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Rivet Rash – The Itch That Won't Heal

"Rivet rash" refers to selective loss of paint from aluminum rivet heads on in-service aircraft, as shown in Figures 1 and 2 and 3. Airlines are dissatisfied with this condition since it greatly detracts from the airplane's decorative paint appearance in areas most visible to the passengers, namely the 41-section (nose) and entry doors. In addition, rivets can "rash" within six months of delivery giving the airplane a prematurely older appearance.

Rivet rash has been a periodic paint problem throughout aerospace history. Several teams were formed to look at the problem with each having some success reducing rivet rash as a major airline decorative paint issue. However, when Boeing implemented the environmentally compliant high solids paints, airlines complaints on rivet rash increased dramatically.

Figure 1. Rivet rash adjacent to forward airstair door

Figure 2. Rivet rash on fuselage structure

To address the problem, a Boeing-Puget Sound area team was formed. The team consisted of engineers and personnel from Boeing Materials Technology (BMT), Manufacturing Research and Development (MR&D) and Phantom Works. The team also included the rivet vendor, Allfast Fastening Systems, Inc. Using a combination of performance and analytical testing, the team found the failure locus in the rivet rash area to be between the rivets' chromate conversion coating and the decorative paint's primer.

The majority of the rivets that rash in the fuselage are the type GF and FV. They are manufactured from 2000 and 7000 series aluminum respectively. The team focused on these rivets types.

Figure 3. Rivet rash around door

Initial attempts to resolve rivet rash concentrated on improving the rivets' conversion coating process. This conversion coating is used to protect the rivets from corrosion during storage prior to installation and provide an appropriate base to adhere paint.

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The chromate conversion coating is applied per MIL-C-5541 and is subsequently leached in hot water until colorless to provide the appropriate appearance for use on unpainted aluminum-clad surfaces.

The work conducted under this initial study increased our understanding of the process steps involved in finishing the rivets and had some improvement in corrosion resistance, but failed to significantly improve paint adhesion. Therefore, the team agreed that a change to the finish system would be required.

Any finish system chosen for the rivets had to demonstrate compliance with existing engineering requirements for the fastener coatings and perform as well or better than the current system with high process robustness. Rivets installed in the fuselage undergo many intermediate processing steps before the final paint scheme is applied, therefore it was necessary to demonstrate that a new finish on the rivets would be compatible with these intermediate steps.

Most rivets are installed in fuselage skins using automated equipment. The skins typically have a Temporary Protective Coating (TPC) applied either before or after the rivets are installed. Some fuselage sections are assembled in Wichita and shipped by rail to Washington for final assembly. After final assembly is complete, the airplane is moved into a paint hangar where the final series of preparatory steps begins.

The first step is to remove the TPC by spraying on a chemical stripper. The stripper is then washed off the plane with water. The plane is then deoxidized; either mechanically by sanding, or chemically by spraying on a chemical deoxidizer. The plane is washed off again with water to remove sanding residue or the chemical deoxidizer, and to verify that a water break-free-surface has been achieved.

Next a clear, chromated conversion coating, Alodine 1000, is sprayed onto the airplane. The Alodine is allowed to dwell on the surface for a specified time period followed by rinsing with water. This coating is necessary to provide a foundation for the primer to adhere to the plane. Finally, primer and topcoat are applied.

The rivet heads see a variety of processes and environments before the primer is applied. Of particular interest is the doubled conversion coating. The rivets have an initial conversion coating applied by the vendor and then they are coated again immediately prior to painting.

The mechanical deoxidation step is supposed to abrade away the original conversion coating, leaving a freshly exposed metal surface for the application of Alodine 1000. Chemical deoxidation does not remove the original conversion coating but it does reactivate it, making it more receptive to the subsequent application of Alodine 1000. Test results showed the failure locus to be between the rivet's conversion coating and the primer, but they were unable to determine if the conversion coating on the rivet was the initial or secondary coating.

The test results did eliminate the possibility that a weak bond between the two layers of conversion coatings caused the rivet rash. Otherwise traces of conversion coating would have been found on both the rivet and the primer on the paint chip. One explanation is that the Alodine 1000 does not adhere to the original conversion coating. This can happen if the deoxidation procedure does not fully reactivate the conversion coating on the rivet's surface. Chromated conversion coatings are known to harden and lose paint adhesion over time. They are also resistant to the deoxidation procedures. Failure of Alodine 1000 to adhere to the original conversion coating would result in the Alodine 1000 being rinsed off the rivet head during the rinse step. The primer that is then applied forms a weak bond to old conversion coating on the rivet that subsequently fails, leading to rivet rash.

While improved chromate conversion coated rivets still lacked acceptable paint adhesion results, rivets installed and tested using other pretreatment options with the decorative paint systems (BMS 10-72 Type VIII/ IX) primer/topcoat system) had quite promising results. Based on initial assessment of available finish systems, Figure 5, three approaches were down-selected for their merit and ability to meet all requirements for aluminum rivets, including improved paint adhesion.

