ENERGY-LIBERATION FIELD IN THE ACTIVE ZONE OF A
BOILING-WATER-WATER REACTOR

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At present, a promising type of reactor for AST built in the USSR is the vessel reactor with a boiling water moderator-coolant and natural circulation. For calculations of such reactors, in particular, for physical calculations of the active zone, a reasonable starting point is the program of physical calculation for water-cooled, water-moderated power reactors [1-3], the construction and operating conditions of which are similar to those adopted for AST reactors: hexagonal fuel-assembly geometry, regulation of the reactivity by inserting absorber clusters, conditions of partial reloading, etc. These programs belong to the category of large-grid algorithms [4] for calculating the active zone, which are intended to insure an acceptable computer calculation time with satisfactory accuracy of calculation of the energy-liberation field, effective breeder coefficient, and working life of the reactor. The method of physical calculation developed for a boiling water-water reactor, which is realized in the BIPR-K program, has the following features in comparison with the BIPR-series programs widely used for water-cooled, water-moderated reactors [1, 2]:

discontinuity of the moderating properties (diffusion coefficients and neutron-migration areas) of the active zone is taken into account;

a thermohydraulic-calculation module is provided, allowing the distribution of the density and flow rates of a steam-water mixture with a specified energy-liberation field in the active zone to be found (it is possible to consider both natural and induced circulation of the heat carrier);

the constants of the physical calculation are approximated by polynomial dependences describing the complex character of the feedback in conditions of moderator-coolant boiling.

In addition to calculating the state of the active zone (energy-liberation field and effective breeding factor), the BIPR-K program provides for simulation of fuel burnup, regulation of the reactivity, reloading, transient processes in adjusting the reactor power, etc. The method of calculating the energy-liberation field realized in the BIPR-K program (in other words, the principles of physical calculation of the reactor) is described below.

**Formulation of the Problem**

Consider a system of two-group diffusion equations

\[
- \text{div} D^b \text{grad} \phi^b(r) + \left(\Sigma_a^b + \Sigma_{\text{in}}^b\right) \phi^b(r) = \frac{1}{k_{\text{ef}}} \left[\nu \Sigma_f^b \phi^b(r) + \nu \Sigma_f^b \phi^f(r)\right];
\]

\[
- \text{div} D^f \text{grad} \Phi^f(r) + \Sigma_0^f \Phi^f(r) = \Sigma_{\text{in}}^f \phi^b(r)
\]

in the three-dimensional region V consisting of some set of cells - regular hexahedral prisms. The prisms are formed by dividing the hexahedral fuel assemblies by a series of equally spaced horizontal planes. The coefficients of the system are assumed to be constant within the calculation cells and to have the usual meanings.

At the boundary G of region V in the direction of the external normal \( \hat{n} \), the specified boundary conditions are assumed

\[
\frac{d\phi^b, r}{dn} \bigg|_{G} = - \frac{1}{d_b, r},
\]

The extrapolation lengths \( d \) may be different for each of the cell boundaries at the boundary G. Both external boundaries (with a reflector) and internal boundaries (definite sections of the regulator not including fuel) are meant by G. The problem of determining the eigenvalues is solved and the minimum eigenvalue \( \lambda = 1 / k_{\text{ef}} \) is found. The group neutron fluxes \( \phi^b(r) \) and \( \phi^f(r) \) are calculated, as well as the mean relative energy liberation over each of the cells

\[
\bar{\Psi} = \Sigma_f^b \Phi^b(r) + \Sigma_f^b \Phi^f(r).
\]