MONITORING OF NEUTRON-PHYSICAL PARAMETERS DURING LOOP TESTING

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In investigations on fuel elements and materials-research assemblies the problem is not only to determine and produce the necessary test conditions but also to monitor those conditions during the entire operating lifetime. Of greatest interest in this connection are radiant heat release and the neutron-flux density, which could vary considerably during a reactor run as a consequence of displacement of the control rods, fission-product build up, etc. The effectiveness of such monitoring depends on the relative positions of the pickups of the monitoring system, the method of determining the energy release (by calculation using the information supplied by the pickups or by direct measurement of the energy release in a specimen with the same nuclear composition as the object under study, etc.). Clearly, the best result is attained when the object under study itself is used as the detector specimen. The calorimetric method using calorimeters-thermodivertors meets these requirements [1].

The present paper is devoted to the creation of a system for monitoring the energy release and the neutron-flux density in fuel composites and structural materials during operating lifetime tests on a VVR-K water-moderated–water-cooled reactor. In this case it is necessary to monitor not only the neutron-physical parameters of the assemblies studied but also the reactor power, for the purpose of ascertaining possible correlations between these characteristics. The latter was accomplished with the aid of bars (monitors) incorporating calorimetric pickups and self-powered detectors (SPD). The calorimetric monitor constituted a battery of calorimeters with specimens of ^{235}U for monitoring energy release in the loop assembly and Fe and Zr for monitoring the γ-component of the reactor radiation and a background calorimeter for determining the heat release in the measuring shell itself.

The SPD bar contained four pickups, one of which was 500 mm long – thus, practically covering the entire height of the reactor core – and three pickups 120 mm long, arranged in succession over the height of the bar. The first pickup gave the integrated characteristic of the neutron field at the measuring site, while the others gave the local characteristic and enabled the position of the control rods to be taken into account.

Depending on the problem (determining the reactor power or monitoring the parameters of the loop assembly) the design and composition of the measuring bars are changed as is also their arrangement in the reactor core. Thus, to determine the power the measuring bars were placed on the boundary of the reactor core (in a separator or tank) where the perturbation introduced by the control rods is a minimum. On the other hand, when monitoring the parameters the measuring devices were placed as close as possible to the object of our investigations or directly in it.

Figure 1 shows the dependence of the signals from the measuring bars on the thermal power of the reactor. As is seen, over the entire operating range these quantities are found to be linearly dependent on the reactor power. Having established a relation between the parameters of the assembly tested (energy release, temperature, etc.) and the signals from the measuring bars, this allows us to do without making direct use of the thermal power of the reactor which at low levels is determined with a large error, and to reproduce the power regimes of the tests with fair accuracy (error ~5%).

Monitoring of the heat release is complicated by the fact that measurements in the objects investigated under normal operating conditions of the reactor (power up to 10 MW) is hindered technically because of the high temperature (1000-1200°C), at which the calorimeters cannot function. Accordingly, the energy release in the loop assembly is determined directly at relatively low power levels while at the same time monitoring

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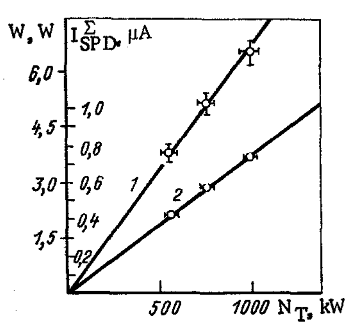

Fig. 1

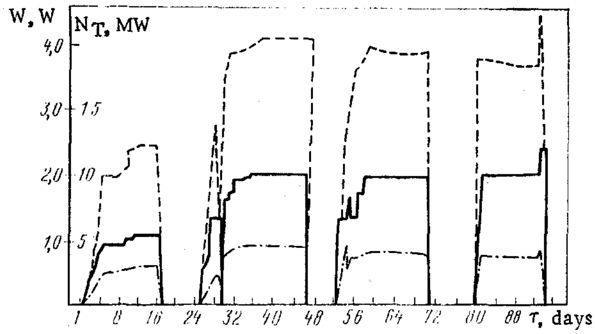

Fig. 2

Fig. 1. Dependence of signals of calorimetric monitor W (1) and current I^{Σ}_{SPD} of SPD pickups on thermal power of reactor.

Fig. 2. Correspondence between indications of calorimetric bar and thermal power of reactor: – – –) energy release in ^{235}U specimen; ——) thermal power of reactor; –·–·–) energy release in ^{10}B specimen.

is carried out by a calorimetric bar with ^{235}U, ^{10}B, Fe, or Zr. The quantities, which are related in a known way to the reactor power, make it possible to monitor the energy release and the radiation conditions at the testing position for any reactor load. The reliability of such monitoring has been confirmed by the results of measurements carried out during two reactor operating runs; the error of the measurements was 10-15%.

The kinetics of heat release in structural materials was investigated during a reactor run. It was shown to increase monotonically (e.g., to 30% for iron specimens) and there are two intervals with a different growth rate: the first, within the limits of three days, is due to withdrawal of the control rods (as a consequence of xenon poisoning) and the buildup of short-lived fission products; the second, a longer interval, but with a smaller growth rate of heat release, is due entirely to the buildup of long-lived sources of γ rays. This picture is repeated when power is built up after a shutdown. The data obtained make it possible in tests to take account of the temperature caused in the tested specimens by the growth of heat release. Figure 2 gives the energy release in the calorimeters with ^{235}U and ^{10}B specimens; it gives the plot of the reactor power N_T. It is seen that all three characteristics correlate well with each other. The breakdown of the correlation at constant thermal power of the reactor indicates a change in the radiation conditions at the testing place [2].

The operating reliability of the calorimetric pickups (maintenance of the sensitivity coefficient, its temperature dependence, etc.) during prolonged tests can be controlled with an electric heater built into the calorimeters.

In conclusion, the authors thank the team operating the VVR-K reactor for assistance in conducting the experiments.

LITERATURE CITED

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