CONTRIBUTIONS TO THE DEVELOPMENT OF THE FIELD OF FERTIGATION EQUIPMENT
/
CONTRIBUTII LA DEZVOLTAREA DOMENIULUI ECHIPAMENTELOR DE FERTIRIGATIE

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ABSTRACT

Specialists in agriculture appreciate that fertigation, due to the many advantages it presents compared to the situation where irrigation and fertilization are performed as distinct technological sequences, is the most efficient method by which the water and fertilizers necessary for the growth and development of plants can be provided.

Through the implementation of the project "Innovative Technologies and Equipment for Irrigation Implementation of the Modern Fertigation Concept" - contract 158/2014, INOE 2000-IHP has made an important contribution to the development of the field of fertilization equipment for fertilization of horticultural crops from protected areas of fruit crops.

REZUMAT

Specialistii din agricultura apreciaza ca fertirigatia, datorita multiplelor avantaje pe care le prezinta comparativ cu situatia in care irigarea si fertilizarea sunt efectuate ca secvente tehnologice distincte, este cea mai eficienta metoda prin care pot fi asigurate apa si fertilizantii necesari cresterii si dezvoltarii plantelor.

Prin derularea proiectului "Tehnologii si echipamente inovative pentru implementarea in agricultura irigata a conceptului modern de fertirigatie"- contract 158/2014, INOE 2000-IHP si-a adus o contributie importanta la dezvoltarea domeniului echipamentelor de fertirigatie destinate fertirigarii culturilor horticole din spatii protejate si culturilor pomicole.

INTRODUCTION

Fertigation is the method by which water and fertilizers (solutions obtained by dissolving water-soluble solid fertilizers) are administered simultaneously with irrigation facilities.

The use of modern localized irrigation techniques (dripping, micro-spraying, underground) leads to a significant reduction in nutrient losses by percolation, allowing for the use of minimal amounts of fertilizer with water spray, minimizing soil and surface water and groundwater pollution.

Choosing the right fertilizer equipment is just as important as choosing the correct nutrients. Incorrect selection of fertilizer equipment may damage parts of the irrigation system, affect the efficient operation of the irrigation system or reduce the effectiveness of nutrients (*Biolan et al, 2010*).

Within the project were used innovative and original technical solutions for the field of fertilization, which focused especially on the injection device, such as double membrane pump (*Avram M., 2005*) with hydraulic control - the switch of slide valve of directional control valve is made hydraulically.

The injection device uses irrigation water as working fluid (drive) from the same pipeline into which the primary solution is injected, which in combination with the irrigation water forms the fertilizer solution.

Compared to membrane pumps on the market, products of prestigious companies in the field: VERDER AIR, DEBEM, TUV, TAPFLO, the injectors constructive variants made within the project do not require electrical energy or compressed air, which ensures their autonomy in operation in any point of the irrigation arrangement.

The overpressure required to the injection of the primary solution is based on the principle of the difference between the active surfaces of the drive chambers and the injection chambers and can be precisely determined, depending on the hydraulic parameters of the irrigation system with which they work in the aggregate, from the design phase of the device.

The flow rate of the injected primary substance can be adjusted to a very large extent by altering the feed rate of the drive chambers by altering the frequency of the central axis of the pump (solidary with the membranes that separate the drive and injection chambers); thereby facilitating the administration of both fertilizers based on nitrogen, phosphorus, potassium, which involves high injection rates and microelements, administered in very low doses.

The fertilization equipment is installed in parallel with the main circuit of the irrigation plant (bypass system) by two quick thimbles, to take off the water used as a moving fluid and to inject the primary solution; this mounting system does not introduce any load losses in the main pipeline of the irrigation installation.

The experimental model of the injection device was made in three constructive variants, getting at the Prototype stage, to obtain a device with technical-functional performances at the level of the requirements of fertigation process for the horticultural crops in the protected areas and the fruit crops, aggregated with drip irrigation and micro-sprinkler systems.

