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Corrosion of Aluminum Alloys in the Presence of Fire-Retardant Aircraft Interior Materials

October 1995

Final Report

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16. Abstract

This research project was to evaluate the potential for fire-retardant materials used in aircraft interiors to cause corrosion of aluminum structural alloys. Service Difficulty Reports (SDR's) were reviewed for several aircraft types, and the most frequent locations for corrosion were identified as fuselage, windows, and frames.

Laboratory experiments were designed and conducted for corrosion testing of common aircraft structural alloys (Al 2024-T3 and Al 7075-T6) in the presence of Ultrasuede, Glenlivit, and Highland Wool, common interior materials. Accelerated corrosion test results showed that, for most test conditions, corrosion was increased for all three fire-retardant materials compared to baseline tests without fire retardants. Chemical composition from EDAX studies of the fire-retardants revealed substantial halogens in Ultrasuede and Glenlivit, but negligible halogens in Highland Wool. Thus, the corrosion results cannot be attributed solely to halogens. Sulfur, which is present in substantial amounts in both Glenlivit and Highland Wool, could be another cause for corrosion observed with these materials.

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EXECUTIVE SUMMARY

This research project was to evaluate the potential for fire-retardant materials used in aircraft interiors to cause corrosion of aluminum structural alloys. This work was initiated based on evidence of some corrosion problems in general aviation, small business jets, and commuter aircraft in areas near fire-retardant interior fabrics. Service Difficulty Reports (SDR) data were studied to measure the magnitude of the problem. Corrosion incidences were reviewed for several aircraft types, and the most frequent locations for corrosion were identified as fuselage, windows, and frames.

Laboratory experiments were designed and conducted for corrosion testing of common aircraft structural alloys (Al 2024-T3 and Al 7075-T6) in the presence of aircraft interior materials. Tests were conducted for Ultrasuede, Glenlivit, and Highland Wool, common interior materials. Accelerated corrosion test conditions included ambient and high temperatures and high-humidity conditions. Control specimens of the aluminum alloys were tested as a baseline without exposure to the fire retardants. Results show that, for most test conditions, corrosion was increased for all three fire-retardant materials compared to the baseline tests without fire retardants. Chemical composition from EDAX studies of the fire-retardants revealed substantial halogens in Ultrasuede and Glenlivit, but negligible halogens in Highland Wool. Thus the corrosion results cannot be attributed solely to halogens. Sulfur, which is present in substantial amounts in both Glenlivit and Highland Wool, could be another cause for corrosion observed with these materials.

1. INTRODUCTION.

The purpose of this research was to investigate the potentially corrosive behavior of upholstery, floor, and wall covering material, currently used in the interiors of general aviation and commuter aircraft. Halogen salts have commonly been used to provide such materials a level of fire retardancy. Federal Aviation Regulations (FAR) 23.853 and 25 853 established the requirement for fire retardancy of seat cushions, and Advisory Circular AC 25.853-1 also addresses their flammability requirements. However, service difficulty reports indicate that the fire-retardant products which are currently being used might be responsible for severe corrosion in aircraft interiors [1,2,3].

General corrosion and corrosion due to fire retardants in particular are a strong function of environment. Alert No. 161, 1991[4], states:

"Reports continue to be received concerning rapidly induced corrosion possible from various flame-retardant fabrics used in aircraft interiors. The latest reports involve a Jetstream 3101 and the Gulfstream Commander 900, both of which had Ultrasuede 357 installed in the cabin interior. Extensive corrosion was found on panels and stringers where the material had been attached. Reports have been received on a wide range of aircraft, including amateur-built, with corrosion caused by the salts (usually bromide or chloride salts) which are used to increase the flame retardancy of materials.

Fabrics which have been treated with any of the above salts can be extremely corrosive when exposed to moisture of any nature. Corrosion occurs very rapidly and is difficult to detect without removing the material. In general, the more synthetic material in a fabric, the more salts required to provide the desired flame retardancy. Metal surfaces contacting this type of interior fabric must be properly treated in order to avoid corrosion. Zinc chromate primer will not provide the required corrosion protection. The use of acid etching and wash primer treatment will provide protection."

This Alert and the cited Service Difficulty Reports implicating fire-retardant materials in accelerated metal corrosion suggested that a research program should be conducted to quantify this corrosion problem. The program should include review of SDR's and laboratory experiments to quantify corrosion of typical aircraft metals in the presence of fire-retardant materials currently in use.

2. CORROSION CASES FROM AIRCRAFT SERVICE DIFFICULTY REPORTS.

Data were obtained from several pertinent sources including General Aviation Airworthiness, "Alerts," aircraft maintenance logs (Cessna), and the FAA Service Difficulty Report data base for FAR part 23 aircraft [4,5]. An extensive search of the Service Difficulty Report data base was done to identify corrosion attributed to a fire-retardant treatment.

Aircraft that have had corrosion due to the use of fire-retardants and have been cited in the data base are classified below. A brief summary of the description of the corrosion as listed in the narrative is also given.

PIPER

Aircraft model PA28161, serial number 287916185;
A report of corrosion under rear seat. The possible cause was leakage at rear seat window causing wetness of the fire-retardant insulation around fitting.

Aircraft model PA23250, serial number 234405291;
A report of corroded longeron tube. Suspected cause was a water leak at the left window where water soaked the side wall insulation. Fire-retardant insulation resting on the tubing triggered corrosion.

Aircraft model PA23250, serial number 277654176;
A report of corrosion on 17134-44 tube and frame 3039206 at station 153.87 below door. Suspected cause was that the flame retardant insulation had gotten wet and held water against the tubing. Corrosion on the tube was found below the battery box.

Aircraft model PA23250, serial number 277554032;
A report of corrosion on 17134-44 tube at station 153.87 on right and left tubes. Suspected cause was that the corrosion was caused by flame-retardant.

Aircraft model PA23250, serial number 277754158;
A report of corrosion at station 153.87 on right side at cabin step. Holes were put in tubes with scribe. This was probably caused by a window leaking water and trapped by fiber glass insulation against the tube.

Aircraft model PA28140, serial number 2825805;
A report of corrosion under left rear seat in the steel plate and rivet heads; corrosion was found to have extended through half the thickness of the plate. The possible cause was the fire-retardant insulation under the seat holding water.

Aircraft model PA28151, serial number 287415687;
A report of steel fittings corrosion. The possible cause was the wet fire-retardant insulation which was in contact with these steel parts.

Aircraft model PA28161, serial number 288116316;
A report of corrosion on the surface of the fitting P/N 62448-03 behind the fiberglass insulation in the lower cockpit. The possible cause of this corrosion was the moisture retained by the fiberglass insulation in contact with the fittings.

Aircraft model PA28161, serial number 287816067;
Corrosion reported on right rear spar and left rear spar in the fittings 6244803 and 6244802 respectively. Moisture leaking in from a side window caused the fiberglass insulation to become saturated. This insulation contacts the fitting, the worst corrosion was noted under the insulation, but very little corrosion was noted on the exposed portion of the fitting outside the aircraft.

Aircraft model PA28181, serial number 288090326;
A report of corrosion in the fittings 6244802 and 6244803 located at lower fuselage. The fittings were located inside the flap torque tubewell, behind flap pillow blocks, and the submitter suggested that the fire-retardant insulation held water and caused the corrosion.

Aircraft model PA28181, serial number 287890373;
A report of corrosion on plates 6244803 and 6244802 under rear seat. Possible cause was the fire-retardant insulation packed under the rear seat became soaked with water and caused these steel plates to corrode.

Aircraft model PA32300, serial number 327940243;
A report of corrosion on the fitting assembly 6538861 in the right wing attachment. Corrosion had built up on steel rear spar attaching plate and cabin caused by the fiber glass insulation holding water. There were no drain holes forward of this bulkhead.

Aircraft model PA60600, serial number 600016;
Corrosion was reported on longerons 210028510, 210028525, and 210028506 on the extruded H sections. This seemed to have been caused by water leaking through windows and being held by the longerons and fire-retardant insulation materials.

Aircraft model PA23160, serial number 231626;
Corrosion reported in frame 1716206 on the lower fuselage. It appeared that moisture was collecting at the point of contact of insulation on the tube causing the corrosion.

Aircraft model PA23250, serial number 273335;
A report of corrosion on frame 3039205 in the fuselage. The corrosion appeared to be caused by fire-retardant insulation between the fuselage frame and the aircraft skin.

Aircraft model PA34200, serial number 3474T0131;
Corrosion reported on bracket 6252200 on the windshield. During inspection it was found that the sponge type fire-retardant insulation in this area trapped water from a leaking windshield seal.

BEECH

Aircraft model 35A33, serial number CD277;
Corrosion reported on the stringers in the cabin right corner, and pitting was formed on the inside surface of skin and stringers. This was probably caused by a leaking door seal which allowed moisture to enter and then became retained in the fire-retardant insulation.

Aircraft model B60, serial number P336;
Corrosion found extensively on structural fuselage in the cabin. This seemed to have been caused by moisture trapped in the fire-retardant insulation around structural members.

Aircraft model 58, serial number TH513;
Report of corrosion on the floor supports 0024400291, 0024400294, 0024400293, and 0024400292 from FS151-FS171. The corrosion reported was intergranular corrosion. Cause of this corrosion was speculated to be from the floor fire-retardant insulation holding water due to a leaking frame door seal.

MOONEY

Aircraft model M20J, serial number 240210;
Corrosion reported on tubes 340155021 and 340155061 in the frame. The cause for corrosion was water retained by the fire-retardant insulation.

Aircraft model M20J, serial number 241098;
Corrosion reported on tubing 340155 at the window area. It was revealed that the fire-retardant insulation was soaked with moisture from leaking windows caused the corrosion.

Aircraft model M20J, serial number 240839;
Corrosion reported on tubing 340117 at the window area. Corrosion was caused by soaked fire-retardant insulation, caused by leaks around left cockpit windows.

Aircraft model M20J, serial number 240414;
A report of corrosion on the fuselage tube below pilot's window. Corrosion was caused by window leakage soaking the fire-retardant insulation.

Aircraft model M20J, serial number 240712;
Corrosion was reported on the structure in the fuselage. The problem seemed to be caused by water entering the fuselage around the side sections and was retained by the fire-retardant insulation.

Aircraft model M20J, serial number 240318;
Corrosion of tube 340155021 on left fuselage. It was revealed that the fire-retardant insulation soaked with moisture from leaking windows caused the corrosion.

Aircraft model M20J, serial number 240656;
Tubing part number 340155 was corroded through tubing wall and severely pitted. Other tubing was also pitted as far back as left side of the baggage bulk head. It was caused by deteriorated cabin window sealant.

Aircraft model M20J, serial number 240921;
Corrosion in the fuselage tubes was reported along with electrical problems from the wires and the connectors in this area. The fire-retardant insulation was soaked with moisture and was the probable cause of corrosion.

Aircraft model M20J, serial number 240746;
Corrosion in the fuselage tubing. Water appeared to have entered side panel areas through poor

bonding of the sealer along the bottom of the windows. This soaked the insulation and rusted the tubing.

Aircraft model M20K, serial number 250020;
Corrosion in tubings 350155009, 340177141, 350155061, 350155021, and through the upper fuselage. It was found that corrosion was due to water soaked fire-retardant insulation from a leak at angle P/N 320009-083+320013.

Aircraft model M20K, serial number 250047;
Corrosion in tube 340155067 in left hand side of the fuselage. Leaking cabin side windows caused the corrosion of the tube structure.

CESSNA

Aircraft model 337A, serial number 3370297;
There was a report of corrosion in the cabin roof interior from FS 135.45 to 165.09 and LBL 13.75 to RBL 13.75. The possible cause was that three of the stiffeners were lying on the loose fire-retardant insulation thus causing galvanic corrosion.

AEROSPATIAL

Aircraft model ATR42300, serial number 37;
The frame in station 17319 was corroded. The fire-retardant insulation blanket was found saturated with moisture and galley fluids which caused the corrosion.

ROCKWELL

Aircraft model NA26560, serial number 306131;
The main fuselage frame was found to have been corroded at fuselage station 206. The frames are of 7178-T6 extrusion and the corrosion appeared to be caused by moisture entering the fire-retardant insulation around window area during manufacture.

3. SUMMARY OF SERVICE DIFFICULTY REPORTS.

Figure 1 presents a histographic representation of various corrosion cases from SDR's with respect to the aircraft manufacturers. Figure 2 presents the locations at which corrosion was reported in SDR's. This graph illustrates that the most frequently observed corrosion was in the fuselage, with especially high occurrences near windows and frames.

