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BLACK SEA SCIENCE 2021

PROCEEDINGS

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4. POWER ENGINEERING AND ENERGY EFFICIENCY

INVESTIGATION OF THE INFLUENCE OF THERMAL MODERNIZATION OF PANEL RESIDENTIAL BUILDINGS IN POLTAVA ON THE HUMIDITY CONDITION OF PANELS IN THE JOINT ZONE

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Abstract: The paper studies the moisture condition of panels in the joint area to thermo-modernization. It was determined that there was no moisture condensation in the joints of 300 mm thick wall panels, while in 350 mm thick panels moisture accumulation occurred in winter, and the condensation zone was located in the thermal insulation of the joint near the windproof layer. After thermo-modernization of the panel walls, the moisture conditions in the joint area have improved, but in the 350 mm thick walls with an open drainage gap the second requirement of the norm is not met either. When the drainage gap is closed with additional insulation, the moisture conditions satisfy the norms.

Keywords: joints of panel walls, humidity, thermal modernization of walls.

I. INTRODUCTION

The wet condition of the external enclosing structures of buildings has a significant impact on their heat-protective properties. As the humidity of the wall material increases, their heat-protective properties decrease, which leads to an increase in heat loss through them, a decrease in the temperature of the inner surface, the appearance of condensate and mold on this surface. This in turn leads to a deterioration of comfortable indoor conditions.

The weak point of panel walls, from the point of view of "thermal protection", is their joints. The heat-protective properties of the joints are worse than other parts of the walls, so all the previously listed disadvantages that occur when increasing the humidity of the wall material in the joints are more pronounced. This is because the joints have less heat transfer resistance than other parts of the walls.

Currently, significant programs are being implemented for thermal modernization of residential buildings. The purpose of the programs is to reduce heat loss through external enclosing structures. Thermal modernization is primarily subject to prefabricated residential buildings built in the second half of the 20th century, which have low thermal insulation properties.

Insulation of external panel walls leads to a change in the temperature distribution across the cross section of the hay, especially in the joint area. This in turn affects the humidity, especially in the joint area. In addition, the insulation layer closes the drainage cavities in the joints, which impairs the removal of moisture from the walls.

Therefore, the study of the impact of thermal modernization of prefabricated houses on the humidity condition of the joints of external wall panels is an urgent problem.

II. LITERATURE ANALYSIS

As shown in [1, 2] in the analysis of the condition of prefabricated houses for further reconstruction highlighted the problem of joints of prefabricated walls both from a structural and thermal point of view. Experience in the operation of prefabricated houses and previous studies have shown that in winter the joints are the most vulnerable part of the walls, so the joints of the panels must have reliable insulating properties that prevent leakage, blowing and condensation in the joint area [3, 4].

Insulating properties of joints are provided by their labyrinth section and elastic consolidation, which compensates for the tendency to open them. Condensate flows down the decompression channels on the side faces of the panels and is then discharged from the wall through drainage holes in the drained joints or through open mouths in open joints. According to [5], joints of closed, draining and open types are used. The choice of type is determined by the design of external wall panels and climatic features of the construction area. The correct choice of joints promotes the drainage mode of external walls in the course of their operation.

Concrete panels are protected from moisture penetration from the outside and from the side of the room by hydrophobic painting, waterproof textured layer of cement mortar, facing with tiles or crushed stone, walls of structural concrete in multilayer structures, etc. However, this insulation allows some moisture, especially in the joints and adjacent to the filling of the slots, and prevents natural drying in good weather. Therefore at construction in zones of oblique rains and in case of a protection of rooms with damp processes there is a necessity of special constructive measures for removal from permeability of thickness of walls.

Thermal insulation of joints is provided by thermal inserts from expanded polystyrene, mineral wool plates and other similar refractory materials. Vertical thermal inserts are externally protected by air insulation from weather-resistant tapes (butyl rubber, nayrit, etc.) on the corresponding glues.

In closed and drained joints, the mouths are vertically and horizontally primed on the outside, and then filled with elastic sealing gaskets and sealing mastics with a protective coating. Water-resistant mastics of the KN2 type are used for priming the concrete surfaces of the mouth. Sealing gaskets are made of bundles of gernite, poroizol, etc.

In drained and open joints from the outside are arranged: forming a labyrinth section horizontal waterproof "ridges" with a height of 80 to 120 mm, respectively, vertical decompression cavities, which condense moisture penetrated beyond the insulation zone, and drainage aprons placed at the intersection of vertical and mountain joints. Aprons are made of weather-resistant materials.

In drained joints, additional elastic gaskets are glued to the waterproof comb within the length of the drainage apron. Moisture on the apron flows through the surface drainage holes 30x20 mm, located at the intersections of the joints. In open joints, the penetration of atmospheric precipitation through vertical mouths is prevented by water-repellent tapes made of weather-resistant materials introduced through special grooves through horizontal ones - a water-protective ridge. The structures of the joints are shown in Fig. 1-3.

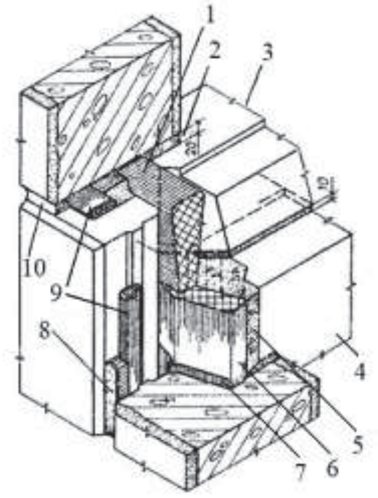


Fig. 1. Closed joint: 1 - horizontal thermal liner; 2 - the seam is filled with cement mortar 20 mm; 3 - reinforced concrete floor slab; 4 - reinforced concrete panel of the inner wall; 5 - concrete M150-200; 6 - vertical thermal liner; 7 - air protection gluing; 8 - elastic gasket; 9 - sealing mastic; 10 - protective coating

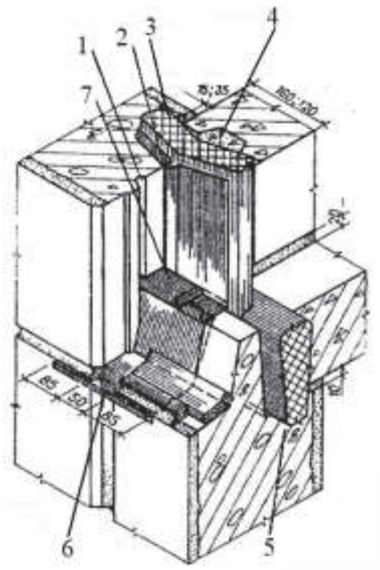


Fig. 2. Drainage joint: 1 - decompression channel; 2 - air protection film; 3 - vertical thermal liner; 4 - concrete M150-200; 5 - horizontal thermal liner; 6 - leaky section of the horizontal seam; 7 - elastic gasket for the length of the drainage channel 220 mm

