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(R) Guidelines for Repair Process Evaluation of Aluminum Bonded Structure

RATIONALE

This document is intended to satisfy the need for a checklist of best practices in implementation of tooling, process steps, and quality controls that help to make sure that a previously substantiated repair design and process requirements are met. This revision adds an appendix of critical processes. The appendix for reporting temperature and pressure has been removed and incorporated into other documents.

TABLE OF CONTENTS

1.	SCOPE	4
1.1	Purpose	4
2.	APPLICABLE DOCUMENTS	4
2.1	SAE Publications	4
2.2	ASTM Publications	5
2.3	EASA Publications	5
2.4	FAA Publications	5
2.5	PRI Publications	5
2.6	U.S. Government Publications	5
2.7	Other Publications	6
3.	DEFINITIONS	6
4.	GENERAL	8
4.1	Overview	8
4.2	Process Flows	8
4.2.1	Process Flows Overview	8
4.2.2	Process Flows Role of Quality Personnel	9
4.2.3	Roles and Responsibility Indicator	9
4.3	Preparation Steps Prior To Repair Accomplishment	9
4.3.1	Identify the Part and Obtain Source Documentation	10
4.3.2	Determine if the Part Requires Removal	11
4.3.3	Assess the Damage	14
4.3.4	Remove the Part if Necessary	14
4.3.5	Identify the Part Construction	15
4.3.6	Make Sure Facilities are Satisfactory	16
4.3.7	Make Sure Personnel are Qualified	16
4.3.8	Remove the Damage	17
4.3.9	Inspect Core Condition and Remove Corroded Core	19
4.3.10	Consider Nondestructive Inspection (NDI) and Testing (NDT)	23
4.3.11	Select Applicable Repair Method	24

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4.3.12 Assess Facilities and Equipment ... 26
4.3.13 Procure Materials/Parts/Consumables ... 29
4.3.14 Inspect the Materials/Parts/Consumables ... 32
4.3.15 Plan for Tooling / Quality Check ... 37
4.3.16 Schedule Repair Activity ... 41
4.4 Repair Accomplishment ... 42
4.4.1 Repair Accomplishment General Steps ... 42
4.4.2 Prepare Surfaces for Bonding ... 42
4.4.3 Prepare Bond Tool ... 48
4.4.4 Bond Line Check/Dry Fit Check ... 49
4.4.5 Staging of Time and Temperature Sensitive (TATS) Materials ... 54
4.4.6 Conduct Layup in Contamination Control Area ... 55
4.4.7 Layup Repair ... 57
4.4.8 Layup of Witness Coupons ... 59
4.4.9 Bag and Cure of Repair ... 60
4.5 Post-Repair Actions and Finishing Sequences ... 67
4.5.1 Post-Repair Actions and Finishing Sequences General Steps ... 67
4.5.2 Remove from Heat Source, Debag and Inspect ... 68
4.5.3 Accomplish NDT Inspection and Mechanical Testing ... 69
4.5.4 Accomplish Finish Sequence to Bond Assembly ... 70
4.5.5 Reassemble Subcomponent Details and Apply Finish to Assembly ... 71
4.5.6 Perform Dimensional and Fit Check ... 72
4.5.7 Accomplish Fire/Heat Protection Procedures ... 73
4.5.8 Accomplish Weight and Balance Procedures ... 73
4.5.9 Document Acoustic Properties ... 74
4.5.10 Identify Repair and Prepare Records ... 74

5. NOTES ... 75
5.1 Revision Indicator ... 75

APPENDIX A REPAIR TOOLING DIMENSIONAL REPORT EXAMPLE ... 76
APPENDIX B STANDARD LEAK TEST EXAMPLE ... 78
APPENDIX C ALUMINUM WITNESS COUPON SUMMARY ... 80
APPENDIX D PROCESS CHECKLIST ... 83

Figure 1 Role indicator key for major flowchart sections ... 9
Figure 2 Repair preparation decision flow ... 10
Figure 3 Part removal decision flow ... 11
Figure 4 Thermal image demonstrates how a metallic fitting acts as a heat sink ... 12
Figure 5 Fitting bolted and sealed on the wedge after wedge manufacture ... 13
Figure 6 Example of overheating during skin removal ... 18
Figure 7 Corrosion of aluminum honeycomb core resulting in a weak bond area ... 20
Figure 8 Example of corroded core weak bond/good bond areas. Note that the corrosion area corresponds with a typical moisture ingress path (exposed honeycomb core edge with only a sealant close-out) ... 21
Figure 9 Examining peeled skin and residual core for evidence of corrosion ... 22
Figure 10 Foaming of adhesive due to the improper application of vacuum pressure ... 25
Figure 11 Autoclave and vacuum processed test coupons. Autoclave processed test coupon (left) shows ideal adhesive bonding condition. Vacuum processed test coupon (right) shows failures due to foaming of film adhesive. ... 26
Figure 12 Facilities determination process checklist ... 27
Figure 13 Catastrophic failure of a flight control wedge assembly that was repaired using alternate (and inappropriate) surface preparation procedures ... 28
Figure 14 Non-PAA aluminum honeycomb core found disintegrated after less than 2 years flight time ... 31
Figure 15 Parts check process flow ... 33
Figure 16 Tooling check process checklist ... 38
Figure 17 Thermocouple diagram showing placement of thermocouples on tool ... 39
Figure 18 Example of tooling placard to keep track of inspection intervals and ensuring compliance to requirements ... 40
Figure 19 Repair scheduling process checklist ... 41
Figure 20 Repair implementation decision flow ... 42

Figure 21 Prepare surfaces for bonding flow ... 43
Figure 22 Fit check process flow ... 49
Figure 23 Example of nonuniform core imprint ... 50
Figure 24 Example of a verification film test cured out and circled thickness indications in areas that appear dark when exposed to a light source ... 51
Figure 25 Tunnel voids shown at the interface between a tool side skin and spar flange for a wedge assembly ... 52
Figure 26 Destructive analysis of a flap vane assembly showing the cured film adhesive between the outer skin and internal core and doubler ... 53
Figure 27 Contamination control process checklist ... 55
Figure 28 Layup process flow ... 57
Figure 29 Bag and cure process flow ... 60
Figure 30 Typical bagging schedule for aluminum bonded repairs ... 62
Figure 31 Example of a thermocouple failure during repair cure ... 66
Figure 32 Post-repair actions and finishing decision flow ... 67
Figure 33 Example of continuous adhesive flash along a bond line edge ... 69
Figure 34 Detail of an assembly jig being used to check for alignment of an attach fitting for a flight control assembly ... 73

1. SCOPE

This SAE Aerospace Information Report (AIR) is intended to be used as a process verification guide for evaluating implementation of key factors in repair of metal bond parts or assemblies in a repair shop environment. This guide is to be used in conjunction with a regulatory approved and substantiated repair and is intended to promote consistency and reliability.

1.1 Purpose

This SAE Aerospace Information Report (AIR) is intended to be used as a guide for regulatory and Customer personnel during the evaluation process of a substantiated repair submitted to the aforementioned parties by a repair station acting on behalf of a Customer to carry out a repair to aluminum bonded structure. This AIR is also intended to be used as a supplement to AS7118 during an audit to evaluate repair station processes.

This document may be used as a reference for a Customer to understand some key considerations that should be taken into account during the repair process. This document is intended for shop level repairs; however, all of the procedures given within this document can also be used to evaluate repairs accomplished on-wing. This document is NOT intended to be a design handbook for repair stations that wish to substantiate repairs that extend beyond the size limits or deviate from the repair instructions of an OEM approved repair manual, such as a CMM, SRM, AMM, etc.

2. APPLICABLE DOCUMENTS

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

AMS-STD-401 Sandwich Constructions and Core Materials: General Test Methods

AIR4844 Composites and Metal Bonding Glossary

AIR4938 Composite and Bonded Structure Technician/Specialist Training Document

AIR5278 Composite and Bonded Structure Engineers: Training Document

AIR5431 Repair Tooling

AIR6292 Guidelines for Repair Process Evaluation of Fiber Reinforced Composite Bonded Structure

AIR6825 Identification and Assessment of Damage to Composite Aircraft Structures Training Document

ARP4916 Masking and Cleaning of Epoxy and Polyester Matrix Thermosetting Composite Materials

ARP5089 Composite Repair NDT/NDI Handbook

ARP5143 Vacuum Bagging of Thermosetting Composite and Metalbond Repairs

ARP5144 Heat Application for Thermosetting Resin Curing

ARP5256 Mixing Resins, Adhesives, and Potting Compounds

AS7118/2 Nadcap Requirements for Metal Bonding

AS7118/3 Nadcap Requirements for Core Processing

Armstrong, K.B., Cole, W., and Bevan, G. (2005). *Care and Repair of Advanced Composites, Second Edition* (ISBN 978-0-7680-1062-6). SAE International. https://doi.org/10.4271/R-336.

2.2 ASTM Publications

Available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, www.astm.org

ASTM C297 Standard Test Method for Flatwise Tensile Strength of Sandwich Constructions

ASTM D1002 Standard Test Method for Apparent Shear Strength of Single Lap Joint Adhesively Bonded Metal Specimens by Tension Loading (Metal to Metal)

ASTM D1781 Standard Test Method for Climbing Drum Peel for Adhesives

ASTM D3167 Standard Test Method for Floating Roller Peel Resistance of Adhesives

ASTM D3762 Standard Test Method for Adhesive-Bonded Surface Durability of Aluminum (Wedge Test)

ASTM D3933 Standard Guide for Preparation of Aluminum Surfaces for Structural Adhesives Bonding (Phosphoric Acid Anodizing)

2.3 EASA Publications

Available from European Union Aviation Safety Agency, Konrad-Adenauer-Ufer 3, D-50668 Cologne, Germany, Tel: +49 221 8999 000, www.easa.europa.eu.

AMC 20-29 Composite Aircraft Structure

2.4 FAA Publications

Available from Federal Aviation Administration, 800 Independence Avenue, SW, Washington, DC 20591, Tel: 866-835-5322, www.faa.gov.

AC 20-107 Composite Aircraft Structure

AC 43-214 Repairs and Alterations to Composite and Bonded Aircraft Structure

2.5 PRI Publications

Available from Performance Review Institute, 161 Thorn Hill Road, Warrendale, PA 15086-7527, Tel: 724-772-1616, www.p-r-i.org.

AC7108/3 Audit Criteria for Metal Bond Surface Preparation

2.6 U.S. Government Publications

Copies of these documents are available online at https://quicksearch.dla.mil.

MIL-C-7438 Core Material, Aluminum, for Sandwich Construction

2.7 Other Publications

Factors Influencing Durability of Sol-Gel Surface Treatments in Metal Bonded Structures [Conference paper]. SAMPE 2002, Long Beach, CA, USA.

Stancin, L.C. and Van Voast, P.J. *Metal Bond Repairs: The Impact of Vacuum Level, Adhesive Type, and Repair Size*. Boeing Commercial Airplanes.

3. DEFINITIONS

Refer to AIR4844 for a more complete composite and metal bonding glossary. New terms that appear in this document are defined below:

AJ: Assembly Jig. When assembling fittings, leading edge skins, latches, or any other part that requires alignment to a theoretical datum, such as a hinge axis or a contour line, an AJ may be necessary equipment during accomplishment of a repair.

AMM: Aircraft Maintenance Manual provided by aircraft manufacturers. Sometimes referred to as “MM” or “OEM MM.”

ASM: Assembly Mandrel. An ASM is any intermediate tool used during original manufacture or during repair to structure that does not have critical effect on the integrity of the final assembly or any of its subcomponent details. It is sometimes necessary to use a lightweight tool that is neither dimensionally controlled nor dimension tolerance critical. Sometimes referred to as a “shop aid.”

BACKING MATERIAL: Material used to support and protect film adhesives and prepreg during storage and kitting prior to layup. Backing materials may be release-coated paper products or plastic films. Backing materials provide a barrier to prevent the adhesive and prepreg from adhering to itself during storage and protect and support the adhesive and prepreg during handling. Also known as backing paper, backing film, separator sheet, carrier sheet, or release film.

BAJ: Bonded Assembly Jig. Tooling used to define and/or maintain appropriate contour of the part being manufactured or repaired during high pressure and temperature cycles (autoclave or vacuum-assisted oven cure).

CAA: Chromic Acid Anodize.

CCA: Controlled Contamination Area. An area that ensures levels of dirt, dust, oils, lubricants, and other containments are controlled for acceptable structural bonding. It may also be referred to as a “clean room” in a shop or factory environment.

CMM: Component Maintenance Manual. Document that details the way in which maintenance tasks shall be accomplished for a specific component. Sometimes referred to as “MM” or “OEM MM.”

CUSTOMER: The Customer may be an owner or an operator of the airplane, or the Customer may be a holder of a spare component. When the component is being repaired at an outside maintenance facility, the Customer is responsible for regulatory oversight of the repair station. A repair station must have a regulatory approved certificate. Repairs are approved and coordinated with the OEM or submitted to the regulatory agency whenever repairs are accomplished outside of an OEM-provided repair documentation (i.e., CMM, SRM, or AMM).

ENGINEERING: Organizations or individuals responsible for providing part-specific repair documentation and all other supporting documentation, such as material and process specification, tool design, inspection criteria, etc. Engineering departments at airlines also have the responsibility to determine acceptability of repair documents and of repaired parts to ensure there is no conflict with the airline’s maintenance program, configuration, reliability program, and interactions with systems. Engineering is responsible to coordinate with OEMs, Regulatory Authorities, or other experts when repairs are outside their area of expertise and/or previous experience. Engineering has the responsibility to make sure that the repair, as correctly implemented, satisfies all regulations for airworthiness.

FAI: First Article Inspection. A planned, complete, independent, and documented inspection of the first viable part and verification process to ensure that prescribed processes have produced an item conforming to engineering requirements.

FCS: Fatigue Critical Structure. Airplane structure that is susceptible to fatigue cracking, which could contribute to a catastrophic failure. Also includes both FCBS (Fatigue Critical Baseline Structure) as defined by the OEM and FCAS (Fatigue Critical Altered Structure) as defined by the operator.

MM: AMM or CMM.

NDI: Nondestructive Inspection. Instrumented inspection techniques that do not require personnel qualification and certification in accordance with applicable technical standards for nondestructive testing personnel. Examples include tap test, automated tap test, and handheld "go-no-go" ultrasonic instruments.

NDT: Nondestructive Testing. Instrumented inspection techniques that require personnel qualification and certification in accordance with accepted standards for nondestructive testing personnel and that is not being considered as nondestructive inspection (NDI). Examples include handheld PE, TTU, X-ray, thermography, eddy current, and Fourier-transform infrared spectroscopy (FTIR).

NHA: Next Higher Assembly.

NTM: Nondestructive Testing Manual.

OEM: Original Equipment Manufacturer.

OML: Outer Mold Line.

PAA: Phosphoric Acid Anodize.

PE: Pulse Echo. Ultrasonic inspection technique where signal is transmitted and received by the same transducer.

PSA: Phosphoric Sulfuric Acid Anodize.

PSE: Principal Structural Element. An element that contributes significantly to the carrying of flight, ground, or pressurization loads and whose integrity is essential in maintaining the overall integrity of the airplane. PSE structures are defined as such by the OEM.

QUALIFIED BONDING PROCESS: The characterization and control of specific parameters used when surface preparation is required to at least one of the structural interfaces prior to bonding. A Qualified Bonding Process is documented after demonstrating repeatable and reliable processing steps. A Qualified Bonding Process entails both development and documentation of the process and demonstration that the process can be executed by the user. Refer to AC 20-107B and AMC 20-29, paragraph 6c for guidance.

QUALIFIED BONDING SYSTEM: The specific combination of substrate, adhesive, type of surface preparation, and cure parameters controlled and validated under a Qualified Bonding Process.

QUALITY: Organizations or individuals responsible for either Quality Assurance (QA) and/or Quality Control (QC) functions.

QA functions typically make sure systems and procedures are in place to ensure all organizations perform as required by documents and policies. QA functions are responsible for making sure documents are up to date, repair technicians are current on training, and equipment is calibrated. QA functions are also responsible for identifying any corrective action that may be required if a defect is identified during a repair.

QC functions are responsible for testing and inspection of products to make sure that the products meet the requirements of the Repair Document. QC checks for defects during the manufacture or repair process. QC methods may include controlled tooling, jigs, NDT, raw material controls, training, qualifications, etc. Quality has the responsibility to make sure that the repair is correctly implemented to meet airworthiness requirements.

REPAIR DOCUMENT: An engineering repair authority that has been approved by the Customer to perform work on a specific part or assembly. An SRM provided by a Customer to a repair station is an example of a Repair Document, as is any other regulatory approved engineering data listed as an approved manual or manual supplement that is maintained by the Customer in accordance with its regulatory approved Operations Specification. A Repair Document may include references to other external documents or specifications that control processes, materials, shop practices, etc. Comply with all external specification references, which are considered part of the Repair Document.

SDR: Service Difficulty Report.

SRM: Structural Repair Manual.

SSI: Structural Significant Item, as determined by the OEM.

TATS: Time and Temperature Sensitive. Materials such a primer and film adhesive that are sensitive to both time and temperature.

THERMAL PROFILE: A set of time-temperature data typically associated with the measurement and control of temperatures on the part and/or repair during the cure cycle.

THERMOCOUPLE PLACEMENT DIAGRAM: A sketch or graphic that identifies each thermocouple wire on a particular area or heat zone of the repair.

TTU: Through Transmission Ultrasonics. Ultrasonic inspection technique where signal is transmitted and received by transducers on opposite sides of the part.

4. GENERAL

4.1 Overview

The following sections define the damage evaluation, preparation, repair, post-repair evaluation, and finishing steps that should occur for any repair to aluminum bonded structure. The procedures contained within this section follow the guidelines and recommendations in AC 43-214. Examples, figures, and best practices are incorporated in each of the sections to illustrate the intent of the step being described. It is not possible to include illustrations that demonstrate each type of consideration that should be made for each step that is described.

A companion document, AIR6292, contains process flows and key process steps for fiber reinforced composite repair. Processes and key process steps in AIR6292 may be applicable to fiber reinforced composite repair and is referenced in this document where appropriate.

This document is complementary to the technical assessments specified in Nadcap AC7108/3, which is available from the Performance Review Institute (PRI). The Nadcap document is used by OEMs primarily for manufacturing audits. Contents are applicable to the repair process.

4.2 Process Flows

4.2.1 Process Flows Overview

The flowchart figures included in this document are intended to show an overview of all steps that should occur during accomplishment of a repair to aluminum bonded structure. Detailed descriptions of each step are referenced within the process flow diagrams. Indications have been made beside each step as to which type of personnel may be needed, as a resource, to complete each task. These indications are not intended to be requirements; however, it is intended to provide assistance in resource planning to facilitate the process flow. Different repair stations may vary in how their organization distributes responsibility; therefore, adherence to any particular designation shown in the following may not match each organization's structure.

4.2.2 Process Flows Role of Quality Personnel

Whenever process flow diagrams indicate that quality personnel be utilized, quality checks should be accomplished by an individual who is different from the party who is directly responsible for accomplishing the repair. This will assure that an independent source will verify conformance to approved materials and processes. Quality check personnel should be knowledgeable about the materials and processes being implemented.

4.2.3 Roles and Responsibility Indicator

Indications have been made beside each step as to which type of personnel may be needed, as a resource, to complete each task (see Figure 1). These indications are not intended to be requirements; however, it is intended to aid in resource planning to facilitate the process flow. Different repair stations may vary in how their organization distributes responsibility; therefore, adherence to any particular designation shown in the following process flowcharts may not match each organization's structure.

M	General Mechanic / Shop Technician.
I	Inspector / NDT Technician
T	Job-Specific Trained Mechanic / Specialist
Q	Shop Inspector / QA / Management
P	Purchasing / Supply Chain / Logistics

Figure 1 - Role indicator key for major flowchart sections

4.3 Preparation Steps Prior to Repair Accomplishment

The following section recommends steps for the identification, removal, and preparation of a repair part. This section includes the procedures to make sure adequate facilities carry out a metal bond repair. Preparation steps must be followed prior to accomplishing the repair in order to validate the repair procedure. The flowchart (see Figure 2) is intended for initial planning purposes.

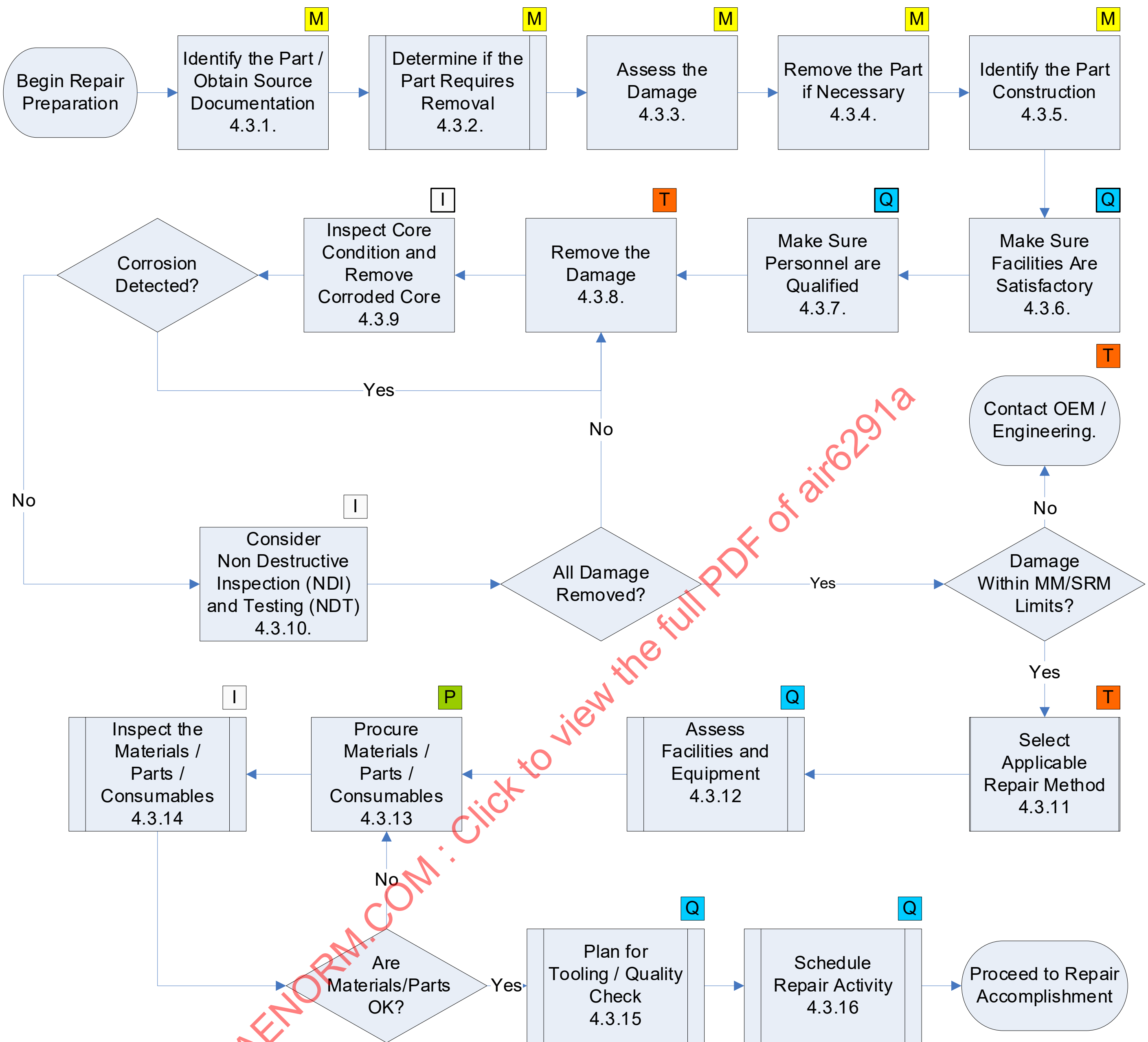


Figure 2 - Repair preparation decision flow

4.3.1 Identify the Part and Obtain Source Documentation

a. Identify the damaged structure by part number and corresponding limitations for repair as specified in authorized source documentation, such as the OEM SRM. Make sure that the manual(s) being used to identify the part has been supplied by the Customer and is applicable for the aircraft serial number. If working on a top level assembly that is already removed from the aircraft, make sure that the manual is applicable to the part number and serial number of the next higher assembly (NHA) component for which the damage is identified.

   1. Identify previous repairs that may affect repair disposition of the part to be repaired.

   2. If no manual is available that is adequate enough to identify the damaged component, contact the OEM and request guidance on proper identification of the structure that is being assessed.

3. The manuals or OEM data should include the following:

   (a) Inspection procedures needed to disposition damage.

   (b) Allowable damage and repair size limits.

   (c) Repair designs and processes for the specified damage sizes and locations described for a given structure.

   NOTE: It is a regulatory requirement that component maintenance and repair manuals and data match the component part number.

