloys may be chemically cleaned and etched as per ASTM D 2651. This procedure states to:

1. Alkaline Degrease – Oakite 164 solution (9-11 oz/gal of water) at 190°F ± 10°F (88°C ± 5°C) for 10-20 minutes. Rinse immediately in large quantities of cold running water.
2. **Optimized FPL Etch Solution (1 liter):**

Material	**Amount**
Distilled Water	700 ml plus balance of liter (see below)
Sodium Dichromate	28 to 67.3 grams
Sulfuric Acid	287.9 to 310.0 grams
Aluminum Chips	1.5 grams/liter of mixed solution

   To prepare 1 liter of this solution, dissolve sodium dichromate in 700 ml of distilled water. Add sulfuric acid and mix well. Add additional distilled water to fill to 1 liter. Heat mixed solution to 66 to 71°C (150 to 160°F). Dissolve 1.5 grams of 2024 bare aluminum chips per liter of mixed solution. Gentle agitation will help aluminum dissolve in about 24 hours.

   To etch aluminum panels, place them in FPL etch solution heated to 66 to 71°C (150 to 160°F). Panels should soak for 12 to 15 minutes.

3. Rinse: Rinse panels in clear running tap water.
4. Dry: Air dry 15 minutes; force dry 10 minutes (minimum) at 140°F (60°C) maximum.
5. If primer is to be used, it should be applied within 4 hours after surface preparation.

Plastics/Rubber

1. Wipe with isopropyl alcohol.*
2. Abrade using fine grit abrasives (180 grit or finer).
3. Wipe with isopropyl alcohol.*

Glass

1. Solvent wipe surface using acetone or MEK.*
2. Apply a thin coating (0.0001 in. or less) of 3M™ Scotch-Weld™ Structural Adhesive Primer EC-3901 to the glass surfaces to be bonded and allow the primer to dry a minimum of 30 minutes @ 75°F (24°C) before bonding.

*When using solvents, extinguish all ignition sources, including pilot lights, and follow the manufacturer's precautions and directions for use. Use solvents in accordance with local regulations.

Figure I-4. Technical data [9] for 2216 B/A epoxy adhesive (continued) (4 of 8)

3M™ Scotch-Weld™
Epoxy Adhesive
2216 B/A

Typical Adhesive Performance Characteristics

A. Typical Shear Properties on Etched Aluminum
ASTM D 1002
Cure: 2 hours @ 150 ± 5°F (66°C ± 2°C), 2 psi pressure

Test Temperature	Overlap Shear (psi) 3M™ Scotch-Weld™ Epoxy Adhesive		
	2216 B/A Gray Adhesive	2216 B/A Tan NS Adhesive	2216 B/A Trans. Adhesive
-423°F (-253°C)	2440	—	—
-320°F (-196°C)	2740	—	—
-100°F (-73°C)	3000	—	—
-67°F (-53°C)	3000	2000	3000
75°F (24°C)	3200	2500	1700
180°F (82°C)	400	400	140

Test Temperature	Shear Modulus (Torsion Pendulum Method)
-148°F (-100°C)	398,000 psi (2745 MPa)
-76°F (-60°C)	318,855 psi (2199 MPa)
-40°F (-40°C)	282,315 psi (1947 MPa)
32°F (0°C)	218,805 psi (1500 MPa)
75°F (24°C)	49,580 psi (342 MPa)

B. Typical T-Peel Strength
ASTM D 1876

Test Temperature	T-Peel Strength (piw) @ 75°F (24°C) 3M™ Scotch-Weld™ Epoxy Adhesive		
	2216 B/A Gray Adhesive	2216 B/A Tan NS Adhesive	2216 B/A Trans. Adhesive
75°F (24°C)	25	25	25

Figure I-4. Technical data [9] for 2216 B/A epoxy adhesive (continued) (5 of 8)

Typical Adhesive Performance Characteristics *(continued)*

C. Overlap Shear Strength After Environmental Aging-Etched Aluminum

Environment	Time	Overlap Shear (psi) 75°F (24°C) 3M™ Scotch-Weld™ Epoxy Adhesive 2216 B/A Gray Adhesive	2216 B/A Tan NS Adhesive	2216 B/A Trans. Adhesive
100% Relative Humidity @ 120°F (49°C)	14 days 30 days 90 days	2950 psi 1985 psi 1505 psi	3400 psi 2650 psi	1390 psi
*Salt Spray @ 75°F (24°C)	14 days 30 days 60 days	2300 psi 500 psi 300 psi	3900 psi 3300 psi	1260 psi
Tap Water @ 75°F (24°C)	14 days 30 days 90 days	3120 psi 2942 psi 2075 psi	3250 psi 2700 psi	1950 psi
Air @ 160°F (71°C)	35 days	4650 psi	4425 psi	
Air @ 300°F (149°C)	40 days	4930 psi	4450 psi	3500 psi
Anti-icing Fluid @ 75°F (24°C)	7 days	3300 psi	3050 psi	2500 psi
Hydraulic Oil @ 75°F (24°C)	30 days	2500 psi	3500 psi	2500 psi
JP-4 Fuel	30 days	2500 psi	2750 psi	2500 psi
Hydrocarbon Fluid	7 days	3300 psi	3100 psi	3000 psi

*Substrate corrosion resulted in adhesive failure.

D. Heat Aging of 3M™ Scotch-Weld™ Epoxy Adhesive 2216 B/A Gray (Cured for 7 days @ 75°F [24°C])

Overlap Shear (psi)	Time aged @ 300°F (149°C)			
Test Temperature	0 days	12 days	40 days	51 days
-67°F (-53°C)	2200	3310	3120	2860
75°F (24°C)	3100	5150	4930	4740
180°F (82°C)	500	1000	760	1120
350°F (177°C)	420	440	560	—

Figure I-4. Technical data [9] for 2216 B/A epoxy adhesive (continued) (6 of 8)

Typical Adhesive Performance Characteristics *(continued)*

E. Overlap Shear Strength on Abraded Metals, Plastics, and Rubbers.

Overlap shear strengths were measured on 1" x 1/2" overlap specimens. These bonds were made individually using 1" by 4" pieces of substrate (Tested per ASTM D 1002).

The thickness of the substrates were: cold rolled, galvanized and stainless steel – 0.056-0.062", copper – 0.032", brass – 0.036", rubbers – 0.125", plastics – 0.125". All surfaces were prepared by solvent wiping/abrading/ solvent wiping.

The jaw separation rate used for testing was 0.1 in/min for metals, 2 in/min for plastics, and 20 in/min for rubbers.

	Overlap Shear (psi) @ 75°F (24°C)	
	3M™ Scotch-Weld™ Epoxy Adhesive	
Substrate	2216 B/A Gray Adhesive	2216 B/A Tan NS Adhesive
Aluminum/Aluminum	1850	2350
Cold Rolled Steel/Cold Rolled Steel	1700	3100
Stainless Steel/Stainless Steel	1900	
Galvanized Steel/Galvanized Steel	1800	
Copper/Copper	1050	
Brass/Brass	850	
Styrene Butadiene Rubber/Steel	200*	
Neoprene Rubber/Steel	220*	
ABS/ABS Plastic	990*	1140*
PVC/PVC, Rigid	940*	
Polycarbonate/Polycarbonate	1170*	1730*
Acrylic/Acrylic	1100*	1110*
Fiber Reinforced Polyester/ Reinforced Polyester	1660*	1650*
Polyphenylene Oxide/PPO	610	610
PC/ABS Alloy / PC/ABS Alloy	1290	1290

*The substrate failed during the test.

Storage

Store products at 60-80°F (16-27°C) for maximum storage life.

Shelf Life

When stored at the recommended temperatures in the original, unopened containers, the shelf life is two years from date of shipment from 3M.

Figure I-4. Technical data [9] for 2216 B/A epoxy adhesive (continued) (7 of 8)

3M™ Scotch-Weld™

Epoxy Adhesive

2216 B/A

Precautionary Information	Refer to Product Label and Material Safety Data Sheet for health and safety information before using this product. For additional health and safety information, call 1-800-364-3577 or (651) 737-6501.
Technical Information	The technical information, recommendations and other statements contained in this document are based upon tests or experience that 3M believes are reliable, but the accuracy or completeness of such information is not guaranteed.
Product Use	Many factors beyond 3M's control and uniquely within user's knowledge and control can affect the use and performance of a 3M product in a particular application. Given the variety of factors that can affect the use and performance of a 3M product, user is solely responsible for evaluating the 3M product and determining whether it is fit for a particular purpose and suitable for user's method of application.
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Limitation of Liability	Except where prohibited by law, 3M will not be liable for any loss or damage arising from the 3M product, whether direct, indirect, special, incidental or consequential, regardless of the legal theory asserted, including warranty, contract, negligence or strict liability.

ISO 9001:2000

This Industrial Adhesives and Tapes Division product was manufactured under a 3M quality system registered to ISO 9001:2000 standards.

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Figure I-4. Technical data [9] for 2216 B/A epoxy adhesive (continued) (8 of 8)

Per the instructions detailed in the technical data sheets shown in figure I-4, the following steps were used for surface preparation using mechanical abrasion:

1. Wipe free of dust with acetone
2. Abrade using 180-grit sandpaper abrasive
3. Wipe again with acetone to remove loose particles

The two parts of the gray epoxy—the base and the accelerator—were mixed using the 2- to 3-volume ratio, respectively. A self-adhesive scrim cloth was applied to the new doubler surface to provide a 12 mil thick bondline. The epoxy mixture was applied evenly on both surfaces—the crack doubler and the new repair doubler. A contact pressure of 2.0 psi was applied to keep the surfaces in contact during cure and a temperature of 150°F was applied for at least two hours to accelerate curing (figure I-5).

Figure I-5. Repair doubler curing at 150°F

This repair doubler disbonded after approximately 800 cycles, as shown in figure I-6. This repair doubler was removed and the surface was cleaned. A second repair doubler with the dimensions shown in figure I-2 was adhesively bonded and mechanically fastened. For the adhesive epoxy, the material, surface preparation, application, and procedure used were identical to that of the first repair. In addition, the second repair doubler was mechanically fastened using CR3223-5-04 CherryMAX® rivets. The fastener hole pattern used is shown in figure I-7. The second repair doubler was sufficient to complete the last 4950 cycles needed to reach the test goal for this phase of 60,000 fatigue cycles.

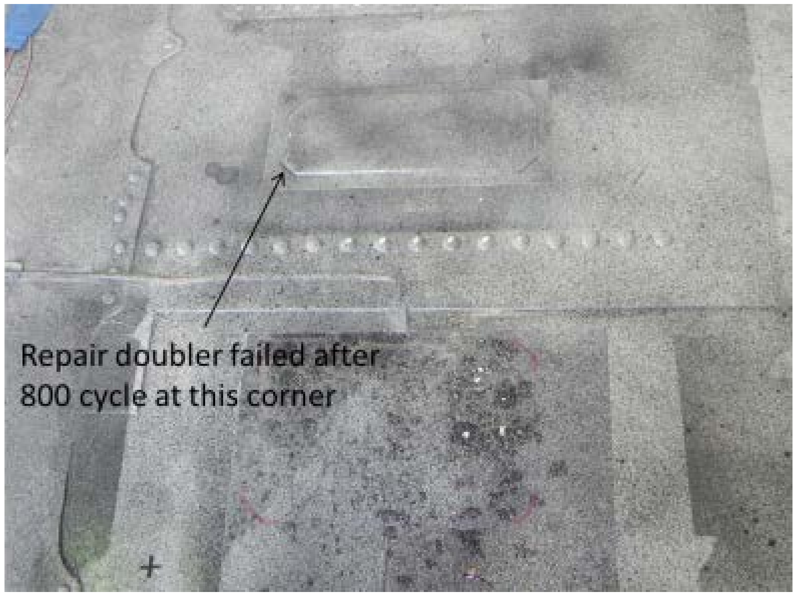

Figure I-6. Repair doubler failed at this corner after 800 cycles

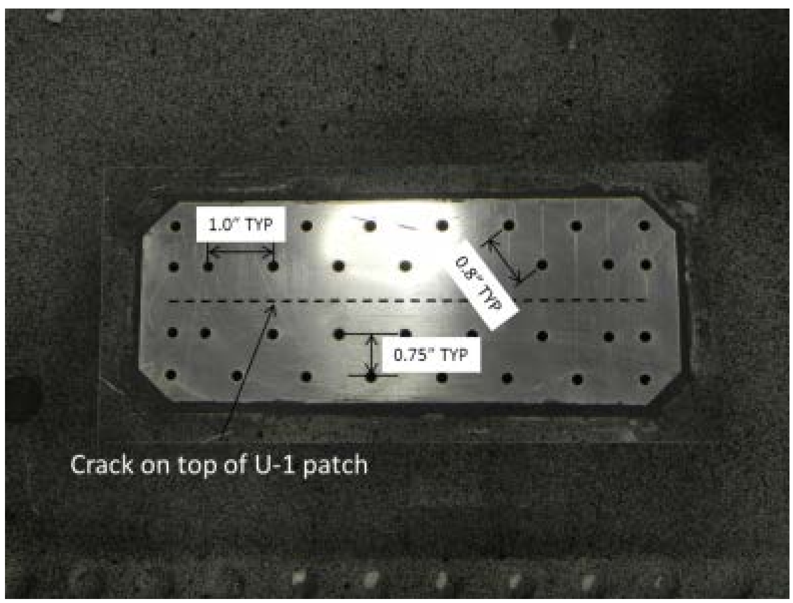

Figure I-7. Fastener hole pattern of second repair doubler

APPENDIX J—INSPECTION RESULTS

Flash thermography and resonance ultrasonic nondestructive evaluation (NDI) (Bondmaster) were used for disbond detection during the test. The thermography results are shown by the images of the second derivative of temperature versus time. The specifications and procedures for using resonance ultrasonic are also documented in this appendix.

