Online Course and Regional Laboratory Development in Composite Maintenance Education, Including Training Repair Manual

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Final Report

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**Abstract**

The major objective of this study was to develop and assess the feasibility of teaching an online class, combined with a regional laboratory, that is consistent with industry training standards published as part of a Cooperative Agreement in a Federal Aviation Administration report and Commercial Aircraft Composite Repair Committee SAE Aerospace Information Report document. These standards consist of terminal course objectives and teaching points. This development represented an application of online teaching methodologies, commonly used in the social sciences such as business management and mathematics, into engineering technology. Engineering courses have not typically used the latest teaching technologies, and this approach will provide specific advantages not commonly achieved in traditional classroom frameworks.

In addition, a training repair manual was developed as an important training tool for the laboratory portion of the class to expose students to the importance and use of authoritative documentation in the conduct of composite materials maintenance. Advantages of the online course approach were demonstrated as follows:

- Greatly reduced education costs due to limited travel expenses
- Ability for the student to fit classroom activities within busy schedules due to the asynchronous nature of online learning
- Independence of global time zone effects
- Ability to involve experts in the composites’ field to participate to a wide student audience, providing access to considerable knowledge and experience which is not as accessible in the traditional classroom.
- Broader student participation, mandated by the online methodology

Three major sections of the course were addressed, annotated by the number of students completing each in the prototype class: (1) a prerequisite course to bring students to a common level of understanding before taking the awareness course, (2) the awareness course, which represents the industry standard developed in earlier phases of this Cooperative Agreement, and (3) a hands-on laboratory.
ACKNOWLEDGEMENTS

This course development was administered by Edmonds Community College and was conducted at various locations worldwide.

The planning and execution of this project were the results of collaborative efforts of many individuals in industry, academia, and government entities. The following individuals played key roles:

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EXECUTIVE SUMMARY

This report documents the results of a Federal Aviation Administration Cooperative Agreement grant titled Critical Composite Maintenance and Repair Issues with Edmonds Community College to investigate the suitability for teaching the awareness course developed under this Cooperative Agreement in an online format.

Through this grant, researchers investigated the feasibility of using online training, in conjunction with regional laboratories, as a way of globally and cost-effectively teaching the awareness course, Critical Composite Maintenance and Repair Issues, previously developed under this grant. Based on student and industry feedback, it was concluded that online training, in conjunction with regional laboratories, can be highly effective for technical course delivery.

Another important aspect of this investigation was to create a nonproprietary training repair manual in an industry-accepted format that simulates the typical structural repair manuals (SRM) used by original equipment manufacturers. The objective was to provide a means for educators to expose students to the process and methodology of using SRMs as authoritative documents in implementing composite repairs, without having to receive manufacturer’s specific permission to avoid copyright violation. This development was in direct response to requests by industry to have access to this type of training tool.

A prototype class was taught, using distance learning for teaching principles that was coupled with attendance at a 3-day regional laboratory, conducted by Abaris Training Resources, Incorporated. Specific advantages of distance learning include reduced travel costs, better access to the course from remote regions, and the ability to use subject matter experts in the discussion sections of the course, which would be difficult in traditional classroom locations. The methodologies of distance learning and its advantages satisfy a pressing need to reach out to global students in a cost-effective fashion. The combination of distance learning and regional laboratories is anticipated to attract many more students, fulfilling the need to bring critical composite maintenance and repair principles to a wide, global audience.

The conclusion that the online format, when combined with regional laboratories, can be used on a global basis in a cost-effective manner is based on participant feedback. Student feedback on all aspects of the distance learning and regional laboratory format was collected. Of the 26 students that completed the course, 16 responded to a survey, which is included in this report, and were favorable about the use of distance learning for teaching the course. This report includes results and suggestions for improvement for the application of distance learning as applied to the course.
1. INTRODUCTION.

The purpose of this report is to provide an assessment for using asynchronous online training formats for teaching technical awareness subjects. The learning experience was enhanced by having a 3-day hands-on laboratory session and the development of a generic nonproprietary structural repair manual (SRM), included in this report as appendix B.

Distance, or online, learning is a new social process that is gaining momentum as a complete substitute for traditional face-to-face class formats. While distance learning is well established in service and social science courses, it has not been used extensively in science and engineering. Online courses use digital technologies to support collaborative, student-centered pedagogy, and are offered by a few hundred mega-universities that operate on a global scale. Students learn by participating in facilitated discussions; in essence, they learn by exploration, which has been shown to greatly increase retention.

The prerequisite course, base knowledge, consisted of an online self-study course, which lasted 2 weeks. Students took an assessment exam on a pass/fail basis. Passing this exam qualified students to take the 6-week online awareness course. The awareness course used a commercially available online platform called Blackboard Academic Suite™, and students participated in an asynchronous fashion. The course concluded with a 3-day laboratory, conducted by Abaris Technical Training Resources, Incorporated, in Reno, Nevada.

Section 3 is a description of the course organization. The training repair manual is described in section 4, and the learning theory is in section 5. Student demographics are summarized in section 6, followed by the course evaluation in section 7, which was based on student feedback.

Summary information from the surveys is included in appendix A. The training repair manual, considered critical for effectively training students the documentation requirements involved with composite maintenance practice, is included in appendix B.

Course content used in this report is described in another report, “Course Development: Maintenance of Composite Aircraft Structures,” DOT/FAA/AR-08/54.

2. BACKGROUND.

Phases I, II, and III of the Cooperative Agreement between the Federal Aviation Administration (FAA) and Edmunds Community College involved the global community of experts in composites’ technology and resulted in an industry standard course created through industry partnerships. These experts, through a series of workshops and a beta course, provided the materials for development of an awareness course. The investigation and development described in this report is referred to as Phase IV. Phase IV extended the content developed in the earlier phases and applies it to online methodologies, in conjunction with a regional laboratory, which incorporated the latest learning theories.

Phase I of the course achieved detailed terminal course objectives and curriculum content that included the collaboration and input from the worldwide community of experts in composite
Phase II built on the success of the approach used in Phase I by continuing to engage composite experts from the field to review progress in the curriculum development. In Phase II, the draft standards received rigorous reviews and updates, while Edmonds Community College developed and delivered the initial class as a beta course. The combination of these efforts ensured that the course content addressed all the necessary safety issues and could be effectively delivered in the desired short course. This included an assessment of the draft standards by supporting industry groups. Experts and candidate students reviewed course materials and laboratories derived from these standards in a beta class held at Edmonds Community College and provided feedback, which was integrated into the development.

Phase III summarized the previous developments in an FAA report, and formalized the relationship between industry and the FAA by establishing written teaching point standards in an SAE document, sponsored by a subcommittee referred to as the Commercial Aircraft Composite Committee, or CACRC. This SAE document, in conjunction with the FAA report, provides the basis for individual course developments throughout the world based on standards provided in this curriculum development.

3. COURSE ORGANIZATION AND FORMAT.

The prerequisite course, developed previously under this Cooperative Agreement, included the following content:

- Composite materials basics
- Maintenance overview of composite structure
- Other critical elements in maintenance

The main course, developed previously under this Cooperative Agreement, included the following content:

- Roles and responsibilities
- Damage types and sources
- Documentation types and sources
- Documentation information
- Lamination fabrication and bonded repair
- Bonded composite repair
- Inspection procedures
- Laminate bolted assembly and repair
- Case studies
The awareness course was administered online through Edmonds Community College using Blackboard Academic Suite as the course delivery medium and was supplemented by a hands-on laboratory conducted by Abaris Technology Resources, Inc., in Reno, Nevada. Blackboard Academic Suite facilitates online teaching by integrating asynchronous communication among students and instructor while combining streaming video and audio to students. It also contained assessment tools via test banks to ensure student learning of the course objectives and content.

Major features that resulted from the Blackboard Academic Suite development included the following:

- An introduction section for each course. Students were introduced to the instructor, asked to view a 15-minute streamed video describing the critical safety and economic reasons for having proper maintenance, and viewed the organization of the course.

- Discussion questions (two per module) where students discussed important topics and interacted in a nonsynchronous time format, which was mandated by the students being located in different time zones. These discussion threads were the primary means of learning for the students, who learned by group and individual exploration of issues facilitated by the instructors.

- Microsoft® PowerPoint® slides for each module, which highlighted the major issues contained in the course.

- Testimonials interspersed throughout the course, in streaming format, to provide meaning before content for the students and enhance the learning process.

- A test bank of questions for assessment. There was one exam for the first course, and a midterm and final exam for the online segment for the second course. The laboratory segment was assessed as a pass-fail grade for the students.

Including laboratory experience as an adjunct to content training is considered to be an essential part of the learning and retention process by students. The course principles provided in either a classroom or asynchronous online format is reinforced by experiential learning, whereby students can practice those principals and reinforce teaching points. Regional laboratories are also important to make the class accessible in a cost-effective manner.

4. TRAINING REPAIR MANUAL DEVELOPMENT.

During the development of content for the course under this Cooperative Agreement, industry feedback recommended that a generic, nonproprietary training repair manual be developed. Training organizations have been limited by copyright in the use of structural repair manuals in education since manufacturers typically regard the content as intellectual property. Yet, it is essential for students to be exposed to SRM use, organization, and methodology.

The training repair manual in appendix B simulates a typical SRM and is organized under an industry-accepted standard, ATA 100, section 51. The specific teaching point is that all repairs
are subject to approved processes, and a first source of approved information is the manufacturer’s SRM. For example, students in a laboratory may participate as team members consisting of technicians, engineers, and inspectors. To simulate actual repair scenarios, students are required to access the training repair manual to design FAA-approved repair methodologies. An additional teaching point is that any repair design that is not specifically described by the training repair manual is not authorized unless approved by the original equipment manufacturer and a designated FAA engineering representative appointed to make such approvals.

The training repair manual is only for teaching purposes and is not authorized for use in actual repair situations.

5. LEARNING THEORY.

Online theory, combined with regional laboratories, provides students with experiential learning in the discussion threads and laboratory exercises.

In particular, online courses allow the combining of new teaching approaches and technologies and are the focus of the following discussion.

Education, especially in the social sciences, is evolving from face-to-face courses using a teacher-centered format to a student-centered online format using the latest technologies currently offered by tens of thousands of local, regional, and national universities. Significantly, engineering and science disciplines have not used asynchronous learning to a great extent. Historically, this learning mode has been adopted by liberal arts and social science courses.

The online teaching environment is designed to be a student-centered rather than a teacher-centered approach. In online teaching environments, most students are working adults. Learning online is primarily self-directed and focused, since there is no physical class to attend. Therefore, everything a teacher does affects how the students learn, from the enthusiasm communicated, the questioning strategies employed in online discussions, and the types of activities and assessments assigned.

Online courses offer a collaborative, global, student-centered format. Asynchronous discussions, made possible by digital technology, are conducted based on Socratic questioning by the students, monitored by a facilitator, with the goal of encouraging the students to discover specific teaching points. Through this process, retention is improved and a nonthreatening environment is provided.

The keys to the learning process in an online educational online environment are the interaction among students, the interaction between faculty and students, and the collaborative learning that results from these interactions. The primary way this is accomplished is through the use of online threaded discussions. Online threaded discussions are critical to the success of learning because they mirror the discussions that take place in a traditional classroom setting. Online discussions take place asynchronously with each student logging on and posting or commenting to the class at different times. Students initiate discussions, ask questions, react to other
students, respond to ideas shared by others in the class, and become more creative in their own learning process. This interaction not only allows students to grow cognitively, but also provides for the formation of learning communities where knowledge is imparted and meaning is cocreated, setting the stage for the accomplishment of learning outcomes. Participation is essential for success in an online course for both instructors and students. Students expect interaction with their instructors. A teacher/facilitator interacts with students a minimum of four times each week.

Blackboard and eCollege® platforms are commercially available online course management systems used by institutions, such as Edmonds Community College and DeVry University, for course work in subjects ranging among business management, liberal arts, and mathematics choices. Blackboard was used for Phase IV.

6. STUDENT DEMOGRAPHICS.

The class demographics for the awareness course were broad-based, including ten people from industry, five from military, ten regulators and two college students. Activities by the students include active participation in the discussion forum, a team project to identify a checklist for maintenance operation effectiveness and preparation for the exams.

The student population was comprised of two distinct groups, advanced students and students with limited experience. The advanced students had a median 19 years aerospace experience and a median 7 years composite experience. The students with limited experience had a median 4 years aerospace experience and a median 2 years composite experience. Based on student feedback (formal and informal), the students with limited experience were at a disadvantage, and their learning was hampered due to the lengthy, in-depth discussions and use of industry acronyms by the advanced students.

The following students were enrolled in the prototype class:

- Jack Banaszek, Professional Engineer, Found Aircraft Canada, Inc.
- Andrew Davidson, Service Support Engineer, Canadian Forces
- Nova Dubovik, Manager, U.S. Air Force
- Kristi Dunks, Engineer, National Transportation Safety Board
- Arinze Eze, Liaison Engineer, Diamond Aircraft Industries, Inc.
- Kent Hearn, Material and Process Engineer, Hawker Beechcraft Corporation
- Mike Hendrix, Inspector, FAA
- Russell Jones, Inspector, FAA
- Brian Julian, Technician, The Boeing Company
- Andrea Kanaya, Research Engineer Associate, Coleman Aerospace
- Mark Kistner, Engineer, U.S. Air Force
- Anna Kolachalama, Engineer, Cessna Aircraft Company
- Mary K. Langlais, Engineer, The Boeing Company
- Tim Lebaron, Engineer, National Transportation Safety Board
- Marco Mariotti, Airworthiness Engineer, Transport Canada
7. COURSE EVALUATION.

