CORRECTION FACTOR FOR FRICTION HEAD LOSS THROUGH LATERAL AND MANIFOLD

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Abstract

The use of drip and sprinkler irrigation systems is increasing rapidly. Both offer not only excellent control of water but also high efficiency in the application of water directly to the root zone. Comparing with other traditional methods, both offer significant reduction in the water consumption. In both types, the system consists of main line, submain, manifold and laterals. The cost of lateral and manifold pipelines may cost 30% to 40% of the total pipeline cost. Both pipelines are provided with several outlets. The designer assumes the pipe of constant diameter and constant discharge. The assumption leads to a percentage of error in the calculation of friction head loss. The assessment of actual friction head loss requires an accurate estimate of correction factor. The paper presents a new proposed correction factor formula which can be used in the estimation of friction head loss through either laterals or manifold of constant diameter and varying velocity. The new formula is compared with other published formulae. Moreover, the paper presents a unique correction factor equation which can be used in the estimation of friction head loss through either lateral or manifold of varying diameter and constant velocity, 1.0 m/s. Lateral or manifold of varying diameter and of constant velocity is compared with that of constant diameter and varying velocity. A "relative saving" is defined. A relationship of "relative saving" is derived and a unique formula is presented to relate the relative saving to the number of outlets. It is shown that the "relative saving" is increasing as the number of outlets increases.

Keywords: Sprinkler and drip irrigation systems, Lateral, manifold, correction factor, relative saving.

INTRODUCTION

Lateral and manifold are hydraulically similar. Each is provided with several outlets. In lateral, outlets are located at dripper locations, while in manifold; outlets are located at lateral locations. In drip irrigation, outlets on both laterals as well as manifold are almost at the same spacing which are the spacing of trees. In sprinkler irrigation, outlets on laterals and manifold may be also assumed to be at the same spacing which are the spacing of sprinklers. Generally, the spacing of sprinklers is longer than the spacing of trees. Therefore, in drip irrigation, the lateral and manifold may be designed of constant pipe diameter. In the calculation of friction head loss, designers assume constant discharge and constant diameter. The resulted head loss has a percentage of error. It may be corrected by considering a correction factor, F_1. However, in sprinkler irrigation, lateral and manifold may be designed of varying pipe diameter and constant velocity. The resulted head loss due to the use of constant discharge and constant diameter may be corrected by considering a different correction factor, F_2. Several papers presented the first correction factor, F_1, however, the second correction factor, F_2, is presented herein as a new concept.

The paper, herein, presents two alternative design methods, design (1) of constant diameter and varying velocity, while, design (2) of varying diameter and constant velocity. Two criterions are included in the comparison between design (1) and design (2). The first is the head loss and the second is the pipeline cost. Therefore, the paper also presents a definition called "relative saving". It is the ratio between the cost of pipeline of design (2) and the cost of pipeline of design (1). A new relationship is derived to calculate the relative saving as a function of the number of outlets provided by either lateral or manifold.

Review of Correction Factor Equations

To estimate the correction factor, F_1, Oron and Walker [1] gave the following equation:

$$F_1 = 0.63837\ n^{-1.8916} + 0.35929 \qquad (1)$$

where F_1 is the correction factor and n is the number of outlets on a given pipe. Values of F_1 are given in Table (2). Howell and Hiler [2] gave the chart, shown in Fig. 1, to determine the correction factor, F_1, versus the outlet umbers. For the same purpose, Christiansen [3] gave the correction coefficient, F_1, for multiple-outlet pipelines as:

$$F_1 = (b+1)^{-1} + (2n)^{-1} + (b-1)^{0.5}/(6n^2) \qquad (2)$$

where b is the exponent of velocity or flow in the head loss equation and n = outlets number.

