METHOD OF CALCULATING AN IRRIGATION SYSTEM WITH
A DIFFERENT ARRANGEMENT OF THE LATERALS

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An irrigation system is a system of branched canals separated from one another. A hydraulic calculation of canals not
having laterals is given in handbooks [2, 4] and textbooks of hydraulics [1]. The parameters of canals are determined by
uniform motion formulas. The situation is far more complex with calculation of canals having laterals. Here when calculating
the region of water diversion we encounter cases of unilateral and bilateral separation of the flow.

Thorough scientific substantiation of the distribution and diversion of water is necessary for increasing the stability
and efficiency of functioning of water-management systems.

The multipurpose use of the country’s water resources requires improvement and development of existing and
creation of new methods of hydraulic or fluid-mechanical calculation of large canals and especially the development of
rigorous methods of calculating open-channel flows with a variable discharge over the length with uni- and bilateral diversion
of the flow. The solution of the problem of reliable monitoring of water discharges and conditions of their delivery is one of
the most important directions of improving water delivery and distribution systems.

The redistribution of discharges and formation of a free surface in the flow separation zone are the main tasks of
hydraulics.

In the case of calculation in the diversion region the usual main equation of hydraulics produces large errors, which
is impermissible when assigning command elevations of water levels in canals. The most complex cases occur with bilateral
diversion of water (Fig. 1).

In the meantime, schemes of bilateral separation of the flow are widespread in interfarm and especially intrafarm
irrigation systems.

We proved that the physical essence of fluid motion with a variable discharge in the case of bilateral diversion is
described by the equation due to G. A. Petrov and P. G. Kiselev [4, 10]

\[
\frac{2aQ}{\rho w^2} \frac{dQ}{d\omega} - \frac{\sigma Q^2}{\rho w^2} d\omega + dh + i_f dx - i_0 dx = 0,
\]

where \(Q\) is the discharge of the flow in the investigated section; \(\omega\) is the cross-sectional area of the flow in the investigated
section; \(i_f\) is the specific hydraulic resistance; \(i_0\) is the bottom slope; \(dh = dP/\gamma\); \(P\) is the hydrodynamic pressure in the
investigated section; \(\alpha\) is the kinetic energy correction factor [10].

The values of the hydraulic parameters figuring in this equation depend on the geometric scheme of separation [6, 9].
Following [10, 11], we introduce the following classical assumptions necessary for using Eq. (1) in practice:

1) the discharge varies uniformly along the path;
2) motion has a single direction, the effect of strong transverse circulation with the turbulence accompanying it is
taken into account in the calculations with the use of the momentum principle;
3) the distribution of pressure in the flow obeys the hydrostatic law, i.e., the flow is considered a parallel jet flow;
4) the value of the velocity-head correction factor along the flow is constant, i.e., \(\alpha_0 = \alpha = \text{const}\);
5) it is assumed that the angles made by the direction of the velocities \(v_{d1}\) and \(v_{d2}\) and the direction of the main
flow are equal to the angles which are formed by the axis of the flow with the axis of the diversions, i.e., \(\angle \beta_{d1} = \angle \phi_{d1}\);\n\(\angle \beta_{d2} = \angle \phi_{d2}\);
6) the slope of the canal is relatively small, consequently, we can neglect its effect on the head and pressure force in canal sections;

7) we will determine friction losses by the same dependences as in the case of uniform motion for \( Q_f = \text{const} \);

8) the effect of air entrained by the flow is negligible, but if necessary an appropriate correction can be introduced in the calculation result.

In view of the difficulty of describing the processes occurring, we will examine nonuniform steady motion for the case of separating fluid particles at an angle of 90° (we assume the specific hydraulic resistance \( i_f \) is equal to zero).

Hereafter we will use Eq. (1) for all theoretical investigations. Equation (1) is based on laws of conservation of momentum and mass and does not have empirical constants, which permits recommending it for solving a wide range of practical problems.

The reliability of Eq. (1) and of the premises and assumptions made when solving it was proved by many experimental investigations conducted by the author in the hydrotechnical laboratory of the All-Union Research Institute of Hydraulic Engineering and Reclamation (VNIIGiM) in 1970-1974 as well as by plotting curves of the free surface for bilateral symmetric separation of the flow in rectangular channels.

Equation (1) in an integral form has the form:

\[
g \omega^2 \frac{Q_n^2}{g} \omega = \omega_1 \omega_2 \frac{Q_n^2}{g} \omega_1 \omega_2 y_1 y_2 - y_1 y_2 - l_0 \frac{\Delta x}{c^2 \omega^3} R = 0,
\]

where \( y \) is the distance from the center of gravity of the cross section \( \omega \) to the free surface of the flow; \( R \) is the hydraulic radius. For wide and shallow channels \( R = h \).

Using Eq. (2), we can determine the depth of the flow directly.

The main differential equation of fluid motion with a variable discharge in the case of bilateral diversion of the water permits solving many theoretical and practical problems of hydraulics of a variable mass. Let us proceed to the solution of one such problem — calculation of the main canal of an irrigation system.

When determining the discharge of the main and diversion canals we will examine several variants of arrangement of the diversion canals on the main canal of the irrigation system (Fig. 2).

**Variant I.** Separation of the flow is bilateral asymmetric (Fig. 3).

In the presence of a backwater in the main canal and laterals (e.g., a cross regulator beyond the region of separation), the discharge in the diversion canals is determined by the formula of a broad-crested weir:

\[
Q_d = m \cdot b \cdot \sqrt{2g} H_m^{3/2}.
\]

For example: