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**EFFECT OF NICKEL PLATING UPON TENSILE
TESTS OF URANIUM-0.75 TITANIUM ALLOY**

V. C. Hemperly

June 1975

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ABSTRACT

Electrolytic-nickel-plated specimens of uranium-0.75 wt % titanium alloy were tested in air at 20 and 100% relative humidities. Tensile-test ductility values were lowered by a high humidity and also by nickel plating alone. Baking the nickel-plated specimens did not eliminate the ductility degradation. Embrittlement because of nickel plating was also evident in tensile tests at -34°C .

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SUMMARY

High humidity levels in the laboratory air produce lowered ductility values in tensile tests of uranium-0.75 titanium (U-0.75 Ti) alloy. One set of specimens, electrolytic nickel plated and unplated, were tested to determine the effect of nickel plating upon ductility degradation by humidity. Ductility values of the nickel-plated specimens were low in both 20 and 100% relative humidity atmospheres, so plating (per se) decreased ductility also. A set of specimens, baked at 150° C for 3 hours after plating and prior to testing, also showed the same lowered ductility phenomenon due to plating. In a third set, embrittlement because of plating was also evident in tests at -34° C.

INTRODUCTION

This study was started to determine the effect of nickel plating U-0.75 Ti alloy upon the tensile-test ductility in both high and low-relative-humidity atmospheres. The phenomenon of lowered ductility in tensile tests of uranium and uranium alloys, under water or in high-humidity air, was originally described by the United Kingdom's Atomic Weapons Research Establishment (AWRE).^(a) More recently, Dow-Rocky Flats^(b) reported marked loss in ductility in tensile tests of the U-0.75 Ti alloy, even at only moderately high relative humidity levels. This interest stemmed from the possibility of protecting the alloy from ductility degradation by atmospheric humidity. When lowered ductility was observed to be related also to nickel plating alone, low-temperature baking was evaluated as a means of eliminating the effect. Baking is the usual technique for removing embrittlement effects from electroplated metals. In addition, there is a degradation of the mechanical properties of this alloy at low test temperatures, so the influence of nickel plating was examined at -34° C.

This study was carried out at the Oak Ridge Y-12 Plant.^(c)

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- (a) Hughes, A. N., et al; "Environmental Factors Affecting the Mechanical Properties of Uranium", *Journal of Nuclear Materials*, 33, pp 159 - 172 (1969).
 - (b) Jackson, R. J.; "Effect of Humidity on Tensile Ductility of Uranium-Titanium Alloys", RFP-2048; Dow Chemical Company, Rocky Flats Division, Golden, Colorado; July 1973.
 - (c) Operated by the Union Carbide Corporation's Nuclear Division for the US Energy Research and Development Administration.

NICKEL-PLATING EFFECTS ON A URANIUM-TITANIUM ALLOY

MATERIALS AND METHODS

The U-0.75 Ti alloy was prepared by comelting titanium sponge and Derby uranium in a vacuum induction furnace using zirconia-coated crucibles. Castings so prepared were homogenized, alpha extruded to hollow cylinders, and then machined to a 20-mm wall thickness prior to heat treatment. These castings were then solution treated at 800° C (in vacuo), water quenched, and age hardened.

Standard tensile-test specimens were machined from this material, etched, and nickel plated. Ferric chloride was used as the etchant and it removed 0.013 to 0.025 mm of metal from the specimens. The metal plate was deposited electrolytically from a sulfamate bath to a thickness of 0.025 to 0.050 mm.

All of the specimens were tested at a strain rate of 0.005/min up to the yield strength (0.2%); thereafter, at a crosshead speed of 3.81 mm/min to fracture. The gage length on the plated specimens was marked on Dyken rather than with center-punch marks in the usual manner.

