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RELAP5/MOD3.2 ANALYSES of KS-1 FACILITY EXPERIMENTS on HEAT TRANSFER PROCESSES in the FULL-LENGTH and PARTIALLY UNCOVERED VVER CORE MODEL CONDUCTED in RUSSIAN RESEARCH CENTER "KURCHATOV INSTITUTE"

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ABSTRACT

Results of RELAP5/MOD3.2 validation analyses of KS-1 experiments with the full-length and partially uncovered VVER core model are presented in this work. The objective of the analyses is to assess the code suitability for description of thermal and hydrodynamical processes in the uncovered core under Small Break LOCA conditions in VVER type reactor.

The tests have been carried out in the experimental section KS-1 VVER Loop model at the KS test facility (RRC KI). This is a semi-integral one loop model of VVER primary coolant system. It includes models of all the main components of a reactor. Fuel assembly (FA) model consists of 19 electrically heated rod simulators of 9 mm OD and 2.505 m height.

In the work special emphases were given to:

- thermal and hydrodynamical processes during reflux condenser mode in the primary coolant system with different mixture levels in the core model and with small heat powers and medium pressures;
- non-equilibrium heat transfer and axial distribution of rod's wall temperatures in the uncovered part of the core model under quasi-steady conditions at constant in time FA power;
- influence of thermal and hydrodynamical processes in the loop's components on the processes in the core model, including influence of steam condensation in the loop's components on an occurrence of counter current flow (CCF) of phases and, consequently, on heat transfer in the core uncovered part.

Results of six tests were chosen for formulation of standard problem INSC SP-V4 for VVER and code simulations of the phenomena in the uncovered core under SB LOCA conditions.

The influences of the main parameters on the heat transfer and rod's wall temperature behavior have been studied in the following ranges of parameters:

- FA model power W=9.4-21.2 kW,
- core model outlet pressure Pout=31-67 bar,
- coolant temperature in the lower plenum model TFin=478-511 K,
- mixture level in the FA channel Lm=0.0, 0.62, 1.62, 1.78, 2.29 m,
- temperature of rod's wall Tw $\leq$ 770 K.

Specific feature of the tests is relatively high intensity of heat transfer from the rods to the coolant in the uncovered part of the FA model, which took place due to heat losses and steam condensation

in the components located above the FA channel in the up-coming branch of the loop. During cooling of the FA model, non-uniform axial and radial distributions of the rod's wall temperature were obtained because of an occurrence of CCF in the uncovered part of the core model. Measured maximum temperature of the rod's wall could take place both at the FA outlet and at different elevations inside the core model in accordance with the test conditions.

Comparisons of the behaviors of the calculated and experimental temperatures of the rod's walls at various elevations in the FA channel allow to draw a conclusion on reasonable or minimal agreements of the general pictures of simulated complex processes with the test data. The essential distinctions of considered tests on modes of CCF in the FA uncovered part are the reasons of significant distinctions in degrees of the agreement between calculation and data from test to test.

The code gives the reasonable agreements between calculated rod temperatures and measured ones *for a turbulent mode of steam flow under CCF conditions* only for the tests with mixture level in the middle part of the FA channel.

For full-length uncovered core and with low mixture level in the FA channel there are significant quantitative and qualitative distinctions between the calculated and measured axial profiles of the rod temperatures in the FA model. *For laminar and transitional modes of steam flow*, the code gives only minimal agreements between calculated rod temperatures and measured ones. The code over predicts temperatures in the FA uncovered part. The calculated rod temperature is much higher (up to 100-150 K) than measured ones at the FA top. This is one of the main problems of the code.

The reason for these deviations between experiments and calculations is too small coefficient of heat transfer from the outer surfaces of the rods to the coolant in the FA uncovered part calculated for conditions of CCF. In this case underprediction for interphase heat transfer may be the other reason for these deviations between experiments and calculations.

The code insufficiently precisely describes processes of hydrodynamics and heat exchange in the conditions of CCF at high mixture level, and also at low mixture level in the FA channel. The inadequate modeling by the code of considered processes at the beginning of core uncovering will result also in non-adequate descriptions of these processes at the subsequent stage of the transient with a mixture level in the middle part of the core where it is expected that the code should work well.

A necessity of additional investigations for a substantiation of updating of the models of the code used for interphase friction and interphase heat exchange in the FA uncovered part in conditions of CCF is shown. It is necessary to continue experimental investigations of the considered phenomena/processes with application to VVER.

Also, it is necessary to carry out the analysis of the code adequacy when modeling heat transfer in the partially uncovered core at various modes of the steam flow and in conditions of the absence of CCF. This analysis should be implemented additionally in a special Standard Problem. This work can be executed on the basis of test data VTI and CKTI at the definition and analysis of the following Standard Problem "Heat transfer in the partially uncovered core at various modes of the steam flow in conditions of the absence of counter current flow of phases".