Abstract

The article presents results of energy inspection of an educational building “Hydrotechnical building-2” of the Saint-Petersburg State Polytechnical University. The energy audit was carried out to estimate energy resources performance and define opportunities for its increase. According to the results of energy audit the analyses of state of energy consumption are provided. The class of energy efficiency is defined. The recommendations and prospective opportunities to save energy and increase power efficiency of “Gidrokorpus-2” are presented as a resume of this article.

Keywords: energy building, energy saving; efficiency; external enclosure structures; insulation coating; renovation of facades.

1. Introduction

Nowadays the term «energy efficiency» is referred to as rational use of energy resources; however sense and importance of this definition was beyond advisory measures and started to be an essential requirement. Thus it is necessary to set the priority for effective use of the fuel and energy resources (FER) and energy produced in the construction industry of Russia. It’s also a must to change a classical approach of accumulation of the volumes extracted and production which is managed much more expensively than introduction of actions for its savings.

The important reason of squandering of FER involves inefficient and sometimes even irrational energy consumption in the sphere of housing and public utility services, in the field of construction manufacturing industry.

The main task of energy saving is to discover opportunities to reduce energy consumption without causing damage to the consumers and the environment. International systems meant for estimation of ecological efficiency of buildings develop and work over the standards of quality in the modern construction industry.

Renovation can be considered as one of the energy efficiency aspects. Reconstruction of buildings and structures has become one of the main directions in the modern construction business development. Reconstruction of facades does not imply a radical change in the building but only sets the goal to improve its image with the use of special technologies.

The goal of energy inspection of “Hydrotechnical building-2” is a search for possible solutions of energy saving and increase of power efficiency of an object. For scientific research of an object the following is required:

- to conduct thermal sensing;
- to fulfill thermotechnical calculations;
- to draw up energy performance of an object;
- to identify class of energy efficiency of an object;
- to develop facade renovation design to increase energy efficiency.

2. Overview

The issue of energy efficiency increase to be solved was considered by the following scientists: Gorshkov A.S., Gagarin V. G., Trutnev M. S., Butovsky I.N. Efimenko M. N., Tabunshchikov Yu. A. Boguslavsky L.D. Monastyrrev P. V., Klychnikov R. Y., Petrichenko, M.R., Vatin N.I. and many others.

The most consistent and reasonable approach was developed by Gagarin V.G. who proposed to improve the mathematical model of the payback of cost with rise of thermal protection level that takes into account discounting savings of operating costs.

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According to his model the most important parameter in determining the economic conditions concerning increase of the thermal security enclosure in the country or region is the limit for the one-time costs and also he suggested to use a complex indicator (a specific coefficient of a heat transfer of a cover of a building which includes parameters of heat-shielding of all protecting designs of a building) with the aim of rationing of heat-shielding of a cover of a building—. This indicator is natural development applied earlier for an assessment of energy saving of the specific thermal characteristic of the building [1].

Gorshkov A. S. develops the schedule of dependence of thermal losses per 1 sq.m of a design protecting from the specified resistance to a heat transfer from where it is visible that change is shown in hyperbolic dependence. However the possibility of economically inefficient capital expenditure for construction designs by decrease in expenses on heating has been noticed. The author cites the schedule to determine the optimum thickness of the wall structure by the method of reduced costs. He produces the diagram to determine the optimum thickness of the walls of aerated concrete with different service life values [3-6].

The technology of use of the liquefied gas to secure centralized supply of energy resources for a complex of buildings remote from the network energy resources have been considered by Nemova D. V., Vatin N.I. and Tseytin D.N. in the works consider The advanced scheme of installation has been developed. It has been offered to use an economic-mathematical model for the first stage of a concept of a settlement, allowing determining costs of energy obtained and equipment payback periods. The method also allows calculating payback periods of the energy saving actions targeted at an increase of thermal protection level of protecting designs of buildings, analyzing the economic efficiency of investments in energy saving activities. The scientists have offered also the model allowing to carry out the specified analysis [7-11].

Petrichenko M.R. has proposed procedure that makes it possible to assign the rate of drop in water level in the upper pool which eliminates failure of earthen structures in the surveys [12-13]. Petrichenko M.R offered to replace the traditional Dupuis formula by the condition of the minimum of the functional reflecting the average quadratic norm of the departure of the curvilinear profile of the free surface from a straight line in the surveys [14-15].

