# Current State of «Shelter» Object

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## INTRODUCTION

On April 26, 1986, the biggest accident in power engineering history took place at the ChNPP Unit 4, which resulted in total destruction of reactor core, damage of reactor department, deaerating stack, turbine hall (TH) and a range of other buildings. Barriers and safety systems, which were protecting the environment from radionuclides contained within the irradiated fuel, were destroyed, and the activity was released from reactor. That release, being of some million curies per day, was occurring in the course of 10 days, from 26.04.86 to 06.05.86, thereafter it dropped at some thousand fold, and subsequently, was gradually reducing (Fig. 1).

The main «Shelter»'s peculiarity **is its remaining potential danger, much more greater, that is accepted by the norms and rules existing for the objects, that contain nuclear hazardous fissile and radioactive materials.**

As a whole, in the view of radiation safety, the «Shelter» object is an opened source of alpha-, beta-, gamma- and neutron radiation, which with its radiation characteristics has no analogues in world practices

Definition of «Shelter» object's current status is described in the addendum to NRBU-97 «Radiation protection from potential exposure sources» (NRBU-97/D-2000).

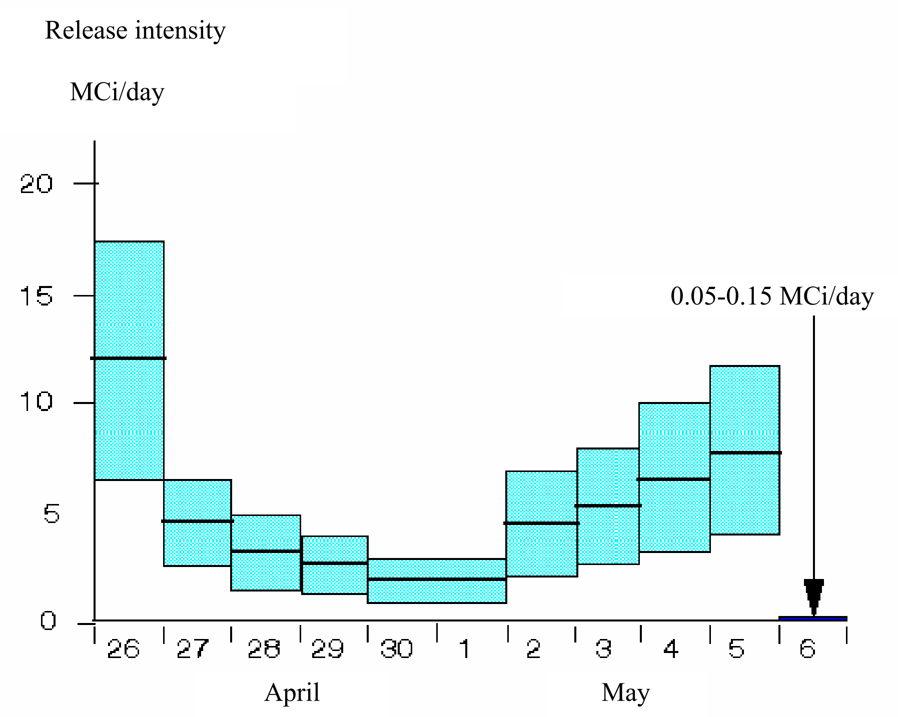


*Figure 1 – Intensity of fission product release of reactor core (the first 10 days)*

It reads: **«…»Shelter» object in its today conditions should be classified as *«the place for surface storage of unorganized RAW («temporary repository of unorganized RAW being in stage of stabilization and reconstruction»).***

## 1. UNIT 4 DESTRUCTIONS AFTER ACCIDENT AND CREATION OF «SHELTER» OBJECT

After the explosion occurred in the 26.04.86 night at ChNPP Unit 4, a part of reactor unit structures, deaerating stack, turbine hall and other buildings become ruined (Fig.2). The main damages of buildings, which it succeeded to detect during the external examination and when penetrating into accessible (due to radiation level and destruction rate) premises, were as regards:

***Reactor unit.***

Active core is completely destroyed. Its fragments were thrown out by the explosion into building breakdown, to the roofs of neighbouring buildings, ventilation pipe sites, scattered along adjoining territory. It was cleared up later, that a part of nuclear fuel came to bottom marks of reactor department in the shape of fuel lava.

Upper plate of biological shield (scheme «E») is torn off from its place and is standing inclined across the reactor vault. Walls and ceilings of reactor Central Hall are destroyed. Ceilings are displaced and walls of drum-separators' premises are destroyed. Reloading machine was torn off and came down. Premises of northern main circulating pumps (MCP) are completely destroyed, premises of southern MCP – are partially destroyed.

***Deaerating stack.***

Two upper floors are destroyed; framework columns are displaced to turbine hall side.

***Turbine hall.***

As a result of fire and debris collapse, roofing is destroyed in many places. Air-blast deformed several building trusses, framework columns along axis A are displaced.

*Figure 2 - Destroyed ChNPP Unit 4*

***Unit of reactor department auxiliary systems.***

It has several local destructions.

***Reactor scram system.***

Is completely destroyed and blocked with building structures.

Except the above main destructions, there were numerous destructions of individual structures and premises, which did not exerted any great influence to general buildings' stability.

***Territory.***

After the explosion occurred, the territory adjoining directly to destroyed unit was contaminated by the scattered fragments of active core: fuel rod debris, graphite stack parts, structure elements. They came to the roof and inside the turbine hall, deaerating stack, on Unit 3 roof, metallic supports of ventilation pipe, etc.

In the middle of 1986 May, the Government Commission took the decision on long-term conservation of Unit 4 aimed at prevention of radionuclides release into the environment and reduction of penetrating radiation impact at the ChNPP site.

In keeping with the CC CPSU and USSR CM Decree No 634-188 of 29.05.86, the USSR Ministry of medium machine-building was vested with “the works for burial of ChNPP power Unit 4 and related to it buildings”. The facility was called as «the Shelter of ChNPP Unit 4».

### 1.1. «Shelter» object structure

The erection of «Shelter» was completed in 1986 November.

On November 30, 1986, the State Acceptance Inspection appointed by the USSR Council of Ministers Decree of October 23, 86, No 2126pc, accepted to the maintenance the ChNPP conservated power Unit No 4 (Fig.3, 4).

In turbine hall between the power units, 2.3-m thick cast concrete wall was erected to mark +19,0, and above – that of 1.4-m thick. In the deaerating stack, partition walls are made of 1-m thick cast reinforced concrete along the row along the row Б between the axes 41-35, and along the axis 41 between the rows Б-В.

In reactor unit, partition wall to mark +12,0 m between the rows Т-Л is made by the way of filling with concrete of transport corridor between the axes 41-42. In other places, existing walls and partitions

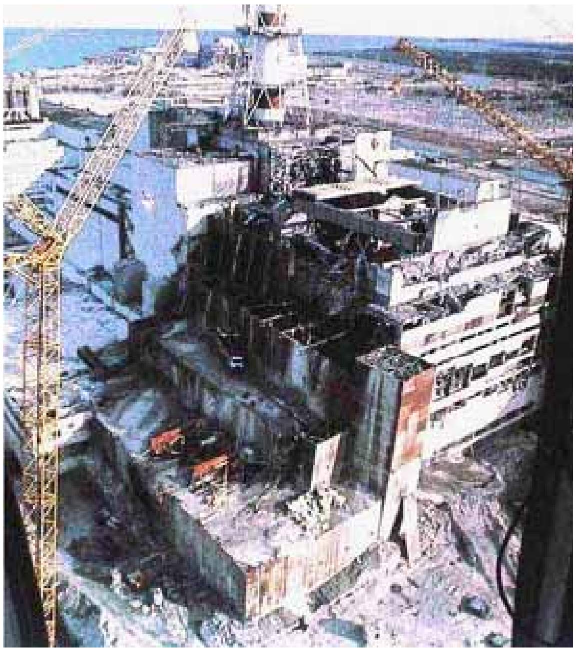

*Figure 3 – Erection of «Shelter» object*

*Figure 4 – A view of «Shelter» object*

after appropriate filling up of apertures, openings, cracks, etc., were used.

Along the Unit 4 perimeter, at first «pioneer» protective ferroconcrete walls were made of height:

- around 6 m from obstruction side (northern unit side);
- around 8 m from southern and western side.

Northern cascade wall was made of concrete in the shape of around 12-m high projections.

Preserved western wall from the outside is closed with the wall having 50-m high buttresses.

To support the main B1/B2 beams installed along the П and Ж rows, around 0,9-m thick debris of ferroconcrete wall at western part were used along axis 50, and ferroconcrete ventilation shafts near the axes 43-44, which preserved after explosion.

Damaged wall site within the area of row Ж before the beams installation is reinforced by steel stay with its subsequent concreting.

Over B1/B2 beams, 27 metallic tubes of 1220-m diameter and 34,5-m length are laid, and over the tubes - the roofing is made of profiled deck – 6 spatial units.

As a support for steel boards in southern side, steel «Mammoth» beam serves, which is installed along the row B, and which, in its turn, rests upon concrete bearers near the axes 41 and 51.

The bearers were made on an obstruction of destroyed ferroconcrete structures of ceilings of two upper floors, equipment and pipeline debris.

For the ceiling of unit site between the axes 40-50 in rows Б-В along the row Б supporting on the another ceiling that was obstructed by destroyed structures, chest beam was designed and manufactured («Octopus»), which serves as a distributing structure.

Over the turbine hall (TH) in the axes 40-50 between the rows А-Б, a new roofing is designed to be made of beam-trusses and steel boards resting, along the row A, upon newly installed spatial columns and preserved cantilevers in columns along the row B. Between the axes 54-50 and 40-34, spatial steel units on existing coating are laid.

## 2. NUCLEARLY HAZARDOUS MATERIALS INSIDE THE «SHELTER» OBJECT (INTEGRAL ESTIMATES)

### 2.1 Nuclear fuel located inside Unit 4 before the accident

Before the accident, nuclear fuel was located in four places of Unit 4 reactor department:

- in active core of RBMK-1000 nuclear reactor;
- in pool for exposition of spent fuel cassettes;
- at site for preparation of fuel cassettes in Central Hall;
- in premises for preparation of fresh fuel.

Distribution of nuclear fuel before the accident is shown in the Table 1.

*Table 1 - Location and amount of nuclear fuel in Unit 4 reactor department premises before accident*

| Premises | Technological assignment of premises | Nuclear fuel amount on uranium, t |
|---|---|---|
| 504/2 | Reactor vault | *190.2 |
| 505/3 | Southern cassette exposition pool | **14.8 |
| 914/2 | Central hall | **5.5 |
| 503/2 | Premises for fresh fuel preparation | **, ***4.1 |
| Total | | **214.6 |

* - to accident moment, reactor active core contained 1659 fuel assemblies (FA), 1 additional absorber (AA) and one unloaded fuel channel. Major part of FA represented the cassettes of first loading with burnup being 11 - 15 MWt · day/kg (U). The core also contained some amount of fresh fuel. Uranium mass in each cassette made up – 0,1147 t. Total mass of fuel loaded in active core, made 190,2 t.

** - data are taken from “Certificate of nuclear fuel amount at Chornobyl NPP Unit 4 at accident moment”, confirmed by Chief Engineer of IA ChNPP on 30.01.96. Besides, the data on fuel amount in exposition pool are delivered on the basis of log for registration of NSD and NM, and in Central Hall and premises 503/2 - on the basis of «Certificate for write-off of fresh nuclear fuel from Unit 4 of 26.04.86».

*** - nuclear fuel from preparation premises (premises 503/2) was removed in 1986 (after accident) to ChNPP fresh fuel storage.

### 2.2. Fuel-containing materials that are currently located in «Shelter» object premises

Currently, inside the «Shelter» object, there are nuclear fuel modifications, which produced in the course of proceeding of accident active stage and during interaction of that fuel with structural materials, dynamic and thermal impact of explosion, as well as during oxidation of uranium dioxide when contacting with air oxygen before and after the reactor burning.

Such modifications include as follows:

#### 2.2.1. Active core fragments

During the mitigation of accident aftermath, a part of active core fragments (ACF) representing fuel pellets, debris of fuel rods, fuel assemblies, graphite, located around the building, was displaced to the breakdown and thereafter buried in cascade wall, a part is collected in containers with high-level waste, another part is buried under the layer of concrete and crushed stone strewn near the Unit. Destroyed fuel that was released on buildings roofs and pipe sites, was thrown down in reactor ruins (Fig.5).

Significant ACF amount must be located in the CH and premises 305/2.

*Figure 5 – Premises 305/2. Southeast sector. Active core fragments*

#### 2.2.2. Lava-like fuel-containing materials (LFCM)

Lava-like materials containing nuclear fuel were detected in many subreactor premises (Fig.6-7). They contained a significant part of uranium located before the accident in active core, and a considerable part of radionuclides, which were produced in reactor.

LFCM represents a heterogeneous solid solution, whose «dissolvent» is vitreous silicate matrix with great amount of diverse impurities, among which uranium oxides, uranium-zirconium-oxygen phase (so called "chernobylite"), and metallic globules are encountered.

Uranium percentage within the LFCM fluctuates within the range from 5 to 10%.

*Figure 6 – Lava in steam discharge valve of SDC*

*Figure 7 – Lava in PSP-1*

#### 2.2.3. Total amount of nuclear fuel in different premises of «Shelter» object

Integral estimate of current nuclear fuel amount in different premises of «Shelter» object are shown in Table 2.

*Table 2 – Fuel amount estimates in «Shelter» object premises*

| Name (numbers) of premises | FCM modifications in premises | Detected fuel, t (U) (estimates for year of 2004) | Notes |
|---|---|---|---|
| Central hall (914/2) | active core fragments | more 21 | Considering 48 assemblies with fresh fuel (5.5 t) Is possible LFCM presence |
| Southern exposition pool (505/3) | active core fragments | 14.8 | 129 spent fuel cassettes. Is possible LFCM presence |
| All upper premises, including CH (mark +24.00 and above) | fuel dust | ~5 on obstruction surface in CH, ~30 total | Estimate 30 t includes surface contamination inside obstruction in CH and in all other premises |
| 304/3 | LFCM | 6 ± 2 | «Horizontal lava flow». FCM are included in breakdown between prem.304/3 and 305/2. |
| 301/5+301/6+303/3 | LFCM | 4.5 ± 2.5 | «Horizontal lava flow» |
| 217/2 | LFCM | 0.4 ± 0.2 | «Elephant foot», «stalactites». LFCM came from «horizontal flow». |
| Subapparatus 305/2 and 504/2 before mark 24m. | fragments of AC, LFCM, dust | 85 ± 25 | Estimates were made for 6 FCM clusters. Origin of all LFCM flows. |
| SDC (210/5+210/6+210/7) | LFCM | 12 ± 6 | «Big vertical flow» and «small vertical flow» |
| PSP-2 (012/14+012/15+012/16) | LFCM | minimum - 3, maximum - 14 | |
| PSP-1 (012/5+012/6+012/7) | LFCM | 1.9 (+1.0; -0.5) | |
| Fuel under cascade wall | fragments of AC, dust | ? | |
| Water in all premises of reactor department | soluble uranium salts, dredge. | ~4 kg | |
| Fuel at «Shelter» site | Fragments AC, dust | 0.75 ± 0.25 | |

Specific activity of some emitters for base fuel content of power Unit 4 for 01.02.2005 is shown in Table 3

*Table 3 - Specific activity of some emitters for base content of power Unit 4 fuel at 01.02.2005, Bq/g uranium*

| Alpha-emitters | Beta-emitters | Beta-gamma-emitters |
|---|---|---|
| Pu-238 --- $6.7 \cdot 10^6$ | Sr-90 --- $7.60 \cdot 10^8$ | Rh-106 --- $1.29 \cdot 10^4$ |
| Pu-239 --- $5.0 \cdot 10^6$ | Y-90 --- $7.60 \cdot 10^8$ | Sb-125 --- $7.12 \cdot 10^5$ |
| Pu-240 --- $8.19 \cdot 10^6$ | Ru-106 --- $1.29 \cdot 10^4$ | Cs-134 --- $1.61 \cdot 10^6$ |
| Pu-241 --- $9.32 \cdot 10^3$ | Pm-147 --- $2.65 \cdot 10^7$ | Cs-137 --- $9.09 \cdot 10^8$ |
| Pu-242 --- $1.30 \cdot 10^4$ | Pu-241 --- $3.89 \cdot 10^8$ | Ce-144 --- $1.20 \cdot 10^3$ |
| Am-241 --- $1.95 \cdot 10^7$ | | Eu-154 --- $1.64 \cdot 10^7$ |
| Am-243 --- $8.73 \cdot 10^3$ | | Eu-155 --- $4.45 \cdot 10^6$ |
| Cm-244 --- $1,07 \cdot 10^6$ | | |
| In sum ≈ 80 Ki/kg uranium | | |

Thus, total activity of fuel currently located in «Shelter» object makes around 14 MCi.

## 3. WATER LOCATED IN «SHELTER» OBJECT PREMISES

One of the main sources of radiation hazard in the object is the water. Water influences the nuclear safety conditions, thus leading to change of reproducing system «FCM+water». Water interacting with the FCM dissolves and transports radionuclides, which, as a result, can come into the environment.

Water coming to the SO in the shape of atmospheric precipitation, condensate and dust-suppressing solutions, moving from upper marks to the premises at SO bottom marks, washes FCM cluster and contaminated surfaces of structural materials. As a result of that processes, high-level alkali-carbonate solutions are produced, representing, practically, liquid radioactive waste. LRW leakings produce permanent and temporary LRW clusters at Unit bottom marks. It is stated that between many LRW clusters exist hydraulic connections.

