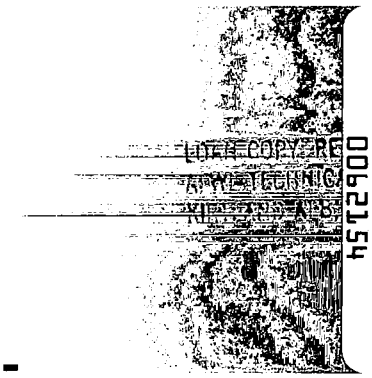

NASA Contractor Report 3617

Service Evaluation of Aluminum-Brazed Titanium (ABTi) Jet Engine Tailpipe Extensions

S. D. Elrod

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Service Evaluation of Aluminum-Brazed Titanium (ABTi) Jet Engine Tailpipe Extensions

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and Space Administration

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Information Branch**

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SUMMARY

Aluminum-brazed titanium (ABTi) tailpipe extensions were installed on three Model 737 aircraft for service evaluation. The tailpipe extensions were inspected at 6- to 12-month intervals for 3 years. At the end of the 3-year service evaluation, two of the three parts showed evidence of corrosion and were returned to Boeing for inspection.

Examination of the tailpipe extensions showed that corrosion occurs primarily in environments where the parts are subjected to frequent rain and high humidity. Other factors contributing to corrosion of ABTi in this application are a hydrophilic sooty coating on the parts and extended periods of nonoperational (parked) status.

ABTi is not acceptable for acoustic components in such applications as jet engine tailpipes under the conditions discussed above. ABTi may be acceptable for acoustic applications in less severe environments. Additional evaluation is required to establish acceptable applications and environments.

INTRODUCTION

Aluminum-brazed titanium (ABTi) was conceived and developed as a structural honeycomb sandwich. (In this case, "structural" means load-bearing components with solid skins on both sides.) As such, all exposed braze alloy (aluminum) was at the edges and could be protected by appropriate coatings; therefore, corrosion was no problem. The temperature regimes that occur in some areas of jet engines are such that ABTi would be an excellent material for parts such as tailpipes. However, the parts also have to perform a sound-attenuation (acoustic) function in this application. The acoustic function requires use of an inner skin that is perforated to make the honeycomb cell resonating chambers. The perforations result in atmospheric exposure of the aluminum braze alloy throughout the panel, where it is extremely difficult to apply a

protective coating. However, the application as a jet engine tailpipe should keep the part sufficiently warm that water should not accumulate and cause corrosion.

To evaluate this potential application, Boeing installed ABTi tailpipe extensions on three Model 737 aircraft in commercial service for a 3-year service evaluation. The cooperating airlines were Aloha, Piedmont, and Western. NASA Contract NAS1-13681 covered the corrosion aspects of the service exposure. This supplementary report to NASA Contractor Report 3418 covers the corrosion behavior of these tailpipes under commercial service conditions.

PROCEDURE

The ABTi tailpipe extensions are straight cylinders placed between the aft end of the engine and the exhaust nozzle. Figure 1 shows the general configuration of the part and its location on the airplane. The extensions are 91.4 cm (36 in.) long and have a 111.8 cm (44 in.) inside diameter. Both skins are 0.51 mm (0.020 in.) thick Ti-6Al-4V; the inner skin is perforated with a staggered array of 1.3 mm (0.050 in.) diameter holes, giving a 9 percent open area. Figure 2 is a photograph of a section of the inner skin. The core is 0.95 cm (3/8 in.) square cell with 0.076 mm (0.003 in.) thick, perforated and corrugated cell walls made from Ti-3Al-2.5V. The parts were fabricated by Boeing Wichita to the requirements of BAC 5967.

The tailpipe extensions were inspected at intervals from 6 to 12 months using visual, eddy-current, and coin-tap techniques. Anomalies were detected in the Aloha and Piedmont pipes; no anomalies were detected in the Western pipe.

At the end of the 3-year evaluation period, the Aloha and Piedmont pipes were returned to Boeing for evaluation; the Western pipe was left in service. Upon receipt by Boeing, the pipes were thoroughly inspected, and 7.6 cm (3 in.) diameter disks were removed from the suspect areas and other representative locations and cut in half through the core for examination.

RESULTS

The inner surfaces of the tailpipes were coated with a hydrophilic black sooty deposit that subsequent examination showed to have penetrated into and coated the inside of the cell walls. Examination of the disks cut from the Aloha pipe showed gross corrosion of the braze fillets in a small--approximately 7.6 by 12.7 cm (3 by 5

in.)--triangular area, with the base of the triangle at the aft end of the pipe on the bottom centerline. The amount of corrosion decreased rapidly forward or up the sides of this area.

The specimens were cleaned to remove the soot coating and examined. Figure 3 is a photomacrograph of a typical specimen with the inner, perforated skin on top and the outer skin on the bottom. Figure 4a is a scanning electron microscope (SEM) photograph of the core and inner skin at the most severely corroded area; the braze fillet is almost entirely gone. Figure 4b is an SEM photograph of the core and outer skin in the same general area as shown in Figure 4a; there is no evidence of significant corrosion. Figure 5 is an SEM photograph of the core and inner skin at a point approximately 12.7 cm (5 in.) away from the area shown in Figure 4; the braze fillet is severely corroded in the vicinity of the perforations, but is essentially intact a short distance away. A disk cut from approximately halfway up the side of the pipe exhibited significant corrosion, essentially equivalent to that shown in Figure 5. The presence of corrosion on the side of the pipe indicates that the sooty coating is hygroscopic as well as hydrophilic.

Examination of the disks cut from the Piedmont pipe showed that the anomalies were primarily artifacts from the original braze operation, with only minor, superficial corrosion. A sample cut from the aft end at the bottom centerline exhibited more extensive corrosion (20-40%), essentially equivalent to that shown in Figure 5.

ANALYSIS AND DISCUSSION

Aloha Airlines operating procedures and environment present very severe corrosion conditions. The aircraft are parked all night every night at Honolulu Airport, where they are subjected to frequent rain and high humidity. Due to the orientation of the engine, any water entering the tailpipe collects near the aft end of the tailpipe extension.

Previous work (refs. 1, 2, and 3) has shown that ABTi ordinarily corrodes only in the presence of liquid water. The absence of corrosion in the bottom of the cell, where water would naturally collect, and the gross corrosion at the top of the cell, where it should be dry, are puzzling. The following could account for the phenomenon (fig. 6):

- The perforations are too small for water to run into the cells. This has been demonstrated by test and by the absence of corrosion in the bottom of the cells.
- The sooty coating is hydrophilic, as demonstrated by test.

- Water coming into contact with the inner skin of the pipe is absorbed by the sooty layer, and to a lesser degree the sooty coating absorbs moisture from the atmosphere. At a skin perforation, the soot wicks a small quantity of water through the perforation and into contact with the adjoining fillets, initiating corrosion. The concept is exemplified in Figure 5, where the fillet is severely corroded in the immediate vicinity of the perforation, but is less corroded a short distance away.
- The quantity of water wicked into the cells is too small to produce any accumulation of water in the bottom of the cells.
- Carbon is cathodic to aluminum and is a known accelerator of corrosion of aluminum in the presence of moisture.

The operating area of Piedmont Airlines, east coast of the United States, is known to be a much less severe corrosion environment than Hawaii. The corrosion evidenced by the pipes from Aloha and Piedmont correlates with these factors.

CONCLUSIONS

ABTi is not acceptable for acoustic components (honeycomb sandwich with a perforated skin) for such applications as jet engine tailpipes.

ABTi may be acceptable for acoustic applications where one or more of the following factors exist:

- Dry environment
- Engine cowlings or other components that do not acquire a hydrophilic/ hygroscopic (soot) coating

Additional tests and evaluation will be required to establish the specific applications and conditions that are acceptable.

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March 1982

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3. Elrod, S. D.; and Lovell, D. T.: SST Technology Follow-on Program, Phase I: Development of Aluminum-Brazed Titanium Honeycomb Sandwich Structure. Report No. FAA-SS-72-03, July 1972.

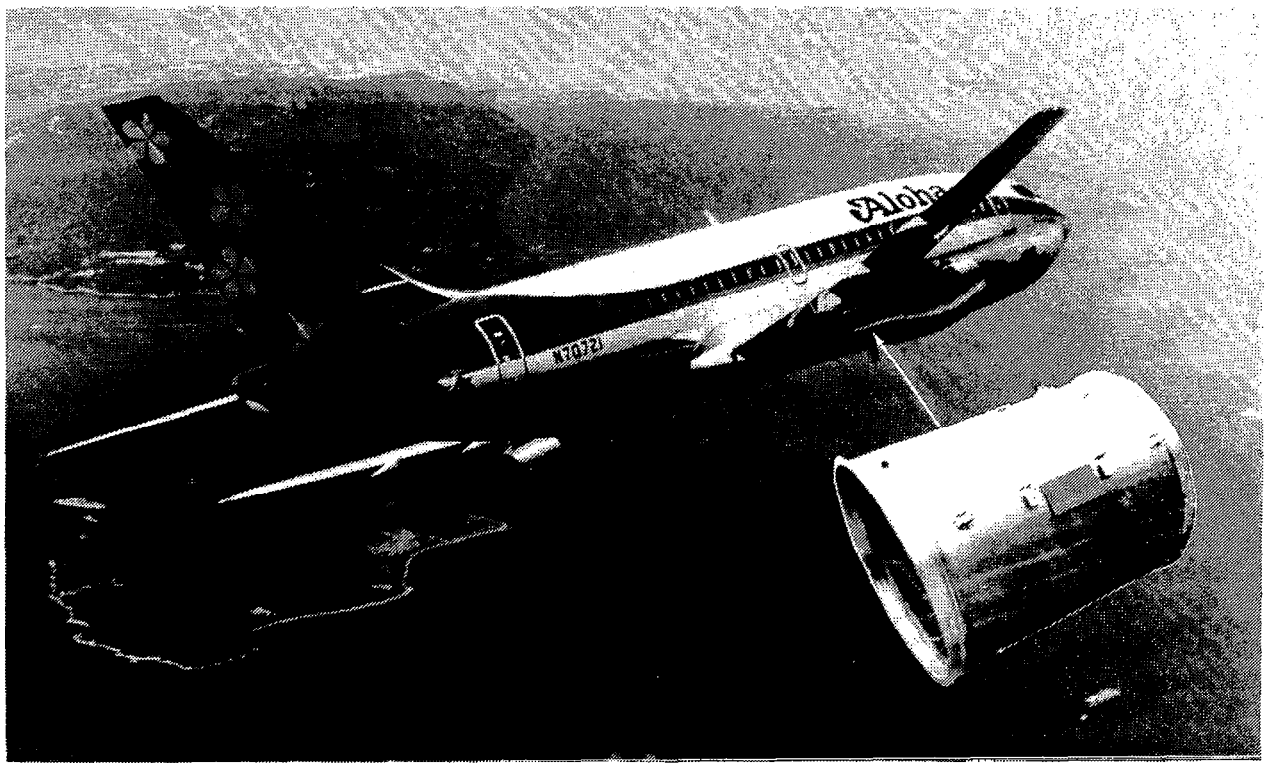


Figure 1. 737 Tailpipe Extension

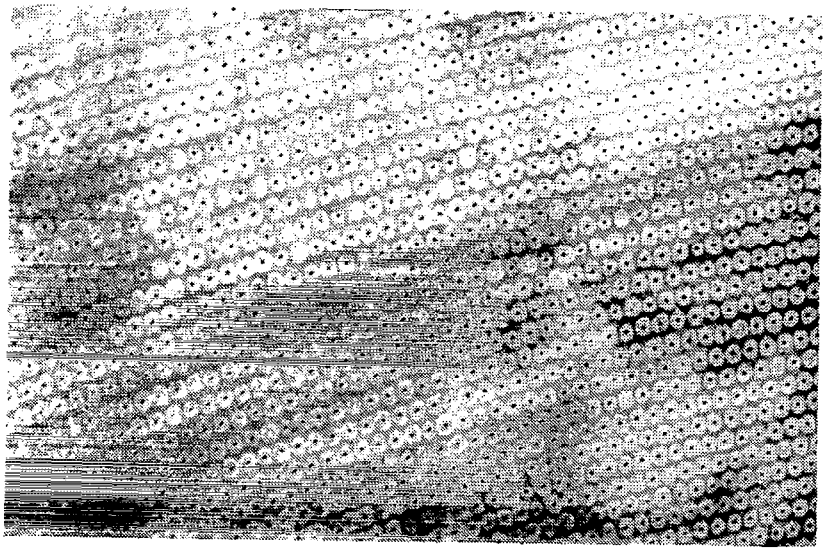


