*Iran Agricultural Research 12:115-128 (1993)*

# NOTE

# EVALUATION OF ENERGY WASTAGE IN AGRICULTURAL PUMPING SYSTEMS IN SHIRAZ REGION OF IRAN[1]

*S. AMIN AND A.R. SEPASKHAH*[2]

Irrigation Department, College of Agriculture, Shiraz University, Shiraz, Iran.

(Received October 7, 1992)

## ABSTRACT

Pumping from groundwater is one of the important methods of supplying irrigation water in Iran. Electrical and diesel-driven pumps are commonly used in our agricultural farms throughout the country. At present, the amount of energy waste of the pumping stations is not known, therefore, the performances of 52 pumps in Shiraz region of Fars province were investigated. The results indicated that the electrical and diesel-driven pumping systems wasted energy by as much as 210 and 178%, based on calculated horsepower, respectively. However, with the present level of the energy price in the region and excluding depreciation and maintenance costs, diesel pumps seem to be more economical than electrical pumping systems. Overall, about 75 million Rials (about $ 35700) will be saved in energy by replacing 1000 electrical pumps by diesel pumping systems during a 5-month running period.

---

1. Part of the research was supported by a grant (71-AG-755-414) from the Research Council of Shiraz University, Shiraz, Iran.

2. Associate Professor and Professor, respectively.

تحقیقات کشاورزی ایران
(۱۳۷۲) ۱۲۸-۱۱۵ :۱۲

# ارزیابی اتلاف انرژی در پمپاژ آب مزارع کشاورزی اطراف شیراز

سیف الله امین و علیرضا سپاسخواه
بترتیب دانشیار و استاد بخش آبیاری دانشکده کشاورزی دانشگاه شیراز، شیراز، ایران.

## چکیــده

در کشورهایی با آب و هوای خشک نظیر ایران بخشی از آبیاری محصولات کشاورزی توسط پمپاژ از سفره‌های آب زیرزمینی صورت می گیرد. بدین‌منظور از موتور پمپهای دیزلی و الکتریکی استفاده می‌شود. تا کنون انرژی تلف شده از طریق پمپاژ در استان فارس مورد ارزیابی قرار نگرفته است، ازاین رو در این تحقیق کارکرد ۵۲ پمپ در مزارع اطراف شیراز بررسی شد. نتایج حاصله نشان می‌دهند که ۳۳۰ تا ۵۵۰ درصد انرژی در پمپهای کشاورزی از دست می‌رود. اتلاف انرژی در پمپهای الکتریکی کمتر از دیزلی است ولی در شرایط کنونی و با توجه به ارزانی قیمت سوخت و بدون درنظر گرفتن هزینه‌های استهلاک و نگهداری، پمپهای دیزلی از پمپهای الکتریکی با صرفه‌ترند. اجمالاً ۷۵ میلیون ریال از طریق جایگزینی ۱۰۰۰ موتور الکتریکی به دیزلی برای یک دوره کارکرد پنج ماهه در انرژی صرفه‌جویی می‌شود.

## INTRODUCTION

Shortage of energy is one of the important problems in the world. On the other hand, energy is a main factor in crop production. In a dry country such as Iran, groundwater by pumping is one of the main irrigation water resources. Electrical and fuel (diesel-engine drive) pumps are two common types of pumps used in irrigation throughout the country. At present, the price of diesel fuel is very low compared to electricity; but in the future the shortage of oil may result in a very high rise in the price of diesel fuel. In this regard, selection of a pump of proper specification with respect to the irrigation requirement will help reduce energy waste in agriculture as electricity or diesel fuel. Energy waste of the pumping stations with different types of pumping systems should be measured throughout the country. The results of such studies might be useful for proper designing and selection of pumping systems for the irrigation requirements.

At present, data on the running efficiencies of pumping stations in the agricultural farms of Iran are scarce (2). Therefore, a sample area with 52 pumps in Shiraz region of the Fars province was selected and the performances of pumps and energy comsumptions were determined during a five-month period of irrigation period (late April to late August).

## MATERIALS AND METHODS

Fifty two 4-stage pumps were surveyed for the amount of energy wastage. The pumps were located in Shiraz region (Fars province, Iran) with a distance of 21 to 84 km from Shiraz. Among these, only eight pumping systems were electrical and the rest were diesel-driven pumps. Fig. 1 shows the sites of the survey area. The pump stations were in Marvdasht, Kaftarak, Poleberengi and Khaneh-Zenian which are in north-east, east, south-east and west of Shiraz, respectively.

