Livestock Watering
FACTSHEET

BRITISH COLUMBIA
Ministry of Agriculture and Lands

UNDERSTANDING GRAVITY-FLOW PIPELINES
Water Flow, Air Locks and Siphons

This Factsheet discusses the problems and solutions of gravity flow pipe system design. Calculating water flow, pipe size, understanding air locks, and using siphons are covered. Examples and references are given.

Introduction

When looking at energy options available to use when designing a livestock watering system, if gravity energy is available at the site it is usually the first to be considered because it is 'free' energy to:
- move water in a pipeline (refer to *Factsheet #590.305-5* in this *Handbook* series)
- provide pressure to a trough
- frost-protect a trough (refer to *Factsheet #590.304-6* in this *Handbook* series)

While water will 'flow-down-hill', gravity pipelines have some specific requirements for trouble-free operation.

How Much Water Will Flow?

The energy due to gravity at a site is equal to the elevation difference between points, such as between the water supply and the trough site. This elevation difference is termed <u>head</u> with units of feet (for water, more accurately, as feet of head of water). In the case of water, this energy is equal to:
- 1 foot of elevation drop = 0.433 psi of pressure head
- or, for every 2.31 feet of elevation drop = 1 psi of pressure head

Pipe size and flow rate must be 'matched' to this energy using the following steps:
- the elevation drop or elevation head is measured
- a flow rate is chosen (refer to *Factsheet #590.304-1* in this *Handbook* series)
- the 'end-of-pipe' pressure is chosen (refer also to *Factsheet #590-304-1*)
- then a pipe size can be chosen (refer to *Factsheet #590.304-2*, page 6, "Example – Gravity System" in this *Handbook* series, for a "simple" system example)
  - different pipe sizes and pipe materials will have different flows for a given elevation drop (i.e., they have different friction losses)

('friction losses' are only 'lost' to the water system as energy is converted into heat)

The "*how-much-will-flow*" question is answered using pipe friction loss tables for the pipe material type and size chosen. All the energy in the elevation head will be used:
- some to provide the 'end-of-pipe' pressure requirement
- the rest will be used up as friction to provide a given flow through the pipe

Hydraulic Theory

Unfortunately, gravity water flow in pipes must be designed to the terrain of a site, so the above is a simplification. If the terrain is a consistent or near consistent grade, one pipe size could be chosen to use the available energy evenly over the full pipe length (as in the above noted Example). But sites often have terrains of varying grades requiring a closer look at pipe sizing requirements, which could include two

(or more) pipe sizes. At this point some knowledge of hydraulic theory is needed. The following is a brief and simplified overview of hydraulic theory useful in understanding gravity water flow in pipes. See the reference material for more detail.

Continuity of Flow Principle. This states that *for constant water flow in a pipe, flow in one part of a pipe is equal to flow at any other part of the pipe*, as shown by:

$$\textbf{Point A } \text{Flow} = \textbf{Point A } \text{Velocity x } \textbf{Point A } \text{Area,}$$
$$= \textbf{Point B } \text{Velocity x } \textbf{Point B } \text{Area, etc}$$

As flow is velocity multiplied by pipe area, changing the pipe cross sectional area (a larger or smaller pipe) will cause a change in velocity. This becomes useful when selecting a pipe size or in negative pressure conditions, page 5.

Water at Rest. When no water is flowing in a gravity-pressured pipe (as when a trough float valve is closed) it is in static equilibrium. Water levels are at static level and pressures in the pipe are termed static heads. As no water is flowing there is no energy loss to friction and the pressures in the pipe are their highest at all points (equal to their elevation below the inlet), highest pressure being at the lowest point.

Water in Motion. When water is flowing in the pipe friction loss occurs that reduces the pressure energy at all points along the pipe. With a constant flow a system is said to be in dynamic equilibrium and pressures are termed dynamic heads.

Hydraulic Grade Line. To fully illustrate the conditions along a pipe, static and dynamic equilibrium conditions can be plotted on a drawing of the profile of the system. When the points of static or dynamic equilibrium are connected they form a line that is termed the hydraulic grade line (**HGL**). This line represents the energy level at each point along the pipe (refer to Figure 1, below). As different flows have different energy levels, they also have different **HGL**'s.
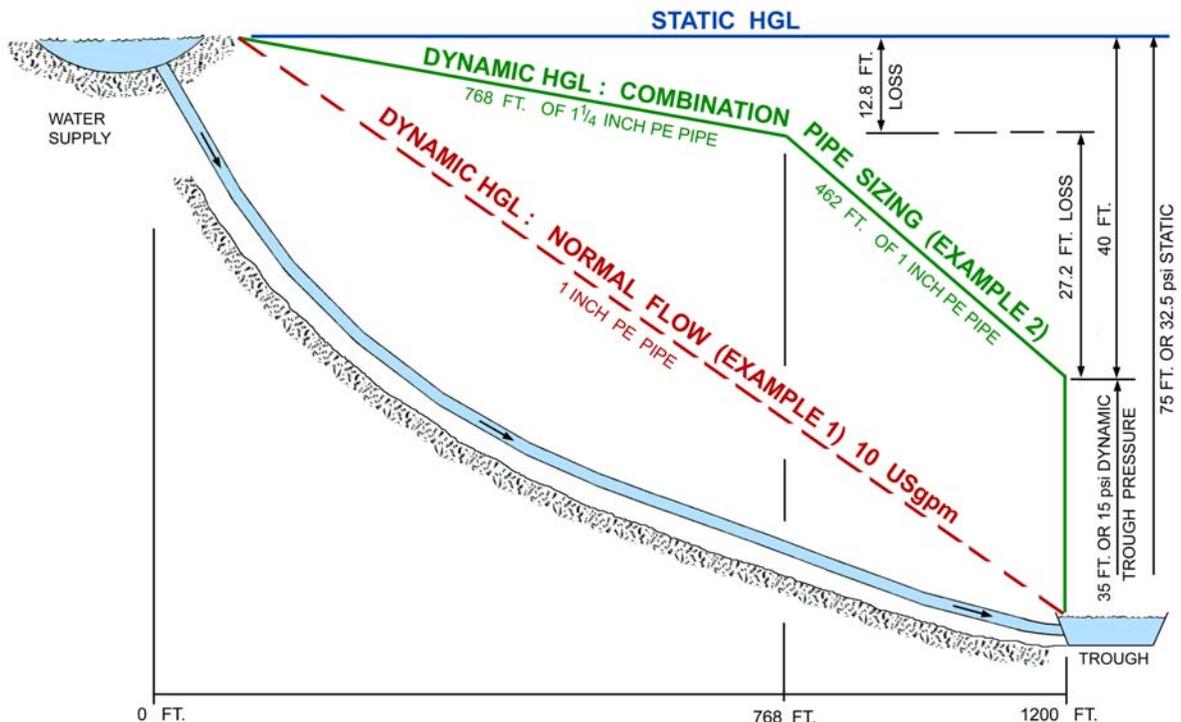
Figure 1 **Profile of a Gravity-Pressured Water System Supplying a Trough :**
Hydraulic Grade Line under Static and Dynamic Conditions in Examples 1 and 2

The **HGL** for static equilibrium is a horizontal line at the level of the water source, as in static conditions the pipe has an energy level equal to its elevation below this water source elevation (no friction loss is occurring).

The **HGL** for dynamic equilibrium is a line sloped downwards from the water inlet to either the pressure at the trough float valve or to zero if the outlet flow is to atmosphere. This line always slopes downward, indicating a 'loss' of energy as water flows downhill and energy is lost due to friction.

Friction. When water is flowing in the pipe energy is lost by the friction of water against the pipe and fittings, and as it enters and exits the pipe, including such obstacles as air trapped in the pipe (see Air Locks, page 6) and is determined by:
- the pipe wall roughness
- the velocity of the water (the flow rate through a given pipe diameter)
- minor (usually) things like fittings, water temperature, suspended particles, etc

For a given pipe size, the greater the flow - the greater the velocity - the greater the energy loss by friction. Friction losses are not linear - doubling the flow may increase the friction loss by up to four times. This energy loss cannot be recovered. As energy in a gravity system is fixed by the elevation difference present, lost energy due to friction is usually an important design factor. Pipe size is selected to 'match' pipe friction loss to the available head to achieve the desired water flow rate.

Natural Flow

When gravity-pressured water is flowing in a pipe that discharges to the atmosphere (say freely into the top of a trough) the maximum flow is occurring. This means the elevation head is all being converted to friction loss. This flow rate can be determined by using the friction loss table (Table 2, *Factsheet #590.304-2*):
- the elevation head (ft) is measured and converted to psi (ft divided by 2.31 = psi)
- the pipe length (ft) is measured
- the available energy for friction loss is calculated
  - elevation head divided by pipe length, expressed as psi per 100 ft (psi/100 ft)
- this value is located on the friction loss table under the column for the pipe type and size and the flow rate for those conditions is read

Note that systems that use a float valve will require some pressure head at the trough that will reduce the energy available for friction thereby reducing the flow below that of the natural rate. Refer to Example 2, next page, and to *Factsheet #590.304-2,* page 6, "Example – Gravity System" in this *Handbook* series, for examples.

Example 1 – Natural Flow

A system is planned that has a 75 feet elevation head and will use 1 inch polyethylene (PE) pipe that is 1200 feet long free flowing into a trough as shown in Figure 1. What will be the natural flow?
- information given: 75 ft elevation head: divided by 2.31 = **32.5 psi**;   and the pipe length is **1200 ft**
- available energy for friction loss is 32.5 psi divided by (1200 ft / 100) = **2.71 psi/100 ft** of pipe
- determine flow rate: from Table 2, page 5, *Factsheet #590.304-2,* a 1 inch PE pipe with a friction loss of 2.71 psi/100 ft will have a flow rate of just under **10 USgpm**
- this natural flow rate of 10 USgpm is the maximum this system can deliver to the trough with a 1 inch PE pipe - if a greater flow is required a larger pipe must be selected (e.g., a 1¼ inch PE pipe on this site would flow just over 20 USgpm)
- note: these flow rates are preferred rates for these pipes - they are in the Table 2 shaded area indicating these flow rates have velocities less than 5 ft/sec, the normal maximum design velocity

Combination Pipes

When a single pipe size does not give the desired friction loss, two pipes will be needed. The following *Combination Pipe Size Equation*, derived from the *Continuity of Flow Principle*, is much quicker than the 'trial and error' method of calculation where various pipe lengths are tried. It is used to calculate pipe lengths for a desired flow rate, when the <u>total head</u> and the <u>total pipe length</u> are known and <u>two pipe sizes</u> have been selected:

$$\text{Smaller Pipe Length} = \frac{100 \times H - (F_{large} \times L)}{F_{small} - F_{large}}$$

Where:
H = the total head available for friction loss (ft)
L = total pipe length (ft)
F_{large} = % friction loss in the larger pipe (psi per 100 ft $\times$ 2.31)
F_{small} = % friction loss in the smaller pipe (psi per 100 ft $\times$ 2.31)

The length of the larger pipe (ft) = **L** minus the calculated **Smaller Pipe Length**

Note that **H** is the total head available for friction loss – it is reduced for any pressure required at the delivery end of the pipe, such as at a trough.

