

UDC 697.347

Bogdan Fediai \*

Limited Liability Company Scientific and Technical Enterprise «ALMAGROUP»

<https://orcid.org/0000-0001-6323-7185>

Dmytro Fedorov

Limited Liability Company Scientific and Technical Enterprise «ALMAGROUP»

<https://orcid.org/0000-0002-2591-7291>

## Mathematical model of thermal regime of uninsulated transit pipes of heating networks layed in frame plasterboard structures of rooms with individual heating

**Abstract.** This article proposes a system of heat balance equations and a comprehensive methodology for determining heat gains from transit district heating pipelines integrated into lightweight gypsum board framed structures. The results derived from the proposed mathematical model were validated against empirical field measurements and compared with existing normative methodologies for assessing heat gains from heat supply transit pipelines. Such methodologies are standardly employed in thermal energy accounting with utility providers and within energy audits of residential and public buildings.

**Keywords:** transit pipelines of district heating networks, heat balance, temperature schedule, heating, thermal energy, energy audit, heat gains, energy demand, energy consumption

\*Corresponding author E-mail: [fed.bn.office@gmail.com](mailto:fed.bn.office@gmail.com)



Copyright © The Author(s). This is an open access article distributed under the terms of the Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International License.

(<https://creativecommons.org/licenses/by-nc-sa/4.0/>)

Received: 02.02.2026

Accepted: 25.02.2026

Published: 31.05.2026

### Introduction.

The thermal regime of a building and its individual rooms depends on numerous factors. Most significant are the protective thermal properties of the external structures and the compliance of engineering heat supply systems with design loads and regulatory standards. Furthermore, these factors are the primary drivers of operational costs during the heating period.

In specific instances, additional operational heating costs—not directly related to the energy efficiency of the building or its heating system—arise from the presence of transit pipelines from district heating networks or distribution subsystems within the consumer's premises. Under these conditions, it becomes essential to accurately determine the amount of thermal energy transferred to the room volume from these transit pipelines.

Analysis of recent research sources and publications. Operational costs for thermal energy consumption are typically determined by heat meter readings. However, when transit pipelines are located in premises with individual heating, or when heat gains from these pipelines are not captured by the consumer's heat meter, an additional thermal load is billed to the consumer [1, 2]. The volume of heat gains from these

pipelines is determined by the heat supplier in accordance with [1] using the following formula, Gcal:

$$Q_{h.g.} = 0,86 \cdot 10^{-6} \cdot q_{h.l.p} \cdot l_{h.l.p} \cdot m_{h.p} \quad (1)$$

where  $0.86 \times 10^{-6}$  is the conversion factor for physical units, W·h to Gcal;

$q_{h.l.p}$  is specific heat loss from insulated pipelines laid in shafts, ducts, chases, or grooves, W/m;

$l_{h.l.p}$  is total length of all transit pipelines located within the premises with individual heating or in a separate room containing transit heating networks, m;

$m_{h.p.}$  is actual number of hours of heat supply service provision during the billing period, h.

Document [1] proposes a specific heat loss value of  $q_{h.l.p} = 7$  for insulated pipelines. For uninsulated pipelines or those with damaged insulation, it is recommended to increase  $q_{h.l.p}$  by 100% (to  $q_{h.l.p} = 7$  W/m) or to utilize values specified in design documentation or derived from an energy audit.

In contrast, the first edition of [1] proposed determining the volume of heat gains from transit pipelines using the following formula, Gcal:

$$Q_{h.g.} = 0,86 \cdot 10^{-6} \cdot 14 \cdot (t - t_{in.norm}) \cdot l \cdot d \cdot \tau \quad (2)$$

where 14 is the overall heat transfer coefficient of the external surface of an uninsulated pipeline, W/(m<sup>2</sup>·K);

$t$  is temperature of the internal surface of the pipeline, °C. According to the recommendations of [1], for any pipeline of the intra-building heating system, a value of 45 °C is adopted for the heating period, and for any pipeline of the intra-building domestic hot water system – 52.5 °C.

$t_{in, norm}$  is normative indoor air temperature of the room/premises, adopted in accordance with the provisions of [1] for the heating period, °C;

$l$  is length of the transit pipeline, m;

$d$  is external diameter of the pipeline, m;

$\tau$  is number of hours in the billing period, h.

The methodology for determining heat gains from uninsulated transit pipelines according to formula (1) in the current edition of [1] differs from the first edition by omitting the influence of pipeline diameters, heat carrier parameters, ambient temperatures, and installation conditions. This simplification leads to significant discrepancies between theoretical calculations and empirical data obtained from field measurements.

