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**WEATHERING EFFECTS ON SELECTED AIRCRAFT
FABRIC COVERING PROCESSES**

Daryl Hammond

This paper examines the effects of accelerated weathering on samples of aircraft covering prepared using the Grade-A cotton with Randolph dope, Ceconite with Randolph dope, Cooper Superflite II, Air-Tech Coatings, and Stits Poly-Fiber processes. The results indicate that although Air-Tech and Superflite processes were the heaviest, both maintained excellent gloss retention over the accelerated weathering cycle. Ceconite with Randolph dope was the least stable in yellowing degradation while Stits was the best performer. Strength degradation was most pronounced in the Superflite process. Thermal stress testing showed all processes exhibited heat and flame resistance loss due to weathering.

BACKGROUND

Most of the large and small aircraft in production today consist of an all-metal design manufactured with lightweight aluminum alloys and steel. An all-metal construction provides strength, durability, and excellent resistance to weathering. However, there are still small aircraft in service today that have a fabric material covering the wings, control surfaces, and fuselage. Fabric aircraft covering is strong and lightweight, but is much less tolerant to the environmental factors of heat, cold, moisture, and sunlight.

Because the deterioration of fabric aircraft covering can have catastrophic consequences if failure occurs in flight, the materials, workmanship, and inspection of fabric used to cover aircraft must be in strict compliance with Federal Aviation Administration (FAA) standards. There are several FAA approved aircraft covering processes that use organic high-grade cotton or synthetic polyester fabrics (U.S. Department of Transportation, 1988). Each process claims to offer the best quality, strength, and resistance to environmental deterioration.

A major problem for aircraft manufacturing companies and maintenance personnel is choosing the fabric and covering method that is not only cost effective in terms of labor and material, but also provides the least weight and degradation over the service life of the aircraft.

Relative effectiveness to reduce weathering degradation was evaluated for aircraft fabric covering prepared using the Grade-A cotton with Randolph dope (Randolph Products, 1996), Ceconite with Randolph dope (Procedure Manual #101), Air-Tech Coatings (Air-Tech, 1997), Cooper Superflite II (Manual D-102A, 1995), and Stits

Poly-Fiber (Goldenbaum, 1997) processes (Hammond, 1999).

**PERFORMANCE TESTS ON WEATHERED
SAMPLES**

After initial design properties of thickness (in.) and weight (per sq. ft.) for each fabric covering process were measured, the performance tests of gloss retention, yellowing, low temperature flexibility, breaking strength, and thermal stress resistance were performed on samples of weathered fabric.

METHOD OF ACCELERATED WEATHERING

The accelerated weathering exposure tests were made using a Fluorescent UV-Condensation Exposure apparatus manufactured under the trade name QUV. The QUV tester and operation support for this research was provided by the University of Missouri – Rolla's Coating Institute, which operates under the direction of Dr. Michael Van De Mark (Hammond, 1999). The QUV tester was programmed to regulate weathering in an operation cycle of 8 hours: four hours of concentrated UV exposure followed by a 4-hour water condensation. Weathered process samples were removed at 400-hour exposure intervals with the final set accumulating 2000 hours of exposure.

DESIGN PROPERTIES

Thickness. The average thickness of each process sample was measured using a digital micrometer. The results are graphically shown in Figure 1 and indicate that Superflite was the thickest at 0.0185" while Stits was the thinnest at 0.0110". Statistically, both were approximately one standard deviation, 0.0027", from the mean value of 0.0145", which indicates about 20% variance from the average.

