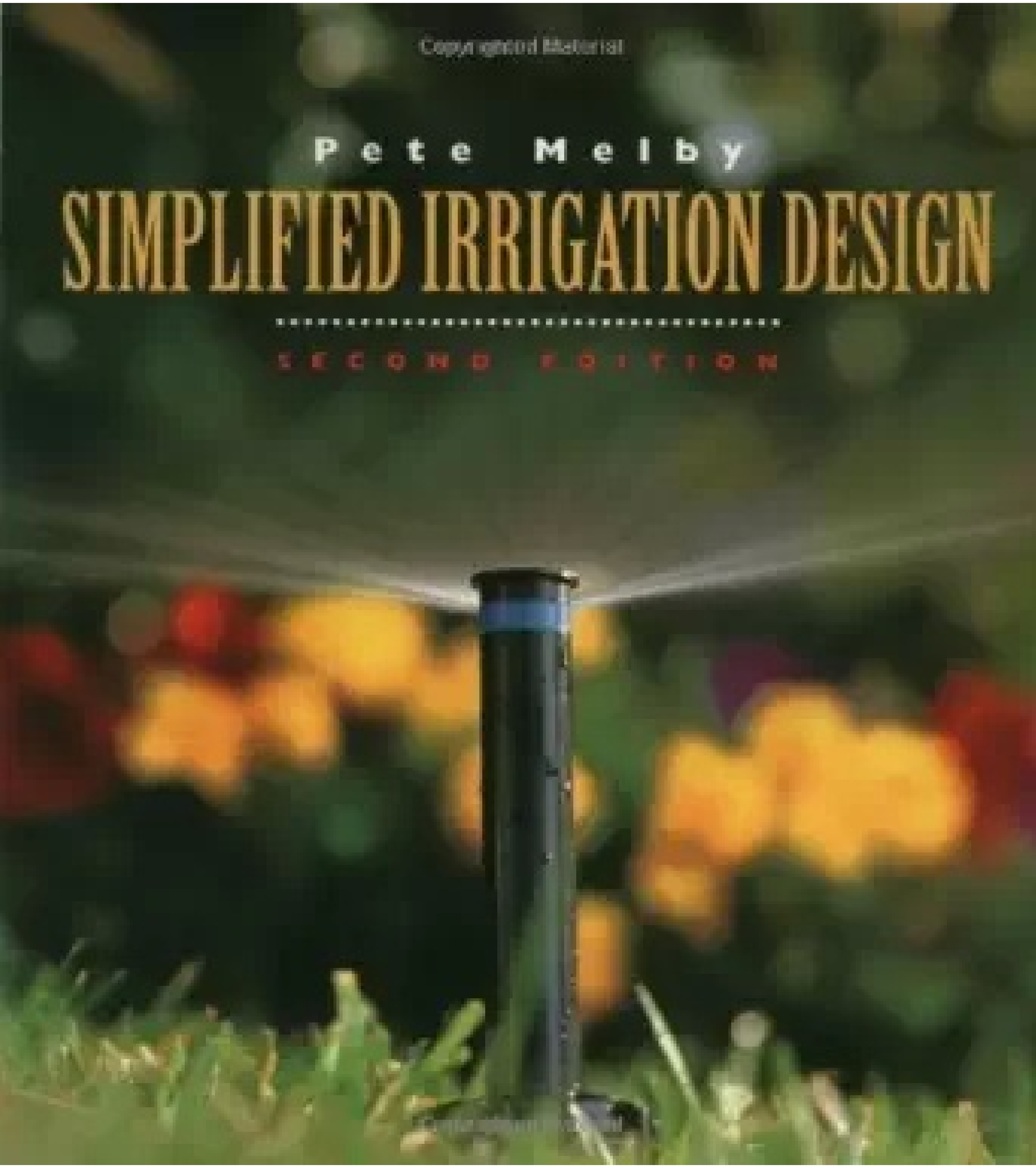

## Pete Melby

# SIMPLIFIED IRRIGATION DESIGN

SECOND EDITION

# Simplified Irrigation Design, 2nd Edition (Landscape Architecture)

Pete Melby

# Simplified Irrigation Design

# Second Edition

Pete Melby, ASLA

Professional Designer and Installer Version

Measurements in Imperial (U. S.) and Metric

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This book is dedicated to Cindy, Mary Hannah, Jane Caroline, and my mother ... .

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# Acknowledgments

This is definitely a "we" book. Many generous and kind people contributed to the creation of this irrigation design learning tool. David Davis and Terry Little, with the Rain Bird Company, began it all by preaching their exciting irrigation design gospel to my students in 1979. At about the same time, the Green Industry began clamoring for landscape architecture and landscape contracting graduates with irrigation knowledge.

Sam Roach and Bill Perry, with the Toro Company, contributed to the field of irrigation design for nearly a decade through conducting effective irrigation design and construction seminars. Rain Bird's Dave Wheeler, Bob Scott, and Dan Pope have generously shared their knowledge as well.

As interest about irrigation design grew, both in the classroom and among practicing professionals, there arose a need for a resource that could impart the principles of irrigation design in a clear and easy-to-comprehend manner. This book evolved to fit that need.

Sam Roach, formerly of Toro, is one of the visionaries who saw the need for a simplified irrigation design manual. In his usual excitable manner, Sam supported the development of the book, both with his knowledge and his company's support. Bill Perry, a traveling civil engineer and Toro distributor, shared his great breadth of irrigation knowledge (and funny stories), which helped to establish rock foundation on which this book was built.

I suppose any technical book is a compilation of the knowledge and experiences of many people. In talking with Bill Speelman and Ken Kline at the Toro Company, I found they knew the answers to all the questions. It was amazing to meet and interview these gentlemen. Dori Fisher introduced me to the experts at Toro, and Linda Carroll assisted in supplying our graphic needs. Ann Hoch at Rain Bird and Michael Boswell at Hardie Irrigation generously supplied graphics for the book as well.

Many irrigation designers and contractors were interviewed to help make this a very practical book. Dr.

Euel Coats, Denny Phillips, Rob Rice, and William Leathers were generous in sharing their experiences. Charles Scoggins, Terrel Buckelew, and Jerry Odom were always gracious about sharing their construction knowledge.

Dr. James Hairston, agronomist, and Dr. Charles Wax, climatologist and geographer, contributed to the creation of a clear and sensible drip irrigation design approach. Mr. John McVey, an agricultural engineer and drip equipment distributor, shared his knowledge and excitement about drip irrigation.

When you are thinking about everyone who has helped you create a significant learning resource, you cannot help but think back to your career roots. Professor Robert "Doc" Reich served as a great role model, and Professor Dave Young kindled my interest in landscape construction. Stuart Mertz, my first employer, showed me what it was like to be a professional landscape architect. Cohort and landscape contracting professor Bob Callaway shared an intense love for teaching. Ed Martin, FASLA, told me what it was like to write a book and served as my confidant.

Once you have accumulated a body of knowledge, you then need to transform thoughts and notes to words, sketches, and photographs. Liz Hughes deciphered those first, scratchy notes into the typed word. My wife volunteered to learn the Display Write Three software program and typed the book draft onto the computer with the untiring spirit of a dedicated soldier. Lou Melby, my mother and mentor, served as editor for the book. Theresa Atwater, an able and enthusiastic typist, made all of the final corrections on the computer. Chuck Kelly, a landscape architect and gifted graphic artist, drew the sketches for the book. Mary Hannah, my two-year-old daughter, tolerated my time away from her to write this book.

Many people contributed their thoughts to the development of this second edition. Cameron Man, FASLA, stressed the need to become acquainted with the metric system. He also promoted the need for landscape architects to direct their efforts toward creating sustainable environments. Many fine professionals at the Toro Company provided invaluable assistance. Jeanie Cantu arranged for me to meet the experts and obtain the most up-to-date information. Ken Kline helped me to understand the international irrigation market and need for irrigation. Kim Jeach provided current materials for this second edition. Scott Glahn and Delancey Spain were invaluable in reviewing text and suggesting ideas for improvement. At Hector Turf in Deerfield Beach, Florida, Chuck

Watson, Rob Korth, and Betsy Collins spent several days showing me the latest in computer-managed water-conserving irrigation systems. Greg Pope, an aspiring landscape architect and talented artist, assisted with drawing revisions. Cindy, my wife, read the new material and let me know whether or not it was comprehensible. My daughters, Mary Hannah, now 9, and Jane Caroline, 5, were understanding about my time away from them and my insistence in talking mostly irrigation for a long while.

# 1

# Introduction

We think you are going to enjoy learning about irrigation design. This book has been written so that you can learn the subject matter without the help of a teacher. All you need to do is read and study each chapter. The material is presented clearly and concisely, and many photos and illustrations are used to convey the ideas.

The chapters are arranged so that each one builds on the ones preceding it. We have organized the subject matter so that you learn how to do irrigation design before getting into the more complicated aspects of irrigation such as basic hydraulics, pipe sizing, friction loss calculations, and determining water pressure.

Because of the mandate for all federal government projects to be completed in metric measurements, we feel it wise to include metric values along with those of the established U.S. (imperial) system. Those desiring to become acquainted with the metric system should read Appendix III before going on to Chapter 2.

Throughout the book, a careful blend of ideas from the perspectives of irrigation system designers and irrigation contractors are presented. Although both professions are an integral part of any irrigation project, our interviews with contractors proved especially enlightening and have greatly contributed to better ways of designing irrigation systems.

Simplified Irrigation Design is an understandable approach to learning about this subject. It really works! As each chapter was written, my wife, who is a music teacher and not very mechanically minded, would review it for comprehensibility. If a chapter did not make sense to her, it was rewritten!

Finally, this is a "we" book. Many irrigation designers, contractors, and equipment manufacturers contributed to its contents. I put it all together with a good instructional approach. We hope you will enjoy this resource and learn a great deal about the exciting field of irrigation design!

# 2

# Sprinkler Head Performance

## Sprinkler Head Patterns

When the water is turned on, it travels through the pipe and is forced out in a pattern determined by the sprinkler head you have selected. Those patterns can be rectilinear or circular. The rectilinear patterns are excellent for medians in boulevards and in that narrow area between the sidewalk and curb. The circular patterns come in various radii from 3 ft (0.92 m) to over 100 ft (30.48 m), and they are used for watering not only curvilinear but also rectilinear and square areas.

Rectilinear patterns are defined by the area they cover, such as 3 ft (0.92 m) X 12 ft (3.66 m) or 9 ft (2.74 m) X 18 ft (5.49 in). Circular patterns, which make up the largest group of sprinkler heads, are defined by the following characteristics:

1. The radius of water throw
2. The arc of the water pattern
3. The trajectory of the water as it is thrown from the sprinkler head

Irrigation manufacturers produce sprinkler heads that have progressively larger radii of throws in order to cover a wide range of areas.

