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Analysis of Personnel Radiation Monitoring Results during NPP Outages

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Abstract: The article provides outcomes of efforts taken by the specialists of radiation safety departments of Ukrainian Nuclear Power Plants (NPPs) to optimize and decrease exposure doses of personnel performing works during outages at NPP units. The article is written based on many years' experience and analysis of radiation hazardous works performed during scheduled maintenance of NPP equipment. It highlights significance of planning radiation doses (dose quotas) and organization of pending works during outages based on lessons learned. The results of works allowed to give due consideration to training of NPP maintenance personnel, improvement of labour conditions, workplace setup and enhancement of radiation protection means.

Key words: NPP, outages, collective dose, dose limit quotas.

1. Introduction

The final purpose of activities performed by NPP radiation safety services is to limit radioactive impact on personnel and population without excessive restraining of useful practical activities and with the acceptable risk (probability) of stochastic effects. The threshold of deterministic effects should not be exceeded [1] [2]. The main criteria used to assess radioactive impact are exposure doses of personnel and population. This study is focused on analysis of personnel exposure doses received while performing radiation hazardous works during NPP outages since these doses are the main contributors to the industrial collective dose.

2. Materials and Methods

The analysis is based on the results of the five-year monitoring of such radiation indicator as collective exposure dose of Energoatom's NPPs personnel performing radiation hazardous works on equipment of power units at the outage. Consideration was given also to the monitoring results for previous years starting from 2003. The analysis was performed both for collective exposure doses of personnel by NPP departments (shops) and by groups of major NPP equipment (reactor facility, steam generator, reactor coolant pump etc.).

3. Results and Discussion

To organize activities on optimization of radiation safety during planning, preparation, implementation and control of works performed when Energoatom's NPPs are on the outage an industrial regulatory document GND 95.1.08.01.54-2003 titled "Methodological guidelines to analyse collective exposure doses of personnel during maintenenance and repair of NPP equipment" [3] was developed and put into force.

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This industrial document sets out common requirements to be met when preparating for and conducting of outages at all NPPs operated by the Company for the areas as follows:

- radiation conditions monitoring;
- classification of radiation hazardous works;
- procedure for analysis of collective exposure doses during preparation and conduction of outage;
- technical means to measure individual doses;
- documentation.

In order to decrease personnel exposure doses optimization of radiation safety at NPPs (introduction of ALARA principle into NPP operation) should cover all aspects of NPP operation and primarily the following areas:

- optimization of work organization (planning, preparation, implementation and monitoring);
- personnel education and training,
- safety culture;
- improvement of technological processes, introduction of technical means for work implementation enabling to decrease personnel exposure doses;
- improvement of labour conditions, equipment of workplaces, improvement of radiation protection means.

The analysis of personnel collective exposure doses during NPP outage is an initial stage of implementing ALARA prinnciple into NPP work practice. Its importance is associated with the decisive contribution of repair works into the overall collective exposure dose of NPP personnel. This analysis is performed to decrease total collective exposure dose of NPP personnel and limit individual dose rates.

Before starting planned outage at each NPP unit of the Company the exosure dose quoatas are set for personnel envolved in repair works. The quotas (budget) of personnel collective exposure doses are defined based on analysis of radiation conditions of NSSS equipment from the previous repairs both for the entire power unit and for the main departments engaged in repairs. The results of radiation measurements and surveys of radiation conditions performed pursuant to Ref. [1] are used for this purpose.

When performing works during outage the personnel collective doses are recorded using operating dosimeters in addition to the individual radiation survey of NPP personnel.

All NPPs have groups of radiation safety specialists (ALARA groups). Their main task is to project and analyse personnel collective doses during outage.

The main areas for decreasing collective doses are:

- reduction of man-hours needed to perform separate activities;
- improvement of radiation conditions in the work implementation area.

To decrease collective doses received during outage the following stages of radiation safety optimization process are defined:

- developing projections for dose rates based on the planned work scope;
- preparation to the outage, clarification of dose rate projections;
- implementation of outage works;
- processing of radiation exposure data;
- preparing report on radiation protection during outage.

