# STUDIES REGARDING THE TECHNIQUE USED FOR APPLYING FERTIRRIGATION ON AGRICULTURAL CROPS

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**Abstract**

Fertirrigation, modern concept of agricultural technique, is the method by which fertilizing substances are distributed to plants simultaneously with irrigation water.
The main advantages of this method arise from the following aspects: it replaces the traditional system of administering chemical fertilizers, which implies the existence of complex machine systems, significant consumption of energy and labour, low coefficient of uniformity of distribution, removal from the crop of plants trampled by the wheels of machinery involved in this technology; it facilitates fast access of fertilizing substances to the plant root system, in convenient time, better valorification of them; studies previously carried out have found that in a classic system of fertilization in normal years in terms of rainfall plants capitalize about 65% of nutrients applied as fertilizer, while in years with drought they can only capitalize 40%; they avoid the phenomenon of lingering of chemical fertilizers to the soil surface (implicitly, losses of active substance through evaporation), long direct contact of them with the leaf system of plants; it allows very accurate dosing of nutrient solution components, depending on the nutritional requirements of plants as determined by chemical analysis of soil; technical solution adopted to develop the equipment for injection of fertilizing substance in irrigation water, in shape of a double membrane displacement pump, ensures proportionality of the injected flow with the flow inside the irrigation installation; the driving fluid that actuates the shaft of the pump, mounted in parallel with the main circuit of the irrigation installation, is represented by water taken from the supply pipe of this pump; overpressure required for the injection of nutrient solution in the same pipe is achieved by adopting the principle of difference in surface between driving chamber and injection chamber; linking between the technical elements of irrigation and the technical elements of fertirrigation, allows that, at the end of watering, when reaching the depth of penetration of water into the area of predominant development of plant root system, to administer all of the necessary plant nutrient solution, as determined in correlation with the state of growing of the crop.

**Key words**: fertirrigation, dosing pump, membranes

The equipments for injecting substances in the water used for irrigation are commonly volumetric pumps with piston or membrane, with simple or double effect.

The precise dosage of fertilizers is performed with volumetric pumps which provide proportionality of the injected flow with the water flow of the irrigation installation.

For administering liquid and solid chemical fertilizers, which are water soluble, INCDIF-ISPIF, subsidiary ICITID Băneasa Giurgiu and IHP Bucharest have designed and developed a pump with membranes and double effect, with mechanical prompt of the hydraulic directional control valve.

## MATERIAL AND METHOD

In agricultural practice four fertirrigation systems are used:

- ***continuous administering***: fertirrigation is performed with constant injection rates, from start till end of this process. Total quantity of fertilizers is continuously injected in the water within the irrigation installations;
- ***three-stage administering***: irrigation starts with no fertilizers administering; injection starts when the soil is wet and it ends before the end of the watering cycle, in order for fertilizers to be cleaned up from the component parts of the irrigation installation;
- ***proportional administering***: flow of the fertilizing solution is proportional to the water flow within the irrigation installation;
- ***quantitative administering***: nutrient solution is injected in calculated quantities on each irrigation plot.

**Description of the installation**

In the construction variant shown in *fig.1*, the installation of fertirrigarion comprises the equipment for injecting permanently the fertilizer in

the water used for irrigation (A), irrigation installation (B) with which the mix fertilizer and water is distributed to plants, the injection control device (C) which allows pressure and flow control and the annexes which make the connection between the fertilizer container, injection equipment and the irrigation installation (D).

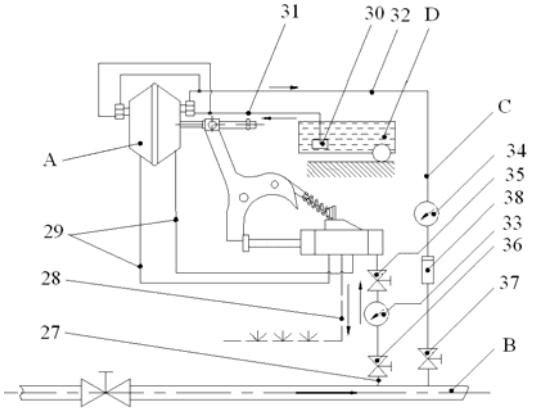


Figure1 **The fertirrigation installation**

**The injection equipment** (*fig. 2*), consists of a double pump with membranes (E) which converts the hydraulic energy produced by water into energy necessary for continuous injection of the fertilizer, the directional control valve (F) which sets the water circuit inside the pump and the mechanical prompt with spring (G) which actuates the slide of the directional control valve at the stroke end.

Novelty of this technical solution regarding the development of the injection equipment is represented by the fact that the driving fluid being used is precisely the water taken from the supply pipe of the irrigation installation; injection of the fertilizer in the same pipe is possible on the basis of the principle of difference between the surfaces that the membranes expose towards the two type of chambers (the driving chambers, respectively the injection ones). In order to increase efficiency of the pump, injection takes place downstream from the constructive parts of the irrigation installation that induce local losses of hydraulic load (shutters, bends).

The pump comprises an assembly of fix component parts, including a central disk (1) and the lateral lids (2) between which are fixed with nuts the tapered membranes (3).

The membranes are jointed by means of the piston (4), axis (5), disks (6), and bolt nut (7) which represent the mobile assembly of the pump.

The two membranes separate four chambers the outer ones with a role of hydraulic motor and the central with a role of a pump.

The holes **g** and **h** in the central disk provide reciprocated the fertilizer charge and discharge functions and the couplings **a** and **b**, mounted on the lateral lids, provide the supply/discharge of water in/from the pump driving chambers.

The axis is coupled with the mechanical prompt (G) by means of the rod (8) and the bolt nut (9).

The couplings **a** and **b** are hydraulically linked to the couplings **k** and **l** from directional control valve F.

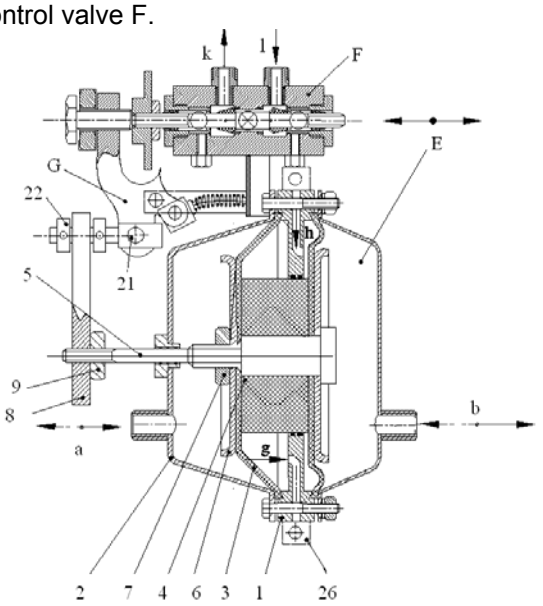


Figure 2 **Injection equipment**

The **directional control valve** (*fig. 3, fig. 4*) consists of a body (10), in which is sliding the axis (11) equipped with valves (12).

In the body of the directional control valve are mounted by pressing the central (13) and lateral valve seats (14), on which are placed alternatively the valves.

The tightness between the valve seats and body and respectively between the lateral seats and axis is made with sealing parts specific for fluid power systems.

The supply with water of the directional control valve is made by means of a coupling **m** and the water discharge by coupling **n**. The technological holes are covered with screws (15).

The axis of the directional control valve is provided at one end with a bush (16) through which is actuated by mechanical prompt **(G).**

The **mechanical prompt** (*fig. 2 and fig. 4*) includes the tipping spring (17) which puts into action the fork (18) by means of a bung jointed with a rotation coupling (19). The fork has at one end a screw which may be adjusted (20), which through the bush (16) sets into operation the axis (11), and the other end it has a coupling (21) (*fig.2*) through which the rod (8) placed between the limiters (22) is coupled to the pump axis (5). The oscillation of the fork (23) is made around an axis (24) (fig.4). The mechanical prompt is set on the body of the directional control valve with the profiles (25) and support (26).

The blocks of the valves (27), connected to the central chambers of the pump through the inlets **g** and **h**, provide the alternative injection with

fertilizer depending on the value of the pressure in the chambers.

The supply with water of the fertirrigation equipment (*fig.1*) is made through the supply circuit (28) between the irrigation installation and the coupling **m** of the hydraulic directional control valve and the discharge of the water from the pump driving chambers is made through the discharge circuit (29) connected to the coupling **n** of the distributor.

The hydraulic link of the directional control valve with the pump is made through two circuits (30) which connect the couplings **k** and **l** of the directional control valve with the couplings **a** and **b** of the pump.

The chemical fertilizer is aspired from a container provided with a filter (31) through the aspiration circuit (32), and the injection is made through the circuit (33).