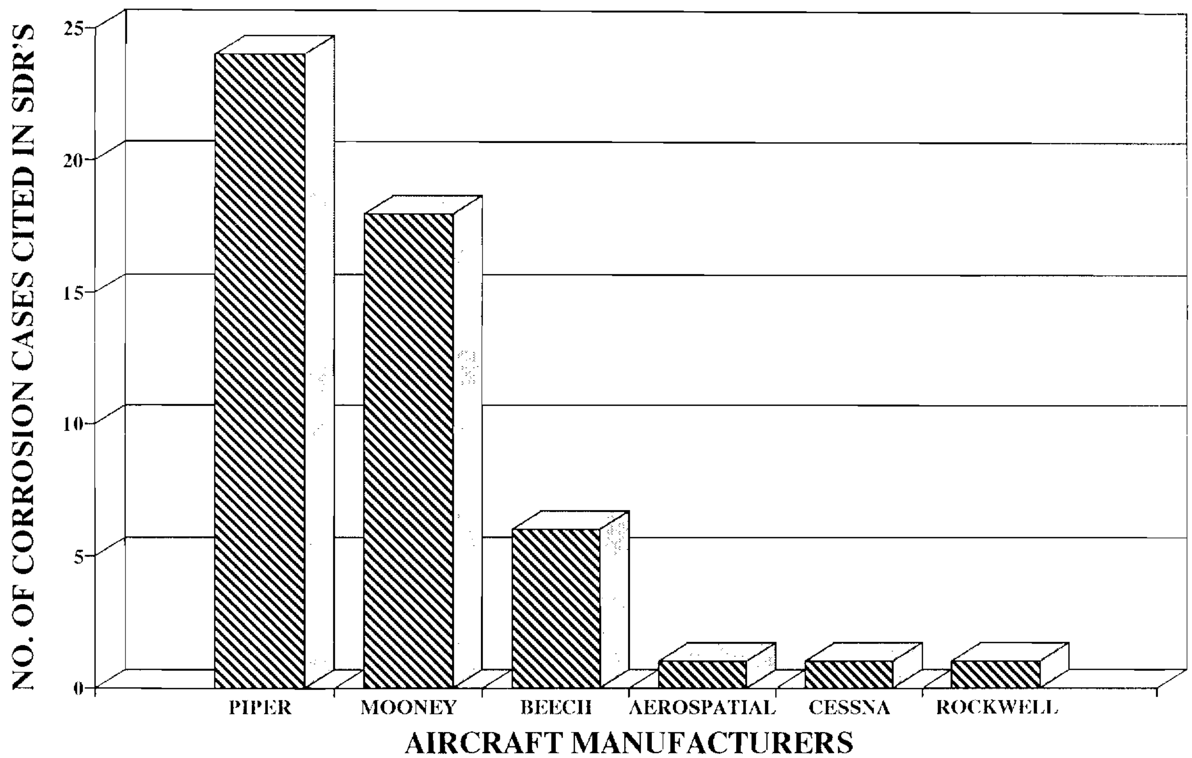

FIGURE 1. CORROSION CASES FROM SERVICE DIFFICULTY REPORTS

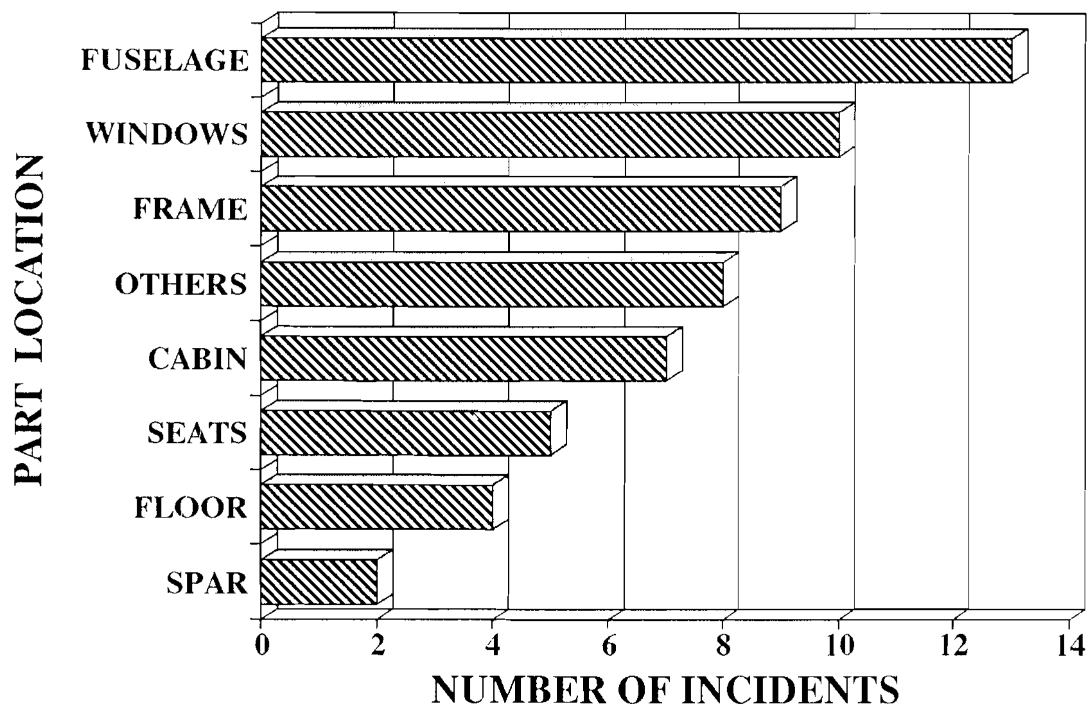

FIGURE 2. CORROSION INCIDENTS BY LOCATION

The following inferences and recommendations are made based on study of the Service Difficulty Report data base.

Reports stated that most of the corrosion was due to the presence of moisture in the fire-retardant insulation. In many of these cases the presence of moisture was due to window leaks, saturation by galley fluids, deterioration of cabin window sealant, and leaking door seals. Following are a series of suggested practices based on review of the SDR's:

- Windows should be leak proof and there should be no deterioration of window sealants.
- Insulation should be contained in a plastic bag so that it does not rest directly against the aircraft skin or structure.
- Interior of the aircraft should be coated with primer.
- Regular visual inspections should be conducted of the insulation in areas that can retain water.
- Insulation should be removed and dried if moisture gets in. It should not come in contact with metallic parts [7,8].

The Service Difficulty Report Data Base clearly raised the question concerning the role of fire-retardant treated materials in accelerated metal corrosion. The lack of pertinent data regarding fire-retardant corrosion suggested the need of controlled laboratory experiments to quantify the problem. To evaluate the corrosiveness of various fire retardants, the following experimental program was designed.

4. LABORATORY CORROSION EXPERIMENTS.

After thorough consideration and research of the existing interiors of small planes, two aircraft structural aluminum alloys, Al 2024-T3 and Al 7075-T6 (bare and clad), were selected to represent the most common materials for floor panels, seats, side wall, and floor tracks [6]. After consultation with local small aircraft manufacturers such as Cessna and Beechcraft, and fire-retardant product manufacturers, three fire-retardant aircraft interior materials were selected for experiments: 1) Ultrasuede, 2) Glenlivit and 3) Highland Wool. In a generic sense, most fire retardants in current use are halide based (bromides, chlorides or fluorides). Ultrasuede and Glenlivit fire-retardants were provided by the Tapis Corporation, and Highland Wool was provided by Cessna Aircraft Company.

The several experimental approaches available [9,10,20] were thoroughly investigated and the search for appropriate testing procedure was narrowed down to the sandwich test. This test method was also recommended by the Tapis Corporation and United States Testing Company, Inc. for evaluating the corrosiveness of fire-retardant materials on aluminum alloys. Alloys, specimen size and fire-retardant aircraft interior materials used during experiments were:

Alloy:	Al 2024-T3 & Al 7075-T6 bare and clad
Specimen size:	2 x 2 inch x 0.040 inch thick (51 x 51 mm x 1.02 mm thick)
Fire-retardant aircraft materials:	Ultrasuede, Glenlivit, Highland Wool

Surfaces of the specimens were cleaned using isopropyl alcohol before the tests. Corrosion test articles consisted of the fire-retardant material "sandwiched" between two aluminum specimens, with a masking tape wrap to maintain uniform contact between the aluminum and the fire-retardant material.(See Figure 3.) The sandwich was then placed in the environmental chamber where the desired humidity and temperature were accurately maintained with digital humidistat and thermostat.

Over 288 tests were performed at room temperature (70°F) and at elevated temperatures (100°F and 130°F), with humidity varying from 50% to 90% for the purpose of accelerating the corrosion process. Time periods used were: 7, 14, and 21 days. These tests included <u>Control specimens</u> for each aluminum alloy which were tested <u>without</u> fire-retardant material applied to determine basic corrosion of the aluminum alloy as a function of temperature and humidity.

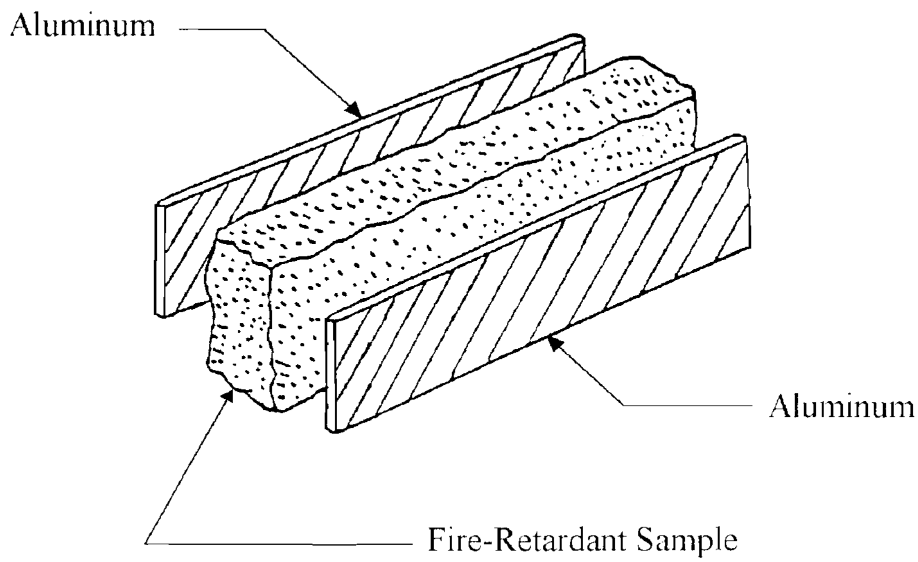

FIGURE 3. ASSEMBLY OF SANDWICH TEST SPECIMEN

After the exposure period, the test and control specimens were removed from the chamber and the fire-retardant material was carefully separated from the aluminum test article. Specimen surfaces were cleaned with warm tap water and wiped with a clean, soft cloth. Specimen panels were photographed with an ordinary camera to record the appearance of the corrosion to the un-aided eye. Later each specimen was examined using an optical microscope and micrographs were prepared. Corrosion characteristics such as uniformity of corrosion and severity of pitting were recorded.

5. EVALUATION OF CORROSION

In order to **grade** corrosion, **three corroded specimens** to be used as references were selected from all the test specimens. The specimens selected were judged to be examples of **severe**, **moderate** and **minimal** corrosion. An arbitrary corrosion level value of 100 was assigned to the specimen judged to have severe corrosion, a value of 50 was assigned to the specimen judged to have moderate corrosion, and a value of 5 was assigned to the specimen judged to have minimal corrosion. Table 1 details the specimens selected as references based on an analysis of the specimen micrographs. Rating for all other specimens was done by comparing the appearance of each specimen with these three reference specimens and interpolating the number to be assigned. Micrographs of the three reference specimens are shown in Figures 4, 5, and 6

TABLE 1. REFERENCE SPECIMENS

Sample Material	Temperature (Deg. F)	Humidity (%)	Duration (Days)	Rating
FR7075-T6 (Ultrasuede)	100	90	21	100
FR2024-T3 (Glenlivit)	100	90	14	50
FR7075-T6 (Highland Wool)	70	50	7	5

Detailed results of these evaluations for 288 specimen sets are given in Tables 2 through 5 in the following section. Each specimen rating listed in the tables indicates the average value for three identical material specimens tested at the same conditions.

