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RESULTS OF ANALYSIS OF TEMPERATURE MONITORING DATA AROUND THE NUCLEARLY HAZARDOUS CLUSTER OF FUEL-CONTAINING MATERIALS IN THE SUB-REACTOR ROOM 305/2 OF THE “SHELTER” OBJECT, INSIDE AND OUTSIDE THE NEW SAFE CONFINEMENT

The results of the analysis of temperature monitoring data were obtained using the information and measuring system (IMS) “Finish” (1991 - 2015) and expert research system, new safe confinement (NSC) integrated control system in the main volume (MV) under the arched space, and the weather station in Chornobyl (1991 - 2023). After the NSC was installed in the design position, a slight increase in average annual MV NSC air temperature was observed before 2021. During the same period, the average annual temperature of concrete around the localization area of nuclearly hazardous clusters of fuel-containing materials (FCM NHC) in room 305/2 of the “Shelter” object increased by 1.3 - 1.4 times and had returned to 0.7 - 0.8 of the value of 1991. From 2021, no next increase in the mean annual temperature of concrete has been noticed. As of 2023, if compared to the monitoring period before Arch pushed into its design position, the calendar shift between the temperature of concrete and the surrounding environment enhanced to 1 month, according to both minimum and maximum average month values.

Keywords: Chornobyl NPP, “Shelter” object, new safe confinement, nuclearly hazardous clusters, fuel-containing materials, temperature, dynamic.

1. Introduction

The accident at the Chornobyl Nuclear Power Plant (ChNPP), which occurred at the 4th power unit in 1986, and its consequences are still the subject of close attention of scientists. According to state-of-the-art concepts, fuel-containing materials (FCM) with the highest concentration of fissile materials are formed at the active stage accident’ of ChNPP Unit 4 and located in the south-eastern part of 305/2 sub-reactor room in a form of nuclearly hazardous clusters (NHC) [1]. After the construction of the “Shelter” object (SO), also known as the Chornobyl Sarcophagus, several research measurement systems were created to understand and monitor the FCM behavior. Based on collected information about the material and energy balances, such FCM NHC are localized in the areas of intensive concrete ablation of sub-reactor slab (SRS) and can contain up to 18 ± 5 t of uranium [2]. Within the framework of SO transformation into an environmentally safe system by the construction of the new safe confinement (NSC), and prior to the protective Arch being set into design position, an integrated automated monitoring system (IAMS), was created [3]. One of the components of IAMS is the nuclear safety monitoring system (NSMS), designed for the early detection of negative trends that may lead to a reduction in the level of nuclear safety of the NSC-SO complex. Some neutron flux density (NFD) and gamma-radiation exposure dose rate (GDR) sensors are located in close vicinity to FCM NHC boundaries [3]. However, as a result, temperature monitoring around the FCM NHC area was lost because the NSMS measuring channels were not provided for performing this function. In 2017, it was decided to create the expert research system (ERS), one of whose functions was to monitor the concrete temperature around the FCM NHC localization area [4]. Analysis of the first results of the ERS operation showed that creating a new monitoring system made it possible to partially compensate for the loss of temperature monitoring around FCM NHC boundaries after the information and measuring system (IMS) “Finish” was decommissioned in 2015. Data, which were obtained for several monitoring points, showed the trends prior to the increase in average monthly temperature values, which were not observed before the NSC installation on design position [4]. Nevertheless, a detailed analysis of the accumulated results of ERS measurements has not yet been carried out. Data on air temperature inside and outside NSC were not considered.

The objective of this work is to present the results of the study of dynamics SRS concrete temperature around FCM NHC localization area, the air temperature in the MV NSC, and the environment.

2. Temperature monitoring system and method of data analysis

The scheme of monitoring zones layout for concrete and air temperatures around the FCM NHC localization area in the NSC-SO complex is presented in Fig. 1. Zone 1 is located inside the SO and monitored by ERS temperature sensors (TS) in 13 monitoring points. Zone 2 and Zone 3 are located in the MV NSC and monitored by south and north zones of under-arched NSC space by two TS, which are part of the NSC integrated control system (ICS). TS location details are presented in Table 1.

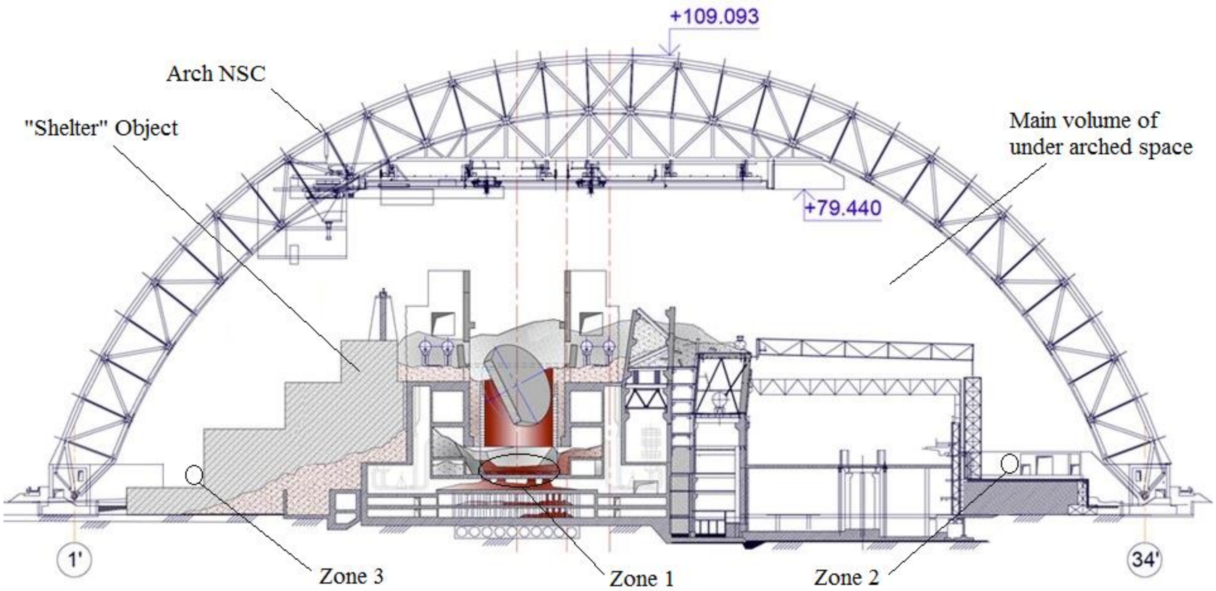

Fig. 1. Location of temperature monitoring zones inside NSC for which data were obtained and analyzed.

Table 1. **Location details about TS layout inside and outside NSC-SO complex**

No. point	Monitoring Zone / System	TS	Location of monitoring point (room in SO)	Borehole legend	Location of TS		
					Elevation, m	Axis	Line
1	Zone 1 / ERS	TS 5	304/3	З-9-Р	+8.9	45_{+4400}	И_{-2000}
2		TS 6	304/3	З-9-Р	+8.9	45_{+5400}	И_{-2000}
3		TS 7	305/2	Ю-12-109	+13.1	46_{+1100}	И_{+3400}
4		TS 8	305/2	Ю-12-109	+12.9	46_{+1200}	И_{+1900}
5		TS 23	305/2	Ю-12-83	+12.0	46_{+2800}	К_{-3000}
6		TS 11	305/2	Ю-9-В	+8.8	45_{+2700}	И_{+1100}
7		TS 12	304/3	Ю-9-В	+8.8	45_{+2700}	И_{-1100}
8		TS 21	307/2	Ю-9-В	+8.8	45_{+2700}	К_{+2200}
9		TS 13	305/2	Ю-9-Б	+8.8	46_{+700}	И_{+900}
10		TS 14	304/3	Ю-9-Б	+8.8	46_{+700}	И_{-300}
11		TS 25	210/5	–	+6.5	45_{+3000}	И_{-1800}
12		TS 26	210/5	–	+6.5	45_{+1500}	И_{-1800}
13		TS 27	210/6	–	+6.5	46_{+3100}	И_{-1800}
14	Zone 2 / ICS	RMS 008	NSC. The area before the entrance to FSAL	–	+11.0 (+125.0 BS)	63_{+3700}	А_{-10250}
15	Zone 3 / ICS	RMS 009	NSC. The area in the forklift movement zone	–	+9.0 (+123.0 BS)	62_{+750}	Е_{+2000}
16	Environment / ChWS	WS	Chornobyl		+123.0 BS	–	–

Note. The location of the TS is according to the construction marks of the ChNPP Unit 4 (SO). Full system names of ICS TS RMS-008 and RMS-009 are RMS-FSAL-VV-UIT-008 and RMS-TEC-MV-UIT-009, correspondingly. FSAL is the acronym for Fire Subdivisions Access Lock of NSC. BS – Baltic system of heights. WS – weather station. The legend of boreholes is given in accordance with the original Cyrillic notation.

To date, the ERS integrates a network of temperature-measuring channels based on five-link thermocouple probes (points *1 - 10*), thermal resistors (points *11 - 13*), and NFD-measuring channels based on an ionizing fission chamber. ERS TS are mounted in the boreholes, which were previously used in the IMS "Finish", and on the walls of the steam distribution corridor (SDC) in the 210/5 - 210/6 rooms. The layout of sensors around the FCM NHC localization area in projection onto the plane of elevation mark +9.1 m is shown in Fig. 2. More detailed ERS information is presented in [5].

Table 2 shows a list of ERS and IMS "Finish" TS, whose installation coordinates are the same. Such a coincidence made it possible to carry out a comparative analysis of the features of concrete temperature dynamics at different distances from the FCM NHC boundaries before (1991 - 2016) and after (2017 - 2023) NSC installation in its design position.

