



AEROSPACE RECOMMENDED PRACTICE

ARP4977™

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Drying of Thermosetting Composite Materials

RATIONALE

This document has been reaffirmed to comply with the SAE 5-year Review policy.

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1. SCOPE:

This SAE Aerospace Recommended Practice (ARP) describes standard methods for drying commercial aircraft composite structures prior to repair and gives general guidelines on use and applicability.

It addresses the removal of liquids that have collected inside the structures through open damage, microcracks, or porosity and the removal of absorbed moisture from the composite material. The methods described in this document shall only be used when specified in an approved repair document or with the agreement of the original equipment manufacturer (OEM) or regulatory authority. If this document is used for the drying of materials other than thermosetting composite materials, the fitness for this purpose must be determined by the user.

1.1 Purpose:

The purpose of this document is to provide a set of standard drying methods that may be referenced in repair documents produced by airlines or airframe and engine manufacturers. It is intended that this document be one of a number of ARPs that will cover other aspects of the techniques required to perform composite repairs. This will provide a suite of available repair techniques that are acceptable for use throughout the commercial aircraft industry.

2. REFERENCES:

2.1 Applicable Documents:

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

2.1.1 SAE Publications: Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

AIR4844	Composites and Metal Bonding Glossary
ARP4916	Masking and Cleaning of Epoxy and Polyester Matrix Thermosetting Composite Materials
ARP5143 DRAFT	Bagging Procedures for the Local Repair of Thermosetting Composite Materials
ARP5144 DRAFT	Heat Application for the Local Repair of Thermosetting Composite Materials

2.2 Applicable References:

Original Equipment Manufacturers (OEM) Manuals

3. GENERAL:

In this document reference is made to visible liquids and absorbed moisture.

Visible Liquids: Visible liquids are split into two categories.

3. (Continued):

Liquids that dry in open air or under heat, leaving no residue or residue that can be easily wiped away and cleaned using the standard methods described in ARP4916. Water and solvents are the most commonly found types.

Liquids that do not dry with standard methods but leave a residue or some remaining liquid that standard cleaning methods will not remove. The most common types are skydrol, jet fuel, and toilet servicing fluid (blue water).

Either category of liquid may result in a degradation of the composite structure.

Absorbed Moisture: Composite structures tend to saturate with moisture. The moisture level, if too high, could be detrimental to the quality of a bonded repair. Drying should be performed in areas that will be in contact with the repair bondline, including repair parts and materials (honeycomb replacement pieces may be dried prior to using when absorbed moisture is a concern).

Some types of composites can also absorb solvents used in solvent cleaning (Aramid reinforced laminates and honeycomb absorb more solvent). The method of absorbed moisture removal (refer to 4.2) may also be used to ensure that solvent has completely evaporated in a shorter time. Bonding prior to complete solvent evaporation can cause low bond strength.

Drying a composite structure will in general consist of:

- a. Removing visible liquids.
- b. Cleaning (when liquid is other than water) and removing any permanently contaminated area.
- c. Drying to obtain a visually dry structure before proceeding with the repair area preparation.
- d. Performing the final drying before bonding.

3.1 Visible Liquid:

- 3.1.1 General: Liquid can collect on structures or inside through existing openings or damaged areas. It can generally be removed by mopping, vacuuming, or by blowing with compressed air (when it is water).

Liquid can also be found inside sandwich panels as the result of skin damage, delamination, debonding, skin microcracks, skin porosity, or a combination of these cases.

Visible liquid in honeycomb panels can cause damage due to freezing (water), to galvanic corrosion of aluminum honeycomb, or to a possible reduction of the structural strength characteristics if left for a long period of time. There is also a risk of having steam pressure build up during a hot bond repair causing delamination or debonding.

Unlike water, other fluids may deteriorate not only the honeycomb and honeycomb/skin bond line, but also the skins. Degradation should be suspected when the substrate shows discoloration.

3.1.1 (Continued):

Removal of liquid from honeycomb panels will usually require the cutting of one skin to obtain access. Contaminated areas that cannot be cleaned (refer to ARP4916) will also have to be cut away.