Circular patterns can cover full circles and arcs, or parts of circles. These arcs are available in many con

figurations. Some sprinkler heads have adjustable arcs that can range from 0° to 360°, depending on the manufacturer.

As the water comes out of the sprinkler head, it travels through space to the ground. The angle at which the water leaves the head is the trajectory of spray. Trajectories of spray include

0° trajectory-This flat spray can be used for throwing water under low shrubs and on tops of hills.

10° trajectory-This low-angle spray can be used under windy conditions for shrubs, ground cover beds, and turf.

25°-28° trajectory-This is the standard trajectory that most sprinklers throw for use on turf.

35° trajectory-This is a stream spray used for watering ground cover, shrubs, and turf.

### Selecting a Head to Fit Your Site

Most companies produce a range of sprinkler heads to cover anything from small, landscaped areas to large, open lawns. The Toro Company, for example, produces the heads listed in Table 2.1 that cover progressively larger and larger areas. You can see that a wide variety of sprinkler heads is available to fit the size of the area that you wish to irrigate. For a residential or small commercial project of 0.5 acre (0.2 hectare) or less, most designers would probably use one or more of the following:

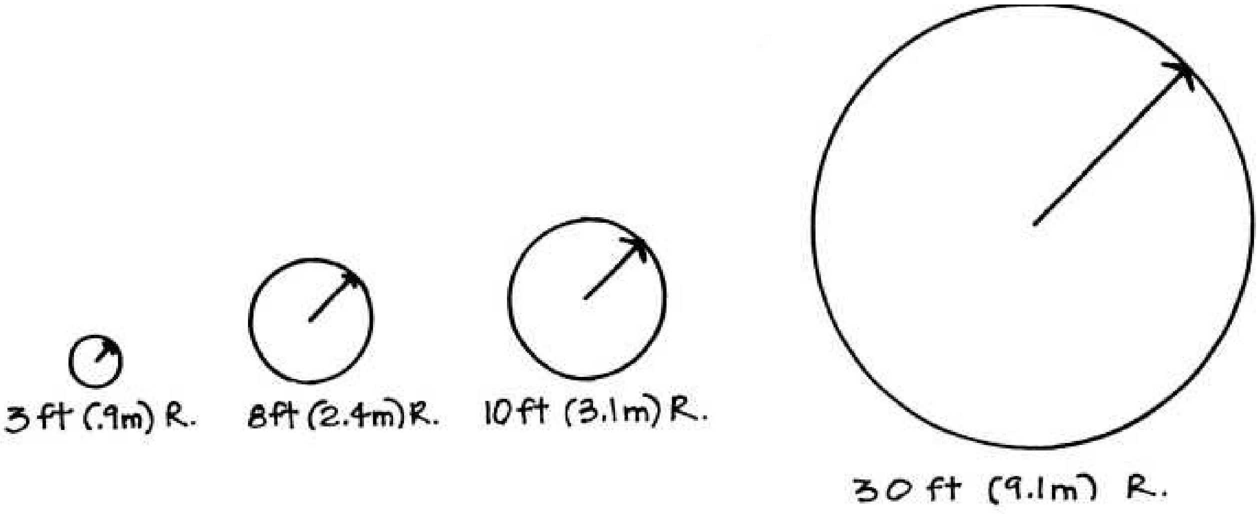


FIGURE 2.1 Sprinkler pattern throw radii.

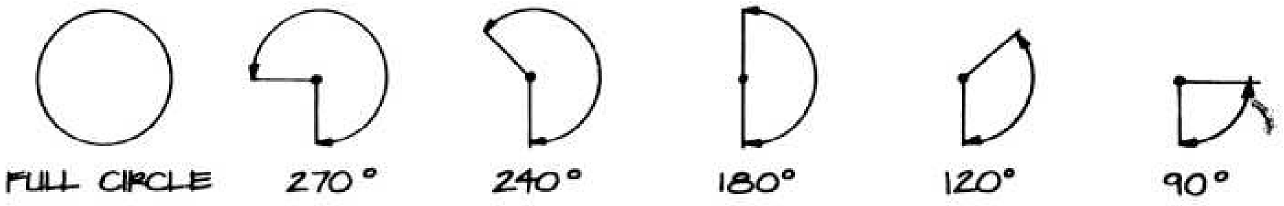


FIGURE 2.2 Sprinkler pattern arcs.

## *TABLE 2.1* **Sprinkler Heads and Radii**

| HEAD TYPE | RADIUS THROWN |
|---|---|
| 570Z Fixed Spray | 0–16 ft (0–4.88 m) |
| Series 300 Stream Rotor | 15–30 ft (4.57–9.14 m) |
| XP-300 Rotor | 28–43 ft (8.54–13.11 m) |
| Super 600 Rotor | 35–50 ft (10.67–15.24 m) |
| Super 700 Rotor | 20–52 ft (6.1–15.85 m) |
| 640 Series Rotor | 47–67 ft (14.33–20.42 m) |
| 2001 Series Rotor | 45–78 ft (13.72–23.78 m) |
| 650 Series Rotor | 56–86 ft (17.07–26.21 m) |
| 660 Series Rotor | 54–86 ft (16.46–26.21 m) |
| 670 Series Rotor | 70–102 ft (21.34–31.09 m) |
| 680 Series Rotor | 67–91 ft (20.42–27.74 m) |
| 690 Series Rotor | 73–108 ft (22.25–32.92 m) |
| 730 Series Rotor | 52–80 ft (15.85–24.39 m) |
| 750 Series Rotor | 56–92 ft (17.07–28.04 m) |
| 760 Series Rotor | 55–78 ft (16.76–23.78 m) |
| 780 Series Rotor | 55–87 ft (16.76–26.52 m) |

Series 570Z Fixed Sprays, for small turf and ground cover beds tip to 16 ft (4.88 m) in size

Series 300 Stream Rotors, for turf or shrub areas smaller than 30 ft (9.14 m) in size

XP-300 Rotors, for turf areas from 28 ft (8.54 m) to 43 ft (13.11 m) in size

Super 600 Rotors, for areas from 35 ft to 50 ft (10.67 m to 15.24 m)

Super 700 Rotors, for areas from 20 ft to 52 ft (6.10 mto15.85m)

The 640 and 2001 rotary heads are generally used for larger turf applications, such as parks or athletic fields. The 650, 660, 670, 680, 690, 730, 750, 760, and 780 rotary sprinklers are primarily used in the golf course industry.

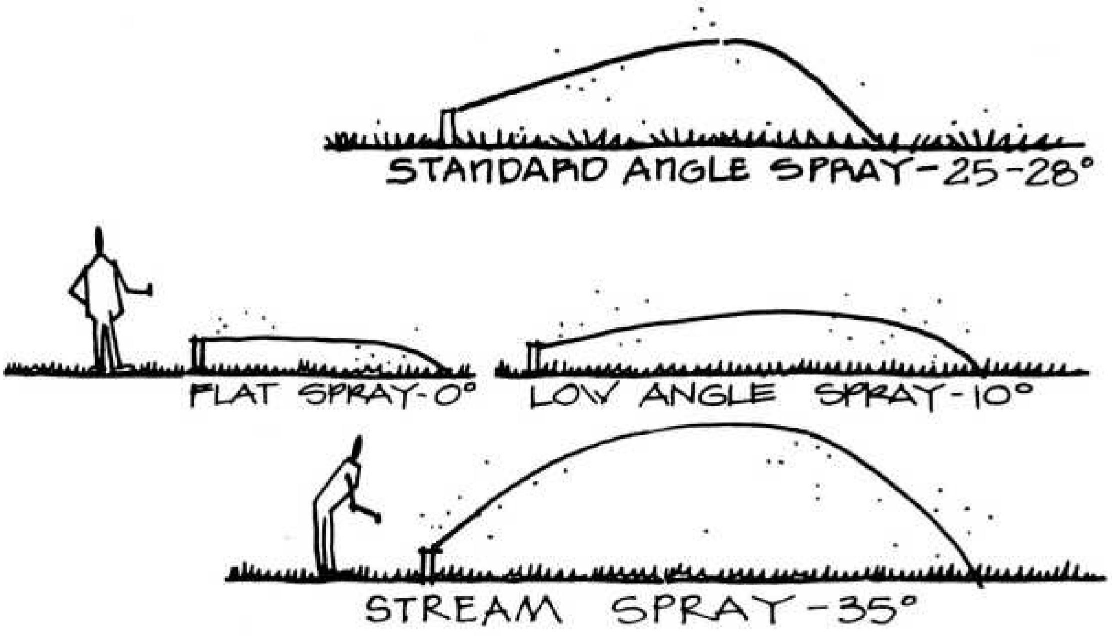


FIGURE 2.3 Typical sprays.

There is an irrigation head for the area that you are designing, and you, as an irrigation designer, must

become familiar with the products produced by irrigation manufacturers.

# 3

# Locating Sprinkler Heads

## Even Water Distribution

We now know that a sprinkler head throws a specific pattern of water and that we select sprinkler heads based upon their radius of water throw. The major consideration in locating an irrigation head is to place it so that water is evenly distributed, as it is during rain. If we locate our irrigation heads so that some areas are quite wet and others are relatively dry, then we are going to encounter turf problems such as these:

- Dead patches
- Uneven color
- Fertilizer damage (After spreading fertilizer, many people turn on their irrigation systems to wash the fertilizer into the soil so that leaves are not burned by the chemicals.)
- Disease caused by over-watering

## Sprinkler Performance

In order to understand how to evenly distribute water with a sprinkler irrigation system, we need to understand how a typical sprinkler head functions. Figure 3.1 depicts a sprinkler head producing a spray pattern, within which several dog pans have been placed. Tests have shown that the dog pans nearest the sprinkler head will catch the most water and that the pans farthest away from the sprinkler head (but within the spray pattern) will catch the least water. We can conclude that the sprinkler head does not by itself produce an even amount of water from the head to the perimeter of the pattern. According to the irrigation industry, a single sprinkler can supply enough water to grow green grass for only two-thirds of the radius of water throw. The outer one-third of the area covered does not receive enough water to sustain good plant growth.

Therefore, to get even water distribution, we must overlap sprinkler spray patterns, as shown in Figure 3.2. This will ensure that an equal amount of water falls in all the dog pans. Manufacturers recommend spacing heads at 50% of the diameter or 100% of the radius. This is called head-to-head coverage. As we said before, we are trying to achieve the same even distribution of water as Mother Nature provides with a gentle rain.