**Northern LRW flow**

Northern LRW flow, whose consumption makes 700 – 800 m3/year, passes through the premises 001/3, where the biggest LRW cluster is localized (Fig.8, point 30). In that premises, numerous leakings are collected from central and northern part of units «B» and RDAS, as well as from the cascade wall side. Further, SO LRW flow percolates through partition wall into Unit 3 RDAS premises, and, finally, comes to premises 0005 sump (Fig.8, point 111). As soon as the sump is filled, LRW is pumped out in ChNPP chemical shop for temporary storage and treatment. Practically, northern LRW flow represents naturally «averaged» leakings from central and northern part of Units «B» and RDAS.

**Southern LRW flow**

Southern LRW flow, whose consumption does not exceed 300 $m^3$/year, passes through the

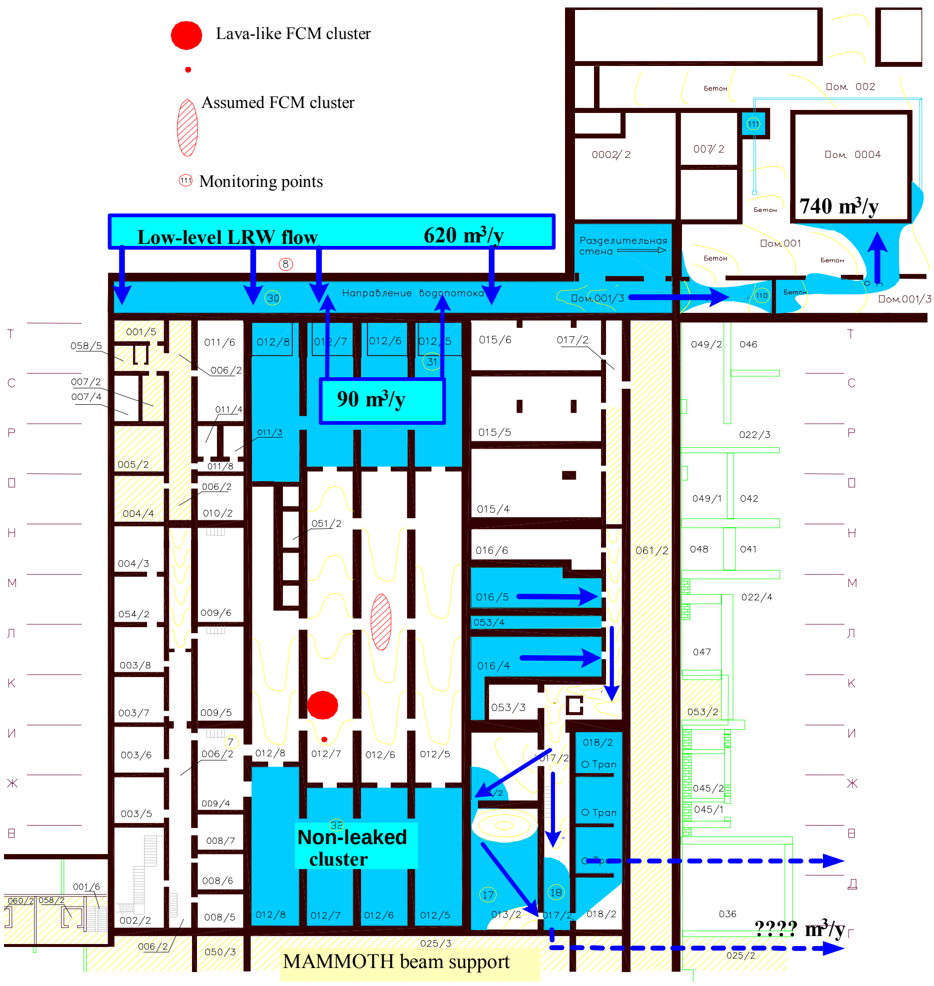


*Figure 8 - SO LRW clusters and flows in pressure suppression pool (mark –0.650) and RDAS unit premises (mark –2.600 and – +6.000)*

premises 017/2 and 061/2 and produces sufficiently large clusters in southern part of that premises (Fig.8, point 18). Water level in this premises is permanent – under intensive inflow, water excess spills over the threshold in premises 018/2, where special sewer system traps are located, or percolates in premises 025/2. In premises 061/2, water level depends on the season – in condensation period, the level increases, in dry period, as a result of evaporation, it reduces. Pathways of LRW leaking from that premises are not defined.

**Radionuclide and chemical content of LRW**

LRW radionuclide content at Unit bottom marks is formed as a result of interaction of atmospheric precipitation, condensation moisture and technogenic solutions with the following nuclear fuel modifications, which were produced during the accident:

- «hot» particles of condensation type;
- dispersed fuel in the shape of $UO_2$ and $U_3O_8$;
- lava-like fuel-containing materials.

Hot particles of aerosol-condensation type define at a significant rate the level of surface contamination of internal premises of «Shelter» object, besides, currently, the biggest contribution into activity is made by $^{137}Cs$ and $^{125}Sb$ isotopes. As a result of these particles dissolution, water contamination occurs with caesium isotopes. The main source of «unit» water contamination with fissile elements and $^{90}Sr$ are oxidated fuel particles ($U_3O_8$). Chemical stability of oxidated particles in relation to water is lower, than that of initial fuel ($UO_2$) and, moreover, of lava-like FCM.

*Table 4 – Average concentrations of radionuclides and uranium in SO LRW main clusters*

| Point numb. | Mark m | Number of premises | Volume $m^3$ | Component concentration, Bq/l | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | **$^{137}$Cs** | **$^{90}$Sr** | **Σ Pu** | **$^{241}$Am** | **ΣU, mg/l** |
| 6 | + 2.20 | 012/16 | 60 $m^3$ | $6.2*10^7$ | $9.9*10^6$ | 4000 | $1.7*10^4$ | 48 |
| - | + 6.00 | 219/2 | 10 $m^3$ | $4.0*10^6$ | $1.0*10^5$ | - | - | 1.1 |
| 17 | - 0.65 | 017/2 | 7 m3 | $5.0*10^6$ | $1.0*10^5$ | - | - | 8.9 |
| 18 | - 0.65 | 013/2 | 20 $m^3$ | $4.0*10^6$ | $0.8*10^5$ | - | - | 1.1 |
| 30 | - 2.60 | 001/3 | 270 $m^3$ | $5.2*10^6$ | $1.0*10^6$ | 360 | $4.0*10^3$ | 3.6 |
| 31 | - 0.65 | 012/5 | 20 $m^3$ | $6.1*10^7$ | $8.9 *10^6$ | 3100 | $1.3*10^4$ | 43 |
| 32 | - 0.65 | 012/7 | 10 $m^3$ | $1.3*10^8$ | $2.2*10^6$ | 4200 | $2.8*10^4$ | 110 |
| 111 | - 6.00 | 0005 | 5 m3 | $6.8*10^6$ | $1.0*10^6$ | 1600 | $2.0*10^3$ | 5.7 |

Atmospheric precipitation, technogenic solutions and condensate during movement from upper marks to bottom ones leach the most soluble concrete components – carbonates, bicarbonates, chlorides and sulphates of alkaline metals. Heavy metals transfer to a solution due to metal structures corrosion. As a result of these processes, formation itself of radionuclide, chemical and phase content of «unit» water occurs. Averaged radionuclide content and activity of main water clusters and flows of «Shelter» object is shown in Table 4. A part of this activity is concentrated in silt sediments, and depending on dryout rate in summer-autumn period, poses a treat as aerosol source.

## 4. FUEL AT «SHELTER» OBJECT INDUSTRIAL SITE

During the accident and works for mitigation of its aftermath, ground layer produced at the site around ChNPP Unit 4, contaminated by released radioactivity. One could succeed to remove it only partially, for site decontamination purposes the active ground was covered with clean materials. As a result, an original «sandwich» produced, in which the materials were located in the following order (from depth - to surface):

***initial ground (pre-accident) – active layer –coating materials.***

It seems as important to study the active layer because of several reasons:

- it may contain considerable fuel amount ;
- displacement of active layer under the influence of natural factors can lead to ground waters contamination;
- conversion of «Shelter» into an ecologically safe system will demand performing works at the Object industrial site, during which the active layer is to be touched upon, that is why one should have maximally full information about it.

As analysis of new data shows, active layer thickness in local zone is predominantly laying within the range of 10 – 30 cm. Total ground volume is estimated (according to value order) at 15000 $m^3$.

Applying the research data and drilling the boreholes, it is offered to take as an expert estimate the fact that the fuel amount in local zone makes (0.75 ± 0.,25) t.

## 5. RADIOACTIVE AEROSOLS OF «SHELTER» OBJECT

Air migration of radionuclides from the «Shelter» object is one of the main sources of environmental contamination under normal operation, and, especially, during the accidents.

Radioactive particles located in the «Shelter» object can be (very roughly) divided into two types – condensation and fuel ones.

The first particles type was produced as a result of condensation of radionuclides having relatively low boiling temperature and coupled from the fuel during accident active stage on particles of dust, soot, graphite, building structures, etc.

The second particles type – fuel particles produced during fuel dispersion and containing isotopes of plutonium, americium, and curium. They can be comfortably divided into two subtypes: «large» fuel particles with size from dozen and hundred micron and «small» fuel particles with average median diameter of 3-4 microns.

Most hazardous in terms of radiation safety are «small» fuel particles.

When performing the works in the «Shelter» object premises, concentration of alpha-active aerosols can reach $10^4$ admissible concentrations.

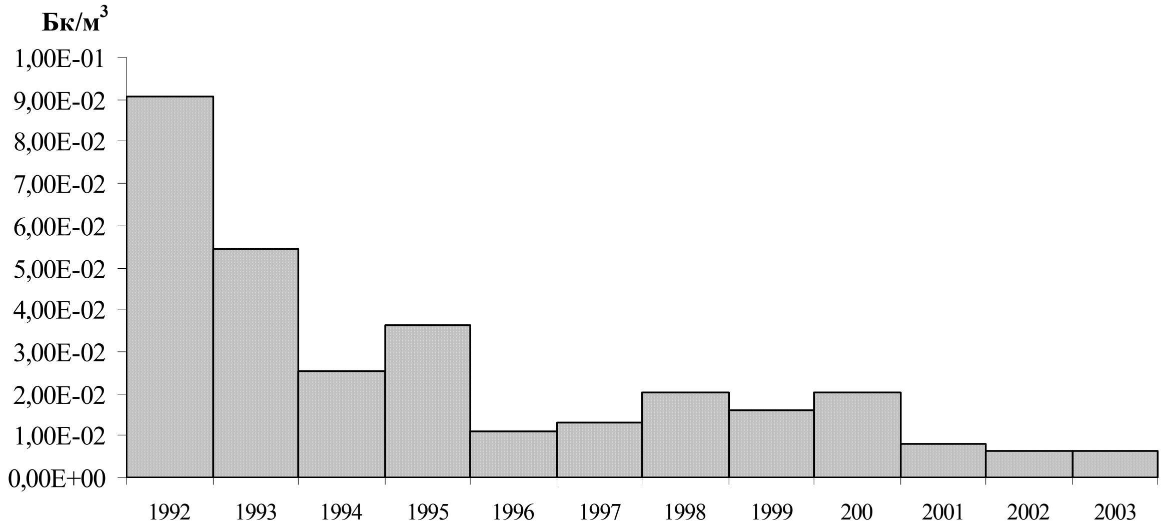


*Figure 9 - Estimates of annual volumetric summary alpha- beta-activity in near-surface air aerosols of «Shelter» object local zone using aspiration facility data*

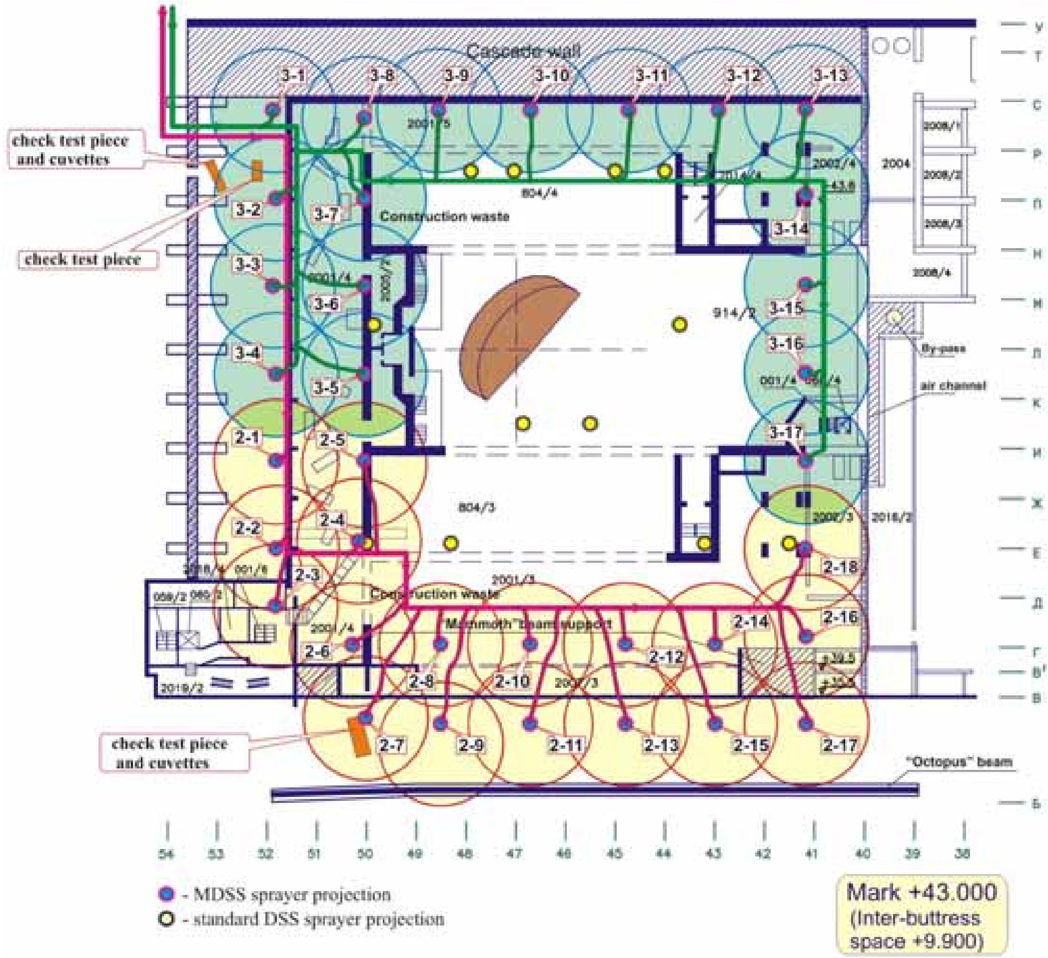


*Figure 10. Scheme of location of collectors and zones covering upgraded DSS.*

In order to reduce aerosols concentrations in the «Shelter» object and their release into atmosphere, stationary dust suppression system (DSS) was commissioned in 1989 end, which includes the system for preparation and supply of dust-suppressing compositions through 14 nozzles located over «Breakdown» surface of central hall. Since December 1989 till now, more 1 000 tons of dust-suppressing compositions were laid, that allowed significantly reducing and stabilizing the aerosols release from the «Shelter» object (Fig.9). To increase regular DSS efficiency, it was upgraded, which included assemblage of two additional collectors and 35 nozzles covering the perimeter of sub-roofing space and the space between Unit 4 western wall and buttress wall (Fig.10).

## 6. SYSTEMS FOR NUCLEAR SAFETY MONITORING

Obtained recently experimental information on distribution, configuration and composition of spent and fresh nuclear fuel for «Shelter» object individual premises does not possess the accuracy, which would be sufficient for substantiated forecast of nuclear safety.

In existing conditions, in terms of nuclear safety provision, the «Shelter» object represents a spatially distributed uncontrollable cluster of nuclear hazardous fissionable materials without emergency protection means.

In current real conditions, the FCM, when moderator is absent, are subcritical ones. However, generation of self-sustained fission chain reaction is not excluded when pouring with water the FCM with great enough fuel heterogeneity.

Currently, to monitor «Shelter» object nuclear safety, readouts of following systems are used:

- information-measuring systems (IMS) «Finish-R», which monitors the FCM conditions (thermo-physical and nuclear-physical parameters);

- FCM monitoring systems (СК FCM) «Signal».Such a configuration was formed relatively not long ago. Complex «Finish-R» is set up as an autonomous system after withdrawal in December 1998 from the structure of research system «Finish». Appropriate operation documentation was designed for it, and metrological certification of measuring channels and hardware was made.

Since 1998, system "Signal" was accepted in pilot-industrial operation. According to its results, the system was adopted as meeting technical documentation and transferred to normal operation mode (technical decision IA ChNPP of 26.03.2000).

## 7. RADIATION PARAMETERS OF «SHELTER» OBJECT

### 7.1 General characterization of radiation state of Object premises

Exposure dose rates (EDR) in internal premises and on «Shelter» roofing are within a very extended range. Thus, a need appears in introducing special classification of industrial, administrative, storage facilities and other premises and territories – to split them into zones due to radiation hazard rate.

Such a classification is realized in the document - "Provision of zoning "Shelter" object premises (2003 year).

In this document, the notion "subzone" is introduced and all the premises are split into three groups, depending on EDR value in them:

«1 subzone» — unattended premises; gamma radiation EDR > 3,3 mR/hour.

«2 subzone» — premises of periodical stay of personnel, gamma radiation EDR 3,3 - 1,6 mR/hour.

«3 subzone» — premises of permanent stay of personnel; gamma radiation EDR < 1,6 mR/hour.

Currently, distribution of «Shelter» premises due to EDR value looks like as follows (see Table 5, compiled on the basis of "Provision of zoning…»).