Furthermore, the results derived from formula (2) lack sufficient accuracy because the boundary conditions on the external surface of the pipeline – as well as the heat carrier parameters at the supply outlet and return inlet – remain undefined during the design stage. Additionally, the methodology for determining the surface area of the pipelines within formula (2) remains problematic. Because the internal surface temperature ( $t$ ) is predetermined, the formula fails to account for the wide variation in temperature schedules typical of modern heating systems and district heating networks.

During energy audits, the assessment of heat gains from transit pipelines over the heating period is typically performed by energy auditors in accordance with the methodology defined in [4]. The heat losses of the distribution subsystems during the  $i$ -th month,  $W \cdot h$ , are calculated using the formula from [4],  $W$ :

$$Q_{H, dis, ts, i} = \sum \Psi_{L, j} \cdot (\theta_{m, i} - \theta_{i, j}) \cdot L_j t_{op, an, i} \quad (3)$$

where  $\Psi_{L, j}$  is the linear heat transfer coefficient of the  $j$ -th pipeline,  $W/(m \cdot K)$ ;

$\theta_{m, i}$  is average heat carrier temperature in the zone during the  $i$ -th month, °C. It is determined according to the temperature schedule for weather-compensated control of the heat carrier based on the average monthly outdoor air temperature for the respective month (Table A.2 of Annex A to [4]).

$L$  is pipeline length, 34 m;

$\theta_{i, j}$  is ambient air temperature, °C;

$j$  is index denoting pipelines with identical boundary conditions;

$t_{op, an, i}$  – heating hours during the  $i$ -th month, h.

The linear heat transfer coefficient for uninsulated pipelines ( $\Psi_{non}$ ) to the air, taking into account the overall heat transfer coefficient that includes

convection and radiation from the external surface,  $W/(m \cdot K)$ , is calculated using the formula from [4]:

$$\Psi_{non} = \frac{\pi}{\left( \frac{1}{2\lambda_p} \ln \frac{d_{p, a}}{d_{p, i}} + \frac{1}{h_a d_{p, a}} \right)} \quad (4)$$

where  $h_a$  – is the overall heat transfer coefficient of the external surface (by convection and radiation),  $W/(m^2 \cdot K)$ . According to clause 15.5.2.2.2 of [4], for uninsulated pipelines,  $h_a = 14 W/(m^2 \cdot K)$ ;

$\lambda_p$  – thermal conductivity of the pipeline material,  $W/(m \cdot K)$ ;

$d_{p, i}$ ,  $d_{p, a}$  – internal and external diameters of the uninsulated pipeline, respectively, m.

The correct assessment of heat gains from transit pipelines using formula (3) is also complicated because the boundary conditions on the external surface of the pipelines and the influence of installation conditions on them remain undefined. It is known that the use of non-walk-through channels increases the thermal resistance of heating networks [5]; the same applies to lightweight gypsum board constructions, niches, and similar structures. In addition, the methodology presented in [4] considers the supply and return pipelines as a single pipeline with a weighted average heat carrier temperature between the supply and return pipelines, in accordance with the temperature schedule of the heat source. This approach also reduces the accuracy of analytical calculations.

The determination of the average heat carrier temperature for individual months of the heating period in [4] is proposed to be performed according to the heat carrier temperature schedule depending on the average monthly outdoor air temperature for the respective month, as per Table A.2 of [4]. At the same time, the determination of heating hours  $t_{op, an}$  is suggested to be carried out with the following simplifications: heating is continuous from November to March, 360 hours in October, and 240 hours in April, as adopted in accordance with [6]. For the conditions of Poltava, the temperature schedule of the heat carrier from boiler plants is calculated within the limits of the start/end of the heating period at an outdoor air temperature of +8 °C. Operating experience of district heating networks in Poltava shows that the heating season typically begins in mid-October and ends in the first half of April.

Table 1 presents the results of calculations of the average heat carrier temperature and heat gains from transit pipelines performed in accordance with [4].

Input data for the calculation: heat carrier temperature schedule 87/65 °C; external diameter of transit pipelines of the heating network 108 mm; internal diameter of transit pipelines of the heating network 100 mm; length of the supply pipeline 17 m; length of the return pipeline 17 m; installation conditions – within a gypsum board enclosure.

