
HYDRAULIC ANALYSIS OF DRIP LATERALS WITH INSIDE WELDED PRESSURE COMPENSATING DRIPPERS

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Abstract : Lately, the drip irrigation systems built with pressure compensating (PC) drippers (emitters) inside welded in the drip laterals, find more and more application in Bulgaria, Turkey, Greece and other countries having well-developed irrigation-based agriculture, especially where the ground is not flat but rather is of hilly nature. The main advantage of these systems is the provision of uniform flow rate along the laterals and batteries (blocks) in the whole drip systems irrespectively of the alteration of the operating pressure, and, besides, this allows long laterals to be designed. The recommended operating pressure starts from 0.5 – 1.0 atm and reaches 4 – 5 atm. Reaching equal drip flow rate in these systems is realized thanks to an elastic membrane with fixed strength parameters, located at the outlet of the nozzles in a specially arranged bed (nest) for this purpose. The advertisement of the applications of those nozzles in the company catalogs is very intensive but is it true for all types of pressure compensating drippers? In laboratory conditions we carried out hydraulic tests of drip laterals with inside welded pressure compensating drippers, cylinder type, in order to find out the head losses along the drip lateral. The laterals were with a nominal outer diameter 16 mm, inner diameter 13.8 mm, thickness of the wall 1.1 mm and flow rate 2.1 l/h, at intervals of 33 cm between the drippers, with lengths 60, 80 and 100 m. The results showed considerable head losses, with great deviations from the ones obtained by analytic way through formulas. For example, in a 100 m long lateral, the losses reach 60 to 75% of the applied operating pressure at the beginning of the lateral. Some specific data from the tests – in case of inlet pressure of 18, 20 and 25 m, the head losses are respectively 12, 14 and 17 m which means that in case of flat ground and such with back slope it is almost impossible to realize a length of 100 m and more of the lateral. All drippers will not operate at the horizontal part of the curve “*pressure-flow rate*” but at the transitional part of this curve. It follows from this that irrespectively of the pressure compensating action of those nozzles, this type of laterals will hardly find application in real conditions in the design of an engineering project for drip irrigation respecting the admissible coefficients of the distribution uniformity of the irrigation water. The same is valid for the other tested laterals as well. Sometimes, laying conventional type of laterals is more appropriate and brings better results. All this is due to the considerable minor head losses in those nozzles because of the sizable constriction of the cross section of the laterals by the nest (bed) of the membrane.

Keywords: drippers, pressure compensating emitters, head losses along drip laterals, minor head losses, elastic membrane

1. INTRODUCTION

Lately, the drip irrigation systems find more and more application, taking into account the limited water resources, on one hand, and on the other hand, the advantages of this type of irrigation – economy of irrigation water and relatively high performance. In Bulgaria and in other places, especially in the arid (dry) zones drip irrigation is used for corn, sunflower, vegetables, herbs and other earthed-up crops instead of the well-known and often used technologies in the past, like rain-like and gravity irrigation. In case of more steep terrain, the necessity of irrigation batteries of large area, and when there is a lack of geodetic surveys and engineering project, drip laterals with inside-welded pressure compensating drippers have been used. The advertisement of the applications of those irrigation laterals in the company sites and catalogs is very intensive but is it true for all types of pressure compensating drippers? In laboratory conditions we carried out hydraulic tests of drip laterals with inside-welded pressure compensating drippers, cylinder type, in order to find out the head losses along the drip lateral.

2. PRINCIPLE OF REGULATION OF THE DRIPPERS' FLOW RATE

Achieving equal flow rate along the length of the laterals under varying operational pressure is realized thanks to an elastic diaphragm made usually of elastic plastic. This diaphragm is fixed before the outlet of the drippers, in a special bed (nest), Fig. 1.

This is valid for almost all types of drip laterals with built-in cylindrical self-regulating nozzles. The elastic diaphragm should possess strictly determinate strength parameters which must not alter with the time, i.e. should not “age”. At the one side of the diaphragm is the outlet reached by the water after flowing in a special labyrinth canal. At the other side is the inlet through which water enters the dripper, directly bending the fixed diaphragm, thereby creating minor resistances at the entrance of the outlet, and, respectively, reduction of the flow rate from the drippers.

In view of the high requirements for distribution uniformity of the water in the drip irrigation systems - 90% for ground slope of up to 5 %, and 80 % for ground slope higher than 5 %, it should be noted that some companies offering drip irrigation systems present in their catalogs incorrect characteristics “*flow rate – pressure*” – with strictly horizontal lines in the operating zone. With other companies this is not so – the operating part of the characteristics is not strictly horizontal but is slightly undulatory, which helps in the design of a better engineering project for drip irrigation.

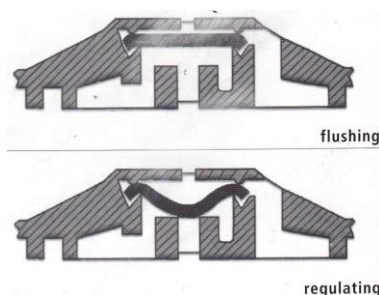


Fig. 1. Elastic diaphragm flow control scheme of pressure compensating drippers [5]

3. RESULTS OF THE HYDRAULIC TEST OF DRIP LATERALS WITH INSIDE-WELDED CYLINDRICAL PRESSURE COMPENSATING NOZZLES

3.1. Scheme of the experimental setup

In order to find the head losses along the laterals, a test site was arranged in the laboratory (Fig. 2 and Fig. 3), where for maintaining a steady lower water level (8) to the operating pump (10) a reservoir with a volume of 3 m³ (11) was used, which was fed by water from the mains (9). In order for the pump to work, a bypass connection (7) to the reservoir was designed.

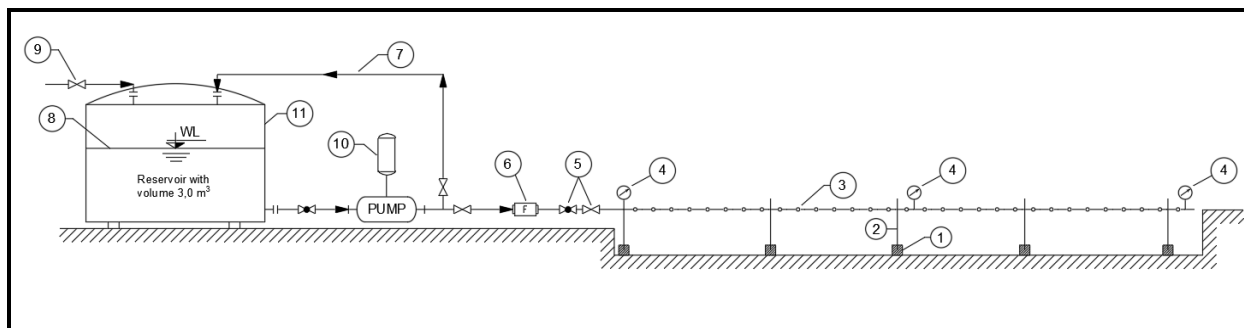


Fig. 2. Experimental setup for testing the laterals for drip irrigation

1 – concrete cube; 2 – steel rods; 3 – lateral on steel wire; 4 – pressure gauge; 5 – valves for regulation of inlet pressure; 6 – screen filters; 7 – by-pass between pump and reservoir; 8 – water level in reservoir; 9 – water supply; 10 – pump; 11 – reservoir with volume 3,0 m³.