*Table 5 - Distribution of investigated «Shelter» premises» on EDR level*

| Radiation conditions, R/hour | Units | | | | |
|---|---|---|---|---|---|
| | Unit «Б» | Unit «В» | Unit RDAS | Unit «Г» (А-Б) | Unit «Г» (Б-Г) |
| to 0,5 | 66 | 17 | 59 | 59 | 140 |
| 0,5 – 1 | 13 | | | | 1 |
| 1 - 5 | 70 | | | 6 | 1 |
| 5 - 10 | 7 | | | 1 | |
| 10 – 50 | 14 | | | | |
| 50 – 100 | 7 | | | | |
| 100 – 500 | 4 | | | | |
| > 500 | 7 | | | | |
| Inaccessible premises | 126 | | 4 | 28 | 7 |

The Table shows that in majority of accessible premises of reactor Unit «Б», the mean value of gamma-radiation EDR does not exceed 1 R/hour. So, inside of more 60 of them, the EDR is lower 0,5 R/hour.

Those premises are excepted, in which fuel-containing materials have penetrated. That premises are characterized by availability of heterogeneous, with high gradients, gamma-field EDR defined by FCM spatial location in premises and by uranium content in FCM and its fission product. Thus, EDR values in premises 305/2 - 1800 R/h (mark +12.200, row $И_{+1200}$, axis $46_{+2800}$) and 1 – 3 R/h (near aperture of northern sliding gate).

The premises 304/3 floor is completely filled with LFCM layer, EDR value in premises - 50 - 350 R/h. EDR value on «heap» of 1-st floor of pressure suppression pool (prem. 012/7) makes around 400 R/h, 10 m northward – around 2 R/h. EDR over open laying LFCM of premises 210/6 SDC ($И_{+1500}$, $47_{-400}$) – 300 R/h and 0,2 – 0,5 R/h over concrete surface in northern part of this premises. In central hall within the area of scheme «E» at mark +39.000 the EDR value makes 280 R/h, at mark +49.000 – 30 R/h.

### 7.2 Radiation conditions on «Shelter» roofing

After explosions, roofing over CH, premises of southern and northern drum-separators, practically ceased its existence. On neighboring roofing, numerous active core fragments were released –assembly parts, graphite, metallic structures elements, etc. Later, during the active stage, considerable amount of fuel dust dropped on them.

Immediately after «Shelter» erection, radiation conditions on its roofing was defined, mainly, by gamma-radiation penetrating from internal premises and coming from neighboring structures. It is clear seen considerable EDR reduction, which occurred as a result of natural decay of emitters and large complex of decontamination works carried out on the roofing.

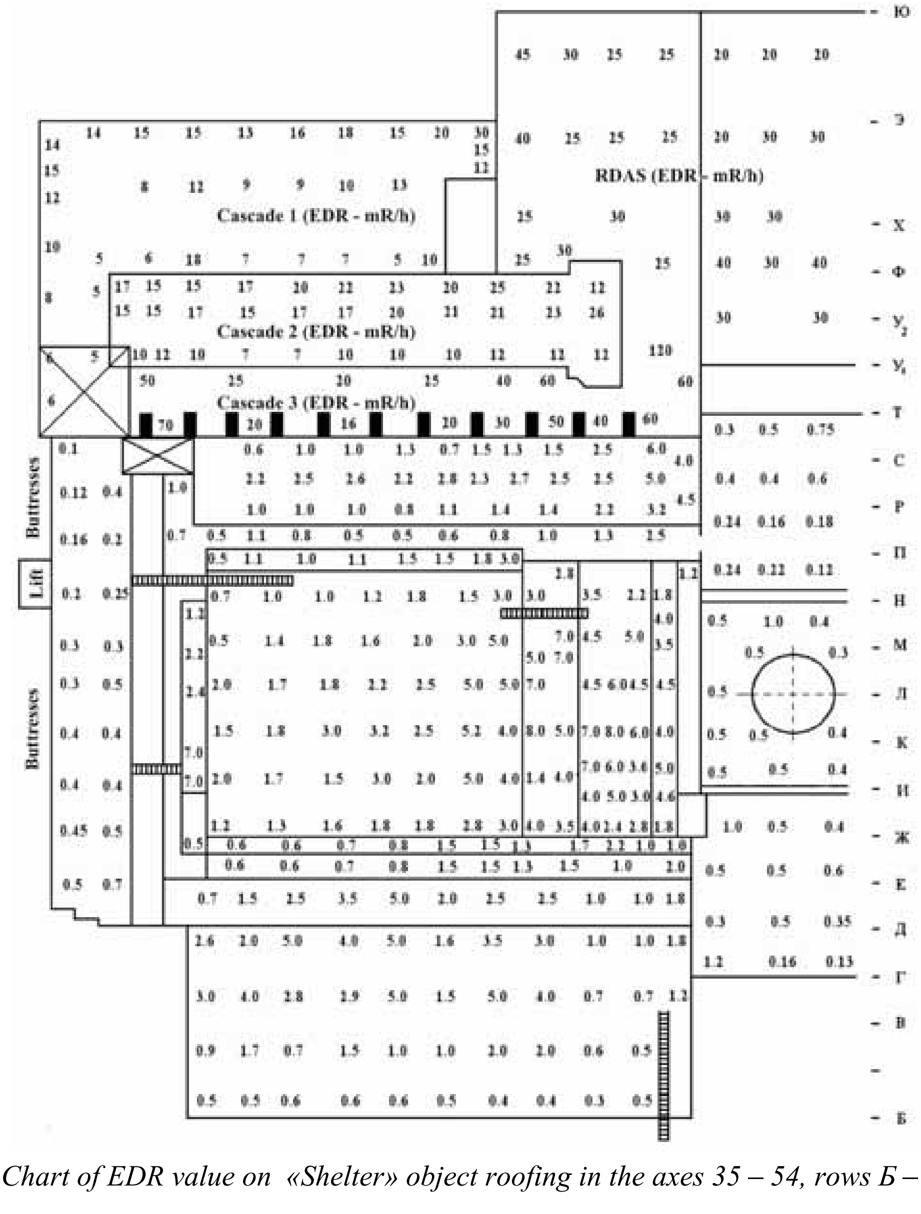


*Figure 11 - Chart of EDR value on «Shelter» object roofing in the axes 35 – 54, rows Б – Ю*

Eventually, in «Shelter» roofing contamination, a great role began playing radioactive dust released from the building through technological openings and coming from neighboring contaminated roofing.

Results of radiation conditions measurement on the roofing, which were made in June 2000, the Fig.11 illustrates.

### 7.3 Contamination rate of premises surfaces and territory

The idea of total contamination rate of surfaces in «Shelter» object premises, BK-3, RDAS, as well as of roads and pavements at industrial site territory is shown in Table 6.

*Table 6 - Contamination rate of premises and territory*

| No | Monitored object | α - contamination rate (readout) $\frac{particles}{cm^2 \times min}$ | | β - contamination rate (readout) $\frac{particles}{cm^2 \times min}$ | |
|---|---|---|---|---|---|
| | | fact | RL | Fact | RL |
| 1 | RDAS unit (premises of personnel permanent stay) | 1 | 1 | 2÷3 | 100 |
| 2 | BQ-3 («clean») | 0 | 0 | 0 | 0 |
| 3 | BQ-3 («dirty») | 0 | 1 | 0 | 100 |
| 4 | premises of periodical personnel stay (4 unit) | 0÷5 | 10 | 10÷150 | 500 |
| 5 | premises of personnel permanent stay (4 unit) | 0÷1 | 5 | 10÷50 | 200 |
| 6 | territory (surfaces of roads and pavements inside industrial site) | 0 | 1 | 20÷100 | 200 |

### 7.4 Radiation conditions at industrial site

EDR at territory close to the SO is defined by two factors: gamma-radiation of «Shelter» itself and emanation of radioactively contaminated grounds and objects located at SO industrial site.

The most contaminated is territory in close vicinity to ChNPP Unit 4, so called local zone of «Shelter» object. Distribution of exposure dose rate in local zone of SO industrial site is shown in Fig.12.

The chart of EDR distribution demonstrates that the contamination of territory has heterogeneous character. Analysis of EDR chart gives a reason to assume the existence of notable contribution of radiation from the SO side from the area of staircase-elevator unit. However, such evident influence is well observed only in a place being close to the SO.

SO influence onto volumetric EDR distribution over industrial site is well illustrated in Fig.13.

Gamma-field intensity increases in eastern direction (when approaching to «Shelter» object) and grows with more height.

Abrupt growth in direction to Unit is observed within the area of row A. One can assume that a cause of above abnormality can be local intensive gamma-radiation sources located on the roof of turbine hall and deaerating stack.

## 8. Carried out and planned SO stabilization measures

«Shelter» object is a unique spatial building, whose structural scheme represents a combination of two constituents:

- «old» structures of destroyed power Unit 4;
- «new» structures erected in the year of 1986 during «Shelter» construction.

Post-accident conditions of power Unit 4 «old» structures are characterized by total or partial destruction, large damages of remained intact elements and junctions, overloading of weight of structures obstructions and equipment collapsed on them, as well as the materials, that were used during accident mitigation period. Bared armature and metal structures are subject to corroding processes. Availability of

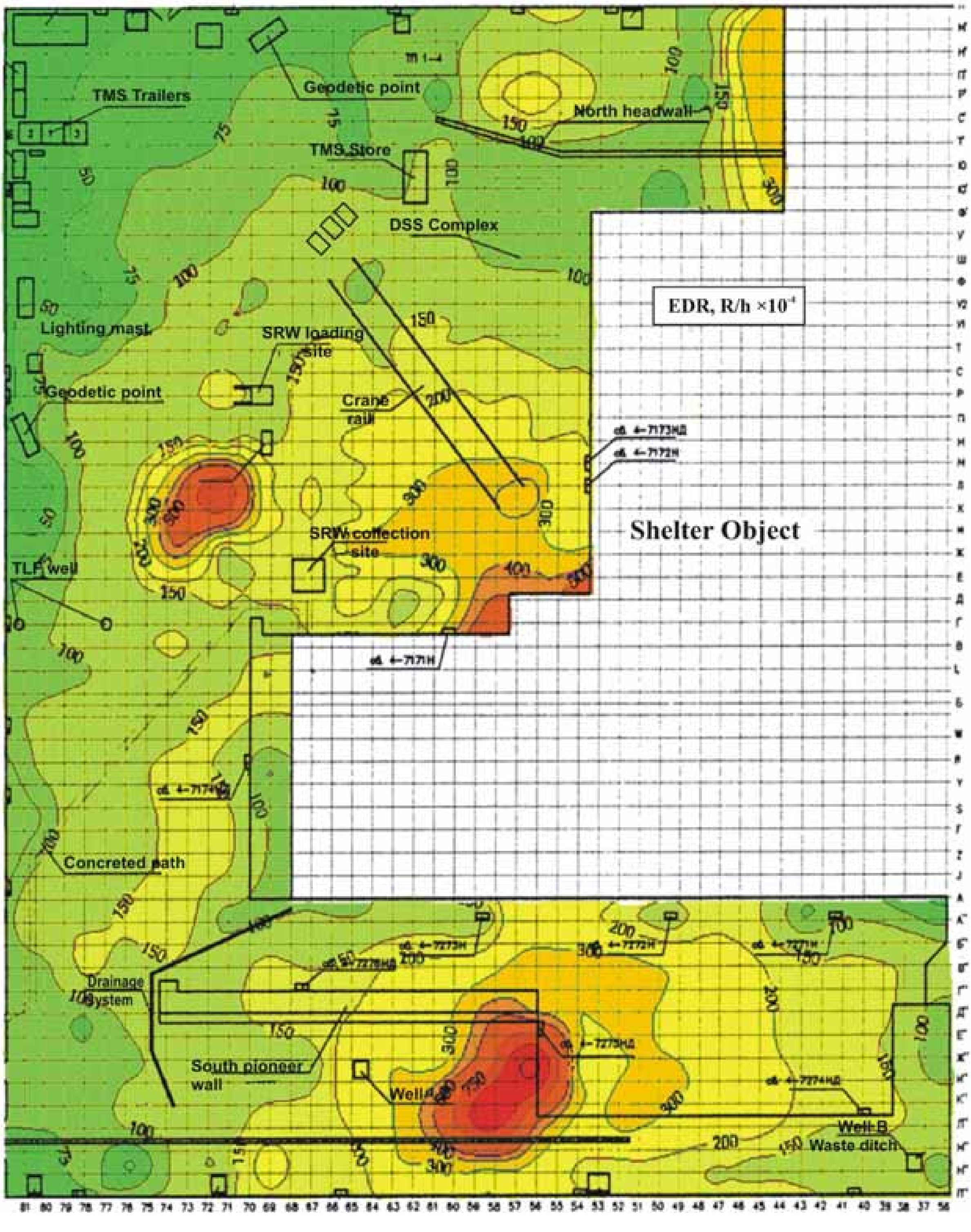


*Figure 12 – Chart of exposure dose rate distribution in local zone as of January 1, 2002.*

such serious defects requires permanent survey over conditions of these structures and taking, in case of need, of stabilization measures.

The «new» structures that were erected after the accident (protective-partition walls and coating's metal structures) were designed in conformity with norms and rules of structural design valid in that time period. However, for this group of structures also the problems exist of their reliability and longevity provision that conditioned by following reasons:

- technologies of remote assemblage and concreting in complicated radiation conditions that were applied, restricted possibility to control the quality of work production ;

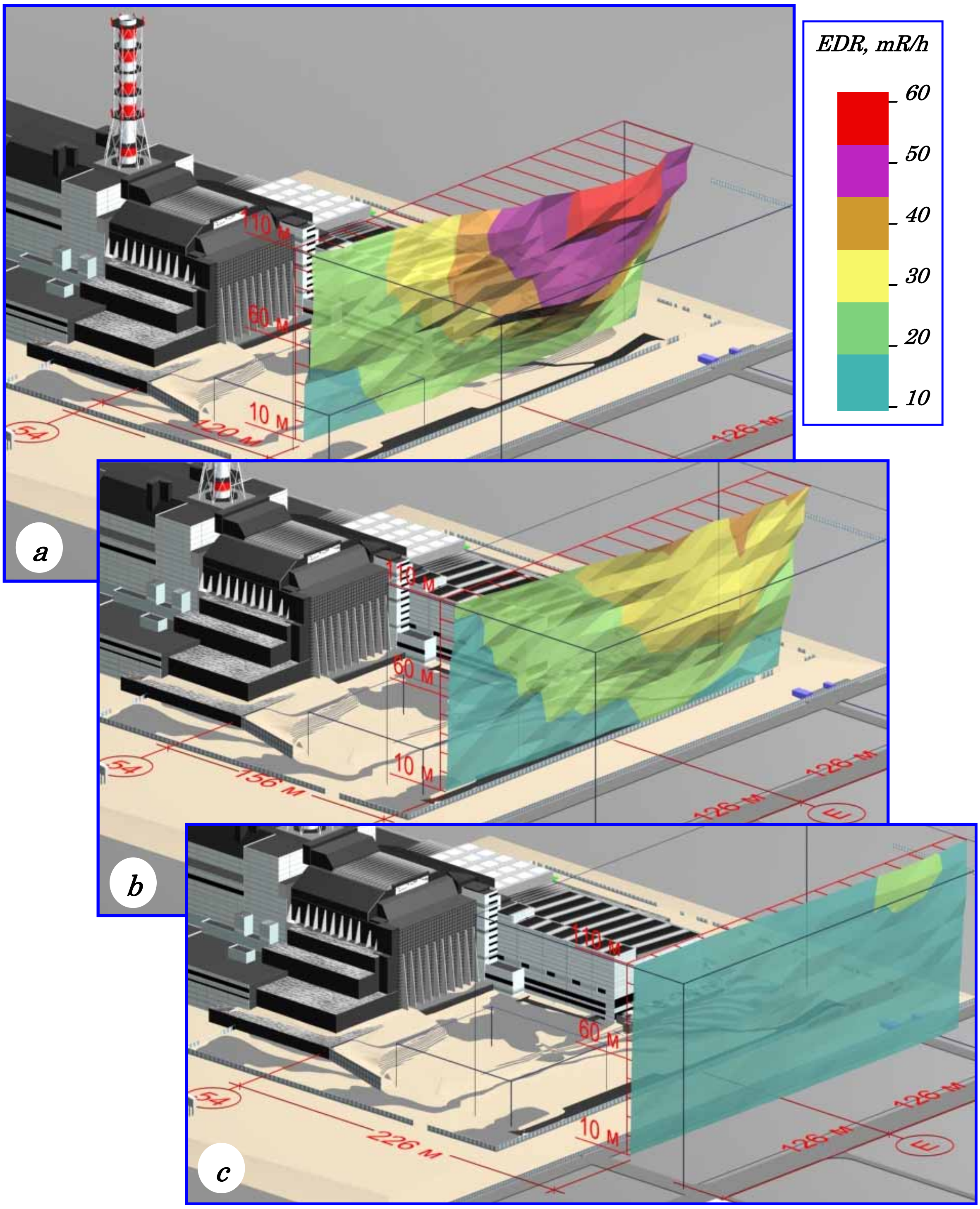


*Figure 13 – Model of gamma-field in NSC erection zone (June 2004)*
***a** – cross-section along axis 54 + 120 m;*
***b** – cross-section along axis 54 + 156 m;*
***c** – cross-section along axis 54 + 226 m*

- structural elements are fragmented – not connected one to another, rest freely upon bearing structures without physical connection and are retained in designed position due to friction forces (i.e. welded-, bolt or other strengthenings of support parts are absent);
- access is embarrassed to elements and metal structures joints for periodical survey and recovery of anticorrodent coating.

The first document, in which a general estimate was given of «Shelter» building structures conditions, was the «Conclusion on reliability and longevity of coating's structures, as well as on radiation safety of reactor department of Chernobyl NPP Unit 4», set forth by Government Commission on October 11 1986 to special commission of USSR Gosstroy.

