Student Workbook

Basic Irrigation Hydraulics

By
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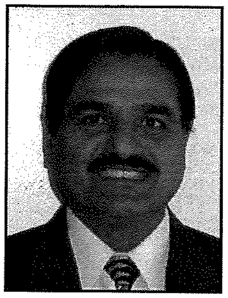

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Ramesh Kumar is professor of the landscape irrigation science program at the California Polytechnic State University, Pomona, California. Dr. Ramesh has a doctorate degree in agricultural engineering from the University of California at Davis. He has been teaching in the bachelor's degree program in landscape irrigation science and in the certificate or minor in landscape irrigation design since 1980.

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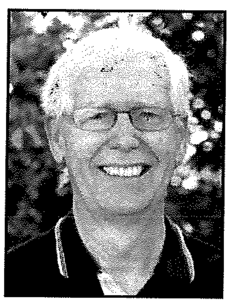

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Eudell Vis is professor emeritus at the California Polytechnic State University, Pomona, California. Eudell has taught in the bachelor's degree program in landscape irrigation science and in the certificate or minor in landscape irrigation design since the early 1980s, and he continues as an advisor to students working on their degrees.

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Vis enjoys working with students involved with the landscape irrigation science student club and serving as an advisor of the Cal Poly Pomona student team that competes in the Planet Student Career Days.

Table of Contents

Introduction to Irrigation Hydraulics

Hydraulics is a branch of science that deals with the dynamics of water or other liquids in motion. In this manual the characteristics of water will be studied — both in motion and at rest. The emphasis will be on the relationships between flow, ***velocity***, and ***pressure*** in typical ***irrigation systems*** that use pipes to convey water. By determining the pressure at the water source, ***pressure losses*** in pipe, fittings, and other components, and by accounting for changes in elevation, the pressure at various points in the irrigation system can be determined.

Knowledge of the basic principles of irrigation hydraulics is essential to designing and maintaining an economical and efficient irrigation system. Understanding the principles outlined in this workbook will lead to irrigation systems that have a more uniform distribution of water and cost less to install and maintain.

How Does Hydraulics Affect an Irrigation System?

Water pressure in an irrigation system affects the performance of sprinkler and ***drip irrigation*** systems, ranging from large agricultural systems to smaller systems for landscapes, and to specialized systems designed for golf courses. Sprinkler systems are designed to deliver a uniform distribution of water over the entire area. By contrast, a drip irrigation system applies water directly to the root area of plants, while the surrounding areas remain dry. Both applications require proper pressure in the irrigation system for adequate water application and management.

Consistent pressure is the primary goal, and it is important to achieve this while at the same time conserving costs, using the least amount of water, and maintaining optimum plant growth and health. In addition, environmental issues, such as irrigation ***runoff***, can be controlled in a system with correct pressure.

Objectives

There are terminologies, concepts, and relationships that describe how water pressure and water flow behave in an irrigation system as some may be lost by runoff or deep percolation. This manual explains how irrigation systems work and how pressure and flow in a system depend on effective design and proper system operation.

Upon completion of this manual, the student will understand basic irrigation terminology and have the skills necessary to calculate pressure and flow for irrigation systems. The student should

- understand water pressure and how it is created in an irrigation system.
- know the difference between static and ***dynamic pressures***.
- be able to calculate ***static pressure***, flow, ***friction losses***, and dynamic pressure for a basic irrigation system.
- be able to use proper units for pressure and flow.

Notes

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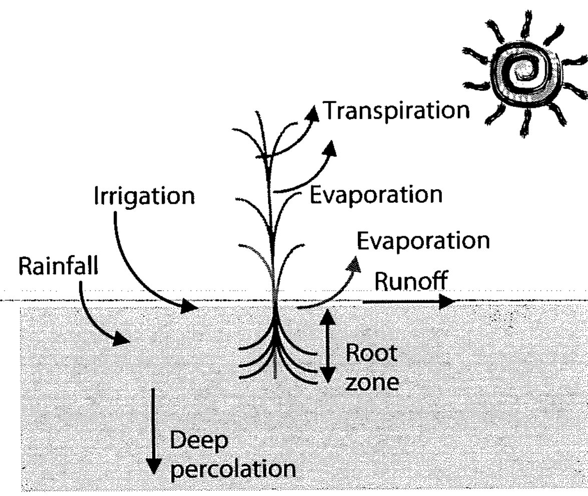
Introduction to Irrigation

Irrigation systems are installed in agricultural and landscape settings to provide water for plants where the annual rainfall is not sufficient. Plants use water in ***transpiration*** and some water is lost through evaporation. Figure 1 illustrates the sources of applied water and the ways water leaves the plant and soil. Note that not all of the water is used beneficially by a plant as some may be lost in runoff or deep percolation. The effectiveness of the irrigation system determines, to a large degree, how much water is actually used by the plants.

Figure 1. Water balance



Irrigation Defined

Irrigation is "the application of water to soil for the purpose of supplying the moisture essential for plant growth," as defined by Hansen et al. (1980). Irrigation systems may also be used for frost protection, environmental cooling, field cultural practices, and other applications. Some common methods of irrigation are ***sprinkler irrigation***, drip irrigation, and ***surface irrigation*** which includes ***flood*** and ***furrow*** methods. There are many variations of these systems, but a basic understanding of irrigation hydraulics can be applied to any system.

Irrigation hydraulics is a study of water behavior at rest and in motion (or in other words a study of pressure and flow). Irrigation hydraulics affects sprinkler and drip ***emitter*** performance, uniform water application, and irrigation system costs.

Pressure is the biggest variable in irrigation systems. Pressure determines how well sprinklers and drip components perform. All manufacturers publish recommended ***operating pressures*** for their products. High and low pressures affect ***sprinkler distribution patterns***, runoff, uniformity and, ultimately, plant health, and appearance.

Notes

Water pressure in an irrigation system can be measured with a pressure gauge mounted in the pipe system or measured with a ***pitot tube*** at a sprinkler nozzle or drip line.

Water pressure in an irrigation system is created in two ways:

- by using the weight of water (such as in a water tank) to exert the force necessary to create pressure in the system
- by using a ***pump*** to mechanically pressurize the system

In many municipal water delivery systems, both of these methods are used to create the water pressure in homes and businesses. Water tanks use gravity to create pressure. These tanks are located on a mountain, tower, or roof. The weight of water in the tanks creates pressure in the pipes. A booster pump may also be used to increase the water pressure to meet the requirements of the irrigation system.

In agricultural, residential, and municipal systems that use well water or water from reservoirs or canals, pumps are used to create pressure in the irrigation system.

Water pressure can be measured and expressed in several ways. Following are the most common units in the United States:

- ***pounds per square inch {psi}***
- ***feet of head*** (height of a water column)

Many manufacturers also list pressure in metric units for product use in other countries.

There are two classifications of pressures:

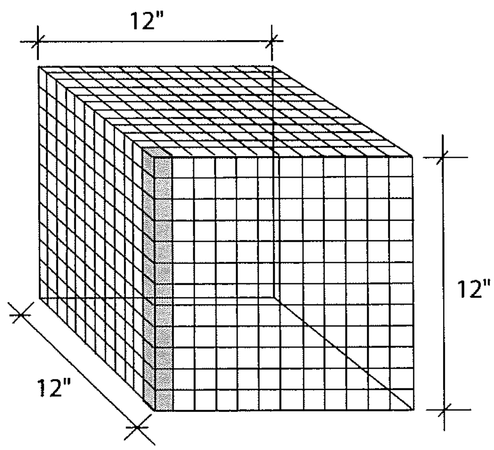
- ***Static*** (hydrostatic) ***pressure*** is the pressure at a point when there is no water movement.
- Dynamic (operating) pressure is the pressure at a point when water is moving.

Notes

Facts About Water (as it relates to pressure and volume)

The following facts about water are used to understand water pressure and volume of water used in irrigation:

Figure 2. 1 cubic foot of water



- The weight of 1 gallon of water is 8.33 pounds.
- The weight of 1 cubic foot of water is 62.4 pounds.
- There are 7.48 gallons in 1 cubic foot.
- The weight of 1 cubic inch of water is 0.0361 pounds.
- An acre-foot of water is
  - enough water to cover 1 acre of land to a depth of 1 foot.
  - about 325,850 gallons.
- CCF is
  - 100 cubic feet, or approximately 748 gallons of water.
  - one of the common units of billing for water consumption.

Creating Water Pressure

Using the Weight of Water

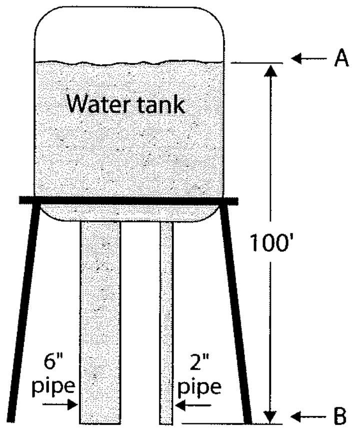
One method of creating water pressure is to use the weight of the water; the other method is to use a pump. This discussion will focus only on using the weight of water. In figure 2, 1 cubic foot of water weighing 62.4 pounds is resting on the bottom of the cube. The area of the bottom is 12 inches by 12 inches, or 144 square inches. Dividing the weight of the 62.4 pounds of 1 cubic foot of water by 144 square inches gives 0.433 psi as shown above in figure 2.

$$\frac{62.4 \text{ lb}}{144 \text{ in.}^2} = 0.433 \text{ psi}$$

In figure 2, the height of the water is 12 inches, or 1 foot, creating a pressure of 0.433 psi. That introduces the second way to express pressure — feet of head. In figure 2, there is "1 foot of head of water."

In figure 3, the water tank system creates 100 feet of head at the bottom of both the 6-inch and 2-inch pipes.

Figure 3. Pressure created by elevation

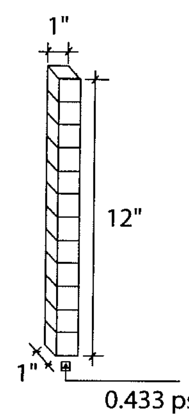


The water tank creates 100 feet of head at point B.

Water Pressure from 1 Foot of Water

Figure 4 shows that a column of water that is 1 foot high and 1 inch square also creates 0.433 psi.

Figure 4. 1 foot of water



$$1 \text{ ft of head} = 12 \text{ in.}^3 \times 0.0361 \text{ lbs/in.}^3 = 0.433 \text{ lb}$$

The area at the bottom of the column is 1 square inch. The weight (force) is 0.433 pounds. Hence, the pressure (force per unit area) is 0.433 pounds per square inch {psi}. Therefore, a column of water 1 foot high will exert a pressure at the bottom of 0.433 psi. This is a very important number because it means that as the column of water gets higher, every 1 foot of height added will increase the pressure at the bottom by 0.433 psi. For example, a column of water 2 feet high creates a pressure at the bottom of 0.866 psi:

$$0.433 \text{ psi/ft} \times 2 \text{ ft} = 0.866 \text{ psi}$$

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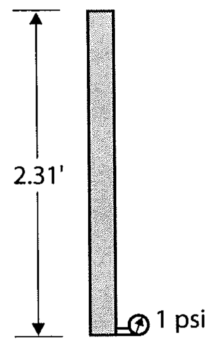
Feet of Head from 1 psi

Figure 5 shows that 2.31 feet of head creates 1 psi.

Figure 5. 1 psi



1 psi = 2.31 ft of head

These are important facts to memorize. They will be used throughout this manual and, more important, in work with irrigation systems.

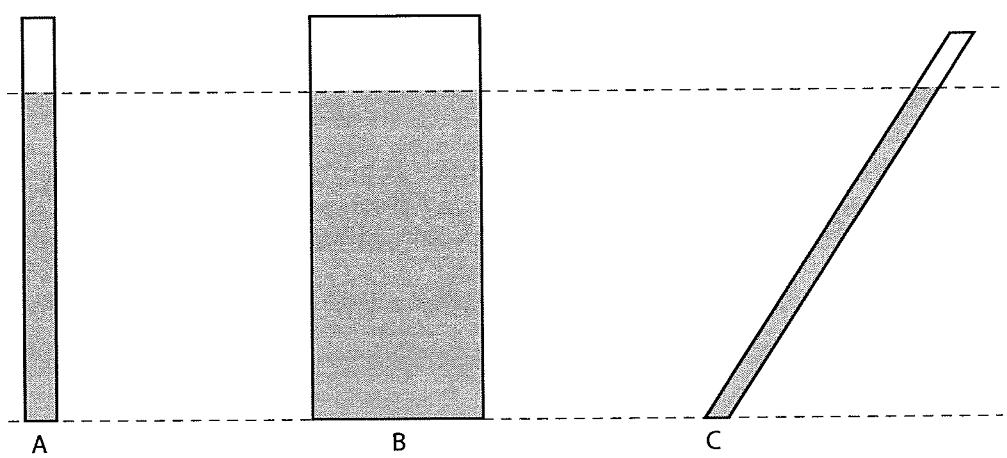
- 1 psi = 2.31 feet of head
- 1 feet of head = 0.433 psi

Shape and Size of Container

In figure 6, does the shape or size of the container make a difference in the pressure at the bottom of A, B, and C?

The shape or size of the container does not make a difference in the pressure at the bottom. The weight of water in all columns, at an equal depth, creates the same pressure resting on 1 square inch — no matter what the size or shape of the container.

Figure 6. Pressure and container size



While this may not seem possible, remember — the pressure is measured as the force on 1 square inch — not the total weight. Imagine pressing your thumb (assume it has an area of 1 square inch) to close a hole in the bottom of tank B. Your thumb is only experiencing pressure due to the height of the water — not the total weight of the water in the tank.

Consider the example of diving into a swimming pool or lake. The deeper one dives, the more pressure builds on the ears. The pressure on the ears does not change with the shape of the pool. Nor does it change whether one is diving into a backyard pool or large lake. *The pressure at any depth is dependent upon the height of the column of water above that point* — not on the shape or size of the container.

What does this mean for an irrigation system?

When sprinklers and drip emitters are at different heights, or irrigation pipes follow the contour of the land, there will be a difference of 0.433 psi for every foot of elevation change. (The effects of improper pressures will be discussed in other irrigation lectures.)

One psi is equal to 2.31 feet of head, and conversely 1 foot of head is equal to 0.433 psi, are very important. These will be used in topics about static and dynamic pressures.

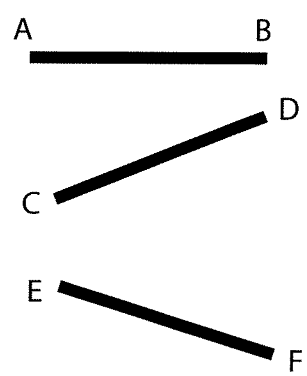
Static Pressure

Introduction

The pressure at a point when there is no water movement is called static pressure. This is the pressure in the system when the valve is closed, and sprinklers or drip emitters are not working.

Only one factor determines the static pressure at any point in an irrigation system — the height of the water in the system. The static pressure in the pipes AB, CD, and EF is exhibited in figure 7 and is explained in more detail in later figures.

Figure 7. Elevation effects on pressure



- Static pressure in the system is the same at all points of equal elevation (A and B).
- Static pressure in the system is lower at a higher elevation (D) than at a lower elevation (C).
- Static pressure in the system is higher at a lower elevation (F) than at a higher elevation (E).

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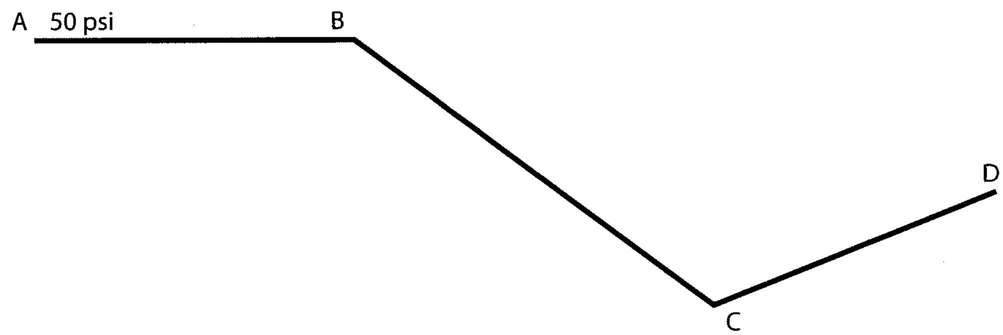
Static Pressure and Elevation

Figure 8 shows static pressure changes in irrigation pipes on level ground (AB), downhill (BC), and uphill (CD) as the elevation changes. Static pressure does not depend on the size or type of pipe; therefore, pipe sizes are not specified.

Figure 8. Elevation impacts on pressure



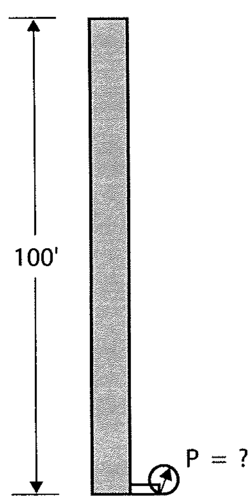
- A and B are at the same elevation. Static pressure at B is the same as at A (50 psi).
- C is lower in elevation than B. Static pressure at C is higher than at B (>50 psi).
- D is at a higher elevation than C. Static pressure at D is lower than at C (>50 psi) but higher than B.

It is common to have elevation differences in an irrigation system, so the effects of elevation on pressure must be known.

Example 1 — Static Pressure Calculation of Pounds per Square Inch from Feet of Head

In this first example use 1 foot of water creates 0.433 psi in pressure.

What is the static pressure at the base of the 100-foot water column?



Answer

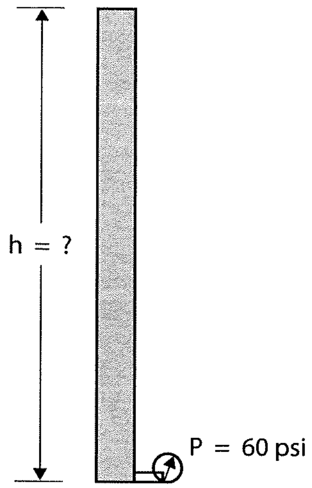
P = 0.433 psi for every foot of head, so for 100 ft of head:

$P = 100 \text{ ft} \times 0.433 \text{ psi/ft} = 43.3 \text{ psi}$

Note: Both factors, 2.31 and 0.433 are shown to three significant digits. All answers will be rounded to three significant digits.

Example 2 — Static Pressure Calculation of Feet of Head from Pounds per Square Inch

For this example, do the reverse. If the pressure at the base of a water column is 60 psi, how high is the water column?



Answer

h = 2.31 ft for every psi, so for 60 psi:

$h = 60.0 \text{ psi} \times 2.31 \text{ ft/psi} = 139 \text{ ft}$

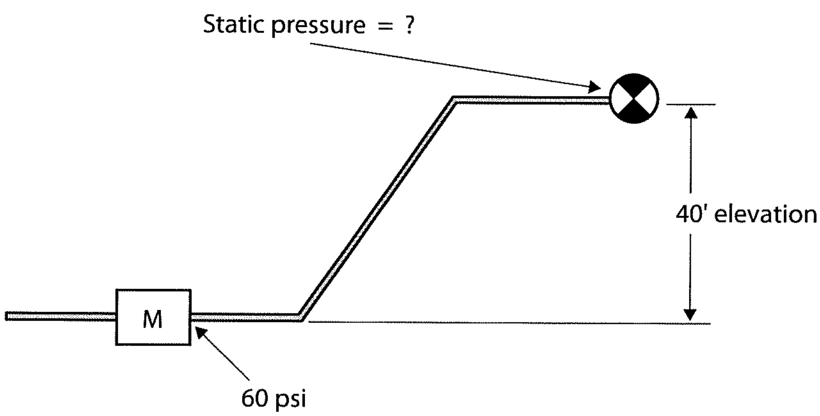
Example 3 — Static Pressure Calculation of Pounds per Square Inch in Inclined Pipe

Consider a common situation where the irrigation pipes are installed parallel to a slope. This pipe starts at the ***water meter*** and is installed up the slope to a valve — a total of 40 feet difference in elevation between the meter and the valve. The valve is closed; therefore, no water is flowing.

