INTERRELATION BETWEEN THE GRAIN ORIENTATION 
AND THE RADIATION GROWTH OF URANIUM RODS

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The results obtained in radiation tests of β-heat-treated uranium rods at temperatures of 200-300; 450-470; 480°C are given. Dependences of the radiation-growth coefficients $G_1$ on the growth index $G_1$ characterizing the grain orientation of the tested specimens were plotted. The elongation component resulting from the radiation growth due to grain orientation was determined. The dependence of the radiation-growth coefficient on the test temperature for weakly-pronounced grain orientations is given. It is shown that the mean values of the linear thermal-expansion coefficient $\alpha$, measured in one direction only, do not provide information on the character and degree of the grain orientation if the latter is not uniaxial.

The grain orientation which appears in uranium as a result of its mechanical treatment is one of the main causes of irreversible changes in the shape of parts exposed to radiation. In [1], a quantitative relationship between the degree to which the grain orientation [010] is pronounced and the radiation growth coefficient was established, and it was shown that the latter tends to zero in a metal with a quasi-isotropic structure. It is known that such a structure can be obtained in uranium subjected to cooling in the β- or γ-phase. However, according to data supplied by various authors, the radiation-growth coefficient of such a metal is not equal to zero; it is equal to 15-30 [2-4]. This may be caused by at least two factors: 1) the presence of weakly pronounced grain orientations in hardened uranium, the existence of which was confirmed by many authors [5, 6]; 2) the conditions under which the fuel elements are tested, where the observed irreversible changes may be caused by factors unconnected with the grain orientation (swelling, creep, thermal oscillations, etc.).

The separate effect of each of these factors on the over-all change in the dimensions of fuel elements containing unalloyed hardened uranium is of great importance, since it provides the possibility of controlling the variation of the shape of fuel-element cores by controlling the degree of grain orientation in uranium and the test conditions.

In the present article, we shall analyze the grain orientations arising in uranium during its heat treatment, and we shall establish a quantitative relationship between the degree of grain orientation and the radiation-growth coefficient of uranium. This investigation was performed in connection with the development of rod fuel elements [7].

Material and the Investigation Method

For the investigations, we used uranium of 99.78-99.80% purity, where the percentage of each of the basic impurities (Fe, Al, Si, C) did not exceed 0.02%. The diameter of the specimens was 4 mm.

Grain orientations with different characteristics, marked in various degrees, were produced by regulating the parameters of the β-heat-treatment of uranium: the characteristics of heating to the temperatures at which the β-phase is present, the exposure time at these temperatures, and the cooling conditions [8].

The grain orientation of hardened uranium was investigated by using the x-ray structural and dilatometric analysis methods.
The "growth index" method, proposed by the authors of [9], was used for describing the grain orientation in connection with anisotropic radiation growth. The quantitative parameter—the growth index GI—was derived from x-ray measurements similar to those used earlier for plotting reverse pole figures [10]. The growth index is found by determining the product between the volume of grains with a certain orientation and the weighting function of the deformation tensor of anisotropic growth.

The choice of the tensor weighting function is based on the observed deformation of uranium (at constant volume), while it does not depend on the deformation mechanism. The expression for the growth index can be written in the following manner:

\[ GI = \sum_i \left\{ P_i - P_r \right\} \left( \cos^2 \beta_i - \cos^2 \alpha_i \right) \]

where \( P_i = \frac{\mathcal{I}_i}{\mathcal{I}} \) is the density of poles, expressed in terms of the intensities (\( \mathcal{I}_i \)) of the x-ray interferences observed on the specimen under investigation and corresponding to the interference (\( \mathcal{I} \)) of a standard specimen with disordered structure; the index \( i \) pertains to the (hk\( l \)) planes; \( P_r = 1 \) is the pole density of a specimen with an isotropic structure; \( \beta_i \) and \( \alpha_i \) are the angles between the crystallographic planes (hk\( l \)) and the planes (010) and (100), respectively.

The growth index yields a single quantitatively defined value for the given grain orientation.

The coefficients of linear thermal expansion (\( \alpha \)) along the rod axis were measured in the temperature range from 20 to 100°C by means of a dilatometer on specimens with a length of 100 mm. The measurement error was equal to ±1% [8].

The radiation tests were performed in experimental gas loops on enriched-uranium specimens at core temperatures of 200-480°C. The temperature was controlled by means of miniature thermocouples, which were placed inside the cores. On the average, the heat release density was 15 MW/t. In order to prevent the corrosion of uranium specimens in the gas stream, they were covered with magnesium-based alloys.