Pipe Design for Small Rural Systems

System Design

Pipe system design requires careful thought and a thorough understanding of the requirements and operating conditions.

In many rural areas advice can be sought from professional designers or the relevant State Department of Primary Industries which provides a design survey at minimal or no cost. PPI recommends that for large or complex systems that their advice is sought.

This guide will be of benefit for small systems or for giving an understanding as to what is involved for larger systems. Under no circumstances can PPI be held responsible for the system design derived from this guide or from advice give by PPI staff.

Design Considerations

The basis of system design is to ensure the most cost effective solution that meets all the performance criteria.

As in all good designs, the solution can only be as good as the information available. So often it is the first step, the information gathering step, that is rushed or not given enough emphasis. It is not accurate enough to assume that "the land is flat" or that "about 1000 gallons per hour will be enough". These assumptions may lead to a system failure or a reduction in the system performance.

The choice or pipe diameter and pressure rating (PN) is determined by assessing the following factors;

- The flow or output required.
- The system pressure (constant or peak).
- The elevation changes along the pipe line.
- System allowance to enable pipes to stay full or drain.
- The friction losses caused by the pipes.
- Ground conditions: rocky, sandy etc.
- Temperatures involved for re-rating.

Flow Output

Water supply to stock feed troughs is usually at very low pressures, but the flow must be calculated to match the drinking requirements of the stock.

Spray irrigation generally requires high pressures and the total flow rate needs to be matched to the total capacity of the sprinklers.

Once the output is determined the pipe sizes can be selected.

Larger diameter pipes carry more water and higher pressures move water more quickly. Remember that flow is proportional to area not diameter.

Doubling the pipe diameter increases the cross sectional area by a factor or four. Significant increases in flow can be achieved by increasing one pipe size.

System Pressure

Pressure is simply the force applied by the fluid across a certain area.

Gravity acting on a drum full of water will push the water out if a hole is drilled in the bottom.

Pumps are a mechanical means of applying force (pressure) to a fluid.

Polyethylene pipe is manufactured in various pressure ratings to withstand different system pressures. Pipe with a high pressure rating has thicker walls and is therefore more expensive. Once the pressure is known the correct pressure rating of pipe can be selected to minimise the cost.

The pressure can be controlled by the selection of the appropriately sized pump when pumping from a dam or river.

Conversion Table		
PN3.2	320kPa	46psi
PN4	400kPa	58psi
PN6.3	630kPa	91psi
PN8	800kPa	116psi
PN10	1000kPa	145psi
PN12.5	1250kPa	181psi
PN16	1600kPa	232psi
PN20	2000kPa	290psi
PN25	2500kPa	363psi

