INTERACTION OF THE METALLIC COMPONENTS OF MELT IN A REACTOR CORE WITH ZIRCONIUM DIOXIDE CERAMIC


The present report is a result of further investigations of thermochemical processes involved in the interaction between the melt of reactor materials and zirconium dioxide based refractories. This information is required for choosing a refractory for the melt trap in the case of a serious accident at a nuclear power plant [1-4].

It is well known that the main components of the core of the most commonly used reactors BBÉR and PWR are uranium dioxide, zirconium, steel, boron, and cadmium. In the case of a heavy accident with core meltdown, a melt of the core materials, whose temperature can reach 2500-2800 K, is formed. In some countries a trap is made for the melt to prevent the radioactivity from escaping in the case of a serious accident. The trap can be placed both inside and outside — at the bottom of the reactor shaft — the backup vessel. The trap material must have a high melting point, it should not oxidize in air and superheated steam, and it must be inert, to a sufficient degree, with respect to the melt. These requirements can be satisfied by the high-refractory oxides with a melting point above 2800 K. They include CaO, MgO, BeO, ZrO₂, HfO₂, ThO₂, and rare-earth oxides, especially CeO₂. However, some of them are subjected to hydration (CaO, MgO, some oxides of rare-earth elements), others are expensive and rare (BeO, HfO₂, Y₂O₃), and still others are subjected to partial reduction in media with a low oxygen content (CeO₂, Pr₂O₁₁) with a sharp drop of the refractoriness. Actually, only zirconium dioxide is a promising material for the trap, since its melting point is about 3000 K, it is chemically quite inert, and it does not form an easy-melting eutectic with uranium oxide [5].

The processes leading to the interaction of the melt with zirconium dioxide will be determined by the local distribution of the materials of the melt, the temperature conditions, and the characteristics of the medium inside the reactor, where water, water vapor, and hydrogen can be present. Therefore, the thermochemical processes will occur in an oxidizing-reducing medium. However, the degree of oxidization will be determined not only by the heating time and the amount of oxidizer, but also by the constructional features of the reactor, which affect, for example, the mixing of the melt. For this reason, the interaction of the zirconium dioxide with the unoxidized main components of the melt (steel, zirconium) must be taken into account.

It has been reported [6] that in an inert medium the interaction of metallic zirconium with its dioxide starts at temperatures above 1900 K, but there is no information about the character of the interaction.

After the melt of low-alloy steel is held for one hour at a temperature of 2500 K in a crucible made of zirconium-dioxide concrete (80% cubic zirconium dioxide in which the molar fraction of the stabilizing additives Y₂O₃ and barium aluminozirconate cement were equal to 6 and 20%, respectively), no erosion of the crucible at the location of the contact of the steel with the concrete was observed. This indicates that there is no appreciable interaction of the zirconium dioxide with iron [2]. In the presence of an oxidizer, however, iron oxides are formed, and together with zirconium dioxide they form an easy-melting eutectic [5].
Since the degree of oxidation of the components of the melt can be different, at the first stage it is of practical and scientific interest to study the interaction of the nonoxidized components (steel, zirconium) with zirconium dioxide. The investigations were performed in an argon atmosphere in order to obtain information in the simplest case for analysis of the experimental results.

Our aim in this investigation was to study the erosion resistance of the ceramic based on zirconium dioxide to the action of a melt of carbon and stainless steel with zirconium, specifically, the possible chemical interaction of iron and zirconium with zirconium dioxide, the degree of action of the melt on the composition of the ceramic, the penetration depth of the melt into the ceramic, and the erosion of the ceramic crucible.

**Formulation of the Experiment.** The experiments were performed by the crucible method (Fig. 1). The crucible material was a ceramic based on cubic zirconium dioxide, stabilized with 11-12 mole% Y₂O₃. The crucibles were fabricated by a technology close to the factory technology. It included pulverization to obtain the required fraction composition (0.63-1 mm, 0.2-0.315 mm, and 1-5 μm), magnetic and chemical purification, mixing of the fractions in a prescribed ratio, introduction of a temporary plasticizing binder, pressing (specific pressure 100 MPa) and annealing (2000 K for 13 h). The properties of the ceramic obtained were as follows: