Asesorías y Tutorías para la Investigación Científica en la Educación Puig-Salabarría S.C.
José María Pino Suárez 400-2 esq a Lerdo de Tejada. Toluca, Estado de México. 7223898475
RFC: ATI120618V12

Revista Dilemas Contemporáneos: Educación, Política y Valores.
http://www.dilemascontemporaneoseducacionpoliticayvalores.com/
Año: VI Número: Edición Especial Artículo no.:74 Período: Marzo, 2019.

TÍTULO: Disminución del consumo de electricidad en las estaciones de bombeo durante el riego mediante unidades de aspersión de soporte múltiple.

AUTORES:

1. F.K. Abdrazakov
2. N.F. Ryzhko
3. S.N. Ryzhko
4. S.A. Horin
5. S.V. Botov

RESUMEN: Se determinaron las principales formas de reducción del consumo de electricidad en las estaciones de bombeo: el uso de rociadores de baja presión; la optimización del modo de operación de la unidad de bombeo; el uso de agregados de baja presión y variables; la regulación de una unidad de consumo de agua para la finalización simultánea del riego por parte de un grupo de máquinas, etc. Justificaban la modernización del rociador de baja presión "Fregat", que regula el consumo de agua y aumenta la fiabilidad de su funcionamiento. Mostraron la efectividad de las máquinas de rociadores de baja presión "Fregat" introducidas durante su operación individual y grupal con las unidades de bombeo.

PALABRAS CLAVES: rociador "Fregat", baja presión, modernización, unidad de bombeo, consumo de energía de riego.

TITLE: Electricity Consumption Decrease at Pump Stations during Watering by Multi-Support Sprinkling Units.

AUTHORS:

1. F.K. Abdrazakov

2. N.F. Ryzhko

3. S.N. Ryzhko

4. S.A. Horin

5. S.V. Botov

ABSTRACT: They were determined the main ways of electricity consumption reduction at pumping stations: the use of low-pressure sprinklers; the optimization of pumping unit operating mode; the use of low-pressure and variable aggregates; the regulation of a unit water consumption for simultaneous completion of watering by a group of machines, etc. They justified modernization of the low-pressure sprinkler "Fregat", which regulates water consumption and increases the reliability of its operation. They showed the effectiveness of low-pressure sprinkler machines "Fregat" introduction during their individual and group operation with the pump units of various types operating.

KEY WORDS: sprinkler "Fregat", low pressure, modernization, pump unit, power consumption of watering.

INTRODUCTION.

Irrigation is an important factor for the stability of agricultural production, the increase of crops and the profits of agricultural producers. In the existing irrigation systems of the Saratov region, high-pressure pumping units of various types (D and QVD) are used to supply water to sprinkling units at pumping stations.

Currently, the main place in RF and the Saratov region irrigation complex is still occupied by the sprinkler “Fregat”, which has a number of significant advantages (automatic irrigation, simple design, high productivity of servicing by 3-4 units, round-the-clock watering, etc.), however, the energy intensity of this machine remains high. This is due to the fact that the pressure at the unit entrance makes 0.5 ... 0.7 MPa, and 0.9 ... 1.1 MPa at the outlet of a pumping station and in a closed network (Lebedev, 1977; Ryzhko, 2009). The cost of electricity for the supply of 1000 m3 of water for most pumping stations in the Saratov region makes 330 ... 570 kWh where "Fregat" is used for irrigation.

The analysis allowed to reveal a number of reasons for the over-expenditure of electricity at the pumping stations, including the following ones:

- the predominant use of high-power pumping units (type D 1250-125) and high-pressure pump units on existing irrigation systems;
- an insufficient number of low-pressure pumping units and sprinklers;
- a non-optimal mode of pumping power unit operation (the number of irrigation sprinklers is smaller than the design values) for the following reasons:
- an insufficient and an inaccurate adjustment of a sprinkler for the required water flow;
- the impossibility to connect a project (or a large) number of operating sprinklers;
- pipeline leaks of the closed irrigation network and sprinklers;
- the wear of pumping power units;
- the absence of water consumption adjustment for sprinklers.
- a significant downtime of sprinklers in anticipation of repair as the result of insufficient organization of operator labor and the lack of spare parts, which leads to non-simultaneous completion of watering by a group of machines;
- an irrational sequence of sprinkler inclusion;

- an inaccurate planning of an optimal number of working sprinklers as the result of irrigation schedule absence;

- the clogging of water intake grids at pumping stations;

- the absence of variable pumping units, which make it possible to exclude the redistribution of electricity during the spring (autumn) period when one sprinkler is operated.

DEVELOPMENT.

