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Experimental and field studies of hydraulic resistances of supply canals and structures of pumping stations

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Abstract.

Abstract. Currently, many authors have studied the uniform axisymmetric pressure head laminar and turbulent movement of water in hydraulic smooth and rough (with uniform roughness) pipes of circular cross-section. The results obtained in the study of a plane-parallel turbulent flow in pressure canals allows here only to outline the structure of the corresponding dependences and to clarify the simplest case of unpressurized fluid movement, when this movement can also be reduced to plane-parallel or, in other words, to movement in canal of infinitely large width with a flat bottom. In all other cases, the only way to solve the problem is experiment. The construction of numerous free-flow watercourses, as well as machine canals of pumping stations, requires scientifically based calculation methods.

INTRODUCTION

Introduction

At present, numerous pumping stations have been created in the irrigation systems of the Republic of Uzbekistan, with the help of which about 50 billion m3 of water are pumped per year for irrigation of more than 2 million hectares of irrigated land. The most important element of these pumping stations (PS) are water supply and water supply machine canals and structures of pumping stations (PS). Turning to the question of those engineering problems, in the solution of which the results of this work can be used, let us select, first of all, from the wide range of design cases related to free-flow canals, the main design case, which we will keep in mind in what follows (as, so to speak, “ starting "). The formulation of the above tasks in most cases boils down to the following - given: soil conditions and the amount of water flow. It is required to find such a slope of the water, at which the shape of its cross-section would be stable (i.e., indelible), and the area of the living section would be the smallest. It is known that such a problem, until recently, was solved by using the concept of "maximum permissible speed" , (referring to the uniform movement of water). The value of this speed was assigned (and is assigned at the present time) on the basis of reference data from the type of soil (and in some cases, depending on the depth of water in the canal). Knowing Vmax and the flow rate, it is easy to find the cross-sectional area, as well as the slope of the canal (using formulas to determine the Shezy coefficient C or the coefficient of hydraulic friction λ and in accordance with the accepted value of the roughness coefficient. Object of research in operation is the Amu-Bukhara machine canal (ABMC), in the area of the damless water intake from the Amudarya river bed. Sections of the ABMC machine canals, from the head structure to the ABMC-I and ABMC-II pumping stations, were taken as the object of hydraulic research.

Method

- **Method**

In the process of research, experimental methods, methods of field observation, as well as generally accepted methods in hydraulics, methods of compiling mathematical models based on the laws of hydromechanics and their numerical calculations were used.

Results and Discussion

The results obtained in the study of a plane-parallel turbulent flow in pressure canals allows us to outline the structure of the corresponding dependencies and clarify the simplest case of unpressurized fluid movement, when this movement can also be reduced to plane-parallel or, in other words, to movement in an infinitely large canal. The results of studying the turbulent uniform free-flow movement of water in smooth canals obtained by various authors for the coefficient in smooth gravity canals are similar in general form, which is obvious from (1):

And it differs only in the values of the constants   decreasing constant in the formula (1) magnitude increases. An extensive study of the turbulent movement of water in free-flow canals of rectangular cross-section with uneven-grained (sandy) artificial roughness of the surface of the bottom and walls of the canal was carried out by the author of the work A.P. Zegzhda. The results of this study led the author to an addiction graph:

For the quadratic area of resistance, the author obtained the dependence:

Where, - absolute grain roughness (the diameter of the grains of sand, which were glued to the surface of the bottom and walls of the canal to create uneven grain roughness) Nikuradze for the area of quadratic resistance in pipes at one time received the dependence:

•Results and Discussion

- **The results of experiments in experimental and field studies of hydraulic resistances of supplying machine canals and structures of pumping stations, the corresponding experiments are presented on models of free-flow canals of rectangular and trapezoidal cross-section. And also, to fill the experimental data, the corresponding series of Bazin's experiments were used on models of free-flow canals - rectangular, trapezoidal and semicircular cross-sections with different roughness. Canals with two types of roughness of the bottom and wall surfaces were investigated: close to smooth (smooth concrete), and a surface with gravel glued on it .**
- **In the above experimental canals of rectangular and trapezoidal cross-section, 4 series of experiments were combined. In each of them, 14 - 16 experimental points were filmed, with a constant slope of the canal bottom . At the same time, 14-16 (usually 16) different flows were passed through the canal, they varied in the range from up to . The Reynolds numbers varied within , and the Froude numbers were . The hydraulic radius varied in each series of experiments in the range from 1.72 to 19.45 cm. In each experiment, the flow rate, temperature and flow depth were measured. In our case , in all experiments, the normal depth of a uniform flow was determined. In the dissertation work, the criteria for recalculating the results of experimental studies on nature are used. At the same time, the geometric dimensions of the experimental canal were recalculated based on the parameters of a real object, taking into account the scale of modeling. Based on experimental studies of the distribution of vertical velocities of the water flow, as well as field data of machine canals ABMC (water consumption in ABMC - I and ABMC-II is) in nature, the water speed on the machine canal is quite high and is equal to (υ=3÷4,5 m/s), the obtained materials of experimental and natural conditions gave similar results.**

Results and Discussion

- **In addition, the following series of Bazin's experiments were processed: Series № 2 (duct with rectangular cross-section: the surface of the bottom and walls of the canal is smooth cement; series № 24 (canal with a semicircular cross-sectional shape; the surface of the bottom and walls of the canal is smooth cement; series № 6 (canal with a rectangular cross-sectional shape; the surface of the bottom and walls of the canal are boards; series № 26 and series № 4 (canal with a rectangular cross-sectional shape; the surface of the bottom and walls of the canal - gravel ; series № 27 (the canal has a semicircular cross-sectional shape; the surface of the bottom and walls of the canal - gravel .**
- **Determination of the coefficient of hydraulic friction ʎ and the Reynolds number, for all series of Bazin's experiments was also carried out according to the usual dependencies. Further, according to the experimental data of our experiments and this series of Bazin's experiments, the heights of the roughness protrusions were determined , - for each defined hydraulic radius , the opposite way at known values of the coefficient of hydraulic friction . The results of the corresponding processing of the data of our series experiments № 1, 3, № 7,8 and Bazin's experiments series № 2, № 24, № 6, № 27, № 9, № 21, № 23 listed in tables 4 – 16 and graphs figure.4.3- 4.13.**
- **At small values of the relative roughness, i.e., in the area of resistance close to smooth, the difference between for canals of rectangular and semicircular cross-section is 12 - 16%, with an increase relationship between increases to 32 – 44%.**
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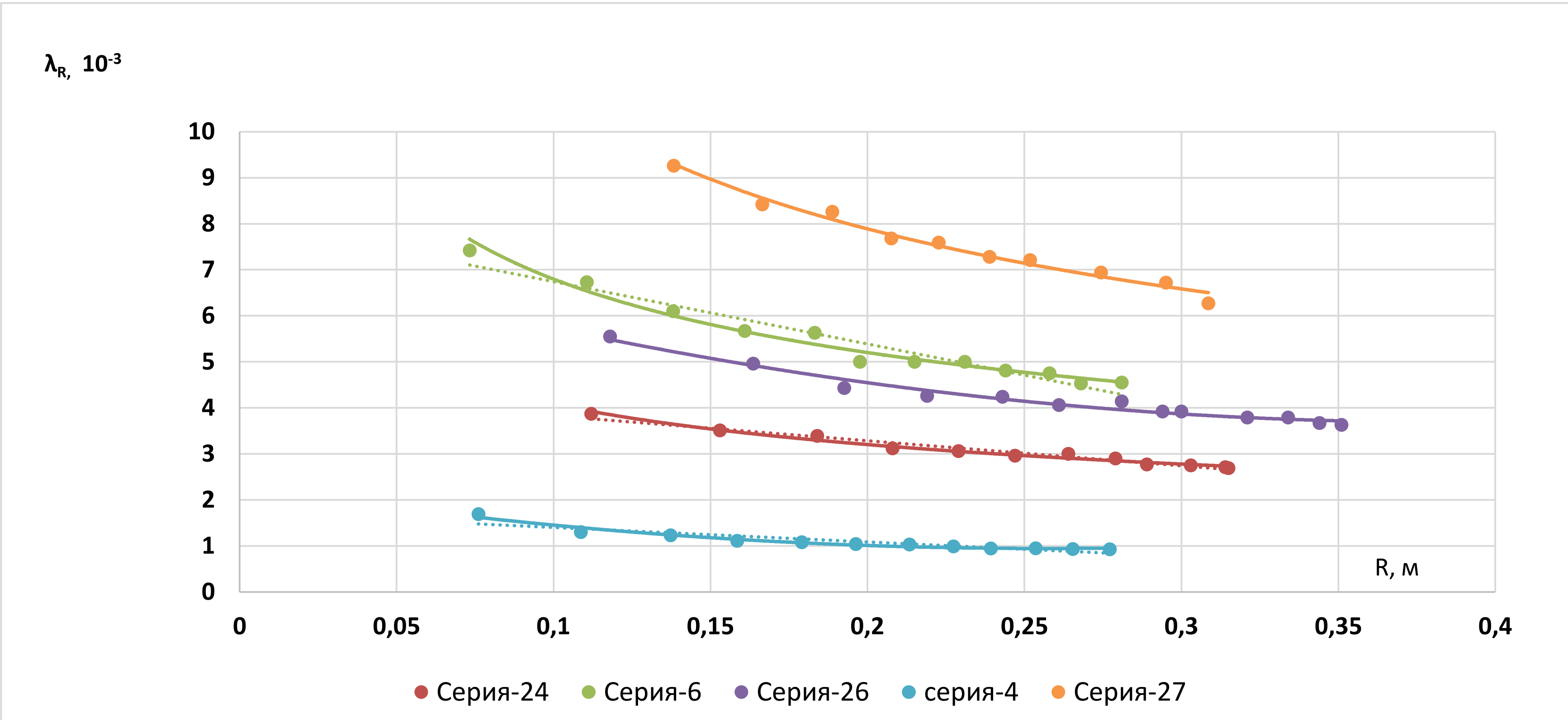
Results and Discussion

Figure. 4.3. Dependence Λ_R from R.

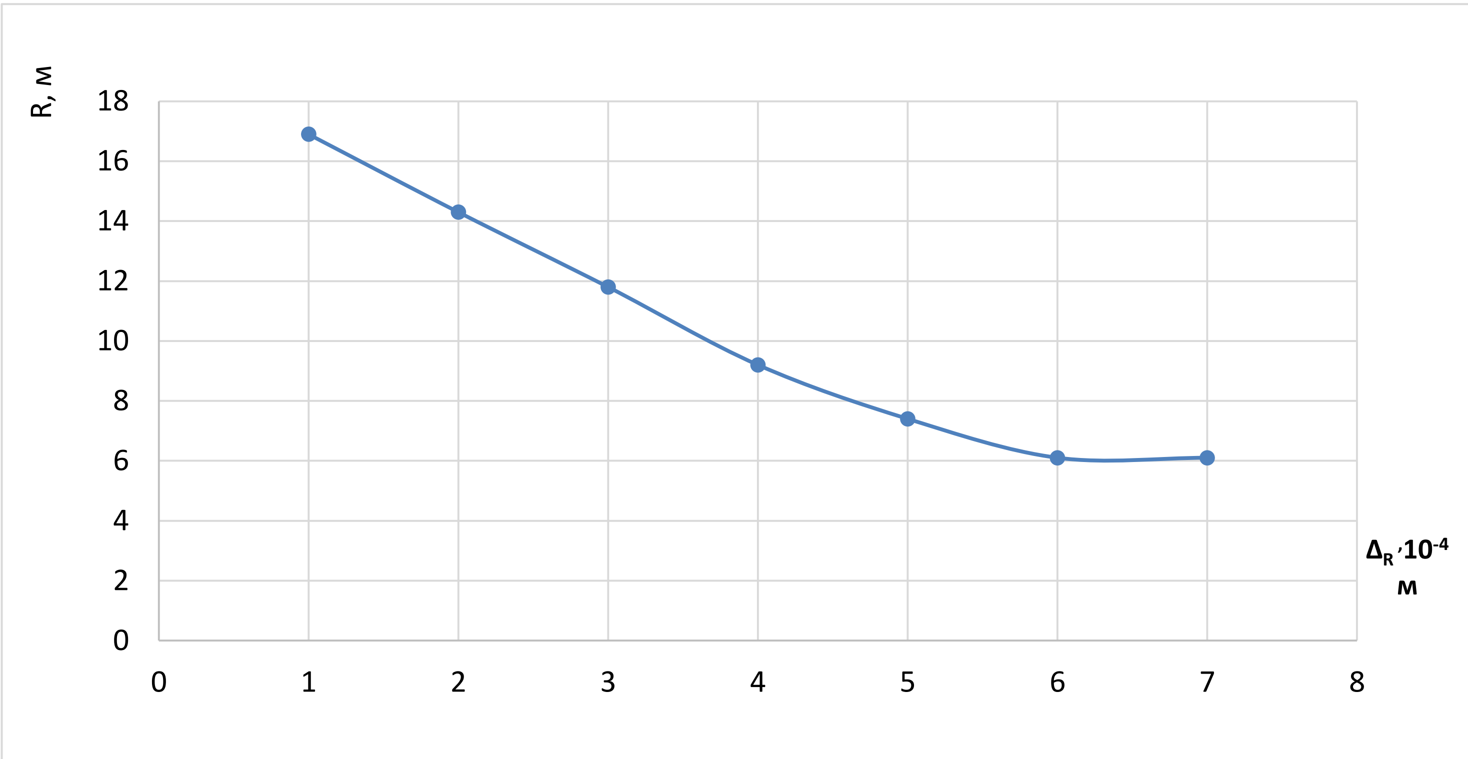


Results and Discussion

- **Figure. 4.3. Dependence λ_R from R.**
- **Processing of Bazin's experiments and the author's experiments.1 – Bazin's experiments, series № 24, semicircular canals, the surface of the bottom and walls of the canals - smooth concrete, series № 6, 26, rectangular and semicircular canals, the surface of the bottom and walls of the canals - boards, series № 4.27, rectangular and semicircular canals, surface the bottom and walls of the canals - gravel .**
-

Results and Discussion

- **Figure 4.4. Dependence . The author's experiments, series No. 9a; rectangular channel; the surface of the bottom and walls of the channel - iron; : i = 2 10^{-4}; T^0=17.5^0; ν = 1.12 ·10^{-6} $м^2$/с; Δэ=11 10^{-4} м.**



Results and Discussion

Bazin's experiments, series no. 24; semicircular channel, bottom and wall surfaces - smooth concrete, D = 1.25м. i = 1,5 10^{-3}

