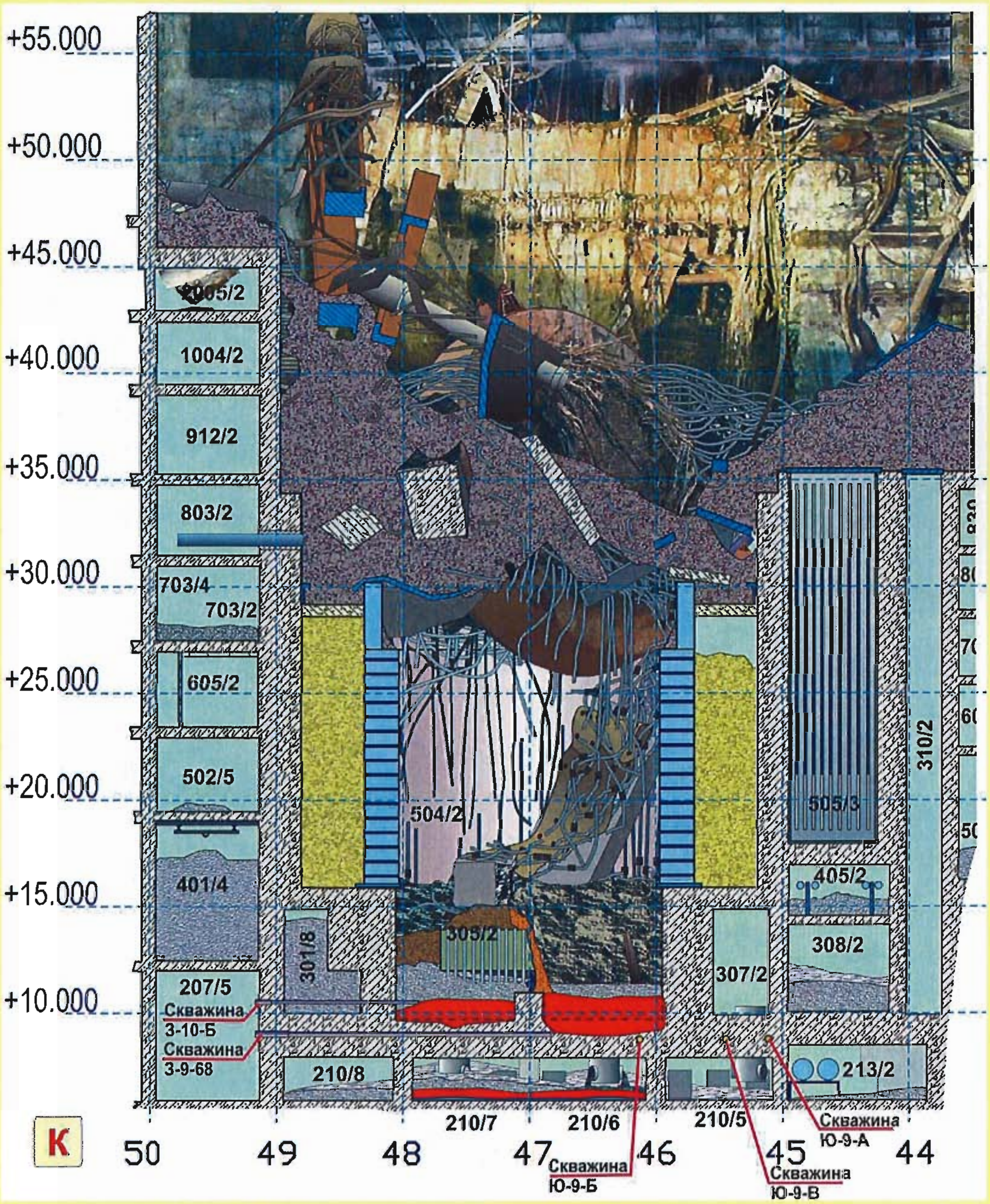
Project № 2916

"Development of the Models for Nuclear Fuel Behavior during Active Phase of Chernobyl Accident"

(Performed under a special Agreement between the International Science and Technology Center and the Russian Research Center "Kurchatov Institute")

DATABASE

on Location and Status of Nuclear Fuel at Unit - 4 of Chernobyl NPP before and after the Accident



Moscow 2007

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"Development of the Models for Nuclear Fuel Behavior during Active Phase of Chernobyl Accident"
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on Location and Status of Nuclear Fuel at Unit - 4 of Chernobyl NPP before and after the Accident

Project Manager: Borovoi A.A.

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CONTENT

ABBREVIATIONS AND DEFINITIONS

BWC	Bottom Water Communications
CB	Condenser battery
CH	Central Hall
Chernobyl NPP	Chernobyl Nuclear Power Plant
EDR	Exposure Dose Rates
FA	Fuel Assembly
FE	Fuel Element
FCM	Fuel Containing Materials
IAEA	International Atomic Energy Agency
LVF	Large Vertical Flow
IBRAE	Nuclear Safety Institute of the Russian Academy of Sciences
LFCM	Lava-like Fuel Containing Materials
MVF	Minor Vertical Flow
Model	Model of nuclear fuel behavior at the active phase of the Chernobyl accident
NSC	New Safe Confinement
OS	Object "Shelter"
Project	Project #2916 "Development of the Models for Nuclear Fuel Behavior during Active Phase of Chernobyl Accident"
PSP	Pressure Suppression Pool
RRC "KI", KI	Federal State Institution Russian Research Center "Kurchatov Institute"
RZM	Refuelling machine (Russian-spelled abbreviation)
SDC	Steam-Distribution Corridor
SDV	Steam-Dumping Valve
SWC	Steam-Water Communications
"Д" ("D")	Lateral (water) biological shield
"Е" ("E")	Upper plate of biological shield
"Л" ("L")	Lateral (water) biological shield
"ОР" ("OR")	Lower plate of biological shield

INTRODUCTION

The database presented was developed for purposes of using in the Project #2916 "Development of the Models for Nuclear Fuel Behavior during Active Phase of Chernobyl Accident".
This Project is being performed under a special Agreement between the International Science and Technology Center (ISTC) and the Russian Research Center "Kurchatov Institute".

Specialists of RRC KI and of the Nuclear Safety Institute of the Russian Academy of Sciences are involved into the Project.

The main objective of the Project is the development of a calculated-analytical model to simulate processes in nuclear fuel of Unit 4 of Chernobyl NPP during the active phase of the accident. The outcomes of the investigation may be used in subsequent "Shelter" transformation activities and be applied for solution of a number of problems related to nuclear power safety.
To develop such a model and describe the processes of generation and spreading of lava-like FCM, we needed a maximum possible amount of data on location and physico-chemical condition of the Unit 4 fuel both before and after the Chernobyl accident.
A variety of data on post-accident status of structures and materials of Unit 4 were also necessary.
Consequently, verification, analysis and structuring of a huge body of experimental material achieved in investigations at the "Shelter" in 1986 – 2005 were indispensable for the establishment of a database on their basis (Task 2 of the Project).

A team of RRC KI's specialists performed such a work in 2004 – 2006. At first an electronic version of the database was generated.

However from the information density standpoint the developed database goes far beyond the Project frames and may be used for solution of many practical tasks related to future activities at the "Shelter". Thus saving of the database for potential use by a variety of specialists in related fields appears expedient.
Accordingly, a decision was made on publishing a paper version of the database (a special brochure) in addition to the electronic version.

As said above, during the database development a variety of data taken from publications, reports, survey certificates, construction drawings, etc. were verified and analyzed. Photo- and video-materials were also studied.
The integral amount of information records used in the database exceeds 6000.
They are grouped into the following major sections:
- fuel, materials and constructions of Unit 4 of Chernobyl NPP before the accident;
- status of fuel, materials and constructions half an hour after the accident (the lava generation onset);
- heat sources during lava (corium) generation;
- physical and chemical processes during lava generation; and
- lava spreading.

The database was being developed and improved under continuous interfaces and with active support of the Project Leader (Dr. L. Tocheny, ISTC), the Project collaborators and experts of the Expert Group on Severe Accident Management (CEG-SAM).
We thank them all for their efficient assistance.

Project Manager at RRC "Kurchatov Institute" Dr. A. Borovoi

STRUCTURE of the DATABASE

MAJOR SECTIONS	SUBSECTIONS		APPENDICES
1. CONSTRUCTIONS AND MATERIALS OF UNIT #4 BEFORE THE ACCIDENT	1.1. Characteristics of nuclear fuel in Unit #4 before the accident		
	1.2. General view of the reactor		
	1.3. Designs and materials of the reactor core		
	1.4. Shielding structures of the reactor and their materials		
	1.5. Rooms involved into lava generation		
2. LAYOUT OF CONSTRUCTIONS AND MATERIALS HALF AN HOUR FOLLOWING THE ACCIDENT	2.1. Status of Unit 4 Rooms after the Active Accident Phase		
	2.2. Data about of materials dropped into the collapsed reactor		
	2.3. Types and Amounts of Materials Involved into Lava-generation Processes		
3. HEAT SOURCES INVOLVED INTO LAVA GENERATION	3.1. Decay heat of Unit 4 fuel after the accident		
	3.2. Heat Due to Graphite Burning		
	3.3. Steam-zirconium reaction		
4. PHYSICAL AND CHEMICAL PROCESSES DURING LAVA ENERATION	4.1. Lava generation	4.1.1. FCM in Room 305/2	4.1.1.1. Appendix (305/2 - 1).
			4.1.1.2. Appendix (305/2 - 1).
5. LAVA SPREADING	5.1. Horizontal lava flow. LFCM at +9 m level mark and in Rooms 217/2 and 017/2	5. 1.1. Lava in Room 304/3	5.1.1.1. Appendix (304/3 –1)
		5.1.2. Lava in Rooms 301/5 and 301/6.	5.1.2.1. Appendix (301/5 – 1)
		5.1.3. Lava in Rooms 217/2 and 017/2.	5.1.3.1. Appendix (217/2 – 1)
	5.2. Large and minor vertical flows	5.2.1. Lava in Room 210/7.	5.2.1.1. Appendix (210/7 – 1)
		5.2.2. Lava in Room 210/6.	5.2.2.1. Appendix (210/6 – 1)
		5.2.3. Lava in Rooms PSP -2.	5.2.3.1. Appendix (PSP-2)
		5.2.4. Lava in Rooms PSP -1.	5.2.4.1. Appendix (PSP-1).
	5.3. Metal spreading		
	5.4. Lava spreading (Fig.)		

1. CONSTRUCTIONS AND MATERIALS OF UNIT #4 BEFORE THE ACCIDENT

1.1. Characteristics of Nuclear Fuel in Unit 4 before the accident

Nuclear Fuel before the accident [1].

Table 1.1. Nuclear Fuel in Unit 4 Rooms before the accident

Room	Function	Amount of Nuclear Fuel (by uranium), ton
504/2	Reactor Shaft	190.2
505/4	Fuel Cassette Cooling Pool	14.8
914/2	Central Hall	5.5
503/2	Fresh Fuel Preparation Facility	4.1
Total		214.6

Characteristics of main radionuclides being in Unit 4 fuel before the accident (Tables 1. 2 and 1.3), [1- 4]

Table 1.2. Characteristics of principal β and γ-active nuclides in Unit 4 fuel before the accident

	Radionuclide	Half-life	Total activity (Bq)	Activity per 1 g U (Bq)
1	^{89}Sr	50,5 d	$4,0\times10^{18}$	$2,1\times10^{10}$
2	$^{90}Sr + ^{90}Y$	28,6 y	$2,3\times10^{17}$	$1,2\times10^{9}$
3	^{95}Zr	64 d	$5,8\times10^{18}$	$3,05\times10^{10}$
4	^{95}Nb	35 d	$5,7\times10^{18}$	$3,0\times10^{10}$
5	^{103}Ru	39 d	$3,8\times10^{18}$	$2,0\times10^{10}$
6	$^{106}Ru + ^{106}Rh$	368 d	$8,6\times10^{17}$	$4,5\times10^{9}$
7	^{125}Sb	2,77 y	$1,5\times10^{16}$	$7,9\times10^{7}$
8	^{134}Cs	2,06 y	$1,7\times10^{17}$	$8,9\times10^{8}$
9	$^{137}Cs + ^{137m}Ba$	30 y	$2,6\times10^{17}$	$1,37\times10^{9}$
10	$^{144}Ce + ^{144}Pr$	284 d	$3,9\times10^{18}$	$2,1\times10^{10}$
11	^{154}Eu	8,8 y	$1,4\times10^{16}$	$7,4\times10^{7}$

Table 1.3. Characteristics of principal α-active nuclides in Unit 4 fuel before the Accident

	Radionuclide	Half-life	Total activity (Bq)	Activity per 1 gU, (Bq)	Total mass (kg)
1	^{238}Pu	87,7 y	$1,3\times10^{15}$	$6,8\times10^{6}$	2
2	^{239}Pu	$2,4\times10^{4}$ y	$9,2\times10^{14}$	$4,8\times10^{6}$	412
3	^{240}Pu	$6,56\times10^{3}$ y	$1,5\times10^{15}$	$7,8\times10^{6}$	185
4	^{241}Pu[1]	14,4 y	$1,8\times10^{17}$	$9,4\times10^{8}$	48
5	^{242}Pu	$3,75\times10^{5}$ y	$2,9\times10^{12}$	$1,5\times10^{4}$	20
6	^{241}Am	433 y	$1,6\times10^{14}$	$8,4\times10^{5}$	12
7	^{243}Am	$7,38\times10^{3}$	$9,7\times10^{12}$	$5,1\times10^{4}$	1,3
8	^{242}Cm	163 d	$4,3\times10^{16}$	$2,3\times10^{8}$	0,35
9	^{244}Cm	18,1 y	$4,0\times10^{14}$	$2,1\times10^{6}$	0,13

[1] ^{241}Pu – a virtually pure β-emitter – has been included into this Table due to its transition into α-emitter (^{241}Am) after β-decay.

The dependence of decay heat and activity of Unit 4 fuel on the time elapsed after the accident taking into account the release of noble gases (Fig.1, [1])

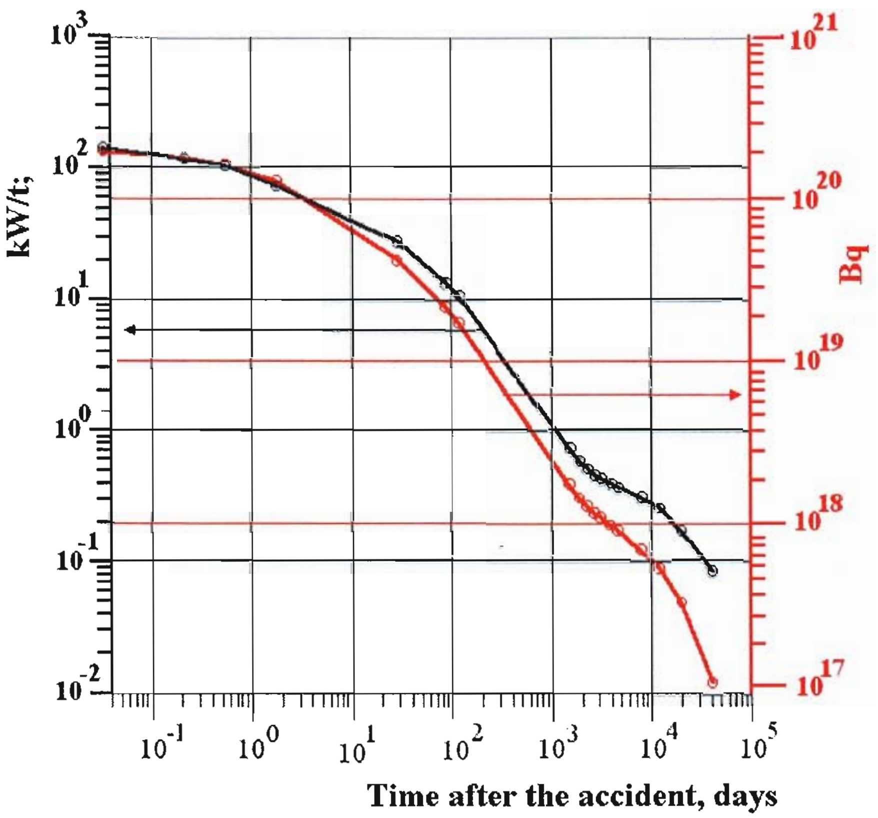


Fig. 1 Dependence of decay heat (upper curve) and activity (bottom curve) of Unit 4 fuel on the time elapsed after the accident

The decay heat power of Chernobyl NPP Unit 4 fuel during the early post-accident days achieved via calculations based on the data of References [2 - 4] (Table 4, Fig. 2)

Table 4. Decay heat power of fuel of Chernobyl NPP Unit 4 reactor during the early post-accident days

Time after accident, h	Decay heat power, kW/t (U)		
	Total	Volatile components	Taking into account the release of volatile components
0	295	65	230
6	135	20	115
12	117	17	100
18	108	15	93
24	102	13,5	89
36	92	12	80
48	86	10,5	75,5
60	81	9,2	71,8
72	76	8	68
84	72	7	65
96	69	6	63
108	66	6	60
120	64	5	59
132	61	5	56
144	59	4	55
156	57	4	53
168	56	3,5	52,5
180	54	3,5	50,5

Time after accident, h	Decay heat power, kW/t (U)		
	Total	Volatile components	Taking into account the release of volatile components
192	53	3	50
204	51	3	48
216	50	2,5	47,5
228	49	2	47
240	48	2	46
252	47	2	45
264	46	2	44
276	45	1,5	43,5
288	44	1,5	42,5
300	43	1,5	41,5

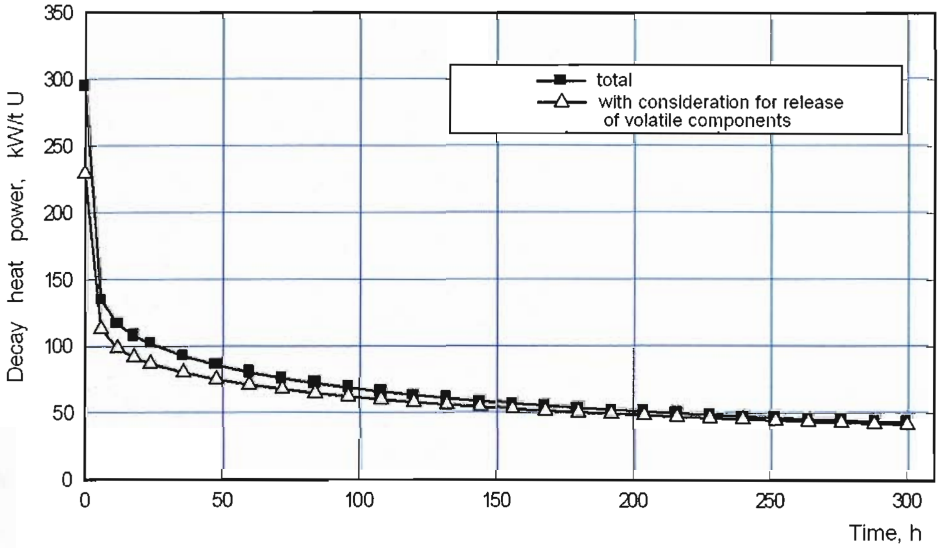


Fig. 1.2. Decay heat power of fuel of Chernobyl NPP Unit 4 reactor after the accident

REFERENCES

1. *The "Shelter" Current Safety Analysis and Forecast Estimates for the Situation Development* (2001) A.A. Borovoi (responsible exec.), ISTC "Shelter" Report, arch. n°3836, Chernobyl, P. 337 (in Russian).

2. Borovoi A.A., Dovbenko A.A. and Stroganov A.A. (1988) *Fuel of Chernobyl NPP Unit 4 (Reference Book)*, Report of CRE of Kurchatov IAE, Chernobyl (in Russian)

3. Begichev S.N., Borovoi A.A., Burlakov E.V., Gavrilov S.L., *et al.* (1990) *Reactor Fuel of the Chernobyl NPP Unit 4 (Desk Reference Book)*, IAE's Preprint n°5268/3, Moscow, P.21 (in Russian).

4. Borovoi A.A., Dovbenko A.A., Smoliankina M. V. and Stroganov, A. A. (1991) *Determining Nuclear-Physical Characteristics of Fuel of the Chernobyl NPP Unit 4*, Report of IBRAE RAS, inv. n°52/11-20, Moscow, P. 63 (in Russian).

1.2. General view of the reactor (RBMK-1000)

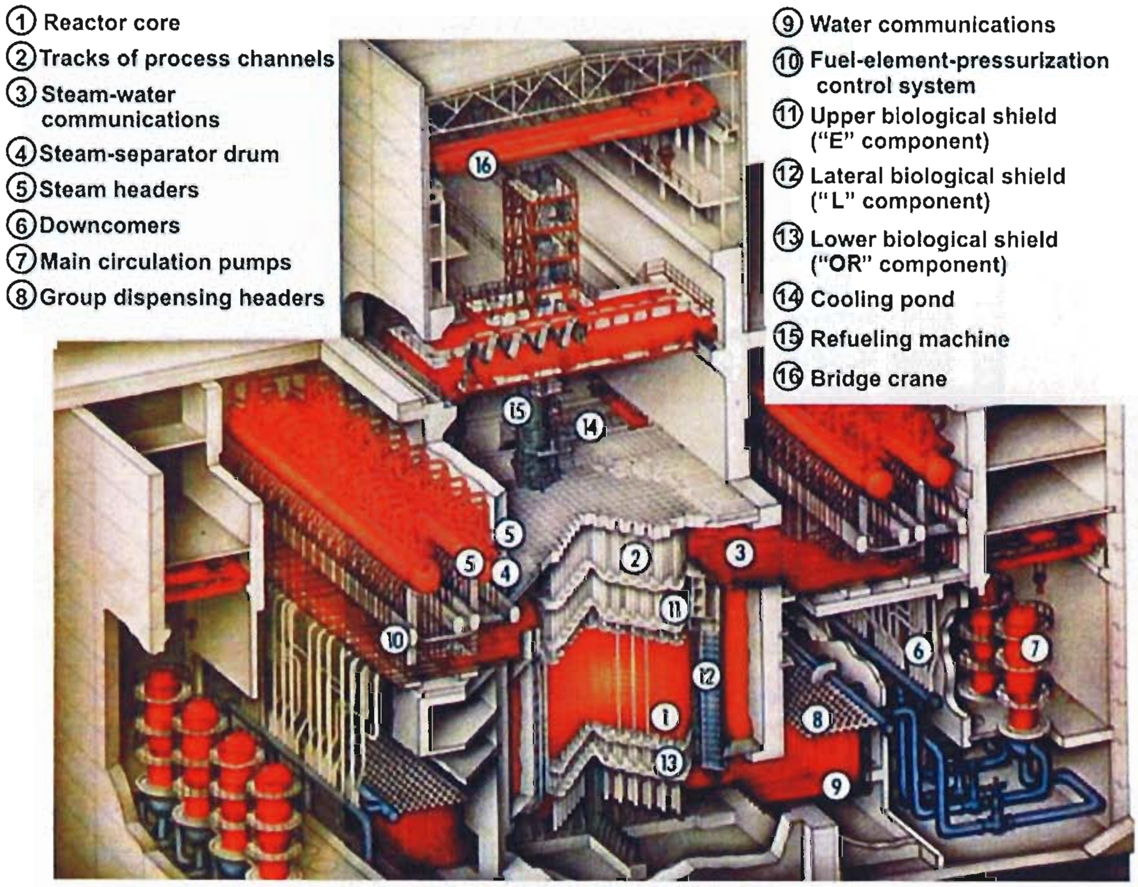


Fig. 1.3

1.3. Designs and materials of the reactor Core [1 – 3]

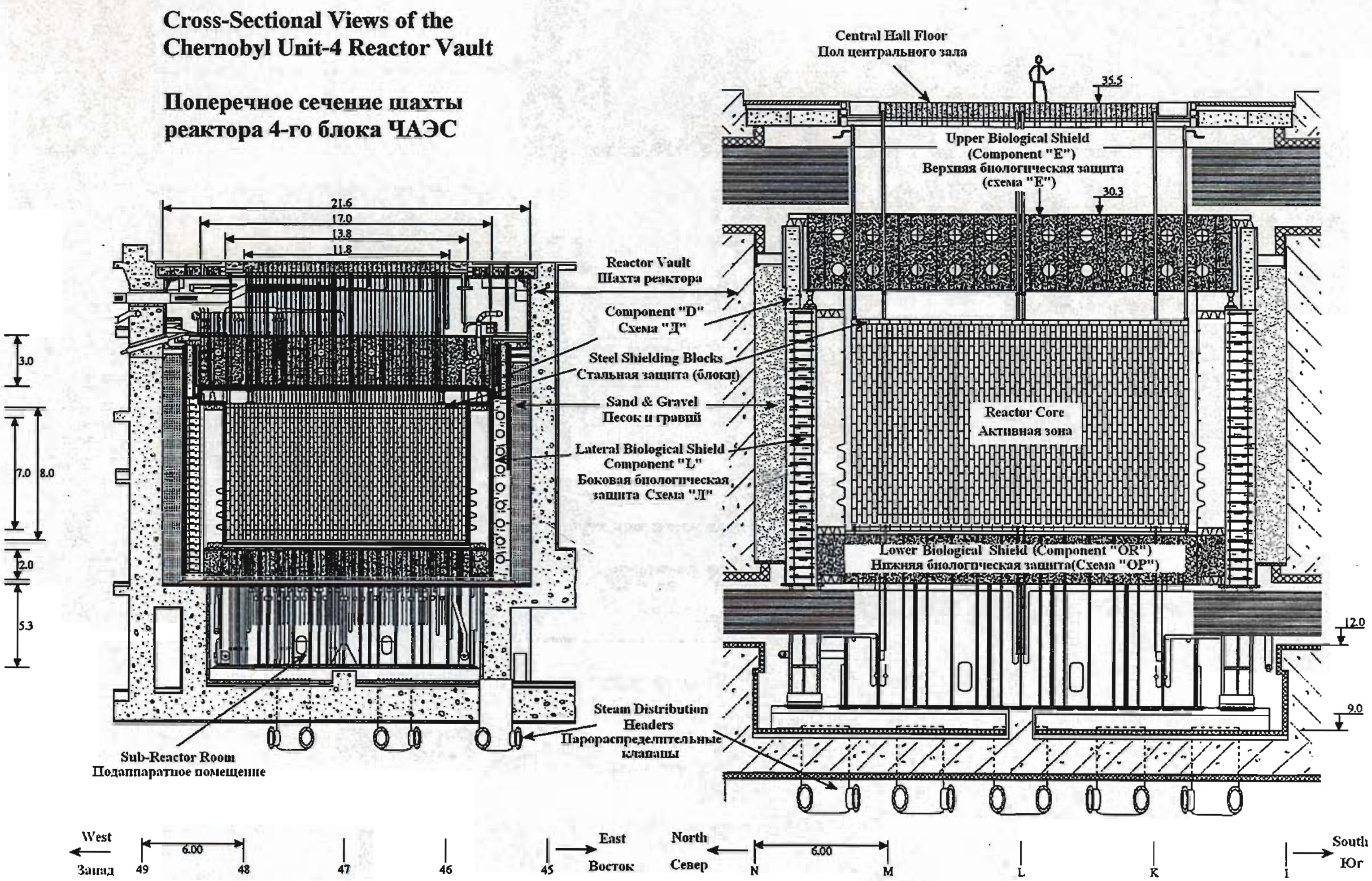


Fig. 1.4

1.3.1. Nuclear Fuel [1- 3].

By the accident instant the reactor core comprised: 1659 Fuel Assemblies (FAs) (Fig. 1.4), 1 additional absorber and 1 non-loaded channel. Most of FAs were of the first fuel lifetime (UO_2, ^{235}U enriched up to 2%). Mean fuel burnup was 12 MW·day/kg (U). The core also contained some amount of fresh fuel. Uranium mass in each FA equaled 0,1147 t. Total mass of the fuel loaded into the core made up 190,2 t.

RBMK's FAs consist of two (the upper and the lower) fragments, each of them including 18 rod-type Fuel Elements (FEs) (Fig. 1.5) comprising pellets of sintered uranium dioxide confined inside a zirconium-alloy cladding (Zirconium – 1,0% Niobium alloy - Zircaloy-1.0). The height of active fuel part in FE is 3.5 m; the total height of RBMK core is 7,0 m. FE diameter equals 13,5 mm. FE arrangement in FA with the required pitch (minimal gap between FEs being 1.7 mm) is supported by spacer grids. The outer covering of the channel is made from a Zirconium-2,5% Niobium alloy (Zircaloy-2,5)

Zircaloy-2,5 and Zircaloy-1,0 in the core are 103 tones and 74 tones respectably.

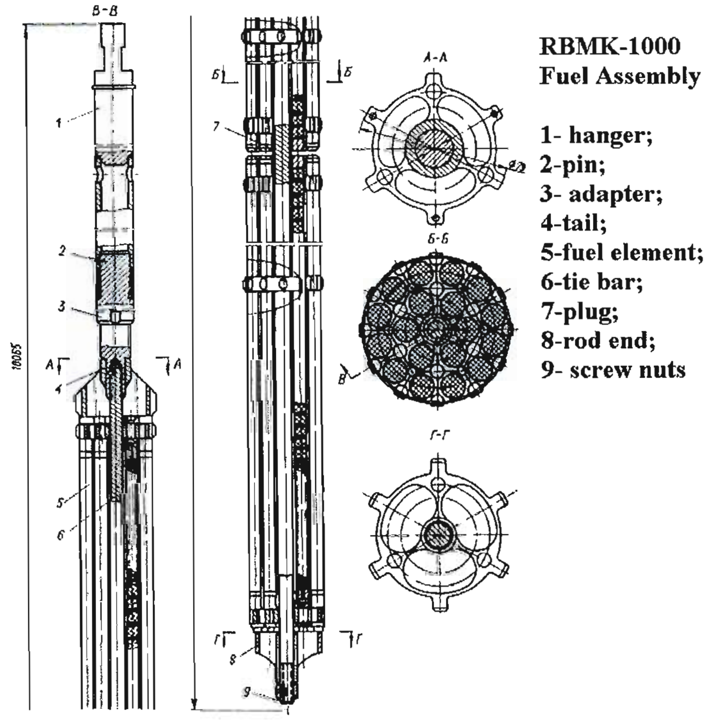


Fig. 1.5

1.3.2. Reactor Graphite Stack

The graphite stack of RBMK-1000 represents a vertical cylinder comprising 2488 graphite columns of about 1500 t integral mass. Graphite columns are assembled of individual 250×250 mm graphite blocks of 1650 kg/m^3 density. The blocks have inside openings 114-mm in diameter forming special tracks inside 2044 columns for arrangement of fuel channels and special channels. 444 columns of lateral reflector are filled with compact graphite rods.

REFERENCES

1. *The "Shelter" Current Safety Analysis and Forecast Estimates for the Situation Development* (2001) Responsible Executor: Borovoi A.A. Report of ISTC "Shelter", Arch. #3836, Chernobyl, P.337 (in Russian).

2. *Chernobyl Nuclear Power Plant: "Technical Specification of Facilities, Equipment and Systems"* (1975), Minenergo of USSR, Kiev (restricted) (in Russian).

3. Dollezhal N.A. and Emelianov I. Ja. (1980) *Channel-type Nuclear Power Reactor*, Atomizdat, Moscow, P.208 (in Russian).

1.4. Shielding constructions of the reactor vault and their materials ([1- 4]).

On the circuit (Fig. 1.5) the basic constructions of the reactor vault before the accident are shown.

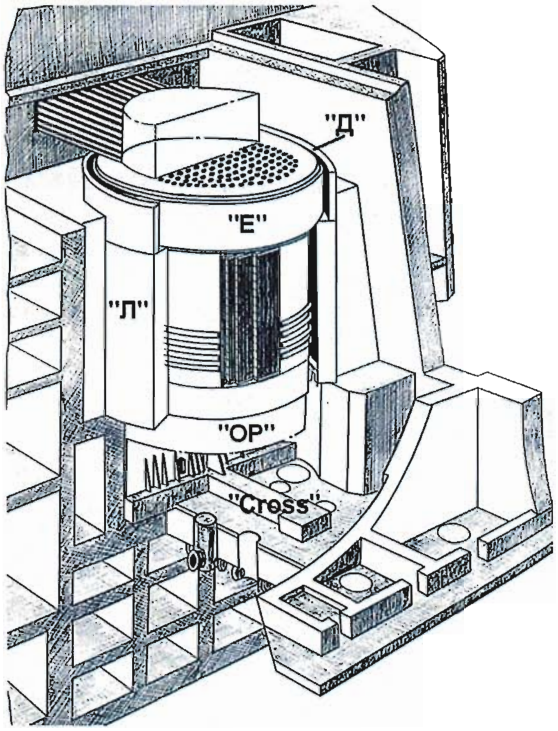


Figure 1.5. Constructions of the reactor vault before the accident:
"E" – upper plate of biological shield (∅ =17.4 m, H=3 m)
"Д"(D) – lateral (water) biological shield
"Л"(L) – lateral (water) biological shield
"OP"(OR) – lower plate of biological shield
"Cross" - metal construction of "C" component and a reinforced-concrete "cross"(Room #305/2)

Scheme "E" – upper plate of biological shield (Fig. 1.5)

The upper metal construction of RBMK-1000 is made of sheet steel 40-mm in thick filled with a mixture of serpentine broken stones. Covering height is 2800 mm; density is 1700 kg/m^3. Total mass of serpentine covering equals 700 t.

Scheme "Л"(L) – lateral (water) biological shield (Fig. 1.5)

The tank represents an annular-section cylinder reservoir 19 m in outer diameter, 16,6 m in inner diameter and 7 m height, made of steel 10ХСНД, 30 mm in thick and water capacity of about 500t.

Scheme "OP"(OR) – lower plate of biological shield (Fig. 1.5)

"OR" represents a wide cylinder 14500 mm in diameter and 2000 mm in height with two lids (the upper lid and the bottom lid) connected in between by stiffening ribs and BWC tubes. The area between the lids was filled with serpentinite mixture (waste of asbestos-concentration plants) - Fig. 1.6.

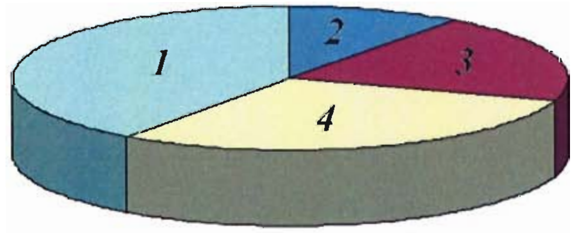


Fig. 1.6. Materials of "OR" component.

1 - Steel 10XH1M – 500 t
2 - Steel OX18H10T – 200 t
3 – Black steel – 230 t
4 - Serpentinite mixture – 410 t
In total: 1340 t

See 2.3.

REFERENCES

1. *The "Shelter" Current Safety Analysis and Forecast Estimates for the Situation Development* (2001) Responsible Executor: Borovoi A.A. Report of ISTC “Shelter”, Arch. #3836, Chernobyl, P.337 (in Russian).

2. *Chernobyl Nuclear Power Plant: “Technical Specification of Facilities, Equipment and Systems”* (1975), Minenergo of USSR, Kiev (restricted) (in Russian).

3. Dollezhal N.A. and Emelianov I. Ja. (1980) *Channel-type Nuclear Power Reactor*, Atomizdat, Moscow, P.208 (in Russian).

4. S. Bogatov, A. Borovoi, S. Gavrilov, A. Lagunenko, E. Pazukhin (2005)
Half an hour after the beginning of the accident, OKPRINT, Moscow, p.22.

1.5. Room involved into lava was generation [1, 2].

As long as the main post-accident LFCM generation processes occurred within the under-reactor room #305/2, its view from above and a brief description are given below (Fig. 1.7, 1.8).

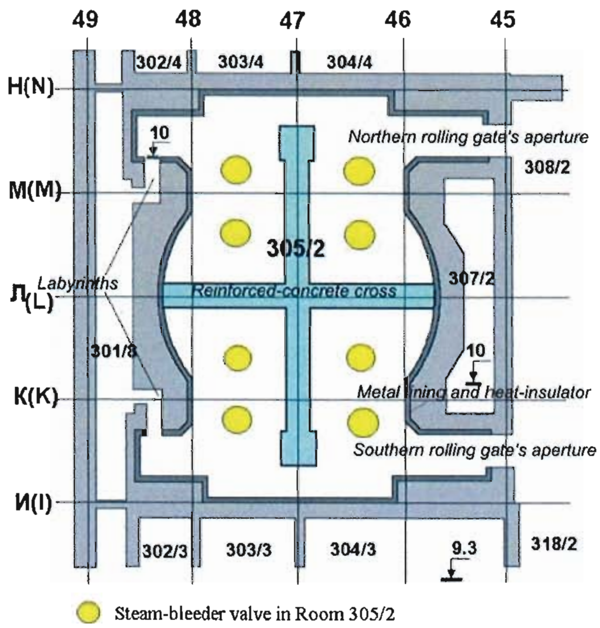


Fig. 1.7. View from above of Room #305/2 and the adjacent rooms (Chernobyl NPP Unit 4).

Before the accident Room #305/2 was confined on top by the bottom metal construction of the reactor – the so-called "reactor basement" or "OR" component.

On the north and on the south Room #305/2 sided with Rooms #404/4 and #404/3 (lower water-communication boxes). Room #305/2's floor represented a steel sheet in 0.3–0.35 m above the structural floor (there is a heat shielding between them). The room's walls were also faced with steel sheets.

The northern and the southern rolling gates leading to Room #308/2 were installed at the southeastern and the northeastern corners of Room #305/2. Special "labyrinths" connecting the under-reactor room with Corridor #301/8 were located at the southwestern and the northwestern corners of Room #305/2.

"OR" component bore on "C" component – a metal structure assembled of steel beams 5,3 m in height that formed a "cross" which center passed via "OR" component's center.
In its turn, "C" component bore on a reinforced concrete "cross" with a beam width (viewed from above) of 1,4 м and 1 m height above the floor level (fig. 1.7, 1.8).

There were inlet openings of 8 steam bleeder valves in the floor of Room #305/2 arranged symmetrically relative to axis #47 and row "L". Communications of the reactor bottom were concentrated in Room #305/2. Tubes of Bottom Water Communications (BWC), which number corresponded to that of process channels, got out of the bottom edge of "OR" component.

Fig. 1.8. Room 305/2 before accident

REFERENCES

1. *The "Shelter" Current Safety Analysis and Forecast Estimates for the Situation Development* (2001) Responsible Executor: Borovoi A.A. Report of ISTC "Shelter", Arch. #3836, Chernobyl, P.337 (in Russian).

2. *Chernobyl Nuclear Power Plant: "Technical Specification of Facilities, Equipment and Systems"* (1975), Minenergo of USSR, Kiev (restricted) (in Russian).

3. Dollezhal N.A. and Emelianov I. Ja. (1980) *Channel-type Nuclear Power Reactor*, Atomizdat, Moscow, P.208 (in Russian).

4. S. Bogatov, A. Borovoi, S. Gavrilov, A. Lagunenko, E. Pazukhin (2005) *Half an hour after the beginning of the accident,* OKPRINT, Moscow, P.22.

2. LAYOUT OF CONSTRUCTIONS AND MATERIALS HALF AN HOUR FOLLOWING THE ACCIDENT

2.1. Status of Unit 4 Rooms after the Active Accident Phase Completion (based on the investigations of 1986 – 2005) [1, 2].

A variety of investigations performed since the accident time have allowed establishing quite reliably the degree and the geometry of destruction of building structures and the condition of Unit 4 materials including those of the reactor.

The data obtained for CH, reactor vault (room #504/2) and under-reactor room #305/2 are presented in this paper.

The post-explosion geometry of these rooms is demonstrated in Figs. 2.1 and 2.2. The Shelter sectional view along the axis 46 (south – north) in Fig. 2.1 illustrates large-scale destructions inside Unit 4. In particular, due to descending by about 4 m of metal construction of "OR" component, the under-reactor room #305/2 became spatially unified with the reactor vault.

Fragments of the former core, Lava-like FCM (LFCM) and fuel dust are the main modifications of Fuel Containing Materials (FCM) in these rooms.

Central Hall above the Reactor Vault (Fig. 2.1, 2. 2).

The upper plate of the reactor biological shield ("E" component) - together with tubes of Steam-Water Communications (SWC), the rest of technological channels and debris of reinforced-concrete structures stuck between the upper steel extension channels - is located on the edge at 15° angle from vertical bearing on metal construction of "D" component on the north-east, and on a reinforced-concrete plate lying on "D" component on the south-west. The bottom edge of "E" component has a level mark of +25.000, the upper one +43.000. This means that its geometric center was lifted up to ~ 5 m, as compared to the before-accident level.

Virtually all space between "E" and "D" components and reactor vault walls on the northwest is filled with the upper steel extension channels and twisted SWC tubes with stuck fragments of building structures and equipment. The central part of the former bottom surface of "E" component seems to have lost virtually all its process channels. Those channels were torn off at the very basement, only a minor fragment over the peripheral ring of "E" component being available. The visually observed fragment of process channels (the "Elena's hair") is located in the area with the following coordinates: 44-46, L-N About 40 channels hang down into the reactor area from "E" component.

In total, 10 to 30 t of fuel (U) can be located on "E" component.

The bridge of the refueling machine leans against the CH's western wall. Its flank is found on the section of the southern steam-separator drum's wall. The refueling machine's container was broken, its bottom fragment lying on the floor above Room #2005/2 in "K"-row area.

The steam-separator drum's walls facing CH were destroyed. No reinforced-concrete panels that formed the CH's northern wall below +46.000 level mark and in the axes 45 – 49 are presently available on their standard places. The remainder of the wall of the northern steam-separator drum (axes 45 - 49) was pressed towards Room #804/4.

A wall fragment (reinforced-concrete plate), which had separated the northern steam-separator drum's room from CH, moved into the reactor vault together with lining.

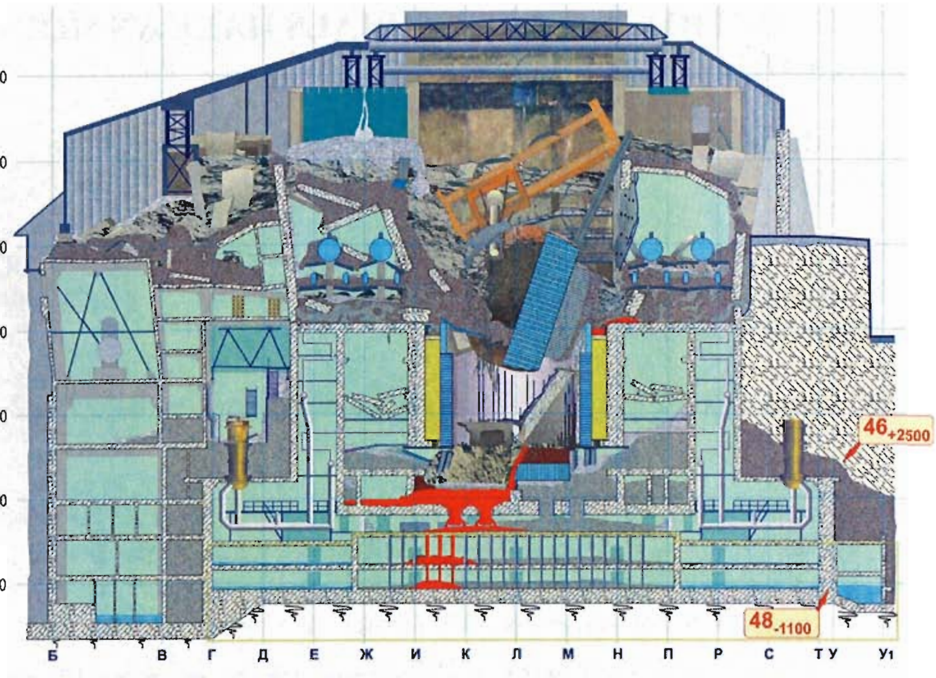


Fig. 2.1. Sectional view of the Shelter (south-north). Solidified LFCM flows are indicated in red.

Reactor Vault and Under-reactor Room (level marks 9 - 24 m, Fig. 2.1 – 2.3, 4.1).

As said above, as a result of the accident the bottom plate or the reactor basement ("OR" component) descended, and the reactor vault became unified with the under-reactor room #305/2.

At present "OR" is located 3.85 m below its "normal" position (direct measurement [7]). Its upper generatrix close to the northern additional support is at +14.100 level mark. The bottom generatrix is at +12.100 level mark, correspondingly.

While creation the Shelter, large amounts of concrete (the so-called "fresh concrete") flew into the reactor vault and Room #305/2, solidified and hided a portion of constructions' debris and FCM.

Information on Room #305/2 was collected in 1988 – 91 using special holes and remote-control mechanisms. Due to high radiation fields survey teams could stay in Room #305/2 for an extremely limited period of time. Only after 1996 specialists managed to make a detailed video filming of the room, take many FCM samples, generalize and verify previous information. As the result, it has become possible to pass from general descriptions of the room to characteristics of individual fuel accumulations therein. However up to present several rather extended areas in Room #305/2 still remain a "*terra incognito*".

For purposes of this work it is rather important that no southeastern sector of "OR" component (see red dotted line in Fig. 3) is presently available because during the second accident phase that component fully melted. Today a flat concrete pad is found on its place (level marks +11.000 - +11.500). The missing sector area is: 100° – 110°.

On top of "OR" component (on the "wreckage") in the northeastern sector a reinforced-concrete plate, fallen from CH, is found at 60°-angle (point *7* at Fig.2.3).

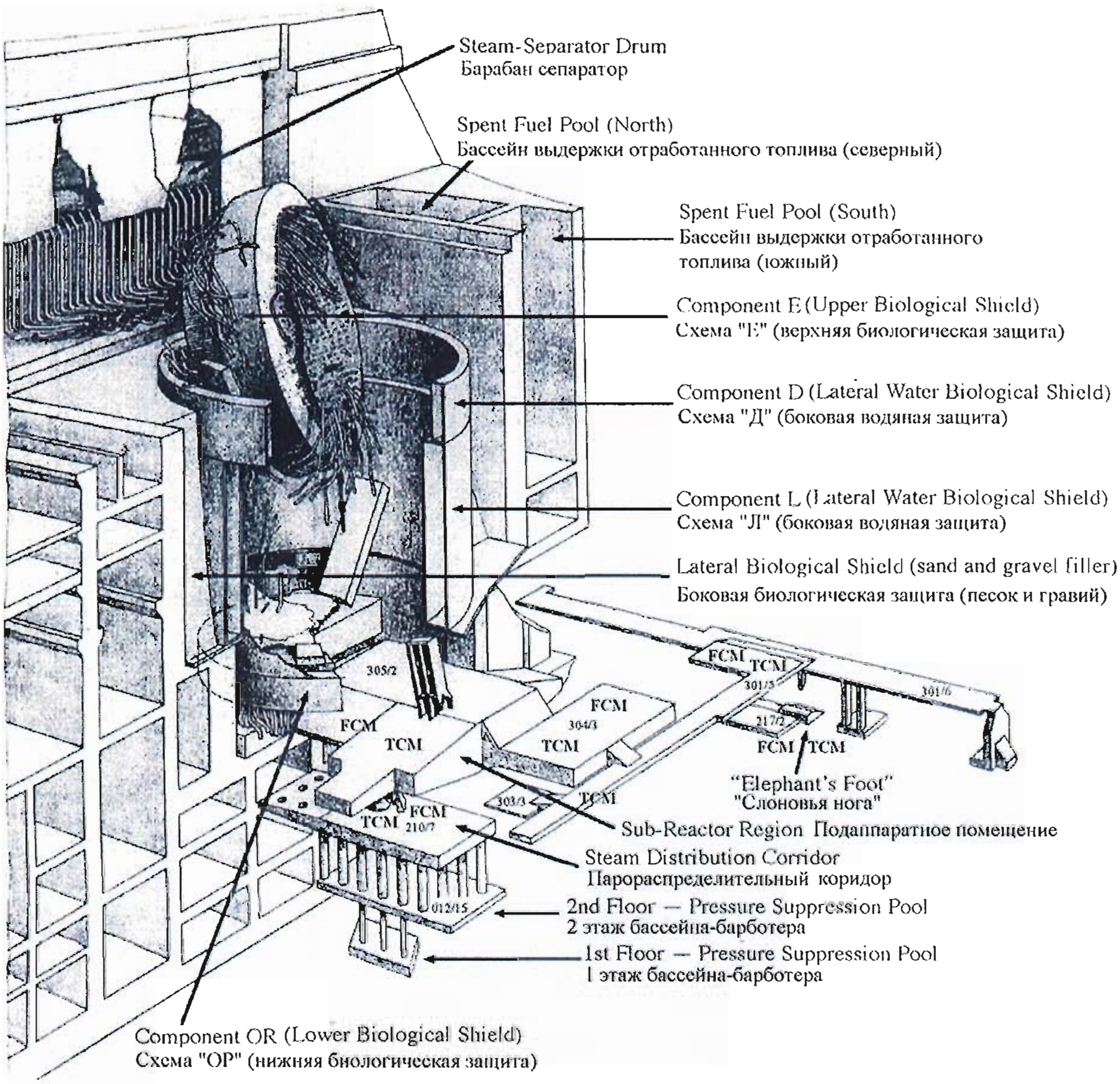
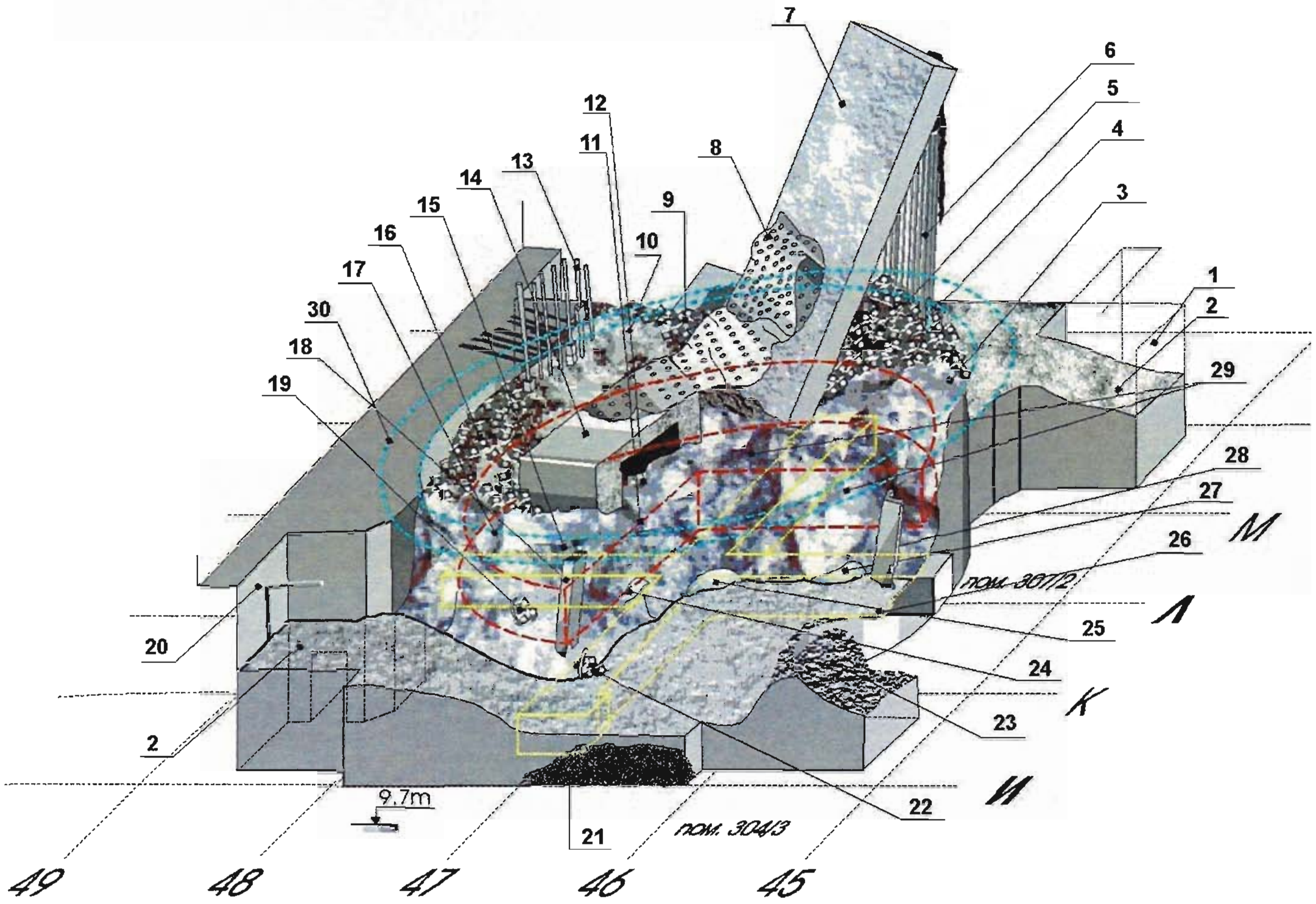


Figure 2.2. Unit 4 constructions after the accident (based on the results of investigations). Several FCM accumulations are indicated.

Reinforced concrete structure by size (in plan), approximately, of 5x2 m and about 2 m of height (point *14* at Fig.2.3) lies at wall verge in southeastern sector.

The wall separating Rooms #304/3 and #305/2 is arched towards Room #304/3 and cracked; at some spots in Room #304/3 the outer layer of concrete was spilled, and the reinforcement is bared. The upper wall fragment is destroyed and inclined towards Room #305/2, the maximum inclination being about 5°. In the area of axis 45_{+2000} on Room #304/3's side the wall has a deep vertical fracture.



1 – Northern rolling gate's aperture
2 –"Fresh concrete" surface
3 – Filling material from the inter-compensatory gap
4 - "Stalagmite"
5- Area filled with core fragments
6 – Cooling channels
7 – Inclined reinforced-concrete plate
8 – Deformed metal sheet
9 - Wreckage fragment (reinforced concrete construction?), (level mark +17.000)
10 - "Trench"
11 - "OP"(OR) component
12 – Hole (level mark +13.000)
13 – Reflector's cooling channels
14 –Reinforced-concrete construction
15 - Wreckage element's fragment (reinforced concrete construction?)
16 –Fuel assemblies with survived fuel elements
17 – Edge of "OP"(OR) component
18 – Southern additional support
19 –Fragments of fuel assemblies
20 – Western wall of Room #305/2
21 – FCM (break in the wall)
22- Graphite blocks and tube fragments (process channels?)
23 – Gravel pile;
24,25,27 – Breaches in the wall from re-melted substance
26 – Burned area in the wall
28 - Column
29 – Wall of a loose re-melted substance
30 – Projection of tank "L" to +15.950 level mark

Figure 2.3. Location of constructions and FCM in Room #305/2.

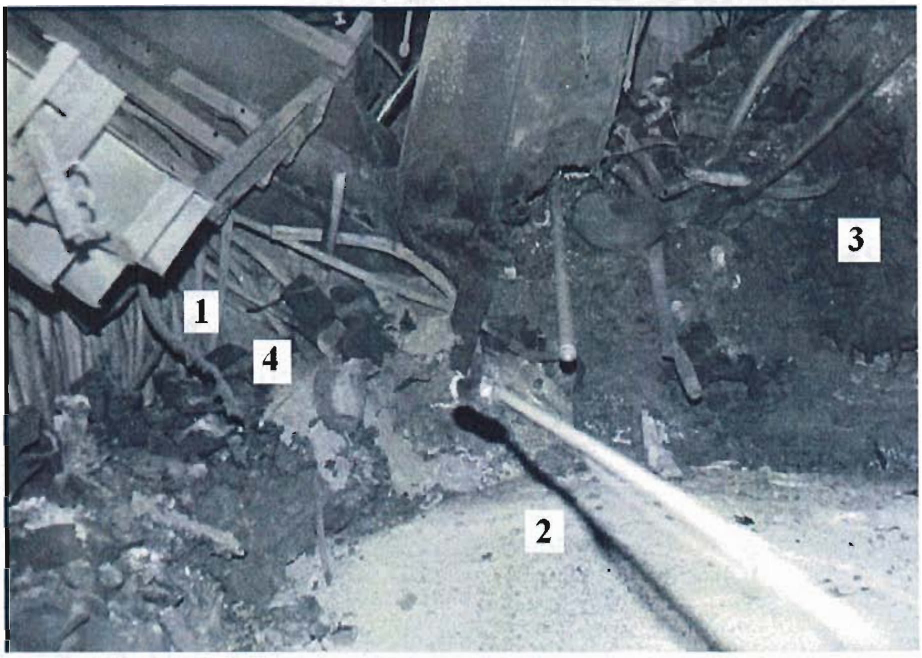


Figure 2.4. Southeastern part of room 305/2

1.Cooling channels

2. "Fresh concrete"

3. *Wall of a loose re-melted substance*

4. Graphite, serpentinite.

REFERENCES

1. *The "Shelter" Current Safety Analysis and Forecast Estimates for the Situation Development* (2001) Responsible Executor: Borovoi A.A. Report of ISTC "Shelter", Arch. #3836, Chernobyl, P.337 (in Russian).

2. S. Bogatov, A. Borovoi, S. Gavrilov, A. Lagunenko, E. Pazukhin (2005) Half an hour after the beginning of the accident, *OKPRINT, Moscow, P.22.*

2.2. Data about of materials dropped into the collapsed reactor

At the very first meeting of the special Governmental Commission by the night of April 26 a decision was taken on dropping some materials down from helicopters into the open reactor vault for purposes of the accident localization. At a later time, after consultations, the list of those materials was defined more exactly [1, 2]. Some of them (boron compounds, in particular, B_4C) consisted of neutron absorbers and must have ensured nuclear safety. Other-type materials (clay, sand, dolomite) were to create a filtering layer and diminish radiation release. It was also expected that dolomite $(MgCa)(CO_3)_2$, after reaching high-temperature areas, would disintegrate forming carbon dioxide. That could have ensured "gas covering", i.e. could have deprived burning graphite of oxygen.

Finally, the last component (lead) was to take up the released heat, melt and prevent the "Chinese syndrome" development.

Table 2.1 contains some characteristics of dropped down materials. The dynamics of material dropping down before May 2, 1986, is illustrated in Figure 2.5.

Table 2.1. Description of dry and liquid materials dropped into the reactor wreck by 18.06.1986

Material	Chemical formula	Mass (t)
Boron carbide	B_4C	~40
Dolomite	$MgCa(CO_3)_2$	~1200*
Marble aggregate, clay, sand, etc.	-	~3500**
Lead (grit +ingots, etc.)	Pb	~6700***
Three-sodium phosphate (solution)	Na_3PO_4	~2500
Solutions (dust-suppressing compositions)	Latex SKS-65gp, "grain" (waste of pulp-and paper industry), liquid glass, polyvinyl alcohol, caoutchouc SKTN, etc.	~2700
Total		~16600

* during the active phase ~ 600 t of materials were dropped;
** about 1800 t of clay and sand were dropped during the active phase;
*** in the course of the first five post-accident days 2400 t of lead were dropped;
By 29.06.1986 1890 t of zeolite were additionally dropped.

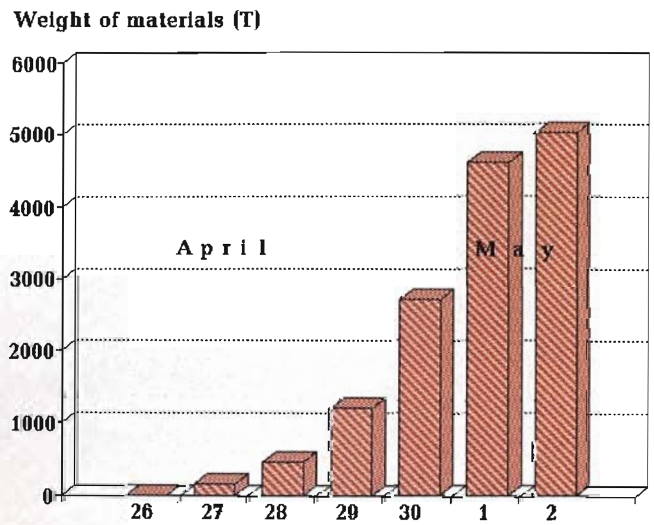


Fig. 2.5. Dynamics of material dropping down

The effects of those materials on the processes in destroyed fuel were used as a basis of the first model (more precisely, of the first description) of the accident active phase progression. The model was reported by the USSR's delegation at the IAEA Post-accident Review Meeting [1].

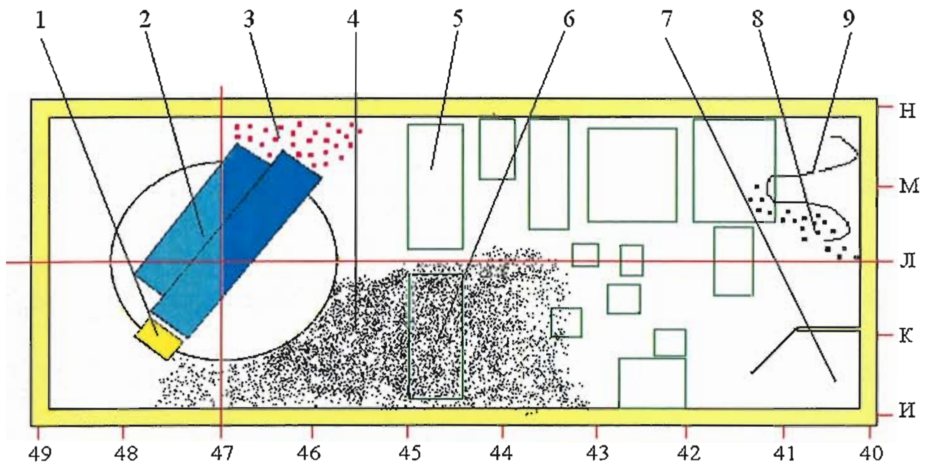
"At the first phase of the accident a release of dispersed fuel from destroyed reactor occurred. Radionuclide composition of the release at that phase approximately corresponded to their concentrations in irradiated fuel but was enriched with volatile nuclides of iodine, tellurium, cesium and noble gases.
During the second phase (April 26 through May 2, 1986) the release rate beyond the damaged unit decreased thanks to the undertaken measures on graphite burning stopping and release filtration...
The third accident phase characterized by a rapid increase in fission product release rate beyond the reactor unit... That was due to fuel heating in the core up to 1700 °C and more due to decay heat.
For the final – the fourth – accident phase (after May 6) a rapid release decrease was typical".

More detailed description of the model under consideration can be found in several subsequent publications.

The main processes were explained in that model by the effects of dropped down materials. In the authors' opinion, at first the cooling process took place due to absorption by lead of a portion of released heat. Next covering of the reactor vault with loose materials caused release decrease. Simultaneously, due to a decrease in heat pick-up by airflow, fuel temperature increased. At the active phase end a "break of radioactivity" through the layer of materials of the covering occurred, i.e. the release increase; after that the release decreased drastically. It seemed then that the above-described dynamics of release had explained entirely the observed situation.

However that – quite orderly and logic in 1986 - model was completely refused already in the course of the first years of systematic investigations inside the "Shelter". According to those investigations, the main assumption of the reactor vault filling with a thick layer of dropped down materials – used as a basis of the initial four-phase model – turned out to be untrue.

Some indications for that fact were already available in 1986. For example, on some photos of the Central Hall (CH) it can be clearly seen that CH is literally filled with dropped down materials, which formed many-meter "hills" (see e.g. Reference [3] and Fig. 2.6). At a later time that fact was confirmed by survey teams, which had penetrated into CH after a long preparative period. Nevertheless, the possibility of location of a portion of dropped down materials in the reactor vault still must not be ruled out.



Legend
1- reinforced-concrete plate; 2-metal construction of scheme "E"; 3-pipes of bottom water communications; 4-wreck of materials dropped down from helicopters; 5- northern cooling pond; 6- southern cooling pond; 7- control room; 8-core fragments; 9-part of metal construction, scheme "КЖ"

Figure 2.6. - Central Hall of Unit 4 after the accident (scheme)

In the mid-1988s the investigators managed to observe directly the reactor vault contents using optical devices and TV cameras [4]. Virtually no dropped down materials were found therein. However, one may also argue: when dropped down materials had reached high-temperature areas, they melted and spread over bottom reactor rooms. Such a process could have occurred indeed, for large amounts of solidified lava-like fuel-containing masses were discovered on bottom floors.

In such a situation lead could have been a proper indicator of the fact that not only reactor constructions, concrete, etc. formed the Unit 4 "lavas", but also materials dropped down from helicopters. However so far virtually no lead has been discovered in the "lava" despite the fact that thousands of tons of that material were dropped down.

Table 2.2 [3] comprises data on lead contents in different types of Lava-like Fuel-Containing Materials (LFCM).

Table 2.2. Lead contents in LFCM samples

LFCM type	Coal-black ceramics	Chocolate-brown ceramics	Slag from piles in PSP*	Pumice from PSP*
Pb (weight %)	(6,5 - 110) $\times 10^{-3}$	(12-240) $\times 10^{-3}$	(1,1 ±0,1) $\times 10^{-2}$	(1,2 ± 0,2) $\times 10^{-2}$

*PSP – Pressure Suppression Pool

If the total LFCM mass is estimated today at ~ 1200 t, the integral amount of lead in the "lava" is <3 t of almost 7 thousand t dropped down from helicopters (i.e., approximately the 5×10^{-4}th fraction!). Thus virtually no lead reached the reactor vault. Consequently, if other components of the dropped materials had reached the reactor vault, their amount could not have been significant enough to have a decisive effect on the release behavior.

Such are the known-by-now facts.

What factors did impede the pilots to fulfill their task?

Most likely, both the risk of colliding with the 150-m ventilation duct and enormously radioactive smoke column did not favor successful "bombing". One more reason is also conceivable: the scheme "E" released by explosion rose almost vertically and –together with the pulled out jumble of pipes – created a specific "shield" that threw the dropping down materials to CH.

There was a bright luminous spot in CH nearby the reactor vault (hot graphite?). In Fig. 2.6 its location is indicated by figure "4". That spot could have been recognized as the vault opening, and the pilots could have directed the dropping materials to that spot. Such a version is discussed in detail in a study by A. Sich [5].

So far the data on dropped down materials have been published more than once (see e.g., References [4], [6] and [7]). Nevertheless, the model based on crucial effects of those materials on fuel behavior in the destroyed reactor (see, e.g., Ref. [8]) is still used and appears from time to time in various articles and reviews (e.g., Reference [9]).

Thus, despite undoubtedly heroic efforts of the pilots, their attempts on reactor filling with dropped down materials failed.

Whether their efforts were useless?

There are opinions that they were even harmful. For example, a viewpoint is known that, as a result of dropping tens of thousands of tons of materials onto Unit 4, damaged constructions could have been destroyed further. That could have produced negative effects on stability of the "Object Shelter" at a later time.

We would like, however, to point out positive effects of the measure under consideration (recall that only the technical side of the problem is addressed here).

Boron-containing materials attained CH, wherein large amounts of reactor core fragments and fuel dust had been thrown in. After covering reactor fuel, they diminished its nuclear hazard (most likely, transferred the fuel it to a "nuclear-safe" condition). In many locations sand, clay and dolomite had covered radioactive debris with a thick layer that facilitated subsequent works of the "Object Shelter" builders, operational personnel and investigators. A minor portion of materials could have reached the reactor vault and could have been involved into lava-generation processes.

REFERENCES

1. *USSR State Committee on the Utilisation of Atomic Energy «The Accident at the Chernobyl NPP and its Consequences»* (1986) IAEA Post Accident Review Meeting, Vienna, 25-29 August 1986.

2. Diachenko A.A. (1996)
The Governmental Commission, in: "*Chernobyl: Catastrophe, Feat, Lessons and Conclusions*", Inter-Vesy, Moscow, pp.183-193 (in Russian).

3. *The "Shelter" Current Safety Analysis and Forecast Estimates for the Situation Development* (2001) Responsible Executor: Borovoi A.A. Report of ISTC "Shelter", Arch. #3836, Chernobyl, P.337 (in Russian).

4. Borovoi A. A. (1990)
Analytical Report (Post- Accident Management of Destroyed Fuel from Chernobyl), IAEA, Work Material, pp. 1 - 99.

5. Sich A. R. (1994)
Chernobyl Accident Management Actions, *Nuclear Safety*, Vol.35, #1, January-June 1994, pp.1-22.

6. Borovoi, A.A., Ibragimov, G.D., Ogorodnik, S.S., *et al.* (1990)
Actual Status of Chernobyl NPP Unit 4 and Nuclear Fuel Stored Therein, Kurchatov IAE Preprint, P. 72 (in Russian).

7. Belayev S., Borovoi, A., Demin V., *et al.* (1991)
The Chernobyl source term, in: *Proceedings of a seminar of comparative assessment of the environmental impact of radionuclides released during three major nuclear accidents: Kyshtym, Windscale, Chernobyl.* Luxembourg, EUR 13574 report, pp. 71- 91.

8. Maslov, V.P., Miasnokov, V.P. and Danilov, V.P. (1987)
Mathematical Simulation of the Damaged Chernobyl NPP's Unit, Nauka, Moscow, P. 144 (in Russian).

9. Sivintsev, Yu. V. and Khrulev, A. A. (1995)
Dynamics of radionuclide release from the damaged unit of Chernobyl NPP in 1986, *J. Atomnaya Energija*, 83, #2, pp. 213—245 (in Russian).

2.3. Types and Amounts of Materials Involved into Lava-generation Processes

Full amount LFCM in the Shelter

Estimations of a full amount of the lava formed at accident were made in works [1-3]. It has made ~ **1200 t.**

Fuel Involved into Lava Generation

(85 ± 25) t of fuel (U) remained in Room #305/2 after the second accident phase completion. However far of the whole of that fuel was incorporated into LFCM. Such a fact is deduced from description of individual accumulations. A considerable part of fuel remained in the room in the core fragment's form.

On the other hand, during the second accident phase a part of fuel (as a lava component) moved from Room #305/2 to lower level marks of the Unit (Fig. 1, next page). For the second phase reconstruction purposes we are mostly interested in the fuel involved into lava-generation processes in Room #305/2 and in the reactor vault, i.e. full amount of uranium contained currently in lava of the under-reactor rooms.

Such-type estimates were performed using several methods and then generalized in References [1 – 4].

The integral fuel amount in LFCM of all under-reactor room makes up (90 ± 30) t.

Zirconium Involved into Lava Generation

According to chemical analysis data, LFCM contains 3,6% - 45 t of zirconium [3].

Graphite Located on "OR" Component and Burnt during Lava Generation

The graphite stack consisted of 2488 vertical columns assembled of 250×250 mm blocks of 1.65 g/cm^3 density. The integral stack mass equaled 1500 t.

Note that, if steel blocks are visually observed on 30% of the survived channels located on "E" component, virtually no graphite blocks are found on the channels. To a first approximation, one can expect that at least 30% of the graphite stack were ejected into the under-roof area. The rest of graphite blocks in the reactor area was partly broken to pieces by the explosion and ejected to the central hall. Small-size fragments and dust could have burnt during early minutes of the accident in the very reactor vault. Thus the amount of graphite remaining within the unified area of rooms #504/2 and #305/2 half an hour after the accident onset could be estimated at about **750 t** (50% of the graphite stack mass).

Materials of "OR" Component Incorporated into LFCM (see section 1.4)

"OR" component (more precisely, its south-eastern quadrant) was the main "building material" during lava generation, and thus its constituting materials merit a special consideration.

Before the accident "OR" component represented a wide cylinder 14500 mm in diameter and 2000 mm in height with two lids (the upper lid and the bottom lid) connected in between by stiffening ribs and BWC tubes. The area between the lids was filled with serpentinite mixture (waste of asbestos-concentration plants) - Fig. 2.7.

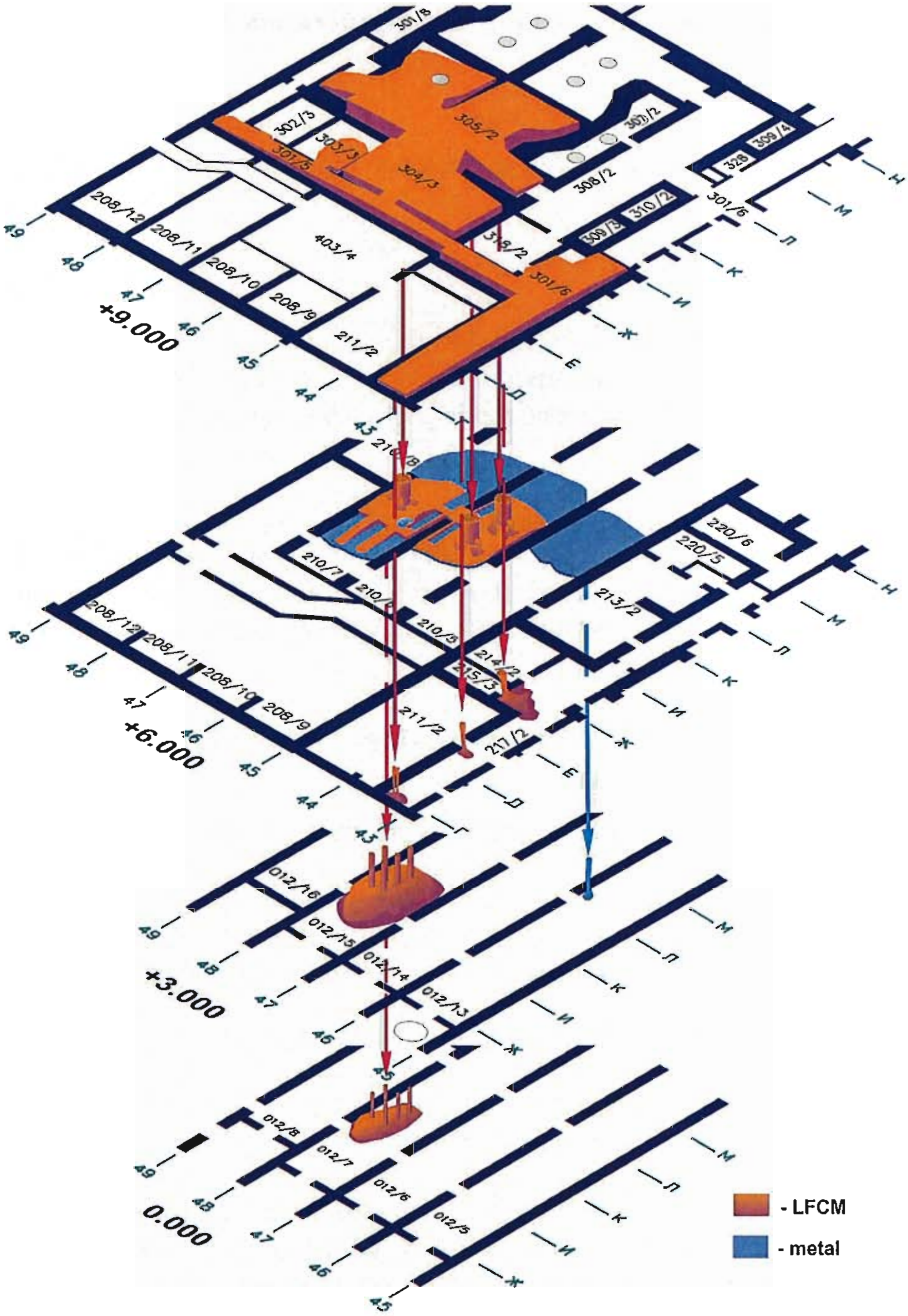


Fig. 2.7. Spreading of LFCM flows over Unit 4 under-reactor rooms.

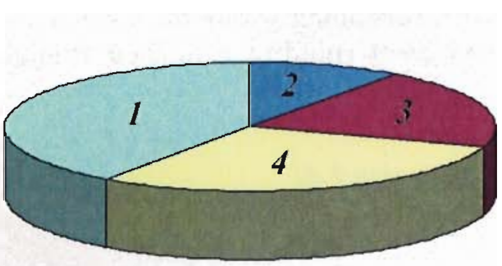


Fig. 2.8. Materials of "OR" component.

1 - Steel 10XH1M – 500 t
2 - Steel OX18H10T – 200 t
3 – Black steel – 230 t
4 - Serpentinite mixture – 410 t
In total: 1340 t

According to the design documentation, the filling-up serpentinite has the following element composition:

SiO_2 – (32 – 40) %	Fe_2O_3 – (3 – 8,5) %	CrO_3 – (0,3 – 2,4) %
MgO – (43 – 45) %	FeO – (0,2 – 2,0) %	Al_2O_3 – (0,6 – 3,5) %

Serpentinite mixture is a mixture consisting of serpentinite broken stones and sand (fraction sizes are 20 mm and up to 3 mm, accordingly) at mass ration 1:2 at maximum density 1,7 t/m^3.
As indicated above, lava incorporated only "OR" materials located within the melted sector, i.e., 1/4 part of materials of "OR" component including:

- steel 10XH1M – **125 t**;
- steel OX18H10T – **50 t**;
- black steel – **57 t**;
- serpentinite mixture – **103 t**.

Serpentinite Mixture of the Compensatory Gap

The compensatory gap between the outer generatrix of "OR" component and "L" tank was filed with a serpentinite mixture of the same composition as "OR" itself. Because the compensatory gap was about 75 m^3 in volume, it contained ~ 130 t of serpentinite mixture. About one half of that amount – i.e. **60 t** - could have been incorporated into LFCM.

Steel Blocks

Steel blocks confined the graphite stack from above and from below. The bottom blocks (above "OR") were 250×250 in size and 100-250 mm in width [5]. According to [6], the mean width of the block's layer was 200 mm. The integral mass of the blocks was about 200 t.

From above, under "E" component, steel blocks of 250×250×250 mm were arranged. The integral mass of those blocks was ~260 t.

About 25% of the bottom block layer (bearings), i.e. **50 tons,** were involved into the lava-generation process.

Most of the upper-layer steel blocks must have dropped into the reactor vault, because the destruction of the major portion of process channels occurred in the area of their connection with the reactor upper head. According to the results of visual observations, about 70% of process channels and cooling channels are currently missing in "E" component. Taking into account those data, one may assume that at the thirtieth minute of the accident ~ 60% of blocks (~160 t) located in the reactor vault above "OR" component. About 1/4 of that amount, i. e. **~40 t,** were involved into the lava-generation process.

BWC Tubes and Other Communications of the Reactor Bottom

BWC tubes (∅57×3,5 mm) and u-bends - steeply curved bends that issued from "OR" bottom (∅60×5 mm) – were made of OX18H10T-grade steel.

There were 1693 working channels, i.e., about 423 channels per ¼ OR. The mean u-bend length was ~4 m. The mean length of BWC tubes located in the immediate vicinity of the room's floor and melted during the accident (the south-eastern sector) equaled ~ 6 m.

Obviously, in the southeastern sector those constructions were melted, their materials being partly incorporated into LFCM. Thus in the southeastern quadrant of Room #305 ~12 t of BWC tubes were melted in the course of the accident.

Taking into account the available data [1 - 4], about 6 t of BWC tubes could have melted in the southwestern quadrant.

The integral amount of materials of reactor bottom communications (including supply manifolds, drainages, etc.) melted during the accident can be estimated at **20 t** (OX18H10T-grade steel).

Materials of "C" Component

"C" component served as a support for "OR" component.
The bottom part of "C" component bore on embedded items of the building basement at +11.000 level mark. It was assembled of beams – rests ~5000 mm in height – arranged over two reciprocally perpendicular planes in the shape of a cross. The upper end of "C" component had lugs and was adjusted to the bottom plate of "OR" component over the contact area. All details of "C" component were made of 10XCHД-grade steel.

According to visual observations, "C" component was crushed but its elements were not melted.

Heat Shielding and Cooling System of Building Constructions

The walls and the floor of Room #305/2 were provided with a heat shielding ~300 mm in width – heat-insulating plates "ПП" of spinneret synthetic wadding. Heat insulation was lined with 12X21H5T-grade steel 10 mm in width. There was a reinforced cement belt 45 mm in width under the heat-insulating layer wherein cooling system's tubes of building structures (Steel #20, ∅34×4 mm) were arranged with 250-700 mm spacing. The integral area of melted metal liner can be estimated at ~140 $м^2$, whereas the tube melting area at ~100 m^2.

Thus, the mass of melted liner is equal to **~10 t** and that of tubes of building constructions' cooling system to **~0,5t**.

Concrete of the Under-reactor Plate and Walls of Room #305/2

Rather roughly, the amount of destroyed and melted concrete can be estimated using, mainly, the results of drilling operations [1, 2]. The area of FCM spreading in the southeastern room's sector makes up 80-96 m^2, the bottom boundary of FCM location being recorded at +9.000 – +9.100 level marks.

The estimates of References [1, 2] allow suggesting that the area of intense destruction and melting of concrete for ~0.5 m depth makes up 80 m^2. Thus, at a density of 2,2 t/m^3, the mass of destroyed and next melted concrete equals 90 t.

The area of FCM spreading in the southwestern room's sector equals 60-92 m^2, the bottom boundary of FCM location being recorded at +9.000 – +9.200 level marks. The area of intense concrete melting for ~0.5 m depth equals 40 m^2.

Thus the mass of destroyed and subsequently melted concrete equals 40 t.
Obviously, under LFCM layer destroyed concrete is located which width can be estimated at ~0,3 m. Thus the mass of this layer is about 80 t.

Therefore, according to our estimates, the mass of destroyed concrete made up 210 t, of which **130 t** were involved into lava generation processes.

Sand from the Area between "L" Tank and Reactor Vault Walls

According to visual observations, a "gravel" pile is found in Room #305/2 just opposite the southern rolling gate originated [4, 7], most likely, from filling material spilled from the area

between "L" tank and reactor vault walls (vault's filling material). According to References [5, 6], such an area is normally filled with mortar sand 1.3 t/m^3 in density.
We assume that that sand could have formed a pile of 40-60 m^3 in Room #305/2 opposite to southern rolling gate in the area of axes 45 – 46_{+3000}. It is also expected that most of the pile's materials - about **30 t** of sand – was melted and incorporated into LFCM.

Plate Floor

Elements of the central part of the plate floor were filled with Iron-Baric-Serpentinite Cement Stones (IBSCS). The peripheral area of the plate floor represented boxes filled with a serpentinite mixture [6] or with IBSCS [5]. Almost the whole of peripheral area of the plate floor is beyond the reactor space projection. Most likely, the central area's blocks were not involved into lava-generation processes; however, a part of them could have "spilled" into the northwestern reactor space area. Thus the probability of involvement of the considered materials into the lava-generation process is rather low.

Based on the above data, a preliminary estimate of the amount of materials involved into lava generation and located in the reactor vault and Room #305/2 by the second accident phase beginning can be made (Table 2.3).

Table 2.3. Materials involved into lava formation processes (preliminary estimate).

Material	Total mass, t	Mass of contained silicon, t
Fuel (U)	90	-
Steel	350*	-
Serpentinite mixture	160	53
Concrete of under-reactor plate	130	48
Reactor vault filling sand	30	12

* In total LFCM can contain 20 t of iron at the most

From Table 2.3 it follows that there was an excess of steel for generation of the whole of LFCM [3]. According to data of Reference [3] the whole of LFCM of Unit 4 contains ~ 390 t of silicon[2]. Silicon concentration in serpentinite mixture is about 33%, in sand – 40% and in concrete – 37%. There are 113 t of silicon in the materials listed in Table 1.

Thus, to observe the balance on silicon, one additionally needs 750 t of concrete (that could have only come there from CH) or 690 t of the vault's filling sand, i.e., the integral mass of sand of the vault filling material that reached Room 305/2 must have been 720 t.

It is obvious that LFCM incorporated both concrete of constructions dropped into reactor vault from CH and sand of the vault filling-origin.

Let us assume that debris of building constructions and concrete fragments attained the reactor vault in a quantity equaling 4 fragments of box-separator's walls 9×6×2 in size. In such a case that concrete 430 m^3 in volume and 950 t in mass could have taken (with 50% fill factor) an area above "OR" of about 5 m in height.

Let us consider that one half of the whole mass of concrete was involved into lava generation providing the lava with ~180 t of silicon. Only sand of the vault's filling material (about 280 t) could have been a source of the rest of silicon (110 t), i.e. ~10% of the whole sand mass in the vault's filing material. Thus the presence of ~300 t of sand in the southern part of Room #305/2 at the second accident phase beginning could have been a quite probable event.
A summary estimate is demonstrated in Table 2.4.

[2] LFCM-generation scenario and silicon balance are considered in detail in Reference [3].

Table 2.4. Materials presented in the reactor vault and in room #305/2 at the beginning of the second accident phase.

Material	Amount in rooms #504/2* and #305/2, t	Incorporated into LFCM, t
Fuel (U)	120	90
Steel	1300**	< 20***
Serpentinite mixture	580	160
Concrete of the under-reactor plate	-	130
Concrete of building constructions dropped into the vault	950	480
Sand of the vault's filling material	300	280
Zirconium	?	45
Graphite	750	-

* within the reactor space boundaries;

** excepting materials of "C" component and non-melted communications of the reactor bottom;

*** 330 t melt and spread over the under-reactor rooms.

REFERENCES

1. *The "Shelter" Current Safety Analysis and Forecast Estimates for the Situation Development* (2001) Responsible Executor: Borovoi A.A. Report of ISTC "Shelter", Arch. #3836, Chernobyl, P.337 (in Russian).

2. *Project 1: " Safety Status of the Chernobyl NPP's "Object Shelter", Subproject n°3: "Nuclear Fuel and Radioactive Waste"* under a Special Agreement with IPSN and GRS of April 23, 1998. Work Report of IHTEM of RRC "KI" for the 3rd Half-yearly Milestone (October 30, 1999), Responsible Executive: Borovoi, A.A., P. 30 (in Russian).

3. Pazukhin E.M. (1999) *Lava-like Fuel Containing Masses of the Chernobyl NPP Unit 4: Topography, Physical & Chemical Properties, Generation Scenario and Environmental Effects.* Doctoral Thesis, Chernobyl, P. 293 (in Russian).

4. Borovoi A.A., Lagunenko A.S. and Pazukhin E.M. (1998) Estimate of fuel amount in the under-reactor room #305/2 of Chernobyl NPP Unit 4, *J. Atomnaya Energiya (Atomic Energy),* 84, n.4, pp. 356 – 362. (in Russian).

5. Anderson, E. B., Bogatov, S.A,Borovoi, A.A., *et al.* (1993) *Lava-like Fuel Containing Masses of the "Object Shelter"*, Preprint of the Ukrainian National Academy ISTC "Shelter" n°93-17, Kiev, p. 44 (in Russian).

6. *Chernobyl Nuclear Power Plant: "Technical Specification of Facilities, Equipment and Systems"* (1975), Minenergo of USSR, Kiev (restricted) (in Russian).

7. Dollezhal N.A. and Emelianov I. Ja. (1980) *Channel-type Nuclear Power Reactor*, Atomizdat, Moscow, P.208 (in Russian).

3. HEAT SOURCES INVOLVED INTO LAVA GENERATION

3.1. Decay heat of Unit 4 fuel after the accident [1 – 4]. (See 1.1)

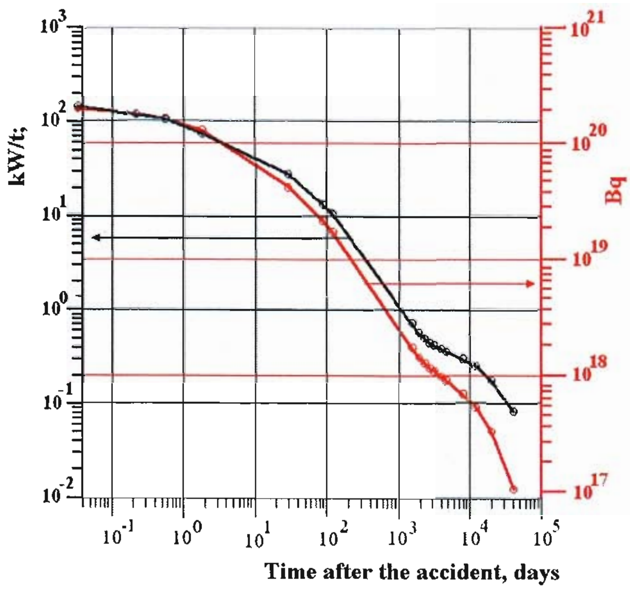


Fig. 3.1. -Dependence of decay heat (upper curve) and activity (bottom curve) of Unit 4 fuel on the time elapsed after the accident

Table 3.1. Decay heat power of fuel of Chernobyl NPP Unit 4 during the early post-accident days

Time after accident, h	Decay heat power, kW/t (U)		
	Total	Volatile components	With consideration for volatile component release
0	295	65	230
6	135	20	115
12	117	17	100
18	108	15	93
24	102	13,5	89
36	92	12	80
48	86	10,5	75,5
60	81	9,2	71, 8
72	76	8	68
84	72	7	65
96	69	6	63
108	66	6	60
120	64	5	59
132	61	5	56
144	59	4	55
156	57	4	53
168	56	3,5	52,5
180	54	3,5	50,5
192	53	3	50
204	51	3	48
216	50	2,5	47,5
228	49	2	47
240	48	2	46
252	47	2	45
264	46	2	44
276	45	1,5	43,5
288	44	1,5	42,5
300	43	1,5	41,5

REFERENCES

1. *The "Shelter" Current Safety Analysis and Forecast Estimates for the Situation Development* (2001) Responsible Executor: Borovoi A.A. Report of ISTC "Shelter", Arch. #3836, Chernobyl, P.337 (in Russian).

2. Borovoi, A.A., Dovbenko, A.A. and Stroganov, A.A. (1988) *Fuel of Chernobyl NPP Unit 4 (Reference Book)*, Report of CRE of Kurchatov IAE, Chernobyl (in Russian)

3. Begichev, S.N., Borovoi, A.A., Burlakov, E.V., Gavrilov, S.L., *et al.* (1990) *Reactor Fuel of the Chernobyl NPP Unit 4 (Desk Reference Book)*, IAE's Preprint n°5268/3, Moscow, P.21 (in Russian).

4. Borovoi, A.A., Dovbenko, A.A., Smoliankina, M. V. and Stroganov, A. A. (1991) *Determining Nuclear-Physical Characteristics of Fuel of the Chernobyl NPP Unit 4*, Report of IBRAE RAS, inv. n°52/11-20, Moscow, P. 63 (in Russian).

3.2. Heat Due to Graphite Burning

Table 3.2. Calculation of integral heat released during burning of 1 t of graphite in RBMK-reactor core

#	Reaction type	ΔH, kJ/mol*)	Heat effect per 1 t (kJ)
1	$C + O_2 = CO_2$	-393,7	Released: $32,8 \cdot 10^6$
2	$C + 1/2O_2 = CO$	-111,5	Released: $9,29 \cdot 10^6$
3	$CO + 1/2O_2 = CO_2$	-282,2	Released: $23,5 \cdot 10^6$
4	$C + CO_2 = 2CO$	170,8	Absorbed: $14,2 \cdot 10^6$
5	$C + H_2O = CO + H_2$	130,4	Absorbed: $15,1 \cdot 10^6$
6	$CO + H_2O = CO_2 + H_2$	-40,40	Released: $33,7 \cdot 10^6$
7	$C + 2H_2 = CH_4$	-74,82	Released: $6,24 \cdot 10^6$
8	Reaction activation energy: $C + 1/2O_2 = CO$	+226,1	Absorbed: $18,8 \cdot 10^6$
	Σ	**-375,3**	**$3,12 \cdot 10^7$**

*) "+" – reaction proceeding with energy absorption;
"-" - reaction proceeding with energy release.

From Table 3.2 it follows that during burning of 1 t of graphite in air saturated with water steam $3,12 \cdot 10^7$ kJ/4,1868 ~$7,45 \cdot 10^6$ (kcal) are released.

3.3. Heat Due to Zirconium-steam Reaction

Chemical reaction of zirconium with water steam was an extra source of heat. Steam – zirconium contact inside zirconium process channels could have resulted in the initiation of the following zirconium-steam reaction:

$$Zr + 2H_2O \rightarrow ZrO_2 + 2H_2\uparrow + [7760 + 1.15\,(T - 2000)]\ {}^{J}/_{g}\ Zr,$$

with release of ~ 160 kcal per mol of zirconium. Estimates of heat release during oxidation of the whole of zirconium and of channel zirconium gave the values of 3.1×10^8 and 1.8×10^8 kcal, respectively. The ultimate conclusion: the contribution of zirconium oxidation to the integral heat release ~ 100 hours after the accident was 20% at the most.

REFERENCES

Kabakchy C. A., Bulgakova G.P. «Radiation chemistry in the nuclear fuel cycle» Course of RchTU by D.I.Mendeleev, 1997, p.180.

4. PHYSICAL AND CHEMICAL PROCESSES DURING LAVA GENERATION

4.1. Lava Generation

The sequence of the Chernobyl lava-generation phases may be briefly described as follows:

1. At a moment an increase in neutron flux in the Unit 4 reactor core of Chernobyl NPP (the south-eastern section) took place that produced an increase in the number of fissions, heat release and a drastic increase in steam concentration in coolant that circulated in zirconium process channels of the graphite stack of the core[3].

The RBMK steam reactivity coefficient (an element of the integral reactive power coefficient) is positive. An intensification of the fission reaction could result in the generation of a larger amount of steam producing an increase in the K-factor leading in its turn to further intensification of the reaction, etc.

Increased steam concentration in process channels led to changes in the cooling regime of fuel assemblies: from that point on zirconium walls of Fuel Element (FE) tubes did not contact with water but with superheated steam which cooling capacity is by far below that of water.

2. As a result of loss of coolant nuclear fuel (UO_2) in both intact and damaged FEs heated up to the zirconium melting point (t_{mlt} = 1852 °C) due to decay heat and a low heat pick-up. Zirconium claddings of FEs melted on the inside and began dissolving fuel pellets with the generation of a liquid uranium-zirconium eutectic.

3. Explosions that had destroyed the core allowed damaged fuel and liquid uranium-zirconium eutectic to interact with constructional materials: metal of "OP" component, serpentinite mixture, sand, concrete, etc. (see Fig. 4.1) [1]. Fig. 1 provides a model of layout of Unit 4 materials in the reactor vault and the under-reactor compartment half an hour after the accident beginning.

As follows from Fig.1, as a result of the accident the reactor basement – "OP" component - moved down and cracked, and its separated fragment (*12* in Fig. 4.1) descended below the main structure (*4*).

As a consequence, the reactor vault (Room #504/2) was united with Room #305/2.

Later on the materials of ¼ "OP" (*12*) formed a component of the lava[4]. At the same time the constructions of ¾ "OP" (*4*) were destroyed considerably less, though visible damages are observed in the break area.
The constructions of "C" component (*2*) were crushed by the descended "OP" component.
Many tubes of Bottom Water Communications (BWC) were also crushed and pressed to the concrete plate of Room 305/2's floor (*5*).
The major portion of serpentinite of the inter-compensatory gap spilled into the annular gap between the descended "OP" component and semicircular western and eastern walls of Room #305/2 or was thrown by the explosion to the northern and the southern areas of that room.

---

[3] The causes of such a burst are not discussed here: there are many versions of the catastrophe occurred, and their analysis is beyond the scope of this paper.

[4] The effect of materials dropped down from helicopters on lava composition is neglected. According to the results of investigations (e.g. [2], [3] and [4]) such materials did not virtually attain the reactor vault (see section 2.2).

Sand from the area between "L" tank (*14*) and the reactor vault walls spilled to the southern part of Room #305/2.

The area above "OR" component was filled with graphite blocks, damaged fuel assemblies and fuel elements and fragments of process channels up to about +17.000 - +18.000 level marks (*3*).

Large amounts of debris of building constructions are found above core fragments (*15*).

4. When uranium-zirconium eutectics contacts silicon dioxide (the major lava component), the following triple system is generated: UO_2-SiO_2-ZrO_2. Minimum temperature of liquidus surface in this system is equal to the melting point of triple eutectic and makes up approximately 1500°C (Fig. 4.2.) [5].

5. Further process of lava generation took place at 1500 °C ÷ 2600 °C[5]. The indicated minimum temperature value may be justified via the need of melting of a large metal mass ("OP" component); the indicated maximum temperature value is confirmed by the presence in silicate matrix of fuel globules with zirconium admixture ('ZrO_2 – UO_2' system) [6].

Due to interactions of irradiated fuel with structural materials in the course of lava generation, LFCM - in addition to uranium, zirconium, silicon and oxygen - comprised a considerable amount of other elements (about twenty elements according to element composition of LFCM).

Analyses of established and possible events that took place immediately after the accident demonstrate the presence of a variety of compositions of fuel with other materials fallen into Room #305/2 and the reactor vault after the explosion. The existence of several lava-generation "centers" is assumed, and each of them had its own characteristic temperatures and generated lava of its own specific composition.

For example, the eutectic mixture (Fig. 2, temperature ~1500 °C) has the following approximate composition: 80 % SiO_2, 15 % UO_2 and 5 % ZrO_2. It is of interest that maximum concentration of fuel in glassy LFCM samples equals ~15 %.

In a case that silicon or other materials are lacking, the 'ZrO_2–UO_2' system having 2500 – 2600°C temperatures is in action.

UO_2 dissolution in SiO_2 proceeds very slowly [7] (eutectic in 'UO_2-SiO_2' binary system is generated at 13% relative concentration of uranium oxide and has the melting point of 1650 °C). At the same time 10% addition of Al_2O_3 to melt results in a violent dissolution of fuel [7]. Addition of ZrO_2 brings to similar results.
At individual lava-generation centers the temperatures of 2850 °C and above producing melting of UO_2 pellets were possible.

On the other hand, in individual locations in case of "successful" composition of materials and an "appropriate" heat regime the process of lava generation could have started at ~ 1000 °C as well [8].

A reconstruction of both the composition and amount of materials available after the accident initiation (half an hour following the reactor collapse) in Room 305/2 and in the reactor vault

[5] Three heat sources should be considered in the lava-generation process: decay heat of nuclear fuel, graphite burning and steam-zirconium reaction (see section 3).

was made in Reference [1] based on analysis of a variety of data on the condition of destroyed rooms, composition of solidified lava and its amount in those rooms (see Table 4.1).

Table 4.1. Materials presented in the reactor vault (Room #504/2) and in the under-reactor room #305/2 at the beginning of the second accident phase (during the process of lava generation and spreading)

Material	Amount in Rooms #504/2* and #305/2 after the accident, t	Incorporated into LFCM, t
Fuel (U)	120	90
Steel	1300**	< 20***
Serpentinite mixture	580	160
Concrete of the under-reactor plate	-	130
Concrete of building constructions dropped into the vault from upper level marks	950	480
Sand of the vault's filling material	300	280
Zirconium	?	45
Graphite	750	virtually no

* within the reactor space boundaries;
** excepting materials of "C" component and non-melted communications of the reactor bottom;
*** 330 t melt and spread over the under-reactor rooms.

Molten materials spread over Room #305/2's floor, attained steam-dumping valves, run inside and reached lower rooms established for steam localization in case of a design-basis accident: Steam-Distribution Corridor (SDC) and two floors of the Pressure-Suppression Pool (PSP-1 and PSP-2) located at +6.00, +3.00 and 0.00 level marks, respectively (Subsection 5.4).

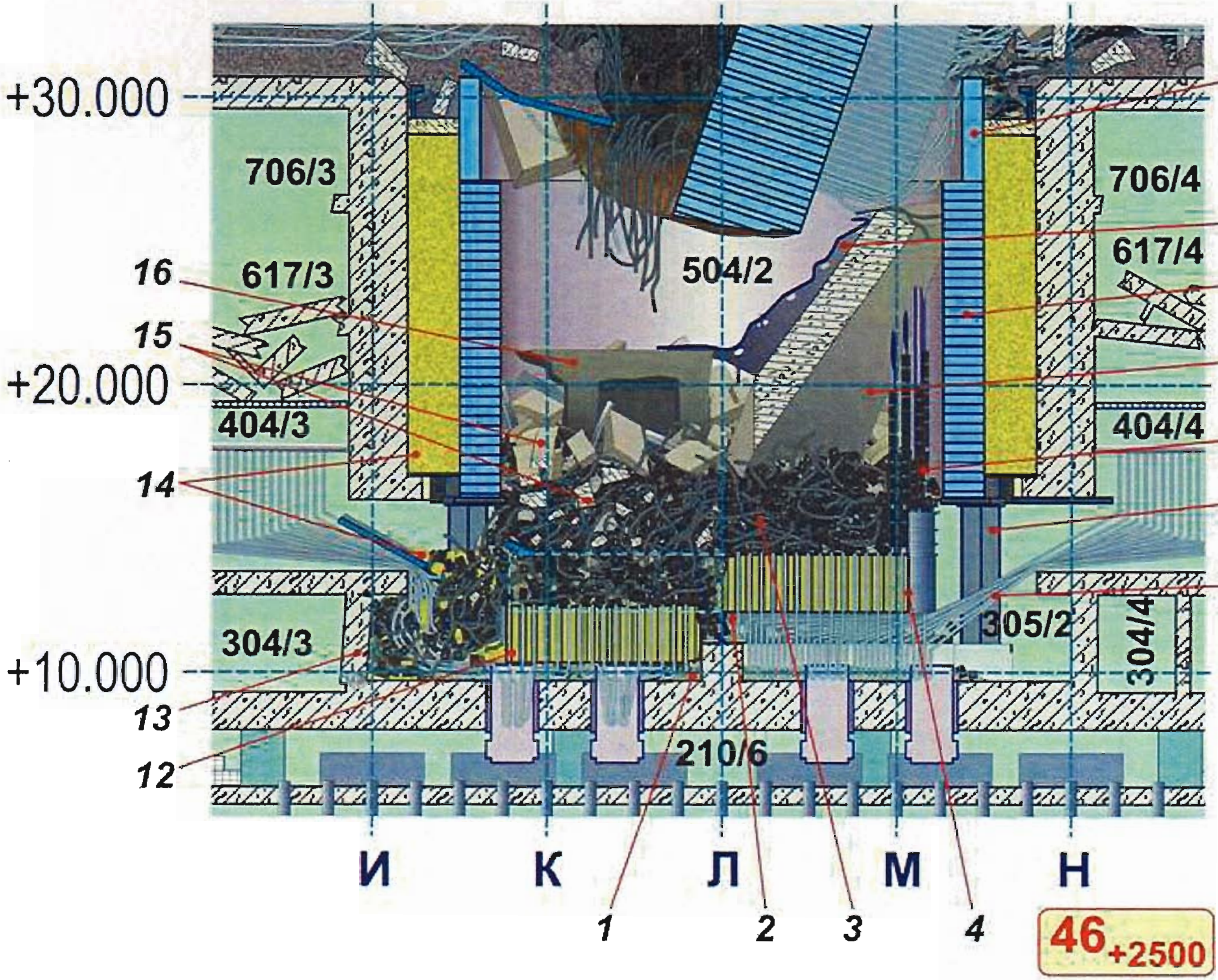


Figure 4.1. Reactor vault and room #305/2 half an hour after the explosion

1. Serpentinite of both "OP" component and the inter-compensatory gap
2. Crushed "C" component ("Cross")
3. Fuel, fuel assemblies, fuel elements, process channels, graphite blocks, fragmented concrete
4. ¾ OP
5. BWC tubes
6. Additional support
7. Reflector (channels and graphite blocks)
8. Reinforced-concrete plate (fragments of wall of separator box)
9. "Л" tank
10. Heat shielding lining of separator box's wall
11. "Д" tank
12. ¼ OP
13. Damaged wall
14. Sand of vault's filling-up-origin
15. Debris of reinforced-concrete constructions
16. Fragment of reinforced-concrete construction

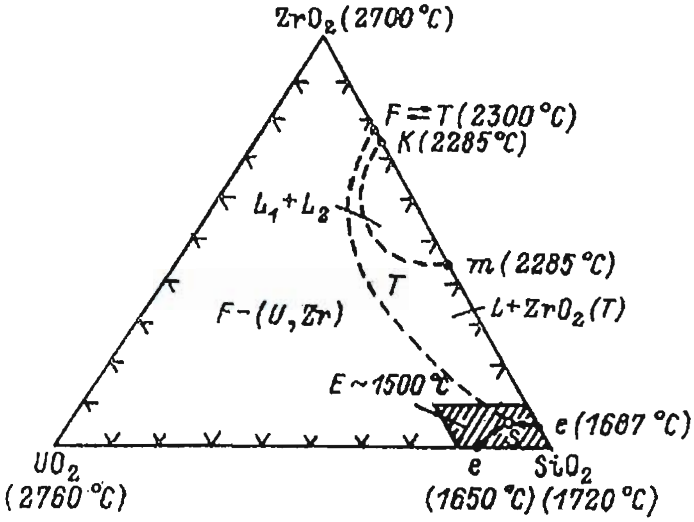


Fig. 4.2. Approximate projection of liquidus surface in 'UO₂-SiO₂-ZrO₂' triple system
F – field of primary crystallization of solid solutions based on U and Zr oxides with fluorite-type structure;
T - field of primary crystallization of tetragonal ZrO_2 ;
S - field of SiO_2 crystallization (cristobalite).
The shaded area corresponds to possible composition of FCM.

Simultaneously, molten materials spread in the horizontal direction as well because a breach in the wall separating Rooms #305/2 and #304/3 had been created during the accident (fig5.1).

REFERENSES

1. Bogatov, S., Borovoi, A., Gavrilov, S., Lagunenko, A., and Pazukhin, E. (2006) *Half an Hour after the Beginning of the Accident*, OKPRINT, Moscow, P. 22 (in Russian).

2. Borovoi, A.A. (1990) *Post- Accident Management of Destroyed Fuel from Chernobyl: Analytical Report*, Work Materials, IAEA, pp. 1 - 99.

3. *The "Shelter" Current Safety Analysis and Forecast Estimates for the Situation Development* (2001) Responsible Executive: Borovoi, A.A. Report of ISTC "Shelter", Arch. #3836, Chernobyl, P.337 (in Russian).

4. Pazukhin, E.M. (1994) Lava-like fuel containing masses of the Chernobyl NPP Unit 4: topography, physical & chemical properties, generation scenario, *J. Radiokhimia*, **36(2)**, 1994, pp. 97-142 (in Russian).

5. *Generalization of Results of Material Studies of FCM for 1991*, (1991) Report of Complex Research Expedition under IAE, #11.07/304 of 16.12.91, Responsible Executive: Denisenko, E. T., Chernobyl, P. 23 (in Russian).

6. Pazukhin, E.M. and Krasnov, V.A. (2004) Concerning a major engineering fault committed while designing RBMK-1000 and the necessity of an important correction of the scenario of the 1986-accident active phase, *Chernobyl Problems*, **15**, pp. 93 – 102 (in Russian).

7. Arutyunyan, R.V., Bolshov, L.A., Vasiliev, A.V. and Strizhov, V.F. (1992) Physical models of severe accidents at nuclear power plants, in: *N. N. Ponomarev-Stepnoy* (eds.), Nauka, Moscow, P. 232 (in Russian).

8. Gonchar, V.V. and Zhidkov, A.V. (2001) Dynamics of high-temperature interactions of damaged nuclear fuel with constructional materials of RBMK, *Chernobyl Problems*, **9**, pp. 25 – 33 (in Russian).

4.1.1. FCM in Room #305/2

Several individual FCM "accumulations" (with consideration for their genesis) may be conventionally distinguished in Room #305/2 on the basis of visual observation data [1], information achieved due to drilling of research holes [2], results of sample analysis and the LFCM generation scenario. Seven such-type "accumulations" are identified in Ref. [3], each of them supposedly containing a large amount of fuel-containing materials (Fig.4.3, 2.3).

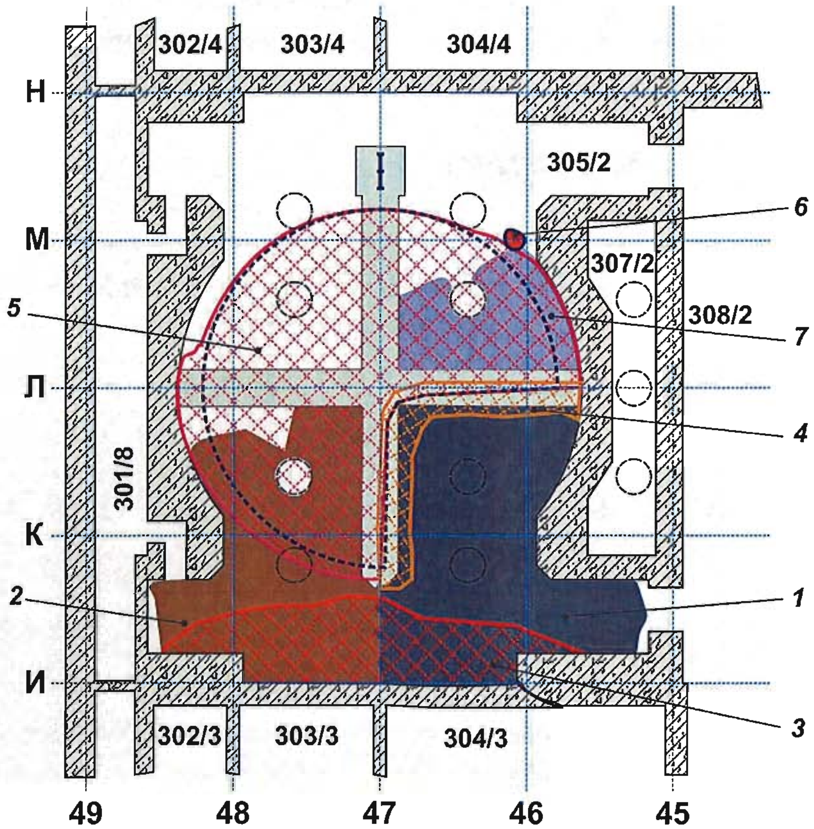


Fig. 4.3. Layout of FCM accumulations in Room #305/2

Accumulation #1

Molten southeastern sector of the reactor support plate ('OP' component). Location of the generation of most of LFCM. Boundaries: reinforced-concrete cross and walls of Room #305/2. Coordinates: 45/47, И/Л, level marks +9.000 – +11.500. FCM are located under a layer of concrete (0.3 – 0.5 m thick) and a wreckage of constructions. Concrete of the under-reactor plate under lava layer down to +9.000 level mark and, partly, the reinforced-concrete cross along the axis 47 were destroyed due to thermal impact, their components being incorporated into lava. LFCM type: mainly black and brown ceramics.

Accumulation 2

Southwestern sector of the room. Boundaries: reinforced-concrete cross and walls of Room #305/2. Coordinates: $47/49_{-2000}$, И/Л, level marks: +9.000 - +12.000.

FCM are located under both 'OP' component and wreckage along the southern wall of the room. Concrete of the under-reactor plate is destroyed, and lava probably attains +9.000 and below level marks. LFCM type: mainly brown and black ceramics.

Accumulation 3

The accumulation includes the wreckage along the southern wall of Room #305/2 generated due to collapse of metal structures and displacement of BWC pipes. Coordinates: $46_{-2000}/48_{+3000}$, И/К$_{-1000}$, level marks +11.000 - +14.000. The wreckage also contains core fragments. The western sector of the wreckage is partly concreted. FCM type: core fragments and LFCM.

Accumulation 4

The accumulation represents a semicircular wall of loose FCM generated during melting of the southeastern sector of ‘OP’ component. Boundaries: above the reinforced-concrete cross along the boundary of lacking southeastern part of ‘OP’ component. FCM type: porous ceramics.

Accumulation 5

The ‘OP’ component and wreckage above it. FCM type (supposedly): fuel assemblies (at least 50 units) and LFCM.

Accumulation 6

The so-called “stalagmite” – solidified dripstone of LFCM generated in the area of the upper part of large reinforced-concrete plate. Coordinates: 46, M; level mark – +16.000.

Accumulation 7

The least known northeastern sector of Room #305/2. Boundaries: area under ‘OP’ component and the “stalagmite”. Coordinates: $46_{-2000}/47_{-1000}$, Л/М, level mark +9.700. LFCM presence is possible.

Expert evaluations of fuel amounts in the above accumulations are presented in Table 4.2.

Table 4.2. FCM distribution over Room #305/2 (expert evaluations)

Room	Accumulation, level marks	Brief characteristic of FCM in the accumulation	FCM volume, m^3	Fuel amount (U), t
305/2	#1, level marks: +9.000 – +11.500	Black and brown ceramics, possibly core fragments	150 ÷ 190	20 ± 3
	#2, level marks: +9.000 – +12.000	Brown ceramics, possibly core fragments	100 ÷ 180	33 ± 8
	#3, level marks: +11.000 – +14.000	LFCM, initial lava components, core fragments	9 ÷ 26	6 ± 4
305/2 и 504/2	#4, level marks: +11.000 – +16.500	Loose FCM	50 ÷ 60	5 ± 2
	#5, level marks: +12.000 – +24.000	LFCM, initial lava components, core fragments	70 ÷ 110	19 ± 7
	#6, level marks: +16.000 – +24.000	“Stalactite” - LFCM	~ 0.7	0.12
305/2	#7, level mark: +9.700	LFCM ?	up to 20 (?)	up to 1.5 (?)