**Table 1 – Results of calculation of heat gains from uninsulated transit pipelines by months of the heating period.**

Name of the parameter	Month of the year											
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Month of the year												
Average monthly outdoor air temperature, °C	-5.6	-4.7	0.3	9	15.4	18.7	20.5	19.7	14.3	7.7	1.3	-3.3
Number of days, days	31	28	31	30	31	30	31	31	30	31	30	31
Heating hours during the i-th month $t_{op,an,i}$ , h	744	672	744	-	-	-	-	-	-	360	720	744
Average heat carrier temperature $\theta_{m,i}$ , °C	44.3	43.5	39	-	-	-	-	-	-	32.14	40	42.14
$Q_{H,dis,ls,i}$ , Gcal	1.99	1.72	1.44	-	-	-	-	-	-	0.36	1.50	1.77
$\sum Q_{H,dis,ls,i}$ , Gcal	8.78											

The data presented in Table 1 illustrate one of the characteristic shortcomings of the methodology outlined in [4]. As noted earlier, the outdoor air temperature corresponding to the start and end of the heat carrier temperature schedule for the city of Poltava is +8 °C, which corresponds to mid-April. At the same time, according to the data in Table A.2 of [4], which are decisive for calculating the average heat carrier temperature for each month, the average monthly air temperature in April is +9 °C. As a result, heat gains from the transit pipelines of the heating networks during the month of April remain unaccounted for in

the heat balance of the premises when performing an energy audit.

However, even under these conditions, as will be shown below, the calculated value of heat gains from the transit pipelines significantly exceeds the actual value.

Table 2 presents a comparison of the results of calculating heat gains from uninsulated transit pipelines of the heating network laid within lightweight gypsum board framed constructions, based on the above-mentioned input data.

**Table 2 – Results of the calculation of heat gains from uninsulated transit pipelines of the heating network over the heating period.**

Results of the calculation of heat gains from uninsulated transit pipelines of the heating network over the heating period		
Heat gains according to methodology [4], Gcal/heating season	Heat gains according to methodology [1], Gcal/heating season	Heat gains according to the first edition of methodology [1], Gcal/heating season
8.78	1.75	4.72

Other methods for assessing heat losses from heat supply system pipelines [5, 7] relate to the installation of district heating pipelines using trenchless methods, in walk-through, semi-walk-through, and non-walk-through channels under soil conditions. These conditions differ significantly from the installation conditions within heated premises.

**Identification of previously unresolved aspects of the general problem.**

Existing methods for the analytical assessment of heat gains from transit pipelines of heat supply systems laid within lightweight gypsum board framed constructions do not provide sufficient accuracy of calculations. The use of modern automated computational systems for mathematical modeling of heat transfer processes allows solving this problem;

however, it requires a high level of scientific and technical qualification of the performers, as well as expensive software products.

#### Problem statement.

In view of the above, there is a need to develop a methodology for assessing heat gains into the volume of a heated room from uninsulated transit pipelines of district heating networks with an accuracy sufficient for engineering calculations.

#### Main material and results.

For the development of a mathematical model of heat exchange, a number of simplifying assumptions were preliminarily adopted: the air temperature in the room is constant and maintained by thermostatic valves of heating devices; the heat carrier temperature at the inlet of the supply pipeline and at the outlet of the return pipeline is predetermined in accordance with the

temperature schedule of the heat source; the model of heat flows is considered on the basis of a point model (averaging the temperature over the surface area of the body and the air volume); the mutual influence of adjacent pipelines is neglected; heat transfer from the external surface of the pipelines occurs to the internal air of the enclosure, while heat exchange between the pipeline and the enclosure walls is neglected; heat exchange with the internal brick wall and the room ceiling is neglected; the heat flow scheme is one-dimensional; the thermal resistance of the steel pipeline wall is neglected — the temperatures on the inner and outer walls of the pipeline are assumed to be the same.

Figure 1 shows the design scheme of heat flows from the district heating pipelines laid in lightweight gypsum board framed constructions to the surrounding environment.

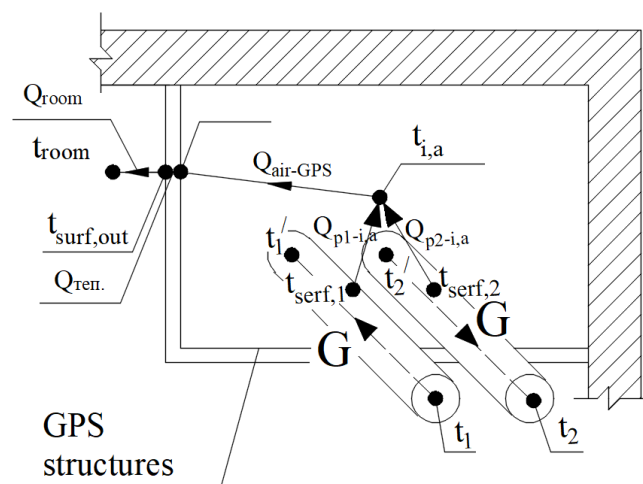


Figure 1 – Schematic diagram of heat flows in lightweight gypsum board framed constructions of a room with transit pipelines of district heating networks.