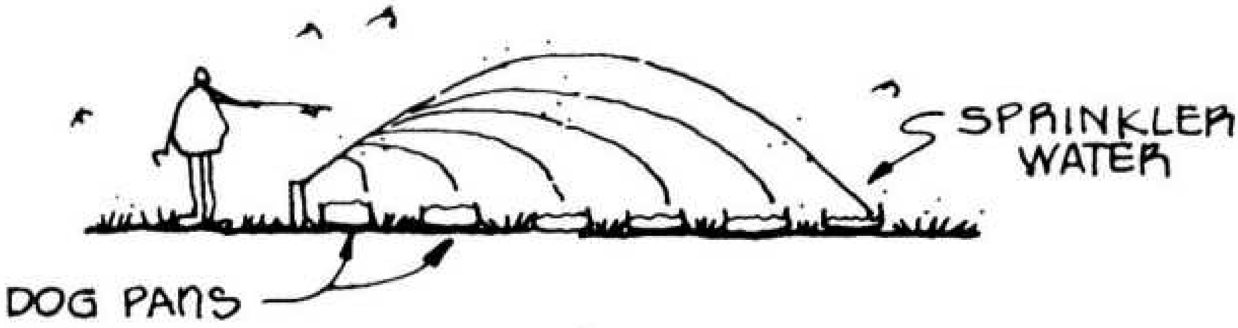


FIGURE 3.1 Sprinkler head water distribution pattern.

### Our First Irrigation Design

Now let us design our first irrigation system. It is not going to be a difficult one, but it will convey the basic principles of laying out sprinkler heads. In our example, we have a square lawn area between a house and a street that we want to irrigate (see Figure 3.3). To do so, we place irrigation heads in the four corners of the property and use quarter-circle spray patterns. This keeps the water inside our intended area of irrigation, and we achieve an even distribution of water because we have overlapped our sprinklers. If we randomly distribute dog pans throughout this area, we should find the same amount of water in each one after irrigation.

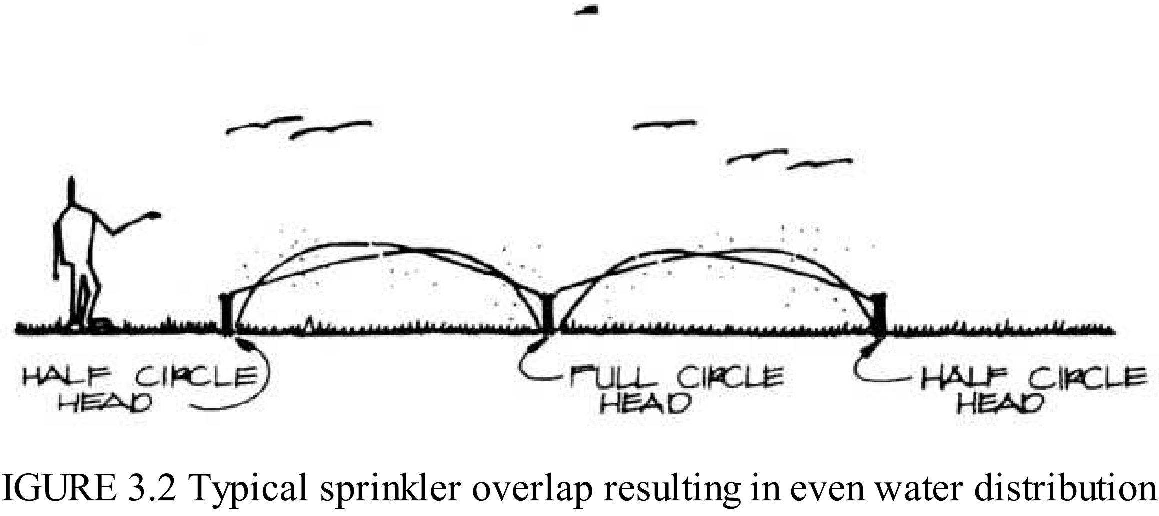


FIGURE 3.2 Typical sprinkler overlap resulting in even water distribution.

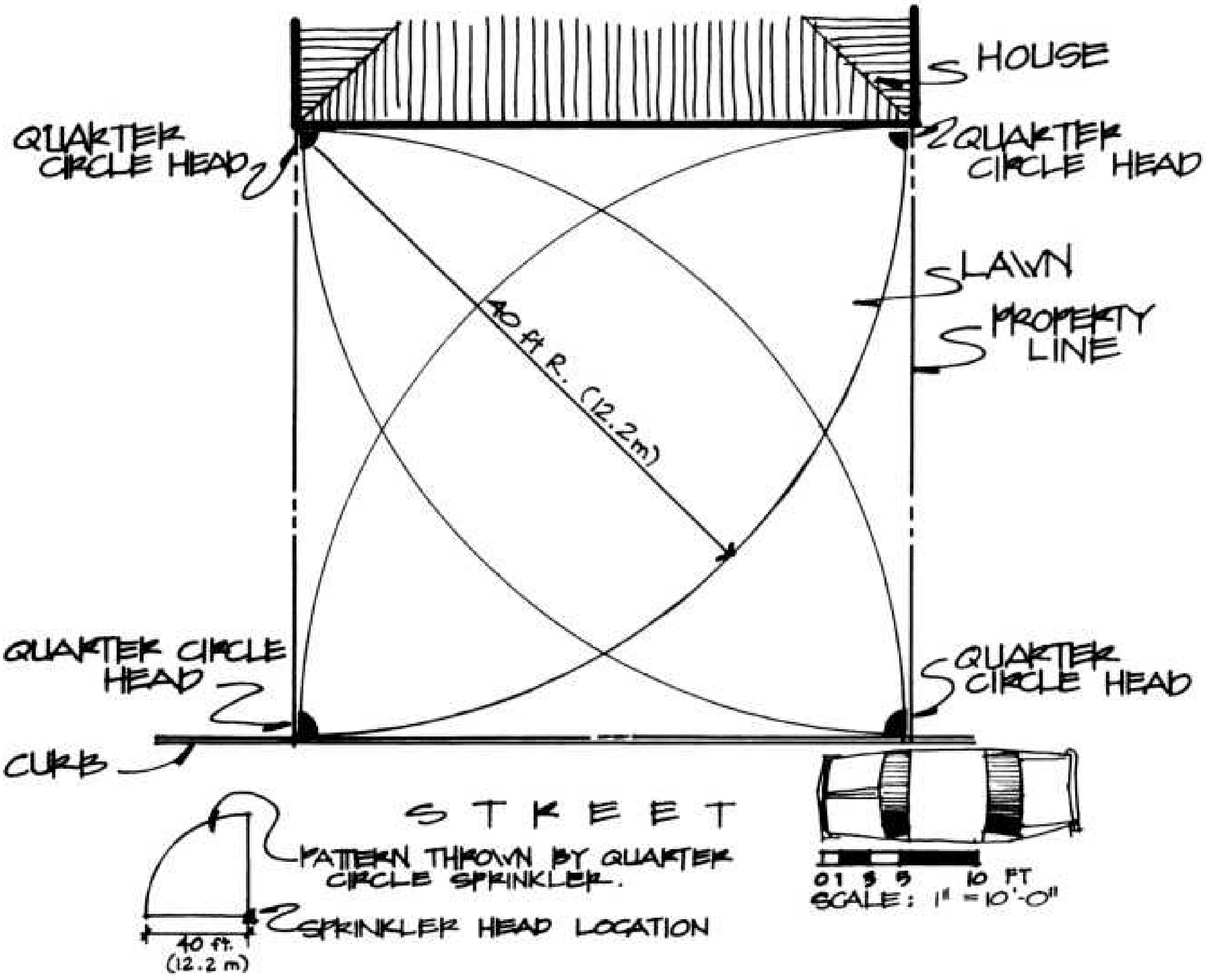


FIGURE 3.3 Our first irrigation design.

## Our Second Irrigation Design

Now let us examine a larger irrigation design problem. Again, we are going to consider a residential situation comprised of a house on a lot with a large front yard.

In this design (Figure 3.4) we have used quartercircle, half-circle, and full-circle spray patterns. We have overlapped our spray patterns to achieve an even distribution of water, like the rain. However, one point we have not discussed yet is the relative cost-efficiency of the system. The more heads we use, the more expensive an irrigation job is going to be. It is our objective as irrigation designers to achieve an even distribution of water with as few irrigation heads as possible. Have we done so? In our second irrigation design, we

have used 15 Series 300 Stream Rotors with a radius of 21 ft (6.4 m). But our sprinkler head layout could have been more efficient if we had used the Super 700 Rotor with a radius of 42 ft (12.8 m). Figure 3.5 shows how the same rectangularly shaped lawn could have been irrigated with 6 instead of 15 heads. This would cut our installation costs approximately in half. The revised design is equally as good as the first design. Placing dog pans throughout the lawn area would reveal the same equal distribution of water as in the first design.

There will be times when an irrigation designer is limited by the water window, or the amount of time available for irrigation. In such situations, a head with higher pressure will apply water at a faster rate.