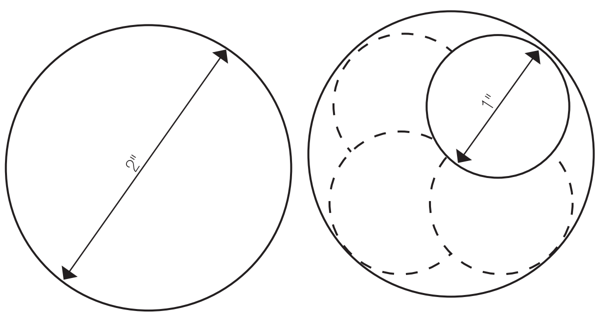
Pressure Conversion

multiply →

MPa	1000	kPa
Bar	100	kPa
Metre Head	10	kPa
psi	6.9	kPa

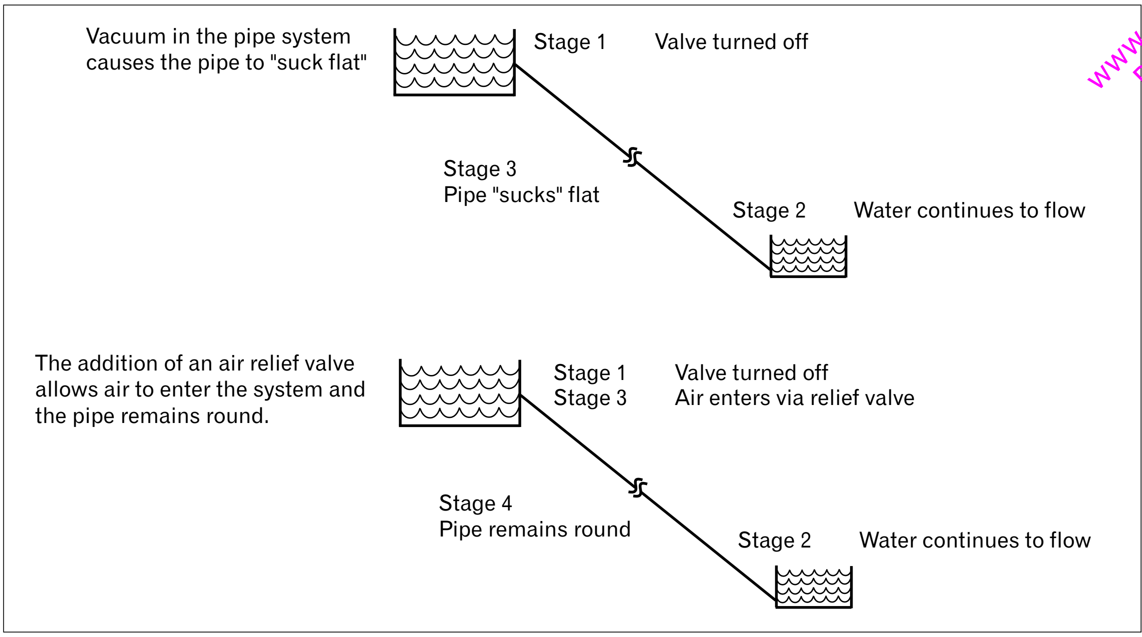
← *divide*

Pressure Conversion Chart



2" pipe carries four times as much water as 1" pipe

How to avoid "sucked" flat pipe – the most common pipe system failure.



Elevation

The relative elevation of the pipe line from the source must be known so that pressure variations and vacuum air relief valves can be allowed for.

The pressure in the total pipe line must be considered before selecting the class of pipe. The pressure will vary along the length of pipe if it is at different elevations.

Polyethylene pipe may 'suck flat' if a vacuum is present in the system. A vacuum is caused when water is allowed to flow down a pipe when the highest point is blocked off.

Note – To understand the forces involved it is often useful to think of the suction or force that is created when you place your hand over the drain when emptying a bath. The force is quite strong yet the drop in distance is very little.

The most common occurrence of a vacuum in rural systems is on pipe lines running downhill from a storage tank or dam.

The valve at the uphill tank is turned off but the water remaining in the pipe is still being acted upon by gravity and is trying to flow out of the pipe. Since neither air nor water can enter at the top, a vacuum is created and the pipe is 'sucked flat'.

This is simply rectified by either placing an air relief valve immediately after the valve or using a valve at the output end. Please refer to the diagram above.

Another occurrence of vacuum in rural pipe lines is where the pipe line crosses over undulating ground.

The crest of each hill accumulates air that has been dissolved in the water and after a period of time becomes a trap. An air relief valve should be placed at the top of every change in undulation.

Generally speaking, either allow the pipes to drain or keep them full.

Friction Loss

Frictional forces act between the water and the pipe wall.

If the frictional force or losses are not taken into account it is possible to have a system where the total frictional forces along the length of the pipe are greater than the force or pressure at the source. In this case the water would be restricted from flowing to the end of the pipe.

