https://doi.org/10.52676/1729-7885-2024-4-5-11
УДК 621.039.587

DEVELOPMENT OF A THERMOPHYSICAL MODEL FOR THE EXPERIMENTAL ASSEMBLY OF THE VCG-135 TEST BENCH TO STUDY THE INTERACTION OF CORIUM WITH METAL-COOLER IN THE CONDITIONS OF A SEVERE ACCIDENT

M. K. Skakov[1], K. O. Toleubekov[2, 3*], M. K. Bekmuldin[2], A. S. Akaev[2]

[1)] RSE "National Nuclear Center of the Republic of Kazakhstan", Kurchatov, Kazakhstan
[2)] Branch "Institute of Atomic Energy" NNC RK, Kurchatov, Kazakhstan
[3)] Shakarim University of Semey City, Semey, Kazakhstan

* *E-mail for contacts: toleubekov@nnc.kz*

This article presents the results of modeling of the temperature field of the experimental assembly of the VCG-135 test bench to study the interaction between model corium and candidate metal-coolers (zinc, antimony and manganese) in the conditions of a severe accident.
The need for modeling is associated with the probability of metal melting in the discharge device due to the heat flow from the heating crucible of the experimental assembly. Thus, the purpose of the modeling was the justification of the integrity of the design of the metal discharge device during the production of liquid corium in the crucible of the experimental assembly.
The thermophysical model was created in the ANSYS software. The temperature field of the experimental assembly was obtained at the moment of obtaining liquid corium as a result of the modeling. An analysis of the results showed that metal in the discharge device wouldn't reach the melting point. In this regard, the discharge device of the experimental assembly can be used in its current design for experiments conducting at the VCG-135 test bench.
At the same time, after the experiments, the thermophysical model was validated by comparing the calculated temperature values with experimental data. Validation of the model shows that the deviation of calculated and experimental temperature values at control points does not exceed acceptable limits (melting of the studied metal before interaction with corium). Thus, the developed thermophysical model can be used to justify further experiments on the VCG-135 test bench with the current experimental assembly.

Keywords: *severe accident, corium, core catcher, metal-cooler, VCG-135 test bench, ANSYS, modeling.*

INTRODUCTION

The most harmful consequences of a severe nuclear reactor accident are the core meltdown with the formation of corium and its release outside the reactor vessel [1–2]. Passive nuclear safety systems are provided in the nuclear power station design in the case of such a scenario. The core catcher is one of the passive safety systems and is the last barrier to the spread of corium during the destruction of the reactor vessel [3–6].

Currently, the National Nuclear Center of the Republic of Kazakhstan is conducting research on the possibility of using the boiling effect of metals to cool the surface of corium in the core catcher of the VVER reactor [7–8].

This idea is based on using the boiling effect of metals on the corium surface in a similar way to water cooling. In this regard, it is appropriate to conduct experimental studies to understand all features of such interaction.

The experiments on the study of the interaction between corium and candidate metal-coolers was conducted at the VCG-135 test bench. The VCG-135 test bench is a sealed water-cooled working chamber with a built-in inductor designed to perform high-temperature thermophysical and materials science studies [9-10]. Figure 1 shows the scheme and appearance of the working chamber of the VCG-135 test bench.

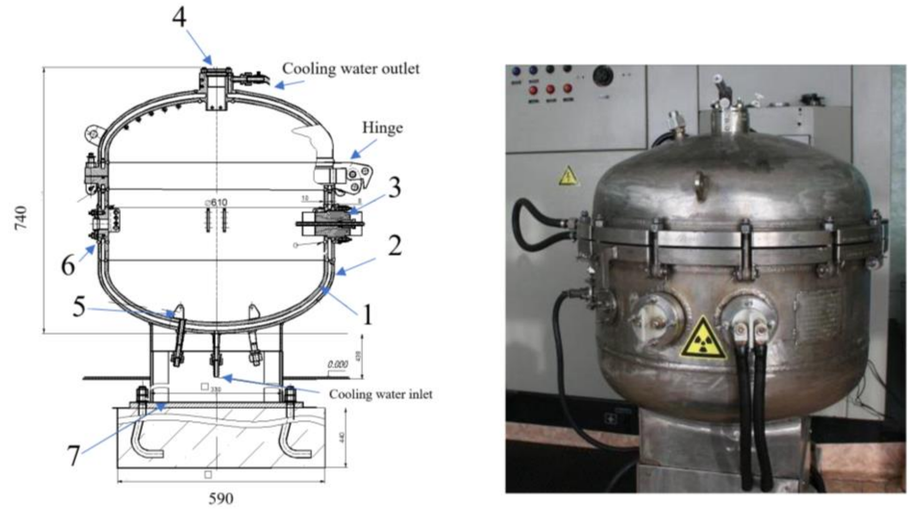
The experimental assembly consisted of a double graphite crucible and a developed metal discharging device. The discharge device made it possible to organize the discharge of solid metal fragments after receiving liquid corium into the crucible. The appearance and scheme of the experimental assembly of the VCG-135 test bench are presented in Figure 2.

The main uncertainty before the experiments was associated with the issue of the probable melting of the studied metal in the discharge device during obtaining of the liquid corium due to the heat flow from the graphite crucible.

In this regard, it was necessary to analyze the integrity of the metal discharge device design during liquid corium obtaining in the crucible of the experimental device before experiments. At the same time, one of the most effective ways for considering this issue with minimal cost is the method of computer modeling.

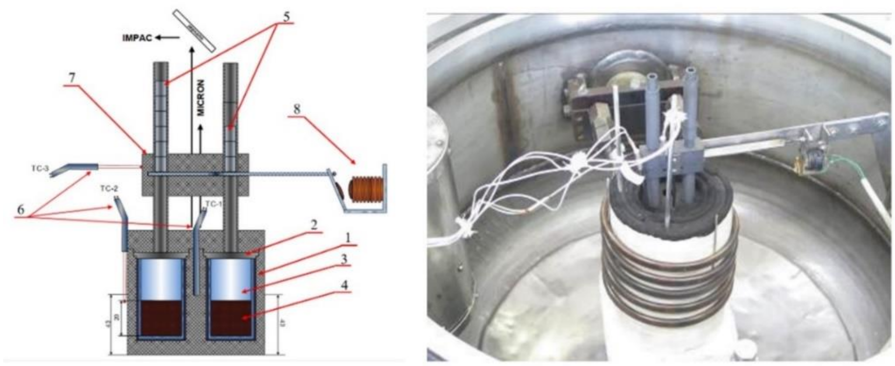
THERMOPHYSICAL MODEL FOR THE EXPERIMENTAL ASSEMBLY OF THE VCG-135 TEST BENCH

The objective of the modeling is to obtain the temperature field of the elements of the experimental assembly of the VCG-135 test bench when the temperature of corium in the crucible reaches ~2250 °C.



1 – inner tank of the power hull; 2 – external tank of the power hull; 3 – inductor current supply; 4 – viewing window; 5 – brackets for mounting the experimental assembly; 6 – electrode holders; 7 – foundation

Figure 1. Appearance and scheme of the working chamber of the stand VCG-135.



1 – graphite crucible; 2 – lid; 3 – tungsten glass; 4 – corium; 5 – metal-cooler; 6 – thermocouple; 7 – device for discharging the metal-cooler; 8 – electromagnetic drive

Figure 2. Experimental assembly in the working chamber of the VCG-135 test bench

To achieve this goal, in this article, an experimental situation is simulated when the corium prototype is heated in the graphite crucible to obtain a melt by method of the induction heating. Calculations of the thermal state of the thermophysical model were performed using the ANSYS software [17].

The thermophysical model for calculations was created based on the scheme of the experimental assembly in which an induction heater was used as a method to obtain a corium melt. Figure 1 shows the scheme of the experimental assembly.

Due to the symmetry of the experimental assembly relative to the central axis, the third-dimensional axisymmetric computational domain was chosen for modeling heat transfer. Figure 3 shows the developed thermophysical model of the experimental assembly. The thermophysical model takes into account the presence of the insulation, however it isn't shown on the figure due to the convenience of visualization.

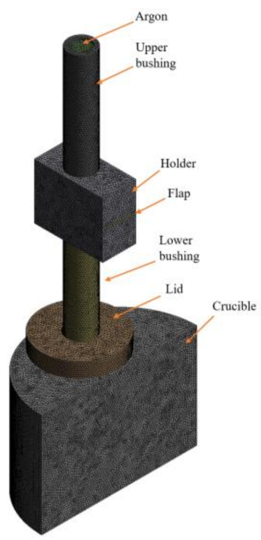


Figure 3. Thermophysical model of the experimental assembly

Control points TC-1, TC-2, TC-3 were selected for temperature control in the experimental assembly at the planned locations of thermocouples in future experiments during the calculation. Figure 2 shows the scheme of the control points locations and, accordingly, future thermocouples.

ELECTRICAL CALCULATION OF THE PARAMETERS OF THE "INDUCTOR-GRAPHITE CRUCIBLE" SYSTEM

It was necessary to calculate the efficiency of the inductor before modeling the induction heating of a graphite crucible. The efficiency shows the amount of energy invested in the inductor and transferred directly to the graphite crucible. Calculation of the efficiency of the inductor of the VCG-135 test bench was carried out using the following formulas according to [12].

The depth of current penetration into the inductor material Δ_1 is calculated by the formula:

$$\Delta_1 = 503 \cdot \sqrt{\frac{\rho_м}{f}} ,$$

where $\rho_м$ - electrical resistivity of copper, $\rho_м = 2 \cdot 10^{-8}$ Ohm·m; f – power supply frequency, f = 66 kHz.

The depth of current penetration into graphite Δ2 is:

$$\Delta_2 = 503 \cdot \sqrt{\frac{\rho_g}{f}} ,$$

where ρ_g – electrical resistivity of graphite, $\rho_g = 1.3 \times 10^{-5}$ Ohm×m;

The relative radius of the melt $\overline{R_2}$, which is used later when determining the values of auxiliary functions, is equal to:

$$\overline{R_2} = \frac{d_1}{\Delta_2 \sqrt{2}} ,$$

where d_1 – graphite crucible diameter, d_1 = 0.14 m,

The active resistance of the inductor r_1 is calculated by:

$$r_1 = \rho_м \cdot \frac{\pi \cdot d_{1p}}{\Delta_1 \cdot h_1 \cdot k_з} ,$$

where d_{1p} – design diameter of the inductor turn, m; h_1 – inductor height, h_1 = 0.12 m; $k_з$ – the fill factor of the inductor, equal to the ratio of the height of the inductor coil, which corresponds to the diameter of the inductor tube, to the winding pitch.

The calculated diameter of the inductor d_{1p} is determined as:

$$d_{1p} = d_o - d_{ext} + \Delta_1 ,$$

where d_o – average diameter of inductor turn, d_o = 0.15 m; d_{ext} – external diameter of the inductor turns tube, d_{ext} = 0.01 m.

Inductor fill factor $k_з$ is determined as:

$$k_з = \frac{n \cdot d_{ext}}{h_1} ,$$

where n – number of inductor turns, n = 5.

Active resistance of the block r_2 is:

$$r_2 = \rho_g \cdot \frac{\pi \cdot d_1^2}{2 \cdot \Delta_2^2 \cdot h_2} \cdot A ,$$

where $A = F\,(\overline{R_2})$ – auxiliary function, which is determined according to the graph in [12]; h_2 – graphite crucible height, h_2 = 0.18 m.

If the condition is met $b_{mp} > 1.5 \cdot \Delta_1$, (copper tube wall thickness b_{mp} = 2 мм), internal reactance of the inductor x_{1b} has a value approximately equal to the active resistance of the inductor:

$$x_{1b} \approx r_1 .$$

Internal block reactance x_2 is equal to:

$$x_2 = \rho_{cor} \cdot \frac{\pi \cdot d_1^2}{2 \cdot \Delta_2^2 \cdot h_2} \cdot B$$

where $B = F\,(\overline{R_2})$ - auxiliary function, which is determined according to the graph in [12].

Leakage reactance x_s of the conventional single-turn inductor is determined by the formula

$$x_s = \omega \cdot \pi^2 \frac{d_2^2 - d_1^2}{h_2} \cdot 10^{-7} ,$$

where ω – circular frequency of the current, calculated as:

$$\omega = 2 \cdot \pi \cdot f .$$

Reactance x_1 of the unloaded inductor is equal to:

$$x_1 = \omega \cdot \pi^2 \frac{d_2^2}{h_1} \cdot k \cdot 10^{-7} ,$$

where d_2 – crucible external diameter, d_2 = 0.14 m; k - correction factor taking into account the end effects of a short inductor (Nagaoka coefficient).

The Nagaoka coefficient is a function of the d_2/h_1 ratio and has a value of 0.4 in the calculation.

The reverse circuit reactance x_0 is determined by the formula:

$$x_0 = x_1 \cdot \frac{h_1}{(h_1 - k \cdot h_2)} .$$

The parameter reduction coefficient C is calculated as:

$$C = \frac{1}{\left(\frac{r_2}{x_0}\right)^2 + \left(1 + \frac{x_s + x_2}{x_0}\right)^2} .$$

Reduced active resistance of the block r_2' is equal to:

$$r_2' = C \cdot r_2 .$$

The reduced reactance of the block x_2' is determined by the formula:

$$x_2' = C \cdot \left[x_s + x_2 + \frac{(x_s + x_2)^2 + r_2^2}{x_0} \right].$$

The equivalent active resistance of the inductor r is equal to:

$$r = r_1 + r_2'.$$

The equivalent reactance of the inductor x is:

$$x = x_{1b} + x_2'.$$

The equivalent impedance of the inductor z is calculated by the formula:

$$z = \sqrt{r^2 + x^2}\ .$$

The electrical efficiency of the inductor $\eta_э$ is equal to:

$$\eta_э = \frac{r_2'}{r}.$$

THE CONDITIONS FOR CONDUCTING NON-STATIONARY CALCULATIONS

The following boundary conditions were determined for the calculation:

a) initial temperature of the experimental assembly – 27 °C;

b) mass of the heated corium – 40 gram;

c) the graphite crucible is heated according to the diagram shown in Figure 4;

d) the corium in the crucible was heated to a temperature of ~2250 °C (readings of the control point TC-1).

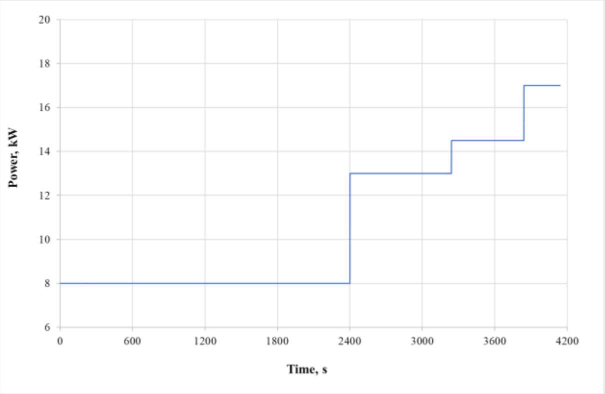


Figure 4. Heating diagram of a graphite crucible

At the same time, the energy released in the graphite crucible was set taking into account the efficiency of the inductor (see the calculation method in the previous section of this article) and experimental readings of the power factor. The calculation of the efficiency of the inductor of the VCG-135 test bench was conducted according to [12]. The electrical parameters of the inductor are shown in Table 1.

Table 1. Electrical parameters of the inductor

Parameter	Value
Active power of the inductor, kW	8–17
Calculated inductor efficiency, %	38
Inductor power factor, *cosφ*	0.58

The thermophysical model takes into account:

– dependence of the properties of the experimental assembly elements on temperature;

– heat exchange by radiation;

– convective heat transfer between the external surfaces of the model and the environment.

Zinc was chosen as the test material in this calculation as the metal with the lowest melting point relative to antimony and manganese. Some properties of corium during computer modeling were used according to literary sources [13–14]. It should be noted that due to shortages of data about dependence of the coefficient of thermal conductivity of corium on temperature, its value was set as a constant. The value of the thermal conductivity coefficient was set similarly to the previously performed calculations of corium heating in the ISTC project No. K-1265 under the INVECOR program [15–16]. The thermophysical properties of the experimental assembly were used according to the [17].

RESULTS OF MODELING THE EXPERIMENTAL ASSEMBLY OF THE VCG-135 TEST BENCH

Figure 5 shows a graph of temperature changes at control points during heating of a graphite crucible according to the proposed diagram. The graph shows that when the required temperature of the corium in the crucible is reached, the temperature in the area of placement of the metal under study will reach ~400 °C (readings of the TC-3 point).

