Livestock Watering
FACTSHEET

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LIVESTOCK WATER SYSTEM DESIGN #2

Selecting Small Diameter Pipe

This Factsheet describes types of pipe, pressure rating systems used, and how to select pipes. It covers pipes of 2-inch diameter, or less, that are used for livestock watering systems. Friction loss tables are given.

Introduction

What size of pipe do I need? *Will this pipe handle the pressure*? Having selected the flow rate, pressure, storage and trough size in the ***Design #1*** (Factsheet #590.304-1) the next step in planning a livestock watering system is pipe selection. The following explains how to select pipes based on the size, pressure rating and pressure loss.

Types of Pipe

For sizes up to 2 inches, three types of materials are commonly used for livestock watering system pipes and fittings. Refer to Table 1, page 4, for pipe specifications.

Steel. Steel is usually used for fittings and short lengths of pipe that may be installed above ground. Galvanized steel should be used, as the zinc coating greatly increases its working life. Steel pipe and fittings should be used for locations where pipe is easily damaged and should not usually be used in underground installations.

Poly Vinyl Chloride. Poly Vinyl Chloride (PVC) is rigid plastic pipe available in pressure ratings from 50 to 315 psi. PVC comes in lengths of 20 feet. Sizes of 2 inch and under are joined by solvent weld. The minimum pressure rating of PVC pipe sizes used for stock water systems is 125 psi; the typical rating used is 160 psi, and 200 psi is also available. PVC pipe and fittings should always be installed underground as the material deteriorates in sunlight and becomes brittle in freezing conditions.

Poly. Polyethylene (PE) pipe is available either flexible or rigid, in pressure ratings from 50 to 160 psi. Flexible PE pipe is available in coils up to 1000 ft long depending on diameter, and it is mostly used in systems where the maximum pressure does not exceed 115 psi. For higher pressures, or for sizes greater than 1 $^{1}/_{4}$ in., PVC pipe offers greater pressure rating and is usually more economical. PE pipe may be installed above or below ground, but is usually buried for protection.

Pipe Rating Systems

Two pressure rating systems are used for Polyethylene and PVC pipe; the schedule system and the class, series or SDR system. Refer to Table 1 for pipe specifications.

Schedule System. Two common ratings of this system are Schedule 40 and Schedule 80. It is the designation for pipe in which the outside diameter, wall thickness, and inside diameter are fixed by specification. The dimensions of plastic pipe produced to these schedules are exactly the same as corresponding iron pipe.

Working pressure varies for different pipe diameters within any schedule. Each pipe size, in each of these schedules, has a recommended working pressure rating. Schedule rated pipe is used mainly for industrial purposes or high pressure.

Class, Series or SDR System. In this system of classification, plastic pipe is designated with respect to its pressure rating, and **the pipe is put into groups all having the same working pressure rating.** For example, series or class 160 has a pressure rating of 160 psi regardless of pipe size. All pipes in a given series have the same safety margin and operate at the same fibre stress.

The pipe is grouped according to its *Standard Dimensional Ratio* (SDR) which is the relationship of outside diameter and pipe wall thickness:

- SDR = outside diameter / wall thickness
- for example, 1 ¼ inch PVC Series 160 pipe has o.d. of 1.660 and wall of 0.064:
  - SDR = 1.660 / 0.064 = 26
  - this pipe has a SDR of 26

Polyethylene Grades. In addition to the above ratings, polyethylene pipe may be available in three grades: CSA certified, medium or regular density, and utility. Stock watering systems will normally require the medium density grade. Utility pipe does not have a satisfactory wall thickness and may not endure winter conditions or installation by the ripping method. CSA certified PE pipe is not usually required (unless the system handles domestic water) and may not be cost effective. Note that the grade of a given size does not affect its friction loss as the i.d. is unchanged.

Poly & PVC: Inside & Outside Diameter

These pipes, and their different properties, change with different pressure ratings:

- PE pipe is joined with *insert fittings* so the inside diameter is unchanged
  - larger pressure ratings have larger outside diameters
  - friction loss for a given pipe size <u>is unchanged</u> by pressure rating
- PVC is joined with '*outside' couplings* so the outside diameter is unchanged
  - larger pressure ratings have smaller inside diameters
  - friction loss for a given pipe size <u>is changed</u> by pressure rating

Refer to Table 1, page 4, for pipe dimensions, etc. and Table 2 for friction loss.

