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EVALUATION OF BRAZING ALLOYS FOR THE

FABRICATION OF INCONEL 718

HONEYCOMB SANDWICH PANELS

REPORT A469 SERIAL NO. 20

MCDONNELL

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Air Force Systems Command, United States
Air Force, Wright-Patterson Air Force Base,
Ohio, or McDonnell Aircraft Corporation,
St. Louis, Missouri

INDEX

CODE (Ni-b)(I-t)(IV-a)(VI-b)
LABORATORY: Structures

EVALUATION OF BRAZING ALLOYS FOR THE FABRICATION OF INCONEL 718 HONEYCOMB SANDWICH PANELS

ABSTRACT

A nickel base structural alloy, Inconel 718, has been considered for use in the fabrication of honeycomb structures capable of sustained operation at elevated temperatures. Four gold-containing braze alloys were selected for compatibility testing with Inconel 718 base metal.

From the results of these tests Premabrace 128 and Premabrace 130 braze alloys appeared to be suitable for honeycomb structure brazing with Inconel 718 as base metal. No evidence was found to indicate that either of these braze alloys are susceptible to crevice corrosion. The Nicoro and Incuro 20 braze alloys were eliminated from testing because of inferior wettability and flow characteristics.
1. INTRODUCTION

 Brazed honeycomb construction can be highly efficient in the production of thin airfoil or control surface panels capable of withstanding the effects of high temperature operation. Inconel 718 has come under consideration as a base metal alloy for this type of structure, but little data concerning the compatibility of Inconel 718 and commercial braze alloys is available. Four gold-containing braze alloys were selected for study as possible Inconel 718 honeycomb brazing materials.

 Wettability, lap shear, crevice corrosion, and edgewise compression tests were conducted in a braze alloy evaluation program by the McDonnell Structures Laboratory during the period 12 June through 27 November 1962.

 2. DESCRIPTION OF TEST ARTICLES

 2.1 Base Metal

 Annealed Inconel 718 sheet stock (0.012, 0.025, and 0.043-inch thick), and honeycomb core (0.002-inch ribbon and 0.25-inch cell size) were furnished for specimen fabrication.

 The chemical composition of Inconel 718, in percent, is tabulated below:

 Ni - 50.0-55.0 C - 0.10 max.
 Cr - 17.0-21.0 Si - 0.75 max.
 Nb-Ta - 4.5-5.75 Mn - 0.50 max.
 Mo - 2.8-3.3 S - 0.03 max.
 Al - 0.2-1.0 Cu - 0.75 max.
 Ti - 0.3-1.3 Fe - balance

 2.2 Braze Alloys

 The four gold-containing braze alloys were in the form of 0.001 or 0.002 inch thick foils. Their chemical compositions and temperature characteristics are listed below:

<table>
<thead>
<tr>
<th></th>
<th>Prembras 128</th>
<th>Prembras 130</th>
<th>Micro</th>
<th>Incuro 20</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Au</td>
<td>72</td>
<td>62</td>
<td>35</td>
<td>20</td>
</tr>
<tr>
<td>% Ni</td>
<td>22</td>
<td>18</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>% Cu</td>
<td>6</td>
<td>62</td>
<td>78</td>
<td></td>
</tr>
<tr>
<td>% Cr</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>% In</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Melt Point</td>
<td>1785°F</td>
<td>1746°F</td>
<td>1832°F</td>
<td>1787°F</td>
</tr>
<tr>
<td>Flow Point</td>
<td>1855°F</td>
<td>1746°F</td>
<td>1886°F</td>
<td>1877°F</td>
</tr>
</tbody>
</table>

 3. TEST PROCEDURE

 3.1 Wettability Tests

 Eighty Inconel 718 test blanks, one square inch in area, were sheared from 0.025 inch thick sheet material. Several of these blanks were cleaned by each of the following procedures:
3.1 Wettability Tests (Continued)

Procedure A - Vapor degreased per PS 12010;
Alkaline cleaned per PS 12030;
Rinsed with tap water, and dried by forced air.

Procedure B - Vapor degreased per PS 12010;
Pickled in 30 percent HNO₃ - 2 percent HF solution (120°F) for ten minutes;
Rinsed in tap water, and dried by forced air.

Procedure C - Vapor degreased per PS 12010;
Liquid honed per PS 12045;
Rinsed in tap water, and dried by forced air.

Procedure D - Vapor degreased per PS 12010;
Alkaline cleaned per PS 12030;
Pickled in 30 percent HNO₃ - 2 percent HF solution (120°F) for ten minutes;
Rinsed with tap water, and dried by forced air.

The specimens were handled with white gloves after cleaning and during layup for brazing. The braze alloys were cleaned with trichlorethylene immediately before application. The braze alloy foils were cut into 0.25-inch squares which were stacked to a depth of 0.006 inch upon each Inconel 718 wettability test blank. Two specimens were prepared with each braze alloy tested for each combination of cleaning procedure and brazing temperature.

