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The Testing Equipment to Study Heat Transfer through a Frame-Panel Enclosure Structure Fragment

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Abstract. Thermal properties of the panel - frame enclosure structures used for construction purposes in the city of Tyumen have been studied. The effect of filtration on the change in the thermal flow rate has been revealed.

1 Introduction

Panel-frame enclosure structures are widely used in present - day construction. Thermal losses in such products mainly depend on the air and/or steam filtration speed rate through insulation layer [1, 2, 3].

However, existing methods of thermotechnical calculations do not take into account this fact [4, 5, 6]. Nevertheless, for energy saving it is important to estimate the heat amount transported through the enclosure structure depending on filtrating degree (mass rate of gas flow). In turn, it is evident that the filtering degree will depend on the pressure difference in the layered construction, which is the frame-panel enclosure structure. Filtrating degree has become especially important after the new insulating layers with selectivity in gas-transmission were invented. Experimental study approach here seems preferable, as it allows to evaluate the thermophysical properties of heat and mass transfer and mathematical model adequacy of the process under study.

It became possible to obtain the temperature distribution on the surface, as well as the actual heat flux density passing through the test structure at various differential pressures that are generated by various modes of built-in fans by using the presented automated research tool set.

2 The objects and methods of study

The aim of this study was to determine some thermophysical properties on the enclosure structure surfaces, such as temperature fields, surface density of heat flow, heat transfer dynamics and its dependence on the mass transfer degree through the layered structure.

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The testing equipment was climate chamber heat-cold-moisture REOCAM TCM – 1000, allowing to use objects in the temperature range -60 ÷ 100°C and relative humidity 20 ÷ 98% in the programmable mode. The main technical specifications are illustrated in Tab. 1.

Table 1. Technical characteristics of REOCAM TCM-100.

Parameter	**units**	**value**
Volume capacity	l	1000
Dimension capacity:		
Width	mm	1000
Depth	mm	1000
Height	mm	1050
Outline dimensions:		
Width	mm	2330
Depth	mm	2015
Height	mm	1490
Mass	kg	1100
Thermal insulation thickness of the chamber	mm	100
Insulation material	Foamed polyurethane	
Temperature range	°C	- 60 ... + 100
Accuracy of temperature by time	°C	from ± 0.01 to ± 0.5
Accuracy of temperature in volume (temperature homogeneity over the working volume, uneven temperature distribution.	°C	from ± 0.5 to ± 1.8
Relative humidity range (at temperatures from 20 to 60 ° C)	%	20…98
Humidity error on time (the uneven moisture distribution), not more	%	± 3
The heating rate	°C /min	1…3
The average rate of cooling to - 40°C, not less	°C / min	2
The average cooling rate -40°C to -70°C, not less	°C / min	1
The speed of air circulation	m/c	2...3
The maximum power consumption	kW	14
Power supply network access	~ 380 V/ 50 Hz, 3f	
Used refrigerants/oils:		
- the refrigeration unit of the upper stage	R404a/Suniso SL22	
- the refrigeration unit of the lower stage	R23/Suniso SL22	
- refrigerating unit of a dehumidifier/cooler	R134a/Suniso SL22	
Interface and protocol of data transmission	RS232, ModBUS-RTU	

The fragment of the enclosure structure under analysis has a layered construction with the frame (see Figure 1, 2, PL. 2).

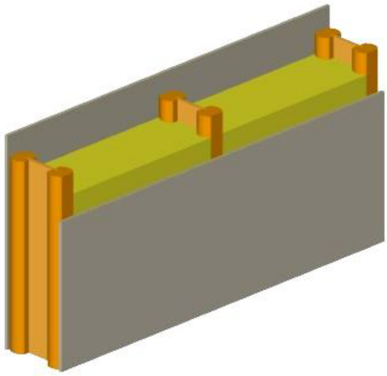

Fig. 1. The enclosure structure

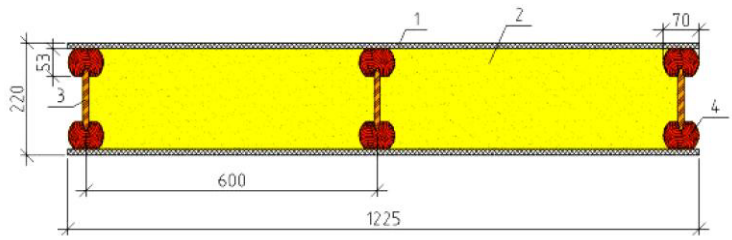

Fig. 1. Horizontal section of the enclosure structure

Table 2. Enclosure structure materials specifications.

Sr.No.	Name title	Thickness, mm	Heat capacity W / (m °C)	Density, kg/m3
1	gypsum-chip board (moisture-resistant)	8	0.41	800
2	slag wool	-	0.046	50
3	oriented standard board	9.5	0.16	600
4	wood (pine)	-	0.229	600

Testing procedure:

1. Thermoelectric sensors (TXK 0006) were attached to internal and external surfaces of the enclosure structure under testing by KPT heat-conducting paste – 8. The sensors were connected to the IT-2 calculator. Temperature sensors placement is shown in fig. 3, 4, 7, 8.

The thermoelectric sensor No. 15 was attached between the external layer of gypsum-chip board and slag wool, and the sensor No. 16 was attached between an inside layer of gypsum-chip board and slag wool to measure the insulation surface temperature both outside, and inside the enclosure structure.

Such geometrical position of sensors and measuring instruments is caused by simultaneous indicating on as large area as possible. Stiffening ribs placement has heat conductivity coefficient other than insulation conductivity coefficient. Specifications of the TXK 0006 thermoelectric sensors and the IT-2 calculator are given in table 3, 4.

Measuring instruments.

Temperature and heat conductivity sensors (multichannel IT-2) consist of an IT-2 block and a set of connection box (compensation devices) UK-4 (1 piece per each of 16 canals). IT-2 are connected to the computer via the RS-232 interface. Each UK-4 contains the integrated temperature sensor of the thermocouple cold ends.

Temperature multichannel IT-2 calculators take temperature sensors readings of the thermocouple cold ends on each of channels and transfer received data to the computer. The computer defines values of surface density of a thermal flow (q) or temperature (t) on the obtained data if necessary.

The received values are displayed on the computer in the form of voltage value (U), q or t. Temperature-cycle test is conducted. During each temperature-cycle test the IT-2 block tests all channels and transfers data to the computer. Calculators can test continuously ie temperature-cycle tests are conducted one by one, or they can conduct the required amount of temperature-cycle test. Calculators also conduct temperature-cycle tests with a programmable delay between cycles from 1 second till 60 min.

Table 3. Specifications of the thermoelectric chromel-copel sensors

Technical specifications	chromel-copel thermocouple 0006
The measured temperatures range, °C	-40…+600
Nominal static properties	chromel-copel (L) (XK (L))
Tolerance class	2
Thermal inertia, c	0.5 ... 12
The protection against dust and water degree	IP51
Protective reinforcement material	steel 12X18H10T
Junction filling	isolated, non-isolated
Conditional pressure range, MPa	0.2...2.0

Table 4. Specifications of the IT-2 calculator

Technical specifications	IT-2
Amount of measuring channels (Depending on model)	16, 32, 48, 64, 80, 96
Voltage measuring range of the sensor output, mV	-99.999…+99.999
Type of display	on the computer screen
The display capacity resolution:	
Voltage U, mV	0.001
Heat flow density q, W / m2	0.01
- Temperature T, ° C	0.01
Main absolute error, mV, not more, where U is the changed modulus value of the measured voltages, mV	± (5 + 1.5 ·10-4 ·Uchanges)
Temperature error of thermocouples cold ends, °C ()	±0.5
Access to PC	RS-232
Degree of protection against solid objects and water ingress according to GOST 14254-96	IP20
Air Temperature, ° C	20±5
Power supply	~ 220 V; 50 Hz
Current consumption, mA, not more	50
Overall dimensions, mm, not more:	
- -IT-2 blocks	250x110x355
- UK-4 complete set device	190x40x80
Weight, kg, no more:	
- IT-2 block	3.5
-entire set	8

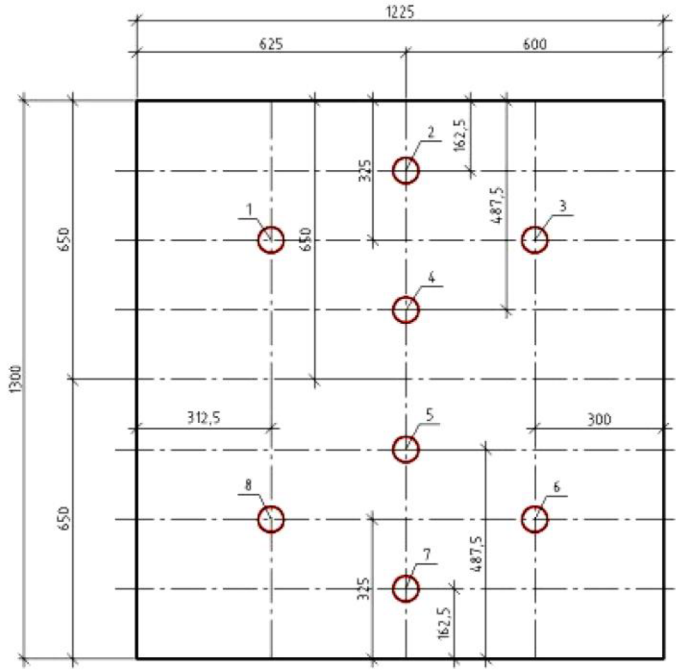

Fig. 3. Placement of the CCT (chromel-copel thermocouple) 0006 thermoelectric sensors on the enclosure structure external surface.

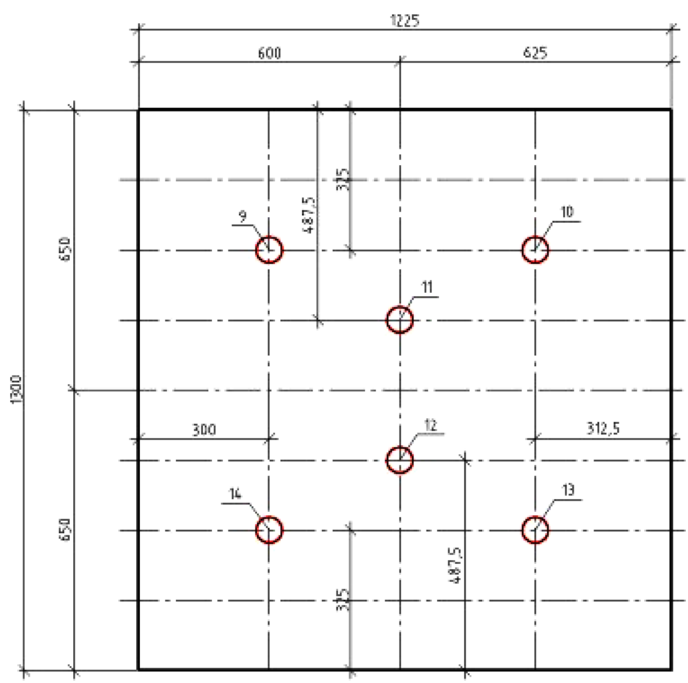

Fig. 4. Placement of the CCT (chromel-copel thermocouple) 0006 thermoelectric sensors on the enclosure structure external surface.

2. Sensors of temperature and thermal flow of ITP of MG 4.03/X(Y) "STREAM" covered with the heat-conducting (organic-silicon Heat-Conducting Paste) SHCP-8 paste were placed on an internal and external surfaces. Placement of temperature and a thermal flow sensors is shown in figures 5, 6, 7, 8. Structurally the calculator is made in the form of the electronic block and the module connected by cables. 4 thermal flow sensors and 6 temperature sensors are connected to the module by cables. The calculator is intended for testing and registration of a thermal flow density and temperatures on surfaces and / or surrounding gaseous and loose media.

Maintenance conditions:

For thermal flow and temperature sensors:

- air temperature is-30 ÷ 70 °C;
- atmospheric pressure is 84,0 ÷ 106,7 kPa (630 ÷.800 mm hg);
- relative air humidity 95% at 35 °C.

For the electronic block:

- air temperature - 20 ÷ 50 °C;
- atmospheric pressure is 84,0 ÷ 106,7 kPa (630 ÷ 800 mm hg);
- relative air humidity 95% at 35 °C.

Specifications of small thermal conductivity meter (STCM) 4.03/X(Y) "STREAM" are given in Tab. 5.

