Formation of local asymmetry of the resulting temperature at the boundary of the serviced area of the premises

Elena Malyavina[1], *Sergey* Landyrev[1,*]

[1]Moscow State University of Civil Engineering, Yaroslavskoe shosse, 26, 129337 Moscow, Russia

Abstract. The required resistance to heat transfer of windows has been normalized for a long time depending on the functional purpose of the building and the difference in the temperature of the indoor air and the temperature of the coldest five-day period. For residential and public buildings, they were in the range of 0.18 – 0.61 m²°C/W. In 1993, with the introduction of requirements for this indicator based on energy savings (according to the number of the degree-days of the heating period), they were increased for windows to the limits of 0.3 – 0.8 m²°C/W. From 15.06.2019, the Amendment №1 to SP 50.13330.2012 "Thermal protection of buildings" came into force and increased the required heat transfer resistances of residential and public buildings to the range of 0.49 – 0.8 m²°C/W. Attention is drawn to the inadequacy of GOST 30494–2011 requirements as for measuring the local asymmetry of the resulting temperature in the center of the room. Such an erroneous requirement is that the radiation temperature, which is an integral part of the resulting one, depends on the measurement place. The radiation temperature in accordance with the V.N. Bogoslovsky's second comfort condition should be checked at the border of the serviced zone. Calculations of the local asymmetry of the radiation temperature, which has been measured at a distance of 0.5 m from the center of the window, showed that the optimal requirements to the center of the room are not met in none of the 19 cities of the Russian Federation for which the calculations were performed. Therefore, when forming the required resistance to the window heat transfer, it is proposed to take into account not only the number of the degree-days of the heating period, but also the calculated outdoor air temperature for the cold period of the year.

1 Introduction

There are still discussions about the rational thermal protection value of external enclosing structures. It is recognized that the room air temperature is mainly maintained by the heating system, and the temperature of the inner surface of the outer enclosing structures depends on the resistance to heat transfer of the structure [1]. Until 1995, the choice of the required (minimum permissible) resistance to heat transfer was normalized based on

* Corresponding author: lanserser@mail.ru

sanitary and hygienic conditions, essentially excluding condensation on the indoor surface of the enclosing structure during the coldest design period. After 1995, higher heat transfer resistances were adopted in comparison with the result of the sanitary and hygienic approach to energy saving requirements. The first approach is based on physically understandable and reasonable formulas. The second approach requires an economic justification [2, 3], which is not available for the external enclosing structures as per the SP 50.13330.2012 with amendments 1 (hereinafter SP 50) normalizing the value of heat transfer resistances.

The required resistance to the window heat transfer has been normalized for a long time depending on the functional purpose of the building and the difference in the temperature of the indoor air and the temperature of the coldest five-day period. For residential and public buildings, they were in the range of 0.18 - 0.61 m²°C/W. In 1993, with the introduction of requirements for this indicator based on energy savings (according to the number of the degree-days of the heating period) for windows, they were increased to the limits of 0.3 - 0.8 m²°C/W. From 15.06.2019, the Amendment № 1 to SP 50.13330.2012 "Thermal protection of buildings" came into force, which increased the required heat transfer resistances of residential and public buildings to the range of 0.49 – 0.8 m²°C/W. However, for medical and preventive, pre-school educational and general educational organizations, as well as the boarding schools, the same level has been left. Those who support a higher required resistance to heat transfer base [4] their positions on the fact that in this cold country, the more powerful the thermal protection, the less heat loss, and with them the load on the heating system. However, in works [5, 6] it is shown that the economic parameters of a building project design depend on the energy consumption to maintain the microclimate in various buildings, not only during the heating period, but also in the rest of the year too. The criterion for choosing the required heat transfer resistance in SP 50 is the degree-day of the heating period of the GSOP, determined by the known indoor temperature of the construction object, the average temperature and the duration of the heating period.

