

APPROACHES TO THE ESTABLISHMENT OF SAFETY CONDITIONS FOR THE FUEL-CONTAINING MATERIALS DURING NEW SAFE CONFINEMENT OPERATION

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Construction of the New Safe Confinement (NSC) above the Shelter over destroyed Chernobyl NPP Unit 4 has been completed. The NSC design is based on boundary conditions for current and potential hazardous impacts of the Shelter. Accordingly, criteria for Shelter safe state have to be established, in particular, criteria for the safe state of fuel-containing material (FCM) accumulations.

The paper presents the results of the development of methodological recommendations for the establishment of acceptance/non-acceptance criteria of FCM accumulations with regard to safety, as well as on the FCM monitoring scope in order to monitor the extent of compliance of FCM state with the established criteria.

Key words: Shelter, New Safe Confinement, fuel containing materials, safety criteria, monitoring.

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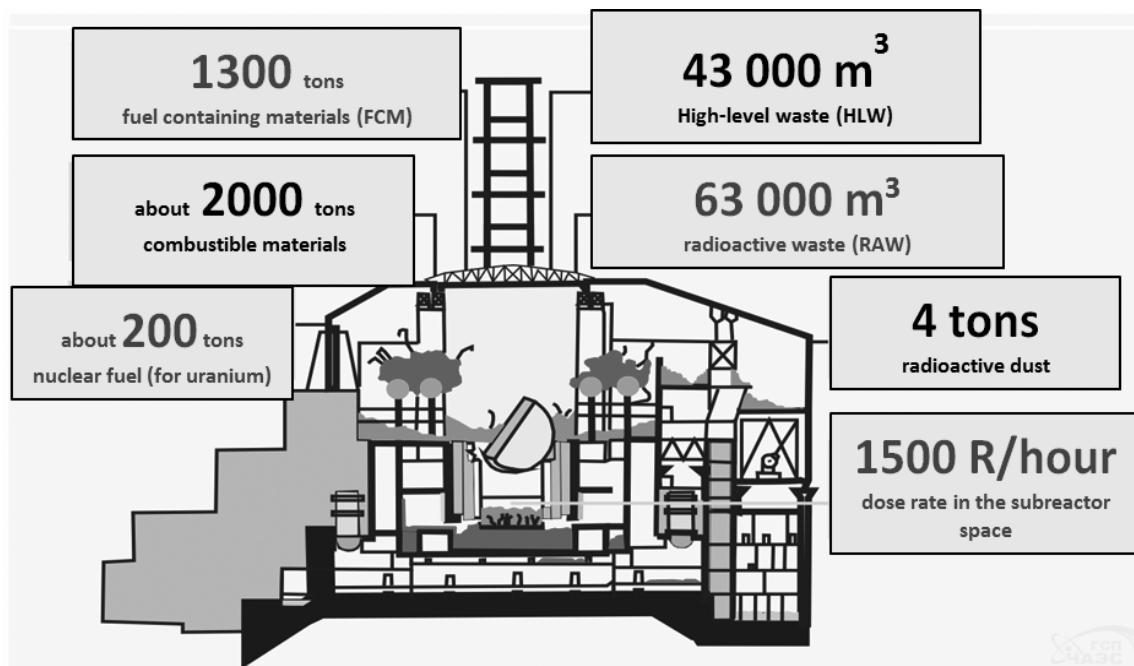


Fig. 1 — The Shelter

The construction of the NSC within the framework of the International Shelter Implementation Plan (SIP) at the Shelter over the destroyed Chernobyl NPP Unit 4 (ChNPP-4) was completed in 2019. The main functions of the NSC are to:

- protect personnel, the public and the environment against nuclear and radiation hazards;

- ensure conditions to dismantle unstable structures of the Shelter, manage radioactive waste and retrieve and dispose FCM and other radioactive material in the future.

NSC design lifetime is not less than 100 years.