When the honeycomb or honeycomb/skin bond line is suspected to be degraded the honeycomb should be replaced. Replacement may be considered in all cases to speed up the repair process.

Before proceeding with the repair area preparation the structure must be clean and visually dry.

3.1.2 Detection: Liquid can be detected visually on or inside structures and in open damage.

The presence of liquid inside honeycomb panels must be suspected when debonding is found or when the surface is in a poor condition (paint deterioration and/or erosion) or shows signs of porosity. A discoloration of the composite is usually the indication of a contamination.

Nondestructive Testing Inspection (NDI) methods such as thermography, ultrasonic checks, or X-rays can confirm the presence of trapped liquid. On glass or aramid structures, moisture meters can also be used.

OEM's Nondestructive Testing Manuals (NTM) must be consulted for details of the various methods and their applicability.

3.1.3 Removal Methods: Depending on the type of fluid and on the location and time available, various methods may be used.

Mopping, vacuuming, blowing compressed air, and vacuum bagging the affected area are possible methods for water removal (refer to 4.1 for details of the various methods). Mopping and vacuuming are also commonly used for the removal of liquids other than water. A thorough cleaning should follow (refer to ARP4916). Should cleaning prove unsuccessful, the contaminated area shall be removed.

3.1.4 Drying Time: The criteria are to have a clean and visually dry structure. The time required will depend on the method used.

3.1.5 Control Methods: A visual check will generally show if all the liquid has been removed. On honeycomb panels, standard nondestructive methods can be used to confirm removal (refer to 3.1.2). If in doubt, additional cells can be cut open. With liquids other than water, once the area is visually clean, local heating (not exceeding 176 °F (80 °C)) could help reveal more absorbed fluid due to the tendency of fluid to seep to the skin surface during heating. A water break test (refer to ARP4916 - Water Break Test Method) will confirm the cleanliness of the structure.

3.2 Absorbed Moisture:

- 3.2.1 General: Composites, as a result of their chemical structure, will absorb moisture when in contact with humid air. The absorption can reach a maximum value (saturation) that depends on the resin system and fiber reinforcement used (carbon, aramid, or glass), on the temperature and on the humidity of the surrounding air. Saturation values can range from 1 to 3% by weight). Nonmetallic honeycomb will generally reach saturation at a higher value (up to 5% for Nomex honeycomb). This moisture saturation combined with a hot environment (hot/wet condition) is one of the most adverse condition met by a structure. It is taken into account at the aircraft design stage and in the testing of the main components.

The effect of moisture during a repair will depend mainly on the curing time and temperature and to a lesser extent on the repair and parent materials. The strength characteristics of the bond line and the repair patch quality could be affected.

Experience has shown that, for repair purposes, complete drying of a composite structure is not necessary. A dry surface will in general be sufficient provided it remains dry for the complete cure cycle. Moisture migration back to the surface during the cure cycle should be taken into account to determine the drying time and temperature. One way of ensuring a dry surface is to carry out a final drying cycle (after the laminate appears dry) at the temperature of the cure for the time of the cure (refer in all cases to OEM's recommendations).

Because only the surface of the laminate will be dried, the drying must take place after all stepping, scarfing, or other material removal steps have been completed.

The repair should be accomplished as soon as possible after drying because the moisture in the laminate will return to the surface at room temperature over a period of time.

Figures 1 and 2 are given to illustrate the length of time typical laminates take to absorb moisture and the time to completely remove all absorbed moisture. These figures are given for information and education only and should not be used to determine drying cycle time and temperature. The slow migration of moisture explains why surface drying is used and shows the importance of drying after material removal.