Weathering Effects on Selected Aircraft Fabric

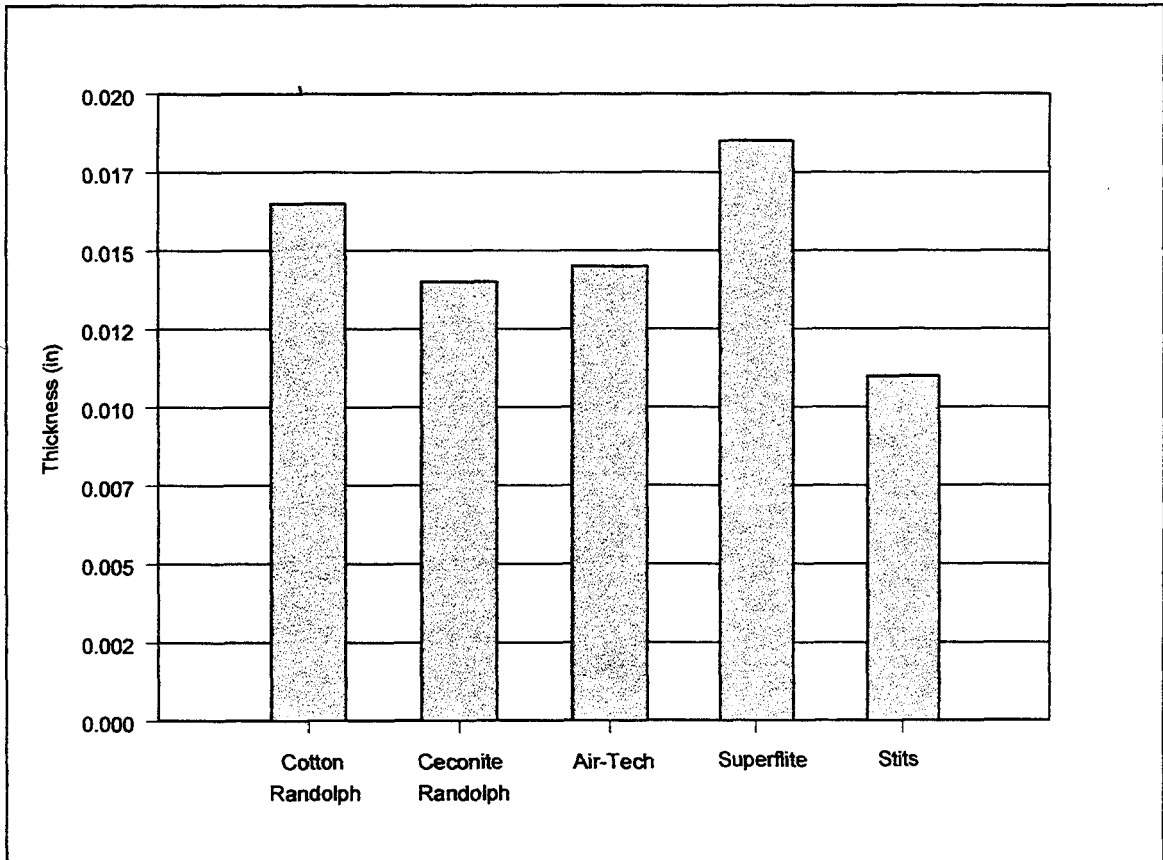


Figure 1. Average Thickness of Process Samples

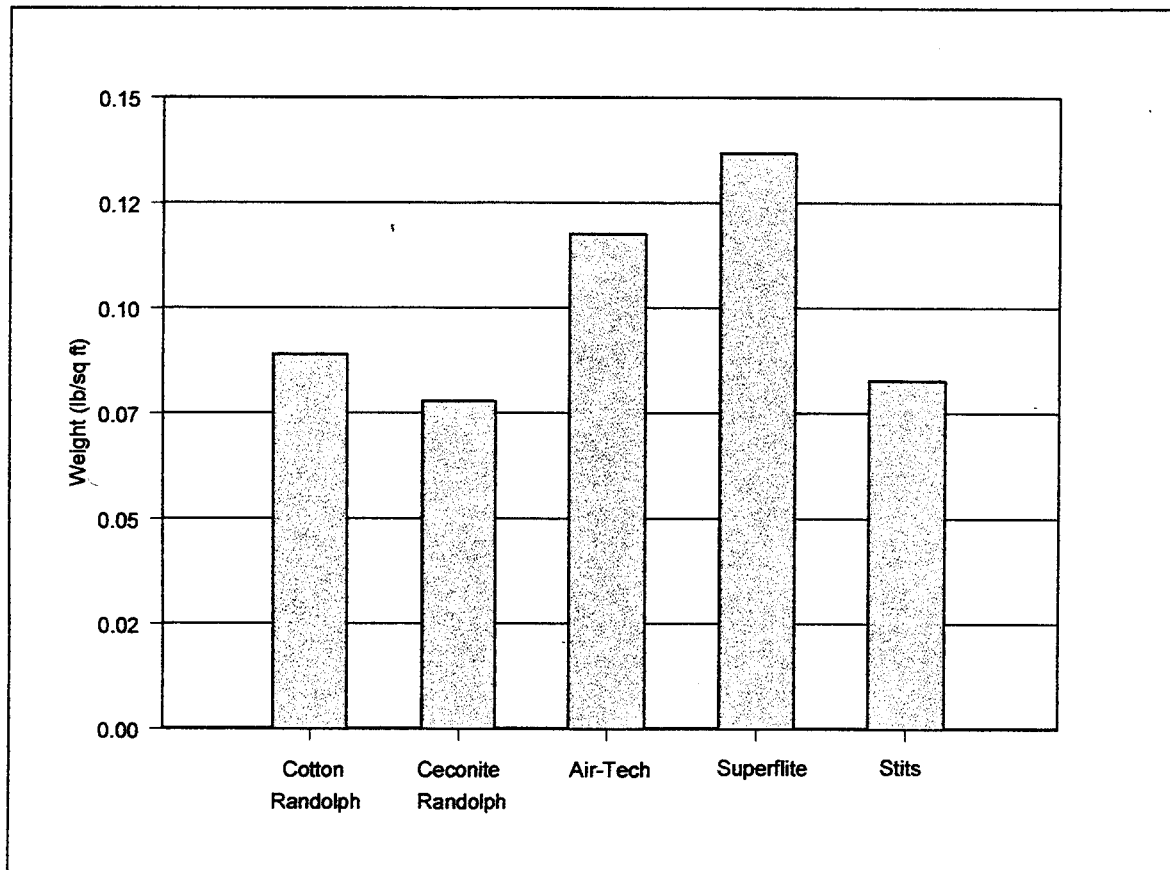


Figure 2. Average Weight of Process Samples

Weight. The weight of each process sample was measured using a precision balance scale. The results are graphically shown in Figure 2 and indicate that the Ceconite with Randolph dope was the lightest at 0.0778 lb/ft², while Superflite was the heaviest at 0.1367 lb/ft². The statistical mean of all samples was 0.0977 lb/ft² with a standard deviation of 0.0238 lb/ft².