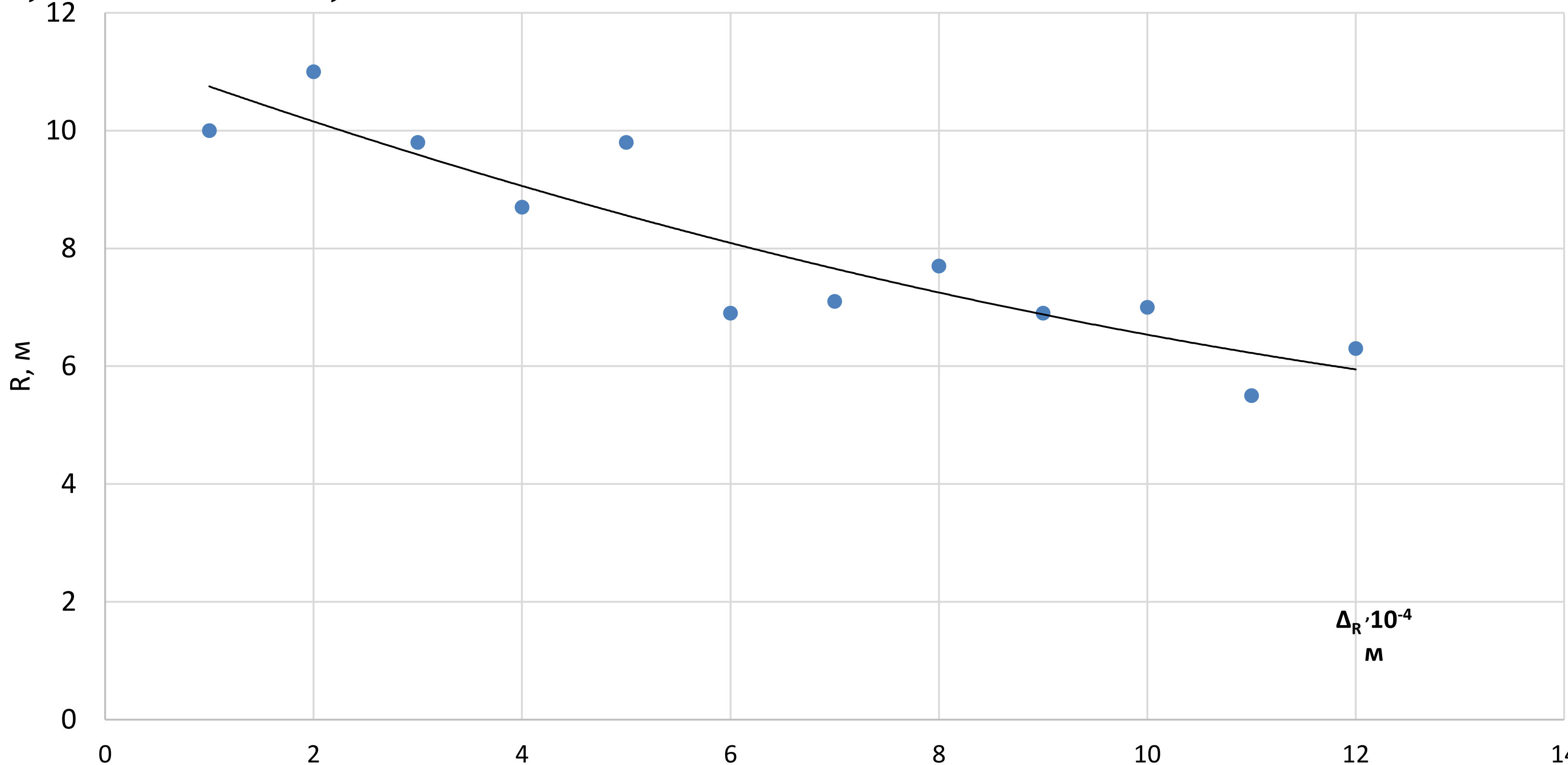
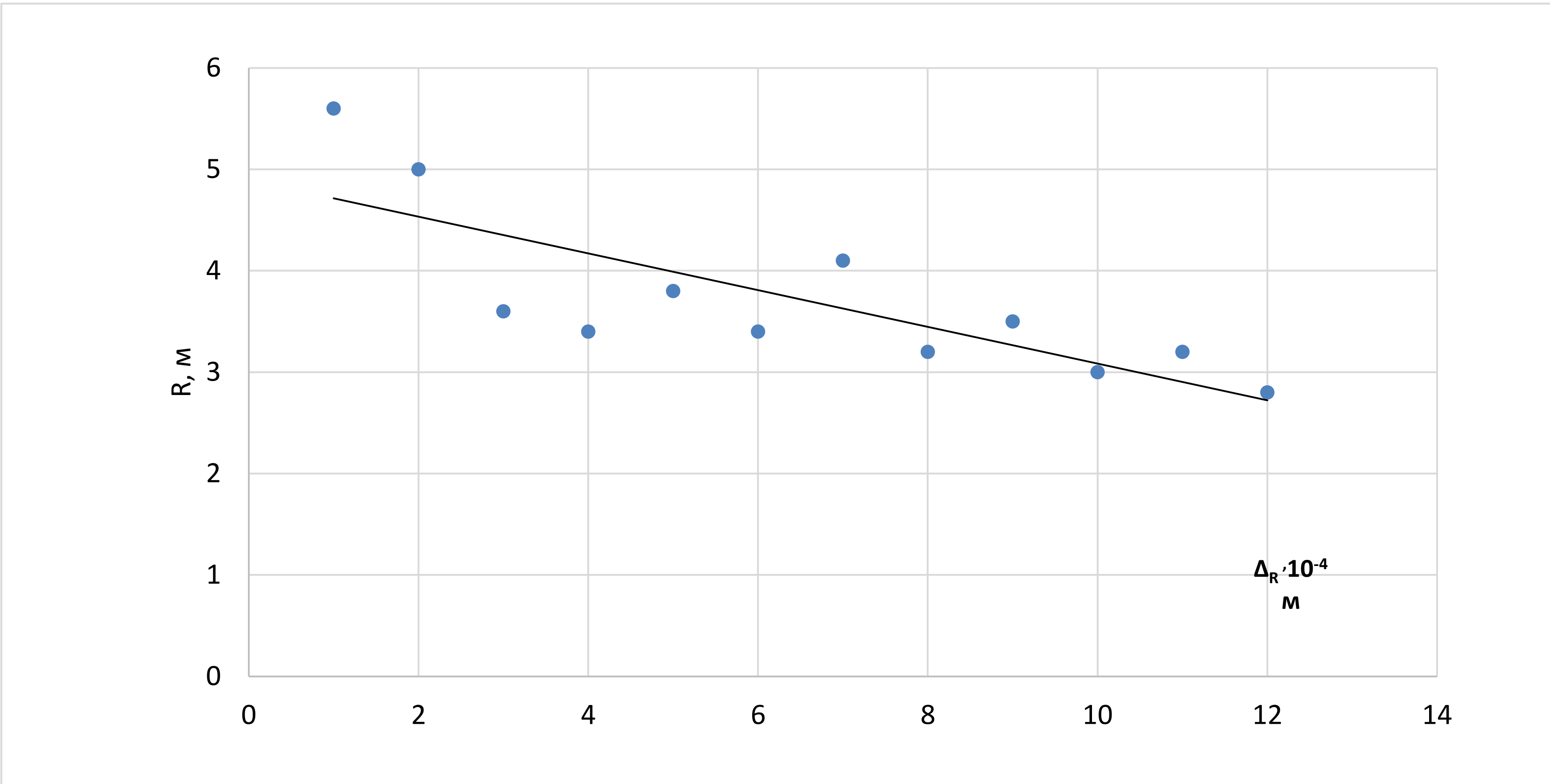
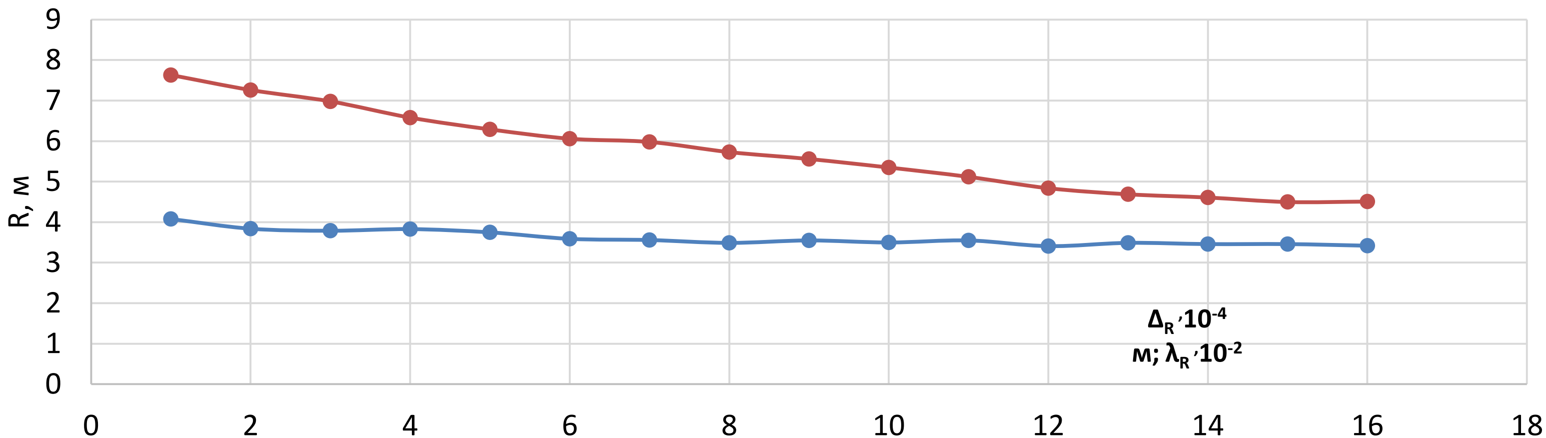


Figure. 4.5.
Processing of Bazin's experiments, series № 26

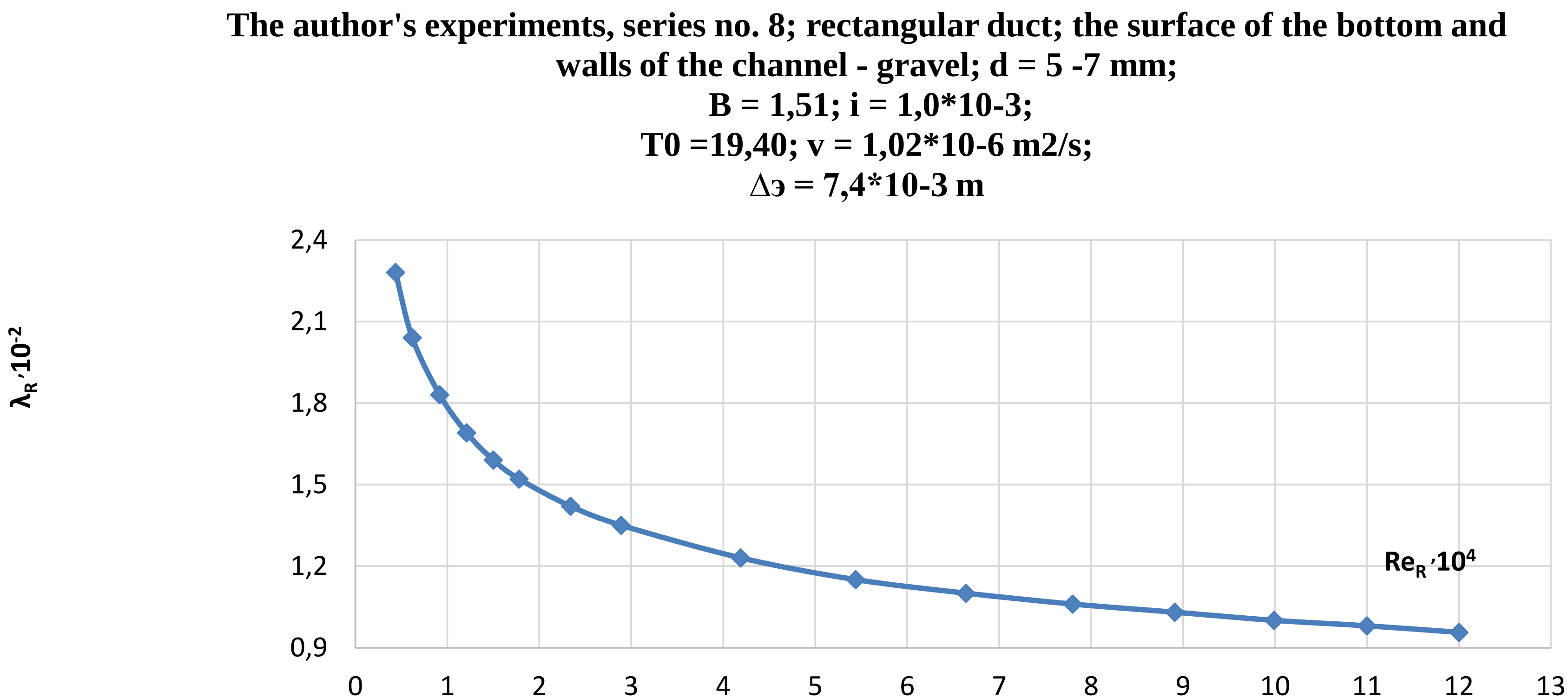


Results and Discussion

The author's experiments, series no. 7; trapezoidal canal; the surface of the bottom and walls of the channel - gravel; d = 5 – 7 mm; вg = 0,16 m; m = 1,732;
i = 1,0 , 10-3; T = 16,20;
v = 1,1 , 10-6 m2/s;