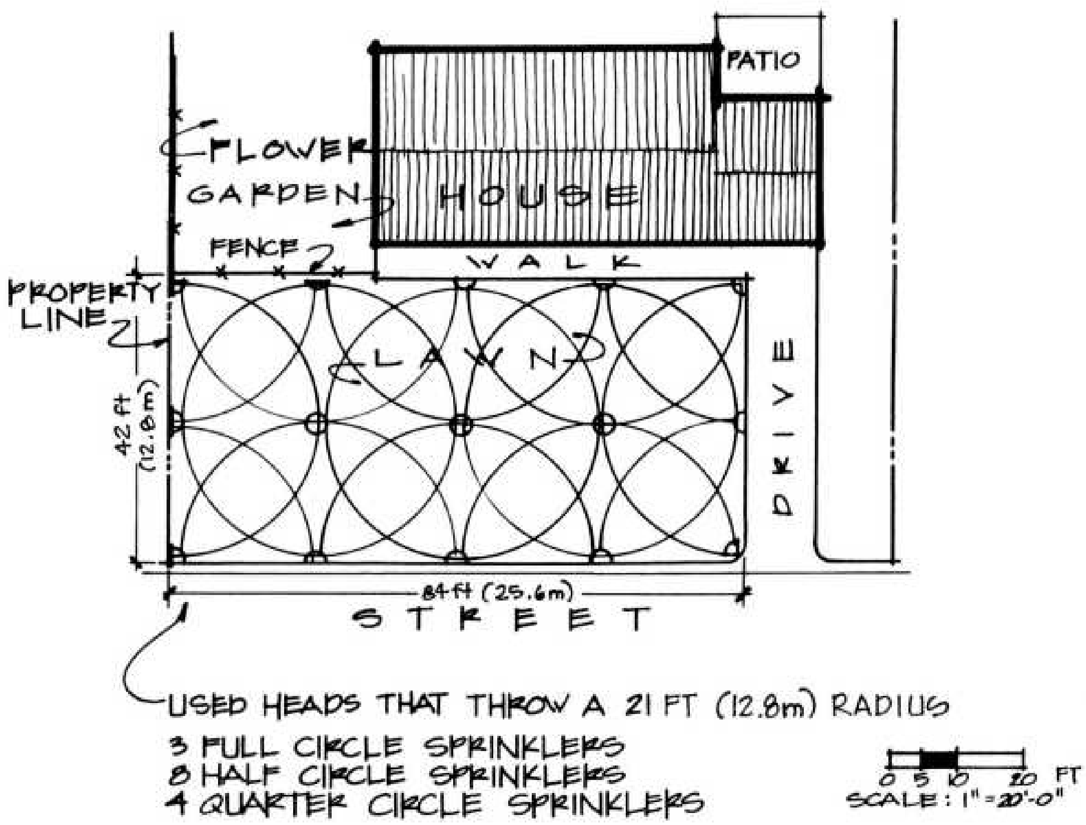
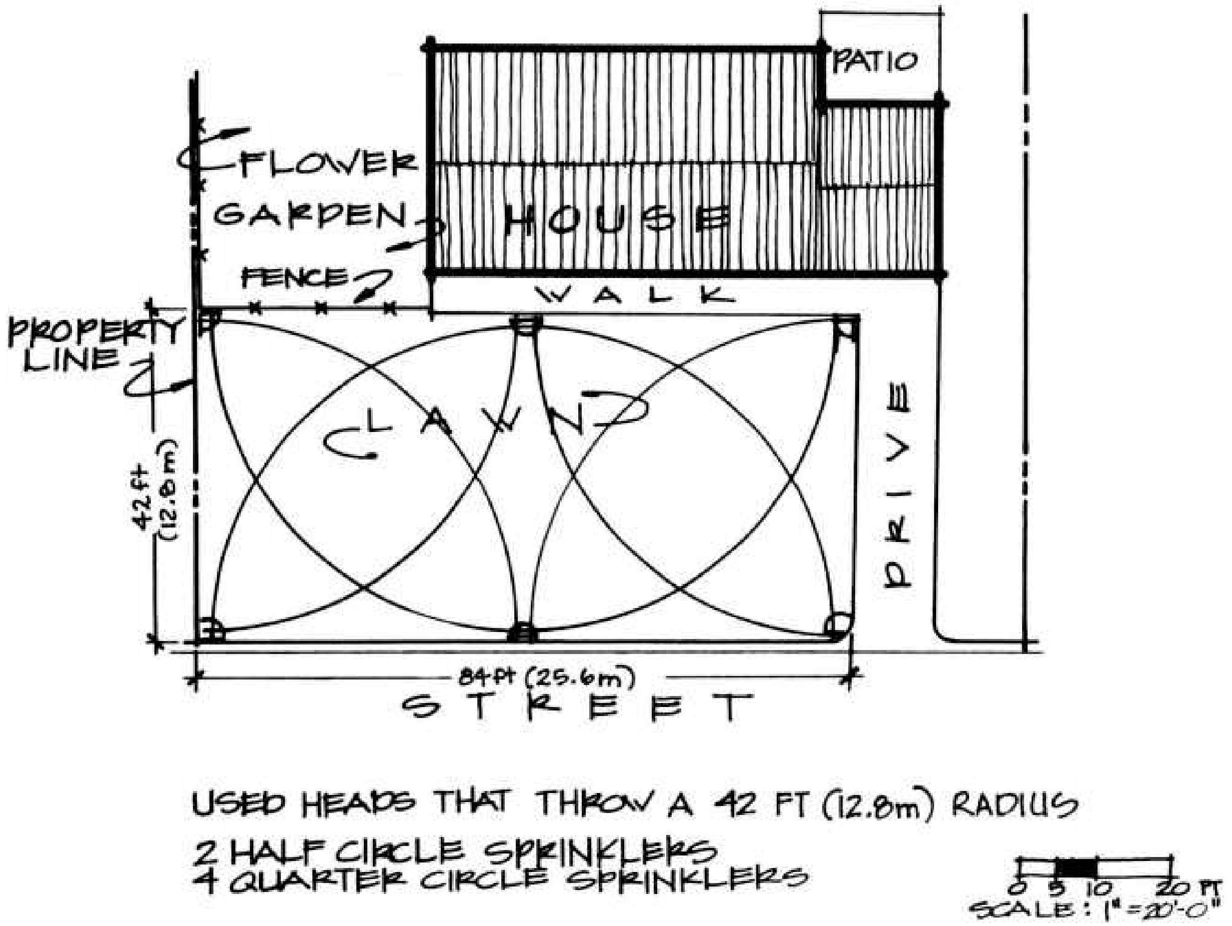


FIGURE 3.4 Our second irrigation design.



USED HEADS THAT THROW A 42 FT (12.8m) RADIUS
2 HALF CIRCLE SPRINKLERS
4 QUARTER CIRCLE SPRINKLERS

FIGURE 3.5 Revised second irrigation design-more cost-efficient.

# 4

# Types of Sprinkler Heads

## Introduction

Now that you understand the essence of irrigation design, we will take a break from our design challenges and become familiar with some of the technical aspects of irrigation. Let us start with sprinkler heads. There are two main types: the fixed spray head and the rotary head.

## Fixed Spray Heads

The fixed spray head is generally composed of two parts: the body and the nozzle. Spray head bodies are usually sold without nozzles, and they come in various sizes, some of which are listed here:

1. Two-inch (50.8-mm) pop-up, used for short grasses, like Bermuda, and for retrofit in old systems

2. Three-inch (76.2-mm) pop-up, used for short grasses and for watering beneath the canopy of tall shrubs

3. Four-inch (101.6 mm) pop-up, used for longer turf, like St. Augustine, and bluegrass, and low ground cover

4. Six-inch (152.4-mm) pop-up, used for tall grass and ground cover

5. Twelve-inch (304.8-mm) pop-up, used for ground cover, flowers, and shrub beds

6. Plastic risers from 1 ft to 3 ft (0.31 m to 0.92 m) tall can be located to water over low- to medium-growing shrubs and grasses. The risers are capped with what is called a shrub adapter and any nozzle that sprays water in many patterns.

Spray nozzles, which screw into the sprinkler body, determine the pattern and amount of water coming out of the spray head. A great variety of patterns and throw radii exist for your selection.

Any nozzle you select will produce a certain amount of water flow. Irrigation designers rate the amount of water that an irrigation head will throw out in terms of gallons per minute (gpm) or liters per minute (L/min). A full-circle 15-ft (4.57-m) Series spray nozzle, according to the manufacturer, will produce 3 gallons (11.4

liters) of water per minute.

Spray heads are stationary sprinklers; they have no moving parts except for the heads, which are popped out of the ground by water pressure and spray water in the pattern you selected (full circle, half circle, and so on). When the pressure is turned off, the riser (head) recedes into the sprinkler body below ground level and out of sight.

A spray head is limited as to the distance it can throw a circle of water, usually a maximum radius of 15 ft to 16 ft (4.57 m to 4.88 m). The tiny water droplets that make up the spray pattern can be propelled only so far before they break up into a mist that winds can easily disrupt.

## Rotary Heads

Rotary heads move in a circular manner and throw water longer distances than spray heads. The word rotary comes from the Latin word rota, which means "wheel." Merriam-Webster's Collegiate Dictionary, 10th edition, defines it as "turning on a central axis, like a wheel ... having rotating parts."

So although spray heads are stationary, rotary heads take and concentrate water into thin streams that can be propelled over long distances as they rotate.

The two basic types of rotary heads most often used today are the impact drive heads and the gear drive heads. The impact drive heads use the stream of water that throws the sprinkler pattern to bump a springloaded bronze or plastic arm that slowly turns the sprinkler head. In the gear drive head, water turns a series of gears in the sprinkler body that cause the sprinkler head to rotate in a slow and quiet manner. Impact heads do make more noise than gear drive heads. The noise level of an irrigation system operated during early morning hours in a populated area can be a problem. Many irrigation systems are scheduled to come on at 4 A.M.

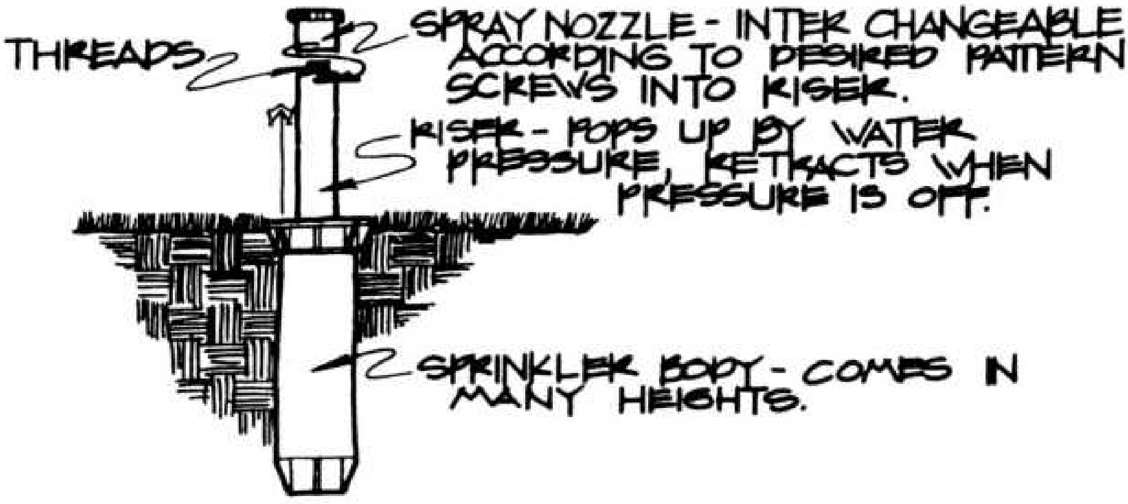


FIGURE 4. 1 Sprinkler head components.

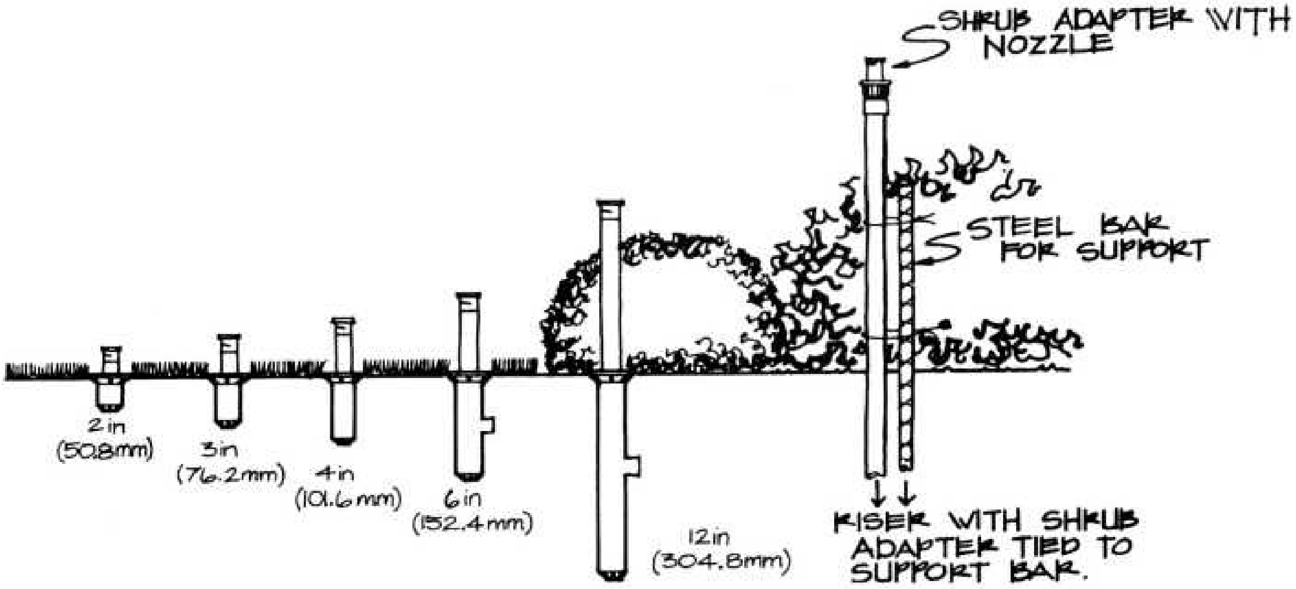


FIGURE 4.2 Sprinkler body height variations.