PERFORMANCE TEST RESULTS

Gloss Test. A 60°-glossmeter was used to measure the gloss reading on each process sample throughout the QUV weathering cycle. The 60°-glossmeter measurement results are graphically shown in Figure 3 and indicate that Superflite samples maintained the highest gloss retention, while the Randolph coatings on the Grade-A cotton and Ceconite fabric performed most poorly over the weathering cycle.

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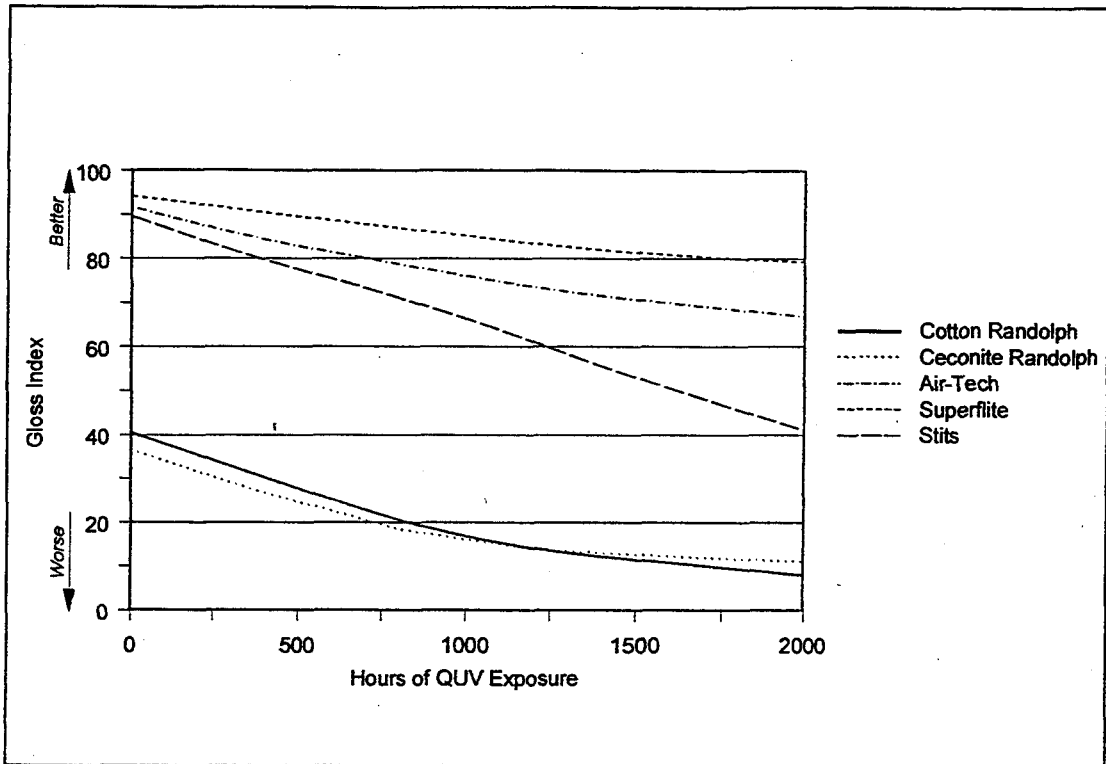