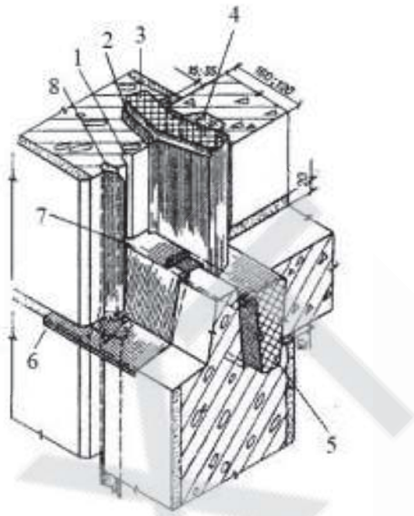


Fig. 3. Open joint: 1 - decompression channel; 2 - air protection film; 3 - vertical thermal liner; 4 - concrete M150-200; 5 - horizontal thermal liner; 6 - drainage apron 220 mm; 7 - elastic gasket for the entire length; 8 - drainage tape

III. OBJECT, SUBJECT, AND METHODS OF RESEARCH

The object of research - the impact of thermal modernization of prefabricated houses on the wet condition of the panels in the joint area

The subject of research - the wet condition of the joints of the panel walls of residential buildings

The method of research of a damp condition of joints of panel walls consisted of the following stages:

1. Construction of the temperature field at the intersection of the joints of the panels. The construction of the temperature field was performed using the program ELCUT.

2. Construction of the field of elasticity of saturated water vapor at the intersection of the joints of the panels. The obtained temperatures based on the temperature field were used for this purpose.

3. Construction of the field of actual elasticities of water vapor at the intersection of the joint. For this purpose, the ELCUT program was used, in which the thermal conductivity of materials was replaced by the vapor permeability coefficient, and the heat transfer coefficients on the surfaces were replaced by moisture exchange coefficients.

4. The field of elasticity of saturated water vapor and the field of actual elasticity

of water vapor were superimposed on each other.

5. The area of condensation of water vapor in the joint area was determined.

6. The amount of moisture coming from the inner surface of the panel to the condensation zone was determined.

7. The amount of moisture emanating from the condensation zone to the outer surface of the panel was determined.

8. Determined the amount of moisture that accumulated in the condensation zone during the year.

9. The amount of moisture leaving the condensation zone during the year was determined.

10. The moisture balance in the joint area of the panels during the year was determined.

IV. RESULTS

Most prefabricated houses in the country were built in the second half of the 20th century. The main part of the housing stock of these houses is concentrated in 5 and 9-storey buildings. In the city of Poltava, most prefabricated houses were built according to the 94 series. In fig. 4 shows the planning solution of prefabricated houses according to the 94 series and shows the location of the characteristic joints of the external wall panels accepted for research.

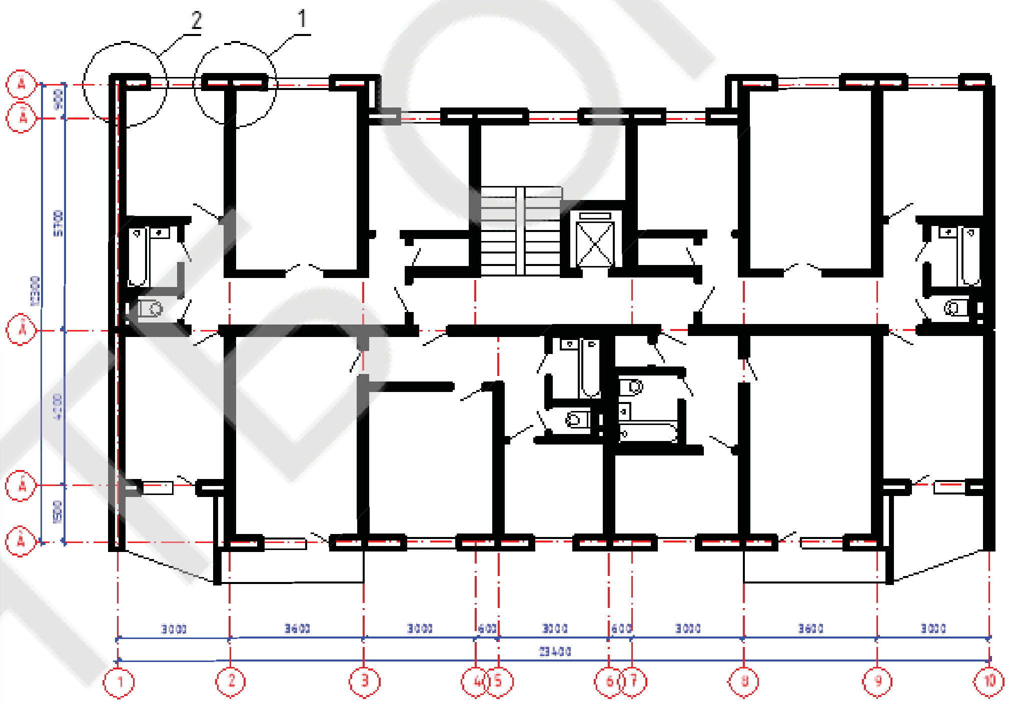


Fig. 4. Planning decision of prefabricated houses according to series 94 with designation of an arrangement of characteristic joints of panels of external walls accepted for research

In the city of Poltava, a drained joint was used in the construction of prefabricated houses. At the same time, in the initial period of construction of prefabricated houses, there was no air protection layer and thermal liner. The thickness of the panels was 300 mm. Subsequently, the wall panels were modified. After taking into account the proposals from the Poltava Civil Engineering Institute at the Poltava DBK in 1982 began to produce wall panels 50 mm thicker. The total thickness of the panels was 350 mm. A thermal insert was additionally installed at the joint of the panel. The thermal liner was made of expanded polystyrene with a density $\rho_0 = 100\ \text{kg/m}^3$, 40 mm thick. The joint was glued with a windproof layer of glassine.

The wet condition of the joints of the panels of residential buildings before the thermal modernization of units 1 and 2 of the joints of the panels with a thickness of 300 and 350 mm was analyzed (see Fig. 5-10).

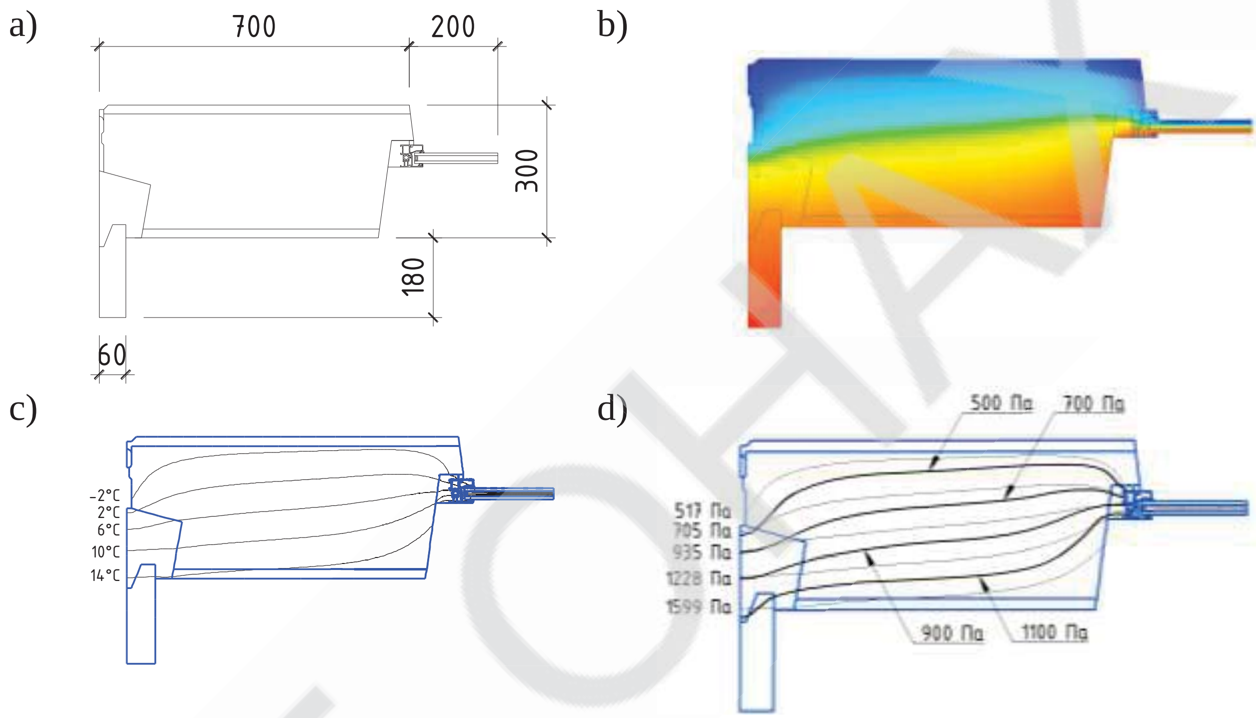


Fig. 5. Investigation of the humidity state of node 1 of the joint of 300 mm thick panels before thermal modernization: a - calculation scheme, b - temperature field in January, c - temperature isotherms at the node section in January, d - isotherms of actual and saturated partial pressure.

As can be seen from Fig. 5, d at all points of intersection the pressure of saturated water vapor is greater than the pressure of the actual partial pressure of water vapor. That is, condensation of water vapor in the section will not occur. This is explained by the fact that the vapor permeability coefficient of expanded clay concrete is slightly different from the vapor permeability coefficient of cement-sand mortar.

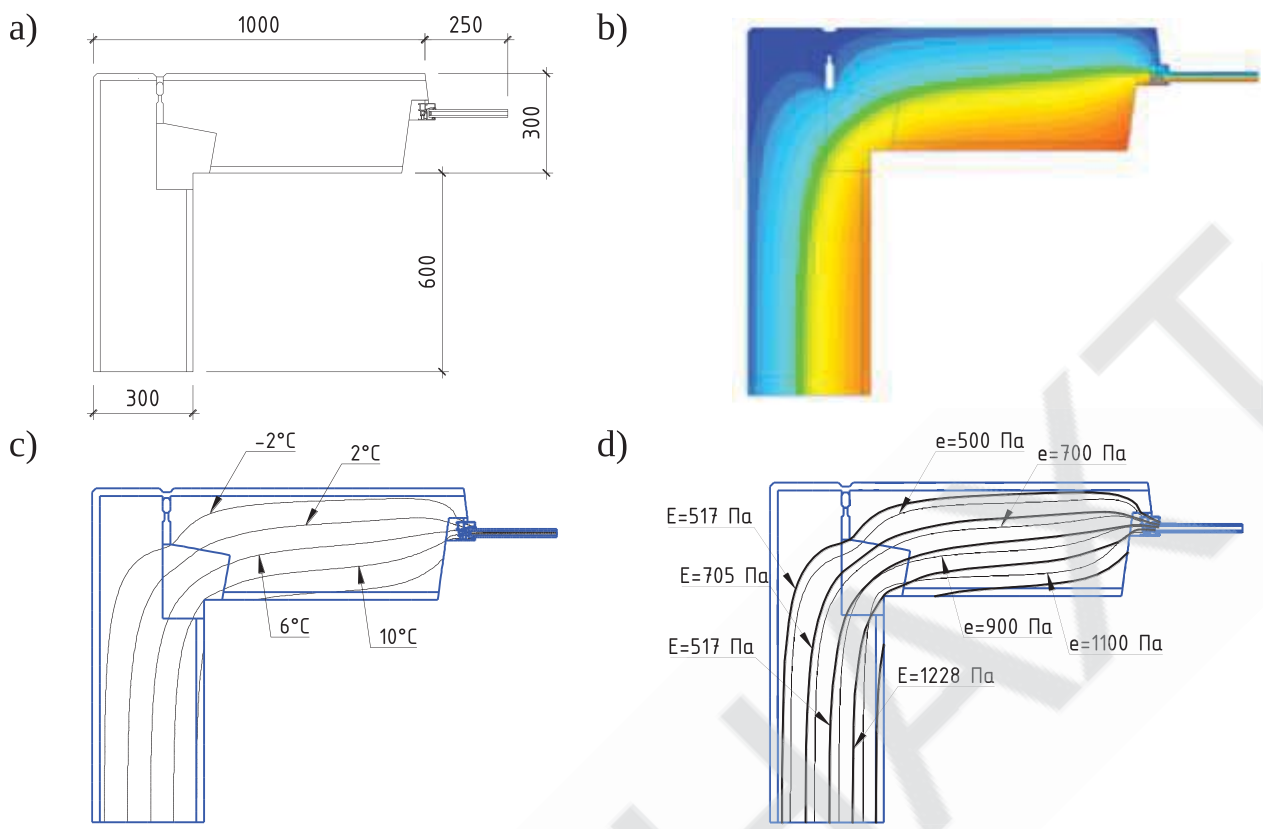
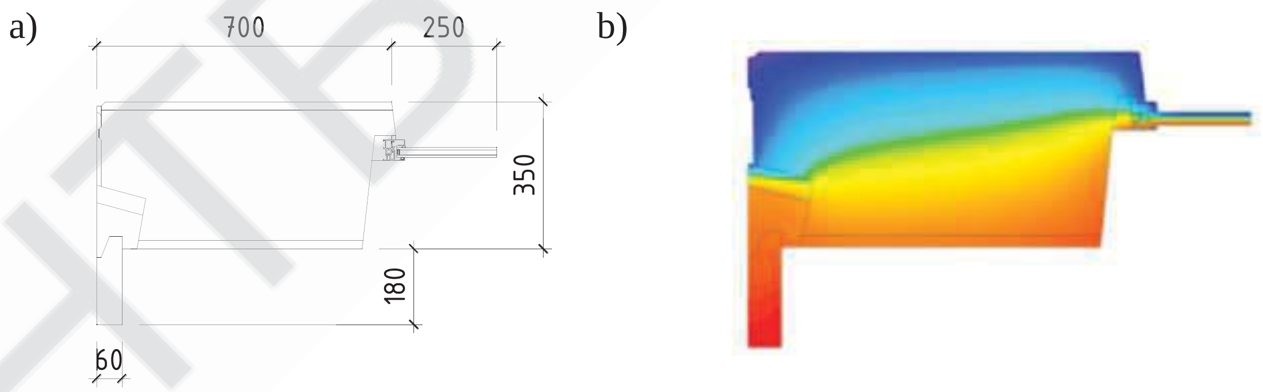


Fig. 6. Investigation of the humidity state of node 2 of 300 mm thick panel joints before thermal modernization: a - calculation scheme, b - temperature field in January, c - temperature isotherms at the node section in January, d - isotherms of actual and saturated partial pressure.

As can be seen from Fig. 6, d at all points of intersection the pressure of saturated water vapor E is greater than the pressure of the actual partial pressure of water vapor e. That is, condensation of water vapor at the intersection will not occur.



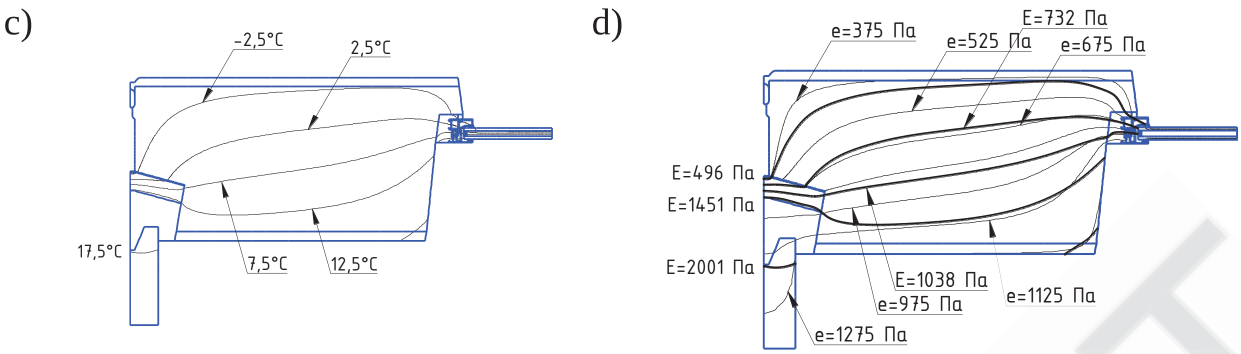


Fig. 7. Investigation of the humidity state of node 1 of the joint of panels with a thickness of 350 mm before thermal modernization: a - calculation scheme, b - temperature field in January, c - isotherms of temperatures at the node intersection in January, d - isotherms of actual and saturated partial pressure.

As can be seen from Fig. 7, d at some points of intersection the pressure of saturated water vapor is greater than the pressure of the actual partial pressure of water vapor. That is, condensation of water vapor occurs in the joint area. This is explained by the fact that the windproof layer at the joint made of a layer of roofing material complicates the release of vapor moisture from the insulation. In Fig. 8 shows the condensation zones of the months of the year in which condensation occurs.

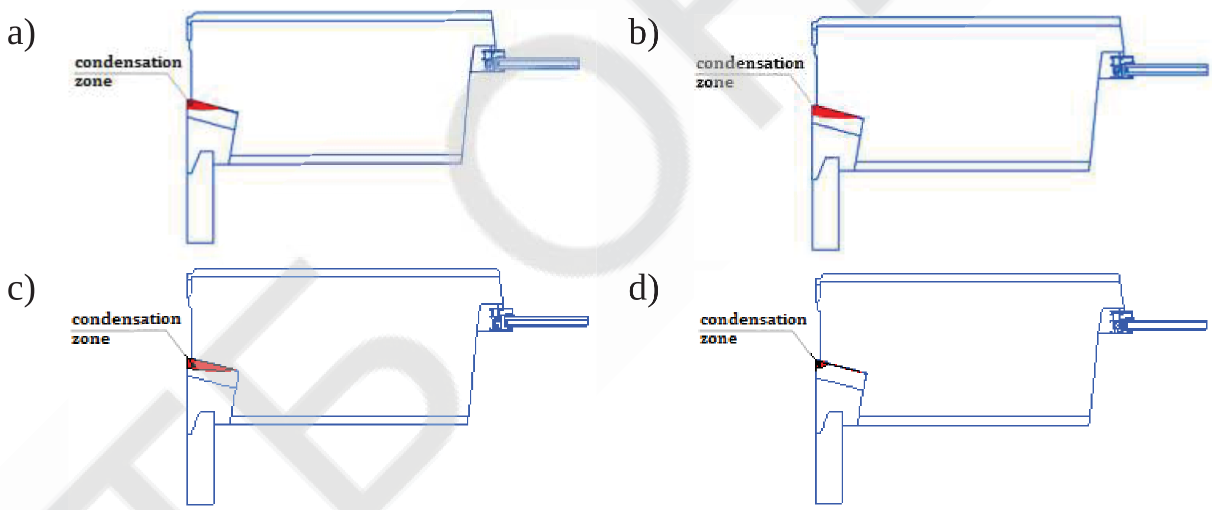


Fig. 8. Water vapor condensation zone in the joint zone of the panels of node 1 of the joint of 350 mm thick panels: a - December, b - January, c - February, d - March.