The «Conclusion …» included as regards:

«Considering low corrosion velocity within the conditions of structures work, under performed protective coatings, one can regard as provided their service life:

- for pipes 30-40 years,
- for beams 30 years».

Unfortunately, in later period these figures, as it were legalized not only for service life of newly erected metal structures, but also for all «Shelter» object as a whole. Often the time of 30 years was indicated in documents, as guaranteed time for safe conditions of «Shelter» object.

At the same time, the mentioned «Conclusion…» had as written:

«In connection with the fact that the shelter of reactor department is being erected on destroyed structures and within the conditions of high radiation levels, it does not seem as possible to obtain reliable data on their bearing capacity, as well as, considering the complexity of structures installation and control of their position..., that leads to essential reduction of bearing capacity of remotely assembled structures...».

So, the main conclusion was that within the conditions, in which the Object was erected, it is impossible to reliably assess its longevity.

That is why immediately after the construction was completed, the works started for research of reliability and additional strengthening (stabilization) of «Shelter» basic bearing structures.

As a whole, three main stages of such works can be distinguished.

During the first stage (1987 – 1991), researches and certification of accessible premises were conducted, and zones of emergency conditions of building structures, which influence the «Shelter» general stability and integrity, were identified.

Three zones were identified that demand conduct of immediate anti-damage works: deaerating stack (premises 635/3), premises for MCP motors (premises 402/3), premises for exhaust ventilation air ducts (premises 805/3).

When surveying the upper tier of deaerating stack framework (rows Б-В axes 41-51) it was stated as regards: columns between the marks +24.27 and +38.60 inclined from vertical to turbine hall side at value 700 - 1100 mm. In places of column junction in mark level around +24.30, fractures produced with around 150-mm wide crack opening, longitudinal effective reinforcement had broken, crack penetration depth into column cross-section depth made 0,6 - 0,9 m. Rigid joint couplings of column and girder were also destructed, that is confirmed by rupture of upper effective reinforcement rods of extended zone and girder shift from supporting cantilevers into mark level +38.60 at 70 - 150 mm. Simultaneously, on the ceiling (above mark +38.60), obstructions of building structures, equipment and materials produced, which were used during the mitigation of accident aftermath, of height being 3...5 m.

Such conditions of upper tier framework structures of deaerating stack were classified as emergency one. Seriousness of situation was conditioned by the fact that the damaged columns along the row Б were overloaded due to leaning against them coating's structures over turbine hall. Destruction of columns would provoke a collapse of this coating, as well as of other metal structures of «Shelter» southern part («Octopus» beam, southern boards-"clubs"). Under a more unfavourable situation development, collapse of «Mammoth» beam supports and a probability of subsequent collapse of metal structures of central hall coating were not excluded.

Based on data collected on conditions of upper tier framework structures of deaerating stack, strengthening of upper zone of ferroconcrete columns of row Б was operatively realized by way of installation of inclined tensions made of two channel bars No 16 welded to dearator tanks filled with the concrete. Simultaneously, knees made of two channel bars No 24 were installed to strengthen the center of girder span in mark level +38.60 (Fig.14).

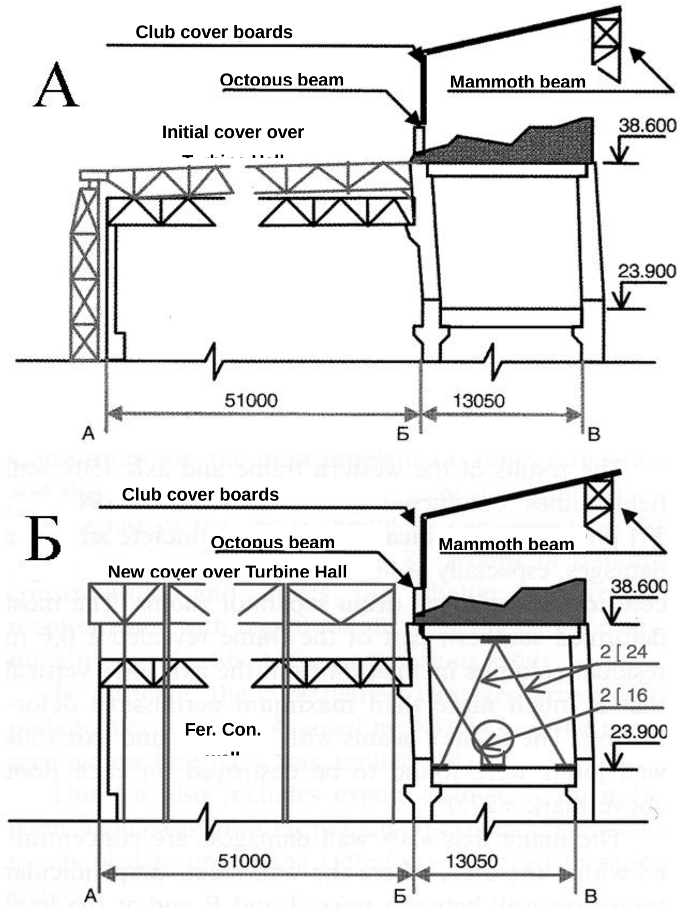


*Figure 14. Structures, which strengthen deaerating stack framework:*
*А - pre-strengthening conditions;*
*Б – post-strengthening conditions.*

Besides, in 1988, trusses of turbine hall coating were dismantled, which were resting upon the cantilevers of row Б columns (design decision of 1986), and instead of them the new coating was assembled with resting upon steel-concrete walls, newly erected in turbine hall between the rows А-Б along axes 41 and 49.

As a result of examination of MCP motors premises (premises 402/3) between the rows Г-Е axes 41-50, it was stated, that wall and columns along the row Г had inclined to row В side of deaerating stack. In the level of supporting cantilevers (mark +30.30), the columns displaced to row В side at 400...600 mm. In coupling joints of girders with the columns, ruptures of upper rods of girder armature and considerable concrete breakoffs were observed.

Column framework and ceiling conditions (mark +31.50) over premises 402⁄3 of southern MCP motors also was recognized as emergency ones.

The strengthening of indicated ceilings concluded in strengthening the supporting sites of girders and was realized by means of installation of the supporting steel structures under girders within the area of their resting upon the column cantilevers (Fig.15). The strengthening structures represented bearing steel trusses, united in spatial units by system of horizontal and vertical connections, and thereafter were remotely slided in designed position along existing crane railways of bridge crane using the winches.

As a result of examinations it was stated that the ceiling (mark +35.50) over premises of exhaust ventilation air ducts (premises 805/3) between the axes 40-50, rows В-Е, is also in emergency condition

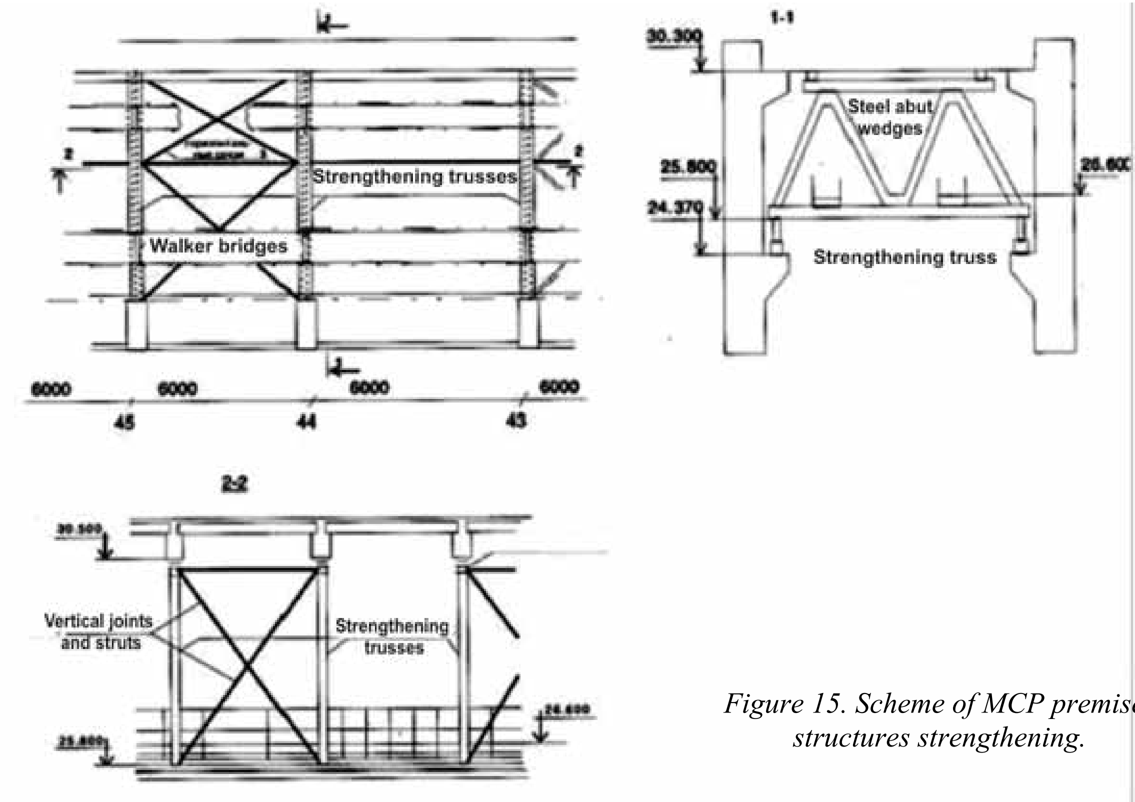


*Figure 15. Scheme of MCP premises structures strengthening.*

and requires the urgent strengthening. Couplings of ferroconcrete girders with the columns along the row Г and ferroconcrete wall near row E are partially destroyed, the girders are displaced from supporting cantilevers.

The ceiling strengthening was performed by way of erection under the bottom girth of ferroconcrete girders of cribworks made of antiseptized wooden half-sleepers (Fig.16).

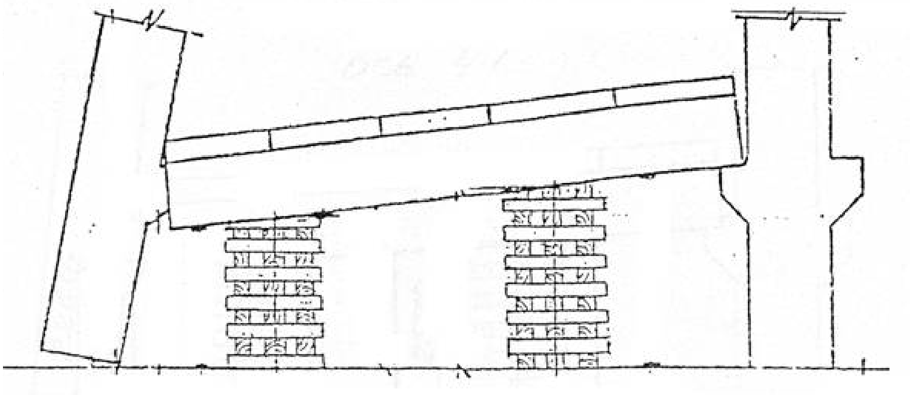

*Figure 16. Scheme of strengthening of structures ceilings over premises 805/3.*

After the earthquake within the ChNPP area on May 30 and 31, 1990, being of 3,5 - 4 number intensity, the «Shelter» was investigated and "Certification of «Shelter» object conditions investigation" written, which reads that no position changes and notable deterioration of main building structures conditions were fixed.

Research peculiarities of the second stage (1992-1997) concluded as regards:

- extension of research volumes (additionally, supporting structures conditions was assessed of western fragment - ferroconcrete wall along the axis 50 with adjoining framework and walls between the axes 49-51′, supporting joint units of Б1 beams and Б2 on the wall along axis 50, protective-partition wall and coating's metal structures, foundation grounds, adjacent structures of units B and RDAS);

- complex approach (combination of field investigations with probabilistic analysis and computational modeling, with creation of physical models).

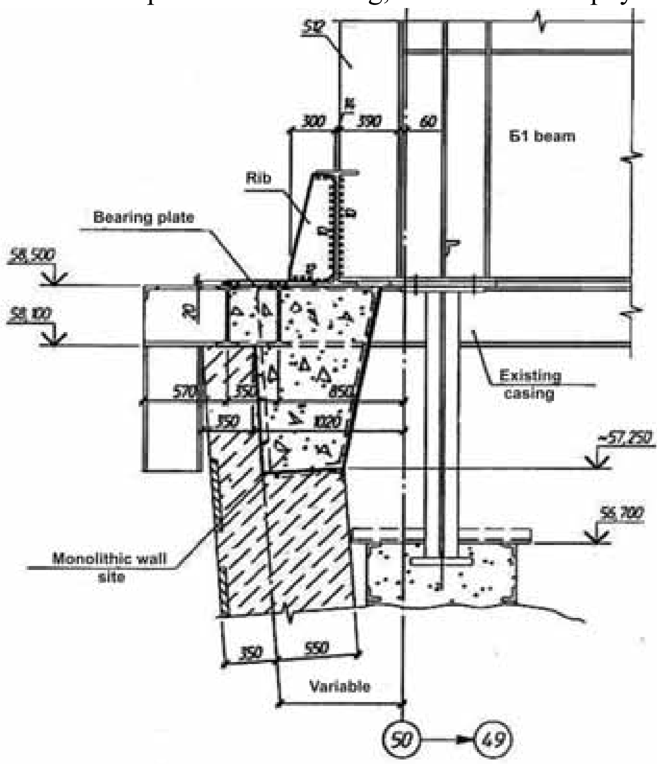


*Figure 17. Strengthening of Б1 beams supporting parts and ferroconcrete wall along axis 50 in place of resting upon it of Б1 beams unit (row Ж)*

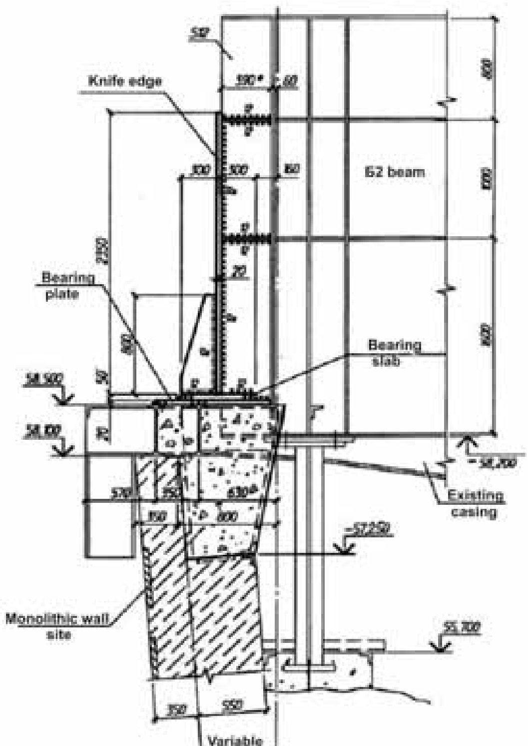


*Figure 18. Strengthening of Б2 beams supporting parts and ferroconcrete wall along axis 50 in place of resting upon it of Б2 beams unit (row Ж)*

Field investigations have revealed a range of major defects of ferroconcrete wall along the axis 50, which influence essentially not only on bearing capacity and stability of above wall, but also the western fragment as a whole, as well as supporting joint units of Б1 beams and Б2 along the row Ж and П. Shift of wall upper part within the area of abutting of Б1 and Б2 beams units (mark +58.50) in relation to wall bottom part (mark +12.50) makes 500-700 m near row П and around 1000 m near row Ж. Indicated position of bearing wall was considered in erecting the «Shelter», on the site of abutting Б1 and Б2 beams unit along axis 50 row Ж, a need arose in installing a concrete support in non-removable bearing metallic casing. Because of a range of reasons, design decisions for installation of such a support (and simultaneous local wall strengthening) were not fully realized.

Using the results of field investigations, which were made in 1993, actual parameters of indicated metallic casing were defined, conditions of its resting upon structures obstructions and on the wall along the axis 50, as well as the rate of its filling with concrete. The conditions of Б1 and Б2 beams supports unit along the axis 50 row Ж were recognized as unsatisfactory.

