Replacement of the containment prestressing system (CPTS) when the NPP unit life extension

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Abstract. The paper deals with the replacement problem of the containment prestressing system (CPTS) at the extending stage of CCB life characteristics. The features of domestic CPTS used in the blocks construction in the 80s and the system developed by the French company Francine - CPTS-M used today as a replacement for the units modernization are studied. The paper describes their features and some problems associated with the monitoring organization of the unit life extension period.

Introduction

The nuclear power industry is one of the most promising directions of the power industry development in our country. For this industry a program of its development has been adopted, involving the construction of new modern NPP units (Order of the Government of the Russian Federation of August 1, 2016 No. 1634). In addition, the program has been developed for the decommissioning outdated NPP units with a run out period of their use (these are RMBK (high power channel-type reactor) type units or units with single individual projects or limited addition of the type LWR-440). At the same time for units with for example a LWR-1000 reactor that have expired a standard operating life and proved to be reliable and safe, it is expected to extend their use for 20-30 years in case of deep modernization before the period extension.

Main study proposals with the justification for the research results

Units equipment with a LWR-1000 reactor is being upgraded as a part of the modernization. Concurrently building structures, including those related to the safety system, are also being renovated. First of all this problem concerns the containment where CPTS is being replaced for the extension period. It is known that the containment prestressing system is designed to compress CCB in order to increase the containment strength and ensure its integrity in the cases related to the design extreme projected event in the reactor compartment or the external impact of a negative factor, for example, a medium-range aircraft falling on the containment [1- 7]. The CPTS design system is made in such a way that plastic channel formers are established in the CCB wall body under construction (refer with Figure 1.)

At the same time, channel formers are laid in a helical-looped pattern in the cylindrical part, and in an orthogonal-loop pattern in the crestal area. The total number of channel formers is 132, including 96 in the cylindrical part and 36 in the crestal area.
Channel formers are reeved with reinforcing ropes each of which consists of 456 parallel-laid high-strength stabilized wires 5 mm in diameter made of carbon steel 5B1400-R1 GOST 7348-81. The reinforcing rope has two anchoring loops at its ends. The rope is installed in the containment channel using the leader. After installation, the ropes are tensioned. The work start on tension the CPTS in the ninety-day period after reaching 100% of the concrete design strength. For containment compression, jacks DG-650/1200 are used (refer with Figure 2).

The tension process is divided into five stages:
1) all the ropes of the cylindrical part and the crestal area are tensioned to a force of 600 tf. At the same time, the tension rope program accepted at the facility is adhered strictly;
2) the ropes of the cylindrical part are tensioned to a force of 800 tf; keeping the same sequence;
3) the ropes of the crestal area are tensioned to a force of 800 tf; keeping the same accepted program;
4) the tension of the containment cylindrical part is performed with a peak force of 1000 tf in random order, excluding the sequential one.
5) all the ropes of the crestal area are tensioned with a peak force of 1000 tf.

After the completing of the containment tension, the attachment points of the ropes to the support ring are preserved. In the future, during preventive and predictive maintenance activities, the tension force of the ropes is checked and the rope tightening or replacement are realized if necessary.

Before putting the containment into operation, it is tested for tightness and strength. These tests are carried out by creating an overpressure inside the containment. The main criterion for assessing the CCB technical condition, based on the requirements of SP-52-102-2004, its reliability and assessment of resource characteristics, is the safety factor, which is determined

\[ K = \frac{\sigma_{\text{limit}}}{\sigma_{\text{add}}} \]  

(1)

where \( \sigma_{\text{limit}} \) is an ultimate strength; \( \sigma_{\text{add}} \) is a permissible stress;
If the monitoring of the CCB geometric parameters is organized and the displacements movements of the given structures points are determined at the corresponding stages of prestressing and testing, then for uniaxial compression we determine that:

\[ \sigma_{\text{limit}} = E \frac{\Delta_{\text{add}}}{l_0} \]  \hspace{1cm} (2)

\[ \sigma_{\text{add}} = E \frac{\Delta_{\text{add}}}{l_0} \]  \hspace{1cm} (3)

