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C O N T E N T S

MANAGEMENT

Theoretical and methodological features of soil water regime optimization in pedagogical technologies of agroengineers training for innovative project activity

Viktor Pryshliak, Vasyl Kurylo
Ukraine, Vinnytsia National Agricultural University
viktor.prishlyak@i.ua

Summary. *Innovative scientific-technical and pedagogical bases of studying in higher education institutions by future specialists in agroengineering of the theory and calculation fundamental questions of sprinkler nozzles and devices of machines for irrigation of agricultural crops are presented. Some constructive schemes of nozzles, namely, deflector, crack, etc. are analyzed. Graphs for determining the range of the jet and determining the rational shape of the nozzle are given. It is proved that all this can be effectively applied both in the educational process during the study of agricultural machinery and equipment by students and in research and production practice. Depending on the purpose, tasks, methods of technological processes of irrigation disintegration of a water jet on drops is analyzed. An algorithm for calculating the working bodies of sprinklers is presented, it can be used by agricultural engineers during their design activities. It is established that it is effective when students first study and analyze the state of agricultural production, for example, during internships, identify shortcomings of technological processes, opportunities for improvement, level of technical support, and then, using theoretical knowledge, mastered methods of engineering calculations, design and construct working bodies of sprinklers. Formulas for determining the radius of the irrigation sector, the maximum angle of the rocker arm at which the nozzle is attached, the total travel time of the rocker arm in both directions, the speed of the liquid in the jet and more are given. The methodological features of functioning of various designs of nozzles of sprinklers are theoretically described. The results of scientific research presented in the article can be used as didactic material in lectures, during laboratory-practical classes, independent work of students, as well as graduate students and scientists at the stage of design and construction of reclamation machines. The main theoretical provisions are recommended to be included in the list of test tasks for assessing the readiness of agricultural engineering for innovative project activities. It is noted that the study of the basics of designing the working bodies of irrigation machines is one of the factors of a holistic conceptual system of protection of soils and water resources. Emphasis is placed on the fact that soil and water resources are important objects and prerequisites for the development of reclamation machines and the formation of special design competencies of agricultural engineers.*
KEYWORDS: *AGROENGINEERING, TECHNOLOGICAL PROCESS, TECHNOLOGY TRAINING, METHODOLOGY, SOIL, WATER RESOURCES, DESIGN, AGRICULTURAL MACHINERY, SOIL PROTECTION.*

1. Introduction

In almost all countries of the world work is being carried out on the development of land reclamation − part of methods aimed at optimizing agricultural production and the general rise in soil productivity. Under hydraulic reclamation is understood a system of measures that regulate the water regime of the territory. Irrigation, drainage, flooding, delay of surface runoff and control of soil erosion belong to hydraulic reclamation and are carried out with the help of hydraulic structures.

The change of water regime should be carried out both at excess, and at insufficient moistening of the soil as for normal development of plants the soil should be moderately moistened [1].

One of the reasons for the insufficient development of technical means of reclamation in Ukraine, including irrigation machines, is the lack of highly qualified agro-engineering personnel [2], able to design machines with optimal parameters and use them efficiently. In this regard, it is advisable to conduct special technical and pedagogical research aimed at developing modern machines for irrigation, improving the methodological support of the educational process, improving its quality, development of professional competencies [3] of agricultural engineers.

The developed pedagogical technology should provide continuity of educational process in designing and designing of cars, studying of soil and water resources, their protection and preservation [4, 5].

2. Prerequisites and means for solving the problem

Curricula for future agricultural engineers provide the study of problematic issues of land reclamation, soil protection and water resources. As it is noted in [2, 5] throughout the period of study during lectures, laboratory-practical classes, practitioners, students study these issues relevant to modern agricultural production systematically and consistently.

During the design of reclamation and tillage machines, agrochemical, mechanical-technological and other characteristics of soil and water resources are taken as initial data. For example, the agrochemical properties of soils that students study, use in their project activities include - the content of humus, nitrogen, phosphorus, potassium, soil acidity; and to the physical and mechanical properties - the specific gravity of the soil, the angles of internal and external friction, particle size, ultimate bearing capacity, modulus of elasticity, humidity, etc. [6].