Fertilizer equipment (*Sovaiala Gh., 2014*) includes as basic elements: an injection device mounted by quick thimbles on a hydraulic circuit parallel to the main circuit of the irrigation system (by-pass system), from which the water used as the moving fluid is taken and in which is injected the primary solution, the primary solution preparation vessel, the monitoring parameters and the adjustment of the working parameters.

MATERIAL AND METHOD

The moving fluid (water from the main hydraulic circuit of the irrigation system) passes through the pressure filter and reaches the hydraulic directional control valve A3.1 (5/2-5 ways and 2 positions) (fig.1). When the slide valve of the directional control valve is in the right position, the connection between the P and A connections is established, supplying the left drive chamber of the pump A1 and the left chamber of the inverter A3.2, which causes the displacement of the mobile assembly of the pump to the right or between the connections B and Drainage, allowing the water to drain from the right drive chamber of the pump and the right chamber of the invertor. During this stroke, from the left injection chamber, by compressing the associated membrane, the injection process of the primary solution through the lower branch of the A2 valve block is performed. The injection pressure places on the seat the left valves - the bottom branch, the right valves - the upper branch and opens the right valve - the bottom branch, thereby injecting the primary solution into the main hydraulic circuit of the irrigation system.

At the same time, the right injection chamber creates a depression, causing the primary solution to flow through the upper branch of the valves block (the left valve is open, the right valve is on the seat). When the C1 hole is released from the inverter body, the connection to the hydraulic directional control valve command is established, causing the slide valve to be switched to the other position.

Double pump with membranes, fig. 2, can be assimilated to a hydraulic amplifier with two identical sections separated by a central disk (4). Rubber-bonded rubber membranes (3) are in the form of discs with a central hole. These are attached between the outer caps of the pump (2, 6) and the front faces of the disc on the outer contour, respectively the front faces of the cylindrical slide valve (5) and the special construction nuts on the inner contour. The membranes separate the drive chambers of the hydraulic amplifier (located on the outside) from the injection chambers (located on the inside).

The connection between the drive chambers and the external hydraulic circuit for the working fluid is achieved through the holes in the lids, and the connection between the injection chambers and the exterior circuit of inlet-discharge primary solution is made through the holes in the central disk. Reversing the movement direction of the mobile pump assembly is accomplished with the hydraulic inverter whose slide valve is integral with it. The difference between the active surfaces of the membranes, which are in contact with the moving fluid (irrigation water) on the outside and the primary solution on the inside, generates the overpressure necessary to carry out the injection process.

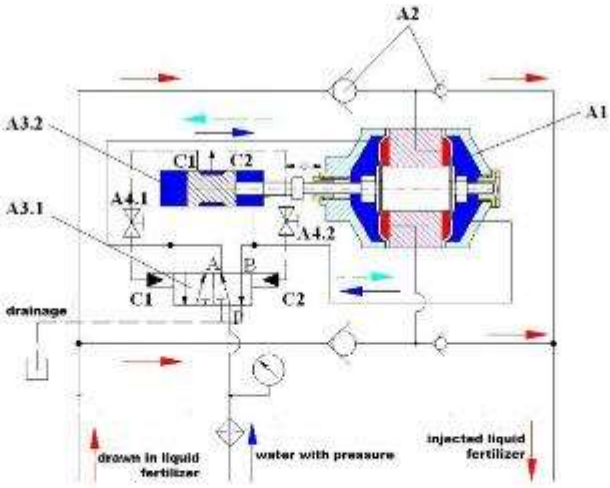

Fig.1-The operating principle of the injection device:
A1 double membrane pump (hydraulic amplifier); A2- Block of injection circuit check valve A3.1- Directional control valve of drive chamber actuator A3.2- Hydraulic sense inverter; A4.1, A4.2-cocks; C1, C2 control chambers (actuators) of the actuator directional control valve.

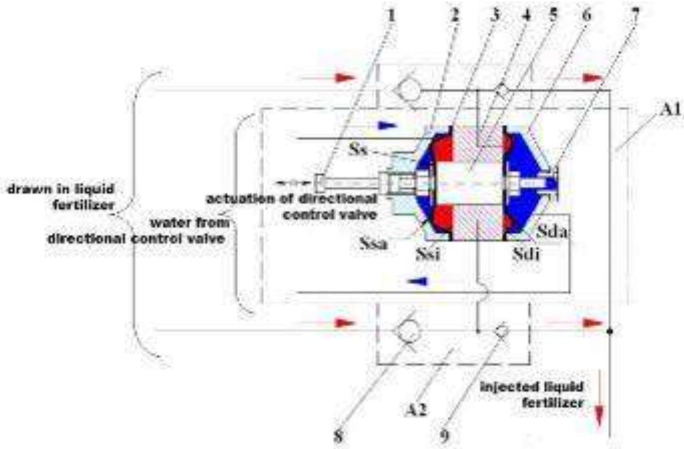

Fig. 2 -The hydraulic scheme of injection device:
1-axial drive rod, 2-left cap, 3-membrane, 4-housing, 5-slide valve, 6-right cap, 7-stop valve, 8-intake valve,9-discharge valve.
- Ssa, Sda - the left and right circular surfaces on which water acts; - Ssi, Sdi - the left and right circular surfaces on which the liquid fertilizer acts; - Ss - the circular surface of the slide valve

The main scheme of the fertilization equipment, variant II (*Sovaiala Gh.,2014*), is presented in fig.3.

An innovative solution for command of directional control valve has been adopted in the injection device, by taking over some hydraulic signals at the stroke ends of the pump mobile assembly by way of constructively solving the slide valve of the directional control valve so as to: provide a short switching time; in the switching phase does not generate a pressure drop in the installation, which will lead to blocking of the pump mobile assembly; once switched, there are forces to keep him in position.

The hydraulic directional control valve, fig. 4, controls the movement direction of the mobile assembly of the injection device; is supplied with pressurized water from the irrigation line before the tap R, which it alternately distributes in the two drive chambers. In this way, the injection chambers increase or decrease their volume by aspirating the primary solution from the Bf container and floating it through the branch with its anti-return valve in the same irrigation line downstream of the R valve at a pressure greater than that in the pipe.

The directional control valve contains a slide valve on which two valves and two command pistons are mounted. On the central position the valves completely close the P port (positive cover).

At the end of the slide valve (eg extreme right position), the right valve seals frontally on a seat ϕD, and the left valve on the cylindrical surface ϕd, in contact with the directional control valve body. Due to the difference between the ϕD and ϕd surfaces, the water under pressure in the pressure circuit P generates a force that opposes switching of the directional control valve:

$$\phi D > \phi d;\ A_D > A_d;\ \text{deci}\ F_D > F_d, \qquad (1)$$

where:

D, d are the diameters of the sections on which the water pressure acts;

AD, Ad areas of the two sections;

F_D and F_d forces acting on the valve assembly; $F = A \cdot p$, p-water pressure, A-area.

In this position of the slide valve, the paths P are set to the drive chamber B of the pump, respectively the engine chamber A at the drainage-Dr.

On switching, by pressure drops the forces unbalance:

$$F_D < F_d + F_{ccd}, \qquad (2)$$

where

F_{ccd} is the force produced by the pressure at the end of the control piston, which is no longer balanced.