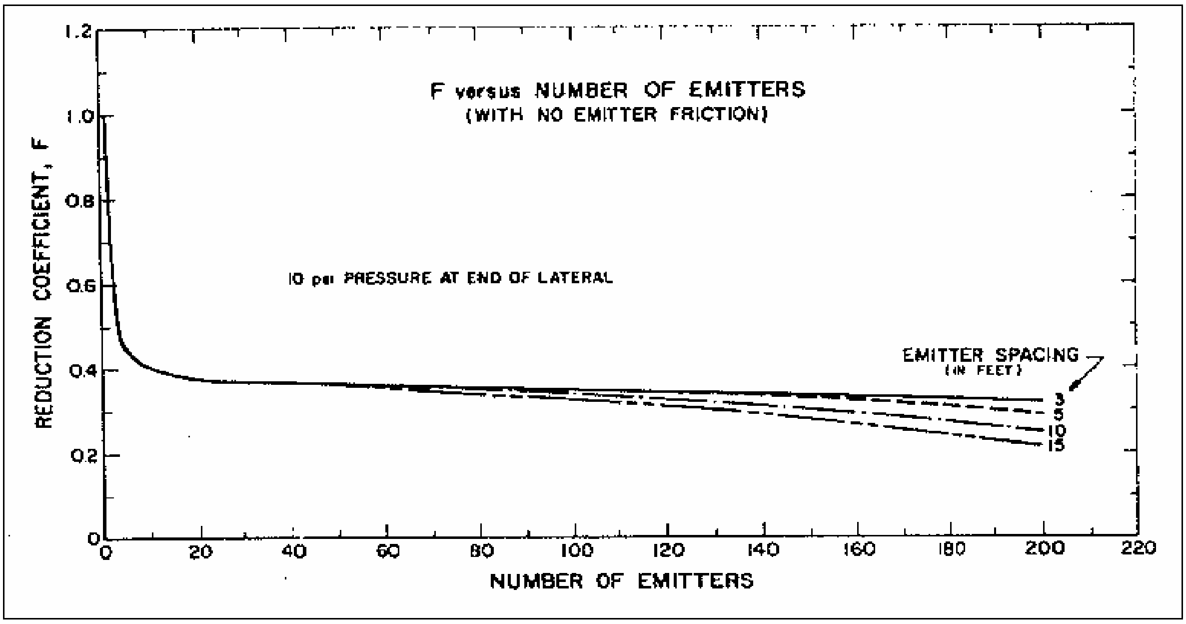

Fig. (1) Correction factor, F_1, by Howell and Hiler, (1974)

1- Estimation of Pipe Diameter

The internal area of pipe, A, is function of the passing discharge and velocity of flow.

$$A = Q / V = \pi * D^2/4 \tag{3}$$

where D is the inner diameter of pipe, So, for certain discharge and velocity, the inner diameter is given by:

$$D = C_1 (Q/V)^{0.5} \tag{4}$$

If the velocity is assumed to be constant = 1.0 m/s, the inner diameter is given by:

$$D = C_1 (Q)^{0.5} \tag{5}$$

where

$$C_1 = (4 / \pi)^{0.5} = 1.128 \tag{6}$$

2- ESTIMATION OF FRICTION HEAD LOSS

2-1 Hazen-Williams Equation

Hazen-Williams equation is widely used in the calculation of friction head loss through different kind of pipes. It can be written as:

$$h_f = 10.77 * L * (Q/C_{HW})^{1.852} * (D)^{-4.865} \tag{7}$$

where,

h_f = friction head loss in meter
L = length of pipeline in meter
Q = discharge in m^3/sec
C_{HW} = Hazen - Williams Coefficient
D = internal diameter of pipe in meter

For PVC pipes, the Coefficient is assumed to be, C_{HW} = 140.

Alternatively, the friction head loss given by Hazen Williams may take the form:

$$h_f = C_2\,[Q]^{C3}\,[D]^{C4}\,L \tag{8}$$

If velocity of flow is assumed to be 1.0 m/s and D is substituted from equation (5), equation (8) may take the form:

$$h_f = C_2\,(C_1)^{C4}(Q)^{C3+0.5C4}\,L \tag{9}$$

Simplification of equation (9) leads to the form:

$$h_f = C_5{*}(Q)^{C6}\,L \tag{10}$$

where values of coefficients, C_1, C_2, C_3, C_4, C_5, C_6 are given in table (1).

Table (1) Values of coefficients used in Simplifying Hazen-Williams equation

Coefficient	C_2	C_3	C_4	$C_5 = C_2\,(C_1)^{c4}$	$C_6 = C_3+0.5C_4$
value	$10.77\,(140)^{-1.852}$ = 0.00114	1.852	- 4.865	= 0.000634	-0.58

2-2 Darcy-Weisbach Equation

$$h_f = f\,(L/d)\,(V)^2/(2g) \tag{11}$$
$$h_f = C_7\,(Q)^2(D^{-5})L \tag{12}$$

where

$$C_7 = [(8\,f/(\pi^2{*}g)]$$

If velocity of flow is assumed to be 1.0 m/s and D is substituted from equation (5), equation (12) may take the form:

$$h_f = C_7\,(C_1)^{-5}\,(Q)^{-0.5}\,L \tag{13}$$

3- PROPOSED CORRECTION FACTORS

3-1 Correction Factor for Lateral or Manifold of Constant Diameter and Varying Velocity

Constant pipe diameter is suitable for the design of both lateral and manifold in drip irrigation, where, spacing of outlets is relatively small and discharge is small. Figure (2) shows longitudinal section through lateral holding 4 outlets. On the other hand, Figure (3) shows longitudinal section through manifold holding 4 laterals. Both are used in the derivation of correction factor, F_1. First outlet is assumed to be after full spacing, S.

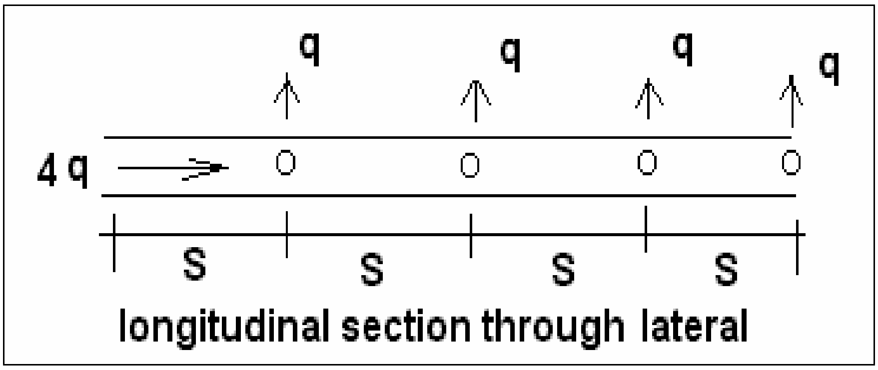

Fig. (2) Lateral of constant diameter and varying velocity holds 4 outlets; sprinklers or drippers

