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TECHNICAL MEMORANDUM

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TITLE: EVALUATION OF "KOLDWELDED" BUTT JOINT TRANSITION PIECE

ABSTRACT

Five specimens of "Koldwelded" joints, 6061-T6 aluminum to annealed pure nickel, were evaluated. Tension and torsion tests and metallurgical evaluation were performed on as-received and thermally-cycled (10 cycles between 70 and 500°F) specimens.

The joint was found to be of a metallurgical nature with a narrow diffusion zone. All mechanical tests produced failure in the aluminum.

APPROVED:

DEPARTMENT HEAD R. S. Carey

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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 consists of joining the two components while at 70°F by pressure using a hydraulic press.

Sample joints between pure nickel and 6061-T6 aluminum alloy were received from Utica Turbine Parts Division and were evaluated. The nominal chemical composition, and room temperature mechanical properties of these materials, are shown in Table I. A typical joint is shown in Figure 1.

II. PROCEDURE

Prior to testing, metallographic specimens were prepared. The structure is shown in Figure 2.

Tensile and torsion tests were run on the as-received joints. Tensile test results are reported in Table 2. Post-test broken tensile specimens are shown in Figure 3a. A torsion sample was run at a twist rate of 80°/min. The post-test specimen is shown in Figure 4. The test results are reported in Table 3.

Two specimens were subjected to a thermal cycling test between 70 and 500°F for 10 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. One of the specimens was subsequently machined into a tensile specimen. The other was sectioned for metallographic examination. The broken post-test tensile specimen is shown in Figure 3b. The microstructure of the bond area after thermal cycling is shown in Figure 5.

III. RESULTS

Metallographic examination of the specimens shows no evidence of non-bonding or oxide entrapment. This is true in both the as-received and cyclic heat-treated samples. There appeared to be a metallurgical type bond with a limited diffusion zone.

Although there is a differential thermal expansion between the two materials (the coefficients are 13.8 and 7.9 inches/inch/°F for 6061-T6 aluminum and pure nickel respectively between 70 and 500°F), no failures resulted during the thermal cycling test.

All tensile test failures occurred in the aluminum approximately ¼ inch from the joint as shown in Figures 3a and b and 5. The joint apparently is stronger than the weaker of the two parent metals - the aluminum.

The thermal exposure lowered the ultimate tensile strength of the system as compared to the as-received samples. This was apparently due to the recovery and recrystallization of the cold-worked structure, which occurred in the aluminum during the elevated temperature exposure. A partially recrystallized grain structure was also produced in the pure nickel. Comparison of Figures 2 and 5 (heat-treated and as-received samples, respectively) shows this change in grain structure.

The thermal cycling of the 6061-T6 aluminum has caused a lowering of the tensile values equivalent to the T-4 condition. This is due to excessive precipitation and agglomeration of the strengthening Mg_2Si particles.

The torsion tests also showed the joint to be more resistant to deformation than the aluminum. A visual indication of the relative resistance to torsion is shown in Figure 4. The loads applied at the moment of test termination is shown in Table 3. The test was terminated when the aluminum failed in the grip area.

IV. CONCLUSIONS

1. The "Koldwelded" joint between 6061-T6 aluminum and pure nickel appears to be a metallurgical type joint with a very limited diffusion zone.
2. The tensile and torsional strengths of "Koldwelded" joints between 6061-T6 aluminum and pure nickel are greater than the aluminum (the weakest number of the system).
3. The "Koldwelded" joint between 6061-T6 aluminum and pure nickel 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.

TABLE 1

COMPOSITION AND PROPERTIES OF THE PARENT MATERIALS

CHEMICAL COMPOSITION

6061 Aluminum	Pure Nickel
Nominal Composition (Weight %):	
1.0 Magnesium	.02 Carbon
.6 Silicon	99.97 Nickel
.25 Copper	.01 Trace Elements
.25 Chromium	
Balance Aluminum	

MECHANICAL PROPERTIES

Ultimate Tensile Strength - (psi)	Elongation In 2 Inches (%)	Temper
6061 Aluminum:		
18,000	30	T-0 Heat Treat
35,000	25	T-4 Heat Treat
45,000	17	T-6 Heat Treat
Pure Nickel:		
50,000	60	Hot Finished
60,000	35	Cold Drawn
50,000	60	Annealed

TABLE 2

RESULTS OF TENSILE TESTS ON "KOLDWELDED" BUTT JOINTS
(6061-T6 ALUMINUM AND PURE NICKEL)

SPECIMEN #	ULTIMATE TENSILE STRENGTH (1) (PSI)	ELONGATION IN 1 INCH (%)	REDUCTION OF AREA (%)	COMMENTS(2)
1	34,300	7.0	59.3	Thermally Cycled
2	51,700	9.0	48.4	As-Received

(1) All specimens failed in the aluminum approximately 1/4 inch from the weld.