Also note that <u>this equation does not take into account severe grade changes</u> which can have specific pipe sizing requirements (see Negative Pressure, next page).

Example 2 – Combination Pipe Sizing

Using the same conditions as Example 1, (75 feet elevation head, using 1200 feet of 1 inch polyethylene pipe supplying a trough), but <u>instead of free flowing, a trough pressure of 15 psi is required</u>, as shown in Figure 1. What pipe size(s) are needed for a 10 USgpm flow?
- <u>information given</u>: 75 ft elevation head;   and the pipe length is **1200 ft**
- <u>trough requires</u> 15 psi $\times$ 2.31 = 35 ft for trough pressure
- <u>elevation head</u> available for friction loss = 75 ft - 35 ft trough pressure = **40 ft** of head
- <u>calculate the available friction loss</u> over the 1200 ft
  - 40 ft / 2.31 ft/psi = 17.3 psi; over the 1200 ft = 17.3 / (1200 / 100) = **1.44 psi/100 ft**
- <u>calculate the flow rate and select the two pipe sizes</u> to be used
  - from Table 2, ***Factsheet #590.304-2***, 1.44 psi/100 ft in 1 inch pipe equates to a flow rate of 7 USgpm
  - as this system has to deliver 10 USgpm, a larger pipe is required – try $1\frac{1}{4}$ inch
  - $1\frac{1}{4}$ inch has 0.72 psi/100ft friction loss at 10 USgpm, so **a combination of 1 & $1\frac{1}{4}$ inch pipe is needed**
- use the *Combination Pipe Size Equation* to select the pipe lengths for an 10 USgpm flow rate:
  - $1\frac{1}{4}$ inch pipe at 10 USgpm = 0.72 psi/100ft friction loss $\times$ 2.31 ft/psi = 1.66 ft / 100 ft = 1.66%
  - 1 inch pipe at 10 USgpm = 2.73 psi/100ft friction loss $\times$ 2.31 ft/psi = 6.31 ft / 100 ft = 6.31%

  $$\text{Smaller (1 inch) Pipe Length} = \frac{(100 \times 40 \text{ ft}) - (1.66 \times 1200 \text{ ft})}{(6.31) - (1.66)} = \textbf{432 ft of 1 inch pipe}$$

  $$\text{Larger (}1\tfrac{1}{4}\text{ inch) Pipe Length} = 1200 \text{ ft} - 432 \text{ ft} = \textbf{768 ft of }1\tfrac{1}{4}\text{ inch pipe}$$

- <u>solution</u>: use a combination of **768 ft of $1\frac{1}{4}$ inch pipe** (loss of 12.8 ft: 0.72 $\times$ 7.68 $\times$ 2.31) and **432 ft of 1 inch pipe** (loss of 27.2 ft: 2.73 $\times$ 4.32 $\times$ 2.31) flowing at 10 USgpm, which will use 40 ft of friction head leaving 35 ft (15 psi) for trough pressure
- <u>note</u>: these two pipe sizes could be in any order (i.e., the larger pipe at either the top or bottom section) but it is normal to use the larger pipe in the top section starting at the intake
- <u>note</u>: the above Example is appropriate for sites <u>with no severe grade changes</u> – see Negative Pressure, next page, for a pipe selection example on a site that has a severe grade change

Negative Pressure

Negative pressure (less than atmospheric) may not always be considered in the design of a pipe system. Negative pressure is usually due to a site terrain limitation and it can be identified by the use of a site drawing showing the **HGL**. It will be evident by comparing the energy available over various pipe sections (various falls per pipe length) and calculating their individual flows.

The **HGL** should always be above the pipeline (i.e., there should always be a positive pressure in the pipe). Should the **HGL** be below the pipe it indicates a negative pressure is present in the pipe. This means flow is being siphoned through this pipe section (i.e., the continuity of flow, page 2, tells us that there can't be different flow rates in the same sized pipe). This is usually undesirable as it indicates the flow rate is being restricted, as well as air can be drawn into the pipe through fittings, etc. (refer to Air Locks, page 7)

The solution is to *match the flow rate in each section* by either:
- <u>installing a valve </u>on the outlet to restrict the flow to that of the upper section
  - system flow is limited, but may be sufficient in some cases
- or, <u>re-sizing the pipe sections</u> (Figure 2, below and Example 3, next page)
  - this will allow a higher flow rate, depending on the pipe sizes

This situation often occurs where the pipe leaving the water source is on a flat grade until it goes down a hill, where the grade is steep. A constant pipe size would have a low natural flow to the hill but then a larger natural flow down the hill, siphoning water through the flat grade to maintain that larger flow in the steep grade.

