A Sampling About For Economic Pipe Diameter Calculation

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Abstract- Pumps are widely used in our homes, in buildings, in industrial applications, in agriculture, in water supply and many other applications, even though we are not aware of them. When designing a pump system, it is necessary to compare different solutions to choose the most efficient and efficient system. To find the most intelligent solution, some basic facts must be revealed. As a result of the experimental work done, the loss coefficients are calculated with the aid of the determined pressure deductions taking into consideration the flow direction for the flat pipes, valves and fittings (elbows, nipples, cuffs, record, curve, reduction and TE (transitional elements) It was calculated and presented in tables. In this study, a program was developed to determine the optimum diameters of the pipes that allow the water from the plant to be transported at a certain distance. Galvanized pipes were used in the study. The least-lost diameters and the lowest economic costs were calculated for these pipes.

Keywords : Centrifugal pump, diameter calculation, pipe losts, economic pipe diameter.

1. Introduction

Pumping systems account for nearly 20% of the world's electrical energy demand and range from 25-50% of the energy usage in certain industrial plant operations[1]. Pumping systems are widespread; they provide domestic services, commercial and agricultural services, municipal water/wastewater services, and industrial services for food processing, chemical, petrochemical, pharmaceutical, and mechanical industries[1]. The initial setup and operating costs of these systems are important parameters that the account must participate in designing and operating the system[6]. Although pumps are typically purchased as individual components, they provide a service only when operating as part of a system. The energy and materials used by a system depend on the design of the pump, the design of the installation, and the way the system is operated. These factors are interdependent. What's more, they must be carefully matched to each other, and remain so throughout their working lives to ensure the lowest energy and maintenance costs, equipment life, and other benefits. The initial purchase price is a small part of the life cycle cost for high usage pumps. While operating requirements may sometimes override energy cost considerations, an optimum solution is still possible[1].

When designing a pump system, it is useful to compare different solutions to choose the most efficient and efficient system. To find the most intelligent solution, some basic facts must be revealed[12]. Over the past decade, the world has been focusing on lifetime cost (PPM) in pump selection. The aim is that when buying a pump, it is not only the purchase price, but the lifetime cost of the pump is important. Purchasing, operation and maintenance within the lifetime cost, cost of production loss in case of failure as much as the cost of energy, cost of dismantling are included[7]. Pump selection is primarily determined by the specification of operating conditions – in other words, the operating properties the pumps will be supplied for. The operating conditions primarily comprise data on the fluid handled (e.g. temperature, density, viscosity, dry substance content, sand content or other substances in the fluid), the expected flow rate and the required head, the suction behaviour and the speed of the centrifugal pump. Also required is information on the drive size and rating, the operating mode, the expected frequency of starts as well as any factors determined by the system or environmental regulations such as the maximum permissible noise emission, permissible vibrations, pipeline forces and potential explosion hazards[4].

2. Centrifugal Pumps

The capacity (flowrate, discharge, or Q) of a pump is the volume of liquid pumped per unit of time, usually measured in SI units in cubic meters per second for hour for small pumps [2]. The functionality and performance of a pump strongly depends on its hydrodynamics [13].

When centrifugal pumps are operated at constant speed, their flow rate Q increases as their head H decreases. In the characteristic head versus flow curve, also referred to as H/Q curve, the head H is plotted against the flow rate Q [4].

Proper pumping system design is the most important single element in minimizing [1]. The most challenging aspect of the design process is cost-effectively matching the pump and motor characteristics to the needs of the system. This process is often complicated by wide variations in flow and pressure requirements [3].

The piping diameter is selected based on the following factors:

• Economy of the whole installation (pumps and system)

• Required lowest flow velocity for the application (e.g., avoid sedimentation)

• Required minimum internal diameter for the application (e.g., solids handling)

• Maximum flow velocity to minimize erosion in piping and fittings

• Plant standard pipe diameters

Decreasing the pipeline diameter has the following effects:

• Piping and component procurement and installation costs will decrease [1].

• Pump installation procurement costs will increase as a result of increased flow losses with consequent requirements for higher head pumps and larger motors. Costs for electrical supply systems will therefore increase [1].

• Operating costs will increase as a result of higher energy usage due to increased friction losses [1].

3. Optimum Pipe Diameter Calculation

As a method in the study, a program was written by using the flow in the pipe, the flow friction losses and the heat transfer equations. Various results have been obtained for optimum selection of system components by calculating optimum pipe and insulation thicknesses in different pipe types, various insulation pedestals. The following formula and equations are used to calculate the flow and heat transfer in the pipe in the related program [6].

The pipeline system with a total length of 2400 m and the pump will be transported to a settlement of 1950 people at a height of 260 m. Daily water consumption per person is 250 lt. The pump to be used in the installation is required to work 2.5 hours a day. The pumps to be used in the pipeline are the pipes selected from the pipe catalog of a company and their products are selected as "Galvanized Threaded Pipe" according to DIN 2440 norm. An economic pipe diameter account will be made for a life of 20 years. Galvanized steel pipes are often used for water cooling systems both in industrial plants and in domestic buildings [14].

The project was carried out with reference to Ibrahim Gentez- economic pipe diameter account booklet.

L : pipeline length : 2400 m

Q : flow : 250 tl / (day * person)

Hg : 260 m

tp : pump run time : 2,5 hour / day

Person number : 1950

n (Project life) : 20 year

g (gravity) : 9,81 m/s^2

μg : engine efficiency : %75 (0,75)

electricity costs : 0,087 $ / kWh (Low Voltage - Single Time - unit prices for 1 kWh with tax January,2019) [8].

Table 1 Pipe specifications and price [9].

Diameter	Rated Diameter (DN)	Outside Diameter (mm)	Wall (mm)	Pipe Unit Price($)
½”	15	21,3	2,65	2,070
¾”	20	26,9	2,65	2,701
1”	25	33,7	3,25	3,902
1 ¼”	32	42,4	3,25	5,006
1 ½”	40	48,3	3,25	5,767
2”	50	60,3	3,65	8,059
2 ½”	65	76,1	3,65	10,355
3”	80	88,9	4,05	13,463
4”	100	114,3	4,50	19,773
5”	125	139,7	4,85	26,716
6”	150	165,1	4,85	31,769

Calculation of all desired values for nominal diameter 15.

3.1. Calculation Of Internal Diameter

Di: Inner diameter

Do: outer diameter

Wall (t): wall diameter

Di = Do – 2*t

Di = 21, 3 – 2*2, 65 = 16 mm

3.2. Calculation Of Flow (Q)

$$Q=\frac{250\,lt}{daily x person}*\frac{1\,daily}{2{,}5\,hours}*\frac{1\,hour}{3600\,sc}*1950 person*\frac{1m3}{1000\,lt}$$

Q = 0,0542 m^3/s = 195 m^3/h (the same value will be used in all diameters).

3.3. Vort (Average Speed) Calculation

$$\text{Vort}=\frac{4*Q}{\pi*(Di)^2}=\frac{4*0{,}0542 m^3/s}{\pi*(0{,}016m)^2}=269{,}403\,\frac{\text{m}}{s}$$

3.4. Reynolds Number of Fluid (Re)

μ (kinematic viscosity) = 1,005* 10$^{(-6)}$ m^2/s

$$\text{Re}=\frac{\text{Vort}*\text{Di}}{\mu}=\frac{(269{,}403\,m/s)*0{,}016\,m}{1{,}005*10^{-6}m^2/s}=4289001{,}369$$

3.5. *Λ (conductivity) Calculation of Value*

Ɛ= Equivalent roughness ratio = 0,15 * 10^{-3}

$$\Lambda = \frac{1,325}{[\ln(\frac{\varepsilon}{3,7*Di}+\frac{5,74}{\mathrm{Re}^{0,9}})]^2} = \frac{1,325}{\left[\ln\left(\frac{0,15*10^{-3}}{3,7*0,016}+\frac{5,74}{(4,289*10^6)^{0,9}}\right)\right]^2} = 0,0372$$