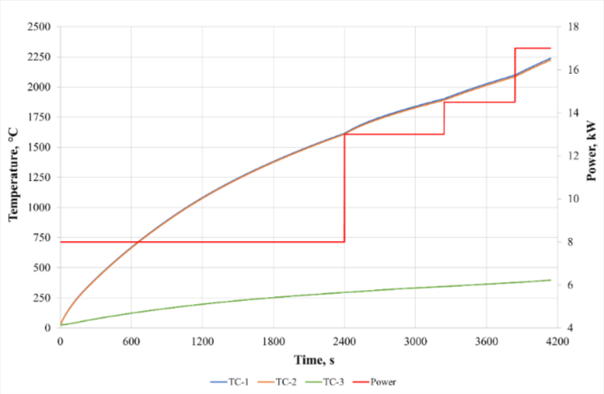


Figure 5. Heating diagram of a graphite crucible

In this regard, it can be argued that temperature of the zinc will not exceed the melting point (~420 °C) due to the heat flow from the heated elements during heating a graphite crucible to produce liquid corium.

Figure 6 shows the temperature field of the experimental assembly at final moment of the time. The figure clearly shows the heating pattern of the experimental device. It can be seen that heat transfer to the area of placement of the metal under study occurs due to thermal conductivity through the lower graphite sleeve.

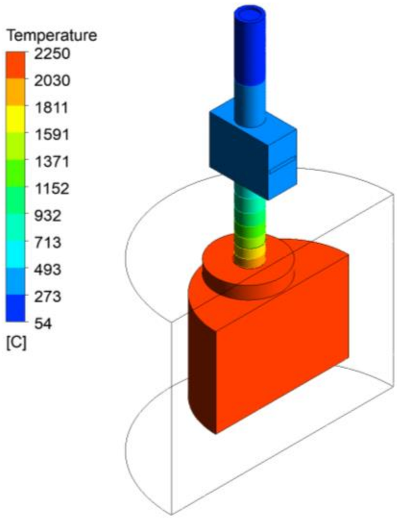


Figure 6. Temperature field of the experimental assembly

VALIDATION OF THE THERMOPHYSICAL MODEL OF THE EXPERIMENTAL ASSEMBLY OF THE VCG-135 TEST BENCH

Figure 7 shows a graph of changes in calculated and experimental temperature values during heating corium in a crucible to ~2250 °C according to the proposed heating diagram. The calculated values are represented in the graph by a dotted line, while the experimental values are represented by a solid line.

A comparison of the calculated and experimental temperature values at points TC-1 and TC-2 shows that the deviations between them average ~8%. At the same time, the deviation in values at the TC-3 control point is no more than 2%.

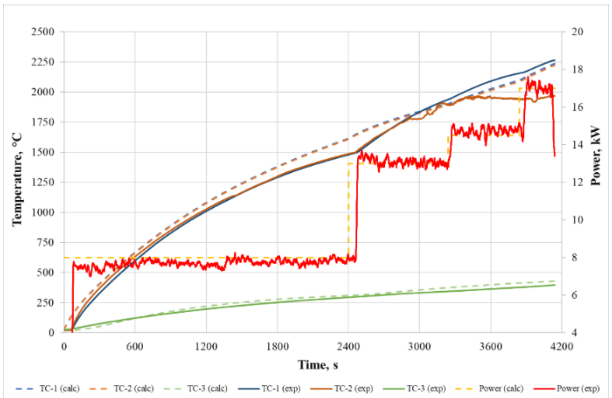


Figure 7. Experimental and calculated temperature values

During the experiment with zinc, the temperature in the area where the studied metal was placed reached about ~406 °C according to the readings of the TC-3 thermocouple at the moment the required temperature of the corium in the crucible was reached. Thus, at the moment the induction heater was turned off, the zinc was in a solid state and, as a result, solid metal was dumped into the crucible with liquid corium.

CONCLUSION

Modeling of the heating process of the graphite crucible of the experimental assembly of the VCG-135 test bench by induction heating. was performed using ANSYS software.The non-statinary caclulation was perfomed in order to study the possibility of melting of the studied metals placed in the upper bushing of the discharge device due to heat fluxes from the heated crucible.