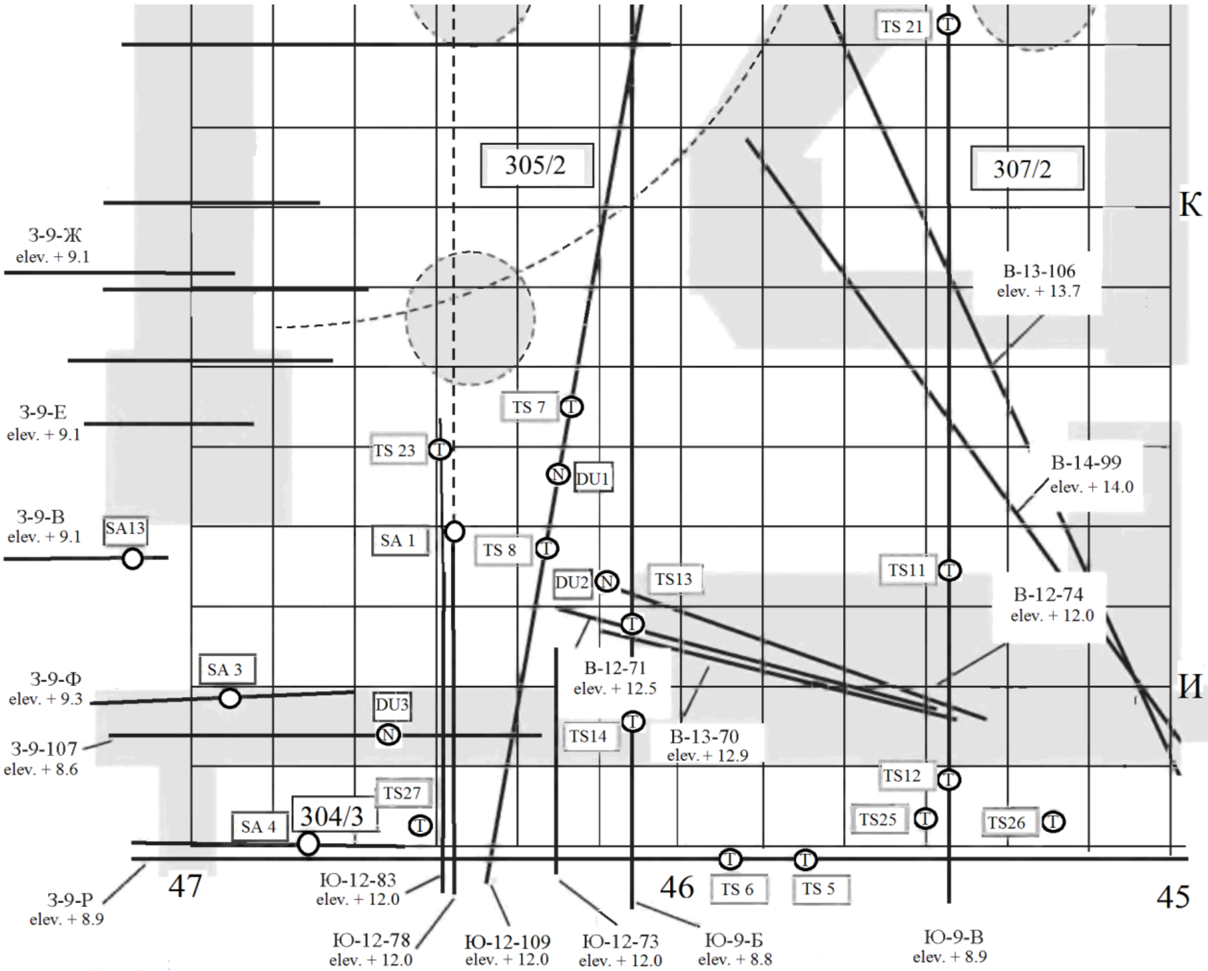

Fig. 2. Scheme of ERS sensors layout: TS 1 – TS 13 designated by the letter "T"; NFD detection units DU 1 - DU 3 designated by the letter "N". Designations SA 1, 3, 4, and 13 correspond to placement locations of center sensor assembles (NFD+GDR) of the IAMS NSMS.

Table 2. **ERS and IMS "Finish" TS whose installation coordinates coincide**

Monitoring system	Number of TS										Note
ERS	TS 5	TS 6	TS 11	TS 12	TS 13	TS 14	TS 21	TS 23	TS 25	TS 27	See Fig. 2
IMS "Finish"	5	51	8	9	60	61	21	15 (23)	16 (25)	18 (27)	See [4]

The ICS was designed to ensure continuous automated control of NSC, its sub-systems, continuous automated and periodic manual monitoring of GDR, volume activity of alpha- and beta-active aerosols in the NSC rooms and ventilation systems, emissions of radioactive substances into the environment through the NSC ventilation pipe. One of the ICS functions is also to monitor the air temperature in MV NSC. The ICS provides information about the NSC state and its controlled parameters to the operators' workplaces and signals when the controlled parameters exceed the threshold values (operational and safety limits). The NSC ICS provides collection, data processing, display, analysis, documentation, and data archiving of controlled parameters of radiation situations inside the NSC. The composition and functions of the ICS are described in the Technical Regulations for the NSC-SO Operation [6] and in [7].

Data on average daily air temperature outside the NSC-SO complex are provided by the Chornobyl weather station (ChWS, see Table 1) in the framework of cooperation with the Institute for Safety Problems of Nuclear Power Plants, National Academy of Sciences of Ukraine (ISP NPP of NAS of Ukraine).

For all monitoring points in places where TS are installed (see Table 1), the average monthly and annual values of SRS concrete or air temperature were assessed. Using the standard functions of Excel 2003, the regression analysis of temperature data (2017 - 2023) was carried out. The trends of average monthly temperature were assessed and described by a linear regression equation separately for two periods: the period of a sustainable increase in the average annual SRS concrete temperature (2017 - 2020), and the period of relative stabilization with a low tendency to decrease its value (2020 - 2023). For air temperature according to ICS and ChWS data, the parameters of the regression equation were determined for the entire observation period. For ERS and IMS “Finish” monitoring points, for which NSC installation coordinates of NSC coincided (see Table 2) and measurement data were available, starting in 1991, a comparison of average annual temperature dynamics for 1991 - 2015 and 2017 - 2023 was carried out.