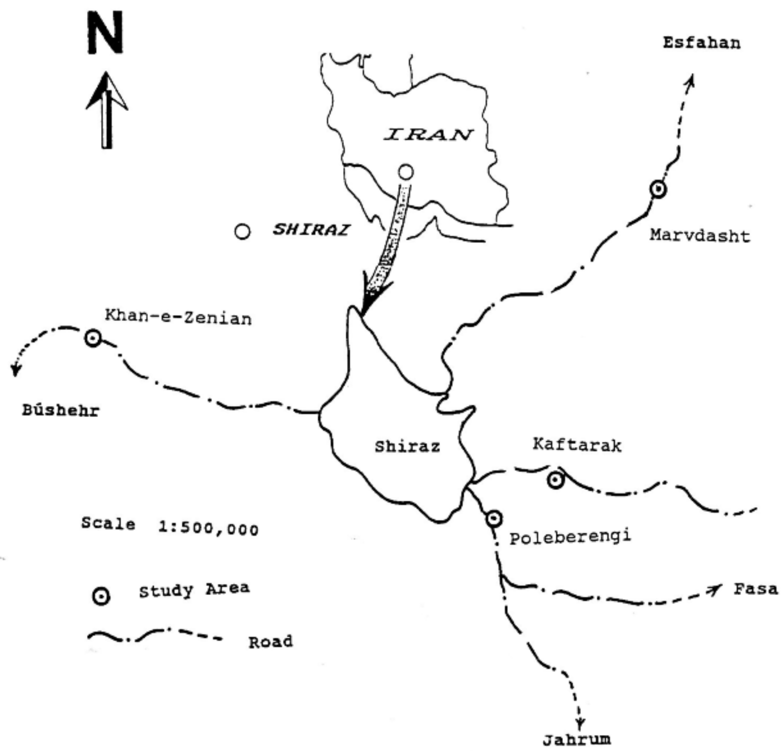


Fig. 1. Location of the study sites in Shiraz region of Fars province, Iran.

Specifications of these pumping systems are shown in Table 1. The pumping systems of numbers 6 to 18 had a suction pipe of 76 mm I.D. whereas the rest of the systems (39 pumps) had a suction pipe of 102 mm I.D. The corresponding impeller diameters were 190 mm and 210 mm for the above mentioned pumping types, respectively. It was assumed that the diesel pumps were running at their rated rpm.

Different parameters such as discharge from the pump, total static head, and number of fittings for each pump were determined. The discharge of the wells was measured by trajectory or volume basis methods (11). The free water surface was determined in each wet well from the eye of the pump at running stage. Then, the vertical distance from eye of the pump to the discharge point was measured. The sum of these two measurements was considered as total static head. The head loss in each piping of the pump systems was calculated using Darcy-Weisbach equation, to be used in the calculation of total dynamic head, H. (12) as follows:

$$h_L = f\ L/D\ (V^2/2g) \qquad [1]$$

where:

$h_L$ = the head loss through the system pipes and fittings, m

f = friction coefficient using Moody diagram (9).

L = length of the pipe or equivalent pipe length of the fittings (9), m

D = suction and/or discharge pipe diameters, m

V = velocity of the flow, $ms^{-1}$

g = acceleration due to gravity, 9.81 $ms^{-2}$

Table 1. Nominal specification of the pumping systems in the study area.