3.6. *"J" Flat Tube Energy Loss That Occurs At Unit Size*

$$j = \frac{\Lambda * \mathrm{Vort}^2}{2*\mathrm{Di}*g} = \frac{0,0371*\left(269,403\frac{m}{s}\right)^2}{2*0,016*9,81m/s^2} = 8578,999mss/m$$

3.7. *Hk Straight Pipe Loss Calculation*

Equipment/instruments especially that create a high-pressure drop and are provided with a bypass line (to have the facility for maintaining process continuity even during maintenance work). i.e. plate heat exchangers, control valves, etc. are provided with a bypass arrangement, which normally has two isolation valves in line of the unit and a flow regulation valve in parallel to this unit. In normal operations, as fluid passes through the main units either the plate heat exchanger or control valve, it exerts an additional pressure drop. Accordingly, the supply pressure for the fluid stream is estimated, which the connecting unit like the centrifugal pump creates. The centrifugal pump is selected based on this created pressure drop by the unit. During bypassing of the connected unit, this additional pressure is eliminated, while running pump discharges the high flow rate as per the typical pump characteristics. To avoid this situation, it is always recommended to use a lower size bypass line with a regulation valve to create pressure equivalent to the main connecting unit [10]. The amount of pipe losses of a private company is shown on the chart.

Hk=J*L=8578,999 mss/m*2400 m=20859597,569 mss

Table 2 Equipment used in installation and loss coefficient value [15].

Equipment	K	Adet	K*Adet
Klope+Strainer	10	1	10
E/xpansion Option	0,4	1	0,4
Shrinkage Element	0,012	1	0,012
Storage Entry	1	1	1
Valve	0,19	1	0,19
Check Valve	2,5	1	2,5
90º Elbow	1,12	3	3,36
Sleeve	0,06	400	24
		ΣK	41,462

One pipe size: 6 m

Total pipeline length: 2400

$\frac{2400}{6}$ =400 Pipes to be used

The K loss coefficient values given in the respective tables for each element that cause the loss of local energy that we can find to test are determined by the average value, which is a criterion emphasizing the loss of energy by the manufacturer firm [5].

3.8. *H_L Calculation of Local Losses*

$$\mathrm{HL}= \Sigma k * \frac{Vort^2}{2*g} = 41,462*\frac{\left(269,403\frac{m}{s}\right)^2}{2*9,81\frac{m}{s^2}} = 153375,423 \text{ mss}$$

3.9. *Hm Calculation of Energies to be Supplied to the System*

Hm=Hk + HL + Hg =20589597,569 mss + 153375,426 mss + 260m =20743232,991 mss

3.10. *Ne Calculation of Effective Power*

γ=9810N/m^3

$$Ne = \frac{\gamma*Q*Hm}{\mu g}*\frac{1kW}{1000W} = \frac{9810\frac{N}{m^3}*\frac{0,0542m^3}{s}*20743232,991}{0,75}*\frac{1kW}{1000W} = 14696580,574\ kW$$

3.11. *Nm Calculation of Engine Power*

α: Safety Factor

Ne ≥34 kW	α : 1,1
34 kW ≥ Ne ≥6 kW	α : 1,2
Ne ≤ 6,2 kW	α : 1,3

Nm=α * Ne =1,1 * 146696580,574

Nm=16166238,632 kW

3.12. *Calculation of Annual Electricity Costs (A.E.C.)*

Energy Market Regulation Board Cost: 22, 1093 penny/kWh [8]

$$\mathrm{A}.E.\mathrm{C}. = Nm * T * \mathrm{Fee} = 16166238,632*\frac{2,5\ hour}{1\ day}*\frac{365,25\ day}{1\ year}*0,36\frac{\$}{kWh} = 531424679,273\ \$/year$$

3.13. *Calculation of Annual Fixed Cost (A.F.C.)*

i: Percentage increase in pipe unit price %15 (0,15)

n : project life 20 years

k : capital repayment factor

$$k = \frac{i*(i+1)^n}{(i+1)^n-1} = \frac{0,15*1,15^{20}}{1,15^{20}-1} = 0,159$$

A.F.C= Pipe unit price * k =2,070*0,159 = 0,330697184 $/(year * m)

3.14. *Annual Total Fixed Cost Calculation (A.T.F.C.)*

A.T.F.C. = A.F.C. * L =0,330697184 $/(year*m) * 2400 m = 793,6732405 $/year

3.15. *Annual Total Cost Calculation (A.T.C.)*

Total cost consists of two components; investment and operating cost.

