Ministry of Education and Science of Ukraine
Black Sea Universities Network

ODESA NATIONAL UNIVERSITY OF TECHNOLOGY

International Competition of Student Scientific Works

BLACK SEA SCIENCE 2022

PROCEEDINGS

Black Sea Science International Competition of Student Scientific Works by Odesa National University of Technology

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ODESA, ONUT 2022

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Proceedings

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Proceedings of International Competition of Student Scientific Works «Black Sea Science 2022» contain the works of winners of the competition.

The author of the work is responsible for the accuracy of the information.

Odesa National University of Technology, 2022.

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INTRODUCTION

International Competition of Student Scientific Works “Black Sea Science” has been held annually since 2018 at the initiative of Odesa National University of Technology (formerly Odesa National Academy of Food Technologies) with the support of the Ministry of Education and Science of Ukraine. It has been supported by Black Sea Universities Network (the Association of 110 higher education institutions from 12 countries of the Black Sea Region) since 2019, and by Iseki-FOOD Association (European Integrating Food Science and Engineering Knowledge into the Food Chain Association) since 2020.

The goal of the competition is to expand international relations and attract students to research activities. It is held in the following fields:

- Food science and technologies
- Economics and administration
- Information technologies, automation and robotics
- Power engineering and energy efficiency
- Ecology and environmental protection

The jury includes both Ukrainian and foreign scientists. In the 4 years that the competition has been held, the jury included scientists from universities of 24 countries: Angola, Azerbaijan, Benin, Bulgaria, China, Czech Republic, France, Georgia, Germany, Greece, Israel, Italy, Kazakhstan, Latvia, Lithuania, Moldova, Pakistan, Poland, Romania, Serbia, Slovakia, Switzerland, Turkey, USA.

At the same time, every year the geography has expanded and the number of foreign jury members has increased: from 46 jury members representing 25 universities from 12 countries in 2018, to 73 jury members of the 46 universities from 19 countries in 2022.

More than a thousand student research papers have been submitted to the competition from both Ukrainian and foreign institutions from 25 countries: China, Poland, Mexico, USA, France, Greece, Germany, Canada, Costa Rica, Brazil, India, Pakistan, Israel, Macedonia, Lithuania, Latvia, Slovakia, Romania, Kyrgyzstan, Kazakhstan, Bulgaria, Moldova, Georgia, Turkey, Serbia.

The interest of foreign students in the competition grew every year. In 2018, the students representing 15 institutions from 7 countries have submitted 33 works. In 2021 the number of submitted works increased to 73, authored by the students of 40 institutions from 18 countries.

The competition is held in two stages. In the first stage, student research papers are reviewed by members of the jury who are experts in the relevant fields. In the second stage of the competition, the winners of the first stage have the opportunity to present their work to a wide audience in person or online.

All participants of the competition and their scientific supervisors are awarded appropriate certificates, and the scientific works of the winners are included in the electronic proceedings of the competition. Every year the competition receives a large number of positive responses from Ukrainian and foreign colleagues with the desire to participate in the coming years.

4. POWER ENGINEERING AND ENERGY EFFICIENCY

TECHNICAL COMPARISON OF INFRARED HEATERS OF LONG-WAVE RANGE

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Abstract. *An urgent problem today is the choice of economic heating in the modernization or design of a new system. The most popular type of heaters are infrared long-wave heaters. Despite its efficiency and cost-effectiveness in the brochures, it is not clear which manufacturer is really. Therefore, the work tested relatively long-wave heaters with a capacity of 600 watts, from a technical point of view, the three main Ukrainian manufacturers - Bilux, Teplov, Teplotema.*

Keywords: *infrared radiation, long-wave heaters; infrared heaters; ceiling heaters; thermal trace; Bilux; Теплов; Heat theme.*

I. INTRODUCTION

Given the situation in the fuel and economic sector, the question arises of finding alternative ways to heat production and technological, economic and other types of premises when modernizing the heating system or designing a new one. One such alternative is infrared ceiling heaters with long-wave radiation.

This principle of heating is called radiant, and has been used since ancient times. For example, in the Roman Empire in special air ducts as a coolant used flue gases from the kitchen, and later specially heated air. After the technical revolution, the types of heating also changed. So in 1985, a Hungarian scientist, Professor Mackashi, proposed the idea of using as a heat carrier air moving in a closed system and give heat to the radiators in places where it is necessary.