During the lectures future agricultural engineers receive general theoretical knowledge, get acquainted with the algorithms for calculating machines. Laboratory-practical classes expand and deepen their knowledge of the basics of the theory, calculation and design of reclamation machines, irrigation systems, land protection and protection of soil and water resources, etc. Students develop the ability to innovative project activities especially deeply during the course and master's theses [2, 7].

At the initial stage of training, future agricultural engineers study the general concepts of erosion processes [2, 7].

Many scientific conferences have addressed the issue of soil and water protection. For example, at the II International Scientific Conference "Protection of Soils and Water Resources", the report was presented − «The main components of studies and research of conserving soils and water in technologies of agroengineers training” [4]. This report partially discloses the scientific and methodological bases for soil and water exploration by future specialists in agroengineering in higher education institutions. Innovative pedagogical technology of development of project activity is based on the method of a consistent cross study of the material based on the objective relationship of disciplines and provides a qualitatively higher level of professional competencies formation of agroengineers on the basis of preservation and even multiplication of natural resources. The report of [4] states that the current issues of soil science are devoted to many works by well-known scholars, for example, P. Zaicka [8], M. Manojlovič [9], R. Meissner [10] and others.

At the IV International Scientific Conference "Soil and Water Resources Protection 2019" candidate of Technical Sciences, Associate Professor Viktor Pryshliak, Dr. in Agriculture, Prof., Corresponding Member of the National Academy of Agrarian Sciences of Ukraine Basil Kurylo a report was made on the topic: «Soil and water resources as important objects and prerequisites for the design of agricultural machines and the formation of professional competencies of an agricultural engineer». The report notes that in pedagogical technologies for the formation of professional competencies of future agricultural engineers in agricultural institutions of higher education, much attention is paid to the problematic issues of soil and water resources. Some concepts and categories used in the educational process during the study of agricultural machinery and equipment by students are analyzed. Depending on the purpose, tasks, receptions of technological processes types of reclamation actions are pointed out, the example of calculation of working bodies of cars is resulted. In general, an innovative pedagogical technology of cross training has been developed, aimed at the formation of professional competencies of future agricultural engineers. It is noted that their activity will be successful provided the efficient use of soil and water resources as important objects and prerequisites for the development of machines.

An important research and production problem is the optimization of nutrient and water regimes of the soil on the slopes. There are different scientific works devoted to the peculiarities of soil preparation for sowing crops on sloping lands, optimization and management of technological processes in these conditions [1, 7, 8, 12, 13].

Bendera I. [14], Duganets V. [15], Man`ko V. [16] and others made a significant contribution to the development of the theory and methods of professional education of future agricultural engineers, improving the quality of formation of their special competencies.

Analysis of agricultural land reclamation measures, features of the educational process in agricultural institutions of higher education showed that the theory and calculation of sprinklers for irrigation machines in the technology of agricultural engineers training for innovative project activities require further scientific development.

3. Results and discussion

Creating an optimal water regime for seed germination, growth and plant development is a very important factor that affects crop yields, quality of products grown. During their training, students study the optimal water regimes for different crops, irrigation technologies and design features of sprinklers. Scientific and pedagogical research has shown that future agricultural engineers have difficulties in calculating the working bodies of sprinklers and it should be noted that the search for optimal design parameters is important for agricultural machinery, and optimal operating modes for agricultural machinery.

High quality of the educational process is achieved when students conduct engineering and technological calculations, participate in laboratory and field research. We will give an example of the theory and calculation of nozzles and devices of sprinklers and installations which is used in scientific and technical activity and pedagogical technologies of preparation of agroengineers for innovative design activity.

Fig. 1 presents a diagram of a reflex nozzle used in sprinklers and installations.