As the heat carrier with a flow rate  $G$  flows through a pipeline of diameter  $d$ , convective heat transfer occurs between the heat carrier and the pipeline walls, leading to its cooling from temperature  $t_1$  to  $t_1'$  in the case of the supply pipeline, and from  $t_2'$  to  $t_2$  in the case of the return pipeline. This heat transfer causes an increase in the temperature of the external surface of the transit pipeline walls to the value  $t_{serf,i}$ . Simultaneously, the process of heat energy transfer occurs in the amount of  $Q_{p1-i,a}$  (from the surface of the supply pipeline) and  $Q_{p2-i,a}$  (from the surface of the return pipeline) to the internal air of the enclosure, resulting in an increase in the temperature of the latter to the value  $t_{i,a}$ .

The heat balance equations for the heat carrier in the supply and return pipelines can then be written as follows, W:

– for the supply pipeline:

$$c \cdot G \cdot \frac{t_1 - t_1'}{3600} = k \cdot \pi \cdot d \cdot l_1 \cdot (t_{aver1} - t_{i,a}) \quad (5)$$

– for the return pipeline:

$$c \cdot G \cdot \frac{(t_2' - t_2)}{3600} = k \cdot \pi \cdot d \cdot l_2 \cdot (t_{aver2} - t_{i,a}) \quad (6)$$

where  $c$  is the specific heat capacity of the heat carrier, J/(kg·°C);

$t_1, t_2$  are, respectively, the temperatures of the heat carrier at the inlet of the supply pipeline and at the outlet of the return pipeline, °C;

$t_1', t_2'$  are, respectively, the temperatures of the heat carrier at the outlet of the supply pipeline and at the inlet of the return pipeline, °C;

$G$  is the hourly mass flow rate of the heat carrier circulating in the pipeline, kg/h;

$t_{i,a}$  is the volume-averaged temperature of the internal air within the duct, °C;

$l_1, l_2$  are, respectively, the lengths of the sections of the supply and return transit pipelines, m;

$d$  is the outer diameter of the transit pipeline, m;

$k$  is the heat transfer coefficient from the surface of the uninsulated pipeline to the internal air of the duct, determined in accordance with the applicable standard [8], W/(m<sup>2</sup>·°C);

$t_{aver1}, t_{aver2}$  are, respectively, the average (along the pipeline length) temperatures of the heat carrier in the supply and return transit pipelines, °C.

In accordance with the previously adopted simplifying assumptions, the average temperature of the heat carrier in the supply pipeline, °C, is given by:

$$t_{aver1} = \frac{t_1 + t'_1}{2} \quad (7)$$

For the return pipeline, the average temperature of the heat carrier in the return pipeline, °C, is given by:

$$t_{aver2} = \frac{t_2 + t'_2}{2} \quad (8)$$

The temperature of the heat carrier at the inlet of the supply pipeline or at the outlet of the return pipeline can be determined by averaging the corresponding values from the heat carrier temperature schedule, which correspond to the duration curve of hourly temperatures, according to the following formula, °C:

$$t_i = \frac{\sum_{i=1}^n t_i \cdot \tau_i}{\sum_{i=1}^n \tau_i} \quad (9)$$

where  $t_i$  is the temperature of the heat transfer fluid according to the temperature schedule, corresponding to the specified values of the outdoor air temperature duration curve within the heating period, °C;

$\tau_i$  is the duration of occurrence of the outdoor air temperature in accordance with the temperature duration curve within the temperature range of the heat transfer fluid temperature schedule, h.

Due to the temperature difference between the internal air of the duct,  $t_{i,a}$ , and the temperature of the inner surface of the duct enclosing structures,  $t_{surf,in}$ , heat transfer occurs between them. The amount of thermal energy transferred from the internal air of the duct to the inner surface of its enclosing structures can be determined using the following expression  $Q_{air-GPS}$ , W:

$$Q_{air-GPS} = \alpha_{in} \cdot F_{GPS} \cdot (t_{i,a} - t_{surf,in}) \quad (10)$$

where  $\alpha_{in}$  is the heat transfer coefficient from the internal air of the duct to the inner surface of the enclosing structures, determined in accordance with the recommendations [8], W/(m<sup>2</sup>·°C);

$F_{GPS}$  is the surface area of the enclosing elements of the frame gypsum plasterboard structure, m<sup>2</sup>;

$t_{surf,in}$  is the area-averaged temperature of the inner surface of the walls of the gypsum plasterboard structure, °C.

Then, the heat balance equation for the internal air of the duct takes the following form:

$$Q_{p1-i,a} + Q_{p2-i,a} = Q_{air-GPS} \quad (11)$$

Or, taking into account Eqs. (1), (2), and (11), we obtain:

$$\begin{aligned} & k \cdot \pi \cdot d \cdot l_1 \cdot (t_{aver1} - t_{i,a}) + \\ & + k \cdot \pi \cdot d \cdot l_2 \cdot (t_{aver2} - t_{i,a}) = \\ & = \alpha_{in} \cdot F_{GPS} \cdot (t_{i,a} - t_{surf,in}) \end{aligned} \quad (12)$$

The heat flux transferred from the internal air of the duct to the inner surface of its enclosing structures leads to an increase in the temperature of the latter and induces heat transfer by conduction between the inner

$t_{surf,in}$  and outer  $t_{surf,out}$  surfaces of the duct walls. The amount of thermal energy transferred by conduction is determined by the well-known relation  $Q_{th,c}$ , W:

$$Q_{th,c} = \sum_{i=1} \frac{\lambda_i}{\delta_i} \cdot F_{GPS} \cdot (t_{surf,in} - t_{surf,out}) \quad (13)$$

where  $\lambda_i$  is the thermal conductivity coefficient of the i-th structural or finishing material of the duct walls, W/(m·°C);

$\delta$  is the thickness of the i-th structural or finishing material of the duct walls, m;

$t_{surf,out}$  is the area-averaged temperature of the outer surface of the gypsum plasterboard structure walls, °C.

Under these conditions, the heat balance equation for the inner surface of the duct enclosing structures takes the following form:

$$\begin{aligned} & \alpha_{in} \cdot F_{GPS} \cdot (t_{i,a} - t_{surf,in}) = \\ & = \sum_{i=1} \frac{\lambda_i}{\delta_i} \cdot F_{GPS} \cdot (t_{surf,in} - t_{surf,out}) \end{aligned} \quad (14)$$

The heat flux  $Q_{th,c}$ , transferred from the inner to the outer surface of the duct enclosing structures due to thermal conduction, increases the temperature of the latter, which results in heat transfer from the outer surface of the duct to the room air in the amount of  $Q_{room}$ .

$$Q_{room} = \alpha_{out} \cdot F_{GPS} \cdot (t_{surf,out} - t_{room}) \quad (15)$$

where  $\alpha_{out}$  is the heat transfer coefficient from the outer surface of the duct enclosing structures to the room air, determined in accordance with the recommendations [8], W/(m<sup>2</sup>·°C).

Then, the heat balance equation for the outer surface of the duct enclosing structures takes the following form:

$$\begin{aligned} & \sum_{i=1} \frac{\lambda_i}{\delta_i} \cdot F_{GPS} \cdot (t_{surf,in} - t_{surf,out}) = \\ & = \alpha_{out} \cdot F_{GPS} \cdot (t_{surf,out} - t_{room}) \end{aligned} \quad (16)$$

Taking into account Eqs. (5) – (8), (12), (14), (16) the system of equations describing the heat exchange of transit district heating pipelines installed within a gypsum plasterboard structure with the room air is formulated in the form presented in Eq. (17).

The solution of the specified system of heat balance equations makes it possible to determine: the temperature of the heat carrier at the outlet of the supply pipeline and at the inlet of the return transit pipeline of the district heating network; the average surface temperature of the supply and return pipelines; the volume-averaged temperature of the internal air within the gypsum plasterboard duct; the area-averaged temperatures of the inner and outer surfaces of the gypsum plasterboard enclosure; and the amount of thermal energy transferred from the transit pipelines to the room volume.

To verify the validity of the developed mathematical model of the thermal regime of transit pipelines, a comparison between the calculated results and in-situ measurement data was performed.

$$\left\{ \begin{array}{l}
 c \cdot G \cdot \frac{t_1 - t_1'}{3600} = k \cdot \pi \cdot d \cdot l_1 \cdot (t_{aver1} - t_{i,a}) \\
 c \cdot G \cdot \frac{(t_2' - t_2)}{3600} = k \cdot \pi \cdot d \cdot l_2 \cdot (t_{aver2} - t_{i,a}) \\
 t_{aver1} = \frac{t_1 + t_1'}{2} \\
 t_{aver2} = \frac{t_2 + t_2'}{2} \\
 k \cdot \pi \cdot d \cdot l_1 \cdot (t_{aver1} - t_{i,a}) + k \cdot \pi \cdot d \cdot l_2 \cdot (t_{aver2} - t_{i,a}) = \alpha_{in} \cdot F_{GPS} \cdot (t_{i,a} - t_{surf,in}) \\
 \alpha_{in} \cdot F_{GPS} \cdot (t_{i,a} - t_{surf,in}) = \sum_{i=1} \frac{\lambda_i}{\delta_i} \cdot F_{GPS} \cdot (t_{surf,in} - t_{surf,out}) \\
 \sum_{i=1} \frac{\lambda_i}{\delta_i} \cdot F_{GPS} \cdot (t_{surf,in} - t_{surf,out}) = \alpha_{out} \cdot F_{GPS} \cdot (t_{surf,out} - t_{room})
 \end{array} \right. \quad (17)$$

Measurements were carried out for uninsulated transit district heating pipelines installed within a gypsum plasterboard structure located beneath the ceiling of a café in Poltava, Ukraine. The area of the enclosing gypsum plasterboard structure was 31.07 m<sup>2</sup>; the total length of the horizontal and vertical sections of the supply pipeline was 17 m, and of the return pipeline 17 m; the pipeline diameter was 108 mm. The measured inlet temperature of the heat carrier in the supply pipeline was 54 °C, while the outlet temperature of the return pipeline was 48 °C; the mass flow rate of the heat carrier was 24,920 kg/h. The area-averaged

temperature of the outer surface of the gypsum plasterboard structure was 28.3 °C, and the room air temperature was 25 °C (maintained at a заданий level by thermostatic valves on the heating devices). Surface temperatures were measured using testo 805i and testo 905 T2 devices.

The calculated results were obtained using the developed mathematical model for the given input data, as well as for a heating system temperature schedule of 87/65°C and for average annual heat carrier temperatures of 58.23/46.47°C. The results are presented in Table 2.

**Table 2 – Results of the thermal regime calculation of transit uninsulated district heating pipelines and the frame gypsum plasterboard structure**

Name of the parameter	Temperature of the heat carrier at the inlet of the supply pipeline / at the outlet of the return transit pipelines of the district heating network, °C		
	54/48	87/65	58.23/46.47
Temperature of the heat carrier at the outlet of the supply pipeline, °C	53.97	86.94	58.198
Temperature of the heat carrier at the inlet of the return pipeline, °C	48.008	65.025	46.477
Area-averaged temperature of the outer surface of the supply transit pipeline, °C	53.987	86.97	58.214
Area-averaged temperature of the outer surface of the return transit pipeline, °C	48.008	65.012	46.477
Volume-averaged temperature of the internal air within the framed gypsum plasterboard structure, °C	37.5	49.51	38.144
Area-averaged temperature of the inner surface of the framed gypsum plasterboard structure	32.55	39.81	32.944
Area-averaged temperature of the outer surface of the framed gypsum plasterboard structure, °C	29.546	33.92	29.78
Duration of the heating period, h	-	-	4272
Heat gains from transit pipelines to the room volume during the heating period, Gcal	-	-	4.15

The relative error between the measured and calculated values of the area-averaged temperature of the outer surface of the framed gypsum plasterboard structure is 4.4%, which is considered sufficiently accurate for engineering calculations and confirms the validity of the proposed mathematical model.

A comparison of the calculated heat gains from transit pipelines to the building volume during the

heating season for the investigated object, obtained using the proposed mathematical model, with the results calculated according to the methodologies presented in [1], [2], shows a significant discrepancy between these values. The comparison of the results is presented in Table 3.

**Table 3 – Comparison of calculated heat gains from transit pipelines obtained using the developed mathematical model with results according to [1], [4].**

Name of the parameter	Result calculated according to methodology [4]	Result calculated according to methodology [1]	Result calculated according to the first version of methodology [1]		Results calculated according to the developed mathematical model
			$t_{\text{ноб.вн}}=20^{\circ}\text{C}$	$t_{\text{ноб.вн}}=25^{\circ}\text{C}$	
Heat gains from transit pipelines during the heating period, Gcal	8,78	1,75	4,72	3,77	4,15

### Conclusions.

The mathematical model developed in this study for the thermal regime of uninsulated transit heating pipelines – specifically those installed within framed gypsum plasterboard structures – provides a level of accuracy suitable for engineering applications. This

model facilitates the evaluation of thermal behavior for both the pipelines and the surrounding frame structure. Furthermore, it enables the precise determination of heat gains into the indoor environment and the assessment of the associated operational expenditures.