| Station No. | rpm | Power kw | Power hp | Station No. | rpm | Power kw | Power hp |
|---|---|---|---|---|---|---|---|
| | *Electrical type* | | | | *Diesel type (cont.)* | | |
| 1 | 1460 | 22 | 30 | 26 | 900-1000 | 14.7-17 | 20-23 |
| 2 | 1460 | 18.5 | 24.5 | 27 | 950 | 15.8 | 21.8 |
| 3 | 1460 | 18.5 | 20.4 | 28 | 950 | 13.8 | 18.7 |
| 4 | 1460 | 18.5 | 20.4 | 29 | 880 | 20.2 | 27.5 |
| 5 | 1460 | 18.5 | 20.4 | 30 | 880 | 17 | 23 |
| 6 | 1460 | 22 | 20.4 | 31 | 880 | 17 | 23 |
| 7 | 1460 | 18.5 | 25.2 | 32 | 880 | 16.2 | 22 |
| 8 | 1460 | 15 | 20.4 | 33 | 880 | 16.2 | 22 |
| | | | | 34 | 850 | 11.8 | 16 |
| | *Diesel type* | | | 35 | 850 | 11.8 | 16 |
| 9 | 1800 | 47.5† | 65 | 36 | 850 | 11.8 | 16 |
| 10 | 950 | 15.8 | 21.5 | 37 | 840 | 15.5 | 21 |
| 11 | 850 | 11.8 | 16 | 38 | 840 | 15.5 | 21 |
| 12 | 800 | 11.8 | 16 | 39 | 800 | 11.8 | 16 |
| 13 | 800 | 11.8 | 16 | 40 | 800 | 11.8 | 16 |
| 14 | 760 | 14.7 | 20 | 41 | 800 | 11.8 | 16 |
| 15 | 700 | 6 | 8 | 42 | 800 | 11.8 | 16 |
| 16 | 700 | 6 | 8 | 43 | 800 | 11.8 | 16 |
| 17 | 700 | 6 | 8 | 44 | 800 | 11.8 | 16 |
| 18 | 700 | 6 | 8 | 45 | 800 | 11.8 | 16 |
| 19 | 2100 | 11.8 | 16 | 46 | 800 | 11.8 | 16 |
| 20 | 2100 | 11.4 | 15.5 | 47 | 700 | 19.1 | 26 |
| 21 | 1800 | 47.8 | 65 | 48 | 700 | 19.1 | 26 |
| 22 | 1800 | 47.8 | 65 | 49 | 650 | 8.8 | 12 |
| 23 | 1050 | 19 | 26 | 50 | - | 20.6 | 23 |
| 24 | 900-1000 | 14.7-17 | 20-23 | 51 | - | 17.7 | 24 |
| 25 | 900-1000 | 14.7-17 | 20-23 | 52 | - | 13.2 | 18 |

† Calculated from nominal horsepower.

For calculation of the friction factor, f, the Hazen-William and Darcy-Weisbach equations have been combined (3) which resulted as:

$$f = 139.8\ C^{-1.85}\ D^{0.135}\ Q^{-0.15} \qquad [2]$$

where:

C = Hazen-William coefficient of relative roughness (3, 9).

D = pipe diameter, mm

Q = pump discharge flow rate, $Ls^{-1}$

Using a C value of 55 (8) for the old trunk (corrugated) connection pipes between strainer and pump will result a general equation for 79 mm to 102 mm I.D. suction pipes to calculate the friction factor in equation [2] as follows:

$$f = 0.16\ Q^{-0.15} \qquad [3]$$

where:

Q = discharge from the pump, $Ls^{-1}$

Minor losses in each system were determined by using the loss coefficient, K, in $K(V^2/2g)$ equation (12).

Sum of the total static head, calculated head loss of the pipe and the minor head losses due to fittings, plus 10% of all of them was considered as total dynamic head (H). Addition of 10% was used to overcome the head loss in the system due to aging (5).

The life of a pumping system depends on the internal wear of the pump and this wear will change the pump performance (4, 5, 6, 7). Therefore, the aging of the pump systems reduces the pump efficiencies. In this regard, the values of the pump efficiencies ($\eta_p$) of the used or old multistage-centrifugal pumps are based on their discharges. The pump efficiencies were proposed by Briscoe (1) as 50%, 55% and 60% for discharge rates of less than 5.6 $Ls^{-1}$, 5.6 $Ls^{-1}$ to 28 $Ls^{-1}$, and greater than 28 $Ls^{-1}$, respectively. These values were used to convert the water horsepower (Whp) to installed motor horsepower (Mhp) using the following equations for different types of pumping system:

$$\text{Electrical systems, motor horsepower} = \frac{QH}{0.55\ \eta_p} \qquad [4]$$

$$\text{Diesel systems, motor horsepower} = \frac{QH}{0.35\ \eta_p} \qquad [5]$$

where:

Q = the pump discharge, $Ls^{-1}$

H = total dynamic head of the system, m

$\eta_p$ = pumping efficiency, related to discharge rate, %

Then, the percentage of the energy wastage was calculated by the following equation:

$$\text{Energy Wastage \%} = \frac{(\text{nominal Mhp} \times \cos\varphi - \text{calculated Mhp})}{\text{calculated Mhp}} \times 100 \qquad [6]$$

Motor horsepower of each electrical system was converted to kW by a conversion factor of 0.736. In the diesel type systems, the performance standard is 2.98 hp-h/liter of diesel fuel for representative power units (5). This amount is also reported to be about 200 g of diesel fuel for every hp-h, (150-230 g/hp-h); (10). For this study 200 g/hp-h was considered to determine the energy wastage in the diesel-engine driven pumps.

## RESULTS AND DISCUSSION

The results of the calculations are shown in Table 2 including the average energy wastage (%) for all electrical and diesel pumps in the study area. On the average, 210% energy is wasted in the electrical and 178% in the diesel systems. Furthermore, the results of empirical equations (1) did not show significant differences between the energy waste for two systems of pumpage. Generally, the results showed high energy wastage in pumpage of irrigation water in the study area.

In 6 cases out of 44 diesel systems (about 14%) the calculated horsepower was almost equal to the nominal horsepower which indicated a proper design and selection of diesel pumping systems.

For further analysis, 18 hours per day running time for irrigation needs during a 5-month period (growing season) has been considered. This will result in about 2790 hours of total running time of pumpage for each system. The energy wasteage as kW-h/pump as electricity and hp-h/pump in the diesel type system are calculated from the average of the data in Table 2. The differences between the average nominal

Table 2. Calculated horsepower by Briscoe (1) proposition and energy wastage for the electrical and diesel type pumps corresponding to their station specifications.

| Station No. | Piping length (m) | Flow rate $Ls^{-1}$ | Trunk lenth (m) | Static head (m) | Head loss (m) | Total dyn. head (m) | Nominal horepower (hp) | Calculated horsepower (hp) | Energy wastage (%) |
|---|---|---|---|---|---|---|---|---|---|
| | | | | *Electrical systems* | | | | | |
| 1 | 28 | 15.1 | 0 | 19.8 | 1.4 | 23.1 | 30.0 | 11.4 | 160 |
| 2 | 25 | 11.5 | 0 | 15.0 | 0.7 | 17.2 | 24.5 | 6.5 | 280 |
| 3 | 24 | 7.9 | 3 | 19.1 | 0.3 | 21.6 | 20.4 | 5.3 | 280 |
| 4 | 33 | 11.0 | 0 | 20.0 | 0.9 | 22.9 | 20.4 | 8.2 | 150 |
| 5 | 29 | 16.8 | 0 | 17.7 | 1.8 | 21.4 | 20.4 | 11.8 | 70 |
| 6 | 39 | 12.1 | 2 | 24.2 | 5.2 | 33.9 | 30.0 | 13.4 | 120 |
| 7 | 35 | 8.9 | 0 | 23.0 | 2.6 | 28.2 | 25.2 | 8.2 | 210 |
| 8 | 26 | 5.8 | 3 | 19.0 | 0.8 | 22.3 | 20.4 | 4.2 | 390 |
| Mean ± SE | | | | | | | 23.9 ± 1.5 | 8.6 ± 1.16 | 210 ± 34 |
| | | | | *Diesel systems* | | | | | |
| 9 | 23 | 5.6 | 0 | 17 | 0.7 | 19.5 | 65 | 5.7 | 1040 |
| 10 | 30 | 8.7 | 2 | 11.2 | 2.1 | 15.3 | 21.5 | 7.0 | 210 |
| 11 | 15 | 5.8 | 2.5 | 21.4 | 0.5 | 24.7 | 16 | 7.5 | 110 |
| 12 | 20 | 10.7 | 2 | 14 | 0.5 | 21.9 | 16 | 12.3 | 30 |
| 13 | 14 | 16.8 | 2 | 15.6 | 0.8 | 18.8 | 16 | 16.5 | - |
| 14 | 25 | 12.0 | 0 | 12 | 3.3 | 21.1 | 20 | 13.3 | 50 |
| 15 | 10 | 10.5 | 2.5 | 9.9 | 1 | 13.3 | 8 | 7.3 | 10 |
| 16 | 10 | 2.4 | 3 | 10.3 | 0.1 | 11.9 | 8 | 1.6 | 380 |
| 17 | 22 | 11.0 | 0 | 15 | 2.5 | 19.2 | 8 | 11.1 | - |
| 18 | 15 | 10.6 | 0 | 9.3 | 1.5 | 12.4 | 8 | 6.9 | 20 |
| 19 | 23 | 11.5 | 3 | 18 | 0.7 | 20.9 | 16 | 12.6 | 30 |
| 20 | 71 | 5.8 | 3 | 12.5 | 0.5 | 14.4 | 15.5 | 4.7 | 230 |
| 21 | 26 | 17.3 | 2 | 17 | 1.7 | 21 | 65 | 19 | 240 |
| 22 | 23 | 8.1 | 0 | 16.5 | 0.3 | 18.5 | 65 | 7.8 | 730 |
| 23 | 17 | 12.6 | 2 | 11 | 0.6 | 13.1 | 26 | 8.6 | 200 |
| 24 | 23 | 10.5 | 0 | 14.9 | 0.6 | 17.5 | 21.5 | 9.6 | 120 |
| 25 | 24 | 14.7 | 0 | 17.2 | 1.2 | 20.2 | 21.5 | 15.5 | 40 |
| 26 | 25 | 10.5 | 0 | 17.5 | 0.6 | 19.9 | 21.5 | 10.9 | 100 |
| 27 | 15 | 12.6 | 0 | 8.9 | 0.5 | 11.5 | 21.5 | 7.6 | 180 |