In other months of the year moisture is released. During the year, $W_{zp} = 0{,}331\ \text{kg/m}^2$ of moisture accumulates in the fence, and $W_{lp} = 0{,}425\ \text{kg/m}^2$ evaporates. The requirement of clause 4.2.2 [6] is fulfilled.

Determine the increase in moisture Δw,%, in the insulation is $\Delta w = 4{,}14\ \%$, which is more than $\Delta w_d = 2{,}5\ \%$. The requirement of clause 4.2.1 [6] is not fulfilled.

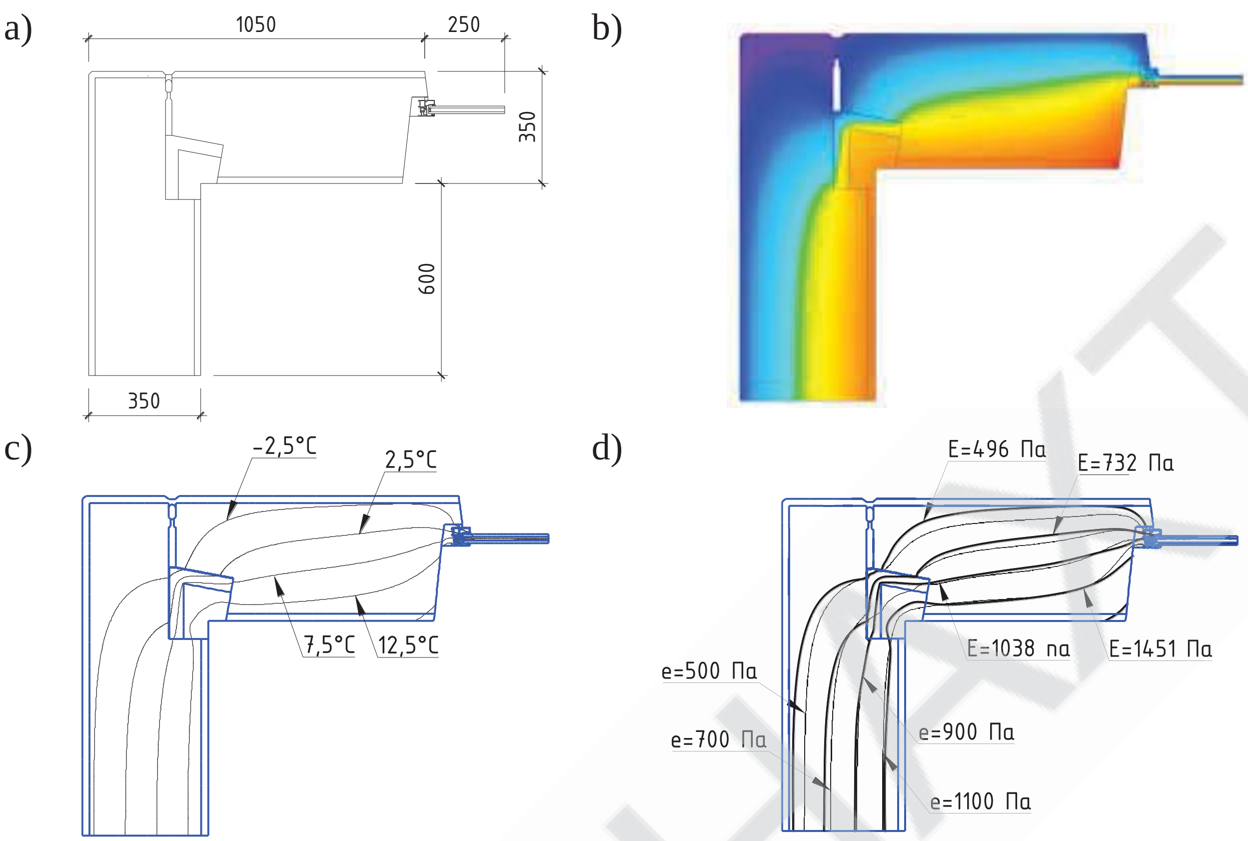
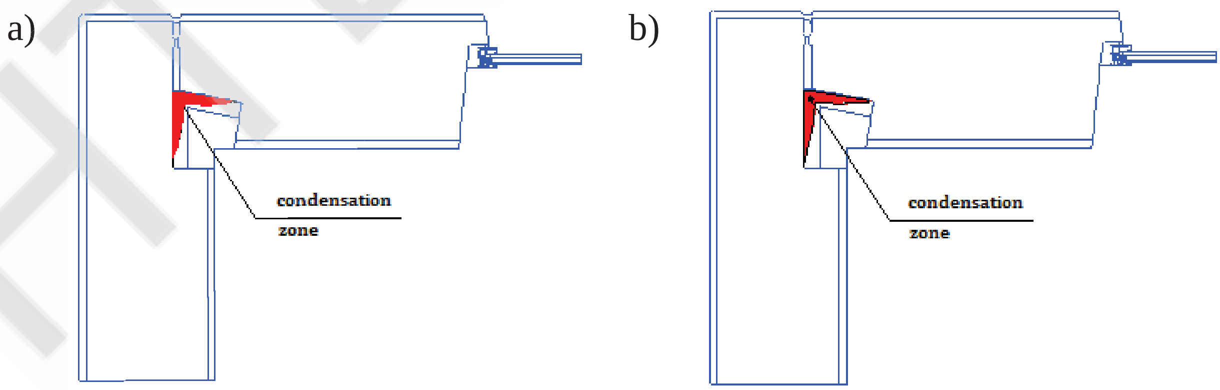


Fig. 9. Investigation of the humidity state of the node 2 of the joint of panels with a thickness of 350 mm before thermal modernization: a - calculation scheme, b - temperature field in January, c - isotherms of temperatures at the intersection of the node in January, d - isotherms of actual and saturated partial pressure.

As can be seen from Fig. 9, d at some points of intersection the pressure of saturated water vapor is greater than the pressure of the actual partial pressure of water vapor. That is, condensation of water vapor occurs in the joint area. This is explained by the fact that the windproof layer at the joint made of a layer of roofing material complicates the release of vapor moisture from the insulation. In Fig. 10 shows the condensation zones of the months of the year in which condensation occurs.