So radiant radiation began to be used again only 40-50 years ago. Radiant energy transfer, other things being equal, is more efficient than convective, as with radiant heating energy is easily transferred over long distances in the room, so heating devices can be placed under the ceiling and in the construction of the fence.

For clarity, it should be explained that heating is due to convective heat transfer, and radiant heaters are also heated by convection. Then why can they be better? It's simple - convective heat transfer of radiant heaters is due to radiation and heating of the surface in front of the heater. On the example of ceiling heaters, we can imagine the heating process as heating all the objects under it (floor, table, chairs, etc.) which in turn give off heat in a convective way into the surrounding space. While in traditional convective heaters heat transfer occurs due to convection into the surrounding space with a heating area limited by the physical size of the heater (eg radiator battery). It is due to this principle that infrared heaters are more efficient and have recently aroused increased interest.

Having determined that infrared heaters are the best choice for installation (at home, in the company, in the greenhouse, etc.), there is a need for technical comparison of similar technological solutions, for example, heaters from different manufacturers.

II. LITERATURE ANALYSIS

Before starting, the existing examples of the study of radiant heaters were analyzed, and the sanitary norms of Ukraine on the indoor microclimate were analyzed for preliminary analysis of the feasibility of using radiant heaters in terms of human impact. According to the sanitary norms of the microclimate, infrared long-wave heaters can be used to heat human habitats (houses, industrial premises, etc.).

An analysis of the literature revealed that the main parameters by which you can choose an infrared heater are the thermal footprint and energy consumption. Based on these two parameters, the final efficiency can be determined.

Thermal footprint will be the most influential factor. It will affect the investment, the method of installation, as the size of the thermal trace depends on the effective location of the heaters and, accordingly, the minimum required number of heaters for a particular heated ivy. Figure 1 shows a diagram of uniform distribution of radiation from infrared heaters.

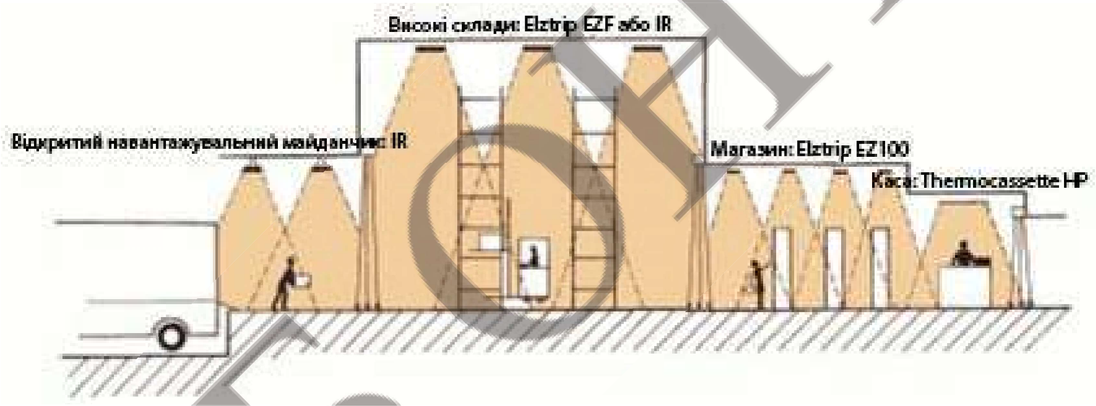


Fig. 1. Scheme of uniform distribution of radiation from infrared heaters

III. OBJECT, SUBJECT, AND METHODS OF RESEARCH

Three heaters were purchased for the study:

- Bilux B600
- Heat theme Home 600
- Thermal BE 600

The sites of the represented manufacturers were analyzed, all manufacturers have certificates of conformity, but only Bilux and Teplov have European certificates of conformity and sanitary conclusions about the safety of exposure to humans, and only Bilux has a certificate of fire safety.

The technical layout of the heaters was also previously inspected (Figs. 2 - 4).

Given the available certificates and conclusions of specialists in sanitary inspection and fire hazard, as well as the layout - it was concluded that some manufacturers are copying their competitors, namely Teplotem is a copy of Bilux.

Fig. 2. Profile of the cross section

(Bilux and Teplotema - truncated trapezoid, Teplov - rectangle)

Fig. 3. Terminal connection, radiating plate connection and thermal insulation of the housing.

The basis of the study

Technical comparison was carried out in the laboratory of the Electrical Building of NTU "KhPI", Department of "Power Stations".

