

Annexure 6.1: Economical Size of Pumping Main

In view of the principles of design given in the subsection for the economic size of the pumping main, a stepwise design process is given below in the form of an excel sheet in print media which can be easily written in electronic media:

1. Establish data required for pumping main.
 - a. Design period - 30 years
 - b. Design life of pump sets - 15 years
 - c. Supply of water in two stages each of 15 years
 - d. First stage supply rate is the average of the initial and intermediate flow rate in MLD (for energy cost only)
 - e. Second stage supply rate is the average of intermediate and ultimate flow rate in MLD (for energy cost only)
 - f. Hours of pumping - 22 hr
 - g. The cost of pipes, at prevailing rates in Rs/metre (if required, the cost includes the cost of excavation, lowering, laying, and jointing of pipes and specials filling of trenches, etc.) can be included. However, these costs are, more or less, constant in different alternatives.
 - h. Cost of first stage pump sets at prevailing rates in Rs/each pump set (pump+ electric motor)
 - i. Similarly, obtain the cost of second stage pump sets
 - j. Cost of electrical energy at prevailing rates in Rs/kWh
 - k. Cost of operation and maintenance cost as per estimate framed for pumping main in Rs/year
 - l. Average hour of pumping (1st Stage) = (S. No. (f)/intermediate flow rate) × average flow rate for first stage
 - m. Average hour of pumping (2nd Stage) = (S. No. (f)/ultimate flow rate) × average flow rate for second stage
2. Select appropriate pipe material considering topography, soil condition, as well as the quality of water to be conveyed.
3. Select different sizes of pipes of chosen material by using Lea's formula.
4. Calculate velocity and frictional losses in pipe length of pumping main and appurtenances for first stage intermediate flow rate and for second stage ultimate flow rate for the selected pipe size.
5. Determine the class of pipe considering total pressure head (static head, i.e., difference of level between the axis of pump and delivery point + head losses due to friction in pipe length of pumping main and its appurtenances for ultimate flow + residual head required at the delivery end). Also consider surge pressure, calculated by formula as given in the section of 'WATER HAMMER'.

6. Determine the total head of pumping of the first stage (static head + frictional losses in step 4 + residual head) and for the second stage (static head + frictional losses as given in step 4 + residual head).
7. Determine kw of pump set taking the total head of pumping and flow rates as given in steps 4 and 6. Add 50% for standby pump sets. (Calculate pump kw by the formula given in “Chapter 4 Pumping Station and Machinery”.
8. Calculate the annual cost of energy as follows:

The annual cost of energy for the first stage = kW of pump × average hours of pumping/day (as given in step 1(l) × 365 days × cost of electrical energy at the prevailing rate as in 1(j).

Similarly, calculate the annual cost for the second stage taking average pumping hours as accurately given in step 1(m).

9. Capitalise annual cost of energy and O&M for first and second stage as given:

$$\text{First Stage capitalised energy cost} = AEC \left\{ \frac{1-(1+r)^{-n}}{r} \right\} \quad (\text{Eq. 1})$$

Where:

AEC = Annual Energy Cost

r = Rate of interest

n = Number of years

$$\text{First stage capitalised O\&M cost} = AOM \left\{ \frac{1-(1+r)^{-n}}{r} \right\} \quad (\text{Eq. 2})$$

Where A.O.M = annual operation/maintenance cost.

Similarly, calculate the capitalised cost for energy and O&M for the second stage.

10. Calculate the PW of future capitalised cost of energy and O & M of the second stage.

$$\text{Present worth second stage energy cost} = \frac{\text{Capitalized 2nd stage energy cost}}{(1+r)^n} \quad (\text{Eq. 3})$$

$$\text{Present worth second stage O\&M cost} = \frac{\text{Capitalized 2nd stage O\&M cost}}{(1+r)^n} \quad (\text{Eq. 4})$$

$$\text{Present worth second stage pump set} = \frac{\text{Capitalized 2nd stage pump set}}{(1+r)^n} \quad (\text{Eq. 5})$$

$$\text{PW of second stage pump set} = \frac{\text{Cost of 2nd stage pump sets}}{(1+r)^n}$$

11. Determine the total investment cost for the selected pipe size as given below:

Pipe size

- a) cost of pipe length
- b) 10% cost of pipe for the cost of specials
- c) cost of pump sets for the first stage
- d) capitalised cost of energy for the first stage

- e) capitalised cost of o/m cost for the first stage
- f) PW of capitalised energy cost for the second stage
- g) PW of capitalised o/m cost for the second stage
- h) PW of cost of pump sets for the second stage

A total of (a) to (h) is the total investment cost for the pipe size.

