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ARGONNE NATIONAL LABORATORY
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PRELIMINARY REPORT ON
CORROSION OF LOW-URANIUM, ZIRCONIUM- BASE ALLOYS

by

A. E. Dwight and A. H. Roebuck

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PRELIMINARY REPORT ON CORROSION OF LOW-URANIUM, ZIRCONIUM-BASE ALLOYS

by

A. E. Dwight and A. H. Roebuck

ABSTRACT

Tests were made to determine the effects of heat treatment and composition on the corrosion resistance of low-uranium, zirconium-base alloys to water at 600F. A total of 57 compositions were tested. The zirconium alloys contained up to 9% natural uranium plus small amounts of tin, antimony, lead, bismuth, yttrium, beryllium, germanium, niobium, nickel, and aluminum in various combinations. Data are presented in both tabular and graphical form.

The effect of heat treatment on corrosion resistance of zirconium-uranium-tin alloys is partially masked by impurities in alloys made from sponge or bomb-reduced zirconium. In ternary alloys made from crystal bar zirconium, the effect of heat treatment on corrosion resistance is definite, and varies with the composition of the alloy.

The range of ternary compositions from approximately 2 to 6 weight-per cent uranium and from 2 to 4 per cent tin, are the most attractive fuel element core alloys.

I. INTRODUCTION

The work discussed in this report was performed as part of a study directed toward the development of corrosion resistant fuel alloys. A total of 57 compositions, utilizing 3 types of zirconium base metal and 3 conditions of heat treatment, were static-corrosion tested in 600F water containing 18 ml of hydrogen per liter of water.

The purposes of these tests were to:

1. Compare the relative corrosion resistance of several unclad zirconium-uranium alloys.
2. Compare the relative corrosion resistance of several alloys made from 3 different types of zirconium metal.
3. Determine the heat treatment imparting the best corrosion resistance.

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No attempt was made to determine the time at which the weight change rate increases sharply or to evaluate the alloys for long-time service. The work described herein is intended to point out the more promising compositions and heat treatment, and to recommend certain ones for more intensive investigations.

In order to better understand the effect of heat treatment on corrosion resistance, a metallographic examination was made. The metallographic work was confined to an alloy containing 4% uranium and 2-1/2% tin, made with crystal bar zirconium, which is considered to be a promising fuel alloy material.

II. CONCLUSIONS

Several conclusions based on the test results are listed below.

1. For the ternary zirconium-uranium-tin alloys up to 9% uranium and 5% tin, rates of weight change generally decreased with increasing tin content and increased with increasing uranium content.

2. Alloys made from Grade I crystal bar zirconium had lower and more consistent weight change rates than alloys made from Bureau of Mines sponge or from Ames bomb-reduced sponge. The difference was particularly noticeable in the binary zirconium-uranium alloys and was somewhat masked by tin when present.

3. In the ternary alloys which contained 4% uranium, a maximum of 5% of a third element and balance zirconium, the elements aluminum, yttrium, niobium, and lead gave very high weight change rates regardless of the heat treatment. On the other hand, beryllium, nickel, germanium, and bismuth generally increased the weight change rates after water quenching from 1700F, but had a lesser effect after slow cooling from 1700F.

4. The zirconium control specimens exhibited the lowest weight change rate after annealing at 1300F.

5. In the binary zirconium-uranium alloys, water quenching from 1700F gave the lowest weight change rate for alloys made with crystal bar; alpha annealing at 1300F gave the lowest weight change rate for alloys made with sponge zirconium. For both types of zirconium, slow cooling from 1700F through the transformation range gave the highest weight change rates.

6. In the binary zirconium-tin alloys containing up to 5% tin, water quenching from 1700F gave the lowest weight change rates, and alpha annealing at 1300F gave the highest.

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7. For the ternary zirconium-uranium-tin alloys containing up to 9% uranium and 5% tin, slow cooling from 1700F through the alpha-beta transformation range generally gave lower weight change rates than water quenching from 1700F.