Boundaries of LFCM Spreading

Based on the information available, an attempt was made on determining the boundaries of LFCM in Room #305/2.

To this end, Room #305/2 was conventionally broken into sectors via passing of characteristic sections. The coordinates of sections were selected on the information-density basis (drilled holes, taken samples, in-hole measurements) (Fig. 4.4).

Using the whole of verified information available (see Appendix (305/2 - 1)) LFCM spreading boundaries were determined for each section.

The types of sections are demonstrated in Figs 4.5 – 4.12 and Figs. 4.14 – 4.16. The layout of all sections at +9.700 level mark is shown in Fig.4.17.

For better visualization a fragment of section of the Chernobyl NPP Unit 4 through row 'K" is demonstrated in Fig. 4.13.

Estimates of the lower LFCM boundary in Room #305/2 performed in conformity with the sections (see Figs. 4.5 – 4.16) are presented in Table 4.3.

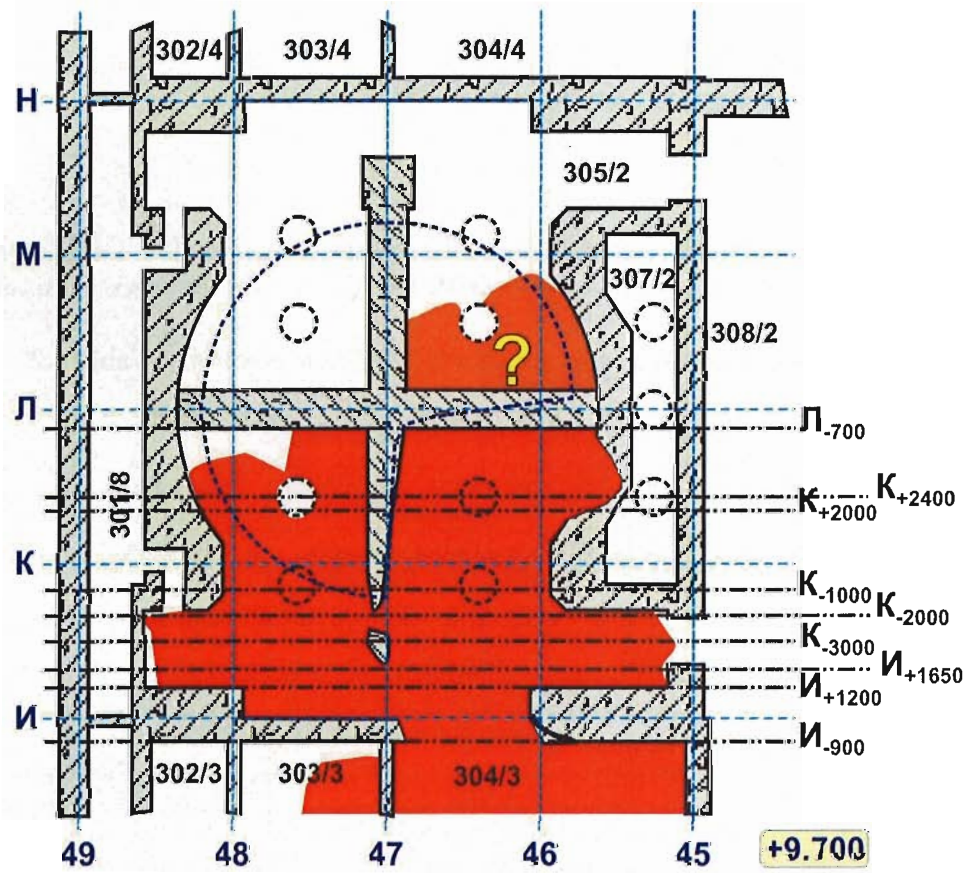


Fig. 4.4. Room #305/2. LFCM at +9.700 level mark. Location of sections

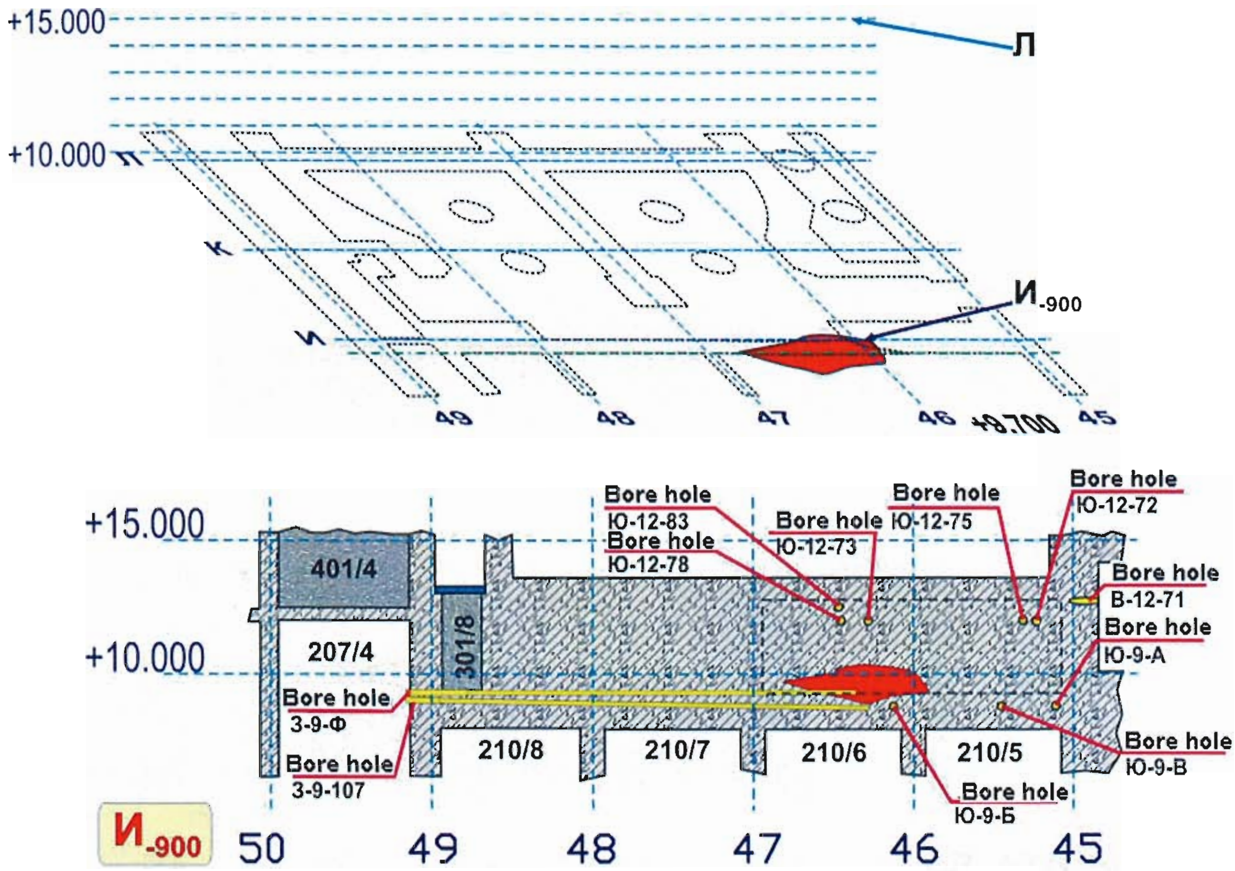


Fig. 4.5. Separating wall in Room #305/2 and Room #304/3. LFCM. Section through row 'И-900'

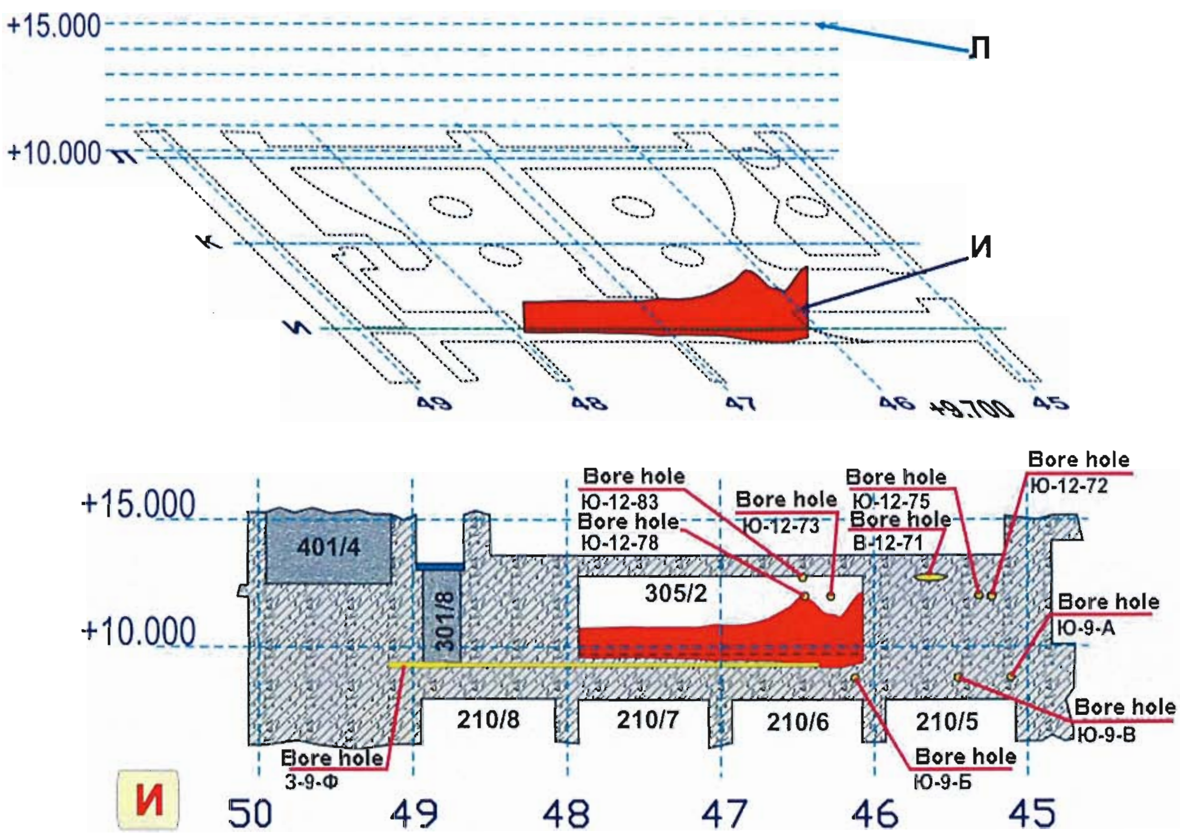


Fig. 4.6. Room #305/2. LFCM. Section through row 'И'

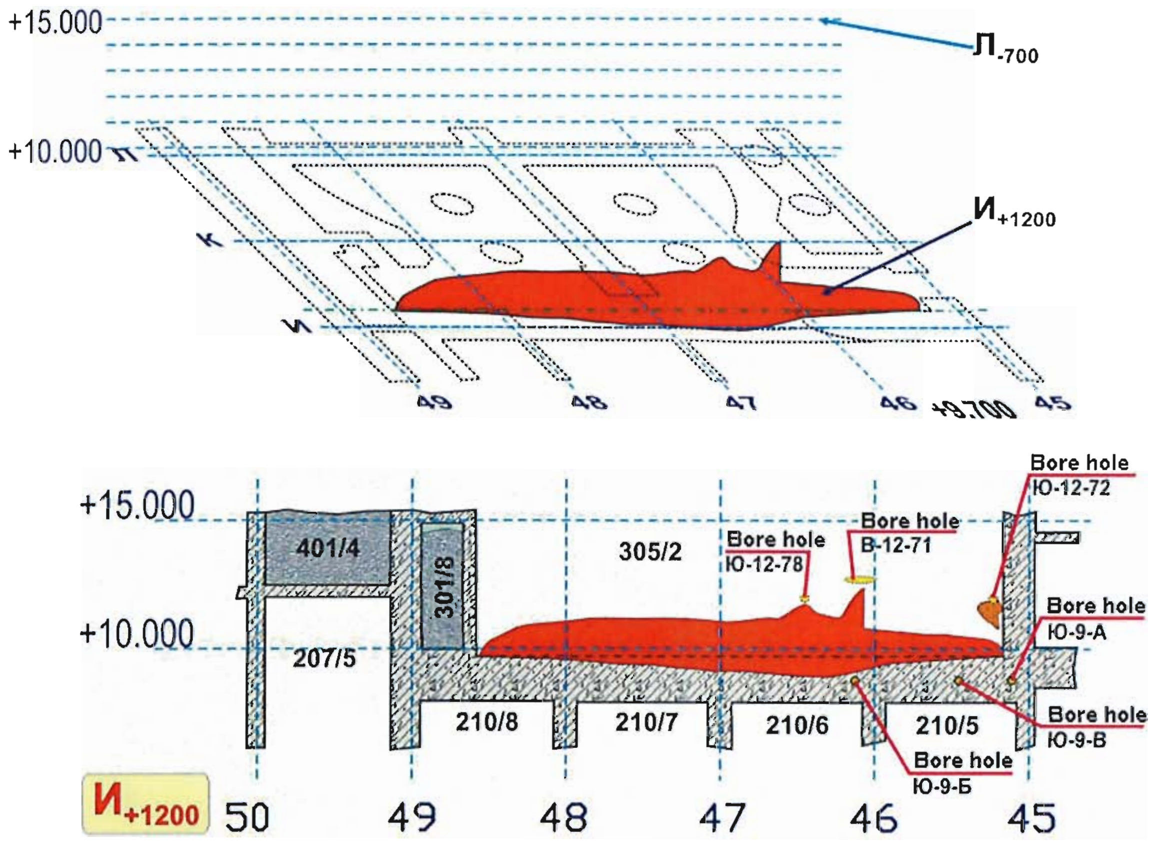


Fig. 4.7. Room #305/2. LFCM. Section through row 'И+1200'

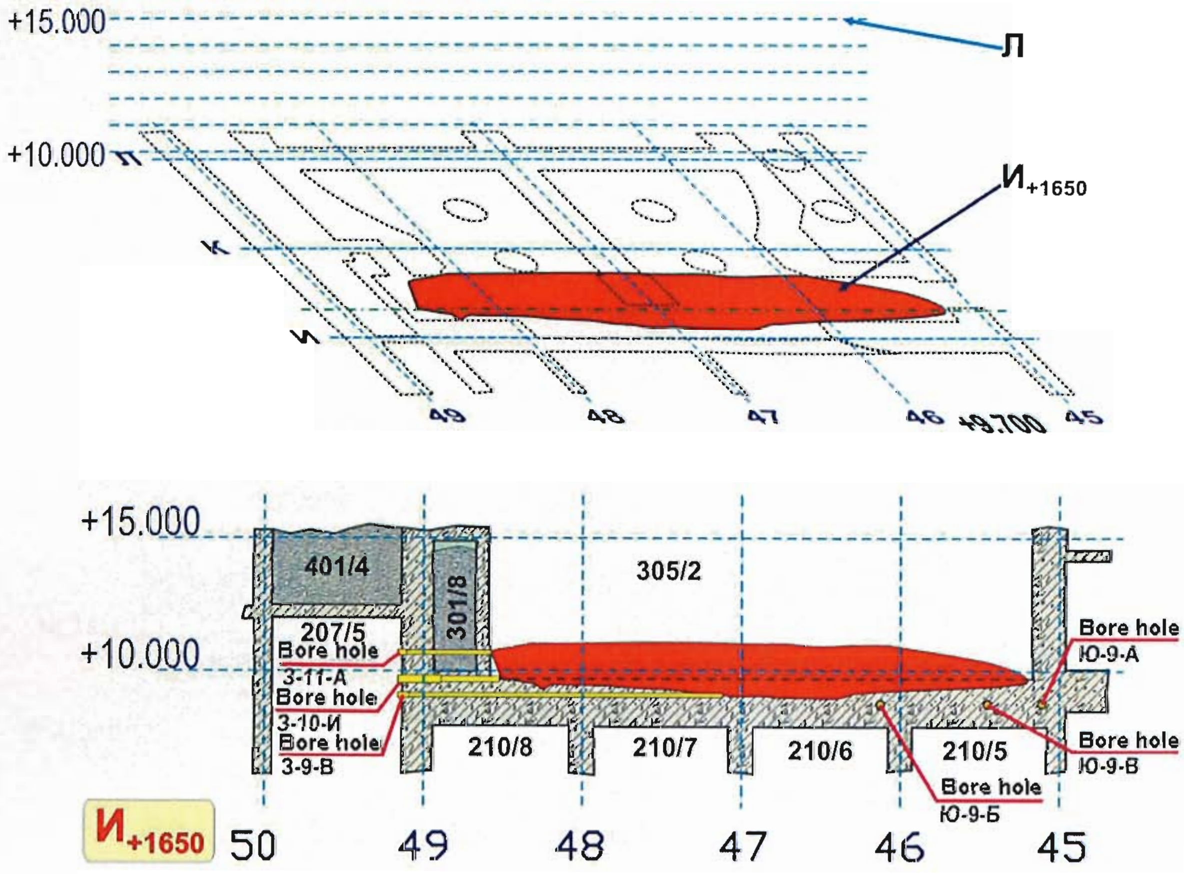


Fig. 4.8. Room #305/2. LFCM. Section through row 'И+1650'

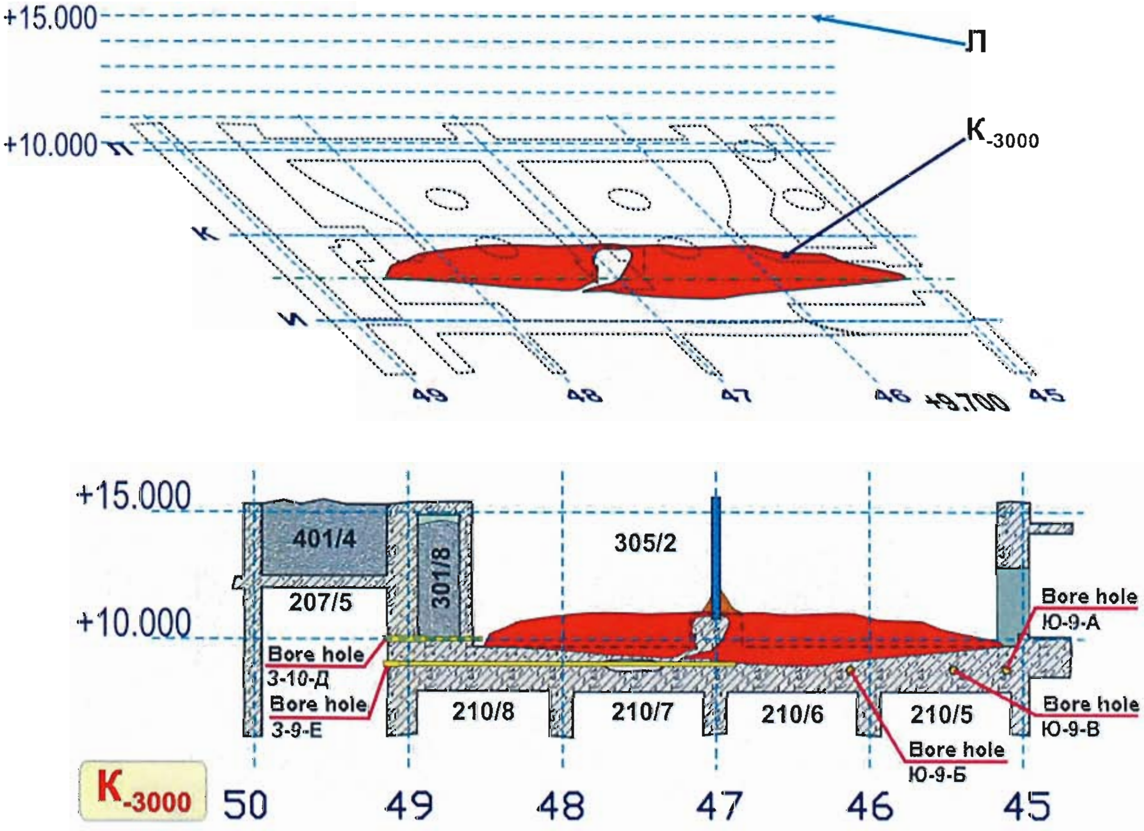


Fig. 4.9. Room #305/2. LFCM. Section through row 'К$_{-3000}$'

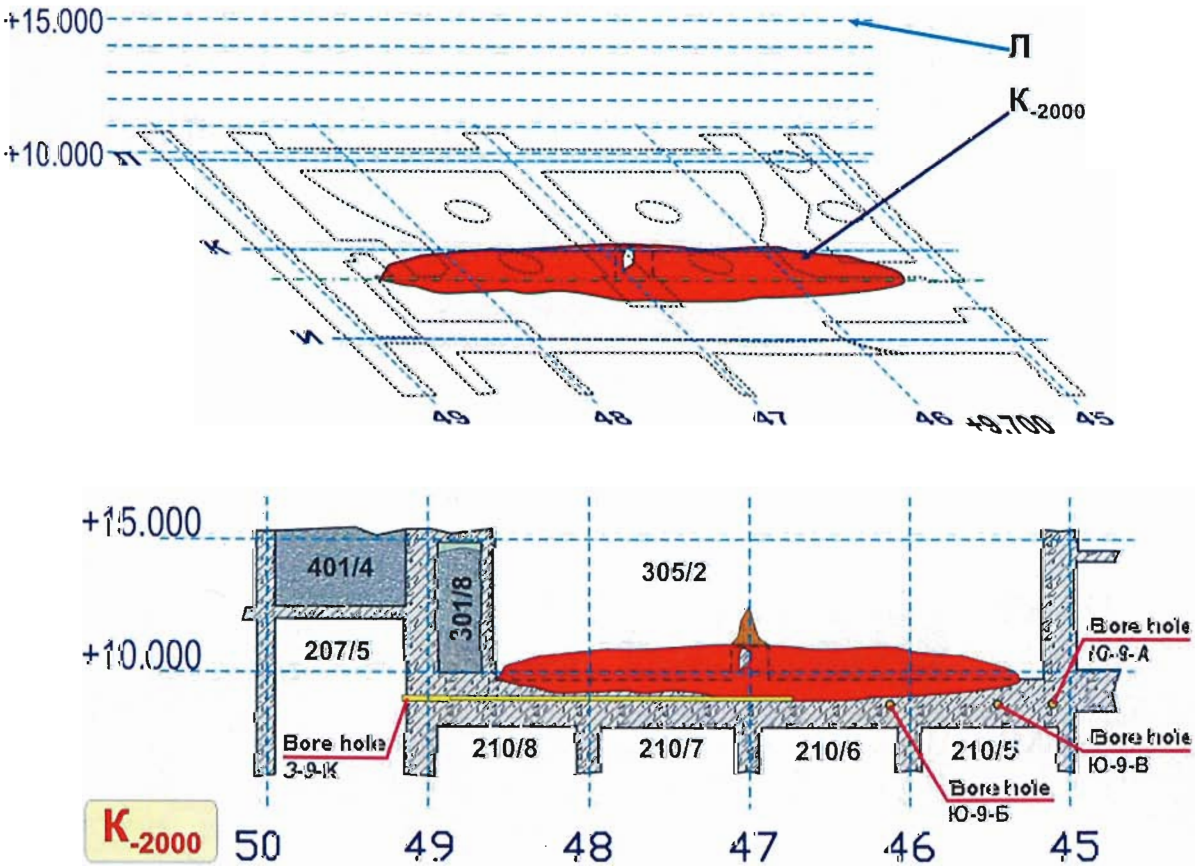


Fig. 4.10. Room #305/2. LFCM. Section through row 'К$_{-2000}$'

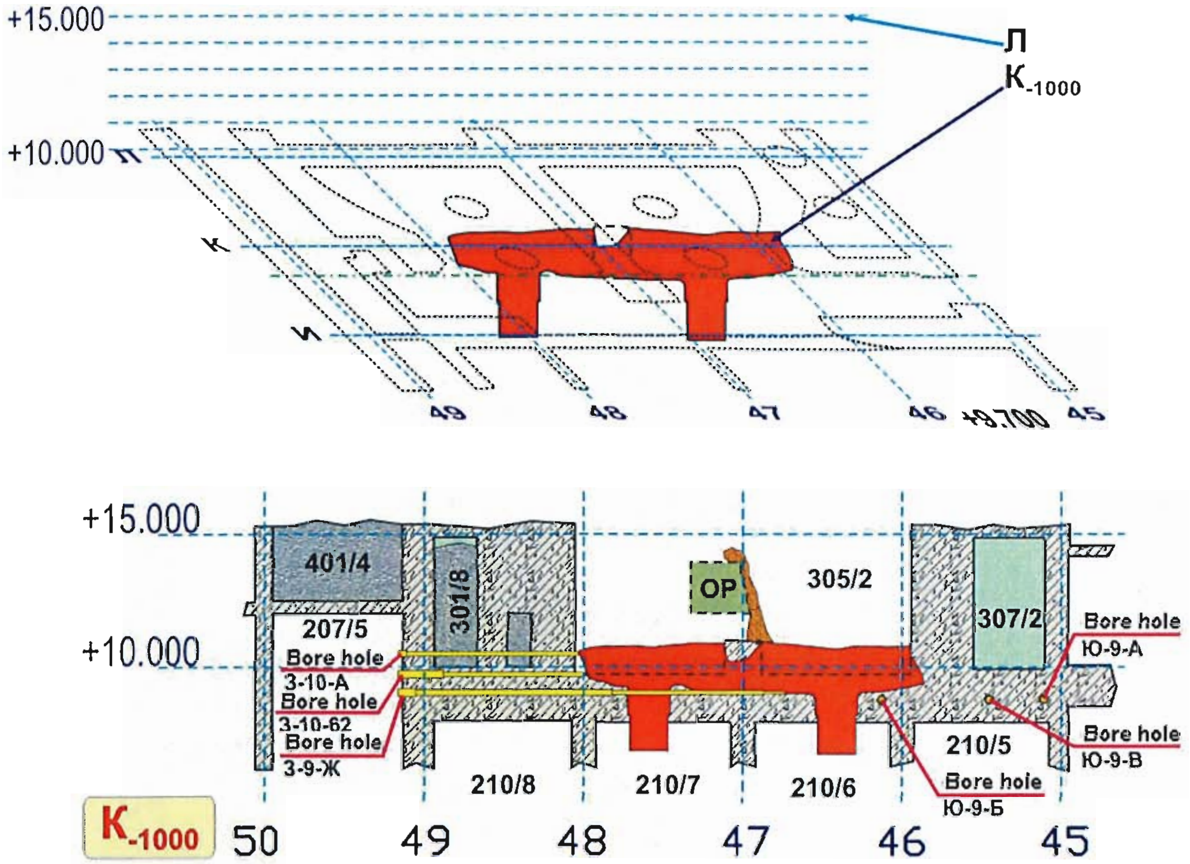


Fig. 4.11. Room #305/2. LFCM. Section through row 'K_{-1000}'

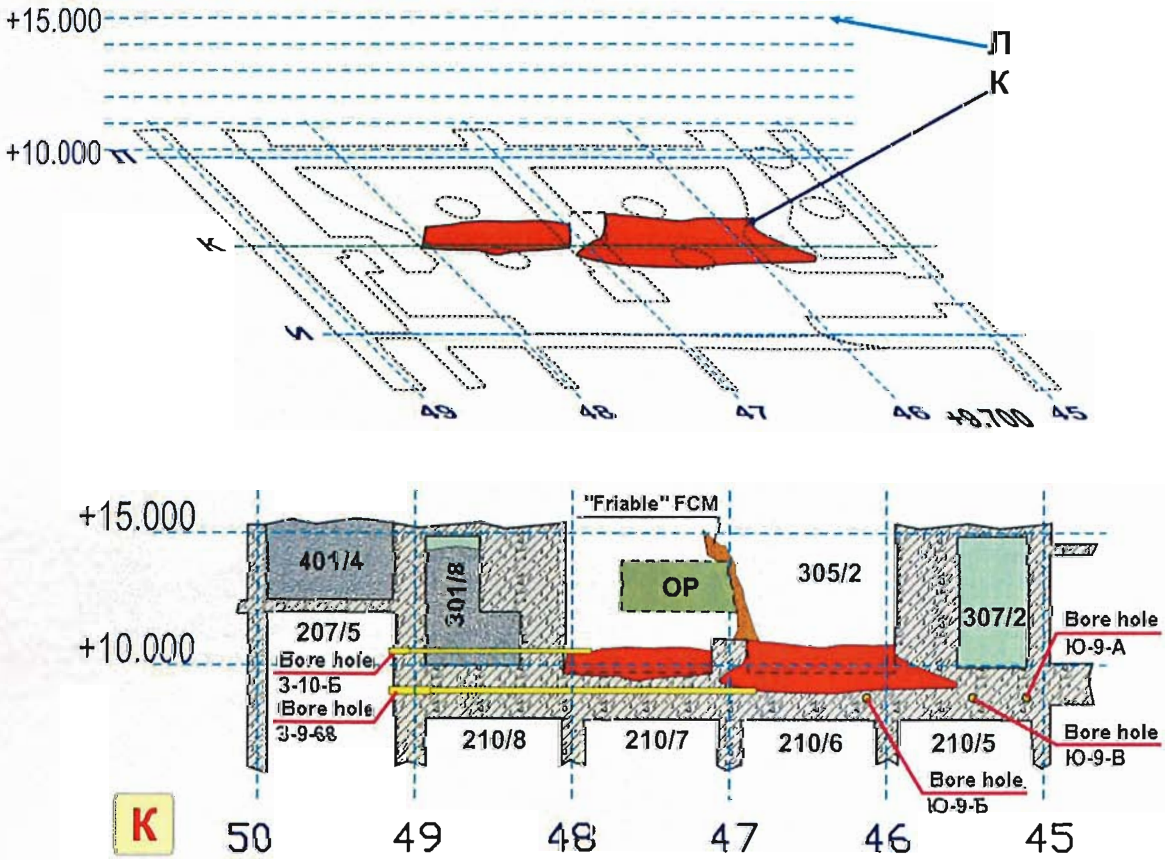


Fig. 4.12. Room #305/2. LFCM. Section through row 'K'

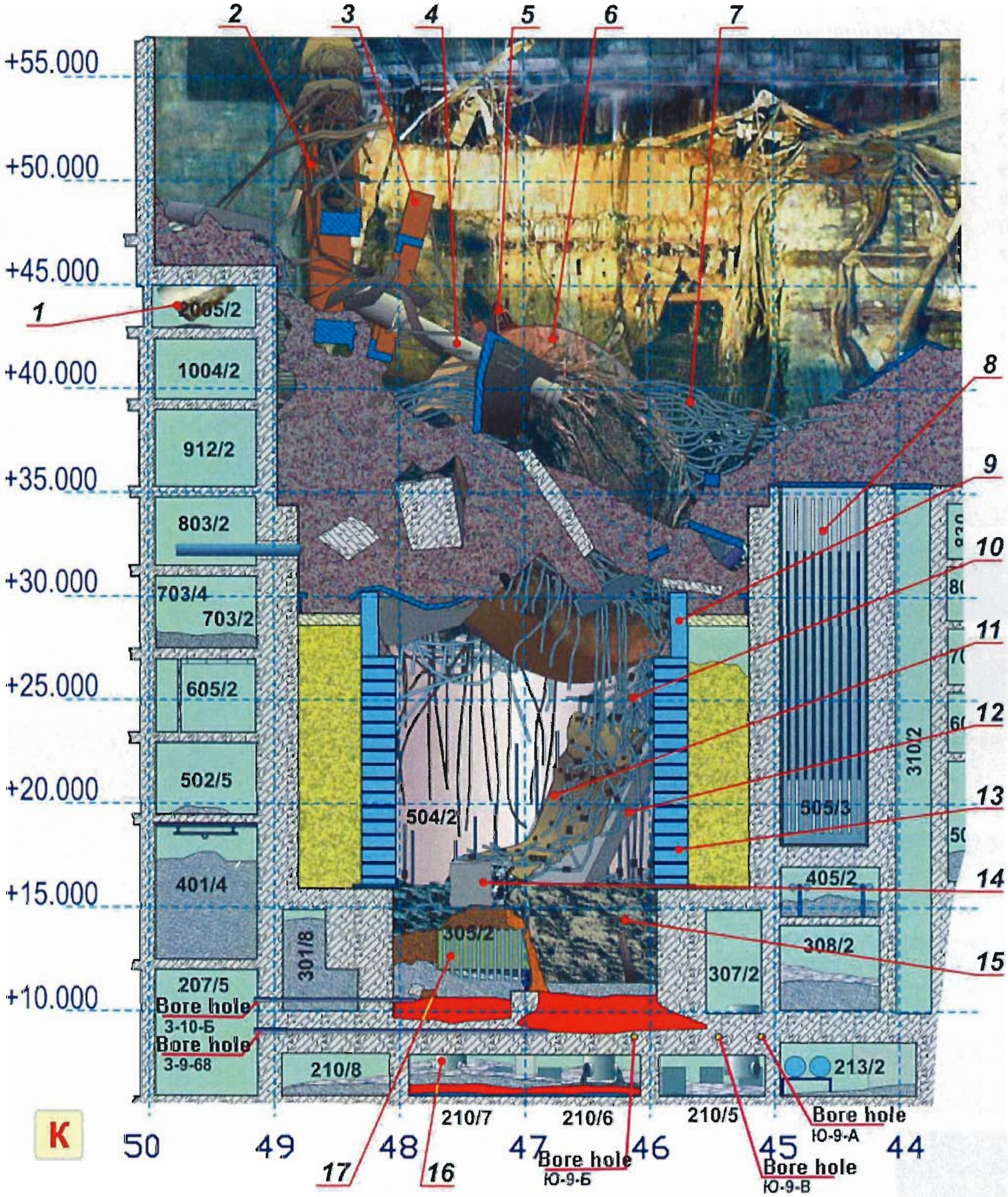
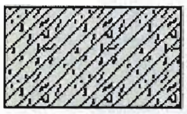
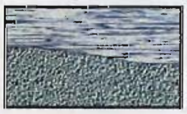


Fig.4.13. Fragment of Unit 4 section through row 'K'

1 - *sealed case of refueling machine (RZM)*
2 - *RZM bridge*
3 -*RZM handling car*
4 - *refueling machine (RZM)*
5 - *diagnostic buoy*
6 - *upper metal structure of the reactor – 'E' component*
7 - *"Elena's hair"*
8 - *assemblies with spent nuclear fuel*
9 - *water tank of biological shield – 'D' component*
10 -*process channels*
11 - *metal liner of heat shielding of the separator box*
12 - *slanting reinforced-concrete plate (wall fragment of the separator box)*
13 - *water tank of biological shield – 'Л' component*
14 - *reinforced concrete structure*
15 - *wall of "loose" FCM*
16 - *steam-dumping valve*
17 - *'OP' component*

 - *reinforced concrete of building structures*

 - *metal structures*

 - *1986-year concrete*

 - *sandy-gravel filling up material*

 - *wreckage in the central hall*

 - *wreckage and FCM in Room #305/2*

 - *LFCM*

 - *metal*

 - *"loose" FCM*

Fig. 4.13. Legend

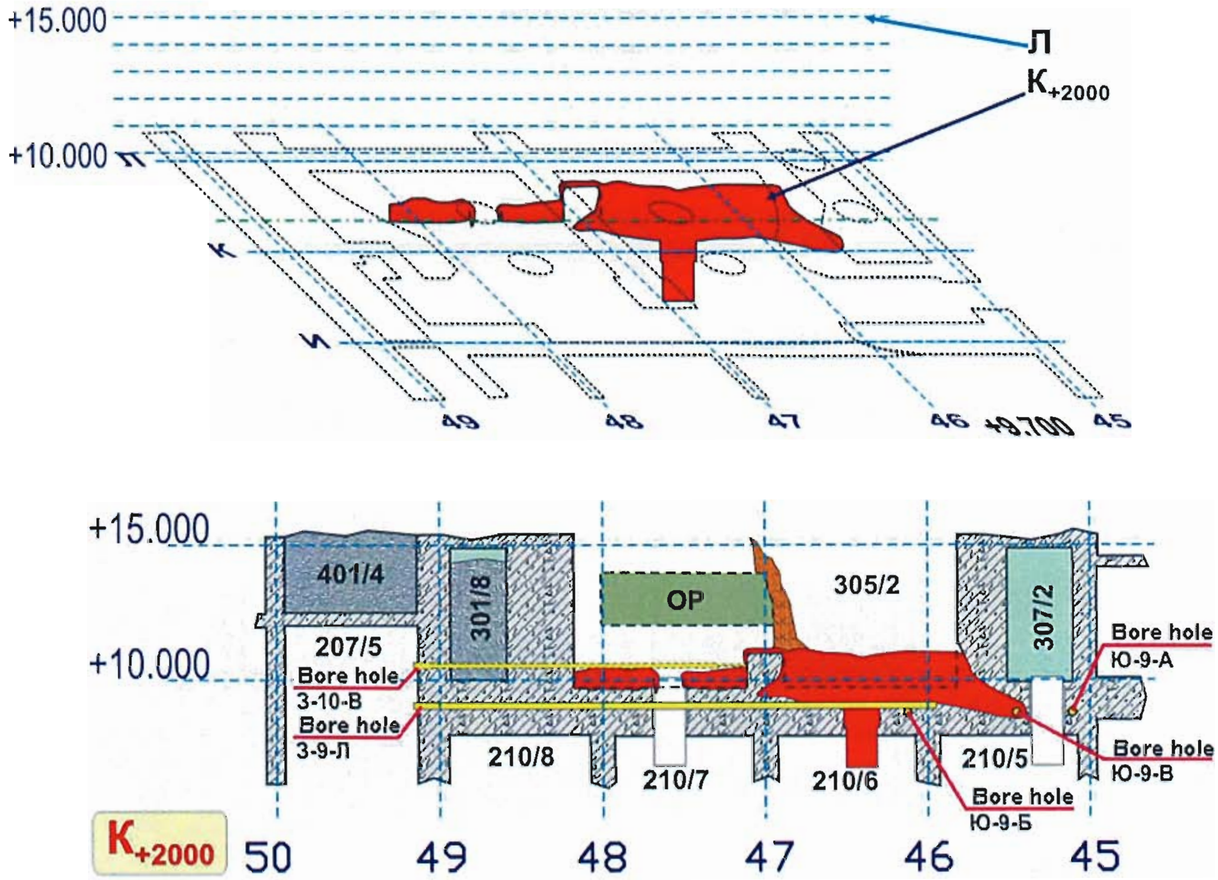


Fig. 4.14. Room #305/2. LFCM. Section through row 'К+2000'

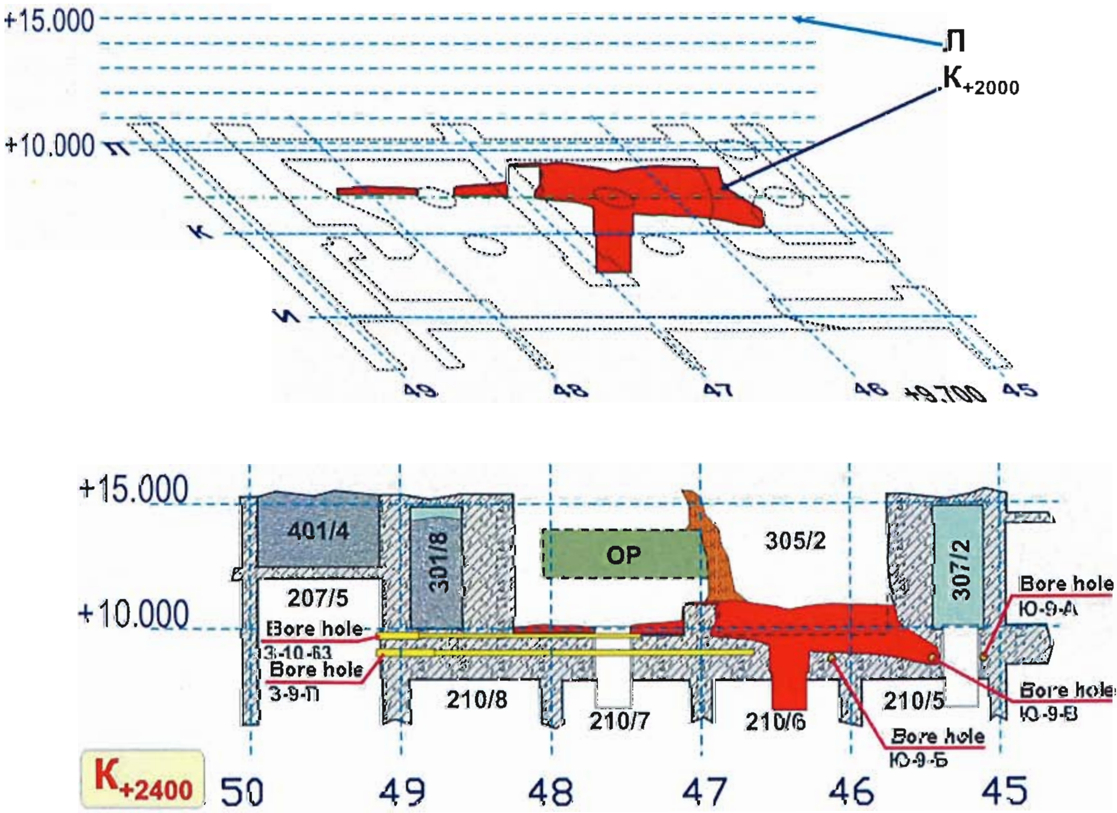
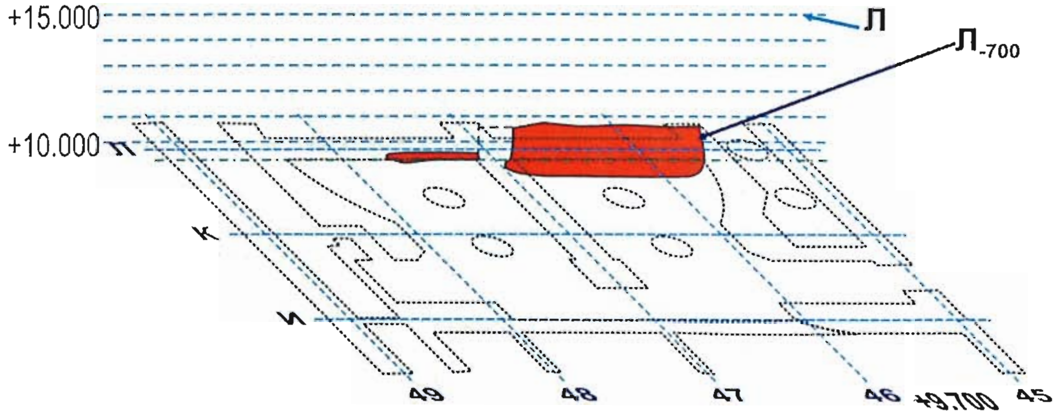


Fig. 4.15. Room #305/2. LFCM. Section through row 'К$_{+2400}$'



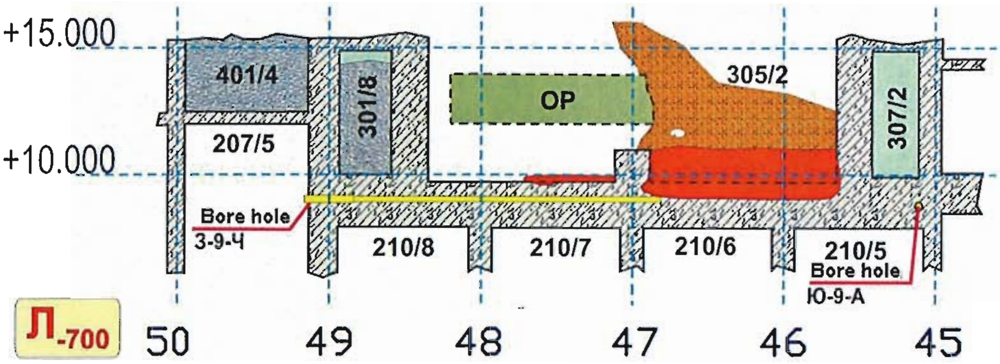


Fig. 4.16. Room #305/2. LFCM. Section through row 'Л$_{-700}$'

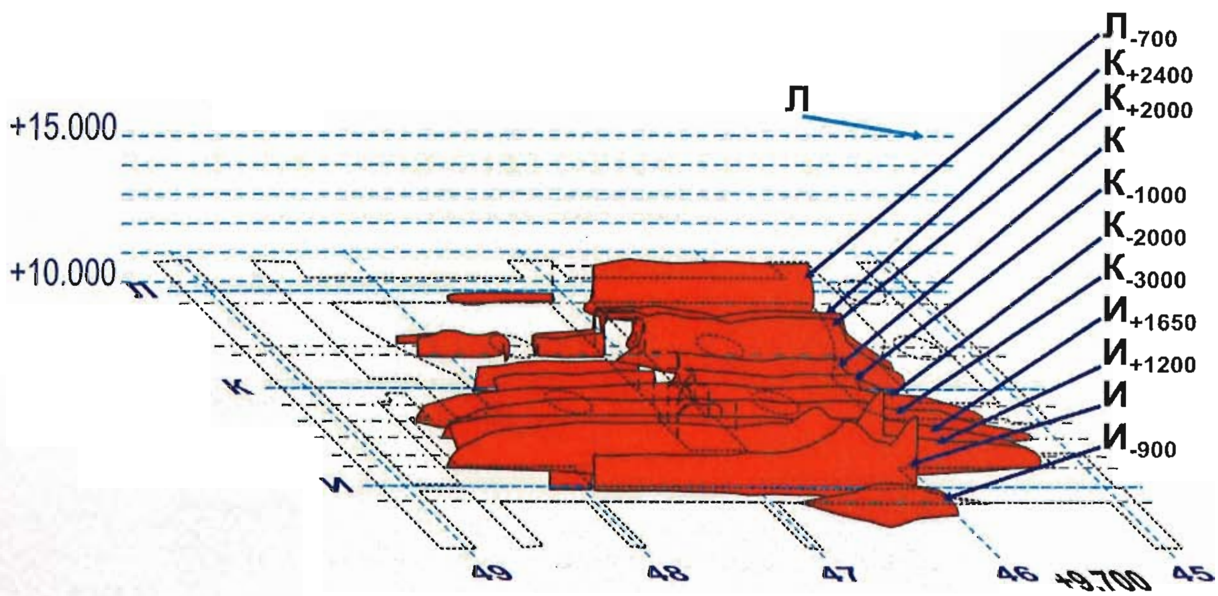


Fig. 4.17. Room #305/2. LFCM. Layout of sections at +9.700 level mark

Table 4.3. Room #305/2. Lower boundary of LFCM, height from level mark +9.000, mm

Axis →							**48**								**47**								**46**								
Distance from axis 49, m	*2.6*	3	4	*4.5*	5	*5.6*	6	*6.5*	7	8	9	10	11	*11.3*	12	*12.4*	13	14	15	16	17	*17.5*	18	*18.6*	19	20	*20.7*	21	*21.7*	22	23
И$_{-900}$																															
																	700	420	140	-100	100		220	260							
И																															
								600	580	580	560	540	520		440		460	460	300	200	220	360									
И$_{+1200}$																															
	700	660	660		600		580		500	400	400	280	200		120		120	40	-40	-80	40		300		480	540		600		660	700
И$_{+1650}$																															
		700	560		480		480		440	380	320	220	140		40		40	0	0	60	200		280		320	400		460		600	700
К$_{-3000}$																															
		700	680		620		560		460	360	320	260	200		160		40	0	-40	-60	100		200		300	400		480		580	680
К$_{-2000}$																															
	700	600	440		200		260		300	220	300	240	40		-40		-40	-60	-60	-40	80		100		160	240		360		600	
К$_{-1000}$																															
							700		360	260	260	160	100		100		0	0	0	0	60		200		600						
										SDV									SDV												
К																															
						700	640		600	500	500	580	640	660	280		60	0	-40	-40	40		100		120	140	160				
															Cross																
К$_{+2000}$																															
					680		660		660	700	700	660	660	680	340		260	60	0	-40	40		60		0	-200		-400	-400		
										SDV					Cross				SDV												
К$_{+2400}$																															
				800	800	800	800	800	800	800	800	800	800	800		700	600	500	280	60	0		-40		-80	-220		-440	-440		
										SDV					Cross				SDV												
Л$_{700}$																															
										700	700	700	700	700		400	180	80	80	60	60		60		80	200					
															Cross																

Coordinates are given from axis 49 toward the drilling area.
In vertical direction the level mark '+9.000' is taken as '**0**': +9.000 = **0**, +9.100 = **100 mm**, +9.200 = **200 mm**,……. +9.700 = **700 mm**.
In the Steam-Dumping Valve (SDV) area the values of lower boundary of LFCM adjoining SDV are given

Expected Accumulations with High Uranium Concentration

In the course of the last few years opinions have been expressed more and more frequently that, in addition to 7 visible FCM-containing locations (see above), there are fuel accumulations with considerable uranium concentration at depth of the under-reactor room.

The hypothesis on existence of such accumulations was first expressed while attempting explaining the so-called "anomalous neutron event" of 1990.

The event consisted in the following (see [3]).

In the second half of June 1990 the information-measuring system "Finish" was recording neutron fluxed in the "Shelter" by means of 5 sensors. Two of them were installed in the reactor space at level marks +18.00 (Channel #48) and +15.00 (Channel #46); the remainder three sensors were located in the under-reactor room #305/2, in SDC (Channel #45) and in Room #304/3 (Channel #50). All sensors were installed using holes; their layout is shown in Fig. 4.18.

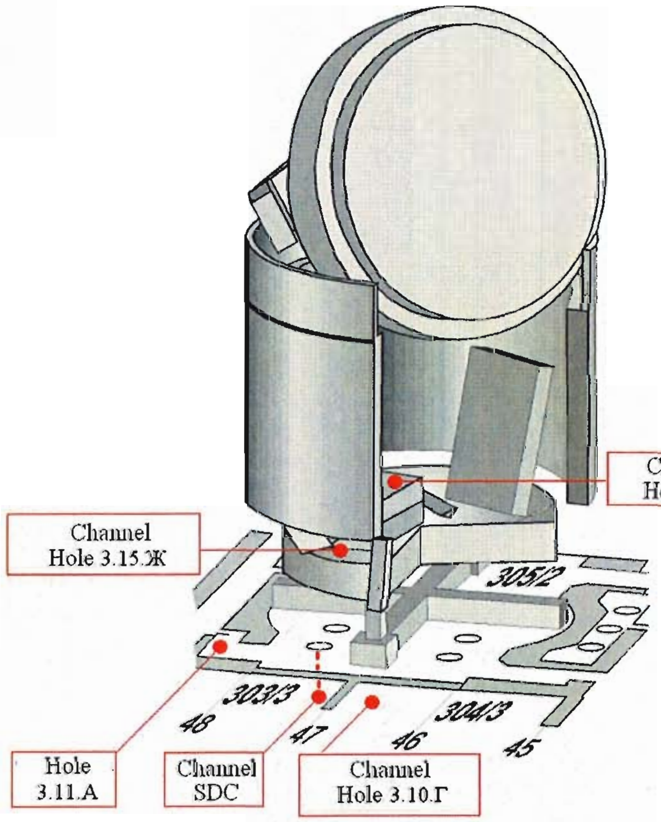


Fig.4.18. Layout of neutron channels of "Finish" system, summer 1990

On 24.06.90 operator's attention was drawn to an increase in counting rate of Channel #50 (~ 4.0 pulse/s instead of ordinary ~ 2,5 pulse/s). Neutron sensor of that channel was installed in Room #304/3 via the hole 3-10-G (from Room #207/4) directly on LFCM surface.

During the following few days (25 through 29 June) the counting rate in the channel increased continuously and exceeded the ordinary level by ~60 times (Fig. 4.19).

Throughout the indicated period actions were being conducted aimed at discovering the causes of such an anomalous behavior of Channel #50.

The whole counting route of Channel #50 of "Finish" system was fully checked, and no failure was detected.

Room #304/3 was examined from Room #318/2 via periscope.

No changes in Room #304/3 were discovered.

To check operability of the sensor and the whole route, a neutron source (^{252}Cf) was delivered to the sensor via the hole on a bar. The response of the counting channel corresponded to the expected one and did not reveal any anomalies.

An additional neutron sensor, introduced via the hole, confirmed the counting rate increase.
Due to further increase in the counting rate in Channel #50 of "Finish" system (up to ~ 160 pulse/s), on 29.06.90 a decision was made on introduction – by two portions – of gadolinium-nitrate solution into Room #304/3. Once the second portion of solution had been introduced, the counting rate decreased during 24 hours down to 2,4 pulse/s.

Throughout that period other neutron channels of "Finish" system recorded ordinary counting rate values.

The most detailed and weighty investigation of the causes of that anomalous event in Room #304/3 in June 1990 was performed by a special commission of the Nuclear Safety Institute of the Russian Academy of Sciences [4].

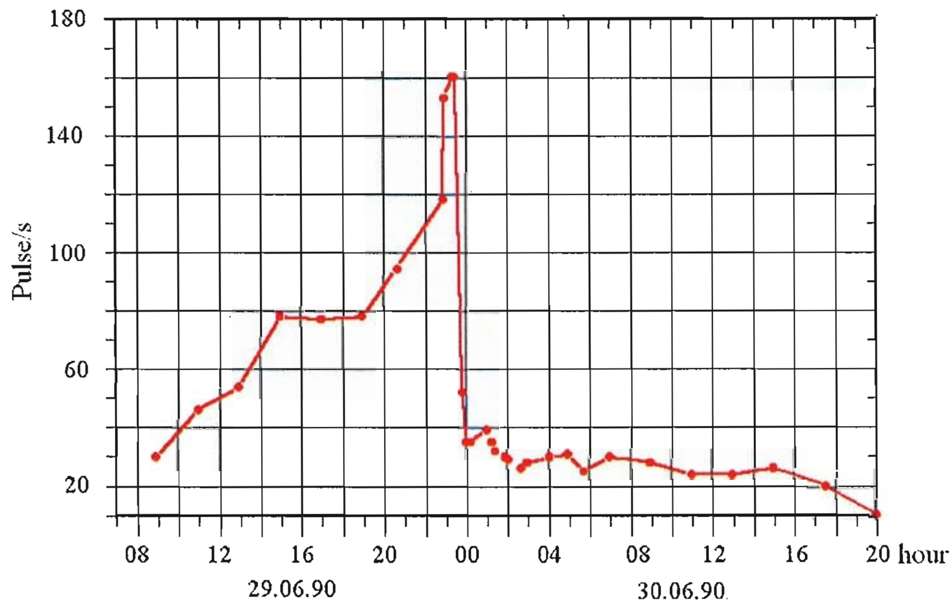


Fig. 17. Time dependence of counting by Channel #50 of "Finish" system, June 29 and 30, 1990

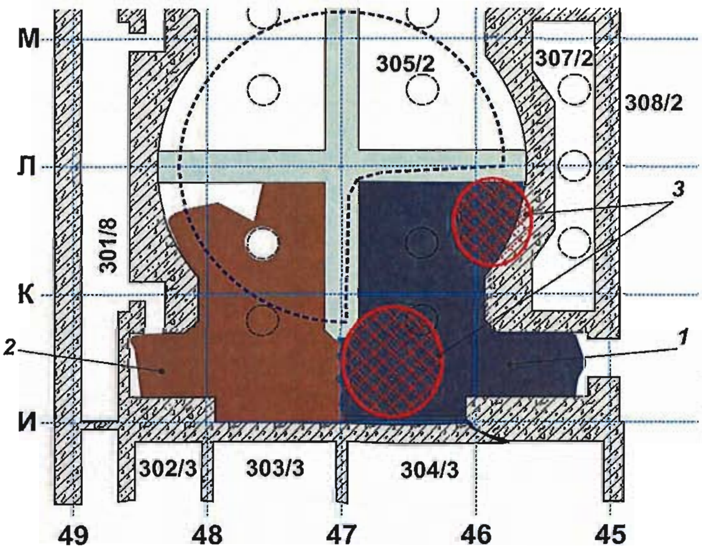
Hypotheses of both "instrumental" and "physical" genesis were checked.
As an example of the latter hypothesis, an assumption was put forward on increase in neutron sensor efficiency due to softening of neutron spectrum resulting from flooding of Room #305/2 with water. However that hypothesis was next rejected: according to calculations, the spectrum-softening effect could not have produced such a considerable increase in counting under any assumptions [5].

After checking of all assumptions only one of them still aroused suspicion: a considerable increase in neutron generation (in extreme case –initiation of self-sustaining chain reaction) within a hypothetical FCM accumulation located in Room #305/2 close to the breach in wall leading to Room #304/3. If so, the sensor responded to scattered neutron radiation that first increased and next – after flooding of the room with gadolinium solution – was absorbed intensively. Specialists of the Physics & Power Engineering Institute came to the same conclusion as well [6].

