ISSN 1454 - 8003
Proceedings of 2017 International Conference on Hydraulics and Pneumatics - HERVEX
November 8-10, Băile Govora, Romania

HYDRAULICALLY CONTROLLED FERTIGATION EQUIPMENT WITH VOLUMETRIC INJECTION DEVICE

Gabriela MATACHE[1], Sava ANGHEL[1], Alina Iolanda POPESCU[1], Ana-Maria POPESCU[1], Gheorghe ȘOVĂIALĂ[1]

[1]The National Institute of Research & Development for Optoelectronics - Hydraulics and Pneumatics Research Institute, INOE 2000-IHP Bucharest

matache.ihp@fluidas.ro, sava.ihp@fluidas.ro, alina.ihp@fluidas.ro, ana-maria.ihp@fuidas.ro, sovaiala.ihp@fluidas.ro

Abstract: *Modern fruit growing pursues total control of plants development, ease of maintenance and harvesting works, automation of all field interventions. The technologies applied to intensive and super-intensive horticultural crops aim to ensure by watering water all that is necessary for the development of the plants, even by insulating the active area of the roots so that the plant depends only on the nutrients that are given by the watering water. We aim to control the growth of plants, sizing production, obtaining high quality products, maintaining and harvesting crops easily.*

Keywords*: Fertigation, injection device, fruit plantations*

1. Introduction

For fertilization application with irrigation water (fertigation), recommended dosages are applied weekly, or at most two weeks, correlated with foliar diagnosis and fruit production [1].
In the technique of water application by fertigation with drip irrigation systems, before applying fertilizer doses, first apply water for about 5 minutes, to flush the installation, then apply the water with dissolved fertilizers; after fertilizing, continue irrigation for another 5-10 minutes to entrain and infiltrate into the soil the last amount of nutrient solution, that could remain on the pipes and on the surface of the soil. [2]
The development of the fertigation equipment field with volumetric injection devices of double pump with membranes started with the implementation of the PD-1 dosing pump [3,4] at ICITID Baneasa Giurgiu whose scheme is presented in figure 1.

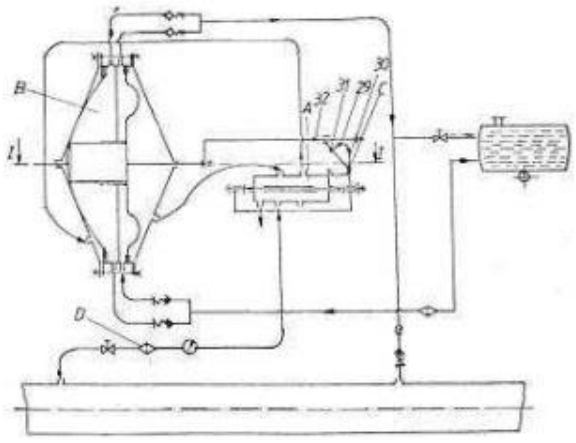

Fig. 1. Fertigation equipment with double volumetric pump type injection device with PD-1 membranes

The injection device, the main component of the fertigation equipment, consists of two membranes (B), directional control valve (A), and the exterior mechanism with swinging spring (C).[5]

Membranes separate four chambers with variable volumes. The active surfaces of the membranes in the outer chambers are larger than the active surfaces of the membranes in the inner compartments which determine appearance of the overpressure necessary for the primary solution injection in the same pipe from which is taken the water used as motion fluid. The directional control valve (A), depending on the position of the slide valve, establishes the water circuits in the two outer chambers. The displacement direction of the slide valve is determined by the position of the arm 31 of the outer mechanism component with swinging spring 29. The mechanism is located between the slide valve of the directional control valve and the movable assembly of the pump (moving the membranes).
Outside the injection device, the equipment consists of a fertilizer tank for preparing the primary solution, a four- check valves battery on the injection circuit, filters, and valves. In operation, the inner chambers vary in volume by making the fertilizer to be absorbed from the tank and discharged into the pipe through check valve battery.
The main inconveniences found in the operation of the equipment consist in the timing of the tilting mechanism, which changes the timing of the slide valve switching of the directional control valve, the degree of filling of the drive and injection chambers, the external positioning of the valves assembly for suction / discharge of the primary solution and of the elements which constitute the hydraulic circuits.