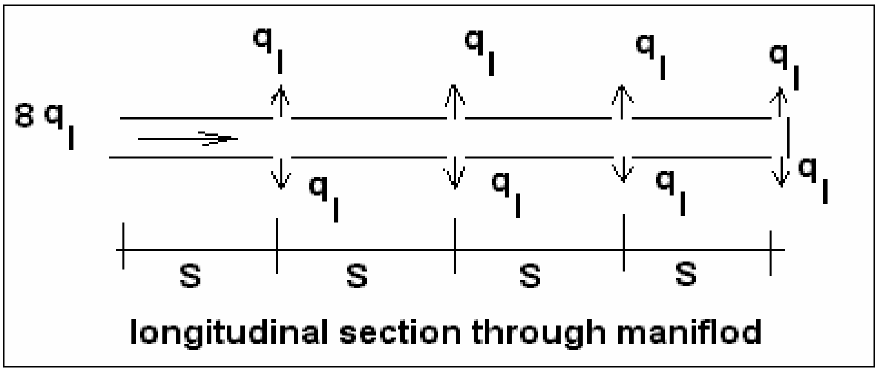

Fig.(3) Manifold of constant diameter and varying velocity holds 4 laterals at each side

3-1-1 Case of Lateral Pipe

The use of Hazen-Williams simple equation (8) leads to the following:

Assumed friction head loss through lateral line = $C_2\,(4q)^{C3}\,D^{C4}\,(4S)$ (14)

Corrected friction head loss through lateral line = $F_1\,C_2\,(4q)^{C3}\,D^{C4}\,(4S)$ (15)

Actual friction head loss through lateral line =

$C_2\,(4q)^{C3}\,D^{C4}\,(S)+C_2\,(3q)^{C3}\,D^{C4}\,(S)+C_2\,(2q)^{C3}\,D^{C4}\,(S)+C_2\,(q)^{C3}\,D^{C4}\,(S)$ (16)

Let equation (15) equals equation (16), then the correction factor, F_1, is given by:

$$F_1 = [(4)^{C3} + (3)^{C3} + (2)^{C3} + (1)^{C3}] / [(4)^{C3+1}] \quad (17)$$

In other words, the correction factor is generally given by:

$$F_1 = [(n)^{C3} + (n-1)^{C3} + (n-2)^{C3} + \cdots\cdots (n-(n-1))^{C3}] / [(n)^{C3+1}] \quad (18)$$

Where, (n-(n-1)) => 1 and C_3 = 1.852, as given in table (2). Values of F_1 against n are given in table (2).

The use of Darcy-Weisbach simple equation (12) leads to:

Assumed friction head loss through lateral line = $C_7 (4q)^2 D^{-5} (4S)$ (19)
Corrected friction head loss through lateral line = $F_1 C_7 (4q)^2 D^{-5} (4S)$ (20)
Actual friction losses through lateral line =
$C_7 (4q)^2 D^{-5} (S) + C_7 (3q)^2 D^{-5} (S) + C_7 (2q)^2 D^{-5} (S) + C_7 (q)^2 D^{-5} (S)$ (21)

Let equation (20) equals equation (21), then the correction factor, F_1, is given by:

$$F_1 = [(4)^2 + (3)^2 + (2)^2 + (1)^2] / [(4)^{2+1}] \quad (22)$$

In other words, the correction factor is generally given by:

$$F_1 = [(n)^2 + (n-1)^2 + (n-2)^2 + \cdots\cdots (n-(n-1))^2] / [(n)^3] \quad (23)$$

where, (n-(n-1)) => 1

3-1-2 Case of Manifold Pipe

The use of Hazen-Williams simple equation (8) leads to the following:

Assumed friction head loss through manifold line = $C_2 (8q_L)^{C3} D^{C4} (4S)$ (24)
Corrected friction head loss through manifold line = $F_1 C_2 (8 q_L)^{C3} D^{C4} (4S)$ (25)
Actual friction head loss through manifold line =
$C_2 (8q_L)^{C3} D^{C4} (S) + C_2 (6 q_L)^{C3} D^{C4} (S) + C_2 (4 q_L)^{C3} D^{C4} (S) + C_2 (2 q_L)^{C3} D^{C4} (S)$ (26)

Let equation (25) equals equation (26), and simplify, then the correction factor, F_1, is given by an equation similar to equation (18).

The use of Darcy-Weisbach simple equation (12) leads to the following:

Assumed friction head loss through manifold line = $C_7 (8 q_L)^2 D^{-5} (4S)$ (27)
Corrected friction head loss through manifold line = $F_1 C_7 (8 q_L)^2 D^{-5} (4S)$ (28)
Actual friction head loss through manifold line =
$C_7 (8q_L)^2 D^{-5} (S) + C_7 (6q_L)^2 D^{-5} (S) + C_7 (4q_L)^2 D^{-5} (S) + C_7 (2q_L)^2 D^{-5} (S)$ (29)

Let equation (28) equals equation (29), and simplify, then the correction factor, F_1, is given by an equation similar to equation (23).

The derivations done for lateral and manifold means that both are similar in applying the correction factor, F_1. Values of correction factor versus outlet numbers for previous papers, equation (1) and equation (2) and that proposed by the present paper, equation (18) and equation (23) are given in table (2). Graphical representation for all values of correction factor is shown in Fig. 4. It is shown that values of F_1 derived in the present paper by applying the equations of Hazen Williams and Darcy Weisbach are close to not only each other but also to those given by Christiansen [3].

