# 29. Designing simple pipelines

## Introduction

**This paper tries to introduce the reader to the principles of pipeline design. It is a very difficult process for people who have not previously been taught the principles of hydraulics to understand and so it has been necessary to simplify the calculations by excluding factors that usually have only a small effect on the design.**

## Terminology

Water flowing along a pipe is a bit like a car travelling along a road. For the car to move it must use energy. That energy can be supplied by the fuel in the fuel tank being burned and by the height of the car above the point it is trying to reach. As the car travels along some of the energy will be used up overcoming the friction in the car's moving parts. On a flat road the energy would all come from the fuel but on a steep slope it could all come from the change in height of the car. (Figure 1.)

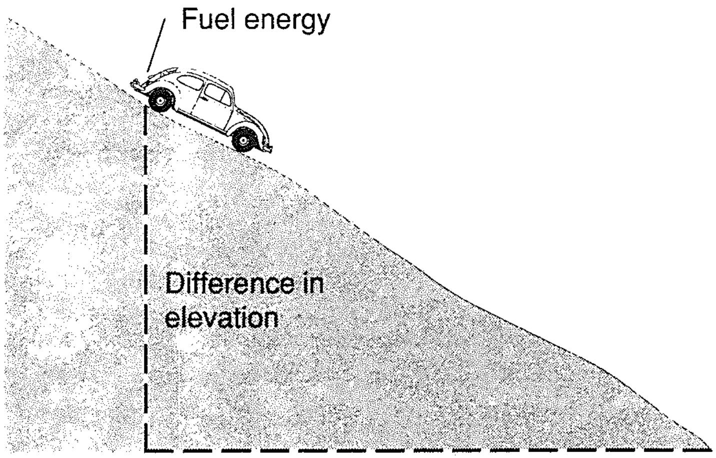


*Figure 1*

In the same way, to overcome the friction of the moving water against the pipe surface, water flowing along a pipe requires energy. Initially, it is all supplied by the change in altitude *(potential energy)* but it can be converted into an internal energy store known as *pressure energy*.

If we connect a glass tube with an open top to the top of a pipe full of water under pressure, provided the pipe is tall enough, the water will rise up the tube until the pressure at the bottom of the tube produced by the weight of the water column is the same as the pressure in the pipe. This column of water is called the *pressure head*. (Figure 2).

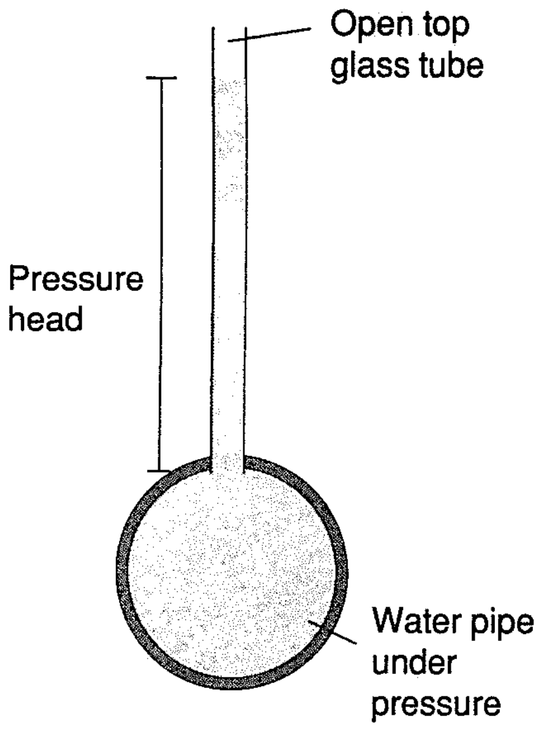


*Figure 2*

# Designing simple pipelines

One big difference between energy in cars and pipes is that the energy in pipes can change the way it is stored. If we assume for a moment that the water can travel along the pipe without using any energy then some or all of the energy can be converted between pressure and potential energy. The total energy, however, remains the same. (Figure 3)