(2) Ten cycles between 70 and 500°F - specimen inserted in furnace at temperature.

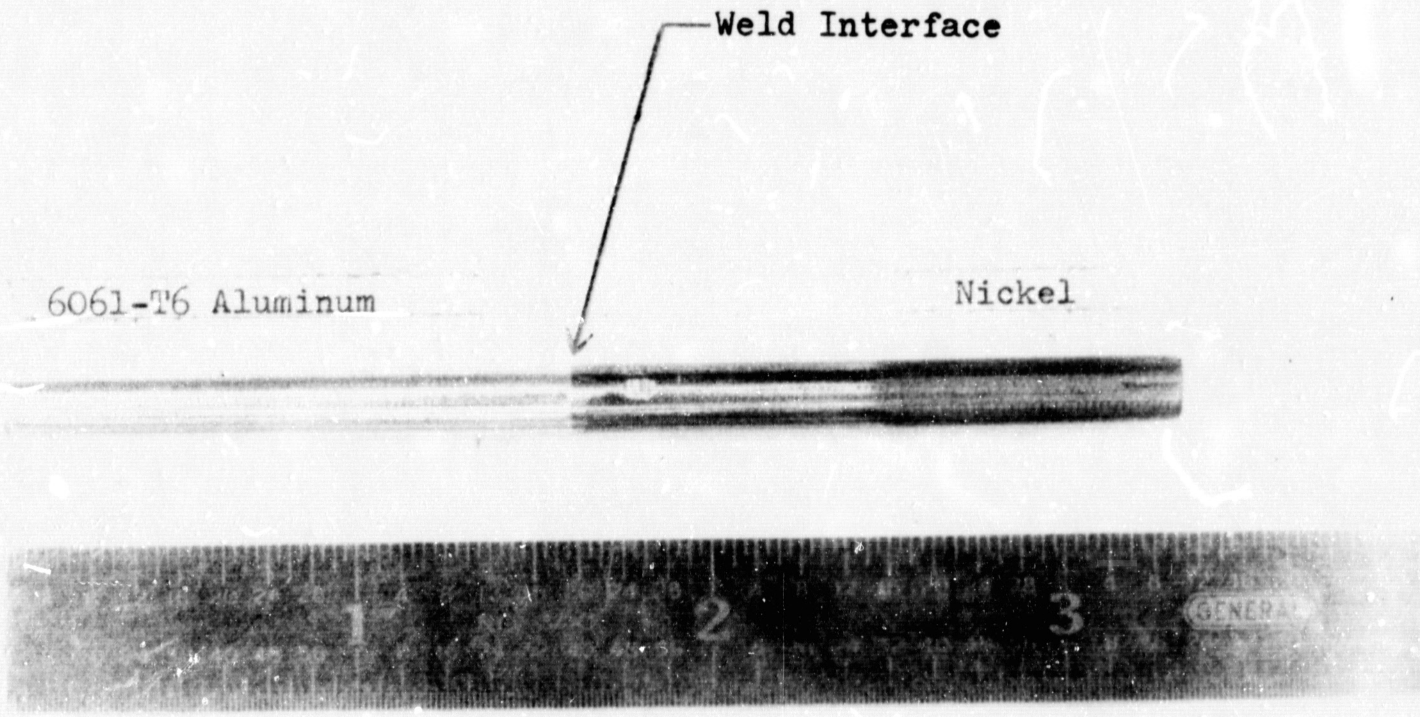
TABLE 3

RESULTS OF TORSION TESTS ON "KOLDWELDED" BUTT JOINTS

(6061-T6 ALUMINUM AND PURE NICKEL)