Gear drive heads pop up from 2.5 in to 4 in (64 mm to 102 mm), depending on the family of heads selected. This height range is enough to clear most grass. If you need to water a large shrub bed, you can get a gear drive sprinkler head and attach it to a plastic riser at whatever height you need. Remember, plastic risers will usually need extra support from the impulse of the sprinkler head. It is recommended that you either attach the plastic riser with stainless steel clamps to a steel reinforcing bar or angle iron driven into the ground beside the riser or mount the head on a copper riser.

Within certain families of gear drive heads, the nozzle can be attached to different body styles in much the same way that the spray heads attach to sprinkler bodies of various heights. There are 3-in (76mm) pop-ups for turf applications, 12-in (305-mm) high pop-ups for shrubs and ground cover, and shrub heads that can be mounted above ground on a plastic riser.

Because rotary heads throw water in a concentrated stream (s), they can cover greater distances than spray heads. Both the impact and gear drive rotary heads throw water from 1 ft to 108 ft (0.31 m to 32.92 m) and farther. Some impact heads throw water 650 ft (198.12 m), but their use is mainly agricultural.

## Comparison of Spray and Rotary Heads

Spray heads have radii from 1 ft to 16 ft (0.31 m to 4.88 m) and cover a smaller area than do the rotary heads. Spray heads distribute a lot of water on the small area they cover, which results in a high precipitation rate (inches/millimeters of water placement per hour). (Precipitation rate is a new term for us, and we will delve into this subject in the next chapter.) Because the spray heads throw out a lot of water at one time, you do not need to run them as long as you do the rotary heads.

Rotary heads distribute a comparatively small amount of water on the large area they cover. As a result, they have a lower precipitation rate than spray heads. Rotary heads often have to be run up to five times longer than spray heads to deliver the same amount of water. A given area would need many more spray heads than rotary heads to cover it; therefore, in terms of square feet (meters), it is less costly to irrigate with rotary heads. Table 4.1 compares performance statistics of spray heads and rotary heads.

*TABLE 4.1* ***Performance Statistics***

**SPRAY HEADS (FULL-CIRCLE)**

| Sprinkler | Water Flow | Radius | Precipitation Rate |
|---|---|---|---|
| 570—15-ft Series | 2.85–4.58 gpm (10.8–17.3 L/min) | 13–16 ft (3.96–4.88 m) | 1.55–1.73 in/hr (39–44 mm/hr) |

**ROTARY HEADS (FULL-CIRCLE)**

| Sprinkler | Water Flow | Radius | Precipitation Rate |
|---|---|---|---|
| Series 300 Stream Rotor | 3.41–7.51 gpm (12.9–28.4 L/min) | 15–30 ft (4.57–9.14 m) | 0.8–1.46 in/hr (20–37 mm/hr) |
| Series XP-300 | 4.04–10.81 gpm (15.3–40.9 L/min) | 28–42 ft (8.54–12.8 m) | 0.41–0.5 in/hr (10–15 mm/hr) |
| Super 600 Series | 1.2–6.71 gpm (4.5–25.4 L/min) | 35–50 ft (10.67–15.24 m) | 0.09–0.32 in/hr (2–8 mm/hr) |
| Super 700 Series | 0.80–9.75 gpm (3–36.9 L/min) | 34–52 ft (10.36–15.85 m) | 0.07–0.35 in/hr (2–9 mm/hr) |

# 5

# Precipitation Rates

## Precipitation Rate

The term precipitation rate simply refers to the number of inches (millimeters) of water that is placed over a certain area per hour. If the sprinkler heads in a front yard deliver 1 in (25 mm) of water over the entire area in 1 hour, then we can say that the precipitation rate of the sprinkler heads is 1 in (25 mm) per hour.

Horticulturists tell us that different plant types have different water requirements that are expressed in inches (millimeters) per week. For example, note the varied water requirements, or evapotranspiration rates (EVTs), of plant types in Table 5.1. The EVT rate varies by season and climatic region of the country. Local EVT rates can be found in the Toro Company's Rainfall Evapotranspiration Data book or can be gotten

from the agronomy departments of university extension services.

*TABLE 5.1* **General Peak Plant Water Demand**

| PLANT TYPE | WATER DEMAND PER WEEK |
|---|---|
| Lawn grasses | 1.5–2 in (38–51 mm) |
| Ground covers | 0.5–1 in (13–25 mm) |
| Shrubs | 1–1.5 in (25–38 mm) |
| Trees | 1–1.5 in (25–38 mm) |
| Roses | 2 in (51 mm) |
| Perennials and annuals | 1.5–2 in (38–51 mm) |
| Vegetables | 2 in (51 mm) |

We know that a sprinkler head distributes a certain number of gallons (liters) of water per minute. To relate this figure to the amount of water that plants need, which is measured in inches (millimeters) per week, we must use a simple formula that derives the precipitation rate for us in inches (millimeters) per hour.

$$\text{Precipitation rate in inches per hour} = \frac{96.3 \times \text{the total gpm in a given area}}{\text{Total square feet of the area being covered}}$$

$$\text{Precipitation rate in millimeters per hour} = \frac{60 \times \text{the total L/min in a given area}}{\text{Square meters of the area being covered}}$$

The 96.3 is a constant that is used to help convert the gallons per minute and the square feet of the area being sprinkled into a figure expressed in inches per hour. It was derived by the following method:

$$1 \text{ gallon} = 231 \text{ in}^3$$

$$1 \text{ ft}^2 = 144 \text{ in}^2$$

$$\frac{231 \text{ in}^3}{144 \text{ in}^2/\text{ft}^2} = 1.604 \text{ in/ft}^2$$

$$1.604 \text{ in/ft}^2 \times 60 \text{ min} = 96.3 \text{ in/ft}^2/\text{hr}$$

The total gpm (L/min) figure is derived by adding the gpm (L/min) figures of all the heads in the area you are sprinkling, which includes full-circle, half circle, quarter-circle, and any other configuration. The square feet (square meters) of the area being covered is the total area being irrigated by the sprinklers for which you calculated the gpm (L/min) total.

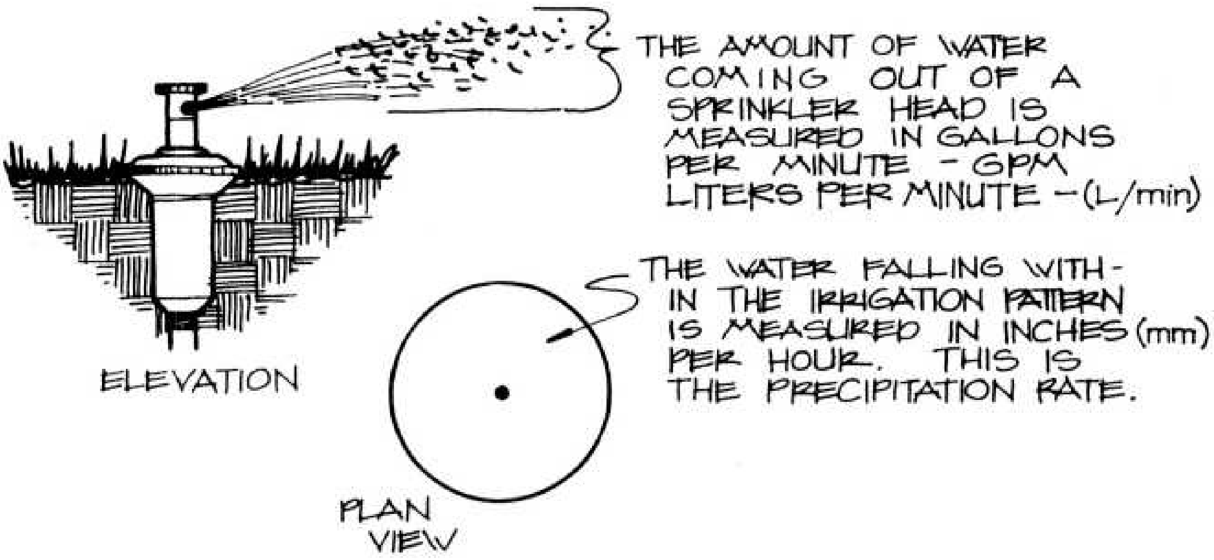


FIGURE 5. 1 Water measurement terms.

So for any given area, take 96.3 (60 for metric), which is the mathematical constant, and multiply it by the gpm (L/min) flow of all the sprinklers in the given area. Divide that figure by the square feet (square meters) of the area being covered. Let us apply the formula to the front yard irrigation in Figure 5.2.

$$\text{Precipitation rate} = \frac{96.3 \times [(4 \text{ heads} \times 1.3 \text{ gpm}) + (2 \text{ heads} \times 2.6 \text{ gpm})]}{37 \times 74 \text{ ft}}$$

$$= \frac{1001.52}{2738}$$

$$\text{Precipitation} = 0.366, \text{ or } 0.37, \text{ in/hr}$$

$$\frac{60 \times [(4 \text{ heads} \times 4.92 \text{ L/min}) + (2 \text{ heads} \times 9.84 \text{ L/min})]}{11.28 \times 22.56 \text{ m}}$$

$$= \frac{2361.6}{254.47}$$

$$\text{Precipitation} = 9.28 \text{ mm/hr}$$

### Watering Time Needed Per Week

From our calculations, we know that our rotary heads are applying 0.37 in (9.28 mm) of water each hour they are on. Looking back at the Plant Water Demand Chart, we see that lawn grass needs 2 in (51 mm) of water per week to flourish. How long and how often do we need to turn on our irrigation system each week to meet that requirement is the question we need to answer. Let us transpose the 0.37 in (9.28 mm) per hour precipitation rate of the sprinkler heads to a weekly watering figure using the following method:

1. Convert the precipitation rate of inches (millimeters) of water per hour to inches (millimeters) of water applied per minute.

$$\frac{\text{0.37 in (9.28 mm) per hour}}{\text{60 minutes per hour}}$$

= 0.006 in (0.1524 mm) per minute—remember, this is the amount of water our sprinkler heads put out each minute.