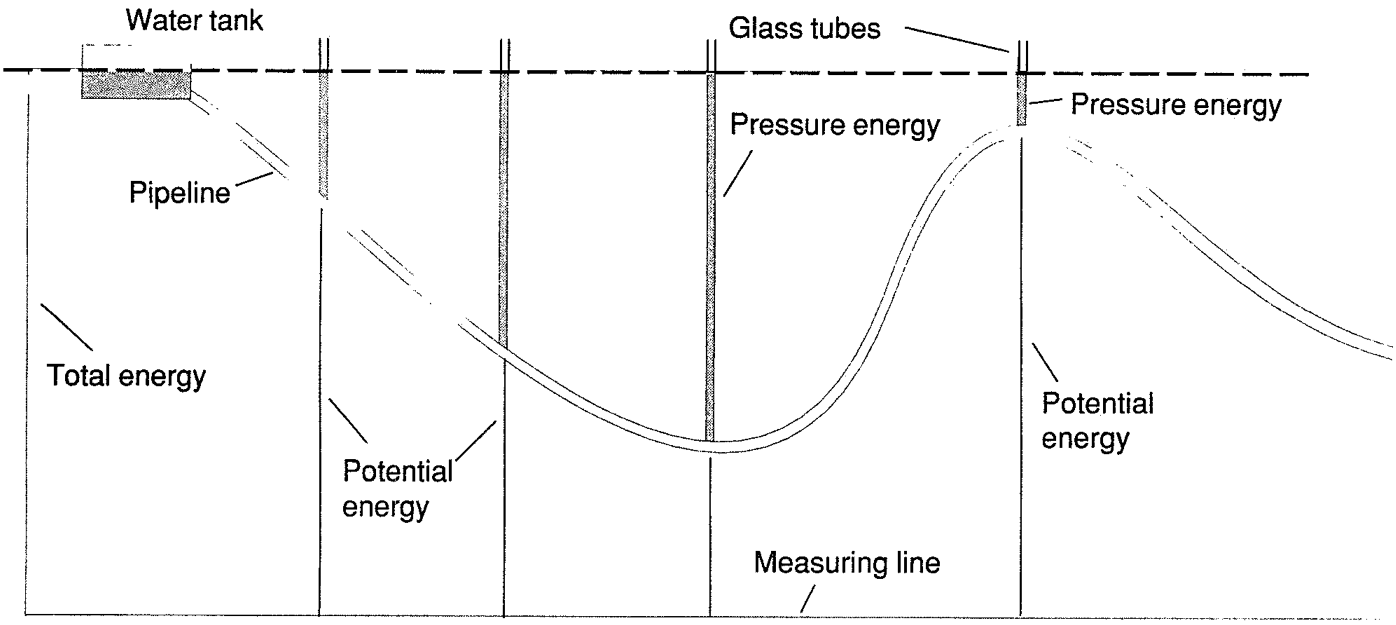


*Figure 3*

In practise energy is used up by friction as the water flows along the pipe such that the total energy available at the end is less than that at the beginning. This would be visible if we could fit a number of glass tubes in our pipeline because the water surface in the tubes would be seen to fall. If we could draw an imaginary line joining up the water levels in the glass tubes we would be able to measure the pressure in the pipe anywhere along the pipe and the difference in height between the line and another imaginary line drawn through the water surface level at the start of the pipeline would show the amount of energy lost. The sloping line is called the *hydraulic gradient line*. (Figure 4).

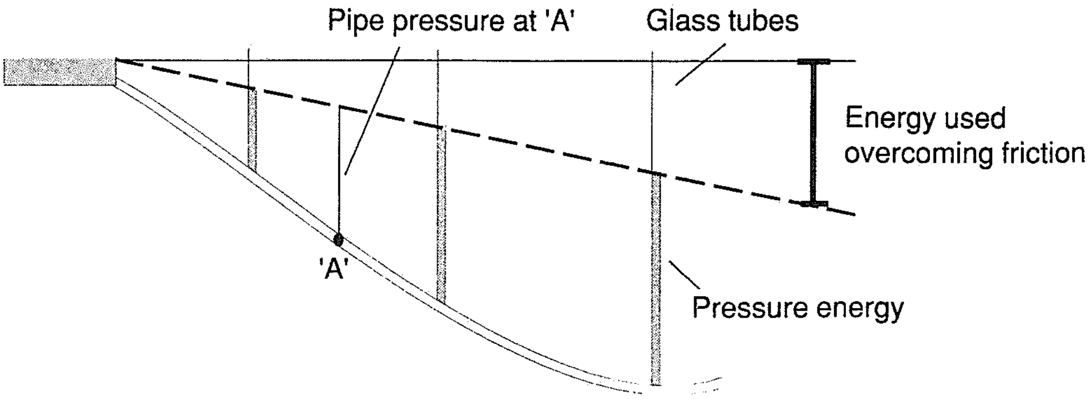


*Figure 4*

## Designing the pipe

If we know how much energy we have at the start and end of a pipeline and we know the pipe length we can work out the slope of the *hydraulic gradient line.* Alternatively the total energy loss can be divided by the length of the pipeline to find the energy lost per metre length of pipe.