4.3.2 Determine if the Part Requires Removal

a. Determine if the damaged structure should be removed from the aircraft before proceeding with any damage removal or repair procedures. For the repair, the damaged structure might need to be removed from the higher assembly (e.g., skin panel from a trailing edge wedge, control surface, or flap) or lower-level parts might need to be removed from structure (e.g., fittings, seals). See Figure 3. Considerations that may drive the decision to remove the structure from the aircraft include, but are not limited to, the following:

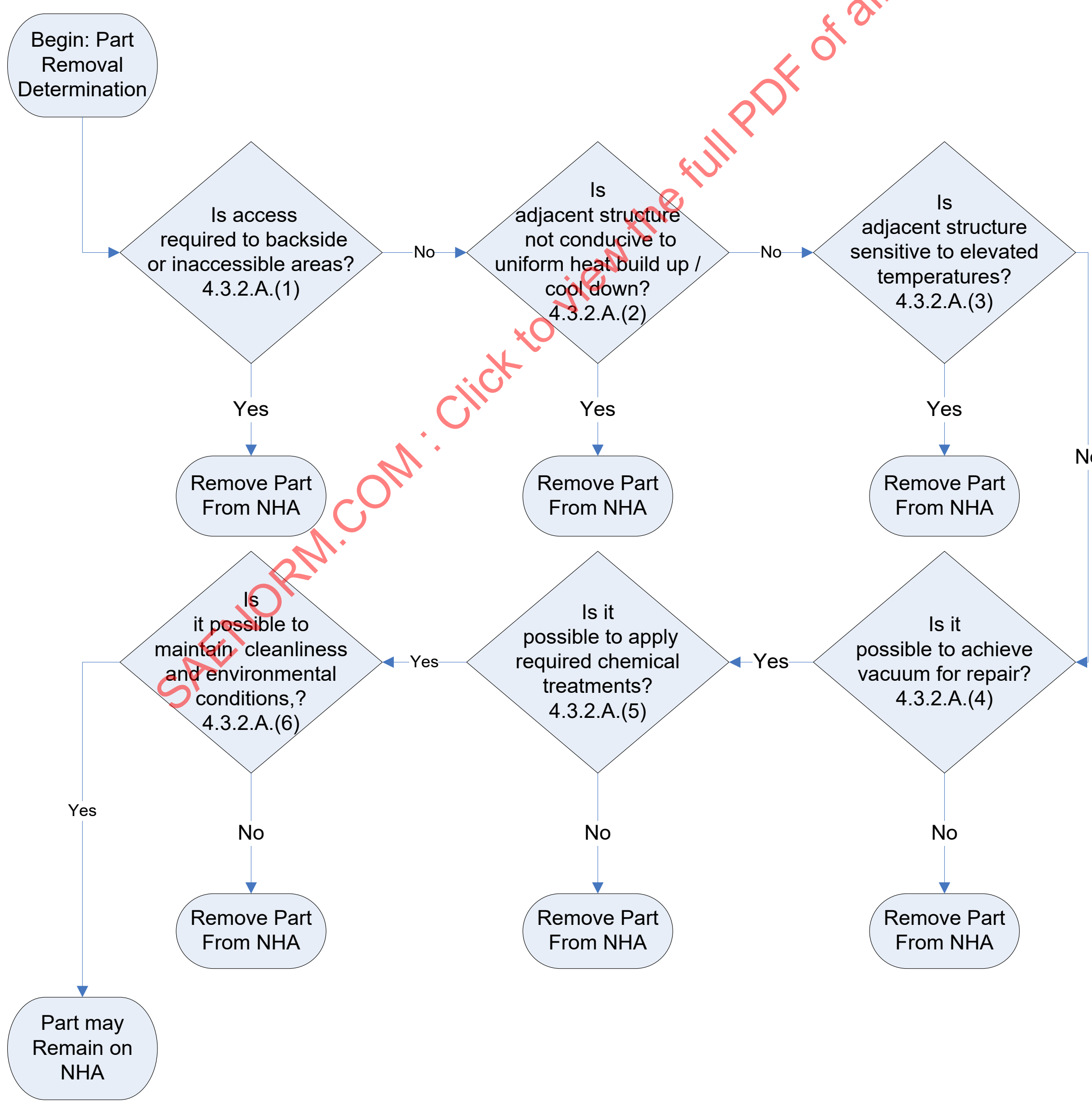


Figure 3 - Part removal decision flow

1. Access is required to areas that are inaccessible in the current situation to embody a repair or would encumber the repair technician's ability to perform all repair steps accurately to the required standard. For example, repairs may require access to the backside, which might not be achievable with the damaged component installed. Removing the part from the next higher assembly can provide the required access. Similarly, fittings close to the damage may need to be removed if the repair will extend beneath the footprint of the fitting.

   NOTE: Consider the complete repair process, including layup and vacuum bagging, when evaluating accessibility. Bagging and heating equipment could make limited space available; therefore, it is important to understand later steps with regard to space requirements.

2. Adjacent structure would not be conducive to uniform heat-up/cooldown rates during an elevated temperature repair cure cycle. An example of this might be performing a hot bond repair to a thin sandwich panel or plate that is adjacent to a large thermal mass, which acts as a heat sink.

   NOTE: Ribs, fittings, and heavy underlying structure are often fastened to bonded structure and can have significant local thermal heat absorption differences during elevated temperature repair. These types of structure often are not a part of the original bonded assembly per the OEM production drawings, which can be helpful in determining if these types of structure should be removed before attempting an elevated temperature repair cure. See Figure 4 for an illustrated example.

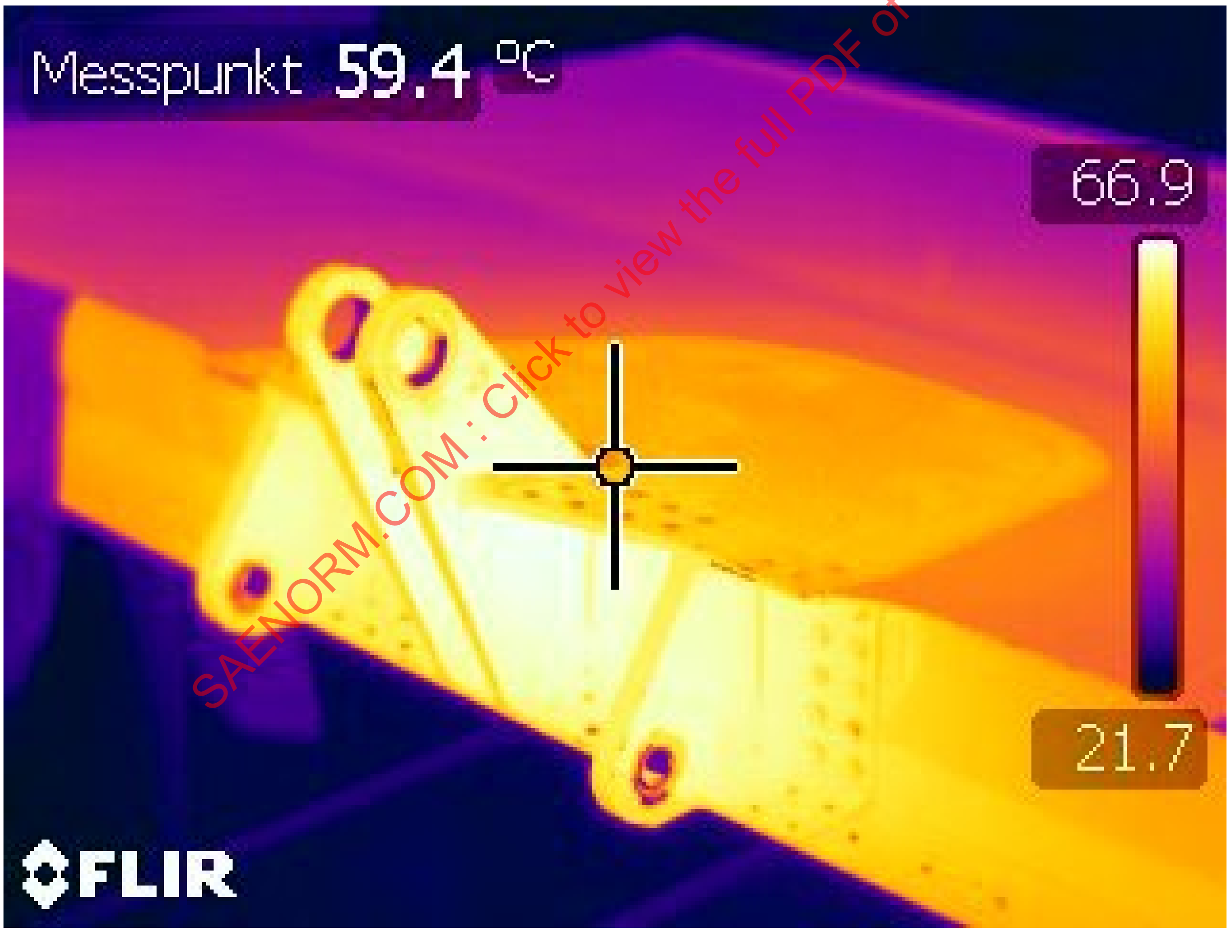


Figure 4 - Thermal image demonstrates how a metallic fitting acts as a heat sink

Thermal imaging can determine areas difficult to heat beforehand. Figure 4 shows a thermal image of a spoiler that has been heated in an oven. After taken out of the oven, the fittings cool at a slower rate than thin composite structure. In the image, the temperature near the fitting is above 60 °C while the structure further away has cooled significantly. This is the reverse of what could happen during the cure cycle in a repair, whereby heat is absorbed by the fitting and the cure temperature might not be reached.

3. Adjacent structure may not be rated at temperatures in the range of an elevated temperature repair cure cycle. Examples include fittings, sealants, or greases that may be damaged if exposed to temperatures beyond that allowed by a Customer-supplied maintenance manual.

NOTE 1: As an example, it is common for some assemblies, such as flight controls, to have independent leading edge structure that is attached to a bonded assembly. These leading edge elements can have fittings containing seals, greased bearings, alloys that are not intended to see exposure to elevated temperatures, finishes, such as paints, primers and other corrosion inhibiting agents that could each be compromised if subjected to high heat. These types of items should be carefully considered before using an elevated repair cure. See Figure 5 for additional detail.

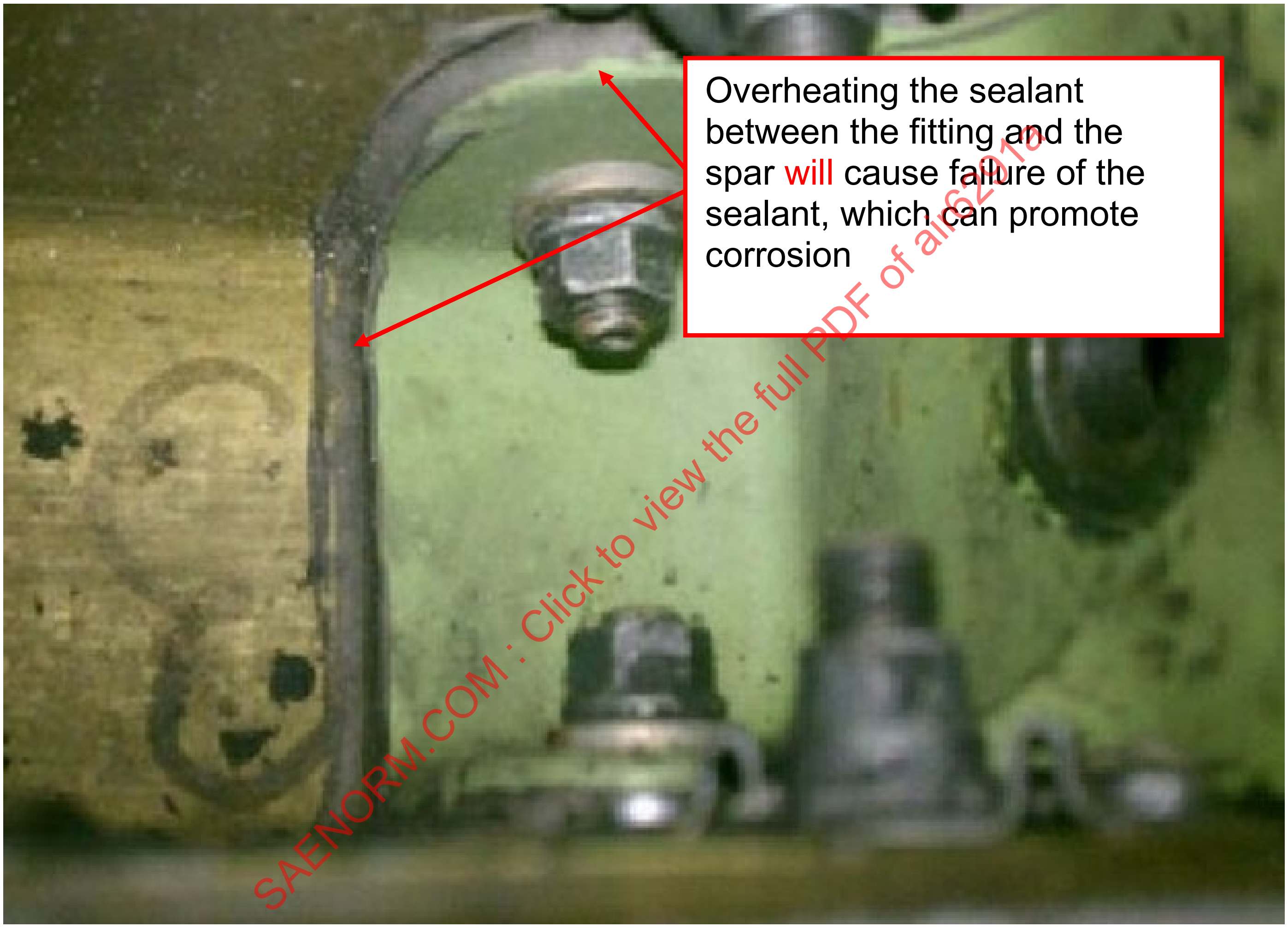


Figure 5 - Fitting bolted and sealed on the wedge after wedge manufacture

NOTE 2: Sealant can fail when heated above maximum permitted temperature.

A fitting (green primer) is bolted on the part (yellow tinted primer). It is likely that the sealant between the part at the fitting cannot withstand the elevated temperature needed to cure a repair. Degradation may not change the appearance or be detectable. Therefore, the fitting must be removed and reinstalled with new sealant after the repair.

4. It may not be possible to adequately apply a vacuum bag that provides the minimum required maintenance manual vacuum pressure and accepted leak rates for a vacuum-assisted repair cure. The following provides examples where disassembly is required to install a vacuum bag to reduce risk of pressure loss during cure:

(a) It can be difficult to maintain vacuum for bonded panels that are attached to other structure if the damage is close enough to a joint that requires that the vacuum bag bridge across two separate assemblies.

(b) It is important to assess the likelihood that an adjacent structure could be subjected to crushing if further disassembly is not accomplished prior to a vacuum bag step.

(c) An assessment should be made on any potential bagging hazards, such as bridging, fastener heads, and sharp or irregularly shaped underlying structure/inserts, to make sure that the bag does not break during cure.

(d) If the original construction is comprised of two sandwich panels that are attached to each other, with air cavities between the two panels, do not bag both panels in one bag, i.e., envelope bagging, to prevent crushing of the two panels. The damaged panel needs to be removed from the assembly.

5. It may not be possible to apply any chemical treatments required by the approved repair data for restoring bond surfaces for structural bonding.

(a) A repair technician can often be tasked with accomplishing surface preparation steps critical to the structural repair bonding where space is limited or access is ergonomically difficult.

CAUTION: The strength of a repair cannot be assured when critical steps in the process are done poorly due to access, ergonomics, or insufficient lighting.

(b) The ability to properly mask adjacent structure is important when applying any chemicals that are designed to chemically treat the existing base metal to prepare a surface for bonding. Having chemical agents seep between two structures during this process can have adverse effects on corrosion initiation or other considerations, such as damaging protective coatings.

6. It may not be possible to maintain maintenance manual required cleanliness, humidity, temperature, or other environmental requirements.

4.3.3 Assess the Damage

a. Identify any previous/existing repairs to the structure being assessed. The proximity of an existing repair to current damage may be relevant in later steps when repair options are considered. The materials and procedures that were used to accomplish the previous repairs must be understood in case these details need to be coordinated with Engineering, the OEM, and/or the Customer.

NOTE: It may be necessary to coordinate with the Customer to obtain historical information regarding the previous/existing repairs that are being assessed.

b. Using maintenance manual(s) and other approved data, determine the damage assessment procedures and make sure that these procedures are applicable to the part number and specific structural elements that are damaged. If removal of the structure from the aircraft or from any NHA will be required or anticipated, make sure that all applicable Customer-supplied maintenance manuals are in hand to accomplish these procedures before proceeding to the next steps.

c. If there are any specific tools or equipment that will be required to perform any removal procedures, procure these in advance before proceeding to the next steps. Examples might include shoring equipment, holding fixtures/slings, overhead cranes, jacks, alignment fixtures, or any other equipment that is nonstandard for performing general maintenance activities.

4.3.4 Remove the Part if Necessary

a. This section is applicable to both the removal of the damaged component from the next higher assembly and to the removal of fittings and parts from the damaged component.

b. If any structure removal instructions were identified in the previous section, review the Customer-supplied maintenance manual removal instructions and make sure that all removal instructions can be accomplished, without deviation, and that all required equipment and tooling is available for the repair.

c. If fittings must be removed, make sure that all tooling is available, if necessary, to realign critical hinge axis points, attach points, and any other critical functional aspects of the fitting upon reinstallation.

1. It may be necessary to set key characteristic alignment points using a specially designed AJ that captures a serial number specific set of key alignment points. Those set of points must be undisturbed until the repair is completed and fittings are reinstalled on the AJ that corresponds to that specific serial number NHA.

d. Perform all structural removals that were identified as being required in Step 4.3.2.a or Step 4.3.3.b. Use special care to not damage any underlying structure, as it is very common to damage lugs, composite laminate plies, and underlying sheet metal and honeycomb structure.

1. Any parts that are to be salvaged and reinstalled after the repair is completed shall be tagged and identified with the part number, NHA part, and serial numbers. The parts shall be stored adjacent to the NHA that is being repaired so that parts do not get lost or misplaced during the repair.

4.3.5 Identify the Part Construction

a. Using the Customer-supplied maintenance manual or other applicable OEM sources, such as Engineering drawings or written correspondence with the OEM, identify the materials of the structure that are damaged or are coincident to the damage site. A general mechanic or shop technician will usually be responsible for identifying part construction. Some identifying tasks may require additional metal bond specific technical knowledge. AIR6825 provides guidance for training for general mechanics or shop technicians to conduct the assessment.

1. Information to obtain may include, but is not limited to, the following:

(a) Skin, doubler, and any substructure part numbers that are damaged, including material type and temper.

(b) Part numbers for honeycomb core, including material identification, as follows: alloy type/material type, foil/wall thickness, cell shape, cell width, nominal density.

(c) Part numbers and material identification of coincident structure, such as spars, fittings, dust covers, gravel shields, and any other features that may be coincident to the damage site.

2. Determine construction details. Identify physical aspects of facesheet and substructure details, including the presence and edge of any internal doubler.

NOTE: The NDT techniques to be used for damage assessment require knowledge of bond line type (e.g., metal to metal or metal to honeycomb core) as well as knowledge of underlying support structure. Follow the supplied maintenance manual, repair manual, or other applicable OEM sources.

3. Identify the materials and adhesives used in the construction. Check against the Repair Document for repair materials that are applicable and available. The decision to process a repair may depend on the initial assessment of the repair materials and whether they can be procured quickly and for acceptable costs.

b. Using the Customer-supplied manual(s), determine if there are acoustic, weight, and/or balance requirements/limits considerations for the structure being assessed. It may become necessary to calculate or measure a new weight, acoustic blockage, and/or balance for the NHA after a repair is accomplished.

NOTE: If NHA requirements exist for weight and/or balance, identify a placard on the NHA that can help to determine previous repair weight and/or balance changes and how much additional rework can be done to the NHA before maximum rework limits are exceeded. Procedurally, this may greatly influence how and if the structure will be repaired. This step should be accomplished as early in the process as possible.

c. Regulatory actions may need coordination with the Customer before continuing with the repair. These regulatory actions are typically related to the type or category of structure. The OEM manuals will define the category of structure.

NOTE: Some customers, such as airlines, have specific unique actions that are required, per their Operations Specification, when working on types of structures such as Primary Structure, PSE, SSI, or FCS. Whenever a part being repaired is any of these categories, the airline is notified so that, if necessary, specific instructions can be given to the repair station on how to comply with the airline's Operation Specification requirements.

Example 4.3.5.c #1: An airline may have special SDR submission requirements for PSE, SSI, and Primary Structure, depending on the level of repair being accomplished.

Example 4.3.5.c #2: Many airlines have specific repair identification procedures and possible follow-up actions that are required on repairs to FCS structure.

1. The airline must have adequate information to identify a repair that might affect these types or categories of structure and that the final regulatory approved work documentation (such as an FAA 8130-3 form or equivalent) contain any required continued airworthiness instructions to the airline.

d. A customer may have additional requirements that must be considered and/or that may need completed before continuing with the repair. These requirements may be related to items such as placards, paint, labeling, mod status, and service bulletin status incorporation.

e. Identify acoustic requirements that may exist in the area of repair. Determine if the repair will be outside the acoustic limits given in the Repair Document. It may be necessary to replace rather than repair the part if acoustic limits will be exceeded.

4.3.6 Make Sure Facilities are Satisfactory

a. Review the Customer-supplied maintenance manual and determine the appropriate facilities and equipment that will be required to accomplish the damage removal instructions.

1. If the damage removal process creates dust and debris, make sure that the damage removal is accomplished outside of any areas adjacent to controlled contamination/layup areas. Before proceeding, make sure to comply with all local regulatory environmental laws, taking note of chromates and asbestos.

2. Make sure that appropriate air filtering devices are available for use, including personal protection equipment (PPE) with proper filtration as well as designated grinding areas, if appropriate for the procedure being accomplished. For heavy grinding of adhesives or other substrates, it may be necessary to dedicate a special booth equipped with filtered air purge/exhaust capability.

CAUTION: The inability to control contaminants in adjacent repair areas may lead to a compromise in the repair strength of adjacent parts or assemblies being laid up/prepared for bonding. Airborne materials, such as carbon dust and silicone particulate, may introduce galvanic corrosion, contaminate bond surfaces, and degrade bond strength that NDI or NDT is not able to detect.

4.3.7 Make Sure Personnel are Qualified

a. The technician responsible for removing the damage should have detailed knowledge of the structure so that, when removing the damage, the structure is not taken to a condition that is beyond economical repair.

NOTE 1: It is common that internally bonded details are damaged beyond economical repair by technicians that do not adequately understand the structural makeup of a bonded assembly.

NOTE 2: AIR4938, AIR5278, and AIR6825 give a summary of education levels and qualifications for assessment and repair of bonded structures. There are regulatory requirements for training.

4.3.8 Remove the Damage

a. Clean and mask the area.

1. Clean and mask the area around the damage to prevent cross-contamination. Refer to ARP4916. Dirt and grime can be misinterpreted as damage when documented by photographs. Follow health and safety instructions.

b. Remove impact damage if small enough for a local repair.

1. If impact damage is small and can be repaired economically by a local removal, then remove the damage per the instructions. Before removing damage, make sure that the repair size for the planned repair procedure permitted in the Repair Document corresponds with the maximum expected damage size.

c. Remove adherends if damage is too large for a local repair.

1. The removal of adherends from an adhesive joint will typically use either cold temperatures or heat to weaken the bond line.

(a) It is best practice to apply cold temperatures using dry ice to avoid heat damage during the removal process, as authorized by the Repair Document.

(b) If the Customer-supplied maintenance manual approves the use of heat sources, such as heat guns, to assist with the removal of adherends from an adhesive joint, use care to avoid subjecting the part to temperatures outside of the maintenance manual specified temperature ranges. An example of a component that has been overheated during removal of adherends is provided in Figure 6.

CAUTION: Overheated areas outside of the intended damage removal zone may result in the alloys and adhesive materials with reduced strength.

(i) Monitoring devices should be used to make sure that the temperature stays within the required range. Perform a visual inspection for discoloration or other indications of damage to finishes or aluminum after the application of high temperatures.

NOTE: Excessively overheated parts also may result in damage that can render the part to be irrepairable beyond reasonable expense (scrap).

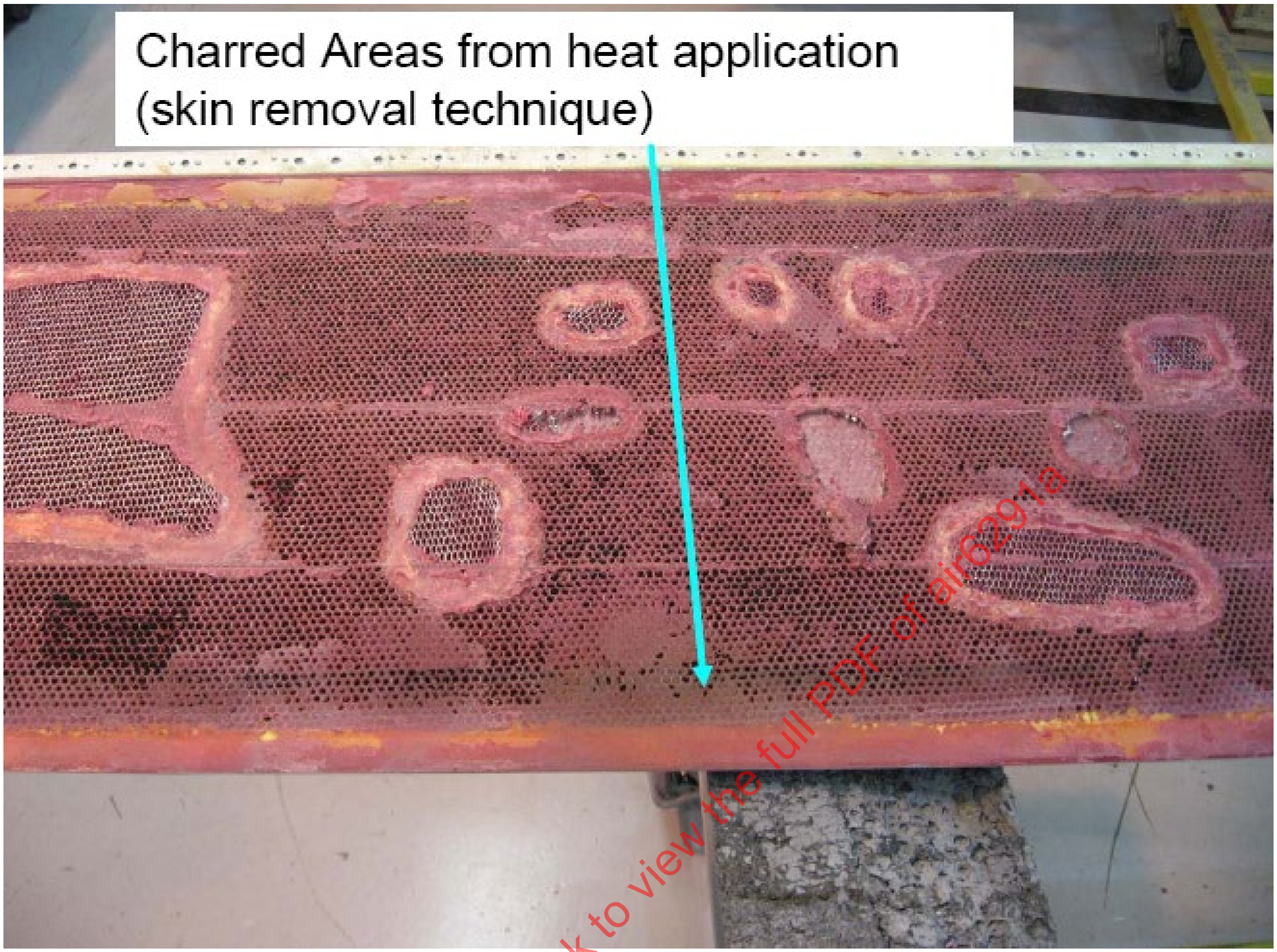


Figure 6 - Example of overheating during skin removal

2. When prying/peeling skins or other damaged structure from the base assembly, tools should be used that will not gouge the base assembly and materials should be selected that are not abrasive (use soft materials such as plastic or wooden scrapers). Make sure that underlying structure will not be damaged during this removal process.

   NOTE: In order to facilitate Step 4.4.2.b, use care to not damage remaining adhesive film to avoid exposing bare metal. Exposed bare metal will require additional repair steps. Residual adhesive may be acceptable if permitted by the Repair Document.

d. Inspect the core condition and remove damaged core.

1. Inspect the part for core damage. A visual inspection for physical damage to the core should be accomplished. Types of core damage include:

   (a) Separation of the cell wall node bonds.

   (b) Crushed cells.

   (c) Fractured or torn wall cells.