A.T.C. = A.T.F.C. + A.E.C. =793,6732405 + 5314246794,273 = 5314246795066,20 $/year

4. Unit Energy Costs And Optimum Diameters

Table 3 Calculation of whole desired values for all nominal diameter

Diameter	out diameter	wall	Price($)	Inner diameter	Flow rate	Vort	Re
15	21,3	2,65	2,070	0,016	0,0542	269,4029	4289001,37
20	26,9	2,65	2,701	0,0216	0,0542	147,8205	3177038,05
25	33,7	3,25	3,902	0,0272	0,0542	93,2190	2522941,98
32	42,4	3,25	5,006	0,0359	0,0542	53,5123	1911532,64
40	48,3	3,25	5,767	0,0418	0,0542	39,4720	1641723,01
50	60,3	3,65	8,059	0,053	0,0542	24,5522	1294792,87
65	76,1	3,65	10,355	0,0688	0,0542	14,5702	997442,18
80	88,9	4,05	13,463	0,0808	0,0542	10,5638	849307,20
100	114,3	4,5	19,773	0,1053	0,0542	6,2199	651700,11
125	139,7	4,85	26,716	0,13	0,0542	4,0809	527877,09
150	165,1	4,85	31,769	0,1554	0,0542	2,8559	441596,02
200	219,1	5	37,778	0,2091	0,0542	1,5774	328187,57
250	273	5,6	47,222	0,2618	0,0542	1,0062	262123,84

diameter	Λ	J (mss/m)	H_K (mss)	H_L(mss)	H_m(mss)
15	0,037106592	8578,998987	20589597,57	153375,4225	20743232,99
20	0,033662559	1735,656715	4165576,115	46176,46663	4212012,582
25	0,031341408	510,3398044	1224815,53	18363,70	1243439,226
32	0,028867061	117,3588326	281661,1982	6051,428529	287972,6267
40	0,027642635	52,51501437	126036,0345	3292,536329	129588,5708
50	0,025901152	15,01499462	36035,98709	1273,890868	37569,87796
65	0,024206154	3,806878909	9136,509381	448,6234282	9845,132809
80	0,023269134	1,637981041	3931,154498	235,8252262	4426,979724
100	0,021898393	0,410067958	984,163099	81,75648625	1325,919585
125	0,02096134	0,136863533	328,4724786	35,19348653	623,6659651
150	0,02027722	0,054242388	130,1817316	17,23580789	407,4175395
200	0,019374883	0,011750	28,20107236	5,257987768	293,4590601
250	0,018901298	0,00372588	8,942112169	2,139720925	271,0818331

Table 4 Calculation of whole desired values for all nominal diameter (continued)

diameter	N_m (kW)	A.E.C($/year)	A.F.C.($/(year * m))	A.T.F.C. ($/year)	A.T.C. ($/year)
15	16166238632	5314246794272,53	0,331	793,6732405	5314246795066,20
20	3282632006	1079083206088,54	0,432	1035,761699	1079083207124,30
25	969074360,9	318558969283,33	0,623	1496,019697	318558970779,35
32	224431466,6	73776233862,30	0,800	1919,312092	73776235781,62
40	100994852,7	33199532944,00	0,921	2211,412837	33199535155,41
50	29280084,39	9625095739,81	1,287	3089,88952	9625098829,70
65	7672804,255	2522242578,58	1,654	3970,54065	2522246549,12
80	3450166,648	1134156031,25	2,151	5162,137734	1134161193,39
100	1033355,429	339689763,33	3,159	7581,57269	339697344,90
125	486054,0699	159778124,14	4,268	10243,82092	159788367,96
150	317520,8594	104377044,51	5,076	12181,25341	104389225,76
200	228707,3185	75181813,28	6,035	14485,11602	75196298,39
250	211267,6266	69448950,56	7,544	18106,39503	69467056,96