The course evaluation is summarized below. Some comments are based on student feedback.

- Asynchronous online training has been shown as an effective way of teaching an awareness class for a subject of technical content.
- Students that took the hands-on laboratory session indicated that it was an important part of the learning process and that it served as a capstone to the online experience.
- Students spent approximately 10 hours per week on the main awareness course, which was as expected and consistent with typical student populations.
- The presence of an SRM, as used in this course, was extremely positive. This is the first time a nonproprietary training repair manual has been available, and it introduced students to the format and use of the manual. The training repair manual is included in appendix B.
- Many students felt that 3 days was not enough time for a hands-on laboratory. However, it is the opinion of this researcher that a trade-off between economics of longer classes and the need for weekend travel would likely cause most course designers to retain the 3-day limit for the course.
- The utility of various teaching tools was evaluated fairly evenly, with the exception of the textbook that students did not seem to require. This is probably due to the availability of expert write-ups in the Blackboard online platform.
- More advance preparation for students unaccustomed to the asynchronous online format would have been helpful.
- Some students were at a disadvantage and therefore frustrated due to poor connectivity, lack of broadband access, and/or slow response by the Edmonds Community College and Blackboard service providers.
• Prerequisite course-written materials could have been enhanced with additional pictures and diagrams.

• Many laboratory participants suggested more emphasis and variety of nondestructive inspection techniques.

In future classes, it is recommended that students be screened and grouped according to experience demographics. Since asynchronous learning occurs through self-discovery, more experienced students can become somewhat intimidating to the less experienced students and can become impatient with basic discussions. More experienced students also tended to have tangential discussions, which in turn, caused some of the less experienced students to feel overwhelmed by the quantity and content of the discussion boards.
### APPENDIX A—STUDENT FEEDBACK

#### Acronyms used in this appendix

PI Comments: Principle Investigator comments and response to student observations, where appropriate.

TCO: Terminal Course Objective

PDF: Document format typically used in digital media transmission

#### Survey Results Summary, by group experience (quantitative)

<table>
<thead>
<tr>
<th>Student Information</th>
<th>Greater than 5.5 Yrs Exp.</th>
<th>Less than 5.5 Yrs Exp.</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Responses</td>
<td>Median</td>
</tr>
<tr>
<td>Number of years aerospace experience:</td>
<td>8</td>
<td>19.0</td>
</tr>
<tr>
<td>Number of years composite materials experience:</td>
<td>8</td>
<td>7.0</td>
</tr>
<tr>
<td>Primary type of aerospace experience</td>
<td>8</td>
<td>7.0</td>
</tr>
<tr>
<td>Attended 3-day laboratory (yes/no):</td>
<td>8</td>
<td>5.0</td>
</tr>
</tbody>
</table>

#### Prerequisite Course (2-week duration)

- Estimated hours per week of involvement (average):
  - Greater than 5.5 Yrs Exp.: 7.5, Median: 6.1, AVG: 8.0, 8.3
  - Less than 5.5 Yrs Exp.: 7.4, Median: 4.3, AVG: 8.4, 8.0

- How well did the course content prepare you for the follow-on course (score 1 to 5):
  - Greater than 5.5 Yrs Exp.: 7.5, Median: 4.6, AVG: 8.0, 4.0
  - Less than 5.5 Yrs Exp.: 7.4, Median: 4.3, AVG: 8.4, 4.0

- How well did the course self-study format prepare you for the follow-on course (score 1 to 5):
  - Greater than 5.5 Yrs Exp.: 7.4, Median: 4.3, AVG: 8.4, 4.0
  - Less than 5.5 Yrs Exp.: 7.4, Median: 4.0, AVG: 8.0, 4.0

- How well did the following teaching tools help in your learning experience and retention (score 1 to 5):
  - Course Material write-up: Greater than 5.5 Yrs Exp.: 7.4, Median: 4.4, AVG: 8.4, 4.1
  - Textbook: Greater than 5.5 Yrs Exp.: 6.4, Median: 3.7, AVG: 7.3, 2.7
  - Exams: Greater than 5.5 Yrs Exp.: 7.5, Median: 4.6, AVG: 8.3, 3.3

#### Critical Composite Maintenance and Repair Issues – Online Course (6-week duration)

- Estimated hours per week of involvement (average including discussion boards):
  - Greater than 5.5 Yrs Exp.: 8.0, Median: 11.6, AVG: 8.9, 8.0
  - Less than 5.5 Yrs Exp.: 8.4, Median: 4.3, AVG: 8.4, 3.4

- How well did the course content achieve an awareness of critical safety issues in composites’ main:
  - Greater than 5.5 Yrs Exp.: 8.5, Median: 4.6, AVG: 8.4, 4.4
  - Less than 5.5 Yrs Exp.: 8.4, Median: 4.3, AVG: 7.4, 3.4

- How well did the course Blackboard format achieve an awareness of critical safety issues in composite:
  - Greater than 5.5 Yrs Exp.: 8.4, Median: 4.3, AVG: 7.4, 3.4
  - Less than 5.5 Yrs Exp.: 8.3, Median: 4.3, AVG: 7.4, 3.4

- Effectiveness of teaching tools for learning materials (score 1 to 5, or NA if you didn’t use):
  - Course Materials (written materials): Greater than 5.5 Yrs Exp.: 8.5, Median: 4.5, AVG: 8.4, 4.3
  - Testimonials by experts: Greater than 5.5 Yrs Exp.: 7.4, Median: 3.6, AVG: 8.3, 3.3
  - Teaching Point Summaries at end of each week: Greater than 5.5 Yrs Exp.: 7.4, Median: 3.6, AVG: 8.4, 3.6
  - Discussion Boards: Greater than 5.5 Yrs Exp.: 8.4, Median: 4.0, AVG: 8.4, 3.8
  - Textbook: Greater than 5.5 Yrs Exp.: 7.4, Median: 3.9, AVG: 7.3, 2.4
  - Exams: Greater than 5.5 Yrs Exp.: 8.4, Median: 4.1, AVG: 8.4, 3.6
  - Team Project/Checklist: Greater than 5.5 Yrs Exp.: 7.4, Median: 3.6, AVG: 8.3, 3.3
  - Website Links: Greater than 5.5 Yrs Exp.: 6.4, Median: 4.0, AVG: 7.3, 3.0
  - Glossary of Terms: Greater than 5.5 Yrs Exp.: 7.5, Median: 4.6, AVG: 6.3, 3.7
  - Acronyms: Greater than 5.5 Yrs Exp.: 6.5, Median: 4.5, AVG: 6.3, 3.5
  - Group Page (Interaction tools for team project): Greater than 5.5 Yrs Exp.: 3.4, Median: 4.3, AVG: 4.4, 3.5

#### 3-Day Laboratory (3-days duration) [For those that attended]

- How well did the laboratory experience achieve an awareness of critical safety issues in composite:
  - Greater than 5.5 Yrs Exp.: 3.4, Median: 4.3, AVG: 3.3, 3.3
  - Less than 5.5 Yrs Exp.: 3.4, Median: 4.3, AVG: 3.3, 3.3

- Effectiveness of laboratory in creating an awareness of the following topics (score 1 to 5):
  - Greater than 5.5 Yrs Exp.: 3.4, Median: 4.3, AVG: 3.3, 3.3
  - Less than 5.5 Yrs Exp.: 3.4, Median: 4.3, AVG: 3.3, 3.3

- Damage assessment of cracked structures (in NDE):
  - Greater than 5.5 Yrs Exp.: 3.2, Median: 2.7, AVG: 3.3, 3.3
  - Less than 5.5 Yrs Exp.: 3.2, Median: 2.7, AVG: 3.3, 3.3

- Repair lay-up techniques:
  - Greater than 5.5 Yrs Exp.: 3.9, Median: 3.7, AVG: 3.5, 4.5
  - Less than 5.5 Yrs Exp.: 3.9, Median: 3.7, AVG: 3.5, 4.5

- Source documentation and other authorities for approving repair disposition:
  - Greater than 5.5 Yrs Exp.: 3.4, Median: 4.0, AVG: 3.4, 4.2
  - Less than 5.5 Yrs Exp.: 3.4, Median: 4.0, AVG: 3.4, 4.2

- Length of time allotted for laboratory was (too much = 1; just right = 2; needed more time = 3):
  - Greater than 5.5 Yrs Exp.: 3.2, Median: 2.0, AVG: 3.1, 2.9
  - Less than 5.5 Yrs Exp.: 3.2, Median: 2.0, AVG: 3.1, 2.9
Survey Results Summary, by group experience (qualitative)

- Prerequisite Course

There was a lot information to absorb. Perhaps there was too much detail provided for a prerequisite course.

Good Overview

I felt there could have been more figures / diagrams / graphs to help explain some of the topics. This would be helpful for the student who is new to composites.

In addition to prerequisite composite information, this course should also provide an introduction to how the online course will work.

Their needs to be more structure to the format in line with the TCO's, maybe even daily test to enforce the material (PI Comment: Probably meant to address the Awareness Course rather than the Prerequisite Course)

Talk more about typical structural behavior more in the pre-req class. I had previous knowledge in the area, but I knew a lot of other students who did and felt lost at times.

Improve write-up visual style and format (e.g. more diagrams and pictures in a .pdf)

The course material could have been better presented (more pictures, friendlier formatting)

- Awareness Course

Instructor’s summary/point of view at the end of each trend would be helpful to see if the discussion was on the right track. Also, this would help realizing the ‘right’ answers to the questions asked. (PI Comment: The teaching points were provided to students at the end of each week, but some students apparently did not, or were unable, to download the PowerPoint slides which described the ‘right’ answers referred to in this comment).

More focus on theory and not individual experience stories

The voluminous response in the discussion board was initially overwhelming (due to the great participation). At times it became discouraging to read all the discussions if you did not keep up continuously. It might be worthwhile limiting the discussion earlier and / starting new threads earlier.

Trying to understand and make sense of some of the threads was difficult. The cascading of the threads / took a while to follow.

The team project was a challenge but access to the group page certainly helped organize things. I would maybe consider groups of three at the most.
For someone like myself exposed for the first time to distance learning on the web, it might be worthwhile to provide and highlight, at a top level, a “must do” list prior to starting the course. For example ‘(A) YOU MUST WRITE A BIO OF YOURSELF, (B) YOU MUST CHECK THE DISCUSSION BOARD AND PARTICIPATE IN THE DISCUSSION etc…’ This could be followed by another list indicating steps on how to do things efficiently. I wasn’t sure what to do at the beginning until Charlie emailed me several days after the course had started to tell that I hadn’t heard from me. (PI Comment: This was covered in the course syllabus, but many students did not focus on this material; future course instructions should provide added emphasis by the instructor for the benefit of the students)

I believe the course content was excellent in terms of providing a good basic understanding of the issues concerning composites and repairs.

As a composite novice, I felt overwhelmed by some of the content and interactions in this course. I have taken many courses using Blackboard and I find it to be a useful learning tool. However, during this course due to my lack of experience, I felt it difficult to understand some of the discussions. I also thought that there was too much chatter rather than actual learning. Because of this, the discussion boards became difficult to work through and gain any meaningful understanding of the information being discussed.

I think the idea of having a distance learning composite course is a good one. The content was available during the course, but I think that the discussion boards should have fallen back on the appropriate reading assignments, rather than class opinion and conjecture.

I think the course was out-done by the participants. Most of the discussions was far above the text. Maybe the technical detail of this course would require more time/longer class to get it all covered.

I felt it was a lot to take in for the period of time we have allotted for the course. It’s also difficult for all of the students to be involved when the level of experience differed so much. I feel maybe persons with less experience should be in a course with others of less experience. It was difficult at times to follow discussion much less participate without the experience. I felt the course was good but difficult to retain so much information. Especially all the NEW information. Maybe splitting up the information into two separation course might help retention of the information.

More videos shows repair and inspections showing how it’s done or what different damages may look like when an inspector is examining an aircraft. More visual aids.

Improve the format of the weekly content. More visual items. Make weekly content a pdf (the spell check squiggly lines in Word can be distracting). Use windows media instead of Realplayer video. Lengthen testimonial videos. Maybe have scheduled chat sessions.

The discussion board was very difficult to keep up with. If you didn’t check the board during work hours, you would be 20-30 posts behind.
I liked discussion boards the best because I had a chance to see other classmates’ point of view about composite repair issues and other composite related.

I thought the course was well thought out but the response time on the ECC website was slow and sometimes frustrating to deal with.

The testimonials by experts did not provide enough in-depth information to actually be useful. If the testimonials were actually 15 minutes long, providing more detail, then they would be useful. Else, they are a waste of time really. The video data can be easily be hosted by the schools website and streamed to the students. The discussion boards need to be formatted in a way that the discussions can be followed easily and clearly. Currently, the discussions seem to jump from topic to topic as you progress down. The exams had issues in that it was not uncommon to have the same question 2 or 3 or 4 times in the same exam. Similarly, a question with “select all that apply” and you select 3 correct answers, with a 4th option that was missed. You should be credited 3 out of 4 and not 0 out of 4. (PI Comment: The mid-term had technical issues; in those cases the instructor did over-ride the mechanized scoring with a fair assessment as suggested by this student)

The amount of time spent on the discussion board was a little too much. The course material could have been better presented (more pictures, friendlier formatting). There was not a lot of emphasis on the textbook material: either put it as suggestion only, or integrate it better with the discussion board and the course material. The website links would also gain from being better integrated within the course material.

- Hands-on Laboratory

Actual hands-on time could be increased by possibly having smaller groups.

Perhaps couple of extra days would eliminate the ‘rush’ aspect and give students more time to do more hands-on practice.

Would like to see an hour of NDI techniques other than visual & tap. I felt the hands on portion was done in the right amount of time. The pace was fast but that’s real world when you are trying to evaluate, research and come up w/ a repair. I wouldn’t change the 3 day length.

Add NDI evaluations other than visual and tap. Other than that lab experience is set up just right for the awareness course.

Different NDI techniques could be presented as opposed to tap test only.

There wasn’t enough time to cover everything. I would like to see more emphasis on NDI techniques on the repairs that were done in the lab.

NDI, but this might be handled with more visual content and real-world examples in the online course.
Have smaller groups (e.g. 2-3 members instead of 5). There would not only be more hands-on-part time but there would be more opportunities for decision-making.

The damage assessment using more than the tap test such as pulse echo or other commonly use techniques.

There should be more time spent on NDI, including hands-on ultrasonic.

The laboratory was great, but required more time. NDI should be more emphasized, and the last day was ‘rushed’.
INTRODUCTION

It is not the intent of this Training Repair Manual to supercede OEM SRM’s, CMM’s or AMM’s, but augment composite training providers with a reference standard towards implementing the source documentation module as outlined by the CACRC.

The Training Repair Manual (TRM) acknowledges industry accepted commercial composite repair procedures and when used in conjunction with a composite training provider, will establish a thorough understanding of OEM source documentation.
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- Allowable Damage
- Repair To Carbon Monolithic Structure
SCOPE

The TRM provides generalized composite material repair schemes as related to ATA Chapter 51 (Structures General.)

Purpose

Establish a base standard involving training technicians using repair schemes related to commercial composite structures. Repairs involving solid laminate, honeycomb sandwich and monolithic structures utilizing carbon, glass and aramid fiber are addressed. Industry standard A-staged and B-staged materials are referenced with applicable curing information. Typical vacuum bagging techniques and hot bonding methods are provided.

APPLICABLE DOCUMENTS

The following publications form a part of this document to the extent specific 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 cited references takes precedence. Nothing in this document, however, supercedes applicable laws and regulations unless a specified exemption has been obtained.

SAE Publications

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Telephone: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), Web address: http://www.sae.org

AIR 4844B Composites and Metal Bonding Glossary
AIR 4938 Composite and Bonded Structure Technician/Specialist: Training Document
AMS 2980A Technical Specification: Carbon Fiber Fabric and Epoxy Resin Wet Lay-Up Repair Material
   AMS 2980/1A through AMS 2980/5
AMS 3970 Carbon Fiber Fabric Repair Prepreg
   AMS 3970/1 through AMS 3970/5
ARP 4916 Masking and Cleaning of Epoxy and Polyester Matrix Thermosetting Composite Materials
ARP 4977 Drying of Thermosetting Composite Materials
ARP 4991 Core Restoration of Thermosetting Composite Components
ARP 5089 Composite Repair NDT/NDI Handbook
ARP 5143 Vacuum Bagging of Thermosetting Composite Components
ARP 5144 Heat Application for Thermosetting Resin Curing
ARP 5266 Mixing Resins, Adhesives and Potting Compounds
ARP 5319 Impregnation of Dry Fabric and Ply Lay-Up
FAA Publications

Available from FAA, 800 Independence Avenue, SW, Washington, DC 20591

AC 145-6
COMPOSITE REPAIR GENERAL (51-00-00)

The Training Repair Manual (TRM) is assembled per Air Transportation Association (ATA) Specification 100 relating to Chapter 51 exclusively. Procedures, Materials and Processes are derived from SAE, ARP and AIR standards.

CAUTION: This manual is not to used to restore unservicable aircraft parts to a servicable condition; but, train technicians in the usage of Structural Repair Manuals (SRM) as relative to Composite Material Repair. Consult the Original Equipment Manufactures AMM's, SRM's and CMM's for repair of aircraft parts.

Overview

Repairs involving composites use materials that are of a hazardous nature. The technician should be trained in the usage of Material Safety Data Sheets (MSDS) and don the appropriate Personal Protective Equipment (PPE) prior to attempting any repair.

Definitions

The following terms are used throughout this manual, and AIR 4844B Composites and Metal Bonding Glossary:

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>AFRP</td>
<td>Aramid Fiber Reinforced Plastic</td>
</tr>
<tr>
<td>Bag side</td>
<td>The side of the part cured against the vacuum bag.</td>
</tr>
<tr>
<td>Bagging</td>
<td>Applying an impermeable layer of film over an uncured part and sealing edges so that a vacuum can be drawn</td>
</tr>
<tr>
<td>Bond ply</td>
<td>Ply of material placed against the honeycomb core material.</td>
</tr>
<tr>
<td>CFRP</td>
<td>Carbon Fiber Reinforced Plastic</td>
</tr>
<tr>
<td>Crack</td>
<td>Fractures in either matrix or both matrix and fibers characterized by an actual separation of material.</td>
</tr>
<tr>
<td>Delamination</td>
<td>Separation of the layers of material in a laminate.</td>
</tr>
<tr>
<td>Disbond</td>
<td>An area within a bonded interface between two adherends in which an adhesion failure or separation has occurred.</td>
</tr>
<tr>
<td>Elevated Temperature Cure</td>
<td>Polymerization of a resin matrix above 150° F. using controlled heat and a positive or negative pressure source.</td>
</tr>
<tr>
<td>Facesheet</td>
<td>Plies that are laminated on one side of a honeycomb sandwich panel.</td>
</tr>
<tr>
<td>Gouge</td>
<td>Channel-like groove causing a cross-sectional change in a fiber reinforced plastic</td>
</tr>
<tr>
<td>GFRP</td>
<td>Glass Fiber Reinforced Plastic</td>
</tr>
<tr>
<td>Wet Lay-up</td>
<td>Method of making or repairing a fiber reinforced part by applying a liquid resin system when the reinforcement is put in place.</td>
</tr>
<tr>
<td>Prepreg</td>
<td>Cloth, mat or unidirectional fibers impregnated with resin then partially cured to the B-stage. Material is then stored at or below 0° F.</td>
</tr>
<tr>
<td>Hole</td>
<td>Penetration of damage through facesheet(s) plies and into honeycomb core material.</td>
</tr>
<tr>
<td>Nick</td>
<td>A small decrease of material typically seen on the edge of a panel.</td>
</tr>
<tr>
<td>Scratch</td>
<td>An elongated surface discontinuity which is infinitely small in width compared to length. Usually caused by a sharp object.</td>
</tr>
<tr>
<td>Tool side</td>
<td>The side of the part cured against the tool (mold or mandrel).</td>
</tr>
</tbody>
</table>
Manual Arrangement

Each subject within this manual, is arranged per ATA specification 100, using a three element, two digit numbering system as follows:

![Diagram showing 1st, 2nd, and 3rd elements of the numbering system, with the example 51-70-00 and their corresponding meanings: Chapter (Structures), Section (Repairs), Subject (General).]

FIGURE 1. ATA SPEC. 100
### ATA Chapter breakdown

Structural Repair Manuals (SRM's) utilize the following ATA specification 100 chapters:

<table>
<thead>
<tr>
<th>CHAPTER</th>
<th>TITLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>51</td>
<td>Structures (General)</td>
</tr>
<tr>
<td>52</td>
<td>Doors</td>
</tr>
<tr>
<td>53</td>
<td>Fuselage</td>
</tr>
<tr>
<td>54</td>
<td>Nacelles/pylons</td>
</tr>
<tr>
<td>55</td>
<td>Stabilizers</td>
</tr>
<tr>
<td>56</td>
<td>Windows</td>
</tr>
<tr>
<td>57</td>
<td>Wings</td>
</tr>
</tbody>
</table>

**TABLE 1.-ATA SPEC 100 CHAPTER BREAKDOWN**

### ATA Chapter 51

Chapter 51 contains information applicable to the entire aircraft in general. It is used in conjunction with detailed repair information contained within the applicable chapter. The TRM is comprised of Chapter 51 exclusively.

<table>
<thead>
<tr>
<th>Chapter – Section - Subject</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>51-00-00</td>
<td>General Repair Information</td>
</tr>
<tr>
<td>51-10-00</td>
<td>Inspection / Damage Removal</td>
</tr>
<tr>
<td>51-20-00</td>
<td>Repair Options</td>
</tr>
<tr>
<td>51-30-00</td>
<td>Materials</td>
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<tr>
<td>51-40-00</td>
<td>Fasteners</td>
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<td>51-60-00</td>
<td>Balanced Surfaces</td>
</tr>
<tr>
<td>51-70-00</td>
<td>Repairs</td>
</tr>
<tr>
<td>51-80-00</td>
<td>Environmental Protection</td>
</tr>
<tr>
<td>51-90-00</td>
<td>Post Inspection</td>
</tr>
<tr>
<td>51-100-00</td>
<td>Typical Honeycomb Panel Structure</td>
</tr>
<tr>
<td>51-120-00</td>
<td>Typical Carbon Monolithic Structure</td>
</tr>
</tbody>
</table>

**TABLE 2.-CHAPTER 51 BREAKDOWN**
Page Blocking

Pages are numbered as follows:

- Pages 1 – 99  Part / Material Identification
- Pages 101 – 199  Allowable Damage Limits
- Pages 201 – 999  Repairs

Figure Numbering

Figure numbers are associated with page referencing as follows:

- Figures 1-99  Identification
- Figures 101 – 199  Allowable Damage
- Figures 201 – 999  Repairs
Manual Usage

Usage of the TRM Chapter 51, involves processing the repair information in a logical order as follows:

A. Proceed to the Repair Flowchart (51-00-01)

B. Perform an Inspection and Damage Assessment (51-10-00)

C. Determine Type and Number of Plies Damaged (51-10-01)

D. Select Repair Option (51-20-00)
   1. Category C (Time-Limited Repair)
   2. Category B (Interim Repair)
   3. Category A (Permanent Repair)

E. Obtain Repair Materials (51-30-00)

F. Perform Repair (51-70-00)
   1. Wet lay-up General (51-70-01)
      (a) Wet Lay-up solid laminate repairs
      (b) Wet Lay-up sandwich structure skin and core damage repairs
   2. Prepreg General (51-70-05)
      (a) Prepreg solid laminate repairs
      (b) Prepreg sandwich structure skin and core damage repairs
   3. Bolted (51-70-10)
      (a) Monolithic Structure Category A Repair

G. Restore Environmental Protection (51-80-00)

H. Post Repair Requirements (51-90-00)
   1. NDT
   2. Surface waviness
   3. Surface resin content
   4. Documentation Completion
REPAIR FLOWCHART (51-00-01)

ATA Chapter

51-10-00  →  ASSESS DAMAGE

51-10-01  →  DETERMINE PART IDENTIFICATION

51-20-00  →  SELECT REPAIR OPTION

51-30-00  →  OBTAIN REPAIR MATERIALS

51-70-00  →  DETERMINE REPAIR METHOD

51-80-00  →  ENVIRONMENTAL PROTECTION

51-90-00  →  POST REPAIR INSPECTION

51-60-00  →  BALANCED UNIT

51-70-05  →  PREPREG

51-40-00  →  FASTENERS

51-70-10  →  BOLTED REPAIRS

OVER MAX MOMENTS  

YES → Rebalance unit

NO → Over max moments

FIGURE 2 REPAIR FLOWCHART
INSPECTION / DAMAGE DETERMINATION (51-10-00)

Referencing ARP 4916, pre-clean the composite part as follows:

1. Perform a visual assessment of the damaged part.

Inspect for visual defects such as burns, disbonds, delaminations, contamination, cracks, scratches, gouges (Ref fig. 1)

![Figure 1 Typical Visual Damage](image_url)

2. Mask the damaged area using Masking Method 2 or 3.

**CAUTION:** Do not allow solvent to remain on part.

3. Select an approved Cleaning Agent.

4. Clean the part referencing Composite Cleaning Methods 4 or 5. Do not allow solvent to dry on part. Apply agent then immediately wipe clean using AMS 3819 cleaning cloths.

**NOTE:** If part is extremely soiled, use Composite Cleaning Methods 1, 2 or 3.
Tap Testing

Tap Testing is an effective method to determine areas of damage on honeycomb panels and limited in scope to solid laminates such as monolithic and edgeband structures.

**NOTE:** Tap Testing is limited to structural areas with 5 or less plies. Use instrumented NDT for thicker structures.

1. Tap test method involves the usage of a metallic object that will resonate when tapped on a composite structure.

2. Tap test in a circular pattern a minimum of 3” beyond the visible damage. A dull sound indicates an area of damage associated with a disbond or delamination.

3. Mark all damage as necessary.
Instrumented NDT Methods

Technicians must be certified by an approved training provider prior to performing instrumented NDT on composite structures. Technicians should use ARP 5089 for reference.

1. Ultrasound NDT requires the usage of a reference standard. Obtain the ply count from the part drawing then set machine operating parameters to coincide with the part thickness.

2. Observe the scope indications and mark the area(s) of damage.
Visible Liquid Removal – Method 1 (Water) ARP 4977

CAUTION: Do not exceed 180°F. when drying composite panels. Excessive heat may generate high vapor pressures within the honeycomb core cells and possibly delaminate the part. Ensure all moisture is removed prior to repairing at elevated temperatures (>212°F.)

Honeycomb panels exposed to the elements are susceptible to moisture ingress. All composite matrix materials are hygroscopic, and over-time, will degrade the glass transition temperature (Tg). Allow a minimum of 1 hour @ 160 +/- 20°F. for drying.

Procedure:

1. Gain access to the water saturated area and absorb as much as possible using an AMS 3819 cleaning cloth.
2. Use a vacuum source and remove water saturated areas.
3. Use clean compressed air and remove residual water from area.
4. Accomplish Absorbed Moisture Removal Method 1,2,3,4 or 5 (Para. 4.2)

NOTE: Excessive moisture should be removed by the use of a drying bag. Reference ARP 5143 Method 5 (para 8.5) for additional procedures.

5. Continue with the repair

Visible Liquid Removal – Method 2 (Liquid Other Than Water) ARP 4977

Aramid (Nomex®) honeycomb core exposed to severe contamination may require core replacement. Trace amounts of contaminate may remain even after through cleaning. Consider removing and replacing contaminated core.

Procedure:

1. Gain access to contaminated area.
2. Use a vacuum source and remove the liquid. (Use of a filter is strongly recommended)
3. Select an approved Cleaning Agent.
4. Remove liquid using Composite Cleaning Method 4 or 5 (refer ARP 4916)
5. Examine core for residual contamination. Re-clean and dry as necessary.
6. Continue with repair
Grouping of Damage

Multiple damage may require consolidation depending on the distance from adjacent damage and/or previously repaired areas. Reference figure 4 Damage Grouping.

Case 1 Multiple damage sites:

1. Measure the distance from edge to edge of the damaged areas.
2. Minimum distance is 6” from edge to edge of the damaged areas.
3. Calculate the diameter of each repair using $\frac{1}{2}$” per ply damaged + 1 additional ply (2 plies for aramid/carbon fibers).
4. If repairs will overlap, consolidate the repair into one repair site.

Case 2 Previous damage sites:

1. Calculate the diameter of new repair using $\frac{1}{2}$” per ply damaged + 1 additional ply (2 plies for aramid/carbon fibers).
2. Measure the distance between outer repair plies. Minimum 1/2” distance between outer repair plies.
3. If outer repair plies will overlap, remove old repair and consolidate into one new repair site.
EXAMPLE:
Panel manufactured with
3 plies 7781 fiberglass
1/2" per ply + 1 additional
Repair will be 2" in diameter
from damage edge

CASE 1
Outer repair ply

CASE 2
PREVIOUS REPAIRED AREA
NEW REPAIRED AREA

FIGURE 3 DAMAGE GROUPING
PART IDENTIFICATION GENERAL (51-10-01)

Composite panels are typically constructed of Fiberglass (GFRP), Aramid (AFRP) or Carbon (CFRP) fibers utilizing preimpregnated polymeric materials originally cured at 250 or 350 degrees fahrenheit. Panels may be solid laminate, monolithic or constructed using honeycomb core materials to increase the strength and stiffness of the part. Honeycomb core materials may be aramid paper or fiberglass reinforced. In addition, a combination of fabrics may be used on any one panel and are classified as a Hybrid composite.

High stress areas (critical areas) are identified by a cross-hatched pattern on the specific part identification. Repairs to these areas require approval from the OEM or designated representative.

CAUTION: Do not attempt repairs to stress critical areas without engineering approval.

250 degree composite materials are utilized for secondary structures (fairing, access panels) with a service temperature not to exceed 200 degrees fahrenheit.

350 degree composite materials are utilized for primary structural elements, flight controls surfaces, engine cowling and whenever a high service temperature or stiffness is required.

NOTE: The primary flight control surfaces are balanced units and before a repair is attempted consult TRM Chapter 51-60-00.

The following ATA Chapters contain the specific part identification:

250 degree honeycomb constructed panels  51-100-00  Page 1

250 degree monolithic structure     51-120-00  Page 1
REPAIR OPTIONS (51-20-00)

Three categories of repairs are provided. Selection criteria should be based upon TRM repair limits, structure composition, operational constraints, materials and equipment availability, repair environment and qualified repair personnel. If practical, a Category A repair should be selected.

Category C Repairs

Time-limited repairs which may use speed tape or aircraft aluminum sheet stock fastened through composite structures. Category C repairs must be inspected every flight and a Category A repair accomplished within 100 flight hours.

NOTE: Repairs using aluminum sheet stock will require drilling and subsequent sealing through the composite part and should be accomplished as a last resort. Part replacement may be required.

Category B Repairs

Interim repairs using bonded materials that do not restore the part to the original strength and stiffness. This repair will allow the part to return to service with a subsequent inspection interval of 1000 flight hours or the next "C" check. If the repair is found serviceable, it is allowed to remain in service with continued inspections intervals.

Category A Repairs

Permanent repairs that restore the original performance characteristics and do not require any further action.
MATERIALS (51-30-00)

All material call-outs are for reference only and may be substituted at the discretion of the training facility. No specific vendor is implied; however, process specifications are used when an applicable ARP / AIR or military specification reference is available. Material call-outs used in the TRM will reference the ITEM # column.

### Expendables

<table>
<thead>
<tr>
<th>ITEM #</th>
<th>Material</th>
<th>Source</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>EX-01</td>
<td>Tongue Depressor</td>
<td>No specified source</td>
<td></td>
</tr>
<tr>
<td>EX-02</td>
<td>Unwaxed paper cup</td>
<td>No specified source</td>
<td></td>
</tr>
<tr>
<td>EX-03</td>
<td>Nitrile Gloves</td>
<td>No specified source</td>
<td></td>
</tr>
<tr>
<td>EX-04</td>
<td>Safety Glasses</td>
<td>No specified source</td>
<td></td>
</tr>
<tr>
<td>EX-05</td>
<td>Ear plugs</td>
<td>No specified source</td>
<td></td>
</tr>
<tr>
<td>EX-06</td>
<td>Tyvex overalls</td>
<td>No specified source</td>
<td></td>
</tr>
<tr>
<td>EX-08</td>
<td>80 Grit Sanding Discs</td>
<td>No specified source</td>
<td></td>
</tr>
<tr>
<td>EX-09</td>
<td>Cleaning Cloth</td>
<td>No specified source</td>
<td>AMS 3819</td>
</tr>
<tr>
<td>EX-10</td>
<td>Stipple Brush</td>
<td>No specified source</td>
<td></td>
</tr>
<tr>
<td>CL-01</td>
<td>Acetone</td>
<td>No specified source</td>
<td></td>
</tr>
<tr>
<td>CL-02</td>
<td>Isopropyl Alcohol</td>
<td>No specified source</td>
<td></td>
</tr>
</tbody>
</table>

**TABLE 1-EXPENDABLE MATERIALS**

### Woven Fabrics

<table>
<thead>
<tr>
<th>ITEM #</th>
<th>Material</th>
<th>Source</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>GF-01</td>
<td>7781 Fiberglass Cloth</td>
<td>No specified source</td>
<td>Mil-C-9084</td>
</tr>
<tr>
<td>GF-02</td>
<td>120 Fiberglass Cloth</td>
<td>No specified source</td>
<td>Mil-C-9084</td>
</tr>
<tr>
<td>CF-01</td>
<td>G0904 3k Carbon Plain weave or Style 282</td>
<td>Hexcel Corporation</td>
<td>AMS 2980</td>
</tr>
<tr>
<td>CF-02</td>
<td>3k-135-8H Style 584</td>
<td>No specified source</td>
<td></td>
</tr>
<tr>
<td>AF-01</td>
<td>120 Aramid</td>
<td>No specified source</td>
<td>AMS 3902</td>
</tr>
<tr>
<td>AF-02</td>
<td>285 Aramid</td>
<td>No specified source</td>
<td>AMS 3902</td>
</tr>
</tbody>
</table>

**TABLE 2-WOVEN FABRICS**

### Laminating Resins

<table>
<thead>
<tr>
<th>ITEM #</th>
<th>Material</th>
<th>Source</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>LR-01</td>
<td>Epocast 52 A/B</td>
<td>Huntsman advanced materials</td>
<td>AMS 2980</td>
</tr>
<tr>
<td>LR-02</td>
<td>Hysol EA9390</td>
<td>Hysol Corporation</td>
<td></td>
</tr>
<tr>
<td>LR-03</td>
<td>Epocast 50A / 946</td>
<td>No specified source</td>
<td></td>
</tr>
<tr>
<td>LR-04</td>
<td>Epocast 50A / 9816</td>
<td>No specified source</td>
<td></td>
</tr>
</tbody>
</table>

**TABLE 3.-LAMINATING RESINS**
## Filler Materials

<table>
<thead>
<tr>
<th>ITEM #</th>
<th>Material</th>
<th>Source</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fil-01</td>
<td>Phenolic microballons</td>
<td>No specified source</td>
<td></td>
</tr>
<tr>
<td>Fil-02</td>
<td>Fumed silica (Cab-O-Sil)</td>
<td>No specified source</td>
<td></td>
</tr>
</tbody>
</table>

**TABLE 4.-FILLER MATERIALS**

## Potting Compounds

<table>
<thead>
<tr>
<th>ITEM #</th>
<th>Material</th>
<th>Source</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>PC-01</td>
<td>LR-01 + 20% Fil-01 or 5% Fil-02</td>
<td>No specified source</td>
<td></td>
</tr>
<tr>
<td>PC-02</td>
<td>LR-02 + 20% Fil-01 or 5% Fil-02</td>
<td>No specified source</td>
<td></td>
</tr>
<tr>
<td>PC-03</td>
<td>EA934</td>
<td>No specified source</td>
<td></td>
</tr>
<tr>
<td>PC-04</td>
<td>EA9394</td>
<td>No specified source</td>
<td></td>
</tr>
</tbody>
</table>

**TABLE 5.-POTTING COMPOUNDS**

## Bagging Materials

<table>
<thead>
<tr>
<th>ITEM #</th>
<th>Material</th>
<th>Source</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>BM-01</td>
<td>Scoured nylon Peel-ply</td>
<td>No specified source</td>
<td></td>
</tr>
<tr>
<td>BM-02</td>
<td>FEP perforated release film</td>
<td>No specified source</td>
<td></td>
</tr>
<tr>
<td>BM-03</td>
<td>FEP Non-perforated release film</td>
<td>No specified source</td>
<td></td>
</tr>
<tr>
<td>BM-04</td>
<td>Release Fabric porous</td>
<td>No specified source</td>
<td></td>
</tr>
<tr>
<td>BM-05</td>
<td>Release Fabric non-porous</td>
<td>No specified source</td>
<td></td>
</tr>
<tr>
<td>BM-06</td>
<td>Nylon Bagging Film</td>
<td>No specified source</td>
<td></td>
</tr>
<tr>
<td>BM-07</td>
<td>Bleeder/Breather Non-woven Polyester 2 oz.</td>
<td>No specified source</td>
<td></td>
</tr>
<tr>
<td>BM-08</td>
<td>Bleeder/Breather Non-woven Polyester 4 oz.</td>
<td>No specified source</td>
<td></td>
</tr>
<tr>
<td>BM-09</td>
<td>Flashbreaker Tape</td>
<td>No specified source</td>
<td></td>
</tr>
<tr>
<td>BM-10</td>
<td>Bag Sealant</td>
<td>No specified source</td>
<td></td>
</tr>
</tbody>
</table>

**TABLE 6.-BAGGING MATERIALS**
Polymeric Materials

Materials that are processed with resin then stored at or below 0 degrees Fahrenheit are known as preimpregnated polymeric materials (prepregs.) The cold storage retards the curing process. Monitoring of the shelf life and out-time are critical to assure mechanical properties are achieved. Allow roll to thaw at room temperature prior to use.

