Calculation of the thermal-insulation properties of window with assembly seams
(also useful for outside doors)

city of Novomoskovsk

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List of standardizing documents

1. GOST 11214-86 “Windows and balcony doors of wood with double panes for residential and public buildings.” Replaces GOST 11214-78
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4. GOST 26602-85 “Windows. Methods for determining heat transmission resistance.”
5. GOST 30971-2002 “Assembly seams of units for attachment of window blocks to wall openings"
6. GOST 52749-2007 “Window assembly seams with vapor-permeable self-expanding tapes”
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8. SNiP 2.04.05-91 “Heating, ventilation and conditioning”
9. SNiP II-3-079 “Structural thermal engineering”
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Reasons for the study

The present investigation was conducted for the purpose of determining the energy efficiency of the use of assembly foam when installing windows.

70% of window assemblies in Russia involves replacement of older windows that were installed in the USSR by modern window systems. A modern window, generally speaking, is a one-, two- or three- chambered glass package in a plastic or wooden binder or framework installed in a window niche with an assembly seam filled with assembly foam.

In the USSR in residential and public buildings in all cases wooden windows were installed with a double pane in a 2-part framework. In accordance with the accepted standards, these windows were not characterized by high energy efficiency. Significant heat losses – up to 30%

heat losses of buildings occurred through the windows. During operation in connection with the wear of the structures, this number increases and may reach 50% Therefore, with consideration of the cold climate of Russia caused by its geography and topography, the technologies used in construction and especially modern technologies of production and assembly of window structures have major significance.

Definitions

Window (GOST 23166-99) – an element of wall or roofing construction intended for communicating internal movements with the surrounding space, natural illumination of rooms and their ventilation, protection against atmospheric and noise effects, consisting of a window passage with slopes, a window block, **a system of sealing the assembly seams,** window ledges, details of runoff and facings.

<u>This means that the system for sealing the assembly seam is part of the window.</u>

Assembly seam (GOST 30971-2002) – an element of the joining assembly of the window block with the window passage, representing in itself a combination of different insulating materials used for filling the assembly gap and having specified characteristics.

In common practice in RUSSIA, the filling of the assembly seam is accomplished with a special material – assembly foam. The assembly foam represents a foam-polyurethane material which possesses the properties of self-expansion when extracted from the bottle, polymerizing after contact with moist air. The function of the assembly foam during the assembly of windows and doors is the following:

- Assuring the physical strength of the construction;
- Heat insulation of the window block,
- Assuring the sealing of the contact joint between window block and the wall opening (absence of air permeation)

Calculation of the heat losses of windows

The heat losses through a window take place by two basic routes:

1. **Due to the phenomenon of heat conduction.**

As in the case of any physical body, a window and its separate elements have thermal conductivity indices. Thermal conductivity is an index, the inverse index of the heat transmission resistance. The higher the thermal transmission resistance is (thermal conductivity accordingly lower), the lower the heat losses, the less heat escapes through the window. Thermal conductivity of a window consists of the thermal conductivity of its individual elements – the glass package, the framework, the assembly seam. By varying the group of data of the elements and their properties it is possible to regulate the total thermal conductivity of a window. Thus, for example, the thermal conductivity of birch or larchwood is lower than the thermal conductivity of PVC which means that windows manufactured from these materials under otherwise identical conditions should be warmer than windows of PVC. And conversely, windows from oak will be colder than windows from PVC because of the same index of thermal conductivity.

2. Due to air-permeability (infiltration)

Since a window consists of separate elements, at the junction sites of these elements the phenomenon of air-permeability is possible in which through these connections warm air exits from the room and conversely cold air penetrates from the outside to replace an equivalent volume of warm air that has departed. In this case the heat losses are equal to the quantity of energy necessary for heating the air coming from the outside. The better the construction is sealed, the lower the heat losses.

In general form, for the purposes of calculating the heat losses of a window we shall separate them into heat losses through the window construction (the glass package in the frame construction) and the assembly seam.