Figure 3. Gloss Index – Weathered Process Samples

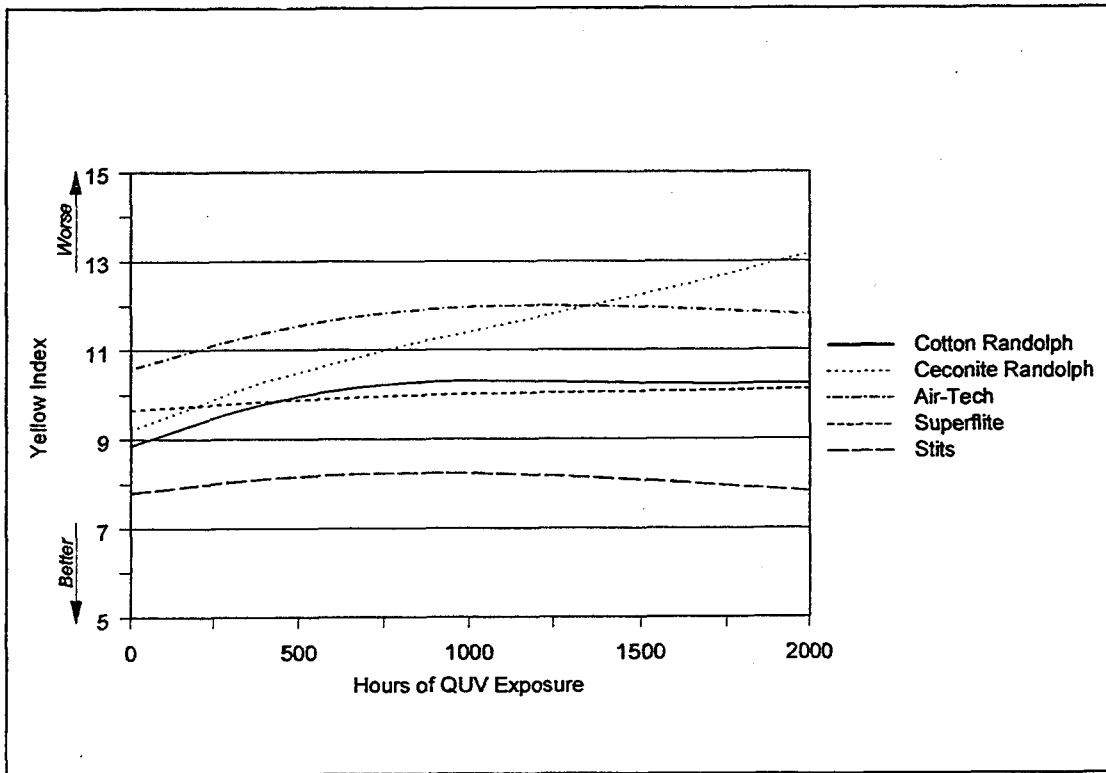


Figure 4. Yellowing Index – Weathered Process Samples

Yellowing Test. A spectrophotometer was used to measure the surface yellowing on each process sample throughout the QUV weathering cycle. The spectrophotometer measurement results are graphically shown in Figure 4 and indicate a general increase in yellowing for all processes through 400 hours of weathering. There is also an indication of yellowing decreasing for all the polyurethane process samples toward the end of the exposure period. Furthermore, Stits maintained the lowest Yellowing Index throughout the weathering cycle.