The safe state of the Shelter within the NSC and, in particular, the FCM safe state, is to be maintained during this period of time. As upcoming tasks, it is foreseen [1] to dismantle unstable Shelter structures, (partly) retrieve FCM and take other measures to transform the Shelter into a state ensuring long-term safety of remaining (not retrieved) radioactive materials. The question of requirements for the retrieval or not of the radioactive material is still open.

A preliminary strategy for FCM retrieval was developed at the beginning of the SIP implementation [2], but a final strategy for FCM retrieval is not available yet.

Further, it should be taken into consideration that the decision on the retrieval of FCM is strongly interconnected with the availability of long-term storage and/or disposal options.

FCM should be maintained in a safe state before its retrieval. Criteria of the safe state of FCM accumulations in the Shelter inside the NSC have not been specified unambiguously and systematically at present. In particular, no criteria for FCM degradation limitation (e.g., dust formation) were specified.

In the framework of the bilateral cooperation with the Gesellschaft f r Anlagen- und Reaktorsicherheit gGmbH (GRS) and the State Scientific and Technical Center for Nuclear and Radiation Safety (SSTC NRS), activities on the «Analysis of Factors Determining the Safe State of the Shelter within New Safe Confinement» [3] were performed. An approach to establish a list of conditions and criteria for the safe state of the Shelter within the NSC was specified based on the activity results.

The current effort is the next stage of a joint study of GRS and SSTC NRS on the safe state of the Shelter, in which framework approaches for the establishment of safety criteria for FCM accumulation conditions in the Shelter are developed.

In the framework of this study, next guidelines were developed:

- 1) on the establishment of acceptance/non-acceptance criteria of FCM state from the point of view of safety;

- 2) on the FCM monitoring scope in order to monitor the extent of compliance of FCM state with the established criteria.

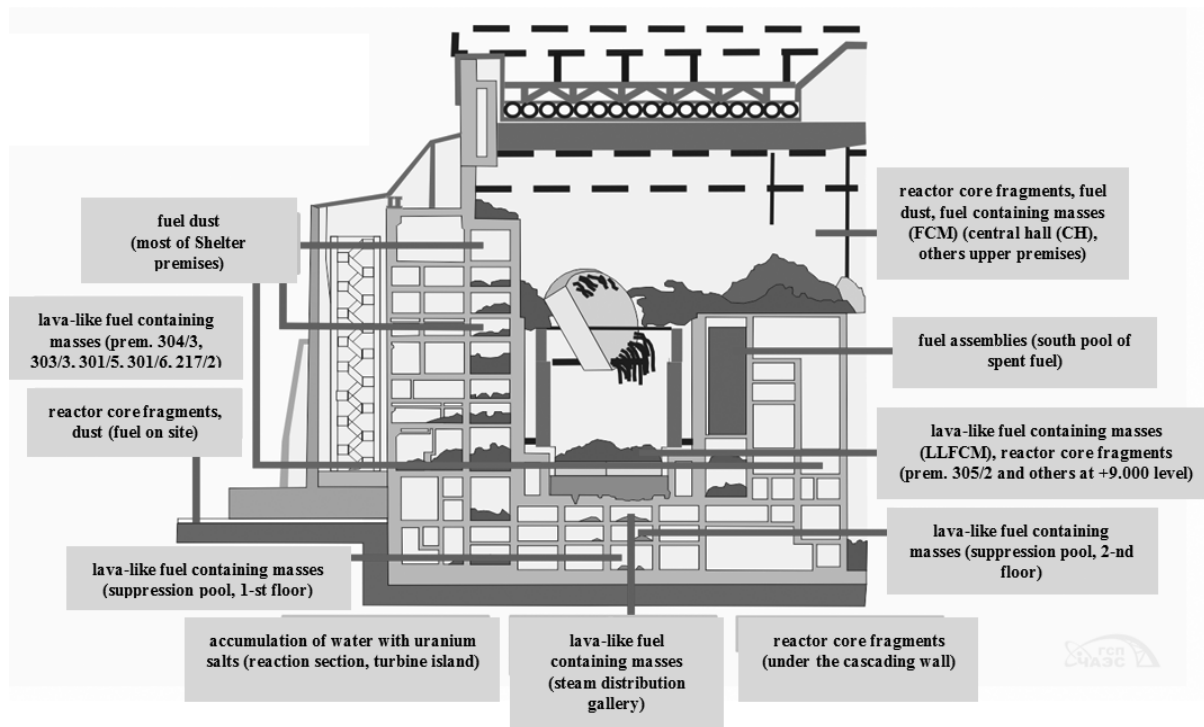


Fig. 2 — Modifications of FCM in Shelter premises

General description of FCM accumulations.
 In the Strategy of Shelter transformation, FCM definition is provided. FCMs are damaged as a result of beyond design-basis accident, ChNPP-4 nuclear fuel, regardless of its physical-chemical state, fuel assemblies of the spent fuel pool of ChNPP-4, as well as any materials (core fragments, mixtures, core melts, solutions, chemical mixtures, dust, etc.) containing nuclear fuel in non-negligible quantities (i.e. its concentration is ≥ 1 weight percent) [4].

Today, the locations of FCM accumulations and their main characteristics have been determined. The Shelter contains the following FCM modifications:

- the core fragments (CF), main part of which was released into the upper floors of the Unit, in particular, into the central hall, during the explosion;
- finely dispersed fuel (dust), hot fuel particles; their size varies from fractions of micron to hundreds of microns, they are observed practically in all Shelter premises;

Table 1 — Premises, in which FCM accumulations are located and the main characteristics

Premise	FCM type	Fuel mass (by uranium) in FCM, t	Content of fuel in FCM average/max, %	Fuel burn-up, MW-day/kg of U average/min	K_{eff} dry/wet (conservatively)
012/15	Lava-like	$8 \pm 3/0.30$	9.9/11.7	11.6/11.1	0.17/0.30
012/7	Lava-like	1.5 ± 0.7	9.8/11.4	11.8/11.4	0.10/0.20
217/2	Lava-like	2*	4.6/5.5	11.7/10.2	0.21/0.32
301/5	Lava-like	3*	4.5/5.5	11.5/10.8	0.15/0.27
301/6	Lava-like	3*	3.7/4.7	12.6/11.5	0.14/0.25

Continue of the table 1

Premise	FCM type	Fuel mass (by uranium) in FCM, t	Content of fuel in FCM average/max, %	Fuel burn-up, MW-day/kg of U average/min	K_{eff} dry/wet (conservatively)
303/3	Lava-like	0.2*	3.7/4.2	12.2/11.7	0.09/0.28
210/7	Lava-like	11	9.8/12.0	11.8/10.6	0.23/0.31
304/3	Lava-like	14*	4.4/5.8	11.5/10.4	0.22/0.35
210/6	Lava-like	25 ± 11	6.8/8.2	12.2/11.4	0.23/0.31
Southern SF pool	129 SNFAs	14.8	100/100	11/**	0.68/**
305/2 + 307/2 + scheme «OR» + reactor shaft	Lava-like, CF	75 (+25. -35)	26/100	10.8/4.5	**
Central hall	48 fresh NFAs with enrichment of 2%	5.5	100	0	**
	CF and, possible, LFCM under rubble	**	**	**	0.97/0.88
	CF in the scheme «E»	10–36	100	**	**

Note to Table:

* — conservative estimate of fuel quantities

** — values are not determined

solidified lava-like fuel containing masses that were generated during the active stage of the accident at high-temperature interaction of the fuel with engineered materials of the Unit and are located on the lower elevations of the Unit;

secondary uranium minerals that were generated from FCM solutions (mainly from water solutions) in the form of crystalline new formations;

FCM in water solutions;

spent NFAs in the spent fuel pool

fresh NFAs in the central hall.

The table 1 presents the premises, in which FCM accumulations are located and the main characteristics of the accumulations [4].

After putting the NSC into operation, the conditions of FCM in the Shelter are changing, which requires regular monitoring and study of the conditions and the development of adequate measures to minimize the negative effects of FCM behavior. Based on the monitoring results, it is necessary to create a model for the expected long-term behavior of FCM.