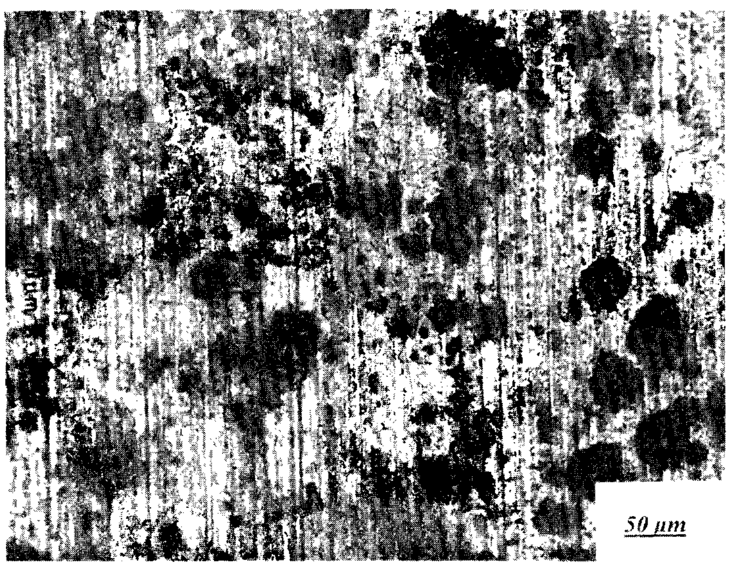

FIGURE 4. MICROGRAPH OF AL 7075-T6 WITH ULTRASUEDE, 100°F, 90% RH, 21 DAYS (SEVERE CORROSION, 100 POINTS)

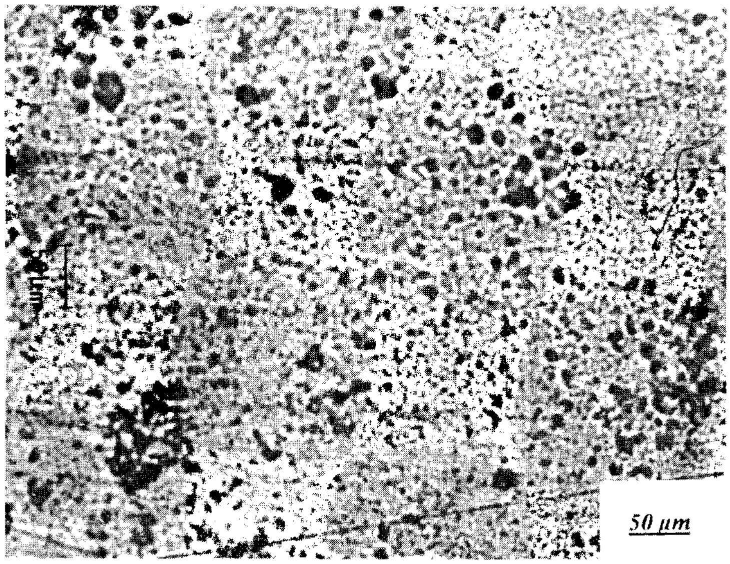

FIGURE 5. MICROGRAPH OF AL 2024-T3 WITH GLENLIVIT, 100°F, 90% RH, 14 DAYS (MODERATE CORROSION, 50 POINTS)

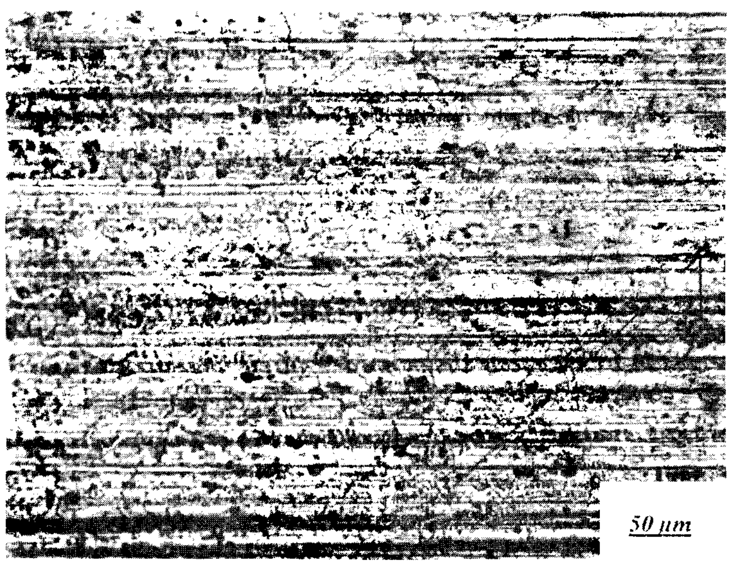

FIGURE 6. MICROGRAPH OF AL 7075-T6 WITH HIGHLAND WOOL, 70°F, 50% RH, 7 DAYS (MINIMAL CORROSION, 5 POINTS)

6. CORROSION RESULTS.

Typical optical micrographs for specimens in each category are presented in figures 7 through 16. Cross sections were cut from the samples and optical micrography was performed where the depth of pitting was the greatest. Figures 17 to 22 present selected cross-sectional micrographs.

The corrosion rating was averaged for each set of three specimens and for the three time durations (average of a total of nine specimens). GB-STAT and STORM [11] software systems were utilized for entry, storage, editing, manipulation, graphics, and statistical analysis of numeric data as they were gathered during corrosion experiments.

Corrosion ratings for each condition with different aluminum alloys, cabin interior materials and various combinations of temperature and humidity for the 288 specimen test sets are shown in Tables 2, 3, 4 and 5, and illustrated graphically in Figures 23 through 33. The rating for each test condition shown is an average for three distinct specimens at that condition. An average for the three different time periods (7, 14, and 21 days) at each temperature and humidity condition is also shown in these tables. In most test conditions, the data show that the intensity of corrosion was increased in the presence of a fire-retardant product. Figures 23 through 33 present data selected from Tables 2, 3, 4, and 5 to illustrate the relative corrosive behavior of the three fire retardants at different test conditions of temperature and humidity. The corrosion values presented in these tables are the average of the 7, 14, and 21 day tests for each material at the temperature and humidity conditions noted.

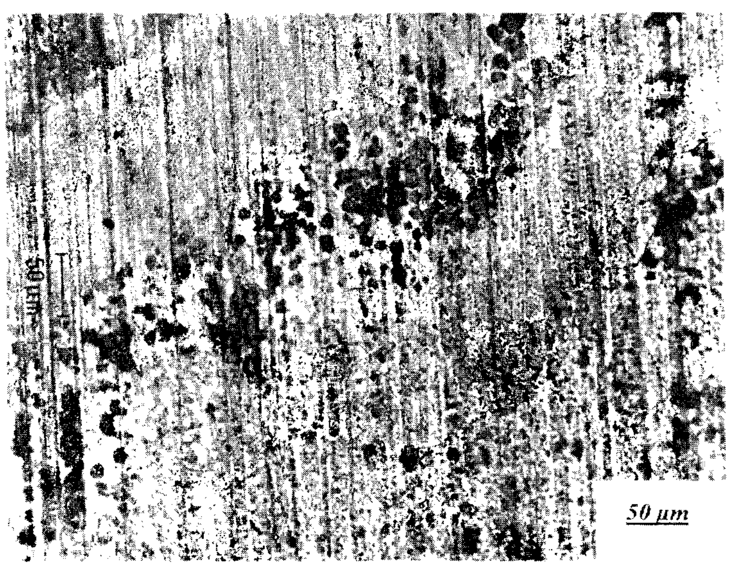

FIGURE 7. AL 2024-T3 WITH ULTRASUEDE, 100°F, 90% RH, 21 DAYS (50 POINTS)

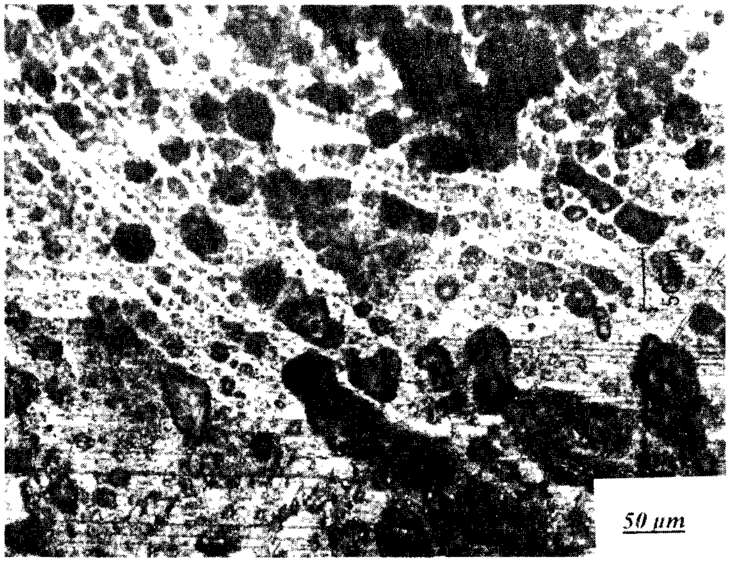

FIGURE 8. AL 2024-T3 WITH ULTRASUEDE, 130°F, 90% RH, 14 DAYS (80 POINTS)

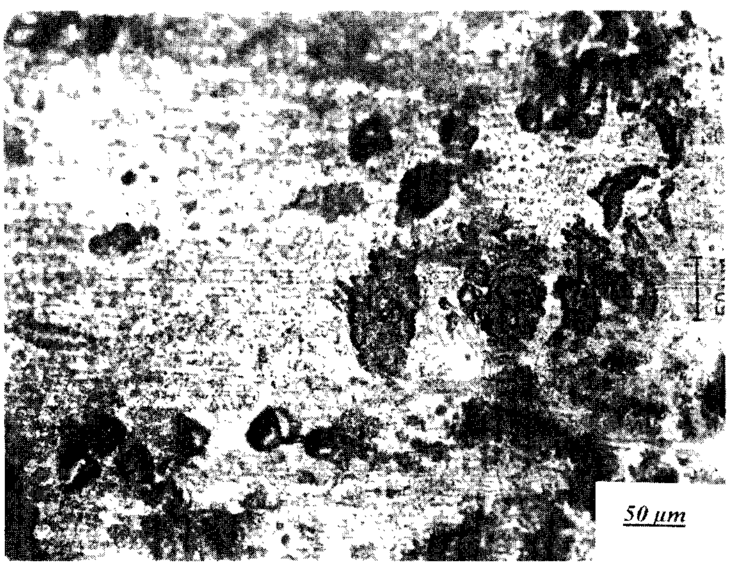

FIGURE 9. AL 7075-T6 WITH ULTRASUEDE, 70°F, 50% RH, 21 DAYS (40 POINTS)

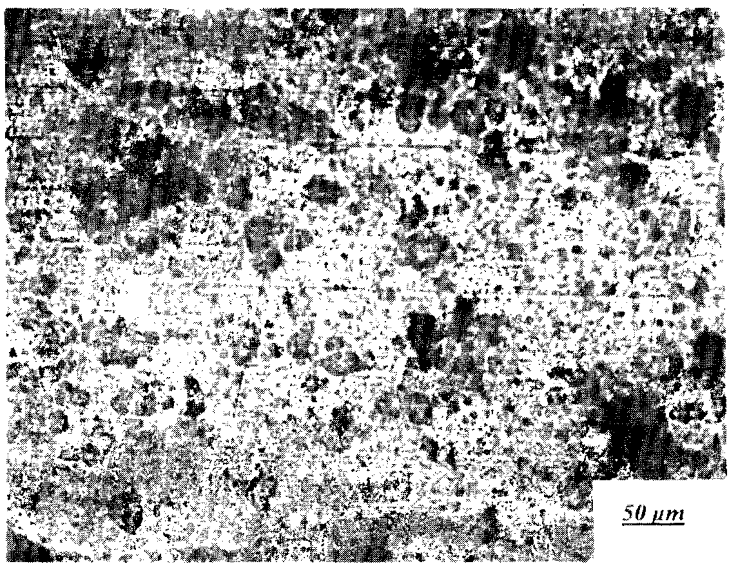

FIGURE 10. AL 7075-T6 ALCLAD WITH ULTRASUEDE, 130°F, 90% RH, 21 DAYS (40 POINTS)

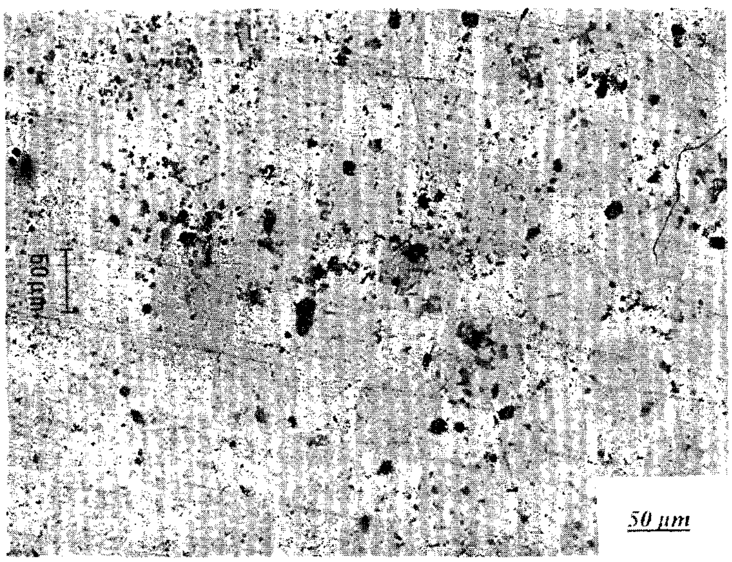

FIGURE 11. AL 2024-T3 WITH GLENLIVIT, 100°F, 90% RH, 21 DAYS (65 POINTS)

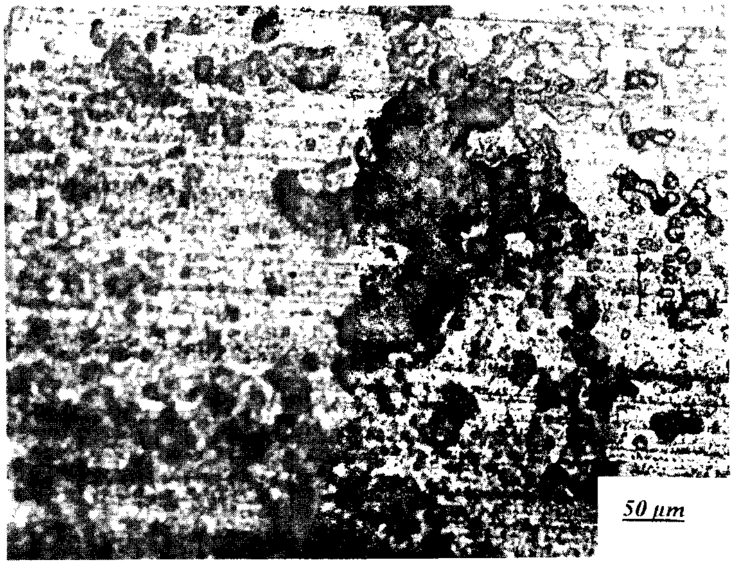

FIGURE 12. AL 2024-T3 ALCLAD WITH GLENLIVIT, 130°F, 50% RH, 14 DAYS (80 POINTS)