In order for the effective neutron multiplication factor K_{eff} to be considerably increased in such an accumulation while flooded by water, the FCM volume must be equal to several cubic meters,

and uranium concentration therein (at medium burnup) must exceed that in LFCM by 4 to 5 times [7].
For example, the accumulation may represent a mixture of lava with non-molten core fragments. Later on a thorough analysis of the data available (see below), as well as the results of measurements performed in 1999 – 2000 along three new itineraries in the breach area within the southeastern quadrant of Room #305/2 [8] confirmed the presence of a large localized FCM massive with higher neutron activity. The massive is situated in the area of +9.000 level mark. One more similar-type accumulation is expected close to Room #307/3's wall in the area of +9.000 - +10.000 level marks north of the above massive (Fig. 4.20).

Among the data available, the results of core-sample analyses [2], distributions of heat flows in Room #305/2 achieved as early as 1988 [9] and observations of neutron fluxes during periods of abnormally high atmospheric precipitations count in favor of the "hidden-accumulation" hypothesis [3].



1 – Mostly black LFCM
2 – Mostly brown LFCM
3 – FCM areas with high fuel concentration

Fig. 4.20. Expected location of areas containing FCM with high uranium concentration

The results of temperature measurements performed using holes in the under-reactor plate (Fig. 19) indicate the presence of a powerful heat source within the southeastern quadrant.

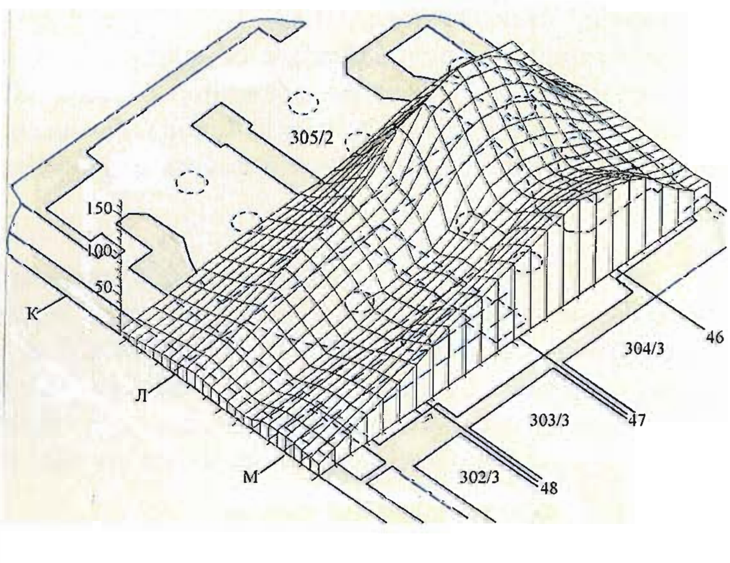


Fig. 4.21. Temperature field in the reactor plate according to the results of 1988 – 1989 investigations

An analysis of correlations was performed between the neutron activity recorded by sensors, the external temperature 'T' and the intensity of atmospheric precipitations using the data of Chernobyl weather station. Such a correlation was indeed traced and was especially pronounced in July 2000 when the amount of atmospheric precipitations was abnormally high (Fig. 4.22).

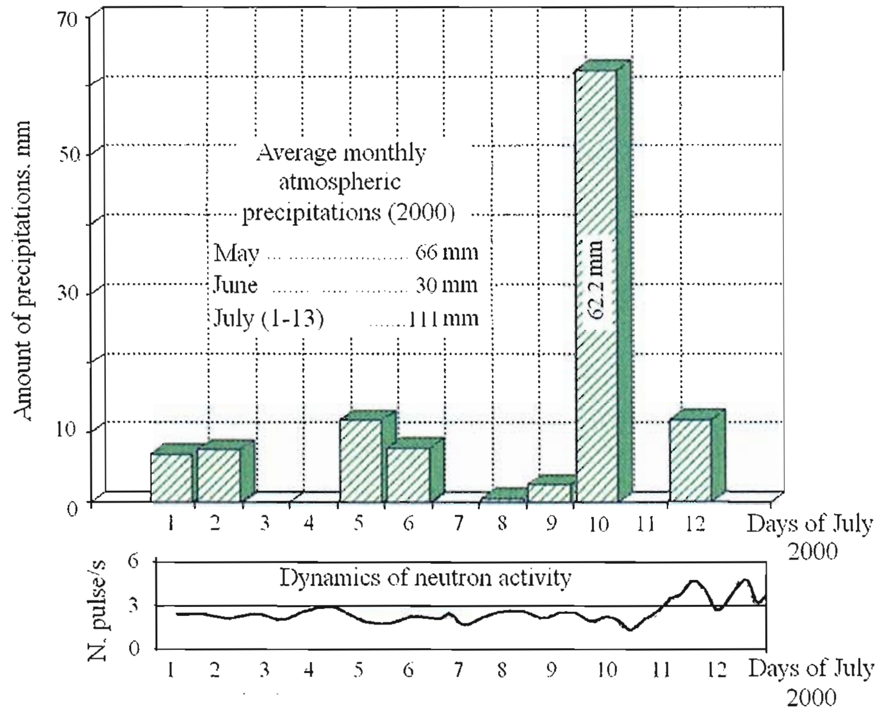


Fig. 4.22. Atmospheric precipitations in July 2000 in the Chernobyl NPP area and the dynamics of neutron activity in Room #305/2 close to the breach

It is worthy of note that water, coming from upper rooms via Room #504/2 and next to the southwestern and the southeastern quadrants of Room #305/2, fills cavities generated due to burns of floor under the breach between Rooms #305/2 and #304/3. Depending on the inflow/outflow rate, the level of water in FCM accumulation in the breach area changes that determines fluctuations of the neutron flux density.

While applying the conservative approach, such fluctuations may be attributed to K_{eff} variations. (The second possible cause is softening of neutron spectrum and thus an increase in sensitivity of neutron sensor).

From the above the following conclusion may be reached: in addition to described 7 FCM-containing locations, there are, to a high probability, fuel accumulations with considerable uranium concentration at depth of the under-reactor room.
However at present no quantitative estimates of fuel concentration in these accumulations can be made.

REFERENCES

1. Borovoi, A.A., Lagunenko, A.S. and Pazukhin, E.M. (1998) Estimate of fuel amount in the under-reactor room #305/2 of Chernobyl NPP Unit 4, *J. Atomnaya Energiya (Atomic Energy),* **84 (4)**, pp. 356 – 361 (in Russian).

2. *Holes in the "Shelter": Generalized Data (Diagram Manuel)* (1998) Report of the ISTC “Shelter” Nuclear & Radiation Safety Department, #09/05-66 of 09.06.98, Chernobyl, P. 117 (in Russian).

3. *The "Shelter" Current Safety Analysis and Forecast Estimates for the Situation Development* (2001) A.A. Borovoi (responsible exec.), ISTC "Shelter" Report, arch. n°3836, Chernobyl, P. 337 (in Russian).

4. *Findings of Expert Commission Concerning the Causes of Abnormal Event in Room #304/3 of the “Shelter” in June 1990* (1992), IBRAE RAS, Moscow, P.67 (in Russian).

5. Brodkin, E.M. (1991) *Variations of Characteristics of Neutron Field above FCM during Generation of Surface Water Layer*, Report of I.V. Kurchatov IAE #30/1-1438-91, P. 19 (in Russian).

6. Frolov, V.V. (1992) *A New Hypothesis on the Genesis of Abnormal Event in the Shelter in June 1990*, FEI Letter of 15.07.92, outgoing #57-07/117 (in Russian).

7. Borovoi, A. A. (2003) *The “Shelter” Nuclear Safety Evaluation and Consequences of a Hypothetical Nuclear Incident at the “Shelter”*, Preprint of IAE-6283/3, Moscow, P. 36 (in Russian).

8. Vysotskiy, E.D., Lagunenko, A.S., Shevchenko, V.G., *at al.* (2000) *Development of Methods and Procedures of Control over Subcriticality of Fuel-containing Materials, Experimental Investigation of the Efficiency of Early Detection Criteria and Technologies of Local Suppression of Subcritical Anomalies*, ISTC “Shelter” Report #3810, Chernobyl, P. 129 (in Russian).

9. *Results of Heat and Radiation Measurements at the Shelter over 1988-1989* (1989) Report of ISTC “Shelter” of Ukrainian National Academy #1379, P. 47 (in Russian).

4.1.1.1. Appendix (305/2 - 1). Holes of Room #305/2 and Description of Samples

The layout of bore holes in Room #305/2 at 9, 10 and 11 m level marks is demonstrated in Figs. 4.23 – 4.25.

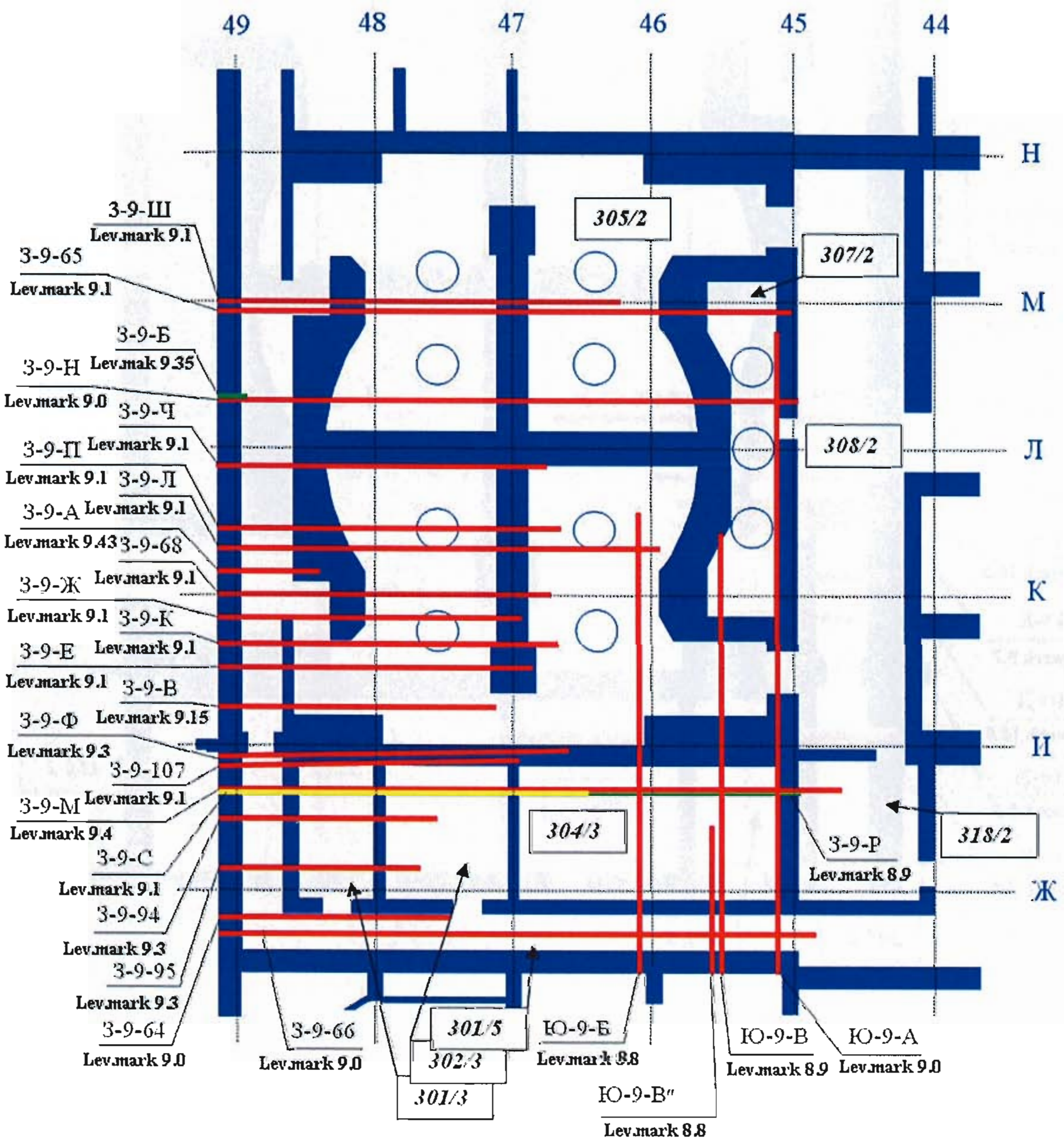


Fig. 4.23. Bore holes at 9 m level mark

Inclined holes:

- 3-9-Ф (horizontal angle –1°);
- 3-9-107 (horizontal angle –1°, vertical angle –1°).

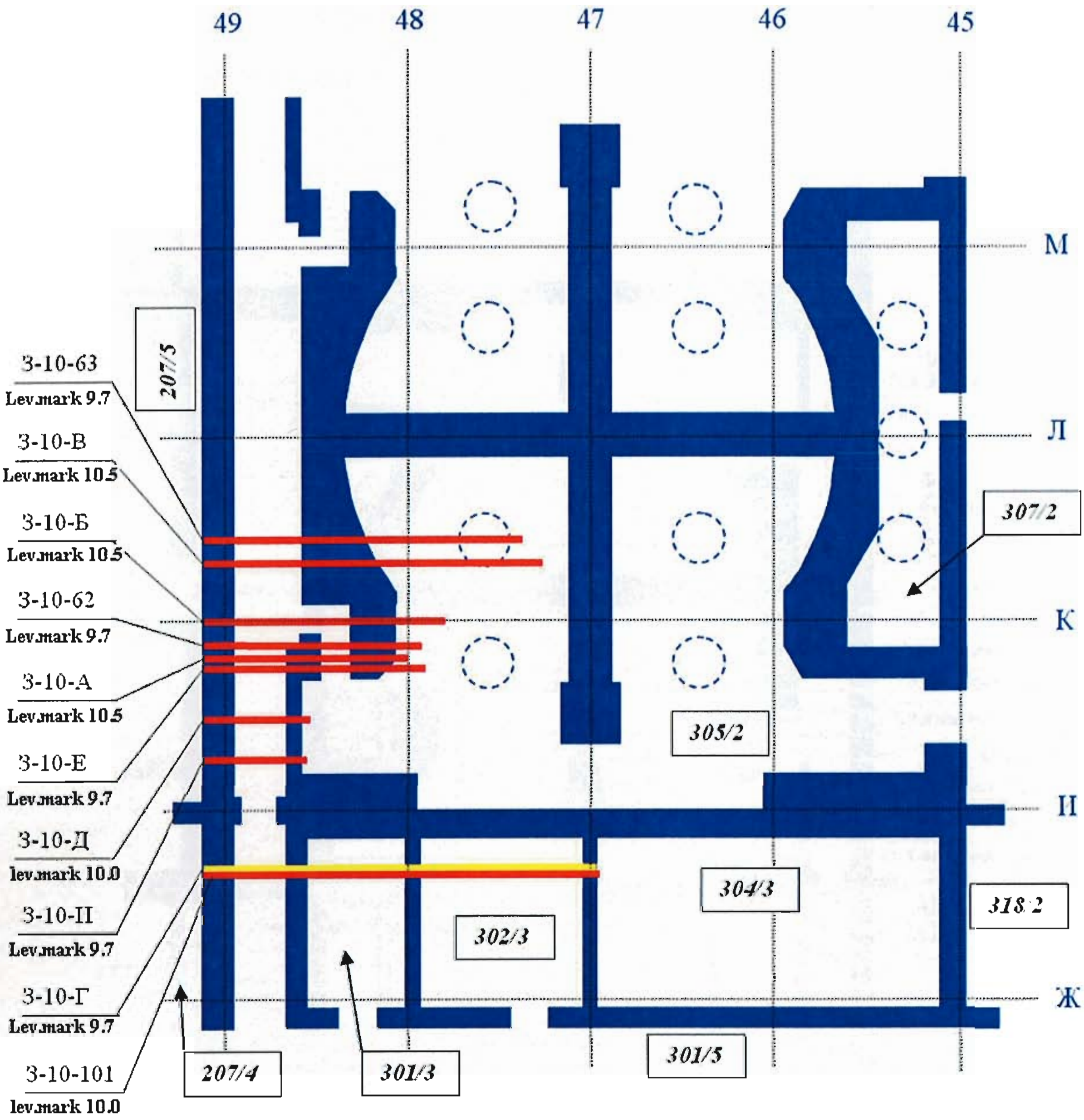


Fig. 4.24. Bore holes at 10 m level mark

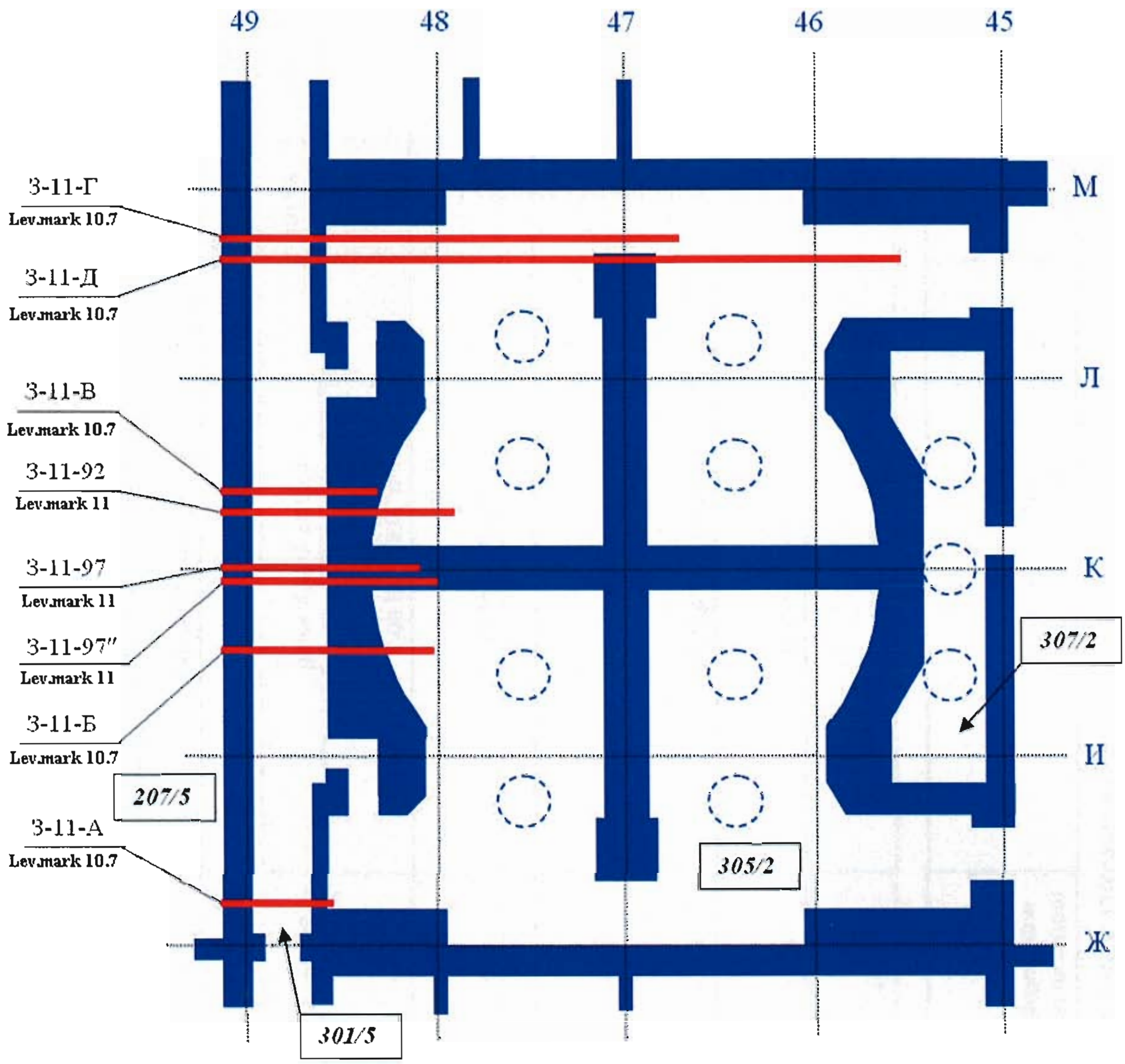


Fig. 4.25. Bore holes at 11 m level mark

Inclined holes

Hole	Vertical angle	Hole bottom, m
3-11-Д	+ 6°	13.1
3-11-В	+ 6°	11.3
3-11-92	+ 6°	11.8
3-11-97	+ 10°	12.1
3-11-97″	+ 10°	12.2
3-11-Б	+ 6°	11.4

The results of studying samples taken from cores while drilling holes in Room #305/2 are presented in Table 1 (EDR – Exposure Dose Rate, NFD – Neutron Flux Density)

Table A.1. FCM Samples Taken in Room #305/2, Cores, EDR, NFD. Distribution by Sections

No	Sample (sample number in ref. source), measured value, core, [Reference]	Area of sampling, EDR & NFD measurement, coordinates	Distance from section, mm	Sample description, EDR, NFD (date)	U, %	U, % (calculation for ^{144}Ce)
			$И_{900}$			
1	(У-5) [1]	46_{+2600}, $И_{400}$, lev.mark +9.300, base of wall between Room #304/3 and Room #305/2, hole #3-9-Ф	+500	Black ceramics	5.70	
2	EDR [2]	46_{+2600}, $И_{400}$, lev.mark +9.300, base of wall between Room #304/3 and Room #305/2, hole #3-9-Ф	+500	~1200 R/h, (6.02.90)		
3	EDR [3]	46_{+1600}, $И_{700}$, lev.mark +8.700, base of wall between Room #304/3 and Room #305/2, hole #3-9-107	+200	360 R/h, (01.11.2000)		
4	NFD [3]	46_{+2600}, $И_{700}$, lev.mark +8.700, base of wall between Room #304/3 and Room #305/2, hole #3-9-107	+200	450 n/($cm^2 \cdot s$) (01.11.2000)		
			И			
5	(У-5) [1]	46_{+2600}, $И_{400}$, lev.mark +9.300, base of wall between Room #304/3 and Room #305/2, hole #3-9-Ф	-400	Black ceramics	5,70	
6	EDR [2]	46_{+2600}, $И_{400}$, lev.mark +9.300, base of wall between Room #304/3 and Room #305/2, hole #3-9-Ф	-400	~1200 R/h, (6.02.90)		
7	(3) [4]	46_{+2700}, И/$И_{+1000}$, lev.mark +12.000, hole Ю-12-78	0 - +1000	Black glassy sample	10,17	10,64
8	(3-1) [4]	46_{+2700}, И/$И_{+1000}$, lev.mark +12.000, hole Ю-12-78	0 - +1000	Black glassy sample	13,58	20,86
9	(8) [4]	46_{+2700}, И/$И_{+1000}$, lev.mark +12.000, hole Ю-12-78	0 - +1000	Deep-brown fragile mass	9,25	12,40
10	EDR [2 ,3]	46_{+2700}, И, lev.mark +12.000, hole Ю-12-78	0	3640 R/h, (11.09.90) 1970 R/h, (01.11.2000)		
11	NFD [3]	46_{+2700}, И, lev.mark +12.000, hole Ю-12-78	0	310 n/($cm^2 \cdot s$) (01.11.2000)		
12	EDR [2]	46_{+2800}, И, lev.mark +12.600, hole Ю-12-83	0	860 R/h, (10.04.90)		
			$И_{+1200}$			

No	Sample (sample number in ref. source), measured value, core, [Reference]	Area of sampling, EDR & NFD measurement, coordinates	Distance from section, mm	Sample description, EDR, NFD (date)	U, %	U, % (calculation for ^{144}Ce)
13	Sample (7) [4]	45_{+1400}, $И_{+1200}$, lev.mark +12.000, hole Ю-12-72	0	Slaggy fragile material of black color	11,73	7,68
14	Sample (6) [4]	46_{+1000}, $И_{+700}$, lev.mark +12.500, hole B-12-71	-500	Black glassy mass	5,04	5,97
15	EDR [2]	46_{+1000}, $И_{+700}$, lev.mark +12.500, hole B-12-71	-500	1660 R/h, (10.02.90)	5,04	5,97
			$И_{+1650}$			
16	Core [2]	$48_{+1200}/48_{+1600}$, $И_{+1650}$, lev.mark +9.150, hole 3-9-B	0	De-structured concrete		
17	Sample (1) [5]	47_{+1400}, $И_{+1650}$, lev.mark +9.150, hole 3-9-B	0	Graphite	10,5	12,83
18	Sample (2) [5]	47_{+1400}, $И_{+1650}$, lev.mark +9.150, hole 3-9-B	0	Graphite	1,39	1,56
19	Sample [2]	$47_{+1400}/47_{+1600}$, $И_{+1650}$, lev.mark +9.150, hole 3-9-B	0	Graphite with swarf (4 samples)	1,6 – 3,7	
20	Sample (K3) [6]	$47_{+700}/47_{+1900}$, $И_{+1650}$, lev.mark +9.150, hole 3-9-B	0	Ceramics ("chocolate") shining at sections	9,96	13,52
21	Sample (K7) [6]	$47_{+700}/47_{+1900}$, $И_{+1650}$, lev.mark +9.150, hole 3-9-B	0	Anthracite-like black glassy mass	5,62	7,42
22	Core [7]	$49_{-2800}/49_{-2400}$, $И_{+1650}$, lev.mark +9.700, hole 3-10-И	0	Concrete containing iron shot, EDR from the core – 150 R/h, (October 1989)		
23	Sample (4) [5]	49_{-2600}, $И_{+1650}$, lev.mark +10.700, hole 3-11-A	0		7,11	7,98
24	Sample (5) [5]	49_{-2600}, $И_{+1650}$, lev.mark +10.700, hole 3-11-A	0		7,28	8,24
25	Core [2]	49_{-2600}, $И_{+1650}$, lev.mark +10.700, hole 3-11-A	0	Light-weight concrete, EDR from the core - 2000 R/h, (January 1988)		
26	EDR [2]	49_{-2600}, $И_{+1650}$, lev.mark +10.700, hole 3-11-A	0	1600 R/h (20.04.88)		
			$К_{3000}$			
27	Sample (4) [5]	47, $К_{3000}$, lev.mark +9.100, hole 3-9-E	0	Graphite	4,56	4,59
28	Core [2]	$47_{+2000}/48_{-1500}$, $К_{3000}$, lev.mark +9.100, hole 3-9-E	0	Cavity in concrete (burn of floor)		
29	Core [2]	$47/47_{+2000}$, $К_{3000}$, lev.mark +9.100, hole 3-9-E	0	De-structured concrete		

No	Sample (sample number in ref. source), measured value, core, [Reference]	Area of sampling, EDR & NFD measurement, coordinates	Distance from section, mm	Sample description, EDR, NFD (date)	U, %	U, % (calculation for ^{144}Ce)
30	Core [2]	$47_{-400}/47$, $К_{-3000}$, lev.mark +9.100, hole 3-9-Е	0	Concrete, metal, EDR from the core – 12 - 30 R/h (June 1988)		
31	EDR [2]	$47_{-400}/47$, $К_{-3000}$, lev.mark +9.100, hole 3-9-Е	0	1600 R/h (10.06.88)		
32	Core [2]	49_{-2900}, $К_{-3000}$, lev.mark +10.000, hole 3-10-Д	0	Concrete, EDR from the core - 200 R/h (April 1989)		
33	Core [2]	47_{+750}, $К_{-3000}$, lev.mark +8.800, hole Ю-9-Б	0	Metal, EDR from core – 3 R/h (May 1989)		
			$К_{-2000}$			
34	Sample (9) [5]	47_{-400}, $К_{-2000}$, lev.mark +9.100, hole 3-9-К	0	Metal	0,59	0,67
35	Sample (10) [5]	47_{-400}, $К_{-2000}$, lev.mark +9.100, hole 3-9-К	0	Graphite	0,02	0,019
36	Sample (11) [5]	47_{-400}, $К_{-2000}$, lev.mark +9.100, hole 3-9-К	0	Fused concrete	4,18	4,68
37	Sample (12) [5]	47_{-400}, $К_{-2000}$, lev.mark +9.100, hole 3-9-К	0	Gray-black concrete	0,01	0,0058
38	Sample (13) [5]	47_{-1600}, $К_{-2000}$, lev.mark +9.100, hole 3-9-К	0	Fused concrete	4,74	5,28
39	Sample (14) [5]	47_{-1600}, $К_{-2000}$, lev.mark +9.100, hole 3-9-К	0	Sand	5,27	5,75
40	Sample (15) [5]	47_{-1600}, $К_{-2000}$, lev.mark +9.100, hole 3-9-К	0	Fused mass (concrete)	4,91	5,54
41	Sample (3-9К) [6]	$47_{-1600}/47_{-400}$, $К_{-2000}$, lev.mark +9.100, hole 3-9-К	0	Concrete-like black smoky mass	8,82	5,54
42	Sample (3-Ф-1) [8]	47_{+800}, $К_{-2000}$, lev.mark +9.100, hole 3-9-К	0	Black sand	4,52	4,85
43	Sample (4-Ф-1) [8]	47_{+800}, $К_{-2000}$, lev.mark +9.100, hole 3-9-К	0	Concrete	0,33	0,35
44	EDR [2]	47_{-1600}, $К_{-2000}$, lev.mark +9.100, hole 3-9-К	0	3260 R/h (02.11.88)		
45	NFD [2]	47_{-1600}, $К_{-2000}$, lev.mark +9.100, hole 3-9-К	0	800 n/(cm^2 · s) (30.01.89)		
46	Core [2]	$47_{-200}/47_{-600}$, $К_{-2000}$, lev.mark +9.100, hole 3-9-К	0	Concrete, EDR from the core - 40 R/h (October 1988)		

No	Sample (sample number in ref. source), measured value, core, [Reference]	Area of sampling, EDR & NFD measurement, coordinates	Distance from section, mm	Sample description, EDR, NFD (date)	U, %	U, % (calculation for ^{144}Ce)
47	Core [2]	$47_{-600}/47_{-1600}$, $К_{2000}$, lev.mark +9.100, hole 3-9-К	0	Mud, metal, EDR from the core - 15 R/h (October 1988)		
48	Core [2]	47_{+750}, $К_{-2000}$, lev.mark +8.800, hole Ю-9-Б	0	Metal, EDR from the core – 2 -5 R/h (May 1989). Burned concrete - 5 R/h (May 1989)		
			$К_{-1000}$			
49	Sample (6) [5]	$48_{-2300}/48_{-2500}$ (SDV), $К_{-1000}$, lev.mark +9.100, hole 3-9-Ж	0	De-structured concrete	4,65	5,32
50	Sample (7) [5]	$48_{-2500}/48_{-2800}$ (SDV), $К_{-1000}$, lev.mark +9.100, hole 3-9-Ж	0	Graphite, dust	9,45	10,73
51	EDR [2]	$48_{-2500}/48_{-2800}$ (SDV), $К_{-1000}$, lev.mark +9.100, hole 3-9-Ж	0	3450 R/h (27.07.88)		
52	Sample (12) [5]	47_{-600}, $К_{-1000}$, lev.mark +9.100, hole 3-9-Ж	0	Graphite	4,07	4,38
53	Sample (13) [5]	47_{-600}, $К_{-1000}$, lev.mark +9.100, hole 3-9-Ж	0	Fused concrete	3,54	3,81
54	Sample (15) [5]	47_{-600}, $К_{-1000}$, lev.mark +9.100, hole 3-9-Ж	0	Fused concrete	3,17	3,44
55	Sample (16) [5]	47_{-600}, $К_{-1000}$, lev.mark +9.100, hole 3-9-Ж	0	De-structured concrete	2,25	2,94
56	Sample (17) [5]	47_{-600}, $К_{-1000}$, lev.mark +9.100, hole 3-9-Ж	0	De-structured concrete	3,50	3,78
57	EDR [2]	47_{-600}, $К_{-1000}$, lev.mark +9.100, hole 3-9-Ж	0	1470 R/h (27.07.88)		
58	Sample (3-9Ж П(У) [6]	47_{-600}, $К_{-1000}$, lev.mark +9.100, hole 3-9-Ж	0	Dark-gray powder		3,35
59	Sample (3-9Ж 1(Ш) [6]	$48_{-2000}/47$, $К_{-1000}$, lev.mark +9.100, hole 3-9-Ж	0	Black glassy mass		2,32
60	Sample (К1) [6]	$48_{-2000}/47$, $К_{-1000}$, lev.mark +9.100, hole 3-9-Ж	0	Foamed solidified light gray mass with partial vitrification	2,26	2,88
61	Sample (К2) [6]	$48_{-2000}/47$, $К_{-1000}$, lev.mark +9.100, hole 3-9-Ж	0	Gray mass with cavities and partial black inclusions	6,32	7,90
62	Core [2]	$48_{-1800}/48_{-2400}$ (SDV), $К_{-1000}$, lev.mark +9.100, hole 3-9-Ж	0	Destroyed concrete, destroyed mass, EDR from the core – 100 - 150 R/h (September 1988)		
63	Sample (К4) [6]	$47/47_{-800}$, $К_{-1000}$, lev.mark +9.100, hole 3-9-Ж	0	Graphite with inclusion of dark small-size (fractions of mm) globules	0,56	0,72

No	Sample (sample number in ref. source), measured value, core, [Reference]	Area of sampling, EDR & NFD measurement, coordinates	Distance from section, mm	Sample description, EDR, NFD (date)	U, %	U, % (calculation for ^{144}Ce)
64	EDR [2]	$47/47_{-800}$, $К_{-1000}$, lev.mark +9.100, hole 3-9-Ж	0	EDR from the core – 5 - 90 R/h (September 1988)		
65	Sample (3-9Ж-1) [6]	47_{-1600}, $К_{-1000}$, lev.mark +9.100, hole 3-9-Ж	0	Dark-gray material similar to a piece of concrete	6,17	1,13
66	Core [2]	$48_{-100}/48_{+200}$ (SDV), $К_{-1000}$, lev.mark +9.700, hole 3-10-62	0	Matel, cladding, EDR from the core – 120 R/h (September 1989)		
67	Core [2]	$48_{+100}/48_{+900}$ (SDV), $К_{-1000}$, lev.mark +10.500, hole 3-10-A	0	Burned concrete with pipes, EDR from the core – 100 R/h (September 1989)		
68	EDR [2]	48_{+900} (SDV), $К_{-1000}$, lev.mark +10.500, hole 3-10-A	-300	2290 R/h (16.02.89)		
69	Core [2]	47_{+750}, $К_{-1000}$, lev.mark +8.800, hole Ю-9-Б	0	Burned concrete, EDR from the core - 5 R/h (May 1989)		
К						
70	Sample (1) [5]	48_{+200}, К, lev.mark +10.500, hole 3-10-Б	0		7,84	8,84
71	Sample (2) [5]	48_{+200}, К, lev.mark +10.500, hole 3-10-Б	0		5,97	6,74
72	Sample [2]	48_{-800}, К, lev.mark +10.500, hole 3-10-Б	0	Burned concrete		9,94
73	Sample [2]	48_{-800}, К, lev.mark +10.500, hole 3-10-Б	0	Cement mortar		7,00
74	Core [2]	48_{-800}, К, lev.mark +10.500, hole 3-10-Б	0	Burned concrete, EDR from the core - 200 R/h (May 1989)		
75	EDR [9]	48_{+100}, К, lev.mark +10.500, hole 3-10-Б	0	830 R/h (03.05.88)		
76	Core [2]	47_{-1000}, К, lev.mark +9.100, hole 3-9-68	0	Metal, EDR from the core - 150 R/h (January 1989)		
77	EDR [2]	47_{+200}, К, lev.mark +9.100, hole 3-9-68	0	940 R/h (21.12.89)		
78	Core [2]	47_{+750}, К, lev.mark +8.800, hole Ю-9-Б	0	Burned concrete, EDR from the core - 5 R/h (May 1989)		
79	МЭД [2]	45_{+2700}, К, lev.mark +8.800, hole Ю-9-В	0	75 R/h (21.05.89)		
$К_{+2000}$						

No	Sample (sample number in ref. source), measured value, core, [Reference]	Area of sampling, EDR & NFD measurement, coordinates	Distance from section, mm	Sample description, EDR, NFD (date)	U, %	U, % (calculation for ^{144}Ce)
80	Sample (1) [10]	47_{-2900}, $К_{+2000}$, lev.mark +9.100, hole 3-9-Л	0	Semi-liquid mass from sample surface	1,31	1,46
81	Core [2]	$47_{-1200}/47_{+600}$, $К_{+2000}$, lev.mark +9.100, hole 3-9-Л	0	Mud, the core is not extracted, EDR from the core 3 - 5 R/h (January 1989)		
82	Core [2]	$46_{-300}/47_{-1200}$, $К_{+2000}$, lev.mark +9.100, hole 3-9-Л	0	No core description, EDR from the core up to 200 R/h, drilling tool – up to 40 R/h (January 1989)		
83	Sample (3) [5]	48_{+300}, $К_{+1800}$, lev.mark +10.500, hole 3-10-В	-200	Black stone	12,69	
84	Sample [2]	48_{-100}, $К_{+1800}$, lev.mark +10.500, hole 3-10-В	-200			5,8
85	Sample [2]	48_{-100}, $К_{+1800}$, lev.mark +10.500, hole 3-10-В	-200			9,0
86	Sample [2]	47_{+600}, $К_{+1800}$, lev.mark +10.500, hole 3-10-В	-200			10,1
87	Core [2]	$47_{+1000}/47_{+1800}$, $К_{+1800}$, lev.mark +10.500, hole 3-10-В	-200	Pipes, metal ∅50 - 100, 15 – 130 R/h (May 1988)		
88	EDR [2]	47_{+1800}, $К_{+1800}$, lev.mark +10.500, с кв. 3-10-В	-200	1130 R/h (09.06.88)		
89	Core [2]	47_{+750}, $К_{+2000}$, lev.mark +8.800, hole Ю-9-Б	0	Burned concrete, EDR from the core - 5 R/h (May 1989)		
90	EDR [2]	45_{+2700}, $К_{+2000}$, lev.mark +8.800, hole Ю-9-В	0	650 R/h (21.05.89)		
91	Core [2]	45_{+2700}, $К_{+1700}/К_{+2100}$, lev.mark +8.800, hole Ю-9-В	-300 - +100	Metal, 20 - 2350 R/h (May 1989)		
92	Sample (3-15Ж) [6]	$48_{-1300}/48_{-300}$, $К_{+1500}$, lev.mark +14.700, hole 3-15-Ж	-500	Graphite with inclusions of corroded metal	0,10	0,023
93	Sample (3-15Ж ШП) [6]	47_{+1000}, $К_{+1500}$, lev.mark +14.700, hole 3-15-Ж	-500	Dark-gray fragments of crushed concrete		2,62
			$К_{+2400}$			
94	Sample (304) [11]	$47+_{2400}$, $К_{+2400}$, lev.mark +9.700, hole 3-10-63	0	FCM (irregular-shape bright gravel of brown color)	0,013	0,009
95	Sample (305) [11]	$47+_{2400}$, $К_{+2400}$, lev.mark +9.700, hole 3-10-63	0	FCM (irregular-shape reddish gravel)	0,021	0,021
96	Sample (291) [12]	$47+_{2400}$, $К_{+2400}$, lev.mark +9.700, hole 3-10-63	0	Gray ceramics with metal	8,10	8,37

No	Sample (sample number in ref. source), measured value, core, [Reference]	Area of sampling, EDR & NFD measurement, coordinates	Distance from section, mm	Sample description, EDR, NFD (date)	U, %	U, % (calculation for ^{144}Ce)
97	Core [2]	48_{-800}, $К_{+2400}$, lev.mark +9.700, hole 3-10-63	0	Metal, EDR from the core - 10 R/h (November 1989)		
98	Core [2]	$47+_{2800}/48_{-1000}$ (SDV -?), $К_{+2400}$, lev.mark +9.700, hole 3-10-63	0	Metal, EDR from the core - 7 R/h (November 1989)		
99	Core [2]	$47+_{2400}/47_{+2700}$, $К_{+2400}$, lev.mark +9.700, hole 3-10-63	0	Metal, EDR from the core - 30 R/h (November 1989)		
100	Core [2]	47_{+750}, $К_{+2400}$, lev.mark +8.800, hole Ю-9-Б	0	Burned concrete, EDR from the core - 75 R/h (May 1989)		
101	Core [2]	45_{+2700}, $К_{+2400}$, lev.mark +8.800, hole Ю-9-В	0	Metal, EDR from the core 700 R/h (May 1989)		
			$Л_{700}$			
102	Core [2]	47_{-800}, $Л_{700}$, lev.mark +9.100, hole 3-9-Ч	0	Metal, detritus, EDR from the core - 7 R/h, (October 1989)		
103	Core [2]	$47_{+1000}/47_{-800}$, $Л_{700}$, lev.mark +9.100, hole 3-9-Ч	0	Drill tool vanishing (October 1989)		
104	Core [2]	$47_{+1200}/47_{-1000}$, $Л_{700}$, lev.mark +9.100, hole 3-9-Ч	0	Metal, pipes - 25 R/h (October 1989)		
105	EDR [2]	48_{-2400}, $Л_{-700}$, lev.mark +9.100, hole 3-9-Ч	0	100 R/h (19.10.89)		
106	EDR [2]	47_{-200}, $Л_{700}$, lev.mark +9.100, hole 3-9-Ч	0	580 R/h (19.10.89)		
			И/К. Heap along the southern wall of Room #305/2			
107	Sample (52) [13]	46/47, И/К, lev.mark +12.000	-	Scattering of fuel element pellets	85,16	66,52
108	Sample (53) [13]	46/47, И, lev.mark +12.000	-	Scattering of fuel element pellets	82,35	57,08
109	Sample (39) [13]	46/47, $И_{+3000}$, lev.mark +12.000	-	Black porous ceramics	5,90	6,48
110	Sample (40) [13]	46/47, $И_{+2000}$, lev.mark +12.000	-	Black porous ceramics	5,87	6,57
111	Sample (4) [4]	46/48, $И_{+2000}/К_{-1000}$, lev.mark ~+12.000	-	Black slaggy sample	54,62	47,21
112	Sample (4-1) [4]	46/48, $И_{+2000}/К_{-1000}$, lev.mark ~+12.000	-	Black slaggy sample	35,98	55,36

No	Sample (sample number in ref. source), measured value, core, [Reference]	Area of sampling, EDR & NFD measurement, coordinates	Distance from section, mm	Sample description, EDR, NFD (date)	U, %	U, % (calculation for ^{144}Ce)
113	Sample (1) [14]	46/48, И/К$_{1000}$, lev.mark ~+12.000	-	Black solid fragile fragments	49,8	
114	Sample (2) [14]	46/48, И/К$_{1000}$, lev.mark ~+12.000	-	Black solid fragile fragments	50,0	
115	Sample (3) [14]	46/48, И/К$_{1000}$, lev.mark ~+12.000	-	Black solid fragile fragments	19,5	
116	Sample (4) [14]	46/48, И/К$_{1000}$, lev.mark ~+12.000	-	Black solid fragile fragments	4,1	
Л$_{3000}$. Heap on "OP" component						
117	Sample (12) [5]	48$_{-800}$/48$_{-1200}$, Л$_{3000}$, lev.mark +15.000, hole 3-15-И	0	Graphite	0,01	0,011
118	Sample (13) [5]	47$_{+1000}$, Л$_{3000}$, lev.mark +15.000, hole 3-15-И	0	De-structured concrete	2,40	2,69
119	Sample (14) [5]	47$_{+1000}$, Л$_{3000}$, lev.mark +15.000, hole 3-15-И	0	Metal	0,64	0,72
120	Sample (16) [5]	47$_{+1500}$, Л$_{3000}$, lev.mark +15.000, hole 3-15-И	0	Small stone in oily mass	2,32	2,66
121	Sample (17) [5]	47$_{+1500}$, Л$_{3000}$, lev.mark +15.000, hole 3-15-И	0	Dark oily mass	1,65	1,88
123	Sample (19) [5]	47$_{+1550}$, Л$_{3000}$, lev.mark +15.000, hole 3-15-И	0	Metal	0,26	0,30
124	Sample (20) [5]	47$_{+1550}$, Л$_{3000}$, lev.mark +15.000, hole 3-15-И	0	Laminated small stone of ashy color	0,11	0,12
125	Sample (3-15И) [6]	47$_{+800}$, Л$_{3000}$, lev.mark +15.000, hole 3-15-И	0	A piece of fuel element of fuel assembly extracted from the hole	88,15	70,39
126	Sample (6) [15]	47/48$_{+1000}$, Л$_{3000}$, lev.mark +16.000 - +18.000	0	A piece of fuel element	88,15	73,39
127	Sample (1) [16]	48+0.7, Л-3, lev.mark15.00, hole 3-15-И	0	A piece of fuel element, the distance from the pellet periphery to the center is 0 – 2 mm	51,09	60,09
128	Sample (2) [16]	48+0.7, Л-3, lev.mark15.00, hole3-15-И	0	A piece of fuel element, the distance from the pellet periphery to the center is 2 – 3 mm	50,09	55,79
129	Sample (3) [16]	48+0.7, Л-3, lev.mark15.00, hole3-15-И	0	A piece of fuel element, the distance from the pellet periphery to the center is 3 – 4 mm	53,05	60,09
130	Sample (4) [16]	48+0.7, Л-3, lev.mark15.00, hole3-15-И	0	A piece of fuel element, fuel pellet center	49,27	56,22

No	Sample (sample number in ref. source), measured value, core, [Reference]	Area of sampling, EDR & NFD measurement, coordinates	Distance from section, mm	Sample description, EDR, NFD (date)	U, %	U, % (calculation for ^{144}Ce)
$Л_{500}$. Heap on "OP" component						
131	Sample (9) [5]	$48_{-500}/48_{-1000}$, $Л_{500}$, lev.mark +15.000, hole 3-15-E	0	Fragments of burnt concrete		3,12
132	Sample (21) [5]	$48_{+400}/48_{-100}$, $Л_{500}$, lev.mark +15.000, hole 3-15-E	0	Black stone	0,02	0,018
133	Sample (24) [5]	$48_{+400}/48_{-100}$, $Л_{500}$, lev.mark +15.000, hole 3-15-E	0	Graphite	0,01	0,006
134	Sample (25) [5]	$48_{+400}/48_{-100}$, $Л_{500}$, lev.mark +15.000, hole 3-15-E	0	Metal tube	0,02	0,010
К/Л. "OP" component and a heap thereon						
135	Sample (302) [11]	48_{-700}, $Л_{1000}$, lev.mark +16.900,hole 3-14-113	-	Graphite	0,01	0,006
136	Sample (292) [12]	47/48, К/Л, lev.mark +16.000 - +18.000, hole 3-14-113	-	Porous brown ceramics	3,7	4,81
137	Sample (293) [17]	47/48, К/Л, lev.mark +16.000 - +18.000, hole 3-14-113	-	Zirconium pipe fragment	0,15	0,24
138	Sample (51) [18]	Reactor vault	-	Fuel from the core, fuel element (fragment)	74,8/	77,25
139	Sample (125) [19]	-	-	Fragments of fuel pellets from fuel element	85,50	69,96
140	Sample (46) [28]	Close to “OP” component	-	Fuel element fragment	85,50	39,18

REFERENCES

1. *Experimental Investigation of Radionuclide Composition of Fuel-containing Masses and High-active New Formations of the "Shelter"* (1990) Report of Kurchatov IAE's Complex Research Expedition #11.07/66 of 31.10.90, Chernobyl, P. 23 (in Russian).

2. *Holes in the "Shelter": Generalized Data (Diagram Manuel)* (1998) Report of the ISTC "Shelter" Nuclear & Radiation Safety Department, #09/05-66 of 09.06.98, Chernobyl, P. 117 (in Russian).

3. *Determining New Representative Locations for Detection Unit Installation and Verification of Bore Holes* (2000), Scherbin, V.N. (resp. execut.) Report of ISTC "Shelter" #3808, Chernobyl, P. 133 (in Russian).

4. *Determining Isotopic Composition of FCM Samples from the "Shelter"* (1990) Report of Kurchatov IAE's Complex Research Expedition #11.07/32 of 26.05.90, Chernobyl, P. 17, ISTC Archive #1499 (in Russian).

5. Levina L.A. and Kheruvimov, A.N. (1989) *Results of Physico-chemical Investigations of Cores from Holes at Level Marks 9 – 15 m over May 1988 – February 1989*, Report of Kurchatov IAE's Complex Research Expedition #11.07-06/19 of 14.02.89, ISTC Archive #1121, P.11 (in Russian).

6. Borovoi A.A. and Kheruvimov A.N. (1990) *Investigations of Radionuclide Composition and Physico-chemical Status of FCM Samples Taken in Rooms of the "Shelter"*, R&D Report of Kurchatov IAE's Complex Research Expedition #11.07/12 of 16.03.90, Chernobyl, P. 20, ISTC Archive #1479 (in Russian).

7. Pazukhin E.M. (1999) *Lava-like Fuel-containing Masses of Chernobyl NPP Unit #4: Topography, Physico-chemical Properties, Generation Scenario and Environmental Effects*, Doctoral Thesis, Chernobyl, P. 293 (in Russian).

8. *Certificate of Works on Analysis of Four Samples from the "Shelter"* (1990) Report of Kurchatov IAE's Complex Research Expedition #11.07-05/86 of 4.08.90, P.2, ISTC Archive #1717(in Russian).

9. Grinchenko G.P., Nenagliadov, A.Yu., Surin, A.I. and Checherov, K.P (1995) *Exposure Gamma Dose Rates in Research Bore Holes of Chernobyl NPP Unit #4*, Preprint of Kurchatov IAE, IAE-5854/3, Moscow, P.25 (in Russian).

10. Bogatov S.A., Demchuk V.V. and Mazur, L.I. (1989) *Certificate of Spectrometric Measurements of Samples Taken in Hole #3.9.Л*, #1.01-02/03 of 2.02.89 (in Russian).

11. *Annotation Report on Radiochemical, Gamma- and Alpha-spectrometric Analyses of FCM Samples Taken in the "Shelter"* (1991), Report of Kurchatov IAE's Complex Research Expedition #11.07/268, Chernobyl, P. 6, ISTC Archive #2019 (in Russian).

12. *Certificate of Experimental Investigation of Radionuclide Composition of Five FCM Samples Taken in the "Shelter' in October 1991* (1991) Kurchatov IAE's Complex Research Expedition #11.07-05/168, Chernobyl, P. 2, ISTC Archive #2215 (in Russian).

13. *Investigation of Fuel Interactions with Structural Materials in the "Shelter"* (1991) Report under Contract #39-901/63-16-2-1 of 10.02.91, Kurchatov IAE's Complex Research Expedition, approved by A.A. Borovoi and E.B. Anderson, #11.07/285 of 13.12.91, Chernobyl – SPb, P. 88 (53 samples), ISTC Archive #2036 (in Russian).

14. *Certificate of Work on Radiochemical Analysis of Samples Taken in the "Shelter"* (1990) #11.07-05/130 of 27.09.90, ISTC Archive #1748 (in Russian).

15. *Complex Investigation of Radionuclide Composition of Samples Taken in the "Shelter" and in the Environment* (1990) Report of Kurchatov IAE's Complex Research Expedition #11.07/30 of 30.04.90, Chernobyl, P.27 (in Russian).

16. *Certificate of Determining Specific Activities of Fission Elements and Isotopes of Plutonium along the Radius of Fuel Element Pellet* (1989) #1.01-02/07 of 5.02.89 (in Russian).

17. *Certificate of Experimental Investigation of Radionuclide Composition of Five FCM Samples from the "Shelter" in October 1991* (1991) Kurchatov IAE's Complex Research Expedition #11.07-05/168, Chernobyl, P. 2 (in Russian).

18. *Investigations of Radionuclide Composition of FCM from the "Shelter"* (1991) Report of Kurchatov IAE's Complex Research Expedition #11.07/139 of 22.04.91, Chernobyl, P.19 (in Russian).

19. *Conducting of Radiochemical Analysis of Fuel Concentration in FCM Samples* (1991) Annotation Report under Contract #1132-ja of 21.02.91 Milestone #6, Report of Kurchatov IAE's Complex Research Expedition #11.07/274 of 29.11.91 (NIO KE), Moscow, P. 7 (in Russian).

4.1.1.2. Appendix (305/-1).

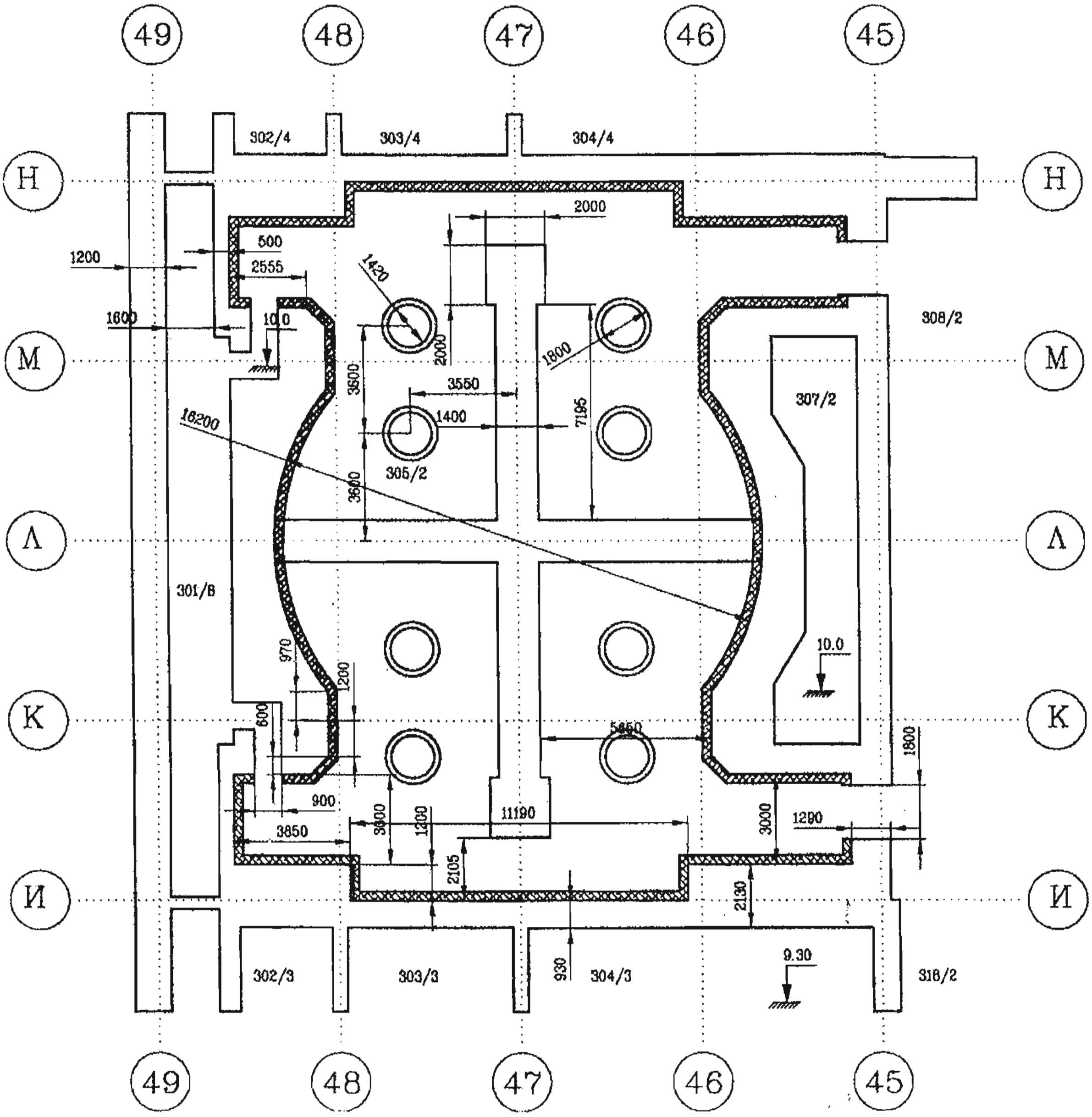


Fig.4.26. Under-reactor room305/2.