Low Temperature Bend Test. A Low Temperature Bend Test was accomplished on each weathered process sample using the guidelines outlined in ASTM D2136-94, Standard Test Method for Coated Fabrics—Low Temperature Bend Test. This pass or fail test evaluates the stiffening properties of material when exposed to low

ambient temperatures. The coating sample is cooled and conditioned at a temperature of -40°F then removed from the cooling chamber and immediately bent around a 5/16" mandrel. The coating passes the test if no cracks are detected under a 5x-power magnification. The results of the test are summarized in Table 1 and indicate there are significant differences in low temperature flexibility among the sample coatings. The Cotton with Randolph dope performed the best with no failures at each weathering interval. Ceconite with Randolph dope passed through 800 hours of QUV weathering. Superflite was the only polyurethane based coating process that passed any of the weathering intervals; this was at the initial and 400 hour exposure times.

Table 1. Low Temperature Bend Test – Weathered Process Data

QUV Hours	Cotton Randolph	Ceconite Randolph	Air-Tech	Superflite	Stits
0	PASS	PASS	FAIL	PASS	FAIL
400	PASS	PASS	FAIL	PASS	FAIL
800	PASS	PASS	FAIL	FAIL	FAIL
1200	PASS	FAIL	FAIL	FAIL	FAIL
1600	PASS	FAIL	FAIL	FAIL	FAIL
2000	PASS	FAIL	FAIL	FAIL	FAIL

Breaking Strength Test. A Breaking Strength Test was accomplished on each weathered sample using the guidelines outlined in ASTM D5035-95, Standard Test Method for Breaking Force and Elongation of Textile Fabrics (Strip Method) and U.S. Department of Transportation (1976) AC65-15A. The force needed to tear the material for each weathered process sample are

graphically shown in Figure 5 and indicate a general decrease in breaking strength throughout the QUV testing cycle. Superflite had the most rapid deterioration. The most consistent process sample was Stits with the highest average mean of 170 lb., starting out at 175 lb. and then decreasing to 155 lb.

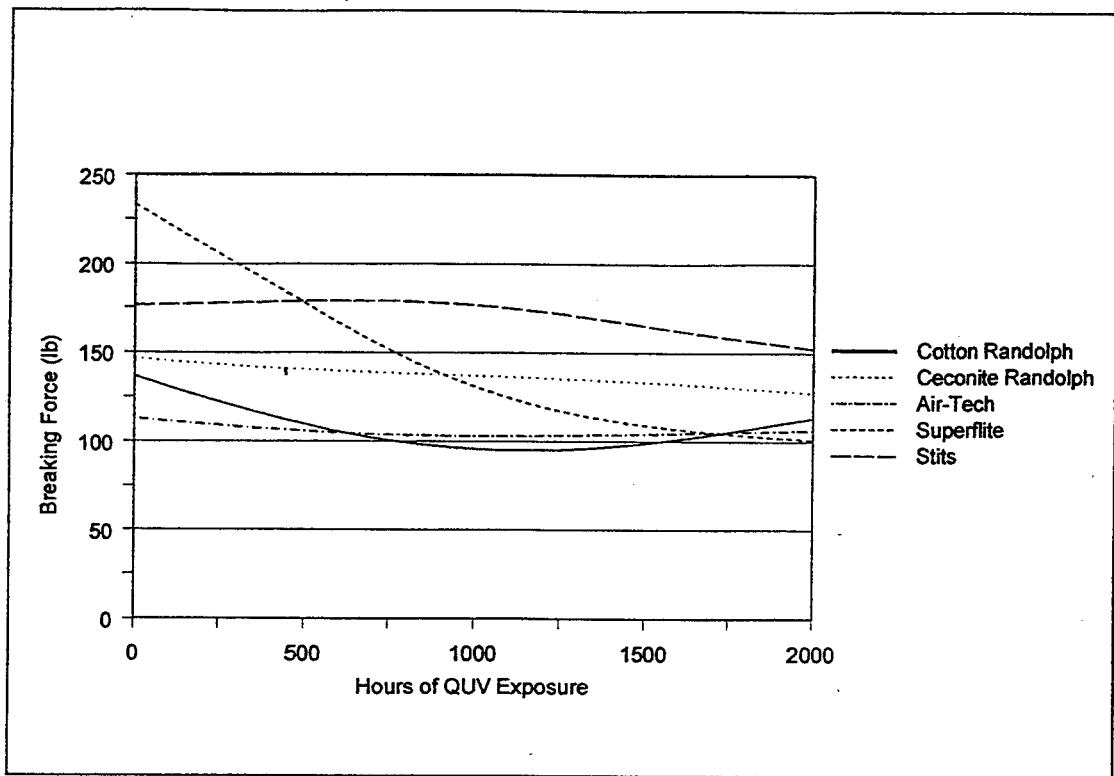
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Figure 5. Breaking Strength (lb.) – Weathered Process Samples