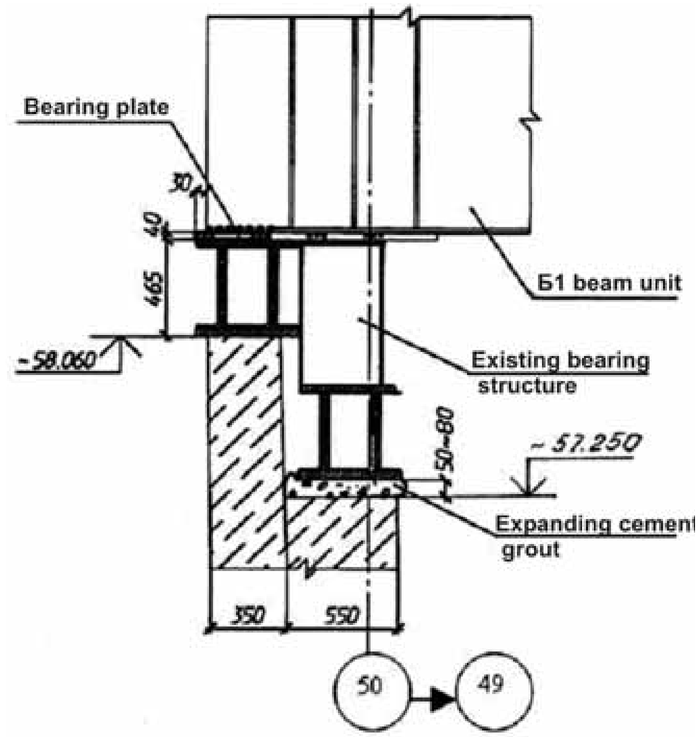


*Figure 19. Strengthening of Б1 beams supporting parts and metallic support under Б1 beams in place of Б1 beams unit abutting on ferroconcrete wall along axis 50 (row П)*

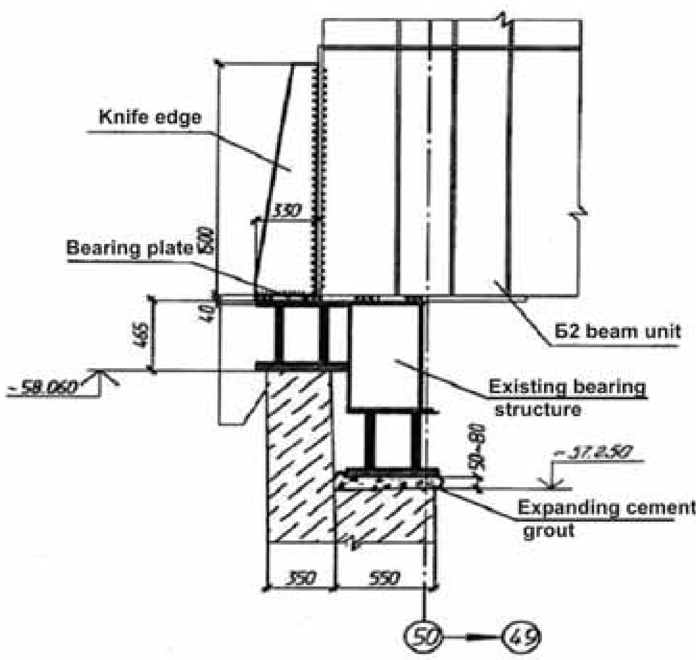


*Figure 20. Strengthening of supporting parts Б2 beams and metallic supports under Б2 beams in place of Б2 beams unit abutting on ferroconcrete wall along axis 50 (row П)*

In 1994, strengthening of support by way of erection under bottom girths of Б1 and Б2 beams unit of metallic posts abutted on concrete surface inside the casing. However, metallic posts installed in 1994 in conformity with indicated design did not strengthen the support, and were seen as made for the safety, since were installed on concrete body, which together with metallic casing rests upon the preserved ceiling fragment at mark +49.95 through the obstruction of building structures.

At the next third stage (since 1998 till now), researches and works for strengthening «Shelter» main bearing building structures acquired system and large-scale character, and they are performed within the framework of international cooperation.

The works started from the strengthening of ventilation pipe (VP-2) structures. Organizations of Ukraine, USA and Canada were involved in them. Strengthening started late in 1997 and was successfully completed in 1998 summer.

Further works for investigation and stabilization of «Shelter» object structures were continued in conformity with Shelter Implementation Plan (SIP) at the «Shelter» object with direct participation of International Consortium ICC (MK) JV (MORRISON KNUDSEN (USA) – leader, BNFL (UK), Ukrainian organizations NIISK, KIEP and ISTC «Shelter») – Package A tender "Civil engineering" winners.

As an urgent measure of SO building structures stabilization, consortium ICC (MK) JV prepared the draft design of strengthening Б1 and Б2 beams supporting joint units along axis 50, which foreseen the strengthening of both supporting sites of metallic beams and of the sites of wall, on which they lean against (Fig.17-20). The project was realized by Ukrainian building organization «Ukrenergobud» in the year of 1999.

According to results of additional field investigations and refined estimates, consortium ICC (MK) JV substantiated the list comprising 15 stabilization measures, whose realization allows providing structures stability during the time exceeding 15 years, i.e., more, than it is needed for construction and commission of new safe confinement (NSC).

Later this list was reduced to 8 stabilization measures, that is fixed in program decision P2 «Decision for stabilization strategy of roofing, support and structures» of December 24, 2000. This decision is based on changed design criteria in the part of changing designed tornado loading for extreme wind loadings.

During 2002-2003, the consortium KSK comprising Ukrainian organizations KIEP, NIISK and ISTC «Shelter» developed and accorded with regulatory bodies the draft design of stabilization measures. Recently, the works started for its realization.

Developed measures were grouped for the following SO zones.

## WESTERN ZONE

Stabilization of "Shelter" object western zone covers the strengthening of western fragment, which includes:

- western buttress wall;
- framework and unit Б walls along the axis 50, 51′ between the rows Д – С;
- Б1, Б2 beams support units along axis 50 rows Ж and П;
- coating between the buttress wall and the wall along axis 50 between the rows Д-С.

Strengthening idea covers the erection of two metallic spatial rod towers with plan sizes being 12×15 m, total height 48 m, with 23-m spatial cantilever span in east direction (Fig.21) to buttress wall west. Indicated towers are installed at mark+14.00 between the rows Е-И and Н-Р in the axes 53-57 on ferroconcrete foundations and connected one to another by spatial systems (trusses) in north- south direction in two levels. The first level corresponds to marks from +26.00 to +32.00; second level – to marks from +44.00 to +50.00. From the eastern side, to spatial truss of second level the brackets are fastened with the step 6 meters that are located in vertical plane, on whose end an abutment of h-beam cross-section is envisaged, adjoining to framework and wall structures along axis 51′. Abutments and brackets are destined for taking horizontal forces in «east-west» direction from the framework and wall

*Figure 21. Stabilization measures 2 «Strengthening of western fragment». Scheme of strengthening's metal structures.*

along the axis 51′ and therewith prevent the wall displacement in western direction. Towers cantilevers are located in Б1 and Б2 beams units range along the rows Ж and П. At the mark +60.00, on cantilevers ends the welded beams are envisaged, on which by means of special joints at mark +60.55 reconstructed butt-ends of Б1, Б2 beams supporting parts units are abutted. At the mark +56.65, on cantilevers, abutments are envisaged in the wall along the axis 50, which are destined for taking probable horizontal forces from seismic impact in «east-west» direction, thus, strengthening the bearing ferroconcrete wall along the axis 50. Besides, on towers cantilevers the spatial truss is abutted of western fragment coating (spatial system of 3-rd level), to which the upper ends of coating knees (mark +58.525) are fastened.

Ferroconcrete foundations under towers are performed in local zone to buttress wall west between the axes 53-59 and rows Д-К и М-С. Concreting of foundations is tentatively assumed from the mark +0.20 to mark +14.00 – foundations top. Between the axes 54-56, foundations are abutted on foundation plate and bearing unit of buttress wall.

Thus, the works for western fragment stabilization will be performed in local zone, in closed space, between the buttress wall and wall along axis 51′, in upper part of ferroconcrete wall along the axis 50 at the levels from mark +56.40 to mark +58.50 along the row Ж, and at the levels from mark +57.40 to mark +58.50 along the row П, under «Shelter» object coating, as well as on western fragment coating.

**SOUTHERN ZONE**

Stabilization of deaerating stack framework must be realized by way of strengthening the framework structures of deaerating stack upper tier along the axes 42-50 and rows Б, В. The works will be performed in non-developed premises Г635/3, whose floor level corresponds to mark +24.27.

Strengthening envisages the installation at mark +37.50 (under ceiling girder with mark +38.60) additional horizontal struts fastened to internal blind walls along the rows Б and В and to upper support unit, installed earlier under the girder, as well as the installation at marks +28.40 and +32.90 two more struts (connecting elements), between the inclined knees of additional support.

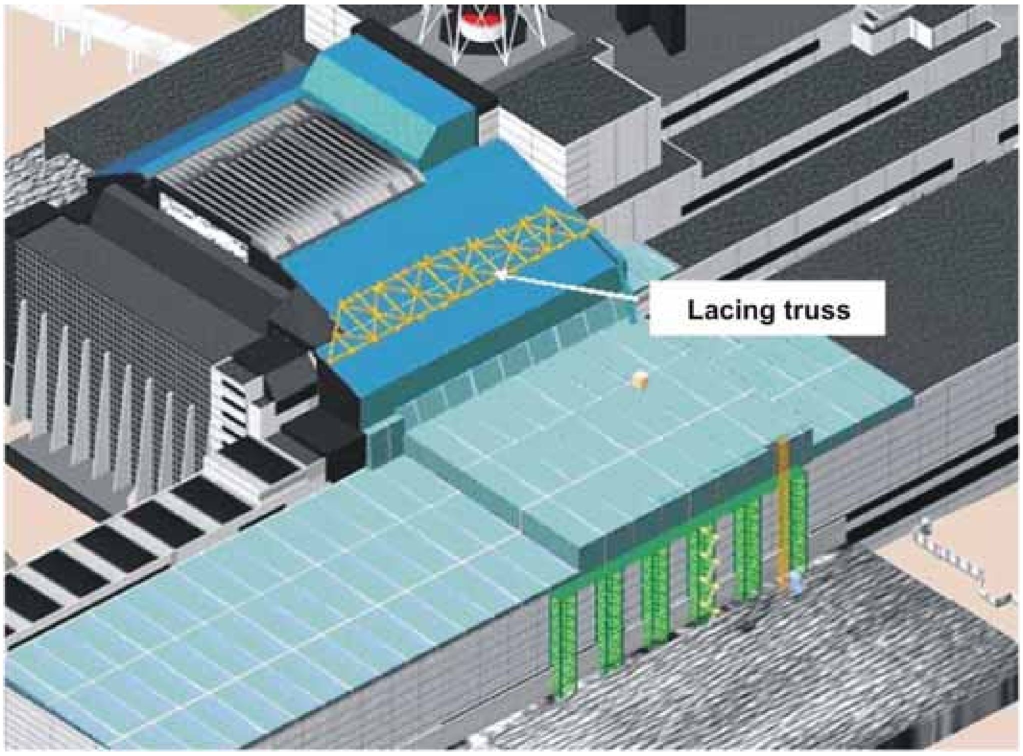


*Figure 22. Scheme of location of connection truss on «Shelter» object coating that unites southern «boards-clubs» and southern roofing boards in a rigid disk*

Strengthening provides the taking of estimated seismic loadings in "north – south" direction. Connection of «southern boards-clubs» with «southern boards».

Installation of connection elements between 'southern boards – clubs" and "southern boards" is made on outward surface coating, on its southern slope, at the site between the axes 41 and 50 along the row B, i.e. over the place of their resting upon the "Mammoth" beam (Fig.22).

Connection will provide withstanding the extreme wind and seismic loadings.

Stabilization of western support of "Mammoth" beam.

All braces of support's vertical connections are strengthened by way of welding to each brace L-beam of additional L-beam forming "small box" with the existing one.

The strengthening provides the taking of extreme, including seismic loading, in "east – west" direction.

**NORTHERN ZONE**

Two measures are planned to simultaneously perform here:

- strengthening of northern buttress walls along axis C and its coupling unit with northern clubs;
- uniting of northern boards-clubs with northern buttress wall using anchor-clamps.

Unification of northern boards-clubs with northern buttress wall will be made by way of installation and strengthening of anchors-clamps on supporting cross-arms of boards-clubs. Anchor parts being sealed are placed in partially concreted wall space and made monolithic when filling with the concrete the space of wall upper part, which was not fully concreted during the erection.

The concreting of upper part of northern buttress wall till designed mark provides its bearing capacity.

Installation of anchors-clamps provides the bearing capacity of northern clubs for horizontal loadings, including extreme ones.

## EASTERN ZONE

Local stabilization of ventilation shaft walls, which support the Б1 beams.

Stabilization is reached by way welding from bottom part to Б1 beam support plate the two abutments made of L-beams that closely adjoin from the both side to wall lateral surfaces, on which the beam is leaned against. Strengthening provides the durability of Б1 beams abutting zone by way of involvement in work for horizontal loadings of all ventilation vault wall thickness.

The strengthening of "Mammoth" beam eastern support, under which the cavities existing in foundation support from northern and eastern side, must be filled with the concrete. Concreting is assumed to perform in a fixed metallic casing-iron-ring.

The fulfillment of planned scope of building and assembly work (BAW) for building structures stabilization within «Shelter» object conditions is a sufficiently complicated engineering task. First of all, it is related to the problem of safety provision for personnel involved in these works, and maintenance of appropriate and sufficient level of radiation and ecological safety of the Object. To decide that tasks within the framework of stabilization project, a range of documents was developed that substantiate the safety during realization of stabilization measures. The main documents include as regards:

- Report on radiation safety;
- Report on environmental impact assessment;
- RAW management program.

**Radiation safety**

Development of design decisions and measures providing radiation protection within the "Shelter" object conditions started from analyzing radiation conditions in assumed workplaces and ways of personnel movement.

After completion of conceptual developments for stabilization, complex pre-project researches were conducted. They also included investigation of radiation conditions.

When developing structural and technological decisions, traditional methods and technologies were applied, which are realized in organizing radiation protection at the «Shelter» object. First of all, they include as follows: protection with time and distance, shielding, use of remote technologies, etc. Taken decisions allowed performing the main assembly works using remotely controlled load-lifting crane, and the sites for acceptance of articles and metal structures, prefabricated assembly were removed at maximally possible distance from the «Shelter» object. Besides, the sites will be shielded from the SO by a protective wall, which will provide the personnel protection during assembly works. An important stage for reducing collective effective dose was the choice of optimal access ways for personnel and load delivery. This circumstance has especially essential character during the work in zones with enhanced EDR values, when changeability of a group or brigade in a shift is made several times.

All complex of measures for provision of personnel radiation protection, during SO stabilization work, is divided into following measures groups:

- organizing;
- radiation-hygienic;
- technical.

**Within the "Shelter" object conditions, the measures of first two groups are compulsory. Their application is regulated by "Shelter" object documentation, and their realization provides the observance of non-exceeding principle.**

The organizing measures include:

- contractor's personnel training;
- organization of work production;
- control and supervision.

Special contractor's personnel training is realized in personnel training centre (PTC) in the town of Slavutich (theoretical training) and at the SO industrial site (practical training). To upgrade the personnel skills for individual technological operations, training ground is created with mock-ups of future workplaces.

Choice of breadboarding units and conditions defining the need in preliminary trainings was made according to the following main indices:

- constrained conditions в planned places for work conduct;
- considerable EDR value at workplace;
- complexity of constructive decision realization;
- opportunity to apply known experience.

When the personnel is trained at mock-ups, the following items are perfected:

- estimate of acceptability of adopted equipment application;
- skills during fulfillment of operations;
- technological process of assembly of strengthening's metal structures;
- time-keeping of all operations;
- recommendations to reduce dose expenses.

**To improve the work conduct safety, as well as to check the observance by contractor for erection of design decisions, including the measures for radiation protection, permanent supervision will be provided over the fulfillment of building and assembly works. Especially, one should monitor the accumulation of collective effective dose (CED) during work production. The above will allow comparing the real collective dose to designed values, and, in case of need, to make in proper time the corrective actions.**

Radiation-hygienic measures include as follows:

- sanitary-hygienic zoning of work conduct place and sanitary-hygienic classification of works;
- provision of personnel with main and additional individual protection gears (IPG), as well as check of their correct application;
- provision of personnel with appropriate equipment and means of personal and collective hygiene;
- medical services and rehabilitation;
- organization of dosimetric control.

To minimize the prevention radioactive substances transport beyond WPZ boundary, except general requirements to zoning, additional zoning of workplace is envisaged, that is concluded as regards: within the limits of a subzone the sites are defined with different essentially differing levels of radioactive contamination. At the boundary of these sites, transport sanitary locks are located, which provide minimal spread of radioactive substances along «Shelter» object territory. Organization of permanent radiation control in these places was defined in conformity with the ALARA principle.

Choice of individual protection gears (IPG) is made in conformity with requirements of regulatory and operation documentation. Volume and nomenclature of additional IPG application was defined in dependence of activity type:

The factors defining the choice of IPGRO types, include:

- character and quantitative content of radioactive and other harmful substances in air (aerosols disperse content and toxicity, availability of steam phase, harmful substance concentration);
- microclimatic conditions at workplace (temperature, relative air humidity, thermal radiation);
- in-air oxygen content at work conduct site;
- heaviness of work being performed;
- protective and operation properties of individual IPGRO samples.

Additional factors, defining the choice of IPGRO types in specific work conditions for structures stabilization, are as regards:

- work conduct time;
- density of surface contamination with radionuclides;
- EDR value;
- work conduct conditions (works in closed space, constrained conditions).

For substantiated choice of IPGRO types, measurement of labour conditions indices is needed, which includes the both radiation condition indices, and microclimate indices in the WPZ. Special attention will be drawn to measurement of radioactive substance concentrations directly in the breathing zone of workers, since when performing some technological operations that concentrations can, dozens, hundred and, even, thousand fold, exceed their average-shift or average-day values defined with application of stationary samplers.

To protect the personnel from beta-radiation, use of protective eyeglasses, shields and dashboards is planned.

For personnel entry to contamination control area (CCA), sanitary checkpoint for 1430 persons will be used. Personnel passage directly to work performance zones will be made through the stationary sanitary locks in deaerating stack. During work production time, additional temporary sanitary locks are assumed to install in the local zone.

Dosimetric control is an integral part of all radiation safety system during realization of stabilization work. As far as the monitoring of external exposure is concerned, the means existing at «Shelter» object are sufficient and adequate to requirements during realization of stabilization measures. Commission of state-of-the-art system of individual dosimetric control (IDC) will improve the situation, since it also meets the requirements for monitoring of external beta-exposure and neutron (emergency) exposure. The operative control of internal exposure can be improved with installation high-sensitive SHE, which will be placed in premises of new sanitary check point, and daily double (before and after shift) monitoring of personnel exposure, which works in the most contaminated work zones, as well as biophysical personnel monitoring.

Shielding is the most effective method of protection of personnel staying in work production zones. Shielding of work production zones and access ways to them will be set up as permanent or temporary.

Permanent shielding represents the boards-shields manufactured of protective materials and placed in special metallic framework. The boards can be installed on existing structures or on new metal strengthening structures (MSS). They are installed during the preparative work and, without absolute need, are not subject to subsequent dismantling.