Pipe Selection

Selecting the correct pipe material and size is important to ensure that stock watering system is economical, functional and capable of providing long service. A three-step procedure should be used to determine the correct pipe size and pressure rating.

1. Choose the Type of Pipe. The type of pipe chosen will determine a number of the features of the system, including the following:

- cost
  - PVC is about one-half the cost of Poly in sizes 1 ¼ or greater
- placement
  - Poly may be surface laid; PVC degrades in sunlight
  - PE may be "ripped in" instead of trenching as for PVC
  - if trenching is not being used, there is no placement advantage of Poly
- connection type
  - PVC glue joints (every 20 ft) are secure once buried
  - Poly clamped joints (up to 1,000 ft) may fail (access to buried pipe a concern)
- connection restriction
  - PVC connections are on the outside of the pipe, allowing 'clean' flow
  - Poly connections are inside with an insert coupling, slightly restricting flow
- ground conditions
  - flexible Poly can be more tolerant of rocky ground than rigid PVC
- freezing conditions
  - flexible Poly may be more tolerant of frost than rigid PVC
  - note that Poly will loose its flexibility and may fail with repeated freezing

2. Calculate Pipe Size Requirement. Water flowing through a pipe is accompanied by a pressure loss due to friction, which will depend on:

- type of pipe
  - PVC has about ½ of the pressure loss from friction of PE under many conditions
- pipe dimensions
  - the length of the pipe and inside diameter
- velocity of water in the pipe
  - the volume of water flowing in a given pipe diameter determine its velocity

Generally, livestock watering systems are designed to limit pipeline flow velocities to a maximum of 5 ft/sec. to minimize friction losses. Flow rates greater than this produce unacceptably high friction loss and may subject the pipeline to water hammer problems if valves or pumps are operated improperly. Conversely, very low flow rates may allow sediments to build up in the pipe.

Pipe sizes are therefore chosen for the required flow rates with acceptable flow velocities. The shaded area on the Friction Loss Table indicates the preferred pipe selections. The example on page 5 outlines the selection process.

For some gravity feed systems with large elevation differences, greater friction losses may be tolerable (i.e., smaller pipe sizes may be selected for a given water flow rate) because pressure loss by friction is "recovered" by elevation drop. Refer to Factsheet #590.304-5 ***Understanding Gravity-Flow Pipelines*** for the many concerns of properly designed gravity systems.

3. Calculate Pipe Pressure Requirement. The pipe selected must have a pressure rating that exceeds the total pressure that can be exerted on the system. This *total pressure head* consists of the sum of the following:

- <u>operating pressure</u> - the pressure required at the waterer
- <u>elevation difference</u> - pressure is gained at the rate of 1 psi for every 2.31 feet
- <u>pressure surge</u> - the sudden closure of a valve or quick pump start up or shut down will create pressure surges in the pipeline known as water hammer
- <u>pipe friction in a pumping system</u> (*a rising main*) - pressure must be added during operation to the system to overcome pressure loss due to water flowing upwards through the pipe (pressure is maximum when the system is operating)
- <u>pipe friction in a gravity system</u> (*a falling main*) - pressure is lost due to water flowing downwards during operation (pressure is maximum when the system is static)

Table 2, page 5, has friction losses for PE and PVC pipe sizes most commonly used for livestock watering systems.

Maximum vs Working Pressure. The safe working pressure for either PE or PVC pipe must not be greater than 72% of the pipe maximum pressure rating. Safe working pressures of these pipes are reduced to allow for pressure surges, etc. This safety margin is a requirement most often specified for larger diameter pipes than those used in livestock watering systems or for systems subjected to water hammer. Smaller diameter pipes may be operated closer to their maximum pressure ratings, however a safety margin should always be allowed.

For an example of pipe selection for a gravity system refer to page 6. For an example of pipe selection for a pump system refer to page 7.

