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Division VIII

METHODOLOGY AND METHODS FOR SAFETY JUSTIFICATION OF INCREASED IN-SERVICE INSPECTION INTERVALS FROM 4 TO 8 YEARS FOR EQUIPMENT AND PIPELINES IN NUCLEAR POWER PLANTS WITH VVER-1000 TYPE REACTORS

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ABSTRACT

In-Service Inspection (ISI) of NPP metal equipment and piping components shall be implemented to prevent unanticipated failures which can cause accident initiating events. ISI involves non-destructive examination, hydraulic testing and technical inspection.

ISI intervals vary between different countries.

The smallest interval there is on the Russian nuclear power plants (NPP,s), which leads to long periods of downtime of power units for carrying out of scheduled preventive maintenance.

Increase the intervals between inspections leads to the reduction of the average annual volume of inspections. This may result in decrease of reliability of the equipment and pipelines.

In the report is proposed criteria, the fulfilment of which is necessary for increasing the interval between inspections. In addition identified methods and technologies, the use of which will allow to provide the above criteria. Furthermore, the application of these methods and technologies leads to significantly increase the reliability of equipment and pipelines at the time of their operation. Examples of the application of new technologies at the operating nuclear power plants are given; they are showing their effectiveness.

Examples relate to the problems of exploitation of heat-exchange tubes of steam generators for NPP with VVER, the main pipelines of nuclear power plants with VVER-440 and RBMK.

METHODOLOGICAL PRINCIPLE FOR THE INCREASE THE ISI INTERVAL

The ISI intervals of the equipment and pipelines metal in different countries is listed in the table №1 [1,2, and other]

The smallest interval is at the Russian nuclear power plants, which leads to long periods of downtime of power units for carrying out of scheduled preventive maintenance [3].

Increase the intervals between inspections leads to the reduction of the average annual volume inspection. This may result in decrease of reliability of the equipment and pipelines [4].

In connection with the above, a question arises about the reliability and safety in the transition from 4 to 8-year periodicity ISI of NPP equipment and pipelines.

It is obvious that the transition to 8-year periodicity of the ISI acceptable, if can recognize the following condition: the transition from 4-year periodicity of the EC on the 8-year periodicity EC must be safe, that is must be done by the ratio of:

The reliability and safety of the components with 8-year periodicity of the ISI	≥	The reliability and safety of the components with 4-year periodicity of the ISI

To perform the above-mentioned conditions required the introduction of special actions, providing higher reliability and safety of the required level.

Table 1. Inspection intervals for Reactor Vessel and Main Circulation Pipelines in Russia, Germany, France and USA (years)

NPP Structural Component	**Russia**		**Germany, KTA 3201.4**	**France, RSE-M**	**USA, ASME XI**
	PNAE G-7-008-89	Draft Document			
Reactor Vessel	4+3 months	4+1****	4	10	10
Main Circulation Pipeline	4*+3 months	4+1****	8**	10***	10***

* - the total inspection effort can be undertaken by means of annual partial inspection;
** - 50% of the total inspection effort must be implemented in 4 years;
*** - partial inspection will be carried out once in 2 years;
**** - additional safety justification is required

The experience of work on operating nuclear power plants, summarised in reports and publications, including monographs [5-9, etc.], shows, that for today it is possible a significant improvement in the reliability and safety of operation of equipment and pipelines by means of special organization of performance of non-destructive testing (NDT), hydraulic tests, technical inspection, control modes of operation of the NPP, the application of special technologies for effective technical solutions, etc. This experience gives the basis to assume, that the next set of actions will ensure safe by the increased frequency of EC up to 8 years:

- introduction in the operational practice of the execution of quantitative estimates of the detectability of the ISI;
- increase of reliability of ISI to the necessary and sufficient level by using instrumental and methodical means;
- application of probabilistic methods to assess strength and lifetime in relationship with the quality of the components, the quality of the ISI and the operating conditions and the adoption of adequate decisions in case of need;
- inventory and assessment of the effect of impact on the reliability of the components specially organized hydraulic tests for strength and density;

- the use of electronic archive for operational modes monitoring and the history of operation in conjunction with regard to their influence on the level of reliability of the equipment and conditions of the ISI and the adoption of technical solutions according to their results;

- dissemination of the initial state of the quality of the components (estimated quantitative characteristics of the residual defects) to an acceptable level;

- application of systemic methods of the analysis of the causes of damage (in case of defects detection in the operation) with the implementation of the principle of feedback (for the stages of design, manufacture, installation or operation) to address the root causes of damage (up to the requirements of the amendments in the normative documents);

- application of special technologies for effective solutions to increase the reliability of elements of the equipment and pipelines in case of detection of shortage of reliability during operation of NPP.

Below are examples of the application of the above-listed actions (technologies) for the three elements of the operating NPP with a deficit of reliability and safety: for heat-exchange tubes of steam generators of VVER-1000 and VVER-440, for the main pipelines of nuclear power plants with VVER-440 and main pipelines Dn800 NPP with RBMK reactors.

EXAMPLES OF ENHANCING RELIABILITY OF THE ELEMENTS OF THE OPERATING NPP

Heat-exchange tubes of steam generators for NPP with VVER-1000 and VVER-440

The problem of ensuring the integrity of heat-exchange tubes (HET) steam generator (SG) is one of the most complex and challenging in the world nuclear power engineering. This problem occurred at nuclear power plants of the Western manufacture more than 20 years ago and is still in the West is not solved.

Loss of precarious work at the nuclear power plant of the Western manufacture numbered in the hundreds of billions of dollars. To solve the problem involved the best experts. However, the problem is not solved before this days.

In Russia for the decision of problems of maintenance of integrity HET have been applied the above technologies on the basis of which document developed RD EO-0552-2004 «Methodical recommendations on application of system methodology of ensuring the integrity of heat-exchange tubes of steam generators of the operating nuclear power plants with VVER-1000 and VVER-440».

The results of RD application are shown in figure 1, where the vertical axis postponed the number of unplanned shutdowns because of the cross-cutting defects in HET, but on the horizontal - calendar time.

From Figure 1 it is visible that after the application of the RD off-schedule shutdowns stopped.

Curve 3 in Fig. 1 refers to the power unit, where RD is not used. The number of unscheduled shutdowns of the power unit for the period under review increased.

In detail the results of the work are described in the monographs [7,9].

The main pipelines DN500 for NPP with VVER-440

In connection with the reconstruction of power units with VVER-440 of the first generation had a problem of prevention of discontinuities of the main circulation pipeline (MCP). The work was carried out in 1988-1994. discussed at the IAEA, has passed the expertise of Western companies (Siemens-KKV, EdF and Framatome). In detail all of the work described in the monograph [8]. Here there are only two results, obtained in the framework of the this work (Fig. 2 and Fig. 3).

The figure 2 shows that after the specially organized the non-destructive testing (NDT) and hydraulic tests (HT), the probability of rupture of MCP has decreased by 4 and more orders of magnitude. It is clear that after HT probability of a rupture for a long time is equal to zero.In Fig. 3 shows another effect received after the execution of works: as a result of specially organized ISI. It is, that in 1990 - 1993 [8] at nuclear power plants have not revealed any defect, except those that have been previously detected and left in operation.