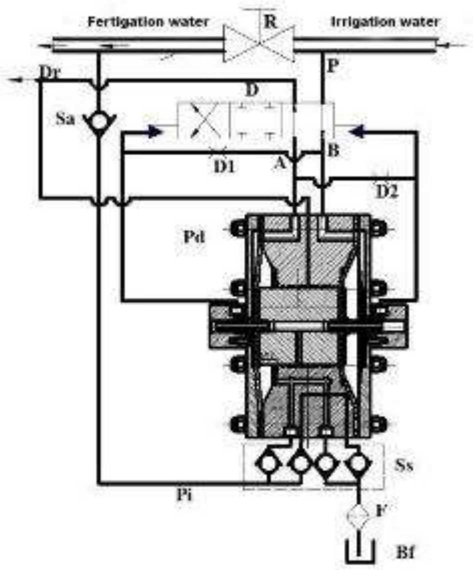

Fig. 3 -The main scheme of the fertigation installation- constructive variant II

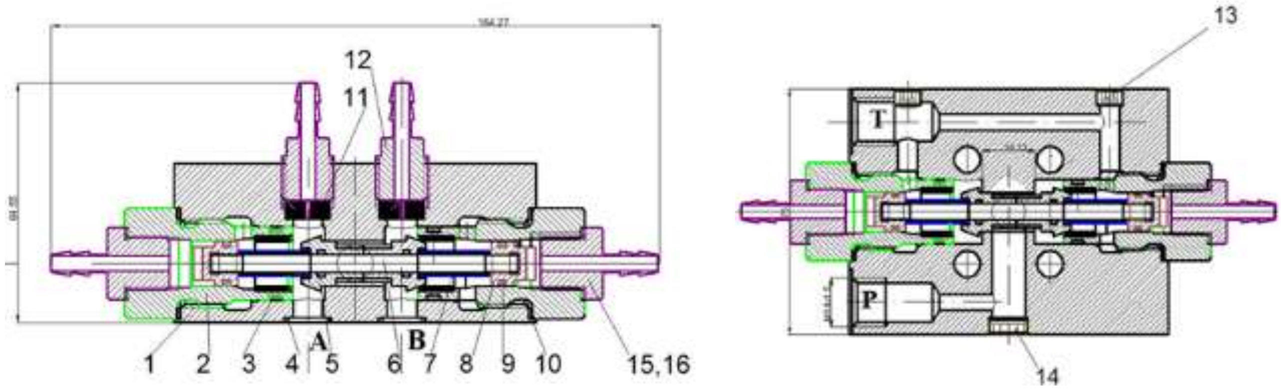

Fig. 4 - Sections through the hydraulic directional control valve of the injection device:
1, 3, 4, 9, 10-hydraulic seals; 2- the chamber of the control piston; 5- the body of the directional control valve; 6-slide valve; 7bushing spacing positioning control piston; 8-control piston; 11, 12- supply fitting of drive chambers; 13, 14- technological cork; A, B- supply ports of drive chambers; P-hole of the pressure connection; T-hole of the tank connection

In the fig.5 shows the hydraulic scheme of the directional control valve.

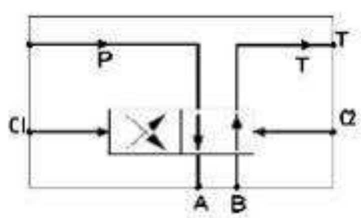

Fig. 5 - The hydraulic scheme of the directional control valve
A, B-links to drive chambers P-pressure connection; T-tank connection;
C1, C2-pistons control chambers

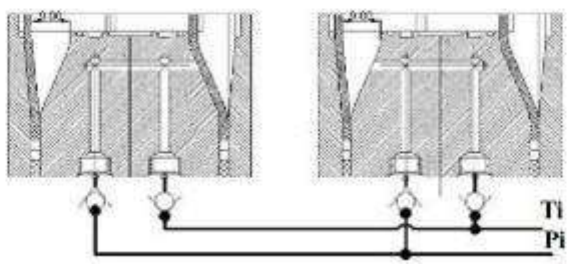

Fig. 6 - Installation diagram for inlet / discharge valves of primary solution

The primary solution inlet / outlet valve block is made up of four check valves with clack and related connecting elements.