**Table 1:** Energy loss in metres per metre length of pipe

| Flow l/h | PIPE MATERIAL AND DIAMETER IN MILLIMETRES | | | | | | | | | | | | Flow l/h |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | POLYTHENE (HDPE) | | | | uPVC | | | | GALVANIZED IRON (GI) | | | | |
| | 12 | 20 | 25 | 38 | 12 | 20 | 25 | 38 | 12 | 20 | 25 | 38 | |
| 500 | 0.18 | 0.01 | 0.00 | 0.00 | 0.21 | 0.01 | 0.00 | 0.00 | 0.28 | 0.02 | 0.00 | 0.00 | 500 |
| 1000 | 0.63 | 0.05 | 0.01 | 0.00 | 0.75 | 0.06 | 0.02 | 0.00 | 1.09 | 0.07 | 0.02 | 0.00 | 1000 |
| 1500 | 1.32 | 0.11 | 0.03 | 0.00 | 1.62 | 0.12 | 0.04 | 0.00 | 2.43 | 0.16 | 0.05 | 0.00 | 1500 |
| 2000 | 2.21 | 0.18 | 0.06 | 0.00 | 2.82 | 0.21 | 0.07 | 0.00 | 4.29 | 0.29 | 0.09 | 0.01 | 2000 |
| 2500 | 3.32 | 0.28 | 0.09 | 0.01 | 4.33 | 0.32 | 0.10 | 0.01 | 6.68 | 0.45 | 0.14 | 0.01 | 2500 |
| 3000 | 4.63 | 0.39 | 0.13 | 0.01 | 6.16 | 0.45 | 0.15 | 0.01 | 9.59 | 0.64 | 0.20 | 0.02 | 3000 |
| 3500 | 6.14 | 0.51 | 0.17 | 0.02 | 8.31 | 0.61 | 0.20 | 0.02 | 13.02 | 0.87 | 0.27 | 0.03 | 3500 |
| 4000 | 7.85 | 0.65 | 0.22 | 0.03 | 10.77 | 0.78 | 0.25 | 0.03 | 16.98 | 1.13 | 0.35 | 0.04 | 4000 |
| 4500 | 9.74 | 0.80 | 0.27 | 0.03 | 13.56 | 0.98 | 0.32 | 0.04 | 21.47 | 1.43 | 0.44 | 0.05 | 4500 |
| 5000 | 11.84 | 0.97 | 0.33 | 0.04 | 16.67 | 1.20 | 0.39 | 0.04 | 26.47 | 1.76 | 0.54 | 0.06 | 5000 |
| 5500 | 14.13 | 1.16 | 0.39 | 0.05 | 20.09 | 1.44 | 0.46 | 0.05 | 32.01 | 2.12 | 0.65 | 0.07 | 5500 |
| 6000 | 16.64 | 1.36 | 0.46 | 0.06 | 23.84 | 1.71 | 0.55 | 0.06 | 38.06 | 2.52 | 0.78 | 0.08 | 6000 |
| 6500 | 19.31 | 1.57 | 0.53 | 0.07 | 27.90 | 1.99 | 0.64 | 0.07 | 44.65 | 2.96 | 0.91 | 0.10 | 6500 |
| 7000 | 22.18 | 1.80 | 0.61 | 0.08 | 32.28 | 2.30 | 0.73 | 0.09 | 51.75 | 3.43 | 1.05 | 0.11 | 7000 |
| 7500 | 25.23 | 2.04 | 0.69 | 0.09 | 36.98 | 2.63 | 0.84 | 0.10 | 59.38 | 3.93 | 1.21 | 0.13 | 7500 |
| 8000 | 28.47 | 2.30 | 0.77 | 0.10 | 42.00 | 2.98 | 0.95 | 0.11 | 67.54 | 4.47 | 1.37 | 0.15 | 8000 |
| 8500 | 31.91 | 2.57 | 0.86 | 0.11 | 47.34 | 3.35 | 1.07 | 0.13 | 76.21 | 5.04 | 1.55 | 0.17 | 8500 |
| 9000 | 35.33 | 2.85 | 0.96 | 0.12 | 52.99 | 3.74 | 1.19 | 0.14 | 85.42 | 5.64 | 1.73 | 0.19 | 9000 |
| 9500 | 39.33 | 3.15 | 1.06 | 0.14 | 58.97 | 4.16 | 1.32 | 0.16 | 95.15 | 6.28 | 1.93 | 0.21 | 9500 |