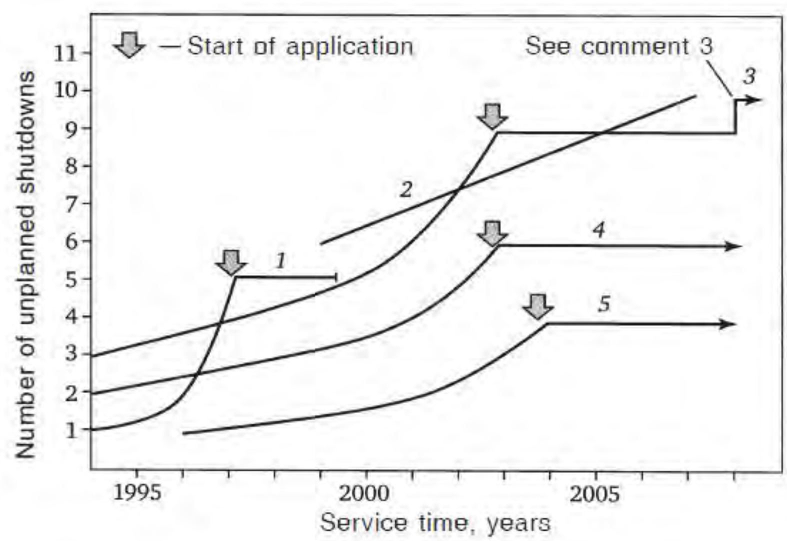

Figure 1. Dynamics of unplanned shutdowns before and after the application of the RD EO-0552-2004(1-Unit 2 BalNPP; 2-Unit 1 KaNPP; 3-Units 3 and 4 NVNPP; 4-Units 1 KolNPP; 5-Unit 2 KolNPP).

Note:

1) the Total positive experience of application of RD - more than 100 SG*years;

2) Unscheduled stop on the block №3 NVNPP in 2008 is connected with the termination of the R D application

This testifies to the fact that the reliability of the pipeline is very high not only on resistance of destruction, but also according to the criterion of defects.

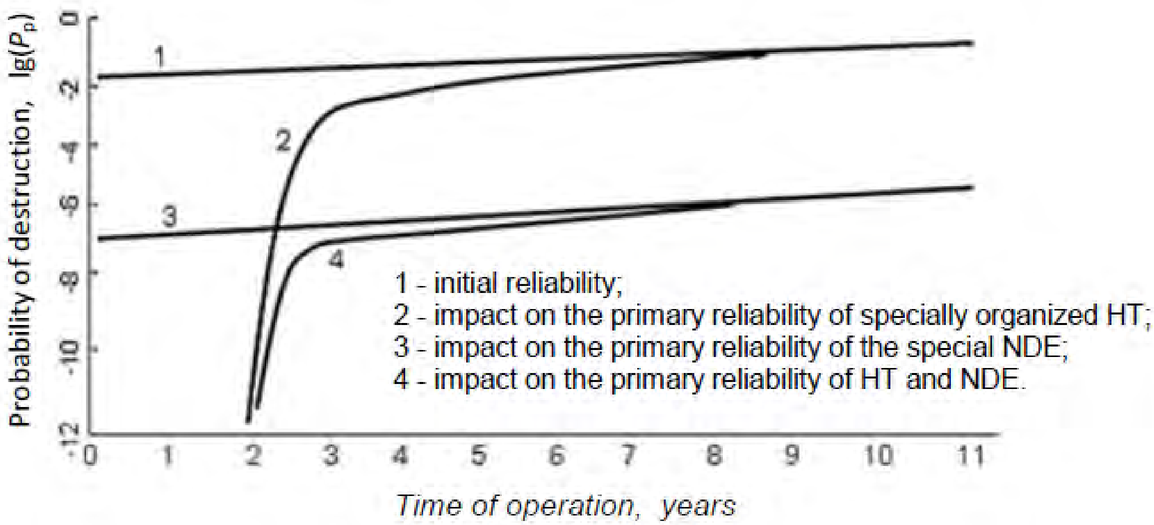

Figure 2. Change in the probability of rupture of the main pipeline of the reactor VVER-440 depending on the activities

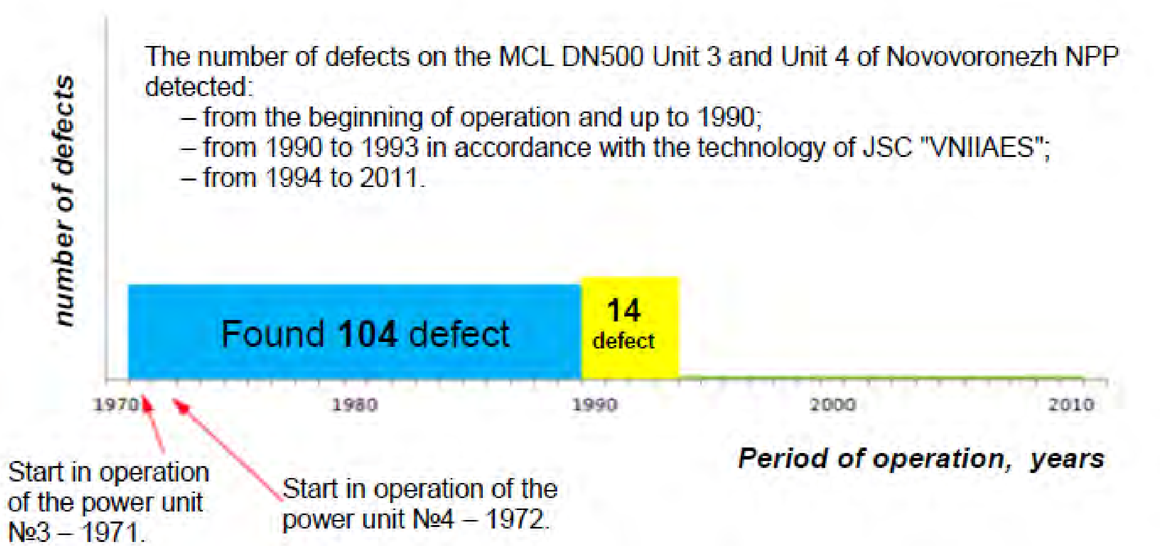

Figure 3. The results of the application of compensatory measures for existing nuclear power plants. Pipelines STC 500 for VVER-440.

Note:

For the period from 1994 to 2010, the new defects not detected. Confirmed that identified earlier and left in the operation of the defects of development do not have.

The main pipelines DN800 nuclear power plants with RBMK

In this example it is shown, that the high reliability of the elements (in this case the mane pipeline DN800 of RBMK) can provide up to the beginning of operation.
In 1982, the problem is identified, associated with a large number of defects at DN800 unit 1 (figure 4a) and unit 2 (figure 4 (b) of Smolensk NPP (SmNPP).

On unit 3 was used specially organized pre-operational non-destructive testing, in the process of which have been identified and removed defects. After the commissioning of the power unit 3 of SmNPP in 1989, a single defect in the process of operation has not been identified (рис.4c). The defects on units 1 and 2 are detected to the present day (figures 4a and 4b).

Thus, the effectiveness of specially organized NDE prior to the beginning of the operation confirmed by the 23-year experience of operation of unit 3 SmNPP. A detailed analysis of the described case is contained in the monograph [5].

The above examples show that at the present time the developed technologies, methods and technical means give significantly improve the reliability of both new and existing power units. In the case of complex application of these technologies the reliability of NPP equipment and pipelines will increase significantly exceed the requirements, imposed by the condition of safe increasing the ISI frequency.