Research methods.

The main ways to save electricity at existing pumping stations is to transfer sprinklers to a low-pressure operation mode and optimize the operating mode of pumping units with the maximum efficiency (Figure 1).

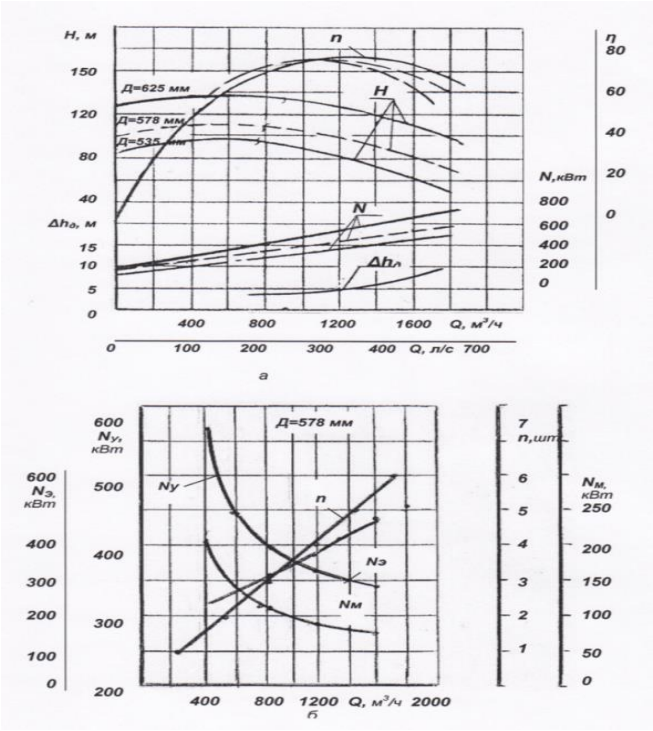


Fig. (1). Consumption-pressure (Q-H) characteristics of the pump D 1250-125a: N_y – electricity consumption for the supply of 1000 m^3 of water, kWh; $N_э$ – consumed power, kW; n – the number of machines operating with the water flow of 80 l/s, pcs.; $N_м$ – the power per one sprinkler, kW.

The consumed power of the electric motor (Ne, kW) for water supply by a pump unit is determined by the following formula (Osman, 2016):

$N_э = Q\ H/\ 102\ \eta_н \cdot \eta_э.$ (1)

where Q – water flow rate of the pump, l/s; H – pressure, m. wat. col.

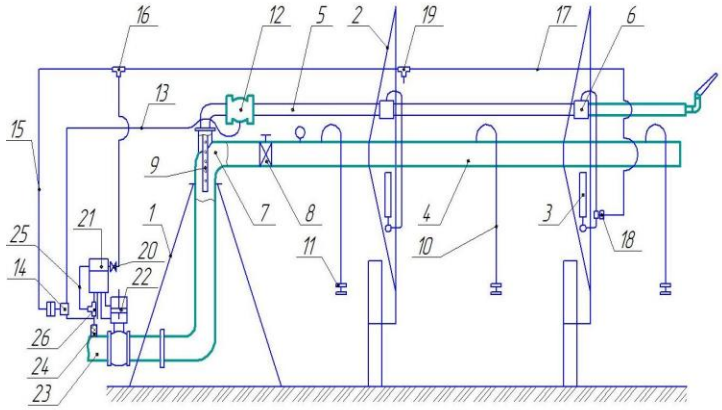
$\eta_н$, $\eta_э$ – the efficiency of the pump and the electric motor.

Specific energy consumption for the supply of 1000 m^3 of water (N_y, кВт·ч) is determined by the following formula:

$N_y = 2{,}72\ H/\eta_н \cdot \eta_э.$ (2)

The minimum consumption of electric energy to supply 1000 m3 of water makes 340 kWh for the pump unit D 1250-125a (Figure 1), when the optimum flow rate of water (346 l/s) is supplied with the pressure at the pump outlet H = 1 MPa for 3-4 "Fregat" units operating simultaneously. With an irrational loading of a pump (during the spring and the autumn period, when the supply of water is often for 1 or 2 machines only), the energy consumption for the supply 1000 m3 of water increases to 500 ... 600 kWh.

In order to increase the number of simultaneously operating sprinklers "Fregat" and to save energy costs for irrigation, it is necessary to use low-pressure machines. We proposed the modernized low-pressure sprinkler "Fregat" with an additional polyethylene pipeline (patent number 159184), laid along the main pipeline of the unit and providing the irrigation water supply to the hydraulic drives of bogies (Figure 2) (Pat, 2016).



б)

в)

а)

Fig. (2). The scheme of a low-pressure sprinkler (a) with an additional polyethylene pipeline, an external washing filter (б). A flushing filter in a water stream and a disk shutter (в).

An external rinsing filter is used (figure 2б) and a washing filter installed in the standpipe of the fixed support (Fig. 2в) are used for additional fine cleaning of the water supply to the hydraulic drives of the bogies. A disk shutter is installed in front of the main pipe-house of the machine, which adjusts the pressure and water flow of the machine (patent applications 2017135034 and 2017139807).

When a polyethylene pipeline diameter was justified, depending on the cyclicity of the hydraulic cylinder of the last bogy and the modification of the sprinkler "Fregat", we took the following into account:

- the cyclicity of the last trolley hydraulic cylinder, stroke/min, $n_{посл}$;

- the cyclicity of the hydraulic cylinder of the intermediate i-th trolley:

$$n_i = n_{посл}(Ri/R_{посл}),$$

where R_i and $R_{посл}$ – are the radii of the i-th and the last carriage movement of the machine, m;

- the total cyclicity of hydraulic cylinders during machine movement: $n_{ДМ} = \sum n_i$;

- hydraulic cylinder cycle time of the last trolley, sec:

$$T_ц = (60/ n_{посл}),$$

- water flow for the hydraulic cylinder of the last trolley, l/s:

$$q = V/ T_ц,$$

where V is the water volume in the hydraulic cylinder, l;

- total water flow for the movement of the whole machine, l/s:

$$q_{ДМ} = \sum q_i,$$

- flow velocity in a polyethylene pipe, m/s:

$$V_п = 10\, q_{\,i}/ (0{,}785 d_{вн}^{2}),$$

where $d_{вн}$ is the internal diameter of a polyethylene pipe, mm;

- the loss of pressure on the i-th pipeline section of the length l_i, m of wat. col.:

$$h = 0{,}685 V_п^{1{,}774} \cdot l_i / d_{вн}^{1{,}226}.$$

The calculations made it possible to determine the pressure losses along the pipeline length, depending on the machine modification and the cyclicity of the last trolley hydraulic cylinder. The results of calculations for the pipeline with the diameter of 90, 75 and 63 mm are given in Table 1 and shown on Figure 3.

Table. (1). The losses of pressure along the length of the polyethylene pipeline when water is supplied to the hydraulic cylinders of the sprinkler "Fregat", depending on the modification of the machine (the number of bogies), the diameter of the polyethylene pipeline (Ø) and the cyclicity of the last trolley hydrocylinder (n)

The number of unit trolleys	The loss of pressure along the length of the polyethylene pipeline, m of wat. col.											
	Ø 90, dext.=81,4 mm				Ø 75, dext=66 mm				Ø 63, dext=57 mm			
	The cyclicity of the hydraulic cylinder of the last machine trolley, n, stroke/min											
	5,5	4,5	4,0	2,0	5,5	4,5	4,0	2,0	5,5	4,5	4,0	2,0
16	4,78	3,34	2,70	0,79	11,98	8,37	6,77	4,98	26,16	18,28	13,63	3,98
15	4,08	2,85	2,31	0,68	11,09	7,76	6,28	1,84	22,3	15,65	12,67	3,70
13	2,81	1,97	1,60	0,47	7,64	5,35	4,33	1,26	15,4	10,79	8,74	2,63
12					6,39	4,48	3,63	1,06	12,89	9,03	7,31	2,14
16+ KDA *	11,6	9,82	8,67	5,16								

*KDA - The polyethylene pipeline provided the supply to the hydraulic drives of bogies and the end device with the water flow of 3 l/s.

Table 1 shows that the mounting a 13 ... 16-supporting "Fregat" sprinklers of an additional polyethylene pipeline with the diameter of 90 mm and the pressure losses along its length are insignificant (0.47 ... 4.78 m H2O). A polyethylene pipeline with the diameter of 75 mm can be considered as an optimal one, since the pressure drop will be 3,6 ... 8,3 m of wat. col. along its length with the cyclicity of the last trolley hydraulic cylinder making 4,0 ... 4,5 stroke / min.