The basic heat transfer resistances of the enclosing structures are selected according to the Table 3 of SP 50. In order to fulfill sanitary and hygienic conditions, SP 50 stipulates a requirement for the temperature on the inner surfaces of the enclosing structures, which must not be lower than the minimum permissible values. To meet the requirement, it is sufficient to satisfy the restrictions of the normalized temperature difference between the indoor air temperature and the temperature of the inner surface of an enclosing structure given in the Table 5 of SP 50. In addition, the clause 5.7 of SP 50 requires that the minimum temperature of the inner surface of the vertical translucent structures glazing should be not lower than 3 ° C, and for industrial buildings it should be not less than 0 ° C. The minimum temperature of the inner surface of vertical translucent structure opaque elements should not be lower than the dew point of the indoor air of the room, at the design temperature of the outdoor air.

However, not all requirements characterizing sanitary and hygienic conditions are listed above. This is about the GOST 30494–2011 normalization of the local asymmetry of the resulting room temperature, which is defined as the difference of the resulting temperatures at a room point, detected by a ball thermometer for two opposite directions. The resulting temperature is the half-sum of the air temperature and the radiation temperature. Since the radiation temperature strongly depends on the place of its measurement, then in accordance with the second comfort condition formulated by V.N. Bogoslovsky [7], the resulting temperature and the resulting temperature local asymmetry should be checked at the boundary of the serviced area. The local asymmetry of the resulting temperature according to GOST 30494-2011 should be no more than 2.5 ° C for optimal indicators and no more than 3.5 ° C for acceptable indicators. A great importance is attached to radiation temperature and local asymmetry in China [8, 9] and in Europe [10-12], in the Russian Federation [13].

2 Methods

The local asymmetry of the radiation temperature is most influenced by the temperature of the window inner surface, which depends on its resistance to heat transfer. In the latest edition of SP 50 for residential buildings, hotels and dormitories, as well as for public, administrative and residential buildings, the window heat transfer resistance was significantly increased, and for medical and preventive, preschool educational and general educational organizations and boarding schools it is left at the level of SP 50.13330.2012. The Table 1 for 19 cities of the Russian Federation shows the values of the calculated temperature of the coldest five-day period with an availability of 0.92 t_5^{92}, the number of degree-days of the degree-day of the heating period (DDHP), the required resistance to the heat transfer of the external walls and windows for medical and preventive, preschool educational and general educational organizations and boarding schools. Moreover, for external walls, the basic required resistance to heat transfer is shown in accordance with the clause 5.2 of SP 50, that is, with a coefficient of 0.63 to the values given in the Table 3 of SP 50. For calculations, provision has been made of an art school classroom, which has dimensions of 6.0x5.4 m in plan. The height of the room in cleanliness is 3.3 m. There are 3.8x1.8 m windows in both exterior walls. The bottom of each window is located at a height of 1 m from the floor. From the corner formed by the outer walls, the windows are at a distance of 1.1 m.

The calculation of the internal surface temperature of all enclosing structures of the corner room at a given resulting temperature of 20 ° C has been provided according to the PC program. The calculation uses the solution of a system of equations of stationary thermal balances of the air and the internal surfaces of all room enclosing structures, where the air temperature and the temperature of each surface facing the room are unknown.

In [14] an ordinary room of the same geometry as the corner one (the 5.4 m long wall is internal) has been examined. Comparison of the calculation results of the ordinary and corner rooms showed that the influence of the second window on the radiation temperature local asymmetry is noticeable. For example, at a height of 1.7 m from the floor in an ordinary room, the maximum temperature asymmetry value at the boundary of the serviced area is 6.28 ° C, and in the corner 6.99 ° C; at a height of 2 m from the floor, these values are 6.31 ° C and 7.04 ° C.

Table 1. Thermal engineering indicators of enclosing structures and the temperature of the internal surfaces of all enclosing structures.

