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REVIEW OF RECENT DEVELOPMENTS
IN THE TECHNOLOGY OF BERYLLIUM

DEFENSE METALS INFORMATION CENTER
BATTELLE MEMORIAL INSTITUTE
COLUMBUS 1, OHIO

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REVIEW OF RECENT DEVELOPMENTS IN THE TECHNOLOGY OF BERYLLIUM

Webster Hodge*

There were no outstanding developments in beryllium technology reported among some 80 reports and articles reviewed during the period August through October, 1961. A number of the items were of interest, however.

General

The processing of beryllium involves the production of the largest sizes of any material made on a commercial production basis by the powder-metallurgy process. Powder valued at \$60 per pound is converted into blocks weighing up to 5 tons. During the past quarter, several excellent publications⁽¹⁻⁵⁾** reviewed this process and stressed the controls of particle size, degree of oxidation, and over-all purity that are required to obtain a satisfactory product.

Refining and Purification

The attempt at Nuclear Metals, Inc. to produce pure beryllium by distillation yielded metal with a high degree of purity, although silicon was not removed efficiently.⁽⁶⁾ However, the purest beryllium obtained by this process showed essentially zero ductility in both tensile and bend tests. Electron-microscope examination of specimens broken at 77 K revealed spherical particles of less than 2 microns' diameter on each fracture surface. Fracture surfaces of single crystals refined at The Franklin Institute, which exhibited considerable room-temperature ductility, did not show these particles. The spherical precipitate particles were not redissolved by a vacuum treatment at 1000 C for 3 hours. The particles could not be identified. Meanwhile, The Franklin Institute⁽⁷⁾ reported results of tensile tests on their single crystals which appear to indicate that impurities in beryllium strongly influence the possible amount of basal plane glide (Table 1).

Joining of Beryllium

Hot-roll planishing of the welding reinforcement along the direction of welding on 0.062-inch beryllium sheet directly after stress relieving (30 minutes at 825 C) resulted in average tensile strengths of 45,300 psi.⁽⁸⁾

*Consultant, Nonferrous Metallurgy Division, Battelle Memorial Institute.

**References are listed at the end of this memorandum.

TABLE 1. RESULTS OF TENSILE TESTS ON BERYLLIUM SINGLE CRYSTALS(7)

Starting Material	No. of Zone Melting Passes	Orientation(a)	Heat Treatment Prior to Testing	Resolved Shear Stress at Yielding, psi	Strain at Fracture, % Glide Strain	Operating Glide Systems
Pechiney	Vacuum cast	$\chi_o = 45^\circ$ λ_o Unknown	Unknown	2000 ± 500	5	Basal plane
Berylco Vacuum-cast ingot	2	$\chi_o = 47^\circ$ $\lambda_o = 51^\circ$	800 C, 1 hr	2400	16	Basal plane
Berylco Vacuum-cast ingot	5	$\chi_o = 20^\circ$ $\lambda_o = 25^\circ$	900 C, 1 hr	1350	64	Prism plane
Pechiney	8	$\chi_o = 48^\circ$ $\lambda_o = 55^\circ$	None	520	156	Basal plane

(a) χ_o = Angle between slip plane and tensile axis.

λ_o = Angle between slip direction and tensile axis.

Resistance-welding experiments revealed that the cooling rate exceeded 3300 C per second at the end of the welding portion of the weld sequence. Defect-free spot welds in 0.040-inch-thick beryllium sheet were consistently obtained by adjusting the post-heat cycle, as shown below, to decrease the cooling rate and by increasing the initial 450-pound welding force to 1500 pounds, 77 cycles after the end of the main weld time.(6)

<u>Time (60 cycles = 1 sec)</u>		<u>Per Cent of Main Welding Current</u>
Preheat	200 cycles	75
Main weld heat	8 cycles	Welding current = 9000 amperes
Post heat	110 cycles	95

Corrosion and Irradiation Behavior
of Beryllium

Changes in the mechanical and physical properties of beryllium as a result of neutron irradiation may be attributed to the displacements produced by energetic neutrons or the products from the $(n, 2n)$ and (n, α) reactions with beryllium, and to the effects produced by agglomeration of the helium produced by these transmutations. The mechanism for gas agglomerating into the large bubbles that cause swelling appears to be the migration of small gas-filled cavities (possibly cylindrical) to inclusions or other suitable nuclei where surface-tension restraining forces are small. Thus, the swelling is probably controlled by the creep properties of the matrix and by the rate of movement of the gas-filled cavities to the large bubbles.(8)

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- (5) Berillii: Khimicheskaya Tekhnologiya i Metallurgiya (Beryllium: Chemical Technology and Metallurgy) G. F. Silina, Yu. I. Zarembo, and L. E. Bertina, Atomizdat, Moscow (1960), p 119.
- (6) Gelles, S. H., Nuclear Metals, Inc., preliminary information under an Air Force contract.
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- (8) Frye, J. H., Jr., Manly, W. D., and Cunningham, J. E., Metallurgy Division Annual Progress Report for Period Ending May 31, 1961, Oak Ridge National Laboratories, U.S. AEC Report ORNL-3160 (August 17, 1961).