### References

1. Міністерство регіонального розвитку, будівництва та житлово-комунального господарства України. (2018). *Про затвердження Методики розподілу між споживачами обсягів спожитих у будівлі комунальних послуг* (Наказ № 315 від 22 листопада 2018 року). <https://zakon.rada.gov.ua/laws/show/z1502-18>
2. Верховна Рада України. (2017). *Про комерційний облік теплової енергії та водопостачання* (Закон України № 2119-VIII від 22 червня 2017 року). <https://zakon.rada.gov.ua/laws/show/2119-19>
3. Phetteplace, G. E. (1995). *Optimal design of piping systems for district heating*. U.S. Army Corps of Engineers, Cold Regions Research & Engineering Laboratory.
4. ДП «УкрНДНЦ». (2022). *ДСТУ 9190:2022. Енергетична ефективність будівель. Метод розрахунку енергоспоживання під час опалення, охолодження, вентиляції, освітлення та гарячого водопостачання*. ДП «УкрНДНЦ».
5. Строй, А. Ф., & Скальський, В. Л. (1981). *Розрахунок і проектування теплових мереж*. Будівельник.
6. ДП «УкрНДНЦ». (2011). *ДСТУ 3992-2000. Кліматологія. Терміни та визначення основних понять*. Мінрегіонбуд України.
7. Щекін, Р. В., Кореневський, С. М., Бем, Г. Е., & Скороходько, Ф. І. (1976). *Довідник по теплопостачанню і вентиляції* (4-те вид., переробл. і допов., кн. 1). Будівельник.
8. ДП «УкрНДНЦ». (2022). *ДСТУ 9191:2022. Теплоізоляція будівель. Метод вибору теплоізоляційного матеріалу для утеплення будівель*. ДП «УкрНДНЦ».
1. Ministry of Regional Development, Construction and Housing and Communal Services of Ukraine. (2018). *On approval of the methodology for distributing among consumers the volumes of utility services consumed in a building* (Order No. 315, November 22, 2018). <https://zakon.rada.gov.ua/laws/show/z1502-18>
2. Verkhovna Rada of Ukraine. (2017). *On commercial metering of thermal energy and water supply* (Law of Ukraine No. 2119-VIII, June 22, 2017). <https://zakon.rada.gov.ua/laws/show/2119-19>
3. Phetteplace, G. E. (1995). *Optimal design of piping systems for district heating*. U.S. Army Corps of Engineers, Cold Regions Research & Engineering Laboratory.
4. Ukrainian National Standardization Body. (2022). *DSTU 9190:2022. Energy performance of buildings. Method for calculating energy use for heating, cooling, ventilation, lighting, and domestic hot water*. SE "UkrNDNC".
5. Stroi, A. F., & Skalskyi, V. L. (1981). *Calculation and design of district heating networks*. Budivelnik.
6. Ukrainian National Standardization Body. (2011). *DSTU 3992-2000. Climatology. Terms and definitions of basic concepts*. Minregionbud of Ukraine.
7. Shchekin, R. V., Korenevskiy, S. M., Bem, H. E., & Skorokhodko, F. I. (1976). *Handbook of district heating and ventilation* (4th ed., rev. & enl., Book 1). Budivelnik.
8. Ukrainian National Standardization Body. (2022). *DSTU 9191:2022. Thermal insulation of buildings. Method for selecting thermal insulation materials for building insulation*. SE "UkrNDNC".

9. Wang, D. (2022). Heat loss along the pipeline and its control measures. *SN Applied Sciences*, 5(1). <https://doi.org/10.1007/s42452-022-05226-2>

10. Příhoda, M., Čarnogurská, M., Pyszko, R., Hlisnikowski, E., & Burda, J. (2020). Heat loss analysis of outdoor piping. *MATEC Web of Conferences*, 328, 03006. <https://doi.org/10.1051/mateconf/202032803006>

11. Hamburg, A., Mikola, A., Parts, T.-M., & Kalamees, T. (2021). Heat loss due to domestic hot water pipes. *Energies*, 14(20), 6446. <https://doi.org/10.3390/en14206446>

12. Hamburg, A., & Kalamees, T. (2020). The influence of heat loss from pipes in an unheated basement on the heating energy consumption of an entire typical apartment building. *E3S Web of Conferences*, 172, 12005. <https://doi.org/10.1051/e3sconf/202017212005>

13. Chicherin, S., Mašatin, V., Siirde, A., & Volkova, A. (2020). Method for assessing heat loss in a district heating network with a focus on the state of insulation and actual demand for useful energy. *Energies*, 13(17), 4505. <https://doi.org/10.3390/en13174505>