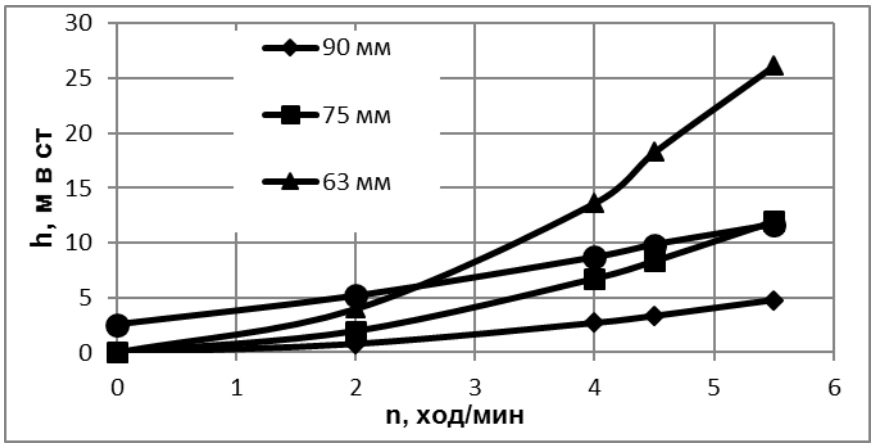


Fig. (3). The loss of pressure (h) along the length of a polyethylene pipeline with the diameter of 90, 75 and 63 mm for the sprinkler "Fregat" with 16 supports, depending on the cyclicity of the last trolley hydraulic cylinder (n) and the water flow rate by the end sprinkler

The calculations made it possible to determine the required pressure at the entrance of the sprinkler Fregat (Table 2), depending on a polyethylene pipeline modification and diameter.

Tabl. (2). The pressure at the entrance of the sprinkler "Fregat", depending on the number of trolleys, the flow rate of water and a polyethylene pipeline diameter (Ø 63 and 75 mm)

Number of trolleys per unit, pcs.	12	13	14	15	16
Water flow rate, l/s	65	75	80	90	90
Unit pressure, MPa at Ø 63 mm	0,37	0,38	0,40	0,42	0,43
at Ø75 mm	0,33	0,34	0,35	0,36	0,37

The calculations show that the use of an additional polyethylene pipeline will reduce the pressure at unit entrance down to 0.37 ... 0.47 MPa as compared with the serial units: 0.53 ... 0.6 MPa (1.4-1.7 times lower).

Study results and discussion.

The efficiency of low-pressure srinkler "Fregat" use and an optimal operation of a pump unit.

The EPF "Red Fighter" at the Ershov district of the Saratov region, carried out the studies concerning the efficiency of low-pressure sprinkler "Fregat" introduction and an optimal operating mode

with the main 250-QVD-570-50 and the exchangeable 150 CVE-350-23/2 pump units (Ryzhko, et al. 2002; Muyambiri and Chabaefe, 2018). According to the project, the main pumping unit 250-QVD-570-50 of the EPF "Red Fighter" provided the watering from 1 to 3 standard high-pressure sprinklers "Fregat" DMU-A-337-65. At that, the specific consumption of electricity for the supply of 1000 m3 of water varied from 463 to 948 kWh, and two units provided the irrigation for 4-6 units (Table 3).

After the upgrade of the "Fregat" sprinkler to a low-pressure operation mode, a 150 CVE-350-23/2 variable pump (with the electric motor of 75 kW) ensured the operation of one 12-foot low-pressure sprinkler "Fregat" DMU-A-337-65. Two variable pumps 150-CVE-350-23/2 provided the work of two 12-foot sprinklers "Fregat".

Tabl. (3). Design and recommended modes of pumping unit operation at PNS No. 22 of the EPF "Red Fighter"

The number of operators for the sprinkler "Fre-gat"	Pump brand - amount, pcs.	RPS pressure, MPa	Consumed power, kWt	Electricity consumption for the supply of 1000 m^3 of water, kWh (Savings, %)
Design operation mode with high-pressure sprinkler "Fregat"				
1	QVD- 1 pcs.	0,95	195	948
2	QVD- 1 pcs.	0,95	228	575
3	QVD- 1 pcs.	0,9	277	463
4	QVD- 2 pcs.	0,95	228+228	575
5	QVD- 2 pcs.	0,95	250+250	520
6	QVD- 2 pcs.	0,9	277+277	463
Advised operation mode with low-pressure sprinkler "Fregat"				
1	CVE- 1 pcs.	0,6	70	352 (259)
2	CVE- 2 pcs.	0,6	70+70	352 (163)
3	QVD- 1 pcs.	0,9	277	463 (0)
4	QVD- 1 pcs.	0,89	310	391 (47)
5	QVD- 1 pcs.	0,75	350	352 (47,7)
6	QVD- 1 pcs.+ CVE-1pcs.	0,7	350+70	352(31,5)

The main pump of the brand 250-QVD-570-50 (with 400 kW of electric motor power) was switched on for simultaneous watering from 3 to 5 units of 12-bearing low-pressure "Fregat" sprinklers. The specific energy consumption for the supply of 1000 m^3 of water during the operation of pumping units in an optimal mode with low-pressure sprinkler machine "Fregat" was reduced to 352 ... 463 kWh (by 31 ... 259%).