The valves are arranged in two parallel planes, at each of chamber an inlet valve and a discharge valve been connected, fig. 6. Inlet valves are connected to the Ti branch, whereby the primary solution aspirated from the Bf container reaches alternately in the two chambers, and the discharge valves in the Pi branch, through which the primary solution is injected into the main pipe of the plant irrigated.

Injection device from the component of fertigation equipment, in the constructive variant III – EM (experimental model) improved / Prototype, (*Sovaiala Gh., 2016*), was designed and built in a compact construction, the piston-membrane mobile assembly, the hydraulic directional control valve, the driving of hydraulic directional control valve, the throttles of the control chambers of hydraulic directional control valve, the block of suction / discharge valves of primary solution being integrated in the carcass . The connection between the functional elements is achieved through holes in the body of the device and the piston of the mobile assembly, being eliminated the external connections, except for those associated with the control chambers of the directional control valve.

The main scheme of the fertilization equipment is shown in fig. 8.

The mobile assembly, fig. 8-sect D-D consists of piston, membranes, outer and inner flanges, special screws for fixing the piston membranes.

Primary solution suction / discharge valve 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 suction nozzles of the primary solution and to the discharge nozzles of primary solution.

In the construction of the two-positions and four-orifices type directional control valve, the alternative with slide valve, with O-rings seal was chosen to allow the components to be executed in H8 / f7 tolerance fields, thus avoiding the extremely precise execution of the hydraulic directional control valve with classic slide valve, where the lost motions between the slide valve and the body are of the micron order. The constructive version of the directional control valve allows operation with irrigation water with a low level of filtration.

The seals have been designed and made with tightening as low as possible, so that the friction forces of the mobile elements are as small as possible.

The slide valve of the directional control valve has a positive coating, the switching is done without loss of pressure.

The control valve of the hydraulic directional control valve, fig. 8 sect. E-E are unblocking valves located in the water tank discharge holes in the control chambers operated in the pump body, to ensure hard closure and opening and to reduce the switching time of 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.

Depending on the position occupied by the slide valve of the directional control valve, fig. 7, the orifice P is connected with the orifices A or B, from which, through 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 with technological plugs.

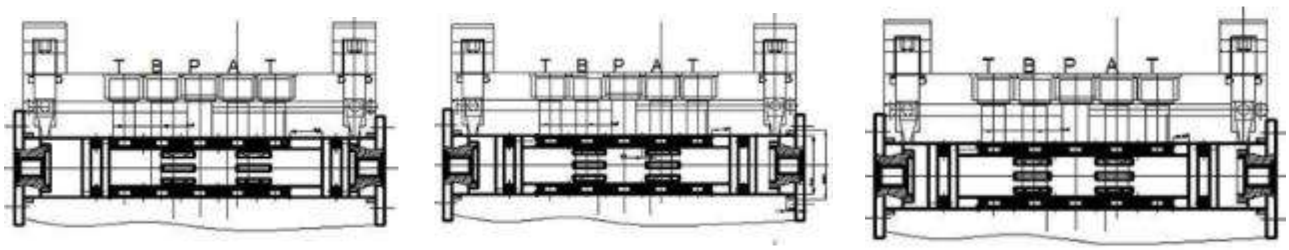

Fig. 7 - Positions of the slide valve of the directional control valve

The T-holes alternately drain the water from the drive chambers (A to T or B to T) during the withdrawal phase of the membrane assembly (reducing the volume of the drive chambers). The water discharged from the drive chambers is distributed to the plants through an assignment tube with dropper built-in.