Petrichenko M.R. has revealed that successful plotting of the depression curve for the plane problem of filtration in homogeneous soils can solve many engineering problems of hydrotechnical construction while organizing surface drawdown or maintaining a difference in the levels of a filtering embankment. To solve this problem it is important to have a representation of an actual position of the depression surface to evaluate the stability of soil masses subject to filtration activity. Determination of the position of the depression curve is based on use of Dupee's hypothesis for an average filtration rate and integral formulas for the flow rate through a homogeneous soil mass. It is explicitly presented that the equation of nonuniform motion is a required condition of the minimum for F(h) (in uniform motion, F(h) = 0). Dupee's depression curve has minimum length and maximum free-surface gradient [16-17].

Petrichenko M.R. has derived an energy-balance equation for an integral flow with a variable flow rate over a particular length. The equation has been applied to the confluence of flows [19-21]. Unsteady heat and mass transfer in combustion chambers of internal combustion (primarily Diesel) engines have been analyzed and experimental data have been reviewed. A stable correlation has appeared to exist between the instantaneous local heat transfer coefficients and the thermal resistance of the pseudolaminar boundary layer on the chamber wall. Other major factors have been also analyzed [18]. Petrichenko M.R. has presented [22-23] an algorithm for the problem of flame propagation rate in combustion of a homogeneous fuel-air mixture in a cylinder of an internal combustion engine. It is assumed that the mixture is not 'overturbulized' and that the front flame is spherical. The model used for the phenomenon is based on a turbulent transport mechanism. In the near-wall area the combustion mechanism follows a fine-scale mechanism, but in the core, a large-scale mechanism. Experiments have allowed determining the character and numerical value of coefficients which consider the effect of turbulence on front flame propagation in the combustion chamber of the engine ZMZ-4021. The principles presented can be used as the basis of an algorithm for heat liberation rate in an internal combustion engine with external mixture formation.

Possibilities of utilizing quasi-stationary techniques in calculating flows through exhaust ducts of internal combustion engines have been discussed in some studies [25] with two major assumptions entertained: gas parameters obey laws and relations prevailing in fully stationary flow, in circumstances of quasi-stationary flow, and pressure remains the same throughout the entire volume of the internal combustion engine system at any fixed instant of time. An approximation analysis has been conducted.

The paper [26] reveals the problems concerning the formation of an oil film in the clearance between a piston ring and the internal combustion engine cylinder liner. An expression is derived for the lift force of the piston ring. The variation of the lift force with piston speed and the speed of the radial movement of the ring has been shown. The results of calculation of oil film thickness under the sealing piston ring in the diesel engines of 1ChN16/17 type have been presented.
The purpose of work [27] has been to obtain a description of the fluctuation for component of the induced difference of the scalar potential in transducers of correlation flow meters and to refine the limits of the non-inductive approximation and possibilities of meeting the requirements imposed on transducers.

New experimental data have been presented [28] on non-stationary and transient operating conditions of closed liquid metal loops with MHD pumps. The investigations have been made by utilizing the automated system of experiment staging, "control system - experiment". It has been shown that the type of the transient process as well as the type of external characteristics of pumps is determined by the magnitude of the system drag coefficient. Characteristic ranges of flow rate and pressure pulsations, both as regards the amplitude and frequency of transient processes as well as the nonlinear effects connected with the startup of high-capacity pumps in a liquid metal loop, have been specified.

The measurement of volumetric flow rate of a liquid-metal heat transfer agent in heat transfer loops is a serious technical problem, which may be solved by applying correlation methods of measurement. The object of the present study is to derive an equation describing the change in the space-time correlation functions of the velocity fluctuation components with increasing the spatial separation and solve this equation for a well-developed turbulent flow of a conducting liquid with axisymmetric mean velocity profile [29].

3. The initial data for calculating heat and power parameters of the building

3.1 The general descriptions of the building

The State Higher Education Institution is located at St. Petersburg, Polytechnicheskaya st, 29 (figure 1).

Figure 1. Hydrotechnical building-2

The general characteristics necessary for further calculations are the following ones:

- the overall height of the building - 24.8 m;
- the heated area - 11180.79 m²;
- the heated volume - 43,605.08 m³;
- the total area of the exterior walls - 14,155.57 m².

The general data of building services systems have been identified. The heat supply source is the municipal network. The coolant of heating system is water with the parameters of 90 - 70 º C. HSS is located in the basement of the building. Heating system represents two-pipe vertical system with the lower adherence to the transit pipelines. The heaters represent tube-type radiators. The stop valves (ball valve on the return) and control valves are installed on the all heating appliances. There is a mechanical ventilation.

3.2 Climate and power characteristics

Design temperature of outdoor air during the cold period is equal to 26 °C. The duration of the heating period amounts to 220 days. Mean temperature of outdoor air of the heating period is equal to 1.8 °C. Heating degree day Dd accounts for 5016 º C•day. Required heat transmission resistance of exterior structure:

- for the exterior walls - \( R_w = 3.08 \text{ (m}^2\text{•ºC) / W} \);
- for coverings - \( R_c = 4.6 \text{ (m}^2\text{•ºC) / W} \);
- for windows - \( R_F = 0.51 \text{ (m}^2\text{•ºC) / watt} \).

Upon thermal camera inspection it has been found out that there were some problematic spots in the buildings envelope. The shooting carried out by thermal imagery device has revealed defects of windows, doors and
external envelops. The thermal image reveals the main spots where there are most heat losses. The heat losses are caused by leakage of air through the gap that is between the window and the installation frame. Therefore there is a massive leakage of indoor heat. Because of the non-functioning ventilation system users of the building often open the windows or just the smaller ventilation windows in order to refresh the indoor air (natural ventilation) (figure 2).

4. Thermotechnical calculations

4.1 Calculated (design) value of heat transmission resistance of external envelops

The value of heat transmission resistance of external envelop has been calculated (design. The results have shown that the actual values of the building (values on the left) are a lot lower than the national norms (values on the right). This means that the buildings structure causes a lot of heat losses.

<table>
<thead>
<tr>
<th></th>
<th>$R$</th>
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<tbody>
<tr>
<td>External walls</td>
<td>$0.8$ (m$^2$ · °C)/W &lt; 3.08 (m$^2$ · °C)/W</td>
</tr>
<tr>
<td>Coverage</td>
<td>$0.88$ (m$^2$ · °C)/W &lt; 4.6 (m$^2$ · °C)/W</td>
</tr>
<tr>
<td>Windows</td>
<td>$0.3$ (m$^2$ · °C)/W &lt; 0.51 (m$^2$ · °C)/W</td>
</tr>
<tr>
<td>Doors</td>
<td>$0.26$ (m$^2$ · °C)/W &lt; 0.79 (m$^2$ · °C)/W</td>
</tr>
</tbody>
</table>

5. Calculation of heat and energy data of buildings

Total heat losses of the building through external envelop including ventilation:

$$Q_{in} = 0.0864 \cdot K_m \cdot D_d \cdot A_e = 0.0864 \cdot 1.67 \cdot 5016 \cdot 14155.57 = 10245074 (MJ) \quad (1)$$

Genre heat gain:

$$Q_{int} = 0.0864 \cdot q_{int} \cdot z_{in} \cdot A_g = 0.0864 \cdot 10 \cdot 220 \cdot 7793.6 = 14281407 (MJ) \quad (2)$$

Heat gain through windows and glasses from sun radiation:

$$Q_s = \tau_s \cdot k_s \cdot (A_{F1} \cdot I_1 + A_{F2} \cdot I_2 + A_{F3} \cdot I_3 + A_{F4} \cdot I_4) + \tau_s \cdot A_{syc} \cdot I_{hor} = 0.78 \cdot 0.76 \cdot (1228.1 + 455 + 210.9 + 455 + 787 + 96 = 809241 (MJ) \quad (3)$$

The amount of energy used for heating of buildings during heating season:

$$Q_h = \left[ Q_{in} + (Q_{int} + Q_s) \cdot \nu \cdot \xi \right] \cdot \beta_h = \left[ 102450074 - (1481407 + 809241) \cdot 0.8 \cdot 0.95 \right] \cdot 1.11 = 111787191 (MJ) \quad (4)$$

$\nu$ – coefficient of lowering heat gain at the expense of heat inertia external envelops; recommended value $\nu = 0.8$;

$\xi$ – coefficient of efficiency auto regulation heat supply in heater system (in double-pipe scheme with thermostats and with central auto regulation on bus $\xi = 0.95$);

$\beta_h$ – coefficient, inclusive coefficient additional heat consumption of heater system, bond discontinuity of nominee heat flow of nomenclative range of heating apparatus, their additional heat losses through parts of external envelops, higher air temperature in rooms, heat losses of pipes, get through unheated rooms, equal to $\beta_h = 1.11$.