Thermal Stress Test. A Thermal Stress Test was accomplished for each weathered process sample using guidance provided in ASTM E162-94, Standard Test Method for Surface Flammability of material using a Radiant Heat Energy Source. The test used in this research provides a means to determine the thermal stress resistance of a coated sample by recording the elapsed time to burn through the material under a 0.5 lb. tension when exposed

to $1,250^{\circ}\text{F} \pm 50^{\circ}$ at the base fabric surface. The time to ignite and burn through a 2" x 1" section of material are graphically shown in Figure 6 and indicate a general reduction in thermal stress resistance throughout the 2000 hours of QUV testing. The Ceconite with Randolph dope had the fastest breaking time while Cotton with Randolph dope had the slowest breaking time

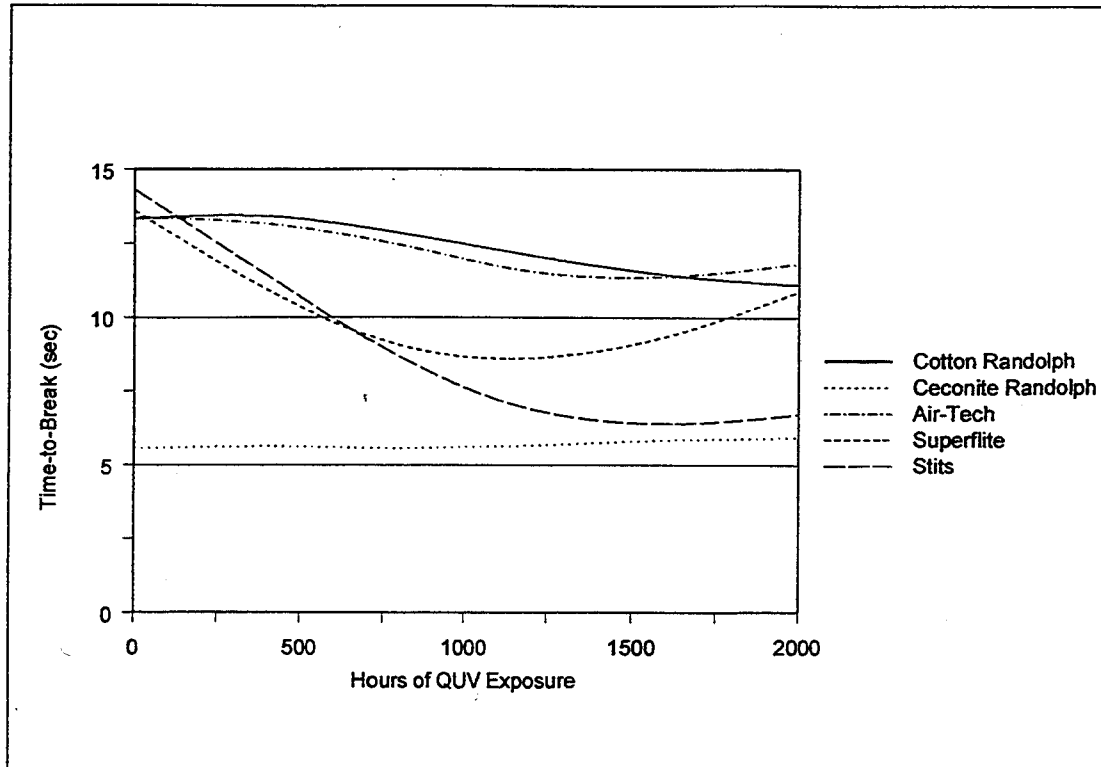


Figure 6. Thermal Stress Time-to-Break (sec.) – Weathered Process Samples

SUMMARY

Design Properties. A comparison of the weight in pounds per square foot (lb/ft²) of the process samples showed that the Air-Tech and Superflite processes add respectively about 20% and 40%, more weight per square foot than the process average. This increase in weight can be attributed to the application of the thick consistency and high solids polyurethane finish used in these processes. For a typical small airplane such as the Piper J-3 Cub, a 40% increase in aircraft fabric weight reduces the useful load approximately 5%.

Performance Properties. The investigation of the gloss retention characteristics of the process samples showed that Superflite and Air-Tech had excellent gloss retention over the complete weathering cycle. This is a result of the polyurethane topcoats, which are extremely durable. Although Stits is polyurethane based, it does not contain high solids that contribute to long term durability like those contained in the Air-Tech and Superflite processes. The gloss retention ability of Randolph dope was not affected by Cotton or Ceconite base fabrics and rapidly lost its gloss

after 400 hours of QUV exposure. All of the processes except Ceconite with Randolph dope were stable in yellowing degradation. Ceconite with Randolph Dope yellowed at a high rate after 800 hours of QUV weathering and ended with the highest Yellowing Index. It appears that Ceconite with Randolph dope is a poor combination for weather related degradation factors. Stits was the most stable with a slight increase in yellowing between 400 and 800 hours of QUV weathering. The vinyl coatings and top coat combinations appear to be effective in reducing yellowing degradation.