Prepreg Fabrics / Tapes

<table>
<thead>
<tr>
<th>ITEM #</th>
<th>Material</th>
<th>Source</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>GF-03</td>
<td>7781 Fiberglass</td>
<td>No specified source</td>
<td>250° curing</td>
</tr>
<tr>
<td>GF-04</td>
<td>120 Fiberglass (M20) or equivalent</td>
<td>Hexcel Corporation</td>
<td>AMS 3970 250° curing</td>
</tr>
<tr>
<td>CF-03</td>
<td>3K Carbon Plain Weave (M20) or equivalent</td>
<td>Hexcel Corporation</td>
<td>AMS 3970 250° curing</td>
</tr>
<tr>
<td>CF-04</td>
<td>3K-135-8H</td>
<td>No specified source</td>
<td>250° curing</td>
</tr>
<tr>
<td>CF-05</td>
<td>Grade 95 carbon uni-tape</td>
<td>No specified source</td>
<td>250° curing</td>
</tr>
<tr>
<td>AF-03</td>
<td>285 Aramid</td>
<td>No specified source</td>
<td>250° curing</td>
</tr>
<tr>
<td>AF-04</td>
<td>120 Aramid</td>
<td>No specified source</td>
<td>250° curing</td>
</tr>
</tbody>
</table>

TABLE 7. 250° CURING PREPREG FABRICS / TAPES

Prepreg Film Adhesives

<table>
<thead>
<tr>
<th>ITEM #</th>
<th>Material</th>
<th>Source</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>FA-01</td>
<td>EA9695 (.050 psf)</td>
<td>Henkel Hysol</td>
<td>AMS 3970</td>
</tr>
<tr>
<td>FA-02</td>
<td>250 curing film adhesive</td>
<td>No specified source</td>
<td>250° curing</td>
</tr>
</tbody>
</table>

TABLE 8. 250° CURING FILM ADHESIVES

Foaming Adhesives

<table>
<thead>
<tr>
<th>ITEM #</th>
<th>Material</th>
<th>Source</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>FM-01</td>
<td>PL685 / MA 562</td>
<td>Henkel</td>
<td>250° curing (roll)</td>
</tr>
<tr>
<td>FM-02</td>
<td>EA 9815</td>
<td>Hysol Corporation</td>
<td>250° curing (cartridge)</td>
</tr>
</tbody>
</table>

TABLE 9. 250° CURING FOAMING ADHESIVES
### Honeycomb Core Materials

<table>
<thead>
<tr>
<th>ITEM #</th>
<th>Material</th>
<th>Source</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>HC-01</td>
<td>1/8&quot; 3.1 hex cell aramid paper</td>
<td>No specified source</td>
<td>HRH 1/8 3.1</td>
</tr>
<tr>
<td>HC-02</td>
<td>3/16 4.0 hex cell fiberglass reinforced</td>
<td>No specified source</td>
<td>Mil-C-8073</td>
</tr>
</tbody>
</table>

**TABLE 10. CORE MATERIALS**

### Sealants

<table>
<thead>
<tr>
<th>ITEM #</th>
<th>Material</th>
<th>Source</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>SE-01</td>
<td>Pro Seal 870 B-2 Faying surface sealant / Wet installation of fasteners</td>
<td>No specified source</td>
<td>Mil-PRF-81733</td>
</tr>
<tr>
<td>SE-02</td>
<td>Pro Seal 870 A 1/2 Aerodynamic smoothing and fairing</td>
<td>No specified source</td>
<td></td>
</tr>
</tbody>
</table>

**TABLE 11. SEALANTS**

### Fabric Substitutions

<table>
<thead>
<tr>
<th>ITEM #</th>
<th>SUBSTITUTE</th>
</tr>
</thead>
<tbody>
<tr>
<td>GF-01</td>
<td>3 plies GF-02</td>
</tr>
<tr>
<td>CF-02</td>
<td>2 plies CF-01</td>
</tr>
<tr>
<td>AF-01</td>
<td>1 ply GF-01</td>
</tr>
<tr>
<td>AF-02</td>
<td>1 ply GF-01 or 3 plies GF-02</td>
</tr>
<tr>
<td>GF-03</td>
<td>3 plies GF-04</td>
</tr>
<tr>
<td>CF-04</td>
<td>2 plies CF-03</td>
</tr>
<tr>
<td>CF-05</td>
<td>1 ply CF-03</td>
</tr>
<tr>
<td>AF-03</td>
<td>1 ply GF-03 or 3 plies GF-04</td>
</tr>
<tr>
<td>AF-04</td>
<td>1 ply GF-04</td>
</tr>
</tbody>
</table>

**TABLE 12. FABRIC SUBSTITUTIONS**
FASTENERS (51-40-00)

Fasteners used for repair of composite structures generally require a clearance fit. The static strength of a composite can be reduced by 25% or more when improperly installed. Repairs that require the usage of fasteners may require wet installation with a faying surface sealant. Refer to the specific repair instruction for applicability.

Drilling General Requirements

Safety glasses should be worn at all times. Select a hand drill that will provide the correct speed for the material. Select the appropriate speed from table 1 and table 2.

NOTE: A backing board will aid in the prevention of fiber breakage during the drilling operation.

Drill bits that meet NAS 907 Type “D” or “J” should be used for drilling titanium and composite materials.

CAUTION: When drilling titanium material, a constant pressure must be maintained. Loss of pressure will cause the material to work harden and subsequent drilling will be extremely difficult.

<table>
<thead>
<tr>
<th>Bit Diameter</th>
<th>DRY</th>
<th>WET</th>
</tr>
</thead>
<tbody>
<tr>
<td>#40</td>
<td>850</td>
<td>1275</td>
</tr>
<tr>
<td>#30</td>
<td>500</td>
<td>750</td>
</tr>
<tr>
<td>#21</td>
<td>375</td>
<td>550</td>
</tr>
<tr>
<td>#10</td>
<td>325</td>
<td>500</td>
</tr>
<tr>
<td>¼”</td>
<td>300</td>
<td>450</td>
</tr>
</tbody>
</table>

TABLE 1-TITANIUM MATERIAL

<table>
<thead>
<tr>
<th>Bit Diameter</th>
<th>DRY</th>
<th>WET</th>
</tr>
</thead>
<tbody>
<tr>
<td>⅛” or less</td>
<td>3500</td>
<td>N/A</td>
</tr>
</tbody>
</table>

TABLE 2-CARBON MATERIAL

FIGURE 1 TYPICAL REAMERS
Hex Drive Lock Bolts (Hi-Loks Figure 2)

Typically used in close tolerance applications where high strength is required. Their usage requires access to the back side of the repair. The bolt is inserted and a threaded self-locking collar is installed. When the correct torque is achieved the hex collar breaks-off. No special tooling is required, however, the holes should be reamed to final size. If a hex drive lock bolt is removed, an oversized lock bolt must be selected and correctly installed. The correct fastener length can be determined by the use of 1/16" grip gage.(Figure 3)

![Figure 2 HI-LOK INSTALLED](image)

![Figure 3 HI-LOK GRIP GAGE](image)

**NOTE:** Do not re-install a removed hex drive lock bolt.

The hole sizes below will provide a close tolerance clearance fit through composite structures

<table>
<thead>
<tr>
<th>Part Number</th>
<th>Titanium</th>
<th>HL10V</th>
<th>HL110V</th>
<th>HL410V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collar Number</td>
<td>Hl79</td>
<td>Hl79</td>
<td>Hl84</td>
<td></td>
</tr>
<tr>
<td>Pin Diameter</td>
<td>Standard</td>
<td>1st Oversize</td>
<td>2nd Oversize</td>
<td>1st Oversize</td>
</tr>
<tr>
<td>Min</td>
<td>Max</td>
<td>Min</td>
<td>Max</td>
<td>Min</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>-6</td>
<td>0.1890</td>
<td>0.1910</td>
<td>0.2031</td>
<td>0.2040</td>
</tr>
<tr>
<td>#12</td>
<td>#11</td>
<td>13/64&quot;</td>
<td>#6</td>
<td>7/32&quot;</td>
</tr>
<tr>
<td>-8</td>
<td>0.2505</td>
<td>0.2570</td>
<td>0.2656</td>
<td>0.2660</td>
</tr>
<tr>
<td>&quot;E&quot;</td>
<td>&quot;F&quot;</td>
<td>17/64&quot;</td>
<td>&quot;H&quot;</td>
<td>&quot;K&quot;</td>
</tr>
</tbody>
</table>

**TABLE 3-HEX DRIVE LOCK BOLT HOLE SIZES**
Blind Bolts (Composi-Lok II Figure 3)

Used on carbon composite structures where access is limited to one side and high bearing loads are required. The shank doesn’t expand minimizing damage to the composite substrate. NAS 1675 tooling is required to drive the hex nut to the predetermined torque value. A large upset head distributes the clamping forces and when the correct torque is achieved, the drive screw fractures and the fastener is set. The correct fastener length can be determined by the use of BFS-1A grip gage.

NOTE: Do not use a standard 1/16” grip gage. Grip lengths for Composi-Lok fasteners are measured in .050” increments.

<table>
<thead>
<tr>
<th>Part Number</th>
<th>Size</th>
<th>Hole Size</th>
<th>J Dia Min</th>
<th>K Max</th>
<th>Screw break-off limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>MBF2110-6</td>
<td>3/16”</td>
<td>.1990-#8</td>
<td>.300</td>
<td>.350</td>
<td>.000 -</td>
</tr>
<tr>
<td>MBF2110-8</td>
<td>1/4”</td>
<td>“G”</td>
<td>.400</td>
<td>.450</td>
<td>.103</td>
</tr>
</tbody>
</table>

TABLE 4-COMPOSI-LOCK BOLT HOLE SIZES

FIGURE 3 COMPOSI-LOK INSTALLED DIMENSIONS
Blind Bolt Installation Standards

UNACCEPTABLE CONDITIONS

ACCEPTABLE INSTALLATION

FIGURE 4 COMPOSI-LOK ACCEPTABLE STANDARDS
BALANCED SURFACES (51-60-00)

The primary flight controls are balanced units. Balancing provides aerodynamic streamlining and control stability. The flight controls surfaces must be balanced within the operational balance limit. The procedure below will determine the rework moments and determine if any repair exceeds the operational limit.

Caution: Check the placard on the inboard spar for previous repairs. Do not accomplish more than four repairs to the flight control surfaces. Removal and static re-balance is required on the fourth repair.

A. Weight and Balance Terminology

1. Operational limit: Range at which the flight control can balance and maintain flight stability

2. Moment Rework: Added repair weight (W_r) multiplied by the arm (A) (center of the damage to the hinge line) 
   \[ W_r \times A = M_r \]

3. Calculated Moment: Balance moment + Moment Rework \[ M + M_r \]

4. Balance Moment: Current flight control moment as placarded on the inboard spar (M)
   a. Positive (+) moments are under balanced causing the flight control surface to be tail heavy (aft C.G.)
   b. Negative (-) moments are overbalanced causing the flight control surface to be nose heavy (fwd C.G.)

5. Weight Reactions:
   a. Positive (+) if flight control surface deflects downward on a balanced support
   b. Negative (-) if flight control surface deflects upward on a balanced support

Note: Distances aft of the hinge centerline are positive (+) and forward of the hinge centerline negative (-)

B. Flight Control Operational Limits

<table>
<thead>
<tr>
<th>Control Surface</th>
<th>Operational Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elevator</td>
<td>-30.00 to -10.00</td>
</tr>
<tr>
<td>Rudder</td>
<td>-35.00 to -5.00</td>
</tr>
<tr>
<td>Aileron</td>
<td>-50.00 to 0.00</td>
</tr>
</tbody>
</table>

TABLE 1. OPERATIONAL FLIGHT CONTROL OPERATIONAL LIMITS
C. Repair Material Weights

Note: The weight of the removed ply(s) and core material will equal the replacement material weight and is not considered in the repair calculation

1. Calculate the additional weight gain for one extra repair ply plus one layer of film adhesive

2. Calculate the additional weight gain for one ply of GF-03 and 2 layers of FM-01 adhesive when replacing core material

Weights listed are for 250 degree curing prepreg materials.

<table>
<thead>
<tr>
<th>Repair Material</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>GF-03</td>
<td>0.00070 lbs sq. in. / ply</td>
</tr>
<tr>
<td>CF-03</td>
<td>0.00047 lbs sq. in. / ply</td>
</tr>
<tr>
<td>FA-02</td>
<td>0.00042 lbs sq. in.</td>
</tr>
<tr>
<td>FM-01</td>
<td>0.00274 lbs sq. in.</td>
</tr>
</tbody>
</table>

TABLE 2 REPAIR MATERIAL WEIGHT

Example Repair Moment Rework Calculation:

Problem: The elevator has visible damage 17" aft of the hinge with a 4" hole approximately 3" in-depth. The elevator is constructed with 3 plies of CF-03 material. Balance moment as placarded is (-)25.00". Damage is locate in a non-critical area

Each repair ply requires a ½" overlap beyond the damage as follows:

- Repair ply 1 = 5" diameter
- Repair ply 2 = 6" diameter
- Repair ply 3 = 7" diameter
- Extra repair ply = 8" diameter (calculate added weight)
- Adhesive film = 8" diameter (calculate added weight)
- Core splice material 4" diameter (calculate added weight)
- Core repair ply 4" diameter (calculate added weight)
- Core repair adhesive film 2 layers 4" diameter (calculate added weight)
D. Example repair weight calculations

1. Determine the surface area of a 8” diameter repair ply \( (\pi \times R^2) \) 
   \[ 3.14159 \times 4^2 = 50.33 \text{ sq.in.} \]

2. Determine the weight of 8” repair ply CF-03 \( (\text{area} \times \text{ply wt}) \) 
   \[ 50.33 \times 0.00047 = 0.02365 \text{ lbs} \]

3. Determine the weight of a 8” diameter FA-02 layer \( \frac{\text{50.33 sq in}}{\text{x 0.00042 lbs sq in}} \) 
   \[ 0.02113 \text{ lbs} \]

4. Determine the weight of FM-01 material based on 4” hole \( (\pi \times D \times \text{Depth} \times \text{lbs sq.in}) \) 
   \[ \frac{3.14159 \times 4 \times 3 \times 0.00274}{\text{= 0.1032 lbs}} \]

5. Determine the surface area of the 4” core repair ply \( (\pi \times R^2) \) 
   \[ 3.14159 \times 2^2 = 12.5664 \text{ sq.in.} \]

6. Determine the weight of the 4” CF-03 ply \( (\text{area} \times \text{ply wt}) \) 
   \[ 12.5664 \times 0.00047 = 0.0059 \text{ lbs} \]

7. Determine the weight of the 4” FA-02 layers \( (\text{area} \times \text{ply wt} \times 2) \) 
   \[ 12.5664 \times 0.00042 \times 2 = 0.01056 \text{ lbs} \]

8. Determine total rework weight
   - Added the weights from line 2,3,4,6,7 above
     
     | Line  | Weight |
     |-------|--------|
     | 2     | 0.02365|
     | 3     | 0.02113|
     | 4     | 0.1032 |
     | 6     | 0.0059 |
     | 7     | 0.01056|
     
     Total Wt. \[ 0.16444 \text{ lbs} \]

E. Example moment rework determination

1. Total repair weight multiplied by the distance to the center of the repair \( (W_r \times \text{arm}) = M_r \text{ Moment Rework} \)
   \[ W_r \times 0.1644 \times 17” = M_r \text{ 2.7954 pound inches} \]

F. Example determine the new calculated balance moment

1. Obtain the balance moment from the placard on the inboard spar of the flight control surface \( M (-)25.00 \)
2. Add the moment rework to the balance moment \( (-) 25.00 + 2.7954 = 22.204 \text{ lb in} = \text{Calculated Moment} \)
3. Check that the Calculated Moment is within the operational limits (figure 1)
4. Record the Calculated Moment as the new Balance Moment on the flight control placard
5. Record the date and the Rework Moment on the placard
REPAIRS (51-70-00)

General repair selection criteria should be based upon the TRM repair limits, material, time and tooling availability. Composite repairs are listed by the structure composition as well as the repair materials involved. Any damage beyond the TRM repair limits require engineering or OEM approval.

Before a repair is attempted, review the applicable repair procedure and check for availability of material call-outs.

This Chapter is divided into repair schemes by structure classification and repair materials. Wet Lay-up repairs are coded \textbf{WR}, Prepreg repairs are coded \textbf{PR} and Bolted repairs are coded \textbf{BR}:

- Wet Lay-up repairs general \textbf{51-70-01}
  - Wet Lay-up solid laminate repair \textbf{WR-01}
  - Wet Lay-up sandwich structure skin and core damage repair \textbf{WR-02}
  - Wet Lay-up sandwich structure skin and core damage to both sides repair \textbf{WR-03}

- Prepreg 250 degree repairs general \textbf{51-70-05}
  - Prepreg solid laminate repair \textbf{PR-01}
  - Prepreg sandwich structure skin and core damage repair \textbf{PR-02}
  - Prepreg sandwich structure skin and core damage to both sides repair \textbf{PR-03}

- Bolted repairs general \textbf{51-70-10}
  - Bolted repair to monolithic structure \textbf{BR-01}
WET LAY-UP REPAIRS GENERAL (51-70-01)

Wet Lay-up repairs WR-01, WR-02 and WR-03 involve laminating dry woven fabrics with a specified epoxy resin system and then cured. Consult the applicable MSDS for safety related information. Before a repair is attempted, determine the part specific information as follows:

- Original fiber type and number of plies
- Original cure temperature
- Ply orientation
- Core ribbon direction (if applicable)
- Critical area(s)
- Repair size limitations
- Repair matrix material availability
- Weight and Balance (if applicable)
- Environmental protection / coating (if applicable)

REPAIR ASSESSMENT:

NOTE: The following repair procedures are common to both WR-01, WR-02 and WR-03 repairs:

A. Perform a damage assessment (reference 51-10-00):
   1. Determine the extent of the damage
   2. If moisture / contamination is present, remove contamination
   3. If multiple areas are damaged, check for minimum distance required between repairs.
   4. Check the allowable and repairable limits of the part. If damage is within the allowable limits, no further action is required

B. Determine type and number of plies damaged
   1. Typical solid laminate and sandwich panel identification refer to (51-100-00)

C. Select the repair option
   1. Determine category A, B or C based on damage size, time, equipment and materials (51-20-00)

NOTE: If practical, perform a category “A” repair.

D. Obtain repair materials (51-30-00)
   1. Repair ply substitution is on a one for one basis (refer to 51-30-00 table 12 for ply substitutions)
   2. Two additional repair plies per facesheet are required
REPAIR PROCEDURE:

A. Remove the damaged area

1. To aid in the prevention of damage to the surrounding composite structure, consider masking the repair area referencing ARP 4916 Method 2 or 3.

2. Measure and mark the material to be removed allowing ½” per ply of damage.

3. Taper sand the structure using EX-08 or finer abrasive referencing AIR 5367 allowing ½” per ply of damaged.

4. Scuff sand to remove any surface gloss ½” larger than the largest repair ply.

CAUTION: Do not break the fibers during scuff sanding

B. Clean the repair area

NOTE: Select the solvent or dry-wipe method

1. Solvent method
   a. Select solvent CL-01 or CL-02.
   b. Clean the part referencing ARP 4916 Composite Cleaning Methods 4 or 5. Do not allow the solvent to dry on the part. Apply solvent then immediately wipe clean using EX-09 cleaning cloths.
   c. Cover the repair area with BM-03 or BM-04 material

2. Dry-wipe method
   a. Obtain some EX-09 cleaning cloths
   b. Wipe the taper sanded and abraded area until all sanding residue is removed.
   c. Cover the repair area with BM-03 or BM-04 material

C. Prepare the Repair Plies

1. Transfer the ply orientation symbol onto the part ARP 5319 (Para 6.d.)

2. Manufacture ply templates if necessary ARP 5319 (Para 6.e.)

3. Place templates onto material BM-03 or BM-04 and trace referencing ARP 5319 (Para 7) (figure 3)

4. Cut the repair fabric a minimum of 2” larger than the ply outlines

D. Prepare the Repair Area for Vacuum Bagging

1. Cut and stack the vacuum bagging materials over the area to be repaired using ARP 5143 (Para 8. method 1)

2. If a heating blanket is used, the blanket must extend a minimum of 2” larger than the largest repair ply; a minimum of 3 thermocouples are required. Verify blanket serviceability using a resistance check referencing ARP 5144 (Para 7.1.3).

CAUTION: Ensure heating blankets and thermocouples are servicable prior to use. Reference ARP 5144 (para 6,7)
3. Usage of a caul plate is optional (.016" to .032" 2024-0 material)

E. Impregnate and Lay-up the Repair Plies

1. Select repair resin LR-01, LR-02, LR-03 or LR-04 based on damage size and category of repair.

NOTE: Repair resins LR-01 and LR-02 require an auxiliary heating source to develop full cure properties.

2. Determine the quantity of laminating resin required
   a. Obtain resin/hardener mix ratio
   b. Weigh the dry fabric and multiply by 20 percent
   c. Perform resin and hardener calculation using ARP 5256 (Para 7.1)

The Fiber/Resin ratio for a cured repair should be 60 percent fiber to 40 percent resin. However, impregnating dry fabric will require at least the same weight as the dry fabric plus an additional amount for sufficient cloth wetting.

NOTE: The impregnated cloth must be applied to the repair area and under vacuum pressure prior to the pot life of the mixed resin.

3. Mix the laminating resin using the manufacturer’s resin/hardener mix ratio

4. Apply mixed resin to the repair fabric
   a. Select Ply Impregnation and Lay-up method 2 or 3 using ARP 5319
   b. Cut-out the repair plies

NOTE: If the repaired area was previously cleaned using the “Dry-Wipe” method, scuff sand the repair area using 180 grit or finer abrasive then clean referencing paragraph B.2. before applying the repair plies.

5. Place the repair plies on the damaged area observing the ply orientation
   a. Filler plies are not considered repair plies
   b. Place the smallest repair ply first
   c. Continue applying the remaining repair plies one at a time

F. Vacuum bag the repair

1. Select ARP 5143 Method 1 (Para 8.1) – Vertical Bleed Cure with or without the use of a heat blanket

2. Apply and maintain a minimum of 22" Hg during the cure cycle

3. Leak check the vacuum bag
   a. Leak rate should not be more than 5" Hg over a 5 minute period
G. Cure the repair ARP 5144

1. Select the cure cycle based on the resin system selected (reference figure 6)
2. Apply heat as required to follow the manufacturer’s recommended cure cycle
3. Record cure cycle at regular intervals (every 5-15 minutes)

H. Examine the repaired area

1. Check for visual signs of resin rich or resin starved areas
2. Check for surface waviness
3. Check for disbonds and delamination using the tap test method chapter 51-10-01

I. Restore the environmental protection (Refer to chapter 51-80-00)

1. Apply conductive coating or lightning protection and check for allowable resistance
2. Apply FR primer and Top-coat as required

J. Perform a Post Repair Inspection (Refer to chapter 51-90-00)

1. Sign and record applicable work documents
2. Return part to service
Wet Lay-Up Solid Laminate Repair WR-01

This repair covers damage to fiberglass, carbon and aramid skins, solid laminate and edgeband areas manufactured with 250° curing polymeric materials.

A. Perform a Repair Assessment 51-70-01 Paragraphs A thru D.

B. Continue the Repair Procedure 51-70-01 Paragraphs A thru J using the following figures as applicable:

1. For repairs to skins without core damage reference figure 1.
2. For repairs to solid laminate structure reference figure 2.
3. For repairs to edgeband areas refer to figure 3.

FIGURE 1 REPAIR TO SKINS WITHOUT CORE DAMAGE
TAPER SAND
1/2” per ply

FLASH TAPE

1/2” overlap

Extra repair plies
Repair plies

FIGURE 2 REPAIR TO SOLID LAMINATE STRUCTURE
FIGURE 3 REPAIR TO EDGEBAND STRUCTURE
Wet Lay-Up Sandwich Structure Skin And Core Damage Repair WR-02 - WR-03

This repair covers damage to fiberglass, carbon and aramid sandwich structures with skin and core damage to one or both skins manufactured with 250º curing polymeric materials. Repair referencing figure 4 and figure 5.

A. Perform a Repair Assessment 51-70-01 Paragraphs A thru D.

B. Remove the damaged core material and determine the core ribbon direction

1. Core repair procedures are based on the size of the hole and the depth of the damage. If core replacement is necessary, replace with the same type and density.

C. Continue the Repair Procedure 51-70-01 Paragraphs A and B.

NOTE: A two-step repair (repair the core then the skin material) is preferred; however, if curing time is a factor, then a one-step repair (core and skin cured together) is acceptable.

D. Repair the core material

1. For core damage size 1” or less, restore the core with potting compound using ARP 4991(Para 5.2) Method 1 or 2.
   a. Select the potting compound from chapter 51-30-00 (Table 5)
   b. Mix the resin and hardener then add the filler material.
   c. Fill cavity with potting compound
   d. Place a layer of BM-01 over the potting compound
   e. Place a layer of BM-03 ½” smaller than the BM-01 material.
   f. Apply a dead weight, or vacuum bag and allow to cure.
   g. The use of an auxiliary heating device will accelerate the cure time. (Reference figure 6)
   i. Remove materials and sand flush with existing core when cured.

2. For core damage greater than 1” in size, remove and replace the core material using the partial depth method 1 or 2 or full depth core restoration method 1 or 2 , referencing ARP 4991 (Para 5.3 figures 5 thru 11).
   a. Select a laminating resin and thoroughly mix the components chapter 51-30-00 (table 3)
   b. For partial and full depth repairs using method 2, apply 2 layers of GF-02 fabric wet with the laminating resin.
   c. Insert the wet GF-02 plies (if method 2 is used) into the hole
   d. Add filler material Fil -01 or Fil-02 to laminating resin mix to obtain a potting compound (51-30-00 table 5.)
   e. Apply potting compound to replacement core and hole edges. Insert the core plug matching the existing ribbon direction.
   f. Apply constant pressure using ARP 4991 (Para 5.3.8) Option A or Option B
   g. Cure the resin (reference figure 6)
   h. Remove the pressure
E. Repair the surface plies

1. For one sided repairs WR-02 (Ref figure 4)
   a. Continue the Repair Procedure 51-70-01 Paragraphs C thru J.

2. For two sided repairs WR-03 (Ref figure 5)
   a. Continue the repair curing one side of the panel, Repair Procedure 51-70-01 Paragraphs C thru J.
   b. Remove bagging materials and repeat the repair sequence on the opposite side of the panel referencing Repair Procedure 51-70-01 Paragraphs C thru J.

---

**FIGURE 4 SANDWICH STRUCTURE SKIN AND CORE DAMAGE REPAIR WR-02**
Taper sand 1/2" overlap per ply
Scuff sand 1/2" larger than largest ply
Repair plies
Two plies GF-01 Optional
Optional Filler ply
Potting Compound per repair instructions
Extra repair ply or plies

FIGURE 5 SANDWICH STRUCTURE SKIN AND CORE DAMAGE TO BOTH SIDES REPAIR WR-03
1. Cure temperature and dwell time are dependent upon the resin system and the repair instructions. Select the resin based on the repair instructions and cure as follows:

   a. LR-01 cure at or 150°F. for 3 hours or 200°F. for 2 hours
   
   b. LR-02 cure at 200°F. for 4 hours
   
   c. LR-03 and LR-04 cure at RT for 16 hours or 150°F. for 3 hours

   FIGURE 6 WET LAYUP CURE CYCLE INFORMATION
PREPREG 250 DEGREE REPAIR GENERAL (51-70-05)

Prepreg materials must be allowed to thaw at room temperature prior to opening the sealed bag. Record the time out on an approved freezer inventory card. Check to ensure the material has not exceeded its maximum out-time prior to usage. Refer to F.A.A. AC145-6 for additional handling and storage requirements. Before a repair is attempted, determine the part specific information as follows:

- Original fiber type and number of plies
- Original cure temperature
- Ply orientation
- Core ribbon direction
- Critical area(s)
- Repair size limitations
- Repair prepreg material availability
- Weight and Balance (if applicable)
- Environmental protection / coating

REPAIR ASSESSMENT:

NOTE: The following repair procedures are common to both PR-01, PR-02 and PR-03 repairs:

A. Perform a damage assessment (51-10-00):
   1. Determine the extent of the damage
   2. If moisture / contamination is present, remove contamination
   3. If multiple areas are damaged, check for minimum distance required between repairs.
   4. Check the allowable and repairable limits of the part. If damage is within the allowable limits, no further action is required

B. Determine type and number of plies damaged
   1. Typical solid laminate and sandwich panel identification refer to (51-100-00)

C. Select the repair option
   1. Determine category A, B or C based on damage size, time, equipment and materials (51-20-00)

NOTE: If practical, perform a category “A” repair.
D. Obtain prepreg repair materials (51-30-00 table 7,8,9)

1. Repair ply substitution is on a one for one basis (refer to 51-30-00 table 12 for ply substitutions)

2. One additional ply per facesheet repaired is required

NOTE: Repair material substitution is at the discretion of the training provider.

REPAIR PROCEDURE:

A. Remove the damaged area

1. To aid in the prevention of damage to the surrounding composite structure, consider masking the repair area referencing ARP 4916 Method 2 or 3.

2. Measure and mark the material to be removed allowing ½” per ply of damage.

3. Taper sand the structure using EX-08 or finer abrasive referencing AIR 5367 allowing ½” per ply damaged.

4. Scuff sand to remove any surface gloss ¾” larger than the largest repair ply.

CAUTION: Do not break the fibers during scuff sanding

B. Clean the repair area

NOTE: Select the solvent or dry-wipe method

1. Solvent method
   a. Select solvent CL-01 or CL-02.
   b. Clean the part referencing ARP 4916 Composite Cleaning Methods 4 or 5. Do not allow the solvent to dry on part. Apply the solvent then immediately wipe clean using EX-09 cleaning cloths.
   c. Cover the repair area with BM-03 or BM-04 material

2. Dry-wipe method
   a. Obtain some EX-09 cleaning cloths
   b. Wipe the taper sanded and abraded area until all sanding residue is removed.
   c. Cover the repair area with BM-03 or BM-04 material
C. Prepare the Prepreg Repair Plies

NOTE: Non-powdered disposable gloves (or equivalent) should be worn while handling prepreg materials.

1. Transfer the ply orientation symbol onto the part ARP 5319 (Para 6.d.)
2. Manufacture ply templates if necessary ARP 5319 (Para 6.e.)
3. Place templates onto the prepreg backing material and trace using a marking pen referencing ARP 5319 (Para 7) (figure 3).
4. Cut the prepreg repair plies

NOTE: The warp direction of the prepreg fabric is identified by a diamond pattern on the backing film.

5. Cut two layers of FA-01 or FA-02 adhesive film ¼” larger than the largest repair ply

D. Prepare the Repair Area for Vacuum Bagging

1. Cut and stack the vacuum bagging materials over the area to be repaired using ARP 5143 (Para 8. method 1)
2. Prepare the hot bonding console (if selected)
   a. The heating blanket must extend a minimum of 2” larger than the largest repair ply; a minimum of 3 thermocouples are required. Verify blanket serviceability using a resistance check referencing ARP 5144 (Para 7.1.3).
   b. Verify equipment calibration is current.

CAUTION: Ensure heating blankets and thermocouples are servicable prior to use. Reference ARP 5144 (para 6,7)

3. Usage of a caul plate is optional (.016” to .032” 2024-0 material)

E. Lay-up the Prepreg Repair Plies

NOTE: If the repaired area was previously cleaned using the “Dry-Wipe” method, scuff sand the repair area using 180 grit or finer abrasive then clean referencing paragraph B.2. before applying the repair plies.

1. Place the repair plies on the damaged area observing the ply orientation
   a. Filler plies are not considered repair plies
   b. Place one layer of FA-01 or FA-02 film adhesive onto the taper sanded area
   c. Apply the smallest repair ply
   d. Continue applying the remaining prepreg repair plies one at a time
   e. Place a layer of FA-02 film adhesive or GF-04 over largest repair ply (optional)
F. Vacuum bag the repair
   1. Select ARP 5143 Method 1 (Para 8.1) – Vertical Bleed Cure with or without the use of a heat blanket
   2. Apply and maintain a minimum of 22” Hg during the cure cycle
   3. Leak check the vacuum bag
      b. Leak rate should not be more than 5” Hg over a 5 minute period

G. Cure the repair ARP 5144
   1. Select the cure cycle based on the prepreg system selected (Refer to figure 6)
   2. Apply heat as required to follow the manufacture's recommended cure cycle
   3. Record cure cycle at regular intervals (every 5-15 minutes)

H. Examine the repaired area
   1. Check for visual signs of resin rich or resin starved areas
   2. Check for surface waviness
   3. Check for disbonds and delamination using the tap test method chapter 51-10-01

I. Restore the environmental protection (Refer to chapter 51-80-00)
   1. Apply conductive coating or lightning protection and check for allowable resistance
   2. Apply FR primer and Top-coat as required

J. Perform a Post Repair Inspection (Refer to chapter 51-90-00)
   1. Sign and record applicable work documents
   2. Return part to service
Prepreg Solid Laminate Repair PR-01

This repair covers damage to fiberglass, carbon and aramid skins, solid laminate and edgeband areas manufactured with 250º curing polymeric materials. Don PPE prior to handling prepreg repair materials.

A. Perform a Repair Assessment 51-70-05 Paragraphs A thru D.

B. Continue the Repair Procedure 51-70-05 Paragraphs A thru J using the following figures as applicable:
   1. For repairs to skins without core damage reference figure 1.
   2. For repairs to solid laminate structure reference figure 2.
   3. For repairs to edgeband areas reference figure 3.
Taper sand 1/2" overlap per ply

Scuff sand 1/2" larger than largest ply

Extra repair ply

Repair plies

Optional Filler ply

FA-02 or GF-03 Optional

FIGURE 1 PREPREG REPAIRS TO SKINS WITHOUT CORE DAMAGE
FIGURE 2 PREPREG REPAIRS TO SOLID LAMINATE STRUCTURE

- **FLASH TAPE**
- **TAPER SAND 1/2" per ply**
- **Repair plies**
- **Extra ply**

-TAP £®AND}
**FIGURE 3 PREPREG REPAIRS TO EDGEBAND**

- **FA-02** or **GF-03**
- **Repair Plies**
- **Taper Sand 1/2" per ply**
- **DO Not sand into the core area**

**Legend**
- **FA-02**
- **Repair Plies**
- **FA-02** or **GF-03**
Prepreg Sandwich Structure Skin And Core Damage Repair PR-02 – PR-03

This repair covers damage to fiberglass, carbon and aramid sandwich structures with skin and core damage to one or both skins manufactured with 250° curing polymeric materials. Repair referencing figure 4 and figure 5.

A. Perform a Repair Assessment 51-70-05 Paragraphs A thru D.

B. Remove the damaged core material and determine the core ribbon direction

1. Core repair procedures are based on the size of the hole and the depth of the damage. If core replacement is necessary, replace with the same type and density.

C. Continue the Repair Procedure 51-70-05 Paragraphs A and B.

NOTE: A two-step repair (repair the core then the skin material) is preferred; however, if curing time is a factor, then a one-step repair (core and skin cured together) is acceptable.

CAUTION: Do not Co-cure A-staged materials (wet-layup) with B-staged (prepreg) materials

D. Repair the core material

1. For core damage size ½ ” or less, restore the core with foaming adhesive
   a. Select FM-01 or FM-02 from chapter 51-30-00 (Table 9) and fill cavity
   b. Vacuum bag using ARP 5143 (Para 8.1)

NOTE: Thermocouple placement for core bonding is important. Refer to ARP 5144 (para 6.6.2) regarding positioning.

   c. Cure the foaming adhesive a minimum of 2 hours at 250 +- 5 degrees (Refer to figure 6)
   d. Remove the bagging materials and sand the foaming adhesive flush with the existing core.
2. For core damage greater than ½ " in size, remove and replace the core material using the partial depth method or the full depth core restoration method.
   
a. Cut the replacement honeycomb core approximately 1/16" smaller than the existing hole
b. Select and cut two plies of FA-01 or FA-02 adhesive film the same size as the hole
c. Select and cut one ply of GF-04 glass the same size as the hole
d. Sandwich the GF-04 ply between the two plies FA-01 or FA-02 adhesive film

CAUTION: Ensure backing films are removed

   e. Apply FM-01 or FM-02 foaming adhesive to the perimeter of the repair core plug
f. Place the sandwiched repair ply in the hole
g. Place the repair core plug into the hole. Install the core plug matching the existing ribbon direction
h. Vacuum bag using ARP 5143 (Para 8.1)

NOTE: Thermocouple placement for core bonding is important. Refer to ARP 5144 (para 6.6.2) regarding positioning.

c. Cure the foaming adhesive a minimum of 2 hours at 260 ± 10 degrees (Refer to figure 6)
d. Remove the bagging materials and sand the replacement core flush with the existing core.

E. Repair the surface plies

1. For one sided repairs PR-02 (ref figure 4)
   
a. Continue the Repair Procedure 51-70-01 Paragraphs C thru J.

2. For two sided repairs PR-03 (ref figure 5)
   
a. Continue the repair curing one side of the panel, Repair Procedure 51-70-01 Paragraphs C thru J.
b. Remove bagging materials and repeat the repair sequence on the opposite side of the panel referencing Repair Procedure 51-70-01 Paragraphs C thru J.
Taper sand 1/2" overlap per ply

Scuff sand 1/2" larger than largest ply

FIGURE 4 SANDWICH STRUCTURE SKIN AND CORE DAMAGE REPAIR PR-02
Taper sand 1/2" overlap per ply both sides

Scuff sand 1/2" larger than largest ply

FA-02

Extra repair ply

Repair plies

Opti onal Filler ply

FA-02 or GF-03

Optional

FA-02 or GF-03

Optional

Model

Repair plies

FIGURE 5 SANDWICH STRUCTURE SKIN AND CORE DAMAGE BOTH SIDES REPAIR PR-03
1. Do not start the dwell time until the lagging thermocouple is within the specified limit.

FIGURE 6 250° PREPREG REPAIR CURE CYCLE INFORMATION
BOLTED REPAIR TO CARBON MONOLITHIC STRUCTURE (51-70-10)

BR-01 Bolted repairs to carbon composite monolithic structure may be necessary when a bonded repair is not practical. Taper sanding monolithic structure may cause additional damage and increase the overall repair size. This repair requires drilling through a titanium doubler and subsequent drilling through the carbon structure. Repairing carbon structures with fasteners requires final reaming to a close-tolerance or clearance fit hole. Repairs following this procedure are classified as a Category “A” repair. Reference figure 1.

WARNING: Installing fasteners into an interference fit hole through carbon monolithic structure will reduce the load carrying capability of the structure.

Before a repair is attempted, determine the part specific information as follows:

- Critical area(s)
- Repair size limitations
- Repair material availability

REPAIR PROCEDURE: (refer to figure 1)

A. Perform a damage assessment (51-10-00):

1. Determine the extent of the damage using an Instrumented NDT method(s)
2. Check the allowable and repairable limits of the part. If damage is within the allowable limits, no further action is required

B. Remove the damaged area

NOTE: Machining/drilling carbon structure will dull high speed drills and router bits quickly. NAS 907 Type “D” /"J” drill bits are preferred.

CAUTION: Carbon fiber dust is conductive and may cause arcing within electrical powered hand tools. Consider the use of pneumatic hand tools.

1. Measure and mark the damaged area
2. Mask the damaged area using ARP 4916 Masking Method 2 or 3
3. Remove the damaged area using a die-grinder or equivalent tool

C. Doubler preparation

WARNING: Titanium dust / chips are an extreme fire hazard. Prevent all sources of ignition. Do not use foam, water, carbon dioxide or carbontetrachloride to extinguish titanium fires. Acceptable extinguishing agents are dry talc, calcium carbonate and sand. Consult the MSDS for detailed information.

1. Reference figure 1 for fastener spacing requirements
2. Cut a sheet of .063” Ti-6AL-4V allowing for 4D edge distance and deburr the edges
3. Center the doubler over the damaged area and lay-out the fastener pattern
4. Remove the doubler and pilot drill the fastener pattern using a #30 drill bit lubricated with cetyl alcohol (Refer to 51-40-00)
D. Carbon structure hole preparation

1. Center the doubler over the repair area

2. Pilot drill through the pre-drilled doubler holes through the carbon structure with a # 30 drill bit

3. Drill the holes alternating from the left to right then fore and aft using temporary fasteners to maintain doubler hole alignment

Note: For future alignment purposes, mark the holes used for temporary fastener installation and re-install in the same order.