2. Remove damaged core.

(a) For full depth core removal, when authorized in the Repair Document, protect the previously bonded skin from damage by leaving the existing skin-to-core adhesive layer intact. Prepare the repair skin-to-core mating surface by only removing any remaining adhesive fillets or other anomalies/irregularities using abrasive methods. Ensure a smooth faying surface for subsequent bonding of the replacement core.

4.3.9 Inspect Core Condition and Remove Corroded Core

a. Inspect the part for corrosion.

1. Visually inspect for local corrosion before finalizing the damage removal process. Aluminum honeycomb core often develops discoloration or white powdery substance (corrosion) on the foil. The non-corroded core should have a continuous silver color. See Figure 7 for an example of how corroded aluminum core can extend beyond the physically disbonded area. Figure 8 shows how corroded aluminum metallic core is exhibited on a flight control surface. Figure 9 shows how failure due to corrosion on either skin or core is visually exhibited on the bond line surface.

NOTE: Use of a direct light source (i.e., flashlight/torch) can help identify discolored core surfaces, which indicates corrosion.

2. To find the limits of any weakly bonded skin, it is recommended that the skin be peeled back in a direction away from the area that has core already exposed from damage removal until strongly bonded skin is reached.

CAUTION: Weakly bonded skin is typically adjacent to disbonded areas. Such weakly bonded skin is not detectable by standard NDI or NDT methods and, if left in place, may result in actual disbond either during cure of a repair or in a relatively short time following the repair when the part is placed back into service.

3. For non-corroded bonded areas, when peeling the skin from the core, typically the cell walls will break or tear or the adhesive fillets will detach completely from the skin and will remain attached to the core. Another sign that corrosion has affected the core is the absence of broken core cells or adhesive fillets still on the skin.

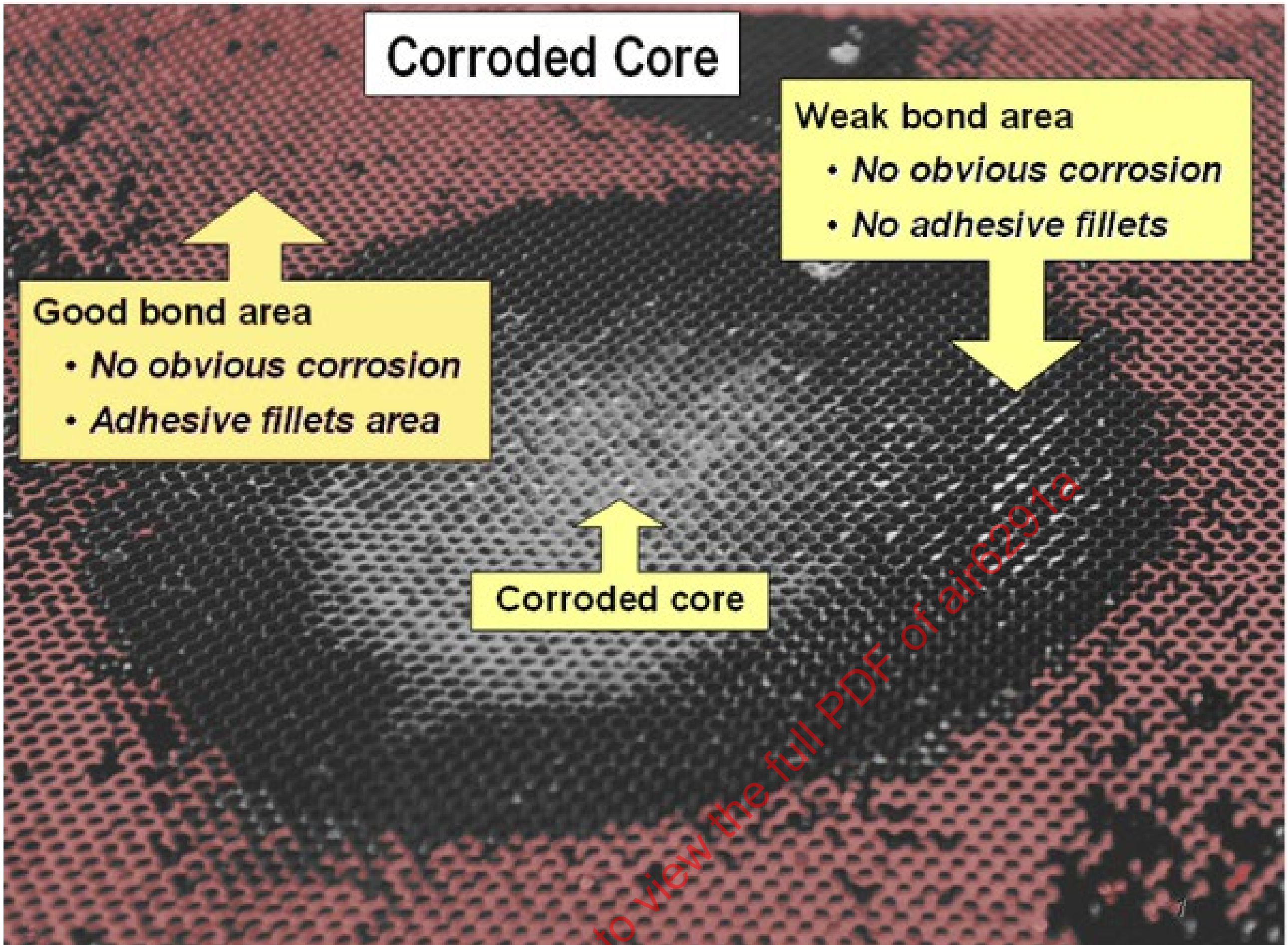


Figure 7 - Corrosion of aluminum honeycomb core resulting in a weak bond area

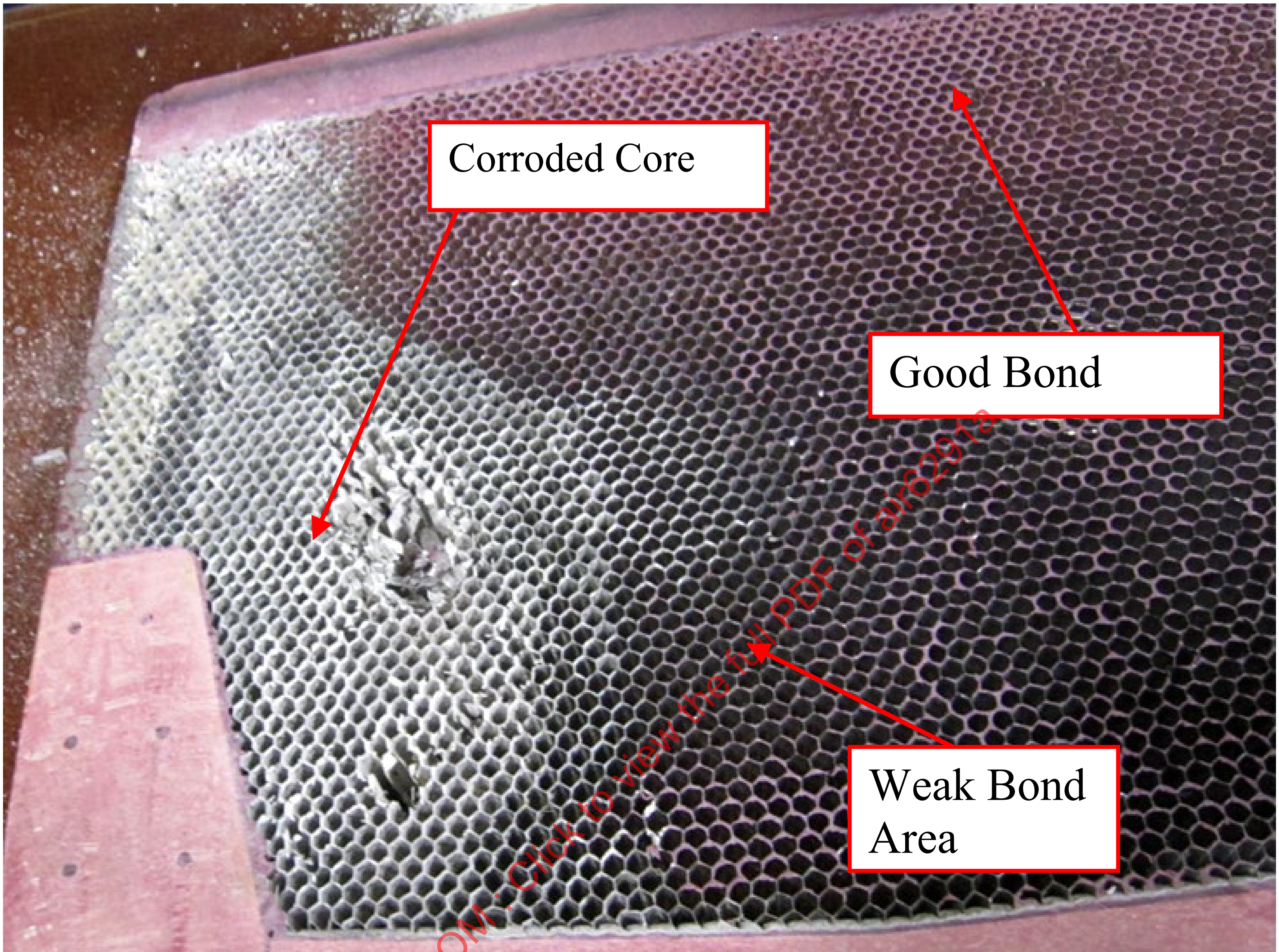


Figure 8 - Example of corroded core weak bond/good bond areas. Note that the corrosion area corresponds with a typical moisture ingress path (exposed honeycomb core edge with only a sealant close-out).

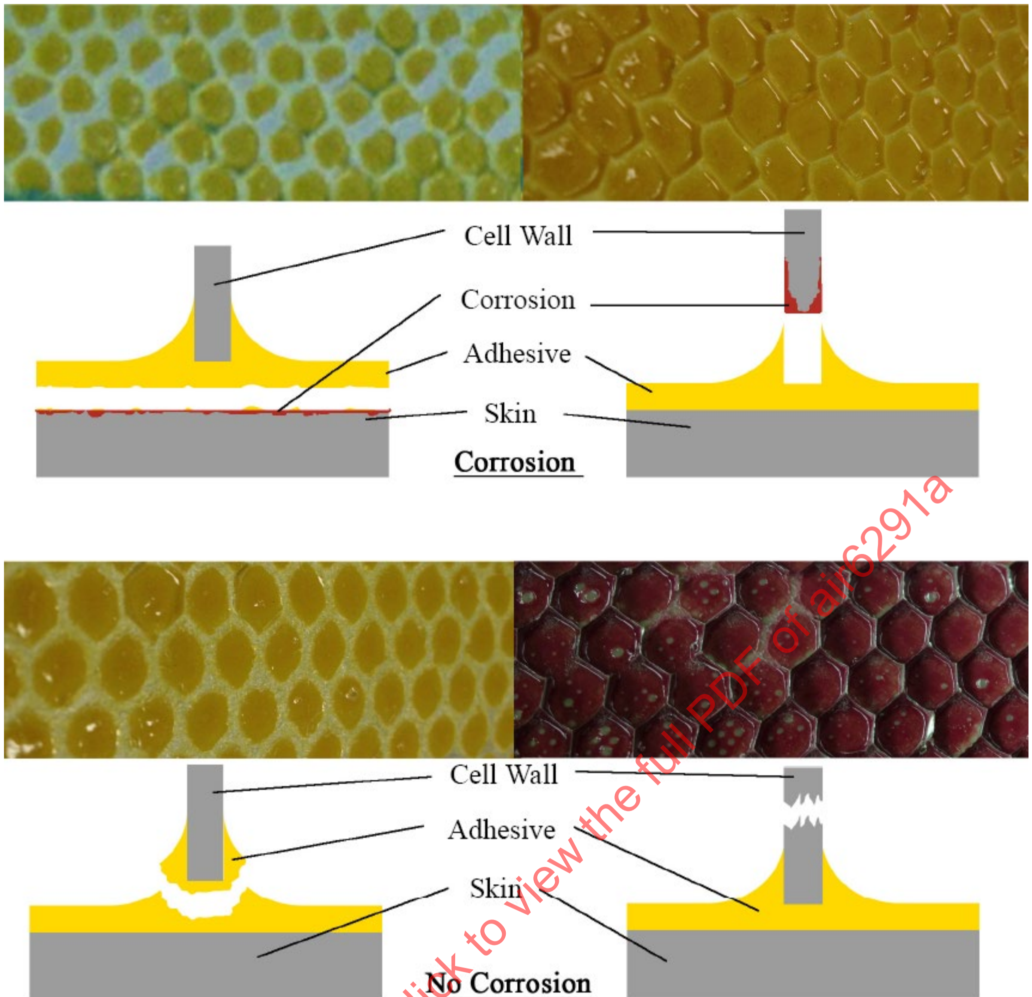


Figure 9 - Examining peeled skin and residual core for evidence of corrosion

NOTE: Failure modes due to corrosion are shown in Figure 9. On the upper left, corrosion occurring in the skin facesheet is shown by a lack of adhesive remaining on the skin when the core has been removed. On the upper right, corrosion that occurs in the cell walls will leave all adhesive on the skin facesheet. The lower photographs show acceptable failure modes. On the lower left, the failure is within the adhesive itself, where some amount of adhesive remains on the skin facesheet. On the lower right, the core cell wall has fractured with no adhesive failures.

b. Remove corroded core.

1. Make sure that corroded core is removed.

CAUTION: Failure to remove corrosion is not acceptable because the strength and durability of the repair cannot be assured. One of the frequently observed causes of failure of repairs in service is due to incomplete removal of corroded core.

2. Verify that no evidence of corrosion exists at the edges of the facesheet cutout. It is necessary to remove additional facesheet areas until there is no longer any visual evidence of corrosion in the core.

4.3.10 Consider Nondestructive Inspection (NDI) and Testing (NDT)

a. Select NDI or NDT method for damage assessment.

1. Select an appropriate NDI or NDT technique to identify the extent of damage and to verify that the damage is completely removed. The Customer-supplied maintenance manual will specify which inspection techniques are approved; however, the following considerations should also be made:

(a) The NDI or NDT technician should be trained or qualified on the equipment that is being used prior to evaluating the condition of any bond and should have passed an evaluation on that equipment in accordance with the organization's repair station manual and should also possess any additional maintenance manual required certificates.

(b) If using audible NDI, such as sonic tap test, it is important that the technician be able to audibly detect a disbond in a joint from a standard that is made from the same gauge adherend that is used on the actual part being repaired. This is to account for individual differences in hearing acuity. The OEM NTM or NDT manual will typically give limits of detectable flaws and thickness limits for the test methods.

NOTE: Tap tests should be performed in an area that has low ambient noise in order to adequately evaluate the audible differences in pitch.

CAUTION: Tap testing is limited in its capability to detect damage. It is only appropriate for thin facesheet (~0.030 inch) sandwich construction.

2. X-ray can be used to help determine if moisture has been removed in sandwich panels.

b. Select NDT method for repair acceptance.

1. Select an appropriate NDT technique to accept the repair. The Customer-supplied maintenance manual will specify which inspection techniques are approved for the acceptance criteria for the repair process and structural configuration. The same considerations apply to repair acceptance NDT as listed in 4.3.10.a.

BEST PRACTICE: NDT methods for inspection of repairs are through transmission ultrasonic (TTU) if two-sided access is available and ultrasonic bond test methods, e.g., pulse echo, (PE), if one-sided access is available.

NOTE: ARP5089 contains a summary of NDT techniques and capabilities.

c. Make sure NDT equipment is acceptable.

1. Before using any NDT method, make sure that the equipment meets the calibration and certification requirements.

2. Make sure that, when required, reference standards are available that match the construction of the part being inspected to make sure that readings of the equipment are calibrated properly.

d. Do the NDT inspection.

1. Do the NDT inspection as specified in the manufacturer's repair and NTM or NDT manuals.

2. If additional damage is detected, repeat Step 4.3.10 until damage is verified to be completely removed.

CAUTION: Moisture or other contaminants may migrate and may be present at locations away from the local area being repaired. Conduct a thorough evaluation and inspection of the part to make sure all contamination has been removed. The durability and strength of the repair cannot be ensured if the contamination is not entirely removed in the part.

3. Remove debris and dust from the repair area and surroundings. Follow health and safety instructions.

4.3.11 Select Applicable Repair Method

a. Review the maintenance manual or SRM section that was determined in Step 4.3.1 for guidance on repairing the damage removed during Step 4.3.8. Make sure that the cleaned-up damage is within the limits given in the manual repair section before proceeding.

   1. If the cleaned-up damage is determined to be outside of the limits established by the maintenance manual repair section as being repairable, contact the Customer engineering department to obtain an approved repair procedure in order to proceed.

b. Determine if there are applicable Repair Documents using the applicable authorized source documentation.

   1. If there are multiple repair solutions in the authorized source documentation, determine which one would best suit the current need.

   2. If currently no repairs could be found in the applicable authorized source documentation, contact the Customer, Engineering, or OEM. It is best practice to provide a damage report when contacting Engineering/OEM/Customer. Check whether the OEM gives guidance on the contents of a damage report in published documentation. The damage report should contain the following:

      (a) Identification of the damaged part and aircraft when the part is installed on the airplane. This would consist of the part number, the serial number of the part when applicable, modification status, the aircraft serial number, the aircraft registration number, and the aircraft operator.

      (b) Description of the type of damage (impact, disbond, gouge, corrosion, etc.) and source of damage when known.

      (c) Size of damage (length, width) and identification of exactly which component details are damaged or disbonded. Different details can have different damage dimensions. It is important to document all damage details (external doubler, skin, internal doublers, core, etc.) to ensure the applicable repair is selected.

      (d) Location of the damage with respect to identifiable positions (fasteners/edges/fittings/changes in geometry).

      (e) Location and description of previous/existing repairs to the structure as assessed in 4.3.3.a when applicable.

      In addition, the damage report can contain the following:

      (f) Photographs of the damage in general overview with either the complete part or easily identifiable section of the aircraft. The photographs should provide information on the location and orientation on the airplane. Local photographs with a scale reference. These should show the damage, a ruler for scale reference, and identifiable features on the part such as edges, fittings, and fasteners. If available, include the outline of the damage found in NDI.

      (g) Detail photographs with scale reference to show the dimensions of the damage. Also, label depth/location of any internal damage if known.

      (h) Propose repair approach based on published repairs. Include the preferred and/or available repair materials.

      (i) References to similar damages could result in a faster response time from the engineering/OEM.

c. The selected repair needs to be conducted using a Qualified Bonding System. Refer to AC20-107B and AMC 20-29. The Repair Document provides instructions on how to implement a repair per a Qualified Bonding Process and must be strictly followed. The capability to conduct a repair to the specified Qualified Bonding Process must be confirmed. The Qualified Bonding Process must be demonstrated with repeatable and reliable processing steps and includes an understanding of the sensitivity of structural performance based upon expected variation permitted per the process. Even characterization outside the process limits is recommended to ensure process robustness. Refer to DOT/FAA/AR-03/53 for an explanation of the critical effect of surface preparation to the adherends for initial strength, long-term durability, fracture toughness, and failure modes of bonded joints.

d. The use of vacuum pressure can have adverse effects on some types of adhesive. Repairs that are accomplished without using proper pressure levels can significantly deteriorate the quality of the bond. Make sure that the proper vacuum techniques are selected for the adhesive. Figures 10 and 11 demonstrate a poor-quality bond due to foaming of adhesive under vacuum pressure.

1. Refer to Stancin and Van Voast for further details on bond strength with respect to growth in repair size.

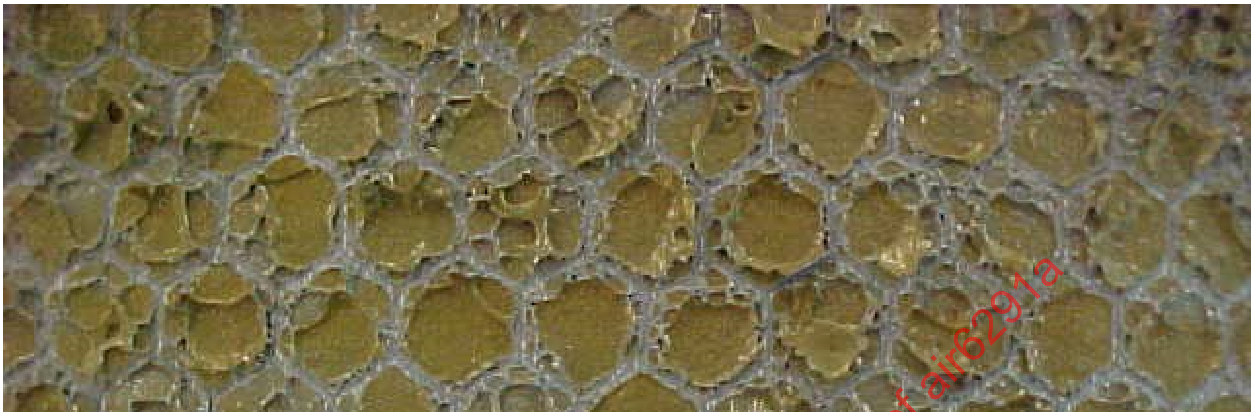


Figure 10 - Foaming of adhesive due to the improper application of vacuum pressure

NOTE: Figure 10 is an illustration of a type of film adhesive that is not able to be cured under vacuum pressure.

e. Other factors that can contribute to foaming of film adhesives include the following: not removing all moisture prior to bonding, improper orientation (scrim cloth up or down) of the film adhesive, improper cure or vacuum integrity, and omitting any required breathing assistants, such as positioning fabrics, which may or may not be required/allowed by the Repair Document.

Figure 11 - Autoclave and vacuum processed test coupons. Autoclave processed test coupon (left) shows ideal adhesive bonding condition. Vacuum processed test coupon (right) shows failures due to foaming of film adhesive.

4.3.12 Assess Facilities and Equipment

a. Make sure that all facility, equipment, and required technician capabilities that are listed within the maintenance manual repair section are within the capabilities of the repair organization that will be accomplishing the repair procedures. See Figure 12.

CHECKLIST ITEM	REFERENCE PARAGRAPH	ACTION
Make sure all on-site repair equipment is up to date.	4.3.12.a.1	
Make sure the environmental conditions can be met.	4.3.12.a.2	
Make sure equipment can provide required vacuum pressure.	4.3.12.a.3	
Make sure cleanliness and contamination control conditions can be met.	4.3.12.a.4	
Make sure the facility has equipment and chemicals for surface prep.	4.3.12.a.5	
Make sure refrigerated storage facilities can maintain temperatures.	4.3.12.a.6	
Make sure shelf life and out time is monitored for TATS materials.	4.3.12.a.7	

Figure 12 - Facilities determination process checklist

1. Verify that all equipment that is required in the Repair Document for accomplishment of the cure is on hand/available and that all certifications and calibrations are current.

   (a) Heat blankets, ovens, or autoclaves are common equipment used for aluminum bonded repairs. Testing and/or calibration are required to make sure that these types of equipment are serviceable prior to use. Refer to ARP5144 for testing methods for heat blankets and thermocouples.

   (b) Thermocouples should be verified, through either certification or test, that the required precision, as defined by the Repair Document, is met for each thermocouple used during the repair.

2. Verify that the environmental conditions that are required by the Repair Document can be met at the time that the repair will be accomplished. The range of acceptable ambient temperature and humidity values should be listed in the Repair Document. AC 43-214 defines requirements for controlling temperature and humidity.

   (a) Humidity and temperature levels in the repair layup area are critical. Depending on the location where the repair will be conducted, it may be difficult to meet both temperature and humidity requirements when the atmospheric temperature and humidity are in extreme conditions.

   CAUTION: Humidity can have profound adverse effects on the chemical bond between aluminum and adhesive and the mechanical properties of structural adhesives. Failure to follow all environmental condition requirements may result in a repair that is structurally noncompliant and may fail in service.

3. Verify that the vacuum required by the Repair Document can be met by the equipment at the altitude where the repair will be accomplished.

   NOTE: During vacuum bag repairs, attain as much vacuum as possible. Studies show that at sea-level there exists about 29.92 in Hg of atmospheric pressure and about a maximum of 27 to 28 in Hg of vacuum level can be achieved. However, at 10000 feet altitude, there exists only about 21.5 in Hg of atmospheric pressure and one can achieve only about a maximum of 16 to 19.2 in Hg of vacuum. Therefore, at higher than sea-level altitudes, use of a high-quality electric vacuum pump may be preferable over the Bernoulli-style aspirator (converts high-pressure air to vacuum) found on most hot bond consoles. Many of the two-stage diaphragm pumps may be rated lower than 28 in Hg; therefore, a technician should be careful when selecting an electric pump. The Repair Document should reflect the acceptable vacuum levels for the repair materials being used and any associated bagging or debulking steps.

4. Review the Repair Document and confirm layup area requirements for contamination control and cleanliness/cleaning schedules can be met.

   (a) A controlled contamination area (CCA) may be required for the repair so that oils, lubricants, dirt/dust, and other contaminants are at levels that are acceptable for structural bonding.

   (b) Specific cleaning procedures and cleaning interval requirements may be required by the Repair Document for the area in which layup is to be conducted.

5. Verify that the facility possesses the required equipment and/or chemicals to accomplish all of the surface preparation procedures that are required in the Repair Document. Inadequate facilities can lead a technician to attempt a surface preparation technique that is inappropriate for the repair being accomplished. As shown in Figure 13, using inappropriate surface preparation techniques can potentially lead to catastrophic events.