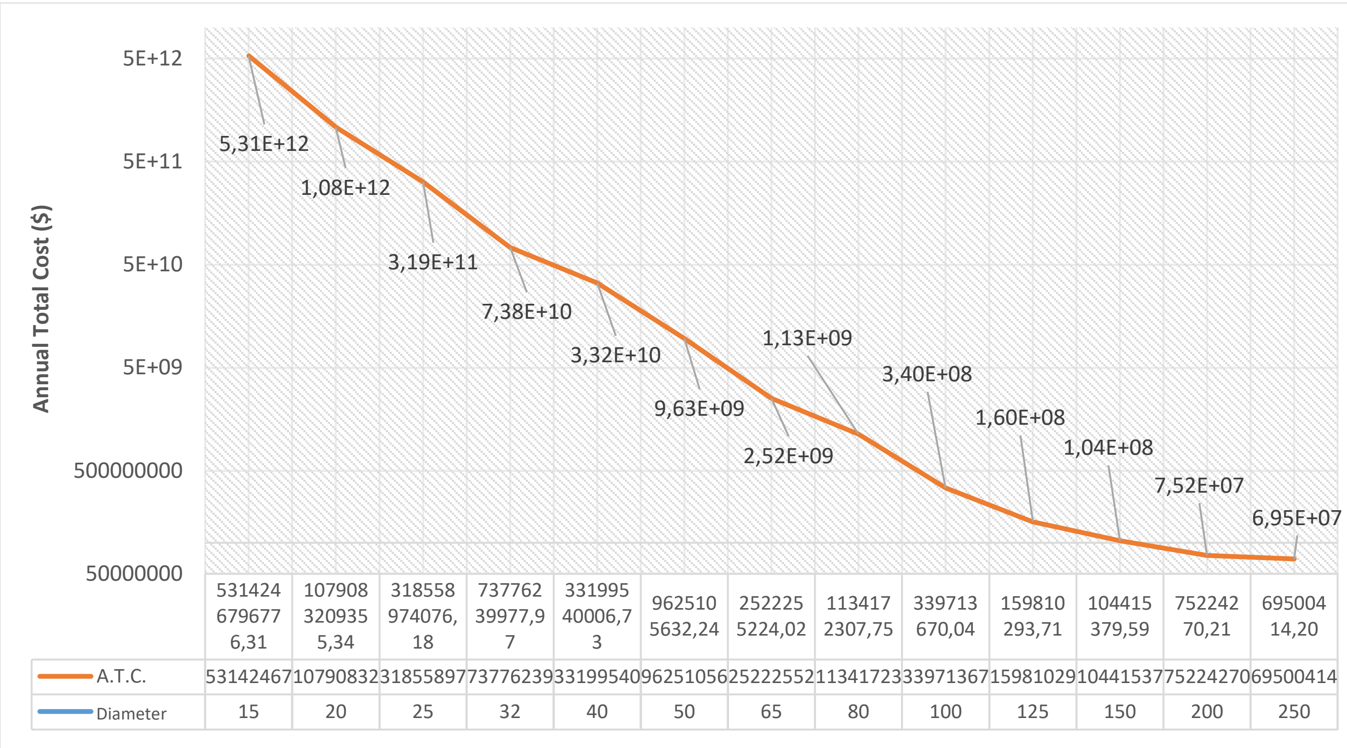

Fig.1. ATC & Diameter Chart.