8. Metallographic examination of a zirconium - 4% uranium, 2-1/2% tin alloy showed that heating into the beta range produced a very coarse grain size and that annealing in the alpha range permitted recrystallization and apparent precipitation of a finely divided second phase. Therefore, it may be postulated that the presence of the finely divided precipitate is harmful to the corrosion resistance of this alloy.

9. Ternary systems which merit further investigation for zirconium-base fuel alloys, in addition to the aforementioned zirconium-uranium-tin alloy, are zirconium-uranium-germanium and zirconium-uranium-antimony.

III. SAMPLE PREPARATION

A. Composition and Fabrication

The nominal and analyzed compositions of the 57 samples are listed in Table I.

Samples numbered 2870 through 2884 are zirconium-uranium-tin and zirconium-uranium-antimony alloys supplied by the Ames Laboratory. The alloys were resistance-melted in graphite crucibles and were made from bomb-reduced zirconium. The castings were cold rolled at Armour Research Foundation and machined into test specimens 3/4 by 3/8 by 1/8 in. at Argonne. Specimens from the castings were retained for test purposes by the Ames Laboratory, the results of which were reported previously.¹

Samples numbered 2885 through 2895, also 3478, are of the zirconium-uranium-tin system. They were made at Armour Research Foundation by arc melting Grade I crystal bar zirconium with alloying elements in a water-cooled copper crucible. The samples were cold-rolled, when possible, at Armour Research Foundation and machined at Argonne.

Samples numbered 2896 through 2899 and 3395 through 3402 are also of the zirconium-uranium-tin system and were made at Armour Research Foundation. However, alloys of this group were made from Bureau of Mines sponge zirconium arc melted in a water-cooled copper crucible.

Samples numbered 3473 through 3486, except 3478, and 3542 through 3547 are alloys of zirconium - 4% uranium with various amounts of antimony, germanium, nickel, niobium, aluminum, yttrium, beryllium, bismuth, and lead. The alloys in this group were arc melted in a water-cooled copper crucible, using Grade I crystal bar. The castings were made at Armour Research Foundation and cold rolled when possible.

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Table 1

NOMINAL AND ANALYZED COMPOSITION OF ZIRCONIUM-BASE ALLOYS

Argonne Sample No.	Alloy Composition							
	Weight - Per Cent						ppm	
	Uranium		Tin		Antimony		Nitrogen	Carbon
	Nom.	Anal.	Nom.	Anal.	Nom.	Anal.	Anal.	Anal.
2870	4	4.21			4	0.14		
2871	9	8.93	2-1/2	2.42				
2872			2-1/2	2.55				
2873	1-1/2	1.67						
2874	9	8.99	5	4.91				
2875	1-1/2	1.49	2-1/2	2.33				
2876	(Zirconium control specimen)						178	570
2877	4	4.03	2-1/2	1.96				
2878	9	8.97						
2879	4	4.00						
2880			5	4.73				
2881	4	4.14			1/2	0.035		
2883	4	4.02	5	4.81				
2884	1-1/2	1.60	5	3.52				
2885	(Zirconium control specimen)						165	120
2886			2-1/2	2.49				
2887			5	4.99				
2888	1-1/2	1.55						
2889	4	3.99						
2890	9	(Chem. sample lost)						
2891	1-1/2	1.54	2-1/2	2.49				
2892	1-1/2	1.48	5	4.72				
2893	4	4.00	2-1/2	2.49				
2894	4	4.03	5	5.04				
2895	9	8.95	2-1/2	2.50				
3478	9	8.80	5	4.99			45	
2896	(Zirconium control specimen)						455	215
2897			2-1/2	2.52				
2898			5	4.99				
2899	1-1/2	(Chem. sample lost)						
3395	4	4.21						
3396	9	9.41						

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Table I (Cont'd.)