The wettability specimens were brazed in a vacuum retort which was evacuated to a pressure lower than one micron before heating. While this vacuum was maintained, the specimens were heated to brazing temperature with a graphite cloth heating element. After brazing, the specimens were cooled to below 600°F under vacuum, and then air cooled to room temperature. Test brazes were conducted at the following temperatures:

<table>
<thead>
<tr>
<th>Braze Alloy</th>
<th>Test Temperatures (°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Premabraze 128</td>
<td>2000, 2050</td>
</tr>
<tr>
<td>Premabraze 130</td>
<td>1800, 1900</td>
</tr>
<tr>
<td>Nicoro</td>
<td>1875, 1925, 2000</td>
</tr>
<tr>
<td>Incuro 20</td>
<td>1860, 1910, 2000</td>
</tr>
</tbody>
</table>

After measurement of the flow radius, the wettability specimens were mounted for metallographic examination.

3.2 Lap Shear Tests

Inconel 718 sheet, 0.043 inch thick, was sheared into pieces 4.5 x 8 inches in area for lap shear brazes. From the wettability test results,
3.2 Lap Shear Tests (Continued)

Cleaning procedure B was selected for the preparation of the Inconel 718 during this phase of the program. Also from the wettability test results, the braze alloys selected for further evaluation were Premabraze 128 and 130.

The lap shear panel parts were cleaned immediately before layup and were handled with white gloves during layup. A 0.002-inch thick braze alloy foil strip was placed between two 4.5 x 8-inch Inconel 718 pieces to form a single panel measuring approximately 9 x 8 inches in area. A 3/4 overlap and the minimum possible clearance were maintained during layup and brazing.

The vacuum brazing procedure followed was similar to that of the wettability test specimens, except that the time at temperature was shortened to three minutes. The Premabraze 128 lap shear panels were brazed at 2050°F, and the Premabraze 130 panels at 1900°F. All lap shear specimen panels were cooled in the retort, under vacuum, to below 60°F before air cooling to room temperature.

After cooling, the specimens were aged by heating at 1325°F for eight hours, then furnace cooling at 100°F/hr to 1150°F, holding at this temperature for eight hours, followed by air cooling to room temperature.

The lap shear panels were friction sawed into 0.75-inch strips with the brazed joint perpendicular to the long axis and deburred to produce specimens as shown in Figure 1 on page 15.

Lap shear specimens brazed with Premabraze 128 and 130 were tested at room temperature and at 1000°F in a 60,000-pound Baldwin universal testing machine. Load was applied at a rate of 3000 lb/min until failure. The specimens tested at 1000°F were heated to temperature in one minute with quartz radiant lamp bars, held at temperature for five minutes, and tested.

Three specimens joined with each braze alloy were exposed to a 20 percent salt spray solution at 95°F for 100 hours per Federal Test Method Standard 151a, Method 811.1. Three additional specimens joined with each alloy were submerged in aerated water at room temperature for 100 hours. After the exposure periods, the specimens were tested in tension at room temperature to determine whether any damage had been sustained from crevice corrosion.

3.3 Honeycomb Brazing Tests

Inconel 718 face skins and cores were prepared for brazing two honeycomb specimens with Premabraze 128 as braze alloy, and two with Premabraze 130. The face skins, measuring 3.5 x 2.3 inches in length and width, were sheared from a 0.012-inch thick sheet, and the matching cores were cut from 0.63-inch material having a 0.002-inch foil thickness.
3.3 Honeycomb Brazing Tests (Continued)

The cores and face skins were cleaned according to Procedure D described in section 3.1. The braze alloys were cleaned with trichlorethylene. The parts were handled with white gloves during layup. A single sheet of 0.002-inch thick braze alloy was laid between each face skin and the core, and the specimens sealed into vacuum envelopes for brazing.

After placing the brazing envelope and specimen in the retort, the envelope and retort were both evacuated to a pressure of less than one micron. With this vacuum maintained upon the envelope, the retort was back filled to provide a differential pressure of approximately two psi on the envelope.

Brazing was conducted at 2050°F with Premabraze 128, and at 1900°F with Premabraze 130 alloy. In each case, the specimens were held for three minutes at brazing temperature and cooled to below 300°F in the envelope under vacuum.

The honeycomb specimens were heat treated similarly to the lap shear specimens, except that they were left in the brazing envelope and a continuous flow of argon gas was maintained throughout the aging cycle.

After heat treatment, the honeycomb edgewise compression specimens were machined to three inches in length and two inches in width. The two-inch ends were ground to a parallelism within 0.001 inch/inch.

With parallel loading plates clamped lightly to the specimen ends, compressive testing was conducted in a 60,000-pound Baldwin universal testing machine. Each specimen was loaded to failure at a rate of 1500 lb/min. One specimen brazed with each filler alloy was tested at room temperature and one of each at 1000°F. The elevated temperature test specimens were heated with quartz radiant lamp banks and held at temperature for fifteen minutes prior to testing. The edgewise compression test setup is shown in Figure 14 on page 26.

L. TEST RESULTS

Premabraze 128 and Premabraze 130 wettability data is tabulated in Tables 1 and 2 on pages 8 and 9. Photographs of all Premabraze 128 and Premabraze 130 wettability specimens are shown in Figures 2 through 5 on pages 16 through 19, with representative specimens of Nicoro and Incuro 20 shown in Figures 6 and 7 on pages 20 and 21. Typical base metal-braze alloy interfaces of Premabraze 128 and Premabraze 130 are shown in Figures 8 and 9 on page 22.

Shear strength data for Premabraze 128 and Premabraze 130, at room temperature and 1000°F, is presented in Tables 3 and 4 on pages 10 and 11.
4. TEST RESULTS (CONTINUED)

The room temperature shear strengths of Premabraze 128 and Premabraze 130, after crevice corrosion tests, are tabulated in Tables 5 and 6 on pages 12 and 13.

Edgewise compression test data obtained by testing honeycomb specimens brazed with Premabraze 128 and with Premabraze 130 braze alloys is presented in Table 7 on page 14. Photographs of all failed compression specimens are shown in Figures 10 and 11, on pages 23 and 24. Photomicrographs of typical honeycomb-to-skin brazed joints are presented in Figures 12 and 13 on page 25.

5. DISCUSSION OF TEST RESULTS

The limited quantity of gold-containing braze alloys available for the wettability tests did not permit the formation of a measurable contact angle. Therefore, a standard wettability rating could not be computed. Braze alloy selection for further testing was, therefore, based upon the measured flow radius. Extremely poor flow characteristics were exhibited by Nicoro and Incoro 20 alloys, regardless of surface preparation or brazing temperature (see Figures 6 and 7 on pages 20 and 21). Further evaluation of these two alloys was not conducted.

Both Premabraze filler alloys showed good flow characteristics, particularly upon Inconel 718 surfaces prepared by cleaning procedures B or D, as described in Section 3.1. Cleaning procedure D, requiring vapor degreasing, alkaline cleaning, HNO₃ - HF pickling, tap water rinsing, and forced air drying was selected for the preparation of Inconel 718 for brazing lap shear and honeycomb specimens.

Evaluation of the lap shear test data in Tables 3 and 4 on pages 10 and 11, revealed that joints brazed with Premabraze 128 failed at higher average shear stresses than did those brazed with Premabraze 130 (50,900 psi versus 46,200 psi) when tested at room temperature. In tests conducted at 1000°F, however, Premabraze 130 joints failed at an average shear stress of 32,500 psi and Premabraze 128 joints at 31,300 psi average.

The lap shear specimens subjected to salt spray and aerated water exposure before room temperature shear tests failed generally at shear stresses higher than those developed by unexposed specimens. This probably was caused by variation in overlap or joint clearance.

Higher failing edgewise compression stresses were exhibited by the honeycomb specimens brazed with Premabraze 128 when tested at room temperature and at 1000°F. A comparison of the test results is tabulated on the following page.
5. DISCUSSION OF TEST RESULTS (CONTINUED)

<table>
<thead>
<tr>
<th>Brazing Alloy</th>
<th>Tensile Edge Wise Compression Stress (psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>H.T.</td>
</tr>
<tr>
<td>Prema-braze 128</td>
<td>167,600</td>
</tr>
<tr>
<td>Prema-braze 130</td>
<td>156,500</td>
</tr>
</tbody>
</table>

Visual examination of the brazed honeycomb specimens indicated that Prema-braze 128 tends to form larger fillets than does Prema-braze 130.

6. CONCLUSION

Both Prema-braze 128 and Prema-braze 130 appeared suitable for brazing Inconel 718. No evidence that either of these braze alloys applied to Inconel 718 is susceptible to crevice corrosion appeared in these test results. Although the mechanical properties of structures brazed with Prema-braze 128 were nearly always higher than those of similar specimens brazed with Prema-braze 130, the lower brazing temperature of Prema-braze 130 may be preferable because of the thermal effects on the Inconel 718 base metal.

Nicooro and Incuro 20 braze test results indicated that these alloys are unsuitable for vacuum brazing Inconel 718.
# Table: OremBraze 128 Wettability Data

