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CONSTITUTION OF URANIUM AND THORIUM ALLOYS

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by

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DISCLAIMER

PREFACE

"Constitution of Uranium and Thorium Alloys" (BMI-1300) supersedes "Compilation of US and UK Uranium and Thorium Constitution Diagrams" (BMI-1000). It is a new reference piece in a modified format. The original "Compilation" has been used extensively and has been reprinted. The present authors believe that this degree of acceptance of the original work implies acceptance of the concept and approach. As a result, they have undertaken this "Compilation" in an attempt to provide an even more useful reference piece. Like its predecessor, this work was written with the cooperation of representatives of the United Kingdom.

The modified Metals Handbook system of notation for the diagrams employed in BMI-1000 was again used in preparing these constitutional diagrams. The symbols a/o for atomic per cent and w/o for weight per cent have been used. In keeping with the general convention, phases have been designated beginning with the base. The inconvenience of having two alpha phases, alpha A and alpha B, in the system A – B is thereby obviated. Some slight but easily reconciled confusion may exist with previous data where the diagram may have been developed for the system B – A.

This "Compilation" is divided into two major sections, uranium alloys and thorium alloys. The major sections are preceded by a discussion of the transformation and melting temperatures of the base metal. Following the discussion are the various systems in alphabetical order. The major sections include both binary and ternary systems. In the previous edition the systems were separated on the basis of whether or not constitutional diagrams were available. For this "Compilation" it was determined that less weight should be given to the presence or absence of a diagram and that utilization of the information was most readily accomplished by a completely alphabetical listing.

Generally, only unclassified references have been used. However, because the unclassified literature is incomplete for several systems, some classified references are given. It is believed that future declassifications may make many now-classified references readily available.

The authors dedicate this volume to the late Henry A. Saller, one of the original editors. His interests and efforts in bringing the original "Compilation" into being have made this "Compilation" a much more straightforward task.

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MELTING POINTS AND ALLOTROPIC MODIFICATIONS OF URANIUM

Reliable reports of the melting point and transformation temperatures of uranium are available in the literature[1]. Further, uranium of ultrahigh purity has been prepared and studied by thermal analysis[2]. The melting point and transformation temperatures which were determined are shown below.

	Temperature, C		
	Heating	Cooling	Average
Melting point	1128.7	1129.0	1128.9
Beta-gamma transformation	772.1	766.7	769.4
Alpha-beta transformation	667.1	657.7	662.4

In order to standardize the construction of diagrams, the average values shown above have been used throughout this volume as the transformation temperatures and melting point of uranium.

The crystal structure of alpha uranium has been determined to be orthorhombic by Jacob and Warren[3], using X-ray powder methods. The data on alpha in the tabulation on page 10 are from their work. Study by Lukesh[4] has confirmed these data on single crystals or uranium.

The structure of alpha uranium may be regarded as being formed by the stacking of corrugated sheets. The binding within the corrugated sheets is largely covalent in nature[5].

The crystal structure of beta uranium is complex and of tetragonal symmetry. Although it was not until recent years that the structure was known to be tetragonal, the major contributors are now in reasonably close agreement about it. The analysis of the structure of beta uranium has been accomplished by two different techniques. Tucker[6] has studied it at room temperature, using single crystals of retained beta in a 1.4 a/o chromium alloy. Thewlis[7] has studied beta both in pure uranium and in the 1.4 a/o chromium alloy at 720 C by high-temperature powder techniques.

Thewlis[7] reports that there are differences in intensity between beta powder patterns of the pure metal and those of the low-chromium alloy at 720 C. Tucker and Senio[8] report that the major discrepancy reported by Thewlis for the powder pattern of the low-chromium alloy is not found in single-crystal data from a sample of identical composition. On this basis, Tucker and Senio[8] conclude that the patterns of the beta structure for the low-chromium alloy and for the pure metal are identical.

The lattice dimensions for beta tabulated below are from Thewlis[7], while the other data for beta are from Tucker and Senio[8]. Tucker[6] reports unit-cell dimensions for single crystals of the 1.4 a/o chromium beta at room temperature to be a = 10.52 and c = 5.57 A, with a measured density of 18.697 g/cm^3. Similar data are reported by Thewlis[7], who gives lattice constants of a = 10.590 ± 0.001 and c = 5.634 ± 0.001 A and a density of 18.56 g/cm^3. These latter data are probably the more precise, since they were obtained by means of powder techniques. At 720 C, the unit-cell dimensions of the 1.4 a/o chromium beta, according to Thewlis[7], are a = 10.763 ± 0.005 and c = 5.652 ± 0.005 A, corresponding to a density of 17.93 g/cm^3.

The structure of gamma uranium has been shown to be body-centered cubic. The data tabulated below are from Thewlis[10]. X-ray data were obtained at 800 C, giving a lattice constant of a = 3.487 A[9].

Lattice constants were also determined for a series of alloys containing 17.3 to 31.2 a/o molybdenum which possessed a retained-gamma structure[9]. A lattice constant of a = 3.474 A at room temperature was determined by extrapolation of these data. Vegard's law was assumed to apply to this system.