Table (2) Values of correction factor, F_1, versus outlet numbers for published papers and that proposed by present paper. (First outlet is at full spacing)

Correction Factor, F_1, Formula	Number of outlets on lateral or manifold									
	1	2	3	4	5	6	7	8	9	10
Oron and Walker [1], Eq. (1)	0.998	0.531	0.439	0.406	0.390	0.381	0.375	0.372	0.369	0.367
Christiansen [3], Eq. (2)	1.005	0.639	0.535	0.485	0.457	0.438	0.425	0.416	0.408	0.402
Present paper Eq. (18)- using Hazen-Williams	1	0.639	0.534	0.485	0.457	0.438	0.425	0.416	0.408	0.402
Present paper Eq. (23)- using Darcy-Weisbach	1	0.625	0.519	0.469	0.440	0.421	0.408	0.398	0.391	0.385

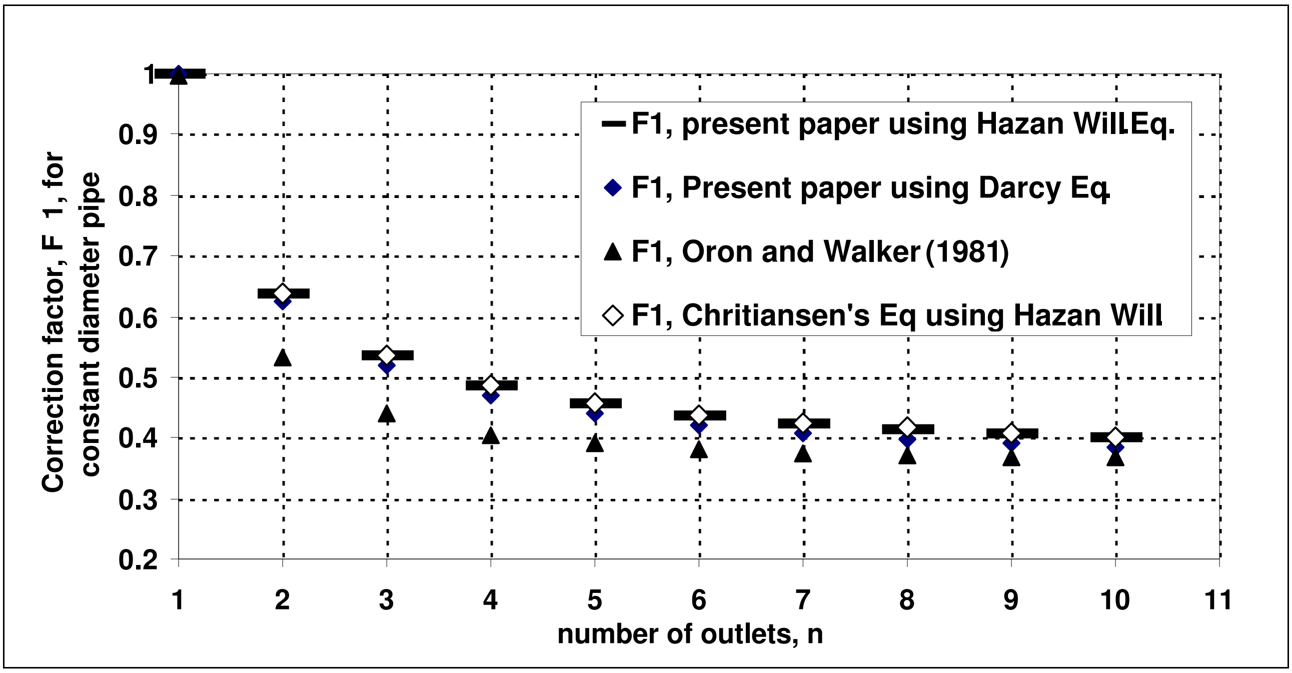

Fig. (4) Correction factor, F_1, for constant diameter pipe holding n outlets

3-2 Correction Factor for Lateral or Manifold of Varying Diameter and Constant Velocity

3-2-1 Case of Lateral or Manifold

Varying pipe diameter is suitable for the design of both lateral and/or manifold in sprinkler irrigation, where, spacing of outlets is relatively long and discharge is large. It is shown in Fig. 5 and Fig. 6 longitudinal sections through laterals and manifolds of varying diameter and constant velocity and holding 4 outlets. First outlet is after full spacing.

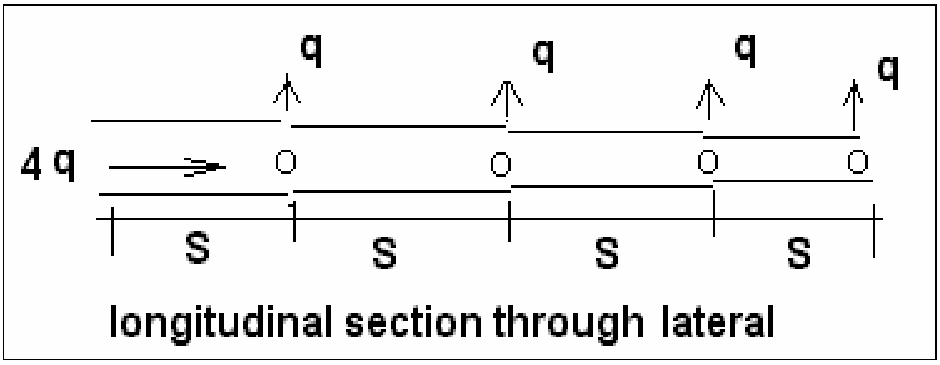

Fig. (5) Lateral of varying diameter and constant velocity holds 4 outlets; sprinklers or drippers