<table>
<thead>
<tr>
<th>Specimen Number</th>
<th>Surface Condition</th>
<th>Braze Temp (°F)</th>
<th>Time at Temp (min)</th>
<th>Wetted Area (in²)</th>
<th>Flow Radius (in)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A</td>
<td>2000</td>
<td>15</td>
<td>0.192</td>
<td>0.123</td>
</tr>
<tr>
<td>2</td>
<td>A</td>
<td></td>
<td></td>
<td>0.133</td>
<td>0.081</td>
</tr>
<tr>
<td>3</td>
<td>B</td>
<td></td>
<td></td>
<td>0.196</td>
<td>0.125</td>
</tr>
<tr>
<td>4</td>
<td>B</td>
<td></td>
<td></td>
<td>0.192</td>
<td>0.123</td>
</tr>
<tr>
<td>5</td>
<td>C</td>
<td></td>
<td></td>
<td>0.216</td>
<td>0.137</td>
</tr>
<tr>
<td>6</td>
<td>C</td>
<td></td>
<td></td>
<td>0.207</td>
<td>0.131</td>
</tr>
<tr>
<td>7</td>
<td>D</td>
<td></td>
<td></td>
<td>0.200</td>
<td>0.127</td>
</tr>
<tr>
<td>8</td>
<td>D</td>
<td></td>
<td></td>
<td>0.183</td>
<td>0.116</td>
</tr>
<tr>
<td>11</td>
<td>A</td>
<td>2050</td>
<td>15</td>
<td>0.166</td>
<td>0.105</td>
</tr>
<tr>
<td>12</td>
<td>A</td>
<td></td>
<td></td>
<td>0.176</td>
<td>0.112</td>
</tr>
<tr>
<td>13</td>
<td>B</td>
<td></td>
<td></td>
<td>0.209</td>
<td>0.133</td>
</tr>
<tr>
<td>14</td>
<td>B</td>
<td></td>
<td></td>
<td>0.232</td>
<td>0.146</td>
</tr>
<tr>
<td>15</td>
<td>C</td>
<td></td>
<td></td>
<td>0.075</td>
<td>0.030</td>
</tr>
<tr>
<td>16</td>
<td>C</td>
<td></td>
<td></td>
<td>0.096</td>
<td>0.050</td>
</tr>
<tr>
<td>17</td>
<td>D</td>
<td></td>
<td></td>
<td>0.210</td>
<td>0.134</td>
</tr>
<tr>
<td>18</td>
<td>D</td>
<td></td>
<td></td>
<td>0.116</td>
<td>0.067</td>
</tr>
</tbody>
</table>

**Notes:**
- A - Vapor degreased and alkaline cleaned.
- B - Vapor degreased and HNO₃-HF pickled.
- C - Vapor degreased and liquid honed.
- D - Vapor degreased, alkaline cleaned and HNO₃-HF pickled.

△ Area of braze alloy after flow.
△ Radius of braze alloy after flow less radius of braze alloy before flow.
△ Braze alloy run off one edge of specimen.
<table>
<thead>
<tr>
<th>Specimen Number</th>
<th>Surface Condition</th>
<th>Brazing Temp (°F)</th>
<th>Time at Temp (min)</th>
<th>Wetted Area (in²)</th>
<th>Flow Radius (in)</th>
</tr>
</thead>
<tbody>
<tr>
<td>21</td>
<td>A</td>
<td>1800</td>
<td>15</td>
<td>0.010</td>
<td>-0.070</td>
</tr>
<tr>
<td>22</td>
<td>A</td>
<td></td>
<td></td>
<td>0.019</td>
<td>-0.048</td>
</tr>
<tr>
<td>23</td>
<td>B</td>
<td></td>
<td></td>
<td>0.010</td>
<td>-0.070</td>
</tr>
<tr>
<td>24</td>
<td>B</td>
<td></td>
<td></td>
<td>0.011</td>
<td>-0.067</td>
</tr>
<tr>
<td>25</td>
<td>C</td>
<td></td>
<td></td>
<td>0</td>
<td>-0.125</td>
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<tr>
<td>26</td>
<td>C</td>
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<td></td>
<td>0</td>
<td>-0.125</td>
</tr>
<tr>
<td>27</td>
<td>D</td>
<td></td>
<td></td>
<td>0.013</td>
<td>-0.060</td>
</tr>
<tr>
<td>28</td>
<td>D</td>
<td></td>
<td></td>
<td>0.012</td>
<td>-0.065</td>
</tr>
<tr>
<td>31</td>
<td>A</td>
<td>1900</td>
<td>15</td>
<td>0.107</td>
<td>0.060</td>
</tr>
<tr>
<td>32</td>
<td>A</td>
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<td></td>
<td>0.146</td>
<td>0.091</td>
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<tr>
<td>33</td>
<td>B</td>
<td></td>
<td></td>
<td>0.144</td>
<td>0.089</td>
</tr>
<tr>
<td>34</td>
<td>B</td>
<td></td>
<td></td>
<td>0.134</td>
<td>0.081</td>
</tr>
<tr>
<td>35</td>
<td>C</td>
<td></td>
<td></td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>36</td>
<td>C</td>
<td></td>
<td></td>
<td>0.162</td>
<td>0.102</td>
</tr>
<tr>
<td>37</td>
<td>D</td>
<td></td>
<td></td>
<td>0.139</td>
<td>0.086</td>
</tr>
<tr>
<td>38</td>
<td>D</td>
<td></td>
<td></td>
<td>0.142</td>
<td>0.088</td>
</tr>
</tbody>
</table>

Notes: 
- A - Vapour degreased and alkaline cleaned.
- B - Vapour degreased and HNO₃-HF pickled.
- C - Vapour degreased and liquid honed.
- D - Vapour degreased, alkaline cleaned and HNO₃-HF pickled.