2. Presentation of the primary solutions injection device

Injection device realized through the execution of the contract 158/2014: Innovative technologies and equipment for the implementation in the irrigated agriculture of the modern fertigation concept (FERTIRIG), is a double pump with directional controlled valve hydraulically commanded.[6]
Injection device, [7,8] figure 2 was designed and realized in a compact way, in the body incorporating the piston-membranes mobile assembly, the hydraulic directional control valve, the driving of the directional control valve, the throttles of the drive chambers of the directional control valve, the suction / discharge valves block of the primary solution. The connection between the functional elements is achieved through the holes practiced in the device body and the movable assembly plunger, eliminating the external connections, except those related to the drive chambers of the directional control valve.
The schematic diagram of the fertilization equipment is shown in fig. 3.

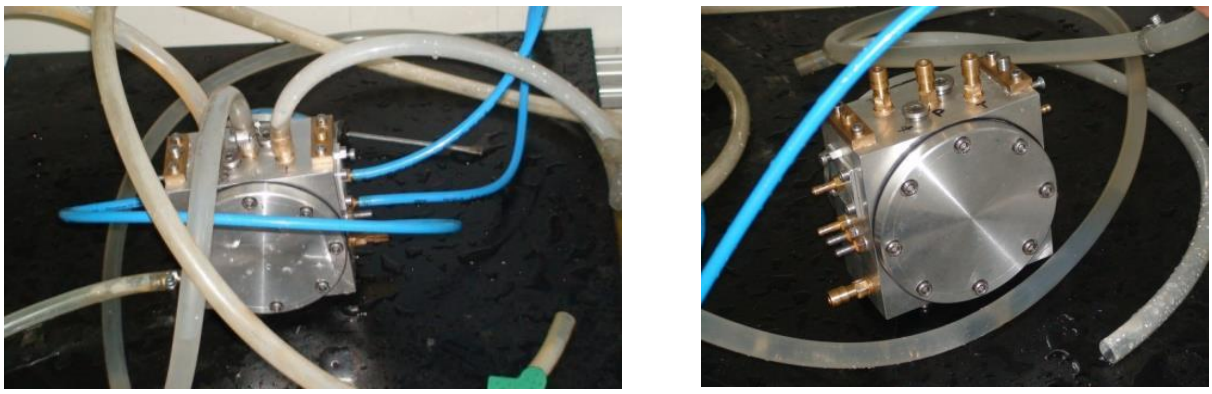

Fig. 2. Double pump type injection device with membranes

The mobile assembly, fig. 3-sect D-D, consists of piston, membranes, outer and inner flanges, special screws for fixing the membranes on the piston.
Primary solution suction / discharge valves assembly; each injection chamber is connected to an intake and discharge valve. The suction / discharge valves of the two injection chambers are interconnected and connected to the nozzles of the primary and discharge solutions.

In the construction of a 4-way, 2-position directional control valve, was chosen the alternative with slide valve, with O-rings seals, to allow the components to be executed in H8 / f7 tolerance fields, thus avoiding the extremely precise execution imposed at hydraulic directional control valves with classic slide valve, where the movements between the slide valve and the body are of the micron order. The versatile version of the directional control valve allows operation with irrigation water with a low filtration level.
The seals have been designed and made with as low as possible tightening, so that the friction forces of the movable elements are as small as possible.
The slide valve has a positive coating, the switching is done without loss of pressure.

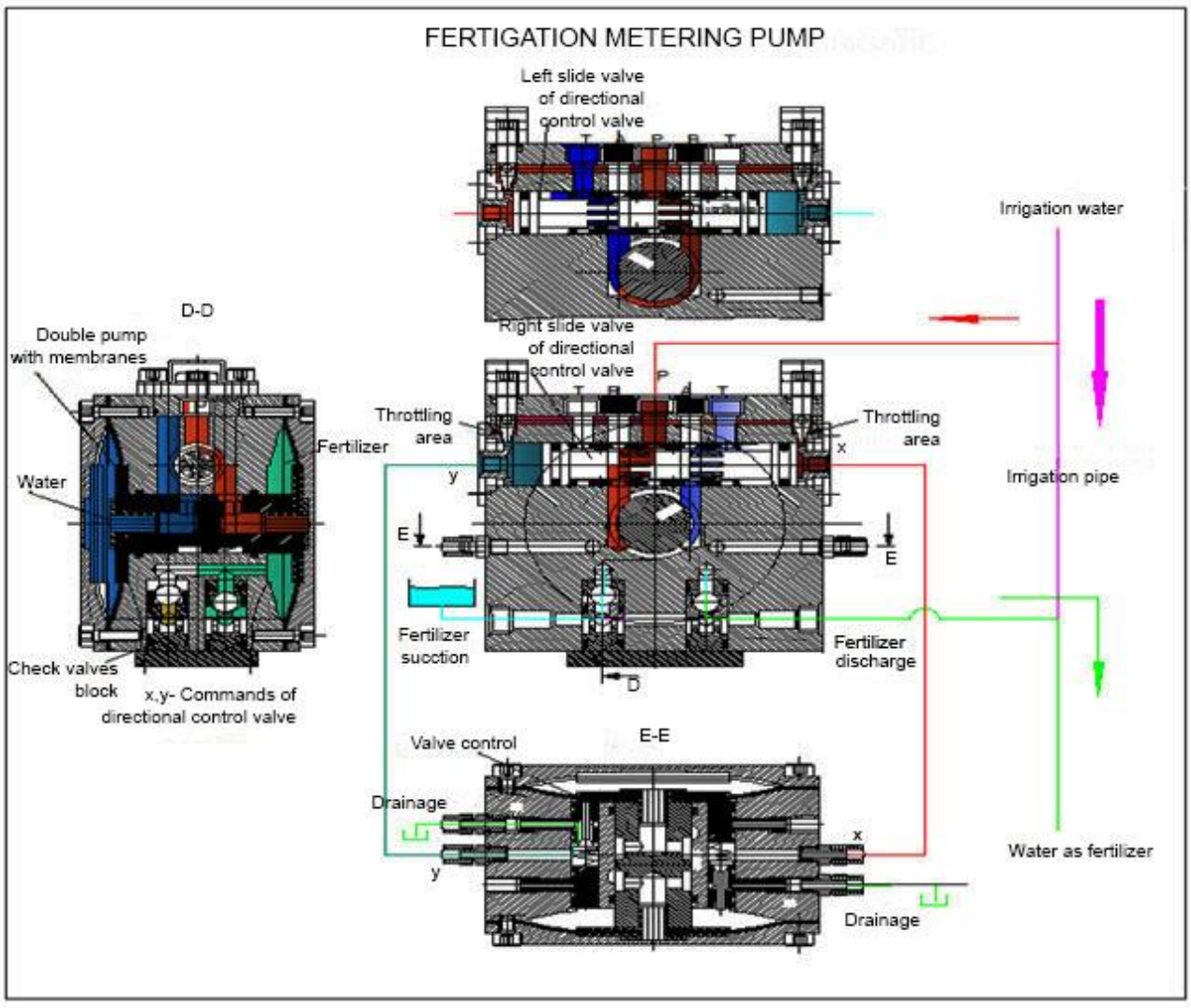

Fig. 3. The basic scheme of fertigation equipment

The control valves of the hydraulic directional control valve, fig.3 sect. E-E are cone-releasing valves, located in the water tank discharge holes in the drive chambers operated in the pump body, to ensure firm closure and opening and to reduce switching time for the directional control valve. The drive chambers are delimited by the outer surfaces of the membranes and the lids, and the injection chambers by the inner surfaces of the membranes and the body.

The operating principle

Depending on the position occupied by the slide valve of the directional control valve, fig. 4, the orifice P is connected to the orifices A or B, from which, by internal holes in the body and the

piston, the pressurized water supply of the drive chambers is provided. Outside, holes A and B are plugged.