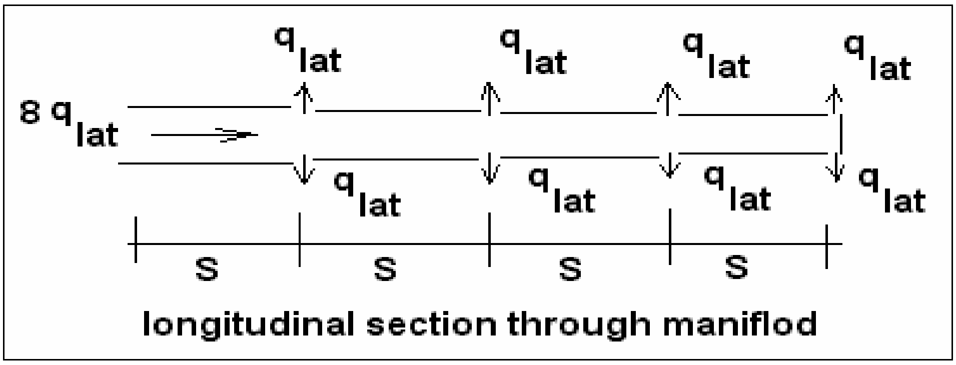

Fig. (6) Manifold of varying diameter and constant velocity holds 4 laterals at each side

The use of Hazen-Williams simple equation (10) leads to the following:

Assumed friction head loss through lateral or manifold line = $C_5\ (4q)^{C6}\ (4S)$ (30)

Corrected friction head loss through lateral or manifold line = $F_2\ C_5\ (4q)^{C6}\ (4S)$ (31)

Actual friction head loss through lateral or manifold line =

$$C_5\ (4q)^{C6}\ (S) + C_5\ (3q)^{C6}\ (S) + C_5\ (2q)^{C6}\ (S) + C_5\ (q)^{C6}\ (S) \qquad (32)$$

Let equation (31) equals equation (32), then the correction factor, F_2, is given by:

$$F_2 = [(4)^{C6} + (3)^{C6} + (2)^{C6} + (1)^{C6}] / [(4)^{C6+1}] \quad (33)$$

In other words, the correction factor, F_2, is generally given by:

$$F_2 = [(n)^{C6} + (n-1)^{C6} + (n-2)^{C6} + \cdots (n-(n-1))^{C6}] / [(n)^{C6+1}] \quad (34)$$

where, (n-(n-1)) => 1, and C_6 =-0.58 , as given in table (2)

The use of Darcy-Weisbach simple equation (13) leads to the following:

Assumed friction head loss through lateral or manifold line = $C_7(C_1)^{-5}(4q)^{-0.5}(4S)$ (35)

Corrected friction head loss through lateral or manifold line=$F_2C_7(C_1)^{-5}(4q)^{-0.5}(4S)$ (36)

Actual friction head loss through lateral or manifold line =
$C_7(C_1)^{-5}(4q)^{-0.5}(S)+C_7(C_1)^{-5}(3q)^{-0.5}(S)+C_7(C_1)^{-5}(2q)^{-0.5}(S)+C_7(C_1)^{-5}(q)^{-0.5}(S)$ (37)

Let equation (36) equals equation (37), then the correction factor, F_2, is given by:

$$F_2 = [(4)^{-0.5} + (3)^{-0.5} + (2)^{-0.5} + (1)^{-0.5}] / [(4)^{-0.5+1}] \quad (38)$$

In other words, the correction factor is generally given by:

$$F_2 = [(n)^{-0.5} + (n-1)^{-0.5} + (n-2)^{-0.5} + \cdots (n-(n-1))^{-0.5}] / [(n)^{-0.5+1}] \quad (39)$$

where, (n-(n-1)) => 1

Values of Correction factor, F_2, as proposed by equations (34) and (39) are given in table (3). Graphical representation of both equations is shown in Fig. 7. It is clear as shown in Fig. 7 that the correction factor, F_2, for a pipe of varying diameter is always greater than one which means that the actual head loss is greater than the estimated by considering a pipe of constant diameter.

Table (3) Values of correction factor, F_2, versus outlet numbers as proposed by Eq. (34) and Eq. (39)

n	1	2	3	4	5	6	7	8	9	10
Proposed formula of F_2 (using Hazen-Williams), Eq. (34)	1.000	1.247	1.385	1.478	1.546	1.598	1.641	1.676	1.707	1.733
Proposed formula F_2 (using Darcy-Weisbach), Eq.(39)	1.000	1.207	1.319	1.392	1.445	1.486	1.519	1.546	1.568	1.588