The injection control device (C) comprises the manometers (34) and (35) and the taps (36), (37), (38).

The annex (**D**) comprises the fertilizer container, the one-way directional valve (39) and the couplings for connecting rapidly at the installation.

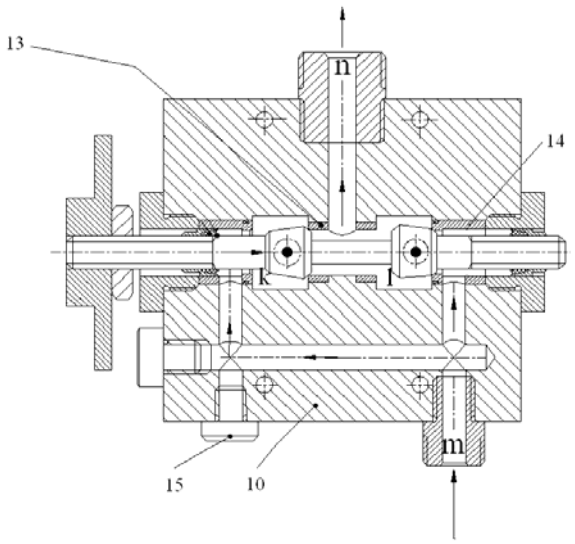


Figure 3 **Section through the hydraulic directional control valve with a horizontal plane**

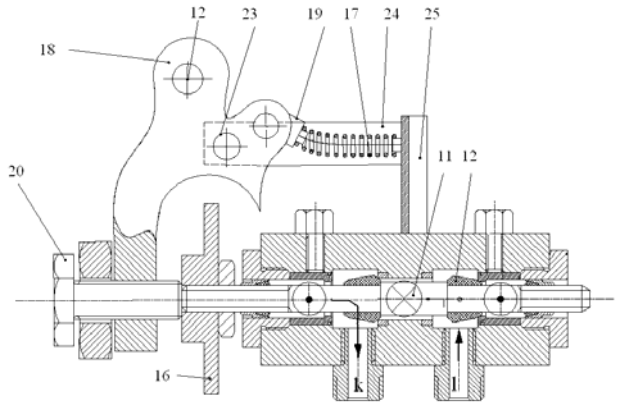


Figure 4 **Section through the hydraulic directional control valve equipped with mechanical prompt with a vertical plane**

**The way the installation works**

The fertirrigation installation with double pump works as follows: on the supply circuit of the irrigation installation (B) (*fig. 1*), are mounted in parallel the double pump with membranes (A) and the control device (C) and annex (D).

Through the supply circuit the water from the irrigation installation reaches the directional control valve and from there, depending on the position of the slide, to one of the driving chambers of the pump.

In the position in which is presented the directional control valve, the water enters on the exterior side of the left membrane by means of couplings k-a; on the opposite side of the membrane is compressed the chemical fertilizer existent in the inner chamber; by the displacement of the piston the water from the driving chambers is discharged by means of couplings b-l and the discharge circuit, and on the interior side of the right membrane is absorbed fertilizer from the container.

The axis (5) operates through the rod (8) and limiters (22) the mechanical prompt (G), which by the oscillation of the fork (18) sets into action axis (11), displacing it on the left; it is opened the discharge circuit (28) for the driving chamber from the left side and is performed the supply with fertilizer on the opposite side of the membrane. The piston (4), which fixes the central zone of the two membranes, slides to the left allowing the water flow to go to the right-side driving chamber. The fertilizer is supplied by means of coupling g, and the injection of fertilizer by coupling h.

For injecting fertilizer at a higher pressure than that from the irrigation installation pipe, when designing the pump it was taken into account the principle of surface difference so that the membranes on the sides which delimit injection chambers have the operational section smaller than the membrane sides which delimit the driving chambers.

The block of injection surfaces, *fig. 5*, comprises four disk valves, two chain valves for each injection chamber. The two lines corresponding to the injection chambers are linked in parallel, at the joints of the intake and outlet circuits.