- Area of Brazed Alloy After Flow
- Radius of Brazed Alloy After Flow - Less Radius of Brazed Alloy Before Flow
- Brazed Alloy ran off one edge of Specimen.
<table>
<thead>
<tr>
<th>TEST TEMP (°F)</th>
<th>BASE METAL THICKNESS (in)</th>
<th>OVERLAP (in)</th>
<th>BASE METAL AREA (in²)</th>
<th>BRAZE JOINT AREA (in²)</th>
<th>LOCATION OF FAILURE</th>
<th>FAILING LOAD (lb)</th>
<th>F_S (psi)</th>
<th>BASE METAL STRESS AT FAILURE (psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>73</td>
<td>0.042</td>
<td>0.140</td>
<td>0.0313</td>
<td>0.106</td>
<td>BJ</td>
<td>5325</td>
<td>50,200</td>
<td>170,100</td>
</tr>
<tr>
<td>74</td>
<td></td>
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<td>5430</td>
<td>49,800</td>
<td>171,300</td>
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<tr>
<td>75</td>
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<td>0.0319</td>
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<td>76</td>
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<td>0.136</td>
<td>0.0318</td>
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<td>4340</td>
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<tr>
<td>77</td>
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<td>0.128</td>
<td>0.0319</td>
<td>0.096</td>
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<td>55,300</td>
<td>166,300</td>
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<tr>
<td>78</td>
<td></td>
<td>0.135</td>
<td>0.0311</td>
<td>0.102</td>
<td>BJ</td>
<td>3063</td>
<td>30,000</td>
<td>98,400</td>
</tr>
<tr>
<td>79</td>
<td></td>
<td>0.140</td>
<td>0.0318</td>
<td>0.106</td>
<td>BJ</td>
<td>3165</td>
<td>29,900</td>
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<tr>
<td>80</td>
<td></td>
<td>0.140</td>
<td>0.0311</td>
<td>0.106</td>
<td>BJ</td>
<td>3570</td>
<td>33,700</td>
<td>114,800</td>
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<tr>
<td>81</td>
<td></td>
<td>0.123</td>
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<td></td>
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<td>0.0321</td>
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<td>3160</td>
<td>34,000</td>
<td>98,400</td>
</tr>
<tr>
<td>83</td>
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<td>0.0315</td>
<td>0.103</td>
<td>BJ</td>
<td>2905</td>
<td>29,200</td>
<td>92,200</td>
</tr>
</tbody>
</table>

Average: 50,900

NOTE: BJ - Braze Joint
### Table 4 - Shear Strength Data for Premabraze 130

<table>
<thead>
<tr>
<th>Test Temp (°F)</th>
<th>Base Metal Thickness (in)</th>
<th>Overlap (in)</th>
<th>Base Metal Area (in²)</th>
<th>Brace Joint Area (in²)</th>
<th>Location of Failure</th>
<th>Failing Load (lb)</th>
<th>$F_{su}$ (psi)</th>
<th>Base Metal Stress at Failure (psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0.043</td>
<td>0.144</td>
<td>0.0319</td>
<td>0.108</td>
<td>BJ</td>
<td>5215</td>
<td>48,300</td>
<td>163,500</td>
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<tr>
<td>01</td>
<td>0.156</td>
<td>0.0324</td>
<td>0.061</td>
<td>0.117</td>
<td>BJ</td>
<td>4420</td>
<td>37,800</td>
<td>136,400</td>
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<tr>
<td>01</td>
<td>0.115</td>
<td>0.0319</td>
<td>0.086</td>
<td>0.117</td>
<td>BJ</td>
<td>5245</td>
<td>61,000</td>
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<td>01</td>
<td>0.140</td>
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<td>0.105</td>
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<td>Average</td>
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*NOTE* BJ = Brace Joint
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<thead>
<tr>
<th>Crevice Corrosion Test</th>
<th>Base Metal Thickness (in)</th>
<th>Overlap (in)</th>
<th>Base Metal Area (in²)</th>
<th>Braze Joint Area (in²)</th>
<th>Location of Failure</th>
<th>Failing Load (lb)</th>
<th>$F_{sv}$ (psi)</th>
<th>Base Metal Stress at Failure (psi)</th>
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<tr>
<td>Sal-spray</td>
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<td>0.111</td>
<td>0.0311</td>
<td>0.084</td>
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<td>0.0310</td>
<td>0.086</td>
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<td>4645</td>
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<td></td>
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<td>0.135</td>
<td>0.0310</td>
<td>0.132</td>
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<td>4655</td>
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<td>150,200</td>
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<td>0.130</td>
<td>0.0312</td>
<td>0.098</td>
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<td>5315</td>
<td>54,200</td>
<td>170,400</td>
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<td>Standard Controlled Humidity</td>
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<td>0.120</td>
<td>0.0312</td>
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<td></td>
<td></td>
<td>0.128</td>
<td>0.0314</td>
<td>0.097</td>
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<tr>
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<td>0.0314</td>
<td>0.097</td>
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<td>52,700</td>
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</tr>
</tbody>
</table>