TABLE 1. PE AND PVC PIPE SPECIFICATIONS [1]

nominal pipe size	pipe type	PE density	PVC schedule	class or series	SDR	outside diameter (in)	wall thickness (in)	inside diameter (in)	weight per 100ft (lb)	max pressure (psi)	safe working pressure (psi)	pipe length per USgal (ft)
0.75 inch	pvc		40		9.3	1.050	0.113	0.824	23	480	see manufacturer.	36.1
	poly	medium		75	14	0.954	0.070	0.824 [2]	8	75	54	36.1
				100	41	1.008	0.092		11	100	72	
				125	32.5	1.056	0.116		14	125	90	
1 inch	pvc			200	21	1.315	0.063	1.155	20	200	144	18.4
	poly	medium		75	15	1.215	0.083	1.049 [2]	12	75	54	22.7
				100	41	1.283	0.117		18	100	72	
				125	32.5	1.343	0.147		23	125	90	
1.25 inch	pvc			160	26	1.660 [3]	0.064	1.532	21	160	115	10.5
				200	21		.079	1.500	27	200	144	10.9
	poly	medium		75	15	1.598	0.109	1.380 [2]	21	75	54	12.9
				100	41	1.688	0.154		31	100	72	
				125	32.5	1.768	0.194		40	125	90	
1.5 inch	pvc			160	26	1.900 [3]	0.080	1.740	31	160	115	8.1
				200	21		0.090	1.720	34	200	144	8.3
	poly	medium		75	15	1.866	0.128	1.610 [2]	29	75	54	9.5
				100	32.5	1.970	0.180		42	100	72	
				125	41	2.142	0.266		54	125	90	
2 inch	pvc			160	26	2.375 [3]	0.091	2.173	44	160	115	5.2
				200	21		0.113	2.149	52	200	144	5.3
	poly	medium		75	15	2.395	0.164	2.067 [2]	48	75	54	5.7
				100	32.5	2.527	0.230		69	100	72	
				125	41	2.645	0.289		89	125	90	

1 pipe and sizes most commonly used in livestock watering systems: PE medium density; PVC Schedule 40, Class 200 and Class 160

2 note that poly pipe of the same size (regardless of series) has the same *inside* diameter

3 note that pvc pipe of the same size (regardless of series) has the same *outside* diameter

Table 2. PE and PVC Pipe Friction Loss [1]

Pressure Loss from Friction given as Psi per 100 Feet of Pipe [2]
Shaded Area Indicates Recommended Pipe Selections [3]
Dotted Line Indicates Approximate Minimum Flow to Ensure Air Flushing in Gravity Lines [4]

Flow (US gpm)	0.75 inch PE	0.75 inch PVC sch. 40	1 inch PE	1 inch PVC C. 200	1.25 inch PE	1.25 inch PVC C. 160	1.5 inch PE	1.5 inch PVC C. 160	2 inch PE	2 inch PVC C. 160
1	0.12	0.11	0.04	0.02						
2	0.45	0.39	0.14	0.07	0.02	0.02				
3	0.95	0.84	0.29	0.14	0.08	0.04	0.04	0.02		
4	1.62	1.42	0.50	0.24	0.13	0.07	0.06	0.04	0.02	0.01
5	2.44	2.15	0.76	0.36	0.20	0.11	0.09	0.05	0.03	0.02
6	3.43	3.02	1.06	0.51	0.28	0.15	0.13	0.08	0.04	0.03
7	4.56	4.01	1.41	0.67	0.37	0.20	0.18	0.10	0.05	0.03
8	5.84	5.14	1.80	0.86	0.47	0.25	0.22	0.13	0.07	0.04
9	7.26	6.39	2.24	1.07	0.59	0.31	0.28	0.16	0.08	0.05
10	8.82	7.77	2.73	1.30	0.72	0.38	0.34	0.20	0.10	0.07
11	10.60	9.27	3.27	1.56	0.86	0.45	0.41	0.23	0.12	0.08
12	12.37	10.89	3.82	1.83	1.01	0.53	0.48	0.28	0.14	0.09
14	16.46	14.48	5.08	2.43	1.34	0.71	0.63	0.37	0.19	0.12
16		18.55	6.51	3.11	1.71	0.91	0.81	0.47	0.24	0.16
18			8.10	3.87	2.13	1.13	1.01	0.58	0.30	0.20
20			9.84	4.71	2.59	1.37	1.22	0.71	0.36	0.24
22			11.74	5.62	3.09	1.64	1.46	0.85	0.43	0.29
24			13.79	6.60	3.63	1.92	1.72	1.00	0.51	0.34
26			16.00	7.65	4.21	2.23	1.99	1.15	0.59	0.39
28				8.78	4.83	2.56	2.28	1.32	0.68	0.45
30				9.98	5.49	2.91	2.59	1.50	0.77	0.51
35					7.31	3.87	3.45	2.00	1.02	0.68
40					9.36	4.95	4.42	2.56	1.31	0.86
45					11.64	6.16	5.50	3.19	1.63	1.08
50					14.14	7.49	6.68	3.88	1.98	1.31
55						8.93	7.97	4.62	2.36	1.56
60						10.49	9.36	5.43	2.78	1.83
65							10.86	6.30	3.22	2.12
70							12.46	7.23	3.69	2.44
75							14.16	8.21	4.20	2.77