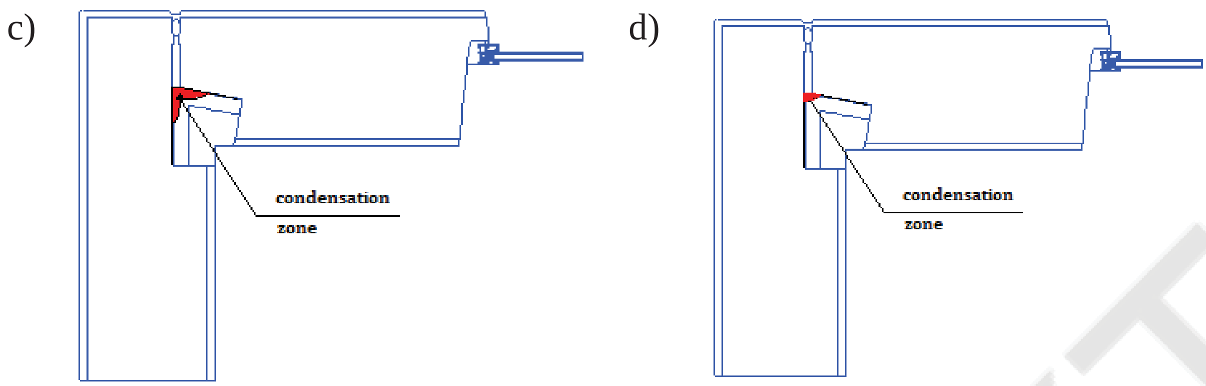


Fig. 10. Condensation zone of water vapor in the zone of joint of panels of node 2 of joint of panels 350 mm thick: a - December, b - January, c - February, d - March.

In other months of the year moisture is released. During the year, $W_{\text{zp}} = 0{,}62\ \text{kg/m}^2$ of moisture accumulates in the fence, and $W_{\text{lp}} = 1{,}444\ \text{kg/m}^2$ evaporates. The requirement of clause 4.2.2 [6] is fulfilled.

Determine the increase in moisture Δw,%, in the insulation is $\Delta w = 7{,}75\ \%$, which is more than $\Delta w_{\text{d}} = 2{,}5\ \%$. The requirement of clause 4.2.1 [6] is not fulfilled.

After analyzing the wet condition of 300 and 350 mm thick panels of houses before thermal modernization, we can conclude that moisture condensation in the joint area of 300 mm thick wall panels does not occur, in 350 mm thick panels moisture accumulates in winter. The condensation zone is located in the joint insulation near the windbreak. This is due to the greater resistance to vapor penetration of the windproof layer than other materials in the joint. Moisture that accumulates in the insulation during the winter period of moisture evaporation evaporates in the summer. That is, the first requirement of the rules [6] is met. The increase in the humidity of the insulation during the winter period of moisture accumulation is more than the allowable increase in humidity in terms of thermal insulation characteristics. The second requirement of the rules [6] is not met.

Determination of the amount of additional insulation of the walls of prefabricated houses was performed according to the method described in [7]. An additional layer of insulation was taken for: longitudinal walls with a thickness of 300 mm - 170 mm; end walls with a thickness of 300 mm - 140 mm; longitudinal walls with a thickness of 350 mm - 160 mm; end walls with a thickness of 350 mm - 130 mm.

Studies of the wet state of the joint of 300 mm and 350 mm thick panels after thermal modernization with a closed drainage cavity showed that condensation of water vapor at the intersection of nodes 1 and 2 will not occur.

Studies of the wet state of the joint of 300 mm thick panels after thermal modernization with an open drainage cavity showed that condensation of water vapor at the intersection of nodes 1 and 2 will not occur.

The results of the analysis of the wet state of the nodes 1 and 2 of the joint of panels with a thickness of 350 mm after thermal modernization with an open drainage cavity are shown in Fig. 11-14.

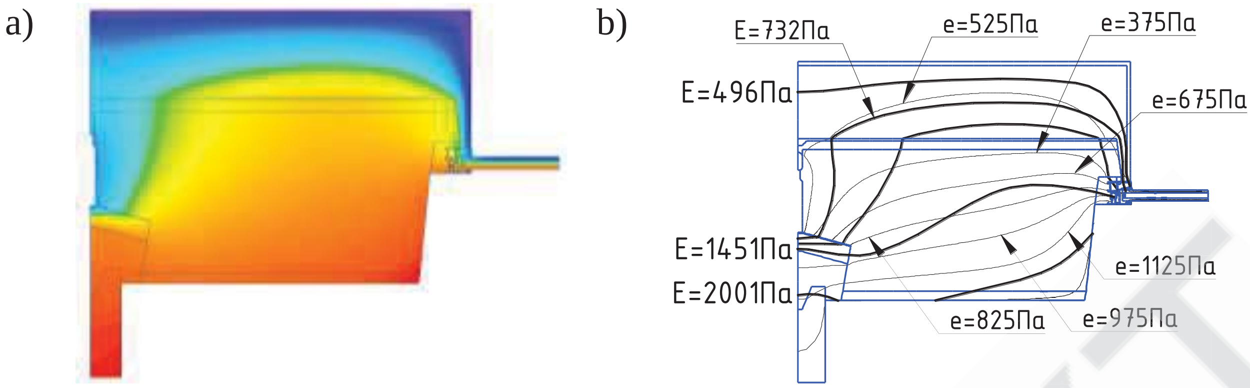
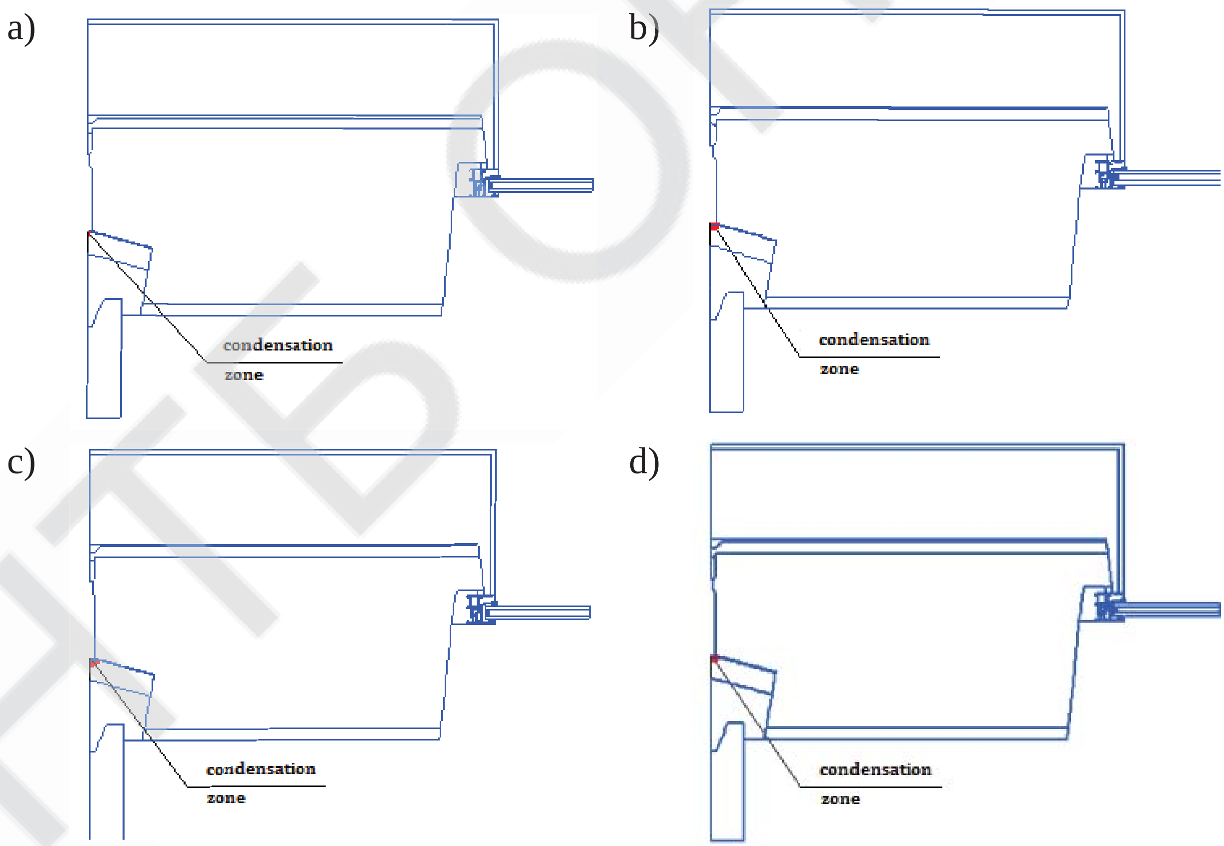