A. Calculation of heat losses for window construction

A .1. Calculation of losses due to thermal condutivity phenomenon

In accordance with SNiP, II-3-79 (appendix 6) the resistance to heat transfer for windows with double glazing in double frames amounts to 0.4 m^2 °C/Watt. The glazing data of the USSR is the standard for residential and public buildings. In accordance with GOST 30674-99, the adjusted resistance to heat transfer of a single-chamber glass package should be no less than 0.35 m² °C/Watt.

The heat losses in Whr per 1 m^2 of such a window construction (disregarding the assembly seam) during the heating period is calculated by the formula:

$$Q = K * A *(t_{in} - t_{out}) *(1 + \Sigma ß)*days*24hr/day,$$ where

K is the coefficient of heat transfer of the surrounding construction equal to the inverse value of the heat transfer resistance, i.e. in our example K = 1/0.4 = 2.5 Watt/ m² °C.

A is the surrounding area. For calculation of 1 m^2 it is equal to unity.

t_{in} is the temperature of the inside air,° C. The optimal conditions for a person to remain in a residential room in accordance with the GOST 30494-96 is a temperature of 20-25° C. For the purposes of calculation we shall use the average value for all regions of the country, which is equal to 22° C.

t_{out} is the calculated winter temperature of outside air,° C, during the heating season. This value is different for different regions of the country. A calculation of the present temperature for different regions of the country was performed by SNiP 23-01-99. In this case the heating season in Russia is established for the period when the average daily temperatures are within a range lower than or equal to +8° C .

β is a coefficient allowing for additional heat losses. , For example, the additional heat losses depend on the strength of the wind, number of floors above ground and the technical state of the window construction. For old worn-out windows additional heat losses that can reach 20% are typical, i.e. for our calculations we shall assume this coefficient to be equal to 0.2.

days]– number of days of the heating period. This value is different for different regions of the country and is also determined in accordance with SNiP 23-01-99.

In simplified form the formula for heat losses for old worn-out windows has the form:

Q= 2.5*(22-tout)*1.2*days*24 (Whr)

A general calculation of this magnitude for different regions of Russia is given in **Table 1:**

Table 1. Calculation of heat losses through window construction of wooden windows with the double glass package per 1 m^2. Wear on the window construction is 20%

City	Duration of heating period (days)	Mean temperature of heating period (°C)	Heat losses per 1 m² for wooden windows in double casements (watts)	Heat losses per season,(Whr)
Astrakhan	167	-1,20	69,60	278 956,80
Arkangelsk	253	-4,40	79,20	480 902,40
Vladivostok	196	-3,90	77,70	365 500,80
Volgograd	178	-2,20	72,60	310 147,20
Vologda	231	-4,10	78,30	434 095,20
Voronezh	196	-3,10	75,30	354 211,20
Ekaterinburg	230	-6,00	84,00	463 680,00
N. Novgorod	215	-4,10	78,30	404 028,00
Irkutsk	240	-8,50	91,50	527 040,00
Krasnodar	149	2,00	60,00	214 560,00
Moscow	**212**	**-3,40**	**76,20**	**387 705,60**
Murmansk	275	-3,20	75,60	498 960,00
Novosibirsk	230	-8,70	92,10	508 392,00
Omsk	221	-8,40	91,20	483 724,80
Samara	203	-5,20	81,60	397 555,20
St. Petersburg	220	-1,80	71,40	376 992,00
Tyumen	220	-7,50	88,50	467 280,00
Khabarovsk	211	-9,30	93,90	475 509,60
Yaroslavl	221	-4,00	78,00	413 712,00
AVERAGE	**214**	**-4,58**	**79,74**	**412 786,99**

The heat transmission resistance given above for a standard 2-chamber glass package without additional heat reflecting coatings amounts to 0.51 m² °C/Watt (according to GOST 30674-99). A similar calculation can be performed for a similar glass package.

Q = 1/0.51*(22-tout)*days*24 (Whr)

In this case it is considered that the glass package is new, and therefore the coefficient for wear is not stated.