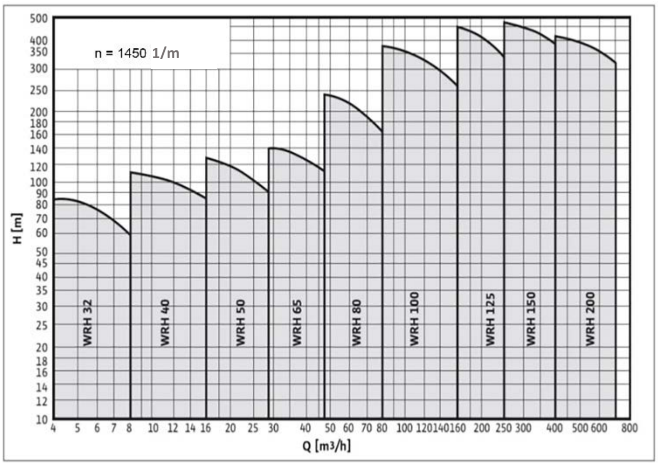

Fig. 2. Selection Table for Horizontal Step Pumps [16].

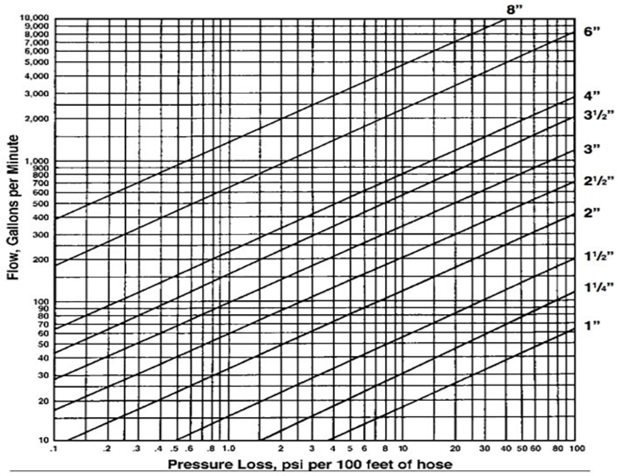

Fig.3. Volumetric Calculation Fluid Chart [11].

5. Conclusion

This approachment is intended to make possible engineers and researchers in detect cost-effective solutions for the pump select. The comparison of results of current work with other state of art works in the literature is presented in Table 1.a., Table 1.b. and Figure1. From the table it is clear that many experiment have worked on economic pump choose. As a result of the experimental work done, the loss coefficients are calculated with the aid of the determined pressure deductions taking into consideration the flow direction for the flat pipes, valves and fittings (elbows, nipples, cuffs, record, curve, reduction and TE transitional elements) that was calculated and presented in tables. When selecting a pump, the pump type, the environmental characteristics of the pump and the installation project should be considered.

For all cases insulated and uninsulated, the use of stainless steel pipes at optimum diameters allows the system to operate with minimal loss. Depending on the increase in pipe diameter, the in-pipe friction losses decrease and this reduces the pump's loss power. The diameter of the smallest of all these increases and decreases is the optimum diameter that should be preferred.

In this study, the process of transporting a certain amount of water to a certain distance has been examined. It is crucial that many criteria be evaluated at the same time in order to select the correct, appropriate and appropriate pump to be understood from the most appropriate pump selection. The environmental characteristics of the pump to be used, the type of pump and the installation project must be carefully considered when selecting a pump. The error that might happen in any of these three items may cause the inefficient operation of our pump no matter how the other parameters are.

According to Table3, to choose the ideal pipe diameter for us, all diameter values are read one by one and we get the closest values to each other. It appears here that the diameters of 150, 200 and 250 mm were determined by A.T.C. very close to each other. When the external factors such as price variability, quantity and so on are considered, they are the closest 200 and 250 mm diameters. If we consider these two diameters from the most economical point of view, 200 mm will be the ideal diameter for us. The energy required from us for this diameter value, manometric pressing pressure Hm: 239,459 m flow rate: 195 m^3/h. If you want to use one pump we can use one multi-stage full centrifugal pump of type WRH125 for 1450 pumps or these pumps can be selected in other pumps that allow WRH 80 and WRH 100 as well from Fig. 2.

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