General Disclaimer

One or more of the Following Statements may affect this Document

- This document has been reproduced from the best copy furnished by the organizational source. It is being released in the interest of making available as much information as possible.

- This document may contain data, which exceeds the sheet parameters. It was furnished in this condition by the organizational source and is the best copy available.

- This document may contain tone-on-tone or color graphs, charts and/or pictures, which have been reproduced in black and white.

- This document is paginated as submitted by the original source.

- Portions of this document are not fully legible due to the historical nature of some of the material. However, it is the best reproduction available from the original submission.
AUTHOR(S): R. A. Mendelson

TITLE: EVALUATION OF COLDWELDED BUTT JOINT TRANSITION PIECE

ABSTRACT

Ten specimens of electrolytic tough pitch copper coldwelded to 6061-T6 aluminum were received from Utica Turbine Parts Division, Kelsey Hayes Company. Tension, torsion, and reverse bend tests were performed as well as a metallurgical evaluation of the joint.

The test results indicate that the joint should be satisfactory for use in the electrical high-current bus system.

NOTE: This document is considered preliminary and is subject to revision as analysis progresses and additional data are acquired. The general reader may encounter internal reference not available to him.
I. INTRODUCTION

Utica Turbine Parts Division, has manufactured equipment for the production of cold butt welds under the name of "Koldweld." The process presently consists of joining the two components while at 70°F by pressure using a hydraulic press.

The process is adaptable for joining aluminum to copper in a punch press type operation at production speeds. Sample joints between electrolytic tough pitch (ETP), copper, and 6061-T6 aluminum alloy were received from Utica Turbine Parts Division and were evaluated.

II. PROCEDURE

Prior to testing, all as-received specimens were x-rayed to evaluate the joint. Metallographic specimens were prepared to microscopically evaluate the joint. The structure is shown in Figure 2.

Tensile, torsion and reverse bend tests were run on the as-received joints. Tensile tests results are reported in Table I. Post-test broken tensile specimens are shown in Figure 5. Torsion samples were run at two twist rates, 50°/min. and 180°/min. The post-test specimen are shown in Figure 3.

Reverse bend tests were run with the specimens loaded as a cantilever beam. Figure 7 schematically describes the test. Duplicate specimens were tested so that the relative position of the materials with respect to point of load application was reversed.

Three specimens were subjected to a thermal cycling test between 70 and 500°F for ten cycles. A cycle consisted of placing the specimens into a furnace preheated to 500°F allowing them to reach furnace temperature and then air cooling. Two of the three specimens were subsequently machined into tensile specimens, while one was sectioned for metallographic examination. The broken post-test tensile specimens are shown in Figure 4. The microstructure of the bond area from the thermally cycled specimen is shown in Figure 3.
III. RESULTS

X-Ray analysis showed no evidence of defects. There was no lack of bond, cracks, or porosity in the bond area. The x-rays also showed no evidence of localized metal-thinning in either of the base materials which might act as a stress riser when the joint is stressed.

No failures resulted during the thermal cycling test, although, there is a differential thermal expansion between the two materials, (the coefficients are 13.8 and 9.5 inches/inch/°F for 6061-T6 aluminum and ETP Copper respectively between 70 and 500°F).

The thermal exposure lowered the ultimate tensile strength of the system (in the ETP Copper where the failure occurred), as compared to the as-received samples.

This was apparently due to the recovery, recrystallization and grain growth which occurred in the ETP Copper during the elevated temperature exposure. Figures 2 and 3 show the comparison between the heat treated and as-received samples. A small recrystallized grain structure produced in the ETP Copper where there were extremely cold worked grains can be seen in Figure 3.

Metallographic examination of the specimens shows no evidence of any non-bonding or oxide entrapment. This is true in both the as-received and cyclic heat treated samples.

All tensile test failures occurred in the ETP Copper approximately 1 1/2 inches from the joint as shown in Figures 4 and 5. The joint is apparently stronger than the weaker of the two parent metals, the ETP Copper. The torsion tests also showed the joint to be more resistant to deformation than the ETP Copper. This was true at the two twisting rates used. A visual indication of the relative resistance to torsion is shown in Figure 6. The loads applied at the moment of test termination are shown in Table II. The test was terminated when the ETP Copper end failed in the grip area.