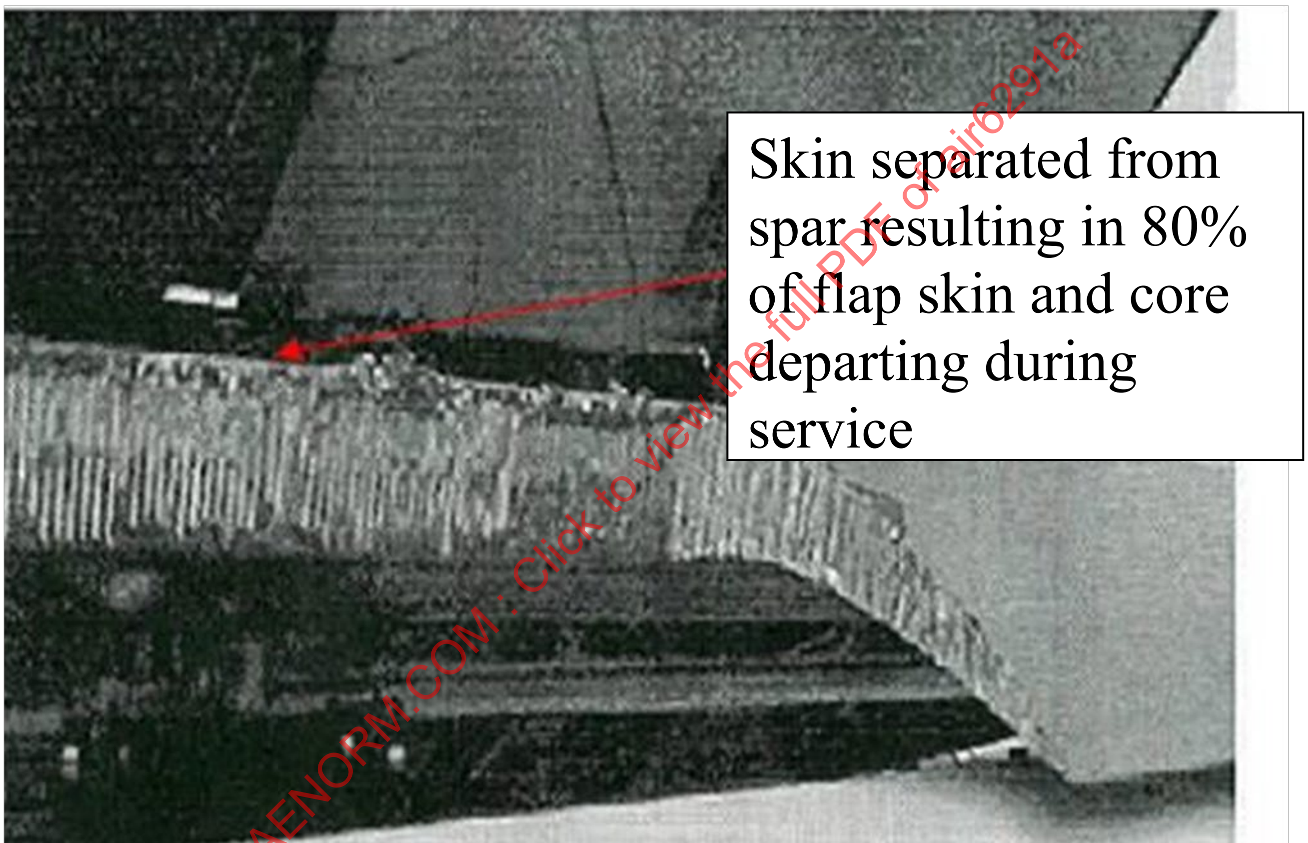


Figure 13 - Catastrophic failure of a flight control wedge assembly that was repaired using alternate (and inappropriate) surface preparation procedures

6. Verify that all refrigerated storage environments have the capability of maintaining the temperature ranges required by all material specifications referenced by the Repair Document.

   (a) It is required to be able to demonstrate that the temperature of all time- and temperature-sensitive materials remains within the tolerance specified in the Repair Document. The following methods are acceptable for monitoring material temperatures (listed in preferred order):

      (i) Continuous automated recording.

      (ii) Automated alarm.

      (iii) Scheduled temperature gauge reading.

NOTE: Backup power generators are recommended for all automated monitoring devices and refrigerators/freezers. It is normal practice that if a power loss or a monitoring gap is experienced, the duration of that event must be subtracted against the remaining out-time of the time- and temperature-sensitive materials. Materials must be scrapped if out-time limits are exceeded.

(b) It is required that all refrigerated environments are equipped with a calibrated temperature recorder or indicator.

(c) It is required that all refrigerated environments are alarmed to indicate temperature excursions.

(d) It is required that a documented procedure exists that describes the actions to be taken after a temperature excursion.

7. Verify that there is a system in place that monitors and records shelf life and out-time for time- and temperature-sensitive materials.

(a) Use of time- and temperature-sensitive materials requires that the repair technician know the material expiration date, understand how much exposure time the material can be subjected to outside of refrigerated environments, and understand the number of defrost cycles before that material can be used in a repair.

4.3.13 Procure Materials/Parts/Consumables

a. Any materials that cannot be verified to meet all of the requirements listed within this section shall not be used on a repair.

b. All personnel that will be receiving, transporting, and storing materials that are procured per this section must be trained to understand and comply with the time and temperature limitations as well as packaging and appropriate contact media requirements.

c. From the approved Repair Document, confirmed as applicable for the subject damage during Step 4.3.11, procure all repair materials that are listed in the Repair Document.

1. For each repair material, check if there is a requirement to have the material qualified/certified to an OEM or industry specification.

Example 4.3.13.c.1: The repair procedure calls out the use of BR127 adhesive primer certified to U.S. Army Drawing #13632068. Using BR127 adhesive primer certified to a different specification would not necessarily meet the requirements of the repair procedure. The manufacturer of the adhesive primer, in this case, may be able to provide additional certification paperwork, or the OEM for the damaged bonded assembly may be able to authorize the use of a different certification. In general, the requirement is not met until either the certification matches the repair procedure or an alternative has been approved through Engineering and the Customer.

2. For each repair material being procured from an outside source, make sure that all materials are being shipped/packaged in accordance with all requirements that are listed in procedures in the Repair Document.

(a) Improper shipping procedures can negatively affect the strength of the materials that are being shipped, especially if the materials are time and temperature sensitive.

NOTE: Time- and temperature-sensitive materials are usually shipped refrigerated or packed with dry ice (frozen carbon dioxide) with temperature monitoring devices to make sure that the temperature of the materials is maintained within specification requirements throughout transportation. Experience has shown that time- and temperature-sensitive materials often are left on receiving docks for extended periods of time before they are routed to a refrigerated area. The cause can often be traced to a lack of training for receiving personnel.

(b) It is important to fully understand all of the requirements for shipping prior to making arrangements for delivery of any material. Improper packaging can result in degradation of sensitive coatings, such as adhesive primer that has been cured to a metal adherend prior to transport. Ultraviolet light can be harmful to some materials.

(c) If there are certain shipping companies that are required to deliver the material to maintain its certification to the required specifications, make sure that these shipping companies are being used. Some Repair Documents require that only specific shipping companies and material distributors be used during the transfer of the material from the OEM to the repair station in order to maintain the mechanical properties of the resins contained within the time- and temperature-sensitive materials. If this is the case, make sure that all distributors and shipping companies used comply with the approved list of suppliers listed in the Repair Document.

3. Before materials arrive from an outside source, read through the procedure in the Repair Document and all referenced material storage and handling requirements to make sure that the facility that will be receiving the materials will have adequate storage/staging capabilities for all materials being procured. For additional details, see Step 4.3.12.a.

(a) For parts and materials that must be kept in a controlled contamination environment, such as clean core or pretreated metal, it should be verified that such a storage space will be available at the receiving facility to maintain cleanliness throughout the lifetime of the material.

(b) Bulk core and core details prior to use should be bagged to protect from dust and contamination.

4. When time- and temperature-sensitive materials are received from an outside source, verify that all receiving tests are being complied with prior to acceptance for use with a repair. Some specifications used in the repair procedure may have requirements to accomplish tests, such as mechanical property, flow, gel, or other tests to make sure that the material has not degraded in any way due to the shipping processes.

(a) Check to make sure that all required receiving inspection tests are performed, as required by the repair specifications, and meet all repair specification requirements before accepting that material into the repair environment. Receiving inspection tests may be required to be accomplished by the distributor and by the repair station that is receiving the material.

5. When working with materials that have known performance issues from service history, the OEM or Customer may be able to approve substitutions to increase the service life of the repaired part. Make sure that approval is obtained from the Customer and Engineering before choosing better performing alternate materials.

Example 4.3.13.c.5: If the repair procedure does not use phosphoric acid anodized (PAA) processes (or laboratory-tested equivalent processes) for aluminum repair details, such as honeycomb core repair plugs or sheet metal/machined parts, it may be possible to revise the procedure to use PAA treated details to improve the longevity of the repair.

NOTE: For possible repair design improvements, refer to AE-27, Design of Durable, Repairable, and Maintainable Aircraft Composites. This document is available through SAE.

6. Service history has shown that aluminum bonding with non-PAA (or equivalent) elements have resulted in more widespread corrosion than comparable parts designed with PAA (or equivalent) treatment processes. See Figure 13 and Figure 14 for cautionary detail.

Example 4.3.13.c.6 #1: If the repair procedure uses 7000 series Clad aluminum sheet, it may be possible to revise the procedure to use comparable 7000 series Bare aluminum sheet replacement with enhanced corrosion treatment. Service history has shown that aluminum bonding with 7000 series Clad materials results in cases of the Clad surface disbonding over time from the aluminum sheet.

Example 4.3.13.c.6 #2: If the Repair Document requires the replacement of aluminum honeycomb core and the repair procedure requires the use of a pour coat liquid adhesive, it may be possible to eliminate the liquid pour coat adhesive if the repair employs the use of PAA treated honeycomb core. Liquid pour coats were often used as a corrosion preventative coating before PAA core was developed. Customer and Engineering evaluation and regulatory approval to eliminate liquid pour coat is required in order to ensure compliance with all regulatory requirements.

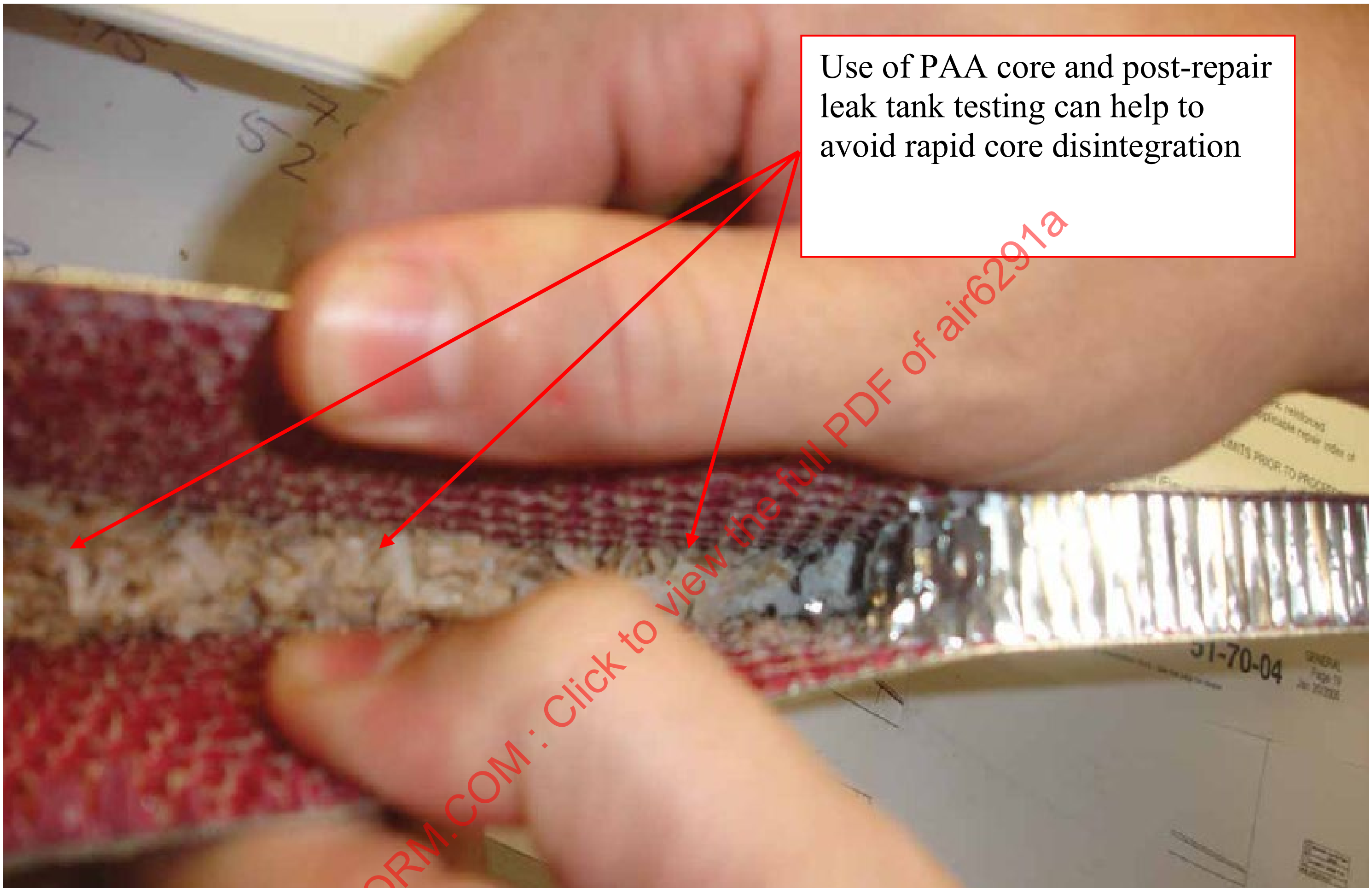


Figure 14 - Non-PAA aluminum honeycomb core found disintegrated after less than 2 years flight time

d. Procure approved consumable and contact materials.

1. From the approved Repair Document, confirmed as applicable for the subject damage during Step 4.3.11, procure all consumable materials that will be used to conduct the repair.

2. For each consumable material, check if there is a requirement to have the material qualified/certified to an OEM or industry specification.

3. Consumable materials may be controlled by the Repair Document because of possible contamination to the bond surface or to adequately prepare the bond surface.

CAUTION: The Repair Document may permit only specific combinations of consumable materials with repair materials for which material compatibility has been shown as a Qualified Bonding System. Materials may be substituted only with authorization from Engineering/OEM/Customer. The strength of the bond may be reduced and cannot be substantiated should materials be substituted.

4. All purchased products that come in contact with the repair material are to be controlled and approved to avoid bond contamination and include the following:

   (a) Marking materials

   (b) Clean rags (non-laundered, lint-free)

   (c) Powder-free gloves

   (d) Sanding material or abrasive paper as per Repair Document

   CAUTION: Stearated abrasive papers containing lubricants or soap to prevent clogging and extend the work life should not be used. Non-stearated adhesive papers must only be used. A residue may be left in the bond line that is not detectible with NDT and result in an under-strength bond.

   (e) Solvents

   (f) Release film

   (g) Mold release

   (h) Peel ply

   CAUTION: As some bonding processes are sensitive to the type of peel ply being used, only peel ply materials specified by the Repair Document are to be used. For the technical explanation for the control of peel plies refer to DOT/FAA/AR-06/28.

4.3.14 Inspect the Materials/Parts/Consumables

See Figure 15 for the process of inspecting repair materials and parts.

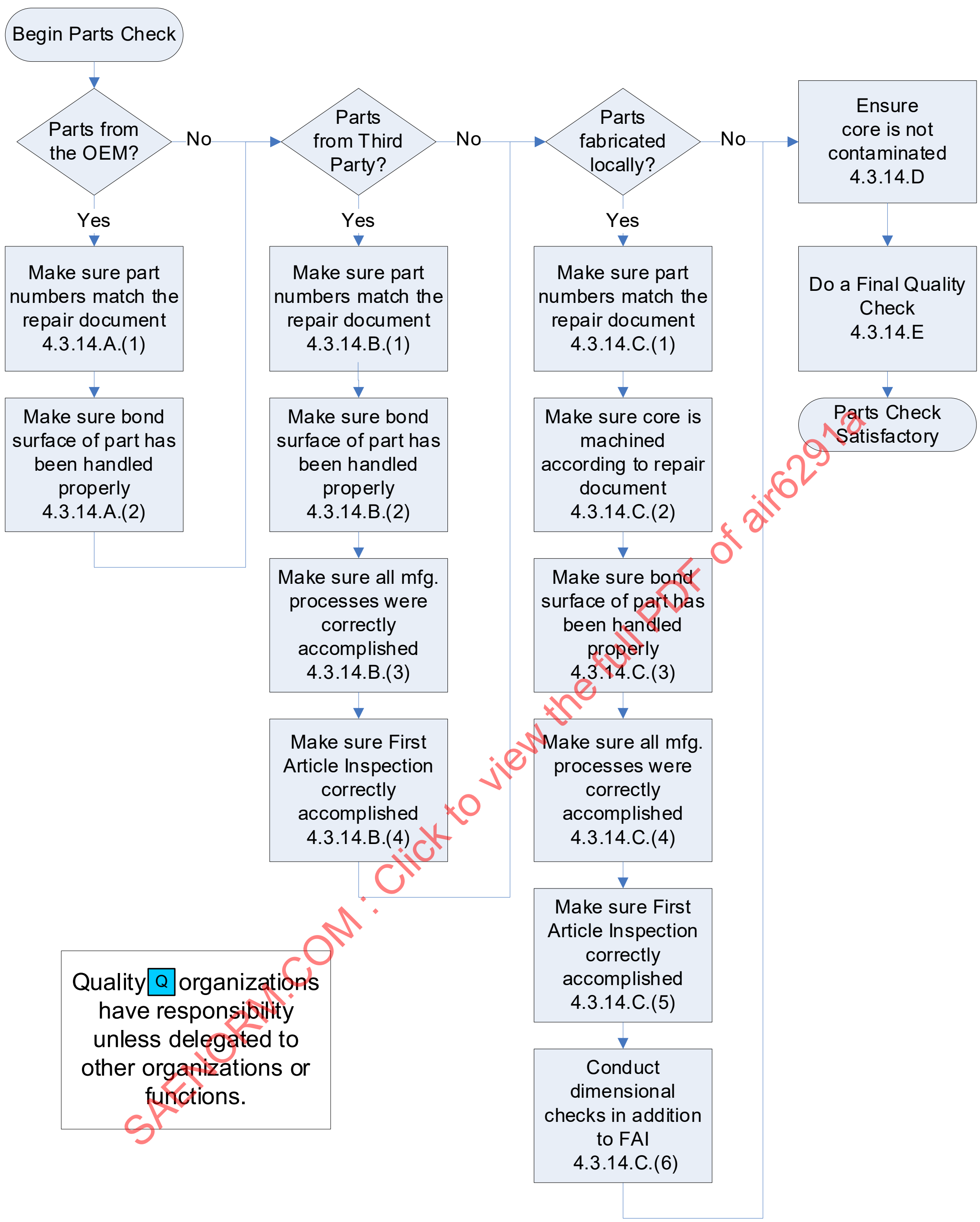


Figure 15 - Parts check process flow

a. OEM Procured Parts

1. Examine the parts to make sure that all OEM purchased parts have the correct part number, as defined in the Repair Document.

2. Make sure that the bond surfaces of the part have been protected, as follows:

   (a) Handling and storage of detail parts can be restrictive, depending on the criticality of the coating/finish of the part. Mishandling these types of parts can severely compromise the bond strength of the repair.

Example 4.3.14.a.2(a) #1: Aluminum honeycomb core that was machined in a clean machining environment using clean machining processes and is labeled as “clean” core (i.e., it can be used in a repair without vapor degreasing) must not be touched with bare hands and should also not be removed from its original sealed packaging until the core is moved to a CCA and is ready for installation into the repair to prevent contamination. The approved contact materials for handling will be listed within the Repair Document or within reference specifications that are in the Repair Document.

Example 4.3.14.a.2(a) #2: Aluminum PAA and bond primer painted aluminum details (such as skins, doublers, spars, ribs, etc.) have delicate bonding surfaces that are very sensitive to contamination and ultraviolet exposure. For these reasons, these details are typically packaged either wrapped in non-waxed kraft paper, sealed in black polyurethane bagging materials, or vacuum sealed to opaque, nonpermeable film. These types of details should be handled without their protective wrappings only in a CCA and should not be touched with bare hands or unapproved contact materials under any circumstances. The approved contact materials for handling should be listed within the Repair Document or within reference specifications that are in the Repair Document.

(b) Some detail parts, such as PAA processed and bond primer painted aluminum parts, have an expiration date associated with them that starts from the date of primer application. It is critical that parts not be used past their expiration date.

(c) When the part arrives to the appropriate location for examination (which may be within a CCA if the part is received ready for bonding), a general visual examination should be conducted to make sure that there are no obvious defects or shipping/handling damage. The part should also be verified to visually match the description of the part shown in the Repair Document.

b. Third-Party Procured Parts

1. Examine the parts to make sure that all repair parts purchased from a third-party fabricator have the correct part number, as defined in the Repair Document.

2. Make sure that the bond surface of the part has been protected as per Step 4.3.14.a.2.

3. Make sure that all manufacturing processes were correctly followed.

(a) The repair station is responsible for verifying that all raw stock and processes that are required by the repair drawings with which the parts are made have been accomplished properly by the third-party fabricator in accordance with the OEM specifications.

(b) Certification of each raw material used and process accomplished, such as raw stock trace, heat-treat certification, PAA and primer processing, honeycomb lot/batch trace, or any other applicable trace/process verification that would be necessary to show conformance to the requirements listed in the repair drawing, should be verified before accepting any parts.

4. A first article inspection (FAI) may be required by the repair drawing for an initial part made by a third-party fabricator to verify that, in addition to those details checked in Step 4.3.14.b.3, all dimensions that are specified in the repair drawing have been satisfied within the repair drawing required tolerances, all grain directions match the repair drawing requirements, and all ribbon directions and cell wall perpendicularity is maintained in accordance with the repair drawing tolerances.

(a) A fit, form, and function check on the next higher assembly as a part of the FAI process can often identify problems with the repair drawing design and can save rework loops later in the Repair Document if these problems are identified and addressed during this step.

(b) The FAI should be accomplished by the repair station. The third-party fabricator cannot perform the FAI on behalf of the repair station.

(c) The fabricator of each repair detail is responsible to inspect 100% of all parts to all required dimensions and tolerances that are listed in the Repair Document/repair drawing. The fabricator is also responsible for all quality checks on supplied parts and processes that lead to a statement of conformity certification.

(d) A receiving/inspection plan should be determined by the repair station based on the findings of the FAI report. This monitoring plan will determine which additional end-item inspections are required for all parts or a sampling of parts received by the specific third-party fabricator that was the supplier of the part that has successfully undergone FAI.

(i) A monitoring plan may allow for reduced sampling based on statistical vendor performance, criticality of the detail repair part, or other factors.

(ii) A continued monitoring plan is only applicable for receiving inspection and is not applicable to inspection at the fabrication source.

c. Locally Fabricated Parts

1. Make sure that for all locally fabricated parts (parts that are fabricated at the repair station accomplishing the repair) have the correct part numbers, as defined in the Repair Document.

2. If machining is required for any honeycomb core detail parts, clean core machining procedures should be followed in accordance with the requirements listed within the Repair Document.

Example 4.3.14.c.2 #1: Use of lubricants should be avoided when machining metallic honeycomb core. If lubricants are required, only those lubricants that are listed specifically as being approved for clean core machining in the Repair Document should be used. Lubricants can contain contaminants that can have significant negative effect on the ability for the honeycomb core to adhere to an adhesive film or resin. Some waxes and other contact agents are not able to be removed through a vapor degrease process; therefore, make sure that all agents that contact the honeycomb core during the machining process are approved for use in the Repair Document.

Care must be taken to make sure that the core remains in a clean environment, considering all surrounding operations that are taking place in the area that the core is being machined. If machines adjacent to those being used for clean core machining use lubrication, the clean core cutting machines should be partitioned in a way that eliminates the possibility for lubricants or oils to enter into the clean core machining areas.

Example 4.3.14.c.2 #2: Tapes or other temporary stabilizing films that are used in the machining process to adhere to the honeycomb core detail parts in order to facilitate suction to a vacuum table should only be used if specifically approved by the Repair Document. Unapproved stabilizing materials can contain contaminants that may prevent the honeycomb core from bonding to the repair area.

(a) Dyes should be used in approved machine lubricants so that contamination can be detected on core products.

(b) Any aluminum honeycomb core that becomes contaminated during the machining process should be cleaned by using the Repair Document approved processes prior to use. Refer to ARP4916 for cleaning aluminum honeycomb core. Vapor degreasing operations are typically used to clean metallic honeycomb core. Some contaminants are not able to be removed through vapor degreasing; therefore, make sure that all requirements are followed in the Repair Document for contamination removal. Cover and protect cleaned details prior to use.

CAUTION: Do not vapor degrease nonmetallic honeycomb core materials, unless otherwise stated in the Repair Document.

3. Make sure that the bond surface of the part has been protected as per Step 4.3.14.a.2.

4. Make sure that all manufacturing processes were correctly followed as per Step 4.3.14.b.3.

5. Make sure that all FAI have been completed as per Step 4.3.14.b.4.

6. Each locally fabricated detail part is required to have all dimensions measured that are listed in the Repair Document/repair drawing and each hard dimension must be verified to be within the specified tolerance. A completed FAI does not remove this requirement.

   A continued monitoring plan, as referenced in Step 4.3.14.b.4(d) is only applicable for receiving inspection and is not applicable to inspection at the fabrication source. One hundred percent of all parts are required to be inspected to all required dimensions and tolerances that are listed in the Repair Document/repair drawing.

d. Ensure Core is Not Contaminated

1. Make sure any honeycomb core is not contaminated. Any core that becomes contaminated during the machining process or was purchased in a nonclean core configuration from the manufacturer should be cleaned by using the Repair Document approved processes prior to use. Refer to ARP4916 for cleaning aluminum honeycomb core. Vapor degreasing operations are typically used to clean metallic honeycomb core. Some contaminants are not able to be removed through vapor degreasing; therefore, make sure that all requirements are followed in the Repair Document for contamination removal.

   CAUTION: Do not vapor degrease nonmetallic honeycomb core materials, unless otherwise stated in the Repair Document.

2. Cover and protect cleaned details prior to use according to manufacturer's requirements.

e. Final Quality Check

1. Quality Check of Materials

   (a) Quality assurance should verify that all consumable materials meet the following requirements:

      (i) All materials are certified to the requirements listed within the Repair Document. See Step 4.3.13.c.1 for details.

      (ii) There was a receiving inspection accomplished on each material being used in the repair, and that part of the receiving inspection requirements was to verify the following:

      - All packaging and shipping requirements were verified to be in accordance with the requirements of the Repair Document. See Step 4.3.13.c.2 for details.
      - Verify that all required receiving inspections have been accomplished in accordance with all certification/specification requirements that are called out in the Repair Document. See Step 4.3.13.c.4 for details.

      (iii) All materials have been stored properly prior to use, including remaining out-time available to be consumed during the Repair Document prior to cure, and the maximum number of times the material was removed from refrigerated storage were not exceeded. Recorded evidence of this must be verified. See Step 4.3.13.c.3 for details.

      (iv) All perishable TATS materials are labeled with identification, storage life, out-time remaining, and/or expiration date.

2. Quality Check of Gathered Detail Parts

(a) Quality assurance should verify that all detail parts gathered/fabricated meet the following requirements:

(i) All part numbers match those that are specified in the Repair Document.

(ii) All detail parts have been stored in an environment that meets the requirements of the Repair Document. See Step 4.3.14.a.2.(a) for additional detail.

(iii) The expiration date of all detail parts has not been exceeded. See Step 4.3.14.a.2.(b) for additional detail.

(iv) All details that were wrapped or stored prior to inspection should be consumed in the repair as soon as possible. If it is required that extended period of time must elapse between unwrapping and usage, these parts should be rewrapped/sealed to protect from UV exposure/contamination.

(v) Accomplish a general visual inspection for obvious defects and verify that no defects are present. See Step 4.3.14.a.2.(c) for additional detail.

(b) For all parts purchased from a third-party fabricator (non-OEM sources) and for all parts that have been locally fabricated, verify the following:

(i) The raw stock trace paperwork and process certification paperwork matches all of the requirements listed in the Repair Document/repair drawing. See Step 4.3.14.b.3 for additional detail.