Table 5. Specifications of STCM 4.03/X(Y) "STREAM"

Name of the specification	**The value of the specification**
1. Testing range: heat flow density channels, W/m2 temperature channel, °C	 from 10 to 999 from - 30 to 100
2 The permissible main relative error limits when testing the heat flow density, % The permissible basic absolute error limits when temperature testing , °C	± 6 ± 0.2
3. Complementary relative error limits at thermal flow density measurement caused by a temperature deviation of a thermal flow sensors from 20 °C, %	±0.5
4 Allowed complementary error limits of channels of temperature measurements caused by a temperature deviation of the electronic block and modules from 20 °C, °C	± 0.05
5 The maximum total amount of thermal flow and temperature sensors connected to the sensor, not less, than ___pieces	100
6. The voltage supply of the calculator and modules	from 1.7 to 3.5
7. The conversion factor of the heat flow sensors, W/(m2•mV), not more	50
8. Sensors thermal resistance, m2•K/W, not more than the temperature heat flow density	0.005 0.001
9. The current consumed by the calculator, not more than, mA	28
10. The current consumed by the module, not more, mA	7
11. Overall dimensions, mm, not more: calculator calculator with larger display screen module	175x90x30 250x350x100 120x75x35 ø12x3

temperature sensors heat flow sensors (rectangular)* heat flow sensors (round)*	from 10x10x1 to 100x100x3 from 0 18x1.5 to 0 100x3
12. Weight, kg, not more electronic unit electronic unit with larger display screen module with ten sensors (cable length 5 m) a single temperature sensor (cable length 5 m) a single heat flux sensor (cable length 5 m)	0.25 1.70 1.20 0.3 0.3
13. The maximum cable length connecting each heat flow and temperature sensor to calculator , m, min.*	50
14. Mean time between failures, hour, not less	20000
15. Average service lifetime, years	10

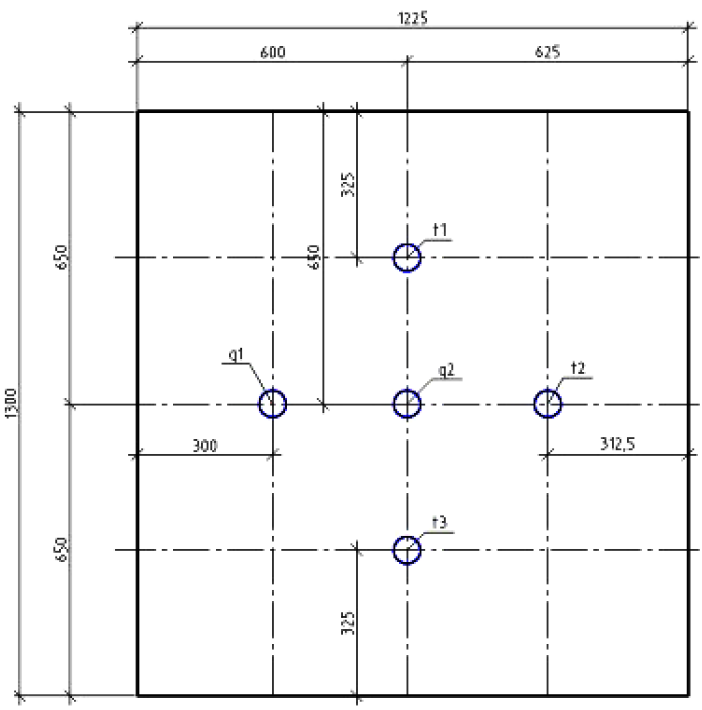

Fig. 5. Placement of temperature and heat flow sensors on the inner surface of the enclosure structure.