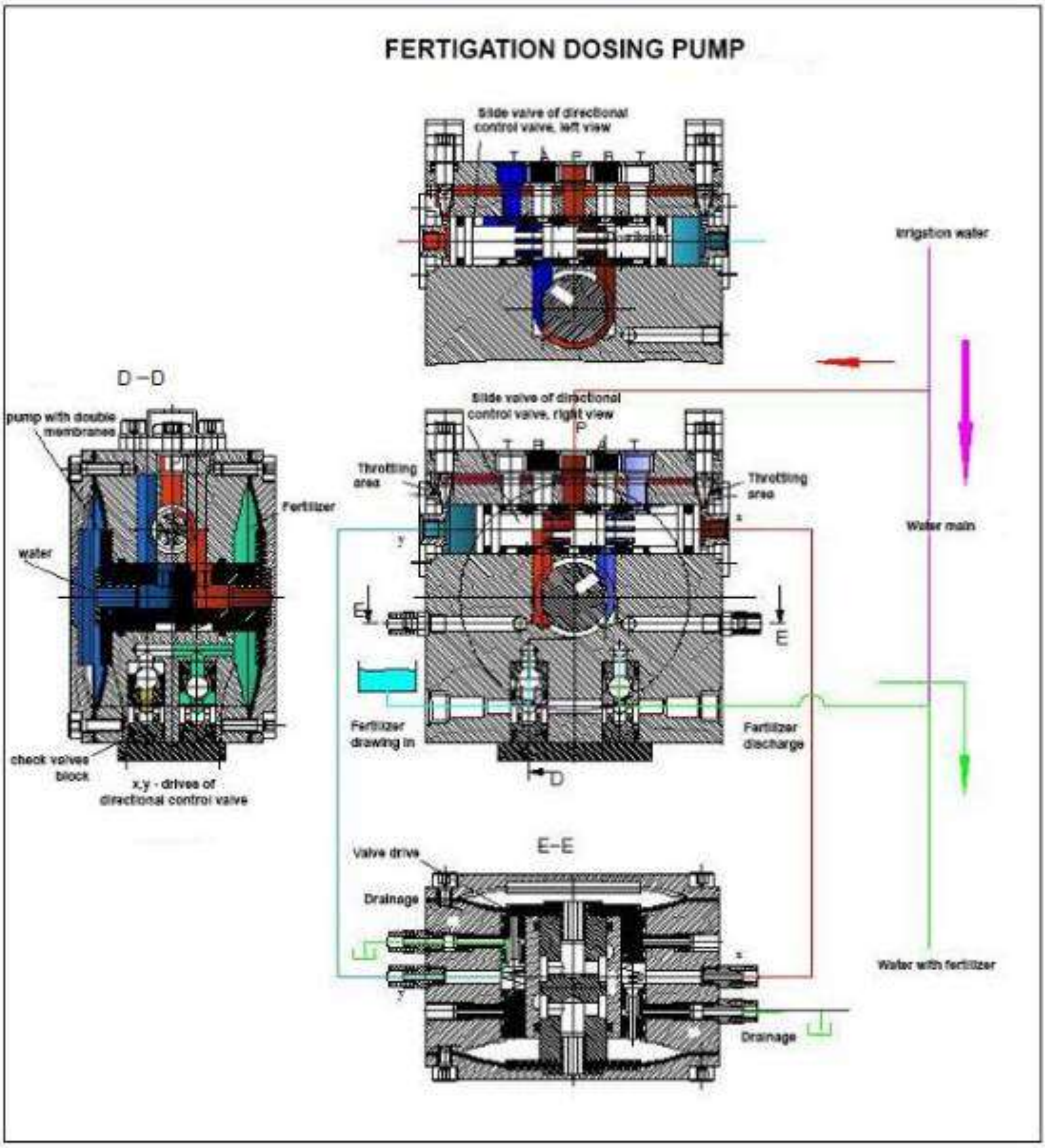

Fig. 8 - Scheme of principle of fertigation equipment

Also from the P port, the Ccs-Ccd control chamber of the hydraulic directional control valve are continuously supplied with pressurized water. The mobile assembly alternately operates through the internal flanges the unblocking valves, which shortly before reaching the end of the stroke, connect one of the control chambers to the atmosphere, causing the switching of the slide valve of the directional control valve from the control chamber under pressure to the pressure discharge chamber.