(ii) An FAI report has been completed and shows that the specific supplier that fabricated the part being inspected has successfully met all inspection requirements, as required by the repair station policies.

(iii) If an FAI report has not been completed, accomplish an FAI inspection. See Step 4.3.14.b.4 for additional detail.

(c) For all parts that have been locally fabricated, verify the following:

(i) A full dimensional inspection has been accomplished that shows that all dimensions are within the specified tolerance as defined in the Repair Document/repair drawing. See Step 4.3.14.c.6 for additional detail.

4.3.15 Plan for Tooling / Quality Check

a. If tooling is required by the repair procedure, for example, a bond assembly jig (BAJ), an assembly mandrel (ASM), or an assembly jig (AJ), refer to the checklist in Figure 16 for the process of inspecting and preparing the repair tools.

NOTE: AIR5431 provides information on repair tooling.

CHECKLIST ITEM	REFERENCE PARAGRAPH	ACTION
Make sure that correct tools will be used to do the repair,	4.3.15.a.1	
Make sure a thermal profile has been accomplished on all tools.	4.3.15.a.2	
Make sure documentation is available for proper use of the tool.	4.3.15.a.3	
Make sure all tools will maintain required geometries.	4.3.15.a.4	
Make sure the tool has been stored correctly.	4.3.15.a.5	
Make sure any required routine repetitive tooling checks have been satisfied.	4.3.15.a.6	
Make sure release agent has been applied according to the Repair Document.	4.3.15.a.7	
Make sure bond line verification has been performed on all tooling.	4.3.15.a.8	

Figure 16 - Tooling check process checklist

1. Make sure that all tools that are specifically called out by tooling part number in the Repair Document are used for the repair.

   (a) Verify that all tools being used during the repair were designed specifically for the part being repaired.

   (b) Any deviations require prior written approval from the Customer.

2. For all BAJs and ASMs, verify that a thermal profile has been accomplished on the tool such that leading and lagging thermocouple locations are identified prior to completing a repair cure. Documentation of the thermal profile should be recorded and kept on file in order to aid the technician during thermocouple placement and autoclave orientation, as shown in Figure 17.

   NOTE: Completing a thermal profile is a critical step to ensuring that repairs are fully cured.

   (a) AJs and ASMs can have large thermal mass (heat sinks) that can disrupt uniform heat-up in a part being repaired. If thermocouples are not placed in areas that represent the leading and lagging heat-up locations on the part/tool, it is possible for overheating/under-heating to occur. This can lead to under-heated or overheated adhesives, which can have appreciable effect on the material properties.

   (b) Positioning of the tool with respect to the convection heat flow direction is also critical and should be noted in the thermal profile report. Changes of the tool position with respect to the convection heat source may require a new thermal profile.

   (c) Using different ovens or autoclaves than were used to develop the thermal profile may also require a new thermal profile. For example, if a thermal profile was conducted at one supplier and a second supplier was selected to conduct a repair using the same process and tooling on the same part, it might be necessary to accomplish a new thermal profile.

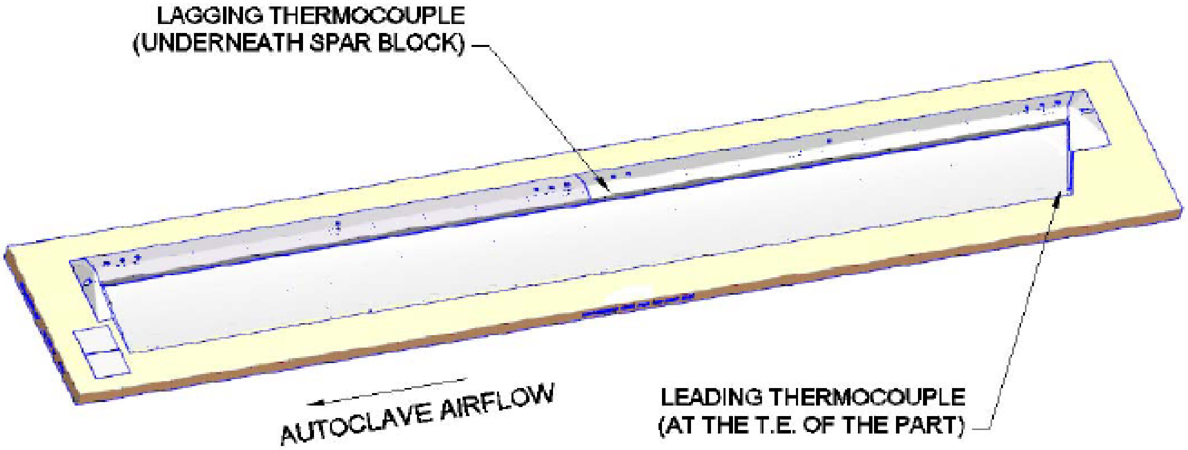


Figure 17 - Thermocouple diagram showing placement of thermocouples on tool

NOTE: After the part and tool have been thermally mapped, the leading and lagging positions are determined and documented, including the orientation of the tool in the autoclave. Figure 17 is an example of a thermocouple diagram showing the thermocouple locations to be used on this tool.

3. Make sure that documentation is available regarding the proper use of the tool, such as a tooling drawing or a tool usage guide/manual. Make sure that all tools are properly labeled and identified to include ownership information.

(a) At a minimum, it should be evident, through these documents, how to properly rig the part that is being repaired on the tool being utilized.

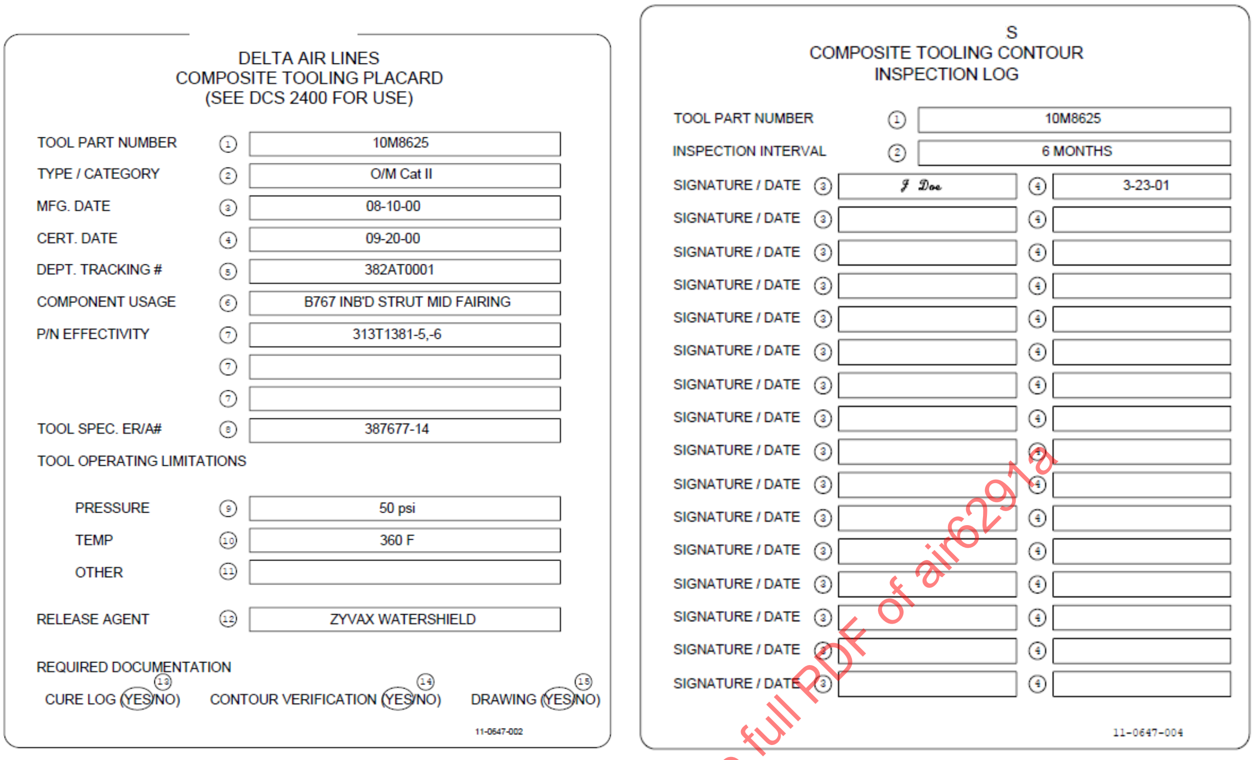
4. Make sure that all tools have been shown to demonstrate, through validation checks, that the final repaired unit will maintain all required geometries, as specified in the Repair Document. See Appendix A for a detailed example of a preferred method of geometry verification.

NOTE: A record of where tooling geometry originates should be kept showing compliance with certification requirements. A repaired component must be validated to show that it meets form, fit, and function of the original engineering definition. High costs resulting from airplane downtime or for rework and scrapping may occur if a repaired component cannot be installed due to failure to meet contour.

5. Prior to use, make sure that the tool being utilized has been stored in accordance with all requirements for humidity, temperature, and any other requirements that are a part of the Repair Document, the tooling drawing, and/or the tool usage guide/manual.

6. Prior to use, make sure that any required routine repetitive tooling checks, such as general visual or dimensional inspections, that are required by the Repair Document Specification, the tooling drawing, and/or the tool usage guide/manual, have been satisfied.

NOTE: Using placards on the tool, as shown in Figure 18, can help to make sure that the technician will have access to required inspection intervals.



DELTA AIR LINES
COMPOSITE TOOLING PLACARD
(SEE DCS 2400 FOR USE)

TOOL PART NUMBER	1	10M8625
TYPE / CATEGORY	2	O/M Cat II
MFG. DATE	3	08-10-00
CERT. DATE	4	09-20-00
DEPT. TRACKING #	5	382AT0001
COMPONENT USAGE	6	B767 INB'D STRUT MID FAIRING
P/N EFFECTIVITY	7	313T1381-5,-6
	7	
	7	
TOOL SPEC. ER/A#	8	387677-14
TOOL OPERATING LIMITATIONS		
PRESSURE	9	50 psi
TEMP	10	360 F
OTHER	11	
RELEASE AGENT	12	ZYVAX WATERSHIELD

REQUIRED DOCUMENTATION
CURE LOG (YES/NO) 13 CONTOUR VERIFICATION (YES/NO) 14 DRAWING (YES/NO) 15

11-0647-002

S
COMPOSITE TOOLING CONTOUR
INSPECTION LOG

TOOL PART NUMBER	1	10M8625		
INSPECTION INTERVAL	2	6 MONTHS		
SIGNATURE / DATE	3	J Doe	4	3-23-01
SIGNATURE / DATE	3		4	
SIGNATURE / DATE	3		4	
SIGNATURE / DATE	3		4	
SIGNATURE / DATE	3		4	
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11-0647-004

Figure 18 - Example of tooling placard to keep track of inspection intervals and ensuring compliance to requirements

7. If a BAJ or an ASM is being used by the Repair Document, make sure that a release agent has been applied to the part-to-tool mating surfaces and that the specific release agent being applied is acceptable in accordance with the Repair Document.

CAUTION 1: Do not apply release agents near repair parts and parts to be repaired. Apply release agents outside of the CCA. Release agents that come in contact with a bonded surface can cause an unsatisfactory repair.

CAUTION 2: Only use release agents approved by the Repair Document. Use of unapproved release agents have been a common source of bond surface contamination. Bond surface contamination will result in a repair with insufficient strength.

(a) If an approved release agent has not been applied, clean the BAJ or ASM and apply an acceptable release agent to the part-to-tool mating surfaces per a process that is allowed by the Repair Document.

(b) Release agents should be cured in accordance with the Repair Document and/or manufacturer's recommended processes.

CAUTION: Uncured release agents are a source of bond surface contamination. Bond surface contamination will result in a repair with insufficient strength.

8. Prior to use, it is best practice to verify that bond line verification has been accomplished to make sure that all repair details and tooling have been fabricated/designed correctly to allow for proper adhesive film thicknesses to be achieved during the cure process. If this has not already been accomplished, see Step 4.4.4 for further guidance.

(a) Bond line thickness verification can identify areas of poor detail part fit-up, resulting in low contact pressure and poor bonding.

(b) If a change in the supplier of any shaped/machined repair details has occurred, or if significant changes have been made to a repair detail drawing that might impact how two details interface during the cure, it may be necessary to conduct a new bond line verification procedure.

(c) Step 4.4.4 gives additional detail on methods that can be used to accomplish a bond line verification check.

4.3.16 Schedule Repair Activity

CHECKLIST ITEM	REFERENCE PARAGRAPH	ACTION
Make sure time-sensitive materials are ready for use at the scheduled time.	4.3.16.a.1	
Make sure trained personnel are available at the scheduled time.	4.3.16.a.2	
Make sure there is adequate out-time left on temperature-sensitive materials.	4.3.16.a.3	
Make sure time-sensitive steps are not affected by shift changes, breaks, or other activities.	4.3.16.a.4	
Make sure all required equipment is available during the scheduled repair time frame.	4.3.16.a.5	
Allocate resources to accomplish the repair.	4.3.16.b	

Figure 19 - Repair scheduling process checklist

a. Consider the following questions and the flowchart in Figure 19 for the process of scheduling the repair activity when scheduling activities related to the repair in order to maintain best practice and limit risk for repair failure:

1. Are all time- and temperature-sensitive materials able to be ready for use at the appropriate time to facilitate repair layup?

2. Are there sufficient trained personnel available during the time period that the repair must be accomplished? All technicians, inspectors, and engineers involved in damage disposition and repair should have the necessary skills to perform their supporting maintenance tasks on a specific structural part.

   (a) Are there key tasks in the process that require unique skills, such as programming cure cycles, operating automated cutting equipment, application of adhesive primer, etc.?

3. Is there adequate out-time left for all time- and temperature-sensitive materials that will be used during the repair to extend up to the time when any CCA space or curing equipment will become available?

4. Are there any time-critical steps, such as chemical treatment steps, primer application/cure procedures, adhesive application procedures, adhesive exposure to environment, and potting compound installation, that could be impacted due to shift change or scheduled break times?

   (a) Are there any shift changes that will occur during the accomplishment of the repair that might inhibit the ability for the entire repair to be completed within the material out-time limits?

5. Is all equipment available for use in the time frame that the repairs need to be completed, such as autoclave/oven queues, CCA layup space, worktable availability, etc.?

b. Allocate resources including personnel, facilities, and equipment that will be necessary to accomplish the instructions in the Repair Document without disrupting the flow of all time-sensitive steps described in Step 4.3.14.a.

4.4 Repair Accomplishment

4.4.1 Repair Accomplishment General Steps

a. The following section includes general steps to ensure the successful completion of a metal bond repair procedure. This section includes the recommended procedures to ensure proper material handling and layup procedures. It is essential that all repair steps be conducted per the Repair Document, taking note of all cautions and additional considerations listed below. The flowchart (see Figure 20) is intended for initial planning purposes; full steps and requirements can be found in the full text of the document, as referenced in each flowchart step.

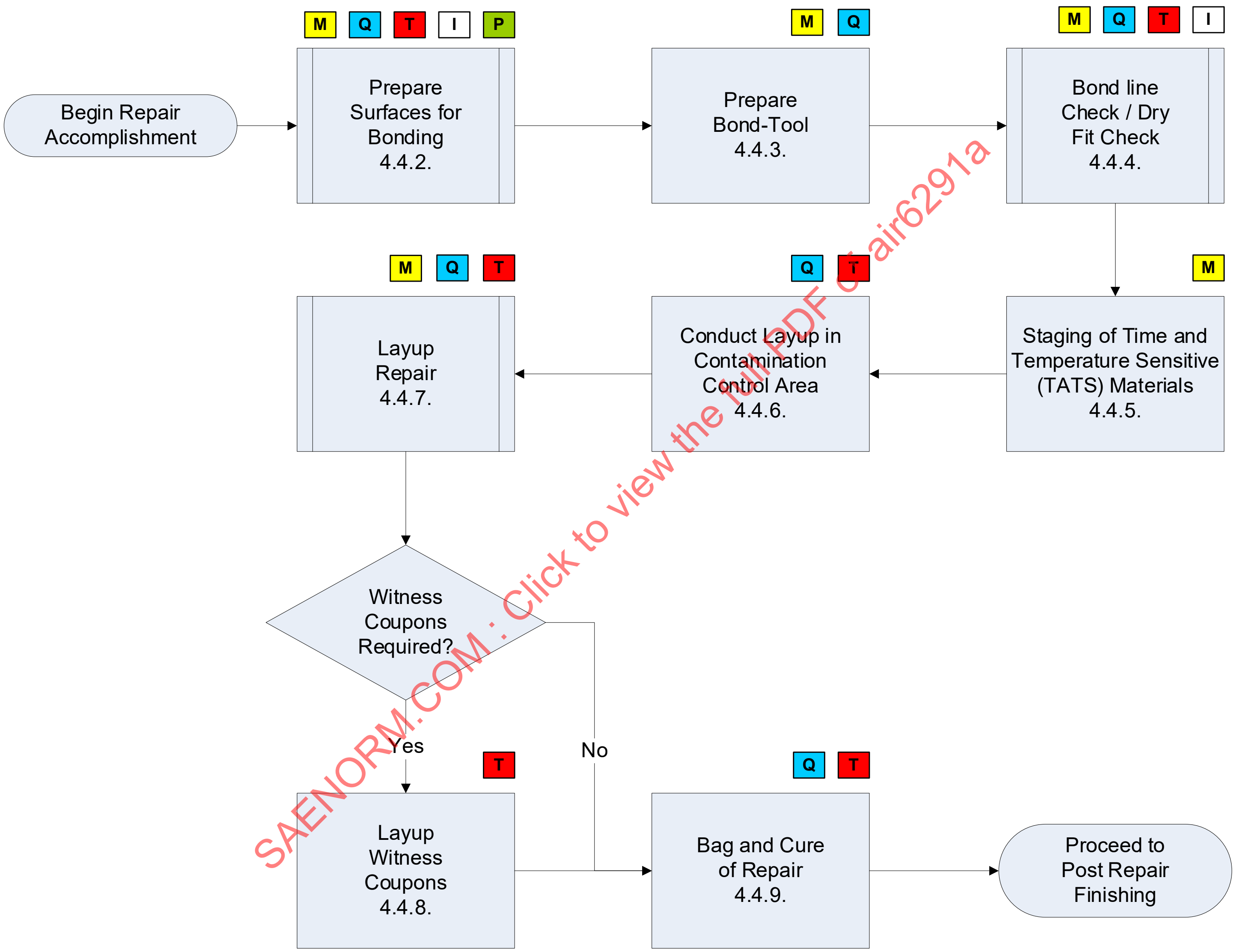

Figure 20 - Repair implementation decision flow

4.4.2 Prepare Surfaces for Bonding

NOTE: Accomplish all machining, chemical treating, and abrading outside of a CCA. See Figure 21 for the necessary steps.

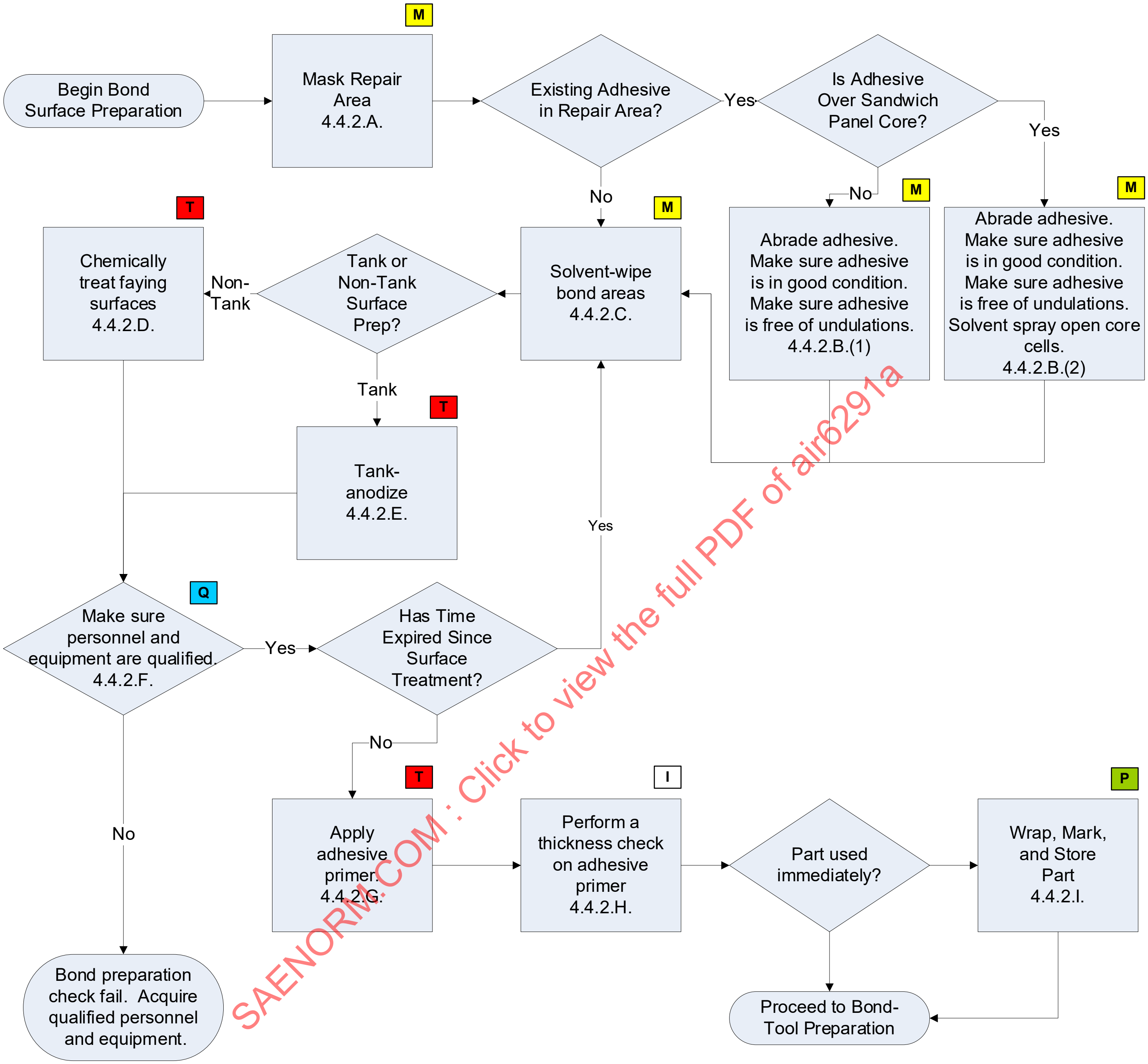

Figure 21 - Prepare surfaces for bonding flow

a. Mask repair area from contaminated surrounding areas on the part being repaired. This should be done in a manner that segregates all potential contaminants from the areas that are not involved in the repair process so that contamination of the area to be bonded will be avoided. Refer to ARP4916 for guidance on masking. See 4.3.13 for discussion on approved contact materials.

b. Where original adhesive film has been exposed during the damage removal process, and where the Repair Document allows for refurbishment of original adhesive, accomplish the following steps to prepare these original adhesive faying surfaces for repair bonding:

1. For adhesive film applied to solid sheet metal or solid machined/extruded details:

   (a) Abrade all exposed adhesive using only abrasive pads that are approved specifically for this task by the Repair Document Specification.

      (i) Use care not to remove the adhesive to the point where bare metal is exposed. Bare metal must be chemically treated using steps that add cost to the repair process.

   (b) Examine the condition of the abraded adhesive and make sure that it meets the requirements for bonding, as specified in the Repair Document. The purpose of the abrasion process is to roughen the surface to promote adhesion during the repair process.

   CAUTION: Discoloration or staining of residual film adhesive can be evidence of fluid ingression. This can reduce the strength of the repair bond.

   (c) After abrasion, the faying surfaces should be verified to be free of undulations and steps to facilitate fit-up with mating repair details later in the Repair Document.

2. For adhesive film applied over honeycomb core:

   (a) Abrade all exposed adhesive using only abrasive pads that are approved specifically for this task by the Repair Document.

   (b) Examine the condition of the abraded adhesive and make sure that it meets the requirements for bonding, as specified in the Repair Document. The purpose of the abrasion process is to roughen the surface to promote adhesion during the repair process.

   (c) Remove any loose adhesive segments that are not firmly attached to a honeycomb cell wall. Pliers can be used to achieve good results; however, use care to not damage any honeycomb core cell walls.

   (d) It may become necessary to solvent spray the honeycomb core areas after adhesive preparation is complete to remove any residual contaminants and dust that may have been introduced during the core cleanup process. This should be accomplished per the instructions listed in the Repair Document. Refer to ARP4916 for additional detail, and ensure conformance to all requirements in the Repair Document.

c. Solvent wipe areas to be repair bonded using solvents and procedures that are approved for use in the Repair Document.

1. A Qualified Bonding System will specify the solvents used and the methods for cleaning the surface. Making sure that the surface is contaminant-free is a key process in obtaining a strong bond line. Make sure solvent being used is dispensed from an original or uncontaminated container. Solvent wipe the areas to be repair bonded just before chemically etching, anodizing, and/or chemically treating, using approved solvents and cloth and following the procedures approved for use in the Repair Document. ARP4916 contains details on solvent cleaning.

   NOTE: It is industry best practice to use ARP4916, Composite Cleaning Method 5 - Wipe Cleaning Using Commercial Solvent - Two Cloth Method, which requires a minimum of two distinct wipes of the bond surface. A final solvent wipe needs to be conducted after removal of visible contamination to make sure the bond surface is clean. Multiple solvent wipes may be required.

   CAUTION 1: Failure to properly clean the bonding areas may weaken the strength of the repair bond by introducing contaminants into the joint.

   CAUTION 2: Do not substitute solvent type or grade.

d. Chemically etch, anodize, and/or chemically treat, in accordance with the Repair Document instructions, all surfaces of the original structure that are solid aluminum where bare metal has been exposed during the damage removal process.

1. Masking may be required to protect surfaces or existing bond lines that are not intended to be chemically etched, anodized, or chemically treated.

   CAUTION: Use only masking agents specifically allowed in the Repair Document in this step. Failure to use masking agents that are approved may result in leakage of the chemical agent into areas such as existing good bond interfaces, which could negatively affect the durability of existing undamaged structure.

2. Abrade the aluminum surface in the specific manner using specific abrasion pads and equipment before application of the approved chemical agent only as given in the Repair Document.

   CAUTION: Abrasion pad types, variation between abrasion pad manufacturers, and sanding patterns can have a significant effect on the bond strength and durability of the adhesive joint.

   NOTE: Refer to *Factors Influencing Durability of Sol-Gel Surface Treatments in Metal Bonded Structures*.

   CAUTION: Unclean and unapproved abrasive materials (sandpapers and abrasive pads) may contain contaminants that can weaken the bond by introduction of impurities. Frequent swapping out of abrasive materials for new materials will also reduce risk of redepositing contaminants that have been removed from the surface being abraded. A contaminated bond surface will weaken the bond and reduce durability. Detection at the time of repair is unlikely. Failure may not occur until after the part returns to service.

