V. F. Kolesov, V. Kh. Khoruzhii, and V. F. Yudintsev

The concept of "autocatalysis" is most often associated with chemistry and chemical technology. Ordinarily, this term refers to the acceleration of a chemical reaction by products of the reaction itself, which play the role of a catalyst. Correspondingly, in the field of reactors the term "autocatalysis" is employed for the acceleration of a nuclear chain reaction or an increase in the production of energy in a nuclear surge under the influence of changes introduced in the reactor medium by the chain reaction itself. Investigations of possible manifestations of autocatalysis in reactors and critical assemblies has always been considered to be important, especially with respect to reactor safety. Works in this direction have been published since the beginning of the 1960s [1--4]. Autocatalytic phenomena associated with both the geometric rearrangement of the distribution of materials in a reactor [1, 2, 4] and with purely nuclear effects resulting from a change in the neutron interaction cross sections of fissioning materials [1, 3] are investigated.

Works on autocatalysis have broached the question of the effect of an internal cavity in the core on the energy release in explosive accidental surges [1, 2]. It has been found that autocatalysis associated with empty cavities does not appear under real conditions of displacements of fissioning material. This is indicated by work performed abroad [1, 2], some works performed in the 1980s at the All-Russia Scientific-Research Institute of Experimental Physics, and recent calculations [5]. The absence of an effect in the present case can be explained by the fact that in an explosion of a critical assembly during an accident the positive contribution to reactivity from displacements of fissioning material inside a cavity is compensated many times over by the negative contribution of the expansion of the core to the reactivity.

New and more comprehensive calculations of explosive surges of fissioning in reactor systems containing cavities have been performed since 1994 at the All-Russia Scientific-Research Institute of Experimental Physics. A multigroup neutron-gas-dynamic program for performing one-dimensional calculations is used. In the first series of calculations [5], the energy release in supercritical metallic uranium or plutonium spherical assemblies with large central cavities was determined. Just as in previous work, no traces of autocatalysis were found in simple hollow systems. However, further calculations traced the effect of various fills in a cavity on the energy release during surges. It was found that some fills result in a sharp increase in energy release during a surge. The effect appears in assemblies with a neutron-absorbing layer placed at the periphery of the cavity, and it is intensified when the rest of the cavity is filled with a neutron moderator [5].

According to the calculations, autocatalysis is especially strongly manifested in assemblies containing a reflector made of a heavy material and the relative effect of an increase in the energy release during a surge increases sharply with increasing cavity radius and decreasing initial supercriticality of the assembly. In any assemblies with or without a reflector, the greatest effect is observed for fills consisting of $^{10}$B and hydrogen. Europium and, possibly, gadolinium, samarium, and hafnium can serve as effective neutron absorbers.

The manifestations of autocatalysis are explained by the release of reactivity in the initial absorber-compensated geometry. The following examples illustrate the significance of the scale of autocatalysis effects. Filling a cavity with a 12 cm radius with boron and hydrogen in a uranium assembly with a tungsten reflector and 5% supercriticality increases by a factor of 230 the energy released in a surge (from 130 to 297000 GJ), and in the same assembly with 0.5% supercriticality it increased by a factor of 40000 (from 0.065 to 2580 GJ) [5].
As was made clear by [6], an effect similar to that discussed here was proposed by E. Teller (USA) at the beginning of the 1940s for application in the first atomic bomb. In spite of the long history of this question, many facts show unequivocally that specialists in the field of reactor technology, both in Russia and abroad, do not know of this effect.

In [5] it is pointed out that the observed autocatalytic effect can potentially increase the scale of accidental surges in reactor plants and therefore make working on them more dangerous. It has been noted that measures to eliminate the sources of this effect must be taken in designing research reactors and in formulating reactor experiments. Other works in this series have also noted the need for a similar investigation of the manifestations of autocatalysis in operating, aperiodic, pulsed reactors at the All-Russia Scientific-Research Institute of Experimental Physics taking account of the dangerous loads in the central channels of the reactors. Later, under the impression that the scale of the observed autocatalytic effect is large, this was also required by the Office of Nuclear Safety at the All-Russia Scientific-Research Institute of Experimental Physics and the Ministry of Atomic Energy of the Russian Federation.

**Calculation of fission surges in BR-1 and BR-K1 reactors.** Of all the aperiodic pulsed reactors operating at the All-Russia Scientific-Research Institute of Experimental Physics [7–10], a systematic calculation of the energy released in surges, taking account of possible autocatalysis, has been performed only for BR-1 [9] and BR-K1 [10] reactors. It has been shown that the expected increase in energy release during surges is greatest in these particular reactors.

The BR-1 and BR-K1 cores (axial section) are displayed in Figs. 1 and 2. The BR-1 core is a hollow cylinder separated into four parts: a stationary top unit, a mobile bottom unit, a regulating unit, and a pulsed unit. To decrease the thermal stresses and the role of the stress concentration factor, the core is divided into disks and the disks are divided in coaxial rings.