The studies were carried out in "Berezovskoye" LLC of the Engels district, and the efficiency of low-pressure sprinkler "Fregat" introduction and the optimum operating conditions of the pump 200 D 90 at RPS-4 were assessed.

There was an over-expenditure of electricity before the modernization of the machines, since the pump unit with a nominal water flow of 240 l/sec provided an alternate water supply to one or two Fregat sprinklers with the water flow rate of 90 l/s (Table 4).

An optimal power consumption was obtained with the simultaneous operation of three sprinklers "Fregat", which were set for a water flow of 80 l/s according to the developed map of the sprinkler adjustment. With an optimal operation mode of a pumping unit, the consumption of electricity for the supply of 1000 m^3 of water is reduced from 389 or 324 kW to 266 kW, by 31.3% and 17.6%, respectively (Table 4).

A simultaneous operation of three sprinklers will provide an annual electricity saving at a pump station of more than 200 thousand rubles (47775 · 4,377 = 209100 rubles).

Table (4). Performance characteristics of a pump unit before and after the upgrade of the sprinkler "Fregat" to the low-pressure regime

Operation indicators	Sprinkler operation mode		
	Existing		Low pressure
Number of working units, pcs.	2	1	3
Water consumption by a pumping station, l/s	180	90	240
Working pressure of a pumping station, atm	8,5	9,5	7,8
Pump efficiency	0,8	0,6	0,82
Power consumption of the pumping station, Kw	210	140	230
Specific consumption of electricity for the supply of 1000 m^3 of water, kWh	324	389	266
The overrun of electricity, %	17,6	31,3	-
The duration of irrigation at the rate of 400 m^3/ha, h	92,4	92,4	100
Power consumption for 1 watering, kW·h	92,4(210+140)= 32555		100·230=23000
Energy saving per 1 irrigation, kWh for a season (5 irrigations) and (thousand rubles).	32555-23000=9555 kW·h 9555·5=47775 kW·h (209 thousand rubles)		

The increase of irrigation operational parameters during the introduction of the low-pressure sprinkler "Fregat" and energy saving have also been received at RPS No. 28 at LLC "ROSAGRO-ZAVOLZHYE". Prior to the modernization, the pumping unit provided a simultaneous irrigation of only 3 sprinklers (Table 5).

Tabl. (5). Performance characteristics of the pump unit before and after "Fregat" sprinkler upgrade for low-pressure operation

Specifications	Before upgrade	After upgrade
Pumping unit brand and power, kW	Д1250-65 (500 kW)	
Nominal water flow, m^3/h	778	1250
The amount of simultaneously operating units, pcs.	3	4
Operating pressure at the pumping station, MPa	1,2	1,0
The pressure at the sprinkler input ("Fregat" No. 4, No. 10, T-L, Bauer), MPa	0,6; 0,4; 0,3	0,4;0,6;0,4; 0,3
Specific energy consumption per 1000 m^3 of water, kWh	570	450
Annual energy saving on the area of 240 hectares with 5 irrigations, kWh (thousand rubles)		210,0

The upgrade of the sprinkler "Fregat" No. 4 to the low-pressure operation mode made it possible to water with four units simultaneously - the sprinkler "Fregat" No. 4 and 10, T-L and Bauer. The specific energy costs for the supply of 1000 m3 of water were reduced from 570 to 450 kWh (by 26.6%), the daily production of operators increased, and the timely watering of an irrigated area was provided. This is achieved through the use of a disc shutter (Figure 2), which allowed to regulate the pressure and water flow in the main pipeline of the unit No. 4.

Low-pressure sprinkler "Fregat" efficiency with the rational sequence of their turning on the irrigated area and at an optimum operating mode of pump units.

The increase of watering operating parameters during group operation of low-pressure sprinkler "Fregat" and energy saving was also received at RPS No. 2 of Engels OS in the LLC "Nashe delo".

Ten most remote units (with a large number of supporting trolleys - 14 ... 16 pcs. and the water consumption of 80 ... 90 l/s, number 1, 7, 9, 10, 15, 16, 17, 18, 19 and 20) have been switched to low pressure among twenty sprinkling units "Fregat" at the farm irrigation area of 917 hectares. This allowed to increase the number of simultaneously working units. If, before the upgrade of 2015, two pumping units D 1250-125 with an electric motor power capacity of 630 kW provided the operation of only 7 ... 8 high-pressure sprinklers "Fregat", then in 2016, after the units were turned to low pressure, one-time watering was carried out by 10 units. The maximum water flow of two aggregates increased from 630 to 700 ... 720 l/s.