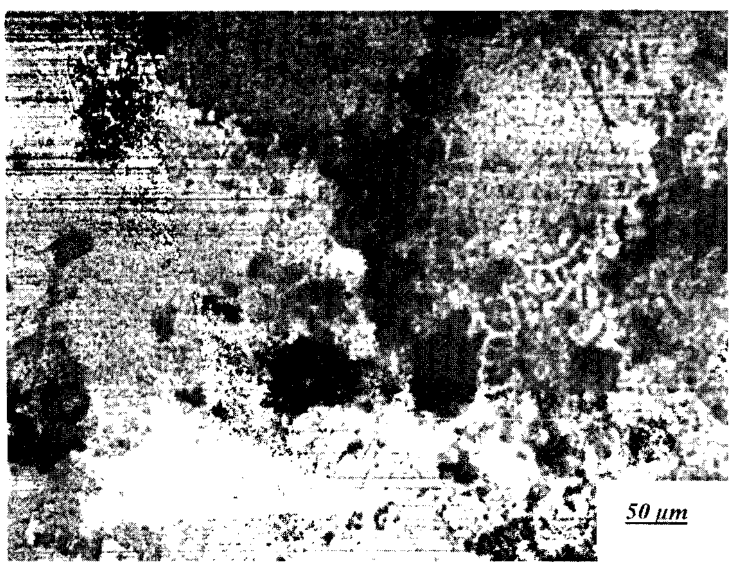

FIGURE 13. AL 7075-T6 ALCLAD WITH GLENLIVIT, 130°F, 50% RH, 21 DAYS (55 POINTS)

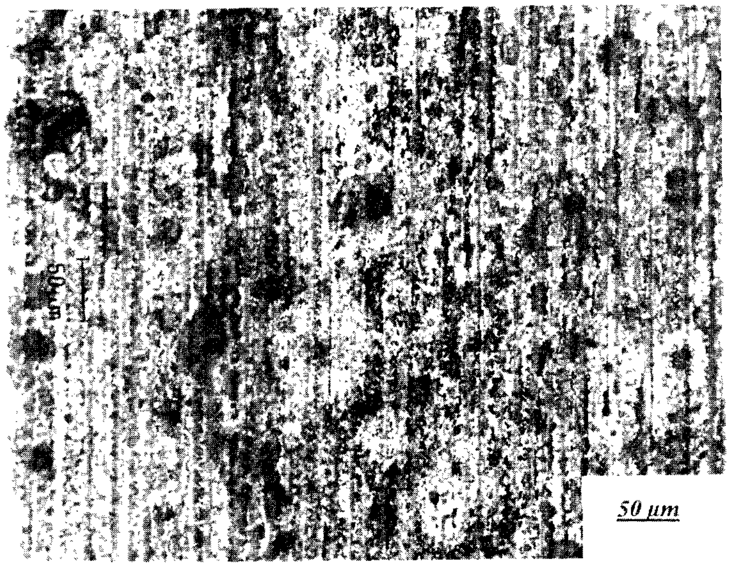

FIGURE 14. AL 2024-T3 WITH GLENLIVIT, 130°F, 90% RH, 21 DAYS
(85 POINTS)

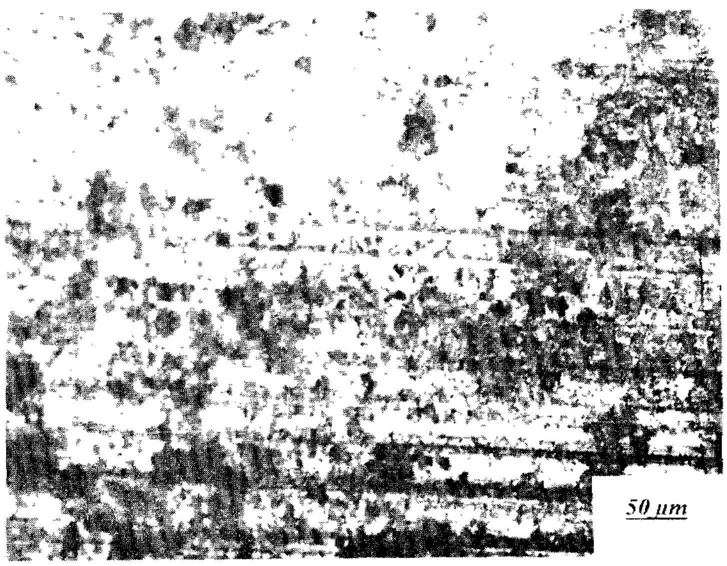

FIGURE 15. AL 2024-T3 WITH HIGHLAND WOOL, 70°F, 90% RH, 7 DAYS
(40 POINTS)

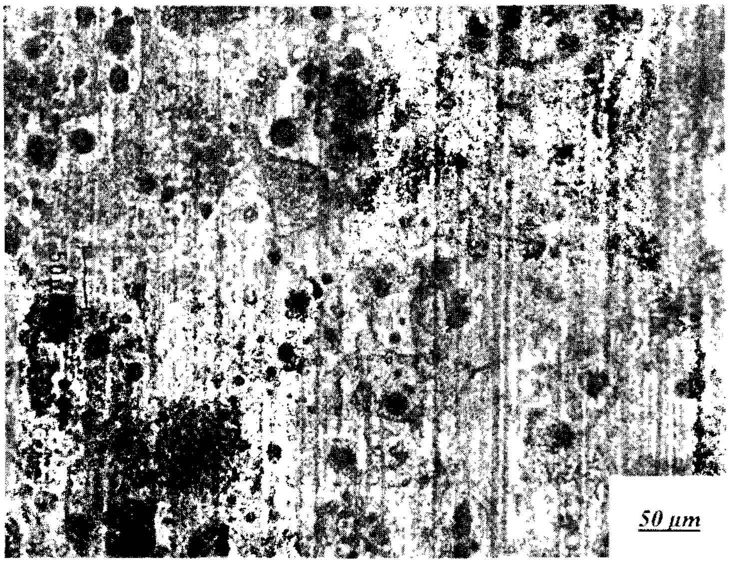

FIGURE 16. AL 7075-T6 WITH HIGHLAND WOOL, 130°F, 50% RH, 7 DAYS (45 POINTS)

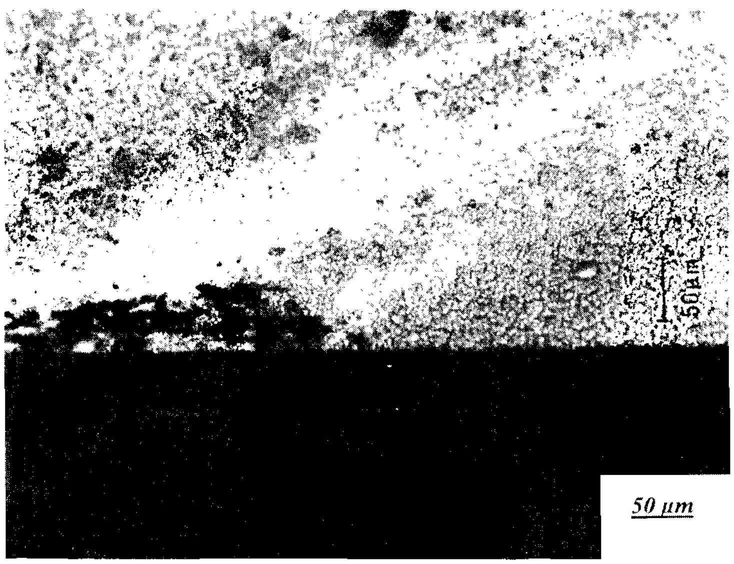

FIGURE 17. AL 2024-T3 ALCLAD WITH ULTRASUEDE, 130°F, 90% RH, 14 DAYS (CROSS SECTION)

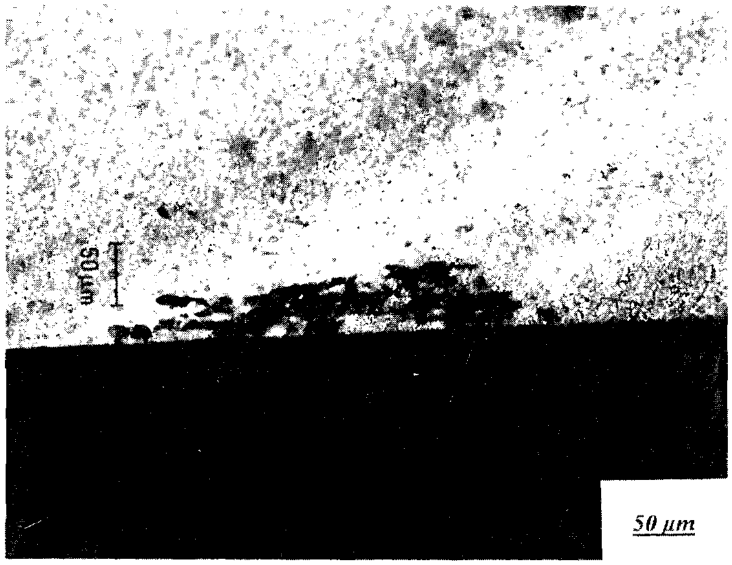

FIGURE 18. AL 7075-T6 WITH ULTRASUEDE, 70°F, 90% RH, 14 DAYS
(CROSS SECTION)

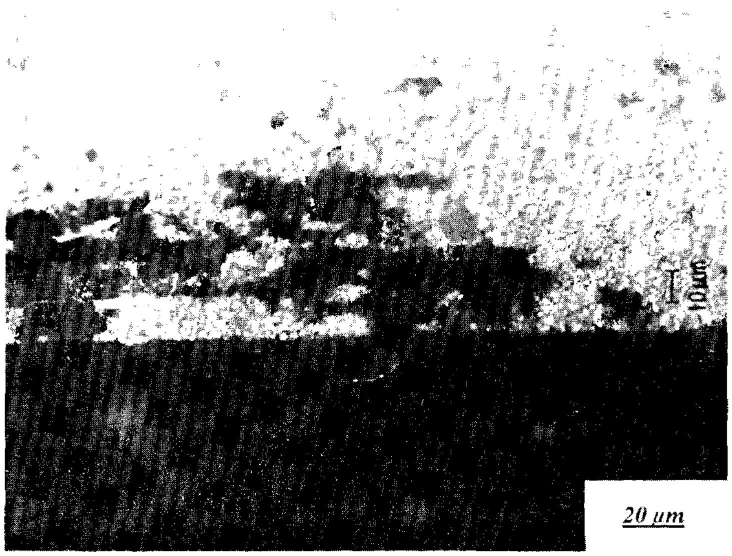

FIGURE 19. AL 7075-T6 WITH GLENLIVIT, 70°F, 50% RH, 14 DAYS
(CROSS SECTION)

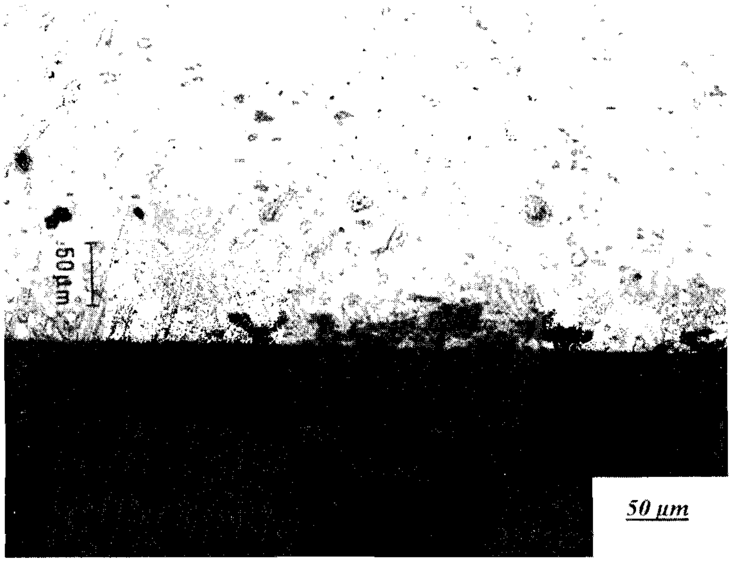

FIGURE 20. AL 7075-T6 WITH GLENLIVIT, 70°F, 50% RH, 21 DAYS
(CROSS SECTION)

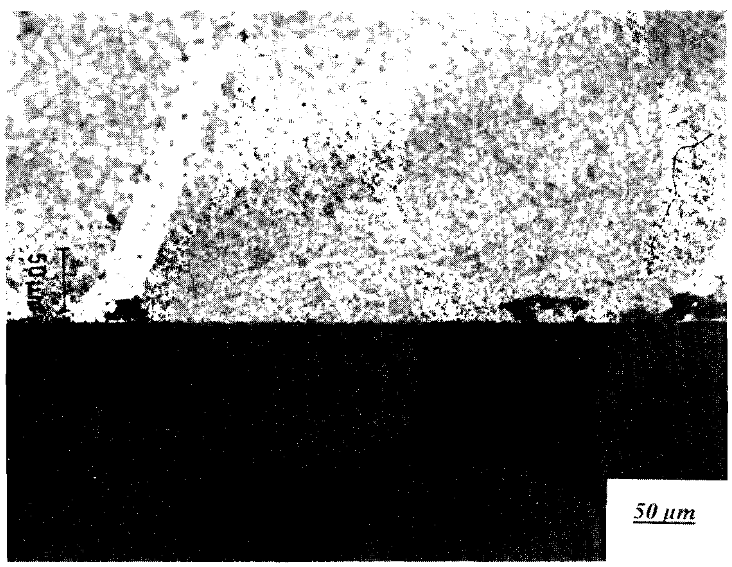

FIGURE 21. AL 2024-T3 ALCLAD WITH HIGHLAND WOOL, 130°F, 90% RH, 21 DAYS
(CROSS SECTION)

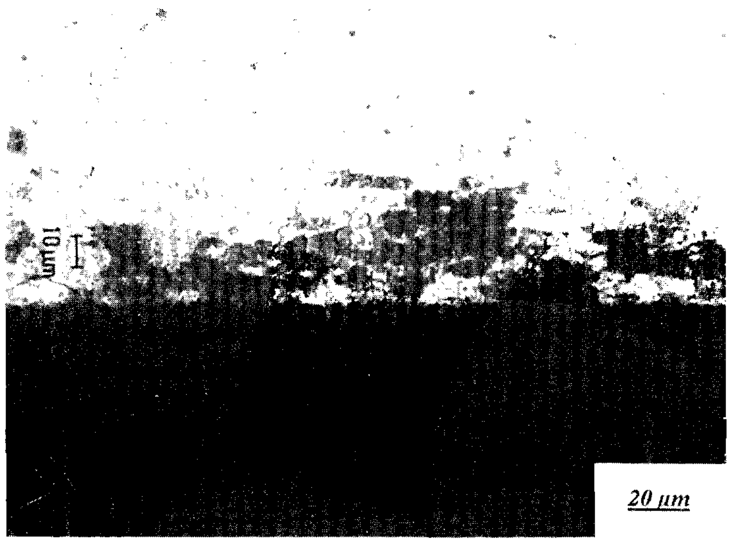

FIGURE 22. AL 7075-T6 WITH HIGHLAND WOOL, 70°F, 90% RH, 14 DAYS (CROSS SECTION)

TABLE 2. ALUMINUM CONTROL SPECIMENS WITHOUT FIRE RETARDANT

Sample Material	Temperature (Deg F)	Humidity (%)	Rating*			Average Rating
			7 Days	14 Days	21 Days	
AL2024-T3	70	50	10	12	20	14
+AL2024-T3	70	90	14	15	22	17
+AL2024-T3	100	50	10	15	14	13
AL2024-T3	100	90	8	12	20	13.3
+AL2024-T3	130	50	10	12	15	12.3
+AL2024-T3	130	90	10	20	25	18.3
AL2024A-T3	70	50	6	5	7	6
AL2024A-T3	70	90	8	12	14	11.3
AL2024A-T3	100	50	6	10	10	8.7
AL2024A-T3	100	90	8	14	14	12
+AL2024A-T3	130	50	2	6	7	5
+AL2024A-T3	130	90	5	10	6	7
+AL7075-T6	70	50	2	5	5	4
AL7075-T6	70	90	10	17	25	17.3
AL7075-T6	100	50	15	22	30	22.3
AL7075-T6	100	90	10	18	15	14.3
+AL7075-T6	130	50	15	18	12	15
+AL7075-T6	130	90	12	13	20	15
AL7075A-T6	70	50	3	8	10	7
AL7075A-T6	70	90	8	12	15	11.7
AL7075A-T6	100	50	8	15	9	10.7
AL7075A-T6	100	90	9	15	14	12.67
+AL7075A-T6	130	50	10	18	17	15
+AL7075A-T6	130	90	2	5	5	4

* Rating is the average of 3 specimens.
+ Average rating for these conditions for all fire-retardant materials are graphically displayed in figures 23 through 33.

NOTE: AL2024-T3 designates Al 2024-T3, AL2024A-T3 designates Al 2024-T3 Alclad, AL7075 designates Al 7075-T6, all tested in the absence of fire-retardant material.

TABLE 3. AVERAGE CORROSION RATING FOR ALUMINUM SPECIMENS WITH ULTRASUEDE

Sample Material	Temperature (Deg F)	Humidity (%)	Rating*			Average Rating
			7 Days	14 Days	21 Days	
FR2024-T3	70	50	8	10	16	11.3
+FR2024-T3	70	90	75	85	85	81.7
+FR2024-T3	100	50	40	40	55	45
FR2024-T3	100	90	65	70	50	61.7
+FR2024-T3	130	50	30	80	40	50
+FR2024-T3	130	90	50	80	60	63.3
FR2024A-T3	70	50	5	10	10	8.3
FR2024A-T3	70	90	10	8	15	11
FR2024A-T3	100	50	10	20	55	28.3
FR2024A-T3	100	90	25	60	65	50
+FR2024A-T3	130	50	75	60	85	73.3
+FR2024A-T3	130	90	60	50	95	68.3
+FR7075-T6	70	50	10	10	40	20
FR7075-T6	70	90	80	65	80	75
FR7075-T6	100	50	10	30	65	35
FR7075-T6	100	90	70	70	75	71.7
+FR7075-T6	130	50	30	45	60	45
+FR7075-T6	130	90	5	5	15	8.3
FR7075A-T6	70	50	5	8	20	11
FR7075A-T6	70	90	50	50	60	53.3
FR7075A-T6	100	50	10	10	30	16.7
FR7075A-T6	100	90	10	18	40	22.7
+FR7075A-T6	130	50	15	40	70	41.7
+FR7075A-T6	130	90	40	15	40	31.7

*Rating is the average of 3 specimens.
+ Average rating for these conditions for all fire-retardant materials are graphically displayed in figures 23 through 33

NOTE: FR2024-T3 designates Al 2024-T3, FR2024A-T3 designates Al 2024-T3 Alclad, FR7075-T6 designates Al 7075-T6, and FR7075A-T6 designates Al 7075-T6 Alclad, all with Ultrasuede.

TABLE 4. AVERAGE CORROSION RATING FOR ALUMINUM SPECIMENS WITH GLENLIVIT

Sample Material	Temperature (Deg F)	Humidity (%)	Rating*			Average Rating
			7 Days	14 Days	21 Days	
FR2024-T3	70	50	12	15	20	15.7
+FR2024-T3	70	90	50	70	80	66.7
+FR2024-T3	100	50	30	45	75	50
FR2024-T3	100	90	65	75	80	73.3
+FR2024-T3	130	50	20	60	75	51.6
+FR2024-T3	130	90	20	18	85	41
FR2024A-T3	70	50	8	12	18	12.7
FR2024A-T3	70	90	20	32	40	30.7
FR2024A-T3	100	50	15	20	60	31.7
FR2024A-T3	100	90	15	50	60	41.7
+FR2024A-T3	130	50	35	80	85	66.7
+FR2024A-T3	130	90	25	85	75	61.7
+FR7075-T6	70	50	40	70	50	53.3
FR7075-T6	70	90	25	85	80	63.3
FR7075-T6	100	50	20	30	85	45
FR7075-T6	100	90	65	70	85	73.3
+FR7075-T6	130	50	25	47	70	47.3
+FR7075-T6	130	90	50	20	30	33.3
FR7075A-T6	70	50	10	8	25	14.3
FR7075A-T6	70	90	40	45	80	55
FR7075A-T6	100	50	7	15	35	19
FR7075A-T6	100	90	20	25	35	26.7
+FR7075A-T6	130	50	20	40	55	38.3
+FR7075A-T6	130	90	20	40	60	40

*Rating is the average of 3 specimens.
+ Average rating for these conditions for all fire-retardant materials are graphically displayed in figures 23 through 33.

NOTE: FR2024-T3 designates Al 2024-T3, FR2024A-T3 designates Al 2024-T3 Alclad, FR7075-T6 designates Al 7075-T6, and FR7075A-T6 designates Al 7075-T6 Alclad, all with Glenlivit.

TABLE 5. AVERAGE CORROSION RATING FOR ALUMINUM SPECIMENS WITH HIGHLAND WOOL

Sample Material	Temperature (Deg F)	Humidity (%)	Rating*			Average Rating
			7 Days	14 Days	21 Days	
FR2024-T3	70	50	8	40	15	21
+FR2024-T3	70	90	40	75	50	55
+FR2024-T3	100	50	25	50	45	40
FR2024-T3	100	90	30	70	35	45
+FR2024-T3	130	50	35	60	60	51.7
+FR2024-T3	130	90	35	35	80	50
FR2024A-T3	70	50	10	18	20	16
FR2024A-T3	70	90	12	22	18	17.3
FR2024A-T3	100	50	28	20	40	29.3
FR2024A-T3	100	90	20	35	50	35
+FR2024A-T3	130	50	55	40	45	46.7
+FR2024A-T3	130	90	35	65	45	48.3
+FR7075-T6	70	50	15	20	30	21.7
FR7075-T6	70	90	50	90	65	68.3
FR7075-T6	100	50	25	35	65	41.7
FR7075-T6	100	90	30	65	75	56.7
+FR7075-T6	130	50	25	35	75	45
+FR7075-T6	130	90	45	80	50	58.3
FR7075A-T6	70	50	5	8	10	7.7
FR7075A-T6	70	90	8	15	12	11.7
FR7075A-T6	100	50	45	55	35	45
FR7075A-T6	100	90	10	20	18	16
+FR7075A-T6	130	50	50	20	45	38.3
+FR7075A-T6	130	90	15	60	65	46.7

*Rating is the average of 3 specimens.
+ Average rating for these conditions for all fire-retardant materials are graphically displayed in figures 23 through 33.

NOTE: FR2024-T3 designates Al 2024-T3, FR2024A-T3 designates Al 2024-T3 Alclad, FR7075-T6 designates Al 7075-T6, and FR7075A-T6 designates Al 7075-T6 Alclad, all with Highland Wool.

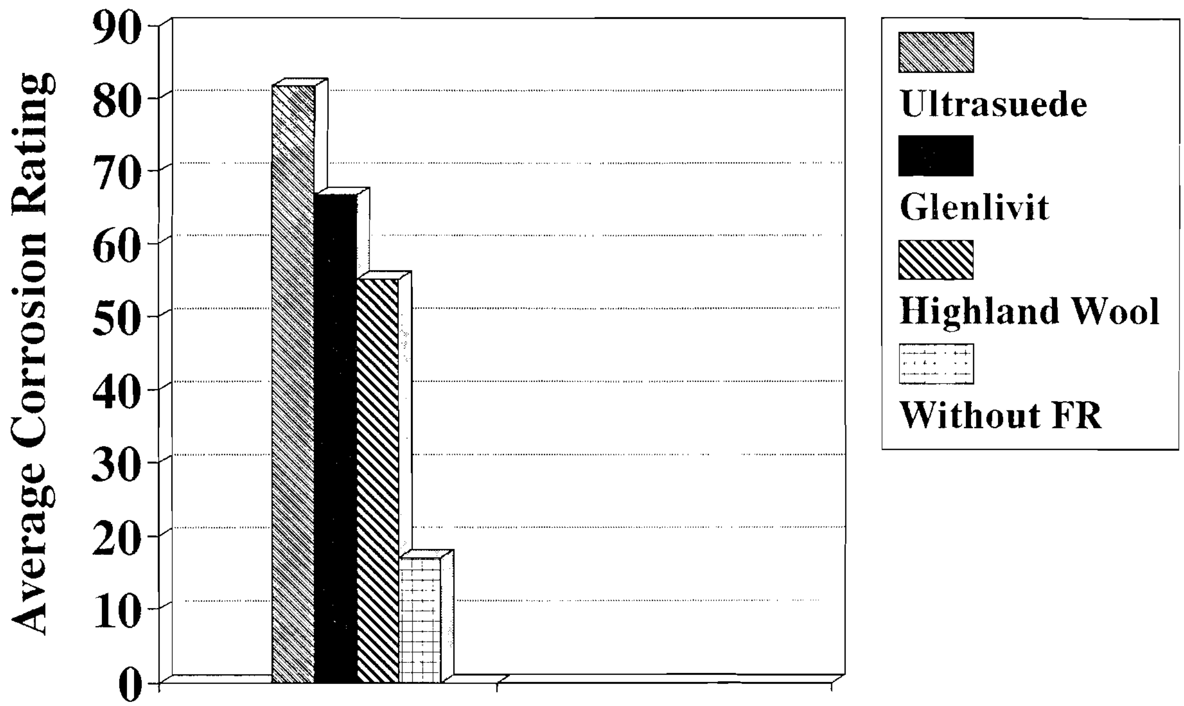

FIGURE 23. AVERAGE CORROSION RATING OF FIRE RETARDANTS WITH AL 2024-T3 (AT 70°F/90% RH)