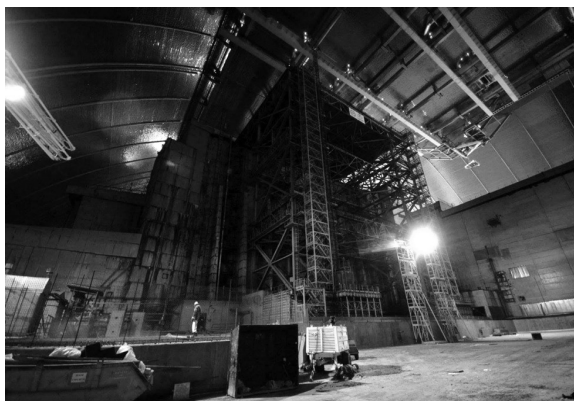


Fig. 3 — The Shelter in the NSC

Limiting conditions for potential Shelter impacts on the medium in the NSC main volume

The limiting conditions for the impact of Shelter on the environment in the main volume of the NSC were considered as part of the study «Analysis of Factors Determining the Safe State of the Shelter within New Safe Confinement» [3].

These limiting conditions determine the limitation/prevention of the following current and potential impacts of the Shelter:

limiting the release of radioactive substances from the Shelter to the main volume of the NSC;

limiting the spread of contaminated water from the Shelter;

prevention of criticality in FCM accumulations.

Limiting the release of radioactive substances from the Shelter. Volumetric activity of radionuclides in the air of NSC main volume is the design parameter that characterizes the release of radioactive substances from the Shelter into the NSC main volume. The limit design value of the average monthly volumetric activity of radionuclides is 210 Bq/m^3 . In determining this criterion, it was assumed that the air is contaminated with radionuclides with ratio of active radionuclide air «typical» for the Shelter (averaged ratio of radionuclides on the basis of the set Shelter air sampling studies). If this criterion is met, the emissions into the environment during operation of the ventilation systems of NSC main volume with the use of filters will not be exceeded. This requirement relates to «active» stages of Shelter transformation, when, in course of activities, rise of dust and aerosols occurs (in particular, in course of dismantling of unstable structures).

Permissible release to the environment will not be exceeded in case of operation of the ventilation system of NSC main volume without filters if volumetric contamination of air does not exceed 40 Bq/m^3 . If this value is exceeded, it is necessary to use filters. For the operation of the ventilation system of the main volume of the NSC without filters, it is advisable to set a lower allowable contamination value of 30 Bq/m^3 (with a certain margin relative to 40 Bq/m^3).

When airborne contamination in the main NSC volume is 30 Bq/m^3 , the total emission limit from the Shelter can be estimated at $30 \text{ Bq/m}^3 \cdot 147,442 \text{ m}^3/\text{h} \approx 4.4 \text{ MBq/h}$. Therefore, the abovementioned results of monitoring show that at existing conditions the release from the Shelter is about 60 times lower than the recommended permissible value of 4.4 MBq/h . It should be mentioned that this estimate is rough, because, on the one hand, the results from monitoring of uncontrolled releases from the Shelter have large inaccuracies, and, on the other hand, when the Shelter is located under the NSC, the air fluxes inside the Shelter will change substantially.

Limiting the spread of contaminated water. In the Shelter state without NSC, water flowed from the Shelter to Unit 3, which led to the problem

of handling this water containing transuranic elements and organic elements.

In addition, the hazard of water release from water accumulations at Shelter lower levels to the hydrogeological medium cannot be excluded.

In the report [5], after installing the NSC in the design position recorded a significant decrease of the contaminated water (CW) in premises at the lower levels of the Shelter (the water is completely dried up in premises 013/2, 014/2, 012/5–8 (southern part), 012/14 — 16 (northern part) and 210/7, that recorded 9 by June 2018). In the remaining concentrations of CWs, with the exception of the accumulations in premise 001/3, an increase in the concentration and volumetric activities of the radionuclides is observed due to the concentration as a result of the evaporation of water.

