

Establishment of resource-saving modes of irrigation pumps

Oleg Glovatskiy^{1,2}, *Rustam Ergashev*^{2,*}, *Umid Sadiev*¹, *Jaloliddin Rashidov*², *Sharof Musaev*³ and *Gulmira Boboeva*⁴

¹Research Institute of Irrigation and Water Problems, Karasu-4 Street, Tashkent, 100187, Uzbekistan

²National research university «Tashkent Institute of Irrigation and Agricultural Mechanization Engineers», 39 Kari Niyaziy Street, Tashkent 100000, Uzbekistan.

³Jizzakh Polytechnical Institute, Jizzakh, 130100, Uzbekistan

⁴Samarkand State University of Architecture and Civil Engineering named after Mirzo Ulugbek. Samarkand 140147, Samarkand, Lolazor street 70.

Abstract. The article presents the results of a study obtained in the process of testing the flow path of modernized centrifugal pumps. The authors proposed the device of new elements based on the calculation of the flow limited only by the side walls. The purpose of this work is to change and refine the calculations of the indicators of the modes of pumping units and the features of the performance of modern vane pumps. They are developed on the basis of the results of a large number of tests carried out by the authors of pump assemblies and operational surveys of irrigation pumping stations in Uzbekistan. The determination of the economically viable duration of the period of operation of pumping units, taking into account changes in energy characteristics and resource-saving operating technologies, was refined when measuring the efficiency of the upgraded pump D2000-100 under various operating modes. The creation of resource-saving methods of operation of pumping units that reduce or eliminate the intensity of cavitation-abrasive wear, including those based on taking into account changes in flow rates in the inter-blade channels of the impeller, is shown in the corresponding characteristics of the upgraded pump.

Key words: machine water lifting, pumping units, flow part of pumps, pressure characteristics, impeller, cavitation-abrasive wear.

1 Introduction

In recent years, the role of machine water lifting systems in the Republic of Uzbekistan has sharply increased, about two thousand pumping stations (PS) have been built and are in operation, which irrigate more than half of all irrigated lands. In the Republic, the area of irrigated land is more than 4.331 million hectares, of which 2.3 million hectares are irrigated with the help of 5301 pumping units (PU) with a capacity of 3616.7 MW, which pump more than 52 billion m³ of irrigation water per year and are the largest consumers electricity in agriculture.

* Corresponding author: rustamrah@mail.ru

Of these, 97.2% have water intake from rivers, 1.9 from collector networks, 0.9% from underground sources. The task of operating organizations is to achieve by 2030 a 25% reduction in the annual volume of electricity consumption by pumping stations with an increase in the efficiency of irrigation systems from 0.63 to 0.73.

Reconstruction and modernization of hydraulic structures and water management systems are becoming increasingly important for the national economy. Particularly great tasks are faced in the field of reconstruction of existing irrigation systems, increasing the efficiency of machine channels for water taken for irrigation.

Large modernization tasks are facing the hydropower industry, since pumping and power equipment at many operating PSs of large and medium power has served its time and needs to be replaced. Axial pumps operate on the unique cascades of the Amubukhara and Karshi canals and have been successfully modernized since the beginning of the 21st century.

The number of centrifugal pumps as a percentage of the total number of vane pumps is 76.2%. Centrifugal pumps provide a smooth and continuous supply of the pumped liquid at high efficiency values. The design of the flow path of horizontal centrifugal pumps and the absence of friction surfaces allow the possibility of pumping contaminated liquids. Ease of direct connection to high-speed drive motors contributes to the compactness of the unit and increase its efficiency.

All these positive qualities of centrifugal pumps have led to the fact that they are, in essence, the main pumps of the irrigation systems of the Republic and also need to be modernized.

2 Methods

When performing this work, the main provisions of the theory of bladed hydraulic machines were used. On the basis of these theories, a method for calculating the wear rate of the elements of the flow part of pumps is proposed. When conducting experimental studies, generally accepted standard methods for testing pumps were used.

Determining the economically justified duration of the overhaul period of operation, taking into account the change in the energy characteristics of the equipment due to cavitation-abrasive wear and the cost of overhaul repairs, is a very important and at the same time extremely difficult task.

As operating experience shows, the wear of various parts of the PU occurs with different intensity. Therefore, the most practical importance is the evaluation of the wear of the PU as a whole and its comparison with the energy characteristics that change due to wear.