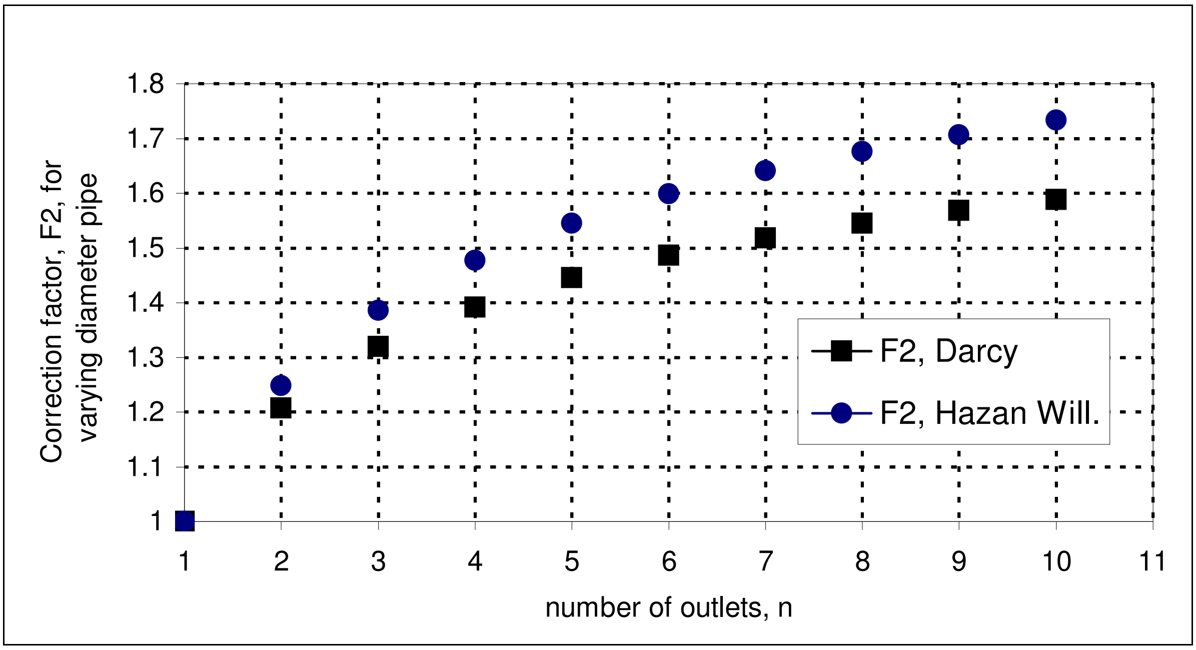

Fig. (7) Correction factor, F_2, for pipe of varying diameter and constant velocity holding n outlets

3-3 Pipeline Cost

The cost of pipe of length, L, may take the following form:

$$\text{Pipe Cost} = c_9\,[D]^{c8}\,L \qquad (40)$$

where c_8, c_9 are constants varying according to market. If velocity of flow is assumed to be 1.0 m/s and D is substituted from equation (5), then:

$$\text{Pipe Cost} = c_9 * c_1\,(Q)^{0.5c8}\,L \qquad (41)$$

3-3-1 Relative Saving Definition

It is shown that lateral or manifold may be estimated by considering two alternative design methods:

1- Design (1) assumes pipe to be of constant diameter and varying velocity
2- Design (2) assumes pipe to be of varying diameter and constant velocity

The first is mainly suitable for drip irrigation when the spacing of outlets is short and the discharge is small. However, the second is mainly suitable for sprinkler irrigation when the spacing of outlets is long and the discharge is large. Correction factor, F_1, for the first design, as shown in Fig. 4, is less than one which means that the corrected friction head loss is less than the estimated by considering constant diameter. However, Correction factor, F_2, for the second design, as shown in Fig. 7, is greater than one which means that the corrected friction head loss is greater than the estimated by considering a constant pipe diameter. On the other hand, if the costs of both design methods are compared, the relative saving must be estimated to decide which one of them is preferable. Therefore, the following definition is of great importance:

$$\text{Relative saving} = \frac{\text{cost of pipe according to design (2)}}{\text{cost of pipe according to design (1)}}$$

3-3-2 Relationship of Relative Saving

According to Equation (41), the cost of pipe is given by:

$$\text{Cost of constant diameter pipe} = C_9\, C_1(4q)^{0.5C8}\,(4S) \quad (42)$$

$$\text{Cost of varying diameter pipe} = C_9C_1(4q)^{0.5C8}\, S + C_9C_1(3q)^{0.5C8}\, S + C_9C_1(2q)^{0.5C8}\, S + C_9\, C_1(q)^{0.5C8}\, S \quad (43)$$

$$\text{Relative saving} = \frac{\text{cost given by equation (43)}}{\text{cost given by equation (42)}}$$

Relative saving =

$$[C_9C_1(4)^{0.5C8} + C_9\, C_1(3)^{0.5C8} + C_9C_1(2)^{0.5C8} + C_9\, C_1(1)^{0.5C8}] / [C_9\, C_1(4)^{0.5C8+1}] \quad (44)$$

$$\text{Relative saving} = [(4)^{0.5C8} + (3)^{0.5C8} + (2)^{0.5C8} + (1)^{0.5C8}]/(4)^{0.5C8+1} \quad (45)$$

In general,

$$\text{Relative saving} = [(n)^{0.5C8} + (n-1)^{0.5C8} + (n-2)^{0.5C8} + \cdots + (n-(n-1))^{0.5C8}] / [(n)^{0.5C8+1}] \quad (46)$$

where n is the number of outlets on either lateral or manifold and (n-(n-1)) =>1, and C_8 is determined according to market. Values of relative saving versus number of outlets for several values of C_8 are given in table (3). Also, relative saving is plotted in Fig. 8 against outlet number, n, for several values of C_8 which is varying according to the market.