Research tools:

1) DALI LT7-P thermal imager - thermal trail survey;

2) Digital technical thermometer testo925 - determination of floor temperature, to determine the initial conditions of the study, measurement of room temperature for the introduction of correction factors in the thermal imager;

3) Wattmeter Etech PM300 (Energy Meter) - determination of energy consumption of heaters;

4) Measuring instrument (Roulette) - used to measure the size of the thermal trace and the height of the samples.

Room parameters - basement with a concrete floor 2 meters deeper than ground level, with a high ceiling (4 m) and a large area (80 m2), which indicates that the heat load of the room significantly exceeds the power of one heater (600 W) and its operation within 1 hour will not change the indoor air temperature. The room temperature throughout the experiment was 18.5 degrees Celsius.

The installation height of the heater is shown in Fig.5.

Thermal trace

The most important characteristics of the thermal trace are its size and average temperature.

The size of the thermal trace can be measured only after the end of the transition process, when the thermal trace does not increase in size. It was experimentally investigated that based on the parameters of the room thermal transition ends in an hour after turning on the heater. The scheme of the thermal trace is shown in Fig. 5. It was also decided to take into account the "real" heat trace - without the influence of heater radiation, namely 10 minutes after turning off and removing the heater from the stand. During this time, the thermal trace does not lose its intensity, but the effect of heater radiation is absent.

Another feature is the division of the thermal trace into efficient and scattering traces, as shown in Fig.5, and because of this there is a need to properly position the heaters on the area as shown in Fig.1.

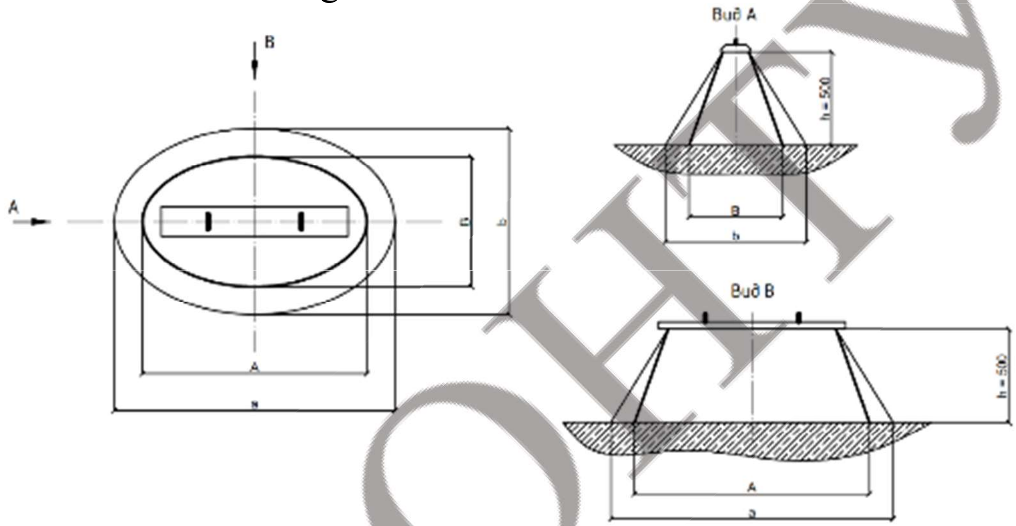
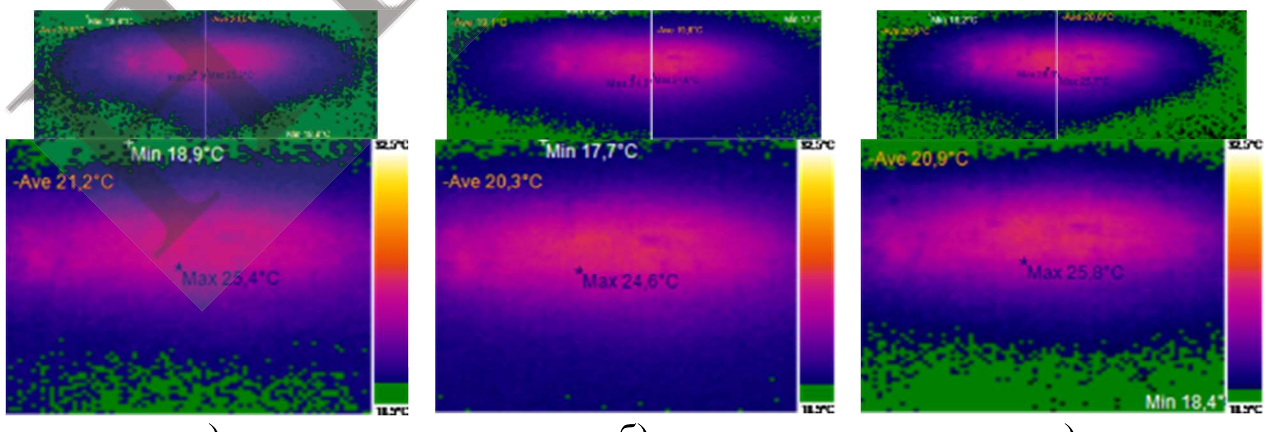