Argonne Sample No.	Alloy Composition							
	Weight - Per Cent						ppm	
	Uranium		Tin		Antimony		Nitrogen	Carbon
	Nom.	Anal.	Nom.	Anal.	Nom.	Anal.	Anal.	Anal.
3397	1-1/2	1.78	2-1/2	2.51				
3398	1-1/2	1.85	5	4.97				
3399	4	3.97	2-1/2	2.48				
3400	4	4.03	5	4.96				
3401	9	8.98	2-1/2	2.52				
3402	9	9.39	5	4.98				
			Yttrium		Germanium			
3473	4	3.99	1-1/4	1.33			48	
3476	4	3.98			0.1	0.10	65	
3477	4	4.03			0.4	0.22	40	
			Beryllium					
3474	4		3		N.D.*			
3475	4		1					
			Niobium		Nickel			
3479	4	4.07	1	0.73			30	
3480	4	3.98	3	3.43			145	
3481	4	4.01			0.1	0.10	370	
3482	4	4.34			0.5	0.507	180	
			Aluminum					
3483	4	4.04	2-1/2	3.00			65	
3484	4	4.01	5	5.24			60	
3485	4	4.01			1/2	0.35	35	
3486	4	3.99			4	3.88	50	
			Lead		Bismuth			
3542	4	4.14	1	0.78			130	135
3543	4	4.37	2-1/2	5.82			175	500
3544	4	4.68	5	4.18			130	320
3545	4	3.98			1	0.70	80	410
3546	4	4.00			2-1/2	3.76	140	340
3547	4	4.17			5	5.78	90	

*Not determined due to health hazard of beryllium.

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Of the above alloys, only those containing beryllium, bismuth, and lead (samples 3474, 3475, and 3542 through 3547) showed visible segregation. Though accurate phase diagrams are lacking for these systems, it is believed that density differences and low solubility in the zirconium-uranium alloy account for the observed segregation.

B. Heat Treatment

It had been reported earlier^{2,4} that zirconium - 2-1/2 weight per cent tin alloys have an improved corrosion resistance when slowly cooled from the beta phase. Furthermore, uranium-base alloys containing niobium or zirconium were reported³ to have improved corrosion resistance when quenched from the gamma phase. It could not be predicted which of the alloys in this program would respond best to slow cooling and which to quenching. Therefore, the following three heat treatments were chosen for this study:

1. Anneal at 1700F one hour in vacuum followed by water quench.
2. Anneal at 1700F one hour in vacuum, cool slowly to 1300F, followed by furnace cool.
3. Anneal at 1300F one hour in vacuum, furnace cool.

The low temperature alpha phase of pure zirconium transforms to the high temperature beta phase at a temperature of 1586F. Therefore, the first heat treatment is a quench from the beta range, the second is a slow cool through the transformation range, and the third is an alpha anneal.

IV. WEIGHT CHANGE DATA

Tests were run in 100-ml capacity, AISI type 347 stainless steel autoclaves containing 50 ml of distilled water. The water was hydrogenated by bubbling hydrogen gas through the water for about a minute. The autoclave consisted of a threaded body, stainless steel gasket, plug, and threaded nut. All interior water or vapor contact areas of the autoclave were stainless steel. During test, samples were in contact with the autoclave wall. A more complete description of the test equipment and procedure may be found elsewhere.⁴

The weight change data are listed in Table II and are also shown graphically in Figures 1 through 12.

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Table II
CORROSION OF ZIRCONIUM-BASE ALLOYS