Quoting exposure dose rates of personnel involved in repairs is an important concept to limit radiation doses during outage.

It should be noted that due to a lot of uncertainties (e.g., the need to perform additional scope of works that could be defined only during the outage after equipment is opened, unpredicted changes of radiation conditions at workplaces etc.) the projection represents a comprehensive task and projection deviations can be rather significant.

Quoting radiation doses of personnel involved in repairs allows to prevent unjustified increase of collective dose rates and forces maintenance departments to take all possible organizational and

technical measures to limit dose rates. However, this concept is efficient provided that a high quality of projections is ensured with consideration of all specifics of a separate outage.

The accuracy of projection and continued monitoring of dose quotas compliance for radiation intensive works during outage (at least weekly) allows to define trends when we may potentially exceed the set quotas and timely respond by taking the required organizational and technical actions to prevent collective doses from going above the set budgets.

In addition to organizational measures RNPP and SUNPP apply financial promotion of main maintenance departments when they adhere to the planned dose budgets. This encourages the personnel performing repairs to do self-checking and ultimately contributes to decreasing of collective dose rates.

The quality of planning exposure levels of maintenance personnel at NPPs operated by the Company can be tracked by analyzing Fig. 1 that shows planned (quotas) and actual doses during outages for the last five years from 2010 to 2014.

In different years of analyzed timeframe the reasons for such a significant inconcinstency of actual and projected dose rates of personnel when performing works during outage were as follows:

- having to perform "non-typical" works for lifetime extension of RNPP and SUNPP units;
- incapability to accuretely define the scope of works and number of attracted contractor's personnel for such long outages;
- lack of experience in planning lifetime extension activites;
- detecting additional scope of works during outage (after equipment is opened) etc.

Since Ref. [1] does not contain specific guidelines regarding the required accuracy of projections of collective doses during outage, this allows NPP specialists to plan a dose budget with high margin ussing an excessively conservative approach.

An extremely large margin of the dose budget does not allow to consider the set dose quotas as effective