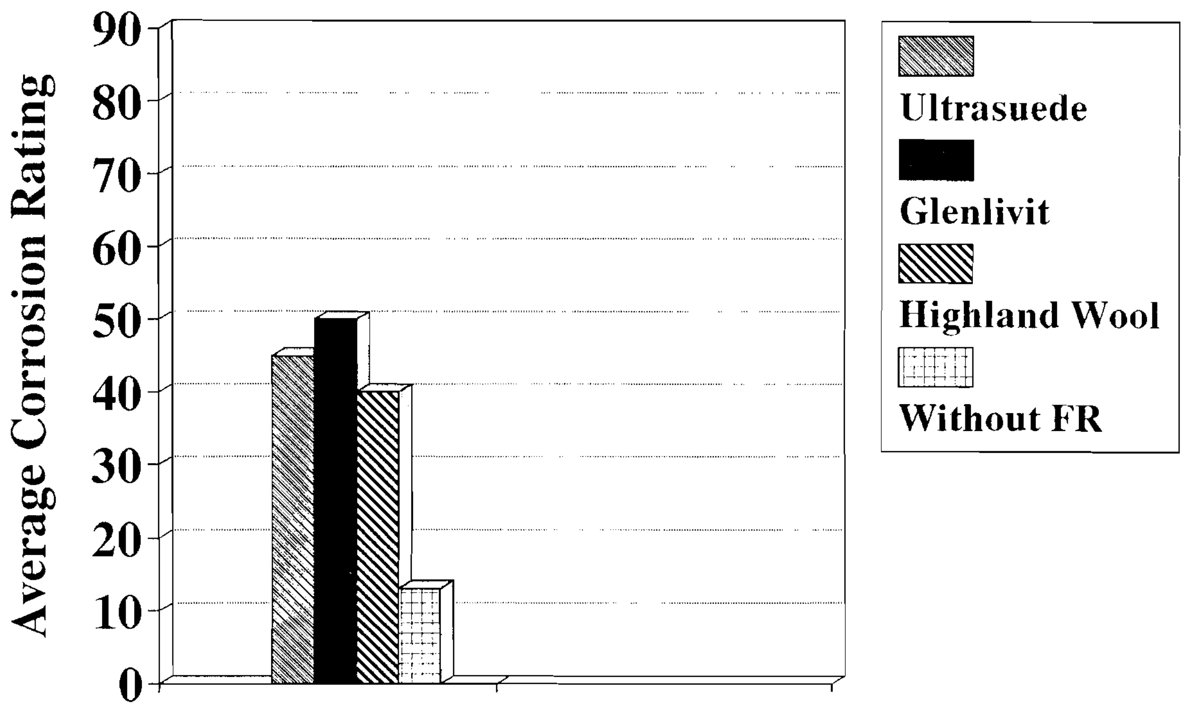

FIGURE 24. AVERAGE CORROSION RATING OF FIRE RETARDANTS WITH AL 2024-T3 (AT 100°F/50% RH)

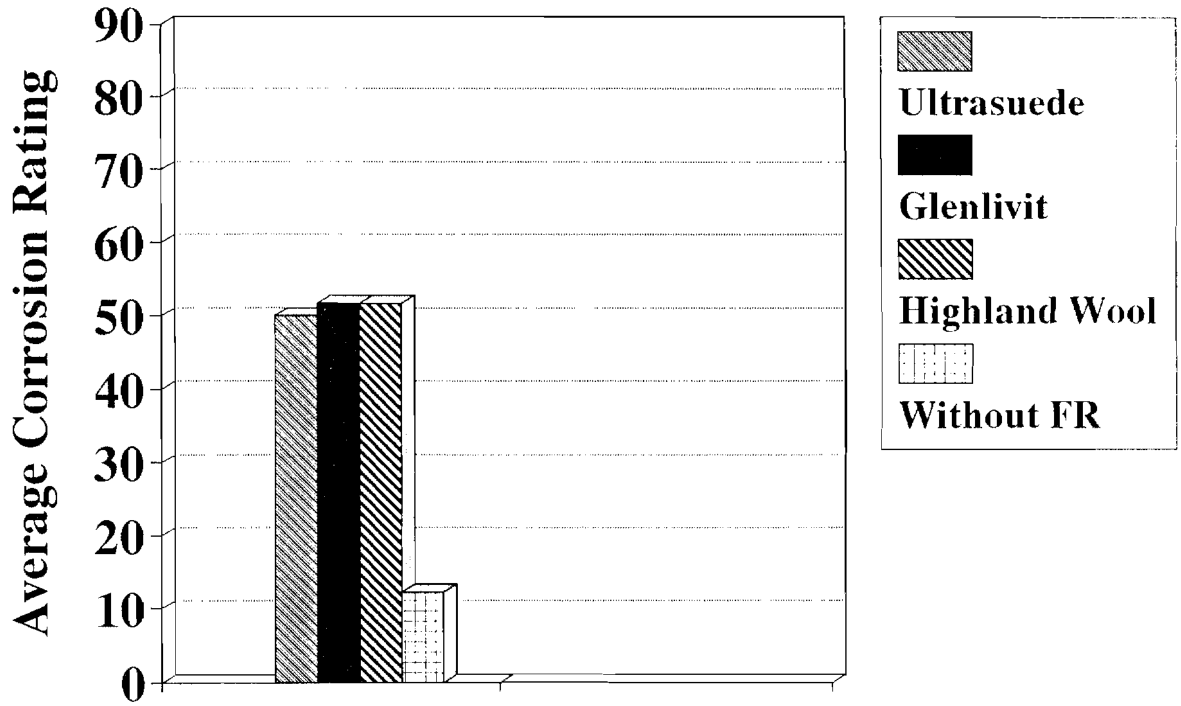

FIGURE 25. AVERAGE CORROSION RATING OF FIRE RETARDANTS WITH AL 2024-T3 (AT 130°F/50% RH)

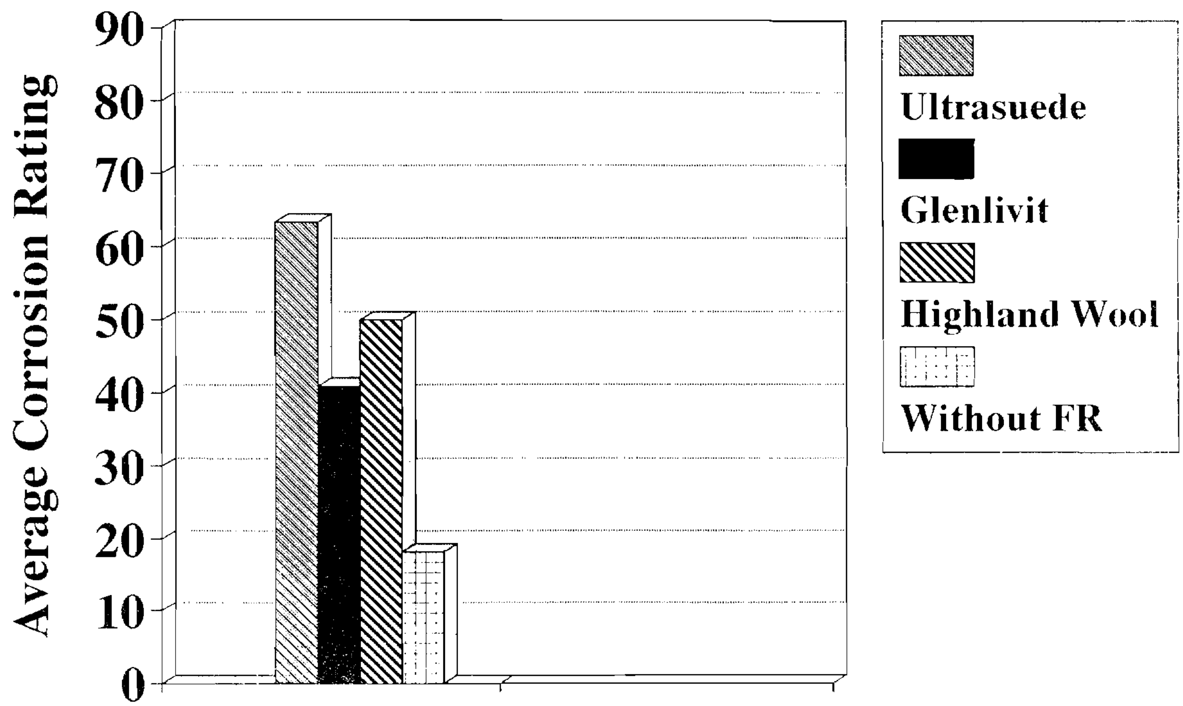

FIGURE 26. AVERAGE CORROSION RATING OF FIRE RETARDANTS WITH AL 2024-T3 (AT 130°F/90% RH)

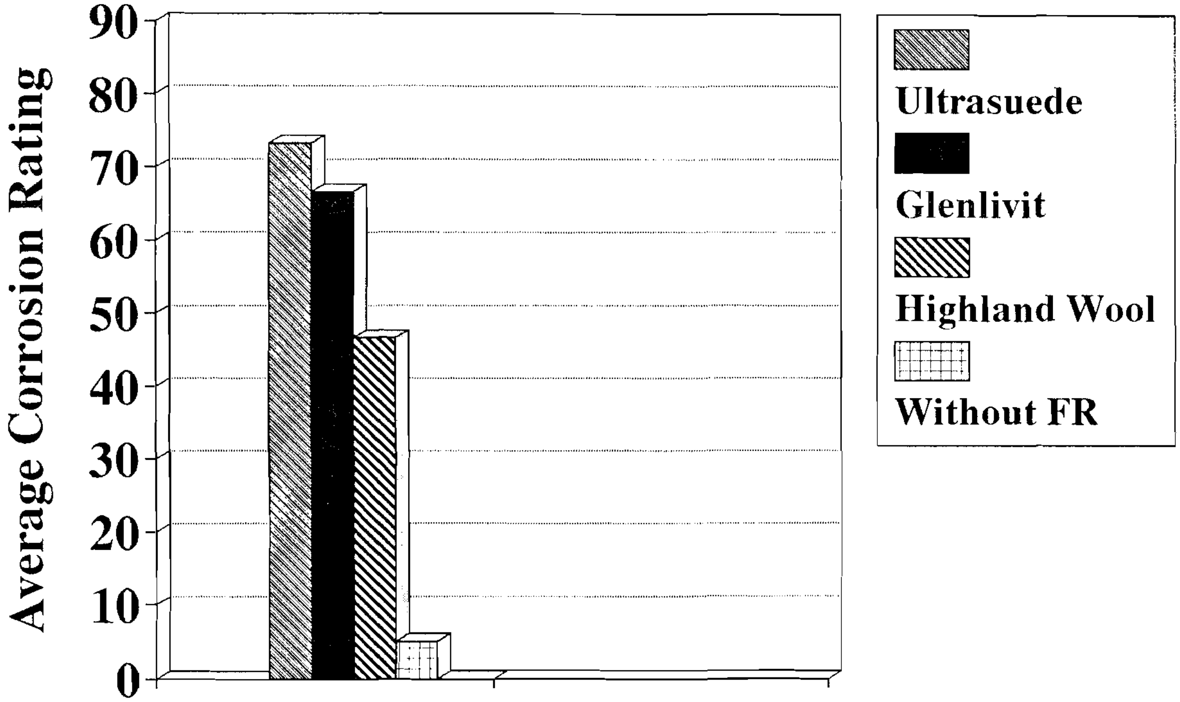

FIGURE 27. AVERAGE CORROSION RATING OF FIRE RETARDANTS WITH AL 2024-T3 ALCLAD (AT 130°F/50% RH)

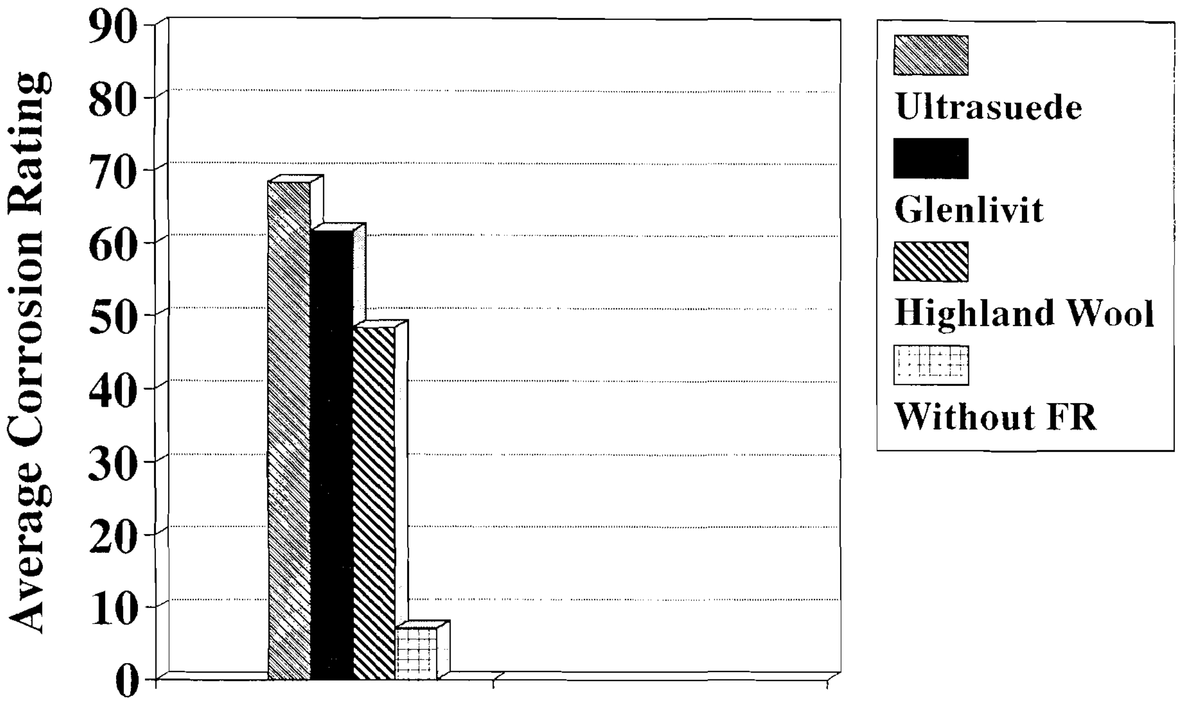

FIGURE 28. AVERAGE CORROSION RATING OF FIRE RETARDANTS WITH AL 2024-T3 ALCLAD (AT 130°F/90% RH)