Taking into account the abovementioned, it is necessary to continue the study of water in the Shelter (accumulations, dynamics of their changes, condensation processes and condensate movement routes, etc.). According to the results of investigations, a criterion for limitation of water accumulation/evaporation in various premises and areas of the Shelter should be established and the flow of water from the Shelter to Unit 3 is to be avoided.

Prevention of criticality in FCM accumulations. Under the existing conditions, all FCM accumulations are subcritical. The criticality incident is not excluded when water is flooded with hypothetically possible nuclear hazardous compositions of FCM in premise 305/2 and in reactor vault, as well as hypothetical compositions in the central hall. Apart from this, criticality incident is possible in case of uncontrolled movement of FCM with the hypothetically possible creation of new nuclear-hazardous accumulations with their simultaneous flooding with water. The criticality incident risk is estimated as low [5].

If structures with FCM accumulations collapse, the accumulations may combine. The possibility/impossibility of criticality of these combined accumulations (without its filling with water) needs further evaluation.

Principal hazards of FCM. Based on the given information here above, the following main hazard factors of FCM can be determined.

In the current state of FCM, the spread of radionuclides occurs by raising and spreading fine dust

(aerosols) in the air and by spreading soluble forms of FCM with water. Thus, given the risks of current negative impacts, the most critical characteristics of the state of FCM are:

the intensity of the destruction of FCM and the appropriate formation of dust (aerosols), as well as the characteristics of dust (aerosols), in particular, dispersion;

radionuclide leaching intensity.

There are also risks of potential negative effects of FCM, in particular:

occurrence of criticality, including, due to the significant accumulation of water in those FCM accumulations, in which criticality is possible;

significant movements of FCM, e.g. as a result of structural collapse in premises where FCM is located.

After installation the NSC in its design position and the access to weather elements has ceased, a slow increase in the density of neutron fluxes at individual monitoring points is observed. This growth is possibly associated with the process of moisture loss and the growth of the neutron multiplication factor in the FCM layer, which is waterlogged in the period before launching of the Arch [8].

In conclusion, it can be stated that the most critical of their performance status FCM are risks associated with the:

water level change in premises where FCM accumulations are located;

collapse of structures in premises where FCM accumulations are located.

For the development and timely implementation of measures to ensure the safe condition of FCM (or to retrieve FCM if it is impossible to ensure acceptable conditions for it), it is necessary to perform a prediction of FCM state. FCM parameters, which are indicators of the predicted change in the state of the FCM, should be determined on the basis of an appropriate model that describes the physico-chemical processes in the FCM and predicts changes in FCM properties.

Methodological procedures for establishing criteria for FCM safe state

Based on the above information, the following list of parameters by which it is advisable to establish a criterion for FCM safe state can be established:

volumetric activity and dispersion of radionuclides in the air of NSC main volume, near FCM accumulations;

the amount and characteristics of dust on FCM accumulations;

specific activity and chemical composition of water passing through FCM accumulations;

neutron flux density in and around FCM accumulations;

the presence of water in FCM accumulations; geometrical configuration of FCM accumulations;

physical and chemical characteristics of FCM based on studies of samples of FCM.

Volumetric activity and dispersion of radionuclides in the air of the main volume of the NSC.

It is advisable to set the criterion of 30 Bq/m³ as an acceptable value for general airborne contamination in the main volume of the NSC. This criterion of total volumetric air activity was established during the design of the NSC, taking into account the data on the ratio of radionuclide activities and aerosols dispersion in air, which were obtained as a result of the Shelter research prior to the design of the NSC.

When the NSC is placed over the Shelter, the ratios of the activities of radionuclides and the dispersion of aerosols may change as a result of changes, in particular, the heat-humidity conditions inside the Shelter.

Considering this, it is recommended to apply such procedure to establish and adjust the criteria for permissible airborne contamination in the main volume of the NSC:

1) To establish as the initial allowable values of volumetric activities for each of the ¹³⁷Cs, ⁹⁰Sr and α -nuclides radionuclides based on the total volumetric activity of 30 Bq/m³ and the existing ratio of radionuclide activities.