City	t_5^{92}, °C	Average wind rate, V, m/s	DDHP, °C·day	$R_o^{тр}$, (m²·°C)/W		Temperature of indoor surface of enclosing structures, °C.				
				walls	Win-dows	Outdoor walls	Win-dows	Partitions	floor	ceiling
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Sochi	-3	2.2	1246	1.151	0.300	17.50/17.46	11.09	19.65/19.56	19.50	19.64
Feodosia	-12	3.6	2343	1.399	0.326	17.23/17.18	8.62	19.56/19.54	19.48	19.63
Astrakhan	-20	3.2	3416	1.635	0.406	17.07/17.02	8.65	19.66/19.55	19.48	19.64
Belgorod	-24	4.3	4095	1.785	0.457	17.03/16.98	8.89	19.65/19.54	19.48	19.63

https://doi.org/10.1051/e3sconf/202337103063

Saint-Petersburg	-24	2.4	4663	1.910	0.499	17.20/17.15	9.72	19.65/19.56	19.49	19.64
Moscow	-26	1.8	4529	1.881	0.489	17.06/17.00	9.10	19.65/19.55	19.48	19.64
Pyalitsa	-26	5.4	6705	2.998	0.635	18.02/17.98	11.42	19.65/19.57	19.52	19.64
Khabarovsk	-29	3.0	6018	2.209	0.601	17.25/17.20	10.56	19.65/19.56	19.49	19.64
Kazan	-29	3.1	5113	2.009	0.534	17.03/16.98	9.44	19.64/19.54	19.48	19.63
Ufa	-33	2.9	5413	2.076	0.556	16.92/16.87	9.05	19.55/19.65	19.48	19.64
Irkutsk	-33	2.1	6431	2.300	0.622	17.18/17.14	10.18	19.66/19.57	19.50	19.65
Perm	-35	2.8	5715	2.142	0.579	16.91/16.86	9.04	19.55/19.65	19.48	19.64
Petropavlovsk-Kamchatsky	-18	4.6	5397	2.072	0.555	17.66/17.62	11.87	19.58/19.65	19.52	19.65
Stavropol	-18	4.7	3259	1.601	0.394	17.14/17.09	8.91	19.54/19.65	19.48	19.63
Ulan-Ude	-35	1.9	6953	2.415	0.648	17.21/17.16	10.12	19.56/19.65	19.50	19.64
Novosibirsk	-37	3.6	6194	2.248	0.609	16.93/16.87	9.19	19.64/19.54	19.47	19.63
Chita	-37	2.0	7426	2.519	0.671	17.22/17.17	10.22	19.64/19.57	19.50	19.65
Vorkuta	-41	5.5	8791	2.820	0.719	17.34/17.29	10.11	19.56/19.65	19.50	19.64
Khanty-Mansiysk Mansiysk	-41	2.7	7121	2.452	0.656	17.00/16.95	9.32	19.56/19.66	19.49	19.64

The air thermal balance takes into account the air convective heat exchange with each inner surface of all enclosing structures (external and internal) and the convective heat of the air heating system. The thermal balance of each internal surface takes into account the radiant heat exchange with each other surface of the room. The radiant heat exchange of surfaces facing the room with each other is carried out taking into account compliance with the law of closure of radiant flows, which consists in the fact that the sum of the irradiance coefficients from each surface to all the others is equal to 1.

3 Results

The Table 1 shows that the temperatures on the inner surface of the internal enclosing structures in different cities under the specified conditions differ little from each other. The temperature of the inner surfaces of the external walls of the corner room lies within 16.87 ° C - 17.66 ° C.

But the temperature of the window inner surface has a greater variation: 8.62° C - 11.87 ° C. Such a discrepancy is explained by the choice of heat transfer resistance of external enclosing structures without taking into account the design outdoor air temperature for the cold period of the year by the number of degree-days of the DDHP. The absurdity of such a choice for windows in cities with the same outdoor temperature is especially clearly visible. If the external walls of residential and public buildings have the required basic heat transfer resistances as per the Table 3 of SP 50 with a coefficient of 0.63 values above 1.15 m²°C/W are given, then for windows they drop to 0.3 m²°C/W. The absence of taking into account the temperature of the coldest five-day period when choosing the window heat transfer resistance is also noted in [15].

The radiation temperature takes the minimum value, and the local asymmetry of the radiation temperature takes the largest value in the heating design winter temperature conditions. In this work, the values of the radiation temperature and the local asymmetry of the radiation temperature with respect to the ball thermometer were estimated by calculation. This calculation used the formula, which is known from the spherical geometry, of the irradiance coefficient from a flat elementary platform to a sphere of the known diameter [16].