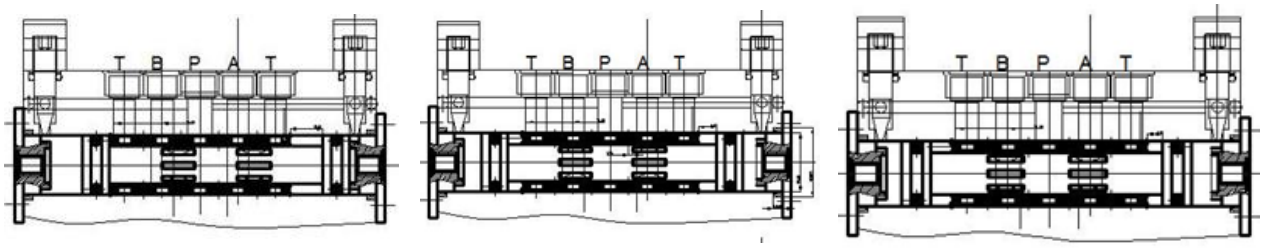

Fig. 4. Slide valve positions of the directional control valve

The T-holes alternately evacuate the liquid from the drive chambers (A to T or B to T) during the withdrawal phase of the membranes assembly (decrease the volume of the drive chambers).
Also from the P port, the Ccs-Ccd drive chambers of the hydraulic directional control valve are continuously supplied with pressurized water. The mobile assembly alternately operates through the internal flanges the pilot controlled valves, which shortly before reaching the end of the stroke, connect one of the drive chambers to the atmosphere, causing the switching of the slide valve of the directional control valve from the pressure drive chamber to the pressure discharge chamber.
The hydraulic switching of the slide valve is made by means of two identical hydraulic circuits, consisting of mechanically pilot controlled throttles and check valves, controlled on the end stroke of the mobile assembly, fig. 5. The slide valve of the directional control valve may take different positions in the directional control valve, depending on the fluid pressure on the ends (Pcs / Pcd - left / right control pressure). If the two valves are closed, the pressure on the ends is equal to the supply pressure (Pcs = Pcd) and the slide valve remains locked in the middle position. If one of the valves is unlocked, the liquid behind the throttle is removed to the outside, the Pcs or Pcd pressure falls only on the throttle, different pressures are applied to the ends of the slide valve and then the slide valve moves, being pushed in the direction of the lower pressure, switching the directional control valve.

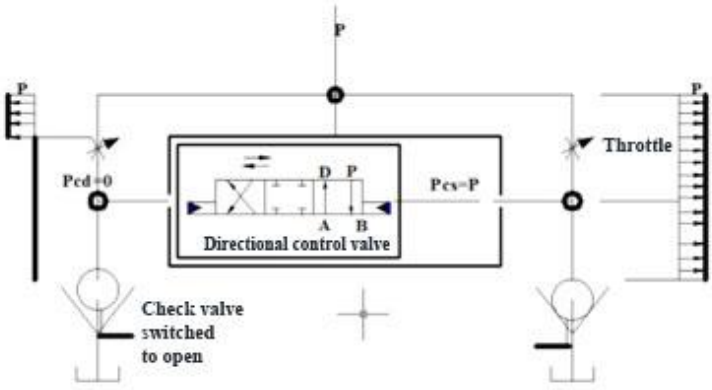

Fig. 5. Pressure circuit in control chambers of the directional control valve

When the mobile assembly reaches the end of the stroke, the inner flange, integral with the piston touches the end of the check valve, releases it and the pressure switches the slide valve, which changes the hydraulic connections with the membranes pump chambers, thus changing the direction of movement of the membrane shaft. After the assembly has reversed, the valve closes and locks the slide valve of the directional control valve in position. At the other end of the stroke is actuated the other valve that also changes the slide valve position, commanding the displacement in the opposite direction. The operation is repeated.

The throttles, which regulate the water flow that arrives into the drive chambers, keep the slide valve of the directional control valve in an equilibrium position and dictate the frequency of the mobile pump assembly.
The pressurized water supply of the left drive chamber causes the mobile assembly moving to the right, with the following effects:
- discharging of the moving fluid from the right drive chamber;
- aspiration of the primary solution in the right injection chamber;
- injection of the primary solution from the left injection chamber.
The volume reducing of the left injection chamber (implicitly increasing the pressure), causes the inlet valve ball to be seated and lifting the discharge valve ball out of the seat. Increasing the right injection chamber volume (implicitly producing a depression) causes the inlet valve ball to be lifted from the seat and seating the discharge valve ball. Injection chambers are alternately connected to the common suction connections (from the primary solution reservoir), respectively the discharge (in the supply pipe of the irrigation system), fig. 3.

3. The stand for testing

The experiments of the fertigation equipment under stand conditions were performed in the Environmental Protection Laboratory of IHP Bucharest.