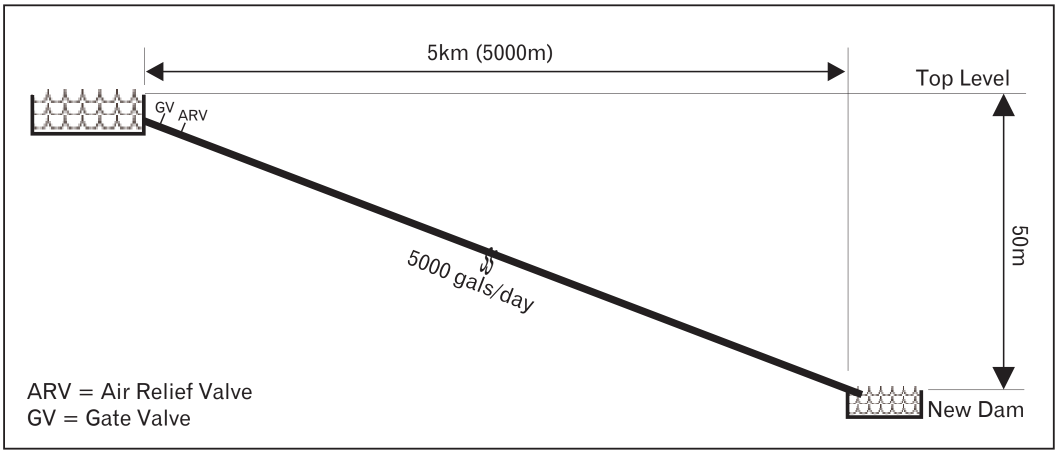
The friction loss is calculated using either the metric or imperial pipe friction charts.

On these charts the friction loss is expressed in "head loss – metres of water per thousand metres of pipe".

Always remember that the friction loss calculated by using the chart must be scaled to the length of the system (ie if a loss of 20m was calculated on the chart this would equate to a loss of 40m over a pipe 2km long or 10m over a pipe 0.5km long).

The sample calculations included will show how the charts are used.

Example 1: Rural Green Imperial Pipe



A small dam is being added to a paddock to supplement the drinking water form some stock. A polyethylene pipe line is to be used to transfer water from the main storage dam to the new dam. The new dam is 50m below the storage dam and they are 5km apart. The stock require 5000 gallons each day. What size and class of pipe is required?

The available head or pressure at the new dam is 50m (i.e. 500kPa or 73psi). Imperial or Rural pipe can be used for the entire system.

The flow required at the outlet is 5000 (UK) gallons per 24 hours.

= 5000 x 4.55 / 24 (1 gallon = 4.55L)
= 947.9L/hr or 0.26L/s

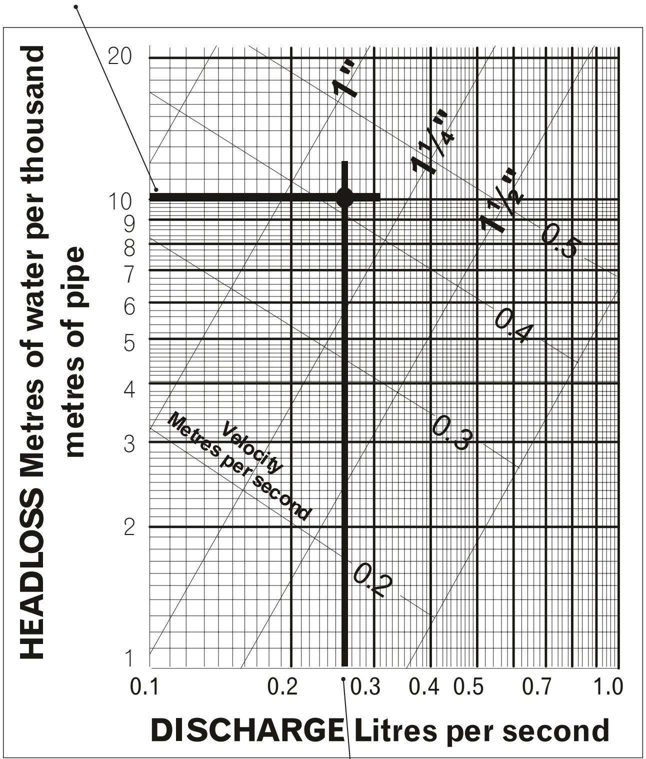
Negligible pressure is required at the output. The only requirements is for open discharge into the dam. Therefore for water to flow the head must not exceed the available head i.e.