(Table 2., Continued):

| Station No. | Piping length (m) | Flow rate $Ls^{-1}$ | Trunk lenth (m) | Static head (m) | Head loss (m) | Total dyn. head (m) | Nominal horepower (hp) | Calculated horsepower (hp) | Energy wastage (%) |
|---|---|---|---|---|---|---|---|---|---|
| 28 | 41 | 13.6 | 0 | 19.5 | 1.6 | 23.2 | 18.7 | 16.5 | 10 |
| 29 | 62 | 8.5 | 2 | 42.5 | 1 | 47.9 | 27.5 | 21.3 | 30 |
| 30 | 38 | 17.3 | 2.5 | 11 | 2.5 | 16.1 | 23 | 14.6 | 60 |
| 31 | 32 | 14.7 | 3 | 26.8 | 1.5 | 32.2 | 23 | 24.8 | - |
| 32 | 52 | 6.3 | 0 | 44.6 | 0.5 | 49.5 | 22 | 16.3 | 30 |
| 33 | 49 | 15.0 | 2.5 | 38 | 2.4 | 44.9 | 22. | 35.3 | - |
| 34 | 114 | 11 | 3 | 11.3 | 3 | 16.4 | 16 | 9.4 | 70 |
| 35 | 23 | 8.4 | 3 | 13.1 | 0.4 | 15 | 16 | 6.6 | 140 |
| 36 | 14 | 5.3 | 3 | 16 | 0.1 | 19.2 | 16 | 5.3 | 200 |
| 37 | 29 | 5.7 | 3 | 22 | 0.3 | 24.5 | 21 | 7.3 | 190 |
| 38 | 23 | 18.9 | 3 | 17.3 | 3.4 | 22.8 | 21 | 22.6 | - |
| 39 | 26 | 16.8 | 1 | 11.5 | 2.7 | 15.6 | 21 | 13.7 | 50 |
| 40 | 23 | 11.3 | 0 | 14.5 | 0.7 | 16.7 | 16 | 9.9 | 60 |
| 41 | 18 | 13.7 | 3 | 9 | 1.3 | 11.3 | 16 | 8.1 | 100 |
| 42 | 18 | 11 | 0 | 11 | 0.5 | 12.7 | 16 | 7.3 | 120 |
| 43 | 30 | 5.8 | 0 | 21.8 | 2.7 | 24 | 16 | 5 | 220 |
| 44 | 22 | 10.8 | 0 | 13 | 0.3 | 14.9 | 16 | 8.4 | 90 |
| 45 | 24 | 13.7 | 0 | 16.9 | 0.1 | 19.7 | 16 | 14.1 | 10 |
| 46 | 319 | 8.0 | 0 | 10.7 | 4.5 | 16.2 | 16 | 6.8 | 140 |
| 47 | 55 | 6.3 | 0 | 39.6 | 0.5 | 44 | 26 | 14.5 | 80 |
| 48 | 55 | 10.5 | 2 | 48.3 | 1.3 | 54.7 | 26 | 30.1 | - |
| 49 | 19 | 6.1 | 4 | 10.7 | 0.4 | 12.1 | 12 | 3.9 | 210 |
| 50 | 17 | 6.3 | 0 | 11 | 0.1 | 15.6 | 28 | 5.1 | 450 |
| 51 | 17 | 10 | 0 | 10 | 0.4 | 12.7 | 24 | 6.7 | 260 |
| 52 | 18 | 3.6 | 3.5 | 14 | 0.1 | 15.6 | 18 | 2.9 | 520 |
| Mean ± SE | | | | | | | 21.7 ± 1.92 | 11.4 ± 1.05 | 178 ± 33 |

