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Efficiency Level of Centrifugal Pumps of Various Designs for Public Water Supply and District Heating Systems

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Abstract: **The goal of the research is to compare the efficiency level of centrifugal pumps of various designs to be used at the second stage pumping stations of public water supply systems and at the main pumping stations of district heating systems. For this purpose, a variety of centrifugal pumps have been analysed and the regression equations with the coefficients of determination have been derived.**

The main conclusion is as follows: horizontal end-suction single-stage close-coupled pumps are less efficient in comparison with vertical in-line multistage close-coupled pumps, when the flow rate is up to 83 m^3/h at the definite range of the head (from 30 to 55 m).

Keywords: **District heating, efficiency, pump design, water supply.**

INTRODUCTION

Nowadays, the most important criterion for selection of different pump alternatives is the level of efficiency. Therefore, selection of the most efficient pump equipment should always be considered first.

It is very important if the certain duty point is located at the most optimal zone of the pump curve. Thus it is possible to achieve a high level of energy efficiency [1]. At the same time, the pump efficiency indicators also depend on its design.

The types of the glanded pump design, which are widely used in low and medium-size public water supply and district heating systems, are as follows: vertical in-line multistage close-coupled, vertical in-line single-stage close-coupled and horizontal end-suction single-stage close-coupled [2], [3] and [4]. So it is crucial to determine the appropriate pump design for the corresponding engineering system, thus contributing to the total energy saving in the world.

EFFICIENCY LEVEL OF PUMP EQUIPMENT OF VARIOUS DESIGNS FOR THE SECOND STAGE PUMPING STATIONS IN PUBLIC WATER SUPPLY SYSTEMS

There is no doubt that the advantage of vertical multistage pumps over horizontal single-stage pumps can be described under certain conditions. This advantage is characterised as the higher efficiency level.

It is very important to define the pump design type to be used and the conditions for its usage. One selection criterion for the respective pump design is its efficiency level in the particular engineering system [9] and [10]. The efficiency level of pumps depends on hydraulic requirements of each system.

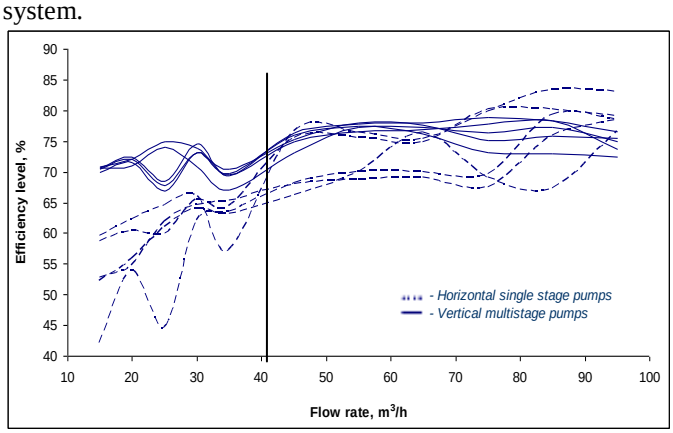

Fig. 1. Comparison of the efficiency level of vertical multistage and horizontal single-stage pumps at different values of flow rate and head (the range of head values varies from 30 to 55 m)

Having performed the pump efficiency analysis, when values of the flow and the head are being changed within a certain range (Q=15÷95 m^3/h @ H=30÷55 m) [5], [6] and [7], it has been found that vertical multistage pumps have the trend to be considerably more efficient than horizontal single-stage pumps, if the flow rate is up to 40 m^3/h (Fig. 1).