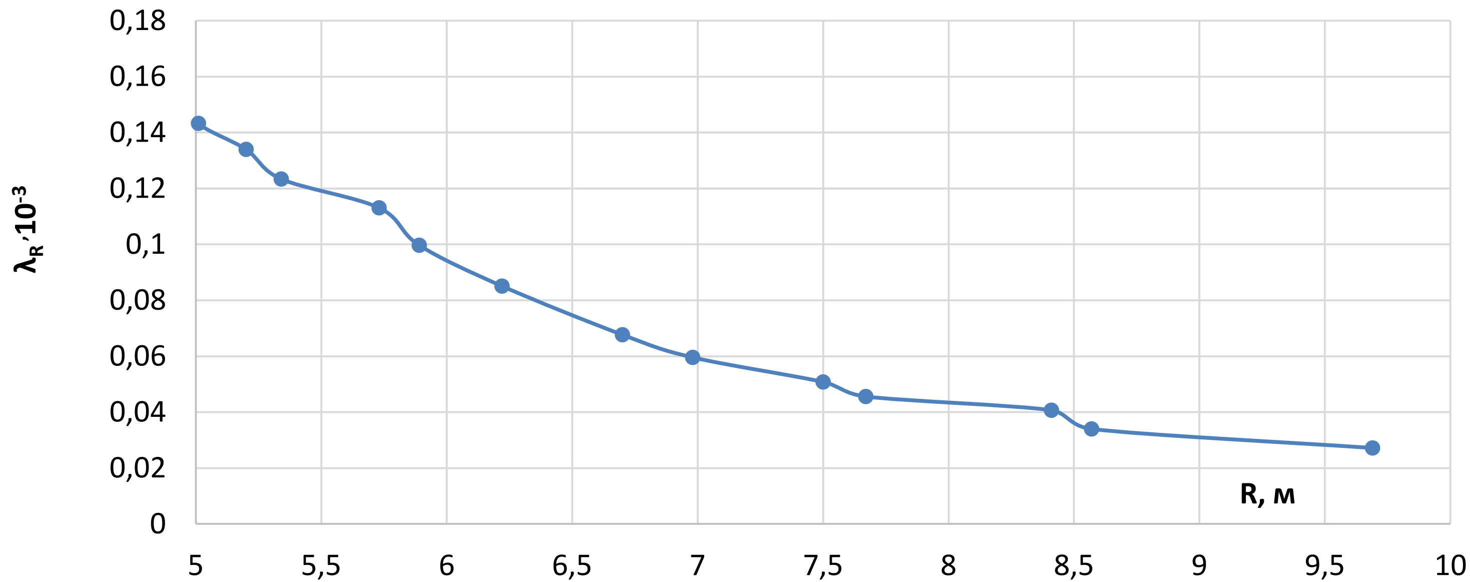


Results and Discussion



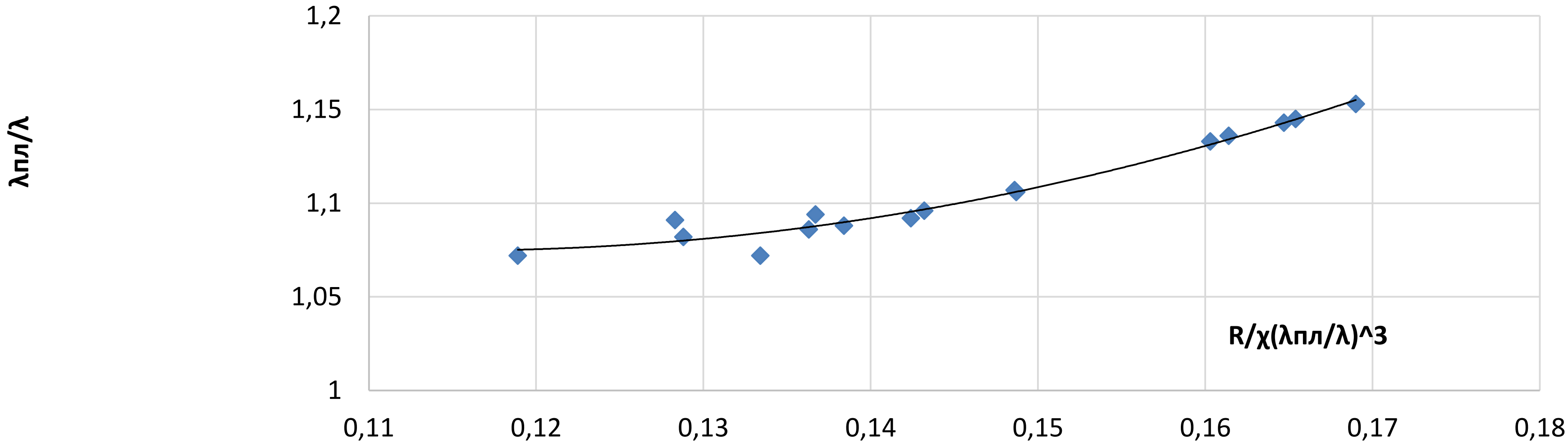
Results and Discussion

The author's experiments, series no. 1; rectangular channel; the surface of the bottom and walls of the channel - smooth concrete; B = 1,51 m;
I = 1,0*10-3; T=200; v = 1,0 * 10-6 m2/s; Δэ = 7,0*10-4 m