2. Divide the lawn grass's weekly water demand (EVT), which was 2 in (51 mm), by the precipitation rate (PR).

$$\frac{\text{2 in (51 mm) per week water need}}{\text{0.006 in (0.1524 mm) of water per minute}} \qquad \frac{\text{EVT}}{\text{PR}}$$

= 334 minutes. This is the amount of time the sprinklers would have to be run each week to deliver 2 in (51 mm) of water.

**Watering Schedule**

Now, do you run those heads for 334 minutes at a time to put down the 2 in (51 mm) of water that the turf needs? It depends. The axiom, or rule, for watering is to water deep and long. Let me say it again for emphasis: water deep and long! In this way plant roots go deeper after water; in times of drought or irrigation system malfunction, the plants are thus able to get available water and survive the crisis.

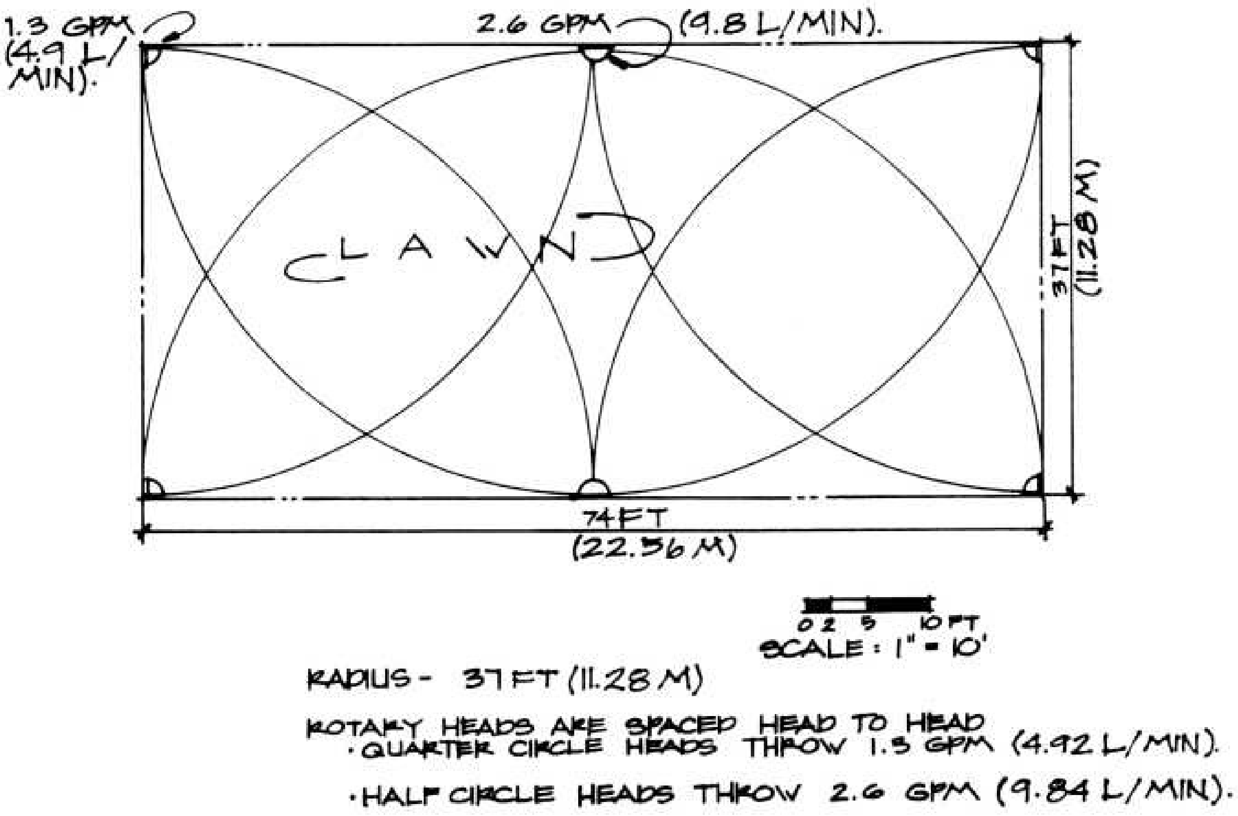


FIGURE 5.2 Front yard irrigation.

If you water in short, frequent intervals, plant roots will gather at the top of the soil where the water is concentrated. During drought or irrigation system breakdown, the plant roots cannot get the deeper water and the plant becomes severely stressed.

What determines how long you water at one time is the ability of the soil you are working with to soak up the water the sprinkler head is putting down. We know we want to water deep and long, but if we are irrigating tight, clay soils, we may only be able to run our system for a few minutes at a time. So we must examine our soil's permeability rate, also commonly called the infiltration rate. This is how fast our soil is able to absorb water in inches (millimeters) of water per hour. Some typical permeability rates for soil in flat areas are listed in Table 5.2; we'll look at how an area's slope affects soil permeability in Chapter 6.

We see that sandy soils soak up water at a much faster rate than do clay soils. In our irrigation example, we are working with clay soil that has a permeability rate of 0.2 in (5 mm) per hour. How much water can we put down without exceeding our soil's ability to absorb that water? Let's think logically:

## *TABLE 5.2* **General Soil Permeability Rates**

| **SOIL TYPE** | **PERMEABILITY RATE** |
|---|---|
| Sandy loams | 1.7 in (43 mm)/hr |
| Silty loams | 1.0 in (25 mm)/hr |
| Clay | 0.2 in (5 mm)/hr |

1. Clay soil will absorb 0.2 in (5 mm) per hour.

2. The sprinkler delivers 0.37 in (9 mm) per hour.

3. Therefore, we know that the sprinkler delivers more water in an hour than can be absorbed by our tight, clay soils.

4. Therefore, let us divide the 0.2 in (5 mm) per hour permeability rate by the 0.006 in (0.1524 mm) per minute precipitation rate.

$$\frac{0.2 \text{ in } (5 \text{ mm})/\text{hr}}{0.006 \text{ in } (0.1524 \text{ mm})/\text{min}}$$

= 33.3, or 34, minutes, the maximum watering time that will not exceed the soil's permeability rate.

Now let us continue with our calculations and determine on what days we will water and for how many minutes on each day.

1. Divide the maximum watering time of 34 minutes into the 334 minutes needed to run the sprinkler to deliver 2 in (51 mm) of water per week to the lawn grass.

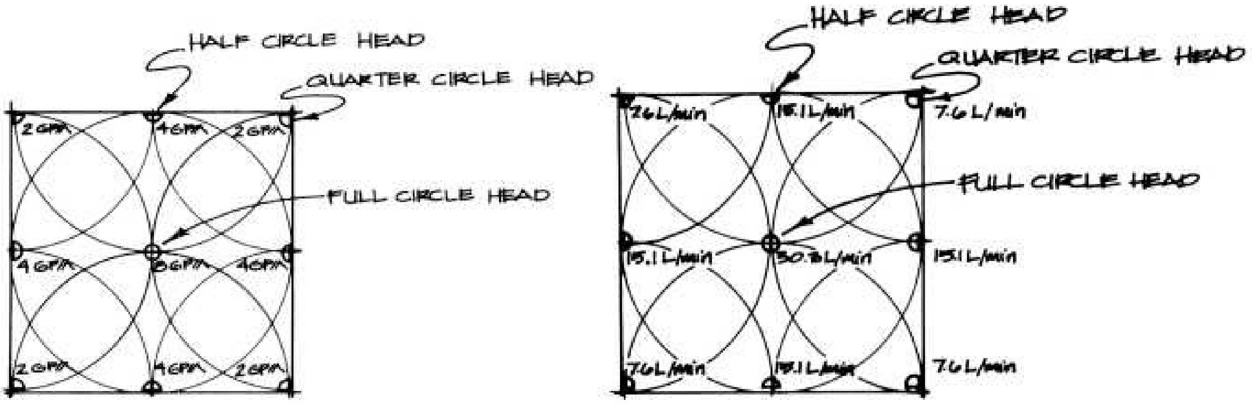


FIGURE 5.3 Matched precipitation heads.

$$\frac{334 \text{ minutes}}{34 \text{ minutes}} = 9.8$$

Let's round off this figure and say that the sprinklers will need to run 10 times a week for 34 minutes at a time in order to deliver 2 in (51 mm) of water on tight, clay soils that have a permeability rate of 0.2 in (5 mm) per hour.

2. We will probably program the automatic controller to run Monday through Friday or five days out of seven, in the early morning and late morning, for 34 minutes at a time. This will be as close to watering deep and long as we can get and will satisfy the need to water 10 times a week. Always allow at least 1 hour between applications of water to get maximum soil infiltration.

Let us look back a minute and examine what would have happened if we had run our sprinklers for more than 34 minutes at a time. Remember, this figure related to the ability of the clay soil to absorb water. Watering more than 34 minutes at a time would result in water puddling, evaporation, and runoff if there was any kind of slope at all. Erosion and water waste would occur.