As a result of the research, the regression equations of the polynomial trend type ($y = a_0 + a_1 * x + a_2 * x^2 + \varepsilon$) and the respective coefficients of determination have been derived.

$$y = -0{,}0026 * x^2 + 0{,}3438 * x + 66{,}304 \qquad (1)$$
$$R^2 = 0{,}7444$$

In this equation (1), y represents the efficiency level of vertical multistage pumps in % and x denotes the flow rate in m^3/h.

$$y = -0{,}0035 * x^2 + 0{,}6764 * x + 44{,}815 \qquad (2)$$
$$R^2 = 0{,}7498$$

In the equation (2), y represents the efficiency level of horizontal single-stage pumps in % and x denotes the flow rate in m^3/h.

It is possible to use these regression equations as a tool for estimating the efficiency level of vertical multistage and horizontal single-stage centrifugal pumps in relation to the definite flow rate.

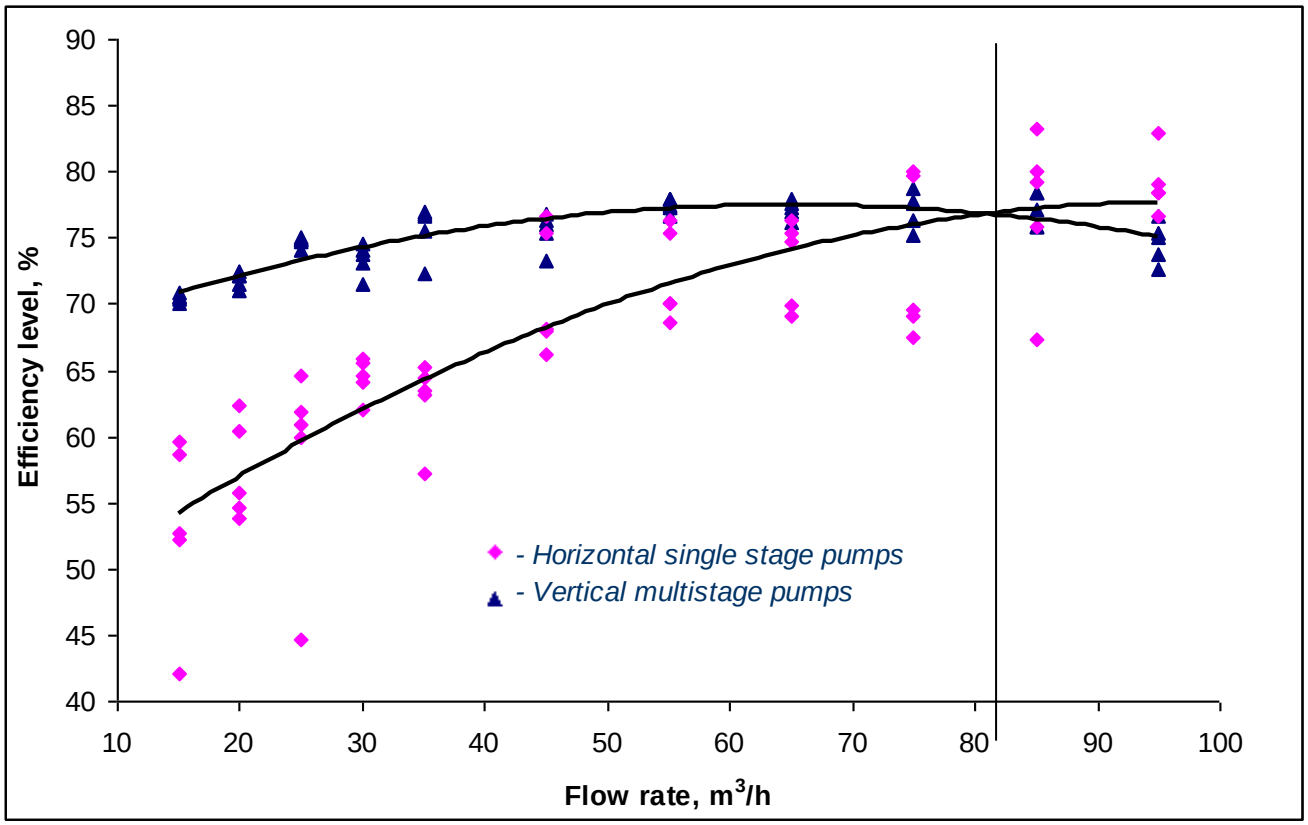

Fig. 2. Comparison of the efficiency level of vertical multistage and horizontal single-stage pumps at different values of flow rate and head (the range of head values varies from 30 m to 55 m)