3. Ensure cleanliness of the repair details that are being chemically treated, in accordance with all cleanliness requirements listed in the Repair Document.

   CAUTION: Chemical agents are not able to properly prepare a contaminated aluminum surface for bonding.

4. All chemicals used during surface preparation for structural bonding must be exactly as specified in the Repair Document.

   (a) The Repair Document may list several surface preparation options with size and/or location limitations that differ for each option.

      CAUTION: Some surface preparation processes do not fully restore the bonding surface to original bonding strength and durability conditions, while a limited selection of surface preparation processes are fully strength restorative. Therefore, follow all limitations listed in the Repair Document to make sure structural strength and durability are not compromised.

      BEST PRACTICE: It is best practice, when replacing significant portions of original structure, to use the same procedures that were used to make the original structure. See Step 4.4.2.e for detail. Nontank surface preparation methods used on large areas can result in poor durability.

   (b) If surface preparation method substitutions are desired, Engineering and the Customer must approve before proceeding.

5. If bond primer is not going to immediately follow the chemical surface preparation procedures, the prepared surfaces must be covered to adequately protect the faying surfaces from contamination until a bond primer can be applied.

6. The Repair Document will require a maximum window of time between chemical treatment and bond primer application. The maximum amount of time is not to be exceeded. If the out-time is exceeded, check the Repair Document to see if the surface can be reactivated or contact the OEM.

   CAUTION: The bond surface will degrade over time when exposed to air, which affects the ability for formation of chemical bonds reducing the bond strength.

e. Tank-anodize newly fabricated repair details per the Repair Document.

1. For treating aluminum parts, phosphoric acid anodizing (PAA), phosphoric sulfuric acid anodizing (PSA), and chromic acid anodizing (CAA) processes are used by various OEMs as an original surface preparation method. Make sure that the required tank process is being utilized in accordance with the Repair Document.

   BEST PRACTICE: Currently, industry best practice is to accomplish an anodize process followed by application of adhesive bond primer.

   NOTE: Each manufacturer may have specific design considerations for each process above, and these design considerations are important to maintain.

2. For processing guidelines specific to PAA on overall process concerns, facilities considerations, and overall quality parameters, refer to ASTM D3933.

3. Make sure that all routine testing, such as lap shear coupon testing and crack wedge extension testing, that is required as a part of tank validation testing by the Repair Document is being complied with before any processing is to take place.

   (a) Include records of all tank validation testing in the permanent records for the bonded repair.

4. Do a visual check before each tank is used to make sure that dust, debris, and other foreign particulate has not settled onto the top of the solution.

   BEST PRACTICE: It is best practice to employ covers over tank solutions when each tank is not actively in use. This helps to ensure that baths that are not used frequently remain free of contaminants.

   NOTE: Continuous closed loop filtered systems can help prevent algae and mold from developing within the solutions.

5. Ensure that, after processing is complete, all processed details remain in a contamination-controlled area prior to application of adhesive primer, as applicable. If it is anticipated that the processed details will not have primer applied immediately, cover the chemically treated aluminum surfaces to protect from possible contamination. The cover should not come into contact with the chemically treated surfaces.

   BEST PRACTICE: It is best practice to locate the adhesive primer application and curing area adjacent to the tank area to eliminate the need to transport bare chemically processed aluminum details through non-contamination controlled areas between the chemical treatment area and the adhesive primer application area.

   (a) Cover the chemically treated aluminum surfaces to protect from possible contamination if it is necessary to transport bare chemically processed aluminum repair details through non-contamination controlled areas.

      BEST PRACTICE: It is best practice to design the process such that the repair parts that are being processed do not need to be removed from the rack that is used to do the chemical treatment process before application of adhesive primer is accomplished. This process will make sure that there is no need to handle the repair parts between anodizing and priming steps.

   (b) Avoid unnecessary handling of the repair parts. Only handle with gloves, as specified in the Repair Document. If parts must be touched with gloves, handle the parts by touching the edges of the details only.

      CAUTION: At no point during the repair process should the repair details that have been chemically processed be touched with bare hands or be exposed to contamination.

f. Adhesive primer application to the chemically treated bonding faying surfaces should occur within the time frame required by the Repair Document. The Repair Document will specify a maximum amount of time between chemical processing and application of primer, if a primer is required.

CAUTION: Some primers are not compatible with certain surface preparation methods. Adhesive primers are selected based on compatibility testing. Only use approved combinations of adhesive primers, chemical treatment methods, and adhesive systems. A Qualified Bonding System will qualify primers with each surface preparation method.

1. Adhesive primer should be applied in a CCA.

2. Proper storage of the adhesive primer should be verified before usage occurs. See Step 4.3.14.e.1.(a) for additional detail.

3. Verification of material specification certificates should occur before usage of any primer materials. See Step 4.3.13.c for additional instructions.

4. Adhesive primer should be applied by trained personnel that meet any minimum sprayer certification requirements that may exist as a requirement within the Repair Document.

   BEST PRACTICE: Best practice requires individuals to pass routine tests each 6 months for primer thickness and/or mechanical coupon testing.

5. Equipment, such as rollers, spray guns, and supply hoses, should be dedicated to a particular adhesive primer type and should be verified to be cleaned in accordance with the manufacturer's recommended procedures prior to use.

   (a) Water-based primer equipment should not be cleaned using solvent-based chemicals, unless specifically authorized by the Repair Document.

g. Apply and cure the adhesive primer.

1. Apply the primer according to the manufacturer's instructions. The Repair Document will specify a maximum amount of time between chemical processing and application of primer. See 4.4.2.d.6.

2. Curing of adhesive primer must occur within a specific time frame that is defined in the Repair Document. The primer curing equipment must be contained within a CCA.

   (a) Temperature monitors should be employed to make sure that the adhesive primer is cured at the required temperature range and minimum/maximum cure times, as specified in the Repair Document.

   CAUTION: Primers need to be fully cured to ensure bonding to the adhesive. If the primer is not fully cured, it will not adhere to the substrate and will result in low bond strength.

3. The date of application of primer must be recorded if the part will not be used immediately. The expiration date for the primer applied part must also be recorded. If the part is not used within the time permitted by the Repair Document, steps as permitted by the Repair Document must be taken to reactivate the primer applied surface before use. Some OEMs may not permit the surface to be reactivated. A Qualified Bonding Process will have evaluated bond strength up to the specified time limits. The bond strength will not be known after the expiration date and thereby must not be used.

h. After adhesive primer application is completed, a thickness check should be accomplished for the final cured adhesive primer layer. The Repair Document will specify the required thickness range, which is dependent on the specific adhesive primer that is being used.

CAUTION: When adhesive primer is applied at a thickness that is above the tolerance range allowed by the Repair Document, the peel and shear properties of the adhesive joint will decrease, as the failure of the joint will increasingly favor failure within the primer.

When adhesive primer is applied at a thickness that is below the tolerance range allowed by the Repair Document, the corrosion-resistance properties of the adhesive joint will decrease, as the aluminum phosphate coating is not robust without a protective coating of the adhesive primer layer when exposed to wet environments and heat.

1. Thickness can be measured using devices that compare eddy current measurements of a bare reference sample with the primer applied and cured detail being measured.

NOTE: All manufacturers' recommendations for calibration should be followed before each use regardless of the device that is used. Refer to the appropriate NTM or NDT manual for guidance.

(a) If a thickness measuring device that relies on eddy current differences is used, make sure to use a reference standard that is made from the same alloy type and similar thickness as the detail being measured. Differences in alloy types can produce readings that are significantly different than actual thicknesses.

(b) For contoured regions or regions that are impossible to measure with a device, reference standards can be developed to compare the color ranges with known thickness values that have been verified with a device that can measure precise thicknesses.

(i) If visual reference standards are used to aid the paint technician in color comparisons, they should be fabricated concurrently with the repair details that are being processed to ensure continuity between the parts being compared and the standard that is being measured.

2. Clad and bare metals will appear different with the same primer applied. Use caution when using visual standards. Visual reference standards are not a recommended method to ensure paint thickness.

i. After the thickness of the adhesive primer has been verified to be within the range that is required by the Repair Document, each primer applied repair detail, unless it is to be immediately used in a repair, should be wrapped. When wrapping the repair details for storage, only wrap in accordance with the Repair Document requirements.

1. Different wrapping materials can have a unique effect on the shelf life of the primer applied repair details that are being wrapped. The Repair Document may have several different types of wrapping materials that are approved for use with varying shelf lives that are associated with each type of wrapping. For example, wrapping a repair detail in clean, non-waxed kraft paper may have a different shelf life of the same repair detail that is wrapped and sealed in 4 mil thick black polyethylene bagging material.

(a) Wrapping the repair detail both protects the primer applied detail from ultraviolet light exposure, which degrades the primer protective layer over time, and from contaminants that may come in contact with the repair details from the time they are processed through shipping and through its storage life.

2. After wrapping is completed, the expiration date of the primer applied repair detail and all repair part numbers, material specifications, and any other information that is required by the Repair Document should be marked on the exterior of the protective wrapping. The expiration of the primer applied details will be determined from the requirements stated within the Repair Document. The start time for this date should be determined from the end of the cure cycle of the adhesive primer from Step 4.4.2.g.

3. After marking is completed, all primer applied details should be stored, as required by the Repair Document. Adhesive primer applied aluminum details should only be unwrapped inside a CCA and before immediate use in conjunction with a repair.

4.4.3 Prepare Bond Tool

a. All BAJ and ASM tooling that was acquired and prepared during accomplishment of Step 4.3.15 should be brought inside the CCA layup environment.

1. Make sure that all tooling has been properly cleaned and released. See Step 4.3.15.a.7 for additional information.

(a) All release agent application must occur outside of the CCA.

CAUTION: Failure to accomplish this step outside of the CCA can introduce agents into the repair bond line that are designed to specifically prohibit bonding. This can potentially degrade the strength of the bonded joint.

(b) Any liquid release agents need to be verified to be completely dried/cured before proceeding. Failure to make sure that the agents are completely cured can complicate layup.

2. After release agents have been applied to the bond tooling and cured, the tooling should be stored in the CCA and covered until use to prevent dust and debris from settling onto the mold surface.

4.4.4 Bond Line Check/Dry Fit Check

See Figure 22 for the necessary steps.

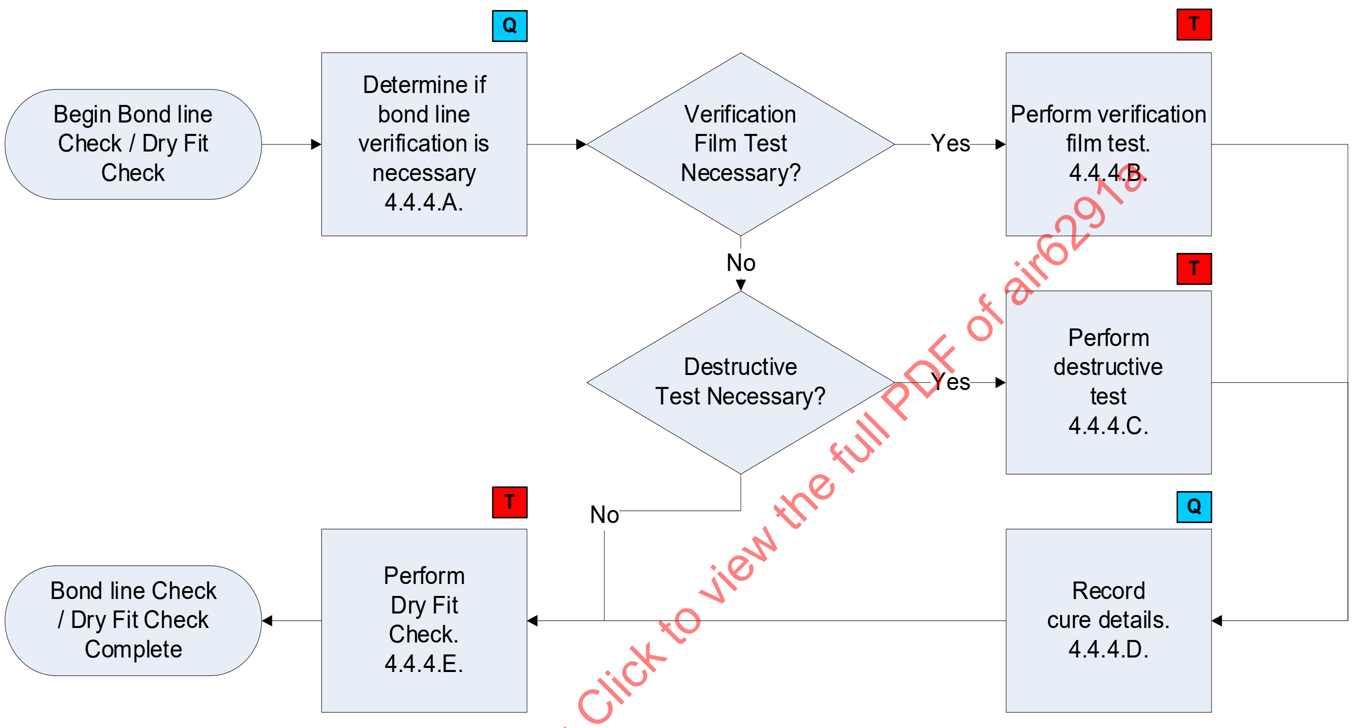

Figure 22 - Fit check process flow

a. Bond line verification should be accomplished when contoured repair details, stretch formed sheet, die formed sheet, pre-bonded core assemblies, internal doubler rebates on spars and core, machined contour parts, chem-milled sheet, or contoured BAJ or ASM tooling are introduced into the repair or other situations where contour mismatch could affect film adhesive thickness/core fillet development.

CAUTION: If bond line check or verification of filleting between the repair detail and core is not performed, it could lead to an in-flight premature failure of the repair.

1. The frequency at which bond line verification occurs will be determined by the complexity of the repair and confidence in the repeatability of the process. Determining the frequency of the verification should include consideration of key dimensional quality checks that are incorporated into the continuous monitoring plan, as described in Step 4.3.14.b.4.

2. A change in the third-party fabricator-supplied shaped repair detail that will be used during the repair or a change in location of the facility accomplishing the repair may also require a new bond line verification.

3. The Repair Document may specify required frequencies and procedures to follow for accomplishment of bond line verification. These required frequencies should be observed, regardless of the details stated above.

b. A verification film test is one method that can be used to perform a bond line verification procedure and bond line thickness check. This can be accomplished using the following steps:

NOTE: Some manufacturer's processes require that all details that come into contact with release film during a verification film test must be cleaned to remove possible fluorinated compounds or other contaminants from the release film that may have transferred to the part. Cleaning procedures should be performed per the instructions listed in the Repair Document.

1. Lay up all repair details as the actual bonded repair would be accomplished per the Repair Document; however, sandwich all adhesive film layers between two sheets of parting film. Only use parting films that are approved contact materials per the Repair Document. It is recommended to use parting films that are durable so that core materials do not cut through the film during the pressurized cure.

2. Do not lay up any foam adhesives.

3. Use only film adhesive types, grades, classes, and number of plies that will be used in the final repair layup.

4. Bag and cure all repair parts (and tool, as applicable) per the Repair Document bagging and curing procedures.

5. After the verification film cure is complete, disassemble all cured film adhesive and parting films from the bonded repair area. Peel the adhesive film away from the parting film. Use care to note on each segment of cured film adhesive the location/orientation with respect to the bonded assembly so that discrepant areas can be mapped. The verification film may be held to a light or backlit.

    (a) Document the results of the following with photographs and notations in a report so that details can be evaluated by Engineering when required by the Customer.

    (b) Where the adhesive film was laid over honeycomb core, examine the cured adhesive film for evidence of uniform and uninterrupted core cell wall imprint. See Figure 23 as an example.

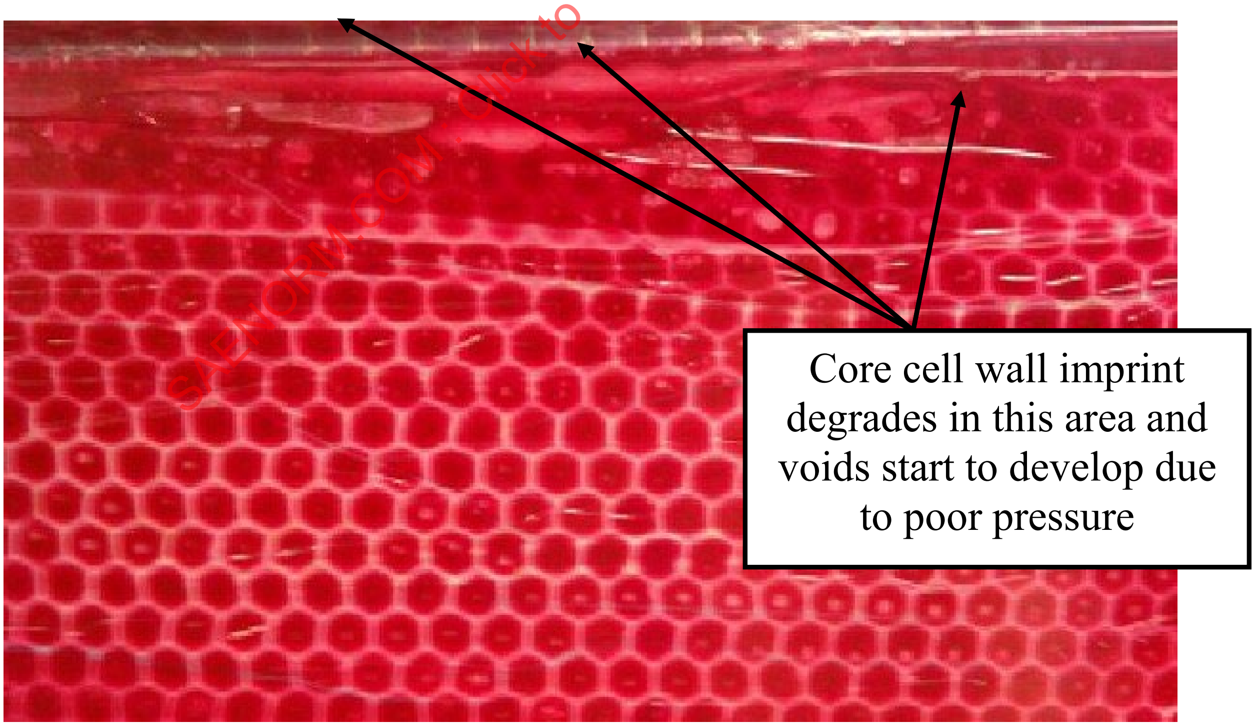

Figure 23 - Example of nonuniform core imprint

    (c) For all areas, circle all dark and light-colored areas and map their locations with respect to features on the part. The mating areas are inspected closely to identify the root cause.

(d) Cut out thick and thin areas of the cured film adhesive and, using a micrometer, measure all areas that are dark and light to make sure that all thicknesses of the cured film adhesive are within the acceptable tolerances for the film adhesive type that was used, in accordance with the Repair Document requirements. See Figure 24 for details. When measuring thickness at core cell wall locations, use a micrometer with a conical tip.

NOTE: High or low areas identified during the inspection can in some cases be corrected by different actions, such as addition of further plies of film adhesive. The Repair Document will limit the number of film adhesive plies than can be used.

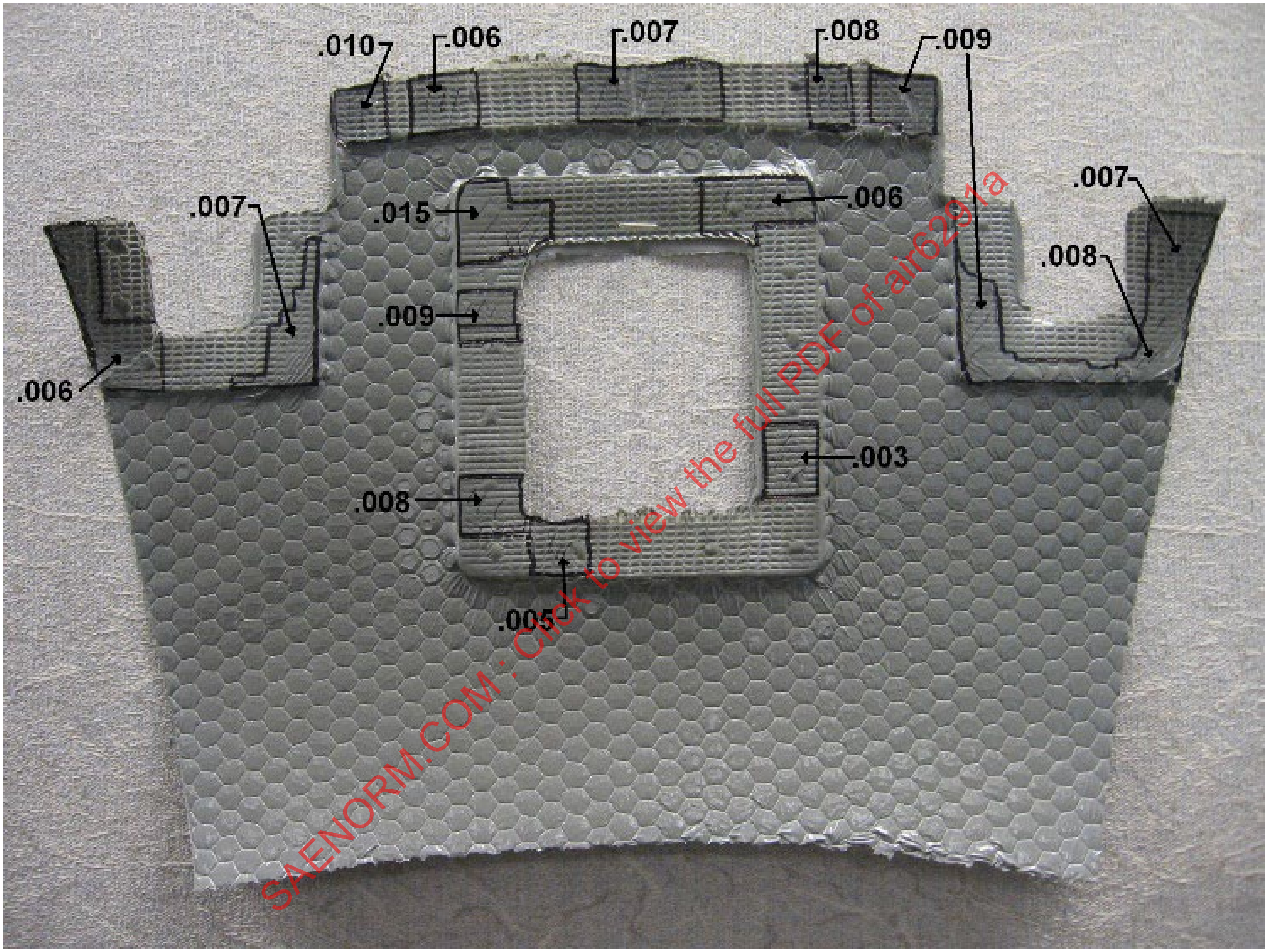

Figure 24 - Example of a verification film test cured out and circled thickness indications in areas that appear dark when exposed to a light source

(e) Check for bubbles, tunnel voids, voids, frothing, or other nonuniform conditions in the adhesive film. These are all indications that the BAJ (or ASM) shaped repair details or bagging procedures were not executed properly and are cause for rejection of the verification film test. See Figure 25 for further details.

(i) Identify any discrepancies and their location with respect to the part being repaired and forward to the Engineering or Tooling department for further evaluations or, if the reason is known, make necessary corrections and repeat the procedure until passing verification film testing can be achieved.

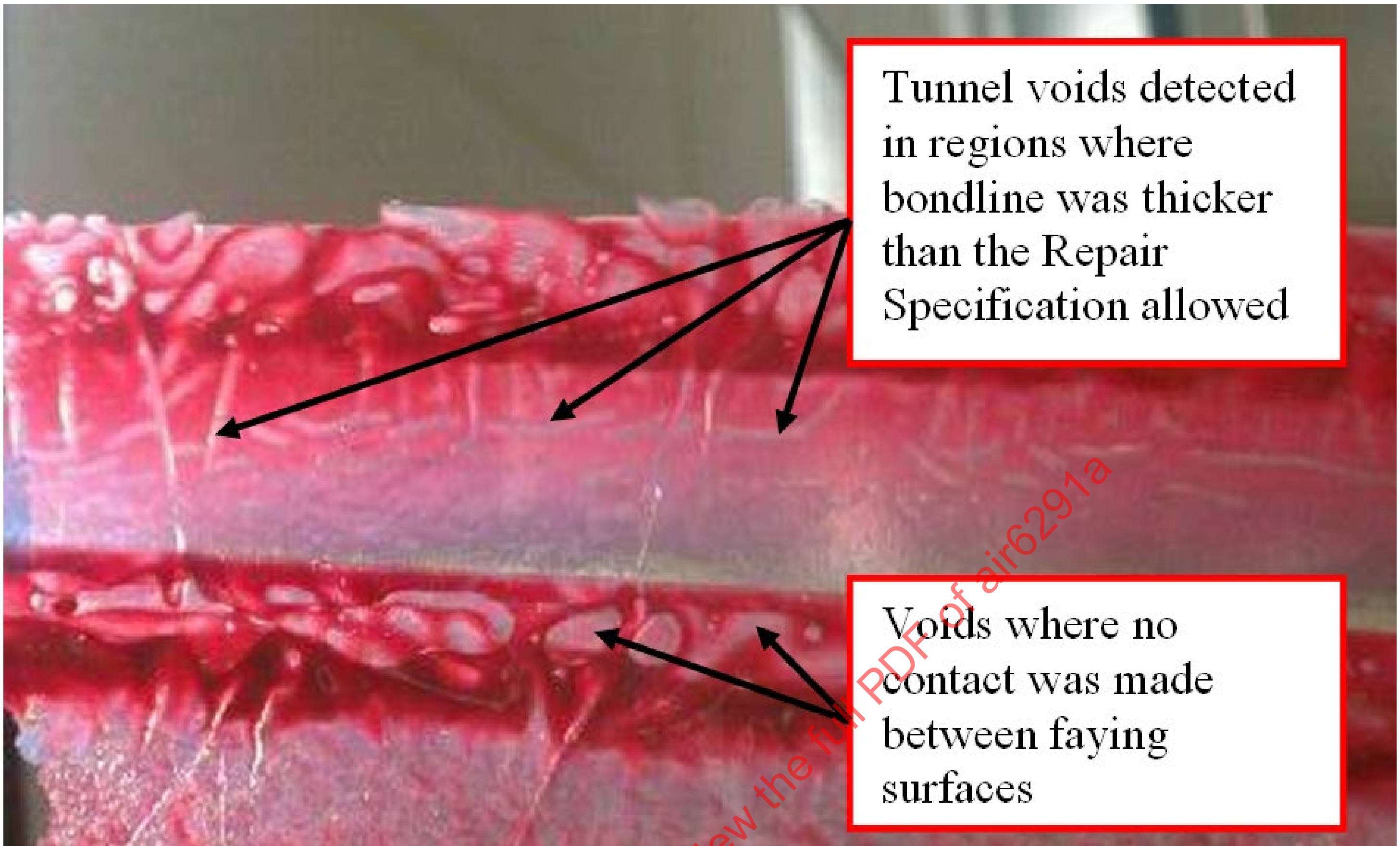

Figure 25 - Tunnel voids shown at the interface between a tool side skin and spar flange for a wedge assembly

c. It may be a requirement in the Repair Document to accomplish a destructive evaluation. A destructive evaluation is one method of accomplishing a bond line check in areas that are impossible to accomplish verification film tests. See Figure 26 for an example of a bond line inspected during a destructive evaluation.

NOTE: OEM fabrication specifications typically mandate destructive evaluation of aluminum bonded assemblies as part of a first part qualification (FPQ) plan. Destructive evaluation is important to assure quality where adherence to process is required and end-item inspectable features are not available. OEM specifications typically permit destructive testing to be waived when geometry is simple and there is acceptable pre-fit, verification film test, and NDT.

1. The following conditions should be taken into consideration when deciding whether to destructively evaluate a repair:

- Ability or inability to conduct a pre-fit check
- Whether or not a reliable method of NDT is available to check for voids
- Verification film test has/has not been conducted and was/was not able to be used to judge effectively for the component that all faying surfaces have adequate contact
- The degree of curvature in the component
- The core is constructed of one piece/multiple details
- The presence of internal doublers/core rebates

- Presence of areas of low pressure that might occur during the autoclave cure cycle (for example, in a sheet-formed pan sandwich application)

- Whether or not the repair is the first in a series of major repairs on a series of components

- Extensive/complex tooling is/is not required

2. The specific details to be evaluated in a destructive evaluation will vary by component but typically include the following: the degree of filleting in core details, consistency of adhesive thickness in non-sandwich faying surfaces, acceptable failure modes in core/facesheet bonding, and checking against the verification film test for measuring final bond thickness.

3. A destructive evaluation is an accomplishment of a layup and cure of the repair parts using a procedure identical to that described in Step 4.4.4.b, except no parting film is used in the layup. The repair is removed, in areas of interest as necessary, to evaluate the bond line conditions.

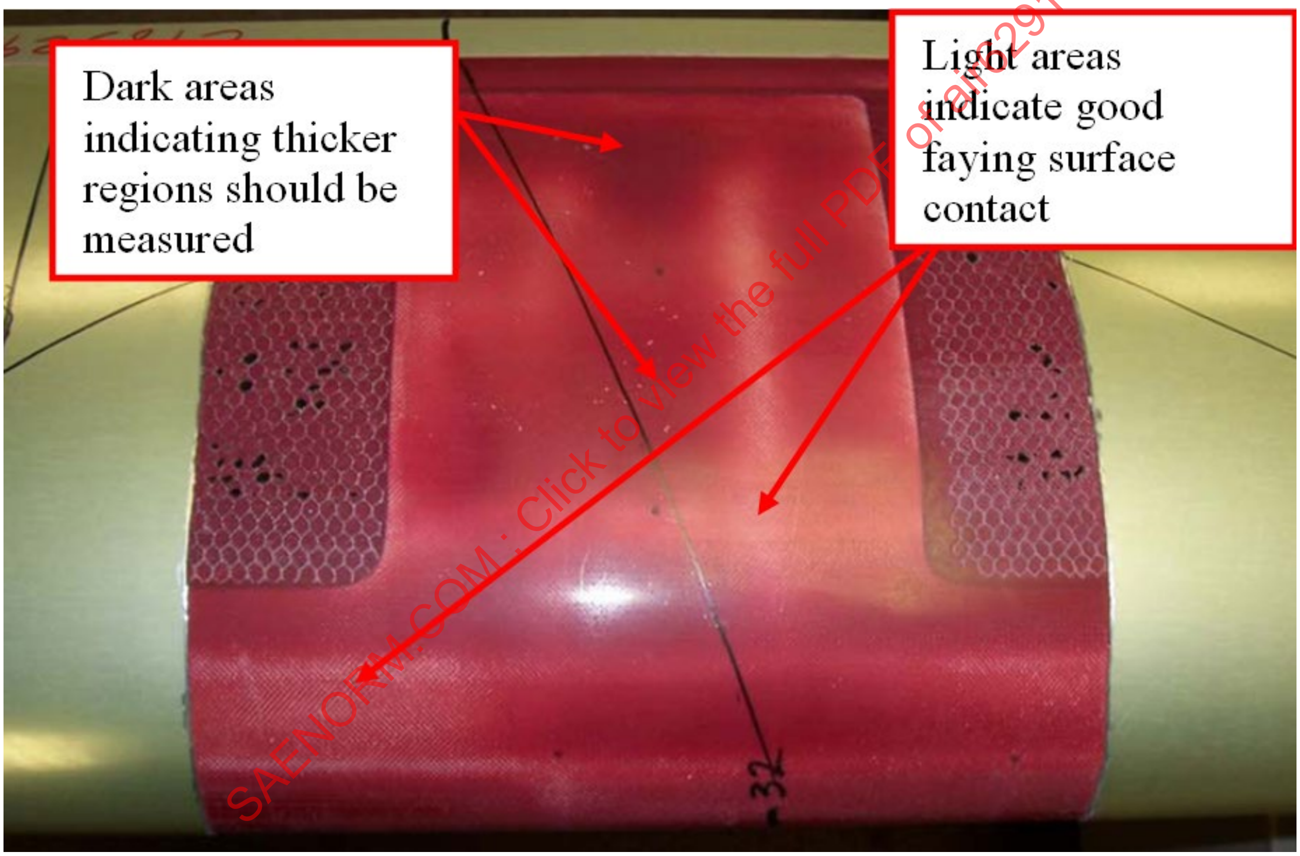

Figure 26 - Destructive analysis of a flap vane assembly showing the cured film adhesive between the outer skin and internal core and doubler

4. This type of test requires re-accomplishment of the repair, at least in part, as it requires disassembly of the parts after the cure is accomplished.

d. Record the cure pressure and film adhesive type, grade, class, number of adhesive film plies used in areas that have more than one ply, and manufacturer specification number that were used to successfully verify the bond line condition as being satisfactory in accordance with the Repair Document requirements. These data will be necessary for duplication during the final repair layup and cure. Retain this information as a record to return to the Customer, as directed by the Customer.

e. Each time a repair is accomplished, regardless if the same work scope has been accomplished in the past using the same repair details, tooling, and Repair Document, a dry fit check should be performed to make sure that all repair details have been fabricated to achieve proper fit. This step can be accomplished before the solid aluminum parts are chemically treated and application of primer.

1. In order to make sure that all adhesive primer applied surfaces are protected, when accomplishing a dry fit separate these delicate surfaces from sharp parts (such as honeycomb core details) using a layer of parting film. Make sure that the parting film being used is approved as a contact material for use by the Repair Document.

2. Make sure that the mismatch between all repair details and the damaged part is within the tolerances that are specified in the Repair Document. Only use the amount of pressure during a dry fit check that is allowed by the Repair Document. Look for movement or deflection in the part after pressure is released, i.e., spring-back, to find low and high spots in the core within the repair area.

4.4.5 Staging of Time and Temperature Sensitive (TATS) Materials

a. Thaw all TATS materials that were verified in Step 4.3.14.e.1 to be acceptable for use with the Repair Document in accordance with all of the requirements listed in the Repair Document.

1. Verify that all TATS materials remain sealed in an airtight moisture-proof bag before proceeding to prevent moisture from condensing inside the bag, which can jeopardize the repair.

(a) If the moisture-proof bag seal has been compromised, the TATS materials should not be used.

(b) Completely thawed materials will not exhibit moisture on the outside or inside of the sealed moisture-proof bag. When all materials are completely thawed, remove the TATS materials from the bag and verify that there is no moisture visible on the materials.

(i) Moisture presence after thawing is cause for rejection of the materials.

(ii) Some materials require that specific temperature ranges be met before unsealing the moisture-proof bagging material.

CAUTION: Durability and strength of the repair cannot be assured after exposure of repair materials to moisture. Moisture may not be visible but may still be present if materials are not warmed to room temperature.

2. Check the remaining out-time of all thawed TATS materials and make sure that there is enough out-time and shelf life left for each material such that the material will remain valid for use until curing can be accomplished.

(a) Some materials can only be cycled in and out of refrigerated environments a limited number of times. Make sure that all cycle requirements are maintained.

CAUTION: Durability and strength of the repair cannot be assured should material exceed out-time and shelf-life limits.

NOTE: The adhesive and prepreg plies or smaller rolls can be cut in advance and stored in separate sealed bags for quicker and easier to thaw.

3. Seal TATS materials in an airtight moisture-proof bag and log out-time exposure for repair materials that will be returned to storage.

4. Mix all two-part adhesives/potting compounds together in wax-free and contaminant-free containers, paying attention to the pot/working life of the two-part materials. Make sure that there will be adequate time to apply these materials before the pot/working life of the material expires; continue to monitor the pot life of adhesives prior to bonding.

WARNING: Mixing large quantities of two-part resins can cause a runaway exothermic reaction (high temperatures) which can cause injury to personnel. Refer to ARP5256 for the procedures to mix resins correctly.

CAUTION: Exceeding the pot/working life of adhesives/potting compounds/laminating resins will affect the workability in the conduct and strength of the repair. Attention needs to be made to the numerous factors that will affect the pot/working life of the adhesives, including temperature, humidity, mixing procedure, and additives.

4.4.6 Conduct Layup in Contamination Control Area

a. Protect the repair layup from contamination through the following steps. See Figure 27.

CHECKLIST ITEM	REFERENCE PARAGRAPH	ACTION
Use gloves approved by the Repair Document.	4.4.6.a.1	
Layup must occur in a CCA.	4.4.6.a.2	
Unapproved materials are not permitted in CCA.	4.4.6.a.3.(a)	
Make sure that CCA is enclosed.	4.4.6.a.3.(b)	
Make sure that compressed air is filtered.	4.4.6.a.3.(c)	
Implement cleaning procedures in the CCA.	4.4.6.a.3.(d)	
Make sure that incoming air is filtered.	4.4.6.a.3.(e)	
Make sure that air pressure within CCA is above ambient.	4.4.6.a.3.(f)	
Make sure that temperature and humidity are maintained.	4.4.6.a.3.(g)	
Make sure that no airborne contaminants exist in CCA.	4.4.6.a.3.(h)	
No food, drink, tobacco products inside the CCA.	4.4.6.a.3.(i)	
Make sure that all aluminum bonding tables are segregated from other composites.	4.4.6.a.3.(j)	
No sanding, stripping, or machining inside the CCA.	4.4.6.a.3.(k)	
No uncured release agents inside the CCA.	4.4.6.a.3.(l)	
No uncured silicones.	4.4.6.a.3.(m)	
No painting inside the CCA.	4.4.6.a.3.(n)	

Figure 27 - Contamination control process checklist

1. While handling adhesives, potting compounds, chemically treated and bond primer applied metal, honeycomb materials, and any other materials that will be bonded as a part of the Repair Document, only handle using gloves that are approved by the Repair Document.

2. Make sure that all layups occur in a CCA that meets the requirements of the Repair Document. The application of polymeric reaction materials, such as adhesive and adhesive primer ,shall be conducted within a CCA.

3. A CCA is characterized by the following list of requirements, which is only a partial list.

CAUTION: Substituting or using unapproved contact materials that have not been approved in the Repair Document can result in failure of the bond line.

(a) Unapproved materials are not permitted in a CCA. Only materials that are approved to come into contact with repair details and adhesives that are used during the repair layup shall be used. Approved materials include such items as specific types of gloves, tapes, release films, etc.

(b) An enclosed area is required.

(c) Compressed air should be free of contaminants.

(d) Routine cleaning procedures have been identified and are being followed. A record should be kept on hand that demonstrates compliance with the cleaning schedule. Sweeping or other dust-dispersing methods of cleaning shall be prohibited when layup is in progress or uncovered materials are present within the CCA.

(e) Incoming air should be filtered.

(f) There should be positive air pressure within the CCA.

(g) Temperature and humidity ranges that are specified in the Repair Document should be monitored and maintained throughout the repair layup.

(i) Failure to maintain temperature and humidity ranges can make layup less controlled or extremely difficult, degrading the technician's likelihood of successful layup in accordance with the Repair Document/repair drawing.

(h) Make sure that inside the CCA there are no combustion engines, machine oils, greases, or airborne contaminants such as fiberglass/carbon dust or other debris from sanding in adjacent work areas.

(i) Make sure that there are no food, drink, or tobacco products inside the CCA at any time.

(j) All tables and work areas that are designated to be used for aluminum bonding should be segregated from those work areas not designated to be used for aluminum or hybrid aluminum/composite layup.

(k) All processes that produce contaminants (e.g., sanding, stripping, trim, and/or routing operations) shall be conducted outside of the CCA to avoid the introduction of contaminants to the layup area.

(l) Tooling release agents shall not be contained within a CCA nor should application of release agents to tools occur within a CCA.

(m) No uncured silicones.

(n) No painting of topcoat or silicone coatings is permitted inside of a CCA. Local touch-up with bonding primer is acceptable.

4.4.7 Layup Repair

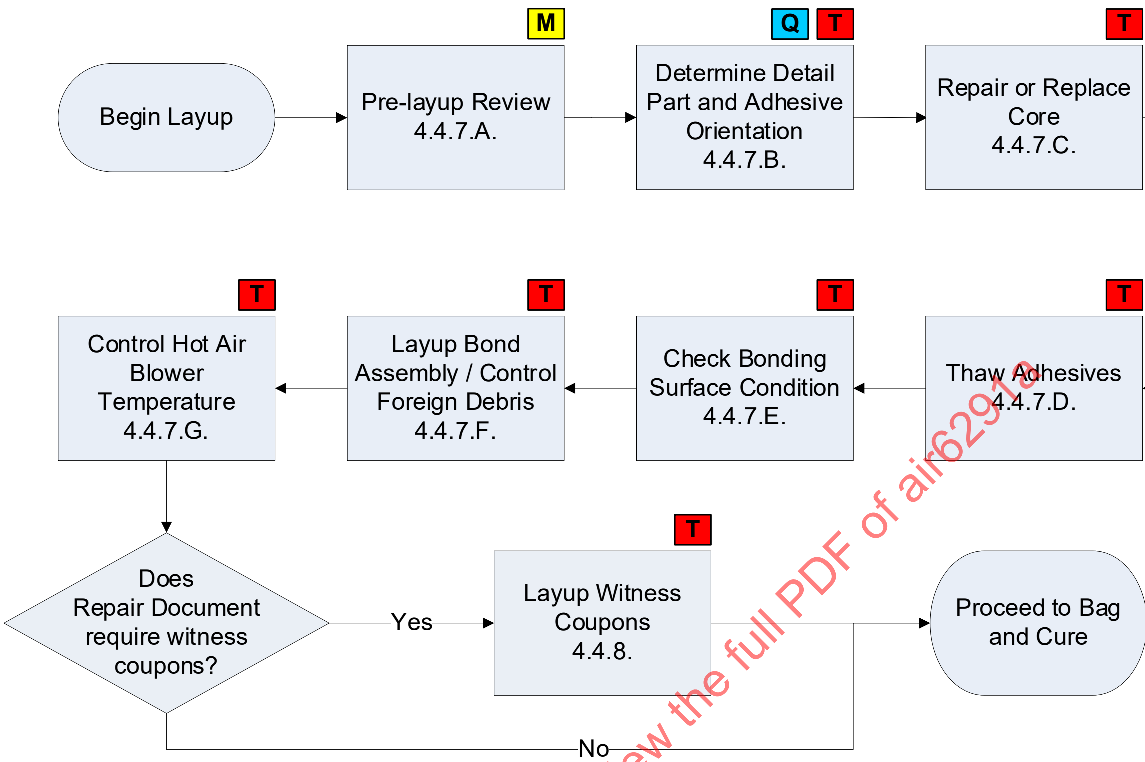

Figure 28 - Layup process flow

a. Make sure that the repair details and adhesives are laid up in accordance with all requirements listed in the Repair Document/repair drawing, including dimensional tolerances.

b. Determine the detail part/adhesive orientation.

1. If there are grain direction requirements for any of the aluminum sheet details, make sure that the grain direction is aligned properly.

2. One side clad sheet materials should be laid up with the clad side facing the appropriate side, according to the Repair Document/repair drawing.

3. Some film adhesives are required to be laid up with a particular side toward honeycomb core due to asymmetrical scrim cloth construction, known as one side tacky (OST).

CAUTION: Peel strength can be negatively affected if the adhesive film is laid up with the incorrect side facing the honeycomb core detail.

c. Core Repair/Replacement

1. Make sure that honeycomb core repair details have the ribbon direction aligned in the proper direction and that the core cell walls are aligned parallel with the original core cell walls within the tolerance provided in the Repair Document/repair drawing.

CAUTION 1: Compression strength can be significantly degraded if the core cell walls are not correctly oriented with respect to the facesheet.

CAUTION 2: Bending strength in the critical loading plane is reinforced by the honeycomb core's ribbon direction. Aligning the ribbon direction in a different plane than what is specified by the Repair Document/repair drawing will result in a repair that will not meet the required strength of the honeycomb sandwich.

2. Honeycomb core cells should be examined before and after curing in place to make sure that there is no cell wall crushing, node separation, over or under expanded regions, or any other defect that might be listed in the Repair Document or other process specifications.

CAUTION: Honeycomb core that is damaged or has misshaped cells will have reduced strength. Rework for defects must follow the Repair Document or other process specifications.

3. The Repair Document should have a tolerance for gaps between honeycomb core details and adjacent structures. It should also specify how much foaming adhesive to use to fill that gap.

d. Adhesive Preparation

1. Ensure the film adhesive is thawed before opening the sealed bag. See 4.4.5 for details. This step may require many hours, depending on the size of the rolls. Confirm there is sufficient out-time remaining to accomplish the layup, vacuum bag, and start the cure.

e. Check that the bond surface is within time limits, not damaged, clean and uncontaminated, and has been protected from UV light and contaminants. The Repair Document will provide instruction for either cleaning the bond surface or for reactivation of the bond surface, if permitted.

1. Refer to Section 4.4.2.C. for discussion on solvent cleaning of bond surfaces.

CAUTION: Do not substitute solvent type or grade. Primers have sensitivity to different solvents and can be damaged if the wrong solvent is used.

2. Refer to Section 4.4.2.G. for discussion on time limits and re-activation for primer applied surfaces.

f. Layup Bond Assembly

1. If a peel ply is used to protect bonding surfaces, there shall be verification that the peel ply is removed and the surfaces are prepared per requirements listed in the Repair Document prior to bonding.

2. Remove the backing material from the adhesive materials and set aside.

CAUTION: Backing material can become embedded in the repair and may not be detectable by NDT. Such foreign object debris (FOD) can result in disbond and reduction of strength.

BEST PRACTICE: After installing, keep the backing material sheets and count the total to prevent leaving them attached to the repair material. Conduct a quality inspection for the number of backing material sheets.

g. When heat tacking is allowed by the Repair Document during layup of the repair, it is critical that the heat guns being utilized do not expose the uncured film adhesives to temperatures that are beyond the temperature range allowed by the Repair Document.

1. The Repair Document may allow a slight amount of heat to be applied with a handheld hot air blower, also known as a heat gun, to the uncured film adhesive to tack or stick it in place. When allowed, the use of heat guns must be controlled for temperature, distance, and total time to avoid exposing the uncured film adhesives to temperatures that are beyond the temperature range allowed by the Repair Document. Heat guns without temperature regulators can quickly raise the material temperature over 700 °F (370 °C) if held too close the part. Typically, heat guns will be controlled to not go over 140 °F (60 °C) and, when used, will be quickly swept back and forth across the part to avoid hot spots.

2. If reticulation is to occur to preserve sound attenuation properties of a perforated skin over an acoustically sensitive repair area, it is critical that the heat reticulation device being used does not heat up the unsupported adhesive film past the temperature range that is allowed by the Repair Document during layup.

3. Overheating during reticulation can accelerate the cure of the adhesive film, thereby weakening the bond between the honeycomb core and facesheet.

CAUTION: Loss of tackiness and increased hardness in the film adhesive is an indication that an over-temperature condition has occurred. Material that has been exposed to an over-temperature condition will have the same issues as a material that is past its out-time or storage life limits. There is increased likelihood for porosity and loss of adhesive flow. Bond strength cannot be assured, as there is reduced chemical adhesion to the base material. Reduced bond strength cannot be found with NDT.

4.4.8 Layup of Witness Coupons

a. Witness coupons may be required by the Repair Document. Witness coupons may be used as an independent check to confirm the reliability of the repair process. For witness coupons to provide meaningful results, it is important that all phases of the repair process that affect bond line integrity of the repair are duplicated on the coupons. The witness coupons should be processed concurrently with the repair. See Appendix C for more information.

NOTE 1: The type of witness coupons should be selected to evaluate the structural properties that cannot be verified by other means nor are inspectable in-process or as end-item.

NOTE 2: Witness coupons should not be used as a replacement for the standard quality control operations. Even though witness coupons are processed concurrently with the full repair, they cannot fully ascertain whether a component has sufficient strength.

NOTE 3: Witness coupons cannot be relied upon to make sure that parts have reached temperature and sufficiently cured. A thermal profile or sufficient number of thermocouples are required on the part to ensure adequate heat-up and cure.

1. The same repair technician(s) should perform layup and cure of witness coupon and repair.

2. Coupon facesheets should be chemically treated and adhesive primer applied in the same batch as the other aluminum sheet and machined aluminum details.

3. Honeycomb core that is used with climbing drum peel tests (refer to ASTM D1781) should be examined to make sure that the core has not been overexpanded or under-expanded. Either condition will skew test results.

4. When applying adhesive primer to the coupon panels, care must be taken to make sure that the primer thickness matches the thickness of the repair details. Primer thickness measurements should also be taken on the coupon panels in order to ensure consistency.

5. Some adhesives are specifically designed for one particular side to face honeycomb core due to asymmetrical scrim cloth design, known as one side tacky (OST). It is critical to follow this requirement in order to achieve climbing honeycomb peel test results that match the process used in the repair.

6. Each coupon should be laid up using the same roll of film adhesive with the same mechanical life and handling life used in the layup of the repair.

7. Each test coupon should be cured concurrently with the repair in the same cure cycle.

8. Witness coupons should be cured on the same tool as the part and under the same vacuum bag.

   (a) In situations where this is not possible, it is acceptable to use a separate tool if a slave bag is employed. The slave bag should be connected to the parent bag via a vacuum port and vacuum hose so that the same atmospheric conditions are experienced by both bags.

4.4.9 Bag and Cure of Repair

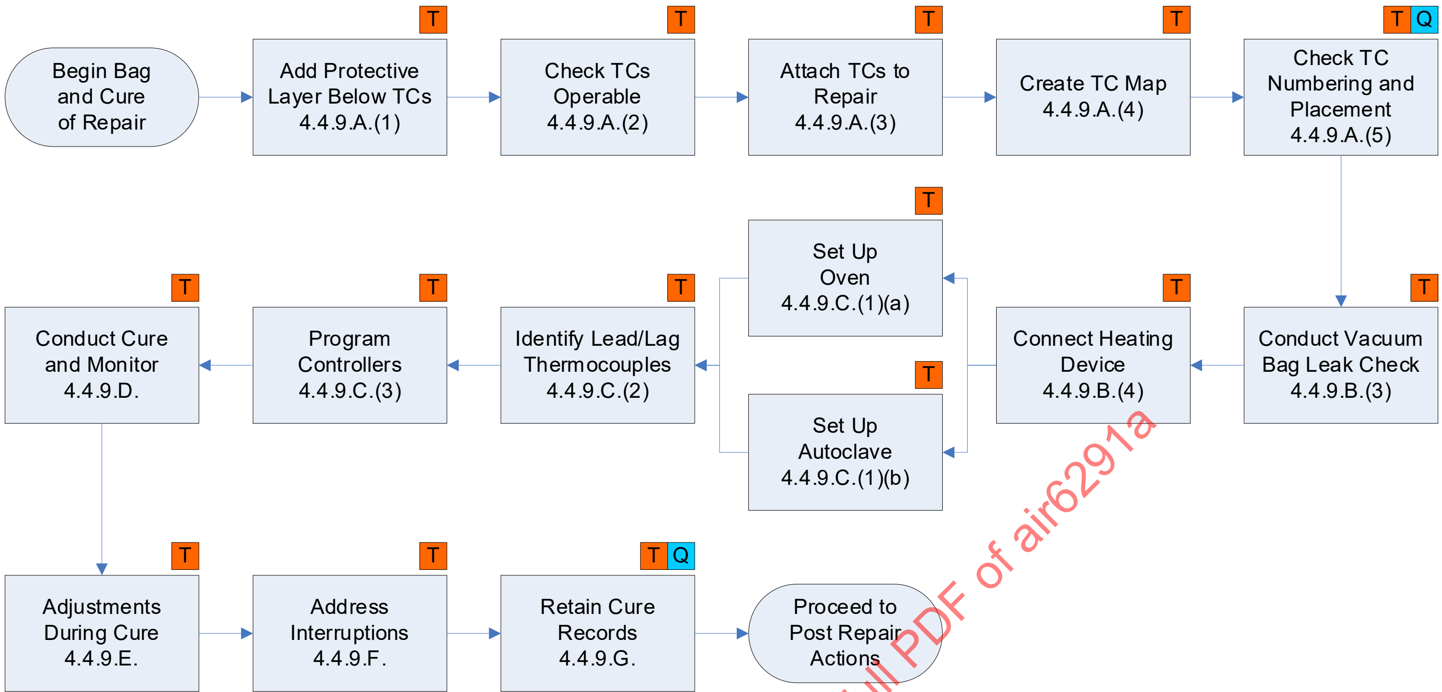

Figure 29 - Bag and cure process flow

a. Place and Map Thermocouples

1. Add Protective Layer Below Thermocouple

(a) Flash breaker tape may be used.

2. Check Thermocouples Operable

(a) Check that thermocouples have been calibrated and have not expired. Refer to ARP5144 for information on thermocouple calibration.

(b) Check on the recorder that thermocouples are responding to the temperature. Finger heat may be used.

(c) Confirm the channel numbering on the recorder matches the number on the thermocouple.

3. Attach Thermocouples to Repair - Hard Tool

(a) The method is only applicable if the entire part is heated in an oven or autoclave. It is not applicable to heat blanket repairs. Refer to AIR6292 for discussion of thermocouple placement and thermal management when using radiant heaters (heat lamps), hot air blower/box, and heat blankets.

(b) Place thermocouples for controlling temperatures at the leading and lagging thermal heat-up locations, as was determined by the thermal profile that was accomplished during Step 4.3.15.a.2.

BEST PRACTICE: Multiple thermocouples should be used at each critical location in the event that a thermocouple fails during cure.