Table 2. Calculation of heat losses through window construction with a double glass package per 1 m²

City	Duration of heating period (Days)	Mean temperature of heating period (°C)	Heat losses for a window with a double chamber double package, (Watts)	Also for a season for plastic windows with 2-chamber glass package, (Whr)
Astrakhan	167	-1,20	45,49	182 324,71
Arkhangelsk	253	-4,40	51,76	314 315,29
Vladivostok	196	-3,90	50,78	238 889,41

Volgograd	178	-2,20	47,45	202 710,59
Vologda	231	-4,10	51,18	283 722,35
Voronezh	196	-3,10	49,22	231 510,59
Ekaterinburg	230	-6,00	54,90	303 058,82
N. Novgorod	215	-4,10	51,18	264 070,59
Irkutsk	240	-8,50	59,80	344 470,59
Krasnodar	149	2,00	39,22	140 235,29
Moscow	**212**	**-3,40**	**49,80**	**253 402,35**
Murmansk	275	-3,20	49,41	326 117,65
Novosibirsk	230	-8,70	60,20	332 282,35
Omsk	221	-8,40	59,61	316 160,00
Samara	203	-5,20	53,33	259 840,00
St. Petersburg	220	-1,80	46,67	246 400,00
Tyumen	220	-7,50	57,84	305 411,76
Khabarovsk	211	-9,30	61,37	310 790,59
Yaroslavl	221	-4,00	50,98	270 400,00
AVERAGE	**214**	**-4,58**	**52,12**	**269 795,42**

This means that on the average throughout Russia the savings from replacement of old windows by windows in a plastic casement during the heating season amounts to (413 – 270 =) 143 kWh of energy per 1 m² of glazing during the heating season. This number is an average since it was computed with certain assumptions. Of course, triple heat packages can be set up in homes as well as heat packages with additional heat reflecting coatings and heat packages filled with argon, but these are an exception rather than the rule.

A2. Calculation of heat losses on window constructions due to air permeability

The heat losses due to infiltration through the window take place due to the incomplete sealing of the joints of the window construction. The standard value for air permeability for wooden windows in accordance with SNiP II-379 is no more than 6 kg. per hour on one square meter of surface area GOST 23166-99 states that air permeability of modern windows is determined on specific types of articles. In this case, the air permeability for articles of class “A” is established at the level 3 $m^3/h{\cdot}m^2$, for class B – 9 $m^3/h{\cdot}m^2$.

Table 1 GOST 23166-99). The standard for modern windows is an air permeability index of greater than 3-4 kg / $h{\cdot}m^2$(2.5 – 3.2 $m^{3/}$ $h{\cdot}m^2$) that is, the difference between the old and new windows in terms of air permeability amounts to about 2.5 kg / $h{\cdot}m^2$.

The expenditure of heat for heating infiltrating outside air in accordance with SNiP 2.041.05-91 is determined by the formula:

$Q = 0.28*G*c*(t_{in} - t_{out})*day*24$ hr/day (Whr)

where

G is the quantity of infiltrating air, kg/h·m^2 In our calculation 2.5 kg/h·m^2

c is the specific heat capacity of air = 1.0056 J/kgK

That is, to calculate the additional effect from lowering the air permeability upon replacing worn windows one should use the formula:

$Q = 0.28*2.5*1.0056*(22-t_{out})*days\ 24.$ (Whr)

The average generalized data on Russia are presented in Table 3.