By combining the equations (1) and (2) and getting the system of the equations (3), it is possible to detect the flow rate when the efficiency level is equal for both types of the pump design.

$$\begin{cases} y = -0{,}0035 * x^2 + 0{,}6764 * x + 44{,}815 \\ y = -0{,}0026 * x^2 + 0{,}3438 * x + 66{,}304 \end{cases} \quad (3)$$

The research gives the result of the 83 m^3/h flow when the efficiency levels are equal for both pump types (Fig. 2).

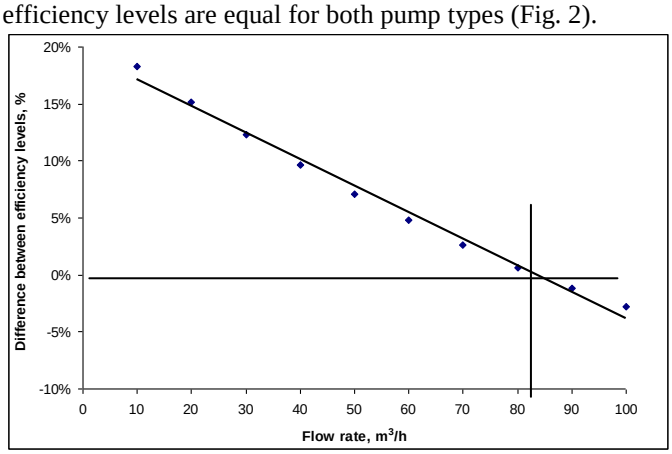

Fig. 3. Difference between the efficiency levels of vertical multistage and horizontal single-stage pumps at different values of flow rate and head (the range of head values varies from 30 m to 55 m)

Thereby, the lower the flow, the more advisable it is to use vertical multistage pumps.

Having compared the difference between the efficiency levels of vertical multistage and horizontal single-stage pumps (Fig. 3), the regression equation of the linear trend type ($y = a_0 + a_1 * x + \varepsilon$) and the respective coefficient of determination have been derived in the research.

$$\begin{aligned} y &= -0{,}0023 * x + 0{,}1951 \\ R^2 &= 0{,}9906 \end{aligned} \quad (4)$$

In this equation (4), y shows the difference between the efficiency levels of vertical multistage and horizontal single-stage pumps in % and x denotes the flow rate in m^3/h.

It is possible to use the regression equation (4) as a tool for analysis of the difference between the efficiency levels of both pump types in relation to the definite flow rate. Thus, it has been proved that vertical multistage pumps are more efficient than horizontal single-stage pumps, when the flow rate is up to 83 m^3/h.

There are different limitations which have been taken into account during the research. These limitations are as follows:

- Q=15÷95 m^3/h @ H=30÷55 m,
- Deviation from the pump efficiency optimum is up to 3%.

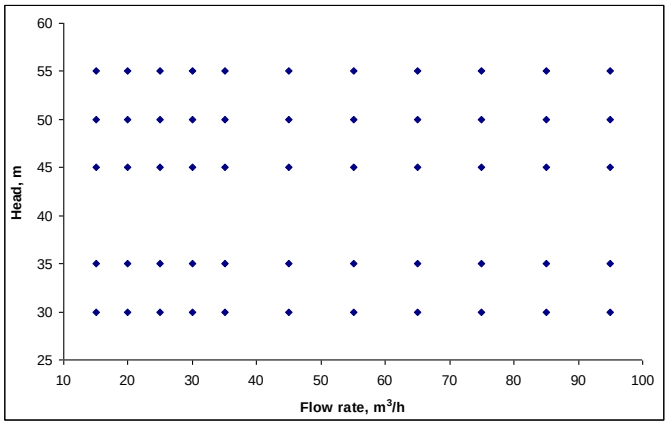

Fig. 4. The duty points of vertical multistage and horizontal single-stage centrifugal pumps analysed in the study

During the study, 110 centrifugal pumps of different design have been analysed (Fig. 4).