3.1 The component of the testing stand

The test stand,[7] fig. 6, provides the hydraulic parameters (flow, pressure) necessary for the functioning of the fertigation equipment, simulating the irrigation system with which it works in the aggregate, being made up of the following components:
- pumping group with water recirculation used as working fluid;
- the water tank with the dimensions of 1130x900x785 and the useful volume of 0.6 m^3;
-the system for adjusting and monitoring the working parameters.
The WILO ECONOMY CO-2 MHI 206 / ER-RBI-CALOR pumping group, equipped with two high-pressure horizontal, without priming centrifugal pumps connected in parallel, provides a maximum flow of 10 m^3 / h and a height of maximum pumping capacity of 67 mCa. Pumping group is equipped with 2 "suction and discharge connections.
The pumping group consists of the following elements:
• Base frame: galvanized and fitted with vibration dampers with adjustable height for optimum sound insulation
• Piping system: suction and discharge connections of 2 ", all stainless steel pipes 1,4571, suitable for connection to all pipes in the installation technique, pipes are dimensioned according to the total hydraulic power of the pumping group
• Two parallel pumps of the MHI 2 series; all components of these pumps that come in contact with the liquid are 1,4301 stainless steel
• Reinforced fittings: each suction and discharge pump with CuZn closure fitting, Ni coated, DVGW marking and discharge retaining clack valve
• Pressure bottle with butyl rubber membrane, recognized as safe from the point of view of food law; designed for inspection and overhaul with CuZn ball valve, Ni-coated, with drainage and passage fitting according to DIN 4807
• Pressure sensor: 4 to 20 mA, located on the output pressure side for control of the central Economy controller
• Pressure display: through the pressure gauge on the outlet pressure side
• Control unit: The equipment is equipped with the Economy ER series regulator
• Components in contact with pumped fluid, corrosion-resistant

Fig. 6. Testing stand of fertigation equipment

The pumped fluids admitted are cooling water, drinking water and technological water. The admitted fluid is generally water without aggressive chemical or mechanical elements and without abrasive or long fiber components.
The water intake in the pumping group is made by an elastic connection element with an end type holender; discharge is done in the same tank, thus ensuring water recirculation.
Fertigation equipment is mounted in a bypass system, on a hydraulic circuit parallel to the group discharge pipe, similar from dimensional point of view and the hydraulic parameters point of view of the liquid transited with the main pipe in the drip or micro-sprinkler irrigation installations.
The connecting pipe of the injector device, fig. 7, includes connecting elements (nipples, sockets, reducing pieces, elbows) and elements that ensure the functionality, adjustment and monitoring of the working parameters (taps, Y path filter, check valve, pressure gauges, pressure reducer with pressure gauge, flow meter).

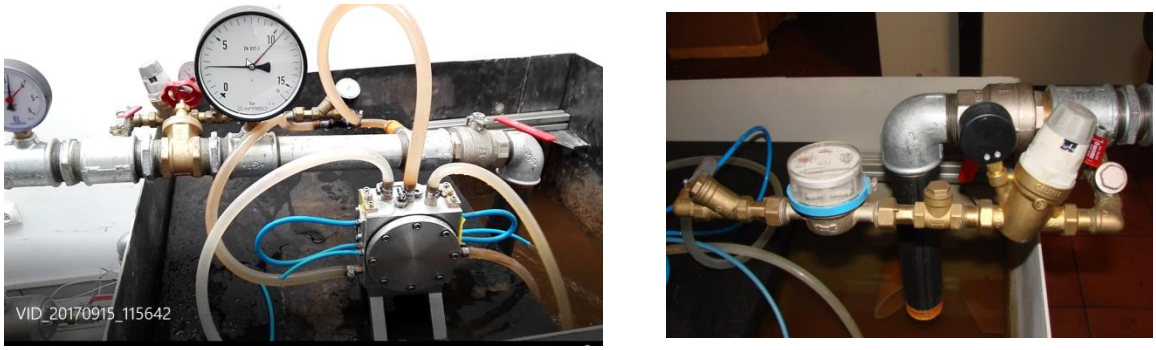

Fig. 7. The connecting pipe of the injector device

The injection device is provided with the following connections, fig. 8: The P-pressure connection, from which the drive chambers and control chambers of the directional control valve are fed; T_{cm} - water exhaust connections from the drive chambers; T_{cc} - water outlet connections from the control chambers of the directional control valve; A_f- the fertilizer aspiration connection; R_f - fertilizer discharge connection.
The pressure connection of the injection device is made from the downstream end of the line. Through the drive and control chamber tank connections, after performing the moving fluid function, the water is freely discharged into the stand tank. Through the A_f connection, the primary solution from the fertilizer tank B_f is absorbed, and the primary solution is injected through the R_f

connection. The circuit of the R_f connector is provided with a tap and pressure gauge to simulate and measure the injection pressure value.