Table (3) Values of relative saving versus number of outlets for several values of C_8

n	1	2	3	4	5	6	7	8	9	10
$C_8 = 2.0$	1	0.750	0.667	0.625	0.600	0.583	0.571	0.563	0.556	0.550
$C_8 = 2.5$	1	0.710	0.619	0.574	0.547	0.530	0.517	0.508	0.501	0.495
$C_8 = 3.0$	1	0.677	0.579	0.532	0.505	0.487	0.474	0.464	0.457	0.451

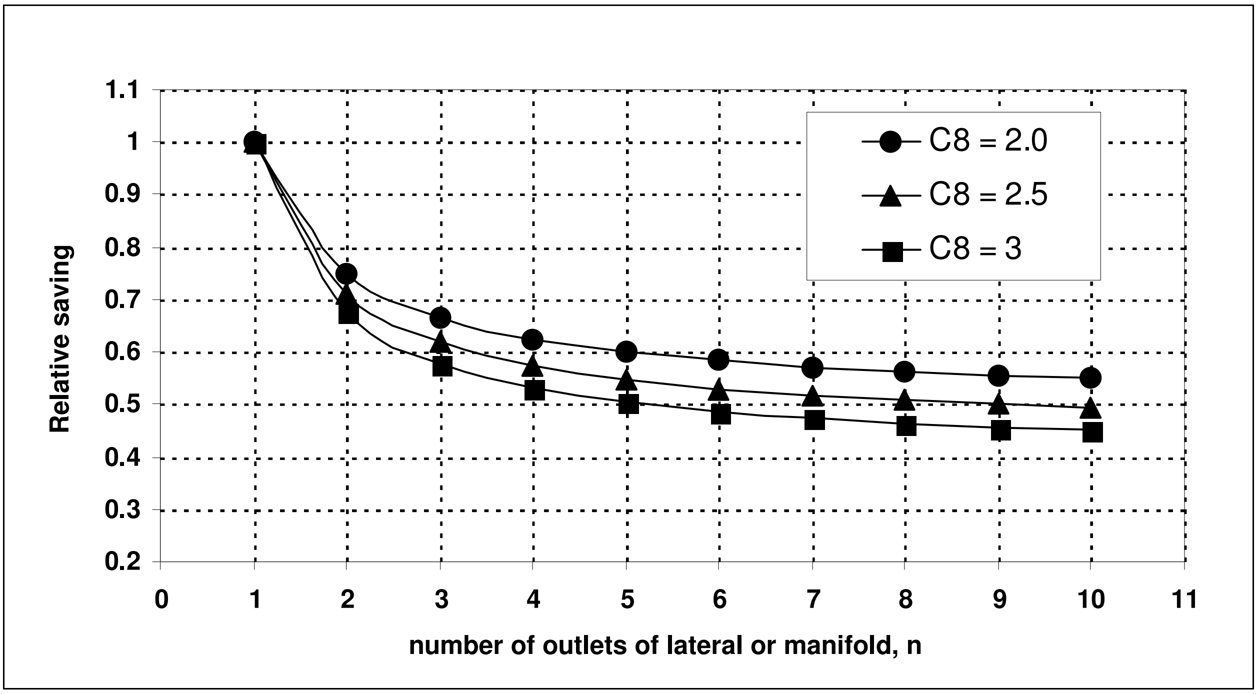

Fig. 8 Relative saving for lateral or manifold of varying diameter and constant velocity

It is shown in Fig. 8 that the values of relative saving decrease as the number of outlets increases. The trend of Fig. 8 means that the second design method is always cheaper than the first design method. Therefore, the second design is preferable from the point of relative saving in pipeline cost, despite, the fact that its friction head loss is greater than that of the first design. However, the effect of this head loss has a very little effect on the pump head. Therefore, the effect on the energy cost is negligible.

To illustrate the idea of applying two alternative design methods, two examples are considered. In example 1, a lateral pipeline of small discharge is assumed to be of constant diameter. In example 2, a manifold is designed by two methods; in the first, the diameter is considered constant, while, in the second, the diameter is considered variable.

Example 1

A lateral of sprinkler irrigation is to be designed to serve 6 sprinklers, 15 m apart. The discharge of each sprinkler is 1.5 m3/hour. Estimate the diameter of lateral line and friction head loss according design (1).

Solution

Lateral discharge, q_l = 6 * 1.5 = 9 m^3/hr

Applying equation (5) leads to

Lateral diameter, D, = C1 $(Q)^{0.5}$ = 1.128*$(9/3600)^{0.5}$ = 0.0564 m = 5.6 cm

Lateral length, L, = 6*15 m = 90 m

Applying equation (10) leads to

Lateral assumed head loss = h_f= C_5*$(Q)^{C6}$ L = 0.000634*$(9/3600)^{-0.58}$ * 90 = 1.843 m

Applying equation (18) leads to

Correction factor $=F_1=[(6)^{1.852}+(5)^{1.852}+(4)^{1.852}+(3)^{1.852}+(2)^{1.852}+(1)^{1.852}]/[(6)^{2.852}] = 0.438$ + corrected head loss = assumed head loss*correction factor, F_1, =1.843*0.438 = 0.807 m

Example 2

A manifold of sprinkler irrigation to be designed to serve 6 laterals of same specifications mentioned above. Give two alternative design methods for the pipeline diameter and determine the relative saving?.