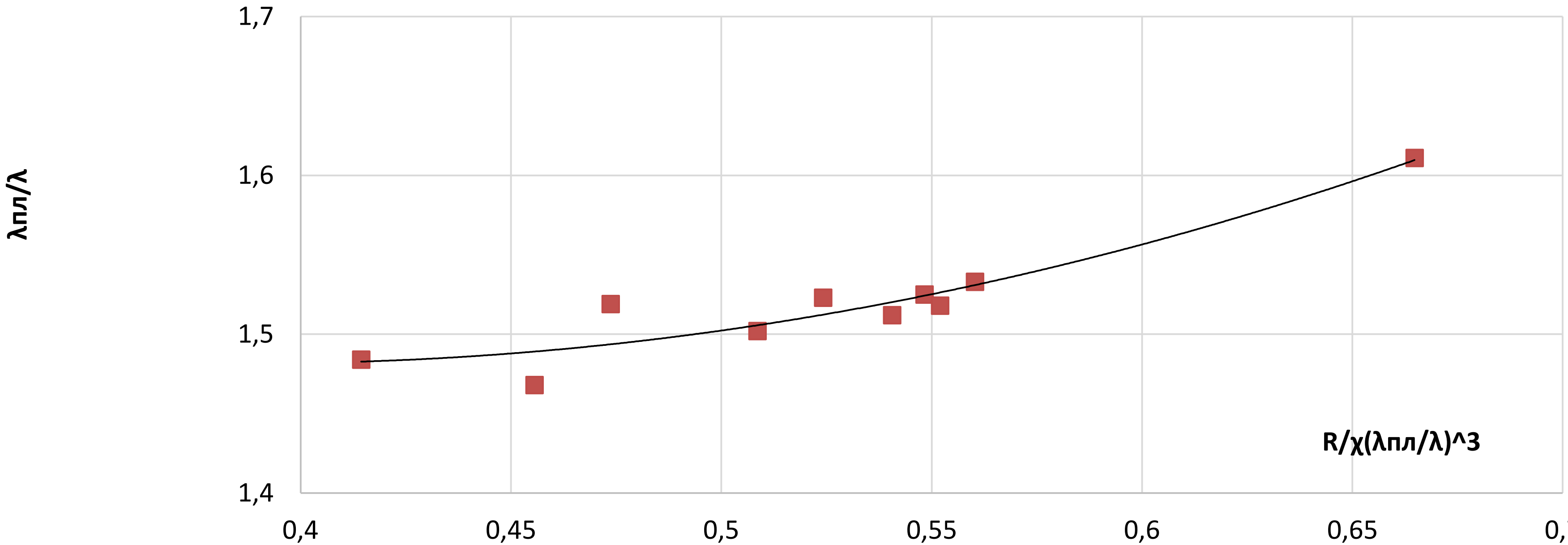
Results and Discussion

The author's experiments, series no. 3; trapezoidal canal; the surface of the bottom and walls of the channel - smooth concrete; bg= 0,16 m;
m =1,732; i = 1,0*10-3;   T0=16,20;
v= 1,1*10-6 m2/s; Δэ= 5,5*10-4 m



Results and Discussion

Bazin's experiments, series number 27; semicircular canal; the surface of the bottom and walls of the channel - gravel; d= 0,01-0,02 m: D = 1,22 m; I = 1, 5 10-3; T0=120; v = 1,23 , 10-6 m2/s; Δэ =12 * 10-3m