The external envelops of 5-store building social educational services do not meet standard requirements. Value of defection calculates specific drain of energy for heating of building from standard requirements is -9%. So, it is a building of E class («Very low») on energy efficiency.

The necessary measures to solve the problems of the buildings:
• Modernization and automatization of ventilation system, heater system;
• Exchange of window to plastic double-glazed windows;
• Rise of thermal properties of external envelops;
• Reconstruction of facades.

6. Reconstruction of facades

The calculation results revealed that the level of thermal protection of the subject of the building is considerably lower than current regulatory requirements for the thermal resistance of the building envelope. Thermal imaging survey has showed the most part of heat through the building envelope. The most effective way to solve the problems mentioned above is a reconstruction of the facades with application of highly effective heat-insulating materials for facade insulation.

Today the most efficient insulation include insulation having a thermal conductivity of not exceeding 0.06 W/(m2 * °C). The data material must be characterized by the availability of raw materials, low energy consumption and low production costs, have the water resistance and frost resistance, mechanical strength, ecological and fire safety.

It was decided to use insulation system ITE PARISO, which includes:
• insulation;
• layer of the adhesive composition for installation of insulation boards to the bearing wall;
• protective coating.

To determine the minimum thickness of a heater it is necessary to conduct a thermal calculation.

\[ R_0 \geq R_{req} \]  \hspace{1cm} (5)

\[ R_{req} = \frac{3,08 \left( m^2 \cdot °C \right)}{W} \]  \hspace{1cm} (6)

\( R_1 \)- heat transmission resistance of ceramic solid brick;
\( R_2 \)- heat transmission resistance of gypsum plaster;
\( R_3 \)- heat transmission resistance of insulation
\( R_4 \)- heat transmission resistance of air gap;

\[ R_0 = \frac{1}{\alpha_{int}} + \frac{\delta}{\lambda_1} + \frac{\delta}{\lambda_2} + \frac{\delta_{ins}}{\lambda_{ins}} + R_{a.g.} + \frac{1}{\alpha_{ext}} = 3,08 \]  \hspace{1cm} (7)

\[ \delta_{ins} = \left( 3,08 \left( \frac{1}{8,7} - \frac{0,55}{0,64} - \frac{0,005}{0,87} - 0,14 - \frac{1}{23} \right) \cdot 0,051 \right) = 98 \text{ mm} \]  \hspace{1cm} (8)

\( \delta \)- the thickness of material;
\( \lambda \)- coefficient of thermal conductivity.

Take a thickness of insulation equal to 100 mm. The section of the wall is shown on a figure 3.
Reconstruction of the facades of the building is shown in the figures 4, 5. A project of reconstruction has been developed where classic and contemporary styles are combined. In general it is called neo-classicism. The following architectural elements have been used in the project: architectural Doric column, pilasters, rustications, cornices, fascia, rosace and balusters.

7. Resume

The results of energy audit of 5-store building social educational services “Hydrotechnical building-2” have been described and analyzed in this article. There have been performed thermotechnical calculations. The class of energy efficiency has been defined. And possible ways to improve the class of energy efficiency of the object have been proposed.

If we compare the values obtained with the normative values for determining the energy efficiency class of the building occupied by the Ministry of Regional Development of the Russian Federation, we can see that the building “Hydrotechnical building-2” doesn’t meet the standards in many respects. Thus the value calculated for specific drain of energy for heating of building based on standard requirements is - 9%. So, it is a building of the “E” class («Very low») in terms of energy efficiency. Thus the building does not meet the standards required. The results of the inspection and analysis are necessary for further research. One of possible solutions of this problem is the reconstruction of facades with the application of thermal insulation material with the thickness of 100 mm.
References