2) To establish as the initial dispersion values of aerosols as current.

3) In the process of monitoring, to make adjustments (reduce) the permissible values of the volumetric activities of ¹³⁷Cs, ⁹⁰Sr radionuclides and α -nuclides in the case of a decrease the AMAD aerosols. Recommended values of volumetric activities of radionuclides are recommended to be reduced as much as the dose per unit concentration of radionuclides in the air increases with increasing AMAD (based on data NRB-97) [6]. At small dispersed particles (about 0.01 microns) sharply increases the internal (inhalation) dose.

Volumetric activity and dispersion of radionuclides in the air near FCM accumulations.

Permissible value for this parameter should be set in a way that the relevant criteria of airborne contamination in the main volume NSC is not be exceeded.

It is advisable to apply the following procedure for establishing and adjusting the criteria for permissible airborne contamination near FCM:

1) To perform sufficient statistics on changes of the volume activities of ^{137}Cs , ^{90}Sr radionuclides and α -nuclides around FCM, and allowable values for these parameters, as an option, to be 10 times more than the measured values, given that the current emission from the Shelter is estimated to be about 60 times less than the recommended value of permissible emission. Certain conservatism is used here (if airborne contamination in the main volume of the NSC is proportional to the level of airborne contamination near FCM, there remains a reserve of about 6 times).

2) To carry out airborne contamination studies in the main volume of the NSC and around FCM at the same time; from the measurement results, determine the experimental relationship between airborne contamination in the main volume of the NSC and near FCM. The permissible values of the volumetric activities of ^{137}Cs , ^{90}Sr radionuclides and α -nuclides in the air around FCM should be corrected taking into account this experimental dependence (as far as possible).

3) Set as the original existing values of dispersion of aerosols in the air near FCM accumulations.

4) In the process of monitoring, make corrections (reductions) of permissible values of the volumetric activity of ^{137}Cs , ^{90}Sr radionuclides and α -nuclides in case of a decrease in AMAD aerosols (see above).

Amount and characteristics of dust on FCM accumulations. It is advisable to apply the following procedure for establishing and adjusting the criteria for the amount and characteristics of dust on FCM accumulations:

1) The initial data on the amount and characteristics of dust on FCM accumulations needs to be determined based on the results of the research.

As characteristics of dust, in particular, the following parameters are used:

specific activity of ^{137}Cs , ^{90}Sr radionuclides and α -nuclides;

particle size distributions (in particular, the ratio between the aerosol and dust fractions).

In addition, as characteristics of dust, use the parameters that are most important in the model of the predicted FCM behavior.

2) To determine experimentally the relationship between the amount and characteristics of dust on FCM accumulations, the volumetric activity of radionuclides and the dispersion of aerosols in the air near FCM accumulations. This work should be planned on the basis of the ALARA principle.

3) Based on the indicated experimental dependences, establish criteria for the permissible amount of dust (depending on dust characteristics) upon reaching which criteria for airborne contamination near FCM accumulations can be achieved.

Specific activity and chemical composition of water passing through FCM accumulations.

The leaching of radionuclides from FCM is an important indicator of the physicochemical state of FCM. Based on the dynamics of changes of the leaching rate for different radionuclides, it is possible to draw certain conclusions about the processes of FCM degradation.

Permissible criteria for specific activity of radionuclides in water samples are advisable to be established based on the model of the predicted behavior of FCM (taking into account the relationship between the intensity of leaching of radionuclides and the processes of FCM degradation).

The procedure for determining the criteria for the chemical composition of water that passed through FCM accumulations is similar to procedure for leaching radionuclides.

Neutron flux density in and around FCM accumulations.