Note: Bj - Braze Joint;
### TABLE 6 - SHEAR STRENGTH DATA FOR PREMABRAZE 130 CREVICE CORROSION SPECIMENS

<table>
<thead>
<tr>
<th>CREVICE CORROSION TEST</th>
<th>BASE METAL THICKNESS (in)</th>
<th>OVERLAP (in)</th>
<th>BASE METAL AREA (in²)</th>
<th>BRAZE JOINT AREA (in²)</th>
<th>LOCATION OF FAILURE</th>
<th>FAILING LOAD (lb)</th>
<th>$F_{su}$ (psi)</th>
<th>BASE METAL STRESS AT FAILURE (psi)</th>
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<tr>
<td>SALT SPRAY</td>
<td>0.043</td>
<td>0.102</td>
<td>0.0318</td>
<td>0.077</td>
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<td>126.300</td>
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<td>4605</td>
<td>60.600</td>
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<td>4385</td>
<td>48.200</td>
<td>136.200</td>
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<tr>
<td>Average</td>
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<td></td>
<td></td>
<td>53.600</td>
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<td></td>
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<tr>
<td>STANDARD CONTROLLED HUMIDITY</td>
<td>0.043</td>
<td>0.114</td>
<td>0.0324</td>
<td>0.066</td>
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<td>44.800</td>
<td>118.800</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td>47.700</td>
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<td></td>
<td></td>
<td>4430</td>
<td>45.200</td>
<td>135.300</td>
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<tr>
<td>Average</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>45.900</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**NOTE:** BJ - Braze Joint
<table>
<thead>
<tr>
<th>TEST TEMP (°F)</th>
<th>LOADING RATE (lb/min)</th>
<th>SKIN THICKNESS (in)</th>
<th>SPECIMEN WIDTH (in)</th>
<th>FAILING LOAD (10)</th>
<th>( F_{fc} ) (psi)</th>
<th>MODE OF FAILURE</th>
</tr>
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<tr>
<td>Rm. Temp.</td>
<td>1500</td>
<td>0.012</td>
<td>2.020</td>
<td>8130</td>
<td>167,600</td>
<td>SKIN AND CORE CRUSHED</td>
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<tr>
<td>1000</td>
<td>1500</td>
<td>0.012</td>
<td>1.990</td>
<td>6800</td>
<td>142,300</td>
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</tr>
</tbody>
</table>

PREMABRAZE 130 SPECIMENS

<table>
<thead>
<tr>
<th>TEST TEMP (°F)</th>
<th>LOADING RATE (lb/min)</th>
<th>SKIN THICKNESS (in)</th>
<th>SPECIMEN WIDTH (in)</th>
<th>FAILING LOAD (10)</th>
<th>( F_{fc} ) (psi)</th>
<th>MODE OF FAILURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rm. Temp.</td>
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<td>0.012</td>
<td>1.985</td>
<td>7450</td>
<td>156,500</td>
<td>SKIN AND CORE CRUSHED</td>
</tr>
<tr>
<td>1000</td>
<td>1500</td>
<td>0.012</td>
<td>1.988</td>
<td>6300</td>
<td>131,300</td>
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</tr>
</tbody>
</table>
FIGURE 2

IN-VITRO WETTABILITY SPECIMENS WITH HEMORRHAGE 1/4" BRAZED AT 2000F

SPECIMENS NO. 1 (LEFT) AND 2 WERE VAPOR DEGRADED AND ALKALINE CLEANED PRIOR TO BRAZING.

SPECIMENS NO. 3 (LEFT) AND 4 WERE VAPOR DEGRADED AND H/P PICKLED PRIOR TO BRAZING.

SPECIMENS NO. 5 (LEFT) AND 6 WERE VAPOR DEGRADED AND 2000F TEMPERED PRIOR TO BRAZING.

SPECIMENS NO. 7 (LEFT) AND 8 WERE VAPOR DEGRADED, ALKALINE CLEANED AND H/P PICKLED PRIOR TO BRAZING.
FIGURE 3

SPECIMENS NO. 11 (LEFT) AND 12 WERE VAPOR DECREASED AND ALKALINE CLEARED PRIOR TO BRAZING.

SPECIMENS 13 (LEFT) AND 14 WERE VAPOR DECREASED AND OIL-LY FEAST PRIOR TO BRAZING.

SPECIMENS NO. 17 AND 18 WERE VAPOR DECREASED, ALKALINE CLEARED AND NITRIDE PROCESSED PRIOR TO BRAZING.
FIGURE 4

SPECIMENS 21 (LEFT) AND 22 WERE VAPOR DEOXYGENATED AND ALKALINE CLEANED PRIOR TO BRAZING.

SPECIMENS 23 (LEFT) AND 24 WERE VAPOR DEOXYGENATED AND KN-CIF PICKLED PRIOR TO BRAZING.