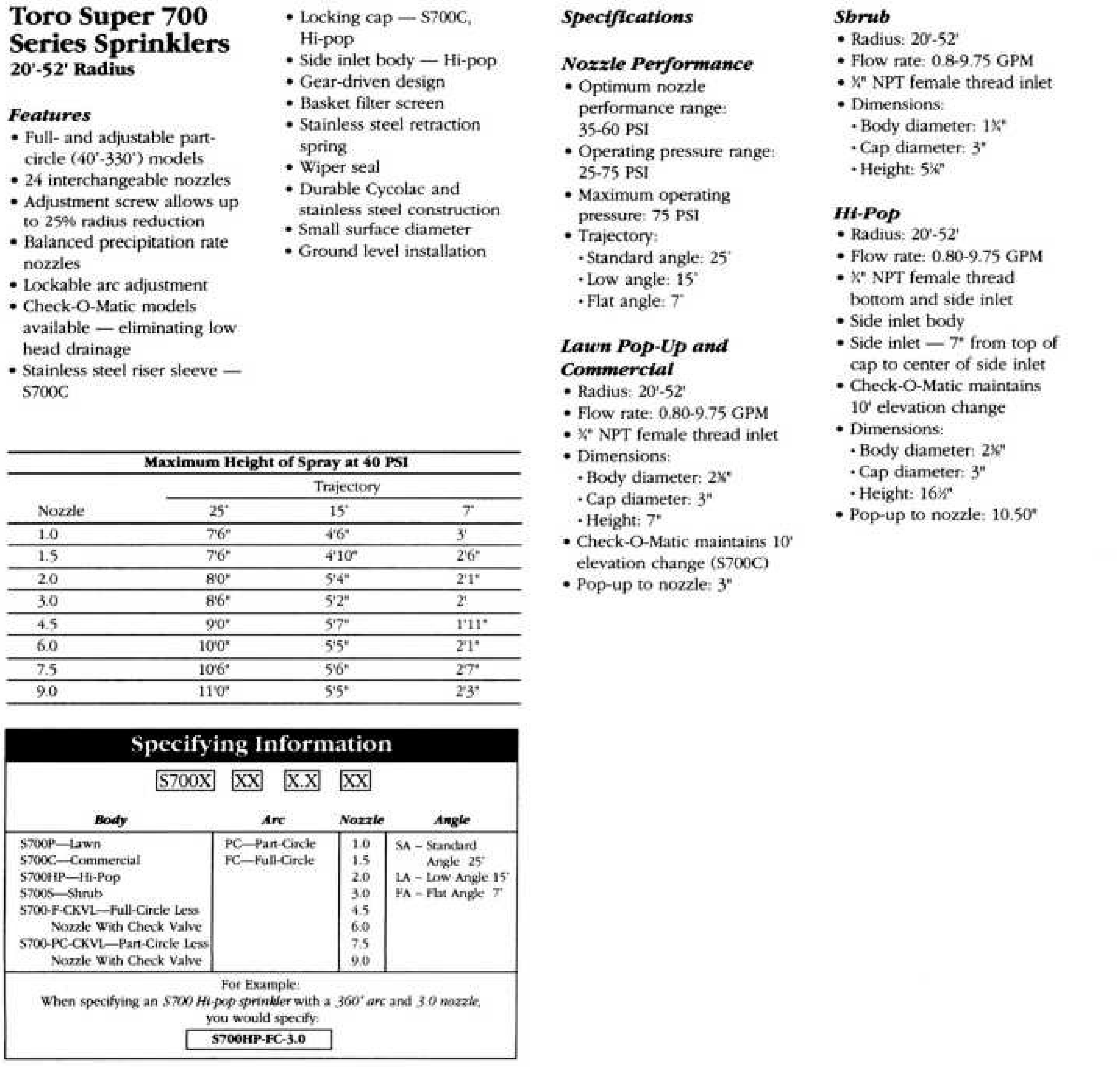
## Matched Precipitation

If you look at an irrigation manufacturer's catalog, you will find that within some families of sprinkler heads, a feature known as matched precipitation is offered. This means that if you are using half-circle heads with fullcircle heads, the half-circle heads will produce half the amount of water that the full circle-heads produce. The half-circle heads are covering half the area that the full-circle heads are covering, so this makes sense. This matched-precipitation feature allows you to mix quarter-, half-, three-quarter, and full-circle patterns together from the same family of heads and still achieve an even distribution of water on all areas of land you are irrigating (see Figure 5.3). With matched precipitation, the full circle heads might throw 8 gpm (30.3 L/min); the half-circle heads, 4 gpm (15.1 L/min); and the quarter-circle heads, 2 gpm (7.6 L/min).

As a designer, you will generally not mix different families of sprinkler heads together. For example, you should not mix spray heads with rotary heads, because their precipitation rates are very different; spray heads have precipitation rates ranging from about 1 in/hr to 2 in/hr (25 mm/hr to 50 mm/hr), whereas rotary heads have precipitation rates ranging from 0.07 in/hr to 1.46 in/hr (2 mm/hr to 37 mm/hr). Mixing different families of heads and precipitation rates will result in some areas being underwatered and some overwatered-what a mess!

## Balanced Precipitation

Nozzles for rotary heads are selected according to their flow rates to balance the precipitation rate in a zone. For example, by using the Super 700 series head, 1.5 nozzles could be used for quarter-circle arcs, 3.0 nozzles for half-circle arcs, and 6.0 nozzles for fullcircle patterns. Figure 5.4 shows that the standard angle 1.5 nozzle, at a midrange of pressure, delivers about 1.5 gpm (5.7 L/min), whereas the 3.0 nozzle delivers about 3 gpm (11.4 L/min) and the 6.0 nozzle delivers almost 6 gpm (22.7 L/min). This manner of selecting rotary sprinkler nozzles based on flow rates will balance the precipitation rates in a zone or circuit.



## Toro Super 700 Series Sprinklers

**20'-52' Radius**

***Features***

- Full- and adjustable part-circle (40°-330°) models
- 24 interchangeable nozzles
- Adjustment screw allows up to 25% radius reduction
- Balanced precipitation rate nozzles
- Lockable arc adjustment
- Check-O-Matic models available — eliminating low head drainage
- Stainless steel riser sleeve — S700C
- Locking cap — S700C, Hi-pop
- Side inlet body — Hi-pop
- Gear-driven design
- Basket filter screen
- Stainless steel retraction spring
- Wiper seal
- Durable Cycolac and stainless steel construction
- Small surface diameter
- Ground level installation

***Specifications***

***Nozzle Performance***

- Optimum nozzle performance range: 35-60 PSI
- Operating pressure range: 25-75 PSI
- Maximum operating pressure: 75 PSI
- Trajectory:
  - Standard angle: 25°
  - Low angle: 15°
  - Flat angle: 7°

***Lawn Pop-Up and Commercial***

- Radius: 20'-52'
- Flow rate: 0.80-9.75 GPM
- ¾" NPT female thread inlet
- Dimensions:
  - Body diameter: 2¾"
  - Cap diameter: 3"
  - Height: 7"
- Check-O-Matic maintains 10' elevation change (S700C)
- Pop-up to nozzle: 3"

***Shrub***

- Radius: 20'-52'
- Flow rate: 0.8-9.75 GPM
- ¾" NPT female thread inlet
- Dimensions:
  - Body diameter: 1¾"
  - Cap diameter: 3"
  - Height: 5¾"

***Hi-Pop***

- Radius: 20'-52'
- Flow rate: 0.80-9.75 GPM
- ¾" NPT female thread bottom and side inlet
- Side inlet body
- Side inlet — 7" from top of cap to center of side inlet
- Check-O-Matic maintains 10' elevation change
- Dimensions:
  - Body diameter: 2¾"
  - Cap diameter: 3"
  - Height: 16½"
- Pop-up to nozzle: 10.50"

**Maximum Height of Spray at 40 PSI**

| | Trajectory | | |
|---|---|---|---|
| Nozzle | 25° | 15° | 7° |
| 1.0 | 7'6" | 4'6" | 3' |
| 1.5 | 7'6" | 4'10" | 2'6" |
| 2.0 | 8'0" | 5'4" | 2'1" |
| 3.0 | 8'6" | 5'2" | 2' |
| 4.5 | 9'0" | 5'7" | 1'11" |
| 6.0 | 10'0" | 5'5" | 2'1" |
| 7.5 | 10'6" | 5'6" | 2'7" |
| 9.0 | 11'0" | 5'5" | 2'3" |

**Specifying Information**

S700X XX X.X XX

| ***Body*** | ***Arc*** | ***Nozzle*** | ***Angle*** |
|---|---|---|---|
| S700P—Lawn<br>S700C—Commercial<br>S700HP—Hi-Pop<br>S700S—Shrub<br>S700-F-CKVL—Full-Circle Less Nozzle With Check Valve<br>S700-PC-CKVL—Part-Circle Less Nozzle With Check Valve | PC—Part-Circle<br>FC—Full-Circle | 1.0<br>1.5<br>2.0<br>3.0<br>4.5<br>6.0<br>7.5<br>9.0 | SA – Standard Angle 25°<br>LA – Low Angle 15°<br>FA – Flat Angle 7° |

For Example:
When specifying an *S700 Hi-pop sprinkler* with a *360° arc* and *3.0 nozzle*, you would specify:

**S700HP-FC-3.0**

FIGURE 5.4 Super 700 performance information. (Source: The Toro Company. Used with permission.)