Numerical calculation has shown that when implementing the proposed heating diagram, the temperature of zinc will not exceed the melting point at the moment when the required temperature of corium is reached in a graphite crucible. At the same time, the melting point of zinc is lower relative to other candidate metals under consideration (antimony and manganese).

In this regard, the experimental assembly in the current design can be used for conducting experiments with candidate metals for cooling corium at the VCG-135 test bench. The proposed heating diagram of corium in a graphite crucible was used during conducting the experiments.

Analysis of the results of non-stationary calculations showed good agreement with experimental data. On average, deviations are within acceptable values. Thus, based on the data on the relative deviations of the calculated and experimental results, it can be stated that the developed thermophysical model is applicable for temperature measurements in the elements of the experimental assembly of the VCG-135 test bench during induction heating.

Funding

This research was funded by the Ministry of Energy of the Republic of Kazakhstan within the framework of the scientific-technical program "Nuclear power engineering development in the Republic of Kazakhstan" (BR24792713).

REFERENCES

1. Journeau, C., Bouyer, V., Cassiaut-Louis, N. et.al. SAFEST roadmap for corium experimental research in Europe. Proceedings of 24th International Conference on Nuclear Engineering (ICONE24). Charlotte, North Carolina, June 26-30, 2016. https://doi.org/10.1115/ICONE24-60916
2. Bechta, S., Ma, W., Miassoedov, A. et.al. On the EU-Japan roadmap for experimental research on corium behavior // Annals of Nuclear Energy. – 2019. – Vol. 124. – P. 541–547. https://doi.org/10.1016/j.anucene.2018.10.019
3. Kukhtevich I.V.; Bezlepkin V.V.; Granovskii V.S. et.al. The concept of localization of the corium melt in the ex-vessel stage of a severe accident at a nuclear power station with a VVER-1000 reactor // Thermal Engineering. – 2001. – Vol. 48, No. 9. – P. 699–706.
4. Sidorov, A.S., Nedorezov, A.B., Rogov, M.F. et.al. The device for core melt localization at the Tyan'van nuclear power station with a VVER-1000 reactor // Teploenergetika. – 2001. – Vol. 9. – P. 8–13.

