



GENERAL PROBLEMS OF THE MODERN RESEARCH AND INNOVATION POLICY

<https://doi.org/10.15407/scine22.03.066>

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INNOVATIVE APPROACH TO THE EXPERIMENTAL REPRODUCTION OF NOMINAL AND ALTERNATIVE FIRE REGIMES

Introduction. The prevention of the destruction of buildings and structures during a fire is ensured through strict compliance with requirements for the necessary fire resistance rating and classification. To guarantee reliable and safe operation during the design and construction stages, building materials and structures classified according to their reaction to fire and assessed by fire resistance class have been required.

Problem Statement. Since modern testing installations (furnaces) predominantly reproduce only the temperature regime of a standard fire, while other heating regimes remain difficult or impossible to simulate, the development and application of specialized testing installations and chambers capable of experimentally providing the required temperature exposures are highly relevant.

Purpose. The purpose of this study is to investigate the possibility of experimentally reproducing the temperature effects of nominal and alternative fire regimes using an innovative experimental installation.

Materials and Methods. The study has been conducted using an installation equipped with a $500 \times 500 \times 500$ mm chamber designed to assess the fire-protective efficiency of coatings. The test specimens consist of 500×500 mm steel plates with fire-protective coatings. External fire, slow-heating fire, and parametric fire regimes have been modeled by regulating the power of the heating elements and adjusting the distance between the heating elements and the specimen. The parametric temperature curve for a 60 m^2 fire compartment has been calculated using the FIN EC software package.

Citation: Veselivskyi, R. B., Kovalyshyn, V. V., Yakovchuk, R. S., Havrys, A. P., And Tarnavskyi, A. B. (2026). Innovative Approach to the Experimental Reproduction of Nominal and Alternative Fire Regimes. *Sci. innov.*, 22(3), 66–79. <https://doi.org/10.15407/scine22.03.066>

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Results. *Experimental tests have confirmed the effectiveness of reproducing nominal and alternative fire regimes using the developed installation. The design features and technical solutions have provided controlled regulation of chamber heating and cooling, ensuring that deviations of the temperature–time curves remain within permissible limits according to DSTU EN 1363-1:2023 and DSTU EN 1363-2:2023.*

Conclusions. *The stable operation of the electric heating elements has ensured effective reproduction of thermal regimes with deviations of less than 10% from standard fire curves. The developed installation has demonstrated its applicability for assessing the fire resistance of structures, determining the effectiveness of fire-protective coatings, and developing experimental and theoretical methods for studying the thermophysical properties of materials under nominal and alternative (realistic) fire regimes.*

Keywords: fire resistance, fire protection, nominal and alternative fire modes, building structure, test facility, electric heating element, civil protection and fire safety.

According to applicable building standards in Ukraine and internationally, the behavior of building structures under fire conditions must be considered at the design stage of a building or structure. A fire results in thermal exposure to building structures, which can lead to the failure of individual structural elements and, in severe cases, the collapse of the entire building. Preventing the destruction of building structures during a fire requires strict compliance with design standards, particularly those related to ensuring the required fire resistance rating of structural elements.

According to [1], depending on the type of building structure — for example, walls, partitions, or floors — the period during which the structure must maintain its thermal and mechanical properties is specified. These properties include integrity, load-bearing capacity, and thermal insulation capacity. For instance, a load-bearing wall in a building with the first degree of fire resistance must maintain its performance characteristics for 150 min, whereas a load-bearing wall in a building with the fourth degree of fire resistance is required to maintain these properties for 30 min. This parameter is critical for limiting the spread of fire within and between buildings and directly affects the safe evacuation of occupants, the protection of property, and the effectiveness of firefighting operations.

The current state of building and structural design is characterized by a wide variety of architectural, planning, and structural solutions, including high-rise buildings, large floor areas, atriums, and

various types of staircases, roofs, and complex-shaped coverings. In addition, modern construction widely uses both traditional building materials and structures — such as steel and reinforced concrete — and their combinations with new materials used for cladding, finishing, or improving structural strength and durability during operation.

To ensure the reliability and safety of buildings and structures, their design and construction require the use of building products and structural elements that are classified according to their reaction to fire and evaluated by fire resistance class [1, 2]. Consequently, studies investigating the influence of fire temperature regimes on the fire resistance of building structures remain highly relevant.

Research on the fire resistance of building structures and the effectiveness of fire-protection coatings is essential for ensuring the safe operation of buildings and structures. In particular, researchers focus on determining the influence of nominal and alternative fire temperature regimes on the fire resistance limits of building structures.

The influence of the standard fire temperature regime on steel building structures is examined in [3–5], where calculation-based and experimental methods for assessing the fire resistance of protected steel structures are presented. These studies also propose methodologies for evaluating fire-protective coatings by solving inverse heat conduction problems based on fire test data. In [6, 7], the authors develop a computational system for analyzing steel, concrete, and composite structures

under standard fire conditions, demonstrating its potential for thermostructural analysis during the design of building structures. Furthermore, the effect of standard fire exposure on the fire resistance of double-bonded precast concrete composite slabs, composite floors, beams, and decks is investigated in [8–11], demonstrating the effectiveness of composite materials and their positive influence on the fire resistance of the studied structures.