Fig. 4. Infrared heater wave distribution diagram
A × B - thermal trace of efficient heating;
a × b is the thermal trace of wave scattering.

IV. RESULTS

In fig. 5 shows thermograms of the real thermal trace of heaters.



a) б) в)

Fig. 5. Thermal trace of heaters
a) Bilux; b) Thermal; c) Heat theme

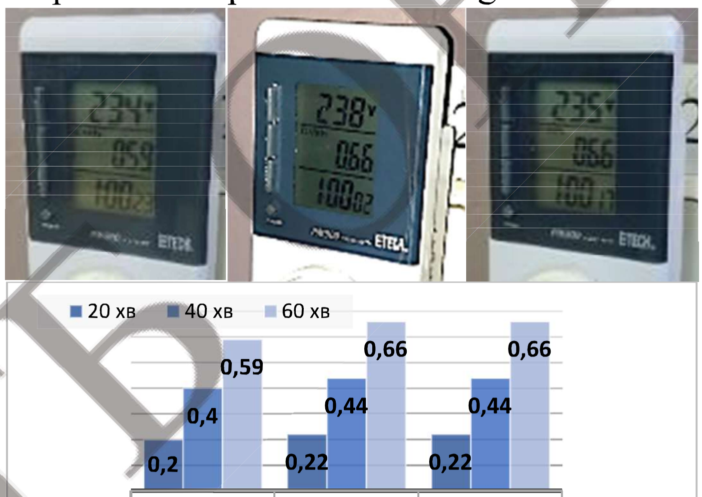
The isotherm of the cold floor measured before the experiment to determine the boundaries of the thermal trace is highlighted in green. The dimensions of the thermal trace were determined by the method of placing a hot object and then measuring the dimensions with a tape measure. Dimension measurements are presented in table.1.

Table 1. Dimensions of the thermal trace

	Bilux	**Teplov**	**Teplotema**
A, mm	1400	1100	1200
a, mm	1800	1200	1700
B, mm	1300	1000	1100
b, mm	1400	1100	1300
Spot form	a × b = 1,98м2 A × B = 1,43м2	a × b = 1,04м2 A × B = 0,86м2	a × b = 1,74м2 A × B = 1,04м2

The area of the trace shape was measured in the AutoCAD software package after full-size visualization.

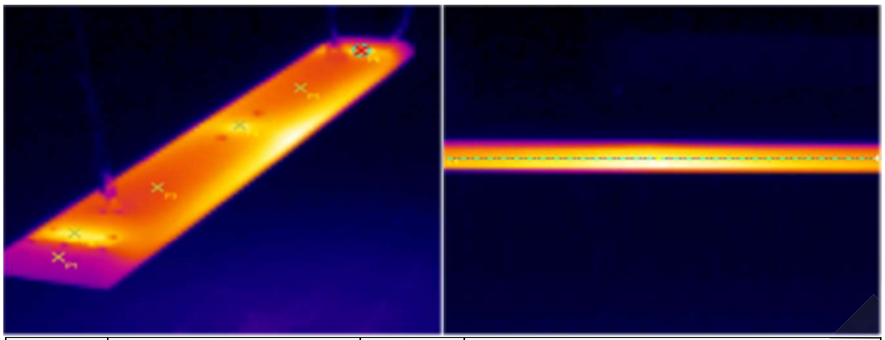
During the operation of the heater, using a wattmeter, energy consumption was measured. Figure 6 shows the results of measurements, which show that the energy consumption of heaters Teplov and Teplotem is 10% higher than nominally stated.