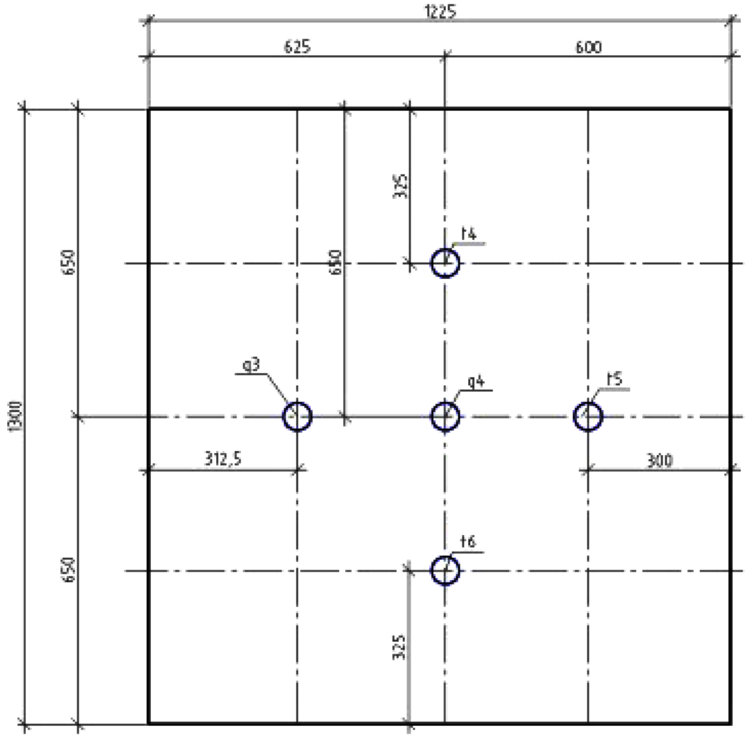

Fig. 6. Placement of temperature and heat flow sensors on the outer surface of the enclosure structure.

Fig. 7. Placement of temperature and heat flow sensors, thermoelectric sensors 0006 CCT (chromel-copel thermocouple) on the outer surface of the enclosure structure.

Fig. 8. Placement of temperature and heat flow sensors, thermoelectric sensors 0006 CCT (chromel-copel thermocouple) 0006 on the inner surface of the enclosure structure.

1. The sample of a enclosure structure under testing was attached to a working chamber by ropes.
2. The mode (cycle) of the camera operation was set. The schedule of the camera operation is given in fig. 9.
3. Gas filtration level through a layered construction was set by method of excess pressure or discharge from outer side.
4. The fragment under testing was exposed continuously to three cycles. Typical thermograms of a cycle are shown in fig. 10; surface densities of a thermal flow and temperature are given in fig. 11.
5. Test results were mathematically processed in the normal extension using Student's test.

3 Results

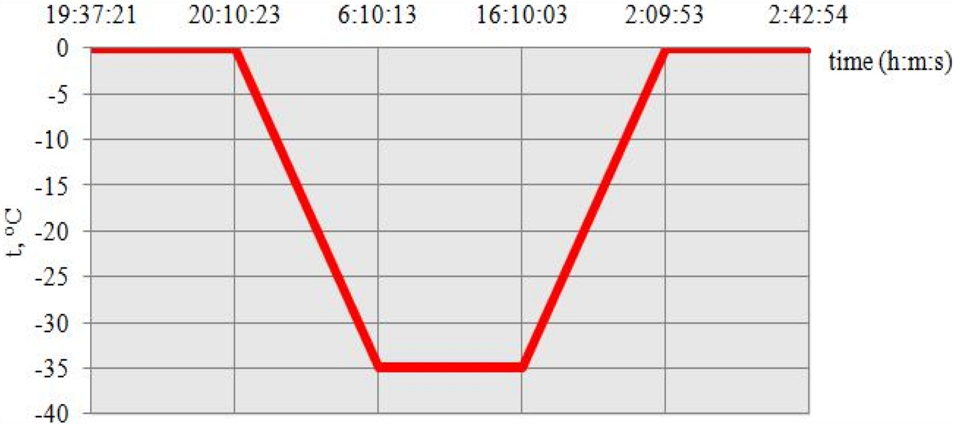

Fig. 9. Mode (cycle) of the camera operation.