The impact of a hydrocarbon fire on cold-rolled steel columns was considered in [12], where the authors used the ABAQUS software package to develop a numerical finite element model to study the fire resistance, structural and thermal response of axially supported columns. Using the ANSYS computer program, Chaojie Song et al. [13] presented an approach to studying the behavior of prestressed reinforced concrete box girders under the influence of hydrocarbon fire, where they presented the response of the girders to the combined effect of the duration of fire exposure and simultaneous structural loading. In study [14], the correlation between the values of the time interval for maintaining the fire resistance of protected steel structures obtained for fire exposure under the temperature conditions of hydrocarbon and external fires and the values of this time interval for the standard temperature regime was estimated by the calculation method. Papers [15, 16] present the behavior and comparison of the effectiveness of reactive fire protective coatings in modeling scenarios of standard and hydrocarbon fires. Also, studies of the fire resistance of building structures using a hydrocarbon fire are relevant to the petroleum and gas chemical industry, which are updated and presented in [17–19].

Studies on determining the impact of the external fire regime and the parametric fire regime on building structures are presented in scholarly research papers [20–24], as a rule, the impact of these alternative fire regimes is reproduced by the calculation method.

Taking into account the review of publications, it should be noted that for the study of fire resistance of building structures and the effectiveness

of fire protection of coatings, the influence of not only the standard fire regime but also the external fire regime, hydrocarbon and parametric regimes is used. Given the fact that modern installations (furnaces) for research usually create the temperature of a standard fire, and the reproduction of other heating modes is difficult, and in some cases impossible, it is important to create and use special installations, test chambers that can experimentally reproduce both standardized and alternative (realistic) temperature effects.

The aim of the work is to study the possibility of experimentally reproducing the thermal effects of nominal and alternative fire modes using an innovative installation, the principle of operation of which is to heat the internal space of the furnace using electric heating elements.

To achieve the set goal, the following tasks were solved:

- ◆ analysis of the use of standardized and alternative temperature regimes to assess the fire resistance class of building structures or the fire protection effectiveness of fire-retardant coatings;
- ◆ using a test installation, the principle of operation of which is to heat the internal space of the furnace using electric heating elements, to investigate the dependence of the heating of the rig chamber on the required temperature regime;
- ◆ conduct experimental studies of the reproducibility of the experimental setup of the external fire regime, the slowly developing fire regime and the parametric fire regime.

The scientific novelty of the work lies in establishing the heating and cooling characteristics of an innovative installation, the principle of operation of which is to heat the internal space of the furnace using electric heating elements during experimental reproduction of nominal and alternative fire modes.

Applicable international standards for assessing the fire resistance of a building structure, which is determined by the time (in min) from the start of the fire test, use standardized nominal modes that correspond to a conditional fire scenario. Thus, standards [25–27] provide for the pos-

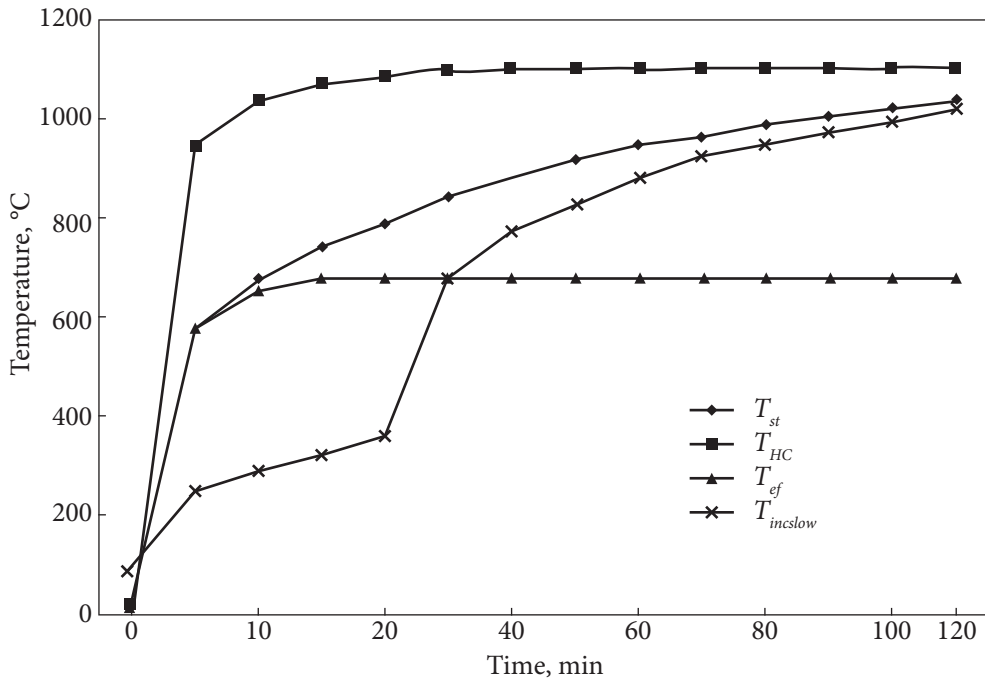


Fig. 1. Curves of temperature regimes: T_{st} is standard temperature regime; T_{HC} is temperature regime of a hydrocarbon fire; T_{ef} is temperature regime of an external fire; $T_{incslow}$ is temperature regime of a slowly developing fire

sibility of determining the fire resistance class of a building structure according to standardized temperature conditions with appropriate designations in the case of using a particular fire mode.