5. Fischer M. The severe accident mitigation concept and the design measures for core melt retention of the European Pressurized Reactor (EPR) // Nucl. Eng. Des. – 2004. – Vol. 230, No. 1–3. – P. 169–180. https://doi.org/10.1016/j.nucengdes.2003.11.034
6. Ki Won Song, Thanh Hung Nguyen, Kwang Soon Ha et al. Experimental study on two-phase flow natural circulation in a core catcher cooling channel for EU-APR1400 using air-water system // Nucl. Eng. Des. – 2017. – Vol. 316. – P. 75–88. https://doi.org/10.1016/j.nucengdes.2017.03.009
7. Skakov, M. Toleubekov, K., Baklanov, V., et.al The method of corium cooling in a core catcher of a light-water nuclear reactor // Eurasian phys. tech. j. – 2022. – Vol. 19. – P. 69–77. https://doi.org/10.31489/2022No3/69-77
8. Skakov, M., Baklanov, V., Toleubekov, K. et.al Modeling of the corium and metals – coolers interaction in a core catcher of a light water reactor // NNC RK Bulletin. – 2023. Issue 2(94). – P. 49–57. https://doi.org/10.52676/1729-7885-2023-2-49-57
9. Mukhamedov, N.Y., Kozhakhmetov, Ye. A. and Tskhe, V.K. Microstructure and mechanical properties of the solidified melt obtained by the in-pile test // Annals of Nuclear Energy. – 2022. – Vol. 179. – P. 109404. https://doi.org/10.1016/j.anucene.2022.109404
10. Vurim, A., Mukhamedova N., Baklanova Y. et al. Information and analytical system as a promising database used to justify the safety of nuclear energy // Nucl. Eng. Des. – 2023. – Vol. 415. – P. 112704. https://doi.org/10.1016/j.nucengdes.2023.112704
11. ANSYS Fluent Tutorial Guide, 2016
12. «Электротермическое оборудование», справочник под общей редакцией Альтгаузена А.П., М.: Энергия. – 1980. [“Elektrotermicheskoe oborudovanie”, spravochnik pod obshchey redaktsiey Al'tgauzena A.P., Moscow.: Energiya. – 1980. (In Russ.)]
13. Асмолов В. Г., Загрязкин В. Н., Астахова Е. В., Вишневский В. Ю., Дьяков Е. К., Котов А. Ю., Репников В. М. Плотность UO_2–ZrO_2-расплавов // Теплофизика высоких температур. – 2003. – Том 41, выпуск 5. – С. 714–719. [Asmolov V. G., Zagryazkin V. N., Astakhova E. V., Vishnevskiy V. Yu., D'yakov E. K., Kotov A. Yu., Repnikov V. M. Plotnost' UO_2–ZrO_2-rasplavov // Teplofizika vysokikh temperatur. – 2003. – Vol. 41, Issue 5. – P. 714–719. (In Russ.)]
14. Позняк И.В., Шатунов А.Н., Печенков А.Ю. Измерение электропроводности расплава кориума // Известия СПбГЭТУ «ЛЭТИ». – 2008. – Вып.10. – С. 39–45. [Poznyak I.V., Shatunov A.N., Pechenkov A.Yu. Izmerenie elektroprovodnosti rasplava koriuma // Izvestiya SPbGETU “LETI”. – 2008. – Issue.10. – P. 39–45.]
15. ICTS project #K-1265 INVECOR (IN-VEssel Corium Retention in accident of water reactor) [Электронный ресурс]. – Режим доступа: https://istc.int/ru/project/DA8802253C138C29C3257052005303CF
16. Бакланов В.В. Приборно-измерительный комплекс для исследования взаимодействия материалов ядерного реактора при тяжелых авариях: диссертация на соискание учёной степени кандидата технических наук, Юргинский технологический институт ТПУ, Югра, 2016. // [Электронный ресурс]. – Режим доступа: https://portal.tpu.ru/portal/pls/portal/!app_ds.ds_view_bknd.download_doc?fileid=4000 [Baklanov V.V. Priborno-izmeritel'nyy kompleks dlya issledovaniya vzaimodeystviya materialov yadernogo reaktora pri tyazhelykh avariyakh: dissertatsiya na soiskanie uchenoy stepeni kandidata tekhnicheskikh nauk, Yurginskiy tekhnologicheskiy institut TPU, Yugra, 2016 // [Electronic resource]. – Access mode: https://portal.tpu.ru/portal/pls/portal/!app_ds.ds_view_bknd.download_doc?fileid=4000 (In Russ.)]
17. Чиркин В.С., «Теплофизические свойства материалов ядерной техники», М.: АТОМИЗДАТ. – 1968. [Chirkin V.S., “Teplofizicheskie svoystva materialov yadernoy tekhniki”, Moscow.: ATOMIZDAT. – 1968. (In Russ.)]

АУЫР АВАРИЯ ЖАҒДАЙЫНДА КОРИУМНЫҢ САЛҚЫНДАТҚЫШ МЕТАЛДАРМЕН ӨЗАРА ӘРЕКЕТІН ЗЕРДЕЛЕУ ҮШІН ВЧГ-135 СТЕНДІН ЭКСПЕРИМЕНТТІК ҚҰРАСТЫРУДЫҢ ТЕПЛОФИЗИКАЛЫҚ МОДЕЛІН ӘЗІРЛЕУ

М. К. Скаков[1], К. О. Толеубеков[2,3*], М. К. Бекмулдин[2], А. С. Акаев[2]

[1)] *«Қазақстан Республикасының Ұлттық ядролық орталығы» РМК, Курчатов, Қазақстан*
[2)] *ҚР ҰЯО РМК «Атом энергиясы институты» филиалы, Курчатов, Қазақстан*
[3)] *Семей қаласындағы Шақарым атындағы университет, Семей, Қазақстан*