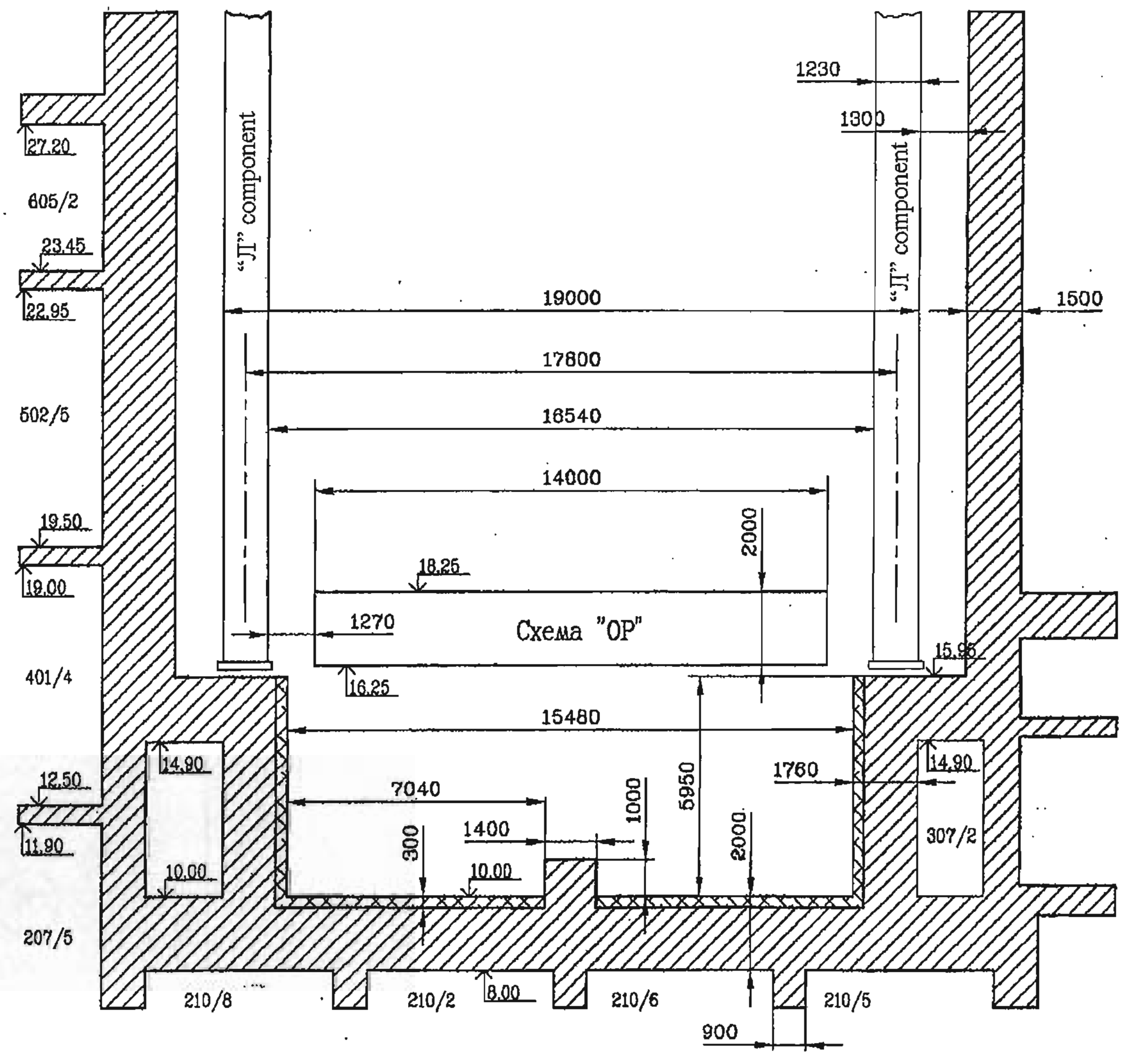


Fig.4.27. Under-reactor room305/2. Vertical section in an axis "L"

5. LAVA SPREADING

5.1. Horizontal Lava Flow at 9-m Level Mark and in Rooms #217/2 and #017/2 (based on [1 – 4])

Lava-like Fuel-Containing Materials (LFCM) generated in Room #305/2 at the second accident phase spread over rooms of Unit #4 in both vertical and horizontal directions. In such a way the Horizontal Lava Flow (HLF) was generated (Fig.1) spreading in many rooms at 9 m level mark.

The HLF flowed out of Room #305/2 via a breach in the wall to Room #304/3 (our view of the shape of the ablation area is depicted in Fig. 2) and spread further over its whole floor. Next via the open door to Room #304/3 the HLF penetrated into Room #301/5 and broke up into two sub-flows: "the western sub-flow" and "the eastern sub-flow".

The western sub-flow penetrated into Room #303/3 via the torn-off-hinge door. The attempts at following the subsequent path of the western sub-flow have been unsuccessful because of a thick layer of concrete that penetrated into Unit #4's rooms during construction of the "Shelter".

The eastern sub-flow reached Room #301/6, then turned south, passed about 15 m and finally attained the row "Г".

Via vertical penetrations LFCM flowed out of Room #301/6 down to +6 m level mark in Room #217/2 and formed "the elephant's foot" (Fig.3), "stalactites" and a "drop".

A minor lava amount, as compared to the whole lava mass, dropped from Room #217/2 to Room #017/2 (0 m level mark).

The HLF path in Room #301/6 in the northern direction stopped, most likely, between the rows "Ж" and "И".

LFCM also penetrated into Room #307/2, however, very little is known so far about these lava masses.

The available information on LFCM forming the "horizontal lava flow" is summarized in Table 5.1. The detailed data are reduced at exposition of concrete rooms.

Table 5.1. Data on LFCM forming the horizontal lava flow (at +9.00 m level mark and in HLF leaks down to the level marks +6.00 m and 0.00 m) [1]

Room	Brief description of FCM accumulation	FCM volume, m^3	Fuel mass (uranium), t	Comment
304/3	A layer of FCM on the room floor 0,6 ÷1 m in thick	50 ÷ 70	6 ± 2	FCM volume in the breach is taken into consideration
303/3	FCM on the floor under a layer of concrete	2 ÷ 7	0,5 ± 0,3	
301/5	FCM on the floor under a layer of concrete and uncovered FCM	8 ÷ 30	2,0±1,5	
301/6	FCM on the floor under a layer of concrete	8 ÷ 30	2,0±1,5	
217/2	"Elephant's foot", "Stalactites", "Drop"	2 ÷ 4	0,4 ± 0,2	
017/2	Individual FCM fragments on "fresh" concrete	a minor volume		FCM presence under concrete is possible

Thus the integral volume of FCM in the HLF and on the lower floors affected by HLF leaks is estimated at (70 ÷ 140) m^3. Measurements of uranium concentrations in HLF samples via three different procedures allowed achieving the following results:

- (4,2 ± 0.4) % (element composition);
- (4,2 ± 1) % (radiochemistry);
- (5,2 ± 1) % (correlation with ^{144}Ce).

The expert calculations were based on the assumption of uranium concentration in FCM of the horizontal lava flow within 4–5% for all accumulations [1].
Under such an assumption the amount of fuel contained in FCM equals (11 ± 4) t.

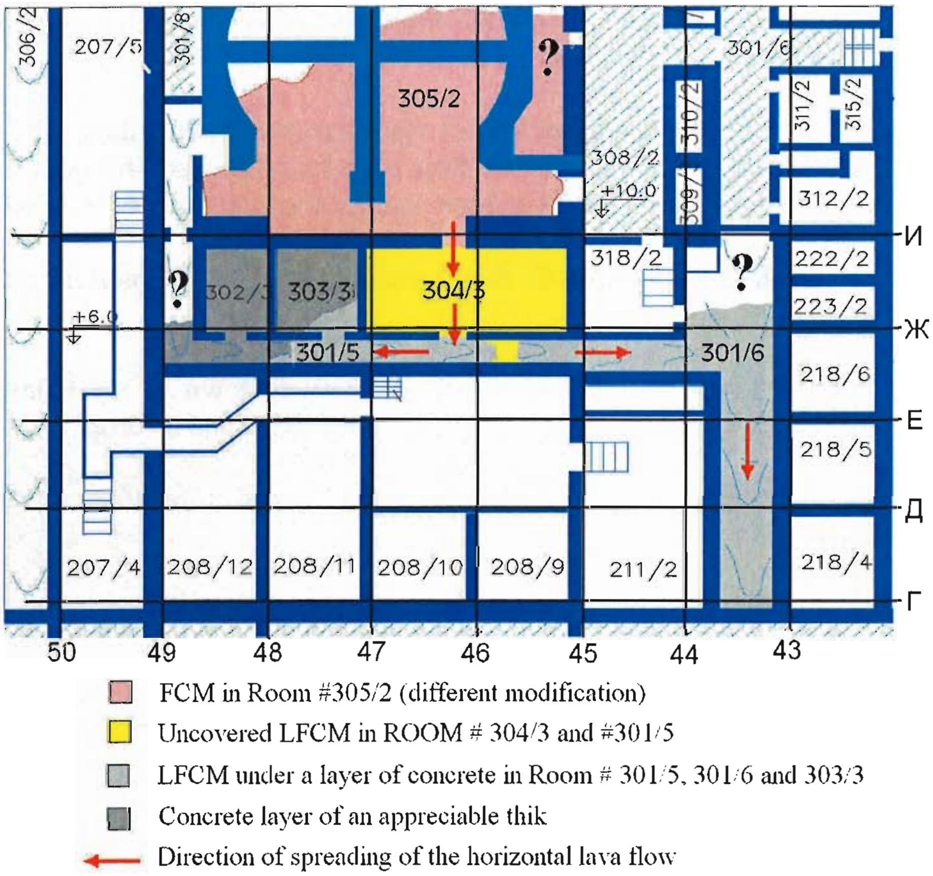


Fig. 5.1. – LFCM spreading over rooms of Unit #4 at 9 m level mark

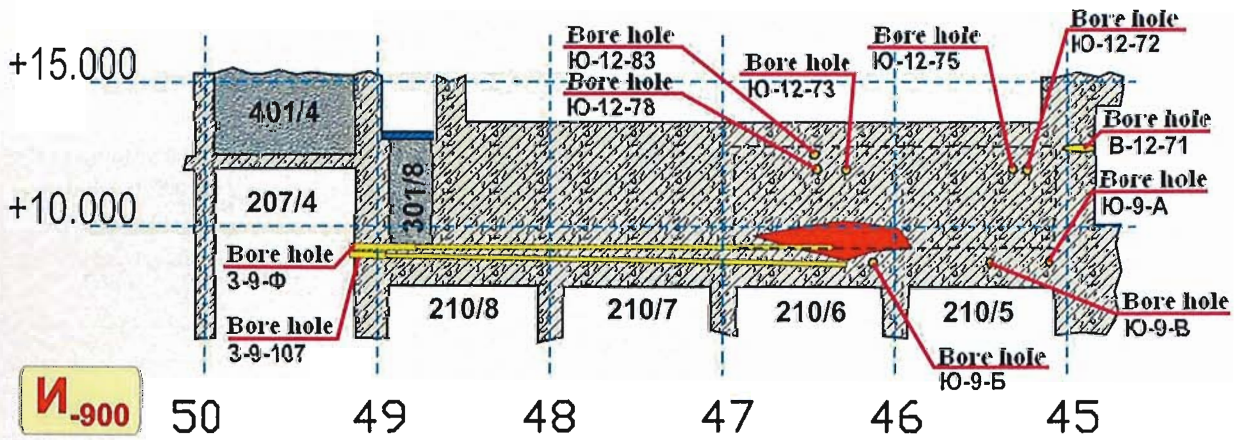


Fig. 5.2. Separating wall between Room #305/2 and Room #304/3. Section through '$И_{-900}$' row. The red spot indicates the location of lava.

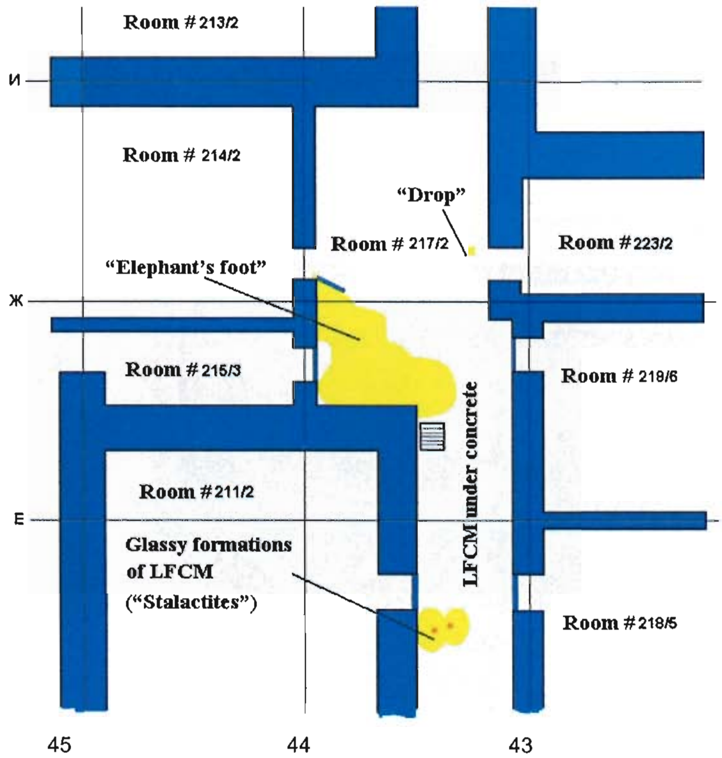


Figure 5.3.
LFCM leaks from the "horizontal lava flow" down to 6 m level mark in Room #217/2

REFERENCES

1. *The "Shelter" Current Safety Analysis and Forecast Estimates for the Situation Development* (2001) Responsible Executor: Borovoi A.A. Report of ISTC "Shelter", Arch. #3836, Chernobyl, P.337 (in Russian).

2. Pazukhin, E.M. (1994) Lava-like Fuel Containing Masses of the Chernobyl NPP Unit 4: Topography, Physical & Chemical Properties, Generation Scenario, *J. Radiokhimia*, 36(2), 1994, pp. 97-142 (in Russian).

3. Borovoi, A.A., Dovbenko, A.A., Smoliankina, M. V. and Stroganov, A. A. (1991) *Determining Nuclear-Physical Characteristics of Fuel of the Chernobyl NPP Unit 4*, Report of IBRAE RAS, inv. n°52/11-20, Moscow, P. 63 (in Russian).

4. Project #1: "Safety Status of the "Shelter" of the Chernobyl NPP". Subproject #3: "Nuclear Fuel and Radioactive Waste" *under a special agreement with IPSN and GRS of April 23, 1998. (1998) Progress Report of IHTEM of RRC "Kurchatov Institute" for the third 6-month period, A.A. Borovoi (responsible exec.), Appendices #2 and ##4-9.*

5.1.1. Lava in Room #304/3 [1- 5]

Uncovered LFCM that filled the whole floor of Room #304/3 may be considered as a single accumulation (Fig.5.4).

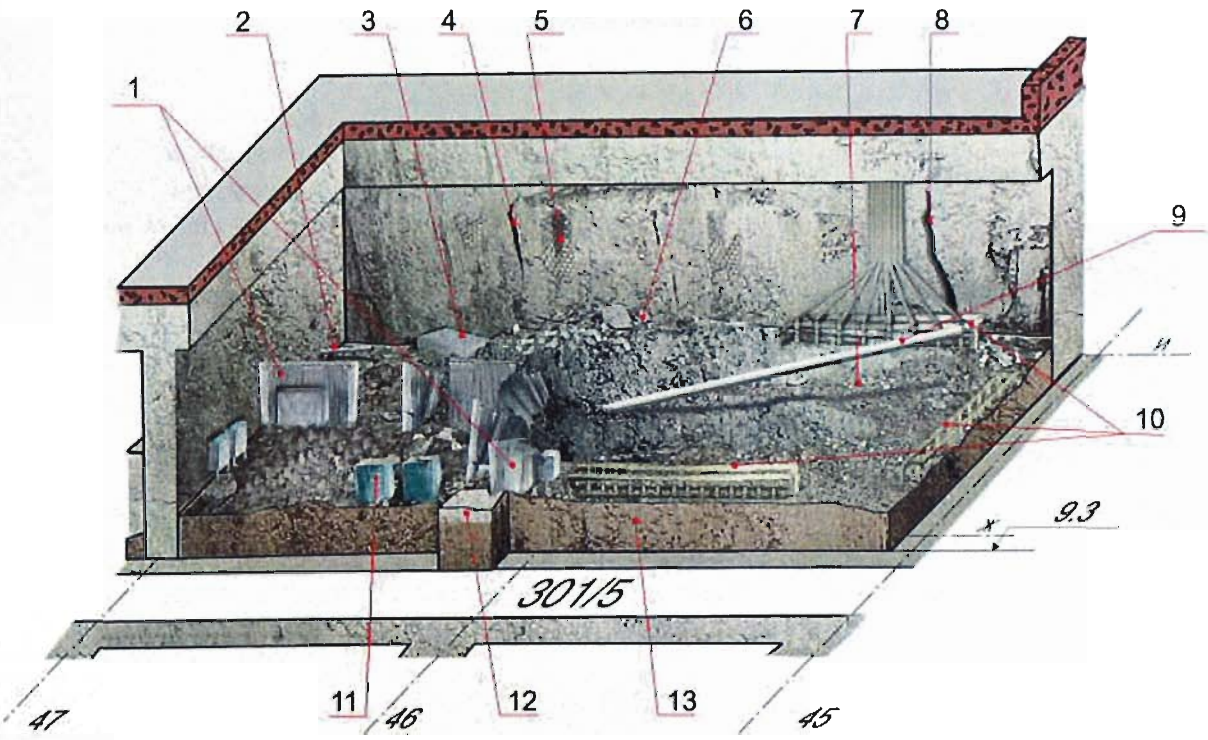


Fig.5.4. – Room #304/3

1 – enclosure of electrical cabinets
2 – neutron flux density sensor (Hole #3–10-G)
3 – a fallen electrical cabinet
4 – cracks in the wall
5 – exposed metal fittings
6 – a rise by the wall separating Rooms #304/3 and #305/2 (level mark +10.30)
7 –area with undulating surface
8 – a deep vertical crack
9 – casing of Hole #B-12-79 drilled from Room #318/2
10 – sampling tubes
11 – containers with refuse and FCM
12 – concrete in the door aperture of Room #304/3
13 – lava layer on the room floor

The LFCM accumulation has a non-homogeneous and cracked surface. The LFCM color is black. According to visual observations, LFCM has a macroporous structure. Solidified lava contains many large cavities, which volume reaches 1-2 cubic decimeters in some cases.

21 bore holes were drilled during the period 1988 - 1990 in the premises 304/3. Drilling was carried out from three main directions - from the west (from the premises 207/4), from the south (premises 208/9) and from the east (premises 318/2).

In compliance with the results of core-sample studies (the hole 'Ю-9-B', level mark 8.8 m), under the high-temperature effects structural concrete within two floor sections of Room #304/3 (the northeast sector) was destroyed and transformed into unbound crushed stone, the length of each floor section with destroyed concrete being about half-meter.

Both the results of analysis of gamma Exposure Dose Rate (EDR) measurements performed in the hole '3-9-P' drilled at 8.9 m level mark, row '$И_{-2000}$', and the presence of destroyed concrete in core samples taken in the hole suggest the floor damage close to the eastern wall of Room #304/3.

The data of EDR measurements in holes drilled in Room # 304/3's floor and in the bottom part of its northern wall, as well as the characteristic of core sample material (destroyed concrete, FCM) give grounds to state the following: there is a vast burnt area on the floor and close to the northern wall.

Other data also indicate the presence of LFCM on the floor of Room #304/3.

E.g., the results of drilling using 'TP-4' remotely-manned system (several vertical holes were drilled in the corridor Room #301/5 in the floor between the axes 46_{-2000} and 45_{+2500}) demonstrated that structural concrete of the Room's floor had been destroyed down to ~ 15 cm at the drilling area.

Reasoning from the fact that the floor of Room #301/5 underwent lesser thermal impact (both on time and intensity) than that of Room #304/3, one may conclude that the lower boundary of LFCM accumulation in Room #304/3 is located ≤ 9.15 m level mark.

In Appendix (304/3 - 1) we give performance of samples from a Room 304/3 and outcomes of their analyses.

Averaged radionuclide composition of samples taken in Room #304/3 is demonstrated in Tables 5.2 and 5.3.

Table 5.2. Averaged radionuclide composition of ceramics samples taken in Room #304/3 (fission and activation products). Data of 34 samples

	Activity of nuclides, MBq/g (ceramics), recalculations as of 26.04.1986							
Nuclide	^{144}Ce	^{137}Cs	^{134}Cs	^{106}Ru	^{125}Sb	^{154}Eu	^{155}Eu	^{90}Sr
Activity	1,0E+03	2,2E+01	1,3E+01	1,2E+01	1,6	1,4	1,99	6,8E+01
Standard deviation	3,0E+02	8,9	5,3	8,3	1,6	2,7E-01	5,0E-01	1,7E+01

Table 5.3. Averaged radionuclide composition of ceramics samples taken in Room #304/3 (transuranics)

	Activity of nuclides, MBq/g (ceramics), recalculations as of 26.04.1986					U, %	Burnup, MW×day/kg U
Nuclide	^{238}Pu	^{239}Pu + ^{240}Pu	^{242}Cm	^{244}Cm	^{241}Am		
Activity	4,9E-01	9,4E-01	2,0E+01	2,6	3,2E-01	4,1	12,3
Standard deviation	6,0E-01	9,7E-01	2,3E+01	1,4E+01	5,7E-01	1,2	0,4

From analyses it follows that black dull lava of Room #304/3 comprises about 4% of fuel. The burnup of fuel contained in black lavas equals (12.3±0.4) MW×day/kg of uranium.
Fuel contained in black dull ceramics of Room #304/3 is depleted in ^{137}Cs by ~ 2 times and in ^{134}Cs by ~ 2 times as well.

Black dull ceramics of Room #304/3 is considerably and non-uniformly depleted in ruthenium. In all studied samples appropriate depletion in ^{154}Eu by ~2.2 times is observed.
The averaged element composition of samples is demonstrated in Table 5.4.

Table 5.4. Room #304/3. Averaged element composition of FCM samples. Data of 19 samples.

Mass fraction, %															
Si	Ca	Ti	Zr	Cu	Na	Ba	U	Al	Mn	Mo	Fe	Mg	Cr	Ni	B
33,0	4,8	1,2 E-01	4,3	2,7 E-03	4,6	1,2 E-01	4,1	3,9	1,5	2,2 E-03	3,5 E-01	2,3	2,0 E-01	9,6 E-02	5,7 E-02
Standard deviation															
2,6	1,15	4,5 E-02	2,9	2,0 E-03	0,51	1,5 E-02	0,57	0,84	1,03	1,8 E-03	7,5 E-02	0,41	1,1 E-01	6,4 E-02	2,6 E-02

Chemical composition of black ceramics of Room #304/3 corresponds, on average, to the LFCM generation scenario in Unit 4 of Chernobyl NPP.

In Ref. [5] the upper boundary of ^{137}Cs amount released from molten LFCM and penetrated into Room #304/3 was estimated. According to the results of performed analysis, the maximum surface contamination level of concrete in Room #304/3 does not exceed 100 MBq/m^2. The total area of ceiling and walls of this room is 200 m^2 at the most. The resulting upper estimate of ^{137}Cs amount released during lava flow spreading is 2×10^4 MBq that does not exceed 0.1% of the amount of ^{137}Cs remained in LFCM matrix.

This fact allows the following conclusion: the most of cesium had released from LFCM before the melt reached Room #304/3, i.e. during lava "cooking" in Room #305/2.

Studying of samples of concrete taken on surfaces of walls in Room #304/3 has demonstrated that they contain a considerably larger amount of ^{125}Sb as compared to that characteristic of a standard fuel composition (by 4 times!). Because the boiling points of oxide and metal antimony are 1456°C and 1637°C, respectively, one can assume that by the instant of lava penetration into the studied room its temperature reached or exceeded 1640°C. This value agrees well with that proposed for the average temperature of lava (1600°C) according to the scenario suggested in Ref [2].

REFERENCES

1. *The "Shelter" Current Safety Analysis and Forecast Estimates for the Situation Development* (2001) Responsible Executor: Borovoi A.A. Report of ISTC "Shelter", Arch. #3836, Chernobyl, P.337 (in Russian).

2. Pazukhin, E.M. (1994) Lava-like Fuel Containing Masses of the Chernobyl NPP Unit 4: Topography, Physical & Chemical Properties, Generation Scenario, *J. Radiokhimia*, 36(2), 1994, pp. 97-142 (in Russian).

3. A. A. Borovoi, A. S. Lagunenko, E. M. Pazukhin
«Fuel containing materials in the premises 304/3», in: "*Chernobyl Problems*", 3, pp.29-32, Chernobyl1988 (in Russian).

6. Borovoi, A.A., Lagunenko, A.S. and Pazukhin, E.M. (2000) New estimates of nuclear fuel amounts at the bottom level marks of the "Shelter",

4. A. A. Borovoi, A. S. Lagunenko, E. M. Pazukhin, F.N. Kolomiets
«Study of samples of lava-like fuel containing materials taken from the different depth of lava». in: "*Chernobyl Problems*", 9, 66-75, Chernobyl 2002 (in Russian).

5. A. A. Borovoi, A. S. Lagunenko, E. M. Pazukhin

“Radiochemical and Selected Physicochemical Characteristics of Lava and Concrete Samples from Subreactor Room no.304/3 of the Fourth Unit of ChNPP fnd Their Connection with the Accident Scenario”, Radiochemistry, Vol.41, No.2, 1999, pp. 187 – 192.

5.1.1.1. Appendix (304/3 –1) Performance of samples from the Room 304/3.

Radionuclide content of samples

Table A.1. Room 304/3. General characterization of samples

№	Number of sample (original number)	FCM, description		Date of analysis	Document
		Place of sampling	Sample description		
1	S00150 (9)	46/47, И/Ж, mark 10.00, surface of semicircle piece	Black ceramics	1.03.89.	*Studying Interactions of Fuel with Constructional Materials in the "Shelter"* (1991) Report under Contract #39-901/63-16-2-1 of 10.02.1991, Complex Expedition under I.V. Kurchatov Institute of Atomic Energy, approved by A.A. Borovoi and E.B. Anderson, Inventory Number 11.07/285 of 13.12.1991, Chernobyl – Saint-Petersburg, P. 88 (in Russian) (53 samples)
2	S00160 (10)	the same, depth 5 cm	- « -	1.03.89.	
3	S00170 (11)	the same, depth 10 cm	- « -	1.03.89.	
4	S00430 (37)	46/47, И-2.5, mark 10.00	Black porous ceramics	1.03.89.	
5	S00440 (38)	46/47, И-1.5, , mark 10.00	Black porous ceramics	1.03.89.	
6	S00780 (19)	46+0.1, И-2, , mark. 9.40, borehole 3-9-M		18.12.88.	Levina, L.A., Kheruvimov, A.N., Results of physicochemical study of cores from bore holes at level marks 9 – 15 м during May 1988 – February 1989 // Report / KE of IAE by I.V.Kurchatov - .№ 11.07-06/09, 14.03.89 (49 samples)
7	S00860 (8)	47-0.2, И-2, , mark 9.70, borehole 3-10-Г		11.06.88.	
8	S01360 (3-9M)	46+0.1, И-2, , mark 9.40, borehole 3-9-M	Dark-brown mass	15.06.89.	Borovoi, A.A. and Kheruvimov, A.N. (1990) *Studying Radionuclide Composition and Physico-chemical Condition of Samples of Fuel-containing Masses Taken in Rooms of the "Shelter"*, R&D Report of Complex Expedition under I.V. Kurchatov Institute of Atomic Energy, Inventory Number 11.07/12 of 16.03.1990, Chernobyl, P.20 (in Russian) (46 samples)
9	S02000 (123)	46/47, И/Ж	Black lava	15.07.90.	Alkhimov, N.B., Kiselev, A.N., Kurguzov, V.V., *et al.* (1991) *Studying Radionuclide Composition of Fuel-containing Materials in the "Shelter"*, Report of Complex Expedition under I.V. Kurchatov Institute of Atomic Energy, Inventory Number 11.07/139 of 22.04.1991, Chernobyl, P.19 (in Russian) (19 samples)
10	S02250 (17)	46+1, И-2.5, mark 10.00	Black ceramics	15.11.91.	Gusev V.F., Kalinichenko, B.S., Kalistratov, V.A., *et al.* (1991) *Conducting Radiochemical Analyses of Fuel Concentration in Samples of Fuel-containing Masses*, Annotation Report under Contract #1132-ja of 21.02.1991, Milestone #6, I.V. Kurchatov Institute of Atomic Energy, Inventory Number 11.07/274 of 29.11.91 (NIO CE), Moscow, P.7 (in Russian) (10 samples)
11	S02260 (41)	48-1.5, И-3.5, mark 10.00	Black ceramics.	15.11.91.	
12	S02270 (42)	48-1.5, И-3.5, mark 10.00	Black ceramics.	15.11.91.	
13	S02280 (83)	46-1, И-2.5, mark 10.00	Black ceramics.	15.11.91.	
14	S02550 (342)	46/47, И/Ж, depth 0.3 m	Black porous lava	25.12.91.	Baev S.A., Gusev V.F., Kalinichenko, B.S., Kalistratov, V.A., Kulazhko V.G., Kurguzov V.V., Lisin, S.K.,., Rodionov Yu.F, Slonov, S.D, Shiryaev V.S. Study of FCM samples from the "Shelter" Report on execution of paragraph 2.4.1 of «Plan of urgent measures for increasing of nuclear and radiation safety of the "Shelter" / МНТЦ «Укрытие» Inventory Number 09/18 of 26.09.92, (in Russian) (13 samples)
15	S02560 (343)	46+1,Ж	Concrete on FCM surface covered by yellow spots	25.12.91.	
16	S02570 (344)	46/47, И/Ж, depth 0.3 m	Black porous lava	25.12.91.	
17	S02580 (345)	46/47, И/Ж, depth 0.3 m	Black porous lava	25.12.91.	
18	S02590 (346)	46/47, И/Ж, depth 0.3 m	Black porous lava with large gas inclusions	25.12.91.	

19	S02890 (У-1)	47-0.2, И-2, mark 9.70, bore hole 3-10-Г, FCM surface	Solidified lava	15.10.90.	Kiselev, A.N., Krol, A.L., Levina, L.A., Lisin, S.K., Obukhova, L.A., Rodionov, Yu.F., Slonov, S.D., Kheruvimov, A.N., Checherov, K.P., Chubko, V.M. and Jashin, Yu.A. (1990) *Experimental Investigation of Radionuclide Composition of Fuel-containing Masses and Highly-active New Formations in the "Shelter"*, R&D Report of Complex Expedition under I.V. Kurchatov Institute of Atomic Energy, Inventory Number #11.07/66 of 31.10.90, Chernobyl, P. 23 (in Russian) (13 samples)
20	S02900 (У-2)	47-0.2, И-2, mark 9.70, bore hole 3-10-Г, depth 5 cm	- " -	15.10.90.	
21	S02910 (У-3)	the same, 30 cm	- " -	15.10.90.	
22	S02920 (У-4)	the same, 15 cm	- " -	15.10.90.	
23	S02930 (У-5)	46+2.6, И-0.5, mark 9.30, the foundation of the wall between 304/3 and 305/2, borehole 3-9-Ф	Black ceramics	15.10.90.	
24	S03120 (1-1)	46/47, И/Ж	Black, hard, fragile piece	15.08.90.	Gorbachev B.I., Evstratenko A.S., Nikulin S.A. Obukhova, L.A., Statement on analysis of samples from premises 304/3 of the Shelter/ KE of IAE by I.V.Kurchatov - inventory # 11.07-05/112, 29.08.98.- 2 p. (6 samples)
25	S03130 (1-2)	46/47, И/Ж	Black, hard, fragile piece	15.08.90.	
26	S03140 (1-3)	46/47, И/Ж	Black, hard, fragile piece	15.08.90.	
27	S03150 (2-1)	46/47, И/Ж	Black, hard, fragile piece	15.08.90.	
28	S03160 (2-2)	46/47, И/Ж	Black, hard, fragile piece	15.08.90.	
29	S03170 (2-3)	46/47, И/Ж	Black, hard, fragile piece	15.08.90.	
30	S03180 (1/75)	46/47, И/Ж	Lavalike FCM	10.09.90.	Gorbachev B.I., Obukhova, L.A., Filippov A.V. Kheruvimov A.N. Statement on radio chemical analysis of samples from the Shelter/ KE of IAE by I.V.Kurchatov - inventory # 11.07-05/114, (10 samples)
31	S03190 (2/76)	46/47, И/Ж	Lavalike FCM	10.09.90.	
32	S03200 (3/77)	46/47, И/Ж	fuel assembly	10.09.90.	
33	S03210 (4/78)	46/47, И/Ж	graphite	10.09.90.	
34	S03220 (5/79)	46/47, И/Ж	Lavalike FCM	10.09.90.	
35	S03230 (6/80)	46/47, И/Ж	Lavalike FCM	10.09.90.	
36	S03240 (7/81)	46/47, И/Ж	Lavalike FCM	10.09.90.	
37	S03250 (8/82)	46/47, И/Ж	fuel assembly	10.09.90.	
38	S03260 (9/83)	46/47, И/Ж	Lavalike FCM	10.09.90.	

Table A.2. Radionuclide content of samples from the Room 304/3 (fission and activation products).

№	Number of sample (original number)	Nuclide activity, MBq/g (of ceramic), recalculated for 26.04.86 .							
		^{144}Ce	^{137}Cs	^{134}Cs	^{106}Ru	^{125}Sb	^{154}Eu	^{155}Eu	^{90}Sr
1	S00150 (9)	1,17E+03	1,87E+01	1,04E+01	2,94E+01	2,47	1,84	2,68	5,10E+01
2	S00160 (10)	1,27E+03	2,93E+01	1,66E+01	6,25E+00	2,57	1,69	2,23	5,70E+01
3	S00170 (11)	1,52E+03	2,86E+01	1,67E+01	3,50E+01	4,03	2,10	2,53	5,60E+01
4	S00430 (37)	1,26E+03	2,60E+01	1,50E+01	2,00E+01		1,60	1,65	6,76E+01
5	S00440 (38)	1,06E+03	2,70E+01	1,50E+01	4,40		1,40	2,12	4,25E+01
6	S00780 (19)	9,51E+02	2,55E+01	1,36E+01	7,41	3,88E-01			
7	S00860 (8)	2,14E+03	5,05E+01	3,17E+01	2,24E+01				
8	S01360 (3-9M)	1,47E+03	2,98E+01	1,70E+01	1,66E+01	3,49			
9	S02000 (123)	1,35E+03	2,74E+01	1,59E+01	1,86E+01				6,31E+01
10	S02250 (17)	4,86E+02	2,02E+01	1,27E+01	1,20E+01				4,97E+01
11	S02260 (41)	5,66E+02	1,02E+01	6,97					6,18E+01
12	S02270 (42)	6,29E+02	6,79	4,30					5,66E+01
13	S02280 (83)	5,63E+02	2,34E+01	1,46E+01	1,50E+01				6,10E+01
14	S02550 (342)	8,53E+02	1,25E+01	6,67E+00			1,17		6,94E+01
15	S02570 (344)	9,46E+02	1,37E+01	7,34	1,43E+01		1,39		6,94E+01
16	S02580 (345)	1,09E+03	3,30E+01	1,80E+01			1,88		6,54E+01
17	S02590 (346)	1,10E+03	2,51E+01	1,40E+01			1,52		7,46E+01
18	S02890 (У-1)	9,75E+02	1,00E+01	5,83	6,55	1,86E-01	1,20	1,31	
19	S02900 (У-2)	1,08E+03	6,62	3,68	6,36	1,80E-01	1,37	2,04	
20	S02910 (У-3)	1,17E+03	1,41E+01	7,91	8,32	2,36E-01	1,401	1,51	
21	S02920 (У-4)	9,66E+02	2,30E+01	1,25E+01	1,15E+01	5,43E-01	9,38E-01	1,66	
22	S02930 (У-5)	9,90E+02	5,41	3,2			1,01	1,21	5,25E+01
23	S03120 (1-1)	1,02E+03	2,54E+01	1,35E+01	5,79		1,32		7,10E+01
24	S03130 (1-2)	1,02E+03	2,54E+01	1,40E+01	1,16E+01		1,32		7,78E+01
25	S03140 (1-3)	1,02E+03	2,54E+01	1,40E+01	5,79		1,32		7,66E+01
26	S03150 (2-1)	1,11E+03	2,98E+01	1,57E+01	5,79		1,44		8,21E+01
27	S03160 (2-2)	1,06E+03	2,87E+01	1,52E+01	7,71		1,32		7,44E+01
28	S03170 (2-3)	1,11E+03	2,76E+01	1,48E+01	5,79		1,32		8,55E+01
29	S03180 (1/75)	1,03E+03	2,48E+01	1,30E+01			1,32		9,45E+01
30	S03190 (2/76)	8,86E+02	2,37E+01	1,30E+01			1,20		8,67E+01
31	S03220 (5/79)	9,84E+02	2,43E+01	1,30E+01			1,20		8,23E+01
32	S03230 (6/80)	8,36E+02	1,99E+01	1,08E+01	4,05		1,15		7,23E+01
33	S03240 (7/81)	8,86E+02	2,21E+01	1,13E+01	2,03		1,14		7,34E+01
34	S03260 (9/83)	8,36E+02	2,10E+01	1,13E+01			1,16		6,34E+01
Main value		1,04E+03	2,25E+01	1,26E+01	1,18E+01	1,57	1,37	1,89	6,81E+01
Standard deviation		3,02E+02	8,93	5,26	8,35	1,57	2,68E-01	5,03E-01	1,26E+01
min		4,86E+02	5,41	3,20	2,03	1,80E-01	9,38E-01	1,21	4,25E+01
max		2,14E+03	5,05E+01	3,17E+01	3,50E+01	4,03	2,10	2,68	9,45E+01

Table A.3. Continuation. Radionuclide content of samples from the Room 304/3 (transuranic).

№ п/п	Number of sample (original number)	Nuclide activity, MBq/g (of ceramic), recalculated for 26.04.86 .					U, %
		^{238}Pu	$^{239}Pu + ^{240}Pu$	^{242}Cm	^{244}Cm	^{241}Am	
1	S00150 (9)	3,55E-01	1,25	7,22	1,47E-01	1,35E-01	4,55
2	S00160 (10)	3,53E-01	1,18	8,05	1,56E-01	1,29E-01	4,92
3	S00170 (11)	5,94E-01	1,28	1,74E+01	1,35E-01	1,34E-01	5,84
4	S00430 (37)	3,60E-01	6,60E-01		9,00E-02	1,54E-01	4,86
5	S00440 (38)	3,60E-01	6,50E-01		9,00E-02	8,06E-02	4,13
6	S00780 (19)						3,71
7	S00860 (8)						8,06
8	S01360 (3-9M)	3,23E-01	6,42E-01	1,12E+01	7,46E-02		5,64
9	S02000 (123)	4,81E-01	8,25E-01	1,62E+01	9,58E-02	1,58E-01	5,14
10	S02250 (17)	4,11E-01	7,57E-01	1,78E+01	8,83E-02	1,04E-01	1,83
11	S02260 (41)	3,26E-01	6,24E-01	1,90E+01	7,84E-02	1,34E-01	2,11
12	S02270 (42)	3,62E-01	6,77E-01	1,60E+01	7,52E-02	7,57E-02	2,37
13	S02280 (83)	3,32E-01	6,17E-01	1,30E+01	7,51E-02	1,46E-02	2,12
14	S02550 (342)	4,14E-01	8,00E-01	2,95E+01	1,49E-01	4,37E-01	3,33
15	S02570 (344)	3,89E-01	7,50E-01	3,85E+01	1,58E-01	6,91E-01	3,69
16	S02580 (345)	5,35E-01	8,60E-01		1,42E-01	3,50E-01	4,21
17	S02590 (346)	4,36E-01	8,10E-01		1,58E-01	5,75E-01	4,25
18	S02890 (У-1)	3,27E-01	6,31E-01	1,44E+01	7,62E-02	1,96E-01	3,73
19	S02900 (У-2)	3,60E-01	6,76E-01	1,60E+01	7,249E-02	1,32E-01	4,18
20	S02910 (У-3)	4,08E-01	7,57E-01	1,78E+01	8,48E-02	1,60E-01	4,52
21	S02920 (У-4)	3,62	6,18	1,30E+02	7,21E-01	3,14	3,75
22	S02930 (У-5)	5,16E-01	1,03	2,18	1,18E-01	7,39E-02	5,70
23	S03120 (1-1)	3,81E-01	6,50E-01	2,02E+01	1,18E-01	2,48E-01	3,97
24	S03130 (1-2)	3,16E-01	6,50E-01	1,61E+01	1,06E-01	2,23E-01	3,93
25	S03140 (1-3)	1,95E-01	8,20E-01	2,02E+01	1,42E-01	5,29E-01	3,93
26	S03150 (2-1)	3,98E-01	8,10E-01	2,34E+01	1,53E-01	4,19E-01	4,34
27	S03160 (2-2)	3,69E-01	7,10E-01	1,94E+01	1,30E-01	2,96E-01	4,15
28	S03170 (2-3)	4,27E-01	8,10E-01		1,53E-01	2,86E-01	4,32
29	S03180 (1/75)	4,19E-01	7,90E-01	1,80E+01	9,22E-02	1,54E-01	4,05
30	S03190 (2/76)	3,38E-01	6,60E-01	1,35E+01	7,69E-02	1,10E-01	3,43
31	S03220 (5/79)		7,40E-01	1,44E+01	9,10E-02		3,84
32	S03230 (6/80)	3,22E-01	5,80E-01	8,29	7,33E-02	1,35E-01	3,25
33	S03240 (7/81)		6,20E-01	1,44E+01	6,85E-02		3,50
34	S03260 (9/83)	3,48E-01	6,40E-01	1,26E+01	7,80E+01	1,07E-01	3,26
Main value		4,93E-01	9,42E-01	2,05E+01	2,56	3,23E-01	4,08
Standard deviation		5,96E-01	9,72E-01	2,30E+01	1,38E+01	5,66E-01	1,18
min		1,95E-01	5,80E-01	2,18	6,85E-02	1,46E-02	1,83
max		3,62	6,18	1,30E+02	7,80E+01	3,14	8,06

Element content

Table A.4. General characterization of samples from the Room 304/3.

№	Number of sample (original number)	FCM description		Reference
		Place of sampling	Sample description	
1	10	46/47, И/Ж, mark 10.00	Black ceramics	*Studying Interactions of Fuel with Constructional Materials in the "Shelter"* (1991) Report under Contract #39-901/63-16-2-1 of 10.02.1991, Complex Expedition under I.V. Kurchatov Institute of Atomic Energy, approved by A.A. Borovoi and E.B. Anderson, Inventory Number 11.07/285 of 13.12.1991, Chernobyl – Saint-Petersburg, P. 88 (in Russian) (53 samples)
2	11	46/47, И-2.5, mark 10.00	Black mat ceramics	
3	12	46/47, И-2.5, mark 10.00	Black mat ceramics	
4	8	46+2.5, И-1	Brown porous ceramics	Borovoi, A.A. and Pazukhin, E.M. (1992) *Studying Fuel-containing Masses in the "Shelter" to Determine Concentrations of Traces of Neutron Absorbers Therein*, Analytical Note under Contract #04-92/62, ISTC "Shelter" of the Ukrainian National Academy, Inventory Number 09/35 of 21.12.1992, Saint-Petersburg - Chernobyl, P.8 (in Russian) (100 samples)
5	9	47-0.5, Ж	Black ceramics	
6	10	47-1, Ж	Black ceramics	
7	11	46, Ж+3	Black ceramics	
8	12	46, И-2	Black ceramics	
9	13	45+2, Ж+2, from surface	Black ceramics	
10	14	The same, from 2 cm depth	Black ceramics	
11	15	46-2, Ж+3	Black ceramics	
12	16	46-2.5, Ж+1, from surface	Black ceramics	
13	17	The same, from 2 cm depth	Black ceramics	
14	18	45+1.5, И-1.5	Black ceramics	
15	19	45+3, И-2	Black ceramics	
16	20	47-1, И-1.5	Black ceramics	
17	21	46+3, И-2.5	Black ceramics	
18	22	46+1.5, Ж+2	Black ceramics	
19	23	46+2, Ж+1.5	Black ceramics	

Table A.5. Element content of the samples from the Room 304/3.

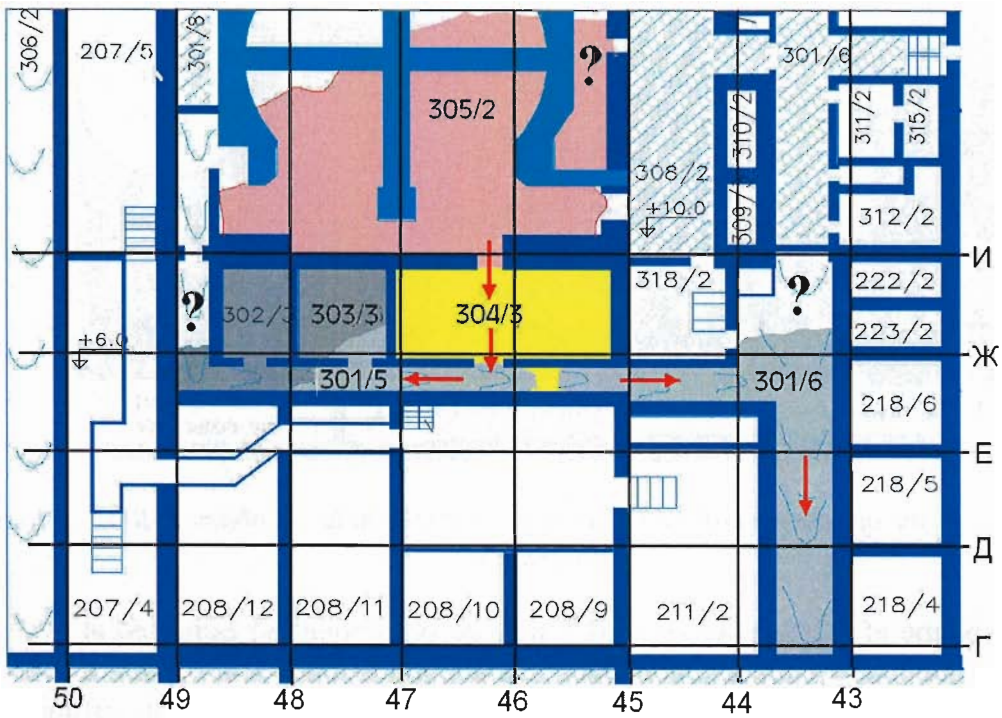
№	original number	Mass content, %																
		Si	Ca	Ti	Zr	Cu	Na	Ba	U	Al	Mn	Mo	Fe	Mg	Cr	Ni	B	Gd
1	10	36,0	3,6	1,0E-01	1,6	4,2E-03	4,7	1,3E-01	3,2	3,4	0,23		0,27	2,00	1,0E-01	1,3E-01	2,0E-02	
2	11	31,0	4,8	9,0E-02	3,0	7,3E-03	4,0	1,0E-01	4,3	4,9	0,36		0,42	2,80	1,6E-01	2,4E-01	3,7E-02	
3	12	32,0	5,9	1,2E-01	2,0	8,1E-03	5,0	1,2E-01	4,0	3,5	0,31		0,36	2,25	1,3E-01	2,0E-01	3,6E-02	
4	8			1,2E-01	7,5	1,3E-03					0,94	1,3E-03			8,8E-02	4,0E-03	1,8E-02	4.0E-02
5	9			9,0E-02	1,5	4,2E-03					2,80				1,2E-01	1,5E-01	2,0E-02	
6	10			6,4E-02	3,1	1,5E-03					0,90	8,6E-04			2,1E-01	5,8E-02	4,6E-02	
7	11			6,2E-02	0,1	2,0E-03					0,42	3,8E-03			2,5E-01	1,0E-01	8,8E-02	2.2E-02
8	12			1,5E-01	0,1	2,2E-03					0,11				2,0E-01	1,6E-01	9,1E-02	3.0E-02
9	13			1,7E-01	2,4	2,0E-03					3,00	3,0E-04			3,5E-01	3,1E-02	7,1E-02	2.6E-02
10	14			6,4E-02	3,0	1,2E-03					1,60	1,3E-03			1,1E-01	8,0E-03	9,5E-02	
11	15			1,6E-01	9,8	2,8E-03					1,70	2,3E-03			4,3E-01	1,3E-01	8,6E-02	4.0E-02
12	16			1,6E-01	7,5	1,5E-03					1,60				1,4E-01	6,4E-02	4,3E-02	2.7E-02
13	17			1,6E-01	5,3	8,0E-04					1,60				1,0E-01	5,2E-02	4,3E-02	
14	18			4,2E-02	5,9	2,9E-03					3,80	5,0E-03			4,0E-01	7,8E-02	5,2E-02	3.0E-02
15	19			2,0E-01	7,3	4,3E-03					1,80	4,7E-03			2,8E-01	1,1E-01	7,1E-02	4.3E-02

№	original number	Mass content, %																
		Si	Ca	Ti	Zr	Cu	Na	Ba	U	Al	Mn	Mo	Fe	Mg	Cr	Ni	B	Gd
16	20			1,3E-01	7,4	1,1E-03					1,70				1,3E-01	6,5E-02	6,0E-02	2.6E-02
17	21			1,8E-01	3,1	1,6E-03					2,60	6,0E-04			3,1E-01	4,5E-02	8,0E-02	2.9E-02
18	22			1,4E-01	> 10	2,0E-03					1,00				2,4E-01	1,5E-01	9,0E-02	2.7E-02
19	23			1,4E-01	7,1	1,4E-03					1,50				1,3E-01	6,1E-02	4,2E-02	2.5E-02
Main value		33,0	4,77	1,23E-01	4,32	2,76E-03	4,57	1,17E-01	3,83	3,93	1,47	2,24E-03	3,50E-01	2,35	2,04E-01	9,66E-02	5,73E-02	3,04E-02
Standard deviation		2,65	1,15	4,52E-02	2,93	2,04E-03	0,51	1,53E-02	0,57	0,84	1,03	1,81E-03	7,55E-02	0,41	1,07E-01	6,41E-02	2,61E-02	6,79E-03
min		31,0	3,60	4,20E-02	0,10	8,00E-04	4,00	1,00E-01	3,20	3,40	0,11	3,00E-04	2,70E-01	2,00	8,80E-02	4,00E-03	1,80E-02	2,20E-02
max		36,0	5,90	2,00E-01	9,80	8,10E-03	5,00	1,30E-01	4,30	4,90	3,80	5,00E-03	4,20E-01	2,80	4,30E-01	2,40E-01	9,50E-02	4,30E-02

5.1.2. Lava in Room #301/5 and Room #301/6 (Refs. [1 – 3])

Room #301/5

The servicing corridor #301/5 is contiguous with rooms ##302/3, 303/3 and 304/3 on the south (Fig. 5.5).



FCM in Room #305/2 (different modification)

Uncovered LFCM in ROOM # 304/3 and #301/5

LFCM under a layer of concrete in Room # 301/5, 301/6 and 303/3

Concrete layer of an appreciable thik

Direction of spreading of the horizontal lava flow

Fig. 5.5. – LFCM spreading over rooms of Unit #4 at +9 m level mark

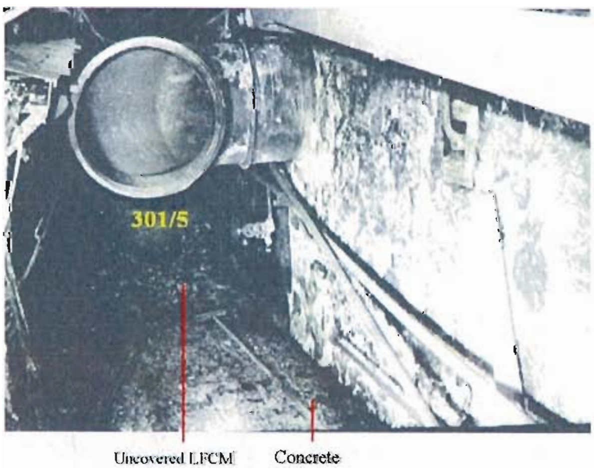


Fig. 5.6.
Corridor # 301/5

The servicing corridor #301/5 is contiguous with Rooms ##302/3, 303/3 and 304/3 on the south (Fig. 5.5, 5.6). On the east, it abuts on the servicing corridor # 301/6. During construction of the “Shelter” the corridor #301/5 was concreted on two sides with “fresh” concrete. The floor section between the axes 45_{+2500} and 46_{-1500} is free of “fresh concrete” and is covered with “open” LFCM partly strewed with building refuse.

According to the results of holing in corridor #301/5 between the axes 46_{-2000} and 45_{+2500} (Fig. 3) using a remotely manned system, the thick of LFCM layer at this location equals about 0.5 m; moreover, at the holing area structural concrete of the room's floor is destroyed down to ~15 cm. Both the results of holing and apparent presence of FCM in Room #301/6 suggest the availability of FCM at the eastern end-wall of corridor #301/5.

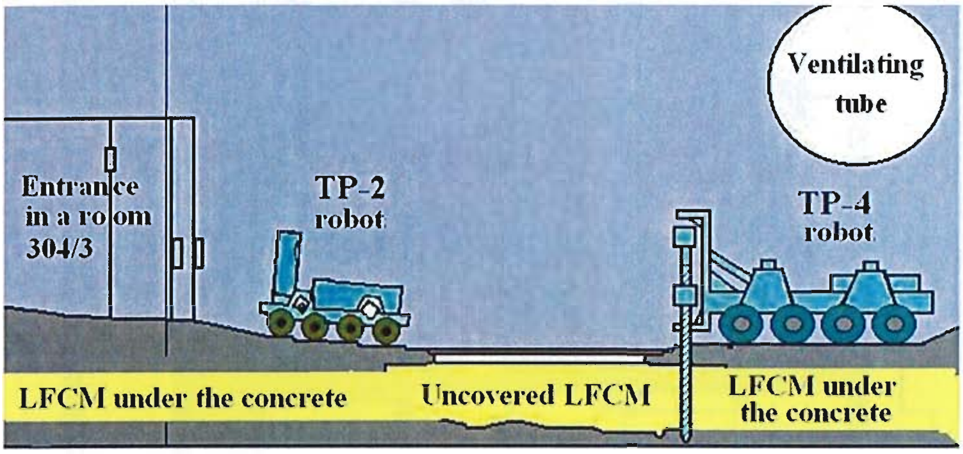


Fig. 5.7. The scheme of research of the Room 301/5 with the help of robots(drilling of concrete, sampling)t

The integral volume of FCM in Room #301/5 may be (very roughly) estimated at (8 ÷ 30) m^3. Taking into account the average density of studied samples ((2.69 ± 0.17) g/cm^3), the integral amount of fuel (U) in Room #301/5 is estimated at (2.0 ± 1.5) t (the experts estimation, see section 5.1).
In Appendix (301 - 1) we give performance of samples from a Room 301/5 and outcomes of their analyses.
Averaged radionuclide composition of samples taken in Room #301/5 is demonstrated in Tables 5.4 and 5.5.

Table 5.4. Averaged radionuclide composition of ceramics samples taken in Room #301/5 (fission and activation products). Data on 11 samples

	Activity of nuclides, MBq/g (ceramics), recalculations as of 26.04.1986							
Nuclide	^{144}Ce	^{137}Cs	^{134}Cs	^{106}Ru	^{125}Sb	^{154}Eu	^{155}Eu	^{90}Sr
Activity	9,0E+02	2,1E+01	1,1E+01	9,3		1,4		5,6E+01
Standard deviation	1,6E+02	5,8	3,1	5,4		2,3E-01		2,1E+01

Table 5.5. Averaged radionuclide composition of ceramics samples taken in Room #301/5 (transuranics)

	Activity of nuclides, MBq/g (ceramics), recalculations as of 26.04.1986					U, %	Burnup, MW×day/kg U
Nuclide	^{238}Pu	^{239}Pu + ^{240}Pu	^{242}Cm	^{244}Cm	^{241}Am		
Activity	4,1E-01	7,7E-01	3,9E+01	1,7E-01	2,9E-01	3,4	10,6
Standard deviation	8,1E-02	2,6E-01	1,9E+01	1,7E-01	2,1E-01	0,49	3,0

There are no data on element composition of samples taken in Room #301/5.

Room #301/6.

The Room #301/6 is a servicing corridor located between the rows “П” and “Г” and the axes #43 and #44 (Fig.1). In the course of the “Shelter” construction the Room #301/6 was concreted, the thick of concrete layer being about 2 m.

The presence of LFCM on the floor of Room #301/6 may be only suggested using the following indirect signs:
- data on LFCM in Room #301/5; and
- information on LFCM penetration into lower floors of Unit #4.

The integral volume of FCM in Room #301/6 may be (very roughly) estimated at $(8 \div 30)\ m^3$. In such a case the integral amount of fuel (U) in Room #301/6 would equal (2.0 ± 1.5) t (the experts estimation, see section 5.1).

