**M. M. Chepurniy, Cand. Sc. (Eng.), Assist. Prof.; N. V. Resydent, Cand. Sc. (Eng.);
E. S. Korzhenko, Cand. Sc. (Eng.), Assist. Prof.**

ANALYSIS OF USING THE BACK PRESSURE TURBINE ПР-6-35/5/1,2 FOR HEAT SUPPLY

There had been analyzed the operation of turbogenerator with steam turbine ПР-6-35/5/1,2 with further determination of the main indices of its efficiency under different steam and electric load.

Key words: *steam generator, steam turbine, electrical generator, coal equivalent, discharge intensity.*

Introduction

The efficiency in power production is the important characteristics of fuel consumption plants. The combined production of heat and electric energy by thermal power plants (TPP) is the progressive technology, which allows to solve the task of energy consumption. That is why it was recognised as one of the main directions in power engineering in Ukraine with emphasis on the legislative level [1]. Despite the significant progress in the development of TPP in Ukraine, the central heat supply is provided not by the TPPs but by the boilers.

The normal operation of TPP may be ensured by the availability of constant heating load. But the decline in output as well as the decrease in consumption of technologic steam disable the TPPs to produce electricity at full capacity. A large number of industrial enterprises include TPPs equipped with back pressure turbines. Such steam turbine plant (STP) with or without the intermediate steam bleeding cannot operate in the self-driven mode, since the production of electric energy is made on the base of vaporous delivery of thermal energy. Today the majority of industrial TPPs operate with the under loaded back pressure turbines, which results in both, the decrease in production of electric energy and non efficient use of fuel, since the decrease in loading decreases the efficiency of the main and the additional equipment of STP. It should also be noted that the decrease in the production of electric energy on TPP stipulates for the increase in the scarcity of the maneuver capacities in the power supply system and complicates its operation under extra operating conditions. The evaluation of the STP's operation efficiency with back pressure turbines without the intermediate steam bleeding under the conditions of variable loading is presented in [2]. Unfortunately, there does not exist such an evaluation for the STP equipped with back pressure turbines with intermediate steam bleeding.

Considering the above, there is a task to make quantitative evaluation of STP's operation with more complicated back pressure turbines which has the intermediate steam bleeding and operates for heating purposes.

Main results

The diagram for using the turbine ПР-6-35/5/1, 2 aimed at covering the heating loading is shown on fig. 1. The turbine has the controlled steam bleeding which feeds the so called «upper» heater of network water 4 and a heater of the system feeding water 19, the «bottom» heater of network water 6 and the de-aerator of atmospheric pressure 14 are fed from the back pressure turbine. The additional (sub-feeding water) is heated in the heaters 9, 10 and 17 by steam condensate from bleeding and back pressure. The both heaters of network water and the heater for feeding water operate during the heating period. During the non heating period, when there operates only the system of hot water supply, the heaters 4 and 19 do not operate.