3. Results and discussion

The calculation results are presented in Tables 3 - 6 and Figs. 3 - 5. In Fig. 5, the long-term dynamics of the average annual temperature of SRS concrete and SDC walls based on a combined sample data of IMS “Finish” (1991 - 2015) and ERS (2017 - 2023), against on background of MV NSC and environment air temperatures.

Table 3. **Average annual concrete temperature around the FCM NHC localization area (M ± std), °C**

Item sensor (SO room)	Monitoring period						
	2017	2018	2019	2020	2021	2022	2023
TS 5 (304/3)	15.2 ± 1.7	16.9 ± 3.2	20.7 ± 1.2	21.6 ± 1.1	21.7 ± 0.9	21.2 ± 0.4	21.3 ± 0.9
TS 6 (304/3)	14.6 ± 1.3	16.0 ± 3.2	19.7 ± 1.0	20.7 ± 1.0	22.0 ± 1.0	21.4 ± 0.5	21.4 ± 1.7
TS 7 (305/2)	17.8 ± 1.5	19.5 ± 3.2	23.1 ± 1.1	23.8 ± 0.9	23.3 ± 1.9	22.7 ± 1.4	21.9 ± 2.7
TS 8 (305/2)	16.6 ± 1.4	18.4 ± 3.1	21.5 ± 1.1	22.2 ± 0.7	22.9 ± 1.8	22.4 ± 0.3	22.2 ± 2.2
TS 23 (305/2)	13.0 ± 2.4	14.4 ± 4.9	18.7 ± 1.8	19.3 ± 1.7	18.2 ± 2.0	17.6 ± 0.6	17.5 ± 2.3
TS 11 (305/2)	15.2 ± 1.7	16.9 ± 3.2	20.7 ± 1.2	21.5 ± 1.0	21.1 ± 1.0	20.3 ± 0.4	20.4 ± 1.0
TS 12 (304/3)	14.6 ± 1.3	16.0 ± 3.2	19.7 ± 1.0	20.6 ± 1.0	20.1 ± 1.0	19.4 ± 0.4	19.4 ± 1.0
TS 21 (307/2)	18.8 ± 2.6	18.2 ± 3.1	21.9 ± 0.9	22.7 ± 0.9	22.2 ± 1.0	21.6 ± 0.4	21.6 ± 1.0
TS 13 (305/2)	17.8 ± 1.5	19.5 ± 3.2	23.1 ± 1.1	23.9 ± 0.9	23.3 ± 1.1	22.8 ± 0.4	22.7 ± 1.0
TS 14 (304/3)	16.6 ± 1.4	18.4 ± 3.1	21.5 ± 1.1	22.2 ± 0.7	21.9 ± 1.1	21.3 ± 0.3	21.3 ± 1.0
TS 25 (210/5)	15.1 ± 2.7	15.9 ± 3.1	19.0 ± 0.9	19.9 ± 0.8	19.2 ± 0.9	18.6 ± 0.2	18.6 ± 0.9
TS 26 (210/5)	14.9 ± 2.6	15.8 ± 3.1	18.9 ± 0.9	19.4 ± 0.6	19.0 ± 0.8	18.5 ± 0.2	18.4 ± 0.8
TS 27 (210/6)	15.6 ± 2.3	16.3 ± 3.2	19.0 ± 0.9	19.8 ± 0.9	19.2 ± 0.8	18.6 ± 0.2	18.6 ± 0.8

Table 4. **Average annual air temperature inside and outside NSC (M ± std), °C**

Monitoring zone	Monitoring period					
	2018	2019	2020	2021	2022	2023
Zone 2 (NSC)	13.0 ± 3.8	15.7 ± 5.1	15.7 ± 4.6	14.3 ± 5.1	13.6 ± 4.7	14.2 ± 4.9
Zone 3 (NSC)	16.0 ± 3.7	17.3 ± 4.5	17.2 ± 4.0	15.9 ± 4.5	15.0 ± 4.1	15.4 ± 4.2
Environment (Chornobyl)	8.7 ± 10.6	9.8 ± 10.5	9.9 ± 10.0	8.2 ± 10.0	8.8 ± 9.4	9.8 ± 10.0

The results obtained made it possible to continue the research [4] and compare the features of temperature dynamics in concrete before and after the installation of the NSC in the design position for four TS (monitoring points) from those presented in Table 2. The gap in the data is due to the consequences of the occupation of the Exclusion Zone by Russian troops, and the fact that personnel of ISP NPP of NAS of Ukraine were able to continue works on the NSC-SO in September 2022 only.