Fig. 3. By-pass between pump and reservoir

3.2. Results of hydraulic tests to determine head losses along the lateral length. The test included drip laterals with circular cross-section, with nominal outer diameter 16 mm, internal diameter 13,8 mm, wall thickness 1,1 mm and inside-welded cylindrical pressure compensating drippers of the company „Irritec”, Italy – with drippers „MULTIBAR PC” with nominal flow rate 2,1 l/h, $CV \leq 3 \%$, and emitter spacing 33 cm. Laterals, 60, 80 and 100 m long were tested, and the results obtained for lengths of 100 m are presented in a table (Table 1) and graphically on Fig. 4.

Table 1. Results of hydraulic tests to determinate head losses along the lateral length with 16 mm diameter for drip irrigation with cylindrical pressure compensating drippers, $L = 100$ m

Inlet Pressure H_{in} m	Distance from beginning, m							Δh_f^{tests}	$\frac{\Delta h_f^{tests}}{H_{in}}$	$\Delta h_f^{calcul.}$	$1 - \frac{\Delta h_f^{calcul.}}{\Delta h_f^{tests}}$	$\frac{\Delta h_f^{tests}}{\Delta h_f^{tests}}_{f, L=50\%}$
	20	30	40	50	60	80	100	m	%	m	%	%
1	2	3	4	5	6	7	8	9	10	11	12	13
6,0	3,8	2,9	2,4	2,0	1,9	1,6	1,5	4,5	75%	NA	NA	89%
8,0	5,0	3,9	3,3	2,8	2,5	2,1	2,0	6,1	76%	NA	NA	87%
10,0	6,3	4,9	4,1	3,6	3,2	2,7	2,6	7,4	74%	NA	NA	86%
12,0	7,5	5,9	5,0	4,3	3,8	3,3	3,2	8,8	73%	NA	NA	88%
14,0	8,8	6,9	5,8	5,0	4,4	3,9	3,8	10,3	73%	5,72	44%	88%
16,0	10,3	8,0	6,7	5,8	5,2	4,6	4,4	11,6	73%	5,87	49%	88%
18,0	11,6	9,1	7,6	6,6	5,9	5,3	5,1	12,9	72%	5,87	54%	88%
20,0	13,1	10,3	8,6	7,5	6,7	6,0	5,8	14,3	71%	5,92	58%	88%
25,0	16,6	13,4	11,4	10,0	9,1	8,2	8,0	17,0	68%	6,07	64%	88%
30,0	20,7	17,1	14,8	13,2	12,1	10,8	10,6	19,4	65%	6,12	68%	87%
35,0	26,6	22,8	20,2	18,6	17,5	16,3	16,0	19,0	54%	5,99	68%	87%
40,0	31,5	28,1	25,7	24,2	23,1	22,0	21,7	18,3	46%	5,97	67%	87%

Note: $\Delta h_f^{calcul.}$ is calculating using Darcy–Weisbach equation with Flow Rate which responses to the pressure in the middle of the lateral length. Local head losses are assumed 15% from friction loss, as described in [2]

NA – Data is Not Available.

Columns description: 1 – Inlet Pressure; 2÷8 – pressure distribution along lateral length; 9 – total head losses from tests; 10 – the part of the total energy which is lost from head losses; 11 – calculating head losses using Darcy–Weisbach equation; 12 – the deviation of the calculated head losses from that of the tests; 13 – the part of total head losses which are realized from the beginning to the middle of the lateral length.