Test Conditions

Media: Distilled water containing 18 cc H₂ per liter water

Temperature: 600F

Time: 185 hr

Nominal Alloy Composition, %. Zirconium plus			Sample No.	Heat Treat.	Rate of Wt. Change, mg/(cm ²)(mo)	Surface	Color	Texture	
Sb*	Sn	U							
4	4		2870	Resistance-Melted Ames Sponge					
				1	+3.05	Powdery	Black	Rough	
				2	1.41	Powdery	Gray	Rough	
		2.5	9	2871	3	4.04	Powdery	Gray	Rough
	1				5.19	Powdery	Gray	Rough	
	2				3.94	Dull film	Dark	Moderately smooth	
		2.5		2872	3	2.34	Dull film	Dark	Rough
	1				0.99	Glossy	Black	Smooth	
	2				1.55	Glossy	Black	Smooth	
		1.5		2873	3	1.84	Dull film	Gray	Smooth
	1				14.1	Pitted	Gray	Heavy spalls	
	2				296.9	Powdery, swollen	Gray	Rough	
		5	9	2874	3	92.0	Loose film	Gray	Very rough
	1				31.0	Pitted	Black	Deep pits	
	2				6.76	Dull film	Dark gray	Moderately smooth	
		2.5	1.5	2875	3	1.42	Dull film	Gray	Smooth
	1				1.06	Glossy	Gray-black	Smooth	
	2				0.84	Glossy	Black	Smooth	
		2.5	4	2877	3	1.42	Dull film	Gray	Smooth
	1				1.34	Lustrous film	Gray	Smooth	
	2				1.9	Lustrous film	Brown	Smooth	
			9	2878	3	1.56	Dull film	Black	Small pits
	1				5.53	Dull film	Gray	Streaks	
	2				187.45	Irregular	Yellow	Distorted & split	
		4		2879	3	3.48	Loose film	Yellow	Very rough
	1				2.19	Dull film	Black	Small pits	
	2				0.28	Pitted	Yellow & Black	Streaks	
		5.5		2880	3	6.70	Dull film	Gray	Light spalls
	1				+0.27	Lustrous film	Black	Smooth	
	2				1.83	Lustrous film	Black	Smooth	
0.5	4		2881	3	0.57	Dull film	Black	Small pits	
				1	1.91	Dull film	Iridescent	Spotty	
				2	-15.5	Dull film	Yellow	Light penetration	
		5		2883	3	+ 2.84	Loose film	Green	Very rough
	1				2.69	Loose film	Black	Light spalls	
	2				2.32	Lustrous film	Black	Smooth	
		5	1.5	2884	3	1.49	Dull film	Black	Small pits
	1				0.86	Lustrous film	Black	Smooth	
	2				1.48	Lustrous film	Black	Smooth	
				2884	3	1.06	Lustrous film	Black	Small pits
	1				0.86	Lustrous film	Black	Smooth	
	2				1.48	Lustrous film	Black	Smooth	

*The amounts shown for antimony represent the nominal percentages added to the alloys. Subsequent chemical analyses, reported in Table I, show the antimony content to be 0.14, and 0.035 for the nominal 4 and 1-1/2 per cent alloys, respectively. The reduction is probably due to volatilization of antimony during melting.

REF ID: A63780

Table II (Cont'd.)

Nominal Alloy Composition, % Zirconium plus			Sample No.	Heat Treat.	Rate of Wt. Change, mg/(cm ²)(mo)	Surface	Color	Texture
Sb*	Sn	U						
5	(Control)	9	2876	2	17.99	Heavy coating	White	Smooth
				3	11.43	Heavy coating	Gray-black	Smooth
			3478	1	2.48	Dull film	Black	Streaks
				2	3.34	Pitted	Brown	Rough
				3	0.85	Dull film	Black	Smooth
			Arc-Melted Grade I Crystal Bar (Armour)					
	(Control)	1.5	2885	2	+3.86	One side dull; one side shiny	White & black	Smooth
				3	0.43	Lustrous film	Black	Smooth
			2886	1	0.31	Dull film	Black	Streaks
				2	0.64	Glossy	Black	Smooth
				3	0.78	Lustrous film	Black	Smooth
			2887	1	0.00	Lustrous film	Black	Smooth
				2	0.36	Lustrous film	Black	No change
				3	0.22	Lustrous film	Black	Smooth
			2888	1	0.54	Dull film	Black	Spotty
				2	-0.21	Flaked	Mottled	Irregular
				3	+2.20	Lustrous film	Black	Small pits
			2889	1	0.79	Lustrous film	Gray	Smooth
				2	-0.86	Spattered	Mottled	Smooth
				3	+0.92			
			2890	1	1.42	Temper film	Iridescent	Smooth
				2	3.15	Dull film	Gray	Smooth
				3	1.99	Dull film	Yellow	Smooth
2891	1	0.78	Lustrous film	Black	Smooth			
	2	0.43	Lustrous film	Iridescent	Smooth			
	3	0.50	No change	Brown	Smooth			
2892	1	+0.47	Lustrous film	Iridescent	Smooth			
	2	0.21	Lustrous film	Iridescent	Smooth			
	3	0.57	No change	Black	Smooth			
2893	1	0.78	Lustrous film	Black	Small cracks			
	2	0.29	Lustrous film	Black	Smooth			
	3	1.63	Lustrous film	Black	Small cracks			
2894	1	0.47	Dull film	Black	Semi-smooth			
	2	0.79	Dull film	Black	Smooth			
	3	1.84	Dull film	Black	Streaks			
2895	1	1.84	Pitted	Black	Heavy spalls			
	2	0.93	Powdery	Gray	Rough			
	3	1.92	Lustrous film	Metallic	Streaks			
Arc-Melted Bureau of Mines Sponge (Armour)								
(Control)	2.5	2896	1	2.09	Slight powder	Gray	Smooth	
			2	6.56	Slight powdery	Gray	Semi-smooth	
			3	0.85	No change	Black	Smooth	
		2897	1	0.62	Lustrous film	Black	Smooth	
			2	0.72	Lustrous film	Black	Smooth	
			3	3.27	Lustrous film	Black	Smooth	
		2898	1	0.31	Lustrous film	Black	Smooth	
			2	0.86	Lustrous	Black	Smooth	
			3	1.77	Dull film	Black	Small pits	