Figure 2. Photograph of Inner Skin Showing Perforations

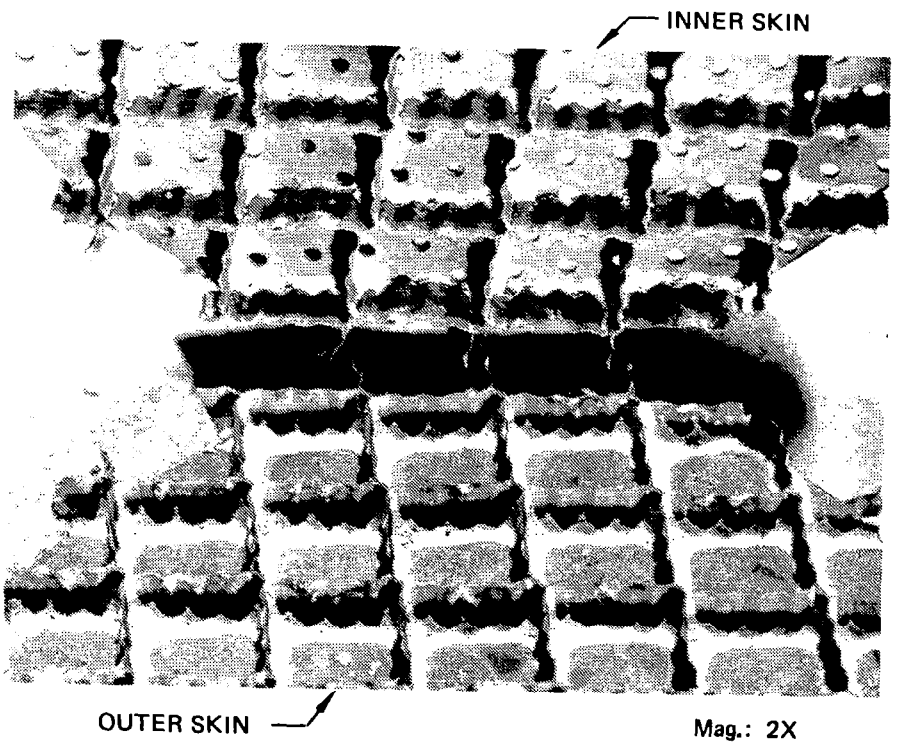
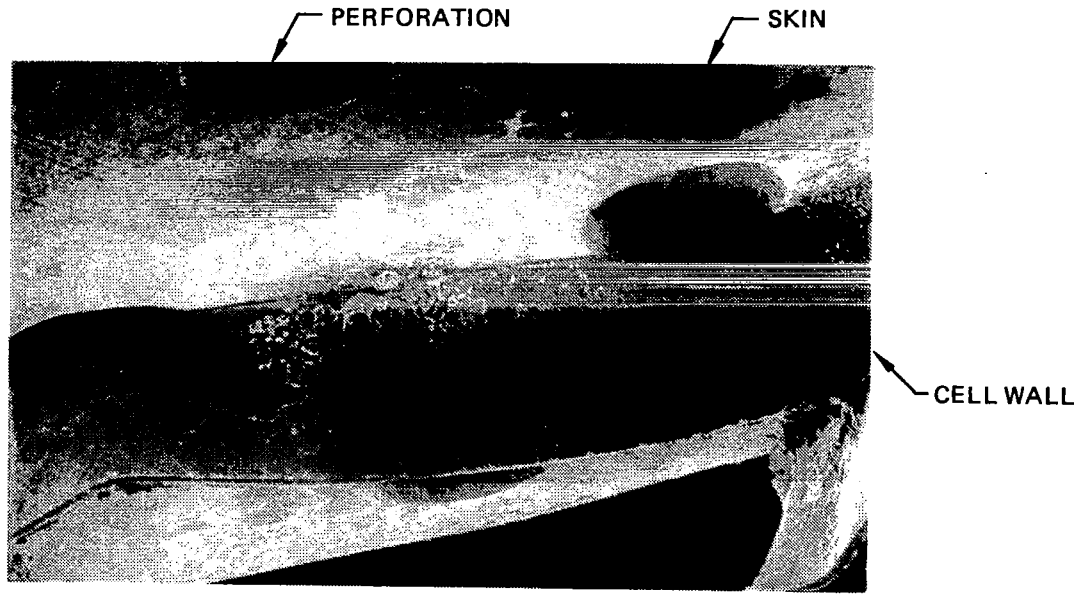