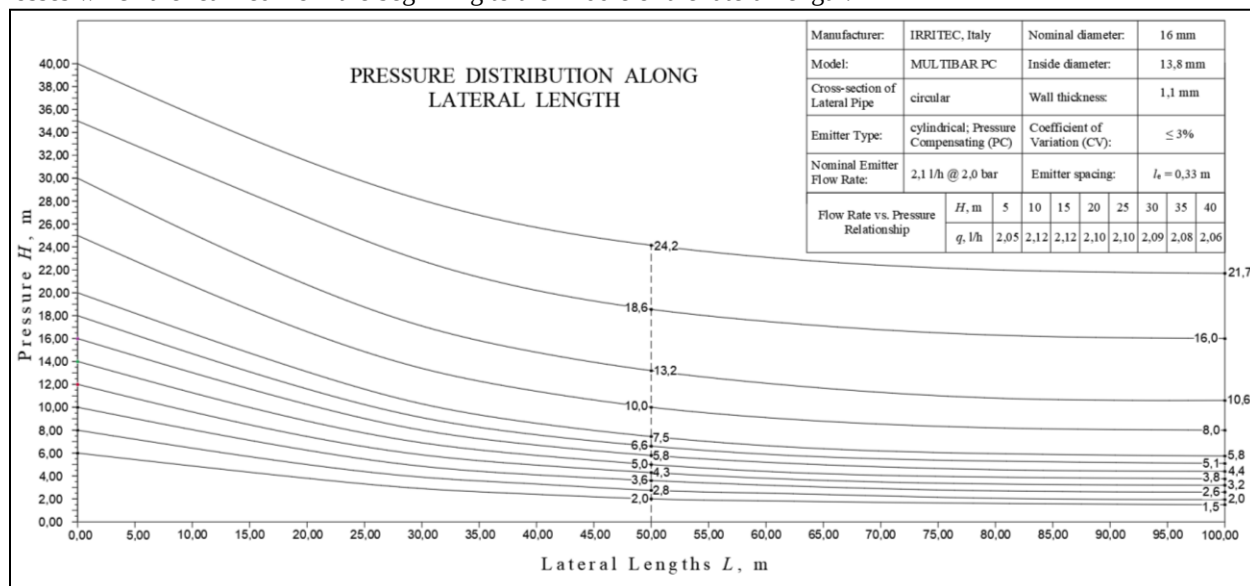


Fig. 4. Results of hydraulic tests to determine head losses along the lateral length with 16 mm diameter for drip irrigation with cylindrical pressure compensating (PC) drippers at 33 cm spacing

3.3. Results of hydraulic tests to determine relationship Flow Rate vs. Pressure of drippers “MULTIBAR PC” with nominal flow rate 2,1 l/h @ 2,0 bar. The tests involved a stand, distribution box type (Fig. 5), where all tested nozzles operate under one and the same pressure, switch on and off simultaneously during the tests.



Fig. 5. Experimental setup for determination of flow rate vs. pressure relationship of drippers

The results obtained are presented graphically on Fig. 6.

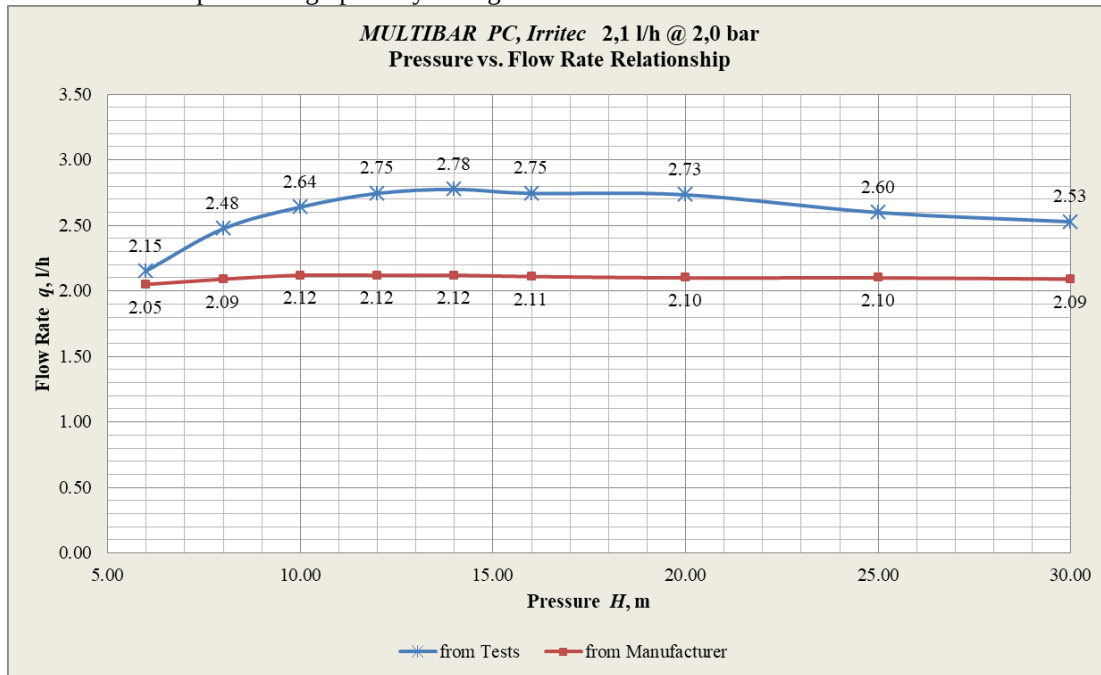


Fig. 6. Results of hydraulic tests for relationship Pressure vs. Flow Rate of drippers “MULTIBAR PC” with nominal flow rate 2,1 l/h @ 2,0 bar.

4. HYDRAULIC ANALYSIS OF THE RESULTS OBTAINED

4.1. Of the head losses along the drip laterals

Data obtained for the pressure variation along the length of the drip laterals differ considerably from the ones calculated analytically (columns 9 and 11 on Table 1), and this difference grows with the increase of the operating pressure at the beginning of the lateral (H_{in}), reaching 68 % for head of 30 – 40 m in the lateral. Besides, the obtained absolute values for head losses in the whole lateral (column 9) are very high and make it almost impossible the design of drip irrigation systems with these laterals on terrains with back (negative) slope ($i_{ter} < 0$). The percentage of the absolute head losses against the inlet pressure H_{in} varies from 75 to 46 % (column 10) under inlet pressure varying from 40 to 8 m. The results from the tests for shorter lateral lengths are similar. Cases for negative terrain slopes are frequently met, and it is imposed the drip laterals to be located over those back slopes in order to diminish the investment costs as well as energy costs. Besides, in case of flat ground and terrains with a small positive slope ($i_{ter} > 0$) these high absolute values of head loss restrict strongly the length of drip laterals and the size of the irrigation batteries especially in the zone of operation with heads less than 25 m, which raises the cost of the project and compromises the well-considered idea for drip laterals with pressure compensating drippers. In some cases, using a conventional (non-pressure compensating) type of emitters is more reasonable and brings better results.

4.2. Of the relationship “flow rate–pressure” of the pressure compensating drippers. Data from the tests indicate relatively very large deviation of the values of the flow rate from those in the catalogs of these nozzles. With the raise of the pressure these deviations grow and reach 23 % for head of 20 m, while for head of 30 m the deviation reaches 17 %, which indicates that if a project is based on the catalog data for these drippers, unreal working parameters for the drip irrigation system will be obtained, and thence the respective associated operational consequences will occur. In this case, the compensating action of the elastic diaphragm cannot be disputed.

5. Main conclusions and recommendations. On the basis of the above mentioned, the following conclusions and recommendations could be drawn up:

- The head losses along the drip laterals with inside-welded cylindrical pressure compensating drippers, as a relative and absolute value, are much greater and considerably differ from the analytically calculated ones, which compromises to a great extent the auto-compensating actions of these nozzles and make them hardly

applicable for terrains with a negative slope, and also flat terrains and such with comparatively small positive slope.

- The preparation of engineering projects for drip irrigation with these laterals and drippers should be in some cases pursued with preliminary experimental hydraulic tests in order to find the actual working parameters.
- For the improvement of the hydraulic characteristics of this type of pressure compensating drippers it will be necessary in the future to consider the avoidance of such a huge membrane construction which hinders the flow of water in the drip laterals.

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