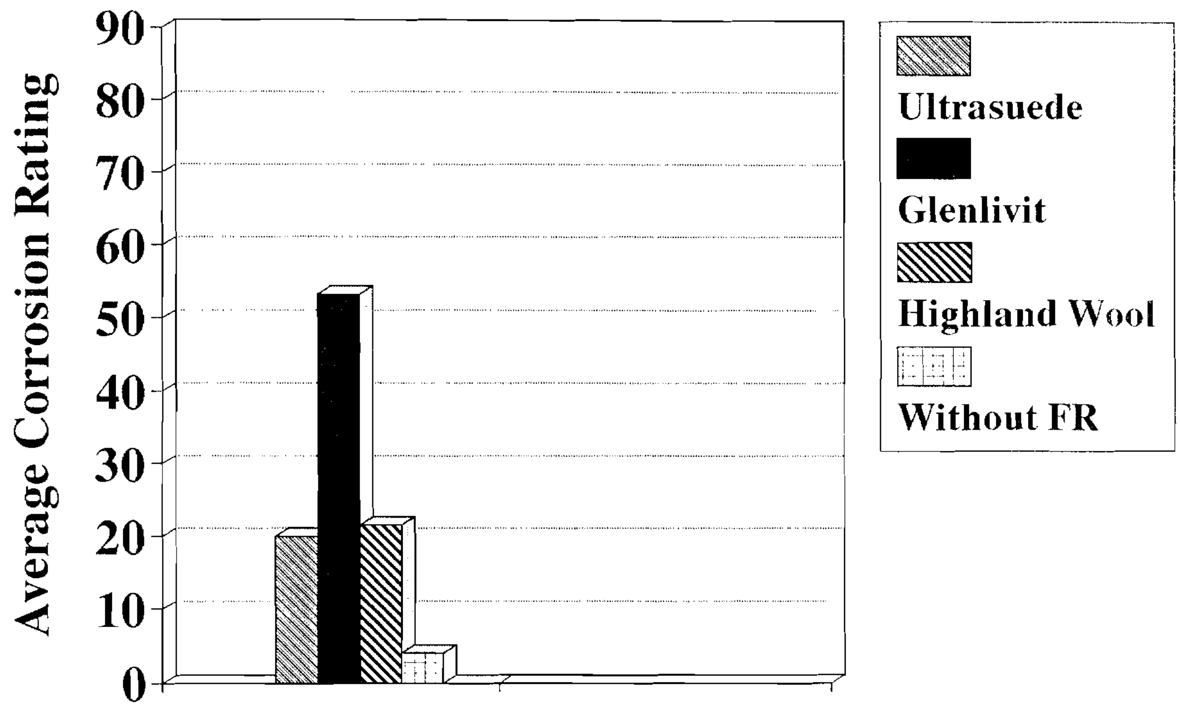

FIGURE 29. AVERAGE CORROSION RATING OF FIRE RETARDANTS WITH AL 7075-T6 (AT 70°F/50% RH)

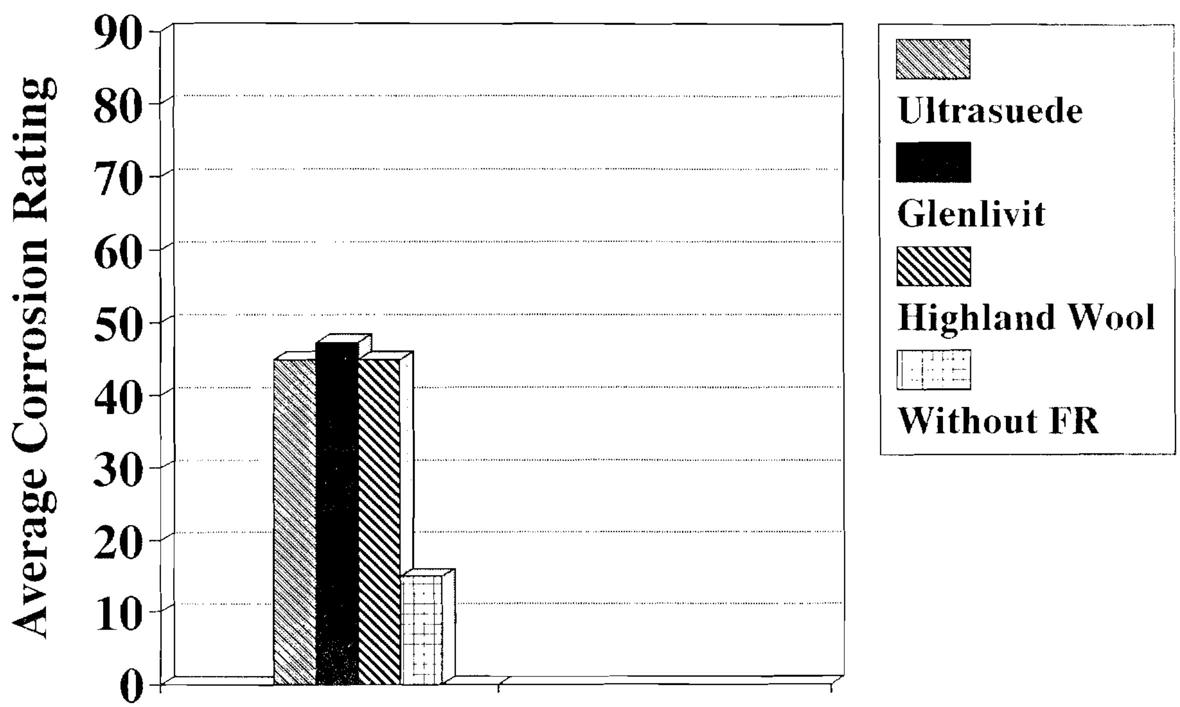

FIGURE 30. AVERAGE CORROSION RATING OF FIRE RETARDANTS WITH AL 7075-T6 (AT 130°F/50% RH)

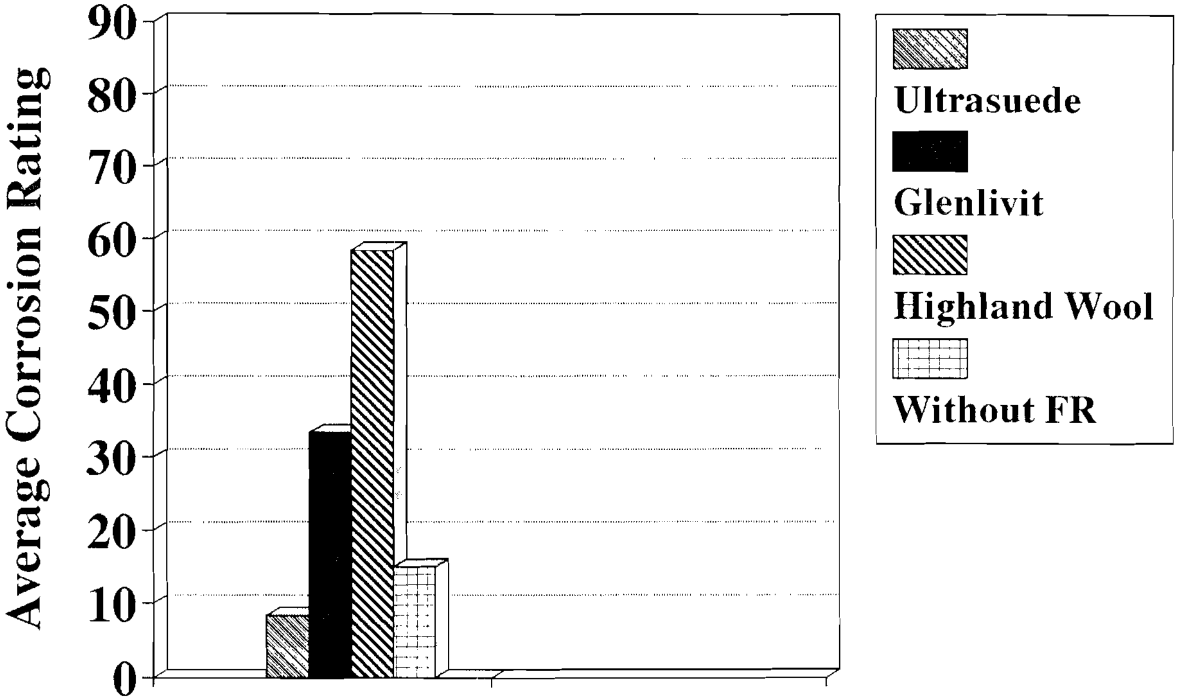

FIGURE 31. AVERAGE CORROSION RATING OF FIRE RETARDANTS WITH AL 7075-T6 (AT 130°F/90% RH)

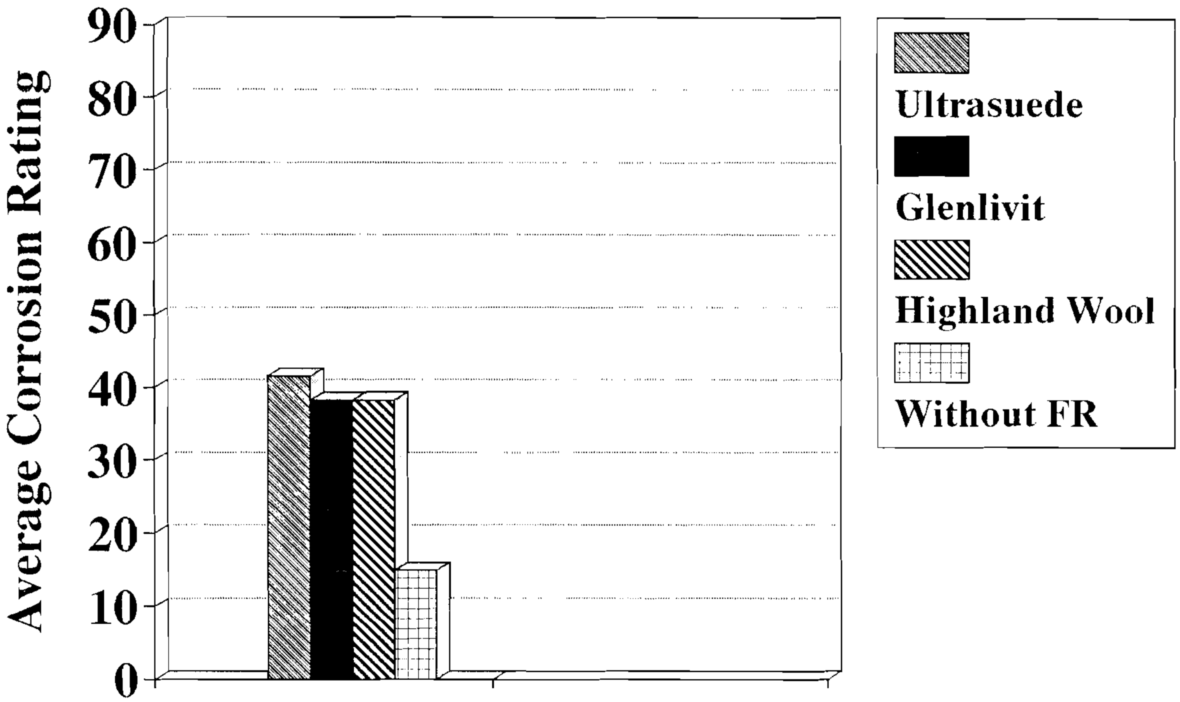

FIGURE 32. AVERAGE CORROSION RATING OF FIRE RETARDANTS WITH AL 7075-T6 ALCLAD (AT 130°F/50% RH)