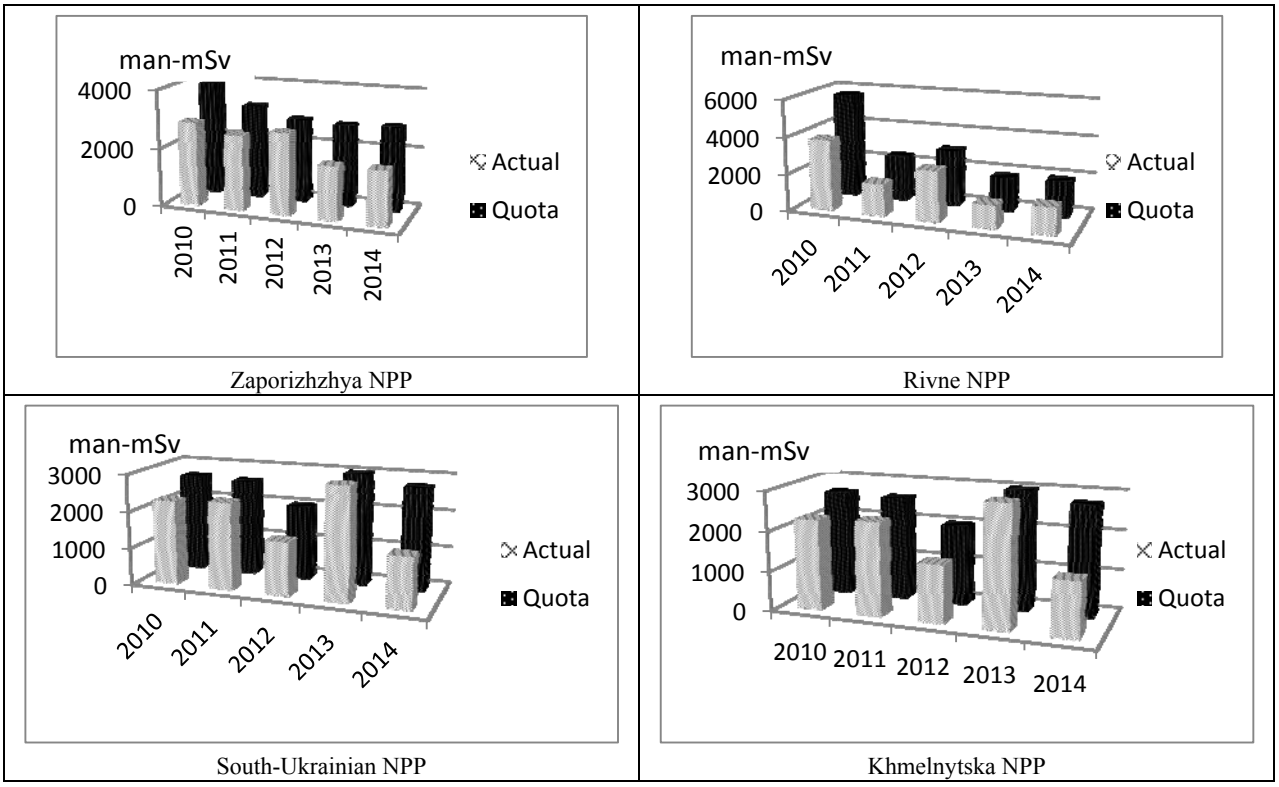

Fig. 1 Planned (quotas) and actual collective dose rates of NPP personnel during 2010-2014 outages at Energoatom's NPPs.

tool to decrease collective doses duing outage. The accuracy of projection must be increased. Based on the accumulated experience we believe that an optimum projection deviation should not exceed 15%. This clause should be introduced into Ref. [1] to prevent NPPs from using extremely conservative approach when planning quotas.

The greater part of collective doses is received by NPP personnel during planned and unplanned outages. Thus, optimizing radiation protection to reduce radiation dose rates should include above all organizational optimization of works performed during outages (planning, preparation, performing and monitoring). For this purpose specific dose limit quotas (budget) have been established for personnel involved in repairs prior to the start of planned outage at each NPP operated by the Company. The collective dose quotas have been established for each unit, as well as for main subdivisions involved in repairs. The preliminary projections of collective dose rates have been developed based on radiation survey of nuclear facility equipment during previous outages with regard to future labor input in repairs.

The accuracy of projected doses for upcoming outages depends on the quality of dose analysis performed during previous scheduled outages. The closer these values are, the more accurate are projections and the higher is radiation safety of personnel involved in equipment repairs.

When developing dose budgets it is important to consider data on radioactivity of primary coolant from reference nuclides during the fuel campaign preceding the outage:

- specific activity of fission products (^{131}I, iodine total, ^{137}Cs, ^{134}Cs);
- specific activity of activation and corrosion products (^{60}Co, ^{54}Mn).

These parameters directly impact radiation conditions at places where maintenance and repair of primary equipment (reactor, main circulation pipeline, reactor coolant pump, steam generator, pressurizer and emergency core cooling system) is performed.

Taking into account data on activity of fission, activation and corrosion products in the primary coolant allows to timely determine the required organizational and administrative actions to decrease iodine content in the air of the working areas at the initial stage of the outage, as well as to consider if there is a need and possibility to perform decontamination works on primary equipment to improve radiation conditions.

Radiation measurements and assessment of radiation situation have been performed in accordance with the established techniques at all stages of preparation and during repairs of radiation hazardous equipment. Map tables have been filled in based on the results of radiation survey readings of radiation hazardous equipment of the primary circuit.

Table 1 Average contribution (%) of separate groups of major equipment to the total collective dose received by NPP personnel during 2010-2014 outages within the Company.

	2010	2011	2012	2013	2014
Reactor facility	20.6	16.2	24.1	17.6	19.4
Main circulation pipeline	7.1	4.7	5.4	7.0	5.9
Reactor coolant pump	3.5	2.9	3.0	3.5	4.2
Steam generator	23.6	16.7	20.8	13.8	17.2
Pressurizer	3.8	2.2	3.0	3.4	2.1
Cooling systems	4.6	3.9	6.6	11.8	9.7
Auxiliary systems	5.1	5.6	7.7	10.3	6.2
Primary purification system	3.0	2.6	2.7	4.4	3.2
Nuclear fuel (refueling)	1.4	1.8	1.5	0.9	0.8
Etc.					

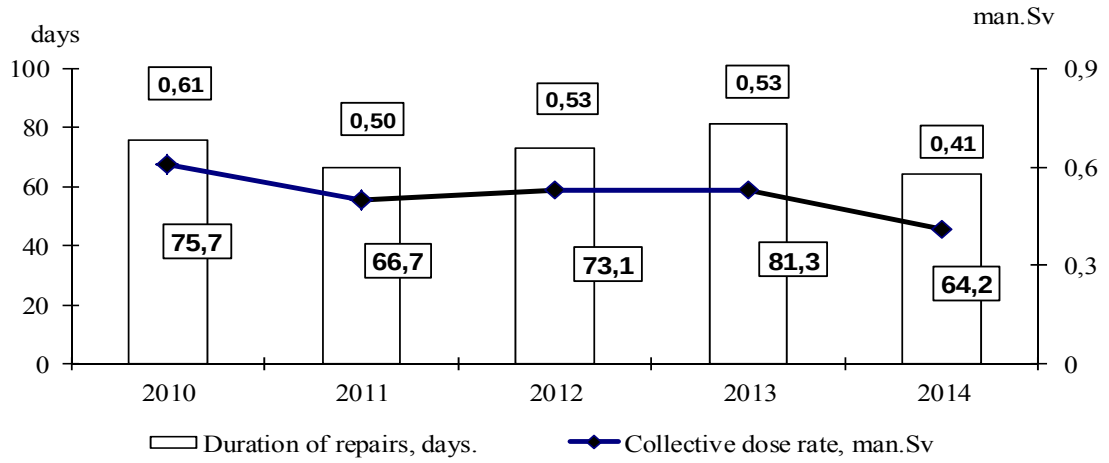

Fig. 2 Personnel collective dose rates and duration of repairs per one NPP unit of NNEGC Energoatom for 2010-2014.

The analysis of actual exposure doses of personnel involved in outages shows that within Energoatom the main contributor to the average total collective dose based on the group of the major equipment for the last five years are repairs of reactor facility—up to 24%, steam generator—up to 24%; cooling systems—up to 12% etc.

The collective dose rates and duration of repairs per one NPP unit of the Company for 2010-2014 are provided in the Fig. 2 below.

Total collective dose rate of NPP personnel involved in repairs of NPP units during 2014 outages within the Company made up 5.80 man·Sv, with 4.32 man·Sv—for major systems.

Therefore, just as in previous years, in 2014 the preliminary forecast of collective dose rates has proved to be correct in practice. More than 50% of the total annual collective dose rate has been received by Energoatom's NPP personnel during repair of reactor facilities and steam generators.

4. Conclusion

Therefore, it is necessary to highlight the need to increase the accuracy of projections when writing dose budgets. An extremely large margin of the dose budget does not allow to consider the set dose quotas as effective tool to decrease collective doses during outage.

Given that doses of maintenance personnel are mainly received during repair of reactor facilities, steam generators and in the main circulation circuit, most of the efforts in using additional protective means (both organizational and technical) must be taken during execution of these works.

The large scope of works performed by radiation safety and protection specialists (Head Office and radiation safety departments of NPPs) in development and monitoring of dose budgets both by NPP departments and by separate radiation hazardous works, as well as in implementation of measures to improve radiation conditions at work places allowed achieving gradual decreasing of repair doses of Energoatom's NPP personnel.

References

[1] Radiation Safety Standards of Ukraine, NRBU-97.

[2] Basic Sanitary Rules for Radiation Safety of Ukraine, 6/177-2995-09-02

[3] GND 95.1.08.01.54-2003. "Methodological Guidelines to Analyse Collective Exposure Doses of Personnel during Maintenenance and Repair of NPP Equipment" (2003).