The static pressure at the meter is 60 psi. The pressure at the valve is less than 60 psi (because it is higher than the meter), but what is the pressure at the valve?

The pressure decreases at the higher elevation. Take 60.0 psi and subtract the loss due to elevation change, 0.433 psi per foot. What is the static pressure at the control valve?

Note: A complete legend of all figure symbols can be found on page 61.



Answer

$\text{Static Pressure} = 60.0 \text{ psi} - (40.0 \text{ psi} \times 0.433 \text{ psi/ft}) = 42.7 \text{ psi}$

If a pressure gauge were installed just before the valve, it would read 42.7 psi. Remember, this is static pressure, so water is not flowing in the pipe.

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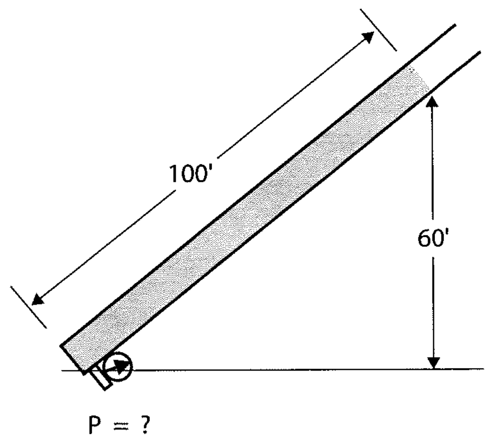
Example 4 — Static Pressure Calculation of Pounds per Square Inch in Inclined Pipe

In example 4, the length of the pipe and the change in elevation are both given. Which dimension is used to calculate the pressure at the bottom of the pipe? What is the static pressure at the base of this pipe?



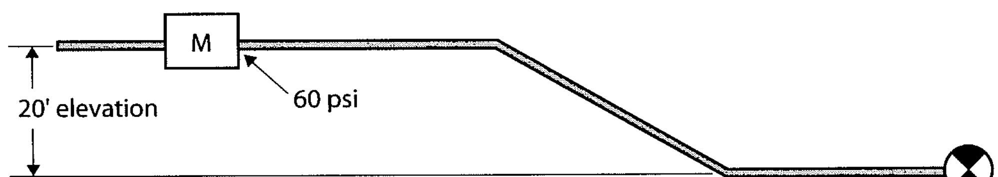
Answer

P = 60.0 ft × 0.433 psi/ft = 26.0 psi

Note: Only the change in elevation, the vertical elevation difference, is needed to calculate the pressure. The length of pipe (100 feet) is ignored.

Example 5 — Static Pressure Calculation of Pounds per Square Inch

Example 5 is similar to example 3, except now the valve is 20 feet lower than the meter. What is the static pressure at the valve?



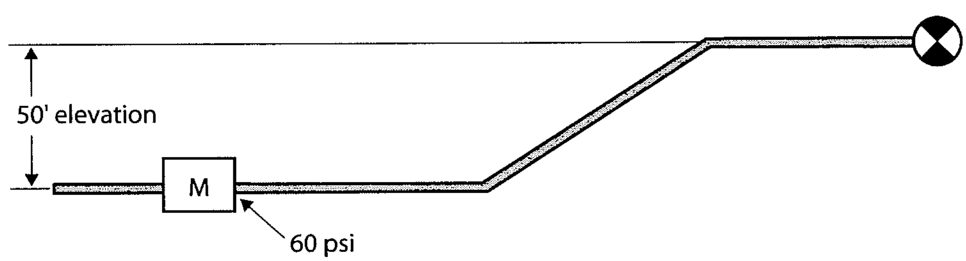
Answer

Pressure increase due to elevation = 20.0 ft × 0.433 psi/ft = 8.66 psi

Pressure at valve = 60.0 psi + 8.66 psi = 68.7 psi

Example 6 — Static Pressure Calculation of Pounds per Square Inch

Example 6 is similar to example 5. What is the static pressure at the valve?



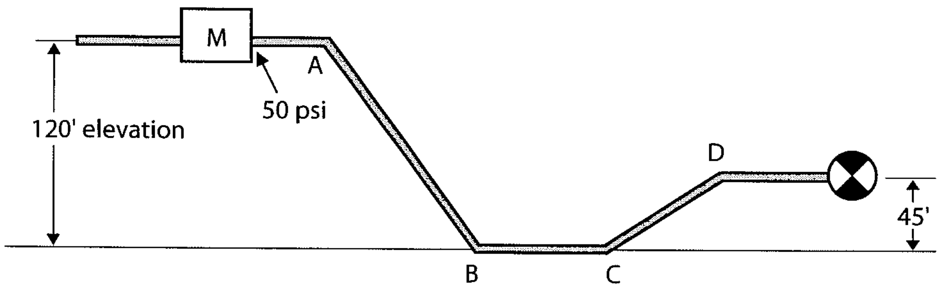
Answer

Pressure decrease due to elevation = 50.0 ft × 0.433 psi/ft = 21.7 psi

Pressure at valve = 60.0 psi − 21.7 psi = 38.3 psi

Example 7 — Static Pressure Calculation of Pounds per Square Inch

Example 7 has several changes in elevation. Start at the meter where the elevation is known to be 50 psi and work from A to B, to C, and to D to determine the pressure that is available at the valve. Calculate the static pressure at A, B, C, D, and at the valve.



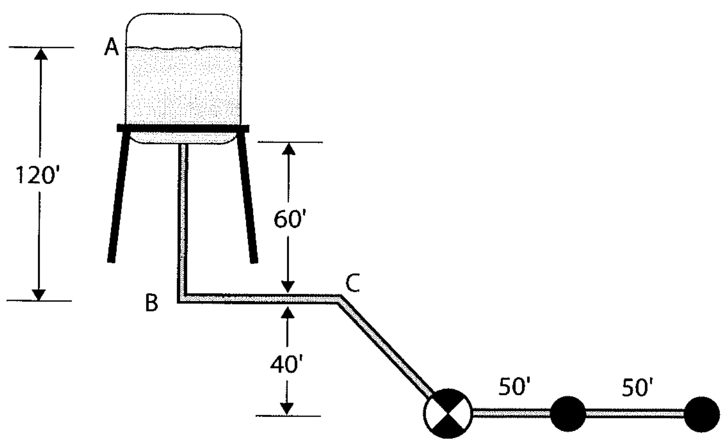
Answer

A = 50.0 psi (same elevation as the meter)
B = 50.0 psi + (120 ft × 0.433 psi/ft) = 102 psi
C = 102 psi (same elevation as B)
D = 102 psi − (45.0 ft × 0.433 psi/ft) = 82.5 psi
Valve = 82.5 psi (same elevation as D)

Example 8 — Static Pressure Calculation of Pounds per Square Inch with Water Tank

In the previous examples, the source of the water supply was not specified and a starting pressure was given. Example 8 has a water tank as a source of water. The pressure at points B, C, and the valve are based on 1 foot of head creating 0.433 psi change. In this case, all the pressure is created by the water in the tank system.

Find the static pressure at points B, C, and the valve.



Answer

B = 120 ft × 0.433 psi/ft = 52.0 psi
C = 52.0 psi
Valve = (120 ft + 40.0 ft) × 0.433 psi/ft = 69.3 psi

Notes

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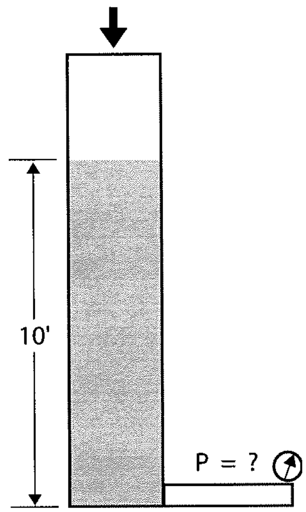
Example 8a — Static Pressure Calculation of Pounds per Square Inch with Standpipe for Low Pressure Pipe Line

What is the static pressure at the base of the 10-foot ***standpipe*** in an orchard?



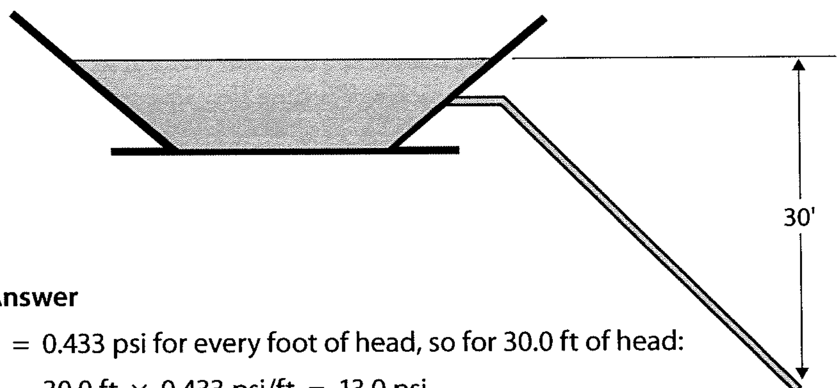
Answer

P = 0.433 psi for every foot of head, so for 10.0 ft of head:

P = 10.0 ft × 0.433 psi/ft = 4.33 psi

Example 8b — Static Pressure Calculation of Pounds per Square Inch for Storage Reservoir for Field Irrigation

What is the static pressure at the base of the outlet pipe from the reservoir?



Answer

P = 0.433 psi for every foot of head, so for 30.0 ft of head:

P = 30.0 ft × 0.433 psi/ft = 13.0 psi

Static Pressure Summary

Static pressure is pressure in an irrigation system when the water is not moving. The difference in the static pressure at two locations is determined by the elevation changes between those locations. One pound per square inch is equal to 2.31 feet of head, and 1 foot of head is equal to 0.433 psi. Both constants are used to calculate pressure in the system. It is important to remember that only the vertical height of water determines static pressure — not the total volume of water that is in the tank, reservoir, or pipe. Additionally, static pressure is not affected by the size or material of the pipe, tank, or reservoir.

The next sections will show how to determine the dynamic pressure, the pressure normally used for irrigation system operation. Static pressure has an important relationship to dynamic pressure as well as being essential for selecting the proper irrigation system components.

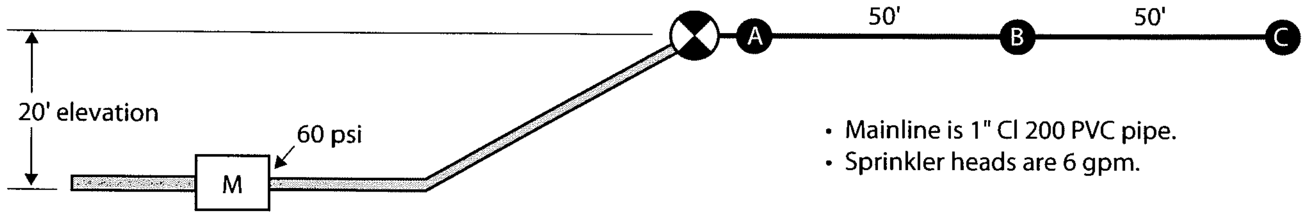
PRACTICE PROBLEMS #1
Static Pressure

(Please use the back of the sheet to complete calculations.)

Name_______________________________

Date_______________________________

1. What is the static pressure at the valve? The valve is closed. No water is flowing.

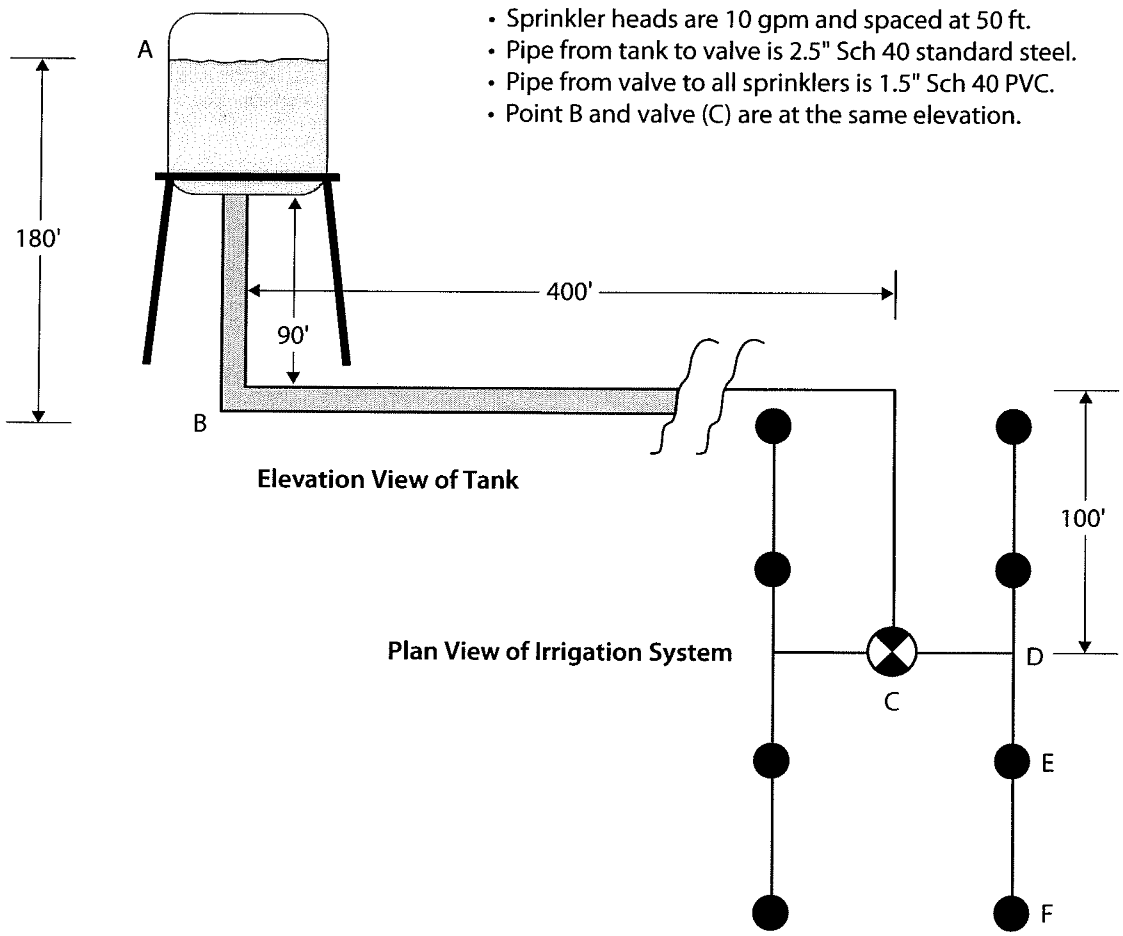


- Mainline is 1" Cl 200 PVC pipe.
- Sprinkler heads are 6 gpm.

P = ______________

2. What is the static pressure at the valve? The valve is closed. No water is flowing.

- Sprinkler heads are 10 gpm and spaced at 50 ft.
- Pipe from tank to valve is 2.5" Sch 40 standard steel.
- Pipe from valve to all sprinklers is 1.5" Sch 40 PVC.
- Point B and valve (C) are at the same elevation.

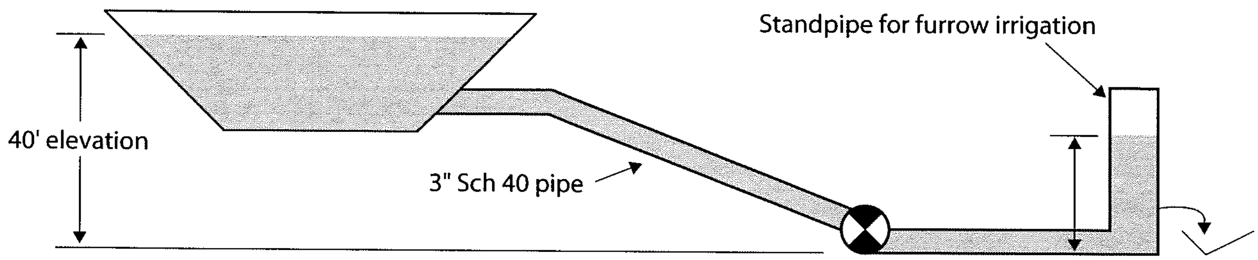


P = ______________

Static Pressure

(Please use the back of the sheet to complete calculations.)

3. What is the static pressure at the valve? The valve is closed. No water is flowing.



P = ____________

Water Movement in Irrigation Systems

When water moves through an irrigation system, it is said to be in a dynamic state. Dynamic pressure is measured in pounds per square inch or feet of head — the same units as static pressure.

The movement of water is commonly described in terms of velocity (speed of water movement) and flow (amount of water moving through the system per unit of time). Velocity is generally measured in ***feet per second {ft/s}***, and the flow is commonly measured in ***gallons per minute {gpm}*** or ***gallons per hour {gph}***. In this section, velocity will not be discussed. Flow in irrigation systems is covered next.

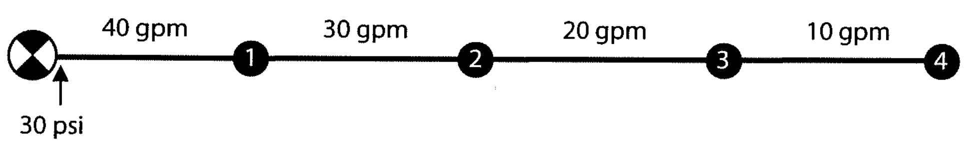
Flow

Flow in a system is dependent upon the number of sprinklers or drip emitters working at the same time. Therefore, each segment of pipe in an irrigation system can have a different flow. Flow is commonly measured in gallons per minute for sprinkler systems and gallons per hour for drip irrigation systems.

It is important to know the flow for each section of pipe to determine the friction losses (covered in the next section) and the correct size of pipe needed to handle the flow.

Example 9 — Flow for a Basic Sprinkler System — Single Lateral Line

In this example, notice that each sprinkler has a flow of 10 gpm and that they are all on one lateral line pipe. Flow in the section of pipe between sprinklers 3 and 4 is 10 gpm because it feeds only one sprinkler. The pipe between sprinklers 2 and 3 has a flow of 20 gpm because it feeds two sprinklers. The total flow for the four sprinklers is 40 gpm.



- Sprinkler heads are 10 gpm at 50 psi.
- Pipe is Cl 200 PVC.

✍ Notes

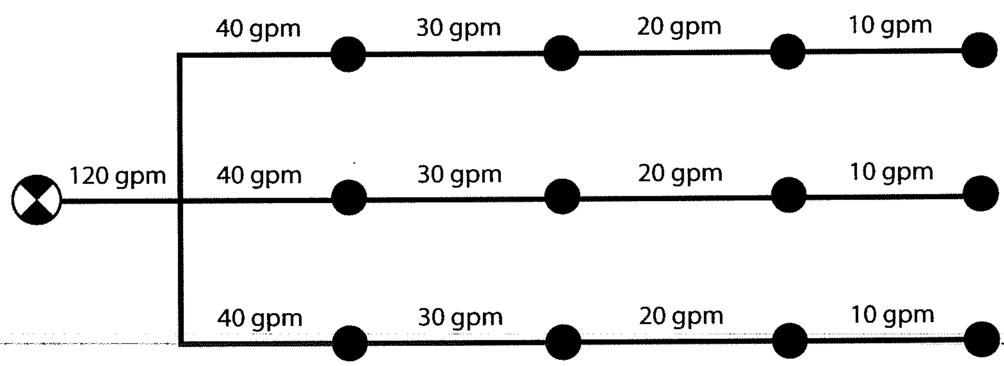
Notes

Example 10 — Flow for a Sprinkler System — Three Lateral Lines

The system shown in example 10 has three lateral line pipes that are controlled by one valve. The flow entering each lateral line is determined by the number of sprinklers on that lateral line (discussed in the previous example). However, the pipe from the valve must carry a total of 120 gpm:

$$40 \text{ gpm} + 40 \text{ gpm} + 40 \text{ gpm} = 120 \text{ gpm}$$

It is obvious that a different sized pipe would be selected to handle 120 gpm than that used for a 10-gpm flow. The appropriate pipe size — the pipe diameter — will be used for friction loss calculations.