TWISTING SPEED DEGREES/MINUTE	ULTIMATE LOAD INCH - LB.	TOTAL TWIST AT FAILURE (DEGREES)*
80	50	720

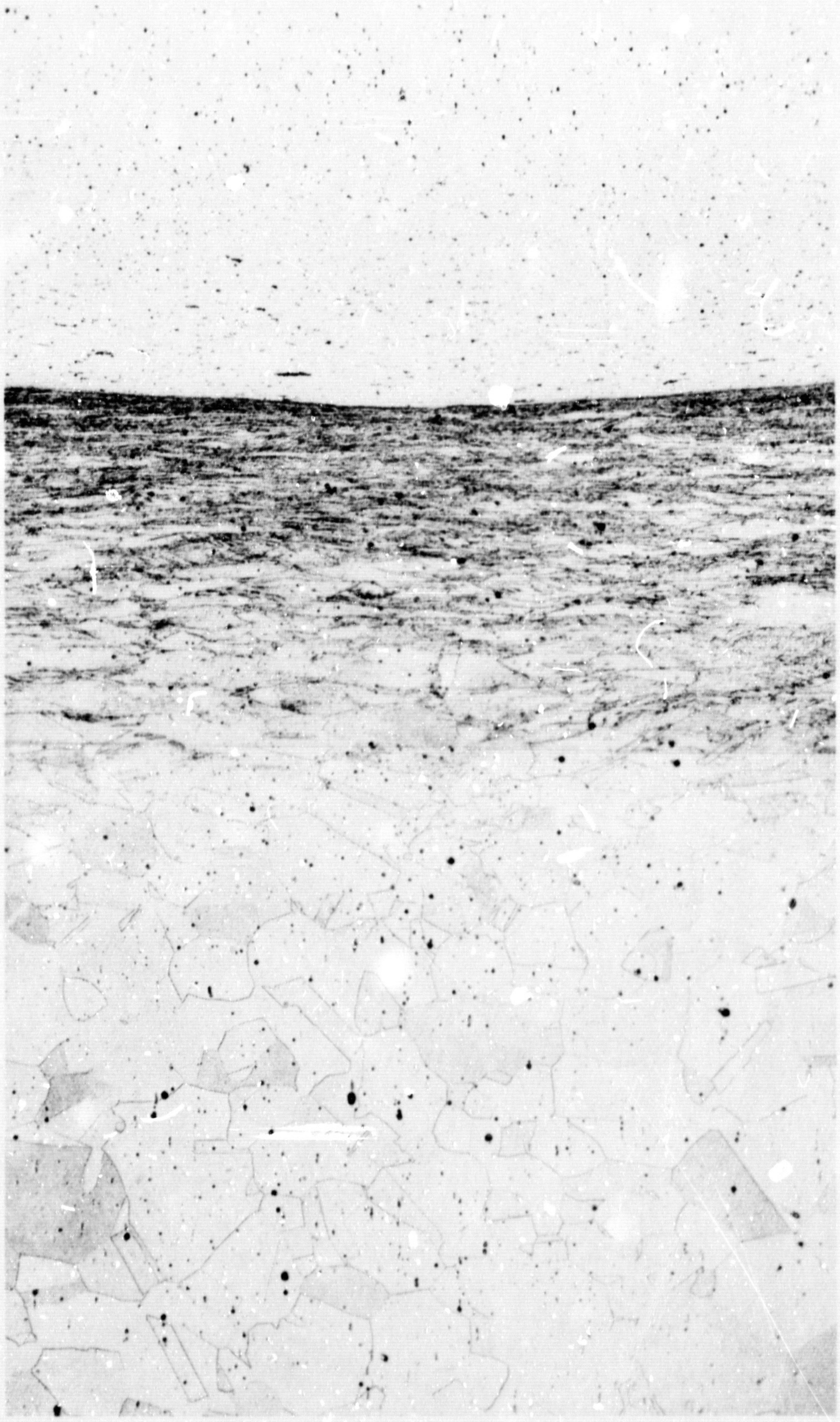
*Test terminated when aluminum failed in grip area.