J.1 THERMOGRAPHY

The setup used to capture thermography data was as follows:

- Capture Frequency: 59.94 Hz
- Acquisition Length:
  - Case 1: Approximately 19 seconds
  - Case 2: Approximately 5 seconds
- Flash Timing:
  - Frame: 10
  - Offset: 0.2 milliseconds
  - Duration: 2 milliseconds

Thermography results for each of the repair types follow.

J.1.1 REFERENCE REPAIR

Thermography images of the R-BE repair are shown in figures J-1–J-4. For this repair, the images are captured at 0, 20,000, 40,000, and 60,000 fatigue cycles and four different time slices (0.5 seconds, 1.5 seconds, 2.5 seconds, and 4 seconds).

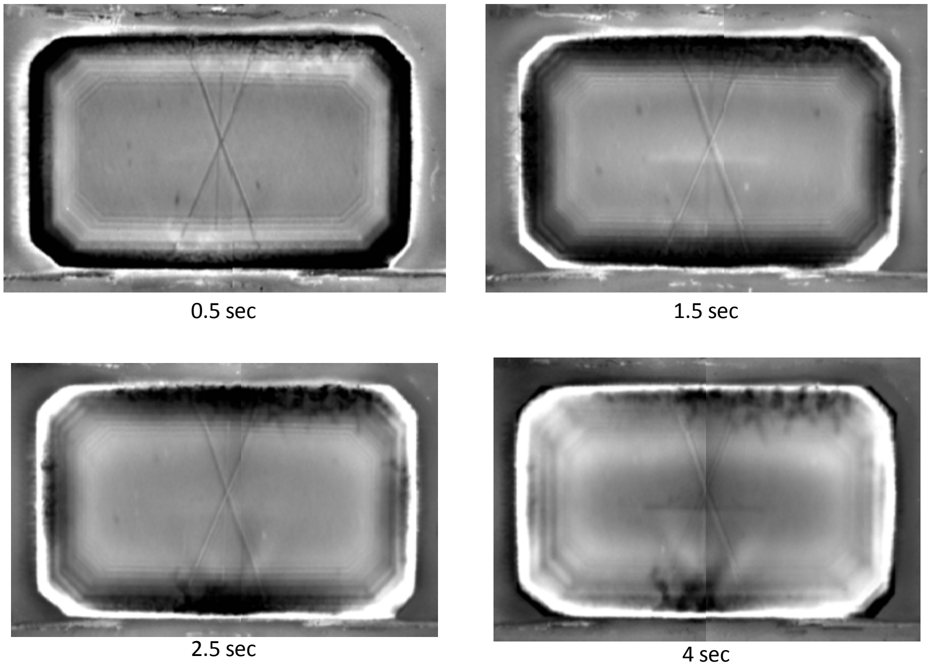

Figure J-1. Images of the 1R repair patch captured using flash thermography at 0 cycles at different time slices

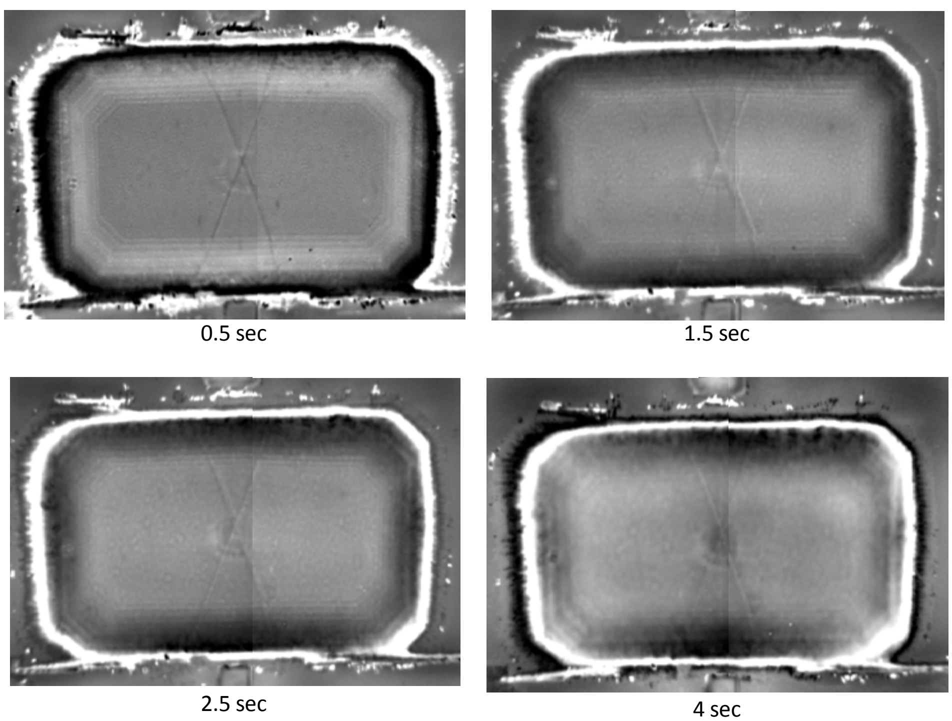

Figure J-2. Images of the 1R repair patch captured using flash thermography at 20,000 cycles at different time slices

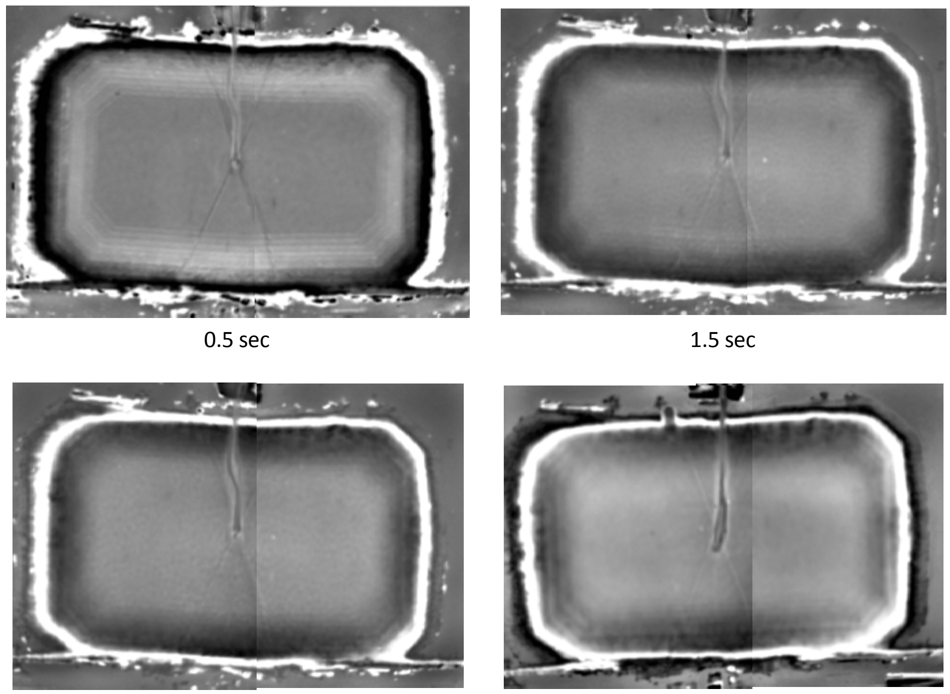

Figure J-3. Images of the 1R repair patch captured using flash thermography at 40,000 cycles at different time slices

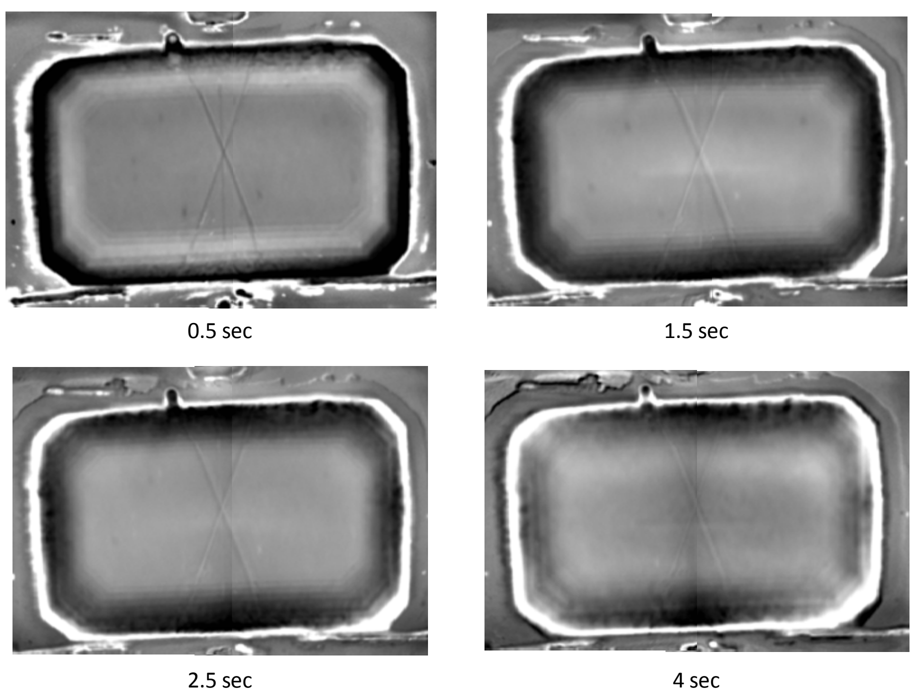

Figure J-4. Images of the 1R repair patch captured using flash thermography at 60,000 cycles at different time slices

J.1.2 TYPE 1: UNDERDESIGNED REPAIRS

Figures J-5–J-8 show the results for the U-BE repair at 0, 20,000, 40,000, and 60,000 fatigue cycles. The images have been captured at four different times (0.5 seconds, 1.5 seconds, 2.5 seconds, and 4 seconds). Figure J-5 shows the crack underneath the repair that is most clearly visible in the image captured at 1.5 seconds. The patch layup is also visible at 1.5 seconds. Overall, none of the images shows any significant disbond between the patch and the panel. Similar trends were seen in the images captured at 20,000, 40,000, and 60,000 cycles.

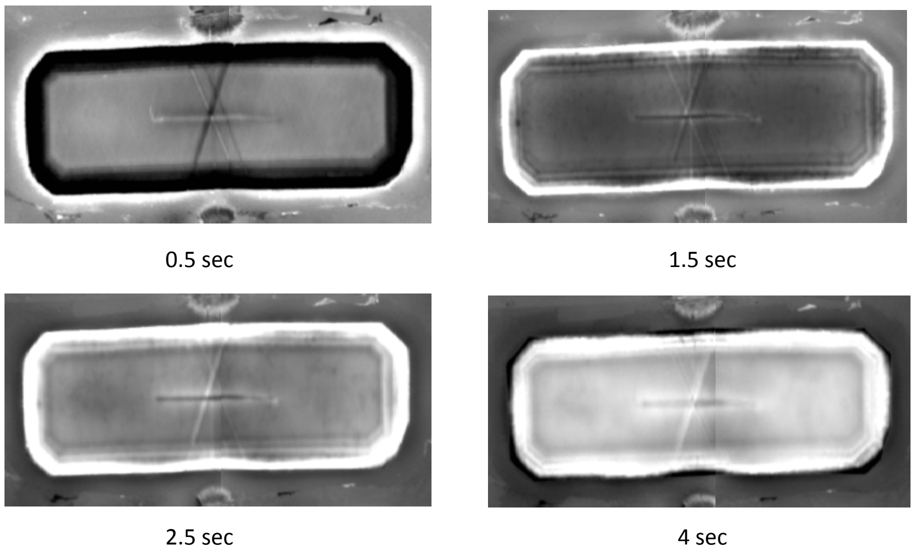

Figure J-5. Images of the U-BE repair patch captured using flash thermography at 0 cycles at different time slices

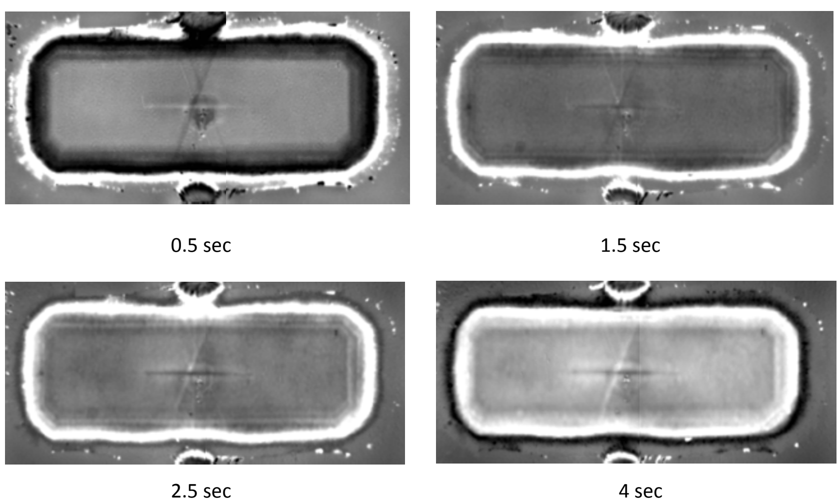

Figure J-6. Images of the U-BE repair patch captured using flash thermography at 20,000 cycles at different time slices