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Table II (Cont'd.)

Nominal Alloy Composition, % Zirconium plus				Sample No.	Heat Treat.	Rate of Wt. Change, mg/(cm ²)(mo)	Surface	Color	Texture
Sb*	Sn	U							
		1.5		2899	1	4.34	Powdery	Gray-white	Rough
					2	-17.02	Powdery	White	Rough
					3	+ 1.56	Lustrous film	Black	Smooth
		4		3395	1	3.19	Loose film	Gray	Very rough
					2	-32.3	Slightly loose coating	White	Heavy
					3	+ 1.77	Pitted	Gray	Streaks
		9		3396	1	5.89	Coating	Gray-white	Heavy
					2	-33.5	Loose coating	Gray-white	Heavy
					3	4.68	Coating	Gray-white	Heavy
	2.5	1.5		3397	1	1.28	Lustrous film	Black	Smooth
					2	0.78	Lustrous film	Black	Smooth
					3	0.71	Lustrous film	Black	Smooth
	5	1.5		3398	1	+ 2.48	Semi-lustrous coating	Black	Smooth
					2	0.19	Lustrous coat.	Black	Smooth
					3	1.06	Lustrous coat.	Black	Smooth
	2.5	4		3399	1	1.94	Faint coating	White	Smooth
					2	0.68	Faint lustrous coating	Black	Smooth
					3	1.56	Faint lustrous coating	Black	Smooth
	5	4		3400	1	1.01	Lustrous coat.	Black	Smooth
					2	0.97	Faint dull coating	Gray	Smooth
					3	- 0.36	Faint lustrous coating	Black	Smooth
	2.5	9		3401	1	1.06	Lustrous coat.	Black	Smooth
					2	0.97	Heavy coating	Gray-white	Rough
					3	1.46	Slightly loose coating	White	Semi-smooth
	5	9		3402	1	0.64	Semi-lustrous coating	Gray-black	Smooth
					2	0.58	Light coating	Gray-white	Semi-smooth
					3	1.91	Heavy coating	Green-gray	Rough
Y	Be	Ge	U						
1-1/4			4	3473	1		Sample disintegrated		
					2		Sample disintegrated		
					3		Sample disintegrated		
	3		4	3474	1	+ 3.49	Dull	Gray-white	Rough
					2	2.71	Dull	White	Rough
					3	1.35	Dull	Gray-white	Rough
	1		4	3475	1	8.11	Dull	Gray-brown	Rough
					2	0.39	Mottled	Black & white	Pitted
					3	0.9	Dull	Gray	Rough
		0.1	4	3476	1	+ 2.7	Powdery	Gray-black	Rough
					2	0.26	Powdery	Gray-white	Smooth
					3	0.4	Powdery	Black	Smooth
		0.4	4	3477	1	8.80	Dull	Black streaked	Pitted
					2	- 0.17	Dull	Gray-white	Smooth
					3	+ 1.07	Loose dull film	Gray streaks	Pitted

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Table II (Cont'd.)