For existing systems with this problem, a second parallel pipe can be installed to increase the flow rate to 'match' the rate in the steep section. For instance, two, 1 inch PE pipes each flowing 5 USgpm (10 USgpm total) have the same friction loss (each at 0.76 psi/100ft) as one, 1¼ inch pipe flowing at 10 USgpm (0.72 psi/100ft).
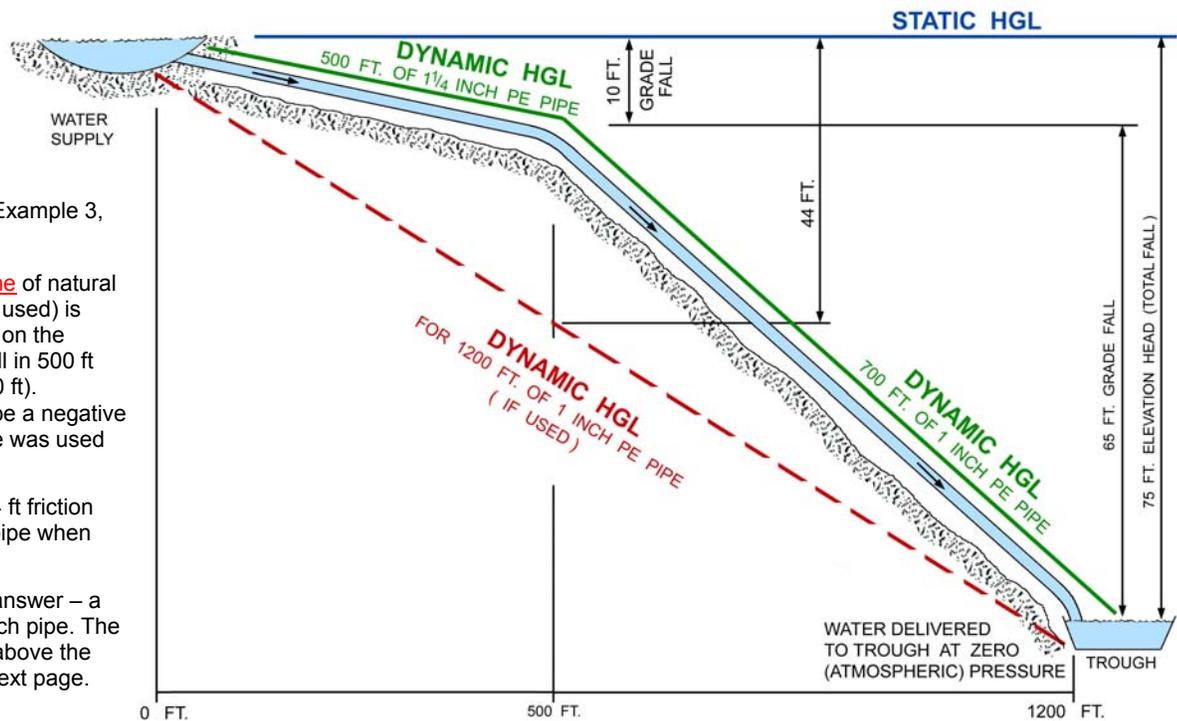
Conditions as given in Example 3, next page.

The HGL <u style="color:red">dashed red line</u> of natural flow (if all 1 inch pipe is used) is below the pipe which is on the ground surface (10 ft fall in 500 ft and then 65 ft fall in 700 ft). Therefore there would be a negative pressure if a 1 inch pipe was used throughout.

Calculations indicate 44 ft friction loss in 500 ft of 1 inch pipe when only 10 ft are available.

Shown is the re-sizing answer – a mix of 1¼ inch and 1 inch pipe. The HGL <u style="color:green">green line</u> is now above the pipe. See Example 3, next page.

Figure 2   Negative Pressure and Hydraulic Grade Line in Example 3

Example 3 – Negative Pressure Conditions

Using the same conditions as Example 1, (75 feet elevation head, using 1200 feet of 1 inch polyethylene pipe free flowing into a trough), but with uneven grade: 10 ft fall in the first 500 ft then 65 ft fall in the last 700 ft, as shown in Figure 2. What pipe size(s) are needed to prevent a negative pressure in the pipe?

- information given: 75 ft elevation head: divided by 2.31 = **32.5 psi**; and the pipe length is **1200 ft**
- average available friction loss (as Example 1) is 32.5 psi / (1200 ft / 100) = **2.71 psi/100 ft**
- natural flow for each section (if separate): the 1 inch pipe is on two very different grades:
  - 10 ft fall / 2.31 / (500 ft / 100) = **0.89 psi/100 ft** = about 5.5 USgpm natural flow
  - 65 ft fall / 2.31 / (700 ft / 100) = **4.02 psi/100 ft** = about 12 USgpm natural flow
- *Continuity of Flow Principle* requires the same flow rate in all sections of a pipe of the same size
- to correct this, different pipe sizes must be selected (larger for top section or smaller for bottom) depending on the flow rate to the trough (the *Combination Pipe Size Equation* doesn't account for grade)
- choose a flow rate: as only 0.89 psi/100ft is available in the top (flatter) section, use this available friction loss to find the flow rate of pipes larger then the current 1 inch (use the Table below)
  - a 1¼ PE pipe has a 0.86 psi/100ft friction loss at 11 USgpm = 9.9 ft loss in 500 ft (10 ft available)
  - the 1 PE pipe has a 3.27 psi/100ft friction loss at 11 USgpm = 52.9 ft loss in 700 ft (65 ft available)
  - total friction loss at 11 USgpm = (9.9 + 52.9) = 62.8 ft, leaving 12.2 ft head (5 psi) at the trough
  - a close 'match' is **11 USgpm with 500 ft of 1¼ inch PE followed by 700 ft of 1 inch PE**
- combinations shown in the Table below: other combinations of pipe sizes will give other flow rates
- for instance, **16 USgpm with 500ft of 1½ inch pipe followed by 700 ft of 1¼ inch pipe**
  - this combination will have 16 psi left at the trough (free flowing would siphon to over 24 USgpm)
- or, **30 USgpm with 500ft of 2 inch pipe followed by 700 ft of 1½ inch pipe**
  - this combination will have 10 psi left at the trough (free flowing would siphon to over 35 USgpm)

Pipe Flow & Friction Loss from Table 2, *Factsheet #590-304-2*, for Example 3

Site Conditions			Polyethylene (PE) Pipe Size (inch)							
Pipe Length	Fall	Available Energy	1		1¼		1½		2	
ft	ft	psi/100ft	flow	loss	flow	loss	flow	loss	flow	loss
500	10	0.89	5	0.76	**11**	0.86	**16**	0.81	**30**	0.77
700	65	4.02	**11**	3.27	**24**	3.63	**35**	3.45	--	--

Air Locks – The Problem

Gravity-pressured flow is prone to partial or total blockage by trapped air pockets. These can be erratic; several hours or days of system use before blockage occurs.

Source of Air. Air may enter a gravity-pressured pipe by:
- first operation of a pipeline after winter draining - the pipe will be full of air and how easily it can escape will determine the ease of getting a flow of water started
- entry at the inlet of the pipe - ensure inlet is submersed sufficiently to prevent a vortex from forming that will draw in air
- entry along the pipe - high points in an undulating pipeline where the water pressure is low enough to draw in air through loose fittings or small holes (see Negative Pressure, pg 5)

- dissolved air coming out of solution due to temperature increase (e.g., black PE pipe laid on the ground) or to pressure decrease (see negative pressures, above)
- entry into the pipe at a stock trough that is installed as a flow-through trough
  - these troughs are often used as a "pressure break" in a gravity feed system but can be points of air entry into the line exiting the trough (as at the main inlet)

How Air Locks Form. Air locks can form either during *static conditions* (no water flow) or *dynamic conditions* (water flow). Air that enters the pipeline when water is flowing must be carried downstream to an outlet to ensure continued water flow. If the system is static, the air must be able to rise and exit at the water inlet point (which, except for siphons, is the highest point in a gravity feed system). If the air becomes trapped in any high point along the pipe an air lock forms.

Total Air Locks. A total air lock can form in a pipe which will completely block the flow of water. Figure 3, below, illustrates a simple, single undulation pipe example where a gravity pipe supplies a float-controlled trough.

When the trough float valve is closed, any air in the pipe that can't escape up and out the water supply pipe end can accumulate in the pipe undulation. In this static condition, the pressures at A and B are the same and equal to the height of water H_W.

In the dynamic condition, the trough float valve is opened, and the trapped air bubble will move down the pipe. Because air has negligible weight compared with water, the pressures at A_1 and B_1 are the same and are equal to the height of water H. Therefore A_1 will support the height of water H behind it and B_1 will support the same height of water H in front of it. If the outlet is higher than H no water will flow.

Solutions, on the next pages, include having a flow rate sufficient to move the air with the water, or using an air release valve at the high point C to automatically let out air before it accumulates to form an air lock (see air release valve picture page 9).
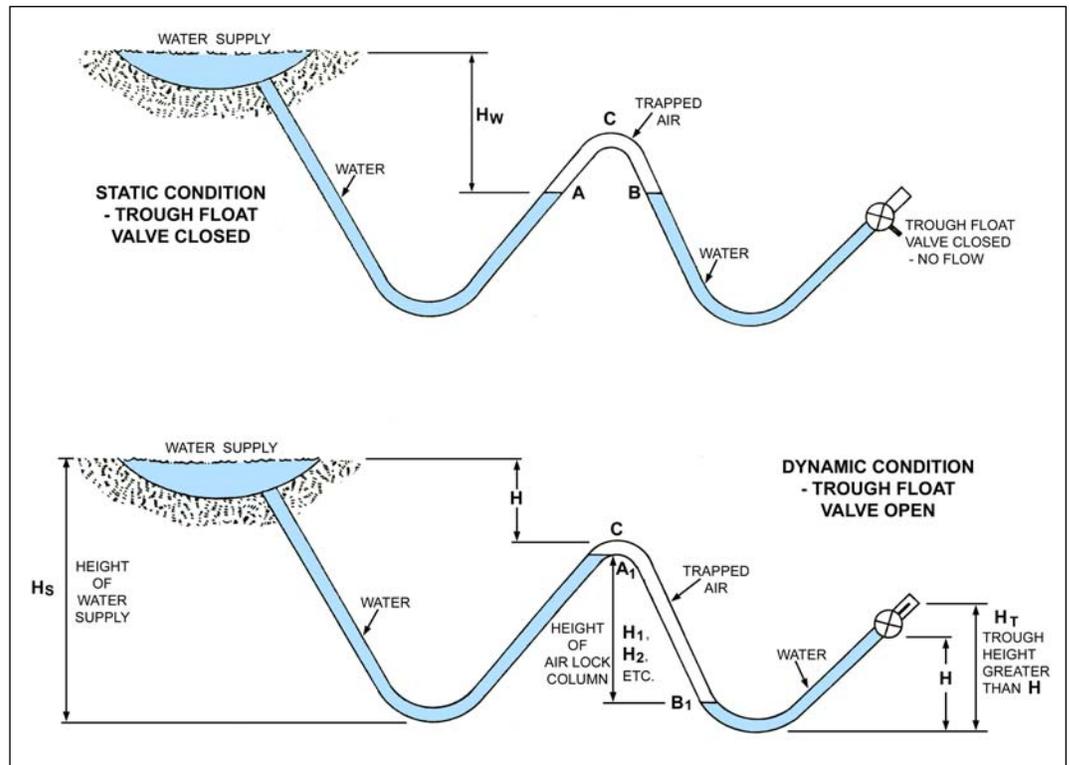
Figure 3   Formation of a Total Air Lock

Multiple Air Locks. In cases where the pipe is laid across many undulations, there is the possibility of an air lock developing at each undulation. The maximum outlet height that water will flow to if each section were to air lock is (Figure 3, previous page):

$$H_T = H_s - (H_1 + H_2 + etc)$$

Where H_T = height of the trough
         H_s = height of the water supply
         H_1 , H_2 = height of each air lock column

Partial Air Locks. If the trough height, H_T, in Figure 3 was lower than the height H a total air lock would not form but there could be a restriction to the flow. Air can remain in the downward portion of the pipe reducing the area available for water flow as shown in Figure 4, below. In this case, the gravity feed system will have some flow, but less than expected, due to this air bubble forming a partial air lock.
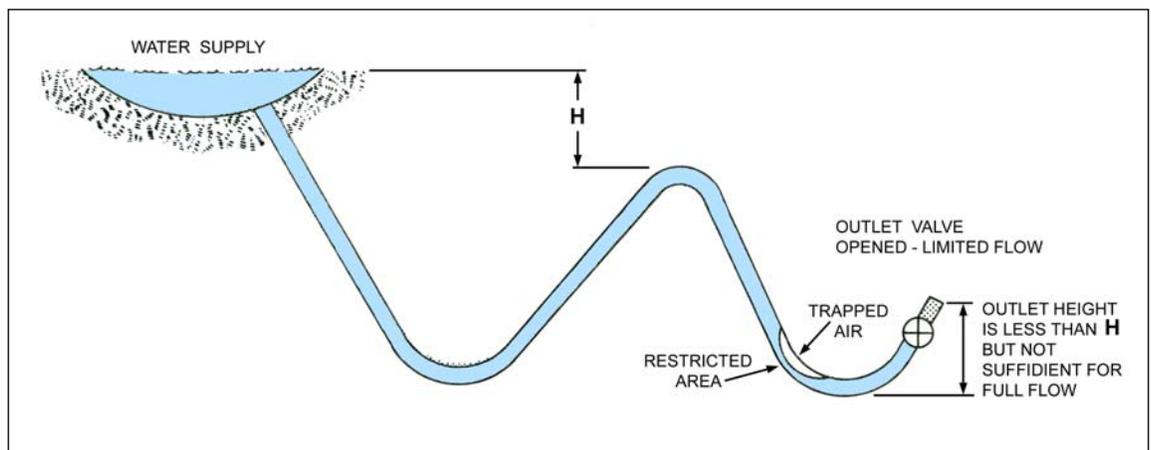
Figure 4   Formation of a Partial Air Lock

**Air Locks –
The Solutions**

The solutions to air lock problems vary depending on the complexity of the system layout, access to the pipe after installation, use in freezing conditions (deeply buried pipes are more awkward to install and maintain air release valves), etc.

One solution is to analyze the pipe system and modify the design:
- a pipe system can be analyzed in detail and the pipe size increased in the critical areas at rise points – this involves calculation of the air compression in the pipe and the resultant head available on the lower side of the air lock
- or, the above can be simplified with the assumption that all the lower side is air filled, add up these air column heights, and subtract from the total head (refer to Multiple Air Locks, above) to determine the maximum delivery height to a trough assuming these worst air lock conditions will occur

A second, and simpler solution (where the terrain allows) is to follow basic installation practices given in Preventing Air Locks, next page.

Preventing Air Locks #1 - Pipe Systems That May Or May Not Air Lock.

The following illustrates the type of pipe systems to be aware of regarding air locks:

- this layout is **unlikely** to have air lock problems as head is sufficient to move air and water flow doesn't rise to the trough
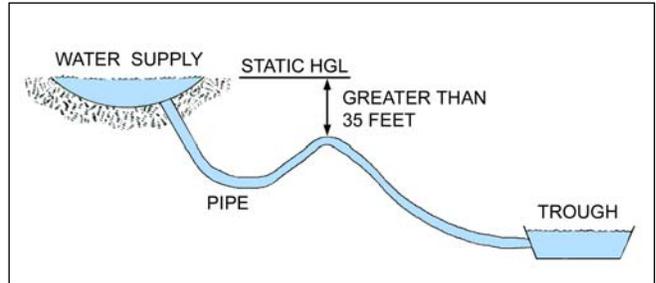
- this layout is **likely** to have air locks problems due to multiple undulations
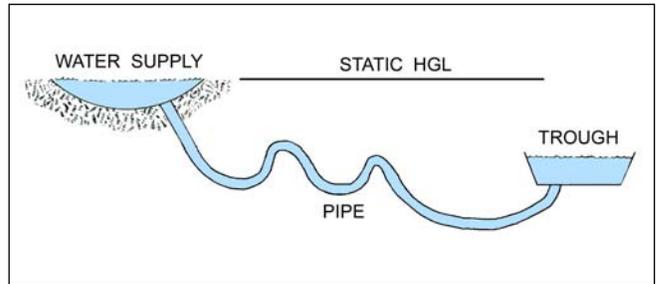
Air Release Valve

Preventing Air Locks #2 – Installation Practices.
Use the following installation practices to prevent air locks:

- prevent air from entering the pipe from sources as listed on pages 6 and 7
  - keep the intake submerged (up to12 inch depth for pipes under 2 inch) to prevent a vortex from forming
  - keep a positive pressure on the pipe (ensure the pipe is below the **HGL** – see page 5)
- should it enter, prevent air from accumulating
  - lay the pipe on a continuous grade eliminating undulations so air bubbles will not accumulate, but exit either through the inlet or air release valves
  - do not attempt to "follow the contour" if the grade is less then 1% (1 ft in 100ft)
  - it is better to go down slope - up to a high point – then down slope again
  - relieve air from high points with standpipes or air release valves (picture left)
  - ensure sufficient water velocity to flush out any air (Table 1, below)
  - if appropriate, locate a trough at a high point to release air (Figure 6, page 11)

Table 1	Flushing Velocities to Prevent Air Locks [1]	
Nominal Pipe Size (in)	**Flushing Velocity (ft/sec)**	**Flushing Flow Rate (US gpm)**
½	1.3	0.6
¾	1.6	2.1
1	1.8	3.6
1 ¼	2.0	7.8
1 ½	2.3	12
2	2.6	24

[1] - from MAF, New Zealand, "*Water Supply Flow Problems*", Potts & Harrington

- note these velocities are all much less than the maximum design rate of 5 ft/sec

- refer to *Factsheet #590.304-2, Selecting Small Diameter Pipe*, Table 2, page 5 - flow rates greater than the dotted line will ensure air is flushed with the water from the pipe

Example 4 – Air Lock

Using the same conditions as Example 1, (75 feet elevation head), but using 1,200 feet of 1¼ inch polyethylene pipe <u>free flowing into a trough</u>, but the pipeline route has a rise over a hill (50 ft elevation) and then up a second slope to the trough that must be at 30 ft elevation (refer to Figure 5, below). The required flow rate is 5 USgpm. Can the trough be set at this elevation with this flow? If not, what are the options?