SPECIMENS 25 (LEFT) AND 26 WERE VAPOR DEOXYGENATED AND LIQUID NITRODE OXIDIZED PRIOR TO BRAZING.
FIGURE 6

INCONEL 718 WETTABLE SPECIMENS WITH NIOBE

TYPICAL LIQUID NIOBE SPECIMEN AT 1875°F, 1925°F and 2000°F

TYPICAL OF REMAINING SPECIMENS (OTHER THAN LIQUID NIOBE)
AT 1875°F AND 1925°F

TYPICAL OF REMAINING SPECIMENS (OTHER THAN LIQUID NIOBE)
AT 2000°F
FIGURE 7
INCONEL 718 WETTABILITY SPECIMENS WITH INCURBO 20

TYPICAL LIQUID HONED SPECIMEN AT 1860°F, 1910°F AND 2000°F

TYPICAL OF REMAINING SPECIMENS (OTHER THAN LIQUID HONED) AT 1860°F AND 1910°F

TYPICAL OF REMAINING SPECIMENS (OTHER THAN LIQUID HONED) AT 2000°F
FIGURE 8 - TYPICAL MICRO STRUCTURE OF PREMABRAZE 128
WETTABILITY SPECIMEN BRAZED AT 2050°F

FIGURE 9 - TYPICAL MICRO STRUCTURE OF PREMABRAZE 130
WETTABILITY SPECIMEN BRAZED AT 1900°F
FIGURE 10 - FAILED BIAXIAL COMPRESSION SPECIMENS
FRMARRAZ 128

TESTED AT ROOM TEMPERATURE
MAG. 1.5X

TESTED AT 1000°F
MAG. 1.5X
FIGURE 11 - FAILED MICROCHIP COMPRESSION SPECIMENS FROM RECRUIT 130

TESTED AT ROOM TEMPERATURE  MAG. 1.5X

TESTED AT 1000X  MAG. 1.5X
FIGURE 1L - ENGLISH COMPRESSION TEST SETUP
## TEST REQUEST

**Title:** Evaluation of Brazing Alloys for the Fabrication of Inconel 718 Honeycomb Sandwich Panels

### Laboratory/Dept. Responsible for Test

- **Test Part No.:** 255 (11-1)
- **Model:** 1116
- **Production Parts for Test Not Required:** N/A
- **Original IDEP**

### Work Requested (HI-4)(I-1)(IV-2)(VI-3)

### Objective

#### 1.0 OBJECTIVE

To obtain information needed for the selection of a brazing alloy for fabrication: temperature resistant honeycomb panels using Inconel 718 honeycomb core, sheet and bar materials. Selection will be based on the results of weldability tests, shear strength of brazed joints, resistance to corrosion and mechanical property tests of sample panels, specimens. Shear and compression tests will be conducted at room temperature and 1000°F.

### Justification

In the design of temperature resistant thin airfoil sections, maximum structural efficiency can be achieved by utilizing brazed honeycomb construction. The nickel base alloy, Inconel 718, is considered one of the more efficient structural materials for this application, and, at the present time, very little information is available on the reutilization of commercially available temperature resistant brazing alloys with Inconel 718.

### Test Plan

Evaluation tests of brazing alloys will be conducted as follows:

#### 3.0 WELDABILITY TESTS

- **Weldability Tests**
  - Test specimens of Inconel 718 sheet containing measured quantities of candidate brazing alloys will be subjected to controlled brazing treatments at brazing temperatures. Since weldability depends to a great extent on metal surface cleanliness; four different cleaning methods will be included as a part of this investigation.

### References/Enclosures

- Reference Manuals
  - BRZ 730
  - IDEP Request
  - Total 1

---

**Approved, Copies, Revisions:**

- **Date:** 08 Jan 1981
- **Page:** 27
Lap shear specimens will be prepared using only those brazing alloys which have adequate wettability as determined in 3.1, above. The brazing temperature and cleaning treatment will also be limited to the most satisfactory temperature and treatment as determined in 3.1.

Crevise Corrosion Tests - Lap shear test specimens, prepared as in 3.2, will also be used in this investigation to determine the effect of salt spray and aerated water on resistance to crevice corrosion of brazed joints.

Tensile Compression Tests - The information obtained in 3.1, 3.2 and 3.3 will be used as a basis for selecting the most suitable brazing alloy or alloys, brazing temperatures and cleaning treatment in fabricating adhesion compression test specimens for final evaluation.

I. TEST MATERIALS

1.1 Inconel 718 sheet, 0.012 inch thick.
1.2 Inconel 718 sheet, 0.040 inch thick.
1.3 Inconel 718 honeycomb core, 0.75 to 1.00 in. thick x 3.125" x 3.125".

2.1 brazing alloys:
2.1.1 Promabraz 128, 0.0015 in. foil.
2.1.2 Promabraz 130, 0.0015 in. foil.
2.1.3 "Coro (Au, Cu, Ti), 0.0015 in. foil.
2.1.4 Inco 20 (Au, Cu, In), 0.0015 in. foil.

2.0 PREPARATION OF TEST SPECIMENS

5.1 Wettability specimens
5.1.1 Shear 0.060 in. inconel 718 sheet in the annealed condition into pieces 1.0 x 1.125 in. Prepare 16 pieces for evaluation of each brazing alloy.