REFERENCES

1. *The "Shelter" Current Safety Analysis and Forecast Estimates for the Situation Development* (2001) Responsible Executor: Borovoi A.A. Report of ISTC “Shelter”, Arch. #3836, Chernobyl, P.337 (in Russian).

2. Pazukhin, E.M. (1994) Lava-like Fuel Containing Masses of the Chernobyl NPP Unit 4: Topography, Physical & Chemical Properties, Generation Scenario, *J. Radiokhimia*, 36(2), 1994, pp. 97-142 (in Russian).

3. *Project 1: “ Safety Status of the Chernobyl NPP's "Object Shelter", Subproject n°3: “Nuclear Fuel and Radioactive Waste”* under a Special Agreement with IPSN and GRS of April 23, 1998. Work Report of IHTEM of RRC "KI" for the 3rd Half-yearly Milestone (October 30, 1999), Responsible Executive: Borovoi A.A., P. 30 (in Russian).

5.1.2.1. Application (301/5 –1) Performance of samples from the Room 301/5.

Radionuclide content of samples

Table A.1. Room 301/5. General characterization of samples.

№	Number of sample (original number))	FCM description		Date of analysis	Reference
		Place of sampling, coordinates	Sample description		
1	S00010(316)	47-2, Ж+1.5, mark 9.60, bore hole Ю-11-117	Black brilliant pieces. Black-brown lava.	1.12.91.	Alkhimov N.B., Kochergin C.M., Obukhova L.A., Kheruvimov A.N., Tsvetkova L.A. ДData on radionuclide content of core samples from bore holes Ю.11.117 // Report / KE of IAE by I.V.Kurchatov.- Inventory № 11.07/321.- Chernobyl, 1992- 10 p. (6 samples) in Russian
2	S00020 (317)	-"-	Black - brown sand. Черно-серый влажный песок.	1.12.91.	
3	S00030(318)	-"-	Brown wet sand	1.12.91.	
4	S00040(319)	-"-	Fragments of black lava.	1.12.91.	
5	S00050(320)	-"-	Grey friable mass.	1.12.91.	
6	S00060(321)	45/46, Ж-1.3/Ж-2,8	Black mat ceramics.	1.12.91.	
7	S01390(301)	45, Ж-2	Dark glassy mass.	15.06.89.	Borovoi, A.A. and Kheruvimov, A.N. (1990) *Studying Radionuclide Composition and Physico-chemical Condition of Samples of Fuel-containing Masses Taken in Rooms of the "Shelter"*, R&D Report of Complex Expedition under I.V. Kurchatov Institute of Atomic Energy, Inventory Number 11.07/12 of 16.03.1990, Chernobyl, P.20 (in Russian) (46 samples)
8	S01640(11)	47+2.9, Ж-1.35, mark 9.00, bore hole. 3-9-64	Black lava	26.05.91.	Alkhimov, N.B., Bogachev, S.I., Evstratenko, A.S., *et al.* (1991) *Studying Radionuclide Composition of FCM Samples Taken in Under-reactor Rooms of Unit #4 of Chernobyl NPP*, Report of Complex Expedition under I.V. Kurchatov Institute of Atomic Energy, Inventory Number 11.06/155 of 11.06.1991 (in Russian) (13 samples)
9	S01750(34)	45/46, Ж-1.3/Ж-2,8	Black ceramics	26.05.91.	
10	S02520(339)	45/46, Ж-1.3/Ж-2.8, depth 0 – 0.1 m	Medium porous Black lava	25.12.91.	Baev S.A., Gusev V.F., Kalinichenko, B.S., Kalistratov, V.A., Kulazhko V.G., Kurguzov V.V., Lisin, S.K.,., Rodionov Yu.F, Slonov, S.D, Shiryaev V.S. Study of FCM samples from the "Shelter" Report on execution of paragraph 2.4.1 of «Plan of urgent measures for increasing of nuclear and radiation safety of the "Shelter" / МНТЦ «Укрытие» Inventory Number 09/18 of 26.09.92, (in Russian) (13 samples)
11	S02530(340)	45/46, Ж-1.3/Ж-2.8, depth 0.1 – 0.25 m	Black porous lava	25.12.91.	
12	S02540(341)	45/46, Ж-1.3/Ж-2.8, depth 0.1 – 0.15 m	Black flaky porous lava	25.12.91.	
13	S02790(2)	45/46, Ж-1.3/Ж-2,8	Dark brown crumb.	11.05.90.	Alexeev I.N., Kalinichenko B.S., Kalistratov V.A. etc. Definition of radionuclide content of FSM samples from the Shelter // Report / KE of IAE by I.V.Kurchatov. Inventory № 11.07/32, 26.05.90 Chernobyl, 1990.- 17 p. (12 samples) (in Russian)
14	S02800(2-1)	45/46, Ж-1.3/Ж-2,8	Dark brown crumb	11.05.90.	

Table A.2. Radionuclide content of samples from Room 301/5 (fission and activation products).

№ п/п	Number of sample (original number))	Nuclide activity, MBq/g (of ceramic), recalculated for 26.04.86							
		^{144}Ce	^{137}Cs	^{134}Cs	^{106}Ru	^{125}Sb	^{154}Eu	^{155}Eu	^{90}Sr
1	S00010 (316)	8,63E+02	2,23E+01	1,26E+01	9,21		1,47		6.53E+01
2	S00020 (317)	6,88E+02	1,25E+01	6,98	6,34		1,05		5.20E+01
3	S00030 (318)	7,90E+02	1,91E+01	1,07E+01	4,13		1,36		5.57E+01
4	S00040 (319)	7,92E+02	9,36	5,16	6,35		1,37		1.07E+01
5	S00060 (321)	9,47E+02	2,27E+01	1,26E+01	2,18E+01		1,35		5.17E+01
6	S01640 (11)	9,80E+02	2,43E+01	1,36E+01	8,29		1,50		
7	S01750 (34)	1,24E+03	3,03E+01	1,65E+01	1,04E+01		1,96		
8	S02520 (339)	1,05E+03	2,39E+01	1,33E+01			1,57		8.03E+01
9	S02530 (340)	9,15E+02	2,16E+01	1,13E+01			1,27		6.50E+01
10	S02540 (341)	9,45E+02	2,25E+01	1,27E+01			1,35		7.07E+01
11	S02800 (2-1)	7,31E+02	1,76E+01	1,05E+01	8,21			1,64	
Main value значение		9.04E+02	2,06E+01	1,14E+01	9,34		1,43		5,64E+01
Standard deviation		1.57E+02	5,78	3,14	5,40		2,35E-01		2,09E+01
min		6.88E+02	9,36	5,16	4,13		1,05		1,07E+01
max		1.24E+03	3,03E+01	1,65E+01	2,18E+01		1,96		8,03E+01

Table A.3. Radionuclide content of samples from Room 301/5 (transuranic).

№ п/п	Number of sample (original number))	Nuclide activity, MBq/g (of ceramic), recalculated for 26.04.86					U, %
		^{238}Pu	^{239}Pu + ^{240}Pu	^{242}Cm	^{244}Cm	^{241}Am	
1	S00010 (316)	3,63E-01	6,81E-01		7,25E-02	9,69E-02	3,32
2	S00020 (317)	3,03E-01	5,71E-02		8,48E-02	7,76E-02	2,65
3	S00030 (318)	4,24E-01	7,19E-01		1,07E-01	2,26E-01	3,04
4	S00040 (319)	3,83E-01	8,74E-01		2,50E-01	6,17E-01	3,06
5	S00060 (321)	3,73E-01	7,96E-01		6,73E-01	7,63E-02	3,66
6	S01640 (11)	4,65E-01	8,34E-01	3,08E+01	9,00E-02	1,83E-01	3,77
7	S01750 (34)	5,17E-01	9,50E-01	2,91E+01	1,10E-01	2,01E-01	4,08
8	S02520 (339)	5,40E-01	9,80E-01	6,42E+01	1,61E-01	5,88E-01	4,07
9	S02530 (340)	4,61E-01	8,70E-01		1,49E-01	5,40E-01	3,59
10	S02540 (341)	4,33E-01	8,40E-01	3,98E+01	1,49E-01	4,61E-01	3,65
11	S02800 (2-1)	2,87E-01	4,90E-01	1,02E+01	5,37E-02	1,75E-01	2,78
Main value значение		4,14E-01	7,36E-01	3,48E+01	1,73E-01	2,95E-01	3,42
Standard deviation		8,09E-02	2,63E-01	1,96E+01	1,75E-01	2,13E-01	0,49
min		2,87E-01	5,71E-02	1,02E+01	5,37E-02	7,63E-02	2,65
max		5,40E-01	9,80E-01	6,42E+01	6,73E-01	6,17E-01	4,08

5.1.3. Lava in Room # 217/2 and Room # 017/2

Lava in Room # 217/2([1 – 3]).

During construction of the "Shelter" the servicing corridor #217/2 was concreted on both sides. At the southern end-wall (row "Г") the concrete surface reaches the room's ceiling.

LFCM penetrated into Room #217/2 from Room #301/6 via penetrations in the ceiling and formed the so-called "Elephant's foot", "Stalactites" and "Drop" (Fig. 5.8 and Fig. 5.9).

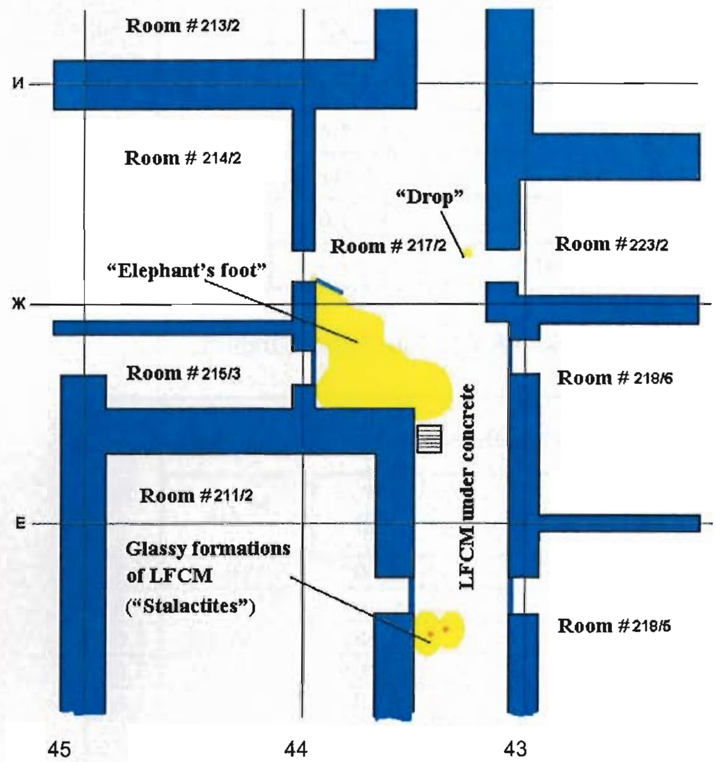


Fig.5.8. LFCM leaks from the "horizontal lava flow" down to +6 m level mark in Room #217/2

Figure 5.9. – Room #217/2. "Elephant's foot" and a "Stalactite"

According to the results of surveys of 1986 - 1988, the surface of glassy formations (black ceramics) was bright. However by 1989 it became dull and was covered with numerous cracks. The integral volume of accumulations makes up 2 – 4 m^3.

With consideration for the average density of studied samples - (2.69 ± 0.17) g/cm^3 - the integral amount of fuel (U) in Room #217/2 is estimated at (0.4 ± 0.15) t (Table 3).

In Appendix (217 - 1) we give performance of samples from a Room 217/2 and outcomes of their analyses.

The averaged radionuclide composition of samples taken in Room #304/3 is demonstrated in Tables 5.6 and 5.7.

Table 5.6. Averaged radionuclide composition of black ceramics samples taken in Room #217/2 (fission and activation products). Data of 27 samples

	Activity of nuclides, MBq/g (ceramics), recalculations as of 26.04.1986							
Nuclide	^{144}Ce	^{137}Cs	^{134}Cs	^{106}Ru	^{125}Sb	^{154}Eu	^{155}Eu	^{90}Sr
Activity	1,2E+03	2,8E+01	1,6E+01	1,3E+01	3,9	1,6	2,1	5,5E+01
Standard deviation	1,5E+02	5,2	2,9	8,6	8,8E-01	2,1E-01	4,5E-01	1,2E+01

Table 5.7. Averaged radionuclide composition of black ceramics samples taken in Room #217/2 (transuranics)

	Activity of nuclides, MBq/g (ceramics), recalculations as of 26.04.1986					U, %	Burnup, MW×day/kg U
Nuclide	^{238}Pu	^{239}Pu + ^{240}Pu	^{242}Cm	^{244}Cm	^{241}Am		
Activity	4,0E-01	8,3E-01	1,2E+01	1,3E-01	1,2E-01	4,6	12,1
Standard deviation	1,0E-01	2,4E-01	7,2,	1,4E-01	3,8E-02	0,58	0,6

The averaged element composition of samples is demonstrated in Table 3.

Table 5.8. Room #217/2. Averaged element composition of FCM samples. Data of 25 samples

Mass fraction, %																
Si	Ca	Ti	Zr	Cu	Na	Ba	U	Al	Mn	Mo	Fe	Mg	Cu	Cr	Ni	B
31,1	6,1	1,6 E-01	4,26	1,5 E-01	4,1	1,3 E-01	4,4	4,6	3,0	4,4 E-03	0,56	2,3	5,3 E-02	2,2 E-01	1,5 E-01	9,7 E-02
Standard deviation																
5,4	2,6	7,0 E-02	1,9	1,6 E-01	1,4	3,5 E-02	0,24	0,99	3,1	3,4 E-03	0,19	0,55	2,8 E-02	1,0 E-01	5,5 E-02	9,7 E-02

Room #017/2 ([1 – 3]).

Room #017/2 is a servicing corridor which southern section is located directly under Room #217/2. On the north the corridor is concreted with "fresh" concrete. FCM of Room #017/2, representing individual fragments of black ceramics, are located close to the staircase between the rows "E" and "Ж" where they penetrated from Room #217/2.

According to estimates, the amount of fuel in this room is minor – < 100 kg.

The averaged radionuclide composition of samples taken in Room #017/2 is demonstrated in Tables 5.9 and 5.10

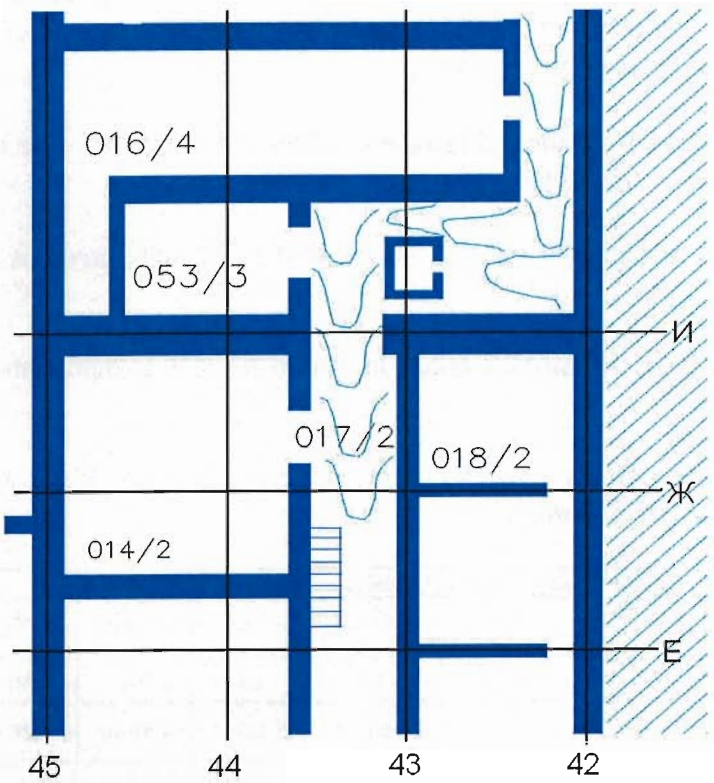


Fig. 5.10.
Room #217/2

Table 5.9. Averaged radionuclide composition of ceramics samples taken in Room #017/2 (fission and activation products). Data of 3 samples

	Activity of nuclides, MBq/g (ceramics), recalculations as of 26.04.1986							
Nuclide	^{144}Ce	^{137}Cs	^{134}Cs	^{106}Ru	^{125}Sb	^{154}Eu	^{155}Eu	^{90}Sr
Activity	1,3E+03	2,7E+01	1,5E+01	7,5	4,5	1,7	2,7	5,9E+01
Standard deviation	6,6E+01	5,0	3,3	3,2	1,5	1,7E-01	3,4E-01	8,1

Table 5.10. Averaged radionuclide composition of ceramics samples taken in Room #017/2 (transuranics)

	Activity of nuclides, MBq/g (ceramics), recalculations as of 26.04.1986					U, %	Burnup, MW×day/kg U
Nuclide	^{238}Pu	$^{239}Pu + ^{240}Pu$	^{242}Cm	^{244}Cm	^{241}Am		
Activity	4,3E-01	1,3	1,2E+01	1,5E-01	1,4E-01	5,00	1,2E+01
Standard deviation	1,1E-01	3,7E-01	4,4	1,3E-02	1,0E-02	0,2	5,5E-01

The element composition of ceramics was studied using one sample only.

REFERENCES

1. *The "Shelter" Current Safety Analysis and Forecast Estimates for the Situation Development* (2001) Responsible Executor: Borovoi A.A. Report of ISTC "Shelter", Arch. #3836, Chernobyl, P.337 (in Russian).

2. Pazukhin, E.M. (1994) Lava-like Fuel Containing Masses of the Chernobyl NPP Unit 4: Topography, Physical & Chemical Properties, Generation Scenario, *J. Radiokhimia*, 36(2), 1994, pp. 97-142 (in Russian).

3. *Project 1: " Safety Status of the Chernobyl NPP's "Object Shelter", Subproject n°3: "Nuclear Fuel and Radioactive Waste"* under a Special Agreement with IPSN and GRS of April 23, 1998. Work Report of IHTEM of RRC "KI" for the 3rd Half-yearly Milestone (October 30, 1999), Responsible Executive: Borovoi, A.A., P. 30 (in Russian).

5.1.3.1. Appendix (217 – 1) Characteristic of Samples Taken in Room #217/2

Radionuclide Composition

Table A.1. Room #217/2.General Characteristics of Samples

##	Sample code (sample number in the reference source)	FCM, description		Date of analysis	Reference source
		Sampling area, coordinates	Sample description		
1	S00070 (1)	43/44, Е/Ж, "stalactite" behind the "Elephant's Foot", level mark 7.00	"Stalactite" of black ceramics hanging down from ceiling	1.03.89.	*Studying Interactions of Fuel with Constructional Materials in the "Shelter"* (1991) Report under Contract #39-901/63-16-2-1 of 10.02.1991, Complex Expedition under I.V. Kurchatov Institute of Atomic Energy, approved by A.A. Borovoi and E.B. Anderson, Inventory Number 11.07/285 of 13.12.1991, Chernobyl – Saint-Petersburg, P. 88 (in Russian) (53 samples)
2	S00080 (2)	idem, level mark 7.10	- « -	1.03.89.	
3	S00090 (3)	idem, level mark 7.20	- « -	1.03.89.	
4	S00100 (4)	idem, level mark 7.30	- « -	1.03.89.	
5	S00110 (5)	idem, level mark 7.40	- « -	1.03.89.	
6	S00120 (6)	idem, level mark 7.50	- « -	1.03.89.	
7	S00130 (7)	idem, level mark 7.60	- « -	1.03.89.	
8	S00140 (8)	idem, level mark 7.70	Black ceramics	1.03.89.	
9	S00210 (15)	43/44, E+3, level mark 6.00, "dripstone deposit" behind the "stalactite", surface of "dripstone deposit"	Black ceramics	1.03.89.	
10	S00220 (16)	idem, 2 cm in depth	- « -	1.03.89.	
11	S00230 (17)	idem, 4 cm in depth	- « -	1.03.89	
12	S00240 (18)	idem, 6 cm in depth	Porous black ceramics	1.03.89.	
13	S00470 (41)	43/44, Е/Д, level mark 6.00	Bright black ceramics	1.03.89.	
14	S00480 (42)	43/44, Е/Ж, level mark 6.00	Dull black ceramics	1.03.89.	
15	S00490 (43)	44, Ж, level mark 6.00, "Elephant's Foot"	Bright black ceramics	1.03.89.	
16	S01130 (319)	44, Ж, level mark 6.00, "Elephant's Foot"	Black ceramics	15.06.89.	Borovoi, A.A. and Kheruvimov, A.N. (1990) *Studying Radionuclide Composition and Physico-chemical Condition of Samples of Fuel-containing Masses Taken in Rooms of the "Shelter"*, R&D Report of Complex Expedition under I.V. Kurchatov Institute of Atomic Energy, Inventory Number 11.07/12 of 16.03.1990, Chernobyl, P.20 (in Russian) (46 samples)
17	S01400 (CH-1)	44, Ж, level mark 6.00, "Elephant's Foot"	Black molten mass of a smooth bright surface	15.06.89.	
18	S01410 (CH-2)	44, Ж, level mark 6.00, "Elephant's Foot"	- " -	15.06.89.	
19	S01420 (CH-3)	44, Ж, level mark 6.00, "Elephant's Foot"	- " -	15.06.89.	
20	S01680 (27лаб)	44, Ж, level mark 6.00, "Elephant's Foot", second "dripstone deposit"	Black bright sintered mass	26.05.91.	Alkhimov, N.B., Bogachev, S.I., Evstratenko, A.S., *et al.* (1991) *Studying Radionuclide Composition of FCM Samples Taken in Under-reactor Rooms of Unit #4 of Chernobyl NPP*, Report of Complex Expedition under I.V. Kurchatov Institute of Atomic Energy, Inventory Number 11.06/155 of 11.06.1991 (in Russian) (13 samples)
21	S01690 (30 лаб)	43/44, Ж/И, level mark 6.00 the "Drop", "bottom"	Black bright fused mass of greenish tint	26.05.91.	
22	S01760 (28 лаб)	43/44, Ж/И, level mark 6.00 the "Drop", "top"	Black mass	26.05.91.	

##	Sample code (sample number in the reference source)	FCM, description		Date of analysis	Reference source
		Sampling area, coordinates	Sample description		
23	S01830 (124)		Black lava	15.06.91.	Kurguzov, V.V., Lisin, S.K., Rodionov, Yu.F., *et al.* (1991) *Precision Radiochemical and Nuclear-physical Analysis of Radionuclide Composition of Five Samples Taken in Rooms of the « Shelter »*, Report of Complex Expedition under I.V. Kurchatov Institute of Atomic Energy, Inventory Number 11.07/161 of 15.06.1991 (in Russian) (5 samples)
24	S02010(124)	43/44, Е/Ж, "Elephant's Foot" 2	Black lava	28.11.90.	Alkhimov, N.B., Kiselev, A.N., Kurguzov, V.V., *et al.* (1991) *Studying Radionuclide Composition of Fuel-containing Materials in the "Shelter"*, Report of Complex Expedition under I.V. Kurchatov Institute of Atomic Energy, Inventory Number 11.07/139 of 22.04.1991, Chernobyl, P.19 (in Russian) (19 samples)
25	S02020(129)	43/44, Е/Ж, "Elephant's Foot" 3	Black lava	28.11.90.	
26	S02030(130)	43+2.2, Д+2.6, "Minor stalactite"	Black lava	28.11.90.	
27	S02330 (19)	44-3.5, Ж-2, level mark 6.00, "Elephant's Foot", on the left	Black lava	15.11.91.	Gusev, V.F., Kalinichenko, B.S., Kalistratov, V.A., *et al.* (1991) *Conducting Radiochemical Analyses of Fuel Concentration in Samples of Fuel-containing Masses*, Annotation Report under Contract #1132-ja of 21.02.1991, Milestone #6, I.V. Kurchatov Institute of Atomic Energy, Inventory Number 11.07/274 of 29.11.91 (NIO CE), Moscow, P.7 (in Russian) (10 samples)
28	S02600(3-1)	44, Ж, level mark 6.00, "Elephant's Foot"	Dust	15.02.91.	Borovoi, A.A. and Kheruvimov, A.N. (1991) *Determining Nuclear-physical Characteristics of FCM-destruction Products*, Report of Complex Expedition under I.V. Kurchatov Institute of Atomic Energy, Inventory Number 11.07/254 of 15.02.1991, Chernobyl, P.18 (in Russian) (17 samples)
29	S02610(3-2)	44, Ж, level mark 6.00, "Elephant's Foot"	Dust	15.02.91.	
30	S02620(3-6)	44, Ж, level mark 6.00, "Elephant's Foot"	Dust	15.02.91.	
31	S02630(3-7)	44, Ж, level mark 6.00, "Elephant's Foot"	Dust	15.02.91.	
32	S02640(2-3)	44, Ж, level mark 6.00, "Elephant's Foot"	Dust	15.02.91.	
33	S02650(2-4)	44, Ж, level mark 6.00, "Elephant's Foot"	Dust	15.02.91.	
34	S02660(2-5)	44, Ж, level mark 6.00, "Elephant's Foot"	Dust	15.02.91.	
35	S02670(1-8)	44, Ж, level mark 6.00, "Elephant's Foot"	Dust	15.02.91.	
36	S02680(1-9)	44, Ж, level mark 6.00, "Elephant's Foot"	Dust	15.02.91.	
37	S02690(1-1)	44, Ж, level mark 6.00, "Elephant's Foot"	Dust	15.02.91.	

Table A.2. Radionuclide Composition of Samples Taken in Room #217/2 (fission and activation products)

#	Sample code (sample number in the reference source)	Activity of nuclides, MBq/g (ceramics), recalculation as of 26.04.86							
		^{144}Ce	^{137}Cs	^{134}Cs	^{106}Ru	^{125}Sb	^{154}Eu	^{155}Eu	^{90}Sr
1	S00070 (1)	1,11E+03	3,22E+01	1,77E+01	1,94E+01	5,09	1,55	1,65	3.76E+01
2	S00080 (2)	1,22E+03	2,75E+01	1,53E+01	1,16E+01	4,06	1,37	1,71	5.84E+01
3	S00090 (3)	1,25E+03	2,74E+01	1,57E+01	2,07E+01	5,25	1,94	1,80	4,28E+01
4	S00100 (4)	1,15E+03	2,54E+01	1,47E+01	7,52	3,20	1,46	2,02	4,44E+01
5	S00110 (5)	1,12E+03	2,14E+01	1,20E+01	1,10E+01	2,76	1,41	2,00	5,70E+01
6	S00120 (6)	1,09E+03	2,17E+01	1,21E+01	2,75E+01	2,21	1,39	1,61	5,59E+01
7	S00130 (7)	1,32E+03	3,46E+01	1,92E+01	6,91	4,36	1,49	2,63	5,14E+01
8	S00140 (8)	1,37E+03	2,53E+01	1,39E+01	8,84	3,49	1,77	2,19	5,04E+01
9	S00210 (15)	1,08E+03	2,81E+01	1,51E+01	5,74	4,00	1,19	1,93	4,31E+01
10	S00220 (16)	1,42E+03	4,49E+01	2,67E+01	3,56E+01	3,76	2,08	3,22	6,31E+01
11	S00230 (17)	1,19E+03	3,19E+01	1,76E+01	5,29	4,40	1,47	2,17	5,65E+01
12	S00240 (18)	1,22E+03	3,42E+01	1,92E+01	5,11	3,83	1,53	2,82	4,25E+01
13	S00470 (41)	1,24E+03	2,70E+01	1,50E+01	1,80E+01		1,50	1,92	4,90E+01
14	S00480 (42)	1,28E+03	2,20E+01	1,30E+01	1,10E+01		1,50	2,07	6,09E+01
15	S00490 (43)	1,36E+03	3,20E+01	1,70E+01	1,90E+01		1,80	1,91	4,66E+01
16	S01130 (319*)	1,18E+03	3,33E+01	1,66E+01	9,51				
17	S01400 (CH-1)	1,09E+03	2,49E+01	1,49E+01	3,22E+01				
18	S01410 (CH-2)	1,11E+03	2,56E+01	1,49E+01	1,44E+01				
19	S01420 (CH-3)	1,44E+03	3,21E+01	1,86E+01	6,48				
20	S01680 (Lab.27)	9,80E+02	2,44E+01	1,34E+01	4,74		1,52		
21	S01690 (Lab.30)	1,03E+03	2,58E+01	1,42E+01	6,25		1,60		
22	S01760 (Lab.28)	1,02E+03	2,60E+01	1,49E+01	5,00		1,60		
23	S01830 (124)	1,11E+03	2,30E+01	1,33E+01	1,67E+01				
24	S02010 (124)	1,36E+03	2,46E+01	1,48E+01	1,89E+01				5,41E+01
25	S02020 (129)	1,30E+03	2,63E+01	1,56E+01	6,34				8,00E+01
26	S02030 (130)	1,14E+03	2,39E+01	1,38E+01	6,82				7,44E+01
27	S02330 (19)	7,37E+02	2,62E+01	1,58E+01	5,98				8,12E+01
Average value		1,18E+03	2,78E+01	1,57E+01	1,28E+01	3,87	1,57	2,11	5,52E+01
Standard deviation		1,54E+02	5,16	2,93	8,62	8,82E-01	2,14E-01	4,52E-01	1,25E+01
min		7,37E+02	2,14E+01	1,20E+01	4,74	2,21	1,19	1,61	3,76E+01
max		1,44E+03	4,49E+01	2,67E+01	3,56E+01	5,25	2,08	3,22	8,12E+01

Table A.3. Radionuclide Composition of Samples Taken in Room #217/2 (transuranic elements)

#	Sample code (sample number in the reference source)	Activity of nuclides, MBq/g (ceramics), recalculation as of 26.04.86					U, %
		^{238}Pu	$^{239}Pu + ^{240}Pu$	^{242}Cm	^{244}Cm	^{241}Am	
1	S00070 (1)	4,28E-01	6,76E-01	7,56	1,24E-01	1,11E-01	4,33
2	S00080 (2)	3,89E-01	9,50E-01	1,06	1,55E-01	1,17E-01	4,75
3	S00090 (3)	2,89E-01	8,41E-01	1,72	1,17E-01	1,43E-01	4,83
4	S00100 (4)	3,47E-01	7,88E-01	6,29	7,90E-01	1,40E-01	4,43
5	S00110 (5)	3,05E-01	9,25E-01	4,95	1,16E-01	1,40E-01	4,35
6	S00120 (6)	3,77E-01	8,33E-01	8,89	1,15E-01	1,27E-01	4,24
7	S00130 (7)	4,17E-01	1,41	6,02	1,31E-01	1,51E-01	5,14
8	S00140 (8)	5,27E-01	1,18	12,3	1,60E-01	1,60E-01	5,00
9	S00210 (15)	4,43E-01	9,68E-01	5,77	1,04E-01	1,15E-01	4,24
10	S00220 (16)	5,09E-01	1,29	2,43E+01	1,19E-01	1,28E-01	5,44
11	S00230 (17)	4,72E-01	9,12E-01	9,36	1,30E-01	1,35E-01	4,64
12	S00240 (18)	3,06E-01	7,69E-01	7,06E+00	8,68E-02	1,21E-01	4,74
13	S00470 (41)	4,00E-01	7,30E-01	1,80E+01	9,00E-02	1,75E-01	4,83
14	S00480 (42)	4,60E-01	8,40E-01	1,50E+01	1,00E-01	1,16E-01	4,91
15	S00490 (43)	5,30E-01	9,70E-01	1,90E+01	1,20E-01	1,44E-01	5,36
16	S01130 (319*)	2,63E-01	6,50E-01				4,69
17	S01400 (CH-1)						4,17
18	S01410 (CH-2)	5,84E-02	1,15E-01	1,98	1,28E-02		4,24
19	S01420 (CH-3)						5,51
20	S01680 (Lab.27)	4,07E-01	6,60E-01	1,62E+01	8,56E-02	3,22E-02	3,79
21	S01690 (Lab.30)	5,50E-01	7,71E-01	1,95E+01	8,31E-02	7,12E-02	4,01
22	S01760 (Lab.28)	4,01E-01	6,67E-01	2,03E+01	6,57E-02	6,32E-02	3,96
23	S01830 (124)	4,72E-01	7,84E-01	2,58E+01	7,69E-02	1,11E-01	4,26
24	S02010 (124)	4,68E-01	7,87E-01	1,88E+01	7,65E-02	8,71E-02	5,16
25	S02020 (129)	4,19E-01	7,45E-01	1,43E+01	8,87E-02	1,31E-01	4,93
26	S02030 (130)	4,11E-01	7,52E-01	1,83E+01	8,88E-02	1,94E-01	4,36
27	S02330 (19)	4,17E-01	7,45E-01	1,36E+01	9,10E-02	6,36E-02	2,78
Average value		4,03E-01	8,30E-01	1,23E+01	1,30E-01	1,21E-01	4,56
Standard deviation		1,04E-01	2,42E-01	7,26p,	1,44E-01	3,77E-02	0,58
min		5,84E-02	1,15E-01	1,06p,	1,28E-02	3,22E-02	2,78
max		5,50E-01	1,41	2,58E+01	7,90E-01	1,94E-01	5,51

Table A.4. Room #217/2. General Characteristics of Samples

#	Sample code (sample number in the reference source)	FCM, description		Reference source
		Sampling area, coordinates	Sample description	
1	1	43/44, Е.Ж, level mark 6.00	Black ceramics	*Studying Interactions of Fuel with Constructional Materials in the "Shelter"* (1991) Report under Contract #39-901/63-16-2-1 of 10.02.1991, Complex Expedition under I.V. Kurchatov Institute of Atomic Energy, approved by A.A. Borovoi and E.B. Anderson, Inventory Number 11.07/285 of 13.12.1991, Chernobyl – Saint-Petersburg, P. 88 (in Russian) (45 samples)
2	2	43/44, Ж-2, level mark 6.00	Black ceramics	
3	3	43/44, Е/Ж, level mark 6.00	Black ceramics	
4	7	43/44, Е/Ж, "stalactite", level mark 7.00	Black ceramics	
5	8	idem, level mark 7.30	Black ceramics	
6	9	idem, level mark 7.60	Black ceramics	
7	15	43/44, Е/Ж, level mark 6.00, "dripstone deposit", surface	Black ceramics	
8	16	idem, from 2-cm depth	Black ceramics	
9	17	idem, from 6-cm depth	Black ceramics	
10	85	44-3, Е+3, "cake" under the staircase	Black ceramics	Borovoi, A.A. and Pazukhin, E.M. (1992) *Studying Fuel-containing Masses in the "Shelter" to Determine Concentrations of Traces of Neutron Absorbers Therein*, Analytical Note under Contract #04-92/62, ISTC "Shelter" of the Ukrainian National Academy, Inventory Number 09/35 of 21.12.1992, Saint-Petersburg - Chernobyl, P.8 (in Russian) (100 samples)
11	86	44-3, Ж-2.5, "cake" under the staircase	Black ceramics	
12	87	43+3, Д+2, "dripstone deposit"	Black ceramics	
13	88	44-3, Ж-2.4, "cake" near the staircase	Black ceramics	
14	89	43+3, Е, "stalactite"	Black ceramics	
15	90	44-3, Ж-1, "Elephant's Foot"	Black ceramics	
16	91	44-2, Ж-1, "Elephant's Foot" I	Black ceramics	
17	92	44-1, Ж-1, "Elephant's Foot" I	Black ceramics	
18	93	44-3, Ж-2, "Elephant's Foot" II	Black ceramics	
19	94	44-2, Ж-2, "Elephant's Foot" II	Black ceramics	
20	95	44-1, Ж-2, "Elephant's Foot" II	Black ceramics	
21	96	44-4.5, Ж-3, "Elephant's Foot" III	Black ceramics	
22	97	44-3, Ж-3, "Elephant's Foot" III	Black ceramics	
23	98	44-2, Ж-3, "Elephant's Foot" III	Black ceramics	
24	99	43+3, Е-3 "stalactite"	Black ceramics	
25	100	43+3, Г+1.5, "stalactite"	Black ceramics	

Table 5. Room #217/2. Element Composition of FCM Samples

##	Sample number in the reference source	Mass fraction, %																
		Si	Ca	Ti	Zr	Cu	Na	Ba	U	Al	Mn	Mo	Fe	Mg	Cr	Ni	B	Gd
1	1	27,0	5,0		3,5	2,2E-03	3,5		4,5	5,7	0,22		0,90	1,40	1,5E-01	7,0E-02	3,5E-02	
2	2	33,0	5,5	1,1E-01	3,1	4,1E-03	4,7	1,2E-01	4,5	4,8	0,25		0,75	2,30	2,0E-01	4,0E-02	5,3E-02	
3	3	29,0	4,5	8,0E-02	3,6	5,9E-03	2,8	2,1E-01	4,8	5,1	0,35		0,63	2,00	2,5E-01	1,2E-01	4,3E-02	
4	7	36,0	4,7	1,2E-01	1,8	3,0E-03	6,6	1,5E-01	4,5	3,3	0,25		0,34	2,00	1,2E-01	1,3E-01	2,1E-02	
5	8	33,0	5,3	1,1E-01	3,2	4,0E-03	5,1	1,1E-01	4,3	3,2	0,31		0,35	2,25	1,0E-01	1,2E-01	3,5E-02	
6	9	35,0	5,0	1,1E-01	2,6	4,0E-03	5,5	1,3E-01	4,4	3,8	0,23		0,46	3,10	2,0E-01	1,5E-01	4,0E-02	
7	15	19,0	13,0	1,8E-01	6,0	3,2E-01	2,4	1,2E-01	4,1	6,0	0,50		0,68	2,50	1,9E-01	1,8E-01	7,4E-02	
8	16	33,0	6,1	1,2E-01	3,1	3,6E-01	3,0	1,0E-01	4,0	5,0	0,30		0,40	3,10	1,2E-01	1,1E-01	4,1E-02	
9	17	35,0	5,5	1,5E-01	2,8	3,1E-01	3,5	1,1E-01	4,3	4,7	0,41		0,56	2,00	3,9E-01	1,6E-01	2,8E-02	
10	85			6,0E-02	4,0	1,3E-03					2,50	2,0E-03			1,9E-01	6,0E-02	5,2E-02	
11	86			5,0E-02	5,2	7,6E-03					3,20	6,8E-03			5,8E-01	7,0E-02	5,6E-02	
12	87			1,8E-01	6,2	3,1E-01					0,60				1,8E-01	1,9E-01	7,2E-02	
13	88			2,2E-01	4,5	3,1E-01					0,56				1,9E-01	1,8E-01	7,2E-02	
14	89			1,3E-01	1,7	3,0E-03					2,30				1,1E-01	1,3E-01	2,5E-02	

##	Sample number in the reference source	Mass fraction, %															
		Si	Ca	Ti	Zr	Cu	Na	Ba	U	Al	Mn	Mo	Fe	Mg	Cr	Ni	B	Gd
15	90			1,8E-01	7,3	3,0E-01					4,00				1,9E-01	2,3E-01	7,2E-02	
16	91			3,0E-01	8,1	3,9E-01					6,00				3,0E-01	1,8E-01	3,8E-01	
17	92			2,7E-01	3,5	2,1E-01					5,30				2,8E-01	2,1E-01	1,5E-01	
18	93			1,7E-01	4,0	3,1E-01					8,00				2,0E-01	1,8E-01	7,1E-02	
19	94			2,7E-01	5,5	4,1E-01					11,00				2,5E-01	2,5E-01	3,6E-01	
20	95			1,1E-01	6,2	3,5E-02					9,70				2,1E-01	1,1E-01	5,9E-02	
21	96			2,5E-01	6,1	3,9E-02					3,20				2,9E-01	2,0E-01	2,3E-01	
22	97			1,9E-01	7,3	3,1E-01					5,00				1,9E-01	1,1E-01	8,7E-02	
23	98			2,3E-01	2,5	1,1E-01					4,10				2,5E-01	1,5E-01	1,9E-01	
24	99			1,8E-01	2,1	8,3E-03					2,50				1,8E-01	1,6E-01	1,4E-01	
25	100			8,0E-02	2,7	6,0E-03					3,60				3,2E-01	2,2E-01	4,1E-02	
Average value		31.11	6,07	1,60E-01	4,26	1,51E-01	4,12	1,31E-01	4,38	4,62	2,98	4,40E-03	0,56	2,29	2,25E-01	1,48E-01	9,71E-02	
Standard deviation		5.40	2,64	6,98E-02	1,86	1,60E-01	1,42	3,52E-02	0,24	0,99	3,11	3,39E-03	0,19	0,55	1,01E-01	5,52E-02	9,71E-02	
min		19.00	4,50	5,00E-02	1,70	1,30E-03	2,40	1,00E-01	4,00	3,20	0,22	2,00E-03	0,34	1,40	1,00E-01	4,00E-02	2,10E-02	
max		36.00	13,00	3,00E-01	8,10	4,10E-01	6,60	2,10E-01	4,80	6,00	11,00	6,80E-03	0,90	3,10	5,80E-01	2,50E-01	3,80E-01	

5.2. Large and Minor Vertical Flows [1 – 8]

Large Vertical Flow

The Large Vertical Flow (LVF) begins at the fourth southern steam-dumping valve in the southwestern section of Room #305/2 (the square of: И/47-И/48-К/48-К/47). Next – the 4th steam-dumping valve in the Steam-Distribution Corridor (SDC), Room 210/7 (Figs. 5.11 – 5.12).

Steam-distribution Corridor

All steam-dumping valves in SDC ends with three short large ducts turned to each other at angle of 120°. Under normal conditions these ducts are closed with diaphragms, its majority at accident was broken.

Within one duct of the 4th valve in Room #210/7 a peculiar solidified "cascade" of brown ceramics with large "drops" and "jets" of metal are observed (Fig. 5.13). The second duct contains a solidified "jet" of coal-black ceramics. The third duct comprises a chocolate-brown solidified mass covering molten and solidified metal up to 50 cm in thick on the Room's floor.

From the SDC's floor upper ends of steam-dumping telescopic pipes stick up by 35 cm; having passed over them, LFCM flowed down and reached the second floor of Pressure-Suppression Pool (PSP), Rooms #012/15 and #012/14 (Figs.5.11 and 5.14).

Second Floor of the Pressure-Suppression Pool

Openly lying LFCM within PSP-2 form a "pile" in Room #012/15 (Fig. 5.14). Its visible section is located in the area between the axes 47_{+500} - 48_{-1000} and the rows И$_{-3000}$ - К.
From the structural viewpoint, the "pile" represents a system of interconnected knolls. Along the edges the "pile" is concreted with "fresh" concrete. On the north side the level of concrete reaches ~ 0,7 m above the floor. Visible surface of the "pile" is covered with a pumice-like layer ~ 10 cm thick.

LFCM are also found in five steam-dumping pipes 404 mm in diameter[6] via which, evidently, lava penetrated to the "pile".

In Room #012/14 four steam-dumping pipes located along the axis 47_{-3000} and the rows Л$_{+1500}$, Л, Л$_{-1500}$ and К$_{+1500}$ are also filled with FCM.

In addition, another FCM accumulation is possibly located along the axis 46_{+1000} (the eastern wall of Room #012/14) between the rows К - М under concrete "influxes" attaining 0,9 m above the floor level (as indicated by high Exposure Dose Rates (EDR) measured above concrete).

First Floor of the Pressure-Suppression Pool

Openly lying LFCM within PSP-1 represent a "pile" in Room #012/7. The "pile", 0,8 m in height above the room's floor, is concreted with "fresh" concrete up to 0.2 - 0.4 m above the floor, its visible section being located within the area between the axes 48_{-500} - 48_{-2500} and the rows И$_{+400}$ - И$_{+3300}$ (Fig. 5.15).

Lava is also contained within steam-dumping pipes 280 mm in diameter located in the "pile" area.

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[6] Pipe coordinates are: - К, К$_{-1500}$, К$_{-3000}$ (along the axis 48_{-3000}) and К$_{-1500}$, К$_{-3000}$ (along the axis 48_{-1100}).

Minor Vertical Flow

The Minor Vertical Flow (MVF) begins at the third and the fourth southern steam-dumping valves in the southeastern section of Room #305/2 (the rectangle of: И/46-И/47-Л/47-Л/46) (Figs 5.11 and 5.12).

Next - SDC, Room #210/6, where solidified coal-black ceramics "flows" out of ducts of the 3rd and the 4th valves. The ducts of steam-dumping valves are filled with black LFCM containing a multitude of minor fragments of metal constructions.

Openly lying FCM are located between the rows И - $К_{+3000}$. The thickness of FCM layer near the 1st duct of the 3rd valve reaches 0.6 m, in the 4th valve area – 0,4 – 0,5 m, and in the И row area it equals 0,1 m.

Re-melted and solidified metal is found in the area of the 4th steam-dumping valve (rows И - К); dull ceramics contains major gas holes and has a minor height above the floor.
Four steam-dumping pipes located along the axis 47_{-3000} and the rows $Л_{+1500}$, Л, $Л_{-1500}$ and $К_{+1500}$ under Room #210/6 are filled with lava.

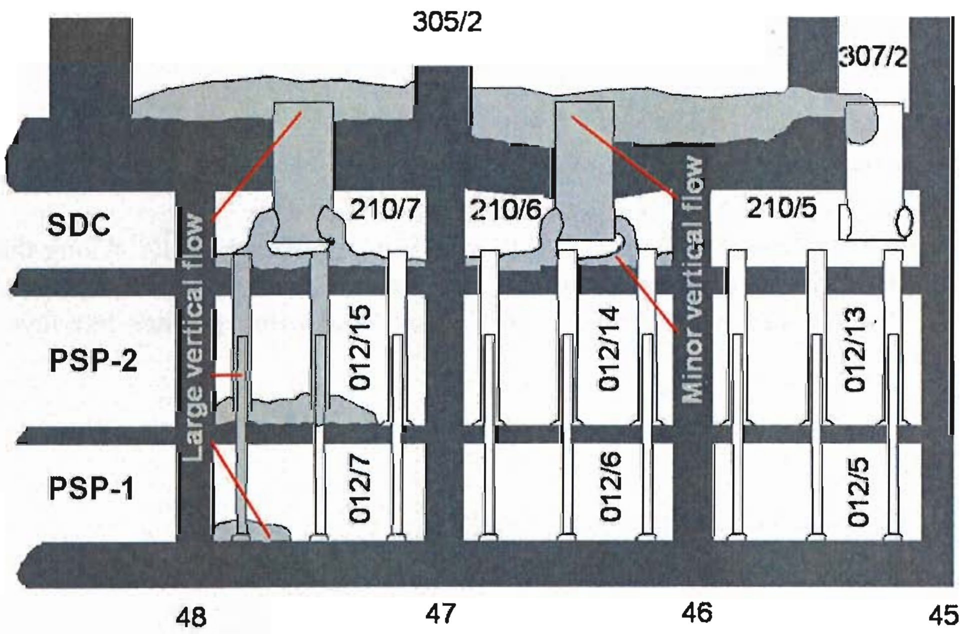
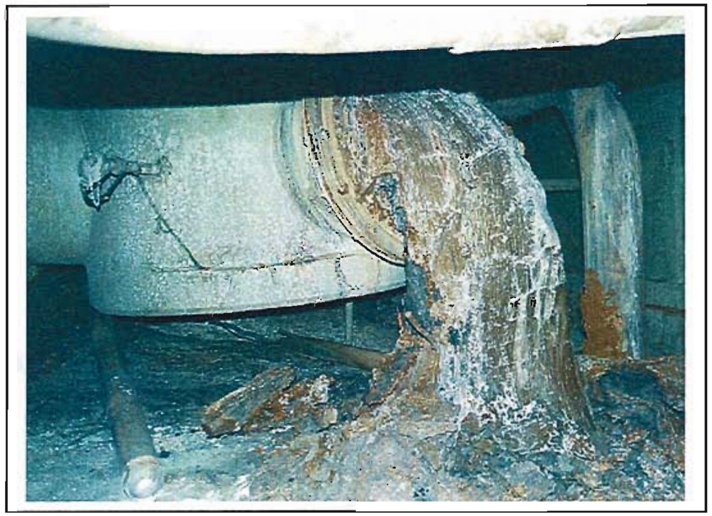


Fig. 5.11. Vertical flows of LFCM in the "Shelter"

Fig. 5.12. LFCM in steam-distribution corridor

Fig. 5.13. Solidified LFCM "jets" flowing out of the 4th steam-distribution valve in Room #210/7



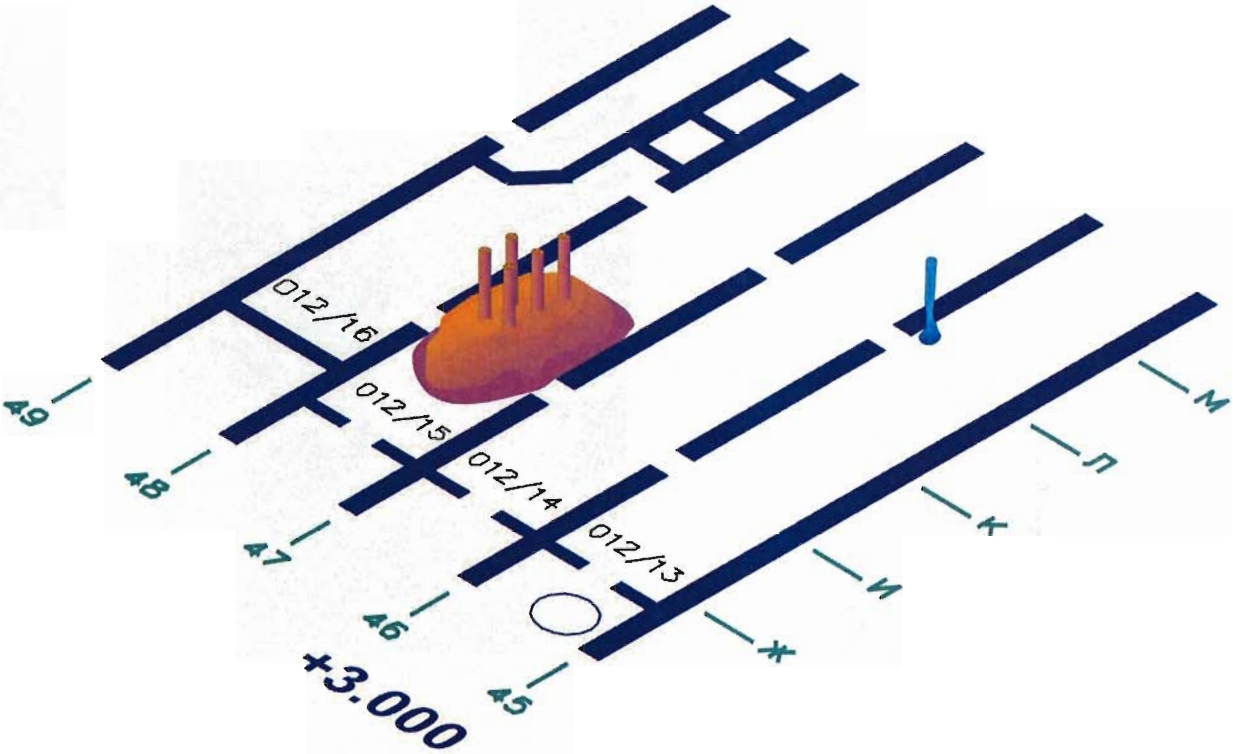


Fig.5.14. LFCM "pile" on the second floor of pressure-suppression pool, Room 012/15

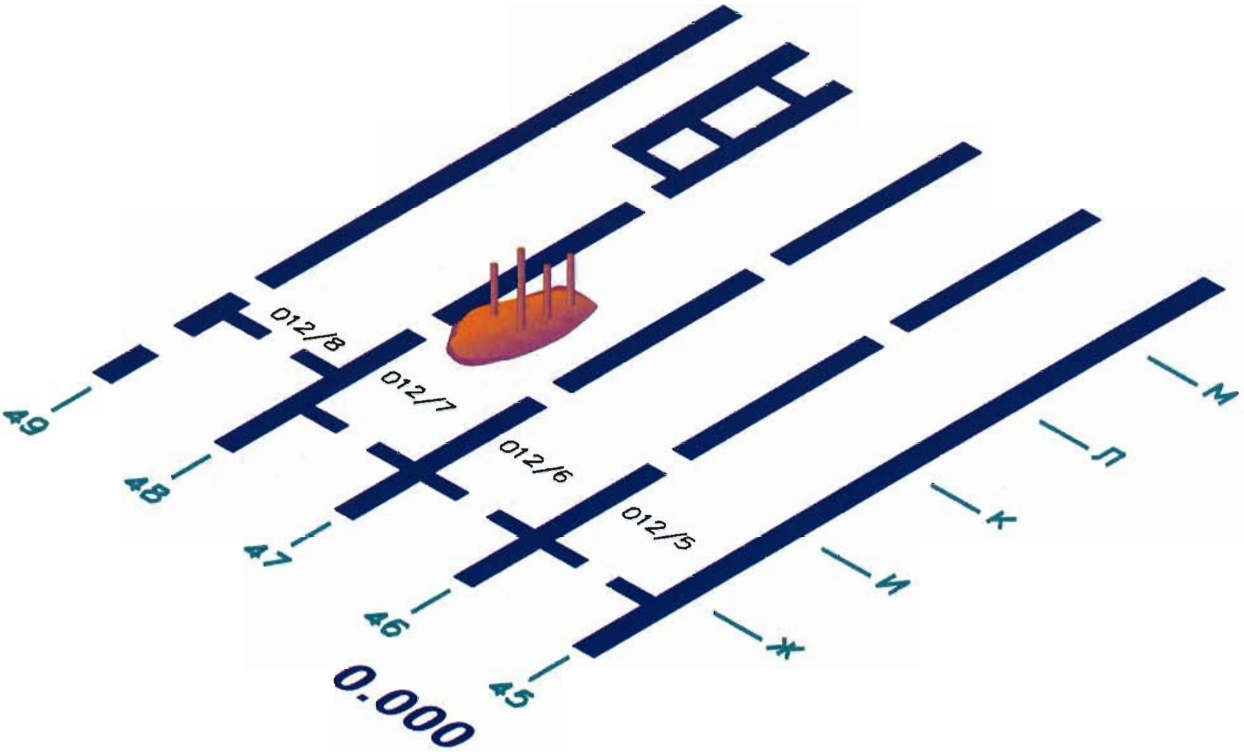


Fig. 5.15. LFCM "pile" on the first floor of pressure-suppression pool, Room #012/7

LFCM thickness in the remaining locations is not large, the ends of steam-dumping pipes of PSP emerging from solidified melt.

The process of generation of black lavas took place within the southeastern section of Room #305/2. According to the results of spectrometric and element analyses, black ceramics of Room #210/6 of SDC and black ceramics of the large horizontal flow are formed by material of the same genesis.

Information on LFCM located in rooms wherein solidification of LVF and MVF took place is summarized in Table 5.11.

Table 5.11. – Data on LFCM forming the "large vertical flow" and the "minor vertical flow" (level marks: +6.000, +3.000 и 0.000) [1]

Room number, level mark	Brief characteristic of FCM accumulation	LFCM volume, m^3	Fuel mass (U), t	Comments
210/7 (6.00). SDC	Solidified lava (mostly brown ceramics) and solidified metal from the 4th steam-dumping valve.	13 ÷ 25	3.5 ÷9.0	LFCM volume in the valve is taken into account
210/6 (6.00). SDC	Solidified lava (mostly black ceramics) and solidified metal from the 3rd and the 4th steam-dumping valves.	17 ÷ 30	2.2 ÷ 6.0	LFCM volume in the valves is taken into account
210/5 (6.00). SDC	Solidified metal on the room's floor	-	-	No fuel has been discovered in the room
Total in SDC (expert evaluation) - (8 ± 5)				
012/15 (3.00) PSP -2	"Pile" on the second floor of PSP	23 ± 6	5,2 ± 2	Fuel in steam-dumping pipes is taken into account
012/14 (3.00) PSP -2	Lava within four pipes located in the area of row Л Lava under concrete layer along the axis 46_{+1000} between the rows К-М	Up to ~ 1,4 (?) Up to ~ 20 (?)	(?) (?)	
Total in PSP-2 (expert evaluation) - (8 ± 3)				
012/7 (0.00) PSP-1	"Pile" on the first floor of PSP	2,5±0,5	0.4 ÷ 1.3	Fuel in steam-dumping pipes is taken into account
012/6 (0.00) PSP-1	Lava within four pipes located	Up to ~ 1 (?)	(?)	
Total in PSP-1 (expert evaluation) – (0.9 ± 0.4)				

REFERENCES

1. *The "Shelter" Current Safety Analysis and Forecast Estimates for the Situation Development* (2001) A.A. Borovoi (responsible exec.), ISTC "Shelter" Report, arch. n°3836, Chernobyl, P. 337 (in Russian).