(c) Place additional thermocouples for monitoring temperatures at:

(i) Locations that could be degraded by elevated temperatures such as sealant or heat-treated aluminum alloys.

(ii) Each test coupon location.

NOTE: Check that thermocouples added for monitoring are not used for control.

4. Create Thermocouple Placement Diagram

(a) Create a thermocouple placement diagram if it has not been created prior to this step.

(b) Use the thermal profile documentation recorded in 4.3.15.a to determine the location and quantity of thermocouples to be placed. The thermocouple placement diagram may come from the Repair Document or may need to be created using the guidelines in the Repair Document. The repair technician has the ownership/responsibility for thermocouple placement according to the general requirements in the Repair Document.

BEST PRACTICE: Mark the thermocouple wires with thermocouple number so that numbering can be known even after vacuum bag has been installed.

5. Check Thermocouple Placement

(a) Prior to bagging, check final placement of thermocouples on the repair against the thermocouple placement diagram. In-process inspection should be conducted by Quality or trained shop personnel for complex repairs.

(b) The thermocouple placement diagram as described in 4.4.9.a.4 may need to be changed during the attachment of the thermocouples. The thermocouple placement diagram must be updated and confirmed to match the final thermocouple placement. All thermocouple locations must be documented on the thermocouple placement diagram for evaluation after cure; this includes leading thermocouple, lagging thermocouple, redundant backup thermocouples, any extra thermocouples, and test coupon thermocouples.

BEST PRACTICE: Take a photograph of the installed thermocouple location prior to bagging.

b. Bag Repair

1. Bag repair and test coupons per the Repair Document instructions.

NOTE: Refer to ARP5143 for additional information and vacuum bagging techniques. ARP5143 bagging figures are intended for nonmetallic composite layups.

2. Figure 30 shows a typical bagging schedule that is appropriate for aluminum bonding.

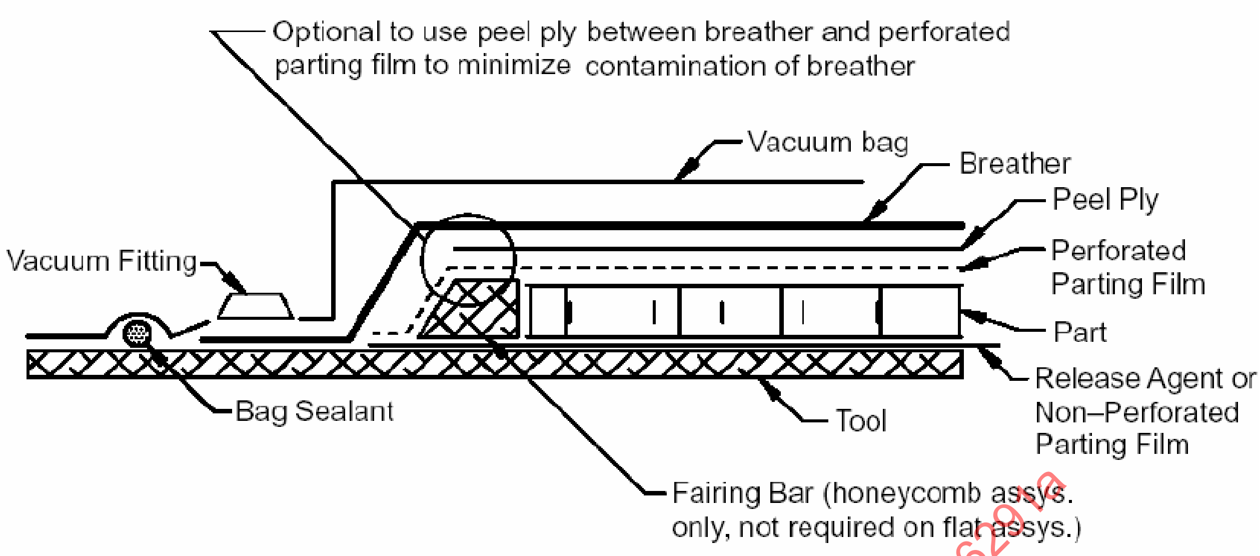

Figure 30 - Typical bagging schedule for aluminum bonded repairs

3. Conduct Vacuum Bag Leak Check

(a) Connect vacuum source to bag port(s) and bring assembly to the proper vacuum level per repair documentation. If proper vacuum cannot be obtained, work the vacuum bag sealant tape joints along bag edge, specifically around the areas, if existing, where the thermocouple and heat blanket wiring enter the bag, until the proper vacuum can be maintained as required by the repair documentation. Refer to ARP5143 for further details.

BEST PRACTICE 1: Even though ARP5143 states that 5 in Hg loss in 5 minutes is acceptable, it is best practice to achieve 1 in Hg loss in 5 minutes to increase the likelihood of an acceptable repair.

BEST PRACTICE 2: Prior to conducting a leak check on the bag, check the ports, hoses, and couplers without connecting to the bag to make sure that leaks once observed are due to bagging exclusively.

4. Connect Heating Devices

(a) Make all connections to heat application device (e.g., heat blanket, heat lamps, oven, autoclave, etc.) and test per the Repair Document and per the general requirements in ARP5144.

NOTE: Refer to ARP5143 for additional information and vacuum bagging techniques.

c. Setup Prior to Cure

The heat source should be set up as required by the Repair Document.

For all heat sources, ensure thermocouples are properly identified and are plugged into the proper locations on the controller. Use the thermocouple placement diagram developed in Step 4.4.9.a.4 and 4.4.9.a.5 or provided in the Repair Document. Refer to ARP5144 for additional information for each heating source.

1. Heat Source Specific Setup

The setup for cure of the repair depends upon the heat source selected. This section provides guidance for specific heat sources. Incorrect application of heat and/or placement of thermocouples can result in under-temperature or over-temperature of the repair area. Refer to AIR6292 for discussion on radiant heaters (heat lamps), hot air blower/box, and heat blankets.

(a) Ovens

(i) Place the part/tool in the oven in the same-orientation as the thermal survey, or as required by the Repair Document.

NOTE 1: Airflow in the oven may impact the uniformity of temperature in the oven. Achieving a uniform temperature may be difficult if there are multiple parts in the oven or if the component is large. Do not place part with the repair area near the bottom of the oven since the lower area of the oven will lose thermal energy to the ground.

NOTE 2: When using air oven temperature, the part temperature could be different to the air temperature, which could lead to a different cure profile. The part temperature will most likely be lagging compared to the air temperature. Ovens controlled by thermocouples on the part or tool are the preferred method to avoid temperature differences between the parts and airflow temperature, which influences the cure profile of the repair material. Thermocouples located on the part or from tool thermal survey need to be used to demonstrate the specified cure profile.

(ii) Make sure that the part is in contact with the airflow but without airflow concentrated on the part. Baffles and ducts may be needed for specific parts to make sure airflow in the oven provides uniform temperature.

(iii) The notes for heat blanket repairs may be applicable to oven cure repairs.

(b) Autoclave

(i) Place the part/tool into the autoclave in the same orientation as the thermal survey, or as required by the Repair Document. Parts should be spread evenly throughout the oven or autoclave to improve air circulation and to eliminate air stagnation points. This will assist in improving the temperature distribution between the various parts being cured.

NOTE: If maintaining a uniform temperature distribution is in doubt, a thermal survey (dry run) on the tools alone will indicate the probable response from an actual cure.

(ii) Load parts into the oven or autoclave with a mix of tools that have similar thermal characteristics, i.e., tool mass, tool design, tool material. Failure to observe the effect of these tool variables could result in tools with low mass reaching cure temperature well in advance of tools with larger mass. The time difference could be significant, which could result in overcure on some parts. Thermal capacity of the oven or autoclave is a critical factor with high tool loading and will dictate heat-up rates and final temperature capability.

2. Identify Lead/Lag TCs

(a) If available from thermal survey or hard tool documentation, keep track of the known leading and lagging thermocouple, which will be needed for programming the controller. Cure hold time will not start until all lagging thermocouples are in the required temperature range.

(b) Identify which thermocouples will be used for control and which will be used for monitoring, which will be needed for programming the controller. Ensure monitoring thermocouples are not used to control the cure.

3. Program Controllers

(a) Program any automated heat application devices per the Repair Document defined heat and pressurization cycle requirements.

(b) Hot bonder programming requires caution to ensure that the desired cure parameters are maintained during the cure. Refer to AIR6292 for areas to consider.

d. Conduct Cure and Monitor

1. Cure the repair per the Repair Document instructions and per the general requirements in ARP5144. The cure profile for ramp to cure temperature, any dwell time, total time at cure, and ramp down must be controlled as part of the Qualified Bonding Process. Vacuum integrity through the repair cure must also be controlled as part of the Qualified Bonding Process.

2. Once initiated, the cure cycle in an oven or autoclave does not provide opportunity for operator physical adjustment.

   (a) The oven or autoclave will be programed to provide cure profile per the Repair Document. For autoclave cure, pressure will also be programmed. Venting the vacuum bag to atmosphere may be specified. The operator will monitor the cure for loss of vacuum, loss of temperature recorder, or loss of thermocouple.

   (b) Oven

      (i) Operator initiates cure cycle using controller.

      (ii) When controlling temperature using part temperature, a time lag between the air temperature and when part temperature equalizes can result in an over-temperature on the surface of the part.

      (iii) When controlling temperature using air temperature, the time lag between air temperature and part temperature can require the cure time to be extended to make sure the part is fully cured.

   (c) Autoclave

      (i) Operator initiates cure cycle. Heat blankets may be used to provide local heating under autoclave assist cure. Operator monitoring during cure is not changed for autoclave assist cure cycles.

3. Non-Oven/Non-Autoclave Heat Sources

   (a) The plan for thermal management should be reviewed by the technician before beginning the cure to ensure the technician is prepared for active management of the repair, especially if the thermal management plan was done by a different person.

   BEST PRACTICE: It is best practice to have a technician continuously monitor the repair cure cycle as the cure is being performed and make sure that all temperature and pressure readings continue to be maintained throughout the cure cycle, as required by the Repair Document.

   (b) Refer to AIR6292 for discussion of cure and monitoring when using radiant heaters (heat lamps), hot air blower/box, and heat blankets.

   (c) The localized nature of the heat source demands may require that a different approach is used for managing the heating procedures as compared to global heating systems, such as autoclaves and ovens, in which the whole part is heated to or near the cure temperature. In a global heating system, any substructures, such as spars, ribs, longerons, etc., are also heated and have a minimal effect on the cure cycle of adjacent adhesive bonds. In a repair scenario involving heat blankets, however, the presence of a substructure can make a very significant difference to the cure cycle experienced by an adhesive. There are severe risks of damage from overheating or under-curing the adhesive, depending on the configuration of the heating system and the deployment of the temperature measurement devices.

e. Adjustments During Cure

1. Based upon temperature and pressure data obtained during the cure cycle, the technician may adjust the cure cycle, as permitted by the Repair Document, to complete the cure.

   NOTE: Some Repair Documents allow for the dwell period of the cure to reset if a lagging thermocouple obtains the dwell temperature and then temporarily drops below the dwell temperature. The technician, in this case, would be able to extend the cure cycle to account for a dwell reset.

f. Address Interruptions

1. General Guidance

(a) Repairs that are conducted with radiant heaters (heat lamps), hot air blower/box, and heat blankets are more likely to experience interruptions due to human interference.

CAUTION: Loss of power to hot bonder or heat source may not be immediately detected. Loss of vacuum or temperatures out-of-range will typically be indicated by audible alarm and a warning on the control screen by the hot bonder.

(b) Interruptions in the cure cycle require immediate action by the technician to correct. Refer to ARP5144.

(c) Interruptions in the cure cycle are acceptable if cure data remains within the cure cycle of the Repair Document and the component passes all post-repair accept/reject criteria.

(d) Interruptions in heat source or controller have the consequence of affecting the cure temperature of the repair. The strength of a repair that does not follow the cure profile in the Repair Document cannot be substantiated for structural strength.

2. Types of Interruptions

(a) Loss of Vacuum/Leaks

CAUTION: Loss of vacuum or pressure during cure results in a cure that does not meet the Repair Document requirements, and the integrity of the repair cannot be ensured. Loss of vacuum may be acceptable depending upon when the leak occurs. Engineering review and approval is required to accept a loss of vacuum during the cure cycle.

(b) Power Interruptions

(i) Power could be interrupted during a repair cure cycle.

(ii) Temporary loss of power, such as the heat source becoming unplugged, requires taking immediate action to restore power. Power interruptions are generally acceptable provided thermocouples stay within cure profile and vacuum is retained.

(c) Instrumentation Failures

CAUTION: Thermocouples often fail during repair cure. If sufficient thermal data is not available to show that the cure was done properly, the integrity of the repair cannot be demonstrated. Figure 31 illustrates the potential effects of damaged or misplaced thermocouples during a repair cure.

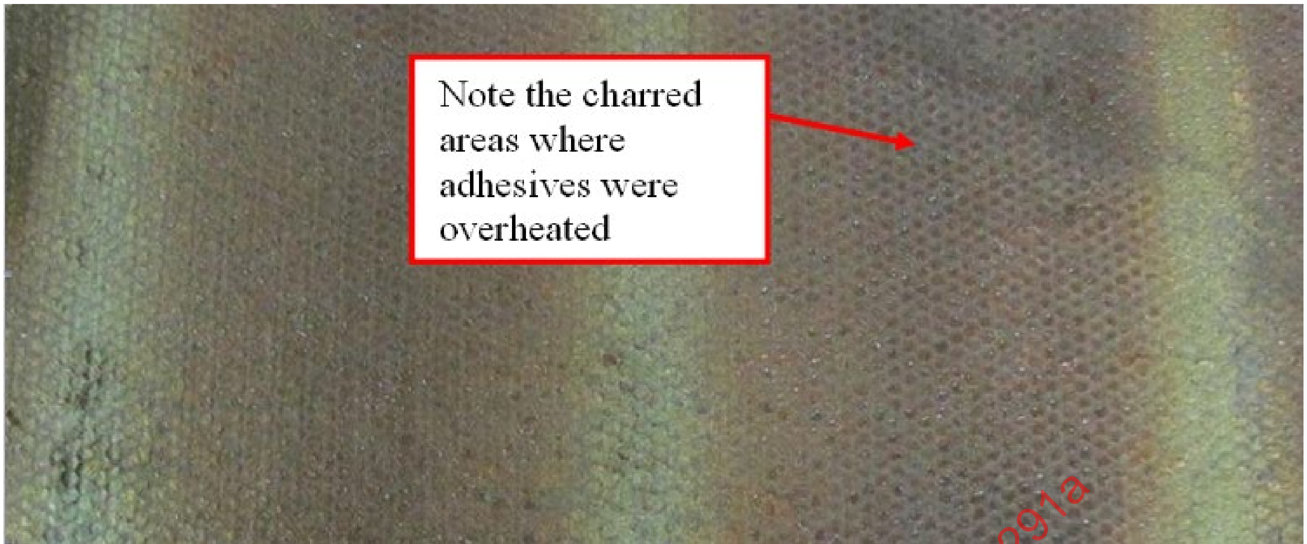

Figure 31 - Example of a thermocouple failure during repair cure

3. Repair Acceptance and Substantiation

   (a) Repair Document may include guidance on interruptions.

   (b) For failures of thermocouples used to monitor the part temperature, it may be possible for Engineering or the Repair Authority to substantiate the repair by using adjacent thermocouples, temperature data from thermal surveys, or temperature data from prior repairs.

   (c) Failure to meet Repair Document cure cycle requires Engineering review and acceptance. Substantiating data or approval for the structural integrity of the repair may need to be provided by the Repair Authority (OEM). The data provided for review should include the complete cure records: leak location, pressure/vacuum, thermocouple temperature record, and thermocouple location.

   (d) If the repair temperature profile and vacuum cannot be demonstrated to be acceptable, the repair must be rejected. Usually, this results in complete removal of the repair and conducting the repair again.

g. Retain Cure Records

1. Complete repair record and retain cure data. Quality function to approve final completed repair record.

   NOTE: It is a best practice to record and retain thermocouple and pressure cure cycle parameters and include with the repair records for post-repair evaluation. A document of the cure record can be used to evaluate whether the repair was processed within the cure process.

2. Record should contain data for temperature, pressure (positive pressure as well as vacuum pressure, as applicable), duration of each step, and alarm messages. Refer to ARP5144, Section 7. A mapping of all thermocouples should also be included in the cure cycle record. Refer to ARP5144 for an example of an acceptable thermal and pressure report.

3. Industry practice is to include the cure record for major repairs to primary structure and high-value secondary structure (e.g., engine nacelle components) as part of the retained detailed shop record.

4.5 Post-Repair Actions and Finishing Sequences

4.5.1 Post-Repair Actions and Finishing Sequences General Steps

a. The following section includes general steps to accomplish post-repair finishing and testing for a metal bond component. It is essential that finishing steps are complied with per the Repair Document; failure to do so may invalidate the repair. Figure 32 is intended for initial planning purposes. Full steps and requirements can be found in the full text of the document, as referenced in each flowchart step.

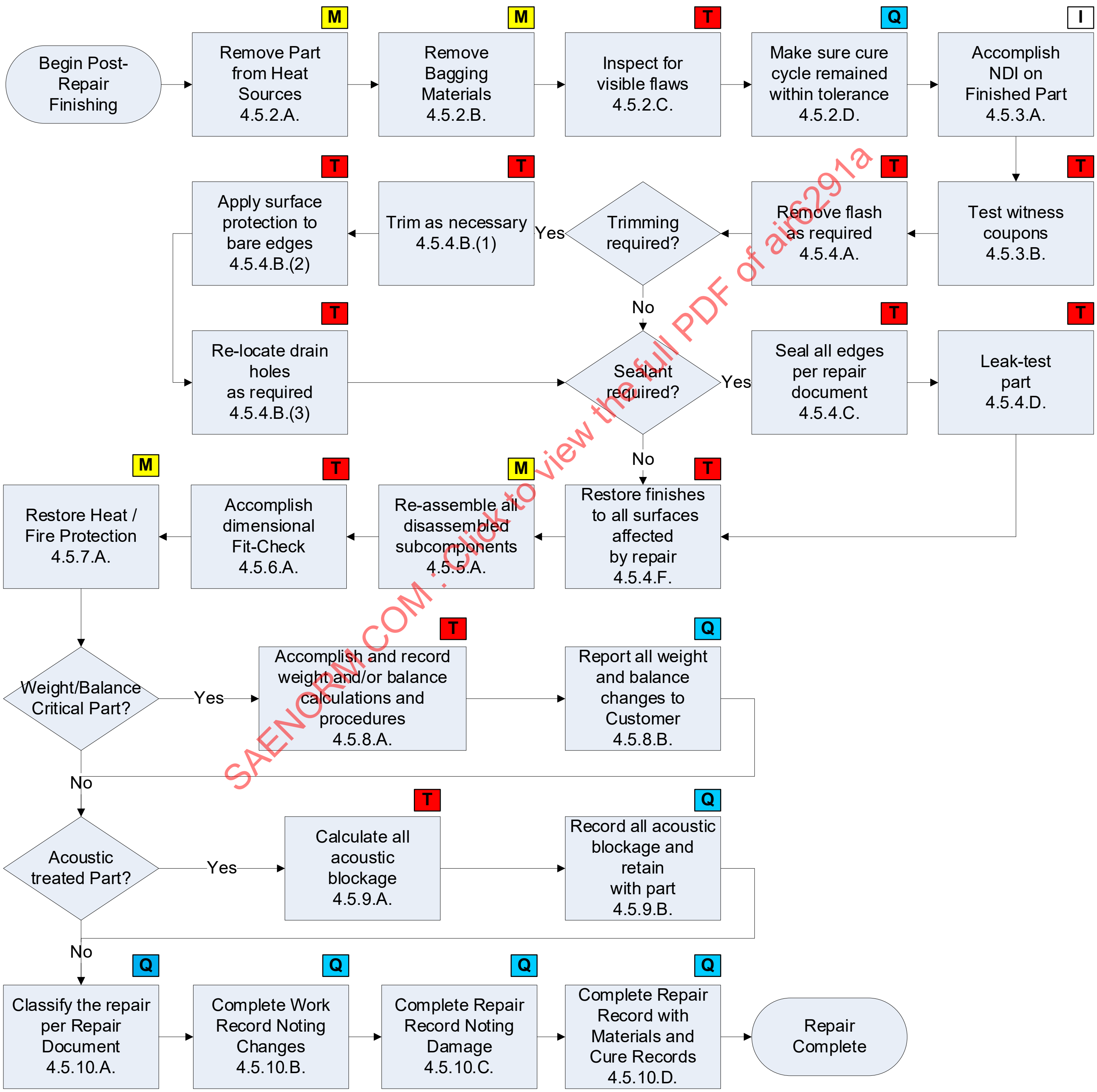

Figure 32 - Post-repair actions and finishing decision flow

4.5.2 Remove from Heat Source, Debag and Inspect

a. Once all heat sources have cooled down to a safe contact temperature, remove the repaired part from all heat sources. Make sure that all Repair Document heat source removal instructions are followed.

b. Remove all bagging materials from the repair area, using care not to damage any heat blankets and using care not to disturb any bonds on the part or the repair area.

1. When removing any tooling, fairing bars, or any aid that was used during the layup, use extreme caution so that the removal process does not damage the part.

CAUTION: Prying against the part to remove tooling can cause damage to the part, which may result in a scrapped part. Some damage might not be visually detectable.

c. Inspect for visible flaws.

1. Make sure that there is continuous adhesive flash visible along all repair bond line edges.

CAUTION: Lack of continuous adhesive flash may be cause for rejection or rework of the repair as allowed by the Repair Document. See Figure 33 for an illustration of continuous adhesive flash.

NOTE: Lack of adhesive flash may be caused by one or more of the following examples: adhesive that has exceeded its out-time limits, incorrect adhesive, poor pressure, improper layup, fit-up.

2. Make sure that there are no visible defects in the cured adhesive flash.

CAUTION: Under-cured adhesive will be soft and tacky. Overheated adhesive will be discolored in appearance. Under-cured or overheated adhesive will be cause for rejection of the repair.

NOTE: Improperly cured adhesive may be caused by one or more of the following examples: incorrect adhesive, improper thermal profile (presence of a fitting acting as a heat sink).

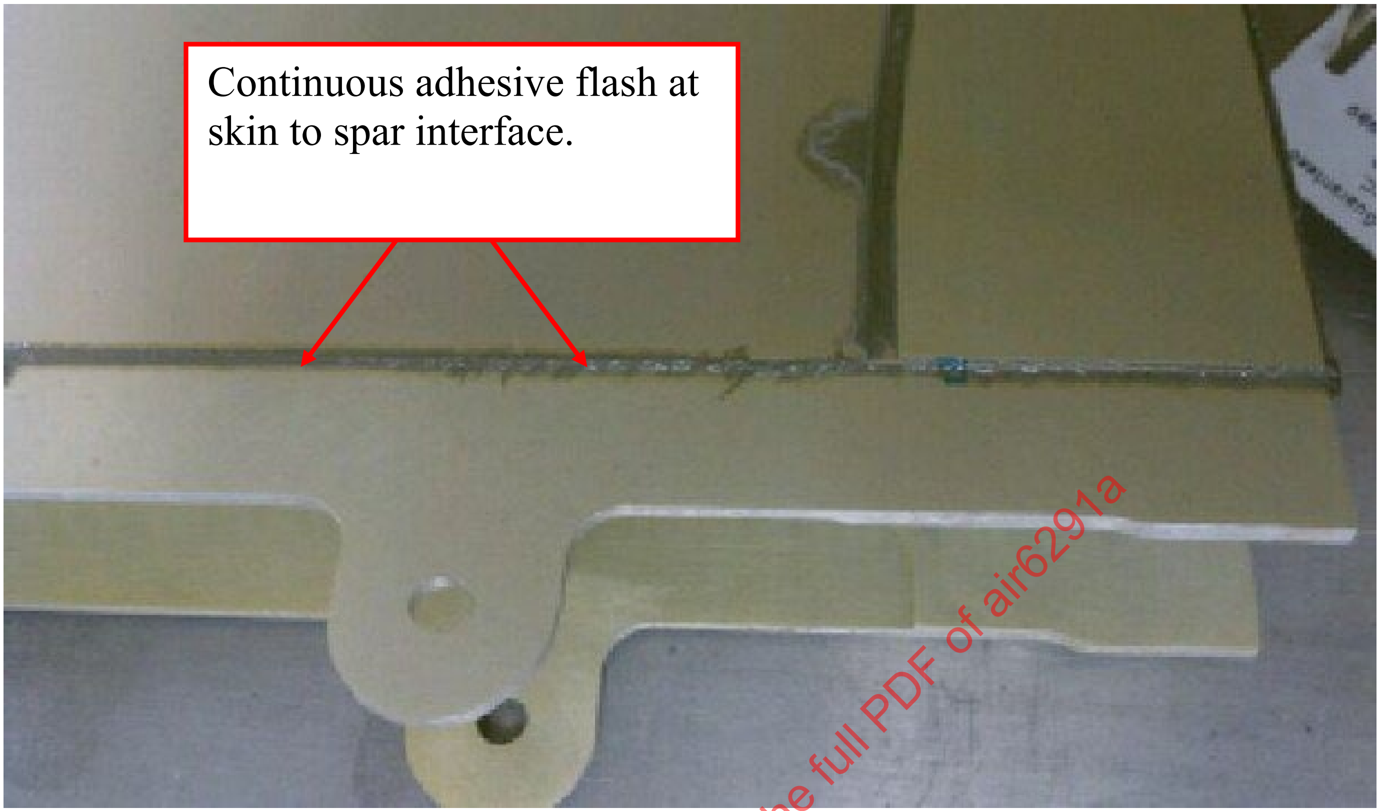

Figure 33 - Example of continuous adhesive flash along a bond line edge

3. Accomplish a detailed visual examination of the repair area.

   (a) Inspect for defects such as waviness, bumps, or gaps.

   CAUTION: Waviness may be an indication of damage to the core due to reuse. See Figure 8 for an example of damaged core caused by skin peel back.

   (b) Make sure that the OML surface contour is within the requirements of the Repair Document when internal rebates or recesses are used.

   CAUTION: Metal bond construction often requires internal rebates on core details. An excessive mismatch will result in either a depression or protrusion on the surface. Incorrect dimensions of the internal rebates or recesses will result in deviations on the OML surface.

d. From the cure cycle record, check to make sure that all pressures and temperatures remained within the specified ranges during the cure process.

   1. If the cure cycle record does not comply with the requirements in the Repair Document, the repair is invalid.

4.5.3 Accomplish NDT Inspection and Mechanical Testing

a. Accomplish NDT, as required by the Repair Document. See Step 4.3.10 for NDT requirements and guidelines.

   1. The common NDT methods for inspection of repairs are through transmission ultrasonic (TTU) if two-sided access is available and ultrasonic bond test methods if one-sided access is available. Refer to the OEM NTM or NDT manual for specific instructions. Refer to repair documentation and manual illustrations/drawings, etc., to understand any visually hidden features, such as core potting, that could incorrectly be interpreted as defects during NDT.