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Formation and Spread of Chernobyl Lavas

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Abstract—The results of implementation of the ISTC Project “Development of a Model of the Behavior of Nuclear Fuel in the Active Stage of the Chernobyl Accident” are summarized. The project work was jointly undertaken by the Russian Research Centre Kurchatov Institute (RNTs KI) and Nuclear Safety Institute, Russian Academy of Sciences (IBRAE RAN). The aim of the project was to systematize a huge amount of data on lava-like fuel-containing materials (LFCM), collected over the 20 years of research work at the Shelter, into database and to develop a model of LFCM formation and spread during early post-accident days. The model will be helpful in producing recommendations on accident prevention and promote development of the best technologies for lava removal, thereby reducing the financial expenses and dose burden. Also, with the model developed, the results of the virtually unique “experiment” with the nuclear fuel of the Unit 4 reactor, organized on a huge scale, can be used for finding solutions to the general nuclear safety problems.

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We summarize here the results of implementation of the ISTC Project “Development of a Model of the Behavior of Nuclear Fuel during the Active Stage of the Chernobyl Accident” by the Russian Research Centre Kurchatov Institute (RNTs KI) jointly with the Nuclear Safety Institute, Russian Academy of Sciences (IBRAE RAN). The aim of the project was to systematize a huge amount of data on lava-like fuel-containing materials (LFCM), collected over the 20 years of research work at the Shelter, into a database and to develop a model of LFCM formation and spread during early post-accident days. This task is being accomplished, above all, as part of practical activities aimed to eliminate of the consequences of the Chernobyl accident. At the present time, conversion of the Shelter to the environmentally safe condition, assisted financially, technically, and organizationally by the entire world community, is under way in Chernobyl. Stabilization of building structures has already been achieved. Today’s agenda includes construction of a new safe Arch confinement to enclose the existing Shelter. The next, most complicated, task will consist in removal from the Shelter of the nuclear fuel and radioactive materials to be eventually disposed of. As known, much of this fuel (~100 t) is part of the lava formed during the accident [1]. In this context, the lava formation and spread model developed can be helpful in determining more precisely the amount, location, and properties of the lava in inaccessible rooms, as well as in producing recommendations on accident prevention, and will promote development of the best lava removal technologies, thereby reducing the financial expenses and dose burden.

Second, the Project goals are topical in view of the fact that, with the lava formation and spread model, the results of the virtually unique “experiment” with the nuclear fuel of the Unit 4 reactor, organized on a huge scale, can be used for finding solutions to the general nuclear safety problems, associated with formation of corium.

After the explosions in Unit 4 of Chernobyl NPP, the condition of the rooms in which the lava formation began had already little in common with the pre-accident situation. The same was true of the structures in these rooms. Therefore, the first task in development of a lava formation model was to reconstruct the condition of the destroyed unit after the explosions (the

Table 1. Materials available in the reactor cavity (room no. 504/2) and in the subreactor room no. 305/2 at the beginning of stage 2 of the accident

Material	Available in room nos. 504/2[a] and 305/2, t	Became part of LFCM, t
Fuel (U)	120	90
Steel	1300[b]	<20[c]
Serpentinite mixture	580	160
Subreactor plate concrete	–	130
Structural concrete that got into the cavity	950	480
Cavity filling materials	300	280
Zirconium	?	45
Graphite	750	Negligible amount

[a] Within the reactor space.
[b] Disregarding scheme S materials and unfused communication lines at the reactor bottom.
[c] 330 t melted and spread over the subreactor rooms.

conditionally chosen time was half an hour after the beginning of the accident). In undertaking these efforts, we did not seek to reconstruct the entire sequence of events that occurred during the accident.

Three data files were used: initial data on the structures and materials of Unit 4; results of inspections of the post-accident condition of the reactor cavity and subreator rooms; and results of examination of the geometry and physicochemical properties of the LFCM accumulations in the Shelter.

We carried out verification, analysis, and systematization of a huge amount of experimental data yielded by the research activities undertaken in Shelter in 1986–2005 by RNTs KI, Radium Institute, IBRAE RAN, Chernobyl NPP, Shelter ISTC, and many other organizations involved in elimination of the consequences of the Chernobyl accident (see, e.g., [1–8]). We used the data contained in articles, reports, inspection acts, as well as construction drawings, etc. Also, photo and video materials were attracted. The collection of information was complete in 2005. For the results, including details on the composition and amount of the materials that became part of the lava (Table 1), see [9, 10].

In simulation of the lava formation processes we took into account three heat energy sources: residual heat liberation from fuel of Unit 4 of Chernobyl NPP; heat energy from graphite burning; and heat energy from the steam–zirconium reaction, of which the first is of deciding importance (Fig. 1).

In formation of lava, many materials that become its part or contacted its major streams acted as peculiar thermometers, which enabled reconstruction of the temperature ranges of the processes involved.

Molten metal. The major source of this metal was steel from the destroyed sector of OR (reactor base) scheme [1]. The temperature at which the metal melted and spread must have exceeded 1500°C. There were metal thermometers in the lava itself. All types of LFCMs comprise metal spheres (globules), which also evidences that the lower limit of the lava formation temperature exceeded 1500°C.

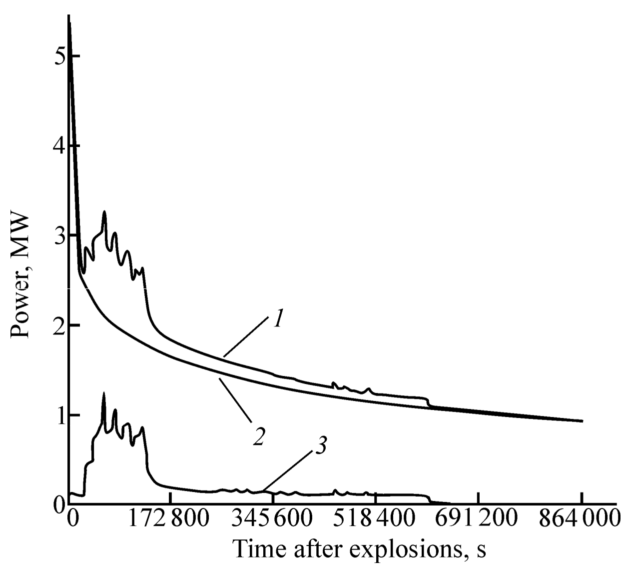

Fig. 1. Contribution to the total thermal power spent for lava formation from various heat energy sources (for one of the lava formation scenarios): (*1*) integrated power spent for the lava formation, (*2*) contribution from residual heat energy liberated by fuel, and (*3*) contribution from chemical reactions.