These approaches were to (1) change to a bare, uncoated rivet; (2) remove the chromate conversion

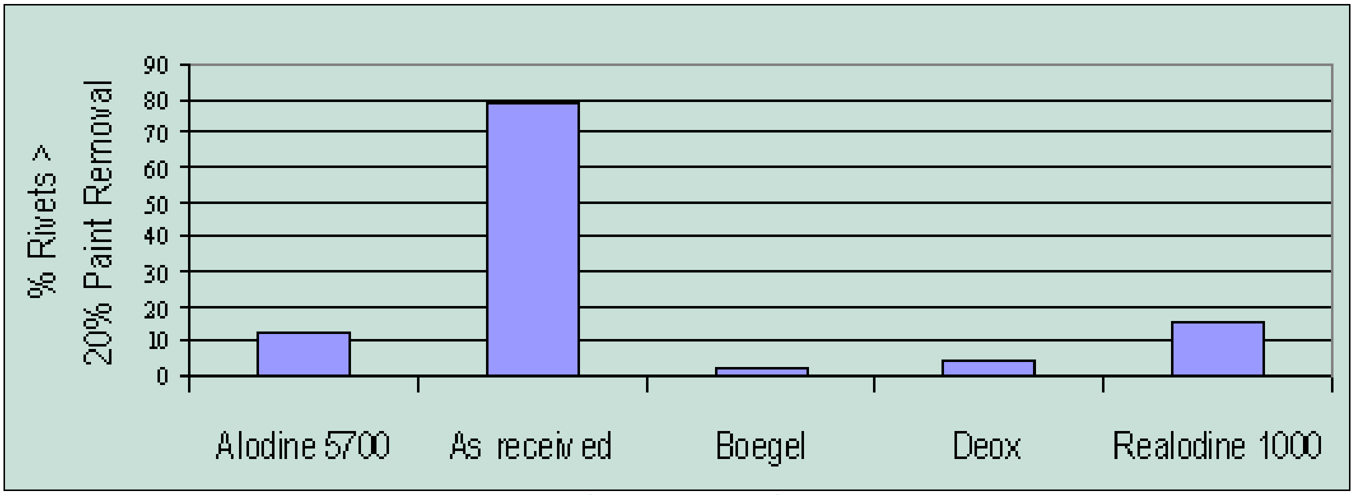

Fig 5. Initial Rivet Coating Adhesion Screening Testing

coating from the top of the rivet by mechanical means (crop-top); and (3) apply Boegel-EPII/AC-131 sol-gel coating, provided by AC Technology (Costa Mesa, CA), to the rivet surface, either by itself or on top of the chromate conversion coating. These three options all eliminate the possibility of applying one chromated conversion coating on top of another.

Testing included assessment of appearance, corrosion protection, adhesion, fatigue, electrical conductivity, automated installation compatibility, joint properties, environmental durability, and rain erosion Other considerations included cost, and manufacturing and schedule impact.

After assessment of the above properties, the Boegel-EPII/AC-131 sol-gel coating system was selected as the one that best met the design targets. Boegel-EPII processes for promoting adhesion on metals have been used in production at The Boeing Company since 1997, with several specifications released covering various applications for painting and bonding on aluminum, titanium, and steel alloys.

The baseline version of Boegel-EPII/AC-131 contains no corrosion inhibitors and thus would not have the stand-alone corrosion resistance necessary to protect the rivets against potential corrosion and pitting when stored in bins in the factory prior to installation on aircraft.

To meet corrosion protection requirements, an inhibitor could be added to the AC-131 formulation, or the sol-gel coating could be applied on top of an existing corrosion-resistant treatment. Testing was conducted using both methodologies, the former using from 500 to 5000 ppm sodium chromate added to the AC-131 and the latter applying the sol-gel on top of the existing chromate conversion coating. Adhesion and corrosion results showed that either approach could effectively solve the problem.

To pose a minimal disruption to the current rivet finishing line, to enable use of the commercially available AC-131 formulation, and to meet schedule deadlines, the process of applying the sol-gel over the clear MIL-C-5541 was selected. This process also allowed the paint hangars to continue without any change in operational procedures.

The resulting rivet with this process will have a multilayer conversion coating system. The original MIL-C-5541 is applied first. The Boegel EPII/AC-131 is applied within 24 hours. These are both colorless coatings and the rivet's appearance is bright and shiny aluminum. These conversion coatings are less than 100 nm thick and do not add to the measurable dimensions of the rivet.

The rivets are then installed in the airplane. Chemical deoxiders used in the paint hangar do not remove the sol-gel from the rivet surface. Mechanical abrasion methods either totally removes the sol-gel leaving a freshly abraded surface or does not completely remove it, either way resulting in good adhesion of the subsequent coating.