horsepower of both types of the pumping system and the calculated horsepower are used in calculation of the net energy wastage during the 5-month period of irrigation (2790 hours running time). The total amount of energy wastage as electricity and diesel fuel are 31000 kW-h/pump and 29000 hp-h/pump for electrical and diesel systems, respectively. The results indicated that for 1000 electrical pumping systems 31000 MW-h electrical energy will be wasted for the pumpage of irrigation water. Saving this amount of electricity by proper design of pumping systems may comfort the life of the residents during summer when electricity shortage is an important problem especially in this part of the country with hot summers.

In the case of diesel-engine driven pumps surveyed in this study, on the average, 2790 running time will consume $2.9 \times 10^4$ hp-h energy per pump. Calculations showed that for the diesel type pumps with 2790 running hours per season 5.8 tons of diesel fuel will be wasted. The total amount of diesel fuel wastage for 1000 pumping systems will be about $5.8 \times 10^3$, tons. Considering 0.68 for specific gravity of diesel fuel (12), the total loss of diesel fuel will be about $5.8 \times 10^6$ liters. This amount of fuel could be used for other industries or, in case of proper design will not pollute the atmosphere.

Considering 5 Rials[1]/(KW-h) for electricity and 10 Rials/L of diesel fuel the total amount of money losses could be calculated. On the average, 160 million Rials ($ 76200) and 85 million Rials ($ 40500) as energy cost will be lost for 1000 electrical and diesel pumps, respectively.

1. 1 US $ = 2100 Rials

## CONCLUSION

The results of this study indicated that the pumping systems in the Shiraz area wasted energy by 178-210% of their rated power. However, with the present level of the energy price, not considering depreciation and maintenance costs, diesel pumps might be more economical than electrical pumping systems. On an overall view, about 75 million Rials (about $ 35700) will be saved in energy by replacing 1000 electrical pumps by diesel systems during a 5-month running period. In spite of this, due to ease of operation of electrical pumping systems proper design and selection of such systems must be considered. Furthermore, the air pollution will also be diminished when the electrical pumps are used instead of diesel type pumps.

## LITERATURE CITED


1. Briscoe, J. 1984. Evaluating pump characteristics in developing countries. Civil Engineering-ASCE, 54:58-61.
2. Fathi-Moghadam, M. 1992. Evaluation of pumping stations efficiencies in Karoun river banks. Research Report No. 144. Martyr Chamran Univ. Research Council, Ahwaz, Iran. 10 p. (In Persian).
3. Giles, R.V. 1977. Schaum's Outline of Theory and Problems of Fluid Mechanics and Hydraulics. 2nd SI Metric Edition. McGraw-Hill Book Company. New York. U.S.A. 274 p.
4. Hansen, V.E., O.W. Israelsen, and G.E., Stringham. 1979. Irrigation Principles and Practices. McGraw-Hill Book Co. New York, U.S.A. 447 p.

5. Hanson B.R. 1988. Benefits and costs of improving pumping efficiency. Cal. Agric. 42:21-22.

6. Hicks, T.G. and T.W. Edwards. 1971. Pump Application Engineering. McGraw-Hill Book Co. New York, U.S.A. 435 p.

7. Karassik, I.J. and R. Carter. 1960. Centrifugal Pumps, Selection, Operation and Maintenance. McGraw-Hill Book Co. New York, U.S.A. 488 p.

8. King, R.C. 1973. Fluid Mechanics. *In*: R.C. King (ed.) Piping Handbook. McGraw-Hill Book Co. New York, U.S.A. pp. 170-183.

9. Streeter, V.L. and E.B. Wilyer, 1983. Fluid Mechanics. First SI Metric Edition. McGraw-Hill International Book Co. New York, U.S.A. 562 p.

10. Tadayon, H., Y. Hassanzadeh, and A. Kia. 1984. Water Machines. Volume I: Pumps. Unpublished (in Persian).

11. United State Department of the Interior Bureau of Reclamation. 1975. Water Measurement Manual. 2nd edition, 328 p.

12. Venard, J.K. and R.L. Street. 1982. Elementary Fluid Mechanics. Sixth edition. John Wiley and Sons. New York, U.S.A. 689 p.