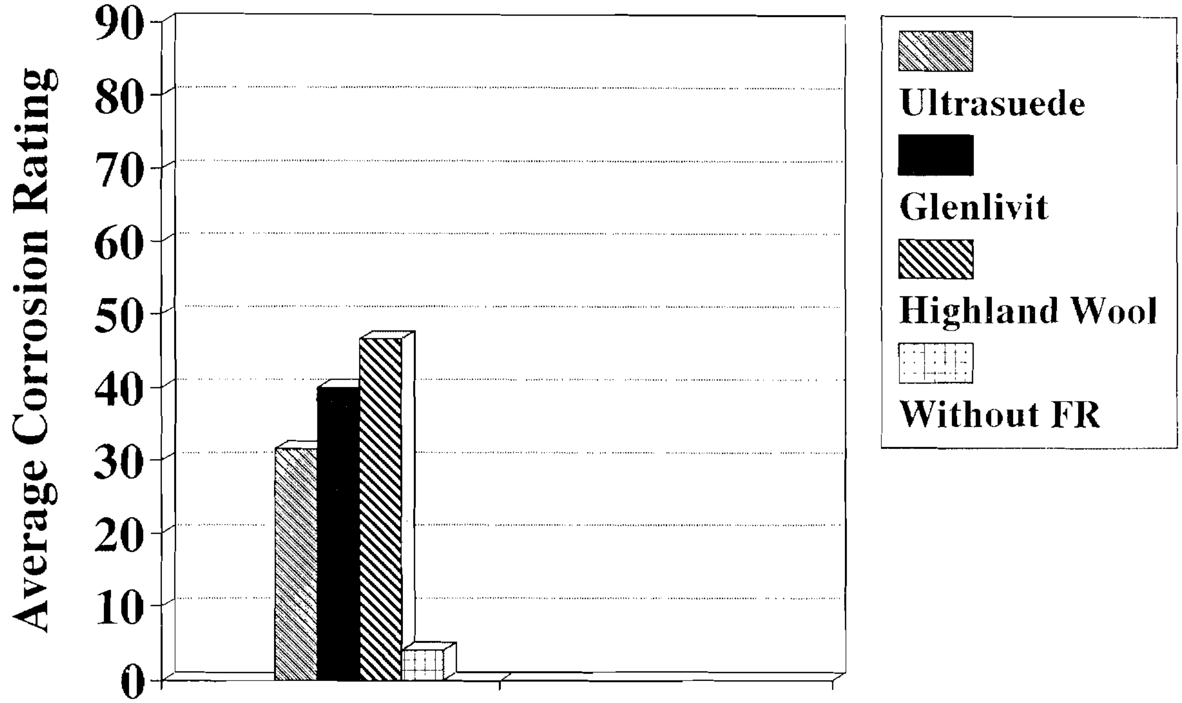

FIGURE 33. AVERAGE CORROSION RATING OF FIRE RETARDANTS WITH AL 7075-T6 ALCLAD (AT 130°F/90% RH)

7. CHEMICAL COMPOSITION OF THE FIRE-RETARDANT MATERIALS.

Ultrasuede, Glenlivit and Highland Wool are fire-retardant materials commonly used in aircraft seats and wall coverings. In order to identify the specific corrosion-causing element, the chemical composition of the fire-retardant must be known. Due to its proprietary nature, this information is not generally released by the manufacturers. This information was obtained by EDAX (Electron Dispersion Analysis of X-rays) microanalysis. X-ray microanalysis graphs for the three aircraft interior fire-retardant materials are given in Figures 34 to 36. The tests were performed to exclude the majority content of hydrocarbons and other materials usually present in interior fabrics and amplified the ability to detect small levels of elements. Table 6 summarizes the results of an EDAX analysis for elements usually associated with the fire retardants. The result given is the mass percent of the given element of the total mass of the elements selected for measurement. Halogen peaks in the EDAX analysis of Ultrasuede show approximately 32% bromine and 23% chlorine. In Glenlivit, negligible bromine and approximately 21% chlorine was found. A negligible amount of bromine and only 0.2% chlorine was found in Highland Wool. There was a significant amount of sulfur present in Glenlivit (49.3%) and Highland Wool (46.7%), but none was observed in the Ultrasuede material. The absence of significant halogen content for Highland Wool and significant sulfur content for Ultrasuede discounts the ideas that either halogens or sulfur are unique causes of increased corrosion.

23-SEP-94 16:22:03 EDAX READY
RATE- 18CPS TIME = 300LSEC
FS - 660CNT PRST = OFF
A = Ultrasuede

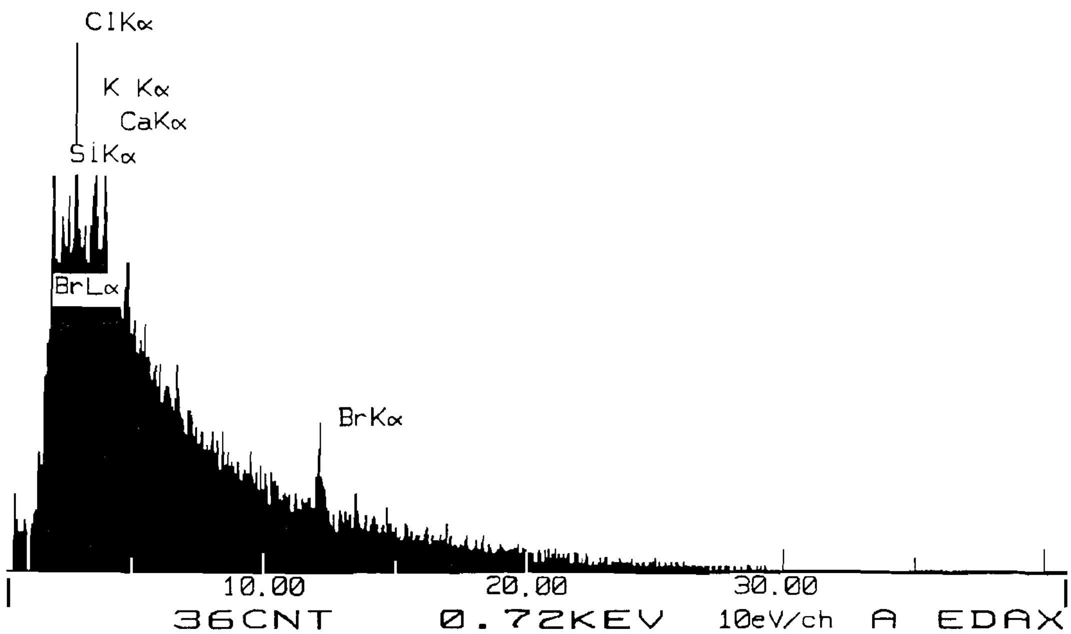

FIGURE 34. EDAX ANALYSIS OF FIRE-RETARDANT ULTRASUEDE

29-SEP-94 13:15:09 EDAX READY
RATE = 2CPS TIME = 300LSEC
FS = 2490CNT PRST = 300LSEC
A = Glenlivit

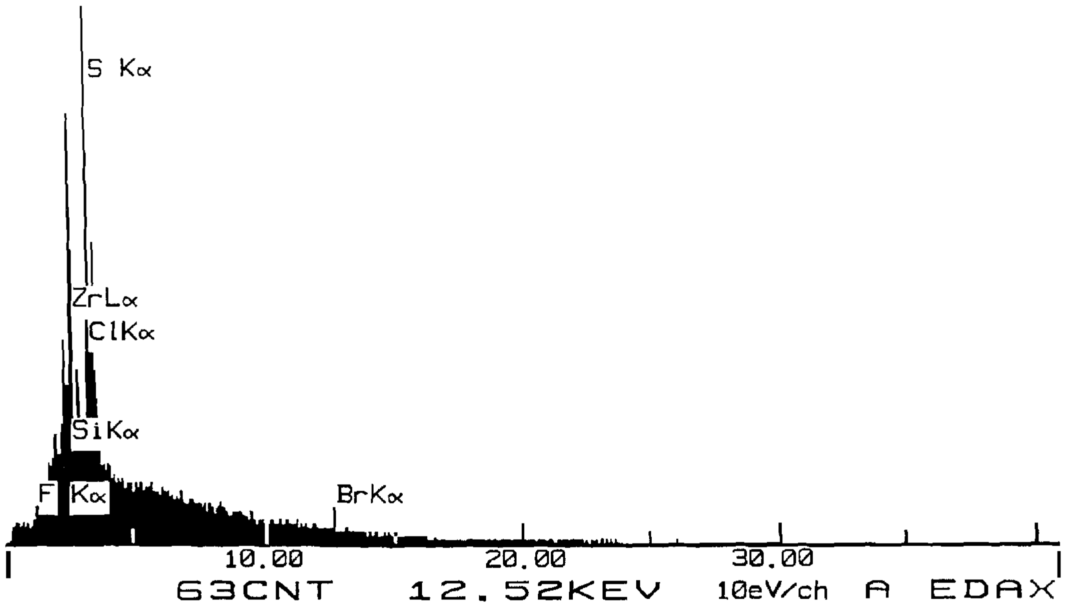

FIGURE 35. EDAX ANALYSIS OF FIRE-RETARDANT GLENLIVIT

23-SEP-94	14:57:40	EDAX READY
RATE = 1 CPS	TIME = 305LSEC	
FS = 2320CNT	PRST = OFF	
A = Highland Wool		

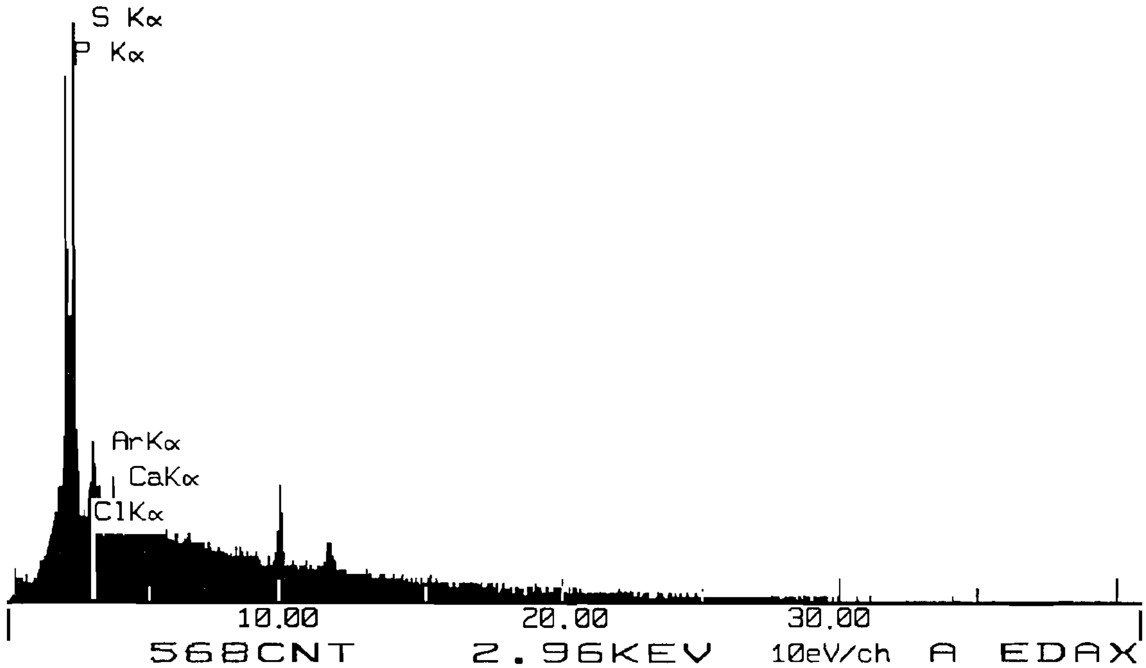

FIGURE 36. EDAX ANALYSIS OF FIRE-RETARDANT HIGHLAND WOOL

TABLE 6. ELEMENTS ASSOCIATED WITH FIRE RETARDANTS PRESENT IN ULTRASUEDE, GLENLIVIT, AND HIGHLAND WOOL.

	Mass Percentage of Total Measurement		
Element	Ultrasuede	Glenlivit	Highland Wool
Bromine	32.1	-	-
Fluorine	-	3.6	-
Chlorine	23.0	21.6	0.2
Zirconium	-	22.5	-
Sulfur	-	49.3	46.7
Silicon	10.9	3.0	-
Phosphorus	-	-	40.9
Argon	-	-	8.5
Calcium	18.3	-	3.7
Potassium	15.7	-	-
Totals	100.0	100.0	100.0

8. CONCLUDING REMARKS.

This research project evaluated the potential for fire-retardant materials used in aircraft interiors to cause corrosion of aluminum structural alloys. This work was initiated based on evidence of some corrosion problems in general aviation, small business jets and commuter aircraft, in areas near fire-retardant interior materials.

Service Difficulty Reports (SDR) data were studied to identify the frequency of fire-retardant related corrosion. The most frequent locations for corrosion were identified as fuselage and windows and frames.

Laboratory experiments were designed and conducted for corrosion testing of common aircraft structural alloys (Al 2024-T3 and Al 7075-T6) in the presence of aircraft interior materials. Tests were conducted for Ultrasuede, Glenlivit and Highland Wool, common interior materials

Results of accelerated corrosion tests show that corrosion was increased for all three fire-retardant materials under most test conditions compared to baseline tests without fire retardants.

Chemical composition from EDAX studies of the fire-retardants reveal substantial halogens in Ultrasuede and Glenlivit, but negligible halogens in Highland Wool. Thus the corrosion results cannot be attributed solely to halogens.

Sulfur, which is present in substantial amounts in both Glenlivit and Highland Wool, could be another cause for corrosion observed with these materials.

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