Inserting (2) and (3) into (1), we get:

\[ K_0 = \frac{\Delta_{\text{limit}}}{\Delta_{\text{add}}} \]  \hspace{1cm} (4)

As applied to CPTS, \( \Delta_{\text{limit}} \) is taken as the displacements of structural points placed on the CCB elements (walls) when it is prestressed. \( \Delta_{\text{add}} \) is taken as the displacements of the same points at the test stage when an internal pressure is 4.6 atm. According to the requirements for containments \( K_0 \geq 1.5 \) at all operation stages, starting with prestressing. In this case, after the tests \( K_0 \) determined by the results, is assumed to be initial. Further, the annual movements \( \delta_i \) are determined annually. Then the current coefficient at any CCB stage is determined as follows:

\[ K_i = K_0 \frac{\Delta_{\text{limit}} + \sum_{i=1}^{m} \delta_i}{\Delta_{\text{used}}} \]  \hspace{1cm} (5)

Here \( f_{\text{deg}} = \Delta_{\text{limit}} + \sum_{i=1}^{m} \delta_i \) is a function of the CCB degradation. Herewith:

\[ d_i = \frac{K_i}{K_0} \]  \hspace{1cm} (6)

where \( d_i \) is a parameter that determines the stock of the current CCB resource.

Thus, obtaining the movements of the studied points at the corresponding stages of the CCB existence, it is possible to assess its technical condition and determine the residual life.

During operation, a continuous monitoring of all NPP systems, including the containment is conducted. One of the main CCB parameters is the assessment of its compression sufficiency level by the CPTS system. This criterion evaluates the permissible level \( K_i \) and can be determined by stresses measuring (reinforced frame and concrete) by the built-in sensor system into the containment wall body, measuring the containment wall displacements in given points on its outer surface or measuring axial forces in a stressed rope [4-5]. At the same time, it is to be pointed out that the compression level is not constant, factors such as temperature, creep of...
concrete, relaxation of CCB construction elements, fatigue properties of reinforcement and rope rheology have a negative effect on it.

After completing the full standard life of the unit, based on the survey results, a decision is made to upgrade it. For example, the reconstruction of a containment is performed by replacing the CPTS for further normative operation with the required compression level.

Nowadays the system CPTS-M developed by the French company Francine is used as a replacement for the domestic system.

This system is made in the form of seven twisted wire reinforced ropes, which are put in a polyethylene coat, fifty-seven wire ropes are combined into a main rope, which replaces the previously used ones. In contrast to the predecessor, after the rope is installed into the channel former, it is injected with concrete, and then the rope is tensioned. The rope tension process is performed in one step, while the rope tension is performed until a peak force of 1000 t. is reached. Replacement of all the system ropes is performed one by one, strictly according to the accepted containment CPTS modernization program.

Summary
Nowadays, the modernization of the pretension system by replacing one system with another is performed without continuity of containment monitoring measures. So, the built-in sensor system into the body of the containment wall as a rule after thirty years of operation is completely inoperable, movements measurements of the containment wall displacements in given points on its outer surface are not timely organized, and only a measuring system of axial forces in a tensioned rope can be used. In addition, the strength test during modernization is not performed, therefore, the values \( \sigma_{ad}, \sigma_{add} \) obtained when the internal pressure is set at 4.6 atm. are not determined, and as a result, \( K_0 \) is not calculated for the new CPTS-M system. The use of the safety factor obtained during the initial containment testing is illegal, since during the design operation period, according to the degradation function, the containment changed its physical and mechanical characteristics within certain limits. Further containment operation for a period of extension of its resource characteristics without knowledge of the initial conditions decreases the certainty of the level of operational suitability and as a result decreases the level of nuclear unit safety.

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