5.1.2 Clean & specimen as follows:
5.1.2.1 Vapor degrease per NASA P-801-12010.
5.1.2.2 Alkaline clean per NASA P-801-12010 type II for 5-15 minutes and rinse.
5.2.1 Shear 6 pieces 4.56 x 4 in. of 0.010 in. annulled inconel 718 sheet material for evaluation of each selected brazing alloy.

5.2.2 Clean all pieces using the nitric method, as determined from cleanliness tests. After cleaning, handle with clean white gloves until brazing in complete.

5.2.3 Pack each piece to case 3 holes 3 x 3 in. with liquid joint filler of 34 oz. covering, and case with 3000 in. shift close to the joint to maintain clearance for brazing alloy.

5.2.4 Place brazing alloy in position in joints of 3 holes for each brazing alloy being evaluated and freeze.

5.2.5 Cone Compression Test Specimens

5.2.5.1 Shear 6 pieces 3.125 x 0.125 in. of 0.312 in. annulled inconel 718 sheet material for each selected brazing alloy.

5.2.5.2 Shear 1 piece of 3.125 x 0.125 in. of 0.312 in. inconel 718, x 0.125 in. for each brazing alloy. Within the stile shall be cut in the 0.312 in. inconel.

5.2.5.3 Shear all pieces using the nitric method as determined from cleanliness tests. After cleaning handle with clean white gloves until brazing in complete.
5.3.4 Assemble compression specimen components with brazing alloy material in a suitable brazing fixture in preparation for brazing.

6.0 BRAZING TREATMENT

6.1 Braze all test specimens in vacuum. (Minimum pressure available).

6.2 Brazing temperatures for wettability tests shall be as shown below. Time at temperature shall be 15 minutes. Cool to room temperature.

Prebraze 128, (1900 and 1950 F.)
Prebraze 130, (1800 and 1850 F.)
Hicoro (Au, Cu, 'H)(1975 and 1925 F.)
Environ 20 (Au, Cu, In) (1860 and 1910 F.)

7.0 HEAT TREATMENT

After brazing, retain all specimens in the brazing envelope and heat to 1125°F, hold for 8 hours, furnace cool at 100°F/hr. to 1150°F, hold at 1150°F for 8 hours and air cool. Circulate pure dry argon through the envelope during heat treatment.

8.0 SPECIMEN PREPARATION

8.1 Shear Specimens - Cut shear panels in strips and machine test specimens to the geometry shown in Figures 1 and 2 for room temperature and elevated temperature specimens respectively. Prepare a total of 12 room temperature specimens and 6 elevated temperature specimens for each alloy.

8.2 Edge Compression Specimens - Machine edges of all specimens in accordance with Paragraph 7.2.1 of AIC report No. ADTC-17. Finished dimensions shall be 2.00 x 3.00 in. x brazed thickness.

9.0 TESTS

9.1 Wettability Tests - Examine all specimens using the method described in T.P. 513-296.

9.2 Shear Tests - Test six specimens in tension at room temperature (0.005 in./min.) and six at 1000 F. Record load at failure, joint shear stress at failure and location of failure.

9.3 Crevice Corrosion Tests - Expose three lap shear specimens to a 20% sodium chloride solution per Ted. Test Method Std. No. 151a, Method 11.1 for 10 hours and load in tension to failure at room
(Continued)...

temperature. In addition, expose three lap shear specimens to 100 hours in a standard controlled humidity environment and test at room temperature. Record load at failure, joint shear stress at failure and location of failure.

9.4 Core Compression Tests - Conduct tests at room temperature and at 10,000 psi in accordance with the procedure described in Paragraph 7.2.2 of ATC Report No. ATC-17. Record load at failure, facing stress at failure and mode of failure.

10.0 DATA REQUIRED

10.1 The following information is required for all tests:

10.1.1 Detailed cleaning procedures.

10.1.2 Detailed brazing procedures. (temperature, time at temperature, etc.)

10.1.3 Detailed heat treating procedures.

10.2 Wetting Tests

10.2.1 Wetting index values.

10.2.2 Photomacrographs and photomicrographs of all specimens.

10.3 Shear Tests

10.3.1 Joint shear stress at failure.

10.3.2 Base metal stress at failure.

10.3.3 Location of failure.

10.3.4 Test temperature.

10.3.5 Loading rate.

10.4 Crevice Corrosion Tests

10.4.1 Complete description of environmental conditions.

10.4.2 Joint shear stress at failure.

10.4.3 Base metal stress at failure.

10.4.4 Location of failure.

10.4.5 Loading rate.

10.4.6 Photomicrographs of any indications or evidence of crevice corrosion.
10.5 **Edge Compression Tests**

10.5.1 Load at failure.

10.5.2 Facing stress at failure.

10.5.3 Mode of failure.

10.5.4 Test temperature.

10.5.5 Loading rate.

10.5.6 Diagrammatic and/or photographic description of test set-up.

10.5.7 Photomicrographs of typical honeycomb-to-skin brazed joints and any unusual conditions observed.

10.5.8 Photographs of failed specimens.

![Diagram of Edge Compression Tests](image)