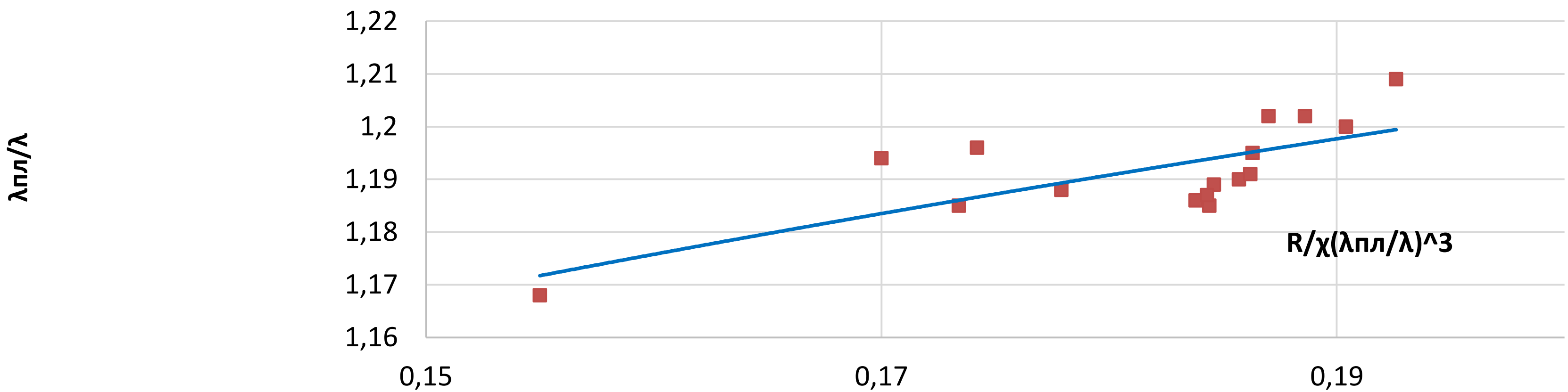


Results and Discussion

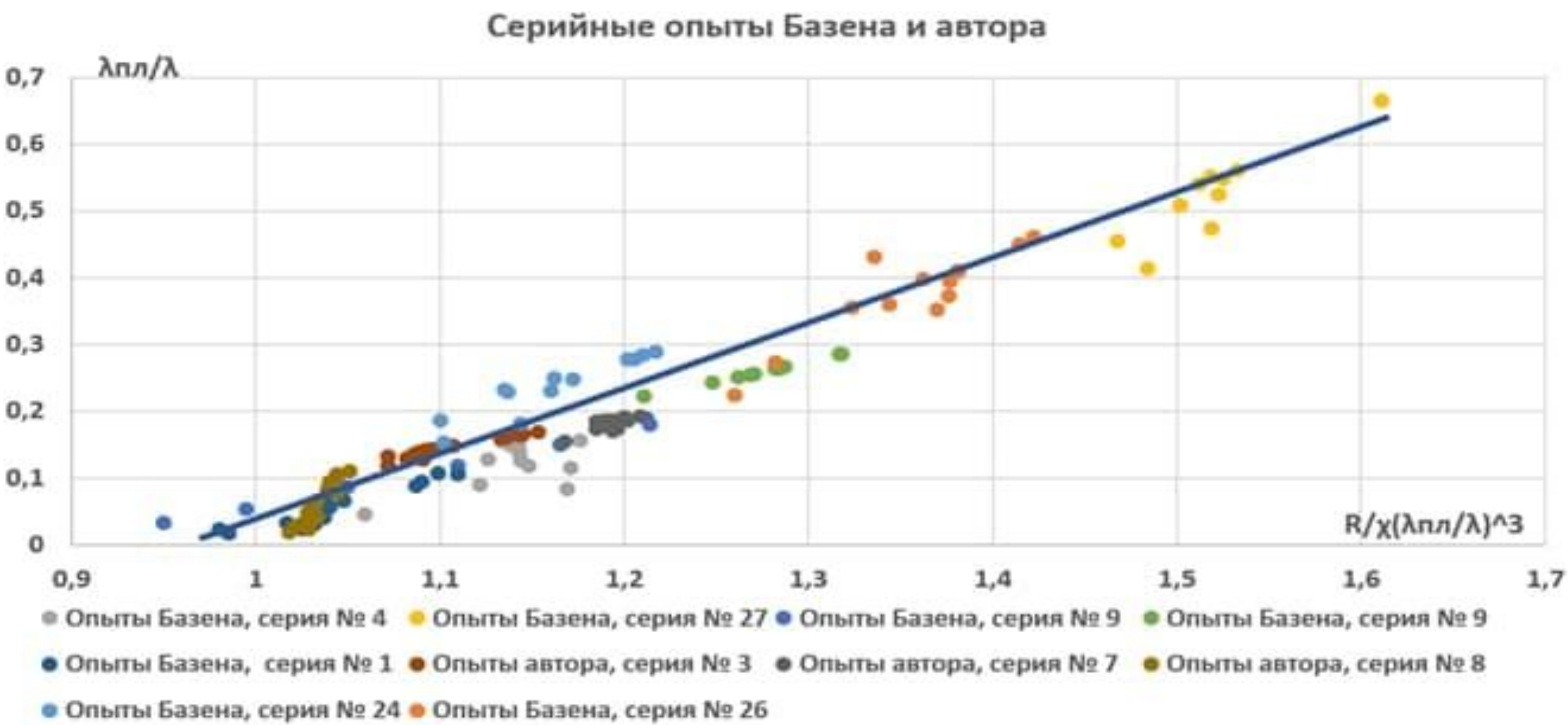
- **Bazin's experimental data in canals with regular cross-sections of various geometric shapes (rectangular, trapezoidal, triangular, semicircular), as well as experimental data on the flow in rectangular and trapezoidal canals obtained in this work; the results of some published data on water flows in canals of various geometric shapes were summarized on the graph below in coordinates , (figure.4.9-4.12).**

Results and Discussion

The author's experiments, series no. 7; trapezoidal canal; the surface of the bottom and walls of the channel - gravel; d = 5 - 7 mm; bg = 0,16 m; m = 1,732; i = 1, 0 10-3; T0 =16,20; v = 1,1 , 10-6 m2/s; Δэ = 5,8 10-3 m



Results and Discussion



Results and Discussion

- **From the above, the following procedure for calculating the coefficient of hydraulic friction follows for free-flow ducts of correct cross-section. The following canal data is assumed to be known; cross-sectional dimensions (bottom width, slope ratio, etc.), type of roughness (uneven-grained, not uneven-grained) and the equivalent absolute height of the roughness protrusions of the wetted surface Δэ ; slope I, canal filling depth *h* and, therefore, the quantity *R/χ*. The sought values are; hydraulic friction coefficient , average flow rate *ϑ*, water consumption *Q*. The values are calculated; *ω*. *χ*. *R*.v_* = *Δ = Δэ/h; from the law of resistance for an infinite wide (flat) canal, for example, with a non-unequal roughness of the wetted surface: (Where, Re^*_h = v*h/v: v* - dynamic flow velocity), the value is calculated for flat flow with depth *h*. Of given formulas for the solution of cubic equation (9) in accordance with the given value *R/χ*, the required value is found .**

Conclusions and recommendation

- **1. Experimental data published in the literature on pressure losses in free-flow canals with a "regular" cross-section, as well as the data of our studies, as well as studies of other authors, show that the value of pressure losses in the above canals is not only a function of the Reynolds number, but also a significant degree (especially in canals with a rough wetted surface) depends on the shape of their cross-section.**

- **2. From consideration of the collected experimental data on losses in the above-mentioned free-flow canals, it follows that for several canals with different cross-sectional shapes, but with the same slopes and the same roughness of the wetted surface, the curves on the graph**
- **( ) will be arranged in the following order (from top to bottom); a very wide rectangular canal, a relatively narrow rectangular canal, trapezoidal and triangular canals, a semicircular cross-section canal.**

- **3. The value of the coefficient of hydraulic friction for a very wide canal or canal of rectangular cross-section, all other things being equal, it has more effect than for a canal of trapezoidal or semicircular cross-section. Corresponding dependence curves of the number at the same time pass approximately parallel to the curve obtained for the law of "smooth resistance".**

- **4. In the area of the supply canal, intense deformations of the Amudarya river canal occur and, according to the calculations, the volume of siltation is 13-15 million m3, of which up to 10% of this value is formed due to a decrease in the transporting capacity of the flow in the supply canal of pumping stations AB-1 and AB-2 (ABMK).**
- **5. Taking into account (according to the recommended dependencies) the effects of the cross-sectional shape and roughness on the value of pressure losses in the free-flow machine canals of pumping stations, of the correct shape, can give a significant economic effect in their design.**

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