12. Repeat steps (4) to (11) by selecting the next available size. Compare with the total cost of the previous alternative, If the total cost is lesser than that of the previous size the process will be continued. Else the previously selected diameter is considered an economical diameter.
13. Prepare comparative statement for total investment cost for each selected size of pipes and select pipe size of least cost investment which is the most economic size of pumping main.

Excel worksheets can be programmed to simplify the calculation.

Economical diameter of rising main - Design steps

INPUT DATA

1) Water requirement :	Year	Discharge
A. Initial	2012	5.00 mld
B. Intermediate	2027	7.50 mld
C. Ultimate	2042	10.00 mld
2) Pumping main	LENGTH	7000.00 M
3) Static head for pump	ST HEAD	50.00 M
4) Design period	YEAR	30 yr.
5) Combined eff. of pump set	EFF. %	70.00 %
6) Cost of Pumping Set	Rs./KW	25000.00 Rs
7) MAAR-Interest Rate - Inflation rate	INTEREST	6.50 %
8) Life of elec. motors	P.Yrs	15 yr.
9) Energy charges /KWH Unit	Rs./KWH	5.00 Rupee
10) Pumping hours for discharge at the end of 15 Years	PUMPING- HOURS	22 hrs
11) Minor head loss as %age of frictional head loss		10.00 %
12) Standby pump capacity	percentage	50.00 %

13) PIPE DATA

Internal diameter in mm.	Material	Class	HWC	Rate per m Rs/M	OMR Rs/m Rs/M
300.00	DI	K-9	140	3664.19	0.00
350.00	DI	K-9	140	4513.91	0.00
400.00	DI	K-9	140	5418.21	0.00
450.00	DI	K-9	140	6543.68	0.00
500.00	DI	K-9	140	7611.06	0.00

$$C_e = \frac{1}{(1+r)^n} = \frac{1}{(1+0.065)^{15}} = 0.39$$

TABLE 1 - VELOCITY AND LOSS OF HEAD FOR DIFFERENT PIPE SIZES

Sl. No.	Internal Pipe diameter (mm)	Frictional Head loss per 1000 m		Velocity (m/s)		Total head in 'm' for 7000 m pipe length including 50 m of static head					
		1st stage flow 7.5 MLD	2nd stage flow MLD	1st stage flow	2nd stage flow	Frictional loss 1st stage flow	Minor head loss for 1st stage flow	Total head for pumping H1 for 1st stage flow	Frictional loss 2nd stage flow	Minor head loss for 2nd stage flow	Total head for pumping H1 for 2nd stage flow
1	2	3	4	5	6	7	8	9	10	11	12
1	300.00	5.06	1.63	1.34	1.79	35.45	3.55	10.00	60.40	6.04	116.44
2	350.00	2.39	4.07	0.98	1.31	16.73	1.67	68.41	28.51	2.85	81.36
3	400.00	1.25	2.13	0.75	1.00	8.73	0.87	59.61	14.88	1.49	65.37
4	450.00	0.70	1.20	0.60	0.79	4.92	0.49	55.41	8.38	0.84	59.21
5	500.00	0.42	0.72	0.48	0.64	2.95	0.29	53.24	5.02	0.50	55.52

*** * Minor head loss = 10% of frictional loss

Table (3)