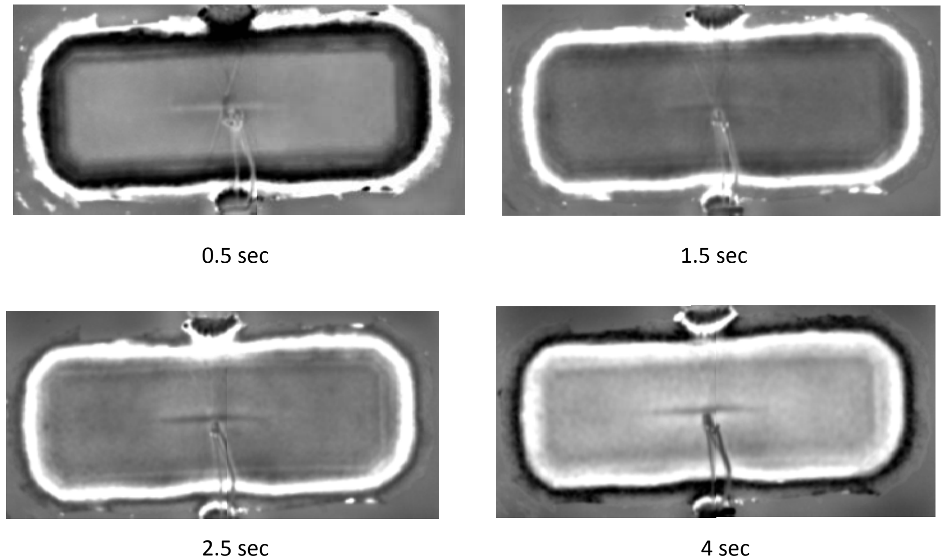

Figure J-7. Images of the U-BE repair patch captured using flash thermography at 40,000 cycles at different time slices

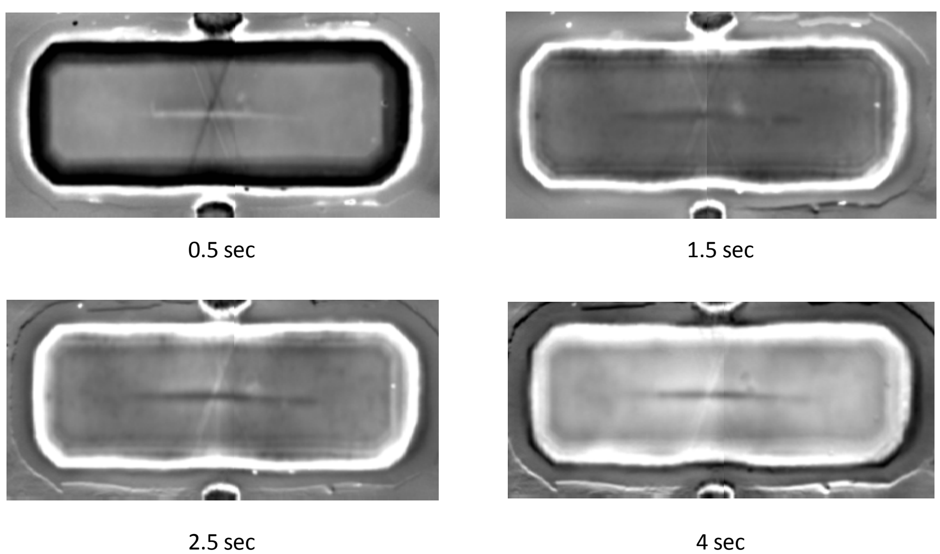

Figure J-8. Images of the U-BE repair patch captured using flash thermography at 60,000 cycles at different time slices

J.1.3 TYPE 2: PARTIAL-DISBOND REPAIRS

Figures J-9–J-12 show the results for the D-BE repair at 0, 20,000, 40,000, and 60,000 fatigue cycles. The images were captured at four different times (0.5 seconds, 1.5 seconds, 2.5 seconds, and 4 seconds). Figure J-9 shows the intentional inserts, which were introduced during patch installation. The edge inserts at three locations are most clearly visible at 1.5 seconds and the Fluorinated Ethylene Propylene (FEP) tabs at the crack tip are very clearly visible at 2.5 seconds.

Similar results are seen in the images captured at 20,000, 40,000, and 60,000 cycles. These results indicated that there was no disbond growth from any of the intentional inserts.

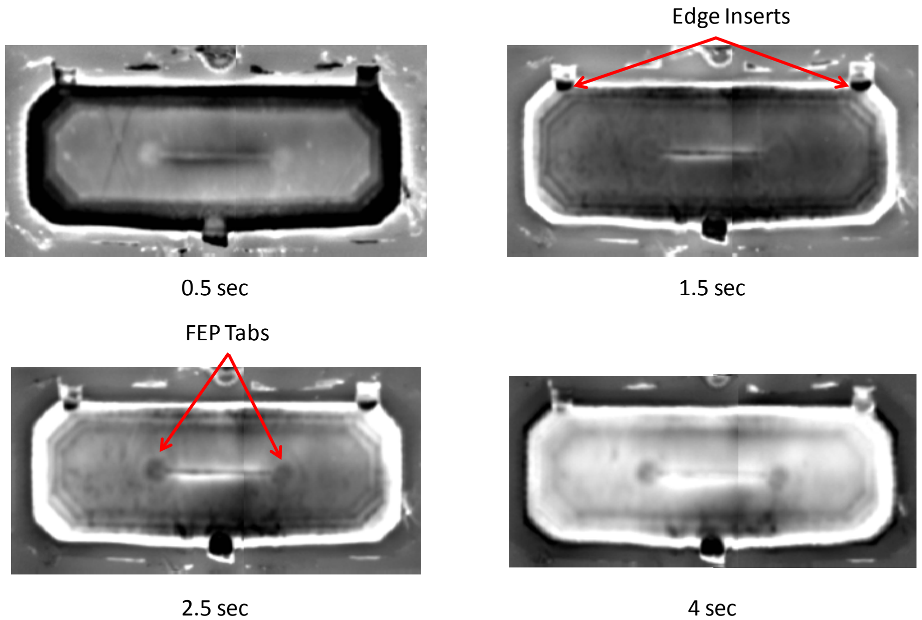

Figure J-9. Images of the D-BE repair patch captured using flash thermography at 0 cycles at different time slices

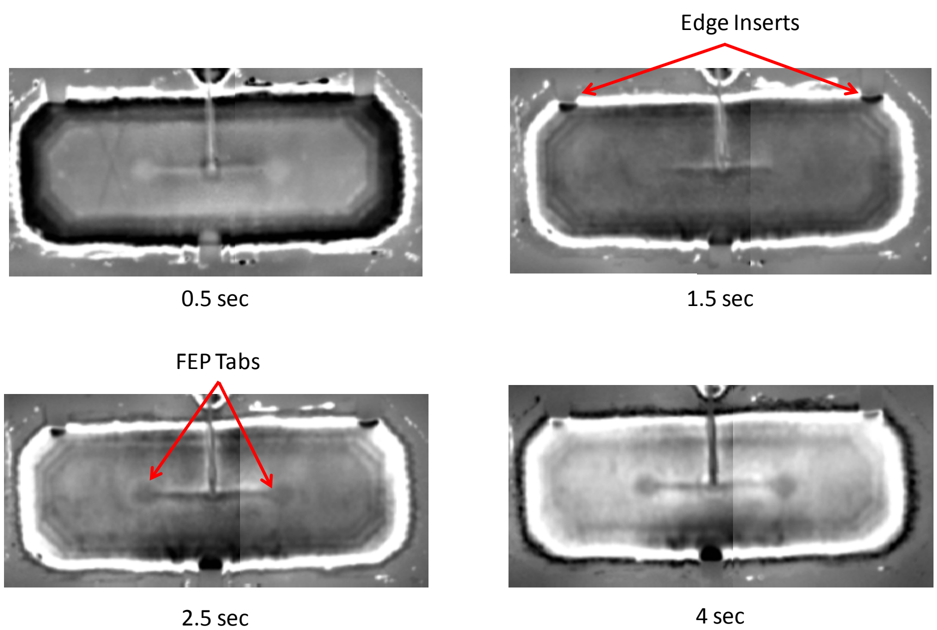

Figure J-10. Images of the D-BE repair patch captured using flash thermography at 20,000 cycles at different time slices

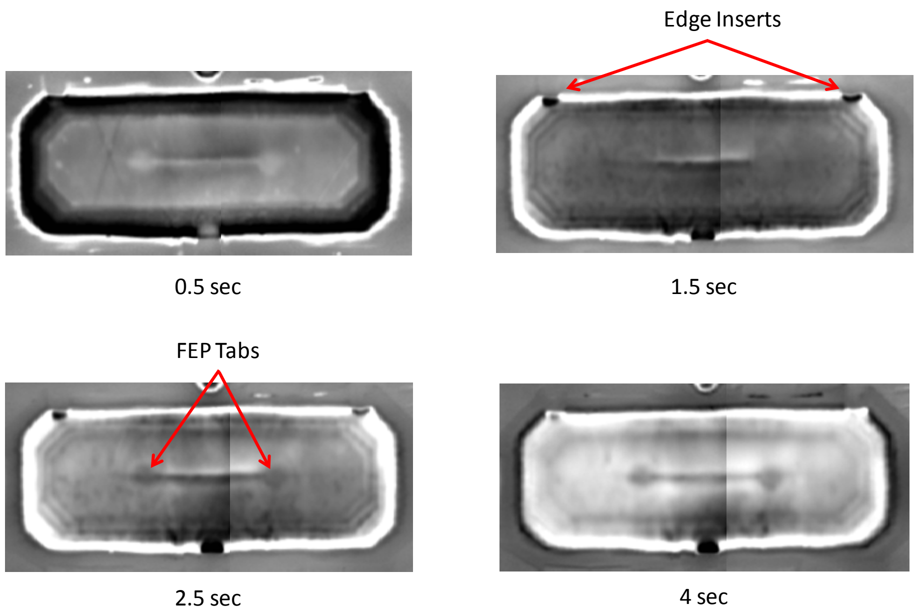

Figure J-11. Images of the D-BE repair patch captured using flash thermography at 40,000 cycles at different time slices

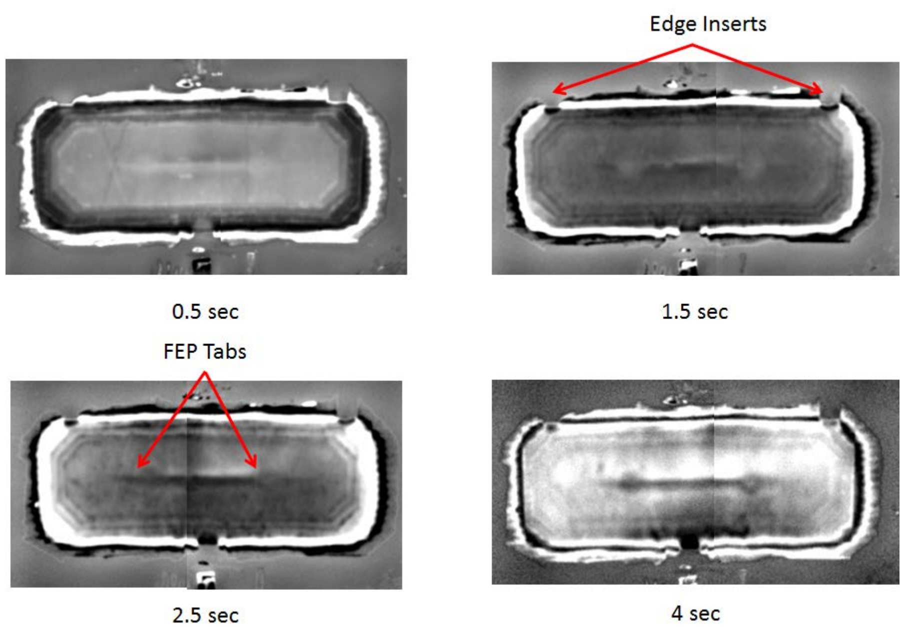

Figure J-12. Images of the D-BE repair patch captured using flash thermography at 60,000 cycles at different time slices

J.1.4 TYPE 3: COMPLIANT REPAIRS

Figures J-13–J-15 show the results for the C-BE repair at 0, 10,000, and 20,000 fatigue cycles. The images have been captured at four different times (0.5 seconds, 1.5 seconds, 2.5 seconds, and 4 seconds). In all the images, there is an indication of a disbond on the aft side crack tip, but no growth was observed from this disbond. Figures J-16–J-18 show the result for the CD-BE repair at 0, 10,000, and 20,000 fatigue cycles. The images were captured at four different times (0.5 seconds, 1.5 seconds, 2.5 seconds, and 4 seconds) and show the intentional inserts, which were introduced during patch installation. The edge inserts at three locations are most clearly visible at 1.5 seconds and the FEP tabs at the crack tip are very clearly visible at 2.5 seconds. These results indicated that there was no disbond growth from any of the intentional inserts.