	Білюкс	Теплов	Теплотема
20 хв	0,2	0,22	0,22
40 хв	0,4	0,44	0,44
60 хв	0,59	0,66	0,66

Fig. 6. Wattmeter readings and energy consumption diagram based on readings

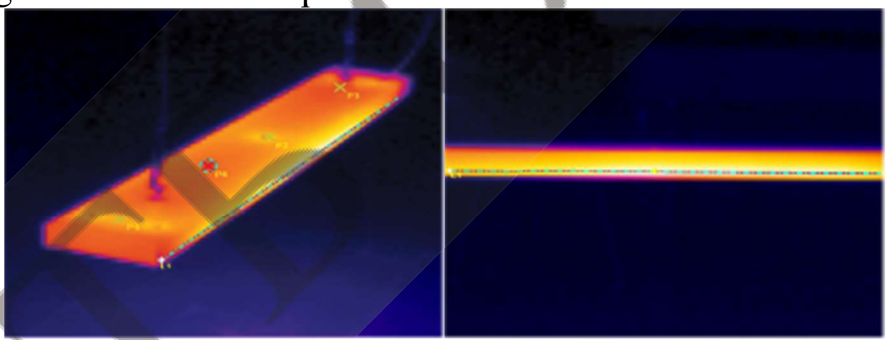
Causes of excessive energy consumption can be heat loss through the housing. As can be seen from Fig. 2 each of the samples has a different thermal insulation. So Bilux has above all a heat-reflecting plate of a streamlined form that is effective so that the energy which can be lost through the case is directed in the direction of effective heating. Teplotema and Teplov have only thermal insulation material in the upper part of the case.



Point	Temperature	№	Average temperature
P1	49,4°C	L1	77,9°C
P2	81,2°C		MAX
P3	60,4°C		83,8°C
P4	80,7°C		MIN
P5	63,4°C		70,6°C
P6	81,2°C	-	-

Fig. 7. Thermogram of the body of the Bilux heater from above on points, and on the side behind the line

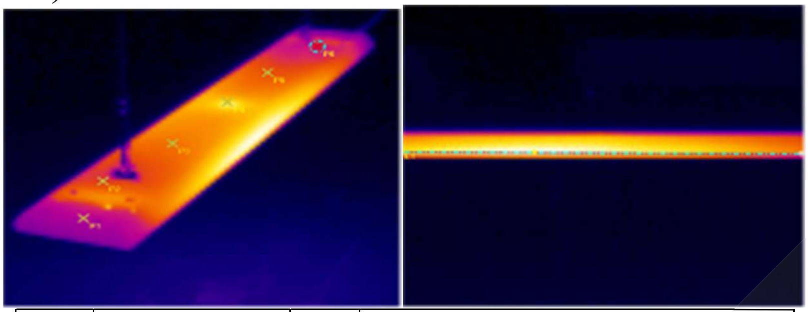
As can be seen from the thermogram, the temperature of the housing is not high, and safe to install under the ceiling using any cladding. The temperature on the side of the heater is the same as the upper part, which means that the temperature is distributed evenly over the housing, which in turn indicates the correctness of the thermal insulation of the housing with the minimum possible losses.



№	Temperature	№	Average temperature
P1	67,7°C	L1	88,8°C
P2	71,8°C		MAX
P3	57,1°C		91,3°C
P4	61,2°C		MIN
-	-		83,8°C

Fig.8. Thermogram of the body of the heater Teplov from above on points, and on the side behind the line

As can be seen from the thermogram, the top of the case has a lower temperature than Bilux, but the temperature on the side is significantly higher, this is due to uneven thermal insulation and the shape of the body of the Teplov heater. Temperatures indicate the fire safety of the heater. However, it should be noted that the housing on top has no ventilation holes, and such a strong insulation without ventilation holes can have a negative impact on the long life of the heater if you need to constantly work at maximum (without thermostat).



№	Temperature	№	Average temperature
1	53,2°C	L1	95,8°C
2	65,7°C		MAX
3	73,8°C		101,9°C
4	88,4°C		MIN
5	68,8°C		79,8°C
6	57,4°C	-	-

Fig. 9. Thermogram of the heater body Heat from above on points, and on the side behind the line

The thermogram shows that despite the similarity of shape and arrangement of the heater Bilux, Teplotema made a mistake using only thermal insulation material and its uneven placement. It can be seen that the temperature at the ends is high, which creates an additional load on the terminal connection and, accordingly, on operational safety. It is also seen that high heat losses are radiated through the side surface.

Energy efficiency

Having determined the main indicators - heat footprint (namely its size) and energy consumption, you can already make a preliminary conclusion about which of the heaters is best for use.

However, any conclusion must be confirmed by mathematical calculations.