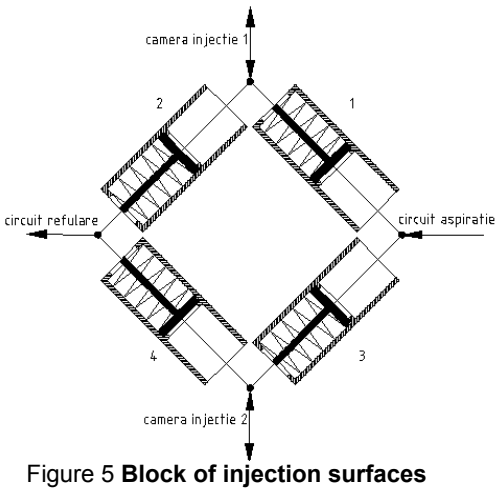


Figure 5 **Block of injection surfaces**

When inside the injection chamber is produced a vacuum, valve 1 opens, allowing access in the chamber for fertilizing solution, disk of valve 2 being drawn off and placed on the seat valve, and thus breaking the outlet circuit on the line of valves 1 and 2.

Simultaneously in the injection chamber 2 is created over-pressure, the disk of valve 3 is placed on the seat valve closing the supply circuit and valve 4 opens, causing repression of the fertilizing substance into the main circuit of the irrigation installation.

Depending on the position that membranes occupy inside the pump body, function of the two valve lines alternates, ensuring continuous injection of fertilizer.

## RESULTS AND DISCUSSIONS

When applying fertilizing substances by the method of fertirrigation, it is very important for the users to know the main issues regarding the compatibility of fertilizers from which those substances are prepared, knowing that certain chemicals should not be mixed in the tank, and others not injected into the system simultaneously; *Table 1* shows compatibility of some fertilizers.

The technical and functional parameters of the dosage pump are shown in table 2 and were determined in lab conditions in the hydraulic hall of ICITID Baneasa Giurgiu.

The minimum pressure from which the pump starts to work is 0.5 bar and the max is of 8 bar.

The eficiency of the injection, regarded as a relation between the amount of injected fertilizer ($v_{inj}$) and the water volume consumed for the operation of the pump ($v_m$), $\frac{v_{inj}}{v_m} \cdot 100$, (%), is determined by the hydraulic parameters of the water from the driving chambers and the concentration of the fertilizing solution.

p - water pressure in the watering installation, bar;

f - frequency of the pump axis, double strokes/ min;

$Q_{inst}$ - the installation flow l/h; l/min;

$q_{inj}$ - injected flow, l/min;

r - concentration of the fertilizer in the water (%)

For a fast estimation of the amount of fertilizer injected depending on the working pressure (which determines the axis frequency) was elaborated the characteristic of the dosing pump, shown in *fig.6*.

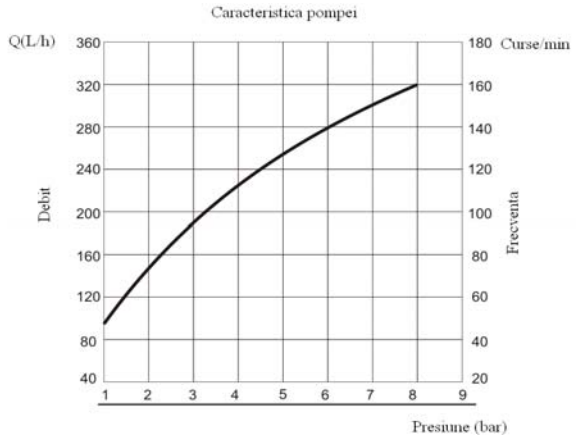


Figure 6 **Characteristic of the dosing pump**

Table 1

**Compatibility of the chemical fertilizers**

| Fertilizer | Ammonium sulphate | Calcium Azotate | sodium azotate | Potassium azotate | Potassium suplphate | Magnesium sulphate |
|---|---|---|---|---|---|---|
| Ammonium sulphate | - | no | yes | yes | yes | yes |
| Calcium azotate | no | - | yes | yes | no | no |
| Potassium azotate | yes | yes | yes | - | yes | yes |
| Potassium sulphate | yes | no | yes | yes | - | yes |

Table 2

**Technical functional parameters of the dosing pump**

| p (bar) | $Q_{inst}$ (l/h) / (l/min) | f (cd/min) | $q_{inj}$ (l/min) | r (%) |
|---|---|---|---|---|
| 2.0 | 384 6.4 | 70 | 2.2 | 0.19 |
| 2.5 | 624 10.5 | 94 | 2.8 | 0.29 |
| 3.0 | 798 13.2 | 112 | 3.4 | 0.42 |
| 3.5 | 960 16.0 | 120 | 3.5 | 0.56 |
| 4.0 | 1140 19.0 | 170 | 4.1 | 1.06 |
| 4.5 | 1200 20.0 | 192 | 4.5 | 0.36 |

Pompa poate injecta cantităţi diferite de soluţie la aceeaşi presiune, prin modificarea debitului şi implicit a frecvenţei axului acesteia, cu ajutorul vanei existente pe circuitul de alimentare cu apă.

