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SUBJECT OR TITLE
Pertinent Facts About Thorium

TO
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FROM
J. V. McMaster

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May 9, 1951

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PERTINENT FACTS ABOUT THORIUM

Object

To consider some properties of thorium which might limit its use as a poisoning material in Hanford Works Piles.

Properties

The following information is taken from the references listed at the end of this memo or is resultant from tests performed at Hanford Works.

From the Literature

The fresh massive metal is silver-white, but turns to a dark grey color when exposed to the air. This color change probably results from the capacity that thorium has for absorption by diffusion or "occlusion"* of hydrogen. This occlusive capacity diminishes as the temperature is increased, but at a temperature of 300-400°C (with the massive metal) hydride formation begins which results in the formation of a black powder having the appearance of finely divided metal. This hydride reacts readily with oxygen forming thoria ($Th\ O_2$) and the amount of this oxide which is present in the metal as the chief impurity limits the rate of hydride formation.

Thorium metal is stable at room temperatures and is unaffected by water, even at 100°C, however, finely powdered thorium is pyrophoric and ribbons of metal burn in air to form the white oxide ($Th\ O_2$). The metal reacts vigorously with fluorine, chlorine, bromine, iodine, and sulfur at temperatures up to 450°C and with nitrogen at 650°C. When the metal is heated with carbon, phosphorous, nitrogen, or boron, the corresponding carbide, phosphide, nitride, or boride is formed.

Thorium dissolves readily in aqua regia or concentrated hydrochloric acid, but the metal becomes passive in concentrated nitric acid and solution stops. Concentrated perchloric, concentrated phosphoric, and dilute hydrochloric, hydrofluoric, nitric, and sulfuric acids attack

* Absorption which does not result in loss of metallic character.

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the metal slowly. Aqueous solutions of alkalies do not affect thorium, but fusion with alkalies has a detrimental effect.

The thermal conductivity and coefficient of linear thermal expansion of thorium metal having a composition of 96.4% free metal 3% combined oxide and carbide, and .6% other impurities are:

Thermal conductivity (100°C)	0.32 watts/cm/0°C or .0765 cal/cm/sec.(°C).
Thermal conductivity (300°C)	0.35 watts/cm/0°C or .0836 ca./cm/sec.(°C).
Coefficient of linear thermal expansion (25-1000°C)	12.2 x 10^{-6} in./°C

Thorium melts at 1827°C and has a boiling point estimated at anywhere from 3000°C to 5200°C. The molecular heat of formation of the oxide is higher than most other metallic oxides. This oxide is inert toward most chemical agents and is one of the most refractory substances known.

From Hanford Works Investigations

Experimental work performed in 1945 with samples of "myrnalloy" showed that the chemical and physical properties were as described in the literature. More important to its considered use in the piles were the results of autoclave tests performed using steam at 170°C (100 psi) for a period of 130 hours. This test, which has been recently repeated on a 40 hour cycle, performed on bare slugs as well as "B" process canned pieces with perforated jackets showed that a black, powdery material is slowly formed under the action of the steam and the initial powder formation tends to inhibit the formation of more. There was no distortion of the slugs and little dimensional change. In the case of the canned pieces it was possible to slip the slugs from the cans despite the presence of the powder between the slug surface and the can wall. The powder was dark grey, metallic looking, and uniformly coated on the still dense surface of each slug. Any surplus of powder was washed off with water, but the tenacious surface film resisted removal by chemical treatment. No satisfactory pickle was found although hot HNO_3-HF brightens darkened surfaces.

Conclusion

From this brief and condensed consideration of thorium and its properties it will suffice to say that thorium is a dense metal exhibiting great chemical inertness, passivity to corrosion, and none of the structural or chemical instabilities evident in uranium. In comparison, thorium has a thermal conductivity about one-seventh that of aluminum, and one and one-third times that of uranium. The coefficient of linear thermal expansion for thorium is approximately one-half that for aluminum.

Radiation effects on the properties of thorium were not available for consideration in this review.

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