CHANGE IN THE PROPERTIES OF GRAPHITE FROM THE REACTOR MASONRY OF THE OBNINSK NUCLEAR POWER PLANT

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Graphite masonry is never replaced during the operational lifetime of uranium-graphite reactors. For this reason, the state of the graphite is extremely important for safe operation. Radiation-induced changes in the properties of the graphite can be predicted only approximately on the basis of investigations [1], since such a prediction neglects many factors that affect the preservation of the masonry. In this connection, for purposes of measuring a set of characteristics of graphite that determine the possibility of further operation of the reactor, core samples are systematically drilled out of the blocks in the masonry [2].

In the present paper we summarize investigations of the changes occurring in the properties of masonry graphite during the operation of the AM-1 reactor in the first nuclear power plant in Obninsk.

AM Reactor. The graphite masonry of the reactor, which was started up in 1954, is 3000 mm in diameter and 4500 mm high. The 1500 mm in diameter and 1700 mm high core consists of blocks of reactor-grade GR-120 graphite. The graphite blocks are 600 mm high hexahedrons with 173 mm "turnkey" edge and 65 mm in diameter openings. The core contains 128 technological channels and 28 safety and control system channels. The lattice spacing is 120 mm. The rated thermal power of the nuclear power plant 30,000 kW was reached in October 1954. However, as a result of leakage in the fuel assemblies, the reactor operates at a lower power (since 1971 not exceeding 10,000 kW).

During the first 2-2.5 years the nuclear power plant operated as a demonstration power-generating unit. In 1956-1957 the AM reactor became a research reactor and is now used for testing new fuel elements and fuel assemblies. Since 1989, targets for the production of medical radioisotopes have been irradiated in the reactor.

Operating Conditions of the Graphite Masonry. During the first few years of reactor operation the temperature of the graphite moderator in the cells of the standard fuel assemblies was equal to 650-700°C. In the individual cells of the central ring, where graphite inserts were placed for the purpose of increasing the neutron flux around the fuel assembly being tested, the temperature of the graphite blocks could reach 850°C. Furthermore, replacement of the safety and control system channels with cooling to safety and control system rods without cooling increases the temperature of the graphite blocks in the cells of the safety and control system up to 700-760°C.

With a reactor power of 10,000 kW the temperature of the blocks in the graphite masonry was equal to 400-550°C. In 1997 all rods were placed in cooled channels. Fuel reloading is performed with the reactor shut down, so that there is no radiation annealing of the graphite.

An inert atmosphere is maintained in the reactor space by additional feeding of nitrogen along the impulse lines of the system monitoring the air tightness of the jackets, connected to the fuel-assembly heads (according to the ratings, the oxygen volume fraction is 0.01-0.05%; the actual volume fraction is 0.5%). Gas passes into the cavities of the fuel assemblies in a direction from top to bottom and flows in the reactor space at the level of the top boundary of the reflector. The excess gas pressure is now maintained equal to 20-50 Pa (previously it was maintained at 200-300 Pa). Since 1972, the additional feeding of nitrogen has been equal to 2-2.2 m³/h (with a reactor-space volume of about 6 m³). Gas losses are due to leaks in the reactor shell.

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Before nitrogen is introduced into the reactor space, oxygen is removed from the nitrogen by means of copper-plated silica gel at 200-220°C. The quality of the gas medium (the content of oxygen, hydrogen, and carbon dioxide gas) is constantly checked by automatic monitoring systems and once a day with an LKhM-8MD chromatograph. The moisture content of the gas is determined by a weighing method; since January 29, 1989, it has been determined by an automatic monitoring device.

Four characteristic periods of operation must be distinguished:

1954-1955. Leakage in the fuel assemblies and channels of the safety and control system was observed. The drainage during this period was equal to 150-180 liters/h. The content of carbon dioxide and hydrogen was 1.5-2 times higher than the admissible norms. The admissible volume fraction of impurities in the gas medium from 1954 to 1971 was equal to 1% in terms of carbon dioxide and oxygen and 0.5% in terms of hydrogen.

1956-1964. There were 11 fuel assemblies with leaks. In the main, the impurity content in the gas medium did not exceed the specifications.

1965-1971. In 1965, SV series fuel assemblies were installed in the reactor and 67 assemblies with leaks were removed in the course of the year. The leaks were located mainly in the zone of the temperature-expansion compensators at the top of the fuel assemblies. A total of 193 fuel assemblies with leaks were removed over this entire period. These were the most unfavorable years for the graphite masonry. The carbon dioxide content in some periods exceeded 2.5%, indicating intense oxidation of the core graphite. The graphite burnup was estimated to be 87 kg or 2% of the total load. After each wet accident, the graphite masonry was dried in stages at 5 and 20% nominal power.

1972-1995. The reactor operated without any leaks occurring in the fuel assemblies. The quality of the nitrogen feed and nitrogen from the reactor space during operation at power are presented in Table 1 (over the period 1992-1994).

As one can see from Table 1, the volume fraction of carbon dioxide gas in the reactor space during operation at power equals 0.1-0.3%. The graphite temperature during this period did not exceed 500°C, and the nitrogen feed flow rate was equal to 2-2.5 m³/h. The moisture content of the gas medium with the reactor shut down was equal to 4-12 g/m³; the nitrogen feed rate was equal to 1.5-2 m³/h; and, the temperature of the graphite masonry was equal to 35-50°C.

### Table 1. Nitrogen Quality in the Reactor Space

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Volume fraction (%) in nitrogen</th>
<th>introduced</th>
<th>actual</th>
<th>from the reactor space</th>
<th>norm</th>
<th>actual</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxygen</td>
<td>≤ 0.1</td>
<td>0.01-0.05</td>
<td>≤ 0.1</td>
<td>0.1-0.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbon dioxide gas</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>≤ 0.3</td>
<td></td>
</tr>
<tr>
<td>Hydrogen</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>≤ 0.1</td>
<td></td>
</tr>
<tr>
<td>Moisture content, g/m³</td>
<td>≤ 0.3</td>
<td>0.1-0.3</td>
<td>≤ 0.1</td>
<td>(3-14)10⁻¹</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

![Fig. 1. AM-1 cartogram with sampling cells in 1971 (1), 1984 (2), 1985-1987 (3), 1990 (4), 1991 (5), and 1996 (6).](image)