Total Head loss	<50m	or
Head Loss per 1000m	<10m	

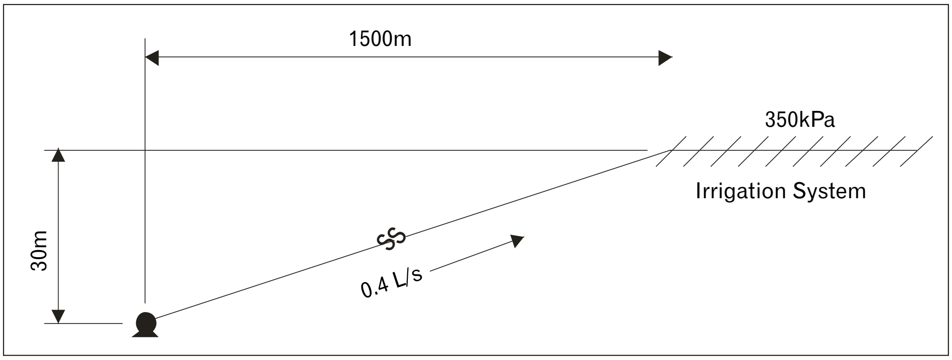
Locate the flow and head loss per 1000m on the friction chart and find the intersection point of the lines drawn perpendicularly to each axis. The optimum pipe size is then selected by choosing the pipe size line which passes under and to the right of the intersection point i.e. 1¼" Rural Green.

It is important that the flow rate and pipe size selected should always remain under 1.5m/s velocity curve. To check this find the intersection of the 10m/1000m pipe line and the 1¼" performance or friction loss curve. Then if you draw a line through this point, parallel to the velocity curves, you will see that the velocity through the pipe is midway between 0.4 and 0.5 m/s. Therefore the 1¼" pipe is the recommended size.

For system and pipe protection don't forget to add either an air relief valve at the top or use a valve at the bottom. Alternatively, why not use a float valve in the new dam so that the level will always be controlled.



Example 2: Metric Pipe



A pump is being used to supply 0.4 Litres per second through polyethylene pipe to an irrigation system. The irrigation system is on a hill which is 30m above the pump. What size and class of pipe is required and what pressure must the pump be able to supply?

The total head in the system is the total of the 30m head due to elevation and the 35m (350kPa) required to operate the irrigation system plus an additional safety margin of between 3 to 5% ie.

Total Head
= (30+35) x 1.05 = 68.3m

Total Head per 1000m
= 68.3/1500/1000= 45.5m

Since the total head is greater than 630kPa and less than 800kPa it can be assumed that some PN8 pipe will be used. As the system rises up the hill the elvation component of pressure will reduce and it will be possible to reduce to PN6.3 pipe.

Using the metric friction chart, locate 0.4 litres per second on the discharge axis and draw a line vertically up. A rough analysis shows that 40mm pipe will give head losses that don't appear excessive.

Using the friction chart 40mm PN6.3 has a Head Loss of 6.6m per 1000m.

Therefore the total head loss with friction is:
6.6 + 45.5 = 52.1m per 1000m

PN6.3 pipe can withstand a pressure of 63m therefore the maximum length of pipe = (63/52.1) x 1000m = 1209m.

40mm pipe is supplied in 150m coils therefore 1200m or 8 coils can be used for a total head of 1200/1000 x 52.1 = 63m.

Using the Friction Chart 40mm PN8 has a head loss of 7.6m per 1000m.

Therefore the total head loss =7.6 + 45.5 = 53.1m per 1000m.

PN8 pipe can withstand a pressure of 80m therefore the maximum length of pipe = ((80-63)/53.1) x 1000m = 320m.

Therefore, a further 300m of PN8 can be used for a total head of 63+(0.3 x 53.1) = 79m.

The polyethylene pipe used for this system would be:

From pump	40mm PN8	300m	2 coils
	40mm PN6.3	1200m	8 coils

The pump would need to be able to deliver 0.4 L/s at a continuous operating pressure of 79m (790kPa, 115psi).

Caution: If a blockage or line closure occurs, then the PN6.3 pipe would be subjected to the pump static pressure loading which may cause the pipe to burst.
If a blockage is likely to occur an alternative solution would be to only use:
40mm of PN8 1500m 10 coils

Note: velocity limit of 1.5m/s also applies to metric pipe, so please refer to "Velocity Limit" section on page 3.