It is impossible to establish a clear relationship between the neutron flux density values in the coordinates of the detectors and the effective neutron multiplication factor K_{eff} due to the insufficiency and uncertainty of the data of FCM accumulations. Therefore, in the Technical Specifications for Shelter operation [7], allowable values for neutron fluxes (safe operation limits) are determined on a conservative basis of the measured values of the neutron flux for a certain period (e.g., 1 year). A statistical analysis of the measurement data is performed and, based on the results of the analysis, the allowable values of neutron fluxes are established (according to the principle of the upper limit from the range of measured values).

This procedure for establishing and correcting the permissible values of the neutron flux is advisable to be used in the future.

Presence of water in FCM accumulations.

According to the study, criticality may occur in hypothetical configurations of FCM mixed with water. At the same time, the volumes of water are quite large [3].

It is advisable to monitor the accumulations of water in premises with FCM. The criterion may be the presence of water in the depressions of premise relief (for example, a layer of water up to 10 cm).

Geometrical configurations of FCM accumulations. Spontaneous changes in the geometric configurations of FCM accumulations is meaning by substantial degradation of FCM.

How much such changes affect the safe condition of the Shelter depends on the specific cases. As basic approach, it is recommended to consider each case as an emergency, and based on the results of the study, draw final conclusions on changes in the state of FCM.

Methodological recommendations for the establishment of the FCM monitoring scope

The following are recommendations for establishing monitoring over the above parameters, according to which it is advisable to establish the requirements for the safe state of FCM.

Monitoring of FCM radiation parameters by the integrated automated monitoring system (IAMS). The IAMS includes a nuclear safety monitoring system (NSMS) and a stationary radiation monitoring system (SRMS) [7]. The NSMS provides a measurement of the neutron flux density and the exposure of gamma dose rate at the sites of FCM accumulations in the Shelter premises.

Nineteen sensor units are used (with sensors measuring of neutron flux density and of gamma dose rate radiation in a common envelope). The sensor units are located in premises 210/6, 304/3, 305/2, 504/2, 505/3, 818/2, 821/2, 914/2.

The NSMS provides regulations monitoring in premises with the main FCM accumulations, in the reactor premise, in the equipment premises and in the premises of steam distribution corridor, as well as in the places in the central hall where the «fresh» fuel can be found (sensors are located under the central hall).

It is necessary to analyze the dynamics of changes in the data of NSMS monitoring:

changes in neutron fluxes may indicate about changes in state subcriticality of FCM;

changes in dose rate may indicate about changes in geometry in FCM accumulations.

In addition to the results of the monitoring of the NSMS, it is advisable to use data from the monitoring systems of the CS FCM «Signal» and ITT «Finish-R».

IAMS SRMS provides continuous automated monitoring of the parameters of the radiation situation in the Shelter premises and monitors: the volume activity of α - and β - aerosols. In the air of the premises of the Shelter there are 11 sensors for measuring the volume activity of α - and β - aerosols.

For specific SRMS sensors, monitoring points will be monitored and points for additional monitoring of likely places affecting changes in the concentration of radioactive substances in the air will be determined, upon reaching the relevant operational limits or safe operation limits established.

Monitoring sensors, that located in block B are informative for monitoring the dynamics of α - and β -aerosols. Information should be more carefully analyzed from sensors in premises 006/2, 206/2.

Monitoring of air contamination near FCM accumulations and in main volume by periodic air sampling. It is advisable to organize the monitoring of airborne contamination, in particular, to ensure the monitoring of the volumetric activity of radionuclides and the dispersion of aerosols in the air in the premises where the main accumulations of FCM are located, and at the borders with the neighboring premises, which are combined with the airflows of the previous premises. Based on these data of radionuclide ratios at different time periods, it will be possible to determine the dynamics of FCM degradation and aerosol transfer from the places of formation.

It is also important to ensure the detection of fine aerosols, which will also provide information about the degradation of FCM.

Monitoring is advisable to be provided in premises where FCM are located (see the table above). It is advisable to organize comparisons of monitoring results in different premises with the presence of FCM of various modifications.