Fig. 11. Investigation of the wet state of node 1 of the joint of panels with a thickness of 350 mm after thermal modernization with an open drainage cavity: a - temperature field in January, b - isotherms of actual and saturated partial pressure.

As can be seen from Fig. 11, b at some points of intersection the pressure of saturated water vapor is greater than the pressure of the actual partial pressure of water vapor. That is, condensation of water vapor occurs in the joint area. This is explained by the fact that the windproof layer at the joint made of a layer of roofing material complicates the release of vapor moisture from the insulation. In Fig. 12 shows the condensation zones of the months of the year in which condensation occurs.



e)

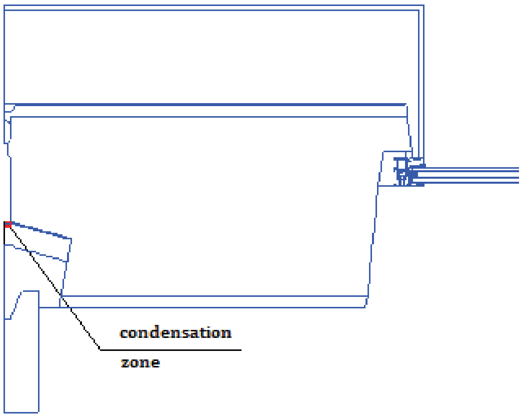


Fig. 12. Water vapor condensation zone in the joint zone of panels: a - November, b - December, c - January, d - February, e - March.

In other months of the year moisture is released. During the year, $W_{\mathrm{zp}} = 0{,}794\ \mathrm{kg/m^2}$ of moisture accumulates in the fence, and $W_{\mathrm{lp}} = 1{,}12\ \mathrm{kg/m^2}$ evaporates. The requirement of clause 4.2.2 [6] is fulfilled.

Determine the increase in moisture Δw,%, in the insulation is $\Delta w = 9{,}9\ \%$, which is more than $\Delta w_{\mathrm{d}} = 2{,}5\ \%$. The requirement of clause 4.2.1 [6] is not fulfilled.

a)

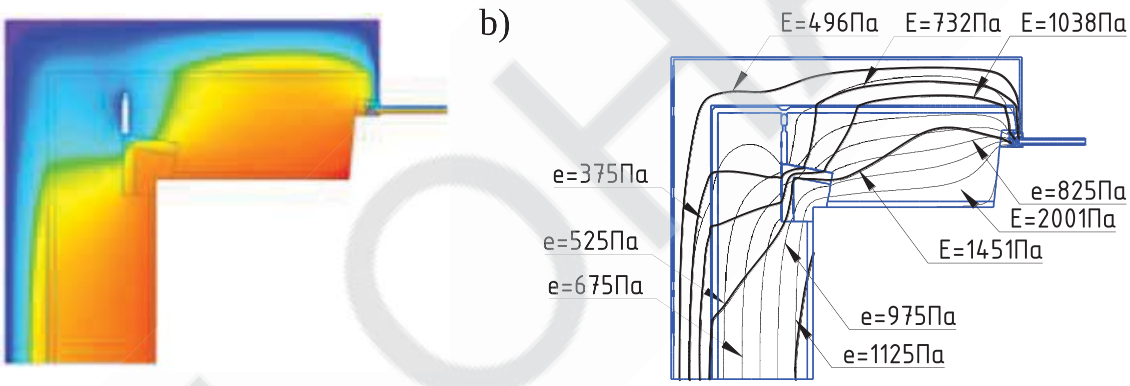
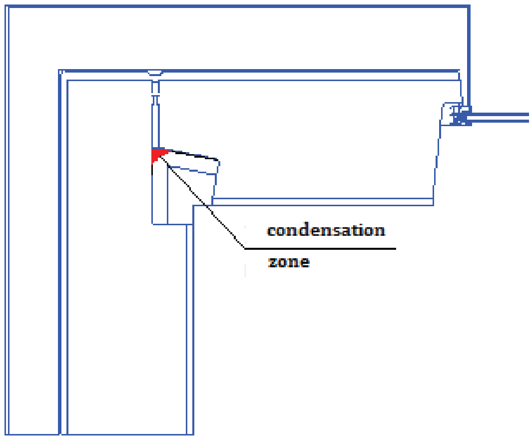


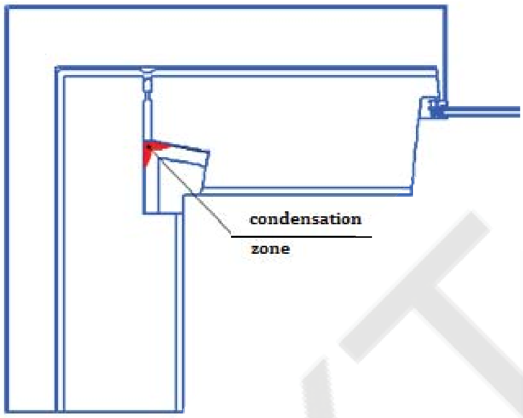
Fig. 13. Investigation of the moisture state of node 2 of the joint of panels with a thickness of 350 mm after thermal modernization with an open drainage cavity: a - temperature field in January, b - isotherms of actual and saturated partial pressure.