Solution

manifold discharge, Q, = 6 * 9 * 2 = 108 m^3/hr

Design (1), constant diameter

manifold diameter, D, $= C_1 (Q)^{0.5} = 1.128*(108/3600)^{0.5} = 0.1954$ m = 19.5 cm

manifold length, L, = 6*15 m = 90 m

manifold assumed head loss = $h_f = C_5*(Q)^{C6}L = 0.000634*(108/3600)^{-0.58} * 90 = 0.436$ m

Correction factor $=F_1=[(6)^{1.852}+(5)^{1.852}+(4)^{1.852}+(3)^{1.852}+(2)^{1.852}+(1)^{1.852}]/[(6)^{2.852}] = 0.438$corrected head loss= assumed head loss*correction factor =0.436*0.438 = 0.191 m

Design (2), varying diameter

Manifold diameters are estimated according to equation (5) and summarized in table (4)

Table (4) discharge and diameters of manifold

Discharge	108 m^3/hr	90	72	54	36	18
diameter	19.5 cm	17.8	16.0	13.8	11.3	8.0

manifold length, L = 6*15 m = 90 m

manifold assumed head loss = $h_f = C_5*(Q)^{C6} L = 0.000634*(108/3600)^{-0.58} * 90=0.436$ m

correction factor, $F_2 =[(6)^{-0.58}+(5)^{-0.58}+(4)^{-0.58}+(3)^{-0.58}+(2)^{-0.58}+(1)^{-0.58}]/[(6)^{0.42}]=1.6$ m corrected head loss = assumed head loss*correction factor, F_2 =0.436*1.6 = 0.7 m

Relative Saving

By applying equation (47) for assumed value of $C_8 = 2.0$

Relative saving$=[(6)^{0.5C8}+(5)^{0.5C8}+(4)^{0.5C8}+(3)^{0.5C8}+(2)^{0.5C8+}(1)^{0.5C8}]/(6)^{0.5C8+1}$ =0.58

Comparison Between Design (1) and Design (2)

The comparison is given in Table (5)

Table (5) Comparison between design (1) & design (2)

	Design (1)	Design (2)
Head loss	0.196 m	0.7 m
Relative saving	Design (2) / Design (1) = 0.58	

The cost of second design is cheaper than that of the first design by almost 60 %. However, the friction head loss of design (2) is about 3.5 times that of design (1). However, the effect of this head loss difference has a very little effect on the pump head. Therefore, the effect on the energy cost is negligible.

4. CONCLUSION

The paper, herein, presents two alternative design methods for the lateral and manifold of either drip or sprinkler irrigation systems. The first design assumes the pipe holding several outlets to be of constant diameter and varying velocity. It is mainly suitable for drip irrigation when the spacing of outlets is short and the discharge is small. However, the second design assumes the pipe to be of varying diameter and constant velocity, 1.0 m/s. It is mainly suitable for sprinkler irrigation when the spacing of outlets is long and the discharge is large.

Relationships, Equation (18) and Equation (23), for correction factor, F_1, according to the first design are derived, and compared with other published relationships. Other relationships, Equation (34) and Equation (39) for the correction factor, F_2, according to the second design are also derived. Values of F_1 are always less than one; however, values of F_2 are always more than one. This means that the friction head loss of the first design is less than that of the second design. However, to compare the cost of both, a new definition, “relative saving”, is presented. “Relative saving” is the ratio between the pipeline cost of second design and the pipeline cost of first design. A relationship is derived to relate the “relative saving” to the number of outlets. It is shown that the relative saving is always less than one which means that the second design is always cheaper than first design. The “relative saving” decreases with the increase of outlet number. Two examples are presented to explain the two alternative design methods. Values of the two correction factors, F_1 and F_2 are estimated and compared. Also, the relative saving is estimated to show that the second design is 60 % cheaper than the first design for 6 outlets on manifold, as an example. Therefore, the second design is preferable from the point of relative saving, despite, the fact that its friction head loss of the second is greater than that of the first design. However, the effect of this head loss has a very little effect on the pump head. Therefore, the effect on the energy cost is negligible.

References

1- Oron, G., and Walker, W. (1981). “Optimal design and operation of permanent irrigation systems.” Water Resources Res. 17(1), 11-17.
2- Howell Terry A. and Hiler Edward A. “Design Trickle Irrigation Laterals for Uniformity”, Journal of Irrigation and drainage Division, ASCE, Vol. 100, No. IR4, December, 1974, pp. 443-454.
3- Christiansen, J. E., “Irrigation By Sprinkling,” Bulletin 670, University of California Agricultural Experiment Station, Berkeley, Calif., Oct., 1942.
4- Dandy G. C. and Hassanli A. M. “Optimum design and operation of multiple subunit drip irrigation systems.” Journal of Irrigation and drainage Division, ASCE, Vol. 122, No. 5, September/October, 1996, Paper No. 7450.

5- Bruce E. Larock, Roland W. Jeppson, and Gary Z. Watters. "Hydraulics of pipeline Systems", International Standard book Number 0-8493-1806-8, CRC Press LLC, 2000.
6- Keller and Bliesner "Sprinkler and Trickle Irrigation", Chapman & Hall, 115 Fifth Avenue, New York, NY 10003, 1990.