During the operation of the sprinklers "Fregat" in high-pressure mode in 2015, the period between watering was 16-18 days, the units worked alternately in three stages. In 2016, the watering cycle of the sprinkler "Fregat" on the irrigated area consisted of alternating work of two groups of units - 10 units in each (Table 6). The pressure at the pumping station was 0.8 MPa, and 0.4 ... 0.6 MPa at unit input, depending on its location. The full cycle period for the irrigation of the whole irrigated area made 11 ... 12 days with irrigation norm of 300 and 410 m3/ha. During the irrigation cycle, two

pumping units were working around the clock and only one unit worked at the end of the cycle (1-2 days) to complete the watering of other units with different lengths or with the downtime because of troubleshooting.

Tabl. (6). Pump unit (PU) specifications before and after the upgrade of the sprinkler "Freat" to a low-pressure operation mode.

Specifications	Years					
	2015	2016	2017			
			1st watering	2nd watering	3rd watering	4th watering
Area watering period, days.	16-18	11-12	10	7	6,5	6,6
Number of hours worked by the units at a pumping station, h.	462	370	347	297	298	299
Number of simultaneously operating sprinklers "Fregat", units.	7-8 from 2 PU	10 from 2 PU	10 from 2 PU 14-15 from 3 PU			
Maximum flow rate of the pumping station, l/s	600-650	680-720	680-720 – 2 PU 900-1300 – 3 PU			
Maximum daily output of the sprinkler "Fregat", ha	50-60	75-80	90-140			
Annual economic effect from the reduction of electricity consumption, mln. rub.	-	1,04	1,5			

In 2017, 14-15 "Fregat" sprinklers were watering this irrigated area at the same time during the operation of three pumping units. If the number of working units decreased to 11-13 pieces, then two pumping units were turned on, and one pump unit operated at the end of the irrigation cycle. This unit provided the water supply for 4-5 units that did not finish their irrigation. This mode of operation allowed to complete the first watering in 10 days, and the second, the third and the fourth watering were completed in 7.0; 6.5 and 6.6 days, respectively (Ryzhko, et al. 2015; Videla, 2018).

During the operation of units at high-pressure mode, the total operating time of pump units was 462 hours in 2015, 370 hours at low pressure in 2016, 347 hours in 2017 with the first watering during a total irrigation cycle of 917 hectares, and at the second, the third and the fourth watering the operation time reduced to 297, 298 and 299 hours, respectively. The cost of one watering cycle by 20 sprinkling units "Fregat" for the spring season of 2016 made 1040.0 thousand rubles. The savings costs per one irrigation cycle due to the unit operating time reduction from 462 to 370 hours amounted to 260 thousand rubles or more than 1.0 million rubles in a season (4 waterings). With the reduction of unit operating time during irrigation down to 299 hours, the saving cost of electricity will be about 375 thousand rubles or 1.5 million rubles per season.

With the output pressure of the pumping station making 0.8 MPa, they reduced the pressure in the closed irrigation network and the magnitude of the water impacts when the "Fregat" units are switched off. This reduces the number of pipelines breaks and increases the reliability of a closed irrigation network operation.

The work with a low-pressure operation of 10 "Fregat" machines ensures the increase of daily output to 75 ... 80 ha/day, the productivity increases by 1.25 times a day. An average daily output of the sprinkler "Fregat" increased to 90 ... 140 ha/day or 1.4 ... 2.3 times in 2017. The increase of sprinkler unit productivity and production allowed to reduce the intensity of operator labor, which allowed to increase the number of reserve days for unit maintenance.

The use of variable units at the pumping station.

Electricity savings can also be realized if the existing pumping stations are more widely used by exchange units.

The sprinklers "Fregat" of various modifications (4, 6, 9, 10, 12 and 16-bearing, with different water consumption) were mounted for maximum use of the irrigation area at EPF "VolzhNIIGim". In order to save energy at the pump station, various types of pumping units were used (SPS 100/100 -

1 piece, SPS-70/80 - 2 pcs and SPS-200/50 - 1 pc.). Such a set of pumping units allows you to supply the required water flow to the units, have the maximum efficiency of pumps and save electricity at the pumping station when the number of working "Fregat" sprinklers varies from 1 to 7 units (Table 7).

Tabl. (7). The number of simultaneously operating low-pressure sprinklers "Fregat" (N_{dm}) and the pressure at the output of pumping stations N_{NS}, depending on the number of pumping units (PU) at "VolzhNIIGiM".