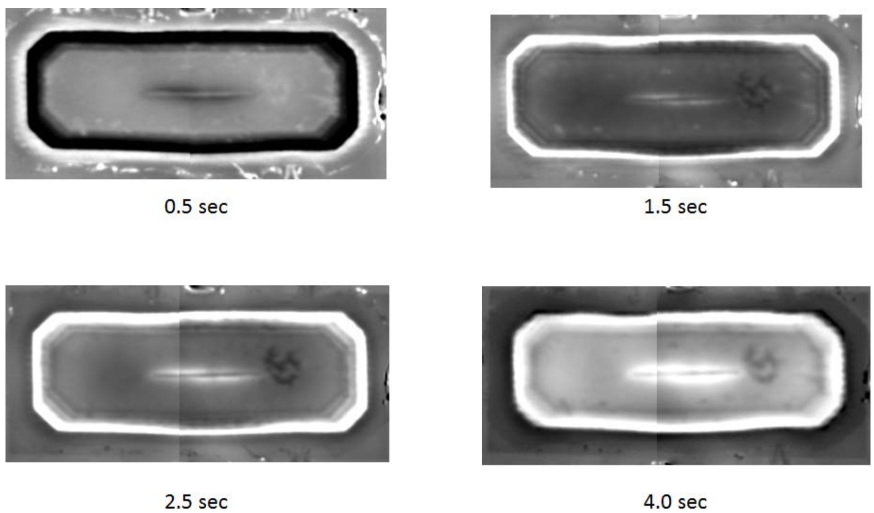

Figure J-13. Images of the C-BE repair patch captured using flash thermography at 0 cycles at different time slices

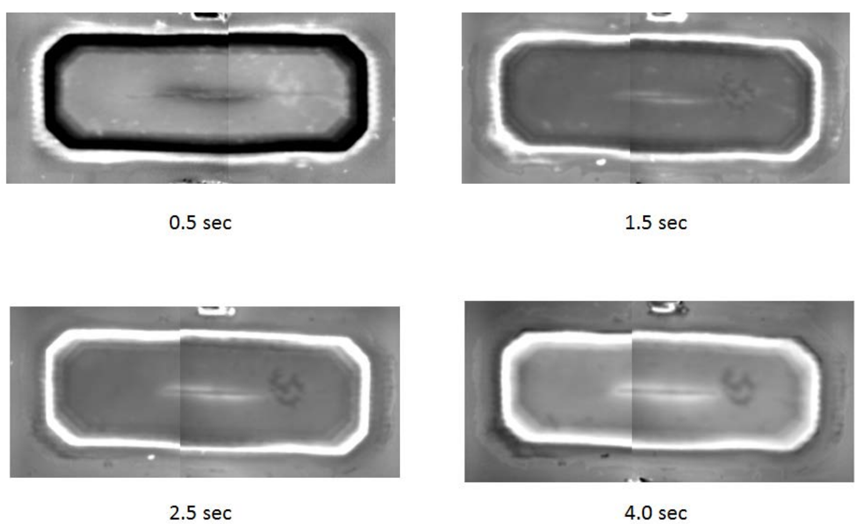

Figure J-14. Images of the C-BE repair patch captured using flash thermography at 10,000 cycles at different time slices

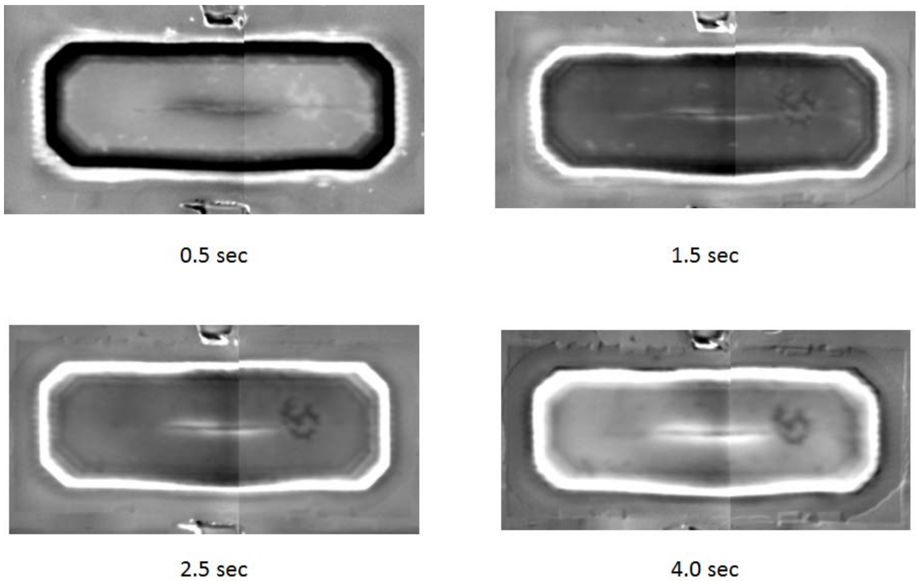

Figure J-15. Images of the C-BE repair patch captured using flash thermography at 20,000 cycles at different time slices

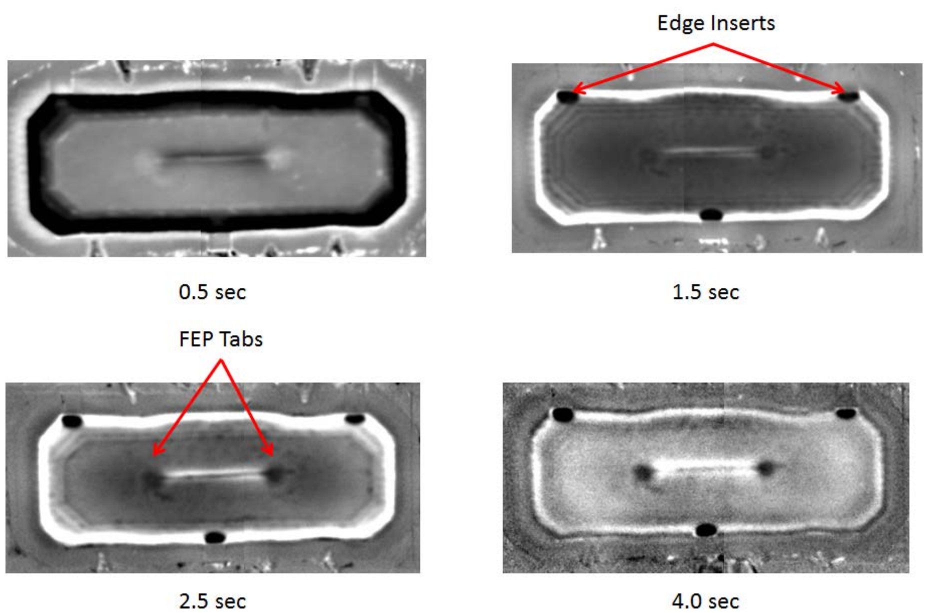

Figure J-16. Images of the CD-BE repair patch captured using flash thermography at 0 cycles at different time slices

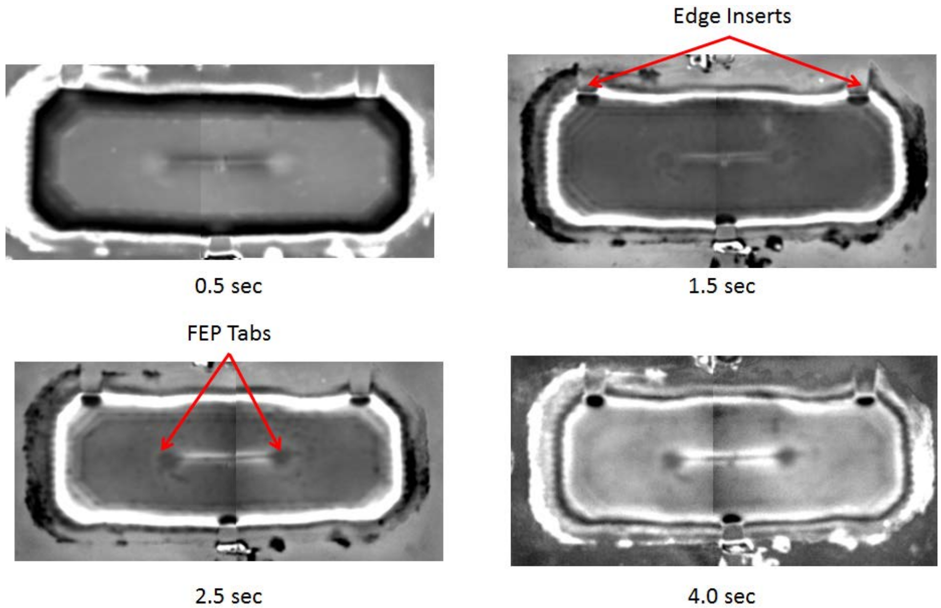

Figure J-17. Images of the CD-BE repair patch captured using flash thermography at 10,000 cycles at different time slices

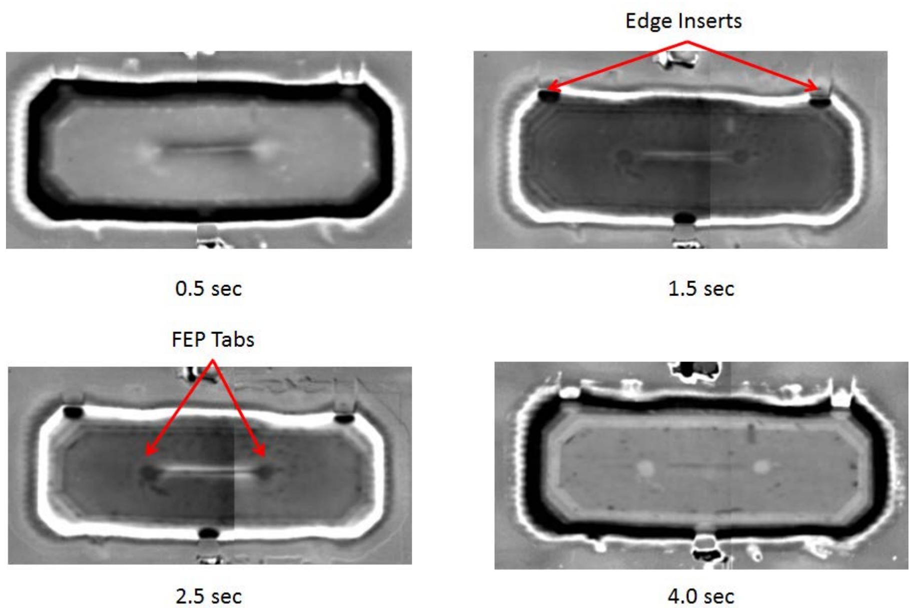

Figure J-18. Images of the CD-BE repair patch captured using flash thermography at 20,000 cycles at different time slices

J.1.5 TYPE 4: REPAIRS WITH IMPACT DAMAGE

Figures J-19–J-22 show the result for the R-BE repair before impact, after impact, and at 10,000 and 20,000 fatigue cycles after impact. Similar to previous phases, the images were captured at four different times (0.5 seconds, 1.5 seconds, 2.5 seconds, and 4 seconds). The thermography images before impact do not show any disband; however, right after impact, thermography shows the disbond along the crack. No disbond growth was observed during fatigue after impact. Similar results were seen for the U-BE repair (figures J-23–J-26).

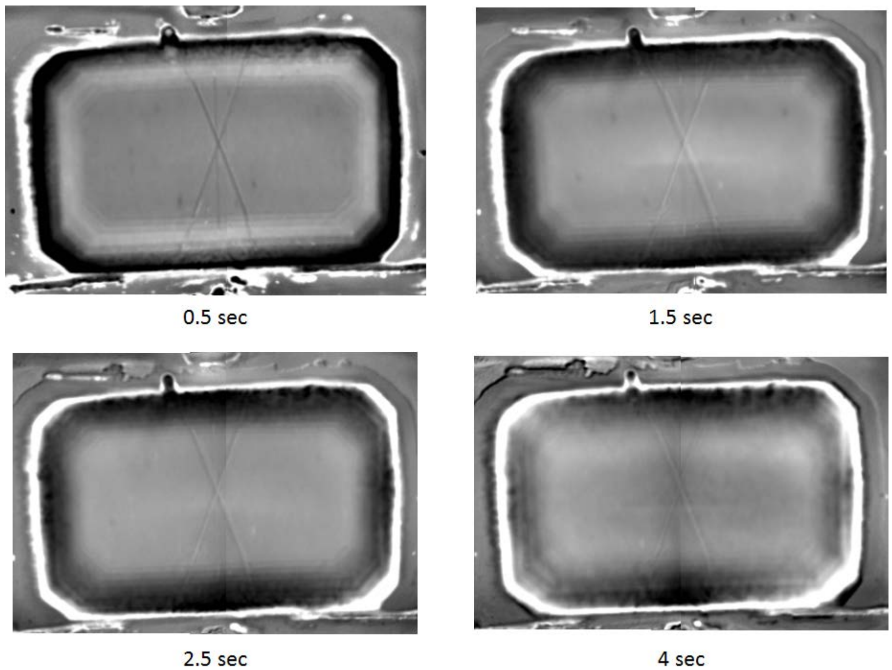

Figure J-19. Images of the R-BE repair patch captured using flash thermography before impact at different time slices

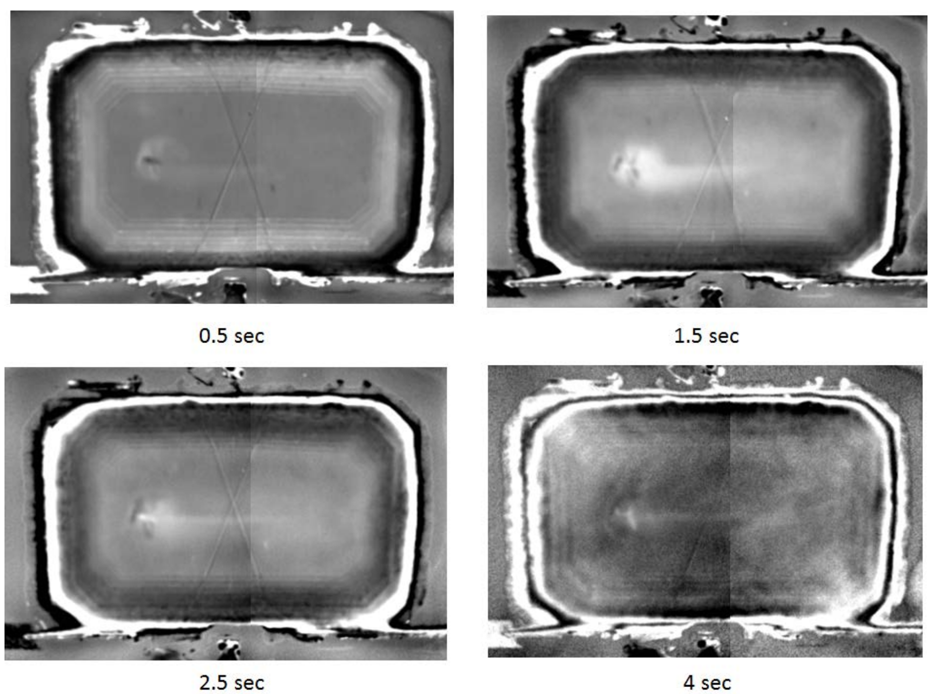

Figure J-20. Images of the R-BE repair patch captured using flash thermography after impact at different time slices

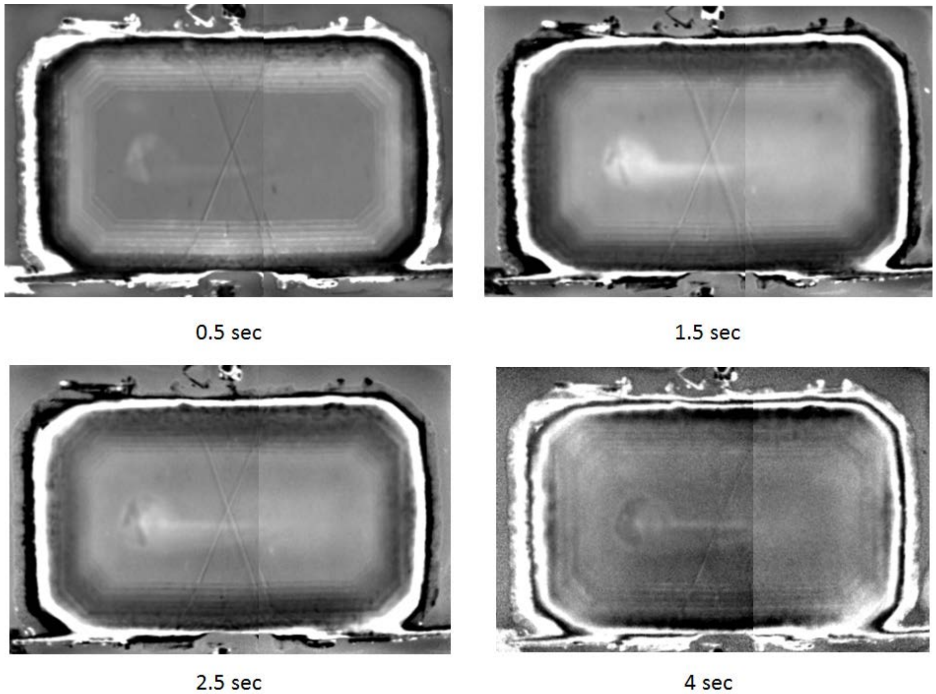

Figure J-21. Images of the R-BE repair patch captured using flash thermography, 10,000 cycles after impact at different time slices

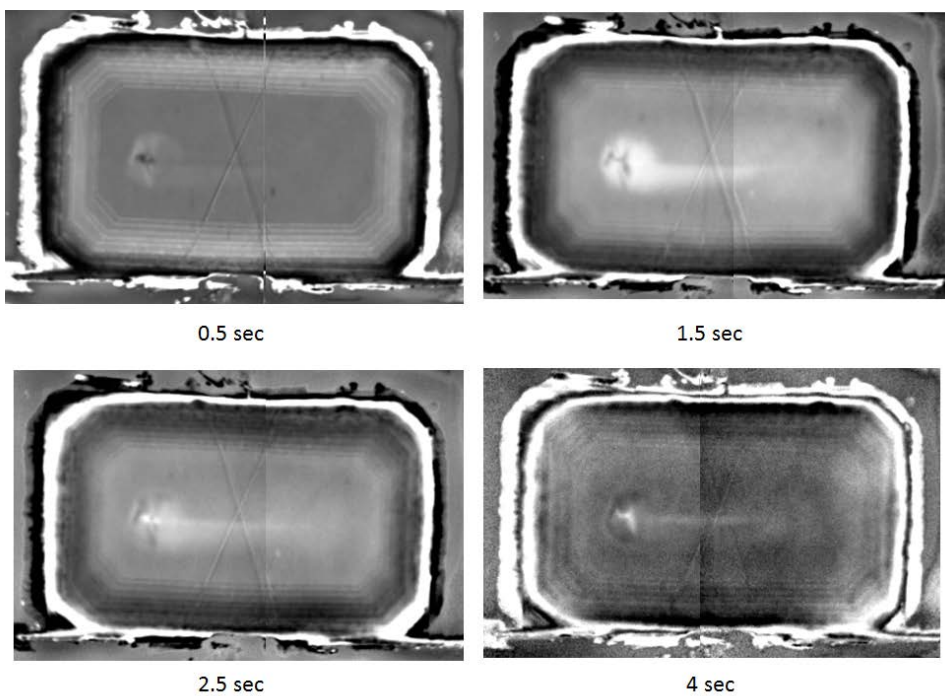

Figure J-22. Images of the R-BE repair patch captured using flash thermography, 20,000 cycles after impact at different time slices

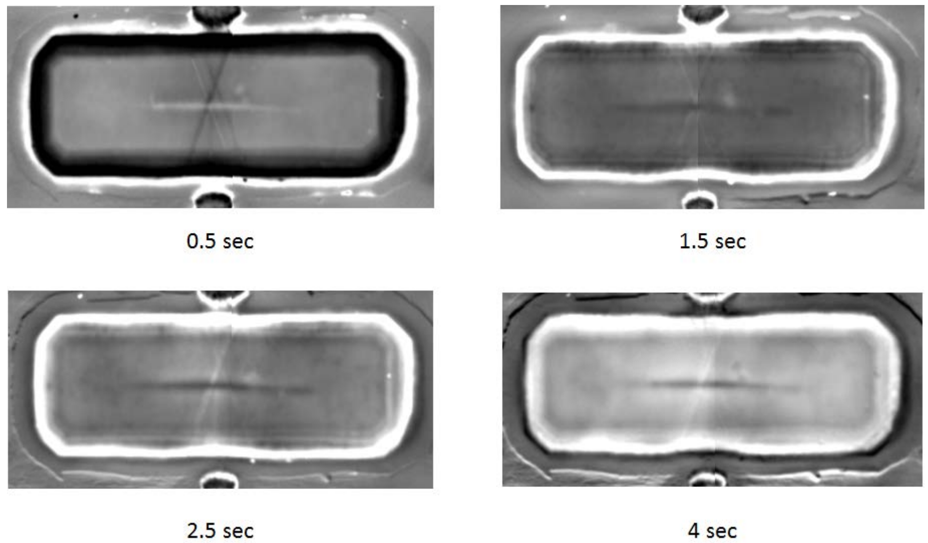

Figure J-23. Images of the U-BE repair patch captured using flash thermography before impact at different time slices

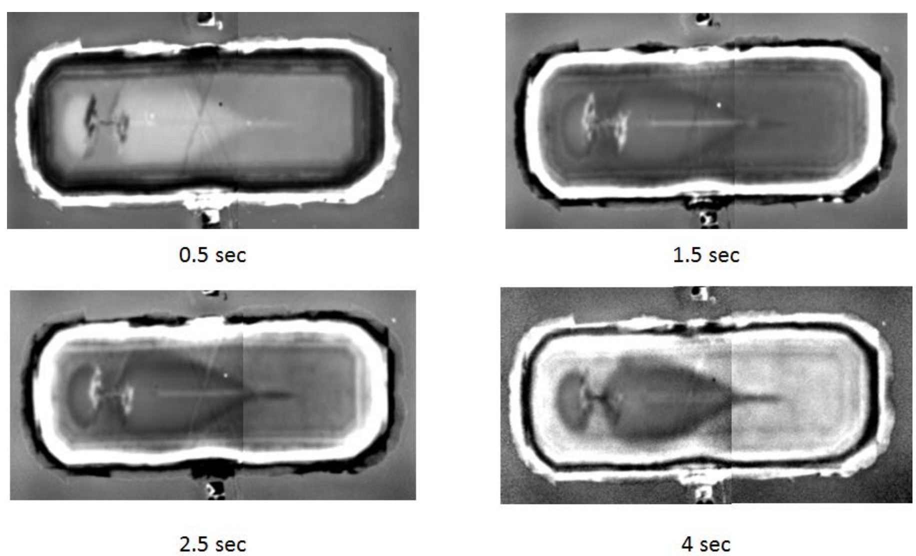

Figure J-24. Images of the U-BE repair patch captured using flash thermography after impact at different time slices

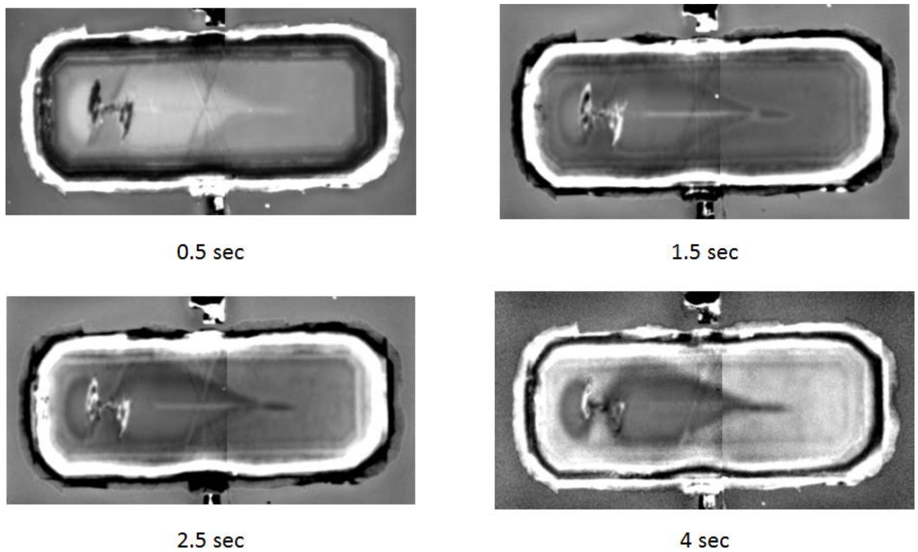

Figure J-25. Images of the U-BE repair patch captured using flash thermography, 10,000 cycles after impact at different time slices

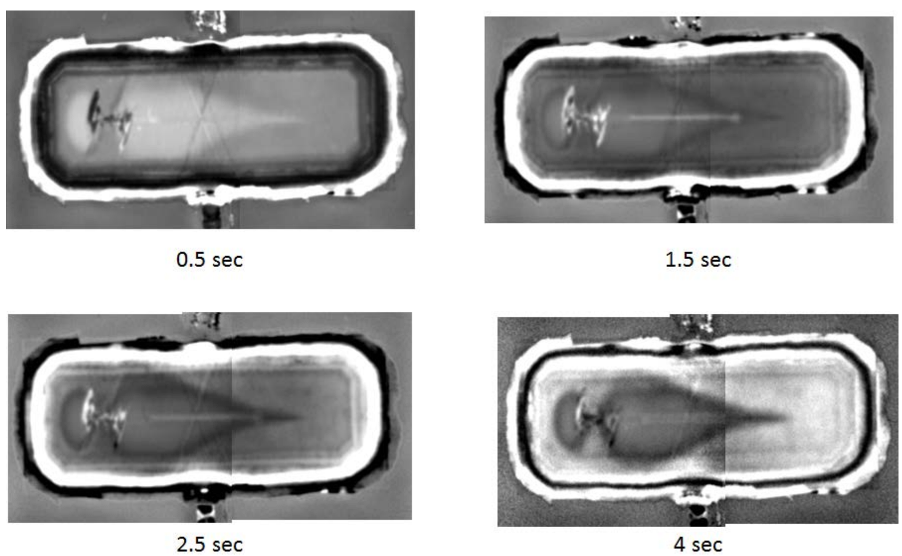

Figure J-26. Images of the U-BE repair patch captured using flash thermography, 20,000 cycles after impact at different time slices

J.2 RESONANCE ULTRASONIC

The resonance ultrasonic NDI was conducted using Olympus BondMaster 1000 equipment. The details of the equipment and resonance ultrasonic procedures follow:

J.2.1 EQUIPMENT

- Tester—Olympus BondMaster 1000
- Probe—Olympus Sonic S-PR-5, 250 kHz resonance probe, P/N 93177995
- Cable—11 pin Fisher, SBM-CPM-P11
- Couplant
- Reference standard (figure J-27)
- Ruler or tape measure
- Permanent marker

J.2.2 PART PREPARATION

Clean exterior patch surface

J.2.3 SETUP

1. Set the BondMaster 1000 according to the following settings:

    a. ANGLE = 169°
    b. HGAIN = -5.0 dB
    c. VGAIN = -5.0 dB FREQ = 248 kHz

2. The system was nulled by placing the probe, with couplant, over an area without a defect on the reference standard (see figure J-28).

3. Similar to the setup of scanning the SHIM, the probe with the couplant was placed over the area with the SHIM anomaly on the reference standard (see figure J-20). The dot moved to the far upper right corner of the screen display on the BondMaster 1000 (see figure J-29).

4. A similar approach was adopted for setting up the system for FEPs.

5. The gain and angle were adjusted to achieve the screen presentation, as shown in figure J-29. This adjustment was made for each case when the probe was set up for NULL, SHIM, and FEP areas.

J.2.4 INSPECTION

1. Using the setup achieved by using reference standards, all the repairs were scanned for any defects.

2. Using this approach, all the intentional defects, in both the FEP and SHIM areas, were detected using the BondMaster 1000.

