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AEC RESEARCH AND DEVELOPMENT REPORT

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Engineering and Equipment

MASTER

CHEMICAL MILLING OF BERYLLIUM

R. C. Anderson
R. L. Ludwig

UNION CARBIDE CORPORATION
NUCLEAR DIVISION
OAK RIDGE Y-12 PLANT

operated for the ATOMIC ENERGY COMMISSION under U. S. GOVERNMENT Contract W-7405 eng 26

UNION
CARBIDE

OAK RIDGE Y-12 PLANT
P. O. Box Y
OAK RIDGE, TENNESSEE 37830

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ABSTRACT

Chemical milling of beryllium ingot sheet was investigated as an inexpensive, alternate method for producing the radiative fins for the SNAP-27 Radioisotope Thermoelectric Generator. Fin specimens were submerged in a sulfuric acid bath maintained at a constant temperature, then slowly rotated while being withdrawn from the bath at a constant rate of speed. This procedure should have produced uniformly tapered fins within a reasonable length of time. However, there were variations in the taper due to the nonuniform thickness of the hot-rolled beryllium sheet and a preferential attack at the rolling defects in the beryllium sheet.

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SUMMARY

Chemical milling of beryllium ingot sheet was investigated as an inexpensive, alternate method for machining the radiative fins for the SNAP-27 Radioisotope Thermoelectric Generator.

Fin specimens were submerged in a sulfuric acid bath maintained at a constant temperature, then slowly rotated while being withdrawn from the bath at a constant rate of speed. This procedure was designed to produce tapered fins. The following points were noted:

1. The rate at which the specimen was withdrawn from the bath had to be increased to 0.112 inch per minute to prevent excess removal of stock.
2. The bath temperature was very critical and had to be maintained at 27° C to obtain the correct taper.
3. A fresh solution was required for each specimen to control the dissolution rate and produce the desired taper of the specimen.
4. To maintain a uniform taper during the chemical milling operation, a uniform thickness of the starting sheet was required.

The results demonstrated that the taper of the beryllium fins could be chemically milled in a sulfuric acid bath within a reasonable length of time, but a variation in the taper existed over the length of the specimen due to the nonuniform thickness of the hot-rolled beryllium ingot sheet.

INTRODUCTION

Chemical milling is a process by which metal is removed by controlled dissolution into a chemical bath. The bath, in essence, is a highly refined pickling solution. Careful attention must be given to the rate of metal removed and to the type of surface left after processing.

Chemical milling is particularly adaptable to the fabrication of various shapes from beryllium sheet, where other types of machining would be either difficult or expensive. Consequently, chemical-milling studies were proposed for beryllium ingot sheet to demonstrate the feasibility and economy of this technique for machining tapered radiative fins for the Radioisotope Thermoelectric Generator designated as SNAP-27.

Each of the twelve radiative fins for the generator was to be 18 inches long, 7 inches wide, and tapered, in the 7-inch direction, from 0.107 ± 0.003 inch at the base to 0.027 ± 0.003 inch at the tip (a 0.080-inch taper) with a tolerance specification of ± 5 percent on all dimensions along the taper.

STEPS IN THE CHEMICAL MILLING STUDY

SPECIMEN PREPARATION

The wrought ingot beryllium sheet from which the specimens were machined was somewhat warped and had a thickness that varied between 0.273 and 0.288 inch. Six specimens (8 1/2" L x 3 1/2" W x 0.273 to 0.288" T) were machined from the ingot beryllium sheet. Prior to chemical milling, surfaces of the plate were prepared by pickling (50% H_3PO_4), vapor degreasing, and immersing in an alkaline bath.

EQUIPMENT

Development equipment for chemical milling beryllium is shown schematically in Figure 1. The assembled equipment consisted of a tank to contain the chemical milling solution, an agitator to stir the solution, heating units and a cooling coil to maintain the temperature of the bath between very close limits, a motor to rotate the specimen to prevent cavitation of the surfaces, and a variable-speed mechanism to lift the specimen from the solution at a constant rate. A photograph of the assembly with the fin specimen in the withdrawn position is presented in Figure 2.

Figure 1. DEVELOPMENT EQUIPMENT FOR THE STUDY OF CHEMICAL MILLING.

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Figure 2. ASSEMBLY WITH THE FIN SPECIMEN IN THE WITHDRAWN POSITION.

TEST PROCEDURE

The bath consisted of ten volume percent sulfuric acid in demineralized water. The beryllium specimen was submerged to a depth of 7 1/4 inches, rotated at three revolutions per minute, and withdrawn from the bath at a constant rate. The first specimen was milled prior to the introduction of the cooling coil. Cooling coils were used in the bath for the balance of the tests in order to compensate for the heat of solution of beryllium in sulfuric acid solution and, therefore, maintain a constant bath temperature throughout the run. The effect of the process variables (bath temperature and withdrawal rate) upon beryllium removal by chemical milling is indicated by the data of Table 1. The thickness measurements of the last three of these fin specimens are plotted in Figure 3. As the curves indicate, there was little difference between the fins tapered at 25 and 27° C, but there was a significant difference obtained from a specimen tapered in the 30° C bath.

Table 1
RESULTS OF CHEMICAL MILLING BERYLLIUM SHEET

Withdrawal Rate (in/min)	Bath Temperature ($^{\circ}$ C)	Taper in Seven Inches (inch)	Bath Condition
0.086	35 - 55	Variable	New
0.086	30	0.048	Used and Replenished
0.086	35	0.139	New
0.112	25	0.073	New
0.112	30	0.100	New
0.112	27	0.080	New

Figure 3. THICKNESS VARIATION OF CHEMICALLY MILLED FINS.

RESULTS

From this study, the following statements can be made:

1. Of the six fin specimens chemically milled, only one was successfully milled to the desired taper of 0.080 inch over the 7 1/4-inch length of the specimen. In this run, the withdrawal rate was increased from 0.086 to 0.112 inch per minute to reduce the taper in 7 1/4 inches to 0.080 inch.
2. The bath temperature was extremely critical and had to be maintained at 27° C to obtain a 0.080-inch taper.
3. A new solution was required for each fin specimen because chemical milling with a used and replenished bath could not be controlled to produce the desired specimen taper.
4. The taper was not uniform on the specimens after chemical milling due to the variation in thickness of the original hot-rolled beryllium ingot sheet and excessive attack at the rolling defects.
5. The chemically milled surface was not pitted as sometimes occurs in this metal removal process.

CONCLUSIONS

Only six chemical-milling tests were conducted on beryllium; consequently, the results cannot be considered conclusive but they do demonstrate that the taper of the beryllium fins can be chemically milled in a sulfuric acid bath within a reasonable length of time. There is some variation in the taper and this may be objectionable because a tolerance of ± 5 percent on all dimensions along the taper is required. Some of this variation is the result of the warped condition of the sheet, nonuniform thickness of the hot-rolled sheet, and preferential attack at the rolling defects.

For this particular application (tapering beryllium fins) chemical milling is not economical in comparison with conventional machining techniques.