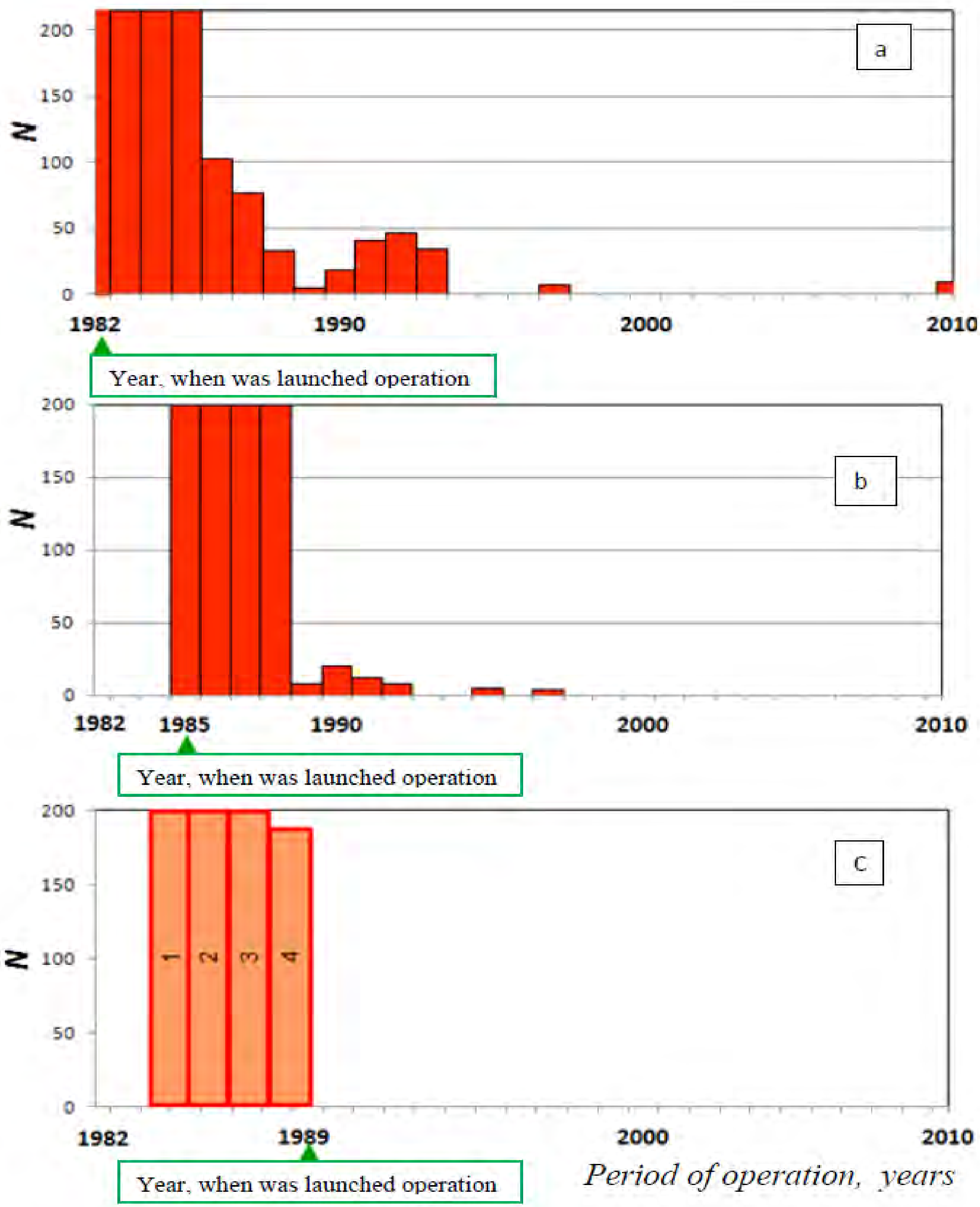

Figure 4. The results of the application of compensatory measures for existing nuclear power plants. Pipelines DN800 MSP RBMK-1000, SmNPP. The vertical axis - the number of detected and repaired defects, N.
a - unit №1; b - unit №2; c - unit №3 - All defects identified and eliminated before the start of the operation. In the operation of the defects are not detected. At the same time: 1 - Control after welding ray (repaired 287 defects); 2 - ultrasonic (630 defects); 3 - Heat treatment + US inspection (202 defect); 4 - Additional control before operation (189 Def.).

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