Figure 3. Photomacrograph of the Inside of 7.6 cm (3 in) Specimen Disk



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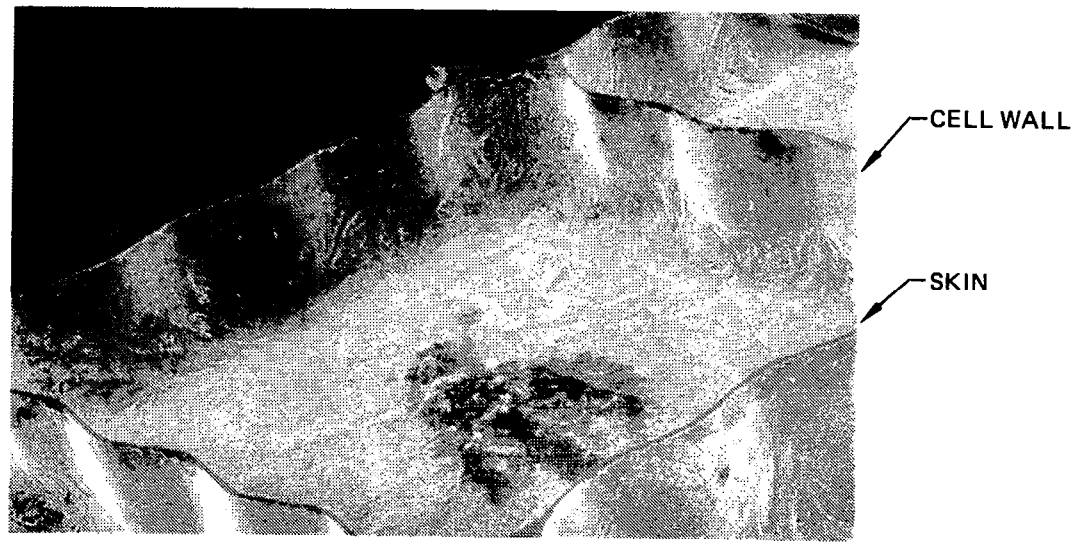
a. Inner Skin Showing Severe Corrosion



Mag.: 25X

b. Outer Skin Showing No Significant Corrosion

Figure 4. SEM Photographs of the Interior of Cells at the Aft Centerline of Aloha Pipe

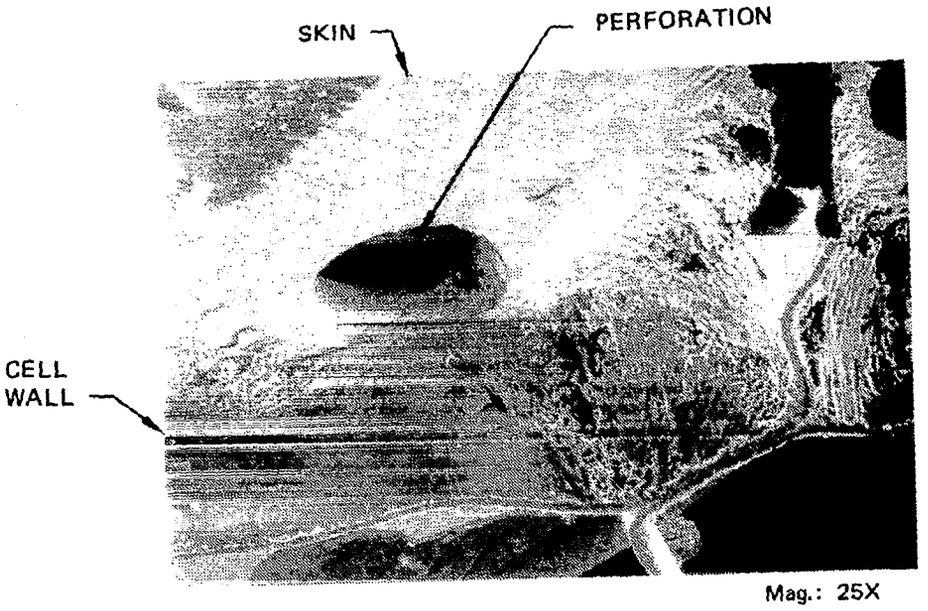


Figure 5. SEM Photograph of the Interior of a Cell Showing Preferential Corrosion in the Vicinity of the Perforation

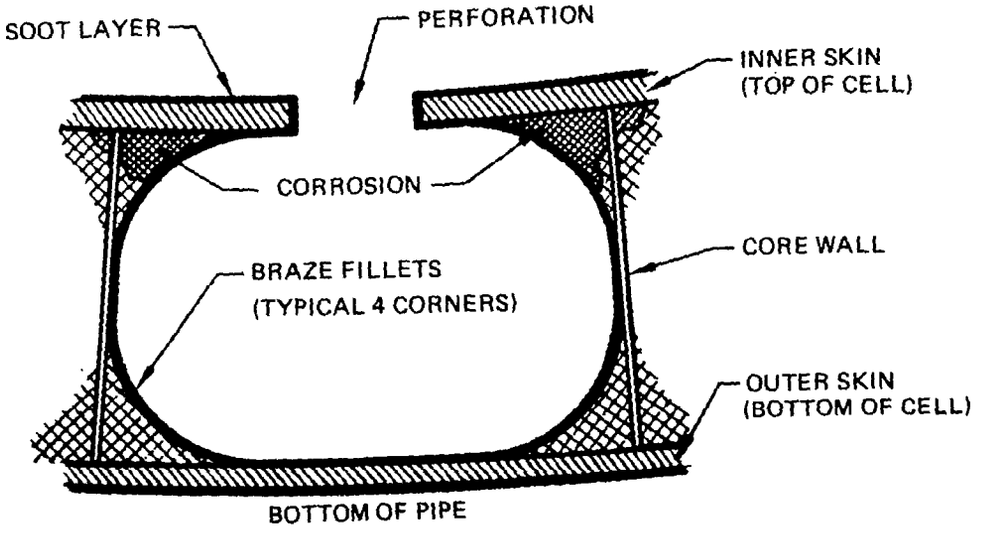


Figure 6. Schematic of a Single Cell Showing Soot Layer and Related Corrosion

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15. Supplementary Notes

Langley Technical Monitor: W. Barry Lisagor
Supplementary Report – Addendum to NASA CR-3418

16. Abstract

Aluminum-brazed titanium (ABTi) jet engine tailpipe extensions were evaluated in commercial service over a 3-year period. The purpose of the evaluation was to determine the corrosion resistance of ABTi in acoustic applications (i.e., honeycomb sandwich incorporating a perforated inner skin). The results showed that ABTi does not have acceptable corrosion resistance in acoustic applications under severe operating conditions, but may be acceptable for acoustic applications in less severe environments.

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