Table 3. Energy-saving from replacing Windows due to the effect of air permeability of window constructions

City	duration of heating season (Days)	temperature during heating season (°C)	reduction in air permeability upon replacement (repair) of Windows, (kg/h·m^2)	reduction of heat losses from infiltration of air during heating season. Whr per 1 sq.m of construction
Astrakhan	167	-1,20	2,50	65 089,92
Arkhangelsk	253	-4,40	2,50	112 210,56
Vladivostok	196	-3,90	2,50	85 283,52
Volgograd	178	-2,20	2,50	72 367,68
Vologda	231	-4,10	2,50	101 288,88
Voronezh	196	-3,10	2,50	82 649,28
Ekaterinburg	230	-6,00	2,50	108 192,00
N. Novgorod	215	-4,10	2,50	94 273,20
Irkutsk	240	-8,50	2,50	122 976,00
Krasnodar	149	2,00	2,50	50 064,00
Moscow	**212**	**-3,40**	2,50	90 464,64
Murmansk	275	-3,20	2,50	116 424,00
Novosibirsk	230	-8,70	2,50	118 624,80
Omsk	221	-8,40	2,50	112 869,12
Samara	203	-5,20	2,50	92 762,88
St. Petersburg	220	-1,80	2,50	87 964,80
Tyumen	220	-7,50	2,50	109 032,00
Khabarovsk	211	-9,30	2,50	110 952,24
Yaroslavl	221	-4,00	2,50	96 532,80
AVERAGE	**214**	**-4,58**	**2,50**	**96 316,96**

Therefore, the total average savings of energy for 1 sq. meter of window construction from replacing the old wooden windows in double casements by new plastic ones on the average in Russia can be estimated at **239 kW·h** for one square meter of surface area (= 143+96).

B. Calculating of heat losses relative to assembly seams

The assembly seam is the most important element of the window. A high quality assembly seam prepared by using high-quality assembly foam has excellent heat-insulating properties, many times exceeding the heat-insulating properties of the window assembly.. In addition, a seam filled with high quality assembly foam is practically totally free of micro-cracks and its air permeability tends towards zero. The standard index for the quantity of closed cells for a professional (spray gun) foam used in Russia is 70%. Such a proportion of closed cells assures a practically total sealing of the layer of assembly foam and the absence of air permeability. Assembly foams with a lower index of closed cells are not recommended for use in Russia categorically since this may result in a significant reduction in the heat-insulating properties of the seam due to the appearance of air permeability.

For assembly seams the indices of heat transfer resistance and air permeability are established in GOST 30971-02. The indices for a high quality seam prepared from assembly foam correspond to the GOST indices for a foam of class 1 or even exceed this index

In the Soviet Union no standards existed for heating assembly foams, and therefore any convenient materials were used, including tow, sawdust, shavings, cotton, paper, rags etc. The heat-insulating properties of such a seam are minimal; in addition, the actual service life of most of the old wooden windows in Russia exceeds 20 years. During this time, any heat-insulating material will lose its properties .The heat-insulating properties of a heater used in such a seam are practically absent.

To calculate the heat-insulating properties of the assembly seam it is necessary to calculate its surface area. The area of the seam depends on its width (width of the gap between the window structure and the contiguous surfaces) and the area of the window structure.

In accordance with GOST 30971-2002 and GOST 52749-2007 with allowance for possible deviations due to unevenness of the construction, the average width of the assembly seam should not exceed 60 mm. In the calculations one will use these figures, although in Russia cases when the width of the assembly seam exceeds 100 mm are not rare. -- in these cases the manufacturer of the assembly foam as a rule will not issue a guarantee for such a seam.

The standard dimensions of windows in Russia are established in GOST 23166-99. For calculation it is proposed that one will assume a window structure of average size 1.46 x 1.47 m. The area of such a window structure will amount to 2.15 m^2.

The total length of the assembly seams for such a window with allowance for the angular overhangs will amount to:

1.46*2+1.47*2+0.06*4 = 6.1 meters.

The area of such a seam will amount to 6.1·0.06 = 0.366 m^2

Therefore, it is possible to derive a coefficient for calculating the area of the assembly seam based on the area of the window. It amounts to 0.17 (0.366/2.15).

<u>This means, for purposes of calculation one can consider on the average that one square meter of window construction involves 0.17 m^2 of assembly seam.</u>

B.1. Calculation of thermally insulating properties of the assembly seam

The same formula is used for calculating the heat losses of the assembly seam due to the phenomena of heat conduction as is also used for the window construction. All of the calculations are performed in the form shown for 1 square meter of window.