It is advisable to provide for the monitoring of aerosols in the main volume of the NSC:

in the locations of unorganized air exits from the Shelter under-roof space (for example, along

the A axis along the machine hall or near the hatches on the light roof);

in the area of the air intake by the ventilation systems of the NSC, which are located near the Shelter;

on transition walkways to the main crane system.

It is recommended to establish the periodically monitoring in view of the predicted change in the state of the FCM, drying of surfaces in the Shelter, changes in air humidity, changes in air flow, etc.

Monitoring of water contamination near FCM accumulations by periodic water sampling. Routine monitoring with sampling is carried out in the premises with main CW accumulations with the accumulation of CW.

In addition to monitoring the specific activity of radionuclides and uranium, it is advisable to provide for monitoring the dynamics of changes in the volume of accumulated water. Monitoring the specific activity of radionuclides, the chemical composition of CW, etc. is recommended to be organized in the premises 012/7, 012/8, 012/6, 012/(13–16), 01/3, 001/3, 210/8, and in premises where the main water flows, for example, in prem. 012/5–8.

Monitoring of geometric parameters and the state of FCM accumulations by means of video observation. Monitoring of geometrical parameters and the state of FCM accumulations with using video surveillance can be performed periodically (constant observations even recording information on a carrier will probably not be expedient due to the slow process of destruction of FCM accumulations). Monitoring is advisable to be organized in premises 210/7, 012/7, 012/15, 304/3. If a change in the configuration of the FCM accumulation is detected, the situation will be analysed, additional laboratory monitoring with sampling will be provided and appropriate measures will be developed.

Monitoring of FCM physical and chemical features by periodic sampling of FCM. It is advisable to organize a periodic sampling of dust and FCM samples with an analysis of the physicochemical properties of dust and FCM samples. It is advisable to investigate the parameters that characterize the degree of current and the predicted volumetric lava-like FCM destruction, alteration of their structure, degradation, diffusion processes, disruption

of the matrix, processes of oxidation of the fuel structures and others. It is advisable to provide sampling in FCM accumulations in premises 012/7, 210/7, 012/15, 304/3.

Conclusions

Based on the performed analysis the following list of parameters by which it is advisable to establish criteria for the safe state of FCM can be highlighted:

volumetric activity and dispersion of radionuclides in the air of the main volume of the NSC and near FCM accumulations;

amount and properties of dust at FCM accumulations;

specific activity and chemical composition of water passing through FCM accumulations;

neutron flux density in and around FCM accumulations;

the presence of water in FCM accumulations;

geometrical configuration of FCM accumulations;

physical and chemical properties of FCM based on FCM samples analysis.

The recommended procedures for the establishment of criteria for the safe state of FCM are based on:

limitation of the release of radioactive aerosols from the Shelter to the main volume of the NSC;

limitations of the release of CW from the Shelter and

the prevention of criticality in FCM accumulations.

It is recommended to analyse and establish dependencies between parameter values at different monitoring points by using experimental data, as well as to investigate the theoretical dependencies between numerical values of monitored parameters and the predicted behaviour of FCM in the context of its degradation.

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Підходи до встановлення критеріїв безпечного стану скупчень паливних матеріалів при експлуатації нового безпечного конфайнмента

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Будівництво нового безпечного конфайнменту над об'єктом «Укриття» (ОУ), що розташований над зруйнованим 4-м блоком Чорнобильської АЕС завершено. Новий безпечний конфаймент спроектовано з врахуванням граничних умов щодо поточних та потенційних небезпечних впливів з боку ОУ. Відповідно, мають бути встановлені критерії безпечного стану ОУ,

зокрема, критерії безпечного стану скупчень паливовмістних матеріалів (ПВМ).

У статті наведені результати розробки методичних рекомендацій щодо встановлення критеріїв прийнятності/неприйнятності стану скупчень ПВМ з погляду безпеки, а також щодо обсягів моніторингу ПВМ для оцінок їх поточного і прогнозованого стану відповідно до встановлених критеріїв.

Ключові слова: об'єкт «Укриття», новий безпечний конфаймент, паливовмістні матеріали, критерії безпеки, моніторинг.

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