Under temporary shielding, specially created sliding protective buildings of box type (PB), shielded attached and sliding sites, is implied. Their manufacture is assumed to make at a plant located outside the exclusion zone. Depending on box location places, they are destined for personnel stay during forced technological breakdowns, control and survey over work process, putting on and off additional IPG, etc.

Except temporary and permanent shielding of work production zone, local shielding of radiation sources can be used – first of all, radwaste clusters close to workplaces. This shielding method can be applied in case of detection (e.g., during obstructions clearing) of intensive radiation sources, and their removal from work zones is embarrassed by different circumstances (e.g., source is located under a concrete layer).

In conformity with ALARA principle, the decisions being developed for shielding were optimized. That process included the reduction of collective effective dose (CED) for personnel, as well as optimization of shielding facility installation thickness and choice of their installation place.

Most important factor for shielding optimization is the data on gamma-radiation angular distributions at workplaces. Optimization was made in the following sequence:

- analysis of results of angular distributions measurements of gamma - radiation intensiveness close to workplace;
- definition of direction to main sources forming EDR in measurement places;
- gamma-radiation sources are identified for measurement places;
- forecast of probable location of sources defining EDR at workplace with considering the distance to sources, possibility to shield workplace from the source by «Shelter» object structures;
- estimate of relative contribution into EDR from identified sources;
- estimate of contribution into EDR of radiation from six main directions, which can be shielded.

When shielding the access ways, as the main parameter defining expediency of shielding, intensity factor of using defined route sites is accepted. Considering large labor expenses for displacement and installation of shields, in the routes inside the «Shelter» object, where is impossible to hoist the shields with load-lifting mechanisms, a conclusion was made on inexpediency of manual shielding of access ways.

When choosing a material for shielding, analysis was made of main characteristics of different materials applicable for gamma – radiation attenuation: lead, steel, concrete, tungsten and depleted uranium.

The analysis has shown, that for work inside the «Shelter» object, the lead is the most preferable material. Use of expensive materials with big atomic number gives no principal advantages, but only increases the design costs.

A quantitative characteristic of efficiency of shielding measures application is preventable CED. According to estimate data, the preventable collective dose of personnel, due to shielding, made **more 35 Sv.**

During stabilization works, a need will arise of involvement of large amount of people (to 150 men per a shift) and machinery. On top of that, simultaneously will be performed large scopes of work in different places, both inside the object, and on industrial site territory. Such a work organization requires an effective management of personnel and of industrial processes. The use of video survey will allow reducing the exposure dose for «Shelter» object personnel and for contractor organizations due to control of observance of installed routes, allowed work time, as well as preliminary familiarization of contractor personnel with the place and character of work conduct. Using video survey system, permanent presence of work leader in place of their conduct is not required in conditions of unfavorable radiation situation.

Estimate of expediency of dust suppression works was based on comparative analysis of positive and negative factors of measure realization.

As positive factors, the following items are considered:

- prevention of dust production during the works and movement of personnel, reduction of probability of additional internal exposure;
- exclusion of probability to transport the dust arisen during personnel movement behind the boundaries of working site and its precipitation on the personnel, which is not linked with the conduct of stabilization measures;
- minimization of environmental influence.

To negative factors additional material expenses, labor- and dose expenses for dust suppression realization can be referred.

When arranging the WPZ and access ways, decontamination is inexpedient, if it will provide reduction of external exposure dose. For instance, the removal of detected sources of intensive gamma-radiation can essentially improve the work production conditions. Such sources can be detected when clearing the WPZ territory, removal of concrete inflows, etc. In considering the expediency of decontamination of WPZ surfaces, e.g. cutting-off of apertures along buttress wall height, decontamination is recognized as inexpedient one. Exclusion makes the decontamination of internal and external surfaces of protecting boxes.

Welding and fire works during realization of stabilization measures are performed outside the structures fencing «Shelter» object or in premises having considerable sizes (e.g., breakdowns of premises 2001/4, 2007/3 et al.). Radioactive aerosols being produced are to be removed. That is why an actual becomes organization of safe removal of discharged air, since this flow can lead to radioactive aerosols resuspension, which will entail considerable increase of radioactive substance concentrations not only in the WPZ, but also in adjoining premises and territory. The above, first of all, is related to the works in internal premises, where the place of probable air release can be distant from WPZ more than at 50 m.

Use of local fan is taken as inexpedient only in individual places.

**Assessment of environmental impact**

The "Shelter" object being an ecologically hazardous facility represents an enhanced treat associated, in first turn, with the penetration of radioactive substance into environment. Despite the fact that currently the radioactive releases from the SO are lower than established reference levels, hazard exists of their considerable intensification as a result of realization of measures for SO structures stabilization. When drafting the project, impacts were assessed to aerial, water mediums, as well as on topsoil, social and technogenic media.

Based on building decisions, release values were estimated in conducting different stabilization works. Results of estimates of radioactive substance releases for each measurement are shown in Fig. 23.

**Impacts onto aerial environment.**

Because of the fact that radioactive release sources are located at different height over earth level, that essentially influences the spread and transport of radioactive substances in aerial environment, release sources grouping was made on this attribute and summary release was calculated. It allowed obtaining maximally probable volumetric contamination at any distance from the SO.

Thus, release sources from earth level are forming a release being of $8{,}12 \cdot 10^6$ Bq, from sources located at SO roofing level, the release will make around $1{,}88 \cdot 10^9$ Bq, and release from ventilation pipe (VP-2) will make around $3{,}2 \cdot 10^8$ Bq.

In Table 7, maximally probable volumetric air contaminations at 10-km and 30-km distance are shown, $ДК_А$ and $ДК_в$, as well as comparisons of concentrations with admissible.

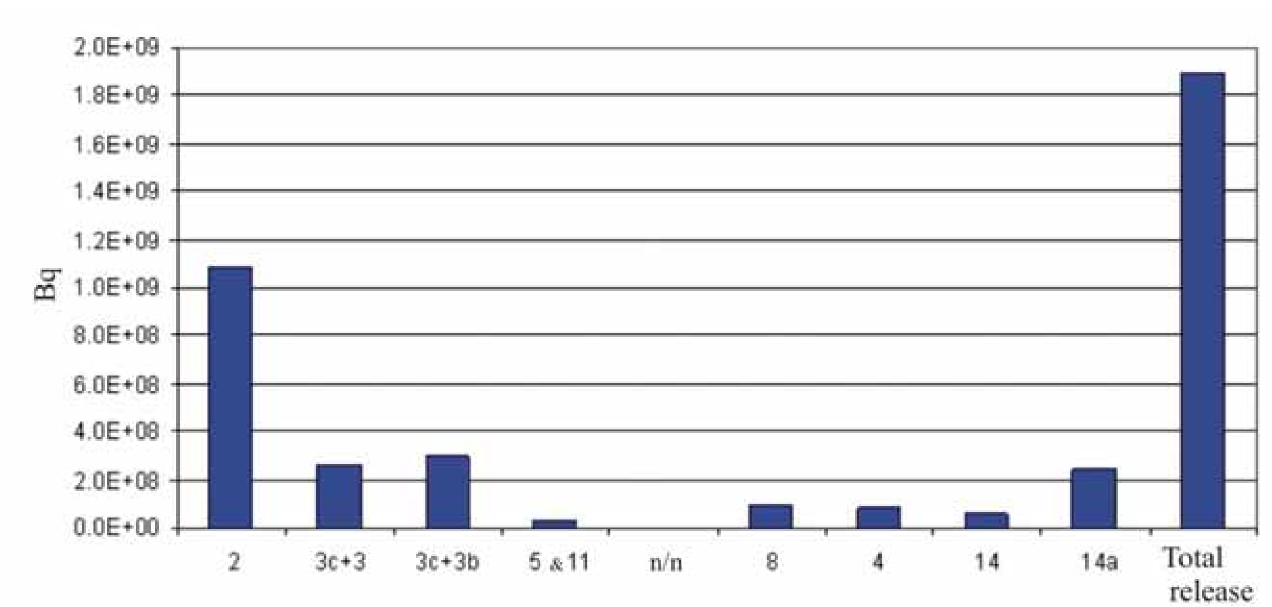


*Fig. 23. Releases during realization of different measures*

*Table 7*

| Nuclides | Admissible concentrations, Bq/m3 | | Concentrations under normal operation, Bq/m3 | | Relation to ДКа | Relation to ДКв |
|---|---|---|---|---|---|---|
| | ДКа | ДКв | 10 km | 30 km | 10 km | 30 km |
| $^{137}Cs$ | 60 | 0.8 | 0.009 | 0.003 | 0.0002 | 0.004 |
| $^{90}Sr$ | 10 | 0.2 | 0.008 | 0.002 | 0.0008 | 0.01 |
| Alpha-emitting transuranic isotopes | 0.03 | 0.0004 | 0.00055 | 0.00016 | 0.018 | 0.40 |

As Table 7 demonstrates, in normal conditions of work realization, impacts to aerial environment will be considerably less than admissible levels.

**Impact to soil**.

The main way of radioactive substance coming onto topsoil is natural precipitation on soil surface of radionuclides from radioactive release in the air, which are produced during the SO stabilization.

Estimates have shown, that the operation, which exerts the most impact to soil medium at small distances from the SO - territory planning in local zone, and at a more distance from the SO - average release during realization of all stabilization measures.

Table 8 shows maximally probable surface contaminations at 10-km distance, as well as their comparison with the RL.

*Table 8*

| Nuclides | Reference levels, Bq/m$^2$ | Surface contaminations under normal conditions at distance 10 km, Bq/m$^2$ | Relation to RL |
|---|---|---|---|
| $^{137}Cs$ | | 3.1 | |
| $^{90}Sr$ | | 2.8 | |
| Beta sum | 33300 | 6.0 | 0.0002 |
| Alpha-emitting transuranic elements | 333 | 0.2 | 0.0006 |

The data demonstrated in Table 8 give the reason to conclude that under normal conditions of work conduct for stabilization, the impacts to soil will not exceed the RL.

**Impact to water medium.**

Due to small values of radioactive releases to air under normal conditions of work conduct, even total penetration of this activity into water medium will not notably reflect at value of its contamination (activity release from exclusion zone by river Prypyat makes around $5 \cdot 10^{12}$ Bq/year).

Impact ways to water medium under an accident - radionuclides precipitation from air release, as well as, washout from soil surface.

A conclusion is made, that under normal conditions of work conduct, and under an accident, no supernormative impact to water medium will occur.

**Effective dose.**

Under normal conditions of work conduct, the dose obtained in the maximum of near-surface concentration, makes around 4 mkSv.

In case of an accident with maximal aftermath, effective dose at 10-km distance will make around 4 mSv, and under a condition, that a man will stay during the accident from lee side from the SO and will not use any IPG. At 30-km distance (at the boundary of exclusion zone), effective dose will make around 1 mSv.

**Impact to plant and animal world, reserved objects.**

As a result of stabilization activities, the most probable impact to plant and animal world will be radionuclides penetration into adjoining ecosystems of neighbouring territories in aerosols composition. On top of that, summary average daily activity amount under a release, which is produced by SO stabilization measures, is essentially less of reference average daily levels of radionuclides releases through VP-2. Based on above, a conclusion is made, that radiation constituent will no exert any influence to natural topsoil of adjoining territories and faunal complexes.

**Impacts to social environment.**

A large scope of works, which is planned to realize during SO structures stabilization, stipulates the involvement of considerable amount of additional personnel, that can exert indirect positive impact to conditions of social environment of the town of Slavutich – satellite town of ChNPP.

Closure of hail growth enterprise, which for Slavutich is ChNPP, increased essentially the probability of deterioration of social status of majority of town inhabitants. Emotional stress provoked by the above exerts a negative impact to psychological condition of public that produces general deterioration of vital activity conditions. Origination of new opportunities for job placement, due to planned SO works will serve to strengthening of confidence in the future and will enhance public well-being.

Guaranteed provision of employment for a part of public when performing the work at the SO, will serve as a factor, contributing to improvement of social environment conditions of Slavutich and for a part of public of other Ukraine's regions.

Analysis of probable impacts to exclusion zone personnel and public, which dwells behind its limits has shown, that a solely probable impact type is radiation factor. Estimates of additional dose loading to personnel and public are conditioned by trouble-free work conduct for SO stabilization, testify a negligibly small size of impacts.

**Impact to technogenic medium.**

At the territory adjoining to SO, acting facilities of housing and communal services and socio-cultural assignment are absent, as well as monuments of architecture, history and culture guarded by the State. In zones of probable impacts, recreational zones and cultivated landscapes are absent.

Stabilization activity does not assume any change of existing conditions of operation of enterprises located (or planned) at ChNPP industrial site and behind its limits (SNFR-2, ПКО SRW et al.). That is why, a solely factor of impacts is the increase of dose loading to personnel of these enterprises. Carried out analysis has shown, that dose loading increase under normal work conduct (maximally 0,0042 mSv) will be negligible.

Performed assessment of environmental impact allowed developing adequate protective measures. The main measures include as regards:

- survey over radionuclides penetration into environment during the work conduct for SO stabilization (radiation monitoring);
- radioecological monitoring of personnel working in ChNPP close and far zones.

Radiation monitoring of natural media, during conduct of SO stabilization measures, must provide obtaining of reliable data on current radiation conditions of components of medium undergoing the impacts. Currently, existing routing monitoring net covering the major part of exclusion zone territory satisfactorily provides representative radioecological monitoring of current conditions of environmental components. It is a sufficient one and there is no need in its expansion and inserting of additional items into existing regulation.

Thus, realization of stabilization measures will increase «Shelter» object radiation safety, and during the conduct of building and assembly works, human and environmental radiation protection will be provided.

**9. NSC conceptual design**

Creation of New safe confinement (NSC), as a part of activity for «Shelter» object (SO) conversion into an ecologically safe system is regulated by ratified by Ukraine of international laws [1-5], laws of Ukraine [6-13], regulatory-legislative acts [14-21] and other documents.

The funds for design are granted by European Bank for Reconstruction and Development (EBRD) on behalf of donor countries.

Conceptual design (Feasibility report) of New safe confinement (CD (NSC FR) was developed by order of State Specialized Enterprise Chernobyl Nuclear Power Plant (SSE ChNPP, town of Chornobyl) by Consortium (comprising: Bechtel International Systems (USA); Electricite' de France (France); and Battelle Memorial Institute (USA)), which performed the works with participation of Ukrainian consortium KSK (comprising: Research and Development Institute for building structures (NIISK, city of Kyiv); Kyiv Research and Development and design-constructor Institute «Energoproekt» (KIEP, city of Kyiv); Interdisciplinary Scientific-Technical Centre «Shelter» (ISTC «Shelter», town of Chornobyl)).

Creation NSC is one of the main stages of conversion of «Shelter» object, representing a treat for environment, into an ecologically safe system.

In conformity with Provisions of Law of Ukraine «Of general fundamentals of further operation and decommission of Chernobyl NPP and conversion of destroyed power Unit 4 of this NPP into an ecologically safe system», NSC creation must provide the achievement of the following goals:

- provision of protection of personnel, public and environment from influence of nuclear and radiation hazard sources associated with the SO existence;
- provision of conditions for realization of activity aimed at SO conversion into an ecologically safe system, including for dismantle/strengthening of unstable SO structures, FCM removal and RAW

*Figure 24. General view of NSC*

management.

Based on above goals of NSC creation, its functions are defined as follows:

• Restriction of radiation influence to public, personnel and environment by established limits under NSC normal operation, violation of normal operation, emergency situations and accidents, including the accidents during the dismantle of unstable structures, and future handling of FCM and RAW;

• Restriction of spread of ionizing radiation and radioactive substances located in the SO under normal operation, violations of normal operation, emergency situations and accidents. The conduct of this function is provided by:

- integrity of NSC fencing structures during a long-term operation period;
- prevention of SO unstable structures collapse, by means of their dismantle or strengthening for a period defined by conditions of NSC safe operation;
- restriction of penetration of rain (storm) and from melted snow water;
- protection of groundwater from contamination with radioactive substances, located in SC.

A general view of NSC is shown in Figure 24. In architectural design, the NSC will present a complex of buildings, which comprise:

• new fencing structural casing;

• internal premises for placement of NSC system equipment, control boards, doghouses and sites for primary treatment of dismantled radioactively contaminated elements;

• auxiliary buildings (sewer-pumping station, building of fire-extinguishing facility, et al.).

Conceptual design envisages the creation, within the framework of NSC design, of the following elements:

• Load-lifting mechanisms to provide the works for NSC operation and SO conversion into an ecologically safe system;

• Systems providing the NSC operation.

New fencing structural casing will represent a metallic structure of arched type with gables. Arched structure will cover the «Shelter» object, a part of Unit B, southern and western pioneer walls, as well as a part of currently existing SO local zone. Eastern gable will abut to existing structures of Plant,

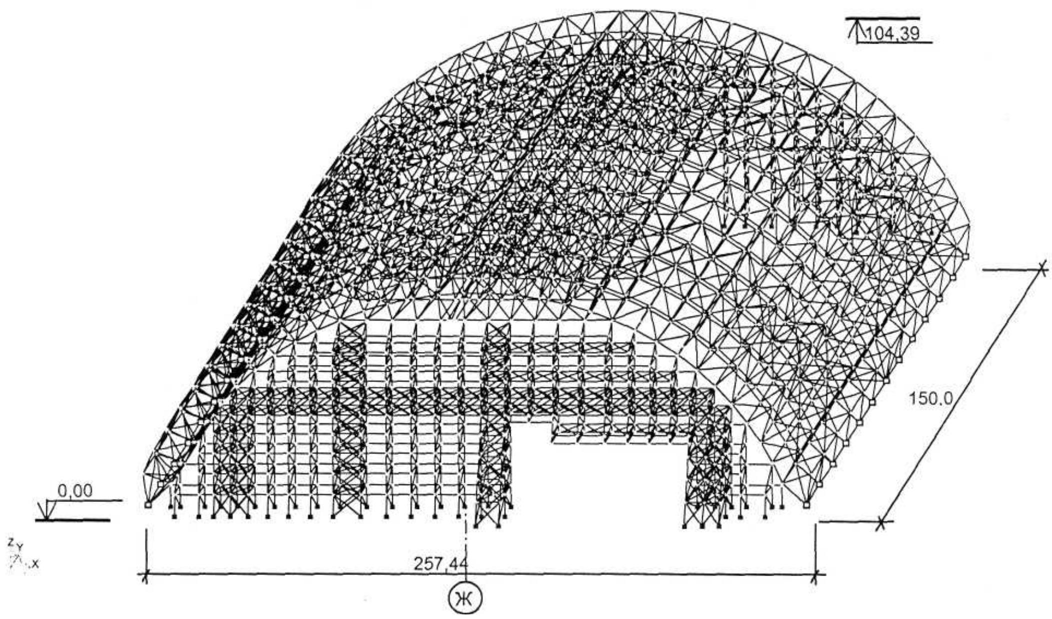


*Figure 25. General view of bearing structures of NSC casing.*

western one will lean upon own foundation. Turbine hall will partially come forward through western wall.