Nominal Alloy Composition, % Zirconium plus				Sample No.	Heat Treat.	Rate of Wt. Change mg/(cm ²)(mo)	Surface	Color	Texture
Al	Ni	Nb	U						
2-1/2	0.1	1	4	3479	1	7.85	Loose film	Gray	Deep pits
		3	4	3480	2	-12.18	Loose film	Cream	Rough
					3	+ 2.65	Powdery	Gray-white	Smooth
					1	7.27	Loose film	Green	Streaks
					2	2.56	Powdery	Tan	Pitted
					3	2.92	Powdery	Brown	Lightly pitted
		4	4	3481	1	6.09	Dull film	Black	Small pits
					2	1.76	Loose film	Gray-black streaked	Fairly smooth
					3	- 0.88	Dull film	Black	Fairly smooth
	0.5	4	4	3482	1	+ 1.92	Lustrous film	Green	Streaks
					2	2.70	Powdery	Tan	Rough
					3	1.58	Shiny adherent	Gray-white	Smooth
		4	4	3483	1	0	Dissolved	Gray	Heavy spalls
					2	-135.5	Loose powdery	Gray-brown	Rough
					3	65.1	Loose powdery	Gray	Rough
		4	4	3484	1	58.67	Partially dissolved	Black	Deep pits
					2	+28.2	Loose scale	Iridescent dark blue	Rough scaled
					3	30.2	Powdery	Light gray	Rough
5	1/2	4	4	3485	1	1.11	Dull	Black	Smooth
					2	0.95	Lustrous	Black	Smooth
					3	0.63	Adherent dull	Gray-black	Fairly smooth
		4	4	3486	1	0.56	Loose film	Gray	Small pits
					2	1.50	Dull	Gray-white	Small pits
					3	0.43	Adherent dull	Black	Smooth
		4	4	3542	1	+14.62	Loose film	Gray	Flaky
					2	1.28	Loose flakes	Gray	Rough
					3	-28.50	Dull	Gray	Crumbly
	2-1/2	4	4	3543	1	+ 4.52	Dull	Gray	Smooth
					2	0.92	Spotted	Black	Lustrous
					3	72.87	Loose film	Black	Smooth
		4	4	3544	1	14.06	Bright	Black	Segregated
					2	2.48	Smooth	Gray	Lustrous
					3	2.67	Dull	Gray	Smooth
		4	4	3545	1	2.08	Spotted	Gray	Smooth
					2	0.92	Adherent dull	Black	Smooth
					3	0.77	Dull	Black	Smooth
	5	4	4	3546	1	3.13	Dull	Gray	Smooth
					2	3.27	Dull	Black	Smooth
					3	0.42	Dull	Gray	Smooth
		4	4	3547	1	5.91	Loose film	Gray	Smooth
					2	4.26	Dull	Gray	Segregated
					3	4.26	Loose flakes	Gray	Segregated