While testing the performances of the dosage pump it was found that the injected flow remains constant at small variation of pressure inside the irrigation installation ensuring an optimum uniformity of the fertilizer at sprinkler. The pump may inject various amounts of solution at the same pressure by changing flow and thus the frequence of its axis by means of the shutter placed on the water supply circuit.

Tests in conditions of experimental poligon upon the fertirrigation equipment were performed in the lab of the institute of horticulture research from Bucharest-Berceni, at the operation on a sprinkle watering installation.

Fertirrigation was applied on tomatoes and cucumbers, which require irrigation rates of 4000-7000 $m^3$/ha, depending on the soil texture.

For a crop of cucumbers, irrigated programmingly on vegetation months with the classic irrigation system (sprinkle and furrows) the rates are as follows: VII: 1000-1200 $m^3$/ha; VIII: 2500-3000 $m^3$/ha; IX: 1500-2000 $m^3$/ha; X: 500-900 $m^3$/ha. The watering rates are ranging between 200-400 $m^3$/ha.

In the case of sprinkling watering with a simultaneous administering of fertilizers (fertirrigation) the rates are 100-200 $m^3$/ha.

The fertirrigation equipment was mounted in parallel with the supply circuit of the sprinkling watering installation, covering an experimental surface of 100 $m^2$, the cucumber crop, hybrid h 350, which had a period of vegetation of 106 days (15.VII-1.XI).

The watering assembly comprised a container of 60 l in which was prepared the mother fertilizing solution, the dosing pump and 8 pipes with sprinklers for distributing the mix irrigation water – fertilizing solution to the plants.

After making periodical soil tests, were determined the following doses of fertilizers adminsistered on phases: 15-30 VII: 100 kg/ha ammonium azotate; 1-30 VIII: 100 kg/ha potassium sulphate and 70 kg/ha ammonium azotate; 1-30.IX: 100 kg/ha potassium sulphate and 80 kg/ha ammonium azotate; 1-31.X: 50 kg/ha potassium sulphate and 50 kg/ha ammonium azotate.

The concentration of fertilizing solution is usually between 1-2%. For a good protection of the plants and soil was found that values below 1% are optimal. Values in the range of 0.2-0.5% ensure the pump operation with high efficiency.

At each applying process was checked the uniformity of distribution of the fertilizer by controlling the concentration of solution at the sprinkler, by means of a conduct meter. Samples were taken from 6 points of the delivery pipes placed at distances of 2 m, 5 m, 15 m, 20 m and 30 m from the injected area.

## CONCLUSIONS

Unlike the classic technological agricultural processes, where crop fertilizing and irrigation are different sequences, fertirrigation is the method through which the fertilizing substances are distributed to the plants simoultaneously with the irrigation water, thus leading to significant energy and labour savings, also to significant increments in production.

Level of capitalizing the active substances from fertilizers applied increases by eliminating losses due to evaporation and facilitating their fast access to the plant root system.

This method allows an extremely precise dosage of fertilizers to prepare nutrient solutions from, providing a high coefficient of uniformity of distribution.

It eliminates the phenomenon of lingering of chemical fertilizers to the soil surface, long direct contact of them with the plant leaf system.

Novelty of the technical solution taken up while developing the injection equipment is represented by the fact that the driving fluid being used is precisely the water taken from the supply pipe of the irrigation installation; injection of the fertilizer in the same pipe is based on the principle of difference between the surfaces that the membranes expose towards the two type of chambers (the driving chambers, respectively the injection ones).

The technical solution adopted to develop the equipment for injection of fertilizing substance in irrigation water, in shape of a double membrane displacement pump, ensures proportionality of the injected flow with the flow inside the irrigation installation.

Linking between the technical elements of irrigation and the technical elements of fertirrigation, allows that, at the end of watering, when reaching the depth of penetration of water into the area of predominant development of plant root system, to administer all of the necessary plant nutrient solution, as determined in correlation with the state of vegetation of the crop.

The dosing pump described can operate in the pressure range 0.5 – 8 bar ; value of the injection flows developed (2.2-4.5 l/min) for the pressure range 2-4.5 bar pleads for the use of this

membrane dosing pump for work in protected areas, as part of units comprising also drip irrigation installations.

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