The obtained data showed that starting from mid-2018, there has been a synchronous change in concrete average monthly and annual temperatures at all monitoring points. Some exceptions are SDC rooms data only. In some years, the maximum concrete temperature in SDC was observed a month earlier than in other controlled rooms. Examples of specific temperature dynamics for a sample of three representative monitoring points, which indicates the preservation of clear temperature gradients in concrete at different distances from the FCM NHC boundaries, are shown in Fig. 3. As can be seen from Table 3, the highest concrete temperature is observed in the immediate vicinity of the FCM NHC localization zone (TS 7, 8 and 13), the lowest – in the SDC rooms (see Fig. 2 also). In our opinion, the data obtained at the TS 23 location indicate that this sensor may be in direct contact with the reactor shaft air. For that reason, it leads to obtaining significantly lower temperature values than in the neighboring monitoring points (see TS 7 and TS 8, Table 3).

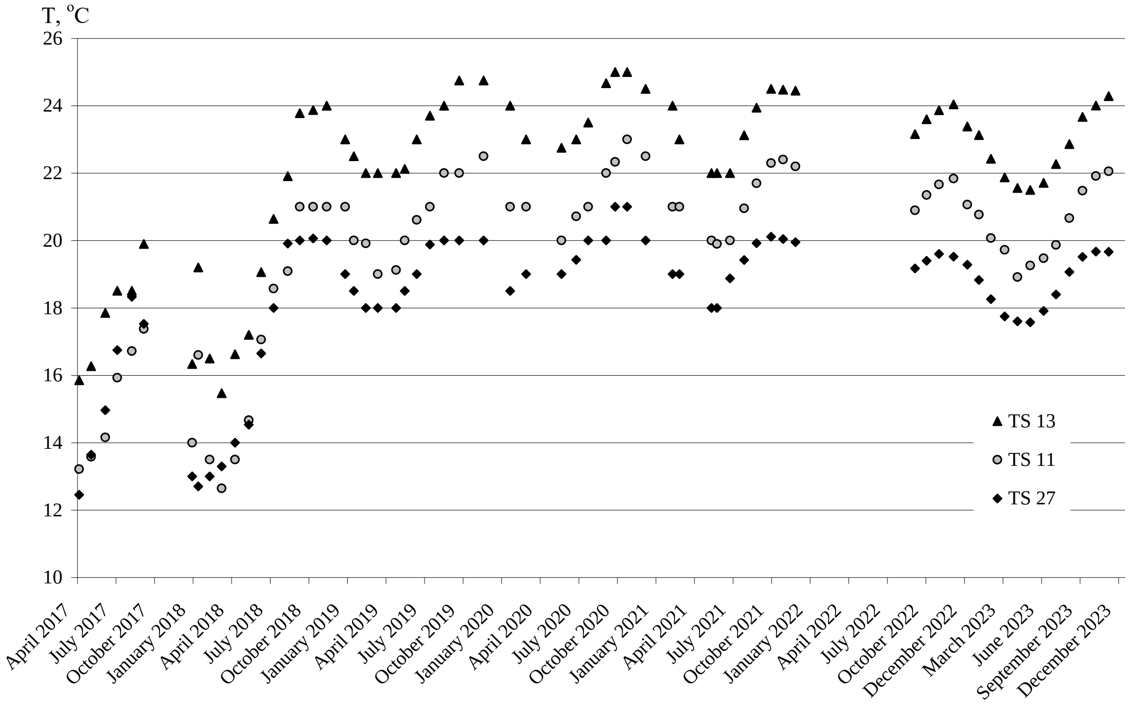

Fig. 3. Examples of dynamics of average monthly concrete temperature around FCM NHC localization area in 305/2 room (TS 11 and TS 13) and in 210/6 room (TS 27).

Table 5. **Regression equations parameters of average monthly values of concrete temperature**

Sensor (SO room)	Parameter of regression equations $f(x) = A \cdot x + B$					
	A_1	B_1	R_1^2	A_2	B_2	R_1^2
TS 5 (304/3)	0.0050	–197.4	0.65	–0.0002	30.8	0.007
TS 6 (304/3)	0.0055	–222.3	0.74	–0.0002	29.8	0.002
TS 7 (305/2)	0.0064	–257.6	0.67	–0.0009	62.4	0.03
TS 8 (305/2)	0.0060	–239.0	0.67	0.0006	–3.7	0.02
TS 23 (305/2)	0.0076	–312.7	0.54	–0.0005	42.2	0.01
TS 11 (305/2)	0.0068	–277.0	0.70	–0.0006	46.7	0.06
TS 12 (304/3)	0.0065	–264.5	0.68	–0.0007	50.1	0.10
TS 21 (307/2)	0.0052	–206.8	0.52	–0.0006	51.1	0.10
TS 13 (305/2)	0.0065	–262.8	0.70	–0.0007	55.0	0.10
TS 14 (304/3)	0.0060	–239.0	0.67	–0.0005	45.5	0.06
TS 25 (210/5)	0.0056	–226.0	0.60	–0.0008	55.6	0.14
TS 26 (210/5)	0.0053	–211.4	0.56	–0.0006	45.1	0.11
TS 27 (210/6)	0.0050	–200.0	0.55	–0.0007	49.0	0.12

Note. The regression parameter subscript corresponds to: 1 – period of a sustainable increase in the average annual SRS concrete temperature (2017 - 2020); 2 – period of relative stabilization of average annual SRS concrete temperature with a low tendency to decrease (2020 - 2023). The unit of measurement x in the regression equation is a day.