Table 2 for the same 19 cities shows these indicators at heights from the floor, which are required by GOST 30494-2011 for adults in a sitting and standing position and for children.

Table 2. Values of radiation temperature and local asymmetry of radiation temperature at the border of the serviced area opposite the middle of the windows.

City	Maximum value of local asymmetry of radiation temperature, °C, at heights from the floor, m				Minimum value of local asymmetry of radiation temperature, °C, at heights from the floor, m			
	1,7	1,1	0,6	0,4	1,7	1,1	0,6	0,4
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Sochi	5.56/5.53	4.28/4.27	2.51/2.51	2.03/2.03	16.36/16.41	16.99/17.05	17.90/17.95	18.16/18.20
Feodosia	7.13/7.10	5.43/5.41	3.08/3.08	2.46/2.46	15.46/15.50	16.31/16.36	17.51/17.56	17.84/17.88
Astrakhan	7.14/7.10	5.47/5.45	3.16/3.15	2.54/2.54	15.45/15.50	16.28/16.33	17.47/17.51	17.80/17.84
Belgorod	6.99/6.96	5.37/5.35	3.13/3.12	2.52/2.52	15.52/15.57	16.34/16.38	17.48/17.53	17.80/17.84
Saint-Petersburg	6.46/6.96	4.97/5.35	2.9/3.12	2.35/2.52	15.83/15.57	16.58/16.38	17.64/17.53	17.93/17.84
Moscow	6.86/6.83	5.28/5.26	3.08/3.08	2.49/2.49	15.59/15.65	16.39/16.44	17.51/17.56	17.83/17.87
Pyalitsa	5.31/5.29	4.01/4.00	2.22/2.22	1.76/1.76	16.59/16.61	17.21/17.26	18.12/18.16	18.36/18.41
Khabarovsk	5.92/5.89	4.58/4.57	2.72/2.72	2.21/2.21	16.13/16.18	16.79/16.85	17.75/17.80	18.02/18.07
Kazan	6.64/6.60	5.13/5.11	3.02/3.02	2.45/2.45	15.71/15.76	16.46/16.52	17.54/17.59	17.85/17.89
Ufa	6.90/6.86	5.33/5.31	3.15/3.14	2.55/2.55	15.55/15.61	16.34/16.39	17.46/17.51	17.78/17.82
Irkutsk	6.17/6.14	4.78/4.76	2.83/2.83	2.30/2.30	15.99/16.05	16.69/16.75	17.69/17.74	17.98/18.02
Perm	6.90/6.87	5.34/5.32	3.15/3.15	2.56/2.56	15.55/15.60	16.33/16.39	17.45/17.50	17.77/17.82
Petropavlovsk-Kamchatsky	5.06/5.04	3.91/3.9	2.31/2.3	1.87/1.87	16.66/16.71	17.23/17.29	18.06/18.10	18.29/18.33
Stavropol	6.96/6.93	5.33/5.31	3.07/3.07	2.47/2.47	15.55/15.59	16.36/16.41	17.52/17.56	17.84/17.88
Ulan-Ude	6.20/6.17	4.79/4.77	2.83/2.82	2.29/2.29	15.98/16.03	16.68/16.74	17.69/17.74	17.98/18.02
Novosibirsk	6.80/6.77	5.26/5.24	3.11/3.11	2.53/2.53	15.59/15.65	16.37/16.43	17.47/17.52	17.79/17.83
Cheat	6.14/6.12	4.75/4.73	2.81/2.8	2.28/2.28	16.02/16.07	16.71/16.77	17.71/17.76	17.99/18.04
Vorkuta	6.19/6.17	4.76/19.19	2.77/2.76	2.23/2.23	15.99/16.05	16.71/16.33	17.73/17.78	18.02/18.06
Khanty-Mansiysk	6.73/6.70	5.20/5.18	3.07/3.06	2.49/2.49	15.66/15.72	16.43/16.49	17.52/17.57	17.83/17.88

All indicators refer to the border of the serviced area opposite the middle of the window in the form of a fraction, where in the numerator there are the values calculated for the frontal orientation on the outer wall with a width of 6 m, in the denominator - the values set for the frontal orientation on the outer wall with a width of 5.4 m.