14. Böhm, B. (2000). On transient heat losses from buried district heating pipes. *International Journal of Energy Research*, 24(15), 1311–1334. [https://doi.org/10.1002/1099-114X\(200012\)24:15<1311::AID-ER648>3.0.CO;2-Q](https://doi.org/10.1002/1099-114X(200012)24:15<1311::AID-ER648>3.0.CO;2-Q)

9. Wang, D. (2022). Heat loss along the pipeline and its control measures. *SN Applied Sciences*, 5(1). <https://doi.org/10.1007/s42452-022-05226-2>

10. Příhoda, M., Čarnogurská, M., Pyszko, R., Hlisnikowski, E., & Burda, J. (2020). Heat loss analysis of outdoor piping. *MATEC Web of Conferences*, 328, 03006. <https://doi.org/10.1051/mateconf/202032803006>

11. Hamburg, A., Mikola, A., Parts, T.-M., & Kalamees, T. (2021). Heat loss due to domestic hot water pipes. *Energies*, 14(20), 6446. <https://doi.org/10.3390/en14206446>

12. Hamburg, A., & Kalamees, T. (2020). The influence of heat loss from pipes in an unheated basement on the heating energy consumption of an entire typical apartment building. *E3S Web of Conferences*, 172, 12005. <https://doi.org/10.1051/e3sconf/202017212005>

13. Chicherin, S., Mašatin, V., Siirde, A., & Volkova, A. (2020). Method for assessing heat loss in a district heating network with a focus on the state of insulation and actual demand for useful energy. *Energies*, 13(17), 4505. <https://doi.org/10.3390/en13174505>

14. Böhm, B. (2000). On transient heat losses from buried district heating pipes. *International Journal of Energy Research*, 24(15), 1311–1334. [https://doi.org/10.1002/1099-114X\(200012\)24:15<1311::AID-ER648>3.0.CO;2-Q](https://doi.org/10.1002/1099-114X(200012)24:15<1311::AID-ER648>3.0.CO;2-Q)

---

Suggested Citation:

APA style

Fediai, B., & Fedorov, D. (2026). Mathematical model of thermal regime of uninsulated transit pipes of heating networks layed in frame plasterboard structures of rooms with individual heating. *Academic Journal. Industrial Machine Building Civil Engineering*, 1(66), 107–115. <https://doi.org/10.26906/znp.2026.66.4351>

DSTU style

Fediai B., Fedorov D. Mathematical model of thermal regime of uninsulated transit pipes of heating networks layed in frame plasterboard structures of rooms with individual heating. *Academic journal. Industrial Machine Building, Civil Engineering*. 2026. Vol. 66, iss. 1. P. 107–115. URL: <https://doi.org/10.26906/znp.2026.66.4351>.

---

Федяй Б.М.\*

ТОВ «НАУКОВО-ТЕХНІЧНЕ ПІДПРИЄМСТВО «АЛЬМАГРУП»  
<https://orcid.org/0000-0001-6323-7185>

Федоров Д.Ф.

ТОВ «НАУКОВО-ТЕХНІЧНЕ ПІДПРИЄМСТВО «АЛЬМАГРУП»  
<https://orcid.org/0000-0002-2591-7291>

## Математична модель теплового режиму неізолюваних транзитних трубопроводів теплових мереж прокладених в каркасних гіпсокартонних конструкціях приміщення з індивідуальним опаленням

**Анотація.** В статті запропоновано систему рівнянь теплового балансу неізолюваних транзитних трубопроводів теплових мереж прокладених в каркасних гіпсокартонних конструкціях приміщення та методику визначення теплонадходжень від зазначених трубопроводів до опалюваного об'єму. Результати розрахунку одержані за допомогою запропонованої математичної моделі співставлено з даними натурних вимірювань та результатами одержаними при використанні існуючих, нормативно визначених, методів оцінки теплонадходжень від транзитних трубопроводів систем теплозабезпечення, які використовуються при розрахунках з комунальними підприємствами за спожиту теплову енергію або при виконанні енергетичних аудитів житлових та громадських будівель.

**Ключові слова:** транзитні трубопроводи теплових мереж, тепловий баланс, температурний графік, опалення, тепла енергія, енергетичний аудит, теплонадходження, енергопотреба, енергоспоживання.

\*Адреса для листування E-mail: [fed.bn.office@gmail.com](mailto:fed.bn.office@gmail.com)

---

Надіслано до редакції:	02.02.2026	Прийнято до друку після рецензування:	25.02.2026	Опубліковано (оприлюднено):	31.05.2026
------------------------	------------	---------------------------------------	------------	-----------------------------	------------

---