Q = K * A *(tin- tout) *(1 + Σ ß)*days*24hr/day (Whr)]

or

Q = K * 0.17 *(22- tout) *(1 + Σ ß))*days*24hr/day (Whr)

Separately, the values of heat transfer of the assembly seam in the USSR were not standardized; therefore one should use the given values of the resistance to heat transfer established generally for wooden windows in double frame glass packages (since the assembly seam represents part of the window), which amounts to 0.4 m^2 °C/Watt (SNiP II-3-79). With allowance for the high degree of wear of the heater it is necessary to use a correction coefficient **ß,** which is equal to **70%,** i.e. the actual resistance to heat transfer of such a seam with allowance for wear amounts to **0.23** m² °C/Watt**. = 1/(K*(1+ Σ ß)) =1 /(0.4^{-1}*(1+0.7)) =1/(2.5*1.7)).**

This magnitude is also the weighted average value between the cement plaster and wood if we consider the fact that the assembly seam is filled only with these materials in a proportion of 20/80.

The formula for the heat losses through the assembly seam for an old window in a wooden glass package with a double casement will have the form:

$$Q = 0.23*0.17*(22-t_{out})*\ days*24hr/day\ (Whr)$$

Table 4 contains the data presented on the heat losses of the assembly seam for worn out wooden windows in general for Russia. The data referred to one square meter of window area.

Table 4

City	duration of heating season (days)	Average temperature of heating season (°C)	Area of assembly seam per 1 m² of window area (m^2)	Heat losses of assembly seam for wooden windows in double casements relative to one square meter of window, (watts)	heat losses of assembly seam for wooden windows in double casements relative to one square meter of window per season, (whr)
Astrakhan	167	-1,2	0,17	17	67 182
Arkhangelsk	253	-4,4	0,17	19	115 817
Vladivostok	196	-3,9	0,17	19	88 025
Volgograd	178	-2,2	0,17	17	74 694
Vologda	231	-4,1	0,17	19	104 545
Voronezh	196	-3,1	0,17	18	85 306
Ekaterinburg	230	-6,0	0,17	20	111 670
N. Novgorod	215	-4,1	0,17	19	97 303
Irkutsk	240	-8,5	0,17	22	126 929
Krasnodar	149	2,0	0,17	14	51 673
Moscow	**212**	**-3,4**	**0,17**	**18**	**93 372**
Murmansk	275	-3,2	0,17	18	120 166
Novosibirsk	230	-8,7	0,17	22	122 438
Omsk	221	-8,4	0,17	22	116 497
Samara	203	-5,2	0,17	20	95 745
St. Petersburg	220	-1,8	0,17	17	90 792
Tyumen	220	-7,5	0,17	21	112 537
Khabarovsk	211	-9,3	0,17	23	114 519
Yaroslavl	221	-4,0	0,17	19	99 636
AVERAGE	**214**	**-4,58**	**0,17**	**19,20**	**99 412,87**

The coefficient of heat conduction of the assembly seam should be used to calculate the heat losses of assembly seams from assembly foam. On the average for gun-applied assembly foams this index in accordance with the quality standards is equal to 0.03-0.033 watts/m^2·°K This magnitude is calculated for a foam layer thickness of 1 m. The thickness of the assembly seam is equal to the thickness of the window profile. A profile 70 mm thick is the standard. Therefore, the coefficient of heat conduction of the assembly seam from assembly foam 70 mm thick is equal to **0.43** watts/m^2·°K **.**

The formula for heat losses will have the form:

$$Q_{б1} = 0.43*0.17*(22- t_{out})*days*24 \text{ hr/day (Whr)}$$

Table 5 contains the data on the heat losses of the assembly seam prepared with an applicator gun. The data pertain to one square meter of window area