If we assume that the room air temperature is the same throughout the volume, then the local asymmetry of the resulting temperature is equal to half of the local asymmetry of the radiation one given in the Table 2.

4 Discussion

It follows from the table that with the air heating system, which has been considered in the calculations, at an outdoor temperature equal to the temperature of the coldest five-day period with an availability of 0.92, the radiation temperature local asymmetry reaches the highest value, and the radiation temperature reaches the lowest value at a height of 1.7 m from the floor. With a window height of 1, 8 m, this level from the floor is close to the center of the window.In cities with the same temperature of the coldest five days, the local asymmetry reaches its highest values in cities with smaller DDHP. At the specified window size in the southern cities of Feodosia and Astrakhan, the indicator is not met even for acceptable conditions. And in Stavropol, Belgorod, Perm, Ufa, Moscow, Novosibirsk, acceptable conditions are achieved at close to the maximum allowed value. But the optimal requirements for the local asymmetry value at a height of 1.7 m from the floor are not met in any of the cities considered, and at a height of 1.1 m are met in 8 cities out of 19.

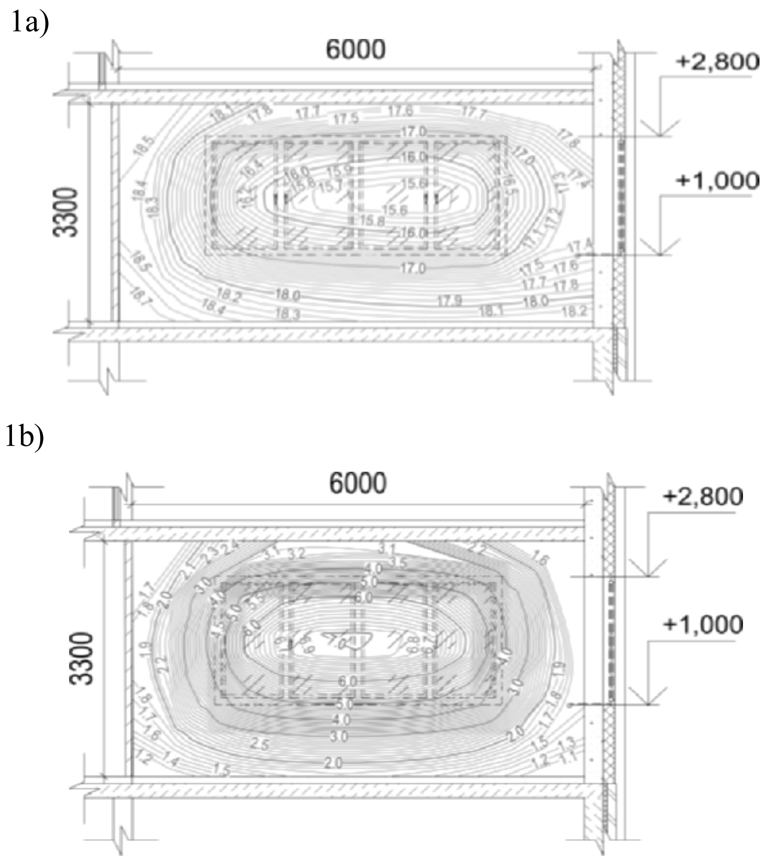

Fig. 1. Distribution of radiation temperature (figure 1a) and local asymmetry of radiation temperature (fig.1b) along the cross section of the room at a distance of 0.5 m from the outer wall with a length of 6m in the design winter period.