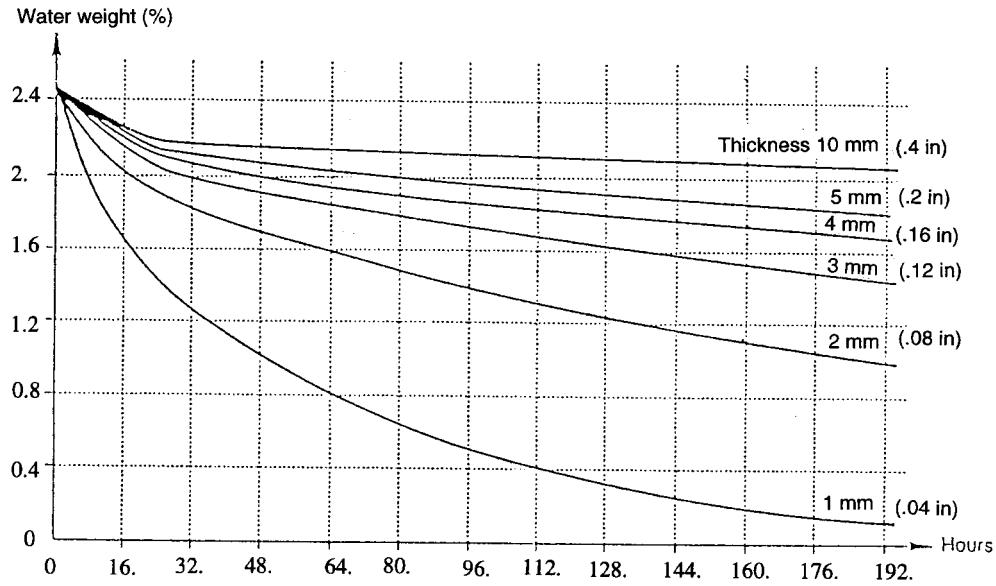
Figure 1 shows the average moisture content plotted against drying time of a composite laminate first saturated with moisture and then dried. The curves represent laminates of different thicknesses. Graphs for two different drying temperatures are shown.

Figure 2 shows a graphical representation of the percentage saturation across a laminate thickness at different time.

Figure 2B represents the values for a skin initially dry and exposed to humid atmosphere from one side.

Figure 2C represents the values for a skin initially saturated and then dried.

TYPICAL DRYING CURVE: CARBON EPOXY MONOLITHIC LAMINATE
70 °C (158 °F) Drying Temperature



TYPICAL DRYING CURVE: CARBON EPOXY MONOLITHIC LAMINATE
90 °C (194 °F) Drying Temperature

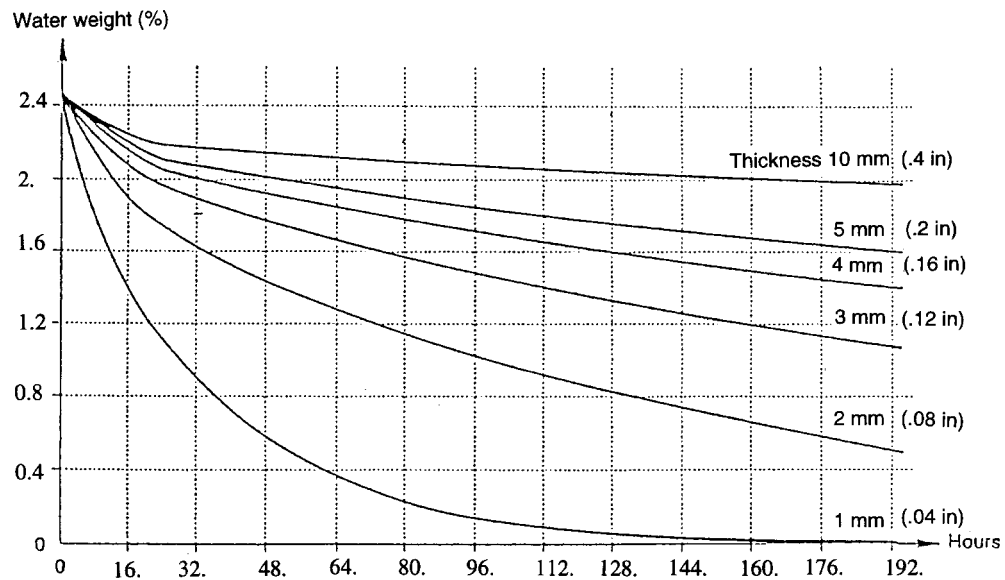


FIGURE 1 - Moisture Content of Typical Laminates
(Average Moisture Through the Thickness)