ACID CLEANING OF AIRPLANE FUSELAGE PRIOR TO PAINTING

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The current process for deoxidizing the airplane fuselage prior to painting involves power abrading with red Scotchbrite™ pads. This mechanical process is very labor intensive and may lead to musculoskeletal injuries, such as carpal tunnel syndrome. Acid cleaners/etchants were investigated to replace power abrading based on several airlines' use of acid etchants to prepare airplanes for repaint. Extensive laboratory tests were conducted with the preferred acid cleaner candidate followed by non-production trials on large panels/body sections and a one-year extended production trial in the 747 paint hangar.

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Introduction

The Everett, Renton, and North Boeing Field paint hangars have power abraded with red Scotchbrite™ pads to mechanically deoxidize the fuselage surface prior to painting since 1970. Acceptable water-break-free surfaces and paint adhesion have resulted. However, the power abrading process is very labor intensive and may lead to musculoskeletal injuries, such as carpal tunnel syndrome. Acid cleaners/etchants were investigated to replace power abrading based on several airlines' use of acid etchants to prepare airplanes for repaint. This chemical process is ergonomically better, may reduce cycle time, and is potentially more effective in terms of uniform paint adhesion on rivets and fasteners.

Background

The Boeing paint hangar process is outlined in figure 1. Initially the airplane rolls into the paint hangar with a green temporary protective coating (TPC) covering the fuselage surface. At this point, painted surfaces which will be repainted in the hangar are sanded. The TPC remover is then applied to a wet film thickness (WFT) of approximately 20 mils. After the TPC remover dwells on the surface for about ten (10) minutes, it is pressure rinsed off with water (<140 °F). The next step involves solvent cleaning with methyl propyl ketone/methyl ethyl ketone (MPK/MEK) (70/30) and either red Scotchbrite™ pads (Everett) or cheesecloth (Renton/North Boeing Field). Contaminants such as sealant splatter and TPC residue are removed during solvent cleaning. After solvent cleaning, the fuselage surface is power abraded using Type A, very fine Scotchbrite™ pads. The aluminum surface and pads are initially wetted prior to removing any final contamination and part of the aluminum oxide layer. Typically Boeing Quality Assurance and/or airline customers inspect for a water-break-free surface after the power abrade step. Finally, Alodine™ 1000L conversion coating is sprayed on the surface. This solution (30–40 volume percent) is allowed to remain wet on the fuselage surface for three (3) to seven (7) minutes before thorough water rinsing. The conversion coating enhances corrosion protection and paint adhesion. After drying the surface, the airplane is primed and topcoated.

TPC Removal
↓
Solvent Clean
(MPK/MEK)
↓
Power Abrade
↓
Alodine™ 1000L
↓
Paint

Figure 1 –Paint Hangar

Laboratory Tests

Screening tests were conducted on eleven acid cleaners/etchants. Four acid solutions did very well on all the paint adhesion tests (dry/wet tape, condensing humidity, filiform corrosion, rain erosion). However, acid cleaner D1 was the optimum candidate based on the following advantages over the other three acid etchants: (1) no fluoride which is preferable from a health/safety standpoint, (2) negligible etch rate on clad aluminum, and (3) minimal attack on K-coded titanium fasteners. The only drawback to acid cleaner D1 was its low ranking on the 4130 steel weight loss test (least critical). Fifty (50) percent by volume was chosen as the optimum concentration for acid cleaner D1/D2 (D2 is non-dyed version of D1) based on excellent clingability and a uniform coating for the entire fifteen minute dwell time. As a result, all subsequent lab tests were conducted at 50 percent concentration. Airplane compatibility (tests 1–15), equipment/waste treatment compatibility (tests 16–18), and corrosion/adhesion performance (tests 19–21) were investigated. Acid cleaner D1/D2 satisfied all test criteria except for the titanium stress corrosion cracking and hydrogen embrittlement requirements (see table 1). In addition, the following techniques were used to characterize the skin quality clad aluminum and rivet/fastener surfaces at different stages in the paint hangar process: (1) FTIR, (2) TOF-SIMS, and (3) ESCA/SEM.

Table 1
Acid Cleaner D1/D2 Lab Test Results

	Test	Result
1.	Sandwich Corrosion	Pass
2.	Acrylic Crazing	Pass
3.	Ti Stress Corrosion Cracking	Fail
4.	Hydrogen Embrittlement	Fail
5.	Sealant Degradation	Pass
6.	Rubber Degradation	Pass
7.	Rubber Discoloration/Leaching	Pass
8.	Etch Rate	Pass
9.	Anodized Surface Weight Loss	Pass
10.	Rivet/Fastener Weight Loss	Pass
11.	Cd Plate Removal	Pass
12.	Gloss/Specularity	Pass
13.	TPC Removal	Pass/Fail
14.	Appearance	Pass
15.	Paint Softening	Pass/Fail
16.	Tape/Paper Compatibility	Pass
17.	Equipment Compatibility	Maintenance
18.	Waste Treatment Plant Compatibility	Pass
19.	Alodine 1000 Coating Weight	Pass
20.	Alodine 1000 Salt Spray	Pass
21.	Paint Adhesion	Pass

Conclusions

1. The acid cleaner D1/D2 process is equivalent to the power abrade process in terms of skin and rivet/fastener paint adhesion. The optimum parameters for the acid cleaner process are 50 percent concentration and a 10–20 minute contact time. Alodine™ 1000L conversion coating is required in combination with acid cleaner D1/D2 in order to achieve adequate paint adhesion.

2. The test panels from the acid cleaner D1/D2 process were generally as clean as the ones that were power abraded based on Fourier Transform Infrared Spectroscopy (FTIR) analysis (figure 2). The small number of samples are simply an indication of the true results, and many more panels would have to be tested to prove that acid cleaning was more effective than power abrading.

3. Time-of-Flight Secondary Ion Mass Spectrometry (TOF-SIMS) analysis revealed no TPC or acid cleaner D1 residue on a skin quality clad aluminum surface after a 15 minute D1 contact time and water rinsing. However, possible reaction by-products in the form of aromatic hydrocarbon species were detected (figure 3).

4. One possible theory on why the oxide thickness of aluminum stayed relatively constant (180 Å) after acid cleaning with solution D1 is that D1 initially <u>dissolves</u>(-) the oxide layer and then <u>forms</u>(+) a thin reaction layer as an adhesion promoter (table 2).

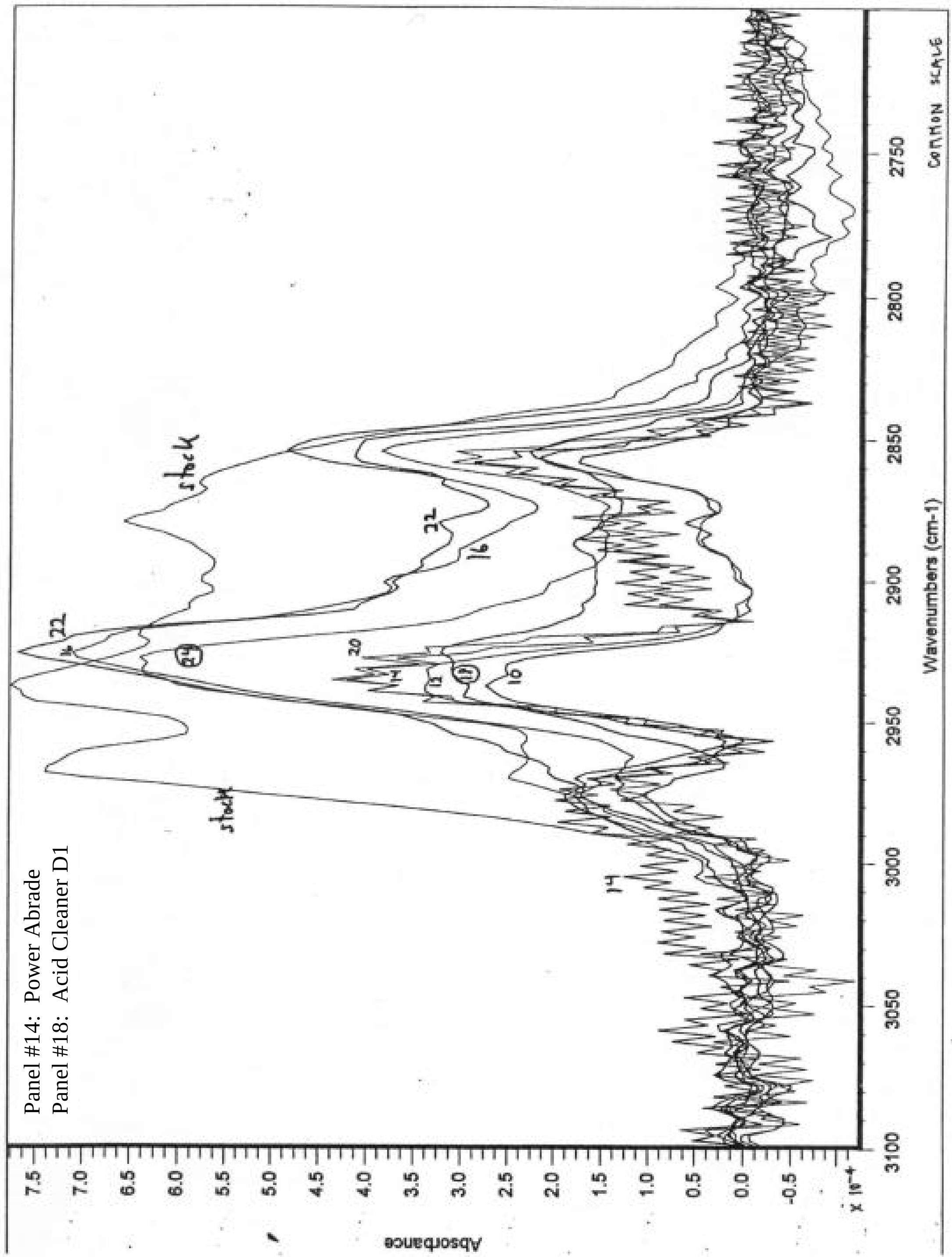

Figure 2 –The C-H Stretch Region of all Nine Aluminum Test Panels (Gold Background)