2. Pazukhin, E.M. (1994) Lava-like Fuel Containing Masses of the Chernobyl NPP Unit 4: Topography, Physical & Chemical Properties, Generation Scenario, *J. Radiokhimia*, 36(2), 1994, pp. 97-142 (in Russian).

3. Borovoi, A.A., Dovbenko, A.A., Smoliankina, M. V. and Stroganov, A. A. (1991) *Determining Nuclear-Physical Characteristics of Fuel of the Chernobyl NPP Unit 4*, Report of IBRAE RAS, inv. n°52/11-20, Moscow, P. 63 (in Russian).

4. *Project #1: "Safety Status of the "Shelter" of the Chernobyl NPP". Subproject #3: "Nuclear Fuel and Radioactive Waste"* under a special agreement with IPSN and GRS of April 23, 1998. (1998) Progress Report of IHTEM of RRC "Kurchatov Institute" for the second 6-month period, A.A. Borovoi (responsible exec.), P. 77.

5. Project #1: "Safety Status of the "Shelter" of the Chernobyl NPP". Subproject #3: "Nuclear Fuel and Radioactive Waste" *under a special agreement with IPSN and GRS of April 23, 1998. (1998) Progress Report of IHTEM of RRC "Kurchatov Institute" for the third 6-month period, A.A. Borovoi (responsible exec.), Appendices #2 and ##4-9.*

6. Borovoi, A.A., Lagunenko, A.S. and Pazukhin, E.M. (2000) New estimates of nuclear fuel amounts at the bottom level marks of the "Shelter", in: "*Chernobyl Problems*", 6, pp.13-16, Chernobyl (in Russian).

7. Borovoi, A.A., Kliuchnikov, A.A, Krasnov, V.A., et al. (2001) Lava-like Fuel Containing Masses in Pressure Suppression Pool and Steam Distribution Corridor of the Chernobyl NPP Unit 4, in: "*Chernobyl Problems*", 7, pp.181-193, Chernobyl (in Russian).

8. Borovoi, A.A., Pazukhin, E.M., Krasnov, V.A., Lagunenko, A.S. and Kliuchnikov, A.A. (2003) Pressure-suppression pool and steam-distribution corridor of Unit #4 of Chernobyl NPP: new data, *J. Radiokhimia*, **45(2)**, p. 184 (in Russian).

5.2.1. Lava in Room #210/7

Lava-like FCM penetrated into Room #210/7 (Fig. 5.16) from the southwestern section of Room #305/2 via the 4th steam-dumping valve. Via the remaining three valves "fresh" concrete (i.e. concrete laid during construction of the "Shelter") was delivered in 1986.

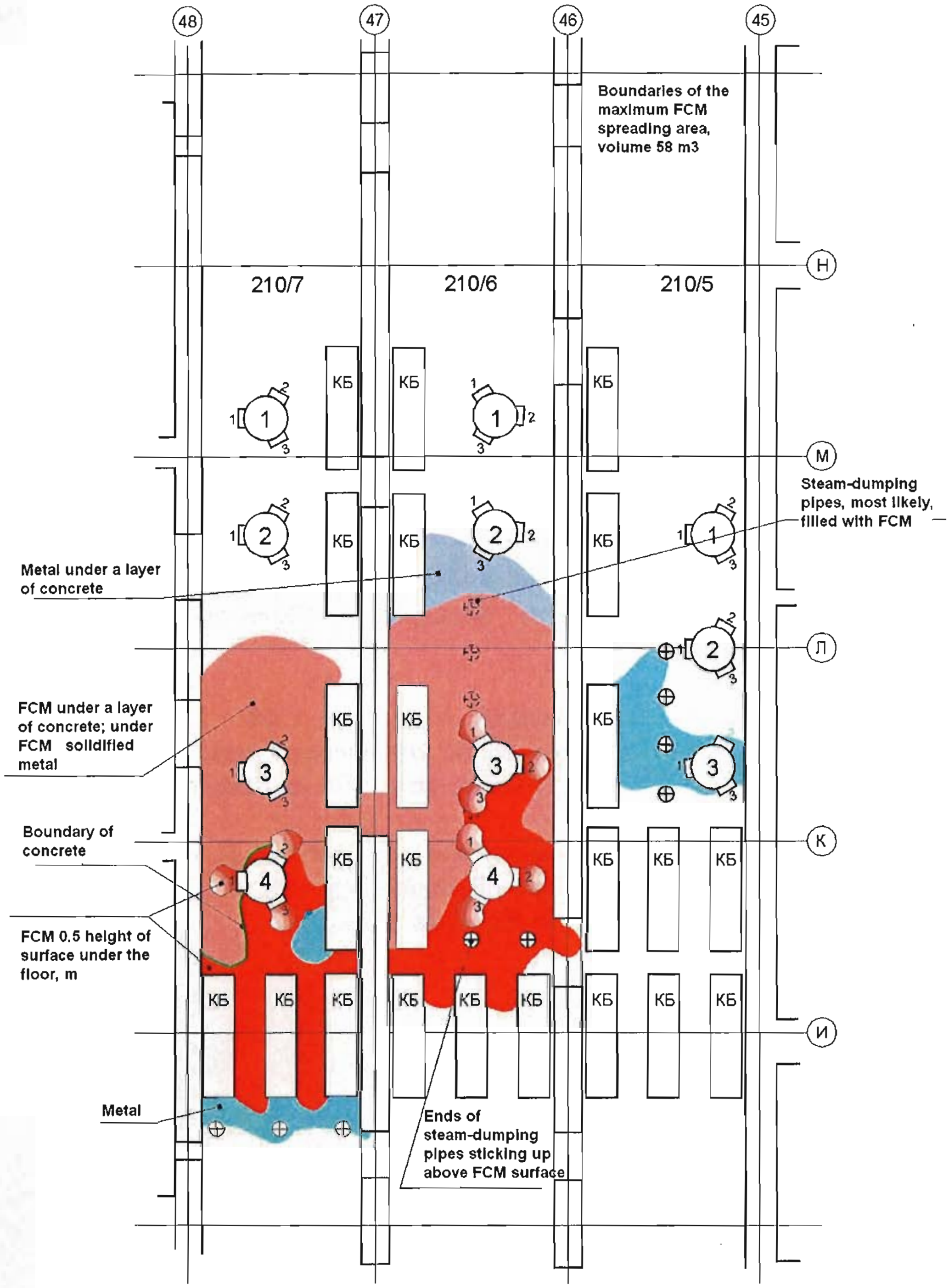


Fig. 5.16. LFCM in steam-distribution corridor

A peculiar solidified "cascade" of brown ceramics with large "drops" and "jets" of metal are observed within one duct of the 4th valve in Room #210/7 (Fig. 5.17).

The second duct contains a solidified "jet" of coal-black ceramics. The third duct comprises a chocolate-brown solidified mass.

Close to the solidified "jet" of FCM and just opposite the third duct right against the condenser battery (row $К_{+3000}$) solidified metal emerges from FCM layer, its height from the room's floor equaling 0,5 m.

Fig.5.17. Solidified "jets" of LFCM flowing out of the 4th steam-distributing valve to Room #210/7

Openly lying FCM are located between the rows $И_{-2500}$ - К. The thickness of FCM layer from the row К up to the row $И_{+1900}$ (ends of condenser batteries) reaches 0,5 m and decreases smoothly within the area limited by walls of condenser batteries approximately down to the floor level ($И_{-2500}$).

From the row $И_{+2000}$ to the row К close to the western wall and next from the row К in the northward direction FCM are covered with a layer of "fresh" concrete.

On the south up to the row $И_{-3000}$ a layer of "poured" metal ~5 cm thick emerges from under FCM.

In 1988 - 1989 six research holes were drilled to Room #210/7. Analysis of the results of drilling shows (hole 3-9-У, row $К_{+500}$, level mark +6.000) that the metal layer on the room's floor has a thick of 5 cm at a minimum, EDR exceeding 100 R/h. Though no FCM were discovered in core samples, high EDR values from the drilled concrete (up to 40 R/h) indicate indirectly the presence of FCM in the hole-track area. The results of studying core samples of other holes drilled north of 3-9-У, i.e. north of the row $Л_{-2600}$ (hole 3-9-Г) have revealed no FCM. This means that the northern boundary of FCM spreading in Room #210/6 (based on the results of drilling only) is located between the rows $К_{+500}$ and $Л_{-2600}$.

All holes drilled in Room #210/7 reach the level of the room's floor in the immediate vicinity of the eastern wall of the room, i.e. at the location of condenser batteries. The presence of considerable amount of LFCM under the batteries is hardly possible due to the following reasons: firstly, metal must have already penetrated into that area and, secondly, while contacting cold walls of condensers, viscous "lava" solidified rapidly.

Taking into account the above said as well as the fact of FCM spreading southward for a distance of 7,5 m from the axis of the 4th steam-dumping valve, one may suggest that the northern boundary of FCM spreading is located in the area of the row $Л_{+500}$.

Characteristics of samples taken in Room 210/7 and the results of their analyses are demonstrated in Appendix (210/7 – 1).

Below only general properties of LFCM are addressed.
23 samples of brown ceramics were studied. U concentration in the samples equals (10,9 ± 1) %[7]. The depletion in ^{137}Cs (% of Cs remained in "lava" as compared to the initial one) is (36 ± 12) %. The burnup calculated for (A^{134}Cs/A^{137}Cs) equals (12,4 ± 0,6) MW×day/kg U, that calculated for A^{238}Pu/$A^{238+239+240}$Pu is (12,5 ± 1,4) MW×day/kg U.

Integration of two burnup samplings calculated for cesium and plutonium produces the average burnup of (12,4 ± 1,1) MW×day/kg U.

Table 5.12. Room 210/7. Averaged Element Composition of LFCM Samples. Data on 18 Samples.

Mass fraction, %													
Si	Ca	Ti	Zr	Na	Ba	Al	Mn	Fe	Mg	Cr	Ni	B	Gd
30	4,8	$14,5\times10^{-2}$	4,9	4,0	$1,7\times10^{-1}$	3,6	$4,1\times10^{-1}$	$8,9\times10^{-1}$	4,2	$2,7\times10^{-1}$	$2,8\times10^{-1}$	$6,5\times10^{-2}$	$2,5\times10^{-2}$
Standard deviation													
4,5	1,1	$4,5\times10^{-2}$	1,2	0,4	$3,0\times10^{-2}$	0,8	$1,7\times10^{-1}$	2×10^{-1}	1,0	9×10^{-2}	$1,9\times10^{-1}$	$1,7\times10^{-2}$	4×10^{-3}

REFERENCES

1. *The "Shelter" Current Safety Analysis and Forecast Estimates for the Situation Development* (2001) A.A. Borovoi (responsible exec.), ISTC "Shelter" Report, arch. n°3836, Chernobyl, P. 337 (in Russian).

2. Borovoi, A.A., Dovbenko, A.A., Smoliankina, M. V. and Stroganov, A. A. (1991) *Determining Nuclear-Physical Characteristics of Fuel of the Chernobyl NPP Unit 4*, Report of IBRAE RAS, inv. n°52/11-20, Moscow, P. 63 (in Russian).

3. *Project #1: "Safety Status of the "Shelter" of the Chernobyl NPP". Subproject #3: "Nuclear Fuel and Radioactive Waste"* under a special agreement with IPSN and GRS of April 23, 1998. (1998) Progress Report of IHTEM of RRC "Kurchatov Institute" for the second 6-month period, A.A. Borovoi (responsible exec.), P. 77.

4. Borovoi, A.A., Lagunenko, A.S. and Pazukhin, E.M. (2000) New estimates of nuclear fuel amounts at the bottom level marks of the "Shelter", in: "*Chernobyl Problems*", 6, pp.13-16, Chernobyl (in Russian).

5. Borovoi, A.A., Kliuchnikov, A.A, Krasnov, V.A., *et al.* (2001) Lava-like Fuel Containing Masses in Pressure Suppression Pool and Steam Distribution Corridor of the Chernobyl NPP Unit 4, in: "*Chernobyl Problems*", 7, pp.181-193, Chernobyl (in Russian).

6. Borovoi, A.A., Pazukhin, E.M., Krasnov, V.A., Lagunenko, A.S. and Kliuchnikov, A.A. (2003) Pressure-suppression pool and steam-distribution corridor of Unit #4 of Chernobyl NPP. New data, *J. Radiokhimia*, **45(2)**, p. 184 (in Russian).

[7] In brackets are indicated: (average value ± standard deviation).

5.2.1.1. Appendix (210/7 – 1). Characteristic of Samples Taken in Room #210/7

Radionuclide Composition

Table A.1. General Characteristics of Samples (Room #210/7)

##	Sample code (sample number in the reference source)	FCM, description			Date of analysis	Reference source
		Room	Coordinates, sampling area	Sample description		
1	S00250 (19)	210/7	47/48, И+2	Brown ceramics. Ellipsoidal fragment, direction – along the depth of the major axis, section at 0 cm depth	1.03.89.	*Studying Interactions of Fuel with Constructional Materials in the "Shelter"* (1991) Report under Contract #39-901/63-16-2-1 of 10.02.1991, Complex Expedition under I.V. Kurchatov Institute of Atomic Energy, approved by A.A. Borovoi and E.B. Anderson, Inventory Number 11.07/285 of 13.12.1991, Chernobyl – Saint-Petersburg, P. 88 (in Russian) (53 samples)
2	S00260 (20)	210/7	47/48, И+2	Section at 1 cm depth	1.03.89.	
3	S00270 (21)	210/7	47/48, И+2	idem – 2 cm	1.03.89.	
4	S00280 (22)	210/7	47/48, И+2	idem – 3 cm	1.03.89.	
5	S00290 (23)	210/7	47/48, И+2	idem – 4 cm	1.03.89.	
6	S00300 (24)	210/7	47/48, И+2	idem – 5 cm	1.03.89.	
7	S00310 (25)	210/7	47/48, И+2	idem – 6 cm	1.03.89.	
8	S00320 (26)	210/7	47/48, И+2	idem – 7 cm	1.03.89.	
9	S00400 (34)	210/7	47/48, И/К	Brown ceramics	1.03.89.	
10	S00410 (35)	210/7	47/48, К-2	Brown ceramics	1.03.89.	
11	S00420 (36)	210/7	47/48, К-3	Brown ceramics	1.03.89.	
12	S00510 (45)	210/7	47/48, И/Ж	Chocolate-brown ceramics	1.03.89.	
13	S00520 (46)	210/7	47/48, Ж	Chocolate-brown ceramics	1.03.89.	
14	S00530 (47)	210/7	47/48, К-1	Chocolate-brown ceramics	1.03.89.	
15	S01140 (614-5)	210/7	47/48, И	Ceramics	15.03.89.	Borovoi, A.A. and Kheruvimov, A.N. (1990) *Studying Radionuclide Composition and Physico-chemical Condition of Samples of Fuel-containing Masses Taken in Rooms of the "Shelter"*, R&D Report of Complex Expedition under I.V. Kurchatov Institute of Atomic Energy, Inventory Number 11.07/12 of 16.03.1990, Chernobyl, P.20 (in Russian) (46 samples)
16	S01150 (614)	210/7	47/48, И	Dense deep-brown ceramics with metal inclusions	15.11.89.	
17	S01160 (615)	210/7	47/48, И	Molten metal, plates	15.07.89.	
18	S01170 (615-8)	210/7	47/48, И	Metal	15.07.89.	
19	S01190 (621П)	210/7	47/48, К	Ceramics from SDC near the valve	15.12.89.	
22	S01460 (614-7)	210/7	47/48, И/Ж	Ceramics	15.03.89.	
21	S01660 (82)	210/7	47/48	Red lava from the floor	26.05.91.	Alkhimov, N.B., Bogachev, S.I., Evstratenko, A.S., Kalistratov, V.A., Kiselev, A.N., Kochergin, S.M., Kulazhko, V.G., Obukhova, L.A., Kheruvimov, A.N. and Checherov, K.P. (1991) *Studying Radionuclide Composition of FCM Samples Taken in Under-reactor Rooms of Unit #4 of Chernobyl NPP*, Report of Complex Expedition under I.V. Kurchatov Institute of Atomic Energy, Inventory Number 11.06/155 of 11.06.1991 (in Russian) (13 samples)
22	S01700 (82-2)	210/7	47/48	Fused piece of metal of a light color "baked" in sample #82	26.05.91.	
23	S01880 (56)	210/7	48-1.5, К-1 4th valve, 1st duct	Brown ceramics	6.04.91.	Alkhimov, N.B., Baev, S.A., Evstratenko, A.S., Kiselev, A.N., Obukhova, L.A., Slonov, N.D., Kheruvimov, A.N., Checherov, K.P., Chkolnik, K.D. and Shubko, V.M. (1991) *Studying Radionuclide Composition of FCM in Rooms of Steam-Distribution Corridor of the "Shelter"*, Report of Complex Expedition under I.V. Kurchatov Institute of Atomic Energy,
24	S01890 (57)	210/7	48-2.5, К 4th valve, 2nd duct	Ceramics of sunburn color	6.04.91.	

##	Sample code (sample number in the reference source)	FCM, description			Date of analysis	Reference source
		Room	Coordinates, sampling area	Sample description		
25	S01900 (58)	210/7	48-2.5, К-2 4th valve, 3rd duct	Deep-brown ceramics	6.04.91.	Inventory Number 11.07/138 of 24.04.91, Chernobyl, P. 15 (in Russian) (8 samples)
26	S03360 (1)	210/7	48+2, Ж+3.5	Glassy mass of a deep-brown color	23.01.89.	Bogatov, S.A., Demchuk, V.V., Mazur, L.I.and Checherov, K.P. (1989) Report on Spectrometric Measurements of Samples Taken in Room #210 of Unit #4 of Chernobyl NPP, Inventory Number 1.01-02/06 of 15.02.89 (in Russian) (2 samples)

Table A.2. Radionuclide Composition of Samples of Brown Ceramics Taken in Steam-Distribution Corridor (fission and activation products)

##	Sample code (sample number in the reference source)	Activity of nuclides, MBq/g (ceramics), recalculation as of 26.04.86							
		^{144}Ce	^{137}Cs	^{134}Cs	^{106}Ru	^{125}Sb	^{154}Eu	^{155}Eu	^{90}Sr
1	S00250 (19)	$2,58 *10^3$	6,57 *10	3,96 *10	1,85 *10	5,36	3,28	5,45	9,39 *10
2	S00260 (20)	$2,71 *10^3$	6,05 *10	3,44 *10	3,62 *10	7,40	4,06	4,46	$1,20 *10^2$
3	S00270 (21)	$2,50 *10^3$	7,56 *10	4,33 *10	2,07 *10	6,20	3,48	3,99	9,95 *10
4	S00280 (22)	$2,74 *10^3$	7,76 *10	4,48 *10	5,90 *10	10,30	3,69	5,12	$1,37 *10^2$
5	S00290 (23)	$2,58 *10^3$	6,00 *10	3,61 *10	2,98 *10	8,02	3,37	4,68	$1,16 *10^2$
6	S00300 (24)	$2,71 *10^3$	8,27 *10	4,71 *10	1,27 *10	5,51	3,84	4,34	$1,01 *10^2$
7	S00310 (25)	$2,68 *10^3$	5,54 *10	3,13 *10	1,39 *10	7,06	3,24	4,31	9,47 *10
8	S00320 (26)	$2,59 *10^3$	5,06 *10	2,71 *10	1,07 *10	7,97	3,66	4,56	$1,02 *10^2$
9	S00400 (34)	$2,51 *10^3$	4,96 *10	2,76 *10	2,47 *10	8,69	3,29	3,69	$1,22 *10^2$
10	S00410 (35)	$2,54 *10^3$	4,71 *10	2,64 *10	3,77 *10	6,30	3,68	3,92	$1,28 *10^2$
11	S00420 (36)	$2,72 *10^3$	4,95 *10	2,74 *10	1,24 *10	6,98	3,94	4,56	$1,13 *10^2$
12	S00510 (45)	$2,80 *10^3$	5,40 *10	3,30 *10	2,20 *10	___	4,10	4,26	6,06 *10
13	S00520 (46)	$2,75 *10^3$	5,20 *10	2,80 *10	2,60 *10	___	3,40	4,30	$1,07 *10^2$
14	S00530 (47)	$2,76 *10^3$	5,50 *10	3,20 *10	4,60 *10	___	4,10	3,39	9,75 *10
15	S01660 (82)	$2,10 *10^3$	5,03 *10	2,72 *10	2,44 *10	___	___	___	___
16	S01670 (86)	$2,70 *10^3$	5,76 *10	3,26 *10	1,48 *10	___	___	___	___
17	S01880 (56)	$2,95 *10^3$	3,04 *10	1,72 *10		$2,41 *10^{-1}$	___	1,15 *10	8,46 *10
18	S01890 (57)	$2,49 *10^3$	2,02 *10	1,12 *10	3,02 *10	$5,80 *10^{-1}$	___	1,14 *10	9,13 *10
19	S01900 (58)	$2,34 *10^3$	2,24 *10	1,25 *10	9,90 *10	$9,99 *10^{-1}$	___	9,57	8,34 *10
20	S01930 (117/2)	$2,30 *10^3$	1,31 *10	6,76 *10	4,14 *10	$4,76 *10^{-1}$	___	8,51	6,65 *10
21	S03020 (1)	$1,94 *10^3$	3,34 *10	1,94 *10	5,89 *10	$2,66 *10^{-1}$	___	4,49	___
22	S03040 (3)	$2,43 *10^3$	4,66 *10	2,51 *10	9,58	$3,38 *10^{-1}$	___	9,11	___
23	S03050 (4)	$2,10 *10^3$	2,32 *10	1,20 *10	6,98	$2,46 *10^{-1}$	___	1,12 *10	___

Table A.3. Radionuclide Composition of Samples of Brown Ceramics Taken in Steam-Distribution Corridor (transuranic elements)

##	Sample code (sample number in the reference source)	Activity of nuclides, MBq/g (ceramics), recalculation as of 26.04.86					U,%
		^{238}Pu	$^{239}Pu + ^{240}Pu$	^{242}Cm	^{244}Cm	^{241}Am	
1	2	11	12	13	14	15	16
1	S00250 (19)	$7,45 *10^{-1}$	1,82	3,31 *10	$2,00 *10^{-1}$	$3,10 *10^{-1}$	9,79
2	S00260 (20)	1,01	2,68	3,19 *10	$1,85 *10^{-1}$	$2,45 *10^{-1}$	10,41
3	S00270 (21)	$9,94 *10^{-1}$	2,13	1,49 *10	$1,96 *10^{-1}$	$2,59 *10^{-1}$	9,58
4	S00280 (22)	$8,00 *10^{-1}$	1,80	2,55 *10	$2,09 *10^{-1}$	$2,75 *10^{-1}$	10,49
5	S00290 (23)	$9,29 *10^{-1}$	2,23	3,32 *10	$2,60 *10^{-1}$	$2,60 *10^{-1}$	9,79
6	S00300 (24)	$8,88 *10^{-1}$	2,28	3,25 *10	$2,56 *10^{-1}$	$3,00 *10^{-1}$	10,40
7	S00310 (25)	$9,18 *10^{-1}$	2,44	3,22 *10	$2,70 *10^{-1}$	$2,76 *10^{-1}$	10,31
8	S00320 (26)	$7,78 *10^{-1}$	3,08	1,42 *10	$2,62 *10^{-1}$	$3,50 *10^{-1}$	10,10
9	S00400 (34)	$9,85 *10^{-1}$	2,97	2,54 *10	$2,45 *10^{-1}$	$3,06 *10^{-1}$	9,69
10	S00410 (35)	$6,32 *10^{-1}$	1,68	3,04 *10	$3,23 *10^{-1}$	$2,35 *10^{-1}$	9,79
11	S00420 (36)	$7,73 *10^{-1}$	2,37	2,37 *10	$2,18 *10^{-1}$	$2,74 *10^{-1}$	10,51
12	S00510 (45)	1,10	2,00	4,10 *10	$2,40 *10^{-1}$	$2,32 *10^{-1}$	10,59
13	S00520 (46)	1,10	2,00	4,00 *10	$2,40 *10^{-1}$	$2,11 *10^{-1}$	10,71
14	S00530 (47)	1,10	2,00	5,00 *10	$2,70 *10^{-1}$	$1,66 *10^{-1}$	10,54
15	S01660 (82)	$9,51 *10^{-1}$	1,73	3,89 *10	$1,57 *10^{-1}$	$1,42 *10^{-1}$	8,15
16	S01670 (86)	$8,60 *10^{-1}$	1,46	4,51 *10	$1,98 *10^{-1}$	$3,63 *10^{-1}$	10,38
17	S01880 (56)	$8,53 *10^{-1}$	1,54	$3,43 *10^{2}$	$1,94 *10^{-2}$	$4,39 *10^{-1}$	10,96
18	S01890 (57)	$9,67 *10^{-1}$	1,68	$3,99 *10^{2}$	$2,16 *10^{-2}$	$5,41 *10^{-1}$	9,65
19	S01900 (58)	$9,22 *10^{-1}$	1,68	$3,54 *10^{2}$	$2,05 *10^{-2}$	$5,16 *10^{-1}$	9,04
20	S01930 (117/2)	$7,83 *10^{-1}$	1,41	$2,99 *10^{2}$	$1,77 *10^{-2}$	$3,29 *10^{-1}$	9,05
21	S03020 (1)	$6,00 *10^{-1}$	1,01	1,98 *10	$1,25 *10^{-1}$	$1,69 *10^{-1}$	7,43
22	S03040 (3)	$7,64 *10^{-1}$	1,46	2,86 *10	$1,92 *10^{-1}$	$2,07 *10^{-1}$	9,46
23	S03050 (4)	$6,80 *10^{-1}$	1,24	2,09 *10	$1,21 *10^{-1}$	$2,86 *10^{-1}$	8,26

Table A.4. Element Composition of Samples of Brown Ceramics Taken in Steam-Distribution Corridor

##	Sample number in the reference source)	Room	Coordinates, sampling area	Sample description	Mass fraction, %																	
					Si	Ca	Ti* 10^2	Zr	Cu* 10^3	Na	Ba* 10	U	Al	Mn* 10	Mo* 10^3	Fe	Mg	Pb* 10^3	Cr* 10	Ni* 10	B* 10^2	Gd* 10^2
1	22	210/7	47/48, И/Ж	Brown ceramics	23	6,2		4,2	1,9	4,0		8,6	4,4	3,2	—	1,0	4,6	23	2,2	1,7	7,0	—
2	23	210/7	47/48, И-2	Brown ceramics	30	5,4	11	6,4	2,1	4,5	1,2	8,6	3,0	2,6	—	0,85	5,1	12	1,5	1,4	9,2	—
3	24	210/7	47/48, И/Ж	Brown ceramics	35	5,5	11	5,3	2,0	4,5	1,8	8,1	2,7	3,5	—	1,1	4,9	24	2,0	1,9	6,9	—
4	25	210/7	47/48, К-1	Brown ceramics	24	5,6		4,6	1,8	3,8		8,2	4,8	9,2	—	1,1	4,3	24	2,4	1,6	10	—
5	26	210/7	47/48, И/К	Brown ceramics	33	3,8	15	5,6	11	4,0	2,0	8,3	4,0	7,3	—	0,9	3,1	32	2,0	1,3	7,0	—
6	27	210/7	47/48, К-3	Brown ceramics	29	4,3	8,0	5,1	18	3,2	1,8	8,5	3,1	5,0	—	0,6	5,0	28	1,5	0,9	4,3	—
7	28	210/7	47/48	Brown ceramics	35	4,7	10	3,2	14	4,0	1,6	8,7	3,3	4,2	—	0,66	2,7	14	2,6	3,0	5,0	—
8	621П (1)	210/7	47/48, К-1	Dense brown ceramics	—	2,7	—	3,5	—	—	—	7,7	—	—	—	8,5	—	—	—	—	—	—
9	26	210/7	48-2, К-1 4th valve, 1st duct	Brown ceramics	—	—	18	4,9	2,3	—	—	—	—	2,5	6,1	—	—	6,0	3,1	2,8	40	2,6
10	27	210/7		Brown ceramics	—	—	9,2	4,5	1,8	—	—	—	—	3,7	2,2	—	—	32	2,8	2,8	5,0	2,3
11	28	210/7	48-3, К-2 4th valve, 3rd duct	Brown ceramics	—	—	15	5,4	2,0	—	—	—	—	2,8	2,3	—	—	5,2	3,5	2,8	5,2	2,0
12	29	210/7	48-1.5, И-2.5, floor	Brown ceramics	—	—	15	4,2	3,0	—	—	—	—	4,1	2,0	—	—	180	3,9	3,4	6,3	2,1
13	30	210/7	48-2.5, И-2.0, floor	Brown ceramics	—	—	17	2,4	2,0	—	—	—	—	3,0	0,3	—	—	15	3,5	3,1	7,1	2,6
14	31	210/7	47+2.0, И-2.0, floor	Brown ceramics	—	—	11	≥10	4,3	—	—	—	—	3,4	6,4	—	—	6,6	4,4	9,6	8,8	2,6

##	Sample number in the reference source)	Room	Coordinates, sampling area	Sample description	Mass fraction, %																	
					Si	Ca	Ti* 10^2	Zr	Cu* 10^3	Na	Ba* 10	U	Al	Mn* 10	Mo* 10^3	Fe	Mg	Pb* 10^3	Cr* 10	Ni* 10	B* 10^2	Gd* 10^2
15	32	210/7	48-3, К-2.5 4th valve, 3rd duct	Brown ceramics	—	—	14	5,0	5,8	—	—	—	—	3,6	3,3	—	—	4,8	3,0	2,6	5,5	2,2
16	33	210/7	idem, depth 3 cm	Brown ceramics	—	—	22	6,0	1,5	—	—	—	—	2,8	2,1	—	—	30	1,3	3,0	5,8	—
17	34	210/7	48, И-2, floor	Brown ceramics	—	—	22	7,5	2,3	—	—	—	—	4,3	5,4	—	—	6,6	3,7	3,3	6,3	3,5
18	35	210/7	48-0.5, И-2.0, floor	Brown ceramics	—	—	19	4,8	2,1	—	—	—	—	3,9	2,8	—	—	5,5	3,3	2,9	4,9	2,5
Average value					29,9	4,8	14,5* 10^{-2}	4,9	—	4,0	1,7* 10^{-1}	8,3	3,6	4,1* 10^{-1}	—	8,9 *10^{-1}	4,2	—	2,7 *10^{-1}	2,8 *10^{-1}	6,5* 10^{-2}	2,5* 10^{-2}
Standard deviation					4,9	1,1	4,5* 10^{-2}	1,2	—	0,4	3,0 *10^{-2}	0,3	0,8	1,7 *10^{-1}	—	2 * 10^{-1}	1,0	—	9 * 10^{-2}	1,9 *10^{-1}	1,7* 10^{-2}	4 * 10^{-3}

Reference Sources

##1 - 7 - *Studying Interactions of Fuel with Constructional Materials in the "Shelter"* (1991) Report under Contract #39-901/63-16-2-1 of 10.02.1991, Complex Expedition under I.V. Kurchatov Institute of Atomic Energy, approved by A.A. Borovoi and E.B. Anderson, Inventory Number 11.07/285 of 13.12.1991, Chernobyl – Saint-Petersburg, P. 94 (in Russian) (45 samples).

#8 – Anderson, E.B., Borovoi, A.A. and Pazukhin, E.M. (1989) *Studying Interactions of Fuel with Constructional Materials in the "Shelter"*, Final Report for 1989 under Contract #2-94/189 of 21.11.88, Inventory Number 11.07/16 of 12.12.1989 (Complex Expedition under I.V. Kurchatov Institute of Atomic Energy), Chernobyl-Leningrad, P. 25 (in Russian) (23 samples).

##9 - 18 Borovoi, A.A. and Pazukhin, E.M. (1992) *Studying Fuel-containing Masses in the "Shelter" to Determine Concentrations of Traces of Neutron Absorbers Therein*, Analytical Note under Contract #04-92/62, ISTC "Shelter" of the Ukrainian National Academy, Inventory Number 09/35 of 21.12.1992, Saint-Petersburg - Chernobyl, P.8 (in Russian) (100 samples)

5.2.2. Lava in Room #210/6

Lava-like FCM penetrated into Room #210/6 from the southeastern section of Room #305/2 via the 3rd and the 4th steam-dumping valves (Fig.5.18).

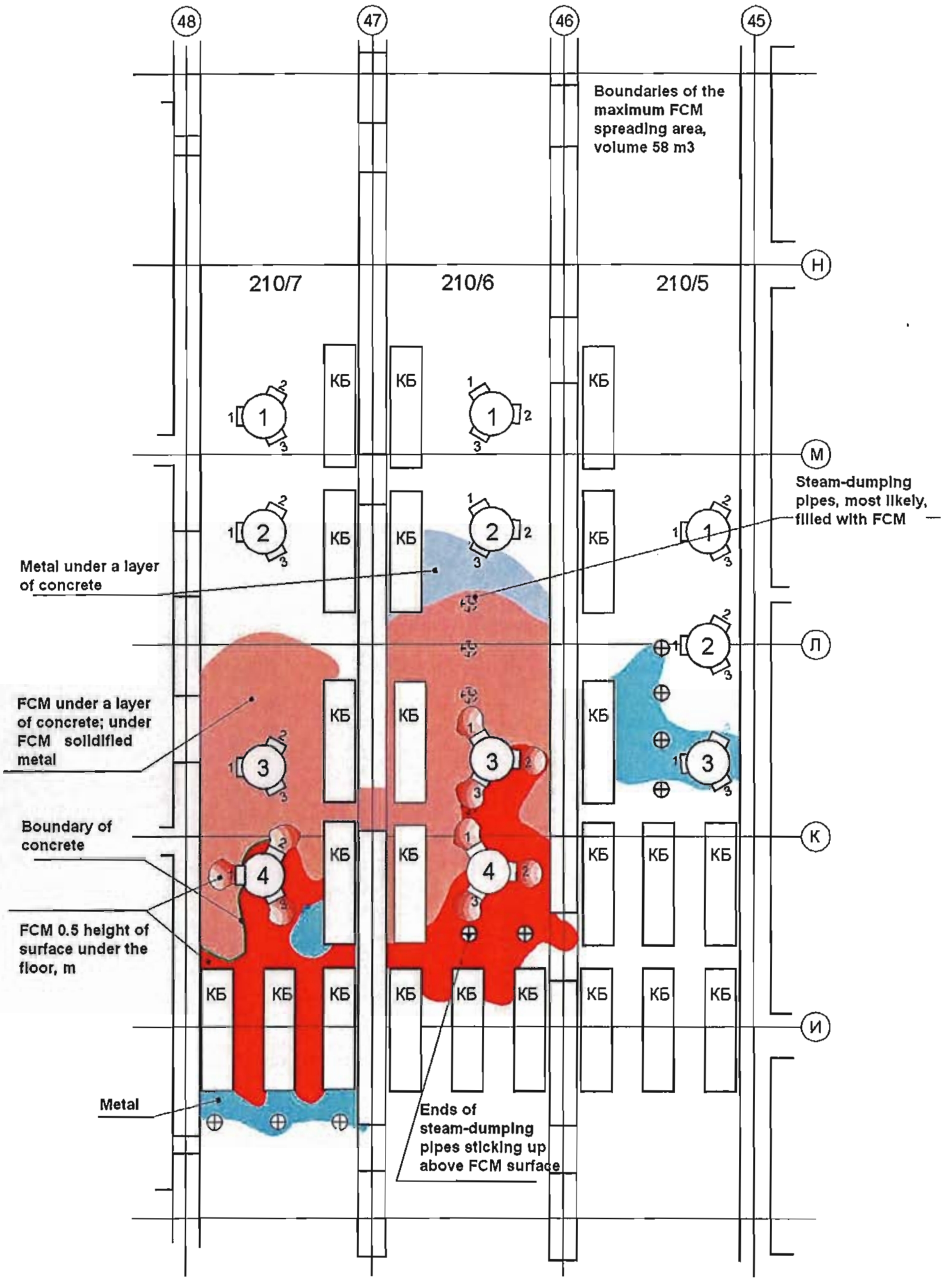


Fig. 5.18. LFCM in steam-distribution corridor

Ducts of steam-dumping valves are filled with **black** LFCM containing a multitude of minor fragments of metal constructions.

New formations – canary-colored spots – are found on the surface of LFCM flowed out of ducts (Fig. 5.19).

Metal liner of the ceiling above the 3rd and the 4th valves is sagged; organic-silicon paint of plating of the wall opposite the 2nd duct is partially burned.

Openly lying FCM are located between the rows И - $К_{+3000}$.

Fig.5.19. Canary-colored spots – new formations on LFCM surface (Room #210/6)

The thickness of FCM layer near the 2nd duct of the 3rd valve reaches 0.6 m, in the 4th valve area - 0.4 - 0.5 m, and in the И row area it equals 0,1 m.

Re-melted and solidified metal is found in the area of the 4th steam-dumping valve (rows И - К); dull ceramics contains major gas holes and has a minor height above the floor.

FCM from the row $И_{+2000}$ up to the row $К_{+2500}$ (the 3rd valve) along condenser batteries located close to the western wall and next northward of the row $К_{+2500}$ are concreted with "fresh" concrete.

According to the investigations in PSP, under the Room #210/6 four steam-dumping pipes arranged along the axis 47_{-3000} and the rows $Л_{+1500}$, Л, $Л_{-1500}$ and $К_{+1500}$ are filled with FCM. The latter suggests that the FCM layer in the row $Л_{+1500}$ area reaches a thick of 0.35 m at a minimum.

Solidified masses of metal are observed visually in Room #210/6 between the rows К-И and are discovered in core samples taken from the oblique hole 3-9-T (row $Л_{+500}$), wherein the metal layer thickness exceeds 0,2 m (EDR up to 200 R/h; no FCM are discovered in the core samples).

Characteristics of samples taken in Room #210/6 and the results of their analyses are demonstrated in "Appendix" (210/6 – 1). Below only general properties of LFCM are addressed.

12 samples of black ceramics were studied.

Uranium concentration in the samples equals (5.8 ± 0.8) %.
The depletion in ^{137}Cs (% of Cs remained in "lava" as compared to the initial one) is (59 ± 14) %.

The burnup calculated using the ratio of activities ($^{134}Cs/^{137}Cs$) makes up (12,1 ± 1,7) MW×day/kg U[8], that calculated using $A^{238}Pu/A^{238+239+240}Pu$ equals (13,5 ± 0,3) MW×day/kg U.

[8] In brackets are indicated: (average value ± standard deviation).

Integration of two burnup samplings calculated for cesium and plutonium produces the average burnup value of (13,0 ± 1,5) MW*day/kg U.

Table 5.13. Room #210/6. Averaged Element Composition of LFCM Samples. Data of 16 Samples.

Mass fraction, %										
Si	Ca	Ti	Zr	Na	Ba	Al	Mn	Mg	Cr	B
28,2	4,5	$11,2\times 10^{-2}$	4,0	3,9	$1,6\times 10^{-1}$	4,0	$3,1\times 10^{-1}$	3,0	$2,6\times 10^{-1}$	$4,5\times 10^{-2}$
Standard deviation										
3,5	1,9	$4,0\times 10^{-2}$	1,2	1,4	$0,6\times 10^{-1}$	0,7	$1,1\times 10^{-1}$	0,4	$1,2\times 10^{-1}$	$1,6\times 10^{-2}$

REFERENCES

1. *The "Shelter" Current Safety Analysis and Forecast Estimates for the Situation Development* (2001) A.A. Borovoi (responsible exec.), ISTC "Shelter" Report, arch. n°3836, Chernobyl, p.337 (in Russian).

2. Borovoi, A.A., Dovbenko, A.A., Smoliankina, M. V. and Stroganov, A. A. (1991) *Determining Nuclear-Physical Characteristics of Fuel of the Chernobyl NPP Unit 4,* Report of IBRAE RAS, inv. n°52/11-20, Moscow, P. 63 (in Russian).

3. *Project #1: "Safety Status of the "Shelter" of the Chernobyl NPP". Subproject #3: "Nuclear Fuel and Radioactive Waste"* under a special agreement with IPSN and GRS of April 23, 1998. (1998) Progress Report of IHTEM of RRC "Kurchatov Institute" for the second 6-month period, A.A. Borovoi (responsible exec.), P. 77.

4. Borovoi, A.A., Lagunenko, A.S. and Pazukhin, E.M. (2000) New estimates of nuclear fuel amounts at the bottom level marks of the "Shelter", in: "*Chernobyl Problems*", 6, pp.13-16, Chernobyl (in Russian).

5. Borovoi, A.A., Kliuchnikov, A.A, Krasnov, V.A., *et al.* (2001) Lava-like Fuel Containing Masses in Pressure Suppression Pool and Steam Distribution Corridor of the Chernobyl NPP Unit 4, in: "*Chernobyl Problems*", 7, pp.181-193, Chernobyl (in Russian).

6. Borovoi, A.A., Pazukhin, E.M., Krasnov, V.A., Lagunenko, A.S. and Kliuchnikov, A.A. (2003) Pressure-suppression pool and steam-distribution corridor of Unit #4 of Chernobyl NPP. New data, *J. Radiokhimia*, 45(2), p. 184 (in Russian).

5.2.2.1. Appendix (210/6 – 1). Characteristic of Samples Taken in Room #210/6

Radionuclide Composition

Table A.1. General Characteristics of Samples (Room #210/6)

##	Sample code (sample number in the reference source)	FCM, description			Date of analysis	Reference source
		Room	Coordinates, sampling area	Sample description		
1	S00500 (44)	210/6	46/47 И/К	Bright black ceramics	1.03.89.	*Studying Interactions of Fuel with Constructional Materials in the "Shelter"* (1991) Report under Contract #39-901/63-16-2-1 of 10.02.1991, Complex Expedition under I.V. Kurchatov Institute of Atomic Energy, approved by A.A. Borovoi and E.B. Anderson, Inventory Number 11.07/285 of 13.12.1991, Chernobyl – Saint-Petersburg, P. 88 (in Russian) (53 samples)
2	S01200 (623П)	210/6	46/47, И	Black ceramics	15.10.89.	Borovoi, A.A. and Kheruvimov, A.N. (1990) *Studying Radionuclide Composition and Physico-chemical Condition of Samples of Fuel-containing Masses Taken in Rooms of the "Shelter"*, R&D Report of Complex Expedition under I.V. Kurchatov Institute of Atomic Energy, Inventory Number 11.07/12 of 16.03.1990, Chernobyl, P.20 (in Russian) (46 samples)
3	S01670 (86)	210/6	46/47	Black lava	26.05.91.	Alkhimov, N.B., Bogachev, S.I., Evstratenko, A.S., Kalistratov, V.A., Kiselev, A.N., Kochergin, S.M., Kulazhko, V.G., Obukhova, L.A., Kheruvimov, A.N. and Checherov, K.P. (1991) *Studying Radionuclide Composition of FCM Samples Taken in Under-reactor Rooms of Unit #4 of Chernobyl NPP*, Report of Complex Expedition under I.V. Kurchatov Institute of Atomic Energy, Inventory Number 11.06/155 of 11.06.1991 (in Russian) (13 samples)
4	S01840 (131)	210/6	46+3, K+1.5 3rd valve, 3rd duct	Canary-colored new formation	15.06.91.	Kurguzov, V.V., Lisin, S.K., Rodionov, Yu.F., Slonov, N.D., Tarasevich, V.P., Shiriaev, V.S., Shubko, V.M. and Jashin, Yu.A. (1991) *Precision Radiochemical and Nuclear-physical Analysis of Radionuclide Composition of Five Samples Taken in Rooms of the « Shelter »*, Report of Complex Expedition under I.V. Kurchatov Institute of Atomic Energy, Inventory Number 11.07/161 of 15.06.1991 (in Russian) (5 samples)
5	S01870 (53)	210/6	Lava "tail"	Black lava of metallic luster	6.04.91.	Alkhimov, N.B., Baev, S.A., Evstratenko, A.S., Kiselev, A.N., Obukhova,

##	Sample code (sample number in the reference source)	FCM, description			Date of analysis	Reference source
		Room	Coordinates, sampling area	Sample description		
6	S01910 (83)	210/6	46+3, Л-2.5 3rd valve, 1st duct	Slaggy, strong sample of black color	6.04.91.	L.A., Slonov, N.D., Kheruvimov, A.N., Checherov, K.P., Shkolnik, K.D. and Shubko, V.M. (1991) *Studying Radionuclide Composition of FCM in Rooms of Steam-Distribution Corridor of the "Shelter"*, Report of Complex Expedition under I.V. Kurchatov Institute of Atomic Energy, Inventory Number 11.07/138 of 24.04.91, Chernobyl, P. 15 (in Russian) (8 samples)
7	S01980 (137)	210/6	46+3, Л-2.5 3rd valve, 1st duct	Black lava	29.09.90.	Alkhimov, N.B., Kiselev, A.N., Kurguzov, V.V., Lisin, S.K., Obukhova, L.A., Rodionov, Yu.F., Kheruvimov, A.N. and Checherov, K.P. (1991) *Studying Radionuclide Composition of Fuel-containing Materials in the "Shelter"*, Report of Complex Expedition under I.V. Kurchatov Institute of Atomic Energy, Inventory Number 11.07/139 of 22.04.1991, Chernobyl, P.19 (in Russian) (19 samples)
8	S01990 (134)	210/6	46+3, K+1.5 3rd valve, 3rd duct	Black lava	29.09.90.	
9	S02300 (30)	210/6	46+1.2, K+2.5 3rd valve, 1st duct, northern left flange	Black lava	5.04.91.	Gusev, V.F., Kalinichenko, B.S., Kalistratov, V.A., Kulazhko, V.G., Kurguzov, V.V., Lisin, S.K., Rodionov, Yu.F., Slonov, N.D., Shiriaev, V.S. and Shubko, V.M. (1991) *Conducting Radiochemical Analyses of Fuel Concentration in Samples of Fuel-containing Masses*, Annotation Report under Contract #1132-ja of 21.02.1991, Milestone #6, I.V. Kurchatov Institute of Atomic Energy, Inventory Number 11.07/274 of 29.11.91 (NIO CE), Moscow, P.7 (in Russian) (10 samples)
10	S02310 (75)	210/6	46+3, K+1.5 3rd valve, 2nd duct, northern right flange	Black lava	5.04.91.	
12	S02320 (93)	210/6	46+1.2, K-0.2 4th valve, 2nd duct	Black lava	5.04.91.	
13	S02970 (54-1)	210/6	46/47	Black lava	15.10.90.	Kiselev, A.N., Krol, A.L., Levina, L.A., Lisitsyn, S.K., Obukhova, L.A., Rodionov, Yu.F., Slonov, S.D., Kheruvimov, A.N., Checherov, K.P., Chubko, V.M. and Jashin, Yu.A. (1990) *Experimental Investigation of Radionuclide Composition of Fuel-containing Masses and Highly-active New Formations in the "Shelter"*, R&D Report of Complex Expedition under I.V. Kurchatov Institute of Atomic Energy, Inventory Number #11.07/66 of 31.10.90, Chernobyl, P. 23 (in Russian) (13 samples)
14	S02980 (55-1)	210/6	46/47	Black-brown lava	15.10.90.	
15	S02990 (55-2)	210/6	46/47	Gray inclusion in black-brown lava	15.10.90.	
16	S03000 (54-2(1))	210/6	46/47	Canary-colored new formation on lava surface, crystals	15.10.90.	
17	S03010 (54-2(2))	210/6	46/47	idem, after removal of black inclusions	15.10.90.	

Table A.2. Radionuclide Composition of Samples of Black Ceramics Taken in SDC (fission and activation products)

##	Sample code (sample number in the reference source)	Activity of nuclides, MBq/g (ceramics), recalculation as of 26.04.86							
		^{144}Ce	^{137}Cs	^{134}Cs	^{106}Ru	^{125}Sb	^{154}Eu	^{155}Eu	^{90}Sr
1	S00500 (44)	$1,22*10^3$	3,90 *10	2,40 *10	5,00 *10	_____	1,90	2,46	5,37 *10
2	S01200 (623П*)	$1,78*10^3$	6,28 *10	3,58 *10	7,18 *10	_____	_____	_____	_____
3	S01460 (614-7)	$1,57*10^3$	5,51 *10	2,16 *10	2,40 *10	1,03	_____	5,72	_____
4	S01650 (25 лаб)	$1,33*10^3$	5,59 *10	3,17 *10	$1,43*10^2$	_____	_____	_____	_____
5	S01870 (53)	$1,54*10^3$	3,63 *10	2,00 *10	6,08 *10	$6,17*10^{-1}$	_____	6,71	6,20 *10
6	S01910 (83)	$1,77*10^3$	5,81 *10	3,38 *10	7,74 *10	$8,91*10^{-1}$	_____	8,53	7,89 *10
7	S01980 (137)	$1,66*10^3$	5,30 *10	3,23 *10	3,58 *10	_____	_____	_____	9,02 *10
8	S02320 (93)	$1,39*10^3$	2,02 *10	1,12 *10	3,29 *10	_____	_____	_____	9,27 *10
9	S02970 (54-1)	$1,58*10^3$	5,88 *10	3,45 *10	4,12 *10	$8,75*10^{-1}$	_____	6,82	_____
10	S02980 (55-1)	$1,43*10^3$	5,32 *10	3,15 *10	6,21 *10	$8,00*10^{-1}$	_____	5,76	_____
11	S02990 (55-2)	$1,31*10^3$	4,12 *10	2,46 *10	3,97 *10	$6,49*10^{-1}$	_____	3,89	_____
12	S03030 (2)	$1,27*10^3$	2,50 *10	1,28 *10	1,76 *10	$1,82*10^{-1}$	_____	4,92	_____

Table A.3. Radionuclide Composition of Samples of Black Ceramics Taken in SDC (transuranic elements)

##	Sample code (sample number in the reference source)	Activity of nuclides, MBq/g (ceramics), recalculation as of 26.04.86					U,%
		^{238}Pu	$^{239}Pu + ^{240}Pu$	^{242}Cm	^{244}Cm	^{241}Am	
1	S00500 (44)	$4,80*10^{-1}$	$8,70*10^{-1}$	1,70 *10	$1,40*10^{-1}$	$1,32*10^{-1}$	4,65
2	S01200 (623)	----	----	----	----	----	6,84
3	S01460 (614-7)	-----	----	----	----	----	6,88
4	S01650 (Lab.25)	$6,28*10^{-1}$	1,13	3,51 *10	$1,48*10^{-1}$	$1,45*10^{-1}$	5,12
5	S01870 (53)	$6,24*10^{-1}$	1,06	$2,52*10^2$	$1,38*10^{-2}$	$1,98*10^{-1}$	5,94
6	S01910 (83)	$6,41*10^{-1}$	1,13	$2,43*10^2$	$1,44*10^{-2}$	$1,91*10^{-1}$	6,77
7	S01980 (137)	$6,54*10^{-1}$	1,09	2,75 *10	$1,37*10^{-1}$	$2,53*10^{-1}$	6,29
8	S02320 (93)	$9,65*10^{-1}$	1,67	4,00 *10	$2,20*10^{-2}$	$4,77*10^{-1}$	5,35
9	S02970 (54-1)	$6,26*10^{-1}$	1,09	2,72 *10	$1,57*10^{-1}$	$3,83*10^{-1}$	6,03
10	S02980 (55-1)	$7,34*10^{-1}$	1,21	2,71 *10	$1,57*10^{-1}$	$3,02*10^{-1}$	5,45
11	S02990 (55-2)	$4,76*10^{-1}$	$8,48*10^{-1}$	1,94 *10	$1,15*10^{-1}$	$3,52*10^{-1}$	4,96
12	S03030 (2)	$4,03*10^{-1}$	$7,65*10^{-1}$	1,38 *10	$8,46*10^{-2}*10^{-1}$	$1,04*10^{-1}$	5,00

Table A.4. Element Composition of Samples of Black Ceramics Taken in Steam-Distribution Corridor

##	Sample number in the reference source)	Room	Coordinates, sampling area	Sample description	Mass fraction, %																
					Si	Ca	Ti* 10^2	Zr	Cu* 10^3	Na	Ba* 10	U	Al	Mn * 10	Mo* 10^3	Fe	Mg	Pb* 10^3	Cr* 10	Ni* 10	B* 10^2
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	4	210/6	46/47, И/К	Dull black ceramics	32	3,8	8,0	2,8	6,0	5,0	1,0	6,0	4,0	3,6	—	5,9	3,4	8,0	3,0	2,1	3,7
2	5	210/7	47/48, И/К	Bright black ceramics	25	5,5	12	2,3	5,5	4,3	1,4	4,3	4,8	2,9	—	3,0	2,7	12	1,4	1,8	4,3
3	6	210/6	46+3, К	Black ceramics	30	4,3	10	2,4	4,1	4,6	1,4	5,0	3,3	4,0	—	4,5	3,1	10	2,2	2,0	4,0
4	14	210/6	46/47, П/Н	Light-gray mass	24	7,8	10	6,0	34	1,5		1,1	4,5	6,0	—	0,8	2,5	28	4,5	1,8	7,4
5	40	210/6	46/47	Gray ceramics	30	3,4	12	3,3	2,3	4,3	2,5	8,3	3,4	4,3	—	0,64	3,2	24	1,9	2,2	6,8
6	623П(1)	210/6	46/47, И	Black ceramics	—	2,2	—	1,8	—	—	—	5,1	—	—	—	8,5	—	—	—	—	—
7	36	210/6	46+2, К 4th valve, 1st duct	Black ceramics	—	—	15	4,2	4,3	—	—	—	—	2,8	6,2	—	—	6,0	5,2	4,8	3,5
8	37	210/6	46+1.5,К+2.5 3rd valve, 2nd duct	Black-brown ceramics	—	—	16	3,5	1,6	—	—	—	—	1,8	1,2	—	—	32	2,0	1,4	3,4
9	38	210/6	46+1.5,К+2.0 3rd valve, 2nd duct	Black-brown ceramics	—	—	11	3,5	1,3	—	—	—	—	1,5	1,2	—	—	30	2,1	1,6	2,9
10	39	210/6	46+1.5, К, floor	Black-brown ceramics	—	—	9,4	5,6	2,8	—	—	—	—	3,1	2,6	—	—	120	2,0	5,2	7,2
11	40	210/6	46+1.5,К+0.5 floor	Black-brown ceramics	—	—	9,0	4,1	4,5	—	—	—	—	3,0	1,9	—	—	1,5	2,5	2,1	3,2
12	41	210/6	46+1.5, К 4th valve, 1st duct	Black ceramics	—	—	20	5,1	1,3	—	—	—	—	2,2	1,9	—	—	45	1,9	1,6	2,9
13	42	210/6	46+1.5, К+1, floor	Black-brown ceramics	—	—	15	4,3	2,1	—	—	—	—	2,5	3,5	—	—	180	1,7	1,4	3,3
14	43	210/6	46, К, floor	Black ceramics	—	—	10	5,2	2,5	—	—	—	—	2,8	4,3	—	—	49	2,3	3,2	4,5
15	44	210/6	46+3, И+2, floor	Black-brown ceramics	—	—	6,0	4,1	1,3	—	—	—	—	2,3	2,0	—	—	40	1,8	5,9	5,2
16	45	210/6	46+3, И+3, floor	Black-brown ceramics	—	—	4,8	5,0	7,5	—	—	—	—	3,1	6,7	—	—	7,2	4,8	7,4	5,6
Average value					28,2	4,5	11,2* 10^{-2}	4,0	—	3,9	1,6 * 10^{-1}	5,7	4,0	3,1 * 10^{-1}	—	—	3,0	—	2,6 * 10^{-1}	—	4,5 *10^{-2}
Standard deviation					3,5	1,9	4,0 * 10^{-2}	1,2	—	1,4	0,6 * 10^{-1}	1,6	0,7	1,1 *10^{-1}	—	—	0,4	—	1,2 * 10^{-1}	—	1,6 * 10^{-2}

Reference Sources

##1 - 5 *Studying Interactions of Fuel with Constructional Materials in the "Shelter"* (1991) Report under Contract #39-901/63-16-2-1 of 10.02.1991, Complex Expedition under I.V. Kurchatov Institute of Atomic Energy, approved by A.A. Borovoi and E.B. Anderson, Inventory Number 11.07/285 of 13.12.1991, Chernobyl – Saint-Petersburg, P. 94 (in Russian) (45 samples).

#6 Anderson, E.B., Borovoi, A.A. and Pazukhin, E.M. (1989) *Studying Interactions of Fuel with Constructional Materials in the "Shelter"*, Final Report for 1989 under Contract #2-94/189 of 21.11.88, Inventory Number 11.07/16 of 12.12.1989 (Complex Expedition under I.V. Kurchatov Institute of Atomic Energy), Chernobyl-Leningrad, P. 25 (in Russian) (23 samples).