The preservation of stable temperature gradients in concrete around the FCM NHC localization area during 2018 - 2023, provided grounds for their quantitative assessment and comparison of their values with those observed before the NSC installation in design position [4]. Before 2015 the temperature gradients in SRS concrete were estimated with the following values: for the eastern direction – from 0.65 to 1.34 ºC/m; for the western and southwestern directions – from 0.60 to 1.68 ºC/m; for the south-eastern and south directions – from 0.42 to 1.54ºC/m [5]. The data obtained in the work indicate that under the operating conditions of the NSC-SO complex, the temperature gradients in the SRS concrete are preserved and, according to the data of 2023, are in the following ranges of values: for the eastern direction – from 0.48 to 0.58ºC/m; for the south-eastern and southern directions – from 0.45 to 1.0ºC/m. Unfortunately, for the western and south-western directions, it is not possible to make such estimates due to the lack of monitoring points. Thus, to 2023 temperature gradients in SRS concrete have decreased, but remain, providing needed conditions for heat dissipation from the FCM NHC surface.

It was previously established that before NSC installation in a design position, there was a calendar shift between the temperature of SRS concrete and the environment. In its dynamics, the temperature of SRS concrete lagged behind the environment by three months [4]. The minimum SRS concrete temperature was observed in March - April and the maximum – in September - October. After the commissioning of the NSC-SO complex, the minimum SRS concrete temperature began to be observed in April - June, and the maximum – in October - December. Thus, the difference between SRS concrete temperature and environment increased, the gap is at least 1 - 1.5 months.

The fact that today's minimum and maximum concrete temperatures have moved can be explained by the fact that in the conditions of hermetic NSC building, the heat inside the SO is retained longer and dissipates into the environment more slowly. If we refer to the data in Fig. 4, you can see that in the dynamics of average monthly MV NSC air and environment temperature, a calendar shift for the minimum and maximum values is also present. In comparison with the environment, the air temperature under the arched space reaches its minimum value with a delay of 1 month, and its maximum value with a delay of 1 - 2 months (see Fig. 4).

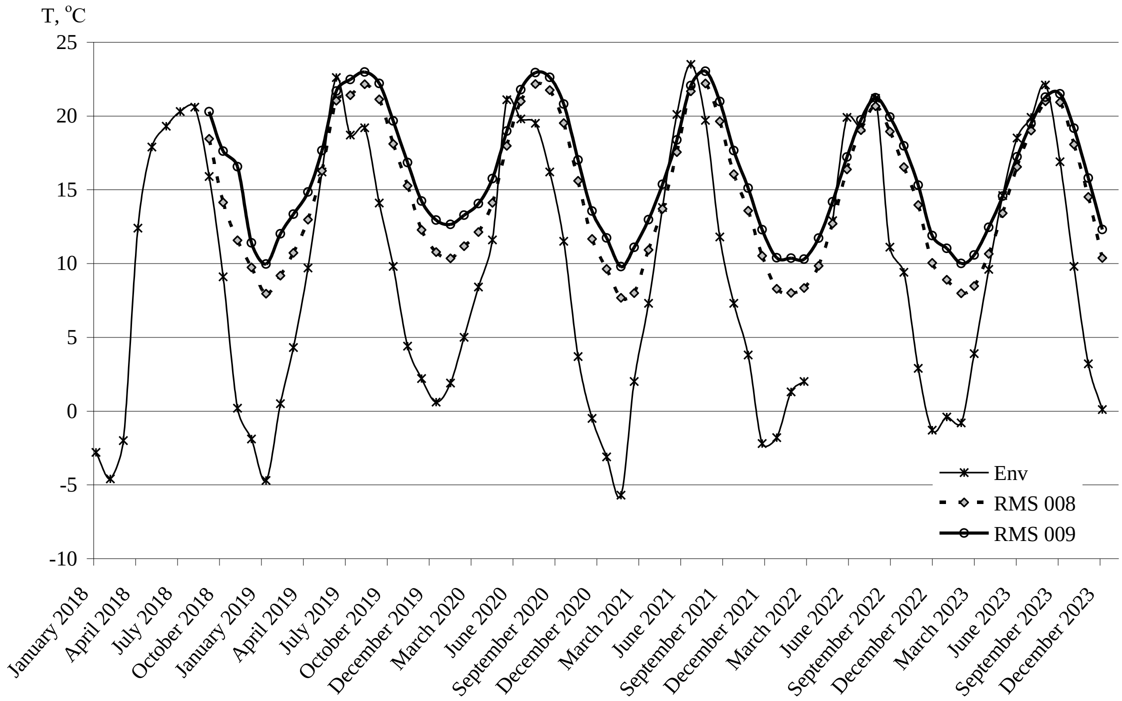

Fig. 4. Dynamics of average monthly air temperature in the MV NSC under arched space monitored by ICS (RMS 008 and RMS 009) and in the environment (Env).