As can be seen from Fig. 13, b at some points of intersection the pressure of saturated water vapor is greater than the pressure of the actual partial pressure of water vapor. That is, condensation of water vapor occurs in the joint area. This is explained by the fact that the windproof layer at the joint made of a layer of roofing material complicates the release of vapor moisture from the insulation. In Fig. 14 shows the condensation zones of the months of the year in which condensation occurs.

a)



b)



c)

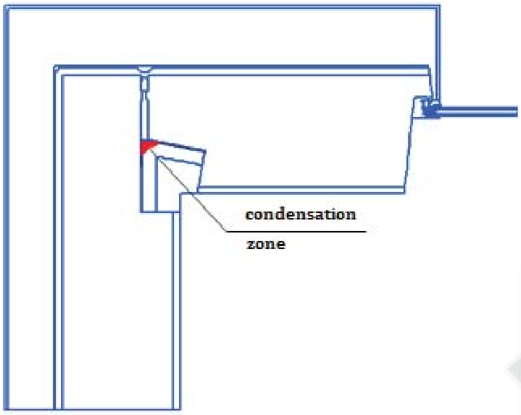


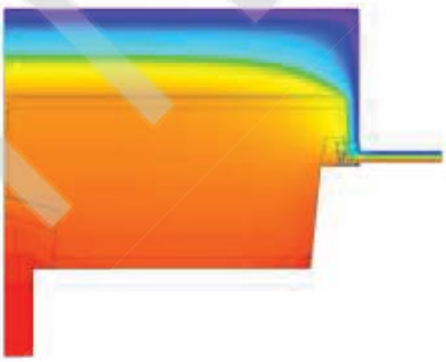
Fig. 14. The condensation zone of water vapor in the joint zone of the panels: a - December, b - January, c - February.

In other months of the year moisture is released. During the year, $W_{zp} = 0{,}449\ \mathrm{kg/m^2}$ of moisture accumulates in the fence, and $W_{lp} = 0{,}453\ \mathrm{kg/m^2}$ evaporates. The requirement of clause 4.2.2 [6] is fulfilled.

Determine the increase in moisture Δw,%, in the insulation is $\Delta w = 5{,}6\ \%$, which is more than $\Delta w_d = 2{,}5\ \%$. The requirement of clause 4.2.1 [6] is not fulfilled.

To eliminate water vapor condensation after thermal modernization, additional insulation (up to 20 mm) was adopted and the wet condition of the joint of 350 mm thick panels after thermal modernization was performed with increasing the finishing layer to 20 mm (Fig. 15-16).

a)



b)

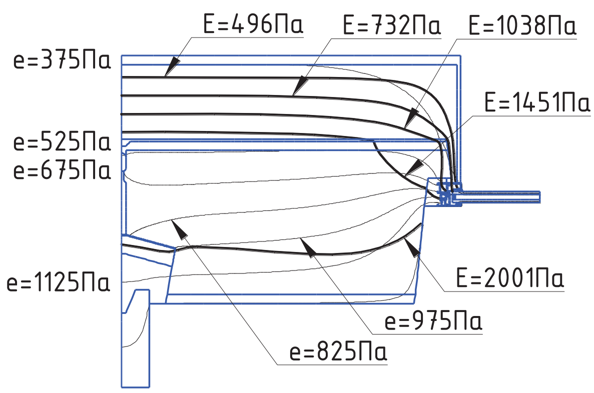
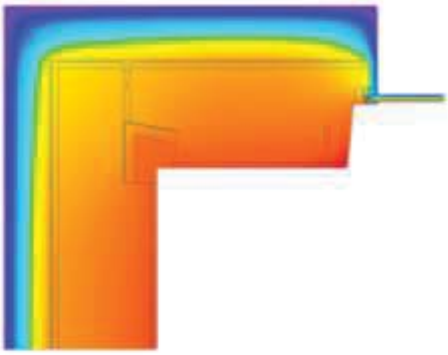


Fig. 15. Investigation of the humidity state of the joint unit 1 of panels with a thickness of 350 mm after thermal modernization with increasing the finishing layer to 20 mm: a - temperature field in January, b - isotherms of actual and saturated partial pressure.

a) 

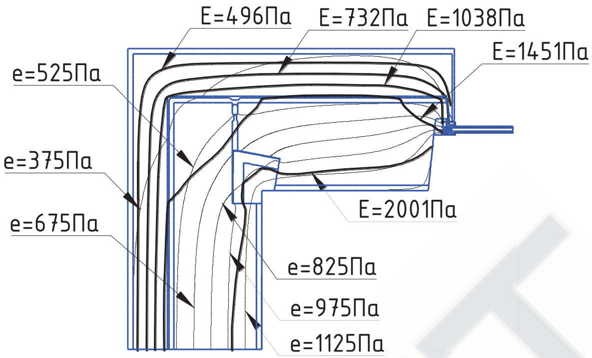
b) 

Fig. 16. Investigation of the wet state of node 2 of the joint of panels with a thickness of 350 mm after thermal modernization with increasing the finishing layer to 20 mm: a - temperature field in January, b - isotherms of actual and saturated partial pressure.

As can be seen from Figure 15, b and 16, b at all points of intersection, the saturated water vapor pressure E is greater than the actual partial water vapor pressure e. That is, water vapor condensation at the intersection will not occur.

V. CONCLUSIONS

The wet condition of the panel walls in the area of their connection plays an important role in the thermal modernization of prefabricated buildings, with insufficient insulation thickness, the formation of condensate is possible. Analysis of the wet joint of the 350 mm thick panels showed that water vapor condensation occurs in the joint area. This is due to the presence of a windproof layer at the joint. The increase in the humidity of the insulation during the winter period of moisture accumulation is more than the allowable increase in humidity in terms of thermal insulation characteristics. After thermal modernization of panel walls, their wet condition in the joint area has improved, but in walls with a thickness of 350 mm with an open drainage cavity, the second requirement of the norms is also not met. At the drainage cavity closed by an additional heater the damp condition satisfies norms.

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