The Breaking Strength Test is the first of the two most important tests conducted on the process samples due to the fact that integrity, stability, and safety of the fabric covering the airframe are extremely important. The rapid strength deterioration of Superflite over the 2000 hours of QUV exposure indicates a problem with adequate UV protection because that is the single biggest factor in polyester deterioration. Although the other process lost some strength over the weathering cycle, they exhibited no inconsistent or unusual behavior.

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The Thermal Stress Test is the second most important test conducted on the process samples due to safety of flight issues. Clearly, all processes lost their thermal stress resistance over the weathering cycle. Ceconite with Randolph dope was a volatile combination, which accounts for its lower time-to-break data curve. Even though the Stits process indicated a decrease in thermal resistance over the QUV weathering cycle, Air-Tech and Stits prepared samples resisted sustained burning after ignition. Superflite had improved thermal stress performance towards the end of the weathering cycle, but its burn characteristics

included emission of thick black acrid smoke, which was significantly different behavior than the other samples.

CONCLUDING COMMENT

It was the intent of this research effort to provide baseline information to the aviation community on the weathering characteristics of various aircraft fabric-covering processes. This study has investigated only a few of the properties that are of interest, but having this solid and unbiased information will ensure sound decisions are made regarding the selection of a covering method that will offer the best performance over the lifetime of the aircraft.□

Daryl Hammond received a Bachelor of Science degree in Electrical and Electronic Engineering from California State University- Sacramento, a Master of Science degree in Electrical Engineering from the Air Force Institute of Technology, and a Doctor of Education degree in Aviation and Space Education from Oklahoma State University. Dr. Hammond is employed as a Human Factors Engineer in the Aural Displays and Bioacoustics Branch of the Air Force Research Laboratory located at Wright-Patterson AFB, OH. He is registered as a Professional Engineer in California, Ohio, and Oklahoma, and is licensed as an Airframe and Powerplant mechanic with Inspection Authorization privileges. He also holds a commercial pilot's certificate with flight instructor ratings for instrument, single, and multi-engine airplane.

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