To identify patterns of changes in hydrodynamic characteristics and hydraulic resistances in the interface structures of machine channels, the authors used the logarithmic law of velocity distribution and methods for accounting for average cross-sectional velocities along the length [1,2]. The theoretical formulas proposed by the authors, obtained on the basis of the energy theory, take into account the features of the wear of PU parts [3,4].

3 Results and Discussion

The purpose of the work: to study the wear of hydromechanical equipment based on the use of theoretical foundations for substantiating regime factors that affect the wear rate of pump parts and improve the hydraulic processes of their flow path.

If the characteristic of the system to which the pump supplies water is known, then the pressure developed by the pump is the sum of the geometric height of the liquid and the

sum of the hydraulic resistances. The amount of losses $\sum h$ depends on the resistance of the walls of the flow path, the number of local resistances and the flow rate Q of the supplied liquid

$$\sum h = SQ^2 = (Al + A_{loc} \sum \zeta), \quad (1)$$

where S - is the impedance of the system;

A - length resistivity;

A_{loc} - specific local resistance;

l - flow path wall length;

$\sum \zeta$ - sum of local resistance coefficients.

The characteristic of centrifugal pumps (as a rule, low speed) is unstable. The Q-H curve of such pumps has a maximum in the zone of low flows. At first, the pump works with a large flow and the system fills with water. If, at the same time, the flow rate of water taken by the consumer is less than the supply ($Q_{con} < Q_p$), then the pump supply will begin to decrease.

While maintaining the condition $Q_{con} < Q_p$, the level would have to increase and, but this is impossible, since the pump is not able to provide a greater pressure.

In this case, the equilibrium is disturbed and the pump-network system enters the so-called surge mode. The pressure developed by the pump drops to the value of the idling pressure H_0 , the pump can no longer hold the liquid column of height H_m pressing on it, and the liquid begins to flow in the opposite direction (if a check valve is not installed on the pump pressure pipe). As soon as the level drops, the pump will resume operation with a flow corresponding to the Q-H characteristic.

If the mode of operation of the system does not change by this time, then the described phenomenon will repeat again. An unstable mode of operation of the pump in the system leads to fluctuations in flow and pressure and may be accompanied by hydraulic shocks in the outlet and pressure pipeline.

An unstable mode of operation of the pump in the system can occur when, at any time, the static head in the network rises above the idle head of the pump, i.e. provided $H_{st} > H_0$. In addition, the cause of the unstable operation of the centrifugal pump in the system is the presence of a battery capacity.

Improvement of anti-cavitation properties throughout the flow part of the pump and regulation of the amount of liquid was achieved due to new elements in the centrifugal pump housing [7,8].

The pump housing is equipped with baffles on the inner surface, in which normally closed hinged valves are installed.

When the impeller rotates, the liquid enters the spiral chamber through the baffles, as a result of which normally closed valves open on the hinges, which bypass the liquid, which has significant energy, into the pressure pipe. With the formation of whirlpool zones of unsteady operation processes, especially when the pump is stopped, reverse flows close the valves, eliminating whirlpools and flow separation from the inner surface of the casing.

Pumps in reclamation PS work together, several pumps supply water to one system [9,10]. The operating point in this case will be at the intersection of the total characteristic of the pumps with the characteristic of the system.

If the dimensions of the centrifugal pump wheel and the number of its revolutions are known, which remain unchanged, then only the values H , Q , η_m can change, and the value of the manometric efficiency factor η_m is assumed to be determined by special experiments [11,12].

The results are shown in the efficiency curves of the factory and upgraded pumps, with the efficiency varying in the operating range from 1000 to 1400 m³/h, from 73 to 86% (Fig. 1).