One specimen was bent by hand using a leverage magnification. It failed in the 6061-T6 aluminum base material after repeated bending. Another specimen was bent in an Instrom Tensile Machine; it was not tested to failure because
of excessive yielding in the ETP Copper.

IV. CONCLUSIONS

1. The "Koldwelded" joint between 6061-T6 aluminum and electrolytic tough pitch copper appears to be a metallurgical type joint with a very limited diffusion zone.

2. "Koldwelded" joints between 6061-T6 aluminum and electrolytic tough pitch copper appears to be stronger than either parent materials when tested in tensile, torsion, and bending.

3. This joint can withstand differential thermal expansion stresses imposed during repeated thermal shocking (to 500°F) and thermal cycling (70 to 500°F) for at least 10 cycles.
REFERENCE:

# TABLE I

RESULTS OF TENSILE TESTS ON "KOLDWELDED" TRANSITION JOINTS

<table>
<thead>
<tr>
<th>SPEC.#</th>
<th>.2% YIELD (psi)</th>
<th>ULTIMATE TENSILE STRENGTH (psi)</th>
<th>ELONGATION IN 2 IN. (%)</th>
<th>REDUCTION OF AREA (%)</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>29,500</td>
<td>34,900</td>
<td>24</td>
<td>72.0</td>
<td>Thermally cycled</td>
</tr>
<tr>
<td>2</td>
<td>30,000</td>
<td>34,400</td>
<td>26</td>
<td>72.6</td>
<td>Thermally cycled</td>
</tr>
<tr>
<td>3</td>
<td>32,700</td>
<td>36,100</td>
<td>21</td>
<td>69.2</td>
<td>As-Received</td>
</tr>
<tr>
<td>4</td>
<td>33,600</td>
<td>35,500</td>
<td>21</td>
<td>71.6</td>
<td>As-Received</td>
</tr>
</tbody>
</table>

(1) All specimens failed in the copper approximately 1½ inches from weld.
(2) Ten cycles between 70 and 500°F - specimens inserted in furnace at temperature.

# TABLE Ia

PROPERTIES OF HOT ROLLED ETP COPPER

<table>
<thead>
<tr>
<th>.2% YIELD (psi)</th>
<th>ULTIMATE TENSILE STRENGTH (psi)</th>
<th>ELONGATION IN 2 IN. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10,000</td>
<td>34,000</td>
<td>45</td>
</tr>
</tbody>
</table>
### TABLE II

**RESULTS OF TORSION TESTS ON "KOLDWELDED" TRANSITION JOINTS**

<table>
<thead>
<tr>
<th>TWISTING SPEED (DEGREES/MIN.)</th>
<th>ULTIMATE LOAD (INCH - LBS.)</th>
<th>TOTAL TWIST (DEGREES)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>364</td>
<td>438.5</td>
</tr>
<tr>
<td>180</td>
<td>273</td>
<td>360</td>
</tr>
</tbody>
</table>

**NOTE:** Test terminated when ETP Copper end failed in grip area.
Figure 1: "Koldwelded" 6061-T6 aluminum/ETP copper joint.
Figure 2: As-received "Koldwelded" 6061-T6 aluminum/ETP copper joint. Flow lines in the aluminum and extreme cold work in the copper adjacent to the interface can be seen.
Figure 3: Thermally cycled (10 cycles between 70 and 500°F) "Koldwelded" 6061-T6 aluminum/ETP copper joint showing the small recrystallized grain size in the ETP copper.
Figure 4: Fractured tensile test specimen of thermally cycled (10 cycles between 70 and 500°F) "Koldwelded" 6061-T6 aluminum alloy/ETP copper joint.

Figure 5: Fractured tensile test specimen of as-received "Koldwelded" 6061-T6 aluminum alloy/ETP copper joint.
Figure 6: Torsion samples of "Koldwelded" 6061-T6 aluminum/ETP Copper joint showing failure in copper grip area.
Figure 7: Sketch of bend test procedure on "Koldwelded" 6061-T6 aluminum/ETP Copper joint.