* *Байланыс үшін E-mail: toleubekov@nnc.kz*

Осы мақалада АЭС-тің ауыр авариясы жағдайында модельдік кориумның кандидаттық салқындатқыш металдармен (мырыш, сурьма және марганец) өзара әрекетін зерделеу үшін ВЧГ-135 стендінің эксперименттік жинағының температуралық өрісін модельдеу нәтижелері келтірілген.
Модельдеу қажеттілігі эксперименттік құрылғының қыздырылатын тигельінен жылу ағыны есебінен шығару құрылғысында металдың балқу ықтималдығымен байланысты. Осылайша, модельдеу мақсаты эксперименттік құрылғының тигелінде сұйық кориум алу кезінде металды шығару құрылғысы конструкциясының тұтастығын негіздеу болды.
Теплофизикалық модель ANSYS бағдарламалық кешенінде әзірленді. Алынған нәтижелерді талдау шығару құрылғысындағы металл балқу нүктесіне жетпейтінін көрсетеді. Осыған байланысты эксперименттік құрастыруды шығару құрылғысы ВЧГ-135 стендінде эксперименттер жүргізу кезінде ағымдағы конструкциялық түрде пайдаланылуы мүмкін.

Сонымен қатар, эксперименттерден кейін температураның есептік мәндерін эксперименттік деректермен салыстыру жолымен жылу физикалық модельді валидациялау жүргізілді. Үлгіні валидациялау бақылау нүктелеріндегі температуралардың есептік және эксперименттік мәндерінің ауытқуы рұқсат етілген шектерден аспайтынын көрсетеді (кориуммен әрекеттеспес бұрын зерттелетін металды балқыту). Осылайша, әзірленген жылу физикалық модель ағымдағы эксперименттік құрастырумен ВЧГ-135 стендінде одан әрі эксперименттерді негіздеу кезінде пайдаланылуы мүмкін.

***Түйін сөздер**: ауыр авария, кориум, балқыма тұзағы, металл–салқындатқыш, ВЧГ-135 стенді, ANSYS, моделдеу.*

РАЗРАБОТКА ТЕПЛОФИЗИЧЕСКОЙ МОДЕЛИ ЭКСПЕРИМЕНТАЛЬНОЙ СБОРКИ СТЕНДА ВЧГ-135 ДЛЯ ИЗУЧЕНИЯ ВЗАИМОДЕЙСТВИЯ КОРИУМА С МЕТАЛЛАМИ-ОХЛАДИТЕЛЯМИ В УСЛОВИЯХ ТЯЖЕЛОЙ АВАРИИ

М. К. Скаков[1], К. О. Толеубеков[2,3*], М. К. Бекмулдин[2], А. С. Акаев[2]

[1)] РГП «Национальный ядерный центр Республики Казахстан», Курчатов, Казахстан
[2)] Филиал «Институт атомной энергии» РГП НЯЦ РК, Курчатов, Казахстан
[3)] Университет имени Шакарима города Семей, Семей, Казахстан

** E-mail для контактов: toleubekov@nnc.kz*

В настоящей статье приведены результаты моделирования температурного поля экспериментальной сборки стенда ВЧГ-135 для изучения взаимодействия модельного кориума с кандидатными металлами-охладителями (цинк, сурьма и марганец) в условиях тяжелой аварии АЭС.
Необходимость моделирования обусловлена вероятностью плавления металла в устройстве сброса за счет теплового потока от нагревающегося тигля экспериментального устройства. Таким образом, цель моделирования заключалась в обосновании целостности конструкции устройства сброса металла во время получения жидкого кориума в тигле экспериментального устройства.
Теплофизическая модель была разработана в программном комплексе ANSYS. Анализ полученных результатов показывает, что металл в устройстве сброса не достигнет точки плавления. В связи с этим, устройство сброса экспериментальной сборки может быть использовано в текущем конструкционном виде при проведении экспериментов на стенде ВЧГ-135.
В тоже время, после экспериментов была проведена валидация теплофизической модели путем сравнения расчетных значений температуры с экспериментальными данным. Валидация модели показывает, что отклонение расчетных и экспериментальных значений температур в контрольных точках не превышают допустимых пределов (плавление исследуемого металла перед взаимодействием с кориумом). Таким образом, разработанная теплофизическая модель может быть использована при обосновании дальнейших экспериментов на стенде ВЧГ-135 с текущей экспериментальной сборкой.

***Ключевые слова**: тяжелая авария, кориум, ловушка расплава, металл–охладитель, стенд ВЧГ-135, ANSYS, моделирование.*