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REVIEW OF RECENT DEVELOPMENTS IN THE TECHNOLOGY OF BERYLLIUM

DEFENSE METALS INFORMATION CENTER
BATTELLE MEMORIAL INSTITUTE
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REVIEW OF RECENT DEVELOPMENTS IN THE TECHNOLOGY OF BERYLLIUM

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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.(6)

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**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	$\chi_o = 45°$ λ_o Unknown	Unknown	2000 ± 500	5	Basal plane
Berylco Vacuum-cast ingot	2	$\chi_o = 47°$ $\lambda_o = 51°$	800 C, 1 hr	2400	16	Basal plane
Berylco Vacuum-cast ingot	5	$\chi_o = 20°$ $\lambda_o = 25°$	900 C, 1 hr	1350	64	Prism plane
Pechiney	8	$\chi_o = 48°$ $\lambda_o = 55°$	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)

Time (60 cycles = 1 sec)		Per Cent of Main Welding Current
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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(6) Gelles, S. H., Nuclear Metals, Inc., preliminary information under an Air Force contract.

(7) Herman, M. and Spangler, G. E., "Ductility of Beryllium Single Crystals Oriented for Basal Slip and Tested in Tension", The Franklin Institute Journal, 271, pp 421-422 (May, 1961).

(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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93	A Review of Recent Developments in Titanium and Titanium Alloy Technology, March 27, 1961, (PB 161243 $0.50)
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