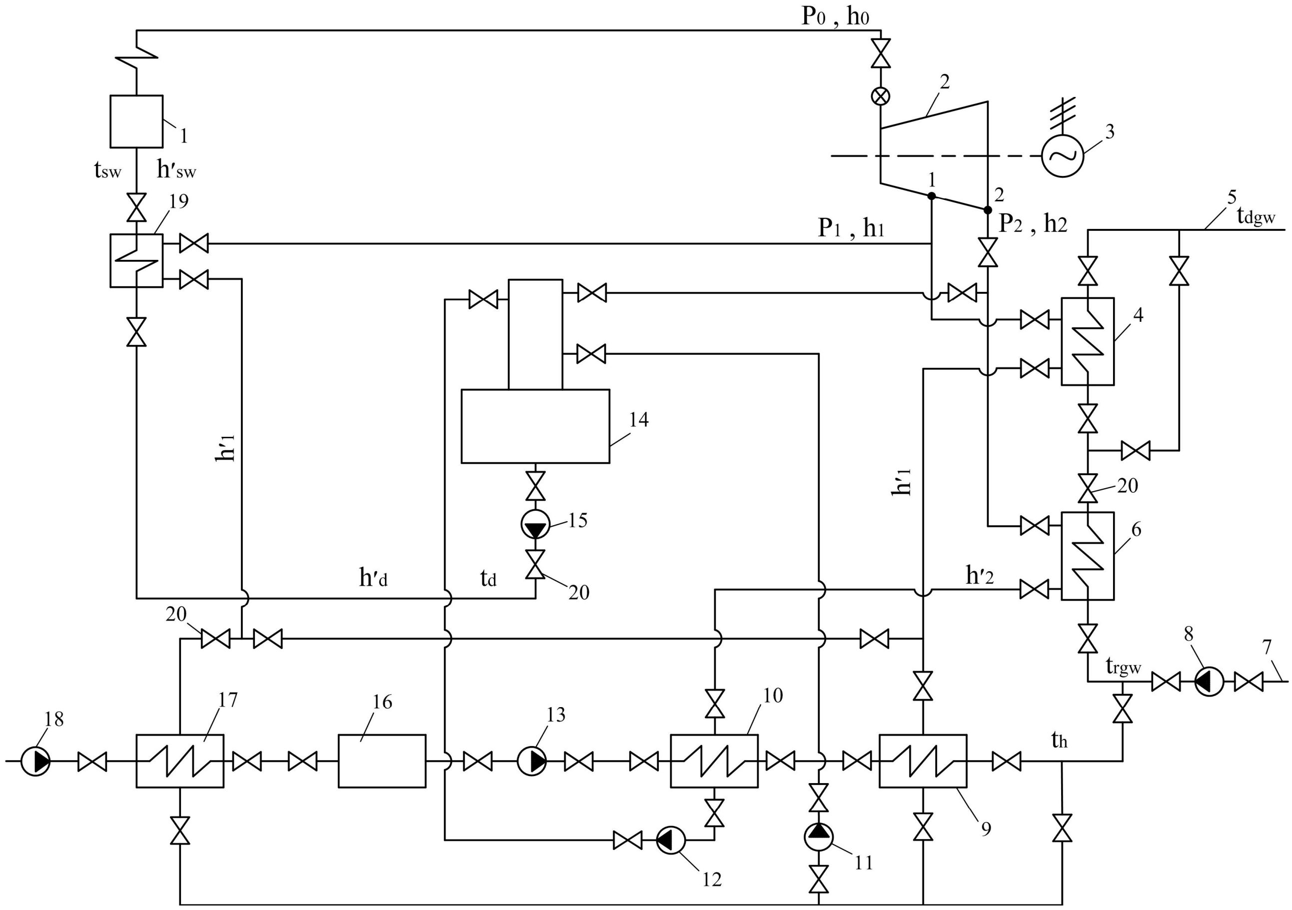

Fig. 1. Principal thermal schema of steam turbine ПР-6-35/5/1,2:
1 – steam generator 2 – steam turbine 3 – electric generator, 4 and 6 – heater of feeding water of high and low pressure correspondingly, 5 and 7 – line of the direct and reverse feeding water correspondingly, 8 – feeding water pump; 9 and 10 – heaters of subfeeding water, 11 and 12 – drainage pumps, 13 – pump of chemically purified water, 14 – deaerator of atmospheric pressure, 15 – feeding pump, 16 – chemical water purification, 17 – heater of feeding water, 18 – pump, 19 – heater of feeding water, 20 – valve.

Using the data [3 – 5] there had been determined the technical characteristics of the turbine ПР-6-35/5/1.2: nominal electric capacity – N = 6 Megawatt, pressure and temperature of steam before the turbine– P_0 = 3.43 MPa and t_0 = 435 ºC, correspondingly; parameters of steam in the regulated bleeding– P_1 = 0.49 MPa, t_1 = 237 ºC; parameters of steam behind the turbine (in back pressure) – P_2 = 0.12 MPa, t_2 = 132 ºC; nominal steam consumption without bleeding – D_0 = 41.5 t/hour (11.527 kg/s), with steam bleeding– D_0' = 54.7 t/hour (15.194 kg/s), correspondingly.

IN the result of building the operating mode of steam in the turbine on the h-S diagram we determine the enthalpies in the typical points, kJ/kg:

$$h_0 = 3305;\ h_1 = 2935;\ h_2 = 2740.$$

Heat drops in turbine, kJ/kg:

before the bleeding

$$H_1 = h_0 - h_1 = 3305 - 2935 = 370\,; \tag{1}$$

Before the back pressure (operational)

$$H_2 = H_p = h_0 - h_2 = 3305 - 2740 = 565\,. \tag{2}$$

Electromechanical efficiency of turbo generator shall be determined under condition that the steam discharge from the controlled bleeding is absent.:

$$\eta_{em} = \frac{N}{D_0 \cdot H_o} = \frac{6000}{11.257 \cdot 565} = 0.921. \qquad (3)$$