These temperature regimes include: standard temperature regime, hydrocarbon fire regime with the “HC” designation, external fire regime with the “ef” designation, slowly developing fire regime with the *IncSlow* designation, and parametric fire regime. The test procedure for additional/alternative modes regulated by [28] provides for the heating conditions of building structures, the need for experimental reproduction of which arises under certain conditions when a scenario different from the values of the temperature impact of the standard fire mode is identified during the development of a real fire. The graphs of the dependence of heating curves in the modes of hydrocarbon fire, slowly developing fire (smoldering fire), external fire and the standard temperature curve are shown in Fig. 1.

An example of a possible use of the hydrocarbon fire regime is in the petrochemical industry, oil

drilling platforms, nuclear power plants, etc. where there is a risk of very high intensity fires, for example, due to a flammable liquid spill. Since hydrocarbon fires are characterized by high temperatures and high speed of development, when experimentally reproducing this mode, the temperature in the test furnace (installation) should vary according to the dependence described by Eq. 1.

$$T = 1080 [1 - 0.325e^{-0.167t} - 0.675e^{-2.5t}] + 20, \quad (1)$$

where: t is the time interval from the beginning of the test, min; T is the average temperature in the furnace, °C.

The need for an experimental assessment of the fire resistance class of building structures under the external fire regime can be justified when a structure or product is exposed to a fire within a fire compartment. For example, when it is necessary to reproduce the impact of a fire on the exterior of isolated exterior walls that may be exposed to fire from different parts of the facade: directly from inside the corresponding fire com-

partment, from below or from the adjacent exterior wall. As a rule, this fire regime can be used to assess the fire resistance class of the building envelope. In this case, the temperature of this curve will be described by Eq. 2.

$$T = 660 [1 - 0.687e^{-0.32t} - 0.313e^{-3.8t}] + 20, \quad (2)$$

where: t is the time interval from the beginning of the test, min; T is the average temperature in the furnace, °C.

The slow fire mode can be used to test structures, usually when they are combined with products or materials that have reactive properties. In this case, the temperature effect on the structures will have the peculiarity of slow heating of the test specimen in the first 20 min from the start of the test. The dependence of the temperature change on time should be in accordance with Eqs. 3 and 4:

for $0 < t \leq 21$

$$T = 154 t^{0.25} + 20; \quad (3)$$

for $t > 21$

$$T = 345 \log_{10} (8 (t - 20) + 1) + 20. \quad (4)$$

It should be noted that [26, 27] provide for the possibility of using a parametric temperature-time dependence to assess the thermal impact of a fire on buildings and structures. When applying this regime, it is assumed that a fire occurs in a compartment up to 500 m² without openings in the coating and a maximum compartment height of 4 m. This temperature regime is characterized by two phases: heating and cooling. During the heating phase, the temperature change dependence is described by Eq. 5.

$$\theta_g = 20 + 1325 (1 - 0.324e^{-0.2t^*} - 0.204e^{-1.7t^*} - 0.472e^{-19t^*}), \quad (5)$$

where: θ_g is the ambient gas temperature in the fire compartment, °C;

$$t^* = t \cdot \Gamma;$$

where: t is the time of fire development, h; Γ is the coefficient that includes the parameters of the fire compartment, such as specific heat capacity, thermal conductivity, density and area of enclosing structures, area of vertical openings, window height and specific fire load.

The cooling stage of the parametric fire regime is described by Eq. 6, $a-c$.

$$\theta_g = \theta_{\max} - 625 (t^* - t_{\max}^* \cdot x) \text{ for } t_{\max}^* \leq 0.5, \quad (6, a)$$

$$\theta_g = \theta_{\max} - 260 (3 - t_{\max}^*) \cdot (t^* - t_{\max}^* \cdot x) \text{ for } 0.5 < t_{\max}^* < 2, \quad (6, b)$$

$$\theta_g = \theta_{\max} - 260 (t^* - t_{\max}^* \cdot x) \text{ for } t_{\max}^* > 2, \quad (6, c)$$

where: θ_{\max} is the maximum temperature.

$$t_{\max}^* = (0.2 \cdot 10^{-3} q_{t,d} / O) \cdot \Gamma \text{ (°C)};$$

$q_{t,d}$, s is the calculated fire load divided by the surface area (MJ/m²); $x = 1.0$ if $t_{\max} > t_{\lim}$, or $x = t_{\lim} \cdot \Gamma / t_{\max}^*$ if $t_{\max} = t_{\lim}$; t_{\lim} is the time of reaching the maximum temperature of the parametric temperature regime, which depends on the fire load.

The considered standardized (nominal) and alternative (parametric) fire temperature regimes make it possible to assess the fire resistance class of building structures and to evaluate the fire-protection effectiveness of fire-protective coatings using both experimental and computational methods. Such approaches do not contradict the applicable standards of Ukraine or international standards. The selection of a possible fire scenario and, consequently, the corresponding temperature exposure plays a key role in the accuracy of the calculated or experimental data obtained regarding the duration during which a structural system, its individual components, or a separate structure is able to satisfy the criteria of load-bearing and/or enclosing capacity. Traditionally, the most comprehensive and reliable results used by both designers and researchers have been obtained through combined theoretical (computational) and experimental studies. In theoretical studies, a computational (computer) model has been developed that most accurately reflects the geometric and thermophysical characteristics of a particular building structure (or structural system) subjected to temperature exposure according to Eqs. (1–6). Such modeling makes it possible to obtain a substantial amount of research data while allowing variation of key parameters,

including fire development conditions, fire load, air flow, compartmentalization into fire compartments, and the thermal properties of enclosing and load-bearing structures.

To confirm the results of theoretical studies, it is necessary to obtain experimental data on the response of an element or structure to the thermal effects of fire for subsequent comparison. Modern test furnaces [30] make it possible to reproduce the standard fire temperature regime, which is logical because the experimental determination of the fire resistance class of building structures during their use in construction is typically performed under such standardized thermal conditions. However, previous studies [31–35] have shown that deviations from the standard fire regime are not uncommon. Consequently, researchers have developed methods that allow temperature effects with such deviations to be correlated with standardized conditions [36–39].

The fundamental standard [1] establishes that calculation methods may be used to assess the fire resistance of the structural system of buildings, parts of structural systems, and individual building structures of any type; to interpolate and extrapolate the results of fire resistance tests of building structures; to evaluate the fire-protection effectiveness of fire-protective coatings; and to determine the scope of the extended application of these results. In addition, it is possible to calculate the fire resistance of building structures under fire conditions other than the standard fire regime. In such cases, approaches based on the consideration of a conditional or real fire scenario should be applied to assess fire resistance.

If the test furnace and equipment comply with the applicable standards and are used correctly, reproducing the standard fire condition does not present significant difficulty. However, the experimental reproduction of other nominal (standardized) and alternative (parametric) fire conditions — such as external fire conditions, slow-heating fire conditions, and parametric fire conditions — requires special attention and further research. As a rule, it is difficult to experimentally reproduce

the temperature–time dependencies described by Eqs. (2–6). This difficulty arises from the design characteristics of test furnaces, the power limitations of burners, and the complexity of accurately controlling temperature variations during heating and cooling.

To investigate the possibility of reproducing the standard fire temperature regime, the external fire regime, the slowly developing fire regime, and the parametric fire regime, an installation for determining the fire protection capacity (efficiency) of fireproof coatings and testing the fire resistance of small fragments of building structures was designed and constructed, the principle of which is to heat the interior of the furnace using electric heating elements [40] (hereinafter referred to as the test installation).

The test installation is a cube with an internal chamber measuring 500 × 500 × 500 mm. The body is thermally insulated with vermiculite plates (50 mm thick) covered with steel sheets. To create a temperature effect on the test samples, a heating radiation panel is used, which consists of three heaters with a power of 4 kW each, powered by 220 V. The test sample is secured using special brackets, which together form a mounting system. The sample for testing fire protection efficiency is a square steel plate (side length 500 mm) with a

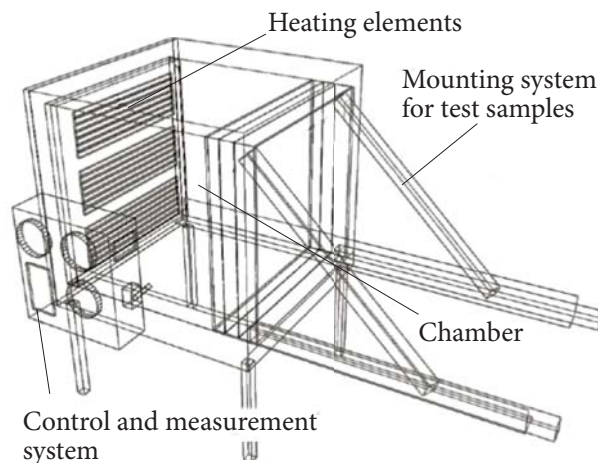


Fig. 2. Structural diagram of the test facility
Source: prepared by the authors.

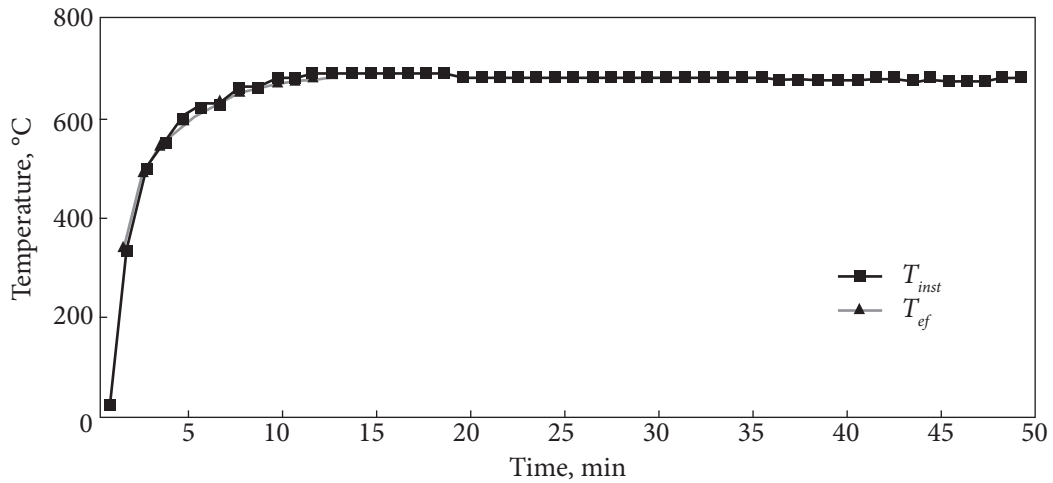


Fig. 3. Temperature and time dependence of the heating of the installation chamber: T_{ef} is normalized temperature regime of the external fire; T_{inst} is the average value of 3 tests of the heating of the installation chamber

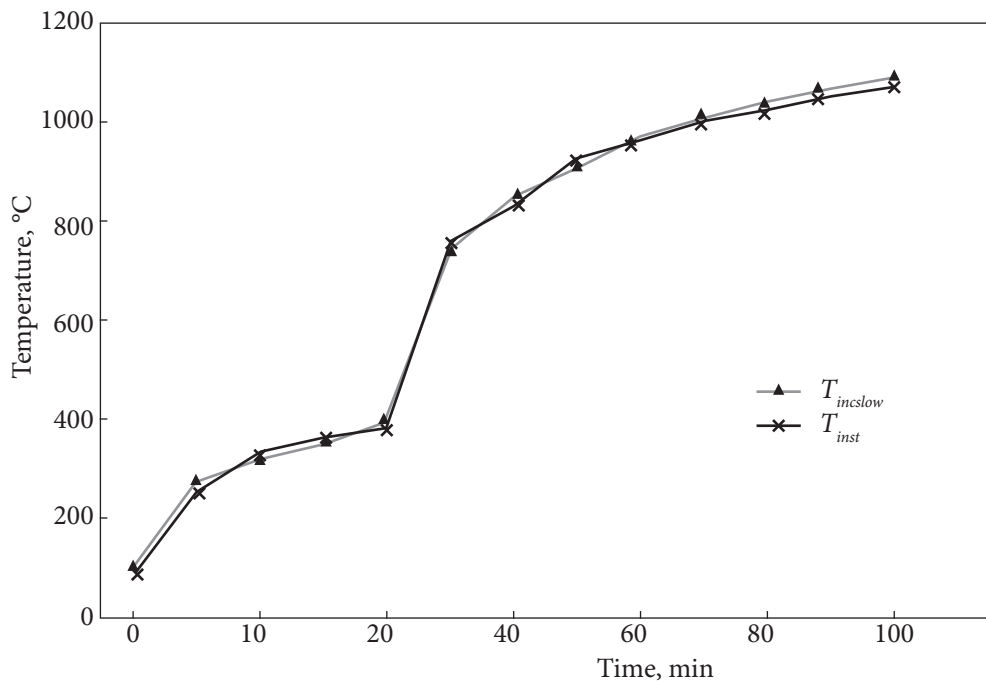


Fig. 4. Temperature and time dependence of the heating of the installation chamber: T_{inslow} is the normalized temperature of a slowly developing fire; T_{inst} is the average value of 3 tests of the heating of the installation chamber

fire-retardant coating on the side exposed to the heat of the test chamber. It is also possible to test other fragments of building structures (enclosing structures) with a side length of 500 mm. To cont-

rol the temperature on the non-heated side of the test sample, 1 to 5 thermocouples are installed. The temperature inside the chamber is controlled by thermocouples located at a distance of 10–15 cm

from the electric heating elements and at the same distance from the test sample, depending on the conditions of the experiments.

A schematic diagram of the test setup is shown in Fig. 2.

Using the design features of the test facility, namely the ability to increase or decrease the temperature on the heating surface of the prototype using the heating temperature regulator and the ability to approach or remove the prototype to the radiation panel along the guides, the standard fire temperature regime was experimentally reproduced. The research data are presented in detail in [40], where the authors performed experimental tests and found that the chamber of the installation warms up evenly and according to the temperature-time dependence $T_s = 345 \lg(8t + 1) + 20$. At the same time, temperature deviations do not exceed the permissible values according to DSTU EN 1363-1:2023 and DSTU EN 1363-2:2023, which takes into account the percentage deviation of the area under the average furnace temperature curve depending on the time interval from the start of the test. During these studies, it was found that for the accuracy and reproducibility of the heating mode in the first 5 min, it is necessary to preheat the installation to 600 °C. This makes it possible to obtain values very close to those established by the temperature-time dependence T_s .

The next stage of the work is an experimental study of the reproducibility of the results on the provision of the external fire mode, the slowly developing fire mode and the parametric fire mode by the experimental installation, taking into account the peculiarities of the experimental study of the reproducibility of the standard fire temperature mode.

Figure 3 shows the results of the experimental reproduction of the thermal effect of the external fire regime, the value of the temperature change over time of which is described by formula 2 and graphically depicted in Fig. 1.

As can be seen from the results of the study, it was possible to reproduce this fire mode within the tolerances regulated by the standards [25, 28]. Given that this mode involves an intense temperature

increase in the first 6 min (up to 613 °C), which is higher than in the standard curve, the installation was preheated to 700 °C. This made it possible to reproduce the peak temperature increase at the initial stage, as predicted by dependence (2).

When reproducing the slowly developing fire regime, the experimental values of the temperature versus time were obtained, which correspond to dependences (3) and (4). As required by the standard, in the first 20 min of the experiment, the temperature of the thermal effect on the prototype was 380 °C. After 25 min of the experiment, the intensity of the temperature increase was ensured by sharply increasing the temperature on the thermostat and bringing the test sample closer to the heating elements. The results of the study are shown in Fig. 4.

For the experimental reproduction of the parametric fire regime, a fire compartment of 60 m² with brick enclosing structures and concrete floor and ceiling was chosen. The fire load was assumed to be 450 MJ/m². This parametric fire regime was modelled using a licensed software package [41]. The schematic floor plan of the fire compartment is shown in Fig. 5, and the geometric and thermal parameters of the building envelope and openings are given in Table 1.

The thermophysical characteristics of the floor and ceiling materials are accepted as for reinforced concrete structures and are as follows: density $\rho = 2400 \text{ kg/m}^3$; specific heat $c = 840 \text{ J/kg/K}$; thermal conductivity $\lambda = 1.5 \text{ W/m/K}$.

Table 1. Geometric and Thermal Parameters of Enclosing Structures and Openings

| Wall number | Length, m | Material (masonry) | | | Openings | |
|-------------|-----------|------------------------------------|----------------------------|--|---------------|----------------|
| | | Density ρ , kg/m ³ | Specific heat c , J/kg/K | Thermal conductivity λ , W/m/K | Width b , m | Height h , m |
| 1 | 10 | 2000 | 880 | 0.58 | 3 | 1.8 |
| 2 | 6 | 2000 | 880 | 0.58 | 2 | 1.6 |
| 3 | 10 | 2000 | 880 | 0.58 | 3 | 2 |
| 4 | 6 | 2000 | 880 | 0.58 | 2 | 2 |

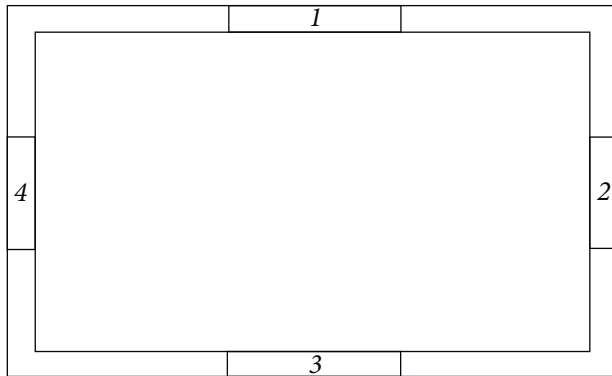


Fig. 5. Floor plan of the fire compartment: 1—4 — wall number of the fire compartment with Opening
 Source: prepared by the authors.

The fire parameters in the adopted fire compartment are shown in Table 2.

According to Appendix A and E [27], the result of the calculation is the values of the parameters that determine the parametric temperature curve for the fire zone.

The parameter values are as follows: opening factor (O) = 0.117 m^{1/2}; thermal absorptivity for the total enclosure (b) = 1453.2 J/(m²s^{1/2}K); the design value of the fire load density, relative to the total boundary structures of the fire compartment ($q_{t,d}$) = 114.4 MJ/m².

Time for maximum gas temperature: $t_{max} = 20.0$ min; $t_{max} = t_{lim} \rightarrow$ fuel-controlled fire.

Table 2. The Fire Parameters

| Parameter | Meaning |
|--|-------------------------|
| Time of fire development (t_{lim}) | 20.0 min |
| The characteristic fire load density per unit floor area ($q_{f,k}$) | 450.0 MJ/m ² |
| Factor of combustion (m) | 0.8 |
| Factor related to the fire activation risk due to the size of the compartment (δ_{q_1}) | 1.144 |
| Factor related to the fire activation risk due to the type of occupancy (δ_{q_2}) | 1.000 |
| Factor related to the different active fire-fighting measures (δ_n) | 1.000 |

The parametric curve graph is described by the functions:

$$\theta_g = 20 + 1325(1 - 0.324e^{-0.002t} - 0.204e^{-0.013t} - 0.472e^{-0.149t}) \text{ — for } t \text{ within } 20\text{—}0,$$

$$\theta_g = 689.632 - 44.166(t - 20) \text{ — for } t \text{ within } 20\text{—}35,$$

$$\theta_g = 20 \text{ — for } t > 35.$$

where: θ_g is the temperature, °C and t is time, min.

Figure 6 shows a graph of temperature versus time during the heating and cooling stages for a selected fire compartment of 60 m².

After obtaining the calculated values of the temperature change of the parametric curve, the next step is to conduct a study on the experimental reproduction of this mode. The results of the experiment are shown in Fig. 7.

As shown by the obtained data, the experimentally reproduced and modeled parametric fire development regime in a fire compartment of 60 m² are in good agreement (Figs. 6, 7). A positive outcome of the study is the successful experimental reproduction of the calculated temperature values during the cooling stage. This is achieved by gradually moving the specimen away from the heating elements and rapidly reducing the temperature using the thermostat.

The experimental results confirm the effectiveness of the proposed innovative approach to the reproduction of nominal and alternative fire regimes using the installation designed to determine the fire-protection capacity (efficiency) of fire-protective coatings and to conduct fire-resistance tests on small fragments of building structures.

The practical significance of these results lies in the possibility of experimentally reproducing both standardized and alternative (realistic) temperature exposures on fragments of building structures. This capability allows a preliminary assessment of the fire resistance limit of such structures and enables the evaluation of the fire-protection effectiveness of fire-retardant coatings.

The studies have demonstrated that the test installation is capable of generating temperature ex-

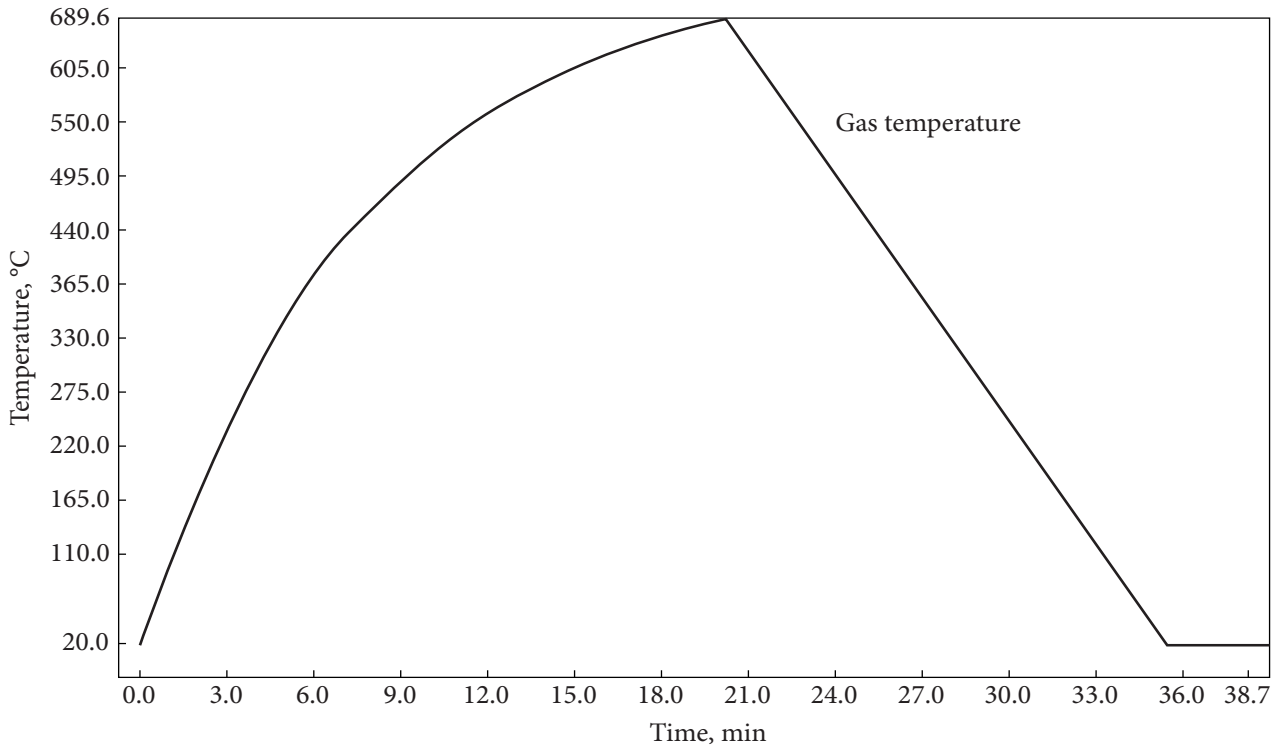


Fig. 6. Temperature versus time graph for a 60 m² fire compartment

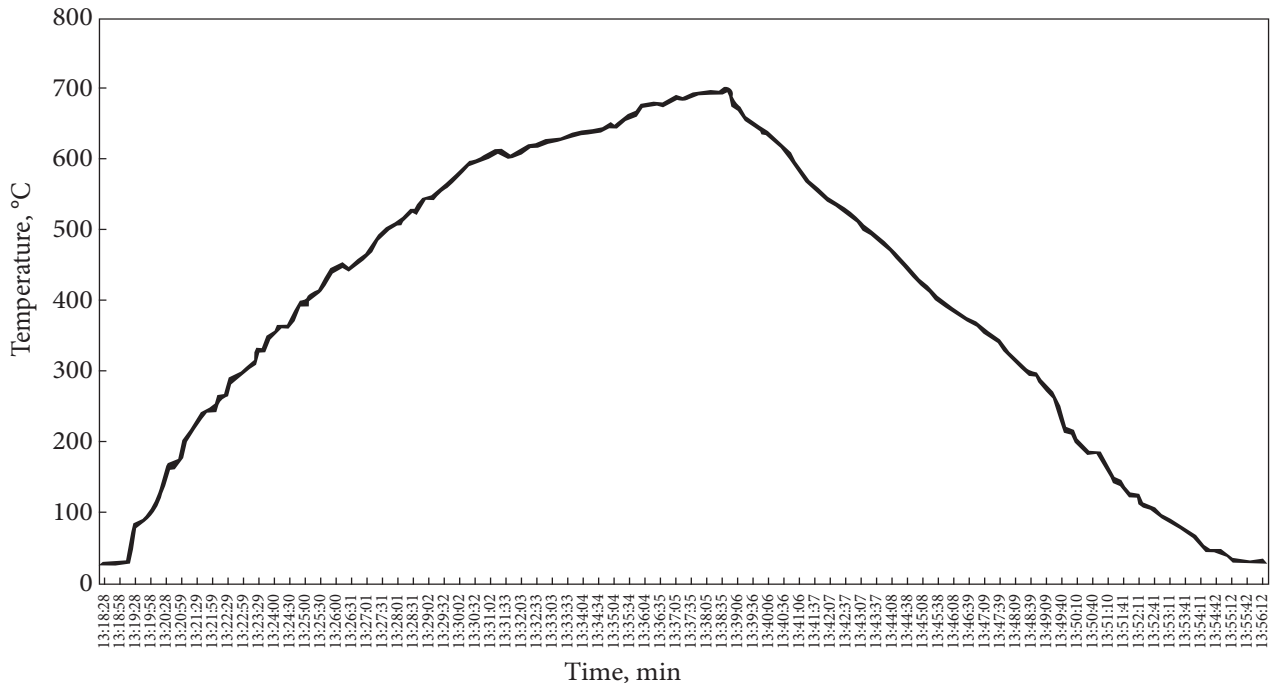


Fig. 7. Experimentally reproduced temperature and time dependence of heating of the installation chamber for a fire compartment of 60 m²

posures that meet the requirements of the standards for assessing the fire resistance of building structures and determining the fire-protection efficiency of fire-protective coatings. Based on the experimental results, both nominal and alternative fire regimes are reproduced, including the external fire regime, the slowly developing fire regime, and the parametric fire regime. The temperature deviation observed during the experiments does not exceed the permissible limits specified in DSTU EN 1363-1:2023 and DSTU EN 1363-2:2023. The stable operation of the electric heating elements generating the thermal exposure ensures effective reproduction of fire regimes, with the difference between the experimentally reproduced thermal conditions and the standardized ones remaining below 10%.

Further scholarly research should focus on the mathematical description of fire temperature regimes during the heating and cooling stages when using the designed installation for determining the fire-protection capacity (efficiency) of fire-protec-

tive coatings and testing the fire resistance of small fragments of building structures. The operating principle of the installation is based on heating the furnace interior using electric heating elements. For this purpose, it is necessary to experimentally investigate the dependence of the maximum fire temperature (regime) on the temperature generated by the heating elements of the installation and on the width of the gap between the tested specimen and the electric heating elements. It is also necessary to study the dependence of the temperature decrease time during the parametric fire regime on the maximum temperature of the parametric regime and on the width of the gap between the specimen and the electric heating elements after the heating elements are switched off. The obtained results provide the basis for the development of an experimental and theoretical method for studying the thermophysical characteristics of fire-retardant materials when assessing the effects of standardized and alternative fire regimes on the fire resistance of building structures.

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Received 05.05.2025

Revised 06.10.2025

Accepted 25.12.2025

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ІННОВАЦІЙНИЙ ПІДХІД ДО ЕКСПЕРИМЕНТАЛЬНОГО ВІДТВОРЕННЯ НОМІНАЛЬНИХ ТА АЛЬТЕРНАТИВНИХ РЕЖИМІВ ПОЖЕЖІ

Вступ. Запобігання руйнуванню будівель і конструкцій під час пожежі забезпечується суворим дотриманням норм щодо необхідної межі та класу вогнестійкості. Для гарантування надійної та безпечної експлуатації під час проектування і зведення слід застосовувати будівельні вироби й конструкції, класифіковані за реакцією на вогонь і оцінені за класом вогнестійкості.

Проблематика. Оскільки сучасні установки (печі) здебільшого відтворюють лише температурний режим стандартної пожежі, а інші режими нагріву є складними або неможливими для моделювання, актуальним є створення та застосування спеціальних випробувальних установок і камер, здатних експериментально забезпечити потрібні температурні впливи.

Мета. Вивчення можливості експериментального відтворення температурного впливу номінальних та альтернативних режимів пожежі з використанням інноваційної установки.

Матеріали й методи. Дослідження виконано на установці з камерою 500 × 500 × 500 мм для оцінки вогнезахисної ефективності покриттів. Зразки — сталеві пластини 500 × 500 мм із покриттям. Режими зовнішньої, повільно розвиваючої та параметричної пожеж моделювали регулюванням потужності нагрівальних елементів і відстані до зразка. Параметричну криву для відсіку 60 м² розраховано у програмі FIN EC.

Результати. Експериментальні випробування підтвердили ефективність відтворення номінальних і альтернативних режимів пожежі за допомогою розробленої установки. Конструкція та технічні рішення забезпечують регулювання нагріву й охолодження камери з відхиленнями температурно-часових залежностей у межах, допустимих ДСТУ EN 1363-1:2023 та ДСТУ EN 1363-2:2023.

Висновки. Стабільна робота електронагрівальних елементів забезпечила ефективне відтворення теплових режимів із розбіжністю зі стандартними менше 10 %. Установку можна застосовувати для оцінки вогнестійкості конструкцій, визначення ефективності вогнезахисних покриттів і розроблення експериментально-теоретичних методів дослідження теплофізичних властивостей матеріалів за номінальних і альтернативних режимів пожежі.

Ключові слова: вогнестійкість, вогнезахист, номінальні та альтернативні режими пожежі, будівельна конструкція, випробувальна установка, електричний нагрівальний елемент, цивільний захист та пожежна безпека.