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## BULK $ThO_2$, A REACTOR MATERIAL

J. R. Johnson
J. M. Warde

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Metallurgy and Ceramics

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METALLURGY DIVISION

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## INTRODUCTION

Thorium, a fertile material, is of interest to the Reactor Program in the production of $U^{233}$. Thorium can be extracted and processed to a very pure bulk metal for fabrication into solid fertile elements. There are advantages, technical and economic, for using fabricated bulk thorium dioxide rather than the metal in some applications. It is the purpose of this paper to point out these advantages and to present briefly the technology related to fabrication, radiation damage and chemical processing of $ThO_2$.

## FABRICATION

A technique has been developed for the economic production of bulk $ThO_2$ in the forms of rods, plates, pellets and tubes. The reactor technologist usually requires fuel or fertile materials having maximum possible density. It was necessary therefore to develop a useful means of obtaining high density $ThO_2$. While this could be accomplished by sintering at temperatures in excess of 2000° C, it would be impractical outside laboratory technology. By the addition of 1/2 wt. per cent CaO to the $ThO_2$, it is possible to attain bulk densities higher than 97% of theoretical and accomplish this at sintering temperatures within the range of commercial practice (1600° C - 1700° C). A rod of $ThO_2$ is shown in Figure 1. This rod was made by pressing $ThO_2$ powder + 1/2 wt. per cent CaO isostatically in a rubber mold at 30,000 psi. It was sintered at 1700° C in air using an air-propane gas fired furnace. Fabrication technology is discussed in detail in other reports.(1)(2)

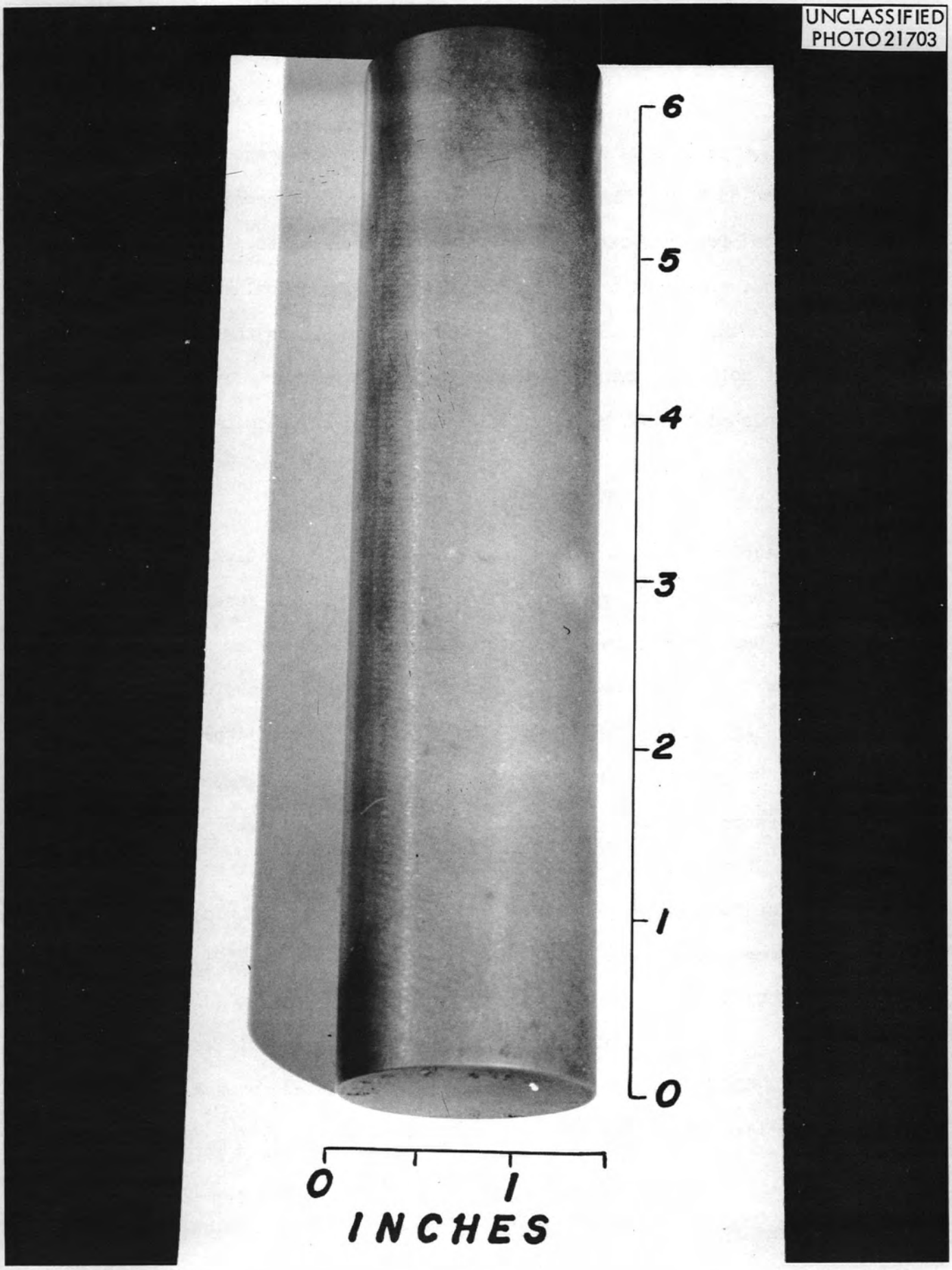


Figure 1

## RADIATION EFFECTS AND CONVERSION

Two thorium oxide rods were sealed in aluminum jackets and exposed in the LITR to an essentially thermal neutron integrated flux, $2 \times 10^{20}$ nvt[3][4]. Details of the rods and their exposure are shown in Table I.

TABLE I

| $ThO_2$ Rod | Length | Diameter | Density | Minimum and Maximum Exposure | Calculated Conversion |
|---|---|---|---|---|---|
| 1 | 4.23" | 0.71" | 8.64 | $1.7 \times 10^{20}$ wt. | .12% |
| 2 | 4.5" | 1.1" | 9.6 | $2.4 \times 10^{20}$ wt. max. | .17% |

There were no significant dimensional changes of the aluminum jackets; all differences in measurement, positive or negative were within experimental error. Figure 2 shows rod No. 1 after removal from its can. A small piece was broken from one end. Rod No. 2 was broken into several pieces. Whether this was done during handling in the "hot" cell, where the cans were gripped in a remotely operated hydraulic vise, or occurred from thermal fracture during irradiation is now known. The cracks were not radial as might be expected from thermal fracture.

While there are slightly less than 80% thorium atoms per unit volume in $ThO_2$ as compared with the metal, the availability of these atoms to neutrons in the center of bulk shapes is sufficiently greater so that total conversion to $U^{233}$ in the oxide is about the same as in the metal.[5]

## PROCESSING

A length of rod No. 2, about 1"-1-1/2" long weighing 212.7 grams was dissolved in 13 M $HNO_3$, .04 M HF solution, the total solution time being 35 hours.[6] While this is somewhat longer than would be required for a metal slug of similar size, the $ThO_2$ could be broken into small fragments before dissolution, which would decrease the solution time markedly. Any comparative economic study must take this into consideration.

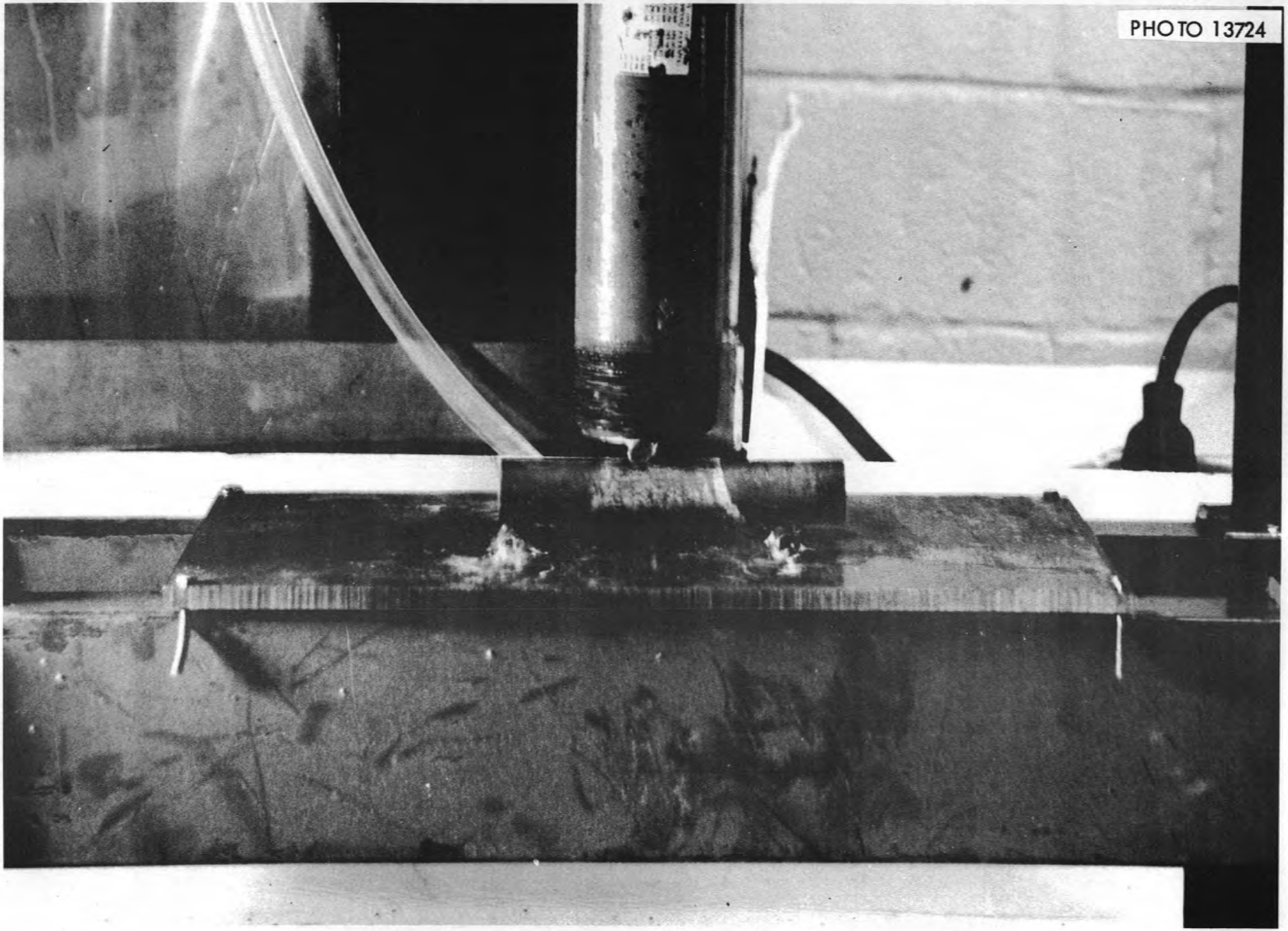


Figure 2

The reported $U^{233}$ content of the slug was 1182 g/ton of thorium or about .13% conversion, a value within the limits calculated from cobalt foil measurements.

## CONCLUSIONS

The results of these experiments demonstrate the feasibility of using $ThO_2$ as a fertile material. Commercial estimates of total fabricated costs of $ThO_2$ rods are of the order of $7.50 to $10.00 per pound, including the material, somewhat less than the cost of comparable metal rods. No catastrophic reaction or reaction of any kind occurs with water up to 300° C. It is unlikely that reactions occur at higher temperatures. Although no intimate bond existed between the $ThO_2$ and its aluminum jacket in these experiments, there was adequate heat transfer. $UO_2$ rods similarly canned in zirconium have been irradiated under higher power densities with corresponding higher thermal stresses with only gross internal cracking resulting. So long as no dimensional changes of the jackets occur the cracking is not considered serious. The economics of conversion to $U^{233}$ and subsequent processing requires further study, but experimental evidence indicates that the oxide is suitable for reactor use.

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(1) Interim Report, Properties of Thorium Oxide Ceramics, C. E. Curtis and J. R. Johnson, ORNL 1809, November 1954.

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(5) Resonance Capture in Thorium and Thorium Oxide Slugs, R. K. Cole, HW-31862, Aug. 1954.

(6) Examination of Irradiated $ThO_2$ Slugs for the $U^{233}/Th$ Ratio, R. P. Wischow, ORNL-CF-55-6-27.