Discharge of steam into the controlled bleeding for the nominal loading shall be determined from the equation of electric capacity of turbogenerator, kg/s

$$N_N = \left[D_1 \cdot H_1 + \left(D_0' - D_1\right)H_o\right] \cdot \eta_{em},$$

$$6000 = \left[D_1 \cdot 370 + \left(15.194 - D_1\right)565\right] \cdot 0.921. \qquad (4)$$

It follows that D_1 = 10.6 kg/s; D_2 = 4.59 kg/s, where D_1 and D_2 – steam discharge from the bleeding and back pressure, correspondingly.

As it was mentioned above, there are two different working regimes of STP during the heating or non–heating seasons. During the heating season the variable modes of STP operation are the results of steam discharge rate changes form the controlled bleeding under conditions of constant steam discharge from the back pressure. The temperature of the feeding water makes up 145 ºC. During the non heating season of STP operation there is no steam discharge from the bleeding and the variable modes are stipulated by changes in steam discharge from the back pressure turbine. The temperature of the feeding water equals the temperature of water in de-aerator (t_d = 104 ºC). The minimum loading of STP is the allowed loading of steam generator, which equals 30% of the nominal steam productivity. There had also been considered the changes in the boiler operation efficiency and the electromechanical efficiency of STP within 30 – 100% of their loading [7, 8]. The calculations of the thermal schema of STP had been made by using the known methods [6, 7]. There had been calculated the main factors, which characterize the efficiency in production of thermal and electric energy by STP without the calculations of energy consumptions for the own needs. The results of the variant calculations are presented as graphics.

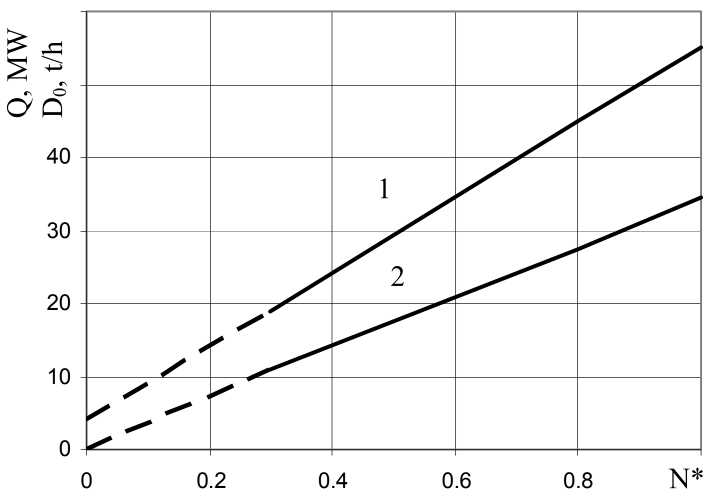

Fig. 2. Diagrams of measuring the steam discharge for the turbine and the produced heat capacity depending on the loading share of the electric generator: *1 – D = f (N*); 2 – Q = f (N*)*

Fig. 2 presents the dependences of the steam discharge and produced thermal capacity under the conditions of steam discharge changes in the controlled bleeding. These dependences are of linear character and shall be approximated according to the formulas:

$$D_0 = 4 + 50{,}7 \cdot N^*; \qquad (5)$$

$$Q = 33{,}415 \cdot N^*, \qquad (6)$$

where $N^* = N_i / N_N$; N_i, N_N – current and nominal capacity of electric generator, correspondingly.

The first item in (5) characterizes the steam discharge for the idle operation of turbo generator.

The [9] shows that the efficiency in STP operation shall be determined by the specific discharge of coal equivalent, which equals, kg/GJ

$$b = B \cdot 10^3 / (N + Q), \tag{7}$$

where B – discharge of coal equivalent, burned in the steam generator, kg/s.

The value b relates to the value of the use of the fuel heat factor by the equation

$$K_{FHU} = \frac{10^3}{b \cdot Q_{lc}^o}, \tag{8}$$

where Q_{lc}^o =29,3 MJ/kg – heat of burning the coal equivalent.

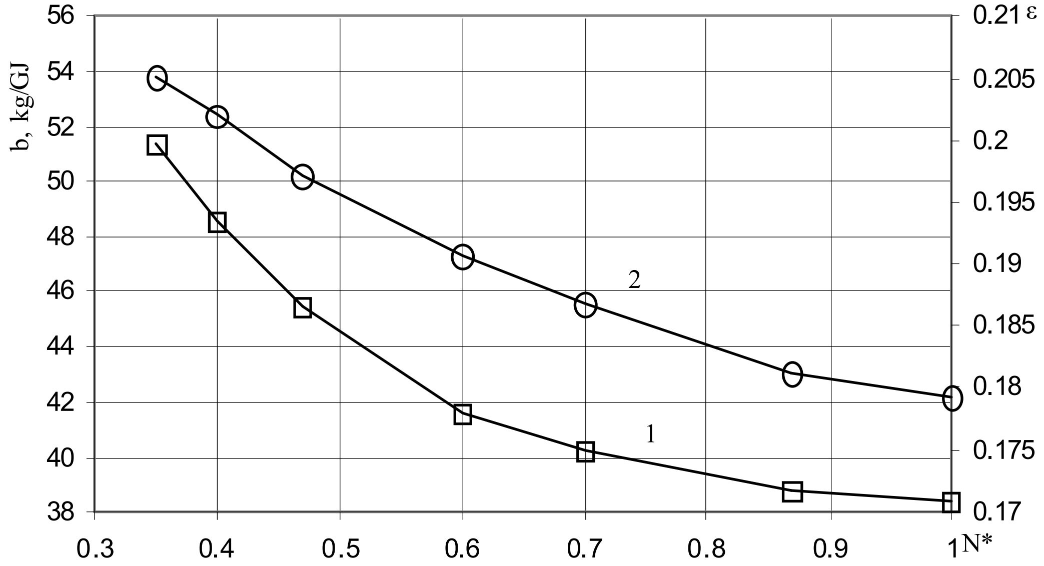

Fig. 3. Current value of the specific discharge of coal equivalent (line1) and factor of production of electric energy on heat supply (line12).

It was assumed [7, 8], that the efficiency of STP operation characterized by the factor of production of electric energy on thermal supply $\varepsilon = N/Q$, the increase in which causes the increase in efficiency of STP operation. The dependences in changing values b and ε are shown in fig. 3. The fig. 3 shows that the efficiency in STP operation sharply decreases during the loading in turbogenerator due to the decrease in steam discharge from the controlled turbine bleeding the. The more inefficient operating modes correspond to the higher values of ε. The later confirms the conclusion [9] that the value ε cannot definitely characterise the operation efficiency of back pressure turbines. The increase in specific discharge of coal equivalent during the unloading of turbogenerator is explained by the significant decrease in electromechanical efficiency of turbogenerator and the efficiency of steam generator.

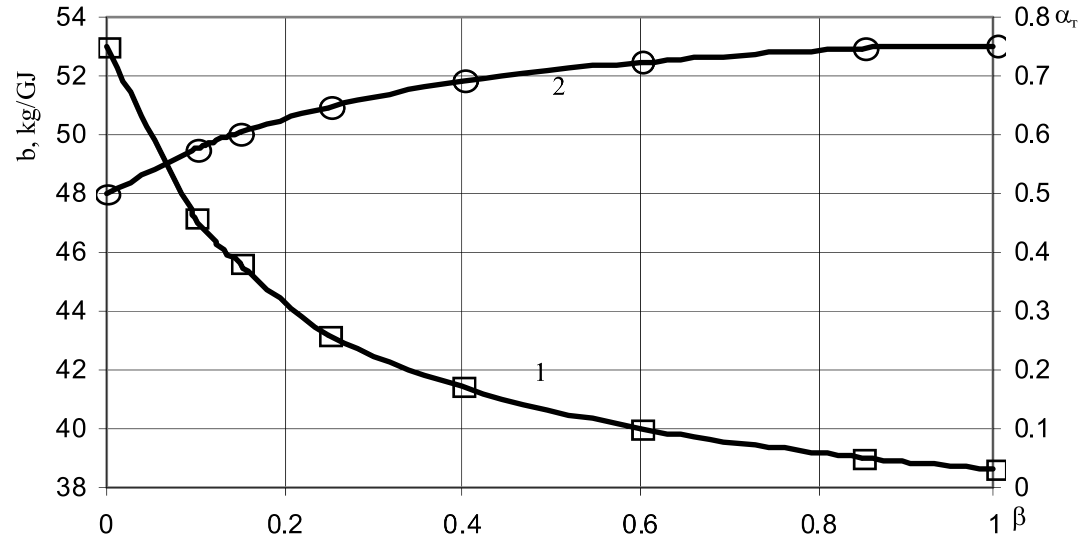

Fig. 4. Dependences: $1 - b = f(\beta)$; $2 - \alpha_T = f_1(\beta)$

The [9] determines that the operation efficiency of back pressure turbines is also characterized by the share of fuel heat α_T, used for the production of heat in STP, that is $\alpha_T = Q/(B \cdot Q_{lc}^o)$. Fig. 4 shows the current values of b and α_T depending on the share of steam discharge from the controlled turbine bleeding β, which characterises the relation of the current steam discharge to the nominal, that is $\beta = D_{1i}/D_{1n}$. Fig. 4 shows that, the lower values of b correspond to higher values of α_T. This proves that the values α_T characterize the efficiency of STP operation. As in Fig. 3, the unload of STP due to the decrease in steam from bleeding sufficiently decreases the efficiency in STP operation and leads to the fuel over discharge.

During the non heating period the operation of steam and turbine plant is characterized by the zero steam discharge from the turbine bleeding. In this case the steam discharge from the back pressure may be increased up to achieving the nominal electric capacity of the electric generator. Under such conditions the loading of the STP shall be determined by the capacity of heat consumers, and the regulation over the operation modes of STP shall be made by changing the steam discharge from the back pressure turbine. The discharge and heat characteristics of STP with the cut steam bleeding are presented in Fig. 5.

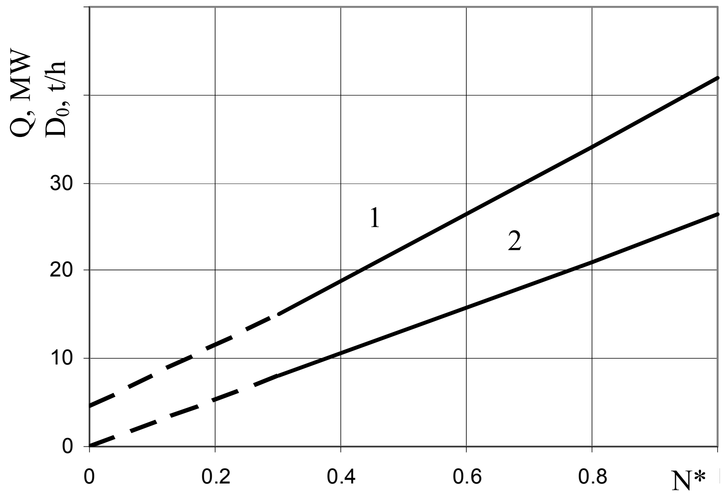

Fig. 5. Dependence of hour discharge of steam for the turbine and for the produced thermal capacity from the share of load on electric generator (view designations in Fig. 2.)

Dependences in Fig. 5. agree qualitatively with the analytical dependences, presented in Fig. 2, and shall be approximated by the formulas:

$$D_0 = 4 + 37{,}5 \cdot N^*; \tag{9}$$

$$Q = 26 \cdot N^*. \tag{10}$$

It is clear that the cut off in steam bleeding decreases the total steam discharge for the turbine and the heat capacity of the produced heat. The efficiency factors of STP operation for different electric loadings are presented in Fig. 6.

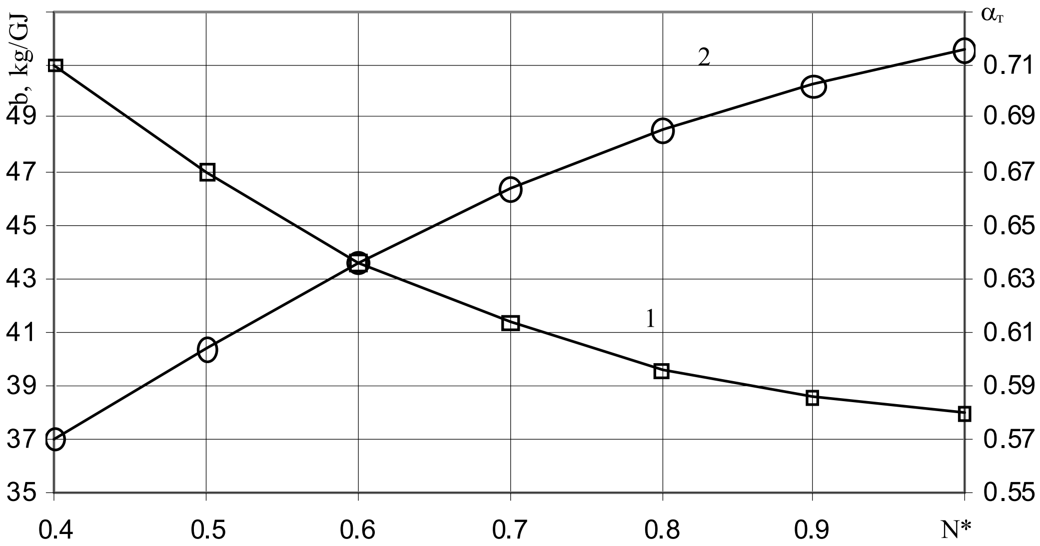

Fig. 6. Character of changing the specific discharges of coal equivalent and factors α_T (view designations in Fig. 4.)

Comparing these dependences with those presented on fig. 3 and 4, allows to see their identical character. The value of the specific discharge of the coal equivalent under the condition of turbine operation with the cut off steam bleeding is however somewhat higher unlike under the operation with steam bleeding. This means that the STP operation with steam bleeding under condition of equal lading of turbogenerator is more efficient and requires less fuel discharge. And in this variant the operation of STP is more efficient and is characterized by higher values of fuel heat share, used for the production of heat.

Conclusions

1. Fuel efficiency in the operation of steam and turbine plants is definitely characterized by the specific discharge of coal equivalent for the joint production of heat and electric energy.
2. The underloading of back pressure turbine with steam bleeding under any operational modes results in significant worsening of STP operation efficiency.
3. The indicator of efficiency in STP operation with back pressure turbines shall not be the factor of electric energy production on heat supply. Such an indictor is the share of heat , used for the production of heat energy.
4. Back pressure turbines with steam bleeding under the conditions of their nominal loading operate more efficiently then the heating boilers and may be recommended for covering the heating loadings.

REFERENCES

1. Закон України про комбіноване виробництво теплової та електричної енергії та використання скидного потенціалу // Відомості Верховної Ради, – 2005 – № 20. – С. 275 – 285.
2. Чепурний М. М. Аналіз роботи протитискових турбін на теплоелектроцентралях / М. М. Чепурний, С. Й. Ткаченко // Вісник Вінницького політехнічного інституту, – 2010 – № 1. – С. 52 – 54.

3. Турбины паровые стационарные для приводов турбогенераторов : ГОСТ 3618-82. – [Чинний від 1983-01-01]. М.: ИПК Издательство стандартов, 1998. – 7 с.

4. Номенклатурный каталог. Энергетическое оборудование для тепловых электростанций и промышленной энергетики / [ред. В. Бутина]. – М.: ЦНИИТЭИ – Тяжмаш, 1997, ч. 3. – 154 с.

5. Кирюхин В. И. Паровые турбины малой мощности КТЗ / В. И. Кирюхин, Н. М.Тараненко, Б. П. Огурцова. – М.: Энергоатомиздат, 1987 – 216 с.

6. Чепурний М. М. Розрахунки теплових схем когенераційних установок / М. М. Чепурний, С. Й. Ткаченко, В. В. Бужинський. – Вінниця: ВНТУ, 2003 – 103 с.

7. Промышленные тепловые электростанции / [под ред. Е. Я. Соколова]. – М.: Энергия, 1979. – 299 с.

8. Горшков А. С. Технико-экономические показатели тепловых электростанции / А. С. Горшков. – М.: Энергия, 1975 – 239 с.

9. Показники ефективності роботи енергетичних установок для сумісного виробництва теплової та електричної енергії [Електронний ресурс]/ М. М. Чепурний, С. Й. Ткаченко, Н. В. Пішеніна // Наукові праці Вінницького національного технічного університету. – № 1. – 2010. Режим доступу до журн.: http://archive.nbuv.gov.ua/e-journals/VNTU/2010_1/2010-1.files/uk/10mmcaee_ua.pdf.

Mark Chepurnyi – Cand. Sc. (Eng.), Professor with the Department of Heat and Power Engineering.

Rezident Nataliia – Cand. Sc. (Eng.), Senior lecturer with the Department for Heat and Power Engineering.

Korzhenko Evgen – Cand. Sc. (Eng.), Assist. Prof. with the Department of Heat and Power Engineering.
Vinnytsia National Technical University.