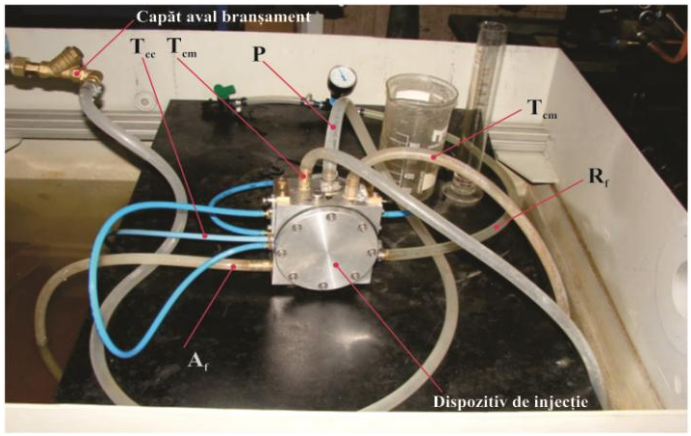

Fig. 8. Connection of the injection device in testing stand

The main discharge circuit of the pumping group is provided with:
- a pressure gauge located before the branching upstream point of the injection device, which measures the pressure value in the main pipe;
- path valve with slide valve, located on the main pipe between the branching point of the injection device, which causes a local pressure drop (which facilitates the injection process);
- path valve with sphere, located on the main pipeline, beyond the branching downstream point of the injection device, which can simulate the hydraulic resistance generated by the irrigation system distribution network.

After the injection device is branched, the values for the following parameters are adjusted:
- pressure of water upstream of the tap with slide valve, through which the pressure drop is created between
the connecting points, to facilitate the injection process, pressure measured by the manometer installed on the main pipe, upstream of the tap;
- working pressure of the injection device, regulated by pressure controller with pressure gauge;
- the flow in the main pipeline, by operation of the valve with sphere, mounted on the main pipeline, downstream of the injection point of the device.

Fig. 9. Laboratory graduated vessels for volumetric measurements

Fig. 10. Recipient for preparation of primary solution

Apart from the measuring and control instruments in the stand, the following were also used:
- recipients for volumetric measurements - laboratory graduated vessels, 500-1000 ml, fig. 9;
- the blank for the preparation of the primary solutions, fig. 10, with a capacity of 50 l, made of polyethylene resistant to corrosive action of chemical substances in fertilizers;

Considering the corrosive action of the fertilizers, in order not to affect the components of the test stand, the aspiration / discharge of the primary solution is made from / in the mixing vessel on a hydraulic circuit separated from the supply circuit with moving fluid of the injection device; the injection pressure value, at which the device operates uniformly and ensures the set parameters, is adjusted from the valve mounted on the discharge hose and is measured with the pressure gauge attached upstream of the tap.

3.2 Performed tests

The technical-functional characteristics achieved under stand conditions of the injection device, determined according to the methodology [4] are shown in Table 1.

Table 1: Technical-functional characteristics of the injection device

Pres. in the watering pipe, bar	**Working pressure of injection device, bar**	**Injection pressure, bar**	**Supply flow of injection device l/min**	**Exhaust flows from drive chambers 1 and 2, l/min**	**Volume of drive chambers 1 and 2, ml**	**Control chambers volume of directional valve 1 and 2, ml**	**Injected flow rate of primary solution, l/min**
3.7	**3.5**	**3.4**	**3.89**	**1.596/1.444**	**42/38**	**11.1/11.6**	**1.400**
4.0	3.0	2.5	4.22	1.720/1.650	19.5/19.0	9.5/8.0	0.570
3.8	3.0	2.4	2.35	0.712/0.736	15.0/15.5	9.5/9.5	0.265
2.8	2.6	2.3	2.34	0.647/0.647	17.5/17.5	14.5/14.0	0.235
2.8	2.0	1.5	2.31	0.612/0.616	17.5/17.6	15.5/15.5	0. 335

Frequency of mobile assembly, double strokes/min	**Control chambers flow of directional valves 1 and 2, l/min**	**Efficiency of injection device** $\eta = Q_{inj}/Q_{supply\ of\ inj.\ device,}$ **%**
38	**0.418/0.432**	**35.9**
98	0.465/0.392	13.5
95	0.451/0.451	11.2
74	0.536/0.518	10.0
70	0.542/0.542	10.0

The device was equipped with balls injection valves, made of two types of material: steel (results shown on the first row of the table), respectively KETRON PEEK polyether-ketone.