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A list of DMIC Memoranda 1-90 may be obtained from DMIC, or see previously issued memoranda.

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91	The Emittance of Titanium and Titanium Alloys, March 17, 1961, (PB 161241 \$0.50)
92	Stress-Rupture Strengths of Selected Alloys, March 23, 1961, (AD 255075 \$0.50)
93	A Review of Recent Developments in Titanium and Titanium Alloy Technology, March 27, 1961, (PB 161243 \$0.50)
94	Review of Recent Developments in the Evaluation of Special Metal Properties, March 28, 1961, (PB 161244 \$0.50)
95	Strengthening Mechanisms in Nickel-Base High-Temperature Alloys, April 4, 1961, (PB 161245 \$0.50)
96	Review of Recent Developments in the Technology of Molybdenum and Molybdenum-Base Alloys, April 7, 1961, (PB 161246 \$0.50)
97	Review of Recent Developments in the Technology of Columbium and Tantalum, April 10, 1961, (PB 161247 \$0.50)
98	Electropolishing and Chemical Polishing of High-Strength, High-Temperature Metals and Alloys, April 12, 1961, (PB 161248 \$0.50)
99	Review of Recent Developments in the Technology of High-Strength Stainless Steels, April 14, 1961, (PB 161249 \$0.50)
100	Review of Current Developments in the Metallurgy of High-Strength Steels, April 20, 1961, (PB 161250 \$0.50)
101	Statistical Analysis of Tensile Properties of Heat-Treated Mo-0.5Ti Sheet, April 24, 1961, (AD 255456 \$0.50)
102	Review of Recent Developments on Oxidation-Resistant Coatings for Refractory Metals, April 26, 1961, (AD 255278 \$0.50)
103	The Emittance of Coated Materials Suitable for Elevated-Temperature Use, May 4, 1961, (AD 256479 \$2.75)
104	Review of Recent Developments in the Technology of Nickel-Base and Cobalt-Base Alloys, May 5, 1961, (AD 255659 \$0.50)
105	Review of Recent Developments in the Metallurgy of Beryllium, May 10, 1961, (AD 256206 \$0.50)
106	Survey of Materials for High-Temperature Bearing and Sliding Applications, May 12, 1961, (AD 257408 \$2.00)
107	A Comparison of the Brittle Behavior of Metallic and Nonmetallic Materials, May 16, 1961, (AD 258042 \$0.50)
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109	Review of Recent Developments in Metals Joining, May 25, 1961, (AD 256852 \$0.50)
110	Glass Fiber for Solid-Propellant Rocket-Motor Cases, June 6, 1961
111	The Emittance of Stainless Steels, June 12, 1961
112	Review of Recent Developments in the Evaluation of Special Metal Properties, June 27, 1961
113	A Review of Recent Developments in Titanium and Titanium Alloy Technology, July 3, 1961

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116	General Recommendations on Design Features for Titanium and Zirconium Production-Melting Furnaces, July 19, 1961
117	Review of Recent Developments in the Technology of High-Strength Stainless Steels, July 14, 1961
118	Review of Recent Developments in the Metallurgy of High-Strength Steels, July 21, 1961
119	The Emittance of Iron, Nickel, Cobalt and Their Alloys, July 25, 1961
120	Review of Recent Developments on Oxidation-Resistant Coatings for Refractory Metals, July 31, 1961
121	Fabricating and Machining Practices for the All-Beta Titanium Alloy, August 3, 1961
122	Review of Recent Developments in the Technology of Nickel-Base and Cobalt-Base Alloys, August 4, 1961
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128	Review of Recent Developments in the Evaluation of Special Metal Properties, September 27, 1961
129	Review of Recent Developments in the Technology of Molybdenum and Molybdenum-Base Alloys, October 6, 1961
130	Review of Recent Developments in the Technology of Columbium and Tantalum, October 10, 1961
131	Review of Recent Developments in the Technology of High-Strength Stainless Steels, October 13, 1961
132	Review of Recent Developments in the Metallurgy of High-Strength Steels, October 20, 1961
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134	Machining of Superalloys and Refractory Metals, October 27, 1961
135	Review of Recent Developments in the Technology of Nickel-Base and Cobalt-Base Alloys, October 31, 1961
136	Fabrication of Tungsten for Solid-Propellant Rocket Nozzles, November 2, 1961
137	Review of Recent Developments on Oxidation-Resistant Coatings for Refractory Metals, November 8, 1961