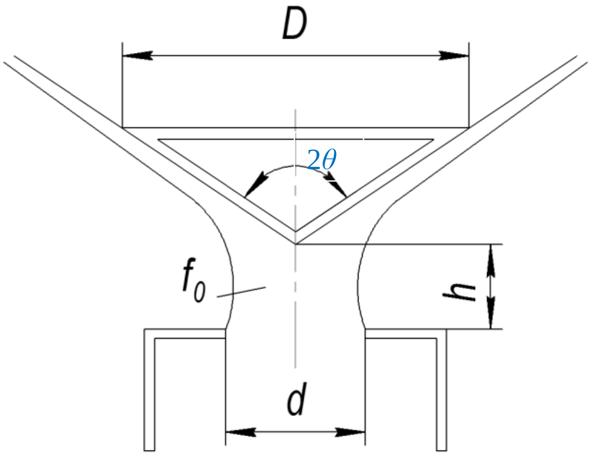

Fig. 1. *The scheme of the deflector nozzle [1]*

Usually take the following ratios: $h = d$; $D = 2d$; $2\theta = 120^0$ (Fig. 1).

Irrigation radius R can be determined by the following formula [Mac488]:

$$R = \frac{H}{0{,}43 + 0{,}0014\dfrac{H}{d}}, \tag{1}$$

where H − pressure in front of the nozzle hole.

One of the important advantages of slotted nozzles (Fig. 2) is their simplicity.

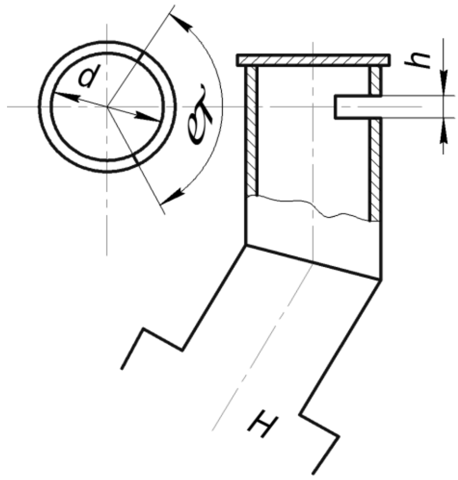

Fig. 2. *Scheme of a slot nozzle.*

Such a nozzle can be obtained by sawing on any pipe. The angle of the spray nozzle φ_p is determined from the following relation: $\varphi_p = (0{,}7 \div 0{,}9)\varphi$.

Smaller values of the numerical coefficient correspond to smaller values of the angle φ.

The radius of the irrigated sector is determined by the formula:

$$R = \frac{H}{1{,}15 + 0{,}0003\dfrac{H}{h}}. \tag{2}$$

The recommended ratio of the length of the slit to its width is 1:5, 1:10. The irrigated area has the shape of a sector with an angle φ_p. Approximately at a distance of $1/5R$ from the nozzle irrigation does not occur.

Medium-jet sprinklers are used on most modern sprinklers and installations. Their designs are mostly of the same type, although they have some significant differences.

The principle of operation is approximately as follows. The jet flowing from the barrel meets on the way a rotary deflector and a reflective blade. The front end of the rocker arm is pushed to the side, and the rocker arm is turned. When leaving the jet, the deflector rotates relative to the rocker arm. The rocker arm, twisting the spring, rotates at an angle of about 90°, then under the action of the spring returns to the previous position.

After reaching the initial position, the rocker strikes the tide on the barrel with its tide and turns it at an angle of 2–5° in the course of movement. The jet at this point hits the back of the deflector and returns it to its original position. Then the front end of the rocker is pushed out of the jet again and the process is repeated.

The barrel performs a continuous rotation. The jet irrigates the circular area. The design can work without a reflecting blade. In this case, more precise adjustment of the position of the deflector relative to the jet is required [1].

With the conditional replacement of the action of the jet on the curved rotary deflector and the blade by the action of only one blade located on the middle radius, in accordance with Figs. 3, a) and b) the value of the angular velocity of the rocker arm after the deflector exits the jet will be

$$\omega = 2\sqrt{\frac{pfr\varphi \sin\alpha}{J_\kappa}}, \qquad (3)$$

where J_k − the moment of inertia of the rocker arm;

φ − the angle of rotation of the rocker arm at which the jet acts on the deflector, $\varphi = (2\div3)\varphi_m$;

p − the pressure in front of the nozzle.

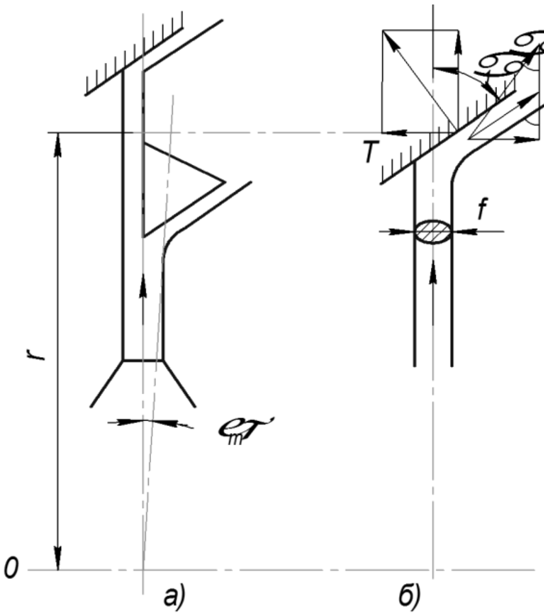

Fig. 3. Scheme of the deflector of the medium-jet sprinkler [1].

Due to the fact that the flow is not completely deflected by the deflector

$$\alpha = (0{,}7 \div 0{,}8)\alpha_1. \qquad (4)$$

The maximum angle of rotation of the rocker arm

$$\varphi_{max} = \frac{2pfr\sin\alpha}{M_n}, \qquad (5)$$

where M_n − the average value of the moment created by the spring during the rotation of the rocker arm.

The angle of rotation of the device in one stroke of the rocker arm

$$\psi_a = \frac{8pfr\varphi\sin\alpha}{M_T}\left[\frac{me^2}{J_\kappa} + \cos^2\theta\right]\cos^2\theta, \qquad (6)$$

where M_T − the moment of friction that slows down the rotation of the apparatus and is equal to the sum of the moments of friction in the bearing and the rubber cup [1].

Full moving time of the rocker arm in both directions

$$t = 4\frac{\sqrt{J_\kappa pfr\varphi\sin\alpha}}{M_n}. \qquad (7)$$

Long-jet sprinklers are used in cases where it is possible and appropriate to create a pressure in the pipes 4 … 6 at.

Common are devices with gear or tine mechanisms of rotation, which are driven by a small turbine, which rotates under the action of the main jet energy, which is formed by the device with a turbine drive.

Mechanisms are often introduced into the structure to provide the apparatus of reverse rotation within the sector of the circle for irrigation in the sector in a given direction. The angle of the sector is usually adjustable.

The jet of water flowing from the nozzle rotates the turbine. On the axis of the turbine there is a gear that rotates the worm gear. The gear through the shaft transmits rotation to the worm gear connected with the worm gear. There is an eccentric pin on the axis of the gear, which makes the frame swing. The ratchet mechanism consisting of two hinged rods, a spring and a pawl is established on a frame. Under the action of a compressed spring, the pawl is pushed away from the stationary gear on one side, due to which a slow intermittent rotation of the sprinkler around the vertical axis is carried out. The fixed gear has a series of protruding fingers. At an emphasis of a shank of a pawl in one of them its position changes, its other party starts to work and the direction of rotation of the device changes.

Thus it is possible to carry out watering on sector.

The number of revolutions of the turbine per minute is determined by the formula:

$$n_T = \frac{60u}{\pi D}, \qquad (8)$$

where u − circular velocity of the ends of the blades in m/s;

D − the diameter of the turbine at the ends of the small blades, m.

The circular speed of the ends of the blades can be determined by the formula

$$u = k_0 v, \qquad (9)$$

where k_0 is the coefficient of circular velocity, $k_0 = 0.7 \ldots 0.8$;

v − the velocity of the liquid in the jet, m/s.

The velocity of the liquid in the jet is determined by the formula

$$v = \varphi\sqrt{2gH}, \qquad (10)$$

where φ − the speed factor, φ = 0,97;

g − acceleration of free fall, g = 9,8 m/s^2;

H − pressure in front of the nozzle, m of water column.

The number of revolutions of the long-jet sprinkler is equal to:

$$n_a = \frac{n_T}{i}, \qquad (11)$$

where i − the total gear ratio between the turbine and the body of the apparatus [1].

In other designs of long-jet sprinklers, in which the driving force that rotates the barrel is the reaction of the jet, the vacuum created by the jet, a special turbine operating from a single jet or a rocker arm that oscillates, as in medium-jet devices.

One device usually forms one or two jets.

The range of the jet for medium- and long-jet nozzles can be determined by one of the following empirical formulas:

$$R = 0{,}42H + 1000d \qquad (12)$$

or

$$R = \frac{H}{0{,}5 + 0{,}25\frac{H}{d}}. \qquad (13)$$

The formulas are valid for the angle of inclination of the jet to the horizon of 30°, i.e. for the angle corresponding to the greatest range, and the ratio

$$\frac{H}{d} \geq 800, \qquad (14)$$

where H − the pressure in front of the nozzle, meter of water column;

d − the diameter of the jet, m.

The range of the jet can also be determined using the experimental graph shown in Fig. 4. For different diameters of jets, a series of curves is constructed that determine the relationship between H and R.

The spray of the jet into droplets is determined by the ratio H/d (Table 1).

***Table 1:** Disintegration of the jet into drops [1]*

H/d	Jet characteristics
up to 900	Solid, which does not fall apart into drops
900−1500	Weak decomposition into drops, not suitable for irrigation
1500−1600	Disintegration into drops of medium size, which are suitable for irrigating grasses in meadows and pastures
1700−1800	Disintegration into droplets of medium size, suitable for irrigation of closed farms. cultures
2000−2200	Disintegration into small drops, suitable for irrigation of all crops
2500−2600	Disintegration into very small drops, suitable for irrigating seedlings of the most delicate plants and flowers

The range of the jet, defined on the graph (Fig. 4), can be obtained only with a properly designed barrel and non-rotating sprinkler.

The range of the jet during the rotation of the apparatus around the vertical axis with a speed of 0,3 … 1 per minute is reduced by 10 … 15% compared to the range of the jet without rotation of the apparatus.

The rational shape of the trunk is shown in Fig. 5. The larger angle of inclination to the horizon is selected at a pressure of 1,5 … 3 at, a smaller − at a pressure of more than 6 … 8 at. Essential for the formation of the initial section of the jet is a sedative 1, which consists of a series of partitions parallel to the axis of the barrel, dividing its living section into a number of narrow channels.

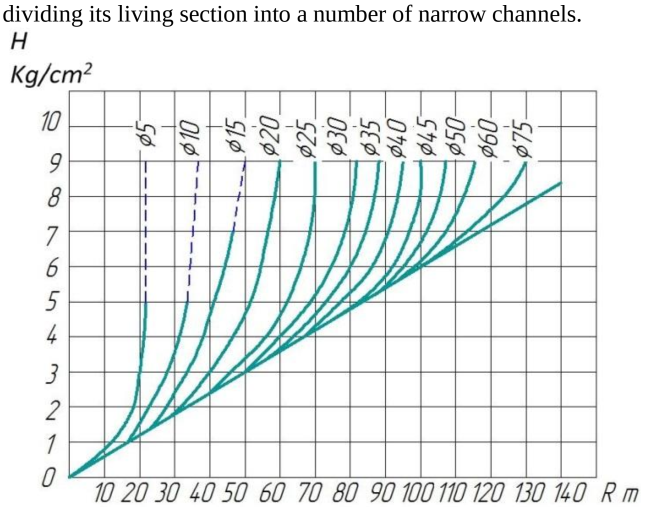

***Fig. 4.** Schedule to determine the range of the jet [1].*

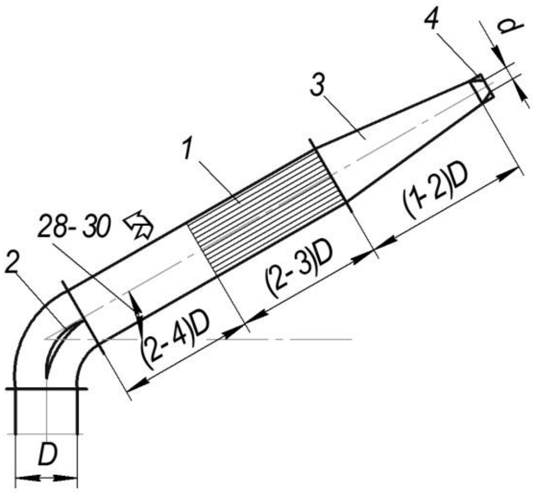

***Fig. 5**. The scheme of a long-jet trunk:*
1 – quietering; 2 − edge; 3 − cone; 4 − nozzle.

The length of the cells of the quietering should be 12 … 15 times their width. The diameters of the barrel and the quietering should be 3 … 4 times the diameter of the nozzle.

In the crank it is necessary to install the edges 2, which prevent the occurrence of transverse circulation of velocity in the flow.

In medium-jet and some long-jet barrels, the cone 3 is not placed, and the nozzle 4 is located directly behind the output end of the sedative. The rational shape of the nozzle is shown in Fig. 6, a.

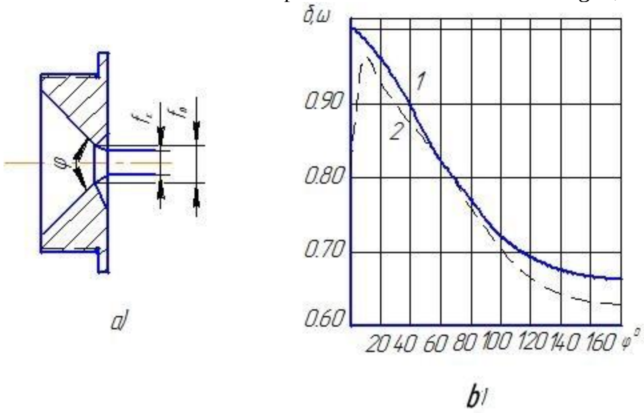

***Fig. 6.** Rational shape of the nozzle.*

Water consumption through such a nozzle is determined by the formula

$$Q = \delta f_0 \sqrt{2gH}\,, \tag{15}$$

where δ − the flow rate, which is determined depending on the angle of conicity of the nozzle φ along curve 2 (Fig. 6, *b*).

Curve 1 gives the value of the compression ratio ε of the jet:

$$\omega = \frac{f_c}{f_0}\,. \tag{16}$$

This factor determines the diameter of the nozzle required to create the desired jet.

Here is an example of laboratory work to determine the moisture content of soils and other agricultural materials [17, 19].

The purpose of this laboratory work is to consolidate and expand knowledge to determine soil moisture, conducting experimental research in the laboratory or field, processing the data and analyzing the results [18, 19].

The theoretical part of the laboratory-practical work analyzes the concept of humidity and the need to determine it at different stages of seed germination and growth and development of plants. That is, humidity is determined in order to:

- operating conditions of agricultural machinery;
- to control the technological process performed by the machine (soil moisture in layers before and after the passage of the working body of the machine, the dynamics of humidity change, etc.);
- to characterize the conditions of development of agricultural plants.

Soil moisture can be determined directly or indirectly.

Direct measurements of soil moisture and some agricultural materials are carried out using special electrical devices. This method is convenient because it does not take much time.

However, errors can often occur depending on the internal structure of the material and its condition, so such measurements should be made only when high accuracy is not required.

The most common way to determine the moisture content of agricultural materials is to dry the samples in electric ovens at a temperature of 100−105° C. Depending on the condition of the material and its physical and mechanical properties, the sampling method, sample size and sample should be different.

The most common way to determine the moisture content of agricultural materials is to dry the samples in electric ovens at a temperature of 100−105° C. Depending on the condition of the material and its physical and mechanical properties, the sampling method, sample size and sample should be different.

The accuracy of determining the moisture content of the material mainly depends on the quality of weighing and drying.

Students during laboratory and practical work determine the absolute humidity of the material (%) as the ratio of the mass of water to the mass of dry material.

Drying cabinet DC-150 designed for drying various agricultural materials in the laboratory. The winding of the slider rheostat is connected in series to the heating element of the drying cabinet, which is placed inside the stand and allows to change the temperature of the cabinet in the range of 85-150° C [17].

The temperature is regulated by moving the handle of the rheostat slider, the extreme positions of which are marked with the inscriptions "Input" and "Output" on the right wall of the stand.

After loading the cabinet, the thermometer is installed in the upper hole of the ventilation cap so that its lower end does not touch the samples placed on the upper board. During heating, the temperature is controlled. If it is necessary to reduce the temperature, change the resistance of the rheostat by moving the slider from right to left.

After getting acquainted with the order of work, students perform it, draw up a report and protect [17, 18].

After studying the mechanical and technological properties of soil and other agricultural materials, students conduct engineering, technological and energy calculations of machinery and equipment for agricultural reclamation. As an example, we will partially consider the laboratory-practical work "Development of complete and incomplete schedules of water supply for crop rotation", which is performed by students of the speciality 208 "Agroengineering", while studying machinery and equipment in agricultural reclamation [1].

Purpose: To study the features and master the method of calculating the internal economic network and the method of drawing up incomplete and complete schedules of water supply in irrigation processes.

First, students learn the basic theoretical principles and definitions, as well as general information about irrigation systems.

Thus, the operation of irrigation systems − a set of organizational and technical measures necessary to maintain all structures of the system in working order and ensure the most efficient use of irrigation water.

On the main and distribution channels, up to watering the farm lands, operation is carried out by management of irrigation system and operational sites.

Distribution of water on farm lands between general and separate irrigation plots, as well as irrigation of crops is carried out through the in-farm irrigation network.

After the completion of the construction of the irrigation system, the internal network of irrigation canals and structures is transferred by act to the water user (farm) and comes entirely under his control.

The water user is responsible for the proper condition of the domestic irrigation network, the rational use of irrigation water, as well as for the effective development of irrigated lands.

The operation of the on-farm irrigation network carried out by the farm consists of the following technological processes:

1) performance of irrigation of agricultural crops according to the plan of water use, in proper agrotechnical terms and according to the necessary norms providing cultivation of high and steady crops;

2) maintenance of domestic irrigation and drainage canals and structures on them in proper condition;

3) prevention of water losses from canals and structures;

4) drainage of excess water into the drainage network to prevent waterlogging and salinization of lands;

5) planting different trees by the canals and organization of plant care.

In these works related to the operation of the on-farm irrigation network, farm workers - irrigators, must take an active part. They must not only irrigate crops, but also repair and prepare irrigation networks and structures for irrigation, mow and spray canal slopes with herbicides; make sure that the canals and structures are in good condition; participate in the preparation of internal water use plans.

Irrigation on farms should be carried out on the basis of a water use plan. The on-farm water use plan of the farm is drawn up simultaneously with the production plan [1].

The knowledge that students aquire in lectures and laboratory-practical classes are used during course and diploma design, research work [20]. Topical issues of soil and water protection must be highlighted here.

4. *Conclusion*

The article presents the results of research of innovative scientific, technical and pedagogical bases of study by future specialists in agroengineering of fundamental questions of the theory and calculation of sprinklers and devices of machines for irrigation of crops. In these innovative pedagogical technologies for the formation of professional competencies of future agricultural engineers, much attention is paid to the problematic issues of optimizing the water regime of seed germination, plant growth and development, protection of soils and water resources. An algorithm for calculating the working bodies of sprinklers is presented, it can be used by agricultural engineers during their design activities. The obtained results of scientific research can be used as didactic material in lectures, during laboratory-practical classes, independent work of students, as well as graduate students and scientists at the stage of design and construction of reclamation machines.

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