CURRENT PROBLEMS OF VVER-1000 REACTOR CORE OPERATION IN UKRAINE

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Planned control rod drop time registration was passed two times a year per reactor unit. In 1992-1993 some control rods at almost all VVER-1000 units exceeded the prescribed 4 second time limit.

There were different versions to consider:

1. deposition on inner side of fuel assembly (FA) guide tubes;
2. corrosion product drift into FA guide tubes;
3. mechanical bowing of FA spring blocks and control rod drives;
4. mechanical bowing of FA guide tubes;
5. radiation creep of the structural materials.

To determine the real cause of that phenomenon, some spent FAs were tested at the hot cell. As a result of testing versions 1-3 were not confirmed. The fourth version seems to be the primary one. The last version cannot be proven due to limited data, and cannot be the main cause.

Large amounts of statistics were obtained in Russia, Ukraine and Bulgaria VVER-1000 [FA curvature, inter-assembly gap, control rod weight diagrams, etc.]. FA guide tube bowing is the same as bowing of fuel rods in the FA. FA bowing has a dollar-type complex form. FA bowing is the consequence of disproportionate FA lengthening and the possible spring block compression value. The bowing has a form of collective movement and cannot be removed momentarily because of FA operation history.

There are some ways to reduce the control rod drop time:

- remove or reduce the main cause (FA bowing);
- reduce hydraulic resistance of the control rod – drive system;
- increase the weight of control rod – drive system.

<u>Correction measures to reduce control rod drop time in VVER-1000 were:</u>

1. To reduce FA bowing the reactor lid level was measured and increased if needed by reactor designer. Also, FA spring block roughness was reduced. From 1999, all FAs have reduced spring block roughness. From our viewpoint, it is also important to construct FA fuel rods, FA guide tubes and the central tube with the same structural material to avoid different temperature lengthening.
2. To reduce hydraulic resistance, perforation of the control rod drive shroud tubes was made.
3. The control rod drive weight was increased on some reactor units (Rovno-3).
4. Operation of the new control rod type with increased weight now is in progress. It is planned that all the old types of control rods will be replaced by the new type, as was done in Russia.

To be sure that the drop time is under regulatory conditions through unit operation, the test period was reduced up to 90 days. One 50% power capacity test per fuel cycle is demanded. It is about 4 tests per fuel cycle. Now almost all correction measures are made. A large number of time measurements were made. Evaluation of the test results shows that the drop time of control rods is the same for both the 50% power capacity test and the test in the hot shutdown state. It is necessary to reduce the test quantity per fuel cycle because of negative impact of transients. The general constructor recommendations were obtained. Technical solutions and corresponding documentation were sent to the regulatory authority. That technical solution is now in expert organization.

More than 7000 individual control rod time tests were made from the main correction measures. The following conclusions have been made from the current statistics data:

- The main role of the vibration factor is proven in the FA bowing process. The greatest drop times and maximum of bowing values are concentrated at the vibration zone (2-4 FA rows from the reactor partition). The first FA row seems to be stable due to the interaction with the reactor partition;
- Bowing relaxation will proceed during several fuel cycles (estimated value is 4-6), and depends on previous FA use history. It seems to be proven that previously bowed FAs effect the new FA, so previously bowed FAs are straightened until the middle of the fuel cycle. At some reactor units small drop time reduction is observed up to half of the fuel cycle from the start time values;
- Control rod drop medium time (t) has almost linear dependence on operation time (τ) [$t=k\times\tau+b$]. Es-

timated by the method of least squares, values of *k* and *b* differ from unit to unit and from cycle to cycle. Values of *k* and *b* are in following ranges: b=2.0÷2.6 *seconds*, k=5-50×10^{-4} *seconds per effective operation day*;

- Control rod drop time distribution changes through operation time. The position of maximum starts to shift after 240 eff.days, and the form of the distribution start to change at the same time. Before 240 eff.days, the distribution essentially does not change.

To guarantee that the control rod system reliability is now within prescribed limits, we should continue testing. Additional analysis is needed. Test frequency can be reduced to avoid additional unreasonable transients.

The FA bowing that was discovered also has neutronics consequences. Core power distribution will change due to local water-uranium ratio changing. So new core calculation methods are needed to avoid DNB (departure from nucleate boiling). One of the possible ways is to recalculate the maximal available K_v values using previously measured inter-assembly gap values {K_v – non-uniformity coefficient of volume power production}. To avoid annual gap measurements, a general contractor now prepares recommendations on the generalised result basement. This way seems to be very effective because there is no need to revise the core calculation code.

Now it is evident that currently proposed phenomenon models do not explain all collected facts. To get the precise theoretical explanation of all facts it is necessary to carry out a great deal of various types unplanned experiments. If we have a proven theoretical model, we can predict zone behaviour.