L-7316 Mag. 1½X

FIGURE 1

"Koldwelded" 6061-T6 Aluminum/Nickel Joint



Composite
L-7313/7314

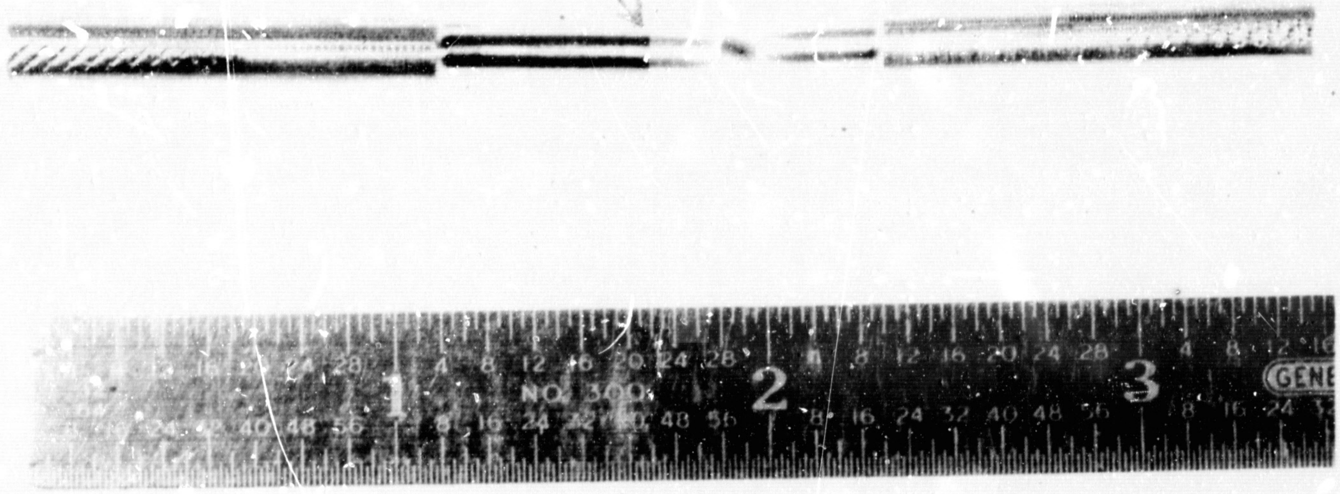
Mag. 50X

FIGURE 2

As-received "Koldwelded" 6061-T6 aluminum/nickel joint.

Weld Interface

Nickel



6061-T6 Aluminum

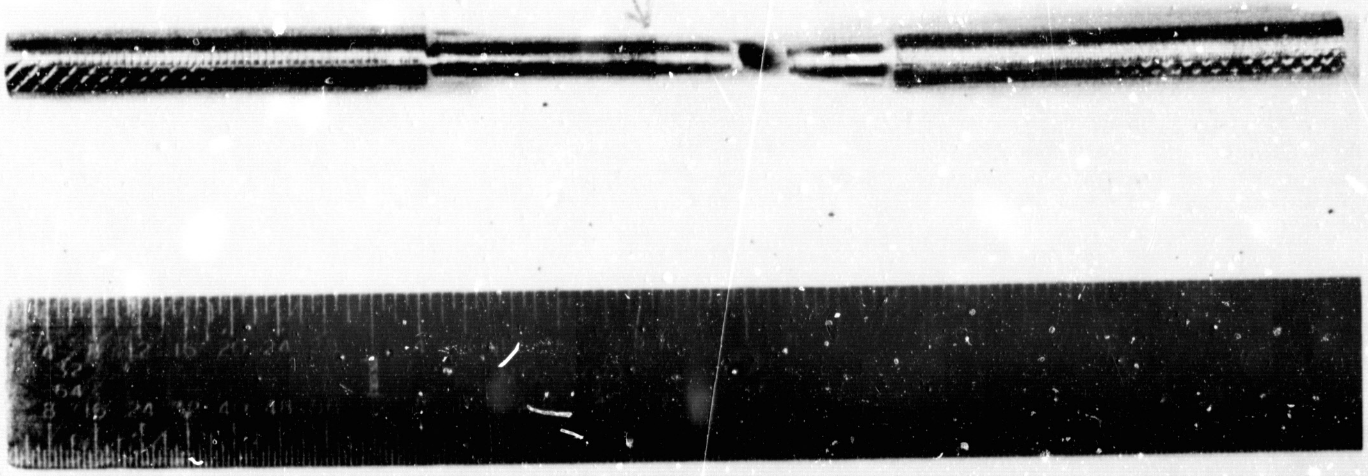
L-7261 Mag. 1½X

FIGURE 3b

Fractured tensile specimen of thermally cycled (10 cycles between 70 and 500°F) "Koldwelded" 6061-T6 aluminum/nickel joint

Weld Interface

Nickel



6061-T6 Aluminum

L-7262 Mag. 1½X

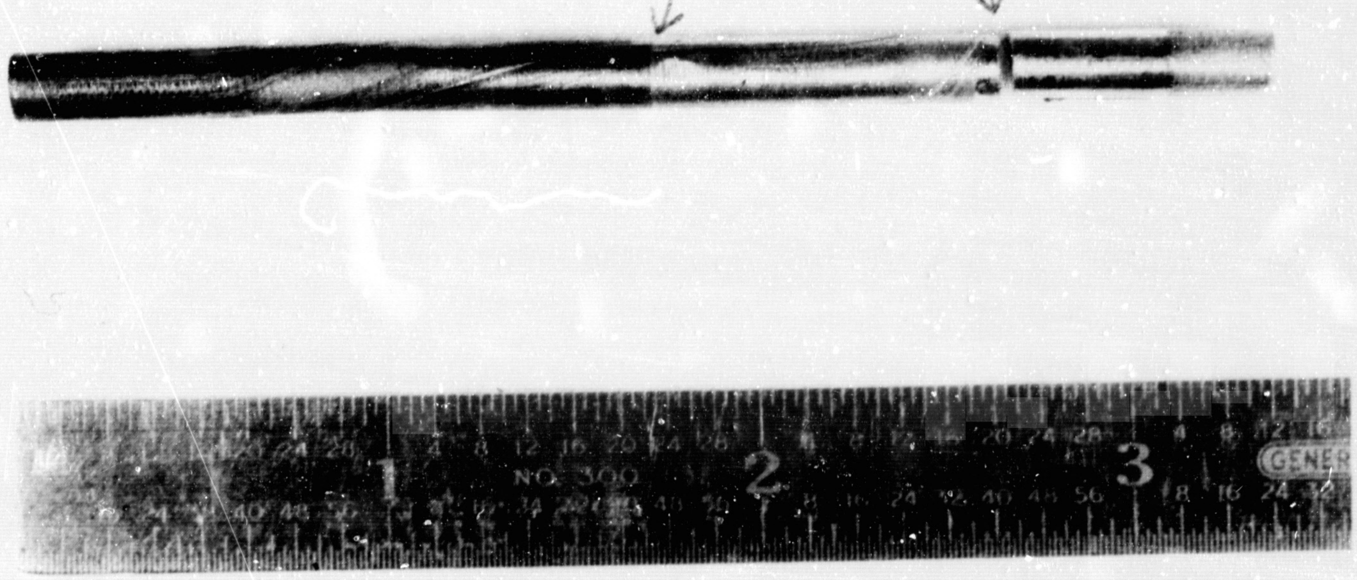
FIGURE 3a

Fractured tensile specimen of as received "Koldwelded" joint

Weld Interface

Failure in aluminum grip area

Nickel



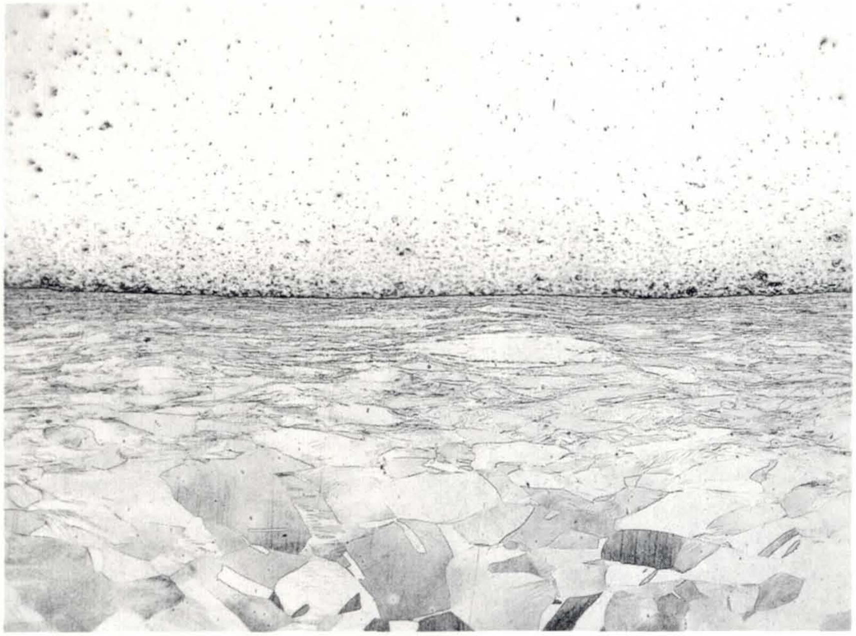
6061-T6 Aluminum

L-7288

Mag. 1½X

FIGURE 4

Post test torsion specimen of "Koldwelded" 6061-T6 aluminum/nickel joint



L-7292 Mag. 50X

FIGURE 5

"Koldwelded" 6061-T6 aluminum/nickel joint --
thermally cycled (10 cycles between 70 and 500°F)