General view of bearing structures of NSC casing is shown in Fig.25. Geometrical sizes of casing make: span - 257,44 m, width - 150 m, height - 108,39 m, thickness -12 m.

In conformity with selected decisions, arched structure consists of bearing and fencing elements:

- Main bearing elements are circular contour arches comprising a range of internal and external arches connected one to another by truss lattice (arched type trusses);
- Fencing structures consist of two decks - outward deck (roofing) and internal (ceiling) deck, which are attached to horizontal purlins fastened to arched truss girths.

Arched structure consists of 13 flat arches. Span between the flat arches makes 12,5 m.

NSC envisages the following systems providing NSC operation:

- Dust suppression system;
- NSC fire systems;
- Ventilation systems;
- Water supply systems;
- Sewer systems;
- Heat supply and conditioning systems;
- Decontaminating solution supply system;
- Compressed air supply system;
- Power supply and electrical safety system;
- Integrated NSC management system;
- Communication and industrial television system;
- Physical protection system;
- Liquid and solid RAW management system.

Main parameters influencing the period of NSC building structures operation are as regards:

- Radiation factors impact;
- Corrosion factors impact.

In conformity with CD (FR) NSC, designed NSC operation term makes 100 years. Indicated term is reached due to:

- consideration during design of extreme loadings and impacts in conformity with acting regulatory documents;
- application of materials with enhanced corroding resistance;
- choice of optimal operation mode;
- structural decisions providing maintainability.

NSC structure envisages a probability of subsequent change of roofing and wall panels in operation period, which does not demand NSC partial opening. Change of panels will be made using shielded platforms of technical maintenance hanged on rails inside and outside of NSC arch main elements.

Within the framework of CD (FR) NSC, strength estimates were made of NSC fencing structural casing and foundations with considering the following external impacts associated with natural phenomenon: seismic impacts; wind loadings; snow loadings; tornado loadings; air temperature changes; lightning impact; precipitations.

In estimating, for seismic impacts the following values were taken:

- Designed earthquake (one time per 100 years)- 5 numbers according to MSK-64 scale
- Maximal estimated earthquake (one time per 10 000 years) - 6 numbers according to MSK-64 scale.

For wind loading, the following values were used (in accord with SNiP 2.01.07-85 and PiNAE-5.6):

- Normative value of wind pressure - 0,3 kPa (30 kgc/$m^2$);
- Estimated loading - 0,42 kPa (42 kgc/$m^2$),
- Extreme loading -0,75 kPa (75 kgc/$m^2$);
- Reliability coefficient for loading-1,4 and 2,5 correspondingly for estimated and extreme loading.

For snow loadings, the following values were used (according to SNiP 2.01.07-85 and PiN AE-5.6, as well as with considering historical climatological data based on repetition rate, one time per 10 000 years):

- Normative value of snow cover weight - 0,7 kPa (70 kgc/$m^2$);
- Estimated loading -1,0 kPa (100 kgc/$m^2$);
- Extreme loading - 2,1 kPa (210 kgc/$m^2$);
- Reliability coefficients for loading - 1,4 and 2,0 correspondingly for estimated and extreme loading.

For tornado loadings, estimate is made in conformity with «Main regulatory requirements and estimated characteristics of tornadoes for Chernobyl NPP site», introduced by Order No 64 of Ukraine's Derzhbud of 21.10.2002.

In conformity with NP 306.1.02/1.034-2000, probability of realization of initial event, bringing to a need of public resettlement in case of exceeding estimated tornado class for newly designed objects of nuclear power engineering should be established equal to $P=1\cdot10^{-6}$ 1/year, and for facilities under construction, operation and reconstruction - $P=1\cdot10^{-5}$ – 1/year. Estimated characteristics of tornado with indicated probability for ChNPP site are shown in Table 9:

*Table 9*

| Estimated tornado characteristics | For tornado with probability $1\cdot10^{-5}$ | For tornado with probability $1\cdot10^{-6}$ |
|---|---|---|
| Estimated class of probable tornado | 1.5 | 3.0 |
| Exceeding probability, (event/year) | $1\cdot10^{-5}$ | $1\cdot10^{-6}$ |
| Maximal velocity of funnel rotation, (m/s) | 50 | 81 |
| Velocity of tornado forward movement, (m/s) | 12.6 | 20.3 |
| Pressure difference between funnel centre and periphery, (gPa) | 31.0 | 81 |
| Length of tornado propagation path, (km) | 5.0 | 28.6 |
| Width of tornado propagation path, (km) | 0.05 | 0.29 |

For air temperature characteristics, the following values were used (according to SNiP 2.01.07-85):

| | | |
|---|---|---|
| • Normative temperature value: | Minimum | -20°C; |
| | Maximum | +26°C; |
| • Estimated temperature value: | Minimum | -22°C; |
| | Maximum | +29°C; |
| • Reliability coefficient for loading | | 1,1; |
| • Extreme temperature values (one time per 10 000 years) | Minimum | -43°C; |
| | Maximum | +45°C. |

Lightning impacts are expected at the level, under which is enough to have lightning-protection system meeting the requirements of PUE and «Instruction for arrangement of lightning-protection for buildings and structures (RD 34-21-122-87).

For maximal precipitation amount, the following values were used:

- On average over 20-minute period - 31 mm;
- Extremely over 20-minute period (one time per 10 000 years) - 72 mm;
- Extremely during a day (one time per 10 000 years) -190 mm.

Strength estimates confirmed that realization of proposed constructive decisions would provide the NSC stability under all considered external impacts associated with natural phenomena. Particularly, stability of NSC main supporting structures and foundations under a class 3.0 tornado is confirmed, and absence of a need, under such initial event, of public evacuation in conformity with criteria of NRBU-97, NRBU-97/D-2000 and NP 306.1.02/1.034-2000.

When developing CD (FR) NSC, the following external technogenic impacts were considered:

- explosion;
- aircraft collapse;
- fire;
- initial events associated with existing ChNPP facilities.

Analysis of impact to NSC structures from explosion sources at the ChNPP site and behind its limits has shown that under such initial events the loadings will be less of expectable by a tornado.

Aircraft collapse was excluded from consideration as a designed base due to following reasons:

- In conformity with the national requirements of acting in Ukraine regulatory-legislative documents, such initial event is not seen for the facilities for RAW and FCM management, to which the SO is referred, and, correspondingly, the NSC;

- B ChNPP zone, organizing-technical measures accorded with appropriate bodies are envisaged, which prevent aircraft flights;
- Based on estimates performed in designing other ChNPP objects, probability of such initial event evaluated at the level of $1 \cdot 10^{-6}$/year. Existing estimates of probability of aircraft collapse on a specified object for western-European countries, where aerial traffic is more intensive, than in Ukraine, makes $<10^{-7}$/year. In conformity with criteria, established in NRBU-97, such a rare initiating event can be not considered.
- Use of this event as a design basis would lead to considerable unjustified increase in cost and making more complicated the NSC structures.

In CD (FR) NSC, aircraft collapse is seen as “out-of-design” event.

Analysis performed at pre-project development stage has shown, that additional impacts influencing NSC design decisions are absent under external fires.

Analysis of initial events associated with existing ChNPP objects has shown, that ventilation pipe VP-2 collapse on the NSC would lead to destruction of bearing structures of casement, and a probability of such event is above, than it is admitted by acting regulations. In this connection, in CD (FR) NSC a conclusion is made on a need to dismantle ventilation pipe before the start of NSC pushing into designed position.

Emergency situations at other ChNPP objects (LRTP, ПКОSRW, SNFR-1, SNFR-2) will not provoke any additional loading on the NSC.

**Main decisions for NSC erection technologies**

Within the framework of CD (FR) NSC, main decisions were developed for such aspects of erection organization as regards: preparation of building territory, infrastructure for provision of construction, possible erection technology is drafted.

Territory preparation works include clearing of building site, works for arrangement of engineering mains at building site, works for planning territory at building site, organization of auxiliary objects for construction.

Proposed in CD (FR) NSC infrastructure for provision of NSC construction must enable delivery of tube and ferroconcrete structures, as well as of building materials, such as concrete, sand, fixturing, armature, etc. Besides, infrastructure must provide power supply, water supply, heat supply, sewer (storm and household), and removal of producible RAW and construction waste.

In CD (FR) NSC, comparative analysis of construction technologies options is made. As a result it was stated, that most preferable option is manufacture of section elements of arched structures at Ukraine's plants, their assembly beyond the site limits with subsequent delivery to assembly site.

Manufacture behind the site limits has a whole range of advantages, since plant-manufactures are equipped with all appropriate infrastructures and possess opportunities to provide required quality control, and considerable part of works will be performed beyond the limits of zone with high radiation fields. On top of that, the amount of equipment, workforce and scope of work, performed at building site, will be minimized.

Assembly of arched structure starts after installation of pushing ways, assembly site and installation of supporting units and bearing beds under the first supportable section. Structure will be assembled of individual 12.5-m wide sections. On top of that, two methods of arched structure assembly are seen.

The first method includes the assembly of arched structure sections using crane with load-lifting capacity 1600 t and two cranes of less load-lifting capacity.

The second method is based on the point that assembly of arched structure sections is made with using winch-hoisters. The both methods are real and technically realized, on top of that, the second one permitting to perform more quantity of assembly works on earth level, that increases their safety and productivity, is considered in CD (FR) NSC as a more preferable.

Pushing of arched structure (Fig.26) is made after installation of pushing ways, foundations under arched structure, foundations of eastern and western gables, as well as completion of assembly of pushing equipment and ventilation pipe dismantle. Most preferable pushing method and, according to CD (FR) NSC estimate results, is the pushing with applying tractive effort. This pushing method provides the required friction coefficient and is more floppy due to possibility to change the amount of ropes and towing jacks at each stage of arched structure pushing.

*Figure 26. Modeling of arched structure's pushing process to «Shelter» object.*

After the arch is pushed in design position, completion of gables arrangement is made and sealing of arched structure. Connection of engineering mains and arched structure equipment can be started after pushing completion and assembly of equipment inside the NSC.

**Management of RAW producible during NSC erection**

Proposed in CD (FR) NSC decisions for RAW management under NSC construction are based on the following positions:

- For management of RAW producible during construction – existing at ChNPP RAW management scheme will be maximally used;
- In defining the decisions for management of RAW producible during construction - main decisions и planned measures, developed within the framework of integrated program of ChNPP RAW management are considered;
- In defining the decisions for control and inventory of nuclear materials and RAW during construction – it is adopted that this activity will be realized within the framework of system existing at the SO;
- Under NSC construction, only the RAW are subject to removal, which are located in building work zones, for the rest RAW located in technogenic layer of local zone and SO industrial site must be provided possibility of their delayed removal during operation or dismantle of NSC.

During the NSC erection, the main RAW volumes will be produced by:

- removal/displacement of on-land objects covered by construction zone (building structures and their fragments, mains, construction waste, etc.) and cleaning of areas from shrubs etc.;
- earthwork (crushed stone, ground, sand, concrete fragments, etc.);
- drilling works (cores containing the above fractions).

SRW, producible under the NSC construction, according to contamination type will be presented as both surface contaminated materials (large-sized fragments structures and buildings being dismantled), and volumetrically contaminated (small-sized fragments and loose waste). Main contamination of indicated materials is expected by radionuclides of $^{137}$Cs, $^{90}$Sr, $^{239+240}$Pu, $^{\text{and } 238\text{Pu}}$, $^{241}$Am, which will determine gamma-radiation EDR, surface and volumetric contamination rate.

As volumetrically contaminated SRW the high-level waste (HLW) are expected, which can be presented as fragments of negligible sizes (active core fragments and strongly contaminated concrete fragments). The rest SRW will be referred to low- and intermediate-level waste (LIL SRW), of predominantly 1 category low-level waste).

During works for removal/displacement of existing mains, removal around 1300 m$^3$ of ground is expected, which received radioactive contamination as a result of 1986 year accident, in which can include the impurities that due to contamination level are referred to SRW 3 category. Performed in CD (FR) NSC estimate of volumes of technogenic layer demanding removal have demonstrated that during creation of NSC foundations, up to 82500 m$^3$ ground can be excavated. It is assumed that the volume of SRW 3 category (HLW) during earthwork would make around 120 m$^3$.

When preparing internal sites under arched structure, additional ground can be excavated in volumes of 24170 m$^3$ (for the most, with contamination at background level values).

General scheme of radioactively contaminated ground management includes two level of their sorting:

- primary sorting according to ground removal place with the purpose:
  - primary identification and HLW segregation using the criterion «EDR of extractable ground»;
  - dividing the rest waste into small-sized and large-sized;

- detailed ground sorting at a specially arranged site with the purpose to divide into the waste subject to burial and, the waste that can be used for backfilling during erection of foundations.

The grounds having high contamination level will be forwarded to interim monitoring point for certification, and from that place they will be transferred for long-term storage/burial:

- to PLRW «Buryakivka»,
- to industrial complex for handling solid radioactive waste (ICSRW) - after its commission.

Large-sized LIL SRW meeting the burial acceptance criteria, after surfaces dust strengthening can be transported directly to PLRW « Buryakivka » or to ICSRW.

To provide the fulfillment of above works, the sites for waste removal and management envisage the following equipment and facilities:

- specially equipped machinery with attached equipment for handling radioactively contaminated materials;
- specially equipped site for ground segregation into categories;
- check points with dosimetric control;
- stations for decontamination of RAW management machinery and equipment.

In order to reduce radioactive substance concentrations in the atmosphere in work production places, use of dust suppression is envisaged.

**Nuclear safety provision**

Under normal conditions of NSC construction, to provide nuclear safety of CD (FR) NSC is envisaged:

- not to worsen the conditions of atmospheric precipitation discharge from existing SO roofing;
- not to create additional apertures in SO roofing, as well as other ways for incoming atmospheric precipitation in premises, where nuclear hazardous FCM clusters are localized;
- not to worsen conditions in part of condensation moisture production as compared to existing conditions;
- not to realize technical decisions, which could change existing water flows system inside the SO and contribute to moisture accumulating in nuclear hazardous zones;
- not to worsen the conditions for functioning of current system for collection and removal of SO radioactively contaminated water;
- exclude the use of technological waters when performing work at the sites adjoining to SO nuclear hazardous zones ;
- exclude conditions violating efficiency of existing system for nuclear safety monitoring:
  - information-measuring system (IMS) «Finish-P»;
  - FCM monitoring systems (MS FCM) «Signal»;
- to go on maintaining FCM in subcritical condition in volume established by acting SO technological regulation, using the existing systems:
  - system for supply of nitric gadolinium solution;
  - facility for operative insertion of neutron-absorbing solution;
  - dust suppression systems (in mode of neutron-absorbing solution supply).
- to realize organizing measures for nuclear safety provision in conformity with acting SO technological regulation.

During NSC construction, to reduce SCR generation risk in emergency situations occurred as a result of SO building structures collapse, CD (FR) NSC envisages as follows:

- Measures for stabilization of SO building structures will be performed before NSC construction start, that will result in reducing collapse risks to acceptable level;

- NSC structures will be designed in conformity with criteria и requirements of nuclear and radiation safety;
- Considerable part of building and assembly works will be performed at safe distance from the SO, which excludes direct mechanical impact to it;
- Building and assembly works in close vicinity from the SO, including NSC pushing, will be realized with applying technologies and technical means с high reliability indices;
- For fire extinguishing in nuclear hazardous zones is assumed using of water-free compositions and/or aqueous compositions with neutron-absorbing additives;

As a whole, during NSC construction (in normal conditions and in emergency situations) with considering envisaged measures, nuclear safety will be provided at the level existing for operated SO. When the NSC will be commissioned, SO nuclear safety level will be essentially improved.

**Radiation safety provision**

Availability of radioactive materials in the SO defines potential radiation hazard of all activity for SO conversion into an ecologically safe system, including activity in NSC design scope. In CD (FR) NSC, measures for provision of radiation safety were prepared with considering the fact that NSC construction and operation will be realized as activity with open ionizing radiation sources.

During NSC design realization, radiation conditions will be defined by:

- availability of radioactive substance in work production zones;
- radiation background created by SO;
- radioactive aerosols release from SO;
- direct activity (dust rise, RAW management, including FCM).

To provide radiation safety, CD (FR) NSC envisages at all stages of NSC design realization:

- organizing measures;
- technical measures;
- sanitary-hygienic measures.

Organizing measures, which are common for all stages of NSC design realization, include:

- personnel training;
- planning of work; organization of safe work production;
- control and supervision.

As designed reference levels of individual exposure of personnel and radiation conditions for all the stages NSC design realization, CD (FR) NSC takes the values established currently at the SO.

During NSC construction, the main technical measures providing radiation safety will include as regards:

- protection with distance;
- shielding;
- dust suppression.

Protection with distance implies minimization of works being performed close to SO, especially on high marks, for the above the CD (FR) NSC envisages the following decisions:

- Part of labor-intensive work will be carried out beyond exclusion zone limits;
- Assemblage of NSC building structures and a range of its technological system will be realized at a far distance from SO (150 m);
- Structures assembly procedure envisages their assemblage on earth level.

Shielding of work production zones will be provided by application of:

- protective boxes;
- relocatable shields;

- shielded attached or traveling platforms;
- shielding of operator cabins for technical means.

Measures for short-term dust suppression (damping with water) will be carried out under probable increase of dust rise in work zone during work production, or personnel movement. Long-term dust suppression (laying of localizing compositions) will be carried out in case of need to localize radioactive contamination (dust-strengthening) on surfaces of transportable large-sized structures and other elements without containerization.

Dosimetric control during construction includes as regards:

- monitoring of radiation conditions, which provides:
  - EDR monitoring;
  - monitoring of contamination levels by radioactive substances of work surfaces of premises, equipment and vehicles;
  - monitoring of volumetric activity of radioactive substance in work zone air;
  - radiation control at all RAW management stages;
- individual dosimetric control (IDC) of personnel including:
  - IDC of external exposure due to beta- and gamma-radiation with application of individual dosimeters;
  - IDC of internal exposure, which is made on the basis of data of direct and indirect biophysical measurements;
- system of operative and long-term planning, inventory and storage of data on individual personnel exposure doses.

Collective effective dose of personnel during NSC construction, preliminary evaluated in CD (FR) NSC with considering realization of indicated measures, made - 450 men-Sievert. It is assumed that realization of organizing and technical measures according to ALARA principle can reduce this value to -250 men -Sievert. The above estimate is subject to more precise definition at the stage of detailed design during preparation of Work Production Project (WPP).

**Assessment of impacts to components surrounding natural environment**

During the works over CD NSC design, estimates of impacts of activity under design to surrounding natural environment were made.

**Impacts to aerial medium**

As a result of performed estimates, for emergency situation scenarios under consideration the following impact levels were established:

- value of radioactive releases penetrating into atmosphere, under condition of SO collapse without NSC, makes around $1{,}59 \cdot 10^{13}$ Bq;
- value of radioactive substance releases, under condition of SO collapse inside NSC, will make from $8{,}49 \cdot 10^{10}$ to $8{,}08 \cdot 10^{11}$ Bq depending on SC ventilation conditions (from 0,1 to 1 SC volume a day).

**Impacts to soils**

Under normal conditions of NSC design realization, impact to soils from SO aerosol releases precipitation till construction completion will be preserved at existing level, negligible as compared to radioactive contamination occurred in the first months after 1986 year accident.

After NSC commission, release amount will reduce.

Under emergency situations, the most soil contamination is predicted in case of base option (SO collapse without NSC) and first option (SO collapse during NSC pushing), under extraordinary meteorological condition (atmosphere stability category on Pasquill F, wind velocity - 1 m/s). On top of that, maximal (along plume central axis), surface contamination values at 10-km distance (additionally to existing contamination) will make from 5% to 60% of existing contamination of ChNPP exclusion zone soils at given distance.

At the boundary of ChNPP exclusion zone, maximal (along plume central axis), additional surface contamination will make from 30% to 100% of existing contamination of soils at the boundary of ChNPP exclusion zone.

Beyond ChNPP EZ limits, at 50-km distance, maximal (along plume central axis) additional surface contamination will make:

- with radionuclide $^{137}Cs$ - 3,2 $10^4$Bq/m$^2$;
- with radionuclide $^{90}Sr$- 2,8 $10^4$Bq/m$^2$;
- with radionuclides $^{238+239/40}Pu$ - 6,5 $10^2$Bq/m$^2$,

that will exceed existing levels in several times.

For SO collapse inside NSC option, maximal soil contamination under analogous meteorological conditions is forecast in dozen-hundred times less (depending on NSC ventilation mode) as compared to contaminations under SO collapse without NSC.

Maximal summary (for all radionuclides) additional surface contamination at 10-km distance is forecast at level of 1,7 $10^4$ Bq/m$^2$ that makes not more 2% of existing contamination of ChNPP EZ soils at given distance.

At the exclusion zone boundary, maximal summary surface contamination is forecast at level 3,3·$10^3$ Bq/m$^2$ that makes not more 10% of existing contamination.

**Impacts to water medium**

Under normal conditions of NSC design realization, impact to surface water from SO aerosol releases precipitation before the completion of construction will be preserved at existing negligible level. After NSC commission, SO releases amount will reduce.

Under emergency situations, impact to surface water will be defined by direct atmospheric precipitation on water surface of river Prypyat, as well as precipitation on its flood plain close to NSC with subsequent radionuclides outflow from drainage areas. Forecast of emergency contaminations of surface waters performed in the EIAR covers Kyiv, Kaniv, Kremenchuh and Kakhovka reservoirs. The largest aftermath are forecast in SO without NSC collapse and SO collapse during NSC pushing.

The biggest peak of $^{90}Sr$ concentrations in water is forecast for 41 day after the accident, and for both options of emergency situation will make:

- for Kyiv reservoir (Kyiv SPP) - 684 Bq/m3;
- for Kaniv reservoir - 389 Bq/m3;
- for Kremenchuh reservoir - 225 Bq/m3;
- for Kakhovka reservoir - 178 Bq/m3.

The maximal value of presented above (for Kyiv reservoir) makes 34% of admissible $^{90}Sr$ concentrations in drinking water.

The maximal $^{137}Cs$ concentration under basic and first options in Kyiv reservoir makes 455 Bq/m3, in Kaniv reservoir - 137 Bq/m3 (correspondingly 32% and 11% of admissible $^{137}Cs$ concentration in drinking water). Maximal concentration of Pu, $^{23}$ Pu and $^{41}$At forecast for Kyiv reservoir, does not exceed 1 Bq/m3 for each radionuclide.

For SO collapse under NSC option, level of radionuclides income depends on NSC ventilation conditions. Under ventilation equal to 1 NSC volume a day, maximal increase of $^{90}Sr$ and $^{137}Cs$ concentrations as compared to background level makes 25% and 91% correspondingly (11% and 2% of admissible concentrations for drinking water). Under ventilation equal to 0,1 SC volume a day, $^{90}Sr$ and Cs concentrations will be an order less, and annual concentrations will be only at 0,3% exceed the background values of indicated radionuclides content in Kyiv reservoir water.

Simulation of impacts to underground water is made in the EIAR with considering the fact that the main contamination source is water infiltration from SO premises 001/3. On top of that, radionuclides transporting by underground waters was considered independently of current contamination of underground waters conditioned by other sources (surface contamination, burial sites near the SO, etc.).

For $^{90}Sr$ possessing the biggest migration capacity, the following results were obtained:

- Under scenario of SO collapse without NSC, concentration in underground waters, exceeding $4 \cdot 10^9$ Bq/m3, will be observed at less 100-meters distance, $1 \cdot 10^2$ Bq/m3 level will be provided yet at 600-m distance from the SO. Contamination field will reach river Prypyat after 800 years, on top of that, $^{90}Sr$ concentration, because of radioactive decay, will drop at $5{,}7 \cdot 10^{-9}$ fold of initial values.
- by SO collapse under NSC, $^{90}Sr$ concentration in underground waters will be reduced, practically, to zero.

Assessments of impacts to geological medium and climate, which were described in the EIAR at conceptual level, has shown the absence of some significant impacts to these medium components.

In connection with existing high contamination level of ChNPP EZ territory, a conclusion is made in EIAR on the fact that impact to flora, fauna and reserved objects within the limits of this territory will be weakly distinguished even under base option of emergency situation (SO collapse without NSC). On top of that, extremely restricted atmospheric transport and availability of background contamination of flora and fauna makes negligible emergency impacts behind the ChNPP EZ limits.

**Estimate of mutual impacts of NSC and objects of surrounding technogenic medium**

As a result of performed impacts analysis, it was defined as regards:

- impacts of emergency situations at LRTP, ICSRW, SNFR-1, SNFR-2 will not entail any additional loading to the NSC;
- unfavourable impact of collapse of existing ventilation pipe of power Unit 4 is ruled out, since it (pipe) is being dismantled. Newly erected pipe will be designed for extreme impacts. On top of that, in conformity with NSC construction schedule, existing ventilation pipe must be dismantled before starting NSC pushing works.

Under normal conditions of NSC design realization, its impact to surrounding technogenic medium will be expressed in displacement of existing life support systems of the SO and ChNPP Unit 3 (electricity supply networks, systems of water supply and household sludge sewer, etc.) located at NSC construction site.

**Assessment of impacts to social environment**

Realization of NSC design will positively impact to social environment in several fields:

- it will essentially reduce the risks of public exposure under emergency situations at the SO;
- it will reduce psychological tension in society associated with SO collapse treat;
- it will provide employment for part able-bodied public of towns of Slavutich, Chernihiv and other settlements;
- it will provide loading of Ukraine’s industrial enterprises during manufacture of NSC structures and components.

**Measures for minimization of environmental impacts**

NSC creation, in itself, is a measure aimed at minimization of SO environmental impacts, since NSC availability will allow:

- isolate RAW located in SO;
- reduce probability of nuclear incidents due to exclusion of atmospheric moisture penetration on FCM clusters inside SO;
- perform works for handling FCM and RAW under protective casing.

Minimization of negative environmental impacts during NSC construction will be achieved by means of realization of following technical and organizing measures:

- dust suppression in earthwork production places;
- dust strengthening;
- decontamination of applicable mechanisms and vehicles;
- application of technologies with minimal dust rise;
- organization and control over RAW transporting and management.

Minimization of negative environmental impacts during NSC operation in the course of dismantling unstable SO structures will be reached by means of realization of the following technical and organizing measures:

- Arrangement of ventilation system, with using aerosol filters for exhaust air cleaning;
- Zoning of NSC territory and premises;
- Dust suppression in work production places;
- Organization of radiation control system;
- Decontamination of vehicles leaving the NSC limits;
- Use of revetment of premises, where radioactive substance release into premises is possible;
- Organization of building structures control system;
- Restriction and control of NSC discharges and releases.

**Estimate of potential exposure**

In CD (FR) NSC, analysis was made of potential exposure of personnel and public as a result of realization of activity associated with NSC construction and operation, and substantiation of non-exceeding of exposure risk criteria defined in NRBU-97/D-2000 was made.

**Estimate of potential exposure during NSC construction**

In CD (FR) NSC, the following emergency situations during NSC construction are seen, which can lead to potential exposure of public and personnel:

- SO fire due to error of personnel/failure of equipment during NSC construction before pushing NSC arch;
- SO collapse due to error personnel/failure of equipment during NSC construction before pushing NSC arch;
- SO collapse due to extreme wind during NSC construction before pushing NSC arch.

Fire at the SO due to error of personnel/failure of equipment during NSC construction before pushing NSC arch can occur as a result of the following initial events:

- ignition of materials during the welding;
- ignition of electrical equipment;
- vehicle accident in local zone.

When assessing potential exposure under a fire at the SO, the following assumption and initial data were applied:

- It is assumed that as a result of fire no SO collapse occurs;
- Total release during origination of fire at the SO makes $4{,}8 \cdot 10^{10}$Bq;
- Fire duration makes 4 hours;

As a result of estimates it was stated that individual effective dose under a fire for non-protected personnel close to SO makes around 12,6 mSv.

At a distance from SO under given initial event, maximal individual dose is formed at around 10-km distance and makes - $7 \cdot 10^{-3}$ mSv. Thus, release influence under a SO fire to personnel located at far distance from the SO, will be negligible.

Dose of public at the ChNPP EZ boundary makes $4\text{-}10^{-3}$ mSv.

Collapse of SO building structures, due to error of personnel/failure of equipment during NSC construction before pushing NSC arch, can occur because of collapse of assembly crane or load on the SO.

In conformity with existing models, volume of SO aerodynamic shadow was estimated - around 106 m3. Thus, conservatively assuming that all activity precipitates in aerodynamic shadow zone, radioactive substances concentration in air makes around $7{,}79 \cdot 10^{6}$ Bq/m3. Cloud existence time is taken as equal to time, during which the wind will pass distance equal to aerodynamic shadow length. Under wind velocity of 3.3 m/s, this time is equal to 45 s. Over this time, individual effective dose for non-protected personnel, close to the SO, makes -58 mSv.

At a more far distance from the SO, maximal individual dose is formed at 1-km distance and makes around 4 mSv. Thus, inhalation dose for personnel located at a bigger distance from the SO will be significantly less, than the above dose close to the SO. Dose for public at the ChNPP EZ boundary makes 0,1 mSv.

**Estimates of potential exposure during NSC operation**

To estimate potential exposure during NSC operation, the following emergency situations under NSC operation are seen, which can lead to potential exposure of public and personnel:

- SO fire under essential reduction of fire protection due to personnel error under NSC operation;
- SO collapse due to earthquake with loss of power supply during SO structures dismantle and NSC operation;
- impossibility to close NSC transport gate due to error of personnel/failure of equipment during SO collapse.

Potential exposure in case of realization of indicated emergency situations is associated with inhalation intake of radioactive aerosols into organism. The source of aerosols origination is a fire or SO collapse. Since these critical events occur after NSC arch is pushed on its place, therefore, producible aerosols are scattered inside the NSC. Eventually, a part of aerosol materials comes into environment, the remained materials precipitate inside the NSC. Reduction of radioactive substance release is provided due to shut off of arched space ventilation. It is evident, that maximal individual dose of potential exposure for personnel staying inside the NSC is essentially higher, than for the personnel being outside the NSC.

Fire at SO under and essential reduction of fire protection due to personnel error during NSC operation can occur as a result of the following initial events:

- ignition of materials in the course of welding;
- ignition of electrical equipment;
- vehicle accident inside the NSC.

In estimating potential exposure by an SO fire, the following assumption and initial data are used:

- It is assumed that as a result of fire, no break of NSC structures integrity will occur;
- Total release during SO fire origination inside the NSC makes $4.8 \cdot 10^{10}$ Bq [2].
- Fire duration makes 4 hours;

Maximal individual dose of potential exposure will be received by personnel located inside the NSC due to radioactive aerosols inhalation, on top of that, inhalation time makes 1 hour (it is assumed that the fire was detected and the personnel was evacuated through 1 hour after origination of strong fire, that is a sufficiently conservative assumption).

Results of estimate have shown that over the time needed for evacuation, maximal individual dose of potential exposure for non-protected personnel inside the NSC makes around 11,3 mSv. Considering the fact that the personnel in NSC will work in IPGRO, or in isolated premises, real dose is forecast at least at order less – 1,1 mSv.

Release from the NSC will make $2 \cdot 10^{8}$ Bq.

Maximal individual dose outside the NSC makes around $4\cdot10^{-4}$mSv. Evidently, that inhalation dose of potential exposure of personnel inside the NSC is essentially less of dose inside the NSC.

Dose of public at the boundary of ChNPP EZ makes $3\cdot10^{-8}$ mSv.

Under SO collapse due to earthquake with loss of power supply during SO structures dismantle and NSC operation, the estimates made have shown as regards. During loss of power supply, failure of NSC control systems can occur, which will entail the event when ventilation system shutters can remain in open position. The above brings to increase of air exchange with surrounding environment to 200% NSC volume per a day and relevant accelerated drop of radioactive aerosols concentrations inside the NSC.

When estimating potential exposure dose, the following assumptions and initial data are used:

- Under earthquake, no NSC structures destruction will occur;
- Total release under collapse of SO structures building inside the NSC makes $7.79\text{-}10^{12}$ Bq:

Maximal individual dose of potential exposure will be received by the personnel located inside the NSC due to radioactive aerosols inhalation; on top of that, inhalation time makes 20 min (maximal time needed for emergency evacuation of worker);

Over the time needed for evacuation, maximal individual dose of potential exposure of personnel inside the NSC makes 44 mSv. Under an essentially more probable particular collapse, the dose makes around 15 mSv.

Release beyond the NSC limits will make $8{,}4\cdot10^{9}$ Bq. Maximal individual dose of personnel outside the NSC will make around 3 mSv (under partial collapse - around 1 mSv). Evidently, that inhalation dose of potential exposure outside the NSC is much more less than the dose inside NSC.

Dose for public at the ChNPP EZ boundary makes around 10 mSv.

**Conclusion**

Choice of all principle technical decisions for NSC is confirmed by estimated substantiations performed within the framework of CD (FR) NSC. Particularly, estimated substantiation are made for different options:

- mode of NSC thermal isolation and ventilation;
- arched structure configuration;
- structural decisions on foundations, et al.

For NSC structure being proposed in CD (FR) NSC, strength estimated substantiations are carried out, which confirm NSC stability under extreme values of different loadings and their combinations. Particularly, stability of supporting structures and NSC foundations is confirmed under a class 3.0 tornado.

In CD (FR) NSC, assessment of environmental impacts during NSC design realization is made. It is shown that under normal realization of design and in emergency situations, "Shelter" object's environmental impacts have essentially smaller aftermath, if the NSC is available, as compared to absence of fencing casing.

In CD (FR) NSC, potential exposure of personnel and public as a result of realization of activity associated with NSC erection and operation is evaluated, and non-exceeding of exposure risk criteria is substantiated, which is defined in NRBU-97/D-2000.

As a whole, in CD (FR) NSC at conceptual level, probability of achievement of set objectives in NSC creation is demonstrated, which are as follows:

- providing protection of personnel, public and environment from the influence of sources of nuclear and radiation hazard associated with the SO existence;

• providing conditions for realization of activity aimed at SO conversion into an ecologically safe system, including that for dismantling/strengthening unstable SO structures, FCM extraction and RAW management.

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