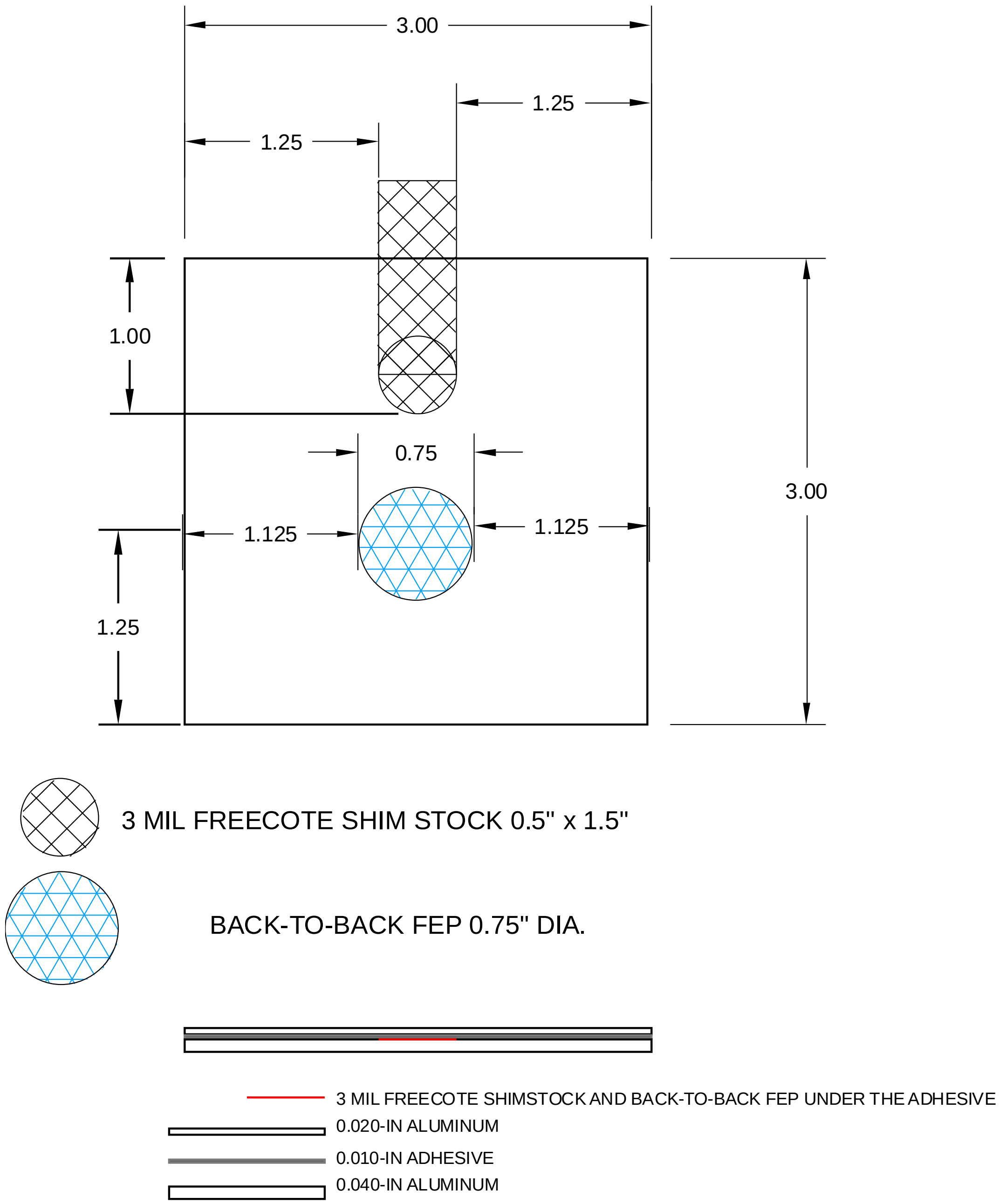

Figure J-27. Reference standard

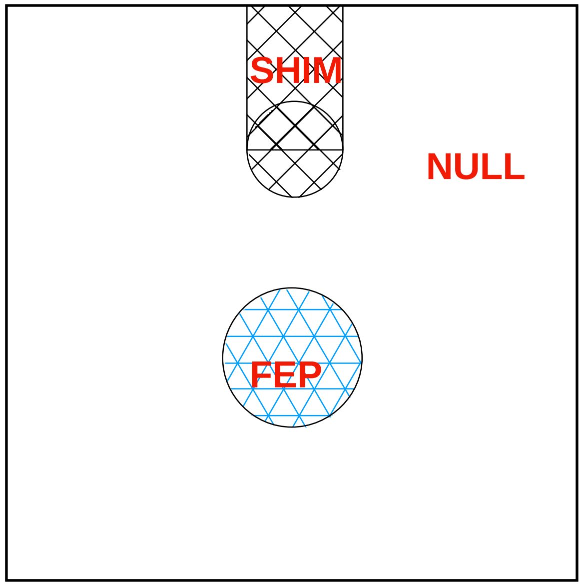

Figure J-28. Reference standard probe locations

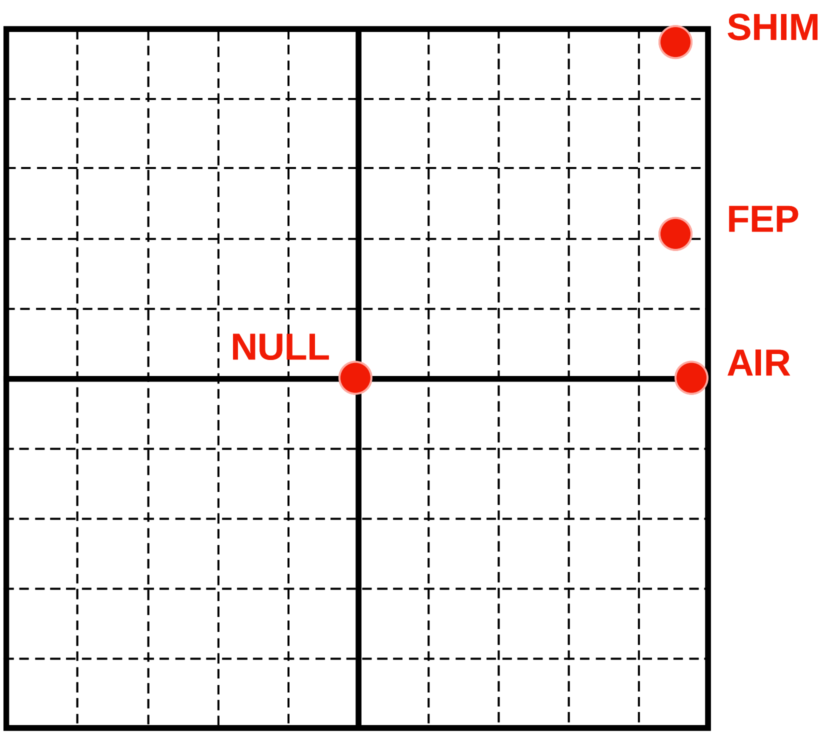

Figure J-29. Screen presentation of the BondMaster 1000

APPENDIX K—STRUCTURAL REPAIR MANUAL REPAIRS

For phase 3 repairs (compliant Boron/Epoxy (B/EP) patch (C-BE) and Compliant B/EP with partial disbond), the crack growth was very significant. The half-crack length for both the repairs was approximately 3″ after 20,000 cycles. Because the crack tip was very close to the patch boundary, it was necessary to stop the crack growth. To continue fatigue testing, both of the repairs were removed and mechanically fastened repairs were installed as per structural repair manual (SRM) 53-30-3 instructions. This appendix details the procedure and materials used for the installation of SRM repairs.

Figure K-1 shows the location of the two SRM repairs on the fuselage panel. Before the installation of the SRM repair, the bonded B/EP repairs were grinded off using 40/80/120/180/220 grit sanding disks. The surface of the fuselage skin was cleaned with acetone and dry air to remove any contaminants left from the previous repair. Next, the eddy current system was used to mark the crack tips for both repair locations.

After marking the crack tips, further procedures were followed in accordance with the B727 SRM skin repair instructions. In this appendix, only the selected steps are discussed.

The cracks were removed by cutting the region around the crack in accordance with SRM 53-30-3 with a pneumatic saw. All the cut-out edges were cleaned and deburred. The area of the cut-out was kept minimal to avoid removing a large skin area. Figure K-2 shows the cut-out region for one of the repairs.

The length of the cutout = total length of the crack + 2 x 0.04″.

Prior to SRM repair installation, the region around the cut-out was inspected again using eddy current to check if there were any cracks on the surface. The size of the SRM repairs was based on the dimensions of the cut-out. The SRM-1 repair was 14.68” x 6.88” for the cut-out, which was 7.45” in length. Figure K-3 shows the dimensions of the SRM-1 repair. Similarly, the SRM-2 repair was 12.02” x 6.88” for the cut-out, which was 6.03” in length. The material for both the repairs was 0.05”-thick 2024-T3 aluminum.

Prior to the repair installation, the skin surface and patches were acid-etched and alonized per SRM 51-10-2. Primer was applied to the skin surface and the patches. Further, the repairs were attached to the panel using PS870 B-2 sealant in accordance with SRM 51-20-4. The fasteners were then inserted through the repair and the panel. Although the SRM recommends using counter-sunk rivets, the MS20470AD-5-5 button head fasteners were used because of the ease of using button head rivets. The spacing between the fasteners on the repairs was 0.78” and the edge rivets were 0.32” away from the edge of the repair, as shown in figure K-3. Figures K-4 and K-5 show the actual image of the SRM repairs after installation.

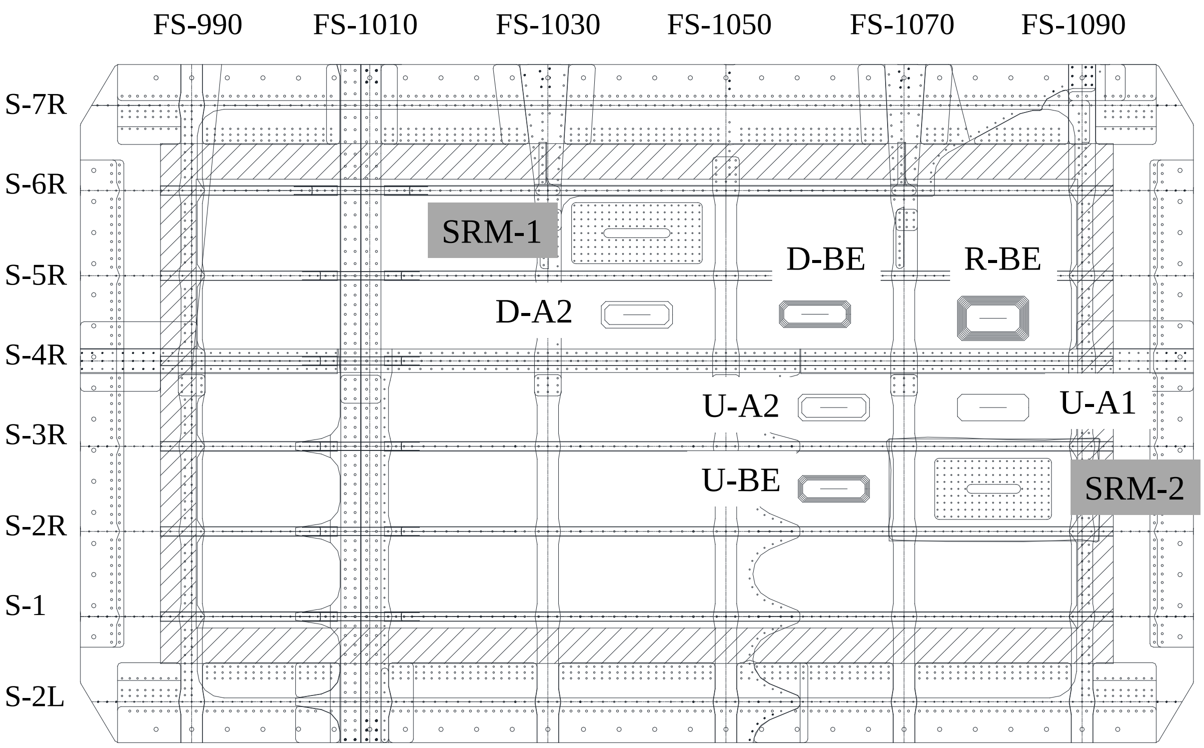

Figure K-1. Location of the SRM-1 and SRM-2 repairs

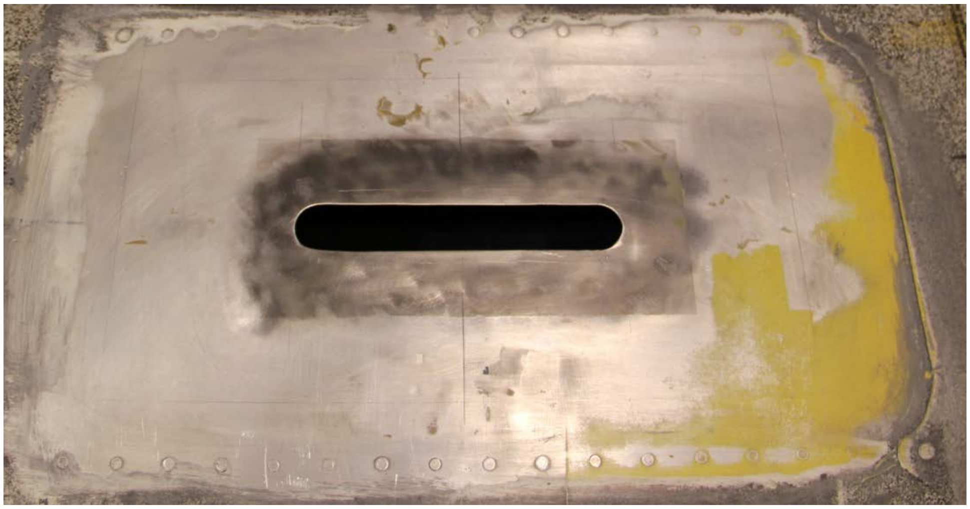

Figure K-2. The cut-out on the fuselage panel before repair installation

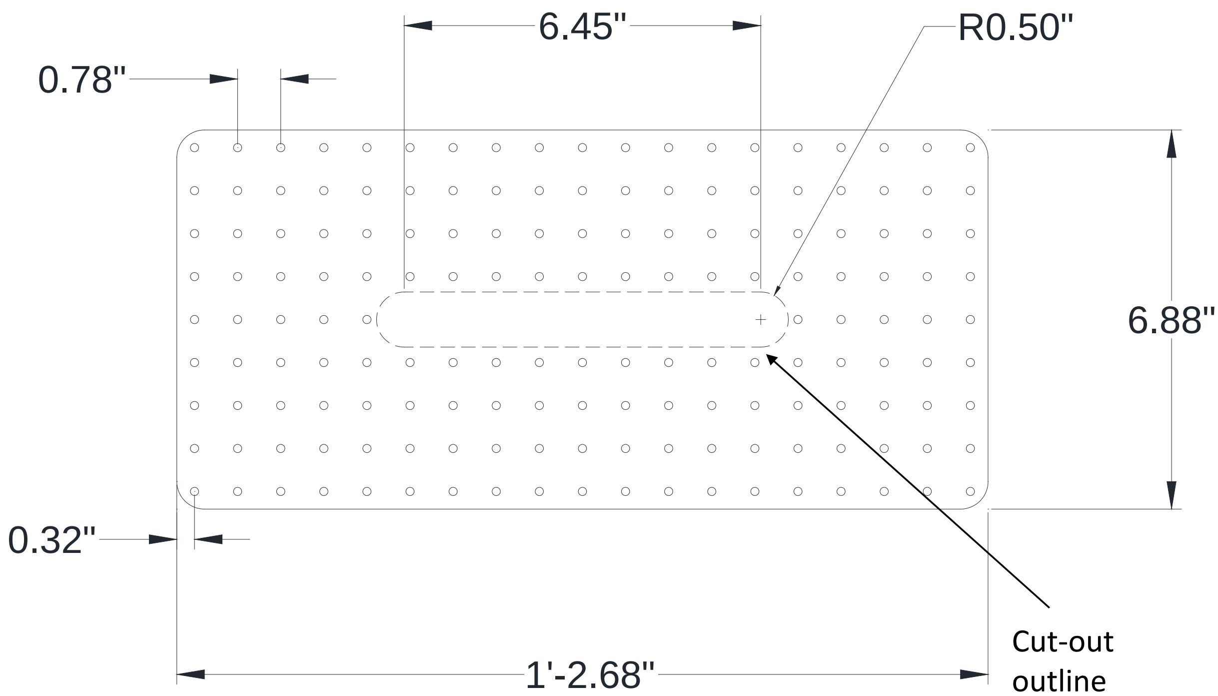

Figure K-3. Drawing of the SRM-1 repair

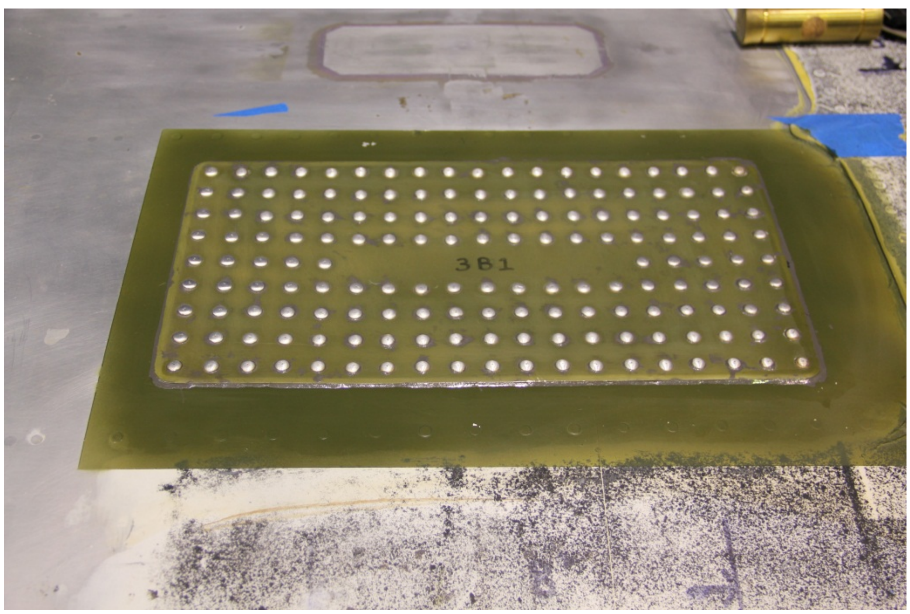

Figure K-4. The SRM-1 repair after installation

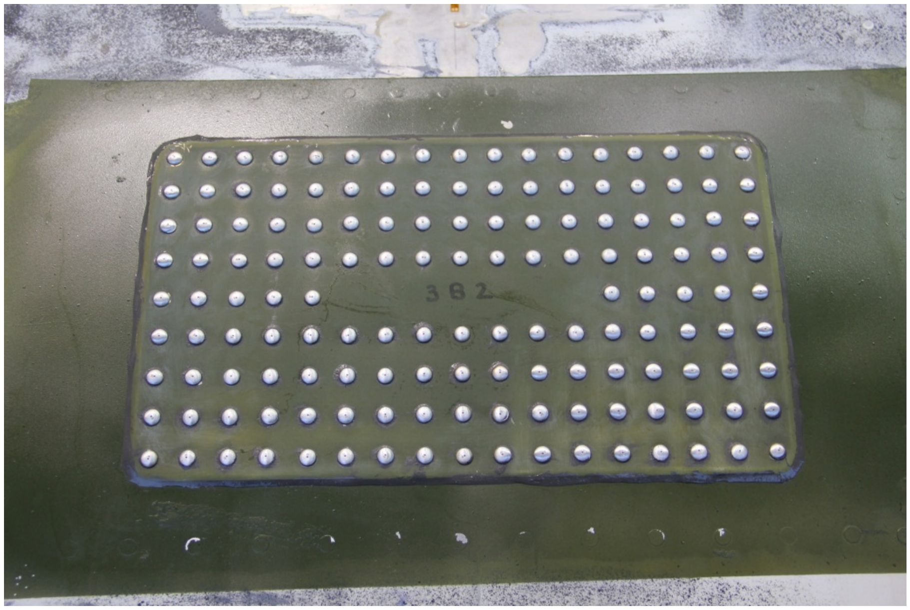

Figure K-5. The SRM-2 repair after installation

APPENDIX L—PROCEDURE OF IMPACT TEST

During phase 4 of the test, the R-BE, U-BE, and U-A2 repairs were impacted. The impact energy levels used were 300 in-lb and 500 in-lb, which corresponds to impact events from a tool drop and from severe hail damage, respectively. This appendix explains the details of the impact procedure and tup used for the impact test. The engineering drawings of the tup used for impact and the complete dimensions of the tup are shown in figure L-1. The tup weighed 15 lb and was dropped from a height of 20″ to produce 300 in-lb energy and from a height of 33.3″ to produce 500 in-lb energy. Figure L-2 shows the actual image of the tup used. Figure L-3 shows the impactor assembly and figure L-4 shows the dimensions of the impactor and the height of impact. Figure L-5 shows the image of the setup used to impact the three repairs. The first step was to align the location of impact, as shown in figure L-6. Figure L-7 shows the tup hitting the patch, which causes the dent in the U-A2 patch shown in figure L-8.

