ON MODERNIZATION OF CONTROL PROCEDURES OF THE HEAT EXCHANGE TUBES OF STEAM GENERATORS OF UKRAINIAN NPPs

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Taking into account the realities, the nuclear power industry of Ukraine will play a key role in generating electricity in wartime and post-war times. The heat exchange equipment is vulnerable in the composition of the NPP, in particular, the heat exchange tubes (HET) of steam generators (SG).

The metal of the SG HET in conditions of the water-chemical regime is exposed to operating factors, which causes damage to the HET. Specialists of the NSC KPTI on fragments of HET (after long-term operation) studied operational damage, their morphology, distribution and their influence on the state of the metal and correlated the results with microstructural and mechanical properties. The patterns of crack initiation and their growth were established. Mathematical models of the evolution of the stressed-deformed metal of key elements of the steam generator piping systems in operating modes were created, which allowed us to study the dependence and sensitivity of the characteristics of defect formations on the parameters and operating conditions.

Based on the results of annual monitoring of defects in the HET of steam generators of the PGV 1000M NPP of Ukraine using non-destructive testing methods, data from many years of measurements were concentrated in a representative (over 10^6 measurements) database, which provided a factual basis for developing plans for future HET inspections of SG for the effective selection of incomplete control zones. Using specially developed models and statistical methods to analyze the accumulated data of many years of measurements of the eddy current control (ECC) of the NPP of Ukraine, results were obtained that indicate that the procedures and algorithms of the plans for monitoring the condition of the SG tubes, which are rigidly established by the relevant regulations for conducting inspections, require modernization.

Regulations were drawn up at the first stages of the NPP's operation several decades ago and have not undergone significant changes since then. Its HET control methods must take into account the results of the ECC, which have accumulated over many years of operation of the PGV-1000 and PGV-1000M SG of the VVER-1000 reactors. Documents regulate the frequency of non- destructive ed-dy current metal control of pipelines with a coverage (due to minimizing costs and downtime) of only 30% of the share - about 3 thousand of the total volume of more than 11 thousand steam generator pipes. According to the measurement results, each HET is qualified by the regulation into one of about ten types - for each such type of tube there is its own period (from annual to 12 years), during which each HET must be diagnosed for its suitability for use or jamming. The type of HET is determined in the regulation according to special criteria that take into account the area of its location, the surrounding conditions, the evolution of neighboring HET and the physicochemical nature of the development of metal defects. It is important that the type of HET may change according to the results of the control, for example, due to changes in the state of neighboring pipes, and for the next year of control, such HET will already have a different type and a period limit until the next control. Thus, for each annual diagnosis, a set of HET of each type is formed, which, according to the regulation, are subject to diagnosis taking into account the time limits for HET types. At the beginning of operation and with a still insignificant history of defect formation, the total number of HET of all types did not exceed the general limit of "no more than a third of measurements" and the frequency of control of tubular goods of all types was not violated. With a significant history of measurements, determining the types became more complicated due to the increase in combinations of real defective structures and applications of the rules of the regulation, because then they are difficult to cover without automation. In addition, the total number of pipes requiring control then exceeds the limit "by a third" and pipes with deferred control accumulate, which violates the regulation in its main design part. Thus, it is necessary to plan the zoning, volume and periodicity of control in such a way as to minimize the risks of not including it under control. Planning the set of controlled HET according to their periodicity gives priority to HET with shorter periods, primarily annual. In addition, regular control further increases their number and pipes with a longer period remain out of control. It is urgently necessary to modify the regulation either in terms of defining types or in relaxing restrictions on control. The control procedure under the regulation focuses on mechanisms and their adequacy and ignores the factor of the volume of work, which becomes significant with years of operation. While the volumes of accumulated measurements, stubs and indications are insignificant, the completeness of the search implemented in the actual measurements of the base of combinations and topologies of local structures with different types of defect formations is achievable for planners, but when the accumulation reaches significant volumes, the "curse of dimension" of the search procedures occurs and it can be implemented only by computer algorithms. Analysis of the accumulated data taking into account the conditions of the regulations shows the complexity of the procedure for analyzing zoning, which reflects the space-time development of physic-chemical features and mechanical-elastic states of the defect formation process. For example, the regulations contain some

restrictions on the volumes of HET control, which leads to the accumulation of tubes with deferred control. Therefore, optimization of the procedures for annual scheduled preventive maintenance of PGV-1000M steam generators, during which defect formations are monitored by ECC methods, is highly relevant in the context of reliable use of relevant resources. The obtained results of statistical processing of accumulated measurements of defect formations allow developing planning of zoning, volumes and periodicity of control procedures and algorithms, which would minimize the risks of not including tubes with a significant de-facto level of probability of defects in control.

Modification of the regulations definitely requires replenishment of the existing base data with up-to-date data on ECC results.