It should be noted that there is a more significant difference in the dynamics of concrete temperature at the 1991 - 2015 and 2017 - 2023 monitoring periods. Before the NSC installation in design position, there was a steady drop in the average annual temperature of SRS concrete, due to a gradual decrease in the power of heat source caused by the spent fuel reactor in FCM composition [2, 4]. It should be noted that the dynamics of concrete temperature in SDC rooms and 305/2 room differed significantly from previous monitoring periods (see Fig. 5). One of the reasons for this difference could be the forced heating of SO rooms during the cold period to reduce humidity. After the commissioning of the NSC-SO complex, the opposite temperature trend began to be observed (see Figs. 3 and 5). The average annual temperature of SRS concrete around the FCM NHC localization area in 2020 increased by 1.3 - 1.4 times compared to 2017. The data presented in Table 5 confirm the presence of a stable linear trend during this observation period. It can be argued that by 2020, the average annual temperature of SRS concrete around the FCM NHC localization area had returned to 0.7 - 0.8 from the value of 1991 (in 305/2 room), and in SDC rooms to 0.98 from the value of 1991 (see Fig. 5). After 2020, the increase in the average annual temperature of concrete and air in the MV NSC stopped and until 2023 there was a weak tendency towards a slight decrease in temperature at all monitoring points (see Tables 4 and 5).

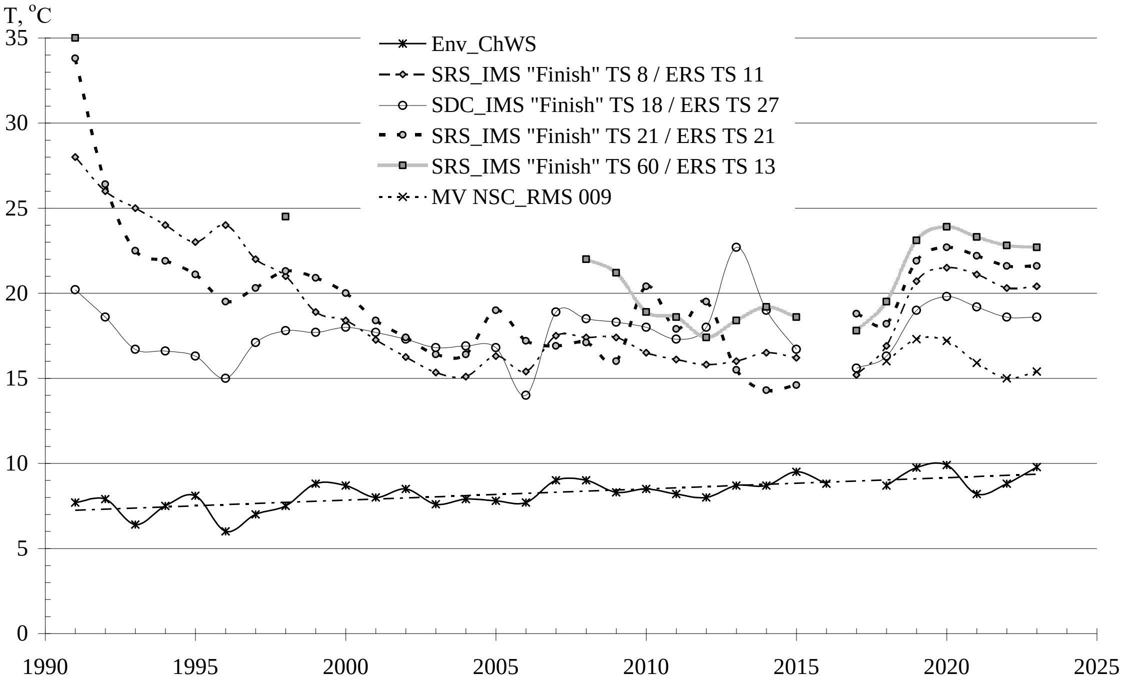

Fig. 5. The long-time dynamics of average annual temperatures of concrete around FCM NHC localization area and air in MV NSC on the background of environmental temperature fluctuations.

According to the data of the NSMS IAMS [4], in the sub-reactor rooms, against the background of falling GDR values, a stable increase of NFD was observed also. At the same time, the monitoring points for which the NFD growth was the highest, in the SRS concrete in close proximity to the boundaries of the localization zone of NHC FCM in 305/2 room, were located [8]. This phenomenon has not been observed before the NSC-SO complex commissioning.

It is unlikely that such behavior of the NFD may be a coincidence with the simultaneous growth of the concrete temperature, but it could be a consequence of changes in the thermal regime and humidity of SRS around the FCM NHC localization area in 305/2 room.

Table 6. **Regression equations parameters for the trend of the average monthly values of air temperature inside and outside the NSC-SO complex**

Monitoring zone	Parameter of regression equations $f(x) = A \cdot x + B$		
	A	B	R_1^2
Zone 2 (NSC)	0.0052	–214.0	0.01
Zone 3 (NSC)	0.0034	–133.4	0.01
Environment (Chornobyl)	0.003	–135.2	0.02
	0.066*	–124.3*	0.51*

Note. The parameters of the environment temperature regression equation, marked with the symbol "*", correspond to the trend in Fig. 5 (1991 - 2023).

At the same time, against the background of another cyclical rise in the average annual environment temperature, the air temperature under the arched space began to slowly rise also (see Table 4 and Fig. 5). It should be noted that during the 1991 - 2023 observation period in the environment, there was a stable trend towards a gradual increase of average annual air temperature (Table 6) against the background of cyclical fluctuations in its value shown in Fig. 5.

4. Conclusions

Thus, the installation of NSC in the design position had a significant impact on the formation of the thermal regime of the SRS. This led to an increase in the calendar shift in the dynamics of the temperature of SRS concrete and environment (the time to reach the minimum and maximum values) and a sharp increase in the temperature of concrete around the localization area of FCM NHC.