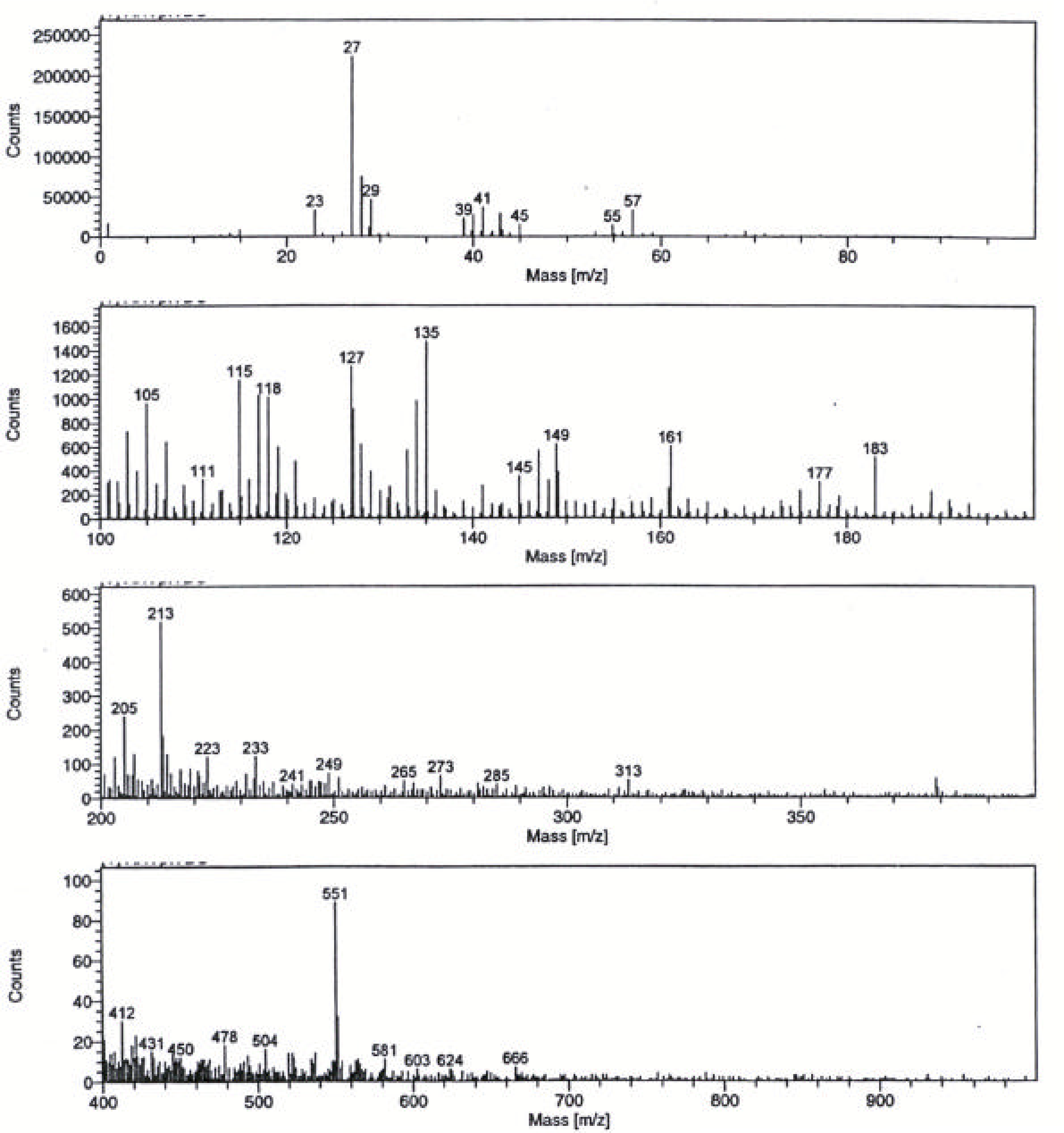

Figure 3 –Positive TOF-SIMS Spectrum of Panel #17 (D1-15 Minutes)

Table 2
Oxide Thickness Values from ESCA Sputter Profiles

Panel No.	Treatment	Oxide Thickness (Å)
0	As Received	165
18	TPC Removal	200
19	MEK	190
20	Power Abrade	260
22	D1 (15 minutes)	180
23	Power Abrade + Alodine 1000L	315
25	D1 (15 minutes) + Alodine 1000L	185