- <u>calculate the head available</u> should an air lock occur
  - head available at the high point = 75 ft - 50 ft = **25 ft** above high point to the water source
  - should an air lock occur at the high point, there would be only this 25 ft head for water flow to the trough including friction and lift to the trough
- <u>calculate the friction loss</u> at the required flow rate of 5 USgpm
  - friction loss for 1200 ft of 1¼ inch PE flowing 5 USgpm from Table 2, *Factsheet #590.304-2* :

    1200 ft × <u>0.20</u> psi = 2.4 psi, × 2.31 ft/psi = **6 ft loss due to friction**
            100 ft
- <u>calculate the trough elevation</u> at 5 USgpm flow with 1¼ inch PE pipe
  - 25 ft (available head) - 6 ft (friction loss) = **19 ft** remaining for maximum trough elevation
- <u>the trough can be located at 19 ft elevation</u> (56 ft below intake) for the system flow rate of 5 USgpm, but the required trough height is 30 ft, so under air lock conditions water will not reach the trough
- <u>the solutions are</u>:
  1- if the water is available, increase the flow rate to the flushing rate - 7.8 USgpm for 1¼ inch pipe
    now there is no air lock, so there is 75 ft - 30 ft head = 45 ft head at the trough
    at 45 ft head / 2.31 / (1200 ft / 100) = 1.62 psi/100ft = about 15 USgpm flow to the trough
  2- if there isn't sufficient water, install a valve on the outlet to restrict this flow to about 8 USgpm
  3- if 8 USgpm is not available, select a 1 inch pipe size
    at 45 ft head / 2.31 / (1200 ft / 100) = 1.62 psi/100ft = about 7.5 USgpm flow to the trough
    this is greater than the flushing rate of 3.6 USgpm for 1 inch pipe, so an air lock will not occur
    if needed, install a valve on the outlet to restrict this flow to the required flow of 5 USgpm
  4- or, install an air release valve at the high point to ensure release of any accumulated air and flow the required 5 USgpm, or one of the above higher flows (on either pipe size)
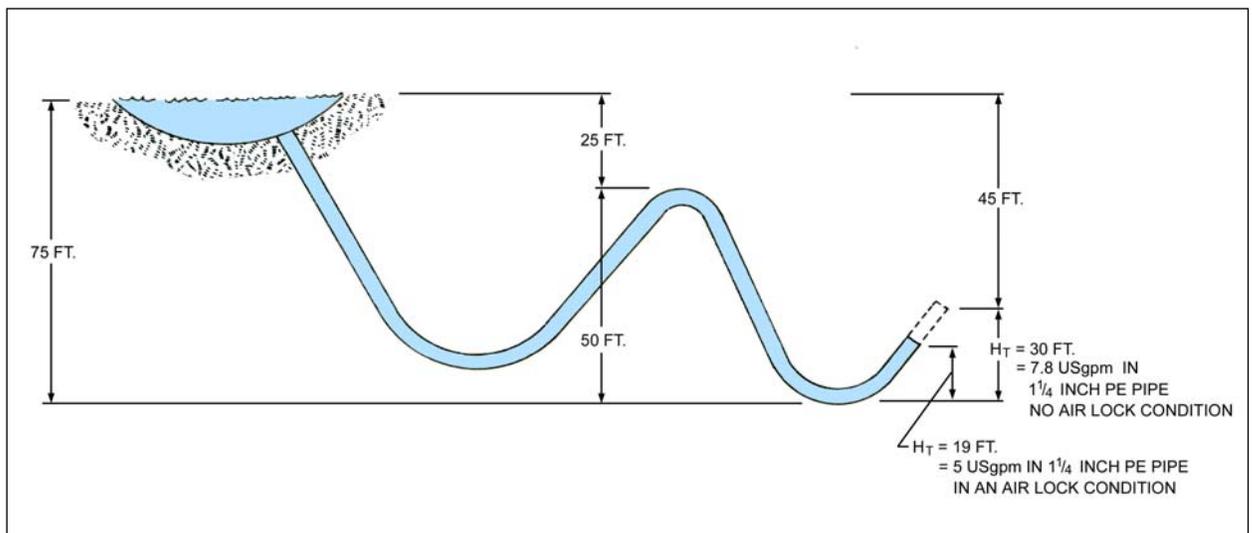
Figure 5   Diagram of Example 4 Air Lock Situation