Pumping unit				N_A, pcs.	H_{HC}, MPa	$N_{ДМ}$, pcs.	Household numbers of working units	Total water flow by units, l/s; (Electricity consumption for the supply of 1000 m^3 of water, kWh)
1	2	3	4					
+	-	-	-	1	0,60	1	4	90; (228)
-	-	+	-	1	0,70	2	6, 9	30+90=120; (258)
+	+	-	+	3	0,60	3	3, 2, 8	100+50+40=190; (228)
-	-	-	+	1	0,60	3	1, 2, 6	38+45+20=103; (227)
-	-	-	+	1	0,50	4	1, 2, 6, 7	38+45+20+40=150; (185)
+	+	+	-	3	0,60	4	3, 4, 5, 2	100+100+30+50=280; (250)
+	+	+	-	3	0,60	4	3, 4, 1, 10	100+100+40+30=270; (260)
+	-	+	-	2	0,60	4	1, 7, 8, 5	40+40+40+30+10=160; (260)
+	-	+	-	2	0,70	4	3, 8, 5, 10	100+40+30+30=200; (270)
+	+	+	-	3	0,76	6	1, 7, 8, 5, 10, 6	40+40+40+30+30+20=200; (300)
+	+	+	-	3	0,82	5	1, 7, 8, 5, 10, KO	40+40+40+30+30+10=190; (310)
+	+	+	-	3	0,60	6	1, 7, 8, 5, 10, 9	40+40+40+30+30+50=230; (290)
+	+	+	+	4	0,70	7	1, 6, 3, 5, 7, 9,10	40+20+100+30+40+50+30=310

Note: 1, 2 - SPS unit 70/80; 3 - SPS unit 100/100; 4 - SPS unit 200/50; DI - drip irrigation.

At EPF "VolzhNIIGim", when the watering by low-pressure sprinkler Fregat, 137,000 kW of electricity was used for the supply of 518,000 m^3 of water. Electricity consumption for the supply of 1000 m^3 of water varies from 185 to 310 kWh (Table 7), it made 265.6 kWh on the average. On the average, 577 kWh were spent to supply 1000 m^3 of water in the Saratov region. The energy saving for water supply made 37% at "VolzhNIIGim".

Low-pressure pump efficiency and the adjustment of the electric motor rotational speed.

Significant energy savings were obtained through the introduction of low-pressure sprinkler "Fregat", "Valley" and low-energy pumps of D1250-65 type at RPS-4 of Komsomolskaya OS in LLC

"Nashe delo". 6 low-pressure sprinklers "Fregat" and 8 sprinklers "Valley" watered the plot of 900 hectares, the specific costs for the supply of 1000 m^3 of water were reduced from 470 ... 658 kW (Table 8) to 241 kW (in 1.9-2.7 times). At the same time, at a non-optimal operation mode of pumping units at PS-43a of CJSC PZ "Meliorator", where the sprinklers "Fregat" and low-pressure sprinklers "Zimmatis" were watering, the saving of electric energy is absent. The annual cost of 1000 m3 of water supply remained high - 475 kW.

Tabl. (8). Electricity consumption for supply of 1000 m3 of water at standard and low-pressure operation conditions at Privolzhskaya OS and Komsomolskaya OS

Pumping station	Farm name	Pump type (sprinklers)	Electric energy costs, kW.h.	The number of moto/ h.	Supplied water volume, thous.m^3	kW.h spent on 1000 m^3
BKPS	CJSC "AF"Volga"	1Д 1250/63 (Zimmatic)	343632	1388	1735	198
PS-A	CJSC "AF"Volga"	1Д 1250/125 (Fregat)	1647434	2003	2503,75	658
RPS-4	LLC "Nashe delo"	1Д 1250/63 (Fregat -H +Valley)	474326	1573	1966,25	241
RPS -5	LLC "Nashe delo"	250 CVA 460 (Fregat)	779328	2238	1656,12	470
PS-43а	CJSC PZ "Meliorator"	Д 1250/125 (Fregat +Zimmatic)	1 263651	2064	2580	489
PS -43б	CJSC PZ "Meliorator"	Д 1250/125 (Fregat)	771539	1337	1671,25	461
PS -4п	CJSC PZ "Meliorator"	Д 1250/125 (Fregat)	526860		1109,178	475
PS -5п	CJSC PZ "Meliorator"	Д 1250/125 (Fregat)	246960		519,116	475
PS -11п	CJSC PZ "Meliorator"	Д 1250/125 (Fregat)	764922		1610,262	475

Even more significant energy savings were obtained by the BKPS of Privolzhsky OS at CJSC "AF"Volga" with the introduction of low-pressure sprinklers Zimmatis and low-energy pumps of D 1250-65 type with the frequency control of the electric motor revolutions. The specific costs for the supply of 1000 m^3 of water were reduced from 470 ... 658 kWh to 198 kWh (2.3-3.3 times).