Table 5

City	Duration of the heating season (days)	Average temperature of the heating season (°C)	area of assembly seam for 1m^2 window area (m^2)	heat losses of assembly sem for new windows with double glass panes m per 1 sq.m of window, (watts)	The same for the season, (whr)
Astrakhan	167	-1,2	0,17	1,69	6 775
Arkhangelsk	253	-4,4	0,17	1,92	11 679
Vladivostok	196	-3,9	0,17	1,89	8 876
Volgograd	178	-2,2	0,17	1,76	7 532
Vologda	231	-4,1	0,17	1,90	10 542
Voronezh	196	-3,1	0,17	1,83	8 602
Ekaterinburg	230	-6,0	0,17	2,04	11 261
N. Novgorod	215	-4,1	0,17	1,90	9 812
Irkutsk	240	-8,5	0,17	2,22	12 800
Krasnodar	149	2,0	0,17	1,46	5 211
Moscow	**212**	**-3,4**	**0,17**	**1,85**	**9 416**
Murmansk	275	-3,2	0,17	1,84	12 118
Novosibirsk	230	-8,7	0,17	2,24	12 347
Omsk	221	-8,4	0,17	2,21	11 748
Samara	203	-5,2	0,17	1,98	9 655
St. Petersburg	220	-1,8	0,17	1,73	9 156
Tyumen	220	-7,5	0,17	2,15	11 348
Khabarovsk	211	-9,3	0,17	2,28	11 548
Yaroslavl	221	-4,0	0,17	1,89	10 047
AVERAGE	**214**	**-4,58**	**0,17**	**1,94**	**10 024,83**

Therefore on the average for Russia the saving of energy from replacement of old windows by windows with a high quality assembly seam amount to (99.4 – 10) = 89.4 kW·h of energy per 1 m^2 of glazing for the heating season.

B2. Calculation of heat losses through assembly seams due to air permeability

The same formula is used for calculating the heat losses of the assembly seam due to infiltration as for calculating the heat losses due to air permeability of the window construction.

$Q = 0.28*G*c*(t_{in} - t_{out})$, (whr) where

G = quantity of infiltrating air, kg/hr.

c = specific heat capacity of air = 1.0056 J/kgK

According to GOST 30971-02, the air permeability of the assembly seam of class one amounts to less than **0.1 m^3/h·m**, which is equivalent to **0.123 kg/h·m.** This index is established for a seam length of 1 m. Generally speaking this magnitude corresponds to the high properties of the assembly foam which prevents air penetration (see above). **According to GOST 52749-2007**

The assembly seam should be air impermeable. To keep the calculations conservative we shall use the value **0.123 kg/h·m**

The air permeability of the assembly seen of the 3rd class according to GOST is equal to **1 m^3/h·m** or **1.23 kg/h·m** To analyze the correctness of this value one can determine the size of a crack through which such a volume of air can penetrate.

In accordance with SNiP 2.04.05-91, the quantity of air in kg/h infiltrating through cracks of enclosing structures is calculated by the formula:

$$G = 3456\ \Sigma A * \Delta p_i^{0,5},$$

Where **A** is the area of the cracks, gaps and spaces in the enclosing construction.

Δp_i is the calculated difference between the pressures on the outer and inner surfaces of the enclosing constructions respectively on the calculated floor when **Δp_1**=10 Pa. To simplify the calculations we shall use the data for the 1st floor, i.e. **Δp_1**=10 Pa, i.e. the formula assumes the form

$$G = 3456 * A * 10^{0,5}.$$

In the case of G = 1.23, the area of the cracks (A) is equal to 0.00011 m^2, which amounts to 0.18% of the area of the assembly seam with a length of 1 m. This area is equivalent to the area of a crack with a length of 1 m and a width of 0.11 mm, i.e. such a crack cannot be seen with the unaided eye. In order for such a volume of cold air (1 m^3) to penetrate into the room the air must pass through such a slit at a speed of 2.5 m/sec or 9 km/h

In reality the area of the cracks of an old worn seam may at times exceed the calculated value and accordingly the volume of air infiltration through such an assembly seam will significantly exceed **1 m^3/h·m.** This calculation was performed in a conservative manner, and therefore in it a figure will be used for the air permeability of an old assembly seam of **1 m^3/h·m or 1.23 kg/h·m.**

Therefore, a reduction in air permeability due to repair of the assembly seam using assembly foam will amount to (1.23 - 0.123) = **1.107 kg** per assembly seam with a length of 1 m. Since the area of the assembly seam with a length of 1 m amounts to 0.06 m^2, the reduction in air permeability for a seam with a total area of 0.17 m^2 will amount to **3.14 kg/h,** which in our calculations is equivalent to a glazed area of **1 m^2**.

Generalized data on the saving of energy from the phenomenon of infiltration due to the use of assembly foam in the assembly seam for the heating season are contained in Table 6.

Table 6.

City	Duration of heating season (days)	average temperature of heating season (°C)	reduction of air permeability of seam of window construction due to the use of assembly foam, kg/h·m^2. Cal fitted for m^2 window	reduction of heat losses from infiltration of air by assembly seam during heating season. Whr per 1 m^2 of construction
Astrakhan	167	-1,2	3,14	81 753
Arkhangelsk	253	-4,4	3,14	140 936
Vladivostok	196	-3,9	3,14	107 116
Volgograd	178	-2,2	3,14	90 894
Vologda	231	-4,1	3,14	127 219
Voronezh	196	-3,1	3,14	103 807
Ekaterinburg	230	-6,0	3,14	135 889
N. Novgorod	215	-4,1	3,14	118 407
Irkutsk	240	-8,5	3,14	154 458
Krasnodar	149	2,0	3,14	62 880
Moscow	**212**	**-3,4**	3,14	113 624
Murmansk	275	-3,2	3,14	146 229
Novosibirsk	230	-8,7	3,14	148 993

Omsk	221	-8,4	3,14	141 764
Samara	203	-5,2	3,14	116 510
St. Petersburg	220	-1,8	3,14	110 484
Tyumen	220	-7,5	3,14	136 944
Khabarovsk	211	-9,3	3,14	139 356
Yaroslavl	221	-4,0	3,140	121 245
AVERAGE	**214**	**-4,58**	**3,14**	**120 974**

Therefore, the total average saving of energy due to the use of the assembly foam in the assembly seam calculated for one square meter of window construction averaged throughout Russia can be estimated as **210 kW·h** (= 89+121).

Analysis of the energy efficiency from replacing worn out windows

By adding up the savings of energy from replacing old wooden windows in double glazing packages by the new windows in a plastic or wooden casement with double glass packages amounts to (210 + 239) = **449 kW·h** of energy per year for the heating season. This figure represents the average value is calculated by averaging over the entire territory of Russia with allowance for different climatic zones, calculated for one square meter of glazing.

In this case 53% (=239/449) within the scope of the present savings accrues to window construction and 47% (=210/449) to the assembly seam supplemented with assembly foam. By increasing the thickness of the glass package, by using additional coverings on the glass is possible also further to increase this savings index due to the growth of the specific weight of the savings accruing per window construction. The savings from repairing the assembly seam remain the same.

Calculation of the energy efficiency of 1 can of insulating foam

The calculation was performed for a can of PROFFLEX 65 PLUS foam (gross weight of bottle 1.02 kg).

The area of the assembly seam that can be foamed with one bottle is found by solving the equation:

0.0 65 m^3 =S· 0.07, where 0.07 is the thickness of the seam in meters.

S = 0.93 m², which is equivalent to the length of the assembly seam of 15.5 m (0.93/0.06) or an area of the window glazing of **5.5 m² (**0.93/0.17).

Therefore, the energy efficiency of one can of a given foam averaged throughout Russia for that heating season is equal to:

1155 kW·h (= 5.5· 210) or

1.15 MW·h or

1 Gcal (=1.15·0.86)

This number pertains only to the energy efficiency of the assembly seam.