Breaking Line Pressure & Releasing Air. Where appropriate, a trough can be used to release air, but the line pressure is reduced to zero, returning to atmospheric pressure. This is sometimes used in gravity systems with large elevation falls creating excess line pressure and where air release is required.
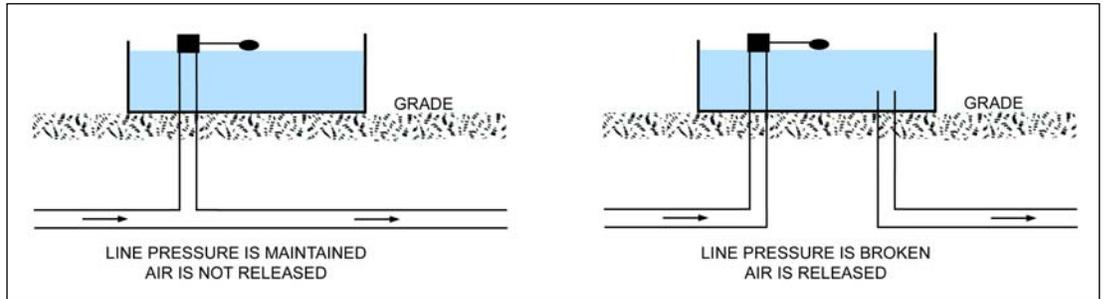
Figure 6   Using a Trough to Release Air

Siphons

Siphons are a unique gravity flow situation where the pipeline goes over a point that is higher than the supply water elevation before falling to the delivery elevation. A siphon uses the differences in elevation and atmospheric pressure to flow water.

If the both ends of the pipe are submerged and air is removed at the high point (primed), atmospheric pressure on the supply water surface will move water up the pipe to the high point (if this point is set at an appropriate elevation) and gravity will move the water from there down to the delivery point.

Alternatively, with a check valve (foot valve) on the intake and a control valve on the outlet, closing the outlet valve, filling up the siphon pipe with water, then opening the outlet valve will start the siphon flow.

Preferred Conditions for a Siphon. A siphon will work better under the following conditions (refer to Figure 7, next page):
- the short leg is as short as possible
- the high point is as low and as close to the inlet water surface as possible
- the high point is less than 15 feet above the **HGL** (decrease by 3 ft for every 3000 ft elevation above sea level)
- the slope of the long leg is greater than the **HGL** slope
- the flushing flow rate (Table 1, page 9) is used to avoid air buildup at the high point
- minimum fall across the siphon is used (refer to Table 2, below)
- an inlet check valve and outlet control valve are used
- an outlet box is used to prevent entry of air into the siphon (water can be piped from this box to the trough)

Table 2		Minimum Elevation Fall (ft) Required Across a Siphon [1]			
Pipe Size	**Flow Rate**	**Length of Siphon Pipe (ft)**			
(inch)	**(USgpm)**	**65**	**130**	**200**	**260**
3	80	3.3	6.2	9.2	11.8
4	160	3.0	5.2	7.5	9.8
6	440	2.6	4.6	6.6	8.9
12	2300	2.0	3.3	4.6	5.6

[1] from *Liquid Assets*, Kondinin Group, West Australia - see Figure 7, next page
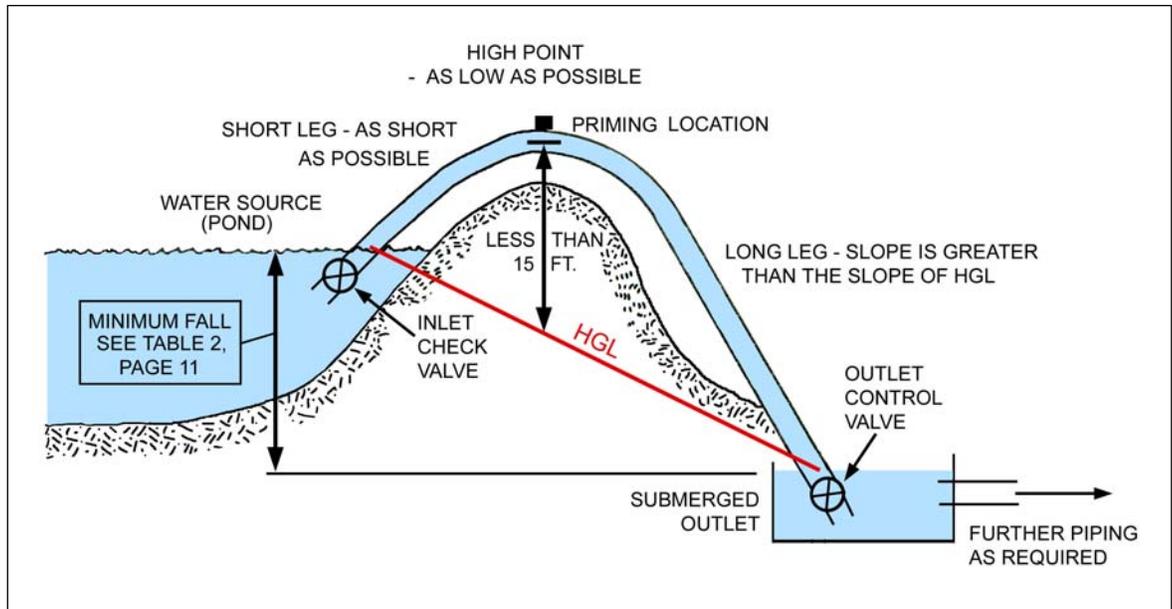
Figure 7   Siphon Showing Preferred Conditions

References

The following were used for this Factsheet and have further information on gravity pipe systems:

A Handbook of Gravity-Flow Water Systems
T.D. Jordan Jr.
Intermediate Technology Publications, 1984
    -this is a UNICEF publication dealing with water systems for small communities

Water Supply Flow Problems – Airlocks in Pipes, #FPP 798
MAF Information Services
New Zealand
    - this Factsheet outlines air lock principles

Water Conveyance with Siphons
Richard Powley
Agriculture and Agri-Food Canada
    - a detailed engineering outline of siphons

Liquid Assets – Water Management for Dryland Agriculture
James Bourchier, Editor
Kondinin Group
West Australia
    -    articles on pipelines, air locks, siphons