Column 2	=	Cost of pump sets
Column 3	=	Annual cost of energy charges and OMR
	=	(33475.16 KW ₁ + OMR) = CR ₁
Column 4	=	Capitalised cost of energy charges and OMR for the first stage
	=	C _f × CR ₁ = 9.4 × Column (3) of Table (3)
Column 5	=	Total capitalised cost for first stage
	=	Column (11) of Table (2) + Column (2) of Table (3) + Column (4) of Table (3)
Column 6	=	Cost of pump set for second stage
Column 7	=	Annual energy and OMR cost
	=	(35155.31 KW ₂ + OMR) = CR ₂
Column 8	=	Capitalised cost of energy and OMR cost for second stage
	=	C _f × CR ₂
	=	9.4 × (Column (7) of Table (3))
Column 9	=	Initial capital investment for annual energy charges, OMR changes and cost of replacement of pump set for the second stage
	=	(Column (6) of Table (3) + Column (8) of Table (3)) × Capitalisation factor for second stage pump cost (C _P) as calculated at step No 8
Column 10	=	Grand Total of capitalised cost for 30 years
	=	Column (5) of Table (3) + Column (9) of Table (3)

TABLE 2 - KILOWATTS & COST OF PUMP SETS REQUIRED FOR DIFFERENT PIPE SIZES AND PIPE COST

Sl.No	Internal Pipe diameter (mm)	Class of pipe	1st stage flow of 7.5 million liters/day			2nd stage flow of 10 million liters/day			Pump Cost including cost of stand by sets as mentioned at input data at Sr.No 12 @ Rs 25000 per KW (Rs in thousand)	Cost of pipe per unit length (Rs)	Cost of 7000 meter pipe line (Rs. In thousand)
			H1 Total head (m)	Total working KW required	Pump Cost	H2 Total head (m)	Total working KW required	Pump Cost including cost of stand by sets as mentioned at input data at Sr.No 12 @ Rs 25000 per KW (Rs in thousand)			
1	2	3	4	5	6	7	8	9	10	11	
1	300.00	K-9	89.00	118.00	4425.00	116.00	205.00	7688.00	3664.19	25649.33	
2	350.00	K-9	88.00	90.00	3375.00	81.00	143.00	5363.00	4513.91	31597.37	
3	400.00	K-9	90.00	80.00	3000.00	68.00	117.00	4388.00	5418.21	37927.67	
4	450.00	K-9	55.00	75.00	2738.00	59.00	104.00	3900.00	6543.68	45805.76	
5	500.00	K-9	53.00	70.00	2625.00	58.00	99.00	3713.00	7611.06	53277.62	

TABLE 3 - COMPARATIVE STATEMENT OF OVERALL COST OF PUMPING MAIN FOR DIFFERENT PIPE SIZES

Sl.No	Capital cost of pump sets including cost of stand by sets @ Rs 25000 per KW (Rs in thousand)	Annual Energy & OMR cost for first stage/Rs thousand)	Capitalised cost of Annual Energy & OMR for first stage (Rs. in thousand)	Total Capitalised cost of first stage (Rs. in thousand)	Capital cost of pump sets including stand by sets @ Rs 25000 per KW (Rs in thousand) for second stage.	Annual Energy & OMR cost for second stage (Rs. thousand)	Capitalised cost of Annual Energy & OMR for second stage (Rs. in thousand)	Initial capital investment for pump sets and annual Energy and OMR cost for second stage (Rs in thousand)	Grand Total of Capitalised cost for 30 yrs (Rs. in thousand)	Internal Pipe diameter (mm)
1	2	3	4	5	6	7	8	9	10	11
1	4425	3950	37141	67215	7688	7207	67765	29338	96553	300.00
2	3375	3013	28330	63302	5363	5027	47267	20464	83766	350.00
3	3000	2678	25180	66107	4388	4113	38673	16743	82850	400.00
4	2738	2444	22980	71524	3900	3656	34376	14883	86407	450.00
5	2625	2343	22030	77932	3713	3480	32721	14167	92099	500.00

Remarks : From this table, it is seen that most economical diameter of main is 400 mm having least capitalised cost.

Note : 1) Total KW and capital cost of pumping machinery shall be calculated including cost of stand by set as mentioned in Sr No 12 of input data
2) Annual energy charges shall be calculated for working KW.