The mecano-hydraulic switching of the slide valve is made by means of two identical hydraulic circuits, controlled at the end of the mobile assembly, consisting of a throttle and a mechanically unblocking valve (see figure below). 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 is the left control pressure, Pcd is the right control pressure). If the two valves are closed, the pressure on the ends is equal to the water pressure (Pcs = Pcd) and the slide valve locks in position. If one of the valves is unlocked then the liquid behind the throttle is removed from the outside, the Pcs or Pcd pressure drops only on the throttle, different pressures are applied to the ends of the slide valve and then the slide valve moves in the direction of the lower pressure switching the directional control valve.

Thus, when the shaft with the membranes reaching the end of the stroke, the shaft plate reaches the end of the check valve to unlock it and the pressure switches the slide valve that changes the hydraulic connections to the membranes pump chambers, thus changing the direction of movement of the membranes shaft. After the shaft - membranes assembly moves backwards, the valve closes and locks the slide valve of the directional control valve in position. At the other end of the stroke the other valve is actuated, that changes the slide valve position commanding the movement in the opposite direction. The operation is repeated. Throttles regulate the fluid flow that fills the left and right control chambers of the slide valve, obtaining a work frequency adjustment.

The pressure in the control chambers of the directional control valve takes values between 0 and the pressure P from the plant according to the state of the unlocking valves, commanding the switching of the directional control valve. The check valves open by actuating the disk in the shaft membrane assembly, namely at the ends of the stroke.

The throttles, which regulate the flow of water that arrives into the control chambers, keep the slide valve of the directional control valve in an equilibrium position and dictate the frequency of the pump mobile assembly.

The pressurized water supply of the left drive chamber causes the mobile assembly to move to the right, with the following effects:

-discharging of the moving fluid from the right drive chamber;

-suction 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 to the discharge (in the supply pipe of the irrigation system), fig. 8.

The physical realization of the injection device - the construction variants I- III - is shown in Fig. 10 a, b, c.

Fig. 9 a - Metering pump for injection of primary solutions - constructional version I

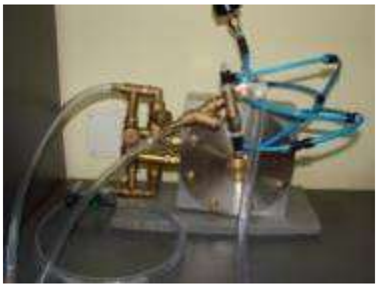

Fig. 9 b - Injection device construction variant II

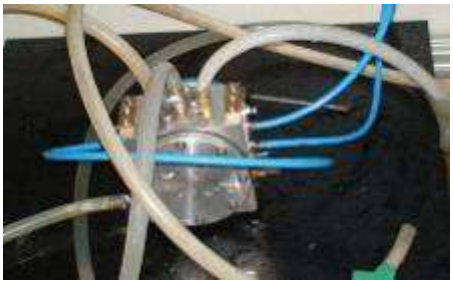

Fig. 9 c - Diaphragm double pump type injector with mechano-hydraulic control of the slide valve of the directional control valve

The fertilization equipment developed within the complex project Technologies for irrigation of agricultural crops in arid, semiarid and subhumid-dry climate, project number PN-III-P1-1.2-PCCDI-2017-0254, Contract no. 27PCCDI / 2018, within PNCDI III, will be designed for aggregate operation with drip, micro-sprinkler and underground irrigation installations. Critical parameters for the injection device of the fertigation equipment, which work in a dynamic regime, are the flows and pressures specific to the underground irrigation systems lower than those for drip and micro-sprinkler irrigation (*Blidaru et al, 1981*).

The drive part of the injection device, the differential piston type, will have to ensure the injection parameters (injected flows, injection pressures, primary solution concentrations) for the localized watering installations mentioned. The irrigation water used as a moving fluid and the primary solution will form the fertilizer solution in the body of the device, being injected into the irrigation water supply pipe without external moving fluid loss (www.dosatron.com).