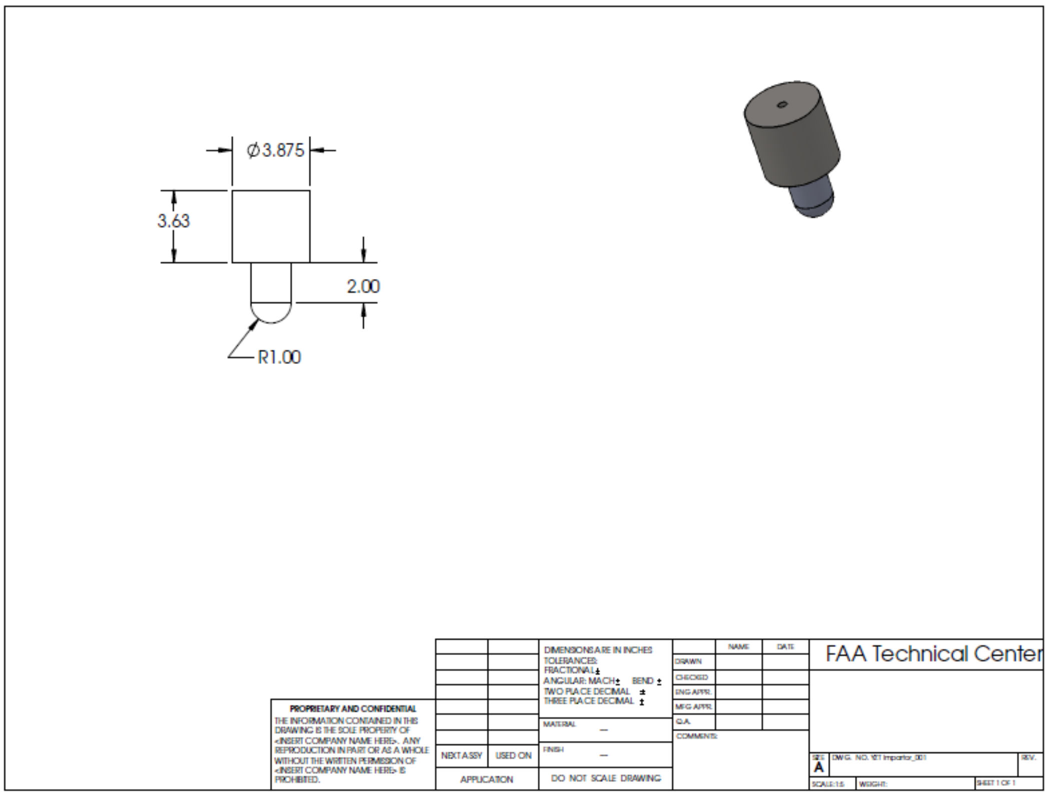

Figure L-1. Engineering drawing of the tup used for impact

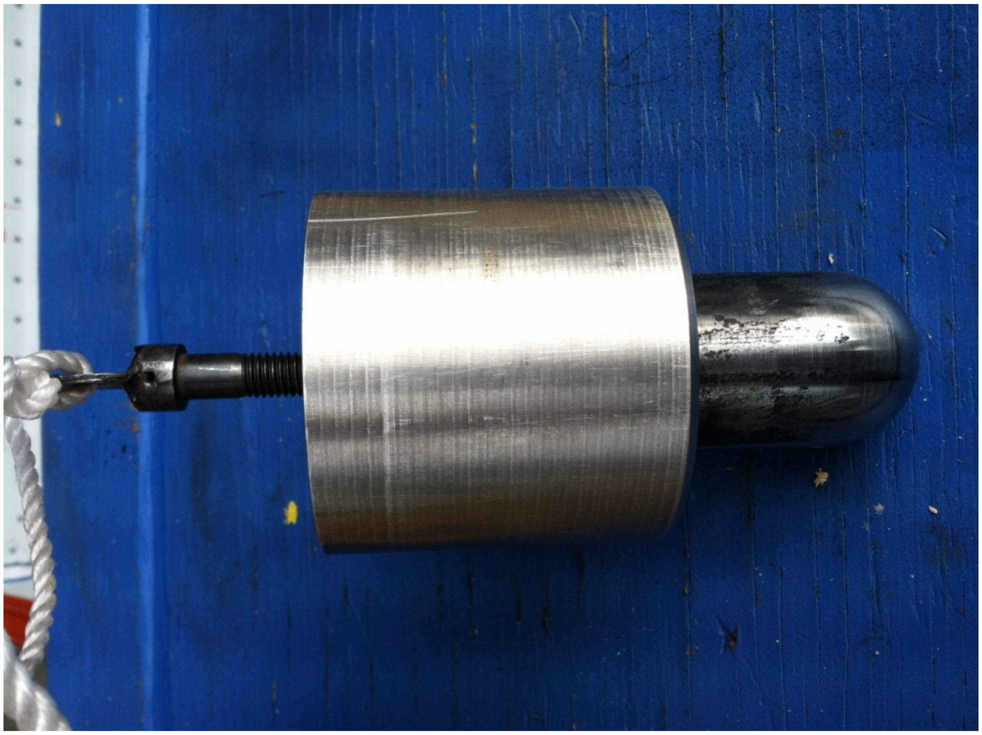

Figure L-2. The tup used for impact

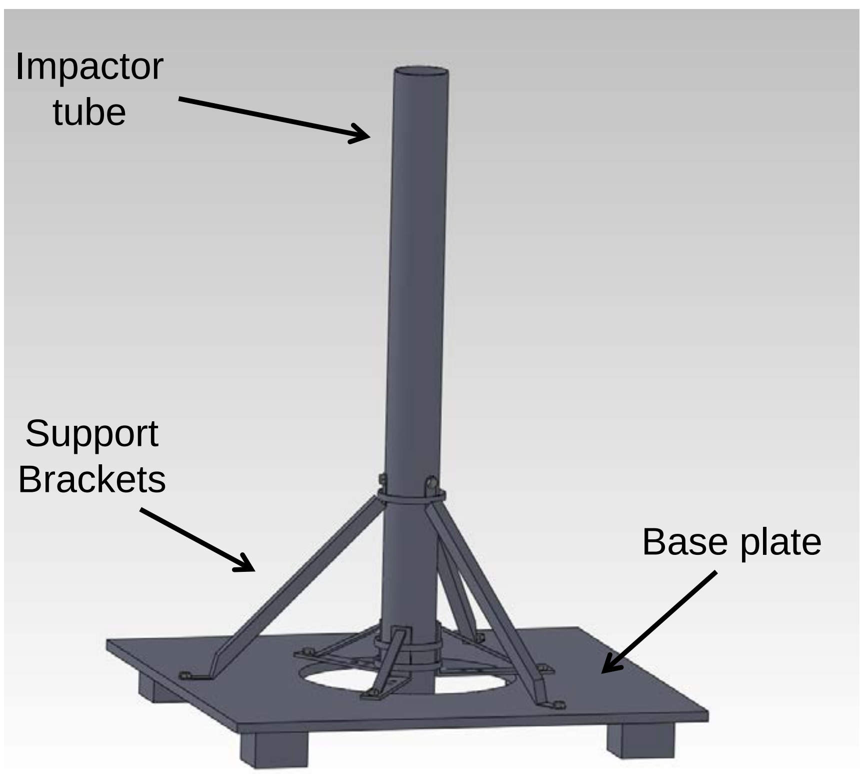

Figure L-3. The impactor assembly

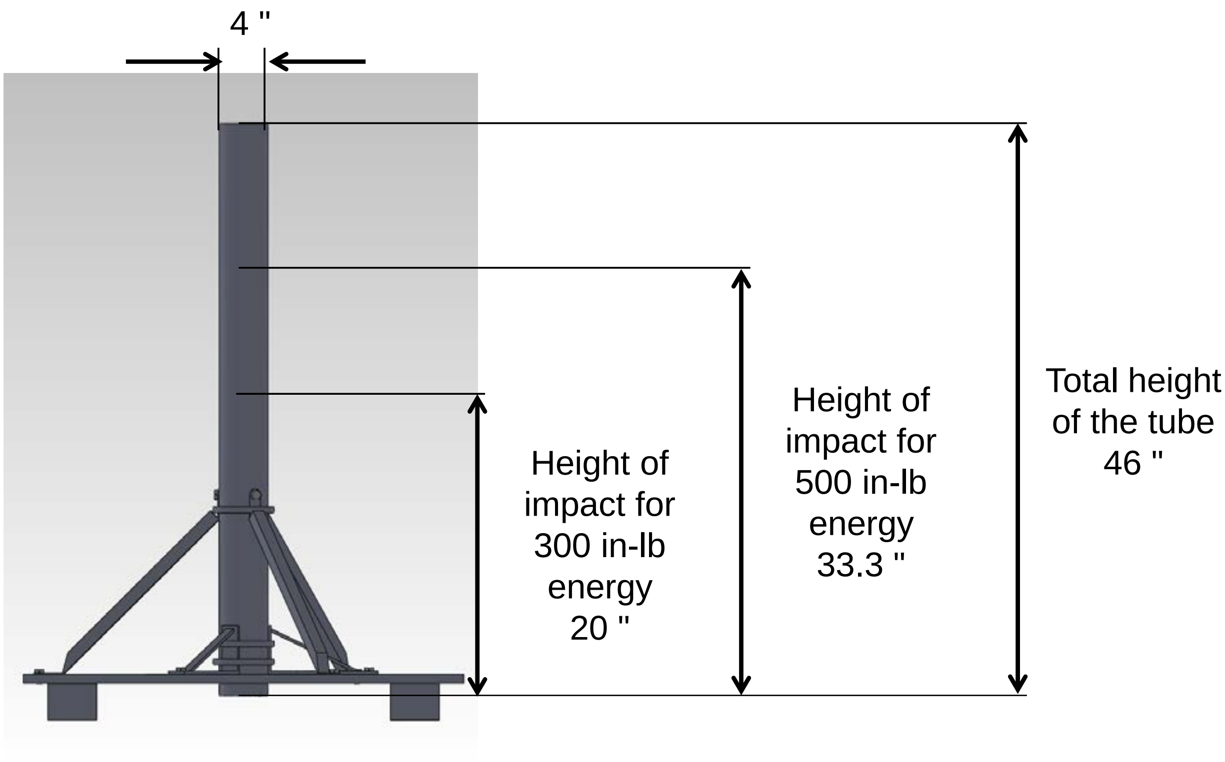

Figure L-4. The impactor dimensions and height of impacts

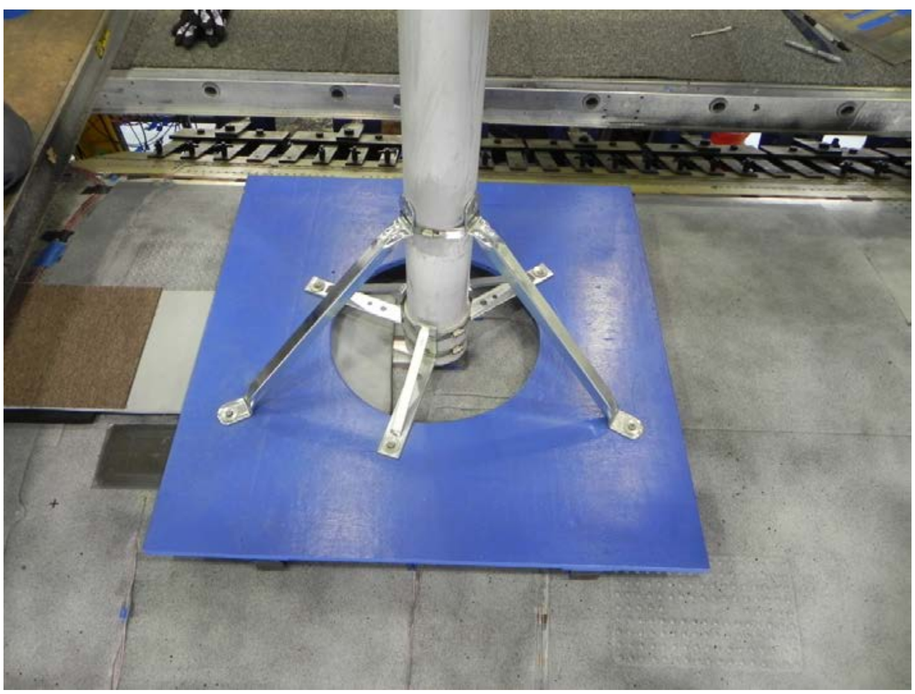

Figure L-5. Setup for impacting one of the repairs

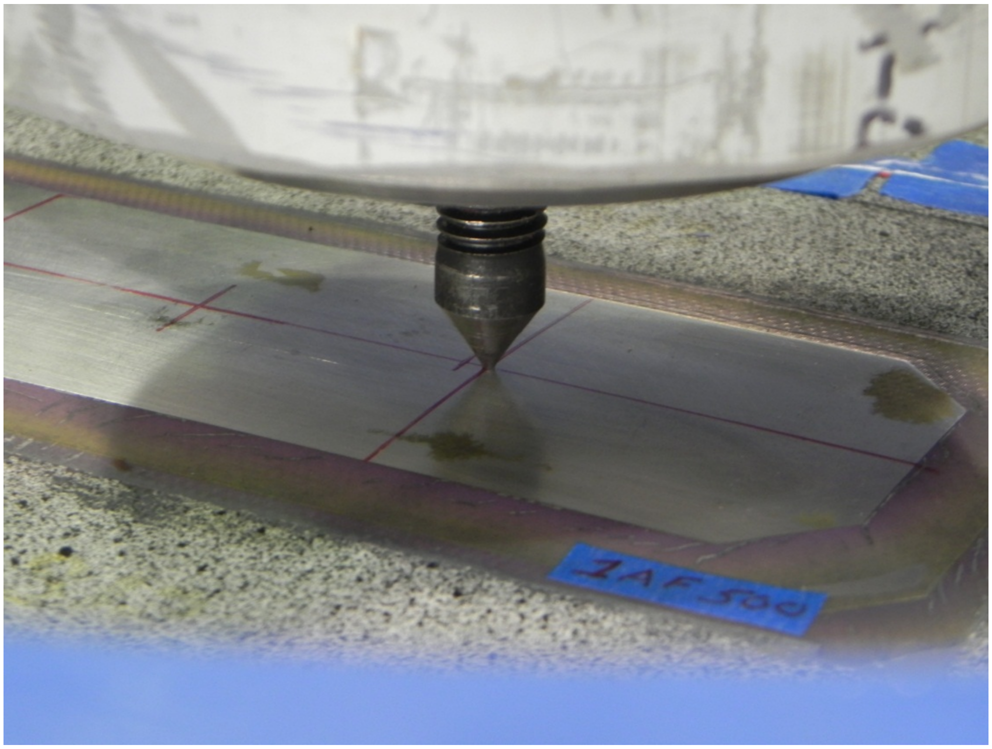

Figure L-6. Aligning the point of impact

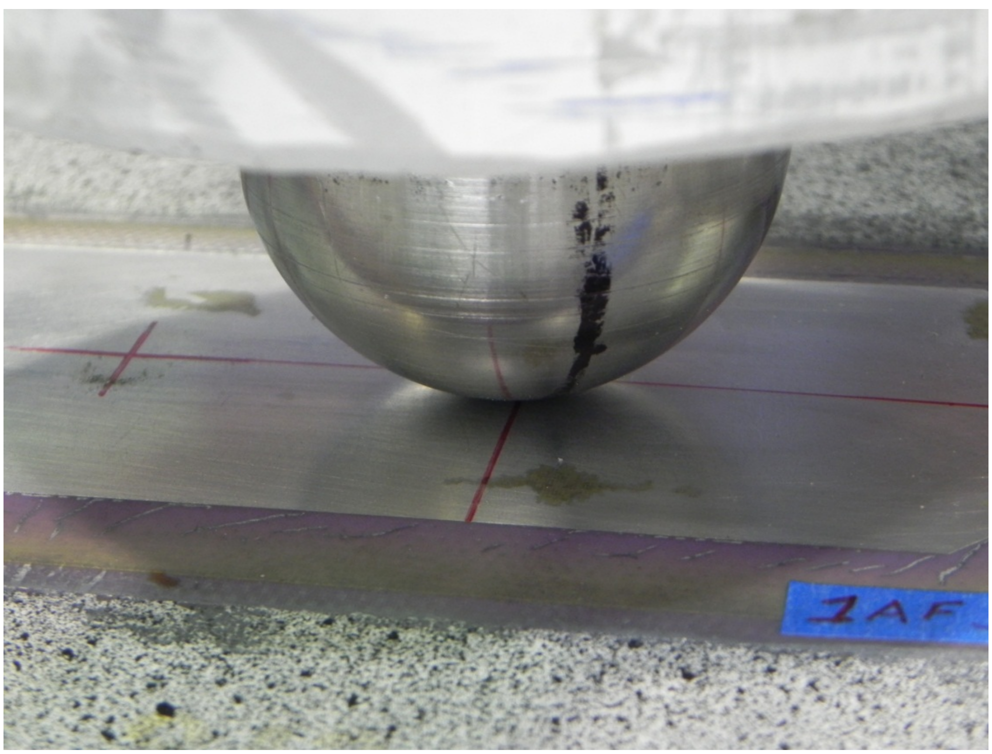

Figure L-7. The tup hitting the patch

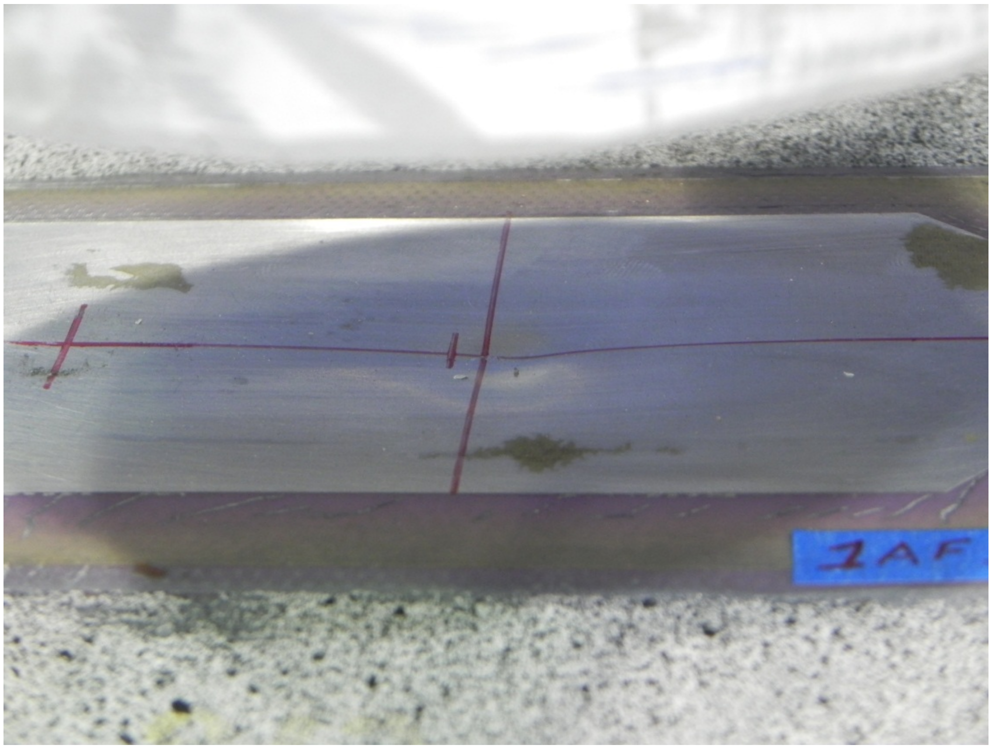

Figure L-8. The dent created in the u-a2 patch due to impact