- Sprinkler heads are 10 gpm.
- Pipe is Cl 200 PVC.

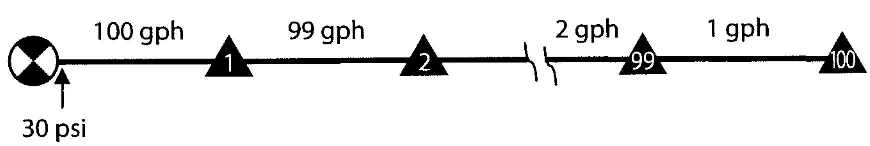
Example 11 — Flow for a Basic Drip System

The drip irrigation lateral line in example 11 has 100 drip emitters (only four are shown). Flow from drip emitters is normally expressed in gallons per hour, and drip tubing is used for the lateral lines rather than PVC pipe. The flow in the last section of drip tubing is for one emitter, or 2 gph. The flow for all 100 emitters is

$$100 \text{ emitters} \times 1 \text{ gph/emitter} = 100 \text{ gph}$$

This can be converted to gallons per minute by dividing by 60 {min}, so

$$\frac{100 \text{ gph}}{60 \text{ m/h}} = 1.67 \text{ gpm}$$



- Drip emitters are 1 gph.
- Pipe is drip tubing.

It is important to remember that the flow in pipes and tubing must be known before the system pressure can be determined. In these examples, flow to each sprinkler or emitter was given. To determine flows for an irrigation design, manufacturer's specifications are used. Flow sensors or water meters can be used to measure flow in installed systems.

Flow Summary

Sprinklers, drip emitters, drip tape, and any devices of this type are designed by the manufacturer to have a certain flow at a certain pressure. These ***flow rates*** are published by the manufacturer for the user. The total flow rate in an irrigation system is the sum of the flow for sprinklers or drip emitters that will operate at the same time. It is important that the flow for every section of the pipe in the system be determined so that the friction losses in the pipes can be estimated. That is the subject of the next section.

✍ Notes

✍ Notes

PRACTICE PROBLEMS #2

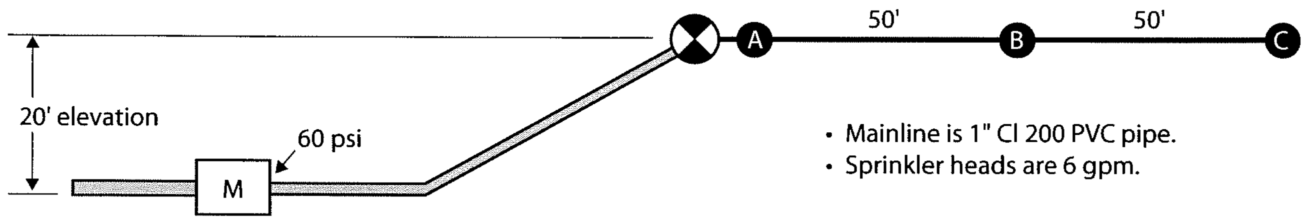
Flow

(Please use the back of the sheet to complete calculations.)

Name______________________

Date______________________

1. What is the flow through the water meter when the valve is turned to the ON position?

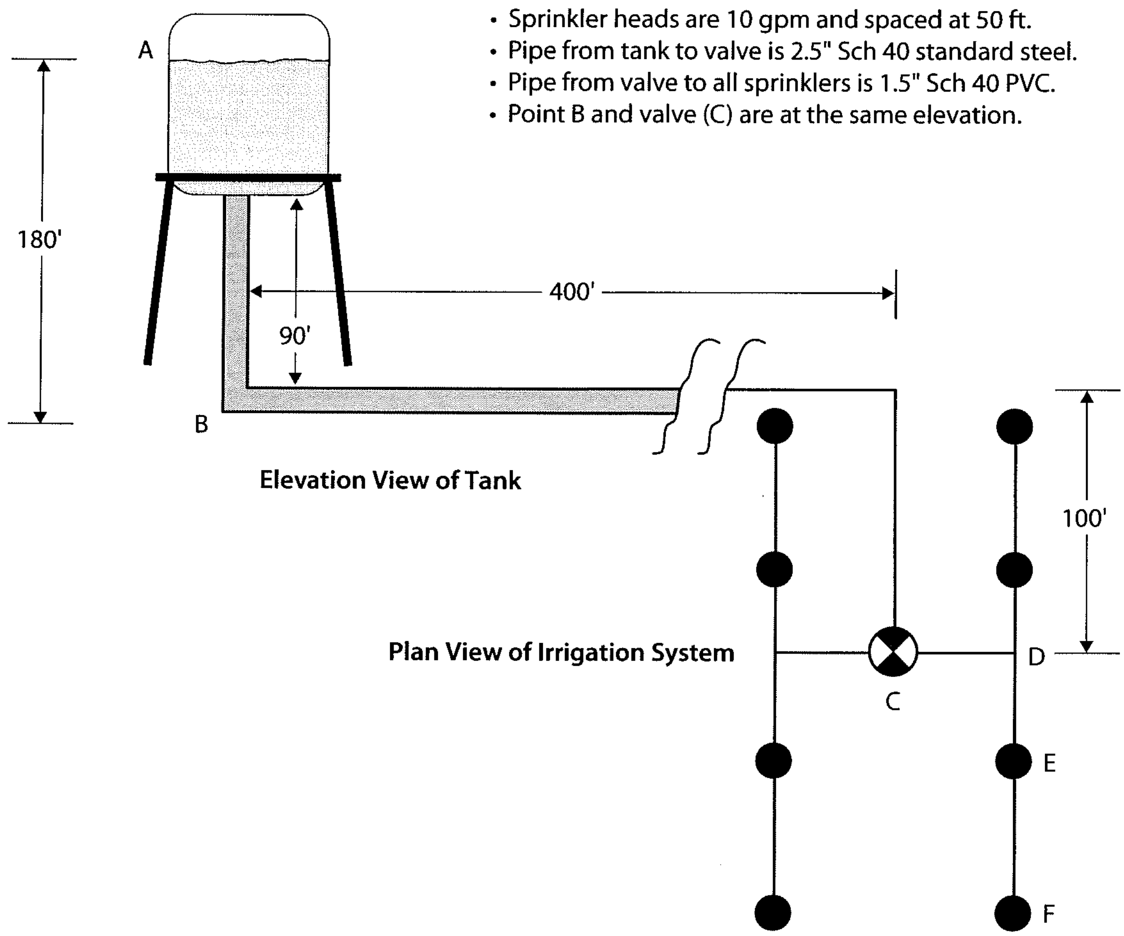


- Mainline is 1" Cl 200 PVC pipe.
- Sprinkler heads are 6 gpm.

Q = __________

2. What is the flow through the valve when the valve is turned to the ON position?

- Sprinkler heads are 10 gpm and spaced at 50 ft.
- Pipe from tank to valve is 2.5" Sch 40 standard steel.
- Pipe from valve to all sprinklers is 1.5" Sch 40 PVC.
- Point B and valve (C) are at the same elevation.



Elevation View of Tank

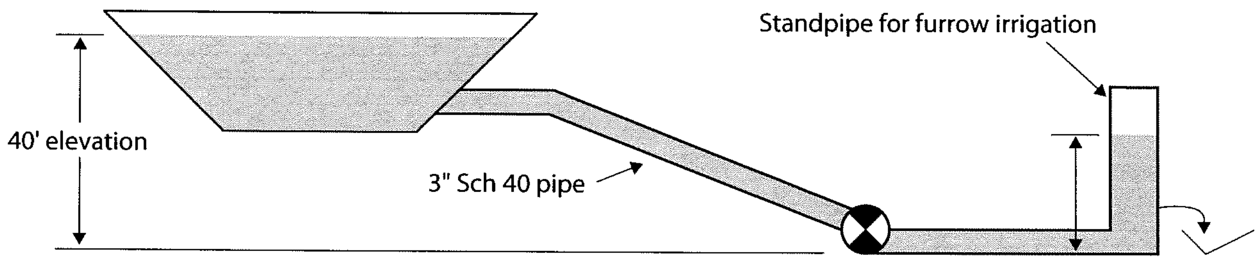
Plan View of Irrigation System

Q = __________

Flow

(Please use the back of the sheet to complete calculations.)

3. What is the flow (in gallons per minute) through the valve when the valve is turned to the ON position? Twenty furrows are being watered at the same time, with 5 gpm being fed to each furrow.



Q = ____________

Introduction to Pipes

Before beginning a discussion about friction losses, it is important to understand a little bit about different pipes and tubing used in irrigation. In almost all irrigation systems, pipe and tubing are necessary components that convey water from the source to the sprinklers and drippers. Some common materials for pipes used in irrigation systems are ***polyvinyl-chloride*** (PVC), ***polyethylene*** (PE), and metals such as steel, aluminum, copper, and concrete. PVC and PE pipe are common for both landscape and agricultural irrigation because of the relatively low cost and ease of installation. The nominal size, inside and outside diameter, friction loss, and other pipe characteristics are published by pipe and irrigation equipment manufacturers.

There are two common classifications of pipes:

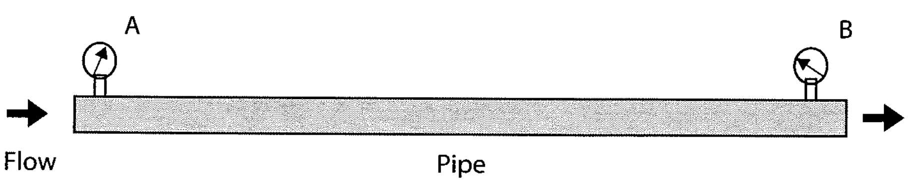
- schedule pipe
- class/SDR pipe

Schedule pipe is available in PVC and steel (e.g., Schedule 40). The pipe wall thickness is fairly constant for all diameters of schedule pipe, but the pressure rating decreases as the diameter of the pipe increases. Class/SDR pipe (e.g., Class 200/SDR21) has a constant pressure rating of 200 psi for all diameters of pipe. All Class 315/SDR13.5 pipe has a pressure rating of 315 psi. The class/SDR rating consistency is made possible by keeping the ratio of the outside pipe diameter to the pipe minimum wall thickness the same.

Friction Loss (Pressure Loss)

When water flows from A to B, there is a pressure loss between those two points on the pipe. Gauge B will read a lower pressure than gauge A. That pressure loss is called friction loss. Values shown in the examples can be obtained from Section A: Friction Loss Charts.

Figure 9. Pressure loss caused by friction



Introduction to Friction Loss

Understanding friction loss is important when working with irrigation systems. The decisions that an irrigation designer, contractor, or irrigation system operator makes regarding pipe sizes, installation procedures, or irrigation scheduling are affected by friction losses. For example, if the friction losses are too large, the pressure at the sprinkler will be too low, and it will not operate effectively. The factors that affect friction losses and the calculations to determine these losses are presented in this section.

✍ Notes

Notes

Factors of Friction Losses

Four factors affect friction losses in pipes and tubing:

- velocity (flow)
- inside diameter of pipe
- roughness of material of the pipe
- length of the pipe

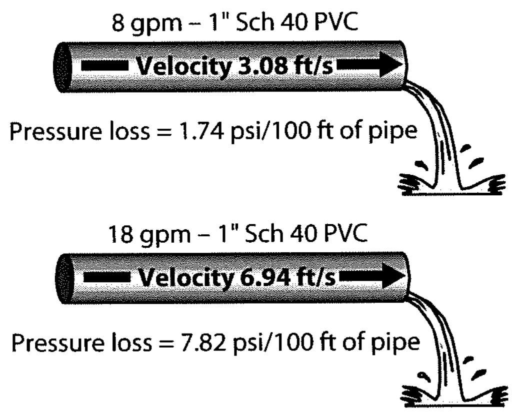
Each of the four factors is considered when using the convenient tables and methods to determine friction losses.

Velocity (Flow)

Velocity is the speed at which water moves through the system. It is measured in feet per second {ft/s}. Water moving in the pipe causes turbulence and results in a loss of dynamic pressure. Increasing the velocity will increase pressure losses.

Figure 10 shows the pressure loss or friction loss in 1-inch Schedule 40 PVC pipe. In the first case, the flow is 8 gpm, resulting in a pressure loss of 1.74 psi per 100 feet of pipe. In the second case, 18 gpm in the same sized pipe causes a 7.82 psi pressure loss. The pressure loss has increased dramatically with the increase in flow from 8 to 18 gpm. Refer to section A for chart. **Note:** With the increase in velocity there is a corresponding increase in flow {gpm}. Velocity and flow are directly related. An increase or decrease in one will result in a corresponding increase or decrease in the other.

Figure 10. Velocity affects friction loss

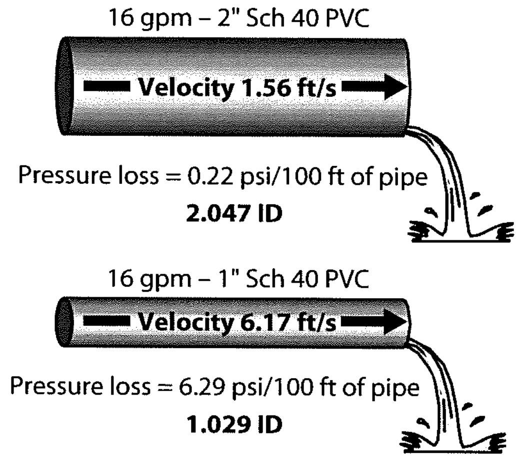


The standard way to express pressure loss for pipes and tubing is in pounds per square inch loss per 100 feet of pipe. For lengths of pipe more or less than 100 feet, the pressure loss is simply increased or decreased proportionally. This method will be illustrated in later examples.

Inside Diameter

The second factor that affects friction loss is the inside diameter [ID] of the pipe. A smaller ID increases the amount of water in contact with the pipe surface. This increased contact increases the friction and consequently increases the dynamic pressure loss. In figure 11, the velocity, length, and roughness remain the same, but the inside pipe diameter is reduced. The reduced ID results in increased friction and reduced dynamic pressure.

Figure 11. Pipe size affects friction loss



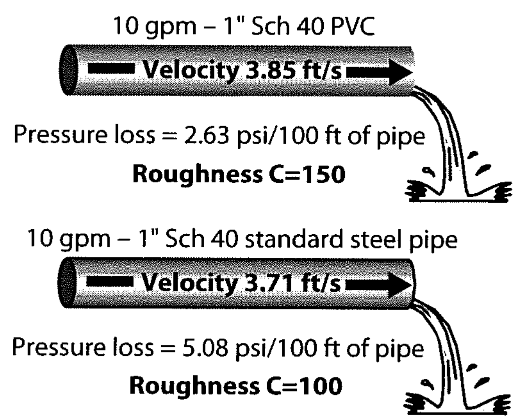
Notice that the ID of the 2-inch pipe is 2.047 inches. The 2-inch measurement is the nominal size of the pipe. The actual ID (as measured with a scale or ruler) is 2.047 inches. The important concept here is that a 16-gpm flow creates a pressure loss of 0.22 psi per 100 feet in the 2-inch pipe, and the same flow of 16 gpm creates a pressure loss of 6.17 psi per 100 feet loss in the 1-inch pipe.

Roughness

Roughness of the inside surface of a pipe and tubing depends on the type of material used to manufacture the pipe. PVC pipe has a smoother inside surface than standard steel pipe. The smooth surface results in lower friction losses. The roughness of the pipe is specified by a roughness factor C — the higher the number, the smoother the pipe. In standard steel pipe C = 100; in PVC pipe C = 150. An increase in roughness of the inside surface of the pipe increases the friction loss.

Figure 12 shows that a flow of 10 gpm in a 1-inch diameter PVC pipe has 2.63 psi loss, compared to 5.08 psi loss for the steel pipe.

Figure 12. Pipe roughness affects friction loss



Note: The velocities are slightly different because the inside diameters are slightly different.

Notes

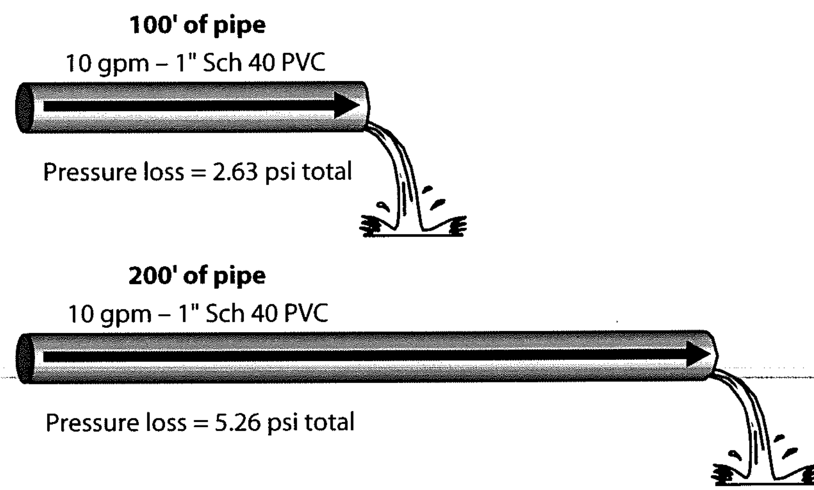
✍ Notes

Length

The last factor that affects friction loss is the length of the pipe. Flow through longer pipes results in greater friction loss at the same flow rate. This is true for all types and sizes of pipe.

Figure 13 shows that the friction loss of 5.26 psi for 200 feet of pipe is twice that for a 100-foot length of pipe at the same flow of 10 gpm.

Figure 13. Length of pipe affects friction loss



All four factors that affect friction loss — velocity (flow), pipe diameter, inside surface of pipe, and pipe length — are used to determine friction loss and dynamic pressure.

How to Find Friction Losses

These four factors affecting pressure loss in pipe were used to develop formulas for calculating the pressure loss associated with various types of pipe. Several equations were developed; the most common in landscape irrigation hydraulics is the Hazen-Williams equation. The Hazen-Williams equation can be represented as follows:

$$H_f = 0.09019 \times \left(\frac{100}{C}\right)^{1.852} \times \frac{Q^{1.852}}{D^{4.866}}$$

where

H_f = pressure loss {psi/100 ft}

C = roughness factor

Q = flow {gpm}

d = inside pipe diameter {in.}

This equation is cumbersome, so a set of charts has been developed based on the Hazen-Williams equation and is shown in appendix A.

Friction loss tables are used to

- determine the pressure loss in the pipe due to friction.
- determine the velocity at various flow rates.
- determine appropriate pipe sizes using pressure losses and/or velocities.

Friction Loss Table

The sample friction loss table includes the following important information:

A **B** Irrigation Association Friction Loss Chart 2008 **D**

Class 200 PVC IPS Plastic Pipe

C → ANSI/ASAE S376.2 ASTM D2241 SDR 21 C=150 ← **E**

psi loss per 100 feet of pipe ← **F**

G **H** **I** **J**

	Nominal size	Shown for convenience Class 315 1/2"		3/4"		1"		1-1/4"		1-1/2"		2"	
	Avg. ID	0.696		0.910		1.169		1.482		1.700		2.129	
	Pipe OD	0.840		1.050		1.315		1.660		1.900		2.375	
	Avg. wall	0.072		0.070		0.073		0.089		0.100		0.123	
	Min. wall	0.062		0.060		0.063		0.079		0.090		0.113	
	Flow (gpm)	Velocity (ft/s)	psi loss	Velocity (ft/s)	psi loss	Velocity (ft/s)	psi loss	Velocity (ft/s)	psi loss	Velocity (ft/s)	psi loss	Velocity (ft/s)	psi loss
K	1	0.84	0.25	0.49	0.07	0.30	0.02	0.19	0.01	0.14	0.00		
	2	1.68	0.90	0.99	0.24	0.60	0.07	0.37	0.02	0.28	0.01	0.18	0.00
L	3	2.53	1.90	1.48	0.52	0.90	0.15	0.56	0.05	0.42	0.02	0.27	0.01
	4	3.37	3.24	1.97	0.88	1.19	0.26	0.74	0.08	0.56	0.04	0.36	0.01
M	5	4.21	4.89	2.46	1.33	1.49	0.39	0.93	0.12	0.71	0.06	0.45	0.02
	6	5.05	6.86	2.96	1.86	1.79	0.55	1.11	0.17	0.85	0.09	0.54	0.03
N	7	5.90	9.12	3.45	2.47	2.09	0.73	1.30	0.23	0.99	0.12	0.63	0.04
	8	6.74	11.68	3.94	3.17	2.39	0.94	1.49	0.30	1.13	0.15	0.72	0.05
	9	7.58	14.53	4.43	3.94	2.69	1.17	1.67	0.37	1.27	0.19	0.81	0.06
	10	8.42	17.66	4.93	4.79	2.99	1.42	1.86	0.45	1.41	0.23	0.90	0.08
	12	10.11	24.75	5.91	6.71	3.58	1.98	2.23	0.63	1.69	0.32	1.08	0.11
	14	11.79	32.93	6.90	8.93	4.18	2.64	2.60	0.83	1.98	0.43	1.26	0.14
	16	13.48	42.16	7.88	11.44	4.78	3.38	2.97	1.07	2.26	0.55	1.44	0.18
	18	15.16	52.44	8.87	14.23	5.37	4.21	3.34	1.33	2.54	0.68	1.62	0.23
	20			9.85	17.29	5.97	5.11	3.72	1.61	2.82	0.83	1.80	0.28

A **Type of pipe** — Represented at the top of the table.

B **Iron pipe size** [IPS] — Indicates that the pipe's outside diameter [OD] dimension corresponds to that of iron pipe. All PVC IPS pipe of the same nominal size has the same outside diameter. For example, all ¾-inch PVC irrigation pipe has an outside diameter of 1.050 inches; thus, all ¾-inch slip fittings will fit on the outside of all types of ¾-inch PVC pipe.

C **ANSI/ASAE** — Represents the standard by which the pipe is manufactured.

D **Standard dimension ratio** [SDR] — Indicates the pipe wall thickness as a ratio of the outside diameter. Dividing the outside diameter by the minimum wall thickness gives the standard dimension ratio. All pipe with SDR 21 has the same pressure rating of 200 psi.

E **C = 150** — Indicates the value of the C factor, which is a measure of the roughness of the inside of the pipe. The lower the number the rougher the surface inside the pipe. This causes a greater pressure loss. For PVC, C = 150; for standard steel pipe, C = 100.

F **Pressure loss per 100** — Pressure losses are psi per 100 feet of pipe.

G **Size** — Indicates the "nominal" pipe size. Nominal means "in name only," so none of the listed pipe dimensions are exactly that size. For example, for ¾-inch pipe, none of the dimensions is actually ¾ inch.

✍ Notes

✍ Notes

H **Outside diameter** [OD] {in.} — Outside pipe diameter.

I **Inside diameter** [ID] {in.} — Inside pipe diameter.

J **Wall thickness** {in.}— Pipe wall thickness.

K **Flow** {gpm} — Flow rate.

L **Velocity** {ft/s} — Speed of water at the corresponding flow rate.

M **psi loss** — Pressure loss per 100 feet of pipe, in pounds per square inch, at the corresponding flow rate. Friction loss is based on average wall thickness and average inside diameter. Specific manufacturer's charts may differ somewhat.

N **Shaded area on the chart** — Designates those flow rates that exceed 5 ft/s. It is recommended that caution be used with flow rates above 5 ft/s in main lines where ***water hammer*** is a concern.

Following is guidance for using the friction loss tables:

1. Find the proper page for pipe material and type. Note that all tables are for 100-foot pipe length.
2. Find the flow {gpm}.
3. Find the corresponding column for the size of pipe.
4. Find the pressure loss corresponding to the specific pipe size under the psi loss column.
5. Find the velocity corresponding to the specific pipe size in the velocity column.

Example 12 — Friction Loss Calculation Using the Tables

Example 12 illustrates how to use the friction loss tables. Find the friction loss in this irrigation pipe:

- Class 200 PVC pipe is 100 feet long.
- Flow is 6 gpm.
- Nominal pipe size is ¾ inch.

Irrigation Association Friction Loss Chart 2008

1 → **Class 200 PVC IPS Plastic Pipe**

ANSI/ASAE S376.2 ASTM D2241 SDR 21 C=150

psi loss per 100 feet of pipe

Nominal size	Shown for convenience Class 315 1/2"		3/4" (3)		1"		1-1/4"		1-1/2"		2"	
Avg. ID	0.696		0.910		1.169		1.482		1.700		2.129	
Pipe OD	0.840		1.050		1.315		1.660		1.900		2.375	
Avg. wall	0.072		0.070		0.073		0.089		0.100		0.123	
Min. wall	0.062		0.060		0.063		0.079		0.090		0.113	
Flow (gpm)	Velocity (ft/s)	psi loss	Velocity (ft/s)	psi loss	Velocity (ft/s)	psi loss	Velocity (ft/s)	psi loss	Velocity (ft/s)	psi loss	Velocity (ft/s)	psi loss
1	0.84	0.25	0.49	0.07	0.30	0.02	0.19	0.01	0.14	0.00		
2	1.68	0.90	0.99	0.24	0.60	0.07	0.37	0.02	0.28	0.01	0.18	0.00
3	2.53	1.90	1.48	0.52	0.90	0.15	0.56	0.05	0.42	0.02	0.27	0.01
4	3.37	3.24	1.97	0.88	[illegible]	0.26	0.74	0.08	0.56	0.04	0.36	0.01
5	4.21	4.89	2.46	1.33	[illegible]	0.39	0.93	0.12	0.71	0.06	0.45	0.02
2 → 6	5.05	6.86	2.96	1.86 (4)	1.79	0.55	1.11	0.17	0.85	0.09	0.54	0.03
7	5.90	9.12	3.45	2.47	2.09	0.73	1.30	0.23	0.99	0.12	0.63	0.04
8	6.74	11.68	3.94	3.17	2.39	0.94	1.49	0.30	1.13	0.15	0.72	0.05
9	7.58	14.53	4.43	3.94	2.69	1.17	1.67	0.37	1.27	0.19	0.81	0.06
10	8.42	17.66	4.93	4.79	2.99	1.42	1.86	0.45	1.41	0.23	0.90	0.08
12	10.11	24.75	5.91	6.71	3.58	1.98	2.23	0.63	1.69	0.32	1.08	0.11
14	11.79	32.93	6.90	8.93	4.18	2.64	2.60	0.83	1.98	0.43	1.26	0.14
16	13.48	42.16	7.88	11.44	4.78	3.38	2.97	1.07	2.26	0.55	1.44	0.18
18	15.16	52.44	8.87	14.23	5.37	4.21	3.34	1.33	2.54	0.68	1.62	0.23
20			9.85	17.29	5.97	5.11	3.72	1.61	2.82	0.83	1.80	0.28

Answer

- **Step 1:** Find the table for Class 200 PVC pipe.
- **Step 2:** Find 6 gpm in the left column.
- **Step 3:** Find the column for ¾" diameter pipe.
- **Step 4:** Read the number in the "psi loss" column below ¾" that corresponds with 6 gpm.
- The friction loss reads 1.86 psi, which is 1.86 psi loss per 100 feet of pipe. Note that each pressure loss number in the table is for 100 feet of pipe.

✍ Notes

Example 13 — Friction Loss Calculation Using the Tables

Example 13 is similar to the previous example, except the pipe is 42 feet long with a ¾-inch diameter and 6-gpm flow. In irrigation systems, pipes are rarely 100 feet long — they may be shorter or longer. Friction loss for a 42-foot length is found by using the same steps.

Irrigation Association Friction Loss Chart 2008

[1] → **Class 200 PVC IPS Plastic Pipe**

ANSI/ASAE S376.2 ASTM D2241 SDR 21 C=150

psi loss per 100 feet of pipe

Nominal size	Shown for convenience Class 315 1/2"		3/4" [3]		1"		1-1/4"		1-1/2"		2"	
Avg. ID	0.696		0.910		1.169		1.482		1.700		2.129	
Pipe OD	0.840		1.050		1.315		1.660		1.900		2.375	
Avg. wall	0.072		0.070		0.073		0.089		0.100		0.123	
Min. wall	0.062		0.060		0.063		0.079		0.090		0.113	
Flow (gpm)	Velocity (ft/s)	psi loss	Velocity (ft/s)	psi loss	Velocity (ft/s)	psi loss	Velocity (ft/s)	psi loss	Velocity (ft/s)	psi loss	Velocity (ft/s)	psi loss
1	0.84	0.25	0.49	0.07	0.30	0.02	0.19	0.01	0.14	0.00		
2	1.68	0.90	0.99	0.24	0.60	0.07	0.37	0.02	0.28	0.01	0.18	0.00
3	2.53	1.90	1.48	0.52	0.90	0.15	0.56	0.05	0.42	0.02	0.27	0.01
4	3.37	3.24	1.97	0.88	1.[illegible] [4]	0.26	0.74	0.08	0.56	0.04	0.36	0.01
5	4.21	4.89	2.46	1.33	1.49	0.39	0.93	0.12	0.71	0.06	0.45	0.02
[2] → 6	5.05	6.86	2.96	1.86	1.79	0.55	1.11	0.17	0.85	0.09	0.54	0.03
7	5.90	9.12	3.45	2.47	2.09	0.73	1.30	0.23	0.99	0.12	0.63	0.04
8	6.74	11.68	3.94	3.17	2.39	0.94	1.49	0.30	1.13	0.15	0.72	0.05
9	7.58	14.53	4.43	3.94	2.69	1.17	1.67	0.37	1.27	0.19	0.81	0.06
10	8.42	17.66	4.93	4.79	2.99	1.42	1.86	0.45	1.41	0.23	0.90	0.08
12	10.11	24.75	5.91	6.71	3.58	1.98	2.23	0.63	1.69	0.32	1.08	0.11
14	11.79	32.93	6.90	8.93	4.18	2.64	2.60	0.83	1.98	0.43	1.26	0.14
16	13.48	42.16	7.88	11.44	4.78	3.38	2.97	1.07	2.26	0.55	1.44	0.18
18	15.16	52.44	8.87	14.23	5.37	4.21	3.34	1.33	2.54	0.68	1.62	0.23
20			9.85	17.29	5.97	5.11	3.72	1.61	2.82	0.83	1.80	0.28

Answer

- **Step 1:** Find the table for Class 200 PVC pipe.
- **Step 2:** Find 6 gpm in the left column.
- **Step 3:** Find the column for ¾" diameter pipe.
- **Step 4:** Read the number in the "psi loss" column below ¾" that corresponds with 6 gpm.
- The friction loss reads 1.86 psi, which is 1.86 psi loss per 100 feet of pipe.
- Multiply 1.86 by the length ratio (42 ÷ 100) = 0.78 psi.

The procedure is the same if the pipe is longer than 100 feet. If the pipe is 192 feet long, multiply 1.86 by (192 ÷ 100) = 3.57 psi.

Friction Loss Summary

It is important to remember that the friction loss in pipes, sometimes called a pressure loss, depends on four factors:

- velocity (flow) — Higher velocity (higher flow) increases friction loss.
- inside diameter of pipe — Larger pipe diameter decreases friction loss.
- roughness of material — Rougher material increases friction loss.
- length of pipe — Longer pipe increases friction loss.

Tables of friction losses are the most common source for these values.

Notes

PRACTICE PROBLEMS #3

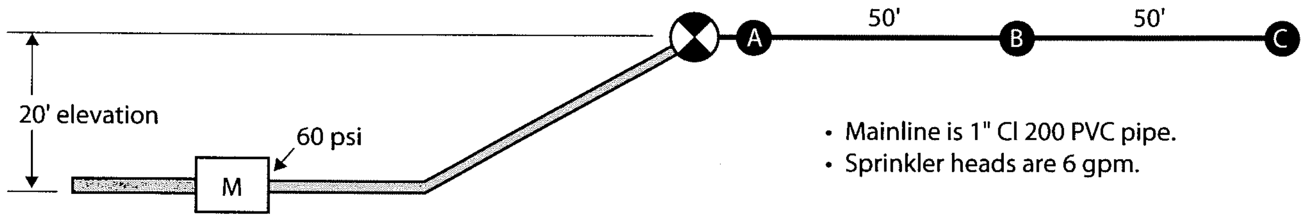
Friction Loss

(Please use the back of the sheet to complete calculations.)

Name________________________________

Date________________________________

1. What is the total friction loss in the pipe from the meter to the last sprinkler C? The pipe length from the meter to the valve is 60 feet. Sprinklers are spaced 50 feet apart.

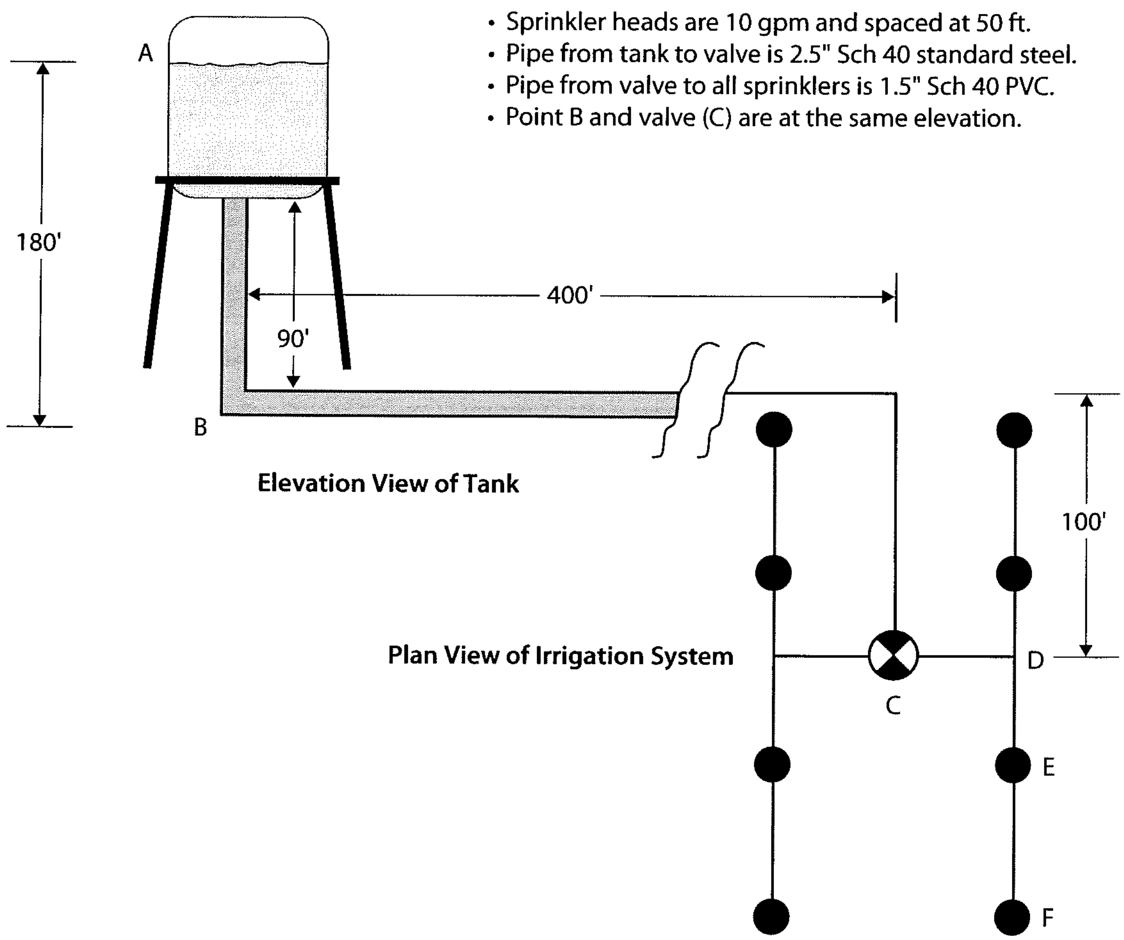


- Mainline is 1" Cl 200 PVC pipe.
- Sprinkler heads are 6 gpm.

h_f = ______________

2. What is the total friction loss in the pipe from the water tank to the last sprinkler F?

- Sprinkler heads are 10 gpm and spaced at 50 ft.
- Pipe from tank to valve is 2.5" Sch 40 standard steel.
- Pipe from valve to all sprinklers is 1.5" Sch 40 PVC.
- Point B and valve (C) are at the same elevation.

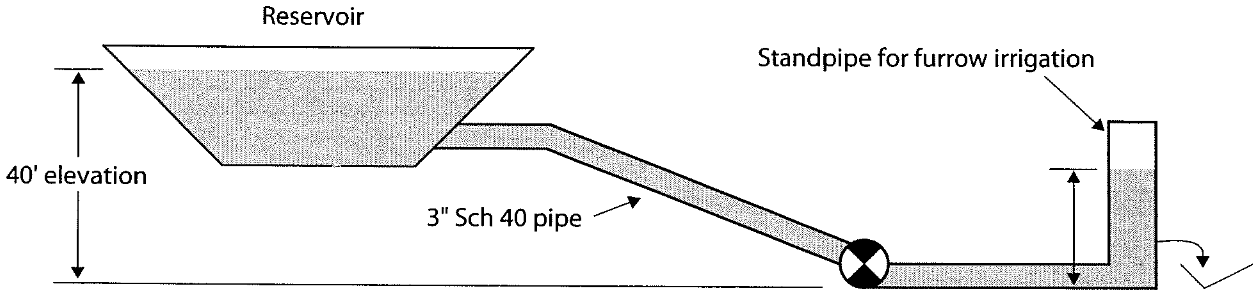


h_f = ______________

PRACTICE PROBLEMS #3
Friction Loss

(Please use the back of the sheet to complete calculations.)

3. What is the total friction loss in the pipe from the reservoir to the standpipe? The pipe length from the reservoir to the standpipe is 600 feet. The pipe is 3-inch Schedule 40 standard steel pipe.



h_f = ____________

Introduction to Dynamic Pressure

Proper dynamic pressure is critical to an efficient irrigation system. Dynamic pressure occurs when water is moving through pipe while the sprinklers or emitters are applying water. If the pressure is too low or too high, the water will not be distributed uniformly over the area, or the quantity of water applied may not be correct. In both cases, plant growth may suffer, and irrigation water may be wasted.

Factors Affecting Dynamic Pressure

Dynamic pressure is affected by the following factors:

- change in elevation (Change in elevation affects static and dynamic pressure in the same way.)
- friction losses in pipe, valves, and fittings (Pressure loss is caused by friction as water moves through the system.)
- velocity head (This is the kinetic energy of water moving within the system; it is a minor loss and won't be calculated here.)
- entrance losses (This is pressure lost as water flows through openings; it is also a minor loss and won't be calculated here.)

Dynamic Pressure Calculation

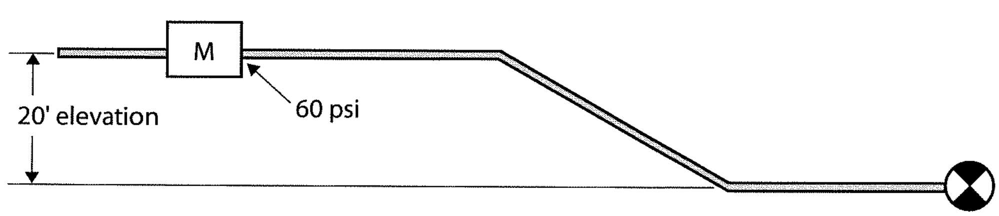
All the information learned in the static pressure and friction loss sections is used to determine the actual dynamic pressure. When calculating dynamic pressure consider the following:

- pressure at the water source
- pressure change due to elevation change
- pressure loss due to friction losses in the pipe
- pressure losses in valves, meter, and other components
- pressure losses due to fittings

Example 14 — Dynamic Pressure Calculation

What is the dynamic pressure at the valve?

A 100-foot length of 2-inch Schedule 40 PVC pipe connects the water meter to the valve. The valve is 20 feet lower in elevation. The flow is 50 gpm. The pressure at the water meter is 60 psi.



Answer

Pressure increase due to elevation = 20.0 ft × 0.433 psi/ft = 8.66 psi

Friction loss (from table for Schedule 40 PVC pipe) = 1.83 psi

$$\text{Pressure at valve} = \text{Pressure at valve} + \text{Pressure increase due to elevation} - \text{Friction loss}$$

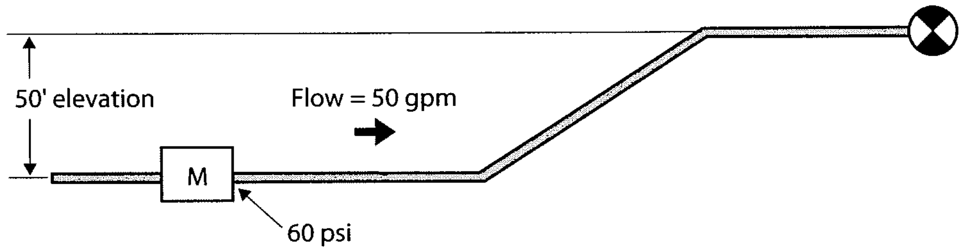
$$= 60.0 \text{ psi} + 8.66 \text{ psi} - 1.83 \text{ psi} = 66.8 \text{ psi}$$

Notes

Notes

Example 15 — Dynamic Pressure Calculation

What is the dynamic pressure at the valve? The valve is 50 feet higher than the water meter (M), the pipe is 2-inch Class 200 PVC, and the pipe length is 200 feet.



Answer

Pressure decrease due to elevation = 50.0 ft × 0.433 psi/ft = 21.7 psi

Friction loss (from friction loss table for Class 200 PVC pipe) = 200 ft × 1.51 psi/100 ft = 3.02 psi

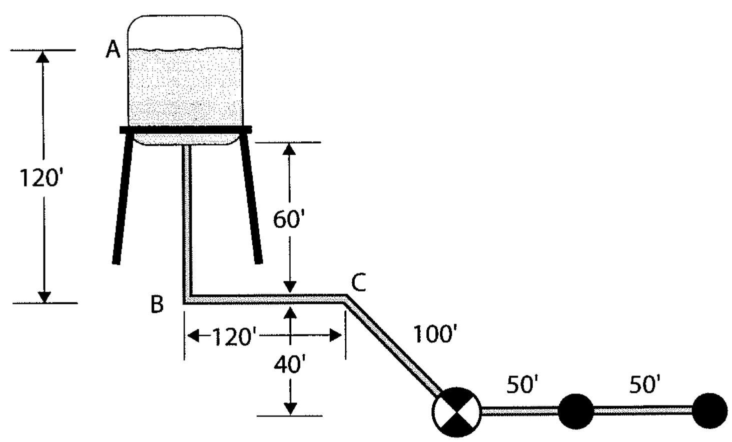
Pressure at valve = Pressure at valve + Pressure due to elevation change − Friction loss

= 60.0 psi − 21.7 psi − 3.02 psi = 35.3 psi

In the previous dynamic pressure examples, the pressure was given at the water meter. The source of the water supply was not given. In example 16, a water tank is the supply source.

Example 16 — Dynamic Pressure Calculation

The valve is open, and the sprinklers are operating with a total flow of 30 gpm. All pipe between the tank and valve is 1.5-inch Schedule 40 PVC. What is the dynamic pressure at the valve? (Ignore any losses in the tank and any fittings.)



Answer

Pressure increase due to elevation = (120 ft + 40.0 ft) × 0.433 psi/ft = 69.3 psi

Friction loss in the pipes = 2.42 psi/100 ft × 280 ft = 6.78 psi

Pressure at the valve = Pressure increase due to elevation − Friction loss = 69.3 psi − 6.78 psi = 62.5 psi

Notes

Friction Losses for Pipe Fittings

Separate tables are available for friction losses in pipe fittings (but are not covered here). Sometimes irrigation designers will use a percentage (usually 10 percent) of pipe friction loss to account for fittings friction losses.

Friction Losses for Other System Components

See the tables and charts in manufacturers' catalogs for friction losses in components such as valves, backflow prevention devices, and filters. The procedure is the same as determining friction loss for pipe. Determine the flow rate in gallons per minute through the component, find the size of the component, and then find the corresponding friction loss in the appropriate table in the catalog.

Use a water meter table for finding friction loss through the water meter (if there is one in the system).

Typical Pressures and Flows for Sprinkler Irrigation

This table shows typical pressures and flow ranges for several categories of sprinklers. When using irrigation systems or troubleshooting in the field, the pressures should be near these pressure ranges. If the dynamic pressure is significantly higher or lower than the indicated pressure, it may indicate a problem that should be investigated.

Table 1. Typical pressures and flows for sprinkler irrigation

Sprinkler type	Radius of throw {ft}	Pressure ranges {psi}	Flow ranges {gpm}
Spray/spinners	5–16	15–30	Up to 4
Small rotors	13–35	25–55	0.5–5
Medium rotors	25–50	25–65	0.75–9.5
Large rotors	50+	50–120	10–40+
Impact rotors	22–45	25–65	1.5–8.4
Guns	100+	100+	80+

Typical Pressures and Flows for Drip Irrigation

The following table shows pressures and flow for several drip and mini spray emitters.

Table 2. Typical pressures and flows for drip irrigation

Drip type	Pressure ranges {psi}	Flow ranges {gph}
On-line drip emitters	10–50	0.5–24
Inline drip emitters	10–50	0.26–2.0
Mini sprays/spitters	10–50	0–30
Drip tape	8–20	10–60 per 100' of tape

Notes

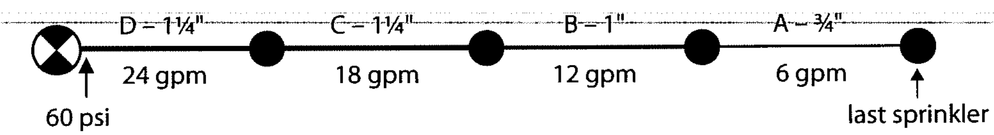
Pressure and Flow Summary

- Each irrigation system has specific pressure requirements for proper operation.
- Each component in the system has its own pressure specifications.
- Various sprinklers/drip emitters have different flows at different pressures.
- Flow requirements for sprinklers are generally given in gallons per minute.
- Flow requirements for mini sprinklers and drip emitters are often given in gallons per hour.

Example 17 — Dynamic Pressure Calculation for a Basic Sprinkler Irrigation System

Example 17shows how to determine the pressure at a sprinkler, in this case the last sprinkler on the lateral line. The diagram shows the outline of the system, and the pressure calculations for the pipe are tabulated for each section of pipe. The pressure losses were taken from the friction loss tables.

Sprinklers are spaced 46 feet apart. The flow for each sprinkler is 6 gpm, and the pipe sizes are indicated. What is the dynamic pressure at the last sprinkler?



- Sprinkler heads are 6 gpm.
- Pipe is Cl 200 PVC.
- Pipe sections are labeled A through D.

Answer

Pipe friction (pressure) loss calculations follow:

Pipe section	Type	Size	gpm	Length	psi loss/ 100'	Actual psi loss
A	Cl 200	¾"	6	46'	1.86	0.86
B	Cl 200	1"	12	46'	1.98	0.91
C	Cl 200	1¼"	18	46'	1.33	0.61
D	Cl 200	1¼"	24	46'	2.26	1.04
Total psi loss in pipe from the valve to the last head						3.42 psi

Pressure at the valve discharge = 60.0 psi

Pressure loss in pipe from valve to last head = 3.42 psi

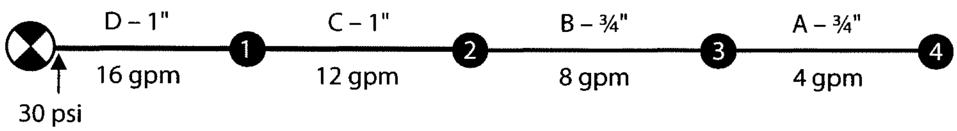
Estimated pressure loss in fittings (10% of pipe loss) = 10% of 3.42 = 0.34 psi

Pressure remaining at the last head = Pressure at the valve discharge − Pressure loss in pipe − Estimated pressure loss in fittings

= 60.0 psi − 3.42 psi − 0.34 psi = 56.2 psi

Example 18 — Dynamic Pressure Calculation for a Basic Sprinkler Irrigation System

In example 18, the distance between sprinklers is less and sprinkler flow rates are less. Sprinklers are spaced 16 feet apart. What is the dynamic pressure at sprinkler 4?



- Sprinkler heads are 4 gpm at 30 psi.
- Pipe is Cl 200 PVC.
- Pipe sections are labeled A through D.

Answer

Pipe friction (pressure) loss calculations follow.

Pipe section	Type	Size	gpm	Length	psi loss/ 100'	Actual psi loss
A	Cl 200	¾"	4	16'	0.88	0.14
B	Cl 200	¾"	8	16'	3.17	0.51
C	Cl 200	1"	12	16'	1.98	0.32
D	Cl 200	1"	16	16'	3.38	0.54
Total psi loss in pipe from the valve to sprinkler 4						1.51 psi

Pressure at the valve discharge = 30.0 psi

Pressure loss in pipe from valve to last head = 1.51 psi

Estimated pressure loss in fittings (10% of pipe loss) = 0.15 psi

Pressure remaining at sprinkler 4 = 30.0 psi – 1.51 psi – 0.15 psi = 28.34 psi (round to 28.3)

✍ Notes

Notes

Example 19 — Dynamic Pressure Calculation for a Sprinkler Irrigation System

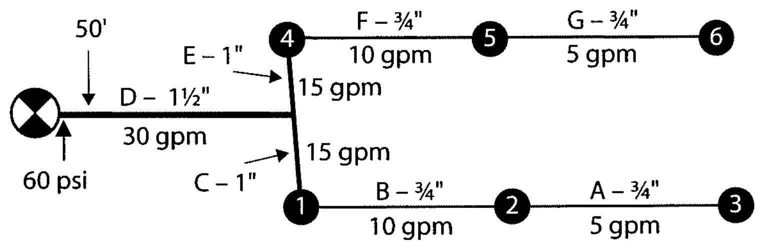
Example 19 shows a sprinkler system with two lateral lines and three sprinklers with 5-gpm flow rates on each lateral line. The flow into each lateral line is for three sprinklers:

$$3 \times 5 \text{ gpm} = 15 \text{ gpm}$$

Therefore, the flow through the pipe to the valve is

$$15 \text{ gpm} + 15 \text{ gpm} = 30 \text{ gpm}$$

Sprinklers are spaced 40 feet apart. The pressure calculations for the pipe are tabulated for each section of pipe. What is the dynamic pressure at sprinkler 3?



- Sprinkler heads are 5 gpm at 30 psi.
- Pipe is Cl 200 PVC.

Answer

Pipe friction (pressure) loss calculations follow.

Pipe section	Type	Size	gpm	Length	psi loss/ 100'	Actual psi loss
A or G	Cl 200	¾"	5	40'	1.33	0.53
B or F	Cl 200	¾"	10	40'	4.79	1.92
C or E	Cl 200	1"	15	20'	3.01	0.60
D	Cl 200	1½"	30	50'	1.75	0.88
Total psi loss in pipe from valve to sprinkler 3						3.93 psi

Pressure at the valve discharge = 60.0 psi

Pressure loss in the pipe from valve to last head = 3.93 psi

Estimated pressure loss in fittings (10% of pipe loss) = 0.39 psi

Pressure remaining at sprinkler 3 = 60.0 psi – 3.93 psi – 0.39 psi = 55.68 psi (round to 55.7 psi)

Dynamic Pressure Summary

Dynamic pressure or operating pressure is the pressure in the system when the sprinklers and drip emitters are operating. The dynamic pressure must be in an acceptable range for the system to operate properly. The dynamic pressure depends upon the pressure at the water source, the friction losses in the pipes and other system components, and the pressure change due to elevation change.

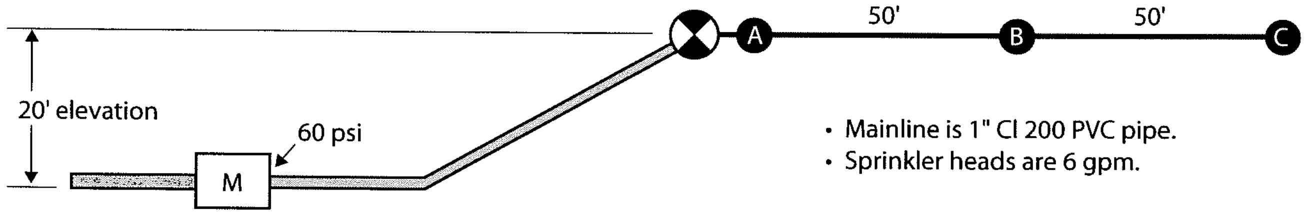
PRACTICE PROBLEMS #4
Dynamic Pressure

(Please use the back of the sheet to complete calculations.)

Name_______________________________

Date_______________________________

1. What is the dynamic pressure at sprinkler A and sprinkler C? The friction loss in the valve is 2 psi. Assume no losses between the valve and sprinkler A.

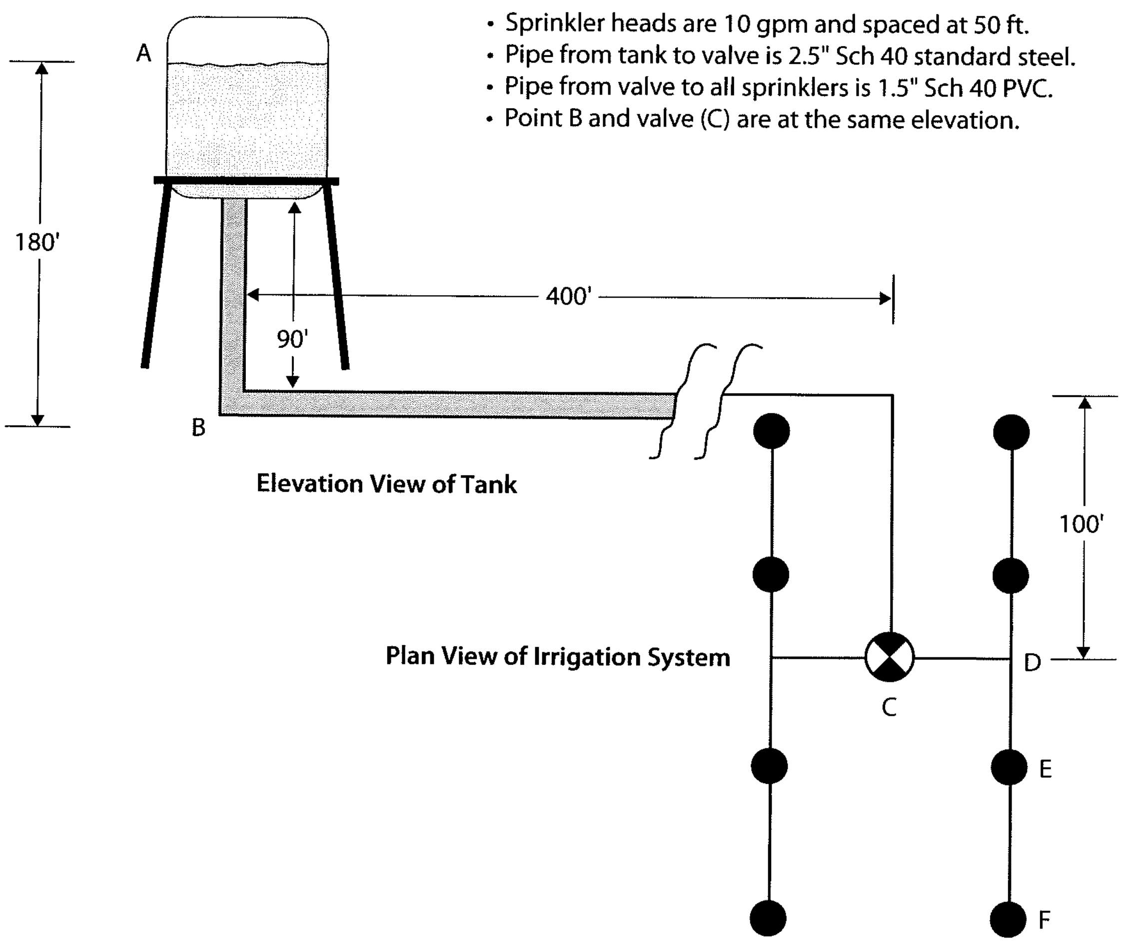


- Mainline is 1" Cl 200 PVC pipe.
- Sprinkler heads are 6 gpm.

P = ____________ for sprinkler A P = ____________ for sprinkler C

2. What is the dynamic pressure at sprinkler F? The friction loss in the valve is 4 psi.

- Sprinkler heads are 10 gpm and spaced at 50 ft.
- Pipe from tank to valve is 2.5" Sch 40 standard steel.
- Pipe from valve to all sprinklers is 1.5" Sch 40 PVC.
- Point B and valve (C) are at the same elevation.

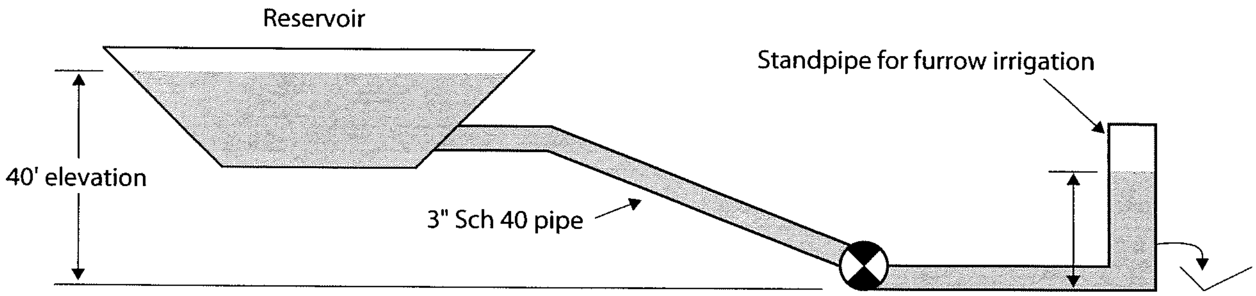


P = ____________

PRACTICE PROBLEMS #4
Dynamic Pressure

(Please use the back of the sheet to complete calculations.)

3. What is the depth of the water in the standpipe when the water is ON? There is a 1 psi loss in the valve.



h = ____________

Hydraulics Summary

The most effective design, operation, and maintenance of an irrigation system can be achieved with a strong understanding of irrigation hydraulics — specifically the pressure and flow in the system.

Static pressure, which is the pressure in the system when water is not moving, is affected by changes in elevation only.

Flow in pipe and tubing depends on the number of sprinklers or drip emitters that are fed by that section of pipe.

Dynamic pressure, the pressure when water is moving, is affected by the following factors:

- changes in elevation
- friction losses in pipe
- friction losses in fittings
- friction losses in all other components

Friction losses are pressure losses due to turbulence in water as it moves through the pipes and tubing. Four factors affect friction loss:

- velocity (flow)
- inside diameter of pipe [ID]
- roughness of material
- length of pipe

Friction losses in fittings and irrigation components were presented; general guidelines to determine values were given.

Notes

References and Suggested Supplemental Reading

Manuals and Books

Barrett, J.M., B.E. Vinchesi, R.D. Dobson, P.J. Roche, and D.F. Zoldoski. 2003. *Golf Course Irrigation: Environmental Design and Management Practices*. New York: John Wiley & Sons.

Hauser, B.A. 1996. *Practical Hydraulics Handbook*. 2nd ed. Boca Raton, Fla.: CRC Press LLC.

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Keeson, L., and C. Code. 1995. *The Complete Irrigation Workbook: Design, Installation, Maintenance & Water Management*. Cleveland, Ohio: G.I.E. Publishers.

Melby, P. 1995. *Simplified Irrigation Design*. 2nd ed. New York: John Wiley & Sons.

Toro Company. 2001. *Technical Data*. Riverside, Calif.: The Toro Co.

Websites

www.irrigation.org — for bookstore with some of the above references

www.hipco-ne.com — Hastings Pipe. Information on gated and aluminum pipe

http://go.usa.gov/Kow — NRCS Irrigation home page

Acknowledgments

The authors are grateful to Hunter Industries and the Irrigation Association for allowing the use of their educational materials as a resource for this Irrigation Association® module.

Glossary of Terms

The following terms can be found in the Irrigation Association's "Glossary of Irrigation Terms" on their website at www.irrigation.org. Symbols located within brackets [ ] indicate the IA-preferred abbreviation or symbol for the term specified. Symbols located within braces { } indicate the IA-preferred unit of measurement for the term specified.

drip irrigation: Microirrigation system (low pressure and low volume) where water is applied to the soil surface as drops or small streams through emitters. Also called *trickle irrigation* or *microirrigation*.

dynamic pressure {psi, kPa}: Measure of water pressure with the water in motion. Also called *working pressure*.

emitter: Small microirrigation dispensing device designed to dissipate pressure and discharge a small uniform flow or trickle of water at a constant discharge, which does not vary significantly because of minor differences in pressure head. Also called a *dripper* or *trickler*.

feet of head: Pressure energy in a liquid system expressed as the equivalent height of a water column above a given datum.

feet per second {ft/s}: Unit of measurement for velocity. See also ***velocity***.

flood irrigation: Method of irrigation where water is applied to the soil surface without flow controls, such as furrows, borders, or corrugations.

flow rate [Q or q] {gpm, gph, gal/min, ft^3/s, L/s, L/min, m^3/h}: Rate of flow or volume per unit period of time.

friction loss [h_f] {psi, ft, kPa, m}: Amount of pressure lost as water flows through an irrigation system due to friction against the pipe walls. See also ***pressure loss***.

ft/s: Acronym for feet per second. See also ***velocity***.

furrow irrigation: Method of surface irrigation where water is supplied to small ditches or furrows for guiding across the field.

gallons per hour {gph}: Rate of flow per hour. See also ***flow rate***.

gallons per minute {gpm}: Rate of flow per minute. See also ***flow rate***.

gph: Acronym for gallons per hour. See also ***flow rate***.

gpm: Acronym for gallons per minute. See also ***flow rate***.

irrigation: Intentional application of water to the soil, usually for the purpose of crop production (reclaiming soils, temperature modification, improving crop quality).

irrigation system: Physical components (pumps, pipelines, valves, nozzles, ditches, gates, siphon tubes, turnout structures) and management used to apply irrigation water by an irrigation method.

operating pressure {psi}: Actual head pressure remaining at the sprinkler head after the total pressure loss from the city main to the critical head is subtracted from the starting static pressure.

pitot tube: Small ell-shaped tube that can be attached to a pressure gauge or other measuring device to measure the velocity head of water discharging from a nozzle or flowing in a pipe.

polyethylene [PE]: Flexible (usually black) plastic material used to make irrigation pipe and other items.

polyvinyl-chloride [PVC]: Semi-rigid plastic material used to make irrigation pipe and other items.

pounds per square inch {psi}: See ***pressure***.

pressure [P, p] {psi , lb/in.^{2}, kPa}: In irrigation, pressure usually describes the amount of energy available to move water through a pipe, sprinkler, or emitter.

pressure loss {psi, kPa, m}: Amount of pressure lost as water flows through a system.

psi: Acronym for pounds per square inch. See also ***pressure***.

pump: Mechanical device that converts mechanical forms of energy into hydraulic energy.

runoff [RO] {in., mm}: Portion of precipitation, snow melt, or irrigation that flows over the soil, eventually making its way to surface water supplies.

standpipe: Water storage structure.

sprinkler distribution pattern: Water depth-distance relationship measured from a single sprinkler head.

sprinkler irrigation: Method of irrigation in which the water is sprayed or sprinkled through the air to the ground surface.

static pressure {psi, kPa, m}: Water pressure when the water is at rest.

surface irrigation: Type of irrigation where water is distributed to the plant material by a ground surface distribution network possibly including rows or dikes.

transpiration [T] {in./day, mm/day}: Process of plant water uptake and use, beginning with absorption through the roots and ending with water vapor escaping into the atmosphere through leaf stomates.

velocity [V, v] {ft/s, m/s}: Speed at which water moves through the system (pipe).

water hammer {psi, kPa}: Shock wave created when the flow of water in a piping system suddenly stops or changes speed. Usually the result of a fast-closing or opening valve.

water meter: Device used to measure flow of water.

Figure Legend

The following symbols are used throughout the figures in this module:

- Main line
- Lateral line
- Valve
- Sprinkler head
- Drip emitter
- Pump
- M Meter

About IA

The Irrigation Association is the leading membership organization for irrigation companies and professionals. Together with its members, IA is committed to promoting efficient irrigation technologies, products, and services and to long-term sustainability of water resources for future generations. IA serves its members and the industry by

- improving industry proficiency through continuing education.
- recognizing and promoting experience and excellence with professional certification.
- influencing water-use policy at the local, state, and national levels.
- ensuring industry standards and codes reflect irrigation best practices.
- providing forums that promote innovative solutions and efficient irrigation practices and products.

For more information, visit www.irrigation.org.

About the Foundation

The Irrigation Foundation advances the irrigation industry using education that both attracts people into the profession and ensures ongoing professional success.

Founded in 1980, the Foundation is a nonprofit, tax-exempt 501(c)(3) corporation whose operations are funded entirely by tax-deductible contributions and program revenue.

For more information, visit www.irrigationfoundation.org.

APPENDIX A

Friction Loss Charts

Class 160 PVC

Class 200 PVC

Class 315 PVC

Schedule 40 PVC

Schedule 40 Steel

Type "K" Copper Tube

Water Meter Pressure Loss Chart

Irrigation Association

Friction Loss Charts 2008

Tables are based upon the following Hazen-Williams Equation:

$$H_f = 0.2083 \times \left(\frac{100}{C}\right)^{1.852} \times \frac{Q^{1.852}}{D^{4.866}}$$

The result is multiplied by 0.433 to give pounds per square inch {psi} loss for 100 feet of pipe.

The velocity values were derived using the following equation:

$$V = \frac{0.408 \times Q_{gpm}}{D^2}$$

The average inside diameter of outside diameter [OD] controlled pipe was based upon subtracting two times the minimum wall thickness plus one-half of the wall thickness tolerance from the outside diameter.

Information for pipe diameters and wall thicknesses came from the following resources:

- *ASABE Standards*. 2007. ANSI/ASAE S376.2 — Design, Installation and Performance of Underground, Thermoplastic Irrigation Pipes
- *Handbook of PVC Pipe*. Uni-Bell PVC Pipe Association
- Appropriate ASTM standards for nonplastic pipes

Pressure ratings for plastic pipes are based on 23°C or 73.4°F.

Head loss decreases (increases) approximately 1 percent for every 3 degrees Fahrenheit above (below) the reference temperature (73.4°F).

Irrigation Association Friction Loss Chart 2008

Class 160 PVC IPS Plastic Pipe

ANSI/ASAE S376.2 ASTM D2241 SDR 26 C=150

psi loss per 100 feet of pipe

Shown for convenience: Class 315 (1/2"), Class 200 (3/4")

Nominal size	1/2" (Class 315)		3/4" (Class 200)		1"		1-1/4"		1-1/2"		2"		2-1/2"		3"		4"		6"	
Avg. ID	0.696		0.910		1.175		1.512		1.734		2.173		2.635		3.210		4.134		6.084	
Pipe OD	0.840		1.050		1.315		1.660		1.900		2.375		2.875		3.500		4.500		6.625	
Avg. wall	0.072		0.070		0.070		0.074		0.083		0.101		0.120		0.145		0.183		0.271	
Min. wall	0.062		0.060		0.060		0.064		0.073		0.091		0.110		0.135		0.173		0.255	
Flow {gpm}	Velocity {ft/s}	psi loss	Velocity {ft/s}	psi loss	Velocity {ft/s}	psi loss	Velocity {ft/s}	psi loss	Velocity {ft/s}	psi loss	Velocity {ft/s}	psi loss	Velocity {ft/s}	psi loss	Velocity {ft/s}	psi loss	Velocity {ft/s}	psi loss	Velocity {ft/s}	psi loss
1	0.84	0.25	0.49	0.07	0.30	0.02	0.18	0.01	0.14	0.00										
2	1.68	0.90	0.99	0.24	0.59	0.07	0.36	0.02	0.27	0.01	0.17	0.00								
3	2.53	1.90	1.48	0.52	0.89	0.15	0.54	0.04	0.41	0.02	0.26	0.01								
4	3.37	3.24	1.97	0.88	1.18	0.25	0.71	0.07	0.54	0.04	0.35	0.01	0.24	0.00						
5	4.21	4.89	2.46	1.33	1.48	0.38	0.89	0.11	0.68	0.06	0.43	0.02	0.29	0.01						
6	5.05	6.86	2.96	1.86	1.77	0.54	1.07	0.16	0.81	0.08	0.52	0.03	0.35	0.01	0.24	0.00				
7	5.90	9.12	3.45	2.47	2.07	0.71	1.25	0.21	0.95	0.11	0.60	0.04	0.41	0.01	0.28	0.01				
8	6.74	11.68	3.94	3.17	2.36	0.91	1.43	0.27	1.09	0.14	0.69	0.05	0.47	0.02	0.32	0.01				
9	7.58	14.53	4.43	3.94	2.66	1.14	1.61	0.33	1.22	0.17	0.78	0.06	0.53	0.02	0.36	0.01				
10	8.42	17.66	4.93	4.79	2.96	1.38	1.78	0.40	1.36	0.21	0.86	0.07	0.59	0.03	0.40	0.01				
12	10.11	24.75	5.91	6.71	3.55	1.94	2.14	0.57	1.63	0.29	1.04	0.10	0.71	0.04	0.48	0.01				
14	11.79	32.93	6.90	8.93	4.14	2.58	2.50	0.76	1.90	0.39	1.21	0.13	0.82	0.05	0.55	0.02				
16	13.48	42.16	7.88	11.44	4.73	3.30	2.86	0.97	2.17	0.50	1.38	0.17	0.94	0.06	0.63	0.02	0.38	0.01		
18	15.16	52.44	8.87	14.23	5.32	4.10	3.21	1.20	2.44	0.62	1.56	0.21	1.06	0.08	0.71	0.03	0.43	0.01		
20			9.85	17.29	5.91	4.99	3.57	1.46	2.71	0.75	1.73	0.25	1.18	0.10	0.79	0.04	0.48	0.01		
22			10.84	20.63	6.50	5.95	3.93	1.74	2.99	0.90	1.90	0.30	1.29	0.12	0.87	0.04	0.53	0.01		
24			11.82	24.24	7.09	6.99	4.28	2.05	3.26	1.05	2.07	0.35	1.41	0.14	0.95	0.05	0.57	0.02		
26			12.81	28.11	7.68	8.11	4.64	2.38	3.53	1.22	2.25	0.41	1.53	0.16	1.03	0.06	0.62	0.02		
28			13.80	32.25	8.27	9.30	5.00	2.73	3.80	1.40	2.42	0.47	1.65	0.18	1.11	0.07	0.67	0.02		
30			14.78	36.64	8.87	10.57	5.35	3.10	4.07	1.59	2.59	0.53	1.76	0.21	1.19	0.08	0.72	0.02		
32					9.46	11.91	5.71	3.49	4.34	1.79	2.76	0.60	1.88	0.23	1.27	0.09	0.76	0.03	0.35	0.00
34					10.05	13.32	6.07	3.91	4.61	2.01	2.94	0.67	2.00	0.26	1.35	0.10	0.81	0.03	0.37	0.00
36					10.64	14.81	6.42	4.34	4.88	2.23	3.11	0.74	2.12	0.29	1.43	0.11	0.86	0.03	0.40	0.00
38					11.23	16.37	6.78	4.80	5.16	2.46	3.28	0.82	2.23	0.32	1.50	0.12	0.91	0.04	0.42	0.01
40					11.82	18.00	7.14	5.28	5.43	2.71	3.46	0.90	2.35	0.35	1.58	0.14	0.95	0.04	0.44	0.01
42					12.41	19.70	7.50	5.78	5.70	2.97	3.63	0.99	2.47	0.39	1.66	0.15	1.00	0.04	0.46	0.01
44					13.00	21.47	7.85	6.30	5.97	3.23	3.80	1.08	2.59	0.42	1.74	0.16	1.05	0.05	0.48	0.01
46					13.59	23.32	8.21	6.84	6.24	3.51	3.97	1.17	2.70	0.46	1.82	0.18	1.10	0.05	0.51	0.01
48					14.18	25.23	8.57	7.40	6.51	3.80	4.15	1.27	2.82	0.50	1.90	0.19	1.15	0.06	0.53	0.01
50					14.78	27.21	8.92	7.98	6.78	4.10	4.32	1.37	2.94	0.53	1.98	0.20	1.19	0.06	0.55	0.01
55							9.82	9.52	7.46	4.89	4.75	1.63	3.23	0.64	2.18	0.24	1.31	0.07	0.61	0.01
60							10.71	11.18	8.14	5.74	5.18	1.91	3.53	0.75	2.38	0.29	1.43	0.08	0.66	0.01
65							11.60	12.97	8.82	6.66	5.62	2.22	3.82	0.87	2.57	0.33	1.55	0.10	0.72	0.01
70							12.49	14.88	9.50	7.64	6.05	2.55	4.11	1.00	2.77	0.38	1.67	0.11	0.77	0.02
75							13.38	16.90	10.18	8.68	6.48	2.89	4.41	1.13	2.97	0.43	1.79	0.13	0.83	0.02
80							14.28	19.05	10.86	9.78	6.91	3.26	4.70	1.28	3.17	0.49	1.91	0.14	0.88	0.02
85									11.53	10.94	7.34	3.65	4.99	1.43	3.37	0.55	2.03	0.16	0.94	0.02
90									12.21	12.16	7.78	4.06	5.29	1.59	3.56	0.61	2.15	0.18	0.99	0.03
95									12.89	13.45	8.21	4.48	5.58	1.76	3.76	0.67	2.27	0.20	1.05	0.03
100									13.57	14.79	8.64	4.93	5.88	1.93	3.96	0.74	2.39	0.22	1.10	0.03
110									14.93	17.64	9.50	5.88	6.46	2.30	4.36	0.88	2.63	0.26	1.21	0.04
120											10.37	6.91	7.05	2.71	4.75	1.04	2.86	0.30	1.32	0.05
130											11.23	8.02	7.64	3.14	5.15	1.20	3.10	0.35	1.43	0.05
140											12.10	9.20	8.23	3.60	5.54	1.38	3.34	0.40	1.54	0.06
150											12.96	10.45	8.81	4.09	5.94	1.57	3.58	0.46	1.65	0.07
160											13.82	11.77	9.40	4.61	6.34	1.76	3.82	0.52	1.76	0.08
170											14.69	13.17	9.99	5.16	6.73	1.97	4.06	0.58	1.87	0.09
180													10.58	5.73	7.13	2.19	4.30	0.64	1.98	0.10
190													11.16	6.34	7.52	2.42	4.54	0.71	2.09	0.11
200													11.75	6.97	7.92	2.67	4.77	0.78	2.20	0.12
220													12.93	8.31	8.71	3.18	5.25	0.93	2.42	0.14
240													14.10	9.77	9.50	3.74	5.73	1.09	2.65	0.17
260															10.29	4.33	6.21	1.27	2.87	0.19
280															11.09	4.97	6.68	1.45	3.09	0.22
300															11.88	5.65	7.16	1.65	3.31	0.25
320															12.67	6.37	7.64	1.86	3.53	0.28
340															13.46	7.12	8.12	2.08	3.75	0.32
360															14.25	7.92	8.59	2.31	3.97	0.35
380																	9.07	2.56	4.19	0.39
400																	9.55	2.81	4.41	0.43
420																	10.03	3.08	4.63	0.47
440																	10.50	3.35	4.85	0.51
460																	10.98	3.64	5.07	0.56
480																	11.46	3.94	5.29	0.60
500																	11.94	4.25	5.51	0.65

Shaded area represents velocities over 5 ft/s. Use with caution.

Irrigation Association Friction Loss Chart 2008

Class 200 PVC IPS Plastic Pipe

ANSI/ASAE S376.2 ASTM D2241 SDR 21 C=150

psi loss per 100 feet of pipe

Nominal size	Shown for convenience Class 315 1/2"		3/4"		1"		1-1/4"		1-1/2"		2"		2-1/2"		3"		4"		6"	
Avg. ID	0.696		0.910		1.169		1.482		1.700		2.129		2.581		3.146		4.046		5.955	
Pipe OD	0.840		1.050		1.315		1.660		1.900		2.375		2.875		3.500		4.500		6.625	
Avg. wall	0.072		0.070		0.073		0.089		0.100		0.123		0.147		0.177		0.227		0.335	
Min. wall	0.062		0.060		0.063		0.079		0.090		0.113		0.137		0.167		0.214		0.316	
Flow (gpm)	Velocity (ft/s)	psi loss	Velocity (ft/s)	psi loss	Velocity (ft/s)	psi loss	Velocity (ft/s)	psi loss	Velocity (ft/s)	psi loss	Velocity (ft/s)	psi loss	Velocity (ft/s)	psi loss	Velocity (ft/s)	psi loss	Velocity (ft/s)	psi loss	Velocity (ft/s)	psi loss
1	0.84	0.25	0.49	0.07	0.30	0.02	0.19	0.01	0.14	0.00										
2	1.68	0.90	0.99	0.24	0.60	0.07	0.37	0.02	0.28	0.01	0.18	0.00								
3	2.53	1.90	1.48	0.52	0.90	0.15	0.56	0.05	0.42	0.02	0.27	0.01								
4	3.37	3.24	1.97	0.88	1.19	0.26	0.74	0.08	0.56	0.04	0.36	0.01	0.24	0.01						
5	4.21	4.89	2.46	1.33	1.49	0.39	0.93	0.12	0.71	0.06	0.45	0.02	0.31	0.01						
6	5.05	6.86	2.96	1.86	1.79	0.55	1.11	0.17	0.85	0.09	0.54	0.03	0.37	0.01	0.25	0.00				
7	5.90	9.12	3.45	2.47	2.09	0.73	1.30	0.23	0.99	0.12	0.63	0.04	0.43	0.02	0.29	0.01				
8	6.74	11.68	3.94	3.17	2.39	0.94	1.49	0.30	1.13	0.15	0.72	0.05	0.49	0.02	0.33	0.01				
9	7.58	14.53	4.43	3.94	2.69	1.17	1.67	0.37	1.27	0.19	0.81	0.06	0.55	0.02	0.37	0.01				
10	8.42	17.66	4.93	4.79	2.99	1.42	1.86	0.45	1.41	0.23	0.90	0.08	0.61	0.03	0.41	0.01				
12	10.11	24.75	5.91	6.71	3.58	1.98	2.23	0.63	1.69	0.32	1.08	0.11	0.73	0.04	0.49	0.02				
14	11.79	32.93	6.90	8.93	4.18	2.64	2.60	0.83	1.98	0.43	1.26	0.14	0.86	0.06	0.58	0.02				
16	13.48	42.16	7.88	11.44	4.78	3.38	2.97	1.07	2.26	0.55	1.44	0.18	0.98	0.07	0.66	0.03	0.40	0.01		
18	15.16	52.44	8.87	14.23	5.37	4.21	3.34	1.33	2.54	0.68	1.62	0.23	1.10	0.09	0.74	0.03	0.45	0.01		
20			9.85	17.29	5.97	5.11	3.72	1.61	2.82	0.83	1.80	0.28	1.22	0.11	0.82	0.04	0.50	0.01		
22			10.84	20.63	6.57	6.10	4.09	1.92	3.11	0.99	1.98	0.33	1.35	0.13	0.91	0.05	0.55	0.01		
24			11.82	24.24	7.17	7.17	4.46	2.26	3.39	1.16	2.16	0.39	1.47	0.15	0.99	0.06	0.60	0.02		
26			12.81	28.11	7.76	8.31	4.83	2.62	3.67	1.34	2.34	0.45	1.59	0.18	1.07	0.07	0.65	0.02		
28			13.80	32.25	8.36	9.53	5.20	3.01	3.95	1.54	2.52	0.52	1.71	0.20	1.15	0.08	0.70	0.02		
30			14.78	36.64	8.96	10.83	5.57	3.41	4.24	1.75	2.70	0.59	1.84	0.23	1.24	0.09	0.75	0.03		
32					9.55	12.21	5.94	3.85	4.52	1.97	2.88	0.66	1.96	0.26	1.32	0.10	0.80	0.03	0.37	0.00
34					10.15	13.66	6.32	4.31	4.80	2.21	3.06	0.74	2.08	0.29	1.40	0.11	0.85	0.03	0.39	0.00
36					10.75	15.18	6.69	4.79	5.08	2.45	3.24	0.82	2.20	0.32	1.48	0.12	0.90	0.04	0.41	0.01
38					11.35	16.78	7.06	5.29	5.36	2.71	3.42	0.91	2.33	0.36	1.57	0.14	0.95	0.04	0.44	0.01
40					11.94	18.45	7.43	5.82	5.65	2.98	3.60	1.00	2.45	0.39	1.65	0.15	1.00	0.04	0.46	0.01
42					12.54	20.20	7.80	6.37	5.93	3.27	3.78	1.09	2.57	0.43	1.73	0.16	1.05	0.05	0.48	0.01
44					13.14	22.02	8.17	6.94	6.21	3.56	3.96	1.19	2.69	0.47	1.81	0.18	1.10	0.05	0.51	0.01
46					13.73	23.91	8.55	7.54	6.49	3.86	4.14	1.29	2.82	0.51	1.90	0.19	1.15	0.06	0.53	0.01
48					14.33	25.87	8.92	8.15	6.78	4.18	4.32	1.40	2.94	0.55	1.98	0.21	1.20	0.06	0.55	0.01
50					14.93	27.90	9.29	8.79	7.06	4.51	4.50	1.51	3.06	0.59	2.06	0.23	1.25	0.07	0.58	0.01
55							10.22	10.49	7.76	5.38	4.95	1.80	3.37	0.71	2.27	0.27	1.37	0.08	0.63	0.01
60							11.15	12.33	8.47	6.32	5.40	2.11	3.67	0.83	2.47	0.32	1.50	0.09	0.69	0.01
65							12.07	14.30	9.18	7.33	5.85	2.45	3.98	0.96	2.68	0.37	1.62	0.11	0.75	0.02
70							13.00	16.40	9.88	8.41	6.30	2.81	4.29	1.10	2.89	0.42	1.74	0.12	0.81	0.02
75							13.93	18.63	10.59	9.56	6.75	3.20	4.59	1.25	3.09	0.48	1.87	0.14	0.86	0.02
80							14.86	21.00	11.29	10.77	7.20	3.60	4.90	1.41	3.30	0.54	1.99	0.16	0.92	0.02
85									12.00	12.05	7.65	4.03	5.21	1.58	3.50	0.60	2.12	0.18	0.98	0.03
90									12.71	13.40	8.10	4.48	5.51	1.76	3.71	0.67	2.24	0.20	1.04	0.03
95									13.41	14.81	8.55	4.95	5.82	1.94	3.92	0.74	2.37	0.22	1.09	0.03
100									14.12	16.28	9.00	5.45	6.12	2.13	4.12	0.81	2.49	0.24	1.15	0.04
110											9.90	6.50	6.74	2.55	4.53	0.97	2.74	0.29	1.27	0.04
120											10.80	7.63	7.35	2.99	4.95	1.14	2.99	0.34	1.38	0.05
130											11.70	8.85	7.96	3.47	5.36	1.32	3.24	0.39	1.50	0.06
140											12.60	10.16	8.57	3.98	5.77	1.52	3.49	0.45	1.61	0.07
150											13.50	11.54	9.19	4.52	6.18	1.73	3.74	0.51	1.73	0.08
160											14.40	13.01	9.80	5.10	6.60	1.95	3.99	0.57	1.84	0.09
170													10.41	5.70	7.01	2.18	4.24	0.64	1.96	0.10
180													11.02	6.34	7.42	2.42	4.49	0.71	2.07	0.11
190													11.64	7.01	7.83	2.67	4.74	0.79	2.19	0.12
200													12.25	7.71	8.24	2.94	4.98	0.86	2.30	0.13
220													13.47	9.19	9.07	3.51	5.48	1.03	2.53	0.16
240													14.70	10.80	9.89	4.12	5.98	1.21	2.76	0.18
260															10.72	4.78	6.48	1.41	2.99	0.21
280															11.54	5.48	6.98	1.61	3.22	0.25
300															12.37	6.23	7.48	1.83	3.45	0.28
320															13.19	7.02	7.98	2.06	3.68	0.31
340															14.02	7.86	8.47	2.31	3.91	0.35
360															14.84	8.73	8.97	2.57	4.14	0.39
380																	9.47	2.84	4.37	0.43
400																	9.97	3.12	4.60	0.48
420																	10.47	3.42	4.83	0.52
440																	10.97	3.72	5.06	0.57
460																	11.46	4.04	5.29	0.62
480																	11.96	4.37	5.52	0.67
500																	12.46	4.72	5.75	0.72

Shaded area represents velocities over 5 ft/s. Use with caution.

Irrigation Association Friction Loss Chart 2008

Class 315 PVC IPS Plastic Pipe

ANSI/ASAE S376.2 ASTM D2241 SDR 13.5 C=150

psi loss per 100 feet of pipe

Nominal size	1/2"		3/4"		1"		1-1/4"		1-1/2"		2"		2-1/2"		3"		4"		6"	
Avg. ID	0.696		0.874		1.101		1.394		1.598		1.983		2.423		2.948		3.794		5.583	
Pipe OD	0.840		1.050		1.315		1.660		1.900		2.375		2.875		3.500		4.500		6.625	
Avg. wall	0.072		0.088		0.107		0.133		0.151		0.196		0.226		0.274		0.353		0.521	
Min. wall	0.062		0.078		0.097		0.123		0.141		0.176		0.213		0.259		0.333		0.491	
Flow (gpm)	Velocity (ft/s)	psi loss	Velocity (ft/s)	psi loss	Velocity (ft/s)	psi loss	Velocity (ft/s)	psi loss	Velocity (ft/s)	psi loss	Velocity (ft/s)	psi loss	Velocity (ft/s)	psi loss	Velocity (ft/s)	psi loss	Velocity (ft/s)	psi loss	Velocity (ft/s)	psi loss
1	0.84	0.25	0.53	0.08	0.34	0.03	0.21	0.01	0.16	0.00										
2	1.68	0.90	1.07	0.30	0.67	0.10	0.42	0.03	0.32	0.02	0.21	0.01								
3	2.53	1.90	1.60	0.63	1.01	0.20	0.63	0.06	0.48	0.03	0.31	0.01								
4	3.37	3.24	2.14	1.07	1.35	0.35	0.84	0.11	0.64	0.06	0.42	0.02	0.28	0.01						
5	4.21	4.89	2.67	1.61	1.68	0.53	1.05	0.17	0.80	0.09	0.52	0.03	0.35	0.01						
6	5.05	6.86	3.20	2.26	2.02	0.74	1.26	0.23	0.96	0.12	0.62	0.04	0.42	0.02	0.28	0.01				
7	5.90	9.12	3.74	3.01	2.36	0.98	1.47	0.31	1.12	0.16	0.73	0.06	0.49	0.02	0.33	0.01				
8	6.74	11.68	4.27	3.86	2.69	1.25	1.68	0.40	1.28	0.20	0.83	0.07	0.56	0.03	0.38	0.01				
9	7.58	14.53	4.81	4.80	3.03	1.56	1.89	0.49	1.44	0.25	0.93	0.09	0.63	0.03	0.42	0.01				
10	8.42	17.66	5.34	5.83	3.37	1.90	2.10	0.60	1.60	0.31	1.04	0.11	0.69	0.04	0.47	0.02				
12	10.11	24.75	6.41	8.17	4.04	2.66	2.52	0.84	1.92	0.43	1.25	0.15	0.83	0.06	0.56	0.02				
14	11.79	32.93	7.48	10.87	4.71	3.53	2.94	1.12	2.24	0.58	1.45	0.20	0.97	0.08	0.66	0.03				
16	13.48	42.16	8.55	13.92	5.39	4.53	3.36	1.44	2.56	0.74	1.66	0.26	1.11	0.10	0.75	0.04	0.45	0.01		
18	15.16	52.44	9.61	17.32	6.06	5.63	3.78	1.79	2.88	0.92	1.87	0.32	1.25	0.12	0.85	0.05	0.51	0.01		
20			10.68	21.05	6.73	6.84	4.20	2.17	3.20	1.12	2.08	0.39	1.39	0.15	0.94	0.06	0.57	0.02		
22			11.75	25.11	7.40	8.16	4.62	2.59	3.52	1.33	2.28	0.47	1.53	0.18	1.03	0.07	0.62	0.02		
24			12.82	29.50	8.08	9.59	5.04	3.04	3.83	1.57	2.49	0.55	1.67	0.21	1.13	0.08	0.68	0.02		
26			13.89	34.21	8.75	11.12	5.46	3.53	4.15	1.82	2.70	0.64	1.81	0.24	1.22	0.09	0.74	0.03		
28			14.96	39.25	9.42	12.76	5.88	4.05	4.47	2.08	2.91	0.73	1.95	0.27	1.31	0.11	0.79	0.03		
30			16.02	44.60	10.10	14.50	6.30	4.60	4.79	2.37	3.11	0.83	2.08	0.31	1.41	0.12	0.85	0.04		
32					10.77	16.34	6.72	5.18	5.11	2.67	3.32	0.93	2.22	0.35	1.50	0.14	0.91	0.04	0.42	0.01
34					11.44	18.28	7.14	5.80	5.43	2.98	3.53	1.04	2.36	0.39	1.60	0.15	0.96	0.04	0.45	0.01
36					12.12	20.32	7.56	6.45	5.75	3.32	3.74	1.16	2.50	0.44	1.69	0.17	1.02	0.05	0.47	0.01
38					12.79	22.46	7.98	7.13	6.07	3.67	3.94	1.28	2.64	0.48	1.78	0.19	1.08	0.05	0.50	0.01
40					13.46	24.70	8.40	7.84	6.39	4.03	4.15	1.41	2.78	0.53	1.88	0.20	1.13	0.06	0.52	0.01
42					14.14	27.04	8.82	8.58	6.71	4.41	4.36	1.54	2.92	0.58	1.97	0.22	1.19	0.07	0.55	0.01
44					14.81	29.47	9.24	9.35	7.03	4.81	4.57	1.68	3.06	0.63	2.07	0.24	1.25	0.07	0.58	0.01
46					15.48	32.00	9.66	10.15	7.35	5.22	4.77	1.83	3.20	0.69	2.16	0.27	1.30	0.08	0.60	0.01
48					16.16	34.62	10.08	10.98	7.67	5.65	4.98	1.98	3.34	0.75	2.25	0.29	1.36	0.08	0.63	0.01
50					16.83	37.34	10.50	11.85	7.99	6.09	5.19	2.13	3.47	0.80	2.35	0.31	1.42	0.09	0.65	0.01
55							11.55	14.13	8.79	7.27	5.71	2.54	3.82	0.96	2.58	0.37	1.56	0.11	0.72	0.02
60							12.60	16.60	9.59	8.54	6.23	2.99	4.17	1.13	2.82	0.43	1.70	0.13	0.79	0.02
65							13.65	19.26	10.39	9.91	6.74	3.47	4.52	1.31	3.05	0.50	1.84	0.15	0.85	0.02
70							14.70	22.09	11.18	11.37	7.26	3.98	4.86	1.50	3.29	0.58	1.98	0.17	0.92	0.03
75							15.75	25.10	11.98	12.91	7.78	4.52	5.21	1.70	3.52	0.66	2.13	0.19	0.98	0.03
80							16.80	28.29	12.78	14.55	8.30	5.09	5.56	1.92	3.76	0.74	2.27	0.22	1.05	0.03
85									13.58	16.28	8.82	5.70	5.91	2.15	3.99	0.83	2.41	0.24	1.11	0.04
90									14.38	18.10	9.34	6.33	6.25	2.39	4.23	0.92	2.55	0.27	1.18	0.04
95									15.18	20.01	9.86	7.00	6.60	2.64	4.46	1.02	2.69	0.30	1.24	0.05
100									15.98	22.00	10.38	7.70	6.95	2.90	4.69	1.12	2.83	0.33	1.31	0.05
110											11.41	9.18	7.64	3.46	5.16	1.33	3.12	0.39	1.44	0.06
120											12.45	10.79	8.34	4.07	5.63	1.57	3.40	0.46	1.57	0.07
130											13.49	12.51	9.03	4.72	6.10	1.82	3.68	0.53	1.70	0.08
140											14.53	14.35	9.73	5.41	6.57	2.08	3.97	0.61	1.83	0.09
150											15.56	16.31	10.42	6.15	7.04	2.37	4.25	0.69	1.96	0.11
160											16.60	18.38	11.12	6.93	7.51	2.67	4.54	0.78	2.09	0.12
170													11.81	7.76	7.98	2.99	4.82	0.87	2.23	0.13
180													12.51	8.62	8.45	3.32	5.10	0.97	2.36	0.15
190													13.20	9.53	8.92	3.67	5.39	1.08	2.49	0.16
200													13.90	10.48	9.39	4.03	5.67	1.18	2.62	0.18
220													15.29	12.50	10.33	4.81	6.24	1.41	2.88	0.22
240													16.68	14.69	11.27	5.66	6.80	1.66	3.14	0.25
260															12.21	6.56	7.37	1.92	3.40	0.29
280															13.15	7.52	7.94	2.20	3.67	0.34
300															14.08	8.55	8.50	2.50	3.93	0.38
320															15.02	9.64	9.07	2.82	4.19	0.43
340															15.96	10.78	9.64	3.16	4.45	0.48
360															16.90	11.98	10.20	3.51	4.71	0.54
380																	10.77	3.88	4.97	0.59
400																	11.34	4.27	5.24	0.65
420																	11.90	4.67	5.50	0.71
440																	12.47	5.09	5.76	0.78
460																	13.04	5.53	6.02	0.84
480																	13.61	5.98	6.28	0.91
500																	14.17	6.45	6.54	0.98

Shaded area represents velocities over 5 ft/s. Use with caution.

Irrigation Association Friction Loss Chart 2008

Schedule 40 PVC IPS Plastic Pipe

ASTM D1785 C=150

psi loss per 100 feet of pipe

Nominal size	1/2"		3/4"		1"		1-1/4"		1-1/2"		2"		2-1/2"		3"		4"		6"	
Avg. ID	0.602		0.804		1.029		1.360		1.590		2.047		2.445		3.042		3.998		6.031	
Pipe OD	0.840		1.050		1.315		1.660		1.900		2.375		2.875		3.500		4.500		6.625	
Avg. wall	0.119		0.123		0.143		0.150		0.155		0.164		0.215		0.229		0.251		0.297	
Min. wall	0.109		0.113		0.133		0.140		0.145		0.154		0.203		0.216		0.237		0.280	
Flow (gpm)	Velocity (ft/s)	psi loss	Velocity (ft/s)	psi loss	Velocity (ft/s)	psi loss	Velocity (ft/s)	psi loss	Velocity (ft/s)	psi loss	Velocity (ft/s)	psi loss	Velocity (ft/s)	psi loss	Velocity (ft/s)	psi loss	Velocity (ft/s)	psi loss	Velocity (ft/s)	psi loss
1	1.13	0.50	0.63	0.12	0.39	0.04	0.22	0.01	0.16	0.00										
2	2.25	1.82	1.26	0.44	0.77	0.13	0.44	0.03	0.32	0.02	0.19	0.00								
3	3.38	3.85	1.89	0.94	1.16	0.28	0.66	0.07	0.48	0.03	0.29	0.01								
4	4.50	6.55	2.52	1.60	1.54	0.48	0.88	0.12	0.65	0.06	0.39	0.02	0.27	0.01						
5	5.63	9.91	3.16	2.42	1.93	0.73	1.10	0.19	0.81	0.09	0.49	0.03	0.34	0.01						
6	6.75	13.89	3.79	3.40	2.31	1.02	1.32	0.26	0.97	0.12	0.58	0.04	0.41	0.02	0.26	0.01				
7	7.88	18.48	4.42	4.52	2.70	1.36	1.54	0.35	1.13	0.16	0.68	0.05	0.48	0.02	0.31	0.01				
8	9.01	23.66	5.05	5.79	3.08	1.74	1.76	0.45	1.29	0.21	0.78	0.06	0.55	0.03	0.35	0.01				
9	10.13	29.43	5.68	7.20	3.47	2.17	1.99	0.56	1.45	0.26	0.88	0.08	0.61	0.03	0.40	0.01				
10	11.26	35.77	6.31	8.75	3.85	2.63	2.21	0.68	1.61	0.32	0.97	0.09	0.68	0.04	0.44	0.01				
12	13.51	50.14	7.57	12.27	4.62	3.69	2.65	0.95	1.94	0.44	1.17	0.13	0.82	0.05	0.53	0.02				
14	15.76	66.71	8.84	16.32	5.39	4.91	3.09	1.26	2.26	0.59	1.36	0.17	0.96	0.07	0.62	0.03				
16	18.01	85.42	10.10	20.90	6.17	6.29	3.53	1.62	2.58	0.76	1.56	0.22	1.09	0.09	0.71	0.03	0.41	0.01		
18	20.26	106.24	11.36	25.99	6.94	7.82	3.97	2.01	2.90	0.94	1.75	0.28	1.23	0.12	0.79	0.04	0.46	0.01		
20			12.62	31.59	7.71	9.51	4.41	2.45	3.23	1.14	1.95	0.33	1.36	0.14	0.88	0.05	0.51	0.01		
22			13.89	37.69	8.48	11.35	4.85	2.92	3.55	1.37	2.14	0.40	1.50	0.17	0.97	0.06	0.56	0.02		
24			15.15	44.28	9.25	13.33	5.29	3.43	3.87	1.60	2.34	0.47	1.64	0.20	1.06	0.07	0.61	0.02		
26			16.41	51.36	10.02	15.46	5.74	3.98	4.20	1.86	2.53	0.54	1.77	0.23	1.15	0.08	0.66	0.02		
28			17.67	58.91	10.79	17.73	6.18	4.56	4.52	2.13	2.73	0.62	1.91	0.26	1.23	0.09	0.71	0.02		
30			18.94	66.94	11.56	20.15	6.62	5.19	4.84	2.42	2.92	0.71	2.05	0.30	1.32	0.10	0.77	0.03		
32					12.33	22.71	7.06	5.85	5.16	2.73	3.12	0.80	2.18	0.34	1.41	0.12	0.82	0.03	0.36	0.00
34					13.10	25.41	7.50	6.54	5.49	3.06	3.31	0.89	2.32	0.38	1.50	0.13	0.87	0.03	0.38	0.00
36					13.87	28.24	7.94	7.27	5.81	3.40	3.51	0.99	2.46	0.42	1.59	0.14	0.92	0.04	0.40	0.01
38					14.64	31.22	8.38	8.04	6.13	3.76	3.70	1.10	2.59	0.46	1.68	0.16	0.97	0.04	0.43	0.01
40					15.41	34.33	8.82	8.84	6.46	4.13	3.89	1.21	2.73	0.51	1.76	0.18	1.02	0.05	0.45	0.01
42					16.18	37.58	9.26	9.67	6.78	4.52	4.09	1.32	2.87	0.56	1.85	0.19	1.07	0.05	0.47	0.01
44					16.95	40.96	9.71	10.54	7.10	4.93	4.28	1.44	3.00	0.61	1.94	0.21	1.12	0.06	0.49	0.01
46					17.73	44.47	10.15	11.45	7.42	5.35	4.48	1.57	3.14	0.66	2.03	0.23	1.17	0.06	0.52	0.01
48					18.50	48.12	10.59	12.39	7.75	5.79	4.67	1.69	3.28	0.71	2.12	0.25	1.23	0.07	0.54	0.01
50					19.27	51.90	11.03	13.36	8.07	6.25	4.87	1.83	3.41	0.77	2.20	0.27	1.28	0.07	0.56	0.01
55							12.13	15.94	8.88	7.45	5.36	2.18	3.75	0.92	2.42	0.32	1.40	0.08	0.62	0.01
60							13.24	18.72	9.68	8.75	5.84	2.56	4.09	1.08	2.65	0.37	1.53	0.10	0.67	0.01
65							14.34	21.72	10.49	10.15	6.33	2.97	4.44	1.25	2.87	0.43	1.66	0.11	0.73	0.02
70							15.44	24.91	11.30	11.65	6.82	3.41	4.78	1.43	3.09	0.50	1.79	0.13	0.79	0.02
75							16.54	28.31	12.10	13.23	7.30	3.87	5.12	1.63	3.31	0.56	1.91	0.15	0.84	0.02
80							17.65	31.90	12.91	14.91	7.79	4.36	5.46	1.84	3.53	0.63	2.04	0.17	0.90	0.02
85									13.72	16.69	8.28	4.88	5.80	2.06	3.75	0.71	2.17	0.19	0.95	0.03
90									14.52	18.55	8.76	5.43	6.14	2.29	3.97	0.79	2.30	0.21	1.01	0.03
95									15.33	20.50	9.25	6.00	6.48	2.53	4.19	0.87	2.42	0.23	1.07	0.03
100									16.14	22.55	9.74	6.59	6.82	2.78	4.41	0.96	2.55	0.25	1.12	0.03
110											10.71	7.87	7.51	3.31	4.85	1.14	2.81	0.30	1.23	0.04
120											11.68	9.24	8.19	3.89	5.29	1.34	3.06	0.36	1.35	0.05
130											12.66	10.72	8.87	4.52	5.73	1.56	3.32	0.41	1.46	0.06
140											13.63	12.30	9.55	5.18	6.17	1.79	3.57	0.47	1.57	0.06
150											14.61	13.97	10.24	5.89	6.61	2.03	3.83	0.54	1.68	0.07
160											15.58	15.75	10.92	6.63	7.05	2.29	4.08	0.61	1.79	0.08
170													11.60	7.42	7.50	2.56	4.34	0.68	1.91	0.09
180													12.28	8.25	7.94	2.85	4.59	0.75	2.02	0.10
190													12.97	9.12	8.38	3.15	4.85	0.83	2.13	0.11
200													13.65	10.03	8.82	3.46	5.11	0.92	2.24	0.12
220													15.01	11.96	9.70	4.13	5.62	1.09	2.47	0.15
240													16.38	14.06	10.58	4.85	6.13	1.28	2.69	0.17
260															11.46	5.63	6.64	1.49	2.92	0.20
280															12.35	6.46	7.15	1.71	3.14	0.23
300															13.23	7.34	7.66	1.94	3.37	0.26
320															14.11	8.27	8.17	2.19	3.59	0.30
340															14.99	9.25	8.68	2.45	3.81	0.33
360															15.87	10.29	9.19	2.72	4.04	0.37
380																	9.70	3.01	4.26	0.41
400																	10.21	3.31	4.49	0.45
420																	10.72	3.62	4.71	0.49
440																	11.23	3.95	4.94	0.53
460																	11.74	4.28	5.16	0.58
480																	12.25	4.64	5.38	0.63
500																	12.76	5.00	5.61	0.68
Working pressure	600 psi		480 psi		450 psi		370 psi		330 psi		300 psi		280 psi		260 psi		220 psi		180 psi	

Shaded area represents velocities over 5 ft/s. Use with caution.

Irrigation Association Friction Loss Chart 2008

Schedule 40 Steel

ASTM B53 C=100

psi loss per 100 feet of pipe

Nominal size	1/2"		3/4"		1"		1-1/4"		1-1/2"		2"		2-1/2"		3"		4"	
Pipe ID	0.622		0.824		1.049		1.38		1.610		2.067		2.469		3.068		4.026	
Pipe OD	0.842		1.050		1.315		1.660		1.900		2.375		2.875		3.500		4.500	
Avg. wall	0.110		0.113		0.133		0.140		0.145		0.154		0.203		0.216		0.237	
Flow {gpm}	Velocity {ft/s}	psi loss	Velocity {ft/s}	psi loss	Velocity {ft/s}	psi loss	Velocity {ft/s}	psi loss	Velocity {ft/s}	psi loss	Velocity {ft/s}	psi loss	Velocity {ft/s}	psi loss	Velocity {ft/s}	psi loss	Velocity {ft/s}	psi loss
1	1.05	0.91	0.60	0.23	0.37	0.07	0.21	0.02	0.16	0.01								
2	2.11	3.28	1.20	0.84	0.74	0.26	0.43	0.07	0.31	0.03								
3	3.16	6.95	1.80	1.77	1.11	0.55	0.64	0.14	0.47	0.07								
4	4.22	11.85	2.40	3.02	1.48	0.93	0.86	0.25	0.63	0.12								
5	5.27	17.91	3.00	4.56	1.85	1.41	1.07	0.37	0.79	0.18								
6	6.33	25.10	3.61	6.39	2.22	1.97	1.29	0.52	0.94	0.25	0.57	0.07						
7	7.38	33.40	4.21	8.50	2.60	2.63	1.50	0.69	1.10	0.33	0.67	0.10						
8	8.44	42.77	4.81	10.88	2.97	3.36	1.71	0.89	1.26	0.42	0.76	0.12						
9	9.49	53.19	5.41	13.54	3.34	4.18	1.93	1.10	1.42	0.52	0.86	0.15						
10	10.55	64.65	6.01	16.45	3.71	5.08	2.14	1.34	1.57	0.63	0.95	0.19						
12	12.65	90.62	7.21	23.06	4.45	7.12	2.57	1.88	1.89	0.89	1.15	0.26	0.80	0.11				
14			8.41	30.68	5.19	9.48	3.00	2.50	2.20	1.18	1.34	0.35	0.94	0.15				
16			9.61	39.29	5.93	12.14	3.43	3.20	2.52	1.51	1.53	0.45	1.07	0.19				
18			10.82	48.87	6.67	15.10	3.86	3.97	2.83	1.88	1.72	0.56	1.20	0.23				
20			12.02	59.40	7.42	18.35	4.28	4.83	3.15	2.28	1.91	0.68	1.34	0.28				
22			13.22	70.87	8.16	21.89	4.71	5.76	3.46	2.72	2.10	0.81	1.47	0.34	0.95	0.12	0.55	0.03
24					8.90	25.72	5.14	6.77	3.78	3.20	2.29	0.95	1.61	0.40	1.04	0.14	0.60	0.04
26					9.64	29.83	5.57	7.85	4.09	3.71	2.48	1.10	1.74	0.46	1.13	0.16	0.65	0.04
28					10.38	34.22	6.00	9.01	4.41	4.25	2.67	1.26	1.87	0.53	1.21	0.18	0.70	0.05
30					11.12	38.88	6.43	10.24	4.72	4.83	2.86	1.43	2.01	0.60	1.30	0.21	0.76	0.06
32					11.86	43.81	6.86	11.54	5.04	5.45	3.06	1.62	2.14	0.68	1.39	0.24	0.81	0.06
34					12.61	49.02	7.28	12.91	5.35	6.10	3.25	1.81	2.28	0.76	1.47	0.26	0.86	0.07
36					13.35	54.49	7.71	14.35	5.67	6.78	3.44	2.01	2.41	0.85	1.56	0.29	0.91	0.08
38							8.14	15.86	5.98	7.49	3.63	2.22	2.54	0.94	1.65	0.33	0.96	0.09
40							8.57	17.44	6.30	8.24	3.82	2.44	2.68	1.03	1.73	0.36	1.01	0.10
42							9.00	19.09	6.61	9.02	4.01	2.67	2.81	1.13	1.82	0.39	1.06	0.10
44							9.43	20.81	6.93	9.83	4.20	2.91	2.94	1.23	1.91	0.43	1.11	0.11
46							9.86	22.59	7.24	10.67	4.39	3.16	3.08	1.33	1.99	0.46	1.16	0.12
48							10.28	24.44	7.56	11.55	4.58	3.42	3.21	1.44	2.08	0.50	1.21	0.13
50							10.71	26.36	7.87	12.45	4.77	3.69	3.35	1.55	2.17	0.54	1.26	0.14
55							11.78	31.45	8.66	14.86	5.25	4.40	3.68	1.85	2.38	0.64	1.38	0.17
60							12.85	36.95	9.44	17.45	5.73	5.17	4.02	2.18	2.60	0.76	1.51	0.20
65							13.93	42.86	10.23	20.24	6.21	6.00	4.35	2.53	2.82	0.88	1.64	0.23
70									11.02	23.22	6.68	6.88	4.69	2.90	3.03	1.01	1.76	0.27
75									11.81	26.39	7.16	7.82	5.02	3.29	3.25	1.14	1.89	0.31
80									12.59	29.74	7.64	8.82	5.35	3.71	3.47	1.29	2.01	0.34
85									13.38	33.27	8.12	9.86	5.69	4.15	3.68	1.44	2.14	0.38
90											8.59	10.96	6.02	4.62	3.90	1.60	2.27	0.43
95											9.07	12.12	6.36	5.10	4.12	1.77	2.39	0.47
100											9.55	13.33	6.69	5.61	4.33	1.95	2.52	0.52
110											10.50	15.90	7.36	6.70	4.77	2.33	2.77	0.62
120											11.46	18.68	8.03	7.87	5.20	2.73	3.02	0.73
130											12.41	21.66	8.70	9.12	5.63	3.17	3.27	0.85
140											13.37	24.85	9.37	10.47	6.07	3.64	3.52	0.97
150													10.04	11.89	6.50	4.13	3.78	1.10
160													10.71	13.40	6.94	4.66	4.03	1.24
170													11.38	15.00	7.37	5.21	4.28	1.39
180													12.05	16.67	7.80	5.79	4.53	1.54
190													12.72	18.43	8.24	6.40	4.78	1.71
200													13.39	20.26	8.67	7.04	5.03	1.88
220															9.54	8.40	5.54	2.24
240															10.40	9.87	6.04	2.63
260															11.27	11.45	6.54	3.05
280															12.14	13.13	7.05	3.50
300															13.00	14.92	7.55	3.98
320															13.87	16.81	8.05	4.48
340																	8.56	5.01
360																	9.06	5.57
380																	9.57	6.16
400																	10.07	6.77
420																	10.57	7.42
440																	11.08	8.08
460																	11.58	8.78
480																	12.08	9.50
500																	12.59	10.24

Shaded area represents velocities over 7 ft/s.
Use with caution where water hammer is a concern.

Irrigation Association Friction Loss Chart 2008

Type "K" Copper Tubing

ASTM B88 C=140

psi loss per 100 feet of pipe

Nominal size	1/2"		5/8"		3/4"		1"		1-1/4"		1-1/2"		2"		2-1/2"		3"	
Pipe ID	0.527		0.652		0.745		0.995		1.245		1.481		1.959		2.435		2.907	
Pipe OD	0.625		0.750		0.875		1.125		1.375		1.625		2.125		2.625		3.125	
Avg. wall	0.049		0.049		0.065		0.065		0.065		0.072		0.083		0.095		0.109	
Flow {gpm}	Velocity {ft/s}	psi loss	Velocity {ft/s}	psi loss	Velocity {ft/s}	psi loss	Velocity {ft/s}	psi loss	Velocity {ft/s}	psi loss	Velocity {ft/s}	psi loss	Velocity {ft/s}	psi loss	Velocity {ft/s}	psi loss	Velocity {ft/s}	psi loss
1	1.47	1.09	0.96	0.39	0.74	0.20	0.41	0.05	0.26	0.02								
2	2.94	3.94	1.92	1.40	1.47	0.73	0.82	0.18	0.53	0.06								
3	4.41	8.35	2.88	2.97	2.21	1.55	1.24	0.38	0.79	0.13								
4	5.88	14:23	3.84	5.05	2.94	2.64	1.65	0.65	1.05	0.22								
5	7.35	21.51	4.80	7.64	3.68	3.99	2.06	0.98	1.32	0.33								
6	8.81	30.15	5.76	10.70	4.41	5.59	2.47	1.37	1.58	0.46	1.12	0.20						
7	10.28	40.12	6.72	14.24	5.15	7.44	2.88	1.82	1.84	0.61	1.30	0.26						
8	11.75	51.37	7.68	18.24	5.88	9.53	3.30	2.33	2.11	0.78	1.49	0.34						
9	13.22	63.90	8.64	22.68	6.62	11.85	3.71	2.90	2.37	0.97	1.67	0.42						
10	14.69	77.66	9.60	27.57	7.35	14.41	4.12	3.52	2.63	1.18	1.86	0.51						
12			11.52	38.64	8.82	20.20	4.95	4.94	3.16	1.66	2.23	0.71	1.28	0.18				
14			13.44	51.41	10.29	26.87	5.77	6.57	3.69	2.21	2.60	0.95	1.49	0.24				
16			15.36	65.83	11.76	34.41	6.59	8.42	4.21	2.83	2.98	1.22	1.70	0.31				
18			17.28	81.88	13.23	42.80	7.42	10.47	4.74	3.52	3.35	1.51	1.91	0.39				
20					14.70	52.02	8.24	12.72	5.26	4.28	3.72	1.84	2.13	0.47				
22					16.17	62.06	9.07	15.18	5.79	5.10	4.09	2.19	2.34	0.56	1.51	0.19	1.06	0.08
24					17.64	72.91	9.89	17.84	6.32	5.99	4.46	2.58	2.55	0.66	1.65	0.23	1.16	0.10
26							10.71	20.69	6.84	6.95	4.84	2.99	2.76	0.77	1.79	0.27	1.26	0.11
28							11.54	23.73	7.37	7.97	5.21	3.43	2.98	0.88	1.93	0.30	1.35	0.13
30							12.36	26.96	7.90	9.06	5.58	3.89	3.19	1.00	2.06	0.35	1.45	0.15
32							13.19	30.39	8.42	10.21	5.95	4.39	3.40	1.12	2.20	0.39	1.54	0.16
34							14.01	34.00	8.95	11.42	6.32	4.91	3.61	1.26	2.34	0.44	1.64	0.18
36							14.84	37.79	9.48	12.70	6.70	5.46	3.83	1.40	2.48	0.49	1.74	0.20
38							15.66	41.77	10.00	14.04	7.07	6.03	4.04	1.55	2.61	0.54	1.83	0.23
40							16.48	45.94	10.53	15.43	7.44	6.63	4.25	1.70	2.75	0.59	1.93	0.25
42							17.31	50.28	11.06	16.89	7.81	7.26	4.47	1.86	2.89	0.65	2.03	0.27
44									11.58	18.41	8.18	7.91	4.68	2.03	3.03	0.70	2.12	0.30
46									12.11	19.99	8.56	8.59	4.89	2.20	3.17	0.76	2.22	0.32
48									12.63	21.63	8.93	9.30	5.10	2.38	3.30	0.83	2.32	0.35
50									13.16	23.33	9.30	10.03	5.32	2.57	3.44	0.89	2.41	0.38
55									14.48	27.84	10.23	11.96	5.85	3.07	3.78	1.06	2.66	0.45
60									15.79	32.70	11.16	14.05	6.38	3.60	4.13	1.25	2.90	0.53
65									17.11	37.93	12.09	16.30	6.91	4.18	4.47	1.45	3.14	0.61
70									18.43	43.51	13.02	18.70	7.44	4.79	4.82	1.66	3.38	0.70
75											13.95	21.24	7.97	5.45	5.16	1.89	3.62	0.80
80											14.88	23.94	8.51	6.14	5.50	2.13	3.86	0.90
85											15.81	26.79	9.04	6.87	5.85	2.38	4.10	1.01
90											16.74	29.78	9.57	7.63	6.19	2.65	4.35	1.12
95											17.67	32.91	10.10	8.44	6.54	2.93	4.59	1.24
100											18.60	36.19	10.63	9.28	6.88	3.22	4.83	1.36
110													11.69	11.07	7.57	3.84	5.31	1.62
120													12.76	13.01	8.26	4.51	5.79	1.91
130													13.82	15.08	8.95	5.23	6.28	2.21
140													14.88	17.30	9.63	6.00	6.76	2.54
150													15.95	19.66	10.32	6.82	7.24	2.88
160													17.01	22.16	11.01	7.69	7.72	3.25
170													18.07	24.79	11.70	8.60	8.21	3.63
180															12.39	9.56	8.69	4.04
190															13.07	10.57	9.17	4.46
200															13.76	11.62	9.66	4.91
220															15.14	13.87	10.62	5.86
240															16.51	16.29	11.59	6.88
260															17.89	18.90	12.55	7.98
280															19.27	21.68	13.52	9.15
300																	14.48	10.40
320																	15.45	11.72
340																	16.42	13.11
360																	17.38	14.58
380																	18.35	16.11
400																		
420																		
440																		
460																		
480																		
500																		

Shaded area represents velocities over 7 ft/s.
Use with caution where water hammer is a concern.

Water Meter Pressure Loss Chart

Typical Pressure Losses {psi}

Flow {gpm}	5/8"	3/4"	1"	Nominal size 1-1/2"	2"	3"	4"
1	0.2	0.1					
2	0.3	0.2					
3	0.4	0.3					
4	0.6	0.5	0.1				
5	0.9	0.6	0.2				
6	1.3	0.7	0.3				
7	1.8	0.8	0.4				
8	2.3	1.0	0.5				
9	3.0	1.3	0.6				
10	3.7	1.6	0.7				
11	4.4	1.9	0.8				
12	5.1	2.2	0.9				
13	6.1	2.6	1.0				
14	7.2	3.1	1.1				
15	8.3	3.6	1.2				
16	9.4	4.1	1.4	0.4			
17	10.7	4.6	1.6	0.5			
18	12.0	5.2	1.8	0.6			
19	13.4	5.8	2.0	0.7			
20	15.0	6.5	2.2	0.8			
22		7.9	2.8	1.0			
24		9.5	3.4	1.2			
26		11.2	4.0	1.4			
28		13.0	4.6	1.6			
30		15.0	5.3	1.8	0.7		
32			6.0	2.1	0.8		
34			6.9	2.4	0.9		
36			7.8	2.7	1.0		
38			8.7	3.0	1.2		
40			9.6	3.3	1.3		
42			10.6	3.6	1.4		
44			11.7	3.9	1.5		
46			12.8	4.2	1.6		
48			13.9	4.5	1.7		
50			15.0	4.9	1.9		
52				5.3	2.1		
54				5.7	2.2		
56				6.2	2.3		
58				6.7	2.5		
60				7.2	2.7	1.0	
65				8.3	3.2	1.1	
70				9.8	3.7	1.3	
75				11.3	4.3	1.5	
80				12.8	4.9	1.6	0.7
90				16.1	6.2	2.0	0.8
100				20.0	7.8	2.5	0.9
110					9.5	2.9	1.0
120					11.3	3.4	1.2
130					13.0	3.9	1.4
140					15.1	4.5	1.6
150					17.3	5.1	1.8
160					20.0	5.8	2.1
170						6.5	2.4
180						7.2	2.7
190						8.0	3.0
200						9.0	3.2
220						11.0	3.9
240						13.0	4.7
260						15.0	5.5
280						17.3	6.3
300						20.0	7.2
350							10.0
400							13.0
450							16.2
500							20.0
75% of max meter capacity	15 gpm	22.5 gpm	37.5 gpm	75 gpm	120 gpm	225 gpm	375 gpm

Shaded areas exceed 75% of maximum safe meter capacity.

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