Since conventional agricultural production systems have caused soil degradation, technologies about arrangement of land and crop rotation, work and fertilization systems, soil ameliorative works and crop protection systems have to be adapted to soil and water protection requirements, and in areas with soils more vulnerable to degradation (including sandy soils in arid, semiarid and subhumid- dry regions that are the subject of the project), soil conservation works are required (*Lal R., 2006*). In fact, the evolution of soils under irrigated regime is more complex and differs from that of other non-irrigated soils (*Paltineanu et al*, 2003), the application of irrigation and fertilization of crops gaining a special character in the sense of the phase recommendations (*Tiscovschi et al, 2013*).

RESULTS

Fertigation equipment was tested under laboratory conditions at IHP Bucharest, in the Environmental Protection Laboratory, on a stand designed to test apparatus and equipment that uses water under pressure as a working fluid.

The test stand, fig. 10, (*Sovaiala Gh., 2016*), provides hydraulic parameters (flow, pressure) necessary for the functioning of the fertilization equipment, simulating the irrigation plant with which it works in the aggregate, that consists 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.

Fig. 10- Testing stand of the fertigation equipment

The WILO ECONOMY CO-2 MHI 206 / ER-RBI-CALOR pumping group, equipped with two high-pressure horizontal, self-priming centrifugal pumps connected in parallel, provides a maximum flow of 10 m^3 / h and a maximum pressure of 6.7 bar.

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.

The injecting device is mounted in a bypass system on a hydraulic circuit parallel to the group discharge pipe, similar dimensionally and from the point of view of hydraulic parameters of the liquid transited with the main pipe in the drip or micro-sprinkler irrigation installations.

Connecting pipe of the injector device, fig. 11 a, b, includes connecting elements (nipples, sockets, reducing pieces, elbows) and elements that ensure the functionality, respectively adjustment and monitoring of the working parameters (taps, Y path filter, check valve, pressure gauges, pressure reducer with pressure gauge, flow meter).

Fig. 11 a, b - Injection device connection

The injection device is provided with the following connections, fig. 12: The P-pressure connection, from which the drive chambers and control chambers of the directional control valve are fed; T_{cm} - water exhaust connections in drive chambers; T_{cc} - water outlet connections in 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. With 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, fig. 13, and the primary solution is injected through the R_f connection. The circuit of the R_f connection is provided with a tap and pressure gauge to simulate the injection / measure the injection pressure value.

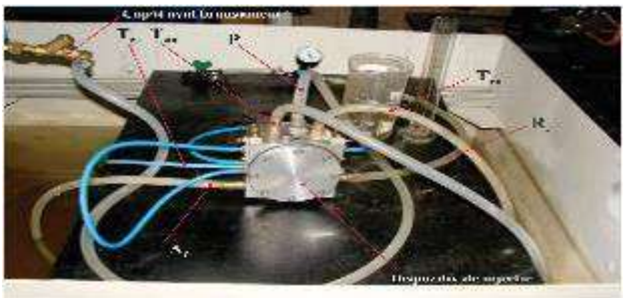

Fig. 12 - Attaching the injection device to the test stand

Fig. 13 - Recipient for the preparation of primary solutions; connections for suction-A_f / discharge-R_f of primary solution

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 the mixing vessel on a hydraulic circuit separated from the drive fluid supply circuit of the injection device; the injection pressure value, at which the device operates uniformly and ensures the required parameters, is adjusted from the valve mounted on the discharge hose and is measured with the manometer attached upstream of the tap.

The technical and functional parameters achieved by the injection device are highlighted in the tab.1.

Table 1

The technical and functional characteristics achieved with the injection device under laboratory conditions

Pressure 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

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) being 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 motor chambers and has values ranging from 3.4 to 1.5 bar;

5. To facilitate the injection process, a tap with slide valve (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 injection device was tested with a 0.2% primary solution prepared from the Magnisal chemical;

8. Equipment samples under operating conditions have validated the reliability of laboratory samples demonstrating the functionality and utility of the product.

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