1 - most commonly used pipe for livestock watering systems: PE medium density; PVC Schedule 40, Class 200 and Class 160

2 - based on: Friction Loss Constants for Poly pipe at C = 140; PVC pipe at C = 150; clear water at 15.6^{0}C; pipes flowing full

3 - shaded friction losses values are recommended pipe selections with flow velocities between 1 and 5 feet per second:
- low flow velocities (low flows / large pipes – less than 1 ft/sec): may allow sediment to settle in the pipe
- high flow velocities (high flows / small pipes – greater than 5 ft/sec): high large friction losses and may have pressure surges

4 - flow rates greater than the dotted lines (for gravity systems) will move air along with the water and out of pockets in the pipe
- for detailed air flushing information refer to ***Factsheet #590.304-5, Understanding Gravity-Flow Pipelines***

Example - Gravity System Pipe Selection

A stock watering system is being developed that requires a flow rate of 7.5 USgpm and a minimum pressure of 22 psi at the trough (from Example 1, Design #1 Factsheet). The source of water is a spring located 100 ft (elevation) above the trough location and requires 2,000 ft. of piping. Polyethylene pipe will be used.

QUESTION **What pipe size and pressure rating are required ?**

Note: this is an example of a "simple" gravity situation, where the slope is considered consistent through out the pipe length. Refer to *Factsheet #590.304-5, Understanding Gravity-Flow Pipelines* for a more detailed look at gravity piping issues (slope is often not consistent and pipe selection is more complicated).

- information given: 7.5 USgpm at 22 psi with 100 ft head to the trough through 2,000 ft of pipe
- calculate the maximum system pressure
  - for gravity systems, the maximum pressure is due to the elevation difference;
    static head = 100 ft elevation x 0.433 psi/ft = 43 psi
  - when the system is static (no water flowing) the pressure is maximum - the pipe at the bottom of the system (at the trough) must withstand **43 psi**
- select suitable pressure rated pipe
  - **series 75 polyethylene** has a maximum pressure rating of 75 psi (Table 1)
  - this allows for a sufficient safety margin using the 72% rule
- calculate the allowable pipe friction loss
  - pressure head available (due to elevation) = 100 ft
  - pressure required at waterer: 22 psi x 2.31 ft/psi = 51 ft
  - therefore, allowable pipe friction loss = **49 ft**
- select the pipe size and calculate the actual system friction loss
  - from Table 2: smallest pipe size available to maintain 5 ft/sec flow velocity for 7.5 gpm is 0.75 inch
  - friction loss for 2,000 ft of 0.75" PE at 7.5 gpm is (from Table 2, previous page):
    extrapolate friction loss: 7 USgpm = 4.56 and 8 USgpm = 5.84
    $2{,}000 \text{ ft} \times \frac{5.20 \text{ psi}}{100 \text{ ft}}$ = 104 psi: converted to feet = 104 psi x 2.31 ft/psi = 240 ft
  - this friction loss exceeds the allowable (49 ft), so a larger pipe must be selected
- select 1 inch PE (extrapolate friction loss: 7 USgpm = 1.41 and 8 USgpm = 1.80):
  $2{,}000 \text{ ft} \times \frac{1.61 \text{ psi}}{100 \text{ ft}}$ = 32 psi: x 2.31 ft/psi = 74 ft – still too large a loss
- select 1 1/4 inch PE (extrapolate friction loss: 7 USgpm = 0.37 and 8 USgpm = 0.47)
  $2{,}000 \text{ ft} \times \frac{0.42 \text{ psi}}{100 \text{ ft}}$ = 8.4 psi: x 2.31 ft/psi = **20 ft** – OK as less than available 49 ft
- in this example **1-1/4 inch PE pipe** is the minimum size that can be selected - the remaining head of 29 ft (49 ft – 20 ft) is available for other losses (entrance, fittings, etc.) or for more trough pressure
- calculate the maximum pressure at the waterer (not counting 'other' losses)
  - pressure head available (due to elevation) = 100 ft
  - pipe friction loss (7.5 USgpm in 1¼ PE pipe) = 20 ft
  - therefore, maximum pressure at the waterer = 80 ft or 34 psi

ANSWER **This system should use 1 1/4 inch PE series 75 pipe as a minimum. If the ground the pipe will be buried in is quite rocky, series 100 or 125 could be chosen for the greater wall thickness (refer to Table 1, wall thickness column). The friction loss remains the same.**

Note: **PVC pipe could be chosen:**

- **1 inch PVC Class 200 pipe (extrapolated 0.77 psi/100 ft loss) with a friction loss of 36 ft**
- **1¼ PVC Class 160 pipe (extrapolated 0.225 psi/100 ft loss) with a friction loss of 11 ft**

Example - Pump System Pipe Selection

Note that the energy in the previous gravity example is limited by the elevation difference of the site. A pump system can be sized to do the work required.

A stock watering system is being developed that requires a flow rate of 7.5 USgpm and a minimum pressure of 22 psi at the trough (from Example 1, Design #1 Factsheet). The source of water is a spring located 100 ft below the trough location and requires 2,000 ft. of piping. Polyethylene pipe will be used.

QUESTION **What pipe size and pressure rating is required?**

- information given: 7.5 USgpm at 22 psi with 100 ft of pump lift to the trough through 2,000 ft of pipe
- calculate the maximum system pressure
  - for pump systems, the maximum pressure is the lift + pressure + friction losses:
  - lift due to elevation = 100 ft elevation
  - pressure head = 22 psi at the trough x 2.31 ft/psi = 51 ft pressure head
  - lift + pressure heads = 100 + 51 = **151 ft**
- calculate the pipe friction loss for pipes suitable for the system
  - from Table 2: smallest pipe size available to maintain 5 ft/sec flow velocity for 7.5 gpm is ¾ inch
  - friction loss for 2,000 ft of 0.75" PE at 7.5 gpm
  - (extrapolate friction loss: 7 USgpm = 4.56 and 8 USgpm = 5.84):

    $2{,}000 \text{ ft} \times \frac{5.20 \text{ psi}}{100 \text{ ft}}$ = 104 psi: converted to feet = 104 psi x 2.31 ft/psi = **240 ft friction loss**
  - the total lift is 151 ft + 240 ft = **391 ft**
- this friction loss is too large (greater than the lift + pressure heads); try larger pipe sizes
  - select 1 inch PE (extrapolate friction loss: 7 USgpm = 1.41 and 8 USgpm = 1.80):

    $2{,}000 \text{ ft} \times \frac{1.61 \text{ psi}}{100 \text{ ft}}$ = 32 psi x 2.31 ft/psi = 74 ft friction loss + 151 ft = **225 ft friction loss**
  - select 1¼inch PE (extrapolate friction loss: 7 USgpm = 0.37 and 8 USgpm = 0.47):

    $2{,}000 \text{ ft} \times \frac{0.42 \text{ psi}}{100 \text{ ft}}$ = 8.4 psi x 2.31 ft/psi = 20 ft friction loss + 151 ft = **171 ft friction loss**
- select a pipe size
  - if ¾ inch PE pipe is used, maximum system pressure = 391 ft x 0.433 psi/ft = **170 psi**
  - if 1 inch PE pipe is used, maximum system pressure = 225 ft x 0.433 psi/ft = **98 psi**
  - if 1¼ inch PE pipe is used, maximum system pressure = 171 ft x 0.433 psi/ft = **74 psi**

ANSWER **In this example, three pipes could be used - two determining factors must be chosen in the final selection:**

- **a pipe pressure rating must be chosen:**
  - **the ¾ inch pipe has an excessive pressure requirement**
  - **the 1 inch pipe would require a 160 psi pressure rating (system at 101 psi)**
  - **the 1¼ inch pipe could use a 100 psi pressure rating (system at 75 psi)**
- **a pump horsepower must be chosen:**
  - **the pump horsepower required to pump the required 7.5 USgpm at the above pressures must be determined to be able to select either the 1 or 1¼ inch pipes**
- **refer to Factsheet #590.304-3, Design #3 for pump sizing method and example**

The final pipe selection in a pump system should be chosen in conjunction with the pump.

Note: **that PVC pipe could also be used where the installation conditions allow. The same friction loss procedure would be completed.**

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