##7 - 16 Borovoi, A.A. and Pazukhin, E.M. (1992) *Studying Fuel-containing Masses in the "Shelter" to Determine Concentrations of Traces of Neutron Absorbers Therein*, Analytical Note under Contract #04-92/62, ISTC "Shelter" of the Ukrainian National Academy, Inventory Number 09/35 of 21.12.1992, Saint-Petersburg - Chernobyl, P.8 (in Russian) (100 samples)

5.2.3. Lava in PSP-2 [1 – 8]

LFCM lying openly in PSP-2 represent a "pile" located in Room #012/15 (Fig. 5.20, 5.21). Its visible section is found between the axes 47_{+1000} - 48_{-500} and the rows $И_{-3000}$ - К.

From the structural viewpoint the "pile" represents a system of interconnected knolls. Along the edges the "pile" is concreted with "fresh" concrete. On the north side the level of concrete reaches ~0,7 m above the floor. Visible surface of the "pile" is covered with a pumice-like layer ~ 10 cm thick.

LFCM are also contained in five steam-dumping pipes 404 mm in diameter[9] via which, evidently, lava penetrated to the "pile".

In Room #012/14 four steam-dumping pipes located along the axis 47_{-3000} and the rows $Л_{+1500}$, Л, $Л_{-1500}$ and $К_{+1500}$ are also probably filled with LFCM.

In addition, another FCM accumulation is possibly located along the axis 46_{+1000} (the eastern wall of Room #012/14) between the rows К - М under concrete "influxes" attaining 0,9 m above the floor level (as indicated by high Exposure Dose Rates (EDR) measured above concrete).

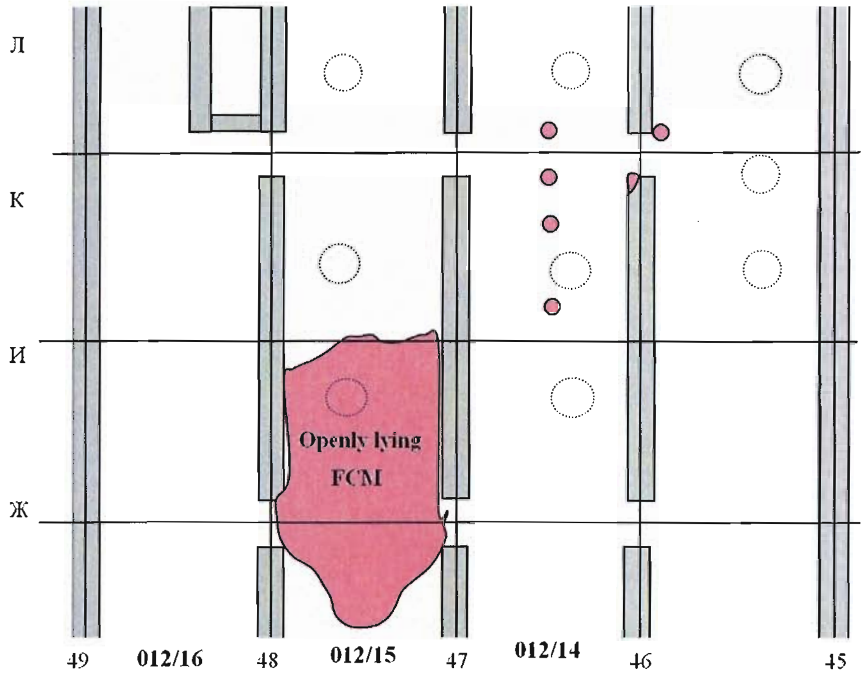


Fig. 5.20. Layout of rooms in the pressure-suppression pool 2 (PSP-2) and locations of LFCM accumulations

[9] Pipe coordinates are: - К, $К_{-1500}$, $К_{-3000}$ (along the axis 48_{-3000}) and $К_{-1500}$, $К_{-3000}$ (along the axis 48_{-1100}).

Fig. 5.21. "Pile" in PSP-2

Characteristics of samples taken in rooms of PSP-2 and the results of their analyses are presented in "Appendix" (ББ-2).
Averaged radionuclide composition of samples taken in PSP-2 is demonstrated in Tables 5.14 and 5.15.

Table 5.14. Averaged radionuclide composition of lava samples taken in PSP-2 (fission and activation products). Data of 15 samples.

Activity of nuclides (fission and activation products), MBq/g (ceramics), recalculation as of 26.04.86								
Nuclide	^{144}Ce	^{137}Cs	^{134}Cs	^{106}Ru	^{125}Sb	^{154}Eu	^{155}Eu	^{90}Sr
Average value	$2,65*10^{3}$	$5,56*10$	$3,13*10$	$3,73*10$	7,52	3,96	4,22	$1,02*10^{2}$
Standard deviation	$4,43*10^{2}$	$1,02*10$	6,21	$2,59*10$	2,18	$3,82*10^{-1}$	$5,65*10^{-1}$	$4,02*10$

Table 5.15. Averaged radionuclide composition of lava samples taken in PSP-2 (transuranic elements)

Activity of nuclides (transuranic elements), MBq/g (ceramics), recalculation as of 26.04.86						U, %	Burnup MW*day/kg (U)
Nuclide	^{238}Pu	^{239}Pu + ^{240}Pu	^{242}Cm	^{244}Cm	^{241}Am		
Average value	$8,45*10^{-1}$	$1,75*10$	$4,61*10$	$2,33*10^{-1}$	$4,56*10^{-1}$	$1,02*10$	12,7
Standard deviation	$1,55*10^{-1}$	$5,62*10^{-1}$	$2,33*10$	$4,59*10^{-2}$	$3,26*10^{-1}$	1,72	1,4

Averaged element composition of samples is demonstrated in Table 5.16.

Table 5.16. PSP-2. Averaged element composition of FCM samples. Data of 23 samples.

Mass fraction, %												
Si	Ca	Zr	Cu	Na	Ba	Mn	Mo	Fe	Mg	Cr	B	Gd
35,5	3,9	4,3	$2,7\times10^{-3}$	1,7	$1,0\times10^{-1}$	$3,0\times10^{-1}$	$4,1\times10^{-3}$	1,4	6,1	$3,2\times10^{-1}$	$7,7\times10^{-2}$	$3,5\times10^{-2}$
Standard deviation												
0,7	1,4	1,8	$1,5\times10^{-3}$	0,1	$1,0\times10^{-2}$	$1,3\times10^{-1}$	$2,1\times10^{-3}$	0,15	1,8	$1,1\times10^{-1}$	$2,0\times10^{-2}$	8×10^{-3}

REFERENCES

1. *The "Shelter" Current Safety Analysis and Forecast Estimates for the Situation Development* (2001) A.A. Borovoi (responsible exec.), ISTC "Shelter" Report, arch. n°3836, Chernobyl, P. 337 (in Russian).

2. Pazukhin, E.M. (1994) Lava-like Fuel Containing Masses of the Chernobyl NPP Unit 4: Topography, Physical & Chemical Properties, Generation Scenario, *J. Radiokhimia*, 36(2), 1994, pp. 97-142 (in Russian).

3. Borovoi, A.A., Dovbenko, A.A., Smoliankina, M. V. and Stroganov, A. A. (1991) *Determining Nuclear-Physical Characteristics of Fuel of the Chernobyl NPP Unit 4*, Report of IBRAE RAS, inv. n°52/11-20, Moscow, P. 63 (in Russian).

4. *Project #1: "Safety Status of the "Shelter" of the Chernobyl NPP". Subproject #3: "Nuclear Fuel and Radioactive Waste"* under a special agreement with IPSN and GRS of April 23, 1998. (1998) Progress Report of IHTEM of RRC "Kurchatov Institute" for the second 6-month period, A.A. Borovoi (responsible exec.), P. 77.

5. Project #1: "Safety Status of the "Shelter" of the Chernobyl NPP". Subproject #3: "Nuclear Fuel and Radioactive Waste" *under a special agreement with IPSN and GRS of April 23, 1998. (1998) Progress Report of IHTEM of RRC "Kurchatov Institute" for the third 6-month period, A.A. Borovoi (responsible exec.), Appendices #2 and ##4-9.*

6. Borovoi, A.A., Lagunenko, A.S. and Pazukhin, E.M. (2000) New estimates of nuclear fuel amounts at the bottom level marks of the "Shelter", in: "*Chernobyl Problems*", 6, pp.13-16, Chernobyl (in Russian).

7. Borovoi, A.A., Kliuchnikov, A.A, Krasnov, V.A., *et al.* (2001) Lava-like Fuel Containing Masses in Pressure Suppression Pool and Steam Distribution Corridor of the Chernobyl NPP Unit 4, in: "*Chernobyl Problems*", 7, pp.181-193, Chernobyl (in Russian).

8. Borovoi, A.A., Pazukhin, E.M., Krasnov, V.A., Lagunenko, A.S. and Kliuchnikov, A.A. (2003) Pressure-suppression pool and steam-distribution corridor of Unit #4 of Chernobyl NPP: new data, *J. Radiokhimia*, **45(2)**, p. 184 (in Russian).

5.2.3.1. Appendix (PSP-2). Characteristic of Samples Taken in Rooms of PSP-2 *Radionuclide Composition*

Table A.1. General Characteristics of Samples (PSP – 2)

##	Sample code (sample number in the reference source)	FCM, description			Date of analysis	Reference source
		Room	Coordinates, sampling area	Sample description		
1	S00370 (31)	012/15	47/48, И/К, "pile"	Brown ceramics. Sampling from a pipe mauled with club hammer, L= 0 cm	1.03.89	*Studying Interactions of Fuel with Constructional Materials in the "Shelter"* (1991) Report under Contract #39-901/63-16-2-1 of 10.02.1991, Complex Expedition under I.V. Kurchatov Institute of Atomic Energy, approved by A.A. Borovoi and E.B. Anderson, Inventory Number 11.07/285 of 13.12.1991, Chernobyl – Saint-Petersburg, P. 88 (in Russian) (53 samples)
2	S00380 (32)	------//------	------//------	idem, L = 2 cm	1.03.89	
3	S00390 (33)	------//------	------//------	idem, L = 5 cm	1.03.89	
4	S00540 (48)	012/15	47/48, К	Dull brown ceramics	1.03.89	
5	S00550 (49)	012/15	47/48, И/К	Dull brown ceramics	1.03.89	
6	S01080 (306Б)	012/15	48, Н	Pumice	26.04.89	Borovoi, A.A. and Kheruvimov, A.N. (1990) *Studying Radionuclide Composition and Physico-chemical Condition of Samples of Fuel-containing Masses Taken in Rooms of the "Shelter"*, R&D Report of Complex Expedition under I.V. Kurchatov Institute of Atomic Energy, Inventory Number 11.07/12 of 16.03.1990, Chernobyl, P.20 (in Russian) (46 samples)
7	S01090 (31)	012/15	47/48, П/Н	Pumice	26.04.89	
8	S01110 (310Б)	012/15	47/48, К/Л	Porous deep-brown material resembling slag	26.04.89	
9	S01120 (310Б(2))	012/15	47/48, К/Л	Porous deep-brown material resembling slag	26.04.89	
10	S01850 (135)	012/15	47/48	Pumice	15.06.91	Kurguzov, V.V., Lisin, S.K., Rodionov (1991) *Precision Radiochemical and Nuclear-physical Analysis of Radionuclide Composition of Five Samples Taken in Rooms of the « Shelter »*, Report of Complex Expedition under I.V. Kurchatov Institute of Atomic Energy, Inventory Number 11.07/161 of 15.06.1991 (in Russian) (5 samples)
11	S01860 (138)	012/15	47/48	Brown lava under pumice	15.06.91	
12	S02210 (2)	012/15	47/48, "pile"	Pinky-gray porous mass	4.09.89	Kheruvimov, A.N.(1989) *Certificate of Studying Radionuclide Composition of Samples Taken in Steam Distribution Corridor*, Inventory Number 1.01.02/16 of 14.05.89 (in Russian) (10 samples)
13	S02340 (40)	012/15	48 - 0.8, И + 0.5	Brown lava	5.04.91	Gusev, V.F., Kalinichenko, B.S., Kalistratov, V.A., Kulazhko, V.G., Kurguzov, V.V., Lisin, S.K., Rodionov, Yu.F., Slonov, N.D., Shiriaev, V.S. and Shubko, V.M. (1991) *Conducting Radiochemical Analyses of Fuel Concentration in Samples of Fuel-containing Masses*, Annotation Report under Contract #1132-ja of 21.02.1991, Milestone #6, I.V. Kurchatov Institute of Atomic Energy, Inventory Number 11.07/274 of 29.11.91 (NIO CE), Moscow, P.7 (in Russian) (10 samples)
14	S02500 (337)	012/15	47/48	Fine-pored brown lava with traces of pumice from 0.2 m depth	1.02.89	Gonin, B.A., Krinitsyn, A.P., Pazukhin, E.M. and Pleskachevskiy, L.A. (1989) Certificate of Sampling in Pressure Suppression Pool of the Steam Distribution Corridor, Inventory Number 1.01-02/02 of 1.02.89 (in Russian) (3 samples)
15	S02510 (338)	012/15	47/48	Fine-pored brown lava with black inclusions partly of spherical shape	1.02.89	

Table A.2. Radionuclide Composition of Samples Taken in PSP-2 (fission and activation products)

##	Sample code (sample number in the reference source)	Activity of nuclides (fission and activation products), MBq/g (ceramics), recalculation as of 26.04.86							
		^{144}Ce	^{137}Cs	^{134}Cs	^{106}Ru	^{125}Sb	^{154}Eu	^{155}Eu	^{90}Sr
1	S00370 (31)	$2,65*10^3$	5,91*10	3,19*10	2,39*10	5,29	3,33	3,48	9,59*10
2	S00380 (32)	$2,73*10^3$	5,33*10	3,14*10	3,09*10	1,05*10	4,18	4,88	$1,12*10^2$
3	S00390 (33)	$2,66*10^3$	5,96*10	3,39*10	1,29*10	6,87	4,30	4,67	$1,05*10^2$
4	S00540 (48)	$2,65*10^3$	4,90*10	2,80*10	---	---	3,90	3,93	8,90*10
5	S00550 (49)	$3,00*10^3$	5,70*10	3,10*10	3,60*10	---	4,10	4,14	8,34*10
6	S01080 (306Б)	---	---	---	---	---	---	---	---
7	S01090 (307Б)	$3,47*10^3$	7,15*10	4,26*10	3,70*10	---	---	---	---
8	S01110 (310Б)	$2,79*10^3$	5,96*10	2,71*10	2,81*10	---	---	---	3,06*10
9	S01120 (310Б(2))	$2,57*10^3$	5,48*10	3,43*10	2,68*10	---	---	---	---
10	S01850 (135)	$2,53*10^3$	4,94*10	2,77*10	$1,08*10^2$	---	---	---	---
11	S01860 (138)	$3,40*10^3$	6,76*10	3,84*10	5,32*10	---	---	---	---
12	S02210 (2)	$2,39*10^3$	5,51*10	3,08*10	1,11*10	7,42	---	---	---
13	S02340 (40)	$1,89*10^3$	6,76*10	3,84*10	5,38*10	---	---	---	---
14	S02500 (337)	$2,33*10^3$	3,90*10	2,20*10	2,56*10	---	---	---	$1,69*10^2$
15	S02510 (338)	$2,02*10^3$	3,53*10	2,00*10	---	---	---	---	$1,35*10^2$
Average value		$2,65*10^3$	5,56*10	3,13*10	3,73*10	7,52	3,96	4,22	$1,02*10^2$
Standard deviation		$4,43*10^2$	1,02*10	6,21	2,59*10	2,18	$3,82*10^{-1}$	$5,65*10^{-1}$	4,02*10

Table A.3. Radionuclide Composition of Samples Taken in PSP-2 (Transuranic Elements)

##	Sample code (sample number in the reference source)	Activity of nuclides (transuranic elements), MBq/g (ceramics), recalculation as of 26.04.86					U, %
		^{238}Pu	$^{239}Pu + ^{240}Pu$	^{242}Cm	^{244}Cm	^{241}Am	
1	S00370 (31)	1,02	1,83	2,82*10	$2,05*10^{-1}$	$3,57*10^{-1}$	10,31
2	S00380 (32)	$7,86*10^{-1}$	3,13	2,77*10	$2,06*10^{-1}$	$3,64*10^{-1}$	10,40
3	S00390 (33)	$9,31*10^{-1}$	2,54	2,58*10	$2,64*10^{-1}$	$3,58*10^{-1}$	10,21
4	S00540 (48)	$9,40*10^{-1}$	1,70	3,00*10	$2,30*10^{-1}$	$1,71*10^{-1}$	10,16
5	S00550 (49)	$9,40*10^{-1}$	1,70	3,30*10	$2,30*10^{-1}$	$2,86*10^{-1}$	11,65
6	S01080 (306Б)	$9,92*10^{-1}$	1,31	---	---	---	---
7	S01090 (307Б)	$4,65*10^{-1}$	1,33	---	---	---	13,22
8	S01110 (310Б)	---	---	---	---	---	11,37
9	S01120 (310Б(2))	---	---	---	---	---	9,67
10	S01850 (135)	$7,21*10^{-1}$	1,38	4,53*10	$1,57*10^{-1}$	$1,45*10^{-1}$	9,73
11	S01860 (138)	$7,98*10^{-1}$	1,37	6,17*10	$2,25*10^{-1}$	$4,82*10^{-1}$	13,04
12	S02210 (2)	---	---	---	---	---	9,21
13	S02340 (40)	$7,90*10^{-1}$	1,37	4,26*10	$2,29*10^{-1}$	$3,56*10^{-1}$	7,26
14	S02500 (337)	$9,70*10^{-1}$	1,90	9,62*10	$3,35*10^{-1}$	1,21	9,00
15	S02510 (338)	7,84*10-1	1,40	7,06*10	$2,48*10^{-1}$	$8,34*10^{-1}$	7,75
	Average value	$8,45*10^{-1}$	1,75*10	4,61*10	$2,33*10^{-1}$	$4,56*10^{-1}$	1,02*10
	Standard deviation	$1,55*10^{-1}$	$5,62*10^{-1}$	2,33*10	$4,59*10^{-2}$	$3,26*10^{-1}$	1,72

Element Composition

Table A.4. Element Composition of Samples Taken in PSP-2

##	Sample # in the reference source)	Room	Coordinates, sampling area	Sample description	Mass fraction, %																
					Si	Ca	Ti $*10^2$	Zr	Cu $*10^3$	Na	Ba *10	Al *10	Mn *10	Mo $*10^3$	Fe	Mg	Pb $*10^3$	Cr *10	Ni $*10^2$	B $*10^2$	Gd $*10^2$
1	2	3	4	5	6	7	8	9	10	11	12	14	15	16	17	18	19	20	21	22	23
1	36	012/15	48, Н	Pumice	36	4,0	22	2,8	2,0	1,6	1,1	34	6,2		1,5	3,9	15	1,8	40	8,4	
2	37	012/15	47/48, П/Н	Pumice	35	5,8	18	3,8	6,6	1,8	0,9	25	3,5		1,5	4,5	12	1,8	40	8,0	
3	306Б	012/15	48, Н	Pumice		2,4						0,94			1,5	5,0		1,4	7,0		
4	307Б	012/15	47/48, П/Н	Pumice											1,2	7,5		1,3	5,2		
5	310Б	012/15	47/48, К/Л	Porous material											1,2	8,3		2,9	4,8		
6	310Б	012/15	47/48, К/Л	idem		3,3						0,75			5,0	7,3		4,3	30		
7	46	012/15	48-1.5, И+1.0, "pile"	Brown ceramics (granules)			23	4,5	130				3,3	8,6			5,8	3,5	3,1	5,4	3,4
8	47	012/15	48-1.5, И+3.0, "pile"	«-»			24	4,2	2,3				3,7	2,6			5,5	4,2	3,8	5,0	4,2
9	48	012/15	47+1.5, И+0.2, "pile"	«-»			10	6,2	2,0				1,8	1,7			10	3,6	11	7,2	3,7
10	49	012/15	47+1.5, И+2.0, "pile"	«-»			15	4,3	1,6				2,0	2,2			6,0	3,3	13	6,4	4,3
11	50	012/15	47+3.0, И-1.0, "pile"	«-»			15	5,4	1,8				1,8	2,5			2,6	3,5	14	8,0	4,7
12	51	012/15	47+3.0, И-1.0, "pile"	Brown ceramics (slag)			7,3	1,4	5,2				3,0	6,4			4,2	2,1	14	6,2	
13	52	012/15	47+3.0, М+2.0, "pile"	Pumice			9,3	2,7	4,8				3,2	6,0			40	2,2	8,9	6,8	
14	53	012/15	47+3.0, И-2.0, "pile"	Brown ceramics (granules)			4,0	6,1	2,9				3,5	5,6			61	4,6	7,2	5,2	3,0
15	54	012/15	48-1.5, И-2.0, "pile"	«-»			20	7,4	4,3				2,2	4,7			3,3	4,3	15	7,2	4,4
16	55	012/15	48-1.5, К, "pile"	«-»			6,8	>10	1,5				4,8	3,4			120	4,7	12	12	2,2
17	56	012/15	48-1.5, К-0.5, "pile"	«-»			11	2,3	1,4				1,0	1,6			5,4	3,1	9,0	6,8	3,8

##	Sample # in the referen ce source)	Room	Coordinates, sampling area	Sample description	Mass fraction, %																
					Si	Ca	Ti $*10^2$	Zr	Cu $*10^3$	Na	Ba $*10$	Al $*10$	Mn $*10$	Mo $*10^3$	Fe	Mg	Pb $*10^3$	Cr $*10$	Ni $*10^2$	B $*10^2$	Gd $*10^2$
18	57	012/15	48-1.5, К-1.0, "pile"	«-»			9,3	4,5	1,5				1,4	1,2			2,3	3,0	9,1	6,2	2,7
19	58	012/15	47+1.2, К, "pile"	«-»			4,8	6,0	11				3,5	4,7			12	3,2	11	10	3,2
20	59	012/15	47+1.2, К-2.0, "pile"	«-»			10	>10	1,8				4,2	4,6			5,4	5,2	15	12	3,6
21	60	012/15	47+1.2, И+1.0, "pile"	«-»			6,0	7,2	1,5				3,9	3,7			6,8	3,1	10	9,0	2,4
22	61	012/15	47+3.0, К-1.5, "pile"	«-»			16	9,5	1,9				1,3				13	2,6	12	9,0	3,3
23	62	012/15	47+3.0, И+3.0, "pile"	«-»			20	5,1	2,7				2,8	6,0			11	3,6	3,3	6,9	4,2
Average value					35,5	3,9		4,3	2,7 $*10^{-3}$	1,7	1,0 $*10^{-1}$		3,0 $*10^{-1}$	4,1 $*10^{-3}$	1,4	6,1		3,2 $*10^{-1}$		7,7 $*10^{-2}$	3,5 $*10^{-2}$
Standard deviation					0,7	1,4		1,8	1,5 $*10^{-3}$	0,1	1,0 $*10^{-2}$		1,3 $*10^{-1}$	2,1 $*10^{-3}$	0,15	1,8		1,1 $*10^{-1}$		2,0 $*10^{-2}$	8 $*10^{-3}$

5.2.4. Lava in PSP-1 (Refs. [1 – 8])

Openly lying FCM represent a "pile" in Room #012/7 (Figs. 5.22 and 5.23).
Taking account of the fact that bottom cuts of steam-dumping pipes are located 1 m above the room's floor, the "pile" top is situated at ~ 0.8 m above the floor.
The "pile" is concreted with "fresh" (1986) concrete up to 0.2 – 0.4 m above the floor, its visible section being located within the area between the axes 48_{-500} - 48_{-2500} and the rows $И_{+400}$ - $И_{+3300}$.
The "pile" is covered partly with a glassy crust and partly with a pumice-like crust; a granular glassy substance of deep-brown color (brown ceramics) – LFCM - is found inside the "pile".
The "pile" volume is estimated at 2.5 ± 0.5 m^3.
The amount of uranium in the "pile" equals $0.4 \div 1$ t.
In March 2000 the "pile" was covered with a layer of radiation-resistant organosilicon material EKOR. That was done for purposes of testing the FCM isolation and conservation method in order to prevent uncontrolled spreading of radionuclides in the future.

Pumice-like FCM in the form of individual fragments are found in many places of PSP-1, some fragments being located on horizontal sections of steam-dumping pipes and metal constructions at a height above 1 m.

FCM are also contained within steam-dumping pipes 280 mm in diameter located in the "pile" area.
Under pessimistic assumptions (LFCM within six steam-dumping pipes; lava has the maximum measured density and maximum fuel content) such pipes might contain ~0.3 t of uranium.
While assuming that LFCM fill two pipes only (at a minimum density and fuel content), the pipes might contain ~0.1 t of uranium.
According to expert evaluations, (0.9 ± 0.3) t of uranium may be located in PSP-1.

A partly fused pipe with a metal drop-shaped "dripstone" is located in Room #012/5 at the intersection of the row Л and the axis 46_{-1000}. Traces of thermal impact are visible on the ceiling close to the fused pipe.

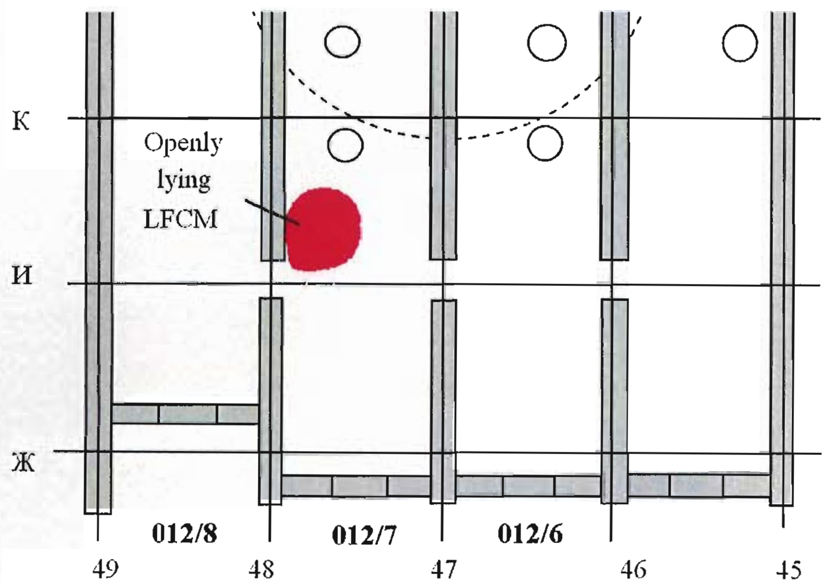


Fig. 5.22. Layout of rooms in the pressure suppression pool 1 (PSP-1) and location of LFCM "pile"

Fig.5.23. LFCM "pile" on the first floor of PSP, Room #012/7

Characteristics of samples taken in rooms of PSP-1 and the results of their analyses are presented in "Appendix" ББ-1(П1).

Averaged radionuclide composition of samples taken in PSP-1 is demonstrated in Tables 5.17 and 5.18.

Table 5.17. Averaged radionuclide composition of lava samples taken in PSP-1 (fission and activation products). Data of 23 samples.

Activity of nuclides (fission and activation products), MBq/g (ceramics), recalculation as of 26.04.86								
Nuclide	^{144}Ce	^{137}Cs	^{134}Cs	^{106}Ru	^{125}Sb	^{154}Eu	^{155}Eu	^{90}Sr
Average value	$2,59*10^3$	5,47*10	3,06*10	2,82*10	3,90	3,84	7,82	$1,08 \cdot 10^2$
Standard deviation	$2,62*10^2$	1,42*10	9,07	1,13*10	3,01	1,09	4,90	$1,15 \cdot 10^1$

Table 5.18. Averaged radionuclide composition of lava samples taken in PSP-1 (transuranic elements)

Activity of nuclides (transuranic elements), MBq/g (ceramics), recalculation as of 26.04.86						U, %	Burnup, MW*day/kg (U)
Nuclide	^{238}Pu	^{239}Pu + ^{240}Pu	^{242}Cm	^{244}Cm	^{241}Am		
Average value	$8,52*10^{-1}$	1,74	3,55*10	$2,24*10^{-1}$	$2,995*10^{-1}$	10,53	12,7
Standard deviation	$1,05*10^{-1}$	$3,93 \cdot 10^{-1}$	1,46	$5,16*10^{-1}$	$2,32*10^{-1}$	1,18	1,4

Averaged element composition of samples is demonstrated in Table 5.19.

Table 5.19. PSP-1. Averaged element composition of FCM samples. Data of 13 samples.

Mass fraction, %											
Si	Ca	Zr	Cu	Na	Ba	Mn	Fe	Mg	Cr	B	Gd
31,2	4,8	4,2	$1,8\times 10^{-3}$	3,5	$1,5\times 10^{-1}$	$4,70\times 10^{-1}$	$8,9\times 10^{-1}$	5,35	$1,8\times 10^{-1}$	$6,1\times 10^{-2}$	$3,4\times 10^{-2}$
Standard deviation											
1,77	2,3	2,4	$1,6\times 10^{-3}$	1,00	$4,53\times 10^{-2}$	$3,1\times 10^{-1}$	$3,7\times 10^{-2}$	1,8	$8,6\times 10^{-2}$	$3,0\times 10^{-2}$	$1,1\times 10^{-2}$

REFERENCES

1. *The "Shelter" Current Safety Analysis and Forecast Estimates for the Situation Development* (2001) A.A. Borovoi (responsible exec.), ISTC "Shelter" Report, arch. n°3836, Chernobyl, P. 337 (in Russian).

2. Pazukhin, E.M. (1994) Lava-like Fuel Containing Masses of the Chernobyl NPP Unit 4: Topography, Physical & Chemical Properties, Generation Scenario, *J. Radiokhimia*, 36(2), 1994, pp. 97-142 (in Russian).

3. Borovoi, A.A., Dovbenko, A.A., Smoliankina, M. V. and Stroganov, A. A. (1991) *Determining Nuclear-Physical Characteristics of Fuel of the Chernobyl NPP Unit 4*, Report of IBRAE RAS, inv. n°52/11-20, Moscow, P. 63 (in Russian).

4. *Project #1: "Safety Status of the "Shelter" of the Chernobyl NPP". Subproject #3: "Nuclear Fuel and Radioactive Waste"* under a special agreement with IPSN and GRS of April 23, 1998. (1998) Progress Report of IHTEM of RRC "Kurchatov Institute" for the second 6-month period, A.A. Borovoi (responsible exec.), P. 77.

5. Project #1: "Safety Status of the "Shelter" of the Chernobyl NPP". Subproject #3: "Nuclear Fuel and Radioactive Waste" *under a special agreement with IPSN and GRS of April 23, 1998. (1998) Progress Report of IHTEM of RRC "Kurchatov Institute" for the third 6-month period, A.A. Borovoi (responsible exec.), Appendices #2 and ##4-9.*

6. Borovoi, A.A., Lagunenko, A.S. and Pazukhin, E.M. (2000) New estimates of nuclear fuel amounts at the bottom level marks of the "Shelter", in: "*Chernobyl Problems*", 6, pp.13-16, Chernobyl (in Russian).

7. Borovoi, A.A., Kliuchnikov, A.A, Krasnov, V.A., *et al.* (2001) Lava-like Fuel Containing Masses in Pressure Suppression Pool and Steam Distribution Corridor of the Chernobyl NPP Unit 4, in: "*Chernobyl Problems*", 7, pp.181-193, Chernobyl (in Russian).

8. Borovoi, A.A., Pazukhin, E.M., Krasnov, V.A., Lagunenko, A.S. and Kliuchnikov, A.A. (2003) Pressure-suppression pool and steam-distribution corridor of Unit #4 of Chernobyl NPP: new data, *J. Radiokhimia*, **45(2)**, p. 184 (in Russian).

5.2.4.1. Appendix (PSP-1). Characteristic of Samples Taken in Rooms of PSP -1

Radionuclide Composition

Table A.1. General Characteristics of Samples (PSP – 1)

##	Sample code	Room	Sampling area, coordinates	Sample description	Date of sampling	Reference source
1	S00330	012/7	Large "pile" 47+3/48 $И/И_{+3000}$[1]	Brown ceramics, sampling from a pipe mauled with club hammer, L=0 cm (maximum depth)	1.03.89	*Studying Interactions of Fuel with Constructional Materials in the "Shelter"* (1991) Report under Contract #39-901/63-16-2-1 of 10.02.1991, Complex Expedition under I.V. Kurchatov Institute of Atomic Energy, approved by A.A. Borovoi and E.B. Anderson, Inventory Number 11.07/285 of 13.12.1991, Chernobyl – Saint-Petersburg, P. 77(in Russian) (53 samples)
2	S00340	--- // ---	--- // ---	idem, L=5 cm	1.03.89	
3	S00350	--- // ---	--- // ---	idem, L=10 cm	1.03.89	
4	S00360	--- // ---	--- // ---	idem , L=15 cm	1.03.89	
5	S00560	012/7	Large "pile" 48,И[2]	Brown ceramics	1.03.89	
6	S00980	012/7	48, Л	Porous heterogeneous material resembling slag	15.04.89	N°26(*) Borovoi, A.A. and Kheruvimov, A.N. (1990) *Studying Radionuclide Composition and Physico-chemical Condition of Samples of Fuel-containing Masses Taken in Rooms of the "Shelter"*, R&D Report of Complex Expedition under I.V. Kurchatov Institute of Atomic Energy, Inventory Number 11.07/12 of 16.03.1990, Chernobyl, P.20, tab. 4 (in Russian) (46 samples)
7	S00990	012/6	46/47, П[3]	Dark porous material resembling glass wool	15.04.89	
8	S01000	012/7	48/47, К	Porous heterogeneous material resembling slag	15.03.89	
9	S01010	--- // ---	--- // ---	--- // ---	15.07.89	
10	S01020	012/8	48/49, М	Pumice	15.04.89	
11	S01030	012/8	49/48, М	Pumice	15.10.89	
12	S01040	012/5	45/46, Ж	Pumice	15.07.89	
13	S01050	012/5	45/46, Ж	Pumice	15.10.89	
14	S01070	012/7	Large "pile" 48,И		15.10.89	
15	S01380	012/5	45/46	Pumice	15.12.89	
16	S01430		"Pile"	Rusty-colored pumice	15.04.89	
17	S01440	012/7	48 , Л	Porous heterogeneous material resembling slag	15.04.89	
18	S02470	012/7		Deep-brown fine-pored lava from 0.25 m depth	15.12.91	Borovoi, A.A. and Kheruvimov, A.N. (1992) *Studying FCM Samples of the "Shelter"*, Report of ISTC "Shelter" of Ukrainian National Academy, Inventory Number 09/18 of 26.09.92, P. 11, Fig. 1, Tab. 4 (in Russian) (13 samples)
19	S02480	012/7		Deep-brown fine-pored lava from 0.25 m depth	15.12.91	
20	S02490	012/7		Deep-brown lava from 0.5 m depth, fine pores from below, large pores from above	15.12.91	
21	S02940	012/5		Porous highly-active FCM on surface of metal constructions	15.10.90	N°30 *Experimental Investigation of Radionuclide Composition of Fuel-containing Masses and Highly-active New Formations in the "Shelter"* (1990) R&D Report of Complex Expedition under I.V. Kurchatov Institute of Atomic Energy, Inventory Number #11.07/66 of 31.10.90, Chernobyl, P. 23 (in Russian) (13 samples)
22	S02950	012/6		--- // ---	15.10.90	
23	S02960	012/8		--- // ---	15.10.90	

(1) Sampling area is located within the axes 47_{+3000} and 48 and the rows И and $И_{+3000}$.
(2) At the intersection of the axis 48 and the row И.
(3) Between the axes 46 and 47, along the row П
(*) - N° in the "Catalogue of Main Sources"

Table A.2. Radionuclide Composition of Samples (Fission and Activation Products)

##	Sample code	Activity of nuclides, MBq/g (ceramics), recalculation as of 26.04.86							
		^{144}Ce	^{137}Cs	^{134}Cs	^{106}Ru	^{125}Sb	^{154}Eu	^{155}Eu	^{90}Sr
1	S000330	$2,65*10^3$	5,83*10	3,27*10	2,55*10	7,59	3,04	4,80	$1,09*10^2$
2	S000340	$2,61*\cdot10^3$	5,13*10	3,07*10	5,80*10	7,15	4,28	4,35	9,46*10
3	S000350	$2,65*10^3$	5,89*10	3,45*10	2,58*10	5,47	3,33	4,13	$1,07*10^2$
4	S000360	$2,48*10^3$	5,53*10	3,06*10	2,56*10	5,89	3,31	4,37	$1,26*10^2$
5	S000560	$2,94*10^3$	4,80*10	2,70*10	1,90*10	-------	4,50	3,86	$1,028*10^2$
6	S000980	-------	7,53*10	3,29*10	15,15	-------	2,85	14,3	-------
7	S000990	-------	6,59*10	2,94*10	15,53	2,23	7,20	12,8	-------
8	S001000	-------	5,24*10	2,97*10	16,79	-------	2,50	-------	-------
9	S001010	-------	5,27*10	2,94*10	3,58*10	-------	4,51	-------	-------
10	S001020	-------	8,02*10	3,72*10	14,60	2,10	3,41	1,66 ·10	-------
11	S001030	-------	6,93*10	5,77*10	43,52	-------	4,59	-------	-------
12	S001040	-------	6,60*10	4,05*10	-------	-------	2,40	13,6	-------
13	S001050	-------	6,88*10	3,53*10	3,53*10	-------	5,15	-------	-------
14	S001070	-------	7,25*10	4,20*10	40,26	-------	5,25	-------	-------
15	S001380	$2,87*10^3$	5,70*10	3,23*10	30,92	6,97	4,43	-------	-------
16	S001430	$2,54*10^3$	4,87*10	25,9	36,92	-------	-------	-------	-------
17	S001440	$2,73*10^3$	5,24*10	2,97*10	26,15	-------	3,41	-------	-------
18	S002470	$2,48*10^3$	4,78*10	26,6	-------	-------	3,44	-------	-------
19	S002480	$2,17*10^3$	3,98*10	22,6	3,53*10	-------	3,28	-------	-------
20	S002490	$2,33*10^3$	4,55*10	26	-------	-------	3,44	-------	-------
21	S002940	$2,70*10^3$	3,07*10	1,70*10	21,12	$5,44*10^{-1}$	3,53	5,63	-------
22	S002950	$2,31*10^3$	2,31*10	12,27	18,65	$4,44*10^{-1}$	3,08	4,32	-------
23	S002960	$2,62*10^3$	3,78*10	21,06	24,52	$5,79*10^{-1}$	3,49	5,11	-------
Average value		$2,59*10^3$	5,47*10	3,06*10	2,82*10	3,90	3,84	7,82	$1,08\cdot10^2$
Standard deviation		$2,62*10^2$	1,42*10	9,07	1,13*10	3,01	1,09	4,90	$1,15\cdot10^1$

Table A.3. Radionuclide Composition of Samples (Transuranic Elements)

##	Sample code	Activity of nuclides, MBq/g (ceramics), recalculation as of 26.04.86					U, %
		^{238}Pu	$^{239}Pu + ^{240}Pu$	^{242}Cm	^{244}Cm	^{241}Am	
1	S000330	1,01	2,21	2,16*10	$1,95*10^{-1}$	$2,83*\cdot10^{-1}$	10,21
2	S000340	$7,84*10^{-1}$	2,54	4,44*10	$2,25*10^{-1}$	$2,32*10^{-1}$	9,91
3	S000350	$7,47*10^{-1}$	2,45	3,30*10	$2,08*10^{-1}$	$2,71*10^{-1}$	10,11
4	S000360	$6,92*10^{-1}$	1,40	2,00*10	$1,85*10^{-1}$	$2,93*10^{-1}$	9,59
5	S000560	1,00	1,90	3,07*10	$2,40*10^{-1}$	$2,66*10^{-1}$	11,32
6	S000980	-------	-------	-------	-------	-------	
7	S000990	-------	-------	-------	-------	-------	
8	S001000	-------	1,35	2,76*10	$1,72*10^{-1}$	-------	9
9	S001010	-------	1,19	2,25*10	$2,78*10^{-1}$	-------	10
10	S001020	-------	-------	-------	-------	-------	
11	S001030	-------	-------	-------	-------	-------	12,5
12	S001040	-------	-------	-------	-------	-------	
13	S001050	-------	-------	-------	-------	-------	12
14	S001070	-------	-------	-------	-------	-------	9,3
15	S001380	$8,68\cdot10^{-1}$	1,70	3,29*10	$1,99*10^{-1}$	$4,52*10^{-1}$	11,51
16	S001430	$9,31*10^{-1}$	1,75	2,92*10	$2,16*10^{-1}$	$1,54*10^{-1}$	9,9
17	S001440	-------	-------	-------	-------	-------	10,5
18	S002470	$9,07*10^{-1}$	1,70	5,01*10	$2,42*10^{-1}$	$1,04*10^{-1}$	9,57
19	S002480	$9,17*10^{-1}$	1,63	7,70*10	$2,93*10^{-1}$	$1,32*10^{-1}$	8,34
20	S002490	$9,17*10^{-1}$	1,80	-------	$3,56*10^{-1}$	$1,84*10^{-1}$	8,93
21	S002940	$7,91*10^{-1}$	1,54	3,61*10	$1,68*10^{-1}$	$1,04*10^{-1}$	10,44
22	S002950	$7,19*10^{-1}$	1,41	3,39*10	$1,77*10^{-1}$	$1,04*10^{-1}$	9,05
23	S002960	$7,90*10^{-1}$	1,56	3,75*10	$2,09*10^{-1}$	$1,24*10^{-1}$	10,14
Average value		$8,52*10^{-1}$	1,74	3,55*10	$2,24*10^{-1}$	$2,995*10^{-1}$	10,53
Standard deviation		$1,05*10^{-1}$	$3,93\cdot10^{-1}$	1,46	$5,16*10^{-1}$	$2,32*10^{-1}$	1,18

Element Composition

Table A.4. Element Composition of Samples

##	Room	Sampling area, coordinates	Sample description	Mass fraction, %															
				Si	Ca	Ti *10	Zr	Cu *10	Na	Ba *10	Al	Mn *10	Fe	Pb $*10^3$	Cr *10	Mg	Ni *10	B $*10^2$	Gd $*10^2$
1	0.12/7	47/48, Л/М	Pumice or porous brown slag	34	2,3	1,1	2,5	1,5	0,96	1,6	2,6	3,0	1,0	11	1,3	3,7	2,5	3.5	н/о
2	0.12/7	48, Л+3	Pumice	36	4,7	1,6	4,1	16	1,3	2,0	3,0	3,2	1,1	10	1,4	4,9	2,8	4.2	н/о
3	0.12/7	47+1, Л	Pumice	31	3,1	1,3	3,0	4,3	1,2	1,5	2,8	2,5	0,8	13	1,1	5,3	2,1	3.9	н/о
4	0.12/7	46/47, П/Н	Fulvous pumice	36	4,7	1,6	4,1	16	1,3	2,0	3,0	6,4	0,9	9,8	2,0	5,0	3,4	7.4	н/о
5	0.12/7	47/48, К/И	Porous fulvous slag	35	5,3	1,8	4,1	3,6	1,4	1,6	2,6	6,4	1,0	11	2,3	5,4	3,2	7.0	5.4
6	0.12/7	48/49, М/Н	Fulvous-brown pumice	35	5,2	1,8	3,0	14	1,2	1,7	2,5	4,4	0,98	10	1,7	5,0	3,4	4.4	2.5
7	0.12/7	45/46, Ж/Е	Fulvous-brown pumice	36	4,3	2,0	2,8	1,8	1,3	1,7	2,6	4,5	1,0	12	1,6	4,6	4,0	8.4	н/о
8	0.12/7	45/46, Ж/Е floor	sludge	32	11	1,4	0,08	8,0	2,6	0,5	3,4	0,84	2,0	12	н/о	4,1	н/о	0.5	3.0
9	0.12/7	47/48, И/К "pile"	Slag, granule	8,1	8,0	2,4	10	54	2,2	н/о	6,8	11	0,84	20	3,8	9,4	4,8	8.0	2.8
10	0.12/7	47/48, И/К "pile"	Slag, light granule	33	5,9	1,8	5,6	21	4,5	1,0	2,1	0,38	0,49	17	0,6	10,3	0,4	0.21	н/о
11	0.12/7	47/48, И/К "pile"	Slag, brown granule	27	3,7	1,4	6,3	37	1,2	н/о	4,5	9,0	0,78	27	2,5	5,2	2,2	9.0	3.4
12	0.12/7	47/48, И/К	Greenish granule	33	4,0	1,5	5,4	28	2,2	1,5	2,7	4,6	0,61	31	2,3	5,0	3,1	7.6	-
13	0.12/7	47/48, И/К	White powder after evaporation of 1 l of water	30	0,1	н/о	н/о	1,0	25	н/о	н/о	н/о	0,09	0,9	-	0,03	-	15	-
Average value				31,2	4,79	1,64*10^{-1}	4,25	1,84	3,57	1,51 $*10^{-1}$	3,24	4,70 $*10^{-1}$	8,92 $*10^{-1}$	1,42 $*10^{-2}$	1,87 $*10^{-1}$	5,35	2,90 $*10^{-1}$	6,09 $*10^{-2}$	3,42 $*10^{-2}$
Standard deviation				1,77	2,33	3,48 $*10^{-2}$	2,45	1,62	1,00	4,53 $*10^{-2}$	1,34	3,11 $*10^{-2}$	3,72 $*10^{-2}$	7,13 $*10^{-3}$	8,58 $*10^{-2}$	2,03	1,14 $*10^{-1}$	3,00 $*10^{-2}$	1,15 $*10^{-2}$

5.3. Spread of Metal

Location of Main Accumulations of Solidified Metal

Molten metal was generated in Room #305/2 during melting of constructions of 'OP' component. However no visible solidified metal formations have been discovered in this room so far.

In the "large vertical flow" metal - as a solidified "dripstone" – is found in Room #210/7 under the third duct of the 4th steam-dumping valve between the rows 'К-И'. The height of the "dripstone" above the floor is about 50 cm (Fig.5.24).

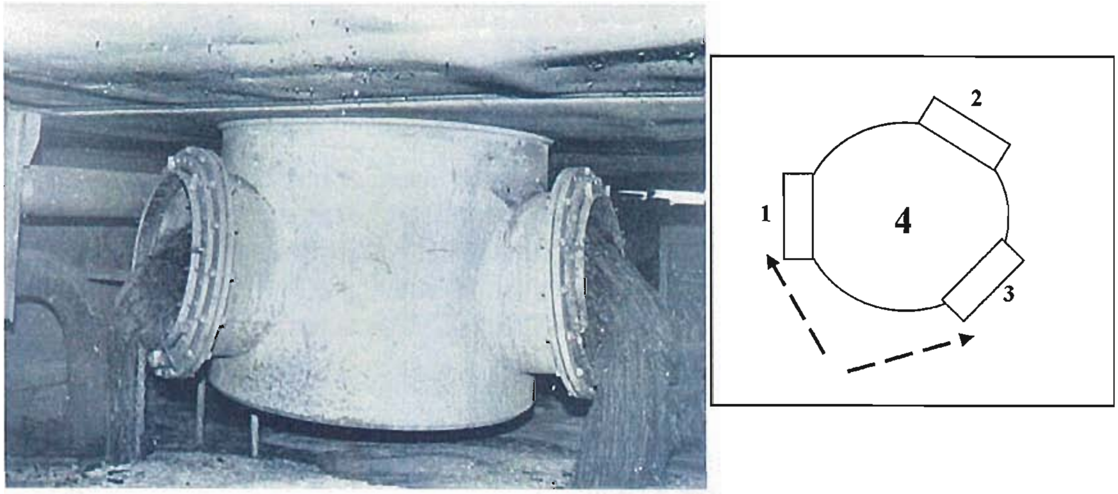


Fig.5.24. – Room #210/7, valve #4. Photo from the southwestern side. Are visible:- duct #3 (on the right) out of which brown lava is "flowing" (a solidified metal "dripstone" is observed on the floor under the duct); and –duct #1 (on the left) wherein metal "jets" are mixed with a solidified "flow" of chocolate-brown ceramics

In addition, in the first duct of the 4th valve metal "jets" are mixed with a solidified "flow" of chocolate-brown ceramics.

In Room #210/7 metal was also discovered while drilling the hole #3-9-X along the row (К+500) (minimum thick of 50 mm), and it is visible from the southern side of the room as a layer up to 50 mm thick under a layer of brown ceramics.

It may be suggested that metal is also located within the 4th valve down to the bottom edge of ducts. No re-melted metal is found in the below-located rooms of pressure-suppression pool (#012/15 and #012/7).

Thus via the large vertical flow molten metal attained steam-distribution corridor only (Fig. 5.25), spread from north to south between the rows 'И' and 'Л' (6 m in each side from valve #4) and solidified there. It is worth noting that the height of solidified metal (50 cm) close to the third duct of valve #4 in Room #210/7 of SDC nearby the condenser battery exceeds that of edges of steam-dumping pipes (35 cm). Nevertheless, no metal penetrated into steam-dumping pipes of PSP evidencing that the temperature of molten FCM was considerably above the metal solidification point (by the instant of metal solidification the melt consistence was rather fluid).

Most likely, metal contained within the "minor vertical flow" flowed out of Room #305/2 into Room #210/6 at once via two steam-dumping valves and spread from south to north between the rows 'И' and 'M'.

Such a suggestion follows from the fact that solidified masses of metal are visible in Room #210/6 between the rows 'К-И' and are also discovered in core samples from the oblique hole #3-9-T (row Л+500) where the thick of metal layer exceeds 200 mm. It is not improbable, however, that a portion of metal from Room #210/6 of SDC could have penetrated into steam-dumping pipes of Room #012/14 in PSP-2 and solidified therein. Such a conclusion follows from both visible partial melting of plating close to the intersection (Л/46) in Room #012/14 and a considerable excess of the integral gamma background measured experimentally close to the central row of steam-dumping pipes between the rows 'К' and 'Л'.

As established recently, a "jet" of metal is visible among coal-black ceramics within the third steam-dumping valve as well (Room #210/6 of SDC).

There is one more location of solidified metal unrelated, however, to LFCM flows at all: Room #210/5 of SDC between the rows 'К-Л' in the area of the 3rd southern valve connecting Room #210/5 with Room #307/2 (see Figs. 5.26 and 5.27). However plugs at the indicated valve are intact, as in case of the second (central) valve. Thus a "pool" of solidified metal under this valve originates from the adjoining Room #210/6 (SDC) rather than from the above located Room #307/2.

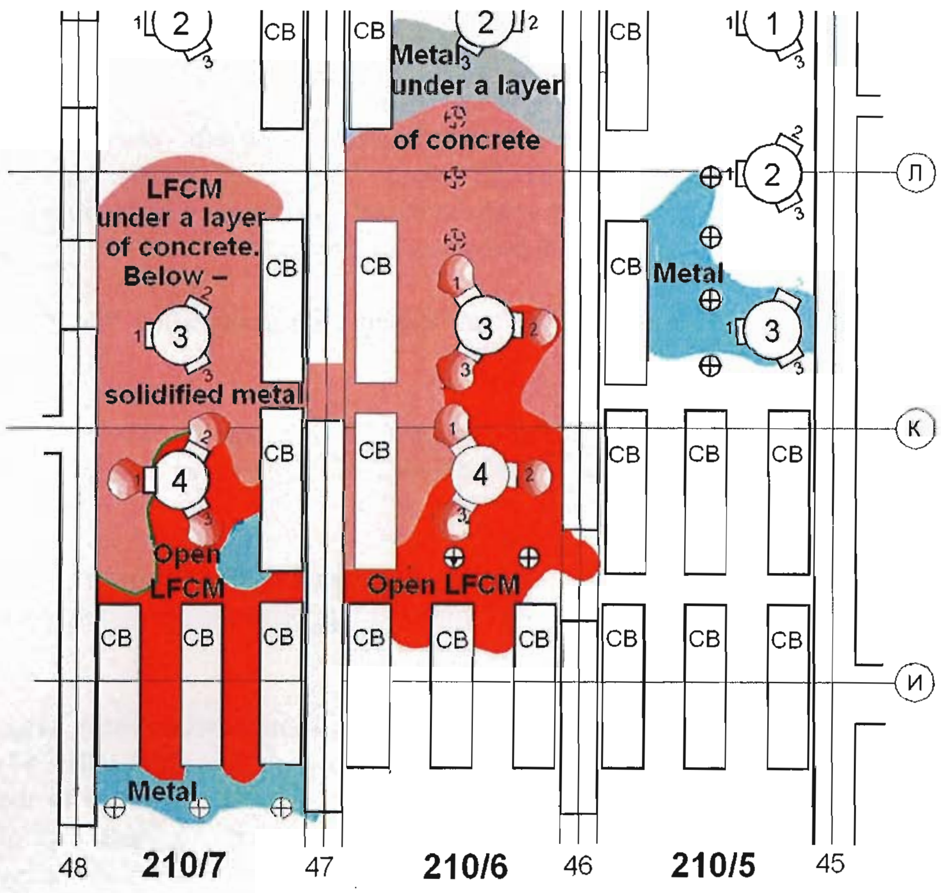


Fig.5.25. Accumulations of FCM and solidified metal in SDC

From Room #210/5 of SDC metal penetrated into the underlying rooms #012/13 and #012/5 of PSP-2 and PSP-1.

In Room #012/13 at 2.2 m level mark, intersection 'Л-46', a cast-iron pipe was partly melted (the so-called "fused pipe"), and a rather large amount of metal flowed out and solidified along the pipe.

Yet lower – in Room #012/5, PSP-1 – a solidified metal melt (the so-called "drop") 200 mm in diameter and 300 mm in height is observed at the pipe-extension (intersection 'Л-46').

Fig. 5.26. Solidified metal on the floor of Room #210/5

Fig.5.27. Solidified metal on the floor of Room 210/5

Metal as a Component of LFCM

All types of LFCM contain metal globules of a regular shape and rather different diameter varying from a few microns to one millimeter.

Results of Chemical and Radiochemical Analyses

According to the results of chemical and radiochemical analyses, a variety of types of observed metal (from micro-inclusions in ceramics to the 'drop' in PSP-1) are fully identical that allows suggesting similar genesis of the whole of molten metal.
The results of analyses are demonstrated in Table 5.20.

Table 5.20. Results of spectrum analysis of metal samples in the "Shelter"

#	Sampling area	Bq/g of metal, recalculation as of 26.04.86		
		Co-60/10^6	Sb-125/10^6	Ru-106/10^8
1.	Metal globules from deep-brown ceramics, pile in PSP-1	6,715	7,766	9,362
2.	Metal globules from black ceramics of SDC, "bank"	3,413	8,318	9,752
3.	Metal globules obtained while washing 'chernobylit', Room #304/3	3,227	4,786	8,071
4.	Globules from brown ceramics, PSP, 47-48, И/К, level mark 3.00	3,349	6,343	8,698
5.	Globules from black ceramics, Room #304/3	3,194	5,591	8,263
6.	Spread and solidified metal in SDC	4,033	8,445	8,856

Significant quantities of ^{144}Ce, ^{137}Cs and ^{134}Cs isotopes were discovered neither in metal globules nor in metal of SDC.

From the data of Table 1 several conclusions may be reached.
As compared to radionuclide composition of FCM, re-melted metal has the following distinctive features:

- no isotopes of ^{144}Ce, ^{137}Cs and ^{134}Cs, i.e. of fuel inclusions;
- very high enrichment in ^{106}Ru and – to a smaller extent – in ^{125}Sb;
- similar concentrations of ^{60}Co, ^{106}Ru and ^{125}Sb isotopes in metal samples taken at different locations being away from each other up to several meters.

To all appearance, in the course of the accident melting of metal went on almost concurrently and within one room only (#305/2). High homogeneity of ^{60}Co distribution over the whole mass of metal from micron-size globules in ceramics mass up to solidified metal in SDC counts in favor of such a conclusion.

Ruthenium and antimony could have penetrated into metal only from fuel through high-temperature extraction of fission fragments.

REFERENCES

1. *The "Shelter" Current Safety Analysis and Forecast Estimates for the Situation Development* (2001) A.A. Borovoi (responsible exec.), ISTC "Shelter" Report, arch. n°3836, Chernobyl, P. 337 (in Russian).

2. Pazukhin, E.M. (1994) Lava-like Fuel Containing Masses of the Chernobyl NPP Unit 4: Topography, Physical & Chemical Properties, Generation Scenario, *J. Radiokhimia*, 36(2), 1994, pp. 97-142 (in Russian).

3. *Research of interaction of fuel with constructional materials in plant Shelter* (1991) RI. The final report under the contract # 39-901/63-16-2-1.

5.4 Lava spreading