CONCLUSIONS.

The use of low-pressure sprinklers "Fregat", "Valley", "Zimmatis", etc. and the transfer of existing pumping units to low-pressure operation, as well as the introduction of low-pressure pumping units, saves the energy on irrigation by cost reduction for the supply of 1000 m^3 of water from 475-658 kWh to 198-241 kWh, which makes about 1.5 million rubles with four irrigation per season at the rate of 400 m^3/ha.

A modernized sprinkler "Fregat" with an additional polyethylene-pipeline was developed, which provides a low-pressure operation mode and water consumption adjustment. When additional equipment is used the reliability of the sprinkling unit operation is increased.

The transfer of sprinklers into a low-pressure operation mode provides the increase of simultaneously operating unit number in 1.3-1.5 times, increases the water flow of a pumping station, reduces the energy consumption for irrigation, reduces the pressure at a pumping station outlet from 0.9 to 1.0 MPa up to 0,5 ... 0,7 MPa, reduces the dynamic loads on the pipeline of a closed irrigation network and the irrigation time of the irrigated area, increases the daily productivity of the units during group operation. All this ensures the maintenance of soil moisture at an optimum level and contributes to the production of stable and high yields of agricultural crops.

BIBLIOGRAPHIC REFERENCES.

1. Lebedev B.M. (1977). Sprinkler units, Theory and design. - M.: Machine-building. 246 p.

2. Muyambiri, B., and Chabaefe, N. N. (2018). The Finance – Growth Nexus in Botswana: A Multivariate Causal Linkage. Dutch Journal of Finance and Management, 2(2), 03. https://doi.org/10.20897/djfm/2634

3. Osman, M. M. (2016). Analysis Maximum and Minimum Principles on Maximum Riemannian Manifolds. International Journal of Engineering, Science and Mathematics, 5(1), 210-218.R

4. Pat. M. (2016). 159184, Russian Federation, A O1G 25/09. Sprinkler / Ryzhko N.F. and another applicant and patent holder: FGBSI "VolzhNIIGiM". - Publ. on 10.02.2016, Bul. № 4.

5. Ryzhko N.F. (2009). The perfection of rain-forming devices for multi-support sprinklers. FSEI HPE "Saratov State Agricultural Academy", Saratov. 176 p.

6. Ryzhko N.F., Ryzhko S.N., Botov S.V., Horin S.A., Organov M.S. (2015). Electricity saving at the pumping stations of irrigation systems of the Saratov Region // Agrarian Scientific Journal of Saratov State University named after N.I. Vavilov, Saratov: FSEI HPE "Saratov State University of Economics"., No. 11. pp. 45-48.

7. Ryzhko N.F., Ugnavy V.L., Shushpanov I.A. (2002). The results of the works on the introduction of low-pressure sprinkler "Fregat" at EPF "Red Fighter" of the Ershov district / The actual problems of land reclamation in the Volga region. Saratov. pp. 133-140.

8. Videla, C. (2018). "Caracterización del discurso sobre innovación curricular en FID en universidades de Chile." Opción 34.86 (2018): 201-234.

DATA OF THE AUTHORS.

1. **F.K. Abdrazakov.** The Federal State Budgetary Educational Institution of Higher Education "Saratov State Agrarian University named after N.I. Vavilov", Saratov, Teatralnaya sq., 1

2. **N.F. Ryzhko**. Federal State Budgetary Scientific Institution "Volzhsky Scientific Research Institute of Hydraulic Engineering and Amelioration", Engels, Saratov Region, Gagarina str., 1

3. **S.N. Ryzhko**. Federal State Budgetary Scientific Institution "Volzhsky Scientific Research Institute of Hydraulic Engineering and Amelioration", Engels, Saratov Region, Gagarina str., 1
4. **S.A. Horin.** Federal State Budgetary Scientific Institution "Volzhsky Scientific Research Institute of Hydraulic Engineering and Amelioration", Engels, Saratov Region, Gagarina str., 1
5. **S.V. Botov.** Federal State Budgetary Scientific Institution "Volzhsky Scientific Research Institute of Hydraulic Engineering and Amelioration", Engels, Saratov Region, Gagarina str., 1

RECIBIDO: 2 de febrero del 2019. **APROBADO**: 13 de febrero del 2019.