EFFICIENCY LEVEL OF PUMP EQUIPMENT OF VARIOUS DESIGNS FOR THE MAIN PUMPING STATIONS IN DISTRICT HEATING SYSTEMS

Horizontal single-stage pumps have a very crucial advantage in comparison with vertical single-stage centrifugal pumps. This advantage is characterised by their high efficiency [1].

Having performed the analysis of efficiency of horizontal and vertical single-stage pumps, when values of the flow rate and the head are being changed within a certain range (Q=20÷220 m^3/h @ H=10÷72 m), it has been found that horizontal single-stage pumps have the trend to be more efficient than vertical single-stage pumps [5], [6] and [7] (Fig. 5).

The regression equations of the polynomial trend type ($y = a_0 + a_1 * x + a_2 * x^2 + \varepsilon$) and the respective coefficients of determination have been derived in the study.

$$y = -0{,}0007 * x^2 + 0{,}2257 * x + 66{,}076 \quad (5)$$
$$R^2 = 0{,}8114$$

In this equation (5), y represents the efficiency level of horizontal single-stage pumps in % and x denotes the flow rate in m^3/h.

$$y = -0{,}0005 * x^2 + 0{,}1679 * x + 64{,}537 \quad (6)$$
$$R^2 = 0{,}8328$$

In the equation (6), y figures the efficiency level of vertical single-stage pumps in % and x denotes the flow rate in m^3/h.

It is possible to use the regression equations as a tool for the estimation of the efficiency level of horizontal and vertical single-stage centrifugal pumps in relation to the definite flow rate.

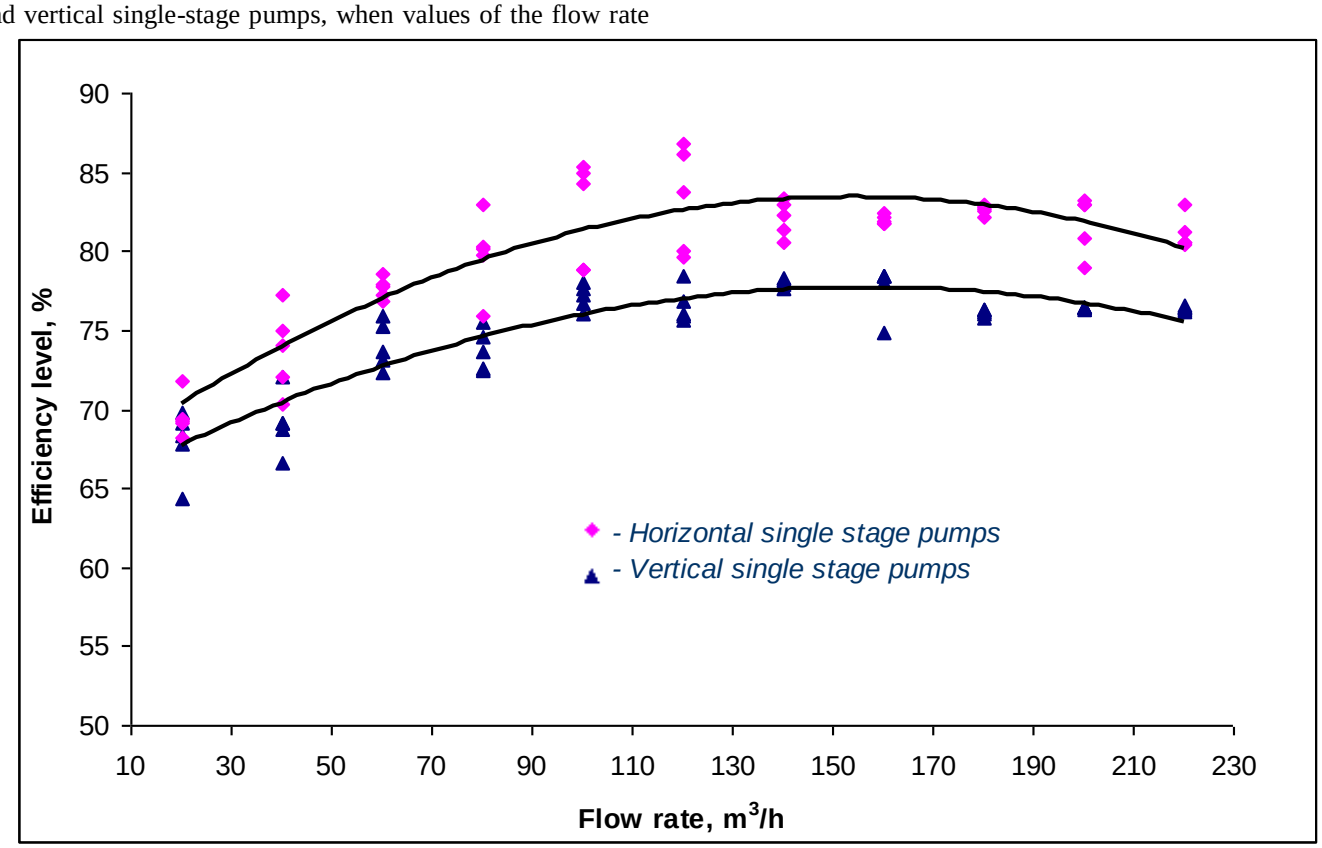

Fig. 5. Comparison of the efficiency level of vertical and horizontal single-stage pumps at different values of the flow rate and head (the range of head values varies from 10 m to 72 m)

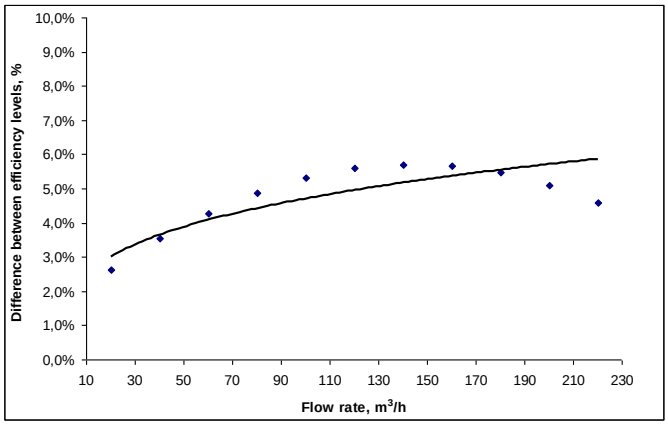

Fig. 6. Difference between the efficiency levels of vertical and horizontal single-stage pumps at different values of the flow rate and head (the range of head values varies from 10 m to 72 m)

The difference between the efficiency levels of vertical and horizontal single-stage pumps (Fig. 6) has been compared and the regression equation of the power trend type ($y = a_1 * x^b + \varepsilon$) and the respective coefficient of determination has been derived in the research.

$$y = 0{,}013 * x^{0{,}2796} \qquad (7)$$
$$R^2 = 0{,}7432$$

In this equation (7), y shows the difference between the efficiency levels of vertical and horizontal single-stage pumps in % and x denotes the flow rate in m^3/h.

It is possible to use the regression equation (7) as a tool for analysing the difference between the efficiency levels of both pump types in relation to the definite flow rate. Thus, it is verified that horizontal single-stage pumps are more efficient than vertical single-stage pumps within the definite range of flow rate (Fig. 6).

There are different limitations which have been taken into account during the research. The limitations are as follows:

- Q=20÷220 m^3/h @ H=10÷72 m,
- Deviation from the pump efficiency optimum is up to 3%.

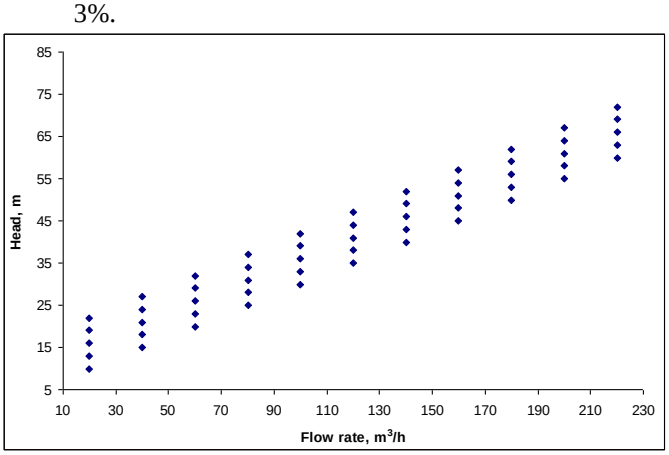

Fig. 7. The duty points of vertical and horizontal single-stage centrifugal pumps analysed in the study

During the study, 110 centrifugal pumps of different design have been analysed (Fig. 7).

CONCLUSIONS

This study shows that vertical in-line multistage close-coupled centrifugal pumps can be recommended for usage at the second stage stations of public water supply systems, when the flow rate is up to 83 m^3/h and the head value varies from 30 to 55 m. When the flow rate exceeds 83 m^3/h, horizontal end-suction single-stage close-coupled centrifugal pumps are to be used. This is due to the constructive features of the pump design which leads to the higher efficiency level.

It has been found in the research that the difference in efficiency levels between centrifugal pumps of the vertical multistage and horizontal single-stage design considerably increases when the flow rate is up to 40 m^3/h.

The research also shows that horizontal end-suction single-stage close-coupled centrifugal pumps are recommended to be used at the main pumping stations of district heating systems, when the flow rate is within the range of 20 to 220 m^3/h, and the head value varies from 10 to 72 m. Vertical in-line single-stage close-coupled centrifugal pumps are less efficient at the aforementioned hydraulic parameters.

RECOMMENDATIONS

It is very advisable to use the regression equation ($y = -0{,}0023 * x + 0{,}1951$) derived in this research for estimation of the potential energy savings in the existing second stage pumping stations of public water supply systems, if horizontal end-suction single-stage centrifugal pumps have to be substituted by vertical in-line multistage close-coupled pumps.

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Egīls Dzelzītis, Deniss Piļščikovs. Dažādas konstrukcijas centrbēdzes sūkņu ekspluatācijas efektivitātes līmeņa analīze sabiedriskajās ūdensapgādes sistēmās un centralizētajos siltumapgādes tīklos

Pētījuma mērķis ir dažādas konstrukcijas centrbēdzes sūkņu efektivitātes līmeņa analīze noteiktajā plūsmas un celšanas augstuma vērtību diapazonā otrā pacēluma sūkņu stacijās sabiedriskās ūdensapgādes sistēmās un galvenajās tīkla sūkņu stacijās centralizētajās siltumapgādes sistēmās.
Tika izpētīti dažādas konstrukcijas centrbēdzes sūkņi ekspluatācijai maza un vidēja mēroga sabiedriskajās ūdensapgādes sistēmās un centralizētajos siltumapgādes tīklos. Ekspluatācijai otrā pacēluma sūkņu stacijās tika analizēti līnijas vertikālie daudzpakāpju un gala iesūces horizontālie vienpakāpes cieši savienotie sausā rotora centrbēdzes sūkņi. Savukārt, kā galvenie tīkla sūkņi centralizētajās siltumapgādes sistēmās tika analizēti vertikālie līnijas un horizontālie gala iesūces vienpakāpes cieši savienotie sausā rotora centrbēdzes sūkņi.
Centrbēdzes sūkņu analīzes gaitā tika iegūti attiecīgi regresijas vienādojumi, ar kuru palīdzību ir iespējams novērtēt potenciālo enerģijas ekonomiju centralizētajās ūdensapgādes un siltumapgādes sistēmās, aizvietojot esošos sūkņus ar attiecīgās konstrukcijas centrbēdzes sūkņiem.
Pētījuma rezultātā tika noteikts, ka vertikālās konstrukcijas daudzpakāpju sūkņiem noteiktajā celšanas augstuma vērtību diapazonā (no 30 m līdz 55 m) efektivitātes līmenis ir lielāks salīdzinājumā ar horizontālās konstrukcijas vienpakāpes centrbēdzes sūkņiem, ja plūsmas vērtību diapazons ir no 15 m^3/h līdz 83 m^3/h. Savukārt, ja plūsmas vērtība ir virs 83 m^3/h, tad efektivitātes rādītājs kļūst augstāks horizontālajiem vienpakāpes cieši savienotajiem gala iesūces sausā rotora centrbēdzes sūkņiem.
Salīdzinot vertikālos līnijas un horizontālos gala iesūces vienpakāpes cieši savienotos sūkņus, tika konstatēts, ka noteiktajā plūsmas un augstuma celšanas vērtību diapazonā (Q=20÷220 m^3/h @ H=10÷72 m) horizontālās konstrukcijas sūkņu efektivitātes rādītājs ir par 3-6% augstāksб nekā vertikālās konstrukcijas centrbēdzes sūkņiem.

Эгилс Дзелзитис, Денис Пильщиков. Анализ уровня эффективности центробежных насосов различной конструкции для эксплуатации в системах централизованного водо- и теплоснабжения

Целью исследования является анализ уровня эффективности центробежных насосов различной конструкции в определенном диапазоне значений производительности и напора для использования на станциях второго подъема в системах централизованного водоснабжения, а также в главных сетевых насосных станциях в системах централизованного теплоснабжения.
Исследовались центробежные насосы различной конструкции с целью дальнейшей эксплуатации в системах водо- и теплоснабжения малой и средней величины. С целью эксплуатации на станциях второго подъема производился анализ вертикальных линейных многоступенчатых и горозонтальных одноступенчатых бокового всоса моноблочных центробежных насосов сухого ротора. В свою очередь, как главные сетевые насосы в системах централизованного теплоснабжения, анализировались вертикальные линейные и горизонтальные бокового всоса моноблочные одноступенчатые центробежные насосы сухого ротора.
В процессе анализа центробежных насосов были выведены соответствующие уравнения регрессии, с помощью которых возможно оценить потенциальную экономию энергии в системах централизованного водо- и теплоснабжения, заменив существующие насоса на центробежные насосы соответствующей конструкции.
В результате исследования было определено, что многоступенчатые насосы вертикальной конструкции в определенном диапазоне значений напора (от 30 м до 55 м) являются более эффективными с точки зрения потребления электроэнергии, чем одноступенчатые центробежные насосы горизонтальной конструкции, если диапазон значений потока от 15 $м^3$/час до 83 $м^3$/час. В свою очередь, если значение потока выше 83 $м^3$/час, то более эффективными являются горизонтальные бокового всоса моноблочные одноступенчатые центробежные насосы сухого ротора.
Производя сравнение вертикальных линейных и горозонтальных бокового всоса одноступенчатых моноблочных насосов, было определено, что в определенном диапазоне значений потока и напора (Q=20÷220 $м^3$/час @ H=10÷72 м) центробежные насосы горизонтальной конструкции на 3-6% являются более эффективными, чем центробежные насосы вертикальной конструкции.