4. Conclusions

Experiments lead to the following conclusions:
1. The minimum pressure at which the injection device operates uniformly and continuously, with the free discharge of the primary solution (without load) was 1.2 bar;
2. The injection device has been tested at preset working pressures in the range of 2-3.5 bar;
3. The minimum bypass flow rate that ensures device operation is 5 l / min;
4. The injection pressure is proportional to the supply pressure of the drive chambers and has values ranging from 3.4 to 1.5 bar;

5. To facilitate the injection process, a tap with slide valve (with fine flow adjustment) is installed between the connecting points of the device, generating a local pressure drop;
6. Injected primary solution flow rate is between 1.4-0.235 l / min (84-14 l / h); the fertigation equipment, depending on the preset working parameters, can administer both basic primary solutions, currently used in fertigation, as well as microelements, which are administered in very small doses.
7. The frequency of the mobile assembly is significantly influenced by the material from which the balls of the injection valves are made; the frequency decreases with the increase in the weight of the balls, with implications on the filling degree of the drive / injection chambers, the injection pressure and the flow rate of the injected primary solution;
8. The injection device was tested with a 0.2% primary solution prepared from the Magnisal chemical. Magnisal is a total water soluble fertilizer that contains 11% nitrogen as NO_3 and 16% magnesium as MgO; the solubility of the product is 173 g / 100 g water at a temperature of 0° C, 200 g / 100 g water at 100 ° C, 225 g / 100 g water at 200 ° C, 256 g / 100 g water at 300 ° C, 289 g / 100 g water at 400 ° C; concentration (%), pH and electrical conductivity (mS / cm) vary as follows: 0.1 / 5.56 / 0.88; 0.2 / 5.51 / 1.69; 0.3 / 5.37 / 2.52; 1.0 / 4.85 / 7.58; 5.0 / 4.06 / 29.9.
9. Equipment samples under operating conditions have validated the reliability of laboratory samples demonstrating the functionality and utility of the product.

References

[1] Z. Borlan, C. Hera, "Agrochemical tables and nomograms" („Tabele și nomograme agrochimice"), Ceres Publishing House, Bucharest,1982;
[2] C. Paltineanu, S. Dumitru, E. Chitu, N. Tanasescu, M. Butac, M.Militaru, P. Ignat, V.Mocanu, "Plum and apple in the soil-plant-atmosphere system, in soils with medium and light texture", (" Prunul si marul in sistemul sol-planta-atmosfera, in soluri cu textura medie si usoara"), Terra Nostra Publishing House, 2017, ISBN 978-606-623-073-5,
[3] I. Biolan, I. Paltineanu, V. Mardare, C. Fagarasanu, A. Galca, S. Biolan, Gh. Sovaiala, I. Serbu, Gh. Crutu, A. Vranceanu, Dosing pump (Pompa dozatoare) – Patent no. 102887/19.02.1991;
[4] I. Biolan, I. Serbu, Gh. Sovaiala, F. Mardare, "Techniques and technologies for crop fertigation" ("Tehnici si tehnologii de fertirigare a culturilor agricole"), Publisher: A.G.I.R., ISBN: 978-973-720-344-1, 2010;
[5] M. Avram, "Hydraulic and pneumatic drive systems. Classic and mechatronic equipment and systems" ("Acţionări hidraulice şi pneumatice – Echipamente şi sisteme clasice şi mecatronice"), Bucharest University Publishing House, ISBN 973-7787-40-4, 2005;
[6] Gh. Sovaiala et al, "Innovative technologies and equipment for the implementation in the irrigated agriculture of the modern concept of fertigation",("Tehnologii si echipamente inovative pentru implementarea in agricultura irigata a conceptului modern de fertirigatie"), PN-II-PT-PCCA-2013-4-0114, contract 158/2014, www.ihp.ro/fertirig
[7] Gh. Sovaiala, S. Anghel, G. Matache, A.-M. Popescu, P.-M. Carlescu, "Injector of primary solutions with hydraulic control", *Scientific Papers -Vol . 59/2016, Agronomy series,* pp. 131-134;
[8] Gh. Sovaiala, S. Anghel, G. Matache, A. I. Popescu, Testing in Operation Conditions of Fertigation Equipment, *"Hidraulica" Magazine*, no.3/2017, ISSN 1453-7303, pp.31-36.