For comparative analysis of the specific energy efficiency of heaters, for thermograms obtained 10 minutes after switching off the device (real thermal trace), for each model was determined the maximum temperature difference in the field (thermal imager frame) heated floor surface, and calculated heat transfer according to Stefan-Boltzmann.

The amount of heat given off by the radiating surface according to Sephane-Boltzmann law is given in formula 1:

$$Q = C_g \cdot \left[\left(\frac{T_1}{100}\right)^4 - \left(\frac{T_2}{100}\right)^4\right] \cdot t \cdot F \quad (1)$$

where C_g – the coefficient of radiation is given, $C_g = 5{,}77 \cdot 0{,}9 = 5{,}193$, Вт/м2·К4;

T_1 – the temperature of the radiating surface, the average temperature of the thermal trace, *K*;

T_2 – ambient temperature, *K*;
t – time, hours;
F – the area of the radiating surface (thermal trace), m2.

$$Q_{Bilux} = 5{,}193 \cdot \left[\left(\frac{(22+273)}{100}\right)^4 - \left(\frac{(18{,}5+273)}{100}\right)^4\right] \cdot 1 \cdot 1{,}98 = 36{,}3658 \text{ Вт},$$

$$Q_{Teplov} = 5{,}193 \cdot \left[\left(\frac{(20{,}9+273)}{100}\right)^4 - \left(\frac{(18{,}5+273)}{100}\right)^4\right] \cdot 1 \cdot 1{,}04 = 13{,}0242 \text{ Вт},$$

$$Q_{Teplotema} = 5{,}193 \cdot \left[\left(\frac{(22{,}1+273)}{100}\right)^4 - \left(\frac{(18{,}5+273)}{100}\right)^4\right] \cdot 1 \cdot 1{,}74 = 32{,}8878 \text{ Вт}.$$

Next, determine the efficiency of the consumed electrical energy to obtain heat given off by the radiating surface, according to formula 2. That is, how many watts of electrical energy is used to obtain one watt of heat:

$$E = W/Q \tag{2}$$

where W – electricity consumed by the heater per hour.

$$E_{Bilux} = \frac{590}{36{,}3658} = 16{,}2241 \text{ W},$$

$$E_{Teplov} = \frac{660}{13{,}0242} = 50{,}6750 \text{ W},$$

$$E_{Teplotema} = \frac{660}{32{,}8878} = 20{,}0683 \text{ Вт}.$$

For indicative results, we express in percentage terms, taking the indication of the efficiency of the heater Bilux for 100%, then:

- efficiency of the Teplov heater = $\frac{16{,}2241}{50{,}6750}\% = 32\%$;
- efficiency of the Teplotem heater = $\frac{16{,}2241}{20{,}0683}\% = 81\%$;

The calculation shows the obvious advantage of the efficiency of the heater Bilux.

V. CONCLUSIONS

During the technical comparison of three samples of long-wave infrared heaters, a physical inspection of all samples was performed, thermal imaging of the thermal trace of each sample, thermal imaging of each sample, analysis of the obtained thermograms.

Based on the above, the following conclusions can be drawn:

1) According to the thermograms of the devices, the Bilux heater has the lowest heat loss through the housing, and the temperature modes of the device indicate reliable operation with long-term use at maximum power;

2) According to the thermograms of devices, the Teplov heater ranks second in reliability, in terms of heat loss Teplov and Bilux heaters can be compared as Teplov has less losses through the top and larger sides, so in balance they are the same in heat loss;

3) According to the thermograms of the devices, the heater from Teplotema is the least reliable and with the highest heat losses through the housing;

4) In terms of thermal trail, the most efficient heater is Bilux, and the least efficient is Teplov;

5) Structurally, the Bilux heater has the best design - the practical shape of the body, and the correct gaps. Teplov has good thermal insulation, but not enough on the side and the rectangular shape is a disadvantage for reliable operation. The heat theme in the analysis shows that it is a copy of Bilux, but not high quality, and errors in copying have made a number of shortcomings that make it unreliable and inefficient.

6) According to the efficiency calculation, Bilux heaters are 68% more efficient than Teplov heaters and 19% more efficient than Teplotem heaters.

Of the presented samples, the best option is the products of Bilux. However, this comparison is incomplete due to the fact that only 3 samples were tested. When choosing from a larger list, it is necessary to make the presented comparison for heaters from other companies.

Summing up, we can add that a quality heater can be purchased only after contacting the manufacturer with a desire to provide complete data on heaters - thermal imaging of the thermal trail, verified data on energy consumption, data on body temperature. These data provide information on real efficiency and heating capacity.

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