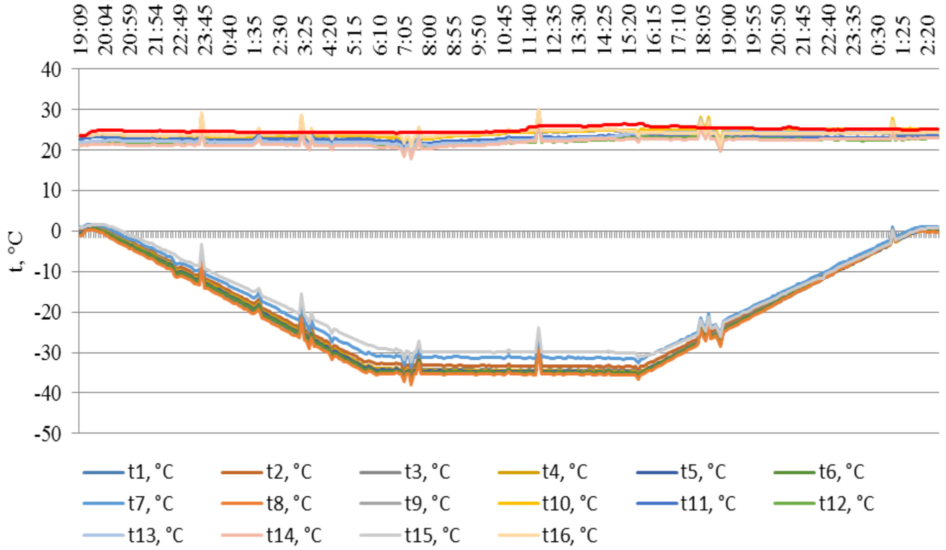

Fig. 10. Mode (cycle) of the camera operation.

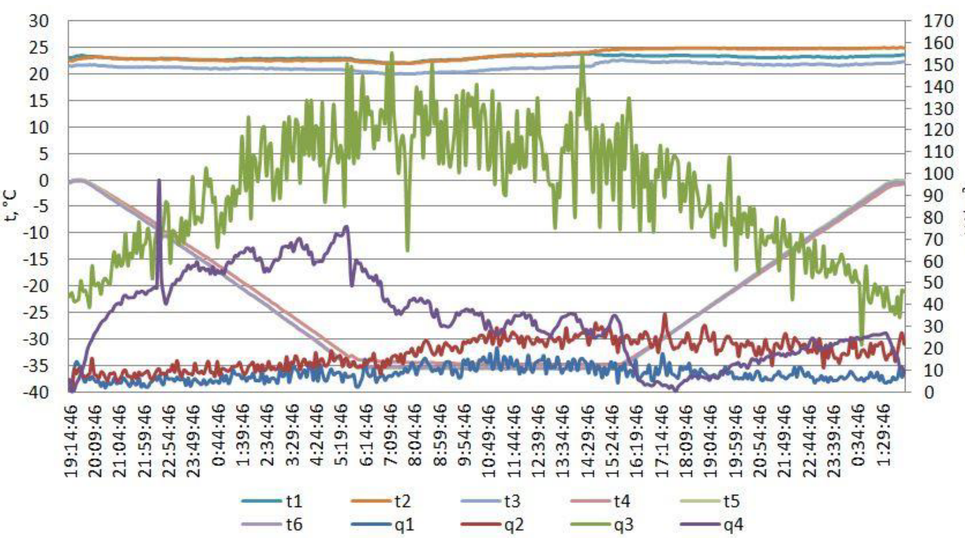

Fig. 11. Surface densities of thermal flows (q) and surface temperatures (t).

4 Conclusions

The presented experimental complex allows to carry out a wide range of heat-physical properties studies necessary to assess the enclosure structure heat saving efficiency.

The testing equipment is completely computer-aided which allows to conduct testing continuously saving results. Statistical processing is also computer-aided which increases the studies efficiency and excludes mistakes.

It is now possible to carry out a comparison of experimental study and simulation (in the measurement points) results in real time. The testing equipment is universal, as it allows to study the heat and mass transfer processes in multilayer enclosure structures without readjustment (or with small readjustment).

The automated research's stand, which was described in the article, allows to make real-time study of the interrelated processes of heat and mass transfer with air filtration, the level of measuring's equipment automation allows us to simulate the impact of external factors such as temperature, barometric pressure difference and to conduct a statistical analysis of the measured data.

New experimental information about the interrelation of distribution of temperature, pressure differential, heat flux density of studied construction of the exterior wall panel in a non-stationary thermal and mass transfer processes occurring in the building materials were received. The results of our research are applicable in the validation of computational models by quantitative comparison of the calculated temperatures distribution, pressure differences and heat flux density.

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