Scribed adhesion testing showed vastly improved adhesion under a variety of exposure and aging conditions. A typical paint adhesion test is shown below, in Figure 6, where complete loss of paint occurs from the heads of the baseline off-the-shelf chromate conversion coated rivets, whereas the sol-gel treated rivets show no paint removal at all in the scribed area.

Figure 6. Rivet adhesion testing comparing off-the-shelf (OTS) rivets (top) to sol-gel coated rivets (bottom)

Adhesion tests were conducted using both types of deoxidation methods (Figure 7.)

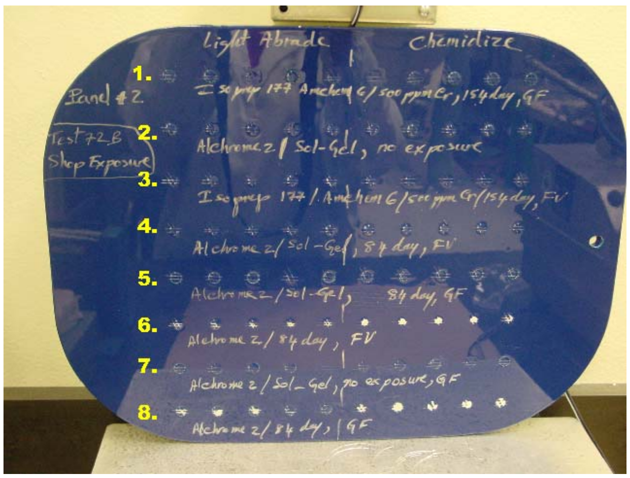

Figure 7. Window cutout panel showing light abrade (right) and Chemidize (left) test rivets.

KEY:

1. **GF rivet, chromated sol-gel, 154 day shop exposure.**
2. **FV rivet, sol-gel over chromate conversion coating, no shop exposure.**
3. **FV rivet, chromated sol-gel, 154 day shop exposure.**
4. **FV rivet, sol-gel over chromate conversion coating, 84 day shop exposure.**
5. **GF rivet, sol-gel over chromate conversion coating, 84 day shop exposure.**
6. **FV rivet, chromate conversion coating, no sol-gel, 84 day shop exposure.**
7. **GF rivet, sol-gel over chromate conversion coating, no shop exposure.**
8. **GF rivet, chromate conversion coating, no sol-gel, 84 day shop exposure.**

Effects of environmental exposure after installation, application of temporary protective coatings, and other manufacturing conditions were also assessed during the test program.

Further efforts to optimize the coating adhesion of the system and manufacturing process for applying the sol-gel coating will continue. However, it is clear from the extensive testing that under all conditions, including rivets aged in a shop environment for 120 days prior to installation, the application of the Boegel-EPII/AC-131 to the rivets will improve coating adhesion to the fasteners.

The implementation plan for the commercial fleet will target the highest need areas first, namely the 41-Section and door areas, followed by the rest of the fuselage. The rivet supplier, Allfast, began processing sol-gel coated FV and GF rivets in March 2003. During the summer of 2003, rivet bins will be selectively filled with the new sol-gel coated rivets and installed on the various aircraft, starting with the 737 in late July 2003.

Customer-delivered aircraft will be monitored subsequent to the new rivet installation to determine the level of effectiveness of the new coatings. Spot monitoring of vendor-supplied rivets is also being carried out to confirm the robustness of the process. (Figure 8.)

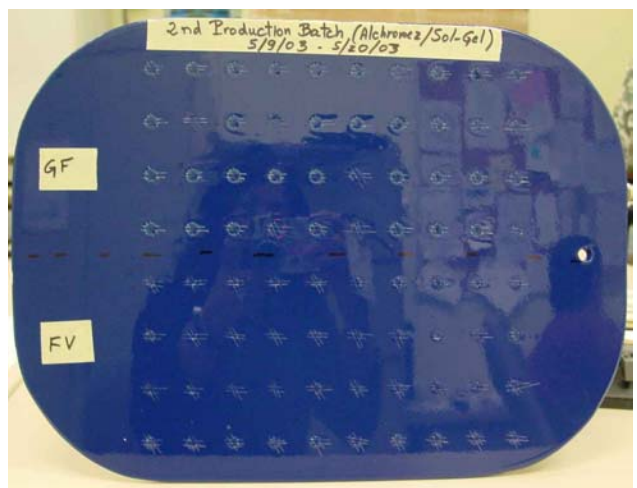

Figure 8. Window cutout panel showing test rivets from the second production batch of sol-gel coated rivets.

*For more information contact Kay Blohowiak at (425)237-4657, email: **kay.y.blohowiak@boeing.com** o r Randy Jahren at (425) 237-4781, e-mail: **randall.l.jahren@boeing.com***