***Note:*** *Pipes are assumed to be a few years old working under normal conditions*

Knowing the energy loss per metre length and the amount of water required it is possible to calculate the most appropriate size of pipe to use. This calculation is difficult to do by hand and so Table 1. gives a selection of useful results. The table shows the energy loss per metre length of pipe for different pipe sizes and different flow rates. The table is also divided into different pipe materials since these too have an effect on the amount of energy used. The best way to explain how to use the table is to give an example.

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## Example

It is hoped to use a spring 2 000m from a village as a source of water. What size of pipe must be laid if a flow of 3000 litres per hour is required and the spring is 50 metres higher than the village? (Figure 5 shows a section along the proposed pipeline.)

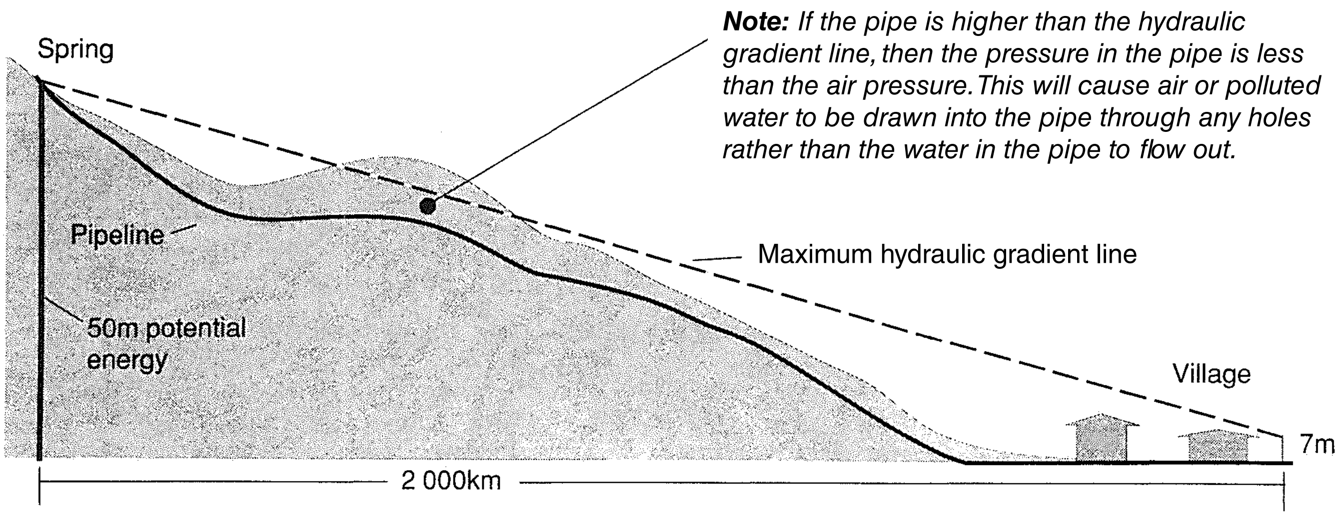


*Figure 5*

| | |
|---|---|
| Energy available at the spring box | 50m (potential energy) |
| Energy needed in the pipe in the village for distributing the water around the pipes in the village and out of the standposts | 7m (pressure energy) |
| Maximum energy that can be lost by friction | 50 - 7 = 43m |
| Energy loss per metre length of Pipe<br>(It is acceptable to use the pipe length if the horizontal length cannot be measured) | $\frac{43}{2000}$ = 0.02 m/m |

From the table, for flows of 3 000 litres per hour we would need 38mm diameter for all pipe materials. This is the maximum flow for a 38mm GI pipe having an energy loss of 0.02m/m but HDPE and uPVC pipes of this diameter would provide 3500 l/h. The selection would depend on the cost, types of pipe available and type of ground in which the pipe was to be laid.

**Note:** *The pipe chosen must always have an actual energy loss less than the maximum allowable loss. Also, the maximum working pressure should be lower than that recommended for the piping used. Technical Brief No. 26: Public standposts gives head losses for pipe fittings and taps.*

## Further reading:


Jordan Jnr, Thomas D., *A Handbook of gravity-flow water systems.* Intermediate Technology Publications, 1984.



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