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A.E.DWIGHT:L.D.,8-6-53

WEIGHT CHANGE RATE, $\text{mg}/(\text{cm}^2)(\text{mo})$

* AMES

† Bu. OF MINES SPONGE

RE-7-11466-A
ANL-JHM-11466

A.E.DWIGHT:V.C., 8-7-53

WEIGHT CHANGE RATE, $\text{mg}/(\text{cm}^2)(\text{mo})$

* AMES

† Bu. OF MINES SPONGE

RE-7-11467-A
ANL-JHM-11467

A.E.DWIGHT:V.C.,8-7-53

WEIGHT CHANGE RATE, $\text{mg}/(\text{cm}^2)(\text{mo})$

* AMES † Bu. OF MINES SPONGE

RE-7-11468-A
ANL-JHM-11468

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RE-7-11470-A
ANL-JHM-11470

FIG. 5
WEIGHT CHANGE RATES FOR SLOW-COOLED
ZIRCONIUM-URANIUM-TIN ALLOYS
MADE FROM CRYSTAL BAR ZIRCONIUM

A.E.DWIGHT:L.B., 8-7-53

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A.E.DWIGHT:L.B., 8-7-53

FIG. 6
WEIGHT CHANGE RATES FOR ANNEALED
ZIRCONIUM-URANIUM-TIN ALLOYS
MADE FROM CRYSTAL BAR ZIRCONIUM

RE-7-11471-A
ANL-JHM-11471

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RE-7-11472-A
ANL-JHM-11472

A.E.DWIGHT:L.B., 8-7-53

FIG. 7
WEIGHT CHANGE RATES FOR QUENCHED
ZIRCONIUM-URANIUM-TIN ALLOYS
MADE FROM SPONGE ZIRCONIUM

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A.E.DWIGHT:L.B., 8-7-53

FIG. 8
WEIGHT CHANGE RATES FOR SLOW-COOLED
ZIRCONIUM-URANIUM-TIN ALLOYS
MADE FROM SPONGE ZIRCONIUM

RE-7-11473-A
ANL-JHM-11473

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RE-7-11474-A
ANL-JHM-11474

A.E.DWIGHT:L.B., 8-7-53

FIG. 9
WEIGHT CHANGE RATES FOR ANNEALED
ZIRCONIUM-URANIUM-TIN ALLOYS
MADE FROM SPONGE ZIRCONIUM

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FIG. 10
WEIGHT CHANGE RATES FOR QUENCHED
ZIRCONIUM-URANIUM-TIN ALLOYS MADE
FROM BOMB-REDUCED ZIRCONIUM

A.E.DWIGHT:L.B., 8-7-53

RE-7-11475-A
ANL-JHM-11475

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FIG. 11
WEIGHT CHANGE RATES FOR SLOW-COOLED
ZIRCONIUM-URANIUM-TIN ALLOYS
MADE FROM BOMB-REDUCED ZIRCONIUM

A.E.DWIGHT:L.B..8-7-53

RE-7-11476-A
ANL-JHM-11476

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V. EFFECT OF HEAT TREATMENT ON MICROSTRUCTURE OF A ZIRCONIUM-4 % URANIUM-2-1/2 % TIN ALLOY

An analysis of the weight change data shown in Figures 4 through 12 shows that the alloy containing 4% uranium - 2-1/2% tin is sensitive both to heat treatment and to the type of zirconium used in preparation. The data further indicate that the alloys of this composition made from crystal bar zirconium have the lowest weight change rate. Sample No. 2893 was selected as being a promising alloy for further investigation. The structures developed by the three heat treatments are shown in Figures 13, 14, and 15. The specimens were etched electrolytically using an etchant containing methyl alcohol, butyl cellosolve and perchloric acid.

The optimum heat treatment varied for different compositions. For the alloy shown in the photomicrographs, however, the slow-cool from 1700F (Figure 14) is the optimum heat treatment. The alpha-phase anneal at 1300F (Figure 15) is the least desirable heat treatment for this composition. On the basis of the limited examination which was made, the mechanism by which heat treatment affects the corrosion resistance was not determined. It is recommended that fuel elements made from zirconium - 4% uranium - 2-1/2% tin alloy be slow-cooled from above the alpha-beta transformation range.

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(NEG. NO. 110)

FIG. 13
PHOTOMICROGRAPH OF ZIRCONIUM-
4% URANIUM-2½% TIN ALLOY
QUENCHED FROM 1700 F. 200X

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(NEG. NO. 111)

FIG. 14
PHOTOMICROGRAPH OF ZIRCONIUM-
4% URANIUM-2½% TIN ALLOY
SLOW-COOLED FROM 1700 F. 200X

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(NEG. NO. 112)

FIG. 15
PHOTOMICROGRAPH OF ZIRCONIUM-
4% URANIUM-2½% TIN ALLOY,
ANNEALED AT 1300 F. 200X

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