The fig.1 shows the distribution of radiation temperature (Fig. 1 a) and local asymmetry of radiation temperature (Fig. 1 b) at the border of the serviced area on the cross section of a room in Belgorod. At the same time, the virtual ball thermometer is located frontally to the wall with a length of 6 m by 0.5 m from it. On the front wall, a dotted line indicates a window in it. This is a corner room, the second window is in the wall on the right. That is why the isolines on which the values of the radiation temperature and the local asymmetry of the radiation temperature are indicated are not symmetrical. Since the window is moved up in height, the radiation temperatures above it are lower than below it.

From the Table 2 it can be seen that Belgorod is not the most problematic city in terms of compliance with sanitary and hygienic standards. Nevertheless, the figure shows that at the border of the serviced area, almost opposite the entire area of the window, the radiation temperature and local asymmetry go beyond the requirements of GOST 30494 (the normalized radiation temperature is easily determined from the normalized resulting temperature and air). This conclusion applies to both children's and medical institutions.

5 Conclusions

1. It can be seen from the conducted research that if the norms of local asymmetry of the resulting temperature related to the center of the room are applied to the boundary of the serviced area, then these norms, as a rule, are not performed.
2. It is necessary to perform broader studies of the provision of sanitary and hygienic standards discussed herein this article in order to establish the window size to meet sanitary and hygienic standards at different areas and the location of windows in the external walls.
3. It is necessary to develop a methodology for calculating the minimum possible resistance to heat transfer of windows to meet the norm of local asymmetry of the resulting temperature at the border of the serviced zone in the estimated winter period, taking into account the GSOP.
4. It is necessary to develop a methodology for calculating the minimum possible resistance to heat transfer of windows to meet the norm of the local asymmetry of the resulting temperature at the border of the serviced area in the estimated winter period, taking into account the DDHP.

References

1. A.G. Perehozhentsev, Bull. of MGSU **2,** 173-185 (2016)
2. V.G. Gagarin, Zhi bo Zhou, Bull. of construction equipment **982,** 58-59 (2016)
3. A.I. Burkov, V.S. Ivashkin, Theory and practice **1,** 139-144 (2020)
4. A.S. Gorshkov, V.I. Livchak, Constr. of unique build. and struct. **3 (30),** 7-37 (2015)
5. E.G. Malyavina, A.A. Frolova, Housing construction **1-2,** 63-68 (2019). https://doi.org/10.31659/0044-4472-2019-1-2-63-68
6. E.G. Malyavina, A.A. Frolova, Agr. Scient. J. **10,** 111-114 (2020). https://doi.org/10.28983/asj.y2020i10pp111-114
7. V.N. Bogoslovsky, Construction thermophysics (thermophysical foundations of heating, ventilation and air conditioning): Textbook for universities– -3rd ed. (S-Pb.: publishing house "AVOK NORTH-WEST", 2006)
8. J. Xiong, X. Zhou, ZW. Lian, JX. You, YB. Lin, Energy and buildings **128,** 155-163 (2016). https://doi.org/10.1016/j.enbuild.2016.06.085

9. S. Zhang, N. Zhu, SL. Lv, Building and env. **187,** 107408 (2021). https://doi.org/10.1016/j.buildenv.2020.107408
10. R. Mora, R. Bean, AVOC **6,** 48-53 (2019)
11. E. Naboni, M. Meloni, S. Coccolo, Jé. Kaempf, Jean-L. Scartezzini, Energy Procedia **122,** 1111-1116 (2017). https://doi.org/10.1016/j.egypro.2017.07.471
12. AS. Azad, D. Rakshit, S. Wan MP Babu, JN. Sarvaiya, DEVSK Kumar, Z. Zhang, AS. Lamano, K. Krishnasayee, CP. Gao, S. Valliappan, A. Goh, A. Seoh, Building and env. **145,** 196-212 (2018). https://doi.org/10.1016/j.buildenv.2018.09.025
13. E.N. Bolotov, AVOC **1,** 4-13 (2018)
14. E.G. Malyavina, A.A. Frolova, S.S. Landyrev, SOC **19,** 36-39 (2021)
15. A.S. Kolychkova, O.S. Annenkova, Polzunovsky almanac **4,** 85-88 (2017)
16. E.G. Malyavina, M.A. Barsukova, Scient. rev. 8, 38-41 (2015)