4. Remove the repair doubler

E. Select the repair option and step-drill the repair holes

1. Access limited to one side of the damaged structure
   a. Use blind fasteners MBF2110-6 refer to chapter 51-40-00 (table 15) for the installation procedure
   b. Step-drill the repair doubler with a #13 drill bit
   c. Deburr the doubler holes
   d. Step-drill the composite structure with a #13 drill bit

Caution: Do not deburr holes in the composite structure

2. Access to both sides of the damaged structure (Blind fasteners are optional)
   a. Use Hex drive lock bolts HL10V-6 with HL79 collars
   b. Step-drill the repair doubler with a #21 drill bit
   c. Deburr the doubler holes
   d. Step-drill the composite structure with a #21 drill bit

Caution: Do not deburr holes in the composite structure
F. Final ream the hole sizes

Note: Drilling through carbon material tends to enlarge the hole by .001” to .003”

1. Place the doubler onto the composite structure and align the holes
2. Use temporary fasteners as needed to maintain hole alignment
3. Final ream the holes with cetyl alcohol lube as follows: (Refer 51-40-00 for reamer speeds)
   a. MBF2111-6 Blind Fasteners ream to .1990” (#8 drill bit)
   b. HL10V-6 Hex drive lockbolts ream to .1900 (#12 drill bit)
   c. Remove the doubler and deburr the holes
   d. Chamfer the outside doubler holes to match the head radius of the repair fastener
   e. Clean the doubler and composite structure with CL-01 or CL-02 and EX-09 cloth

G. Install the repair doubler

1. Apply one layer of SE-01 to the faying surfaces
2. Position the doubler onto the composite structure and align with temporary fasteners
3. Use a grip gage and determine the correct fastener grip (ref 51-40-00)

NOTE: For blind bolts use grip gage BFS-1A ; for hex lockbolts use any 1/16” grip gage

4. Install the repair fasteners in the open holes
5. Remove the temporary fasteners and install the remaining repair fasteners
6. Inspect the installed fasteners
   a. Reference 51-40-00 for acceptable fastener installation standards
   b. Remove and replace unserviceable fasteners
   c. It is acceptable to oversize the holes to a maximum of 1/32”

H. Apply a fillet seal using SE-02 or equivalent around the repair doubler edges

I. Restore the environmental protection chapter 51-80-00 (Para E)

J. Perform a Post-Inspection (51-90-00)
Maintain 2D to 4D edge distance

Doubler .063” Titanium

Repair Fastener Location

FIGURE 1 BOLTED REPAIR TO CARBON MONOLITHIC STRUCTURE
ENVIROMENTAL RESTORATION (51-80-00)

Protection from the elements is essential for the prolonged life of bonded composite structures. Moisture, lightning, static, temperature, galvanic corrosion, rain erosion and ultra-violet light, can attack the resin matrix causing delamination, disbonding and microcracking of the resin matrix. Attack from the elements will eventually cause lowering of the tensile and shear strength (mechanical properties) of bonded composite structures. Special protection procedures are employed to prevent deterioration of bonded composite structures.

Composite structures are zoned according to the degree of environmental protection required as follows:

A. Zone 1 Structure protection:

Lightning will attempt to strike zone 1 areas first. These area are the wing tips, radome, vertical and horizontal stablizer tips, flight control outboard surfaces and engine cowlings. Zone 1 protection requires a low resistance conductive path to dissipate the energy quickly to the metallic airframe as follows:

1. Copper Mesh
2. Aluminum Flame Spray
3. Aluminized Glass Cloth
4. Aluminum Mesh Primed

B. Zone 1 Restoration

1. Repair the damaged composite structure

Note: If repairing with mesh materials, it is acceptable to apply the mesh to the outer layer concurrently with the composite structure repair

2. Determine type of protection on the structure
3. Lightly abrade the composite surface exposing ½” of the existing protective layer
4. Reapply the same protective material and bond using LR-03 or LR-04 material
5. Cure resin
6. Lightly sand and apply a paint compatible primer and dry
7. Apply finish top-coat to match existing paint scheme
C. Zone 2,3 Structure Protection:

Areas that need an electrical path to dissipate static charges on the surfaces. These area are the fuselage wing to body fairings and access panels. Typical protection uses a conductive paint applied to the surface. Static charges carry through the conductive coating to the attachment fasteners where the charge is dissipated to the airframe.

D. Zone 2,3 Restoration

1. Repair the damaged composite structure
2. Lightly abrade the composite surface exposing ½” of the existing conductive protective layer
3. Mix conductive coating according to the manufactures instructions and allow to sit for 30 minutes
4. Apply conductive coating to the repair area and allow to flash for 15 minutes
5. Apply radiant heat ARP 5144 (Para 7.2) to the conductive coating for 1 hour at 125 degrees F.
6. Obtain a digital multimeter and place the test leads with ½” separation onto the conductive coating
7. Measure the resistance of the coating. 50,000 ohms is the maximum resistance
8. Apply a paint compatible primer and dry
9. Apply finish top-coat to match existing paint scheme

E. General Protection:

Composite structures that do not require electrical conductivity will require protection some sort of environmental protection. Typical structures will use a primer with a finish paint scheme.

1. Light scuff composite structure to remove any surface gloss
2. Apply a paint compatible primer and dry
3. Apply finish top-coat to match the existing paint scheme
POST REPAIR CONSIDERATIONS (51-90-00)

Composite structures subjected to repairs may suffer from damages due to undetected moisture, contamination, heat induced disbonding or delaminations, impact damage, fiber breakage and technician skill level. A thorough post repair inspection should be conducted before the structure is returned to service.

A. Non-Destructive Testing
   1. Perform a tap test or pulse-echo inspection 51-10-01
   2. Record any area of disbond or delamination
   3. Repair any areas that are unserviceable

B. Surface waviness
   1. Excessive deviation may be caused by incorrect scarfing, gouging and core sanding
   2. Composite structures located in Reduced Vertical Separation Minimum (RVSM) areas may require additional rework to produce a smooth surface.
   3. Apply an aerodynamic smoothing compound when the deviation is more than .1” as measured with a straight edge or when cosmetic appearance is required.

C. Surface resin content
   1. Check for resin rich areas
      a. Problem areas caused by insufficient vacuum pressure (bridging) and insufficient bleeder schedules
      b. Acceptable condition provided the area does not contain trapped air pockets
      c. Sanding to remove the excess resin area(s) is acceptable. Use care not to damage the substrate
   2. Check for resin starved areas
      a. Areas that appear dry may be due to excessive bleeding, high ramp rates, and insufficient application of resin to the repair area
      b. Seal resin starved area with LR-03 or LR-04 and cure
      c. Refinish as necessary

D. Documentation completion
   1. Review the repair instructions
   2. Submit the cure cycle information (if applicable)
   3. Sign repair documentation and submit
TYPICAL HONEYCOMB PANEL STRUCTURE (51-100-00)

FIGURE 1 TYPICAL HONEYCOMB PANEL IDENTIFICATION
<table>
<thead>
<tr>
<th>PLY NUMBER</th>
<th>MATERIAL</th>
<th>PLY ORIENTATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>AF-01</td>
<td>0-90</td>
</tr>
<tr>
<td>P2, P7</td>
<td>CF-03</td>
<td>0-90</td>
</tr>
<tr>
<td>P3, P6</td>
<td>CF-03</td>
<td>± 45</td>
</tr>
<tr>
<td>P4, P5 doublers</td>
<td>CF-03</td>
<td>0-90</td>
</tr>
<tr>
<td>P8</td>
<td>GF-01</td>
<td>0-90</td>
</tr>
<tr>
<td>Adhesive Film</td>
<td>FA-02</td>
<td></td>
</tr>
<tr>
<td>Core Material</td>
<td>HC-01</td>
<td></td>
</tr>
</tbody>
</table>

**TABLE 1 HONEYCOMB STRUCTURE IDENTIFICATION**

Notes:

GF-01 is an acceptable alternate for AF-01 material

HC-01 core material thickness and density can be substituted based on availability
Table 101/102 provides acceptable damage limits and recommended action for minor damage. Damage exceeding these limits must be repaired. The allowables are classified by the location on the part.

<table>
<thead>
<tr>
<th>Damage</th>
<th>Allowables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scratches</td>
<td>2” length with no damage to the fiber substrate</td>
</tr>
<tr>
<td>Gouges</td>
<td>1” length / .100 width. / 10% depth edgeband area only Apply LR-03 and 1 ply GF-01</td>
</tr>
<tr>
<td>Nicks</td>
<td>.100 depth to edgeband area only. Blend to remove damaged area</td>
</tr>
<tr>
<td>Dents</td>
<td>Not allowed</td>
</tr>
<tr>
<td>Edge Erosion</td>
<td>10% of edgeband thickness / 5” length</td>
</tr>
<tr>
<td>Paint Deterioration</td>
<td>5% of the total surface area</td>
</tr>
</tbody>
</table>

**TABLE 101 SOLID LAMINATE / EDGE BAND AREAS**

<table>
<thead>
<tr>
<th>Damage</th>
<th>Allowables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scratches</td>
<td>2” length with no damage to the fiber substrate</td>
</tr>
<tr>
<td>Gouges</td>
<td>1” length / .100 width Not allowed if the substrate is damaged</td>
</tr>
<tr>
<td>Nicks</td>
<td>.25 length with no damage to the substrate</td>
</tr>
<tr>
<td>Dents</td>
<td>1” diameter / .100 depth max with no detected delamination No more than 1 dent per core detail area</td>
</tr>
<tr>
<td>Paint Deterioration</td>
<td>5% of the total surface area</td>
</tr>
</tbody>
</table>

**TABLE 102 CORE DETAIL (FIELD) AREAS**
## Repair To Typical Honeycomb Panel Structure

<table>
<thead>
<tr>
<th>Damage Type</th>
<th>Category “C” Repair</th>
<th>Category “B” Repair</th>
<th>Category “A” Repair</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hole</td>
<td>2” dia max</td>
<td>150°F.</td>
<td>200°F.</td>
</tr>
<tr>
<td></td>
<td>Repair with speed tape ref. ARP 4916 Para 11.1</td>
<td>2” dia max</td>
<td></td>
</tr>
<tr>
<td>Crack</td>
<td>1” length max.</td>
<td>2” length max</td>
<td>No size restriction</td>
</tr>
<tr>
<td></td>
<td>damage located to the core detail area only</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Repair with speed tape ref. ARP 4916 Para 11.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Delamination</td>
<td>1” dia max over the core detail area only.</td>
<td>4” max damage size</td>
<td>8” max damage size</td>
</tr>
<tr>
<td></td>
<td>Inject delamination using LR-03 resin ref. ARP 4991 Para 5.1.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gouges / Nicks</td>
<td>1” length with damage to no more than two plies</td>
<td>2” length max</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Repair with speed tape ref. ARP 4916 Para 11.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dents</td>
<td>2” dia max</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**TABLE 201 HONEYCOMB STRUCTURE REPAIR LIMITS**

1. Repair Procedure 51-70-01 using LR-03 or LR-04 resin systems
2. Repair Procedure 51-70-01 using LR-01 or LR-02 resin systems
3. Repair Procedure 51-70-05 Tooling may be required to prevent panel distortion. Use one extra ply per side of the repair.
4. 50% of the core detail area may be repaired or the max repair size whichever limit is the most restrictive. Two extra repair plies are required. If damage penetrates both sides of the panel, apply two extra plies for each side of the repair. Distribute the extra plies as follows: Hybrid panels with carbon fibers get both extra plies. Fiber orientation is the same as the original ply. Allow ½” overlap per repair ply.
TYPICAL CARBON MONOLITHIC STRUCTURE (51-120-00)

Critical Area

A-A

P12
P11
P10
P9
P8
P7
P6
P5
P4
P3
P2
P1

TOOLSIDE

FIGURE 1 CARBON MONOLITHIC STRUCTURE IDENTIFICATION
<table>
<thead>
<tr>
<th>PLY NUMBER</th>
<th>MATERIAL</th>
<th>PLY ORIENTATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1, P12, P5, P8</td>
<td>CF-03</td>
<td>0</td>
</tr>
<tr>
<td>P2, P11, P6, P7</td>
<td>CF-03</td>
<td>+45</td>
</tr>
<tr>
<td>P3, P10</td>
<td>CF-03</td>
<td>90</td>
</tr>
<tr>
<td>P4, P9</td>
<td>CF-03</td>
<td>-45</td>
</tr>
</tbody>
</table>

TABLE 1 CARBON MONOLITHIC STRUCTURE IDENTIFICATION
Table 101 provides acceptable damage limits and recommended action for minor damage. Damage exceeding these limits must be repaired.

<table>
<thead>
<tr>
<th>Damage</th>
<th>Allowables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scratches</td>
<td>2” length with no damage to the fiber substrate</td>
</tr>
<tr>
<td>Gouges</td>
<td>.25 length / .100 width / .010 depth Apply LR-03 and 1 ply CF-01</td>
</tr>
<tr>
<td>Nicks</td>
<td>Not allowed</td>
</tr>
<tr>
<td>Dents</td>
<td>Not allowed</td>
</tr>
<tr>
<td>Edge Erosion</td>
<td>5% of edgeband thickness / 5” length</td>
</tr>
<tr>
<td>Paint Deterioration</td>
<td>5% of the total surface area</td>
</tr>
</tbody>
</table>

TABLE 101 CARBON MONOLITHIC STRUCTURE ALLOWABLES
## Repair To Carbon Monolithic Structure

<table>
<thead>
<tr>
<th>Damage Type</th>
<th>Category “C” Repair</th>
<th>Category “B” Repair</th>
<th>Category “A” Repair</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hole</td>
<td>Not Authorized</td>
<td>200°F. <img src="#" alt="1" /></td>
<td>250°F. <img src="#" alt="2" /> <img src="#" alt="3" /> Bolted Repair <img src="#" alt="4" /></td>
</tr>
<tr>
<td>Crack</td>
<td>Not Authorized</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Delamination</td>
<td>Not Authorized</td>
<td></td>
<td>½” dia max and no more than 6 plies in-depth</td>
</tr>
<tr>
<td>Gouges / Nicks</td>
<td>1” length / .020 max depth</td>
<td>blend out damage to produce a smooth surface</td>
<td>2 sq in max</td>
</tr>
<tr>
<td>Dents</td>
<td>Not Authorized</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Critical Areas</td>
<td>Not Authorized</td>
<td>Contact the OEM for repair disposition</td>
<td></td>
</tr>
</tbody>
</table>

**TABLE 201 CARBON MONOLITHIC STRUCTURE REPAIR LIMITS**

1. Repair Procedure 51-70-01 using LR-01 or LR-02 resin systems. Use two extra plies
2. Repair Procedure 51-70-05 Tooling may be required to prevent panel distortion. Use one extra ply per side of the repair
3. Fiber orientation is the same as the original ply. Taper sand at a 30 : 1 ratio per repair ply
4. Repair Procedure 51-70-10