The creation of a buffer zone between the SO building and the environment in the form of under arched space, where the air temperature is maintained in the range from 8 to 23 degrees, led to the fact that the average annual temperature of SRS concrete returned to values close to 1991. Before the NSC installation in a design position, the dynamics of concrete temperature around the localization area of FCM NHC generally corresponded to the law of decrease in power of residual heat release of spent fuel. The NSC commissioning introduced significant changes to previously known patterns of formation of the thermal regime of the SRS concrete around the localization area of FCM NHC. To predict the further course of events, a longer observation period is necessary.

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REFERENCES

1. V.O. Krasnov et al. *Object "Ukryttya": 30 Years After the Accident: A monograph* (Chornobyl: Institute for Safety Problems of Nuclear Power Plants, 2016) 512 p. (Ukr)
2. O.V. Mikhajlov, A.O. Doroshenko. Update results about dynamics of under-reactor slab temperature and total heat extraction from the zone of localization of nuclearly hazardous clusters in room 305/2 of the Chernobyl NPP object "Ukryttya". Problemy Bezpeky Atomnykh Electrostantsii i Chornobylia (Problems of Nuclear Power Plants' Safety and of Chornobyl) 29 (2017) 105. (Rus)
3. M.V. Saveliev et al. The nuclear safety monitoring system for fuel containing materials located in destroyed Unit No. 4 of the Chornobyl NPP and proposals for its modernization. Nucl. Phys. At. Energy 23(3) (2022) 172.
4. O.V. Mykhailov et al. Long-term temperature dynamics at the peripherals on nuclearly hazardous clusters of fuel-containing materials located in room 305/2 of "Shelter" object before and after new safe confinement installation into a design position. Nucl. Phys. At. Energy 23(4) (2022) 245.
5. O.V. Mikhajlov et al. Temperature of concrete around localization area boundaries of nuclear hazardous clusters of fuel-containing materials inside ChNPP "Shelter" object of the Chornobyl NPP. Yaderna Enerhetyka ta Dovkillya (Nuclear Power and the Environment) 2(27) (2023) 20. (Ukr)
6. Technological regulations for the operation of the "NSC-SO" complex (1E-S-NSC-SO), Inv. No. 110 dated August 25, 2021 (Slavutych: State Specialized Enterprise "Chornobyl NPP", 2021) 114 p. (Ukr)
7. V.O. Krasnov et al. *The Shelter Object in Conditions of the New Safe Confinement* (Chornobyl: Institute for Safety Problems of Nuclear Power Plants, 2021) 344 p. (Ukr)
8. O.V. Mykhailov et al. Features of neutron flux density and gamma-radiation exposure dose rate dynamics in ChNPP Shelter object after the new safe confinement commissioning. Yaderna Enerhetyka ta Dovkillya (Nuclear Power and the Environment) 2(27) (2023) 44.

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РЕЗУЛЬТАТИ АНАЛІЗУ ДАНИХ МОНІТОРИНГУ ТЕМПЕРАТУРИ НАВКОЛО ЯДЕРНО-НЕБЕЗПЕЧНОГО СКУПЧЕННЯ ПАЛИВОВМІСНИХ МАТЕРІАЛІВ У ПІДРЕАКТОРНОМУ ПРИМІЩЕННІ 305/2 ОБ'ЄКТА «УКРИТТЯ», ВСЕРЕДИНІ ТА ЗОВНІ НОВОГО БЕЗПЕЧНОГО КОНФАЙНМЕНТА

Представлено результати комплексного аналізу результатів моніторингу температури бетону навколо ядерно-небезпечних скупчень паливовмісних матеріалів (ЯНС ПВМ) у підреакторних приміщеннях зруйнованого 4-го енергоблока Чорнобильської АЕС до і після введення в експлуатацію комплексу нового безпечного конфайнменту – Об'єкт «Укриття» (НБК-ОУ), температури повітря в основному об'ємі підаркового простору та температури навколишнього середовища. Розглянуто масиви даних, отриманих за допомогою інформаційно-вимірювальної системи «Фініш» (1991 - 2015 рр.), експертно-дослідницької системи і інтегрованої системи контролю НБК-ОУ (2018 - 2023 рр.), а також дані багаторічних спостережень за температурою навколишнього середовища, отримані метеостанцією в м. Чорнобиль (1991 - 2023 рр.). Встановлено, що на фоні тенденції до незначного підвищення середньорічної температури повітря у підарковому просторі середньорічна температура бетону навколо зони локалізації ЯНС ПВМ з моменту введення в експлуатацію комплексу НБК-ОУ збільшилася в 1,3 - 1,4 раза і у 2020 р. наблизилася до 0,7 - 0,8 від її значення у 1991 р. З 2021 р. подальше підвищення середньорічної температури бетону не спостерігається. Станом на 2023 р., порівняно з періодом моніторингу до насування арки НБК у проектне положення, календарний зсув між температурою бетону і навколишнього середовища як за мінімальним, так і максимальним середньомісячними значеннями збільшився на 1 місяць.

Ключові слова: Чорнобильська АЕС, об'єкт «Укриття», новий безпечний конфайнмент, ядерно-небезпечні скупчення, паливовмісні матеріали, температура, динаміка.

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