TEST RESULTS

Table 1 lists the tensile-test results of the U-0.75 Ti alloy in 20 and 100% relative humidity air, in both the unplated and electrolytic-nickel-plated condition. In general, the tensile strength was found to be inversely proportional to the ductility values, while yield strength was essentially unaffected by either relative humidity or nickel plating. In the 20% relative humidity atmosphere, nickel plating lowered the test ductility values; in the 100% relative humidity atmosphere, ductility was low for both the unplated and nickel-plated specimens.

Nickel plating lowered the ductility values, elongation, and reduction in area; baking in vacuo at 150° C for three hours after nickel plating left them unaffected (Table 2). The material in this series had been aged to a higher ductility level than that of the first series.

The results from an experiment to determine the effect of nickel plating upon tensile tests made at -34° C are summarized in Table 3. The lower test temperatures, alone, decreased the ductility values; nickel plating decreased them even further.

Table 1
TENSILE TESTS OF URANIUM-0.75
TITANIUM ALLOY IN AIR AT
TWO RELATIVE HUMIDITIES
(Average of 4 Specimens)

Tensile Strength (MPa)	Yield Strength ⁽¹⁾ (MPa)	Elongation ⁽²⁾ (%)	Reduction in Area (%)
<u>20% rh air, Unplated</u>			
1530	960	16.3	14.5
<u>20% rh Air, Electrolytic Nickel Plate</u>			
1485	940	11.0	9.6
<u>100% rh Air, Unplated</u>			
1340	934	3.8	4.0
<u>100% rh Air, Electrolytic Nickel Plate</u>			
1417	947	8.3	7.2

(1) At 0.2% offset.

(2) In a 25.4-mm gage length.

In all of the tensile tests of nickel-plated U-0.75 Ti alloy, the electrolytic plate adhered tightly to the specimen and did not crack throughout the test. Such behavior is not always the case with nickel-plated unalloyed uranium.

CONCLUSIONS

Tests performed in this study demonstrate that nickel plating does degrade the tensile-test ductility values of the U-0.75 Ti alloy. The tests herein also confirm the previous experience of low ductility when testing in air at high humidity levels. On the other hand, the yield strength is essentially unaffected by either nickel plating or different relative-humidity levels. This observation suggests that degradation of the tensile-test ductility occurs only above the yield strength stress level. Therefore, ductility degradation from nickel plating is not a significant factor in service conditions below the yield strength.

Table 2
TENSILE TESTS OF NICKEL-PLATED
URANIUM-0.75 TITANIUM
ALLOY IN AIR
(Average of 3 Specimens)

Tensile Strength (MPa)	Yield Strength ⁽¹⁾ (MPa)	Elongation ⁽²⁾ (%)	Reduction in Area (%)
<u>Unplated</u>			
1472	920	21.0	27.7
<u>Nickel Plated, Unbaked</u>			
1466	917	15.0	13.2
<u>Nickel Plated, Baked</u>			
1458	884	16.6	14.4

(1) At 0.2% offset.

(2) In a 25.4-mm gage length.

Table 3
TENSILE TESTS OF NICKEL-PLATED URANIUM-0.75
TITANIUM ALLOY IN AIR AT TWO TEMPERATURES
(Average of 3 Specimens)

Test Temperature	Tensile Strength (MPa)	Yield Strength ⁽¹⁾ (MPa)	Elongation ⁽¹⁾ (%)	Reduction in Area (%)
<u>Unplated</u>				
RT	1490	916	22.0	33.5
34° C	1531	988	7.3	5.7
<u>Nickel Plated</u>				
RT	1484	936	16.7	19.4
34° C	1447	984	4.7	4.4

(1) At 0.2% offset.

(2) In a 25.4-mm gage length.

Embrittlement of plated metals is frequently associated with hydrogen absorption during plating, and the effect is normally removed by low-temperature baking. In this study, baking did not return the tensile test ductility of the U-0.75 Ti alloy to the level of that of the unplated specimens. Consequently, low-temperature baking is not a useful technique with this alloy.

Nickel plating the U-0.75 Ti alloy tensile specimens also reduced the ductility values when the tests were performed at a low temperature (-34° C).

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