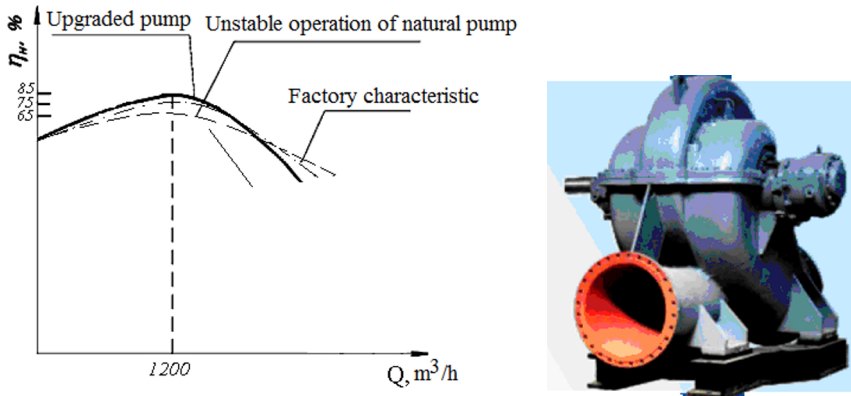


Fig. 1. Efficiency of pump D2000-100 under various operating modes

In the optimal mode, in the studied sections of the flow path, the law of constancy of the moment of velocity is valid, $rv_u = \text{const}$.

From here

$$Q = \int dQ = \int B / r dr ; \quad (2)$$

where r - is the outer radius of the section.

The existing methods for changing the modes of reclamation pumps do not fully take into account the functions of the hydraulic structures of the PS to ensure the reliability of operation [13,14].

The article considers the flow in a system limited only by the side walls in the form of a surface of revolution. To obtain a laminar flow, it is sufficient to place a bounding wall according to the shape of the found streamline (Fig. 2).

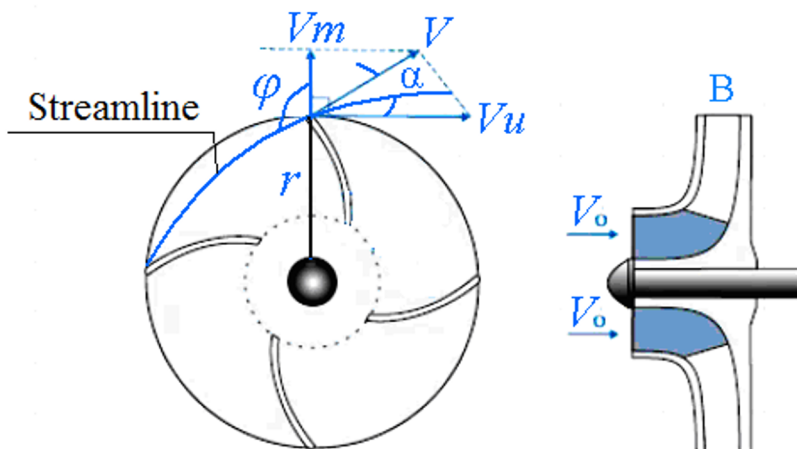


Fig.2. Building a streamline

With a decrease in the geometric pressure, the hydraulic resistance curves go down and the operating point will move along the curve to the right. The change in pump head (dynamic pressure drop) ΔH that occurs in the system as it is filled depends on the position

of the pump operating point on the H-Q curve and decreases as the operating point moves to the left. According to the calculated data, the pump D2000-100-2M-0, 730 rpm, the characteristic of which is shown in Fig. 3 with the operating point E, is plotted on the characteristic field the operating point A, corresponding to the upgraded pump wheel with the characteristics Q and N_m , by reducing the wheel diameter from 855 mm up to $D_m=790$ mm, shown in the figure by dotted lines.

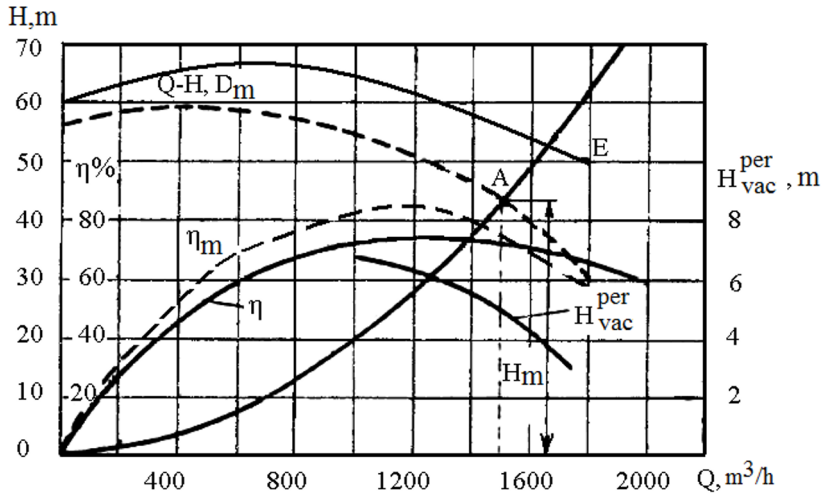


Fig. 3. Characterization of the upgraded pump.

Since the operating point of the pump must be in the working area on the curve, which takes place with the correct selection of the pump, when filling the system, a dynamic pressure drop will occur, the magnitude of which can be controlled.

This dynamic head difference can be used as a command to turn off the pumping unit when the pressure head is full.

When using a dynamic head drop as a command to turn off the electric motor of the pump, the dependence of its value on hydraulic resistances was investigated, when the case may occur that the dynamic head drop will be equal to zero. Therefore, the control of the headwater level by the proposed method cannot be carried out.

We also considered cases when the points of intersection of the characteristics of the system with the characteristics of the pumps lay on the working sections of the characteristics of these pumps, that is, in the region of maximum efficiency.

In many cases, not the minimum, but the maximum value of the pressure with the valve closed is determined. Such a requirement is usually caused by considerations related to energy savings, taking into account the fact that with a flatter Q - H curve, partial supply losses are reduced. This is not always true, since the slope of the power curve is affected by the shape of the efficiency curve, if the set head value with the valve closed is too small, then the normal load mode should be shifted to the left of the flow corresponding to the maximum efficiency of the pump. In high-pressure pumps, the influence of water heating due to internal hydraulic losses, including disk losses, on its density is noted. Thus, the temperature increase due to the loss of water pumping at $t^{\circ}>20^{\circ}\text{C}$ and $p=125$ atmospheres is about 1°C , which leads to a decrease in density measured in kg/m^3 by 2.7% and to a decrease in outlet pressure at constant pressure at 3.5 atmospheres. Therefore, in pumps with a stable Q-H characteristic from pumping cold water, a decrease in pressure near the zero flow mode and cavitation phenomena can be observed when operating on warm water [15,16].

The working body of centrifugal pumps with areas subject to the most severe erosion is the impeller. Numerous experimental studies and extensive experience in the operation of hydraulic machines of various types make it possible to fairly accurately determine the most characteristic areas of pumps subject to cavitation erosion and abrasive destruction to establish the boundaries of these areas. Under working conditions, one of the types of wear, as a rule, is predominant, and the destroyed surface has its characteristic features (Fig. 4).



Fig. 4. Wear of impellers of PS Amubuhara-2

The turbulent mixing of the flow caused by the design features of the impeller, as well as the content of undissolved air and gases in the water, are the causes of the onset and development of cavitation at pressures in the flow that exceed the vapor pressure of water at a given temperature. Developed cavitation phenomena lead to erosive destruction of wheel elements. The intensity of these destructions sharply increases with the content of suspended sediments in water [17, 18]. The walls of the impeller chambers are subjected to the most severe destruction in pumps.

Due to the separation of the flow caused by the mismatch between the angles of the flow and the blades, in some cases, increased destruction of the straightener blades is possible. In pumps with a volute, cavitation erosion is exposed to the walls of the outlet at their interface with the impeller chamber. The intensity of wear of the elements of the flow path of hydraulic machines due to cavitation and abrasion by suspended deposits is directly dependent on the operating modes.

The proposed method for determining the cavitation-free operation of pumps provides that the specific energy of the flow at its entry into the impeller, referred to the wheel axis, is sufficient to create at this moment velocities and accelerations in the flow and overcome resistance without a drop in local pressure to a value that causes the onset of cavitation. In this regard, it is not the magnitude of the absolute pressure at the impeller inlet that is of decisive importance, but its excess over the magnitude and energy corresponding to the pressure of the saturated vapor of the liquid. These provisions are used in modern operating instructions for pumps [19,20].

Sedimentation tanks are included in the composition of the head waterworks, carrying a large amount of suspended sediments (more than $0.2\text{--}0.5\text{ kg/m}^3$), which, settling in water conduits, reduce their throughput, abrade the metal lining of water conduits, impellers and other elements of pumps. The introduction of the developed designs of sedimentation tanks improves the operating conditions of machine channels.

4 Conclusions

1. On the basis of many years of experience in the operation of PU in the Republic of Uzbekistan, the authors have developed measures to reduce the intensity of their wear. It has been confirmed that the intensity of wear of the elements of the flow path of hydraulic

machines due to cavitation and abrasion by suspended deposits is directly dependent on the operating modes.

2. Identification of the operating modes of the PU, the most dangerous in terms of cavitation-abrasive destruction of parts, was determined during reliability tests. When using a dynamic pressure drop as a command to turn off the pump, the dependence of its value on hydraulic resistances was studied.

3. Determining the economically viable duration of the operation period of pumping units, taking into account changes in energy characteristics and energy-saving technologies for its operation, was refined when measuring the efficiency of the upgraded pump D2000-100 under various operating modes.

4. Creation of resource-saving methods of operation of pumping units that reduce or eliminate the intensity of cavitation-abrasive wear, including those based on taking into account changes in flow rates in the impeller interblade channels and the corresponding characteristics of the upgraded pump.

References

1. Oleg Glovatskii, Shavkat Usmanov, Rustam Ergashev, Bekmamat Hamdamov and Alexander Gazaryan Hydrometric flow measurement in water management E3S Web of Conferences 365, 03016 (2023) <https://doi.org/10.1051/e3sconf/202336503016> [CONMECHYDRO - 2022](#)
2. Glovatsky O.Ya., Ergashev R.R. Reliability assessment and measures for resources-saving on water lifting engine systems in the republic of Uzbekistan. *Journal «Perspectives of Innovations, Economics and Business»* Volume 4. Issue 1. - Prague 2010. - pp. 111-113.
3. Glovatsky O.Ya., Talipov Sh. New methods of dynamic control of the pumping unit of large pumping stations. Proceedings of SANIIRI. V. 2. Modern problems of water resources management. - Tashkent, 2003. - S. 24-31.
4. Mamojonov M., Uralov B. Reasons for the decrease in water supply of pumping units of irrigation systems. *Agriculture of Uzbekistan*. - 2005. - No. 1. - S. 27-29.
5. O. Glovatskii, A. Dzhurabekov, U. Sadiev, Sh. Rustamov, J. Rashidov and A. Saparov Improving the Efficiency of Irrigation Pumps Cite as: AIP Conference Proceedings 2612, 020030 (2023); <https://doi.org/10.1063/5.0113295>
6. M. Mamazhanov, B. Uralov, S. Khidirov Influence of hydroabrasive wear of parts of centrifugal and axial pumps on the efficiency of operation of irrigation pumping stations *Journal "Irrigation and Melioration"*. Tashkent, 2019. - No. 1 (15). - P. 37-42.
7. Glovatsky O.Ya., Rustamov Sh.R. Centrifugal pump, No. FAP 00940. Patent, 07.31.2014.
8. Glovatsky O.Ya., Ergashev R.R., Mukhammedov U.A., Nasyrova N.R. Centrifugal pump, No. FAP 01330. Patent, 09.28.2018.
9. O.N. Pomerantsev, E.E. Nazarkin Regulation of the operation of a centrifugal pump by supplying air to the suction pipeline. *Environmental engineering*. 2017. - №4. - P. 15-19.
10. Rustamov Sh.R., Ergashev R.R., Nasyrova N.R. Modernization of water supply devices of centrifugal pumps. *Materials of the anniversary international scientific-practical conference "Integrated reclamation - a means of increasing the productivity of agricultural land."* - Moscow, 2015. - p.252-256.
11. Mukhamedov U.A., Rustamov Sh.R., Glovatsky O.Ya. Improvement of flow distribution in the flow part of centrifugal pumps by constructive methods, - Tashkent, 2015. - p.295-299.

12. O.Ya.Glovatsky, Ergashev R.R., Rustamov S.R. Improvement to usages and studies of large pumping stations. Monograph L.A.P. LAMBERT Academic Publishing. Saarbruken, 2013. 170 p.
13. Shomayramov M. A., Talipov Sh. G., Nasyrova N. R. Methods for improving the safety and stability of operation of machine water lifting systems. *Scientific and practical journal "Ways to improve the efficiency of irrigated agriculture"* - Novocherkassk, 2018. - No. 3 (71). -WITH. 118-123.
14. Shomayramov M.A., Talipov Sh. G., Nasyrova N. R. Methods for improving the safety and stability of operation of machine water lifting systems. *Scientific and practical journal "Ways to improve the efficiency of irrigated agriculture"* - Novocherkassk, 2018. - No. 3 (71). -WITH. 118-123.
15. O.Ya.Glovatsky, A.B.Saparov, O.R.Azizov Cavitation phenomena of the flow part and impellers of vane pumps. Materials of the international scientific-online conference on "innovative achievements in science – 2020"Chelyabinsk-Ferghana, - 2020, Pp. 521-527.
16. Oleg Glovatsky, Rustam Ergashev, Azamat Saparov, Mustafu Berdiev and Bobur Shodiev Cavitation-abrasive wear working collectors of pumps. IOP Conference Series: Materials Science and Engineering (2020) 869 042006.
17. Rustamov Sh.R., Nasirova N.R. Constructive peculiarities of modernized centrifugal pump. *European science review*, № 3–4, 2018. Vienna. Pp-278-280.
18. Carter R., Karassik I.J. Specific speed chart for centrifugal pumps. *Industry and Power*, No 3, 2005.
19. Jong-Woong Choi Young-Do Choi Chang-Goo Kim Young-Ho Lee Flow uniformity in a multi-intake pump sump model // *Journal of Mechanical Science and Technology*, - Volume 24, July 2010, Issue 7. Pp. 1389–1400.
20. Glovatskii, R Ergashev, J Rashidov, M Mirzaev, A Sulstonov, and N Nasyrova Experience in using methods for monitoring the energy efficiency of hydraulic systems ICECAE-2022 IOP Conf. Series: Earth and Environmental Science 1142 (2023) 012004 <https://doi:10.1088/1755-1315/1142/1/012004>
21. pumping stations //E3S Web of Conferences. – EDP Sciences, 2021. – T. 263. – C. 02030.
22. Ergashev R. et al. The forces acting on the teeth of catching machine //E3S Web of Conferences. – EDP Sciences, 2021. – T. 274. – C. 03009.
23. Nasyrova N. et al. Design aspects of operation of water supply facilities of pumping stations //E3S Web of Conferences. – EDP Sciences, 2021. – T. 274. – C. 03008.
24. Glovatskii O. et al. Achieving reliability and energy savings in operate of pumping stations //E3S Web of Conferences. – EDP Sciences, 2021. – T. 264. – C. 03003.
25. Glovatskii O. et al. Achieving reliability and energy savings in operate of pumping stations //E3S Web of Conferences. – EDP Sciences, 2021. – T. 264. – C. 03003.
26. Ergashev R. et al. Influence of cavitation on pressure pulsation through impeller of large pumps //E3S Web of Conferences. – EDP Sciences, 2021. – T. 264. – C. 03004.
27. Ergashev R. et al. Development of energy-saving modes of irrigation pump stations //IOP Conference Series: Materials Science and Engineering. – IOP Publishing, 2020. – T. 883. – №. 1. – C. 012017.
28. Kodirov, D., Muratov, K., Davirov, A., Normuminov, J., Mamadjanov, B., Shukuraliyev, A., ... & Musayev, S. (2023, March). Study on the effective use of solar and hydro energy for powering agriculture and water management. In IOP Conference Series: Earth and Environmental Science (Vol. 1142, No. 1, p. 012029). IOP Publishing.
29. Ergashev, R., Bekchanov, F., Musaev, S., Saydullaev, S., & Kholbutaev, B. (2023). Reducing vibration of pumping units of reclamation systems. In E3S Web of Conferences (Vol. 365, p. 03021). EDP Sciences.

30. Makhmudov, I. E., Mirzaev, A. A., Murodov, N. K., Ernazarov, A. I., Rajabov, A. K., Musaev, S. M., ... & Ustemirov, S. R. (2022). Socio-Economic Situation In The Water Management Of The Republic Of Uzbekistan And The Regulatory-Legal And Economical Frameworks For The Implementing Of Water-Saving Technologies. *Journal of Positive School Psychology*, 2951-2955.
31. Ernazarovich, M. I., Kuvatovich, A. M., Ernazarovna, M. D., Mamarajabovich, M. S., & Muhtarialievna, R. M. (2022). Development Of A High-Performance Technology For Mixing Ozone With Water For The Preparation Of Drinking Water From The Reservoir. *Journal of Positive School Psychology*, 2921-2925.