# Nozzle Performance Information

## S700 Nozzles

| Nozzle Size (Color) | PSI | 25° STANDARD ANGLE |  |  |  | 15° LOW ANGLE |  |  |  | 7° FLAT ANGLE |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  | Rad | GPM | □ | △ | Rad | GPM | □ | △ | Rad | GPM | □ | △ |
| 1.0<br>YELLOW | 25 | 34 | 0.80 | 0.06 | 0.07 | 30 | 0.80 | 0.08 | 0.09 | 21 | 0.80 | 0.17 | 0.17 |
|  | 30 | 35 | 0.89 | 0.07 | 0.07 | 31 | 0.89 | 0.09 | 0.09 | 22 | 0.89 | 0.17 | 0.18 |
|  | 35 | 36 | 0.96 | 0.07 | 0.07 | 32 | 0.96 | 0.09 | 0.09 | 23 | 0.96 | 0.17 | 0.17 |
|  | 40 | 36 | 1.03 | 0.07 | 0.08 | 33 | 1.03 | 0.09 | 0.09 | 24 | 1.03 | 0.16 | 0.17 |
|  | 45 | 37 | 1.10 | 0.07 | 0.08 | 34 | 1.10 | 0.09 | 0.09 | 25 | 1.10 | 0.16 | 0.17 |
|  | 50 | 37 | 1.16 | 0.08 | 0.08 | 35 | 1.16 | 0.09 | 0.09 | 25 | 1.16 | 0.17 | 0.18 |
|  | 55 | 38 | 1.21 | 0.08 | 0.08 | 35 | 1.21 | 0.09 | 0.10 | 26 | 1.21 | 0.16 | 0.17 |
|  | 60 | 38 | 1.26 | 0.08 | 0.08 | 36 | 1.26 | 0.09 | 0.09 | 27 | 1.26 | 0.16 | 0.17 |
| 1.5<br>ORANGE | 25 | 35 | 1.11 | 0.08 | 0.09 | 30 | 1.11 | 0.11 | 0.12 | 21 | 1.11 | 0.23 | 0.24 |
|  | 30 | 36 | 1.23 | 0.09 | 0.09 | 31 | 1.23 | 0.12 | 0.12 | 22 | 1.23 | 0.23 | 0.24 |
|  | 35 | 37 | 1.34 | 0.09 | 0.09 | 32 | 1.34 | 0.12 | 0.13 | 23 | 1.34 | 0.23 | 0.24 |
|  | 40 | 38 | 1.45 | 0.09 | 0.10 | 33 | 1.45 | 0.12 | 0.13 | 24 | 1.45 | 0.23 | 0.24 |
|  | 45 | 39 | 1.55 | 0.09 | 0.10 | 34 | 1.55 | 0.12 | 0.13 | 25 | 1.55 | 0.23 | 0.24 |
|  | 50 | 40 | 1.64 | 0.09 | 0.10 | 35 | 1.64 | 0.12 | 0.13 | 26 | 1.64 | 0.22 | 0.23 |
|  | 55 | 40 | 1.72 | 0.10 | 0.10 | 36 | 1.72 | 0.12 | 0.13 | 27 | 1.72 | 0.22 | 0.23 |
|  | 60 | 41 | 1.80 | 0.10 | 0.10 | 37 | 1.80 | 0.12 | 0.13 | 28 | 1.80 | 0.21 | 0.22 |
| 2.0<br>RED | 25 | 35 | 1.42 | 0.11 | 0.11 | 31 | 1.42 | 0.14 | 0.14 | 21 | 1.42 | 0.30 | 0.31 |
|  | 30 | 36 | 4.58 | 0.11 | 0.12 | 32 | 1.58 | 0.14 | 0.15 | 22 | 1.58 | 0.30 | 0.31 |
|  | 35 | 31 | 1.73 | 0.12 | 0.12 | 33 | 1.73 | 0.15 | 0.15 | 24 | 1.73 | 0.28 | 0.29 |
|  | 40 | 39 | 1.86 | 0.11 | 0.12 | 35 | 1.86 | 0.14 | 0.15 | 25 | 1.86 | 0.27 | 0.29 |
|  | 45 | 40 | 1.99 | 0.11 | 0.12 | 36 | 1.99 | 0.14 | 0.15 | 26 | 1.99 | 0.27 | 0.28 |
|  | 50 | 41 | 2.11 | 0.12 | 0.12 | 37 | 2.11 | 0.14 | 0.15 | 27 | 2.11 | 0.27 | 0.28 |
|  | 55 | 42 | 2.21 | 0.12 | 0.12 | 38 | 2.21 | 0.14 | 0.15 | 28 | 2.21 | 0.26 | 0.27 |
|  | 60 | 43 | 2.31 | 0.11 | 0.12 | 39 | 2.31 | 0.14 | 0.15 | 29 | 2.31 | 0.25 | 0.26 |
| 3.0<br>BLACK | 25 | 38 | 2.40 | 0.15 | 0.16 | 33 | 2.40 | 0.20 | 0.21 | 22 | 2.40 | 0.46 | 0.48 |
|  | 30 | 39 | 2.66 | 0.16 | 0.17 | 34 | 2.66 | 0.21 | 0.22 | 23 | 2.66 | 0.46 | 0.48 |
|  | 35 | 40 | 2.89 | 0.17 | 0.17 | 35 | 2.89 | 0.22 | 0.23 | 25 | 2.89 | 0.42 | 0.45 |
|  | 40 | 41 | 3.12 | 0.17 | 0.18 | 37 | 3.12 | 0.21 | 0.22 | 26 | 3.12 | 0.42 | 0.44 |
|  | 45 | 42 | 3.32 | 0.17 | 0.18 | 38 | 3.32 | 0.21 | 0.22 | 27 | 3.32 | 0.42 | 0.44 |
|  | 50 | 43 | 3.52 | 0.17 | 0.18 | 39 | 3.52 | 0.21 | 0.22 | 28 | 3.52 | 0.41 | 0.43 |
|  | 55 | 44 | 3.69 | 0.18 | 0.18 | 40 | 3.69 | 0.21 | 0.22 | 29 | 3.69 | 0.40 | 0.42 |
|  | 60 | 45 | 3.86 | 0.18 | 0.18 | 41 | 3.86 | 0.21 | 0.22 | 30 | 3.86 | 0.39 | 0.41 |
| 4.5<br>BLUE | 25 | 39 | 2.80 | 0.17 | 0.18 | 34 | 2.80 | 0.22 | 0.23 | 22 | 2.80 | 0.53 | 0.56 |
|  | 30 | 40 | 3.13 | 0.18 | 0.19 | 36 | 3.13 | 0.22 | 0.23 | 25 | 3.13 | 0.46 | 0.48 |
|  | 35 | 41 | 3.43 | 0.19 | 0.20 | 31 | 3.43 | 0.23 | 0.24 | 27 | 3.43 | 0.43 | 0.45 |
|  | 40 | 43 | 3.71 | 0.18 | 0.19 | 39 | 3.71 | 0.22 | 0.23 | 29 | 3.71 | 0.41 | 0.42 |
|  | 45 | 45 | 3.98 | 0.18 | 0.19 | 41 | 3.98 | 0.22 | 0.23 | 30 | 3.98 | 0.41 | 0.43 |
|  | 50 | 46 | 4.23 | 0.18 | 0.19 | 42 | 4.23 | 0.22 | 0.23 | 31 | 4.23 | 0.40 | 0.42 |
|  | 55 | 46 | 4.44 | 0.19 | 0.20 | 42 | 4.44 | 0.23 | 0.24 | 33 | 4.44 | 0.37 | 0.39 |
|  | 60 | 47 | 4.64 | 0.19 | 0.20 | 43 | 4.64 | 0.23 | 0.24 | 34 | 4.64 | 0.37 | 0.39 |
| 6.0<br>GREEN | 25 | 39 | 4.13 | 0.25 | 0.26 | 35 | 4.13 | 0.31 | 0.32 | 22 | 4.13 | 0.78 | 0.82 |
|  | 30 | 42 | 4.63 | 0.24 | 0.25 | 36 | 4.63 | 0.33 | 0.34 | 25 | 4.63 | 0.68 | 0.71 |
|  | 35 | 44 | 5.08 | 0.24 | 0.25 | 38 | 5.08 | 0.32 | 0.34 | 27 | 5.08 | 0.64 | 0.67 |
|  | 40 | 46 | 5.50 | 0.24 | 0.25 | 39 | 5.50 | 0.33 | 0.35 | 30 | 5.50 | 0.56 | 0.59 |
|  | 45 | 47 | 5.90 | 0.25 | 0.26 | 41 | 5.90 | 0.32 | 0.34 | 32 | 5.90 | 0.53 | 0.55 |
|  | 50 | 49 | 6.28 | 0.24 | 0.25 | 43 | 6.28 | 0.31 | 0.33 | 33 | 6.28 | 0.53 | 0.56 |
|  | 55 | 50 | 6.58 | 0.24 | 0.25 | 45 | 6.58 | 0.30 | 0.34 | 34 | 6.58 | 0.52 | 0.55 |
|  | 60 | 51 | 6.88 | 0.24 | 0.25 | 47 | 6.88 | 0.29 | 0.30 | 35 | 6.88 | 0.52 | 0.54 |
| 7.5<br>BEIGE | 25 | 41 | 5.35 | 0.29 | 0.31 | 35 | 5.35 | 0.40 | 0.42 | 20 | 5.35 | 1.23 | 1.29 |
|  | 30 | 42 | 5.92 | 0.31 | 0.32 | 37 | 5.92 | 0.40 | 0.42 | 22 | 5.92 | 1.12 | 1.18 |
|  | 35 | 44 | 6.45 | 0.31 | 0.32 | 39 | 6.45 | 0.39 | 0.41 | 25 | 6.45 | 0.95 | 0.99 |
|  | 40 | 46 | 6.94 | 0.30 | 0.32 | 42 | 6.94 | 0.36 | 0.38 | 27 | 6.94 | 0.87 | 0.92 |
|  | 45 | 48 | 7.41 | 0.30 | 0.31 | 43 | 7.41 | 0.37 | 0.39 | 29 | 7.41 | 0.81 | 0.85 |
|  | 50 | 50 | 7.84 | 0.29 | 0.30 | 45 | 7.84 | 0.36 | 0.37 | 31 | 7.84 | 0.75 | 0.79 |
|  | 55 | 50 | 8.22 | 0.30 | 0.32 | 46 | 8.22 | 0.36 | 0.37 | 34 | 8.22 | 0.65 | 0.68 |
|  | 60 | 51 | 8.59 | 0.30 | 0.32 | 47 | 8.59 | 0.36 | 0.37 | 38 | 8.59 | 0.55 | 0.57 |
| 9.0<br>GRAY | 25 | 42 | 5.64 | 0.29 | 0.31 | 34 | 5.64 | 0.45 | 0.47 | 21 | 5.64 | 1.18 | 1.23 |
|  | 30 | 45 | 6.28 | 0.29 | 0.30 | 36 | 6.28 | 0.45 | 0.47 | 23 | 6.28 | 1.09 | 1.14 |
|  | 35 | 47 | 6.87 | 0.29 | 0.30 | 38 | 6.87 | 0.44 | 0.46 | 25 | 6.87 | 1.01 | 1.06 |
|  | 40 | 48 | 7.42 | 0.30 | 0.31 | 41 | 7.42 | 0.41 | 0.43 | 27 | 7.42 | 0.94 | 0.98 |
|  | 45 | 50 | 7.93 | 0.29 | 0.31 | 42 | 7.93 | 0.41 | 0.43 | 30 | 7.93 | 0.81 | 0.85 |
|  | 50 | 51 | 8.90 | 0.31 | 0.33 | 44 | 8.90 | 0.42 | 0.44 | 32 | 8.90 | 0.80 | 0.84 |
|  | 55 | 51 | 9.33 | 0.33 | 0.35 | 46 | 9.33 | 0.41 | 0.42 | 35 | 9.33 | 0.70 | 0.73 |
|  | 60 | 52 | 9.75 | 0.33 | 0.35 | 48 | 9.75 | 0.39 | 0.41 | 37 | 9.75 | 0.65 | 0.69 |

*△ Precipitation rates are for triangular spacing, shown in inches per hour, calculated at 55% of diameter.*
*□ Precipitation rates are for square spacing, shown in inches per hour, calculated at 50% of diameter.*
*All performance specifications are based on the stated working pressure available at the base of the sprinkler head.*

FIGURE 5.4 (continued)

It is general practice to begin laying out rotary sprinklers by selecting half-circle nozzles based on the radius needed in a zone. The radius of the fullcircle heads is usually reduced to meet the half-circle radius. Quarter-circle radii are usually not quite long enough to meet the desired radius, but this is acceptable because, generally, few quarter-circle arc patterns are used.

This, then, is the process for creating balanced precipitation. Remember that with matched precipitation, the flow rates of the different arcs are matched within the nozzle family. With balanced precipitation, the irrigation designer selects different nozzles based on their flow rates so that different arcs within a zone can be run together. This will create a balanced precipitation condition.

# 6

# Determining Geographical Areas

Now that you have an idea about how to lay out irrigation heads and determine precipitation rates for those heads, you are now ready to look at a more complicated irrigation design, in which all of the areas of the landscape are not going to have the same watering needs. This is what we call a "real world" situation.

One of the first things you should do when developing an irrigation design is to look at the site and divide it into geographical areas that share similar plant water needs, soil permeability rates, sun or shade conditions, and slope conditions. The following list is composed of plants that have different water needs and soils that have different permeability rates. Each item could be divided into its own geographical area:

1. Lawn grass on a flat site or a slope
2. Row or group of trees
3. Flower garden
4. Native plants
5. Shrubs under trees
6. Ground cover or lawn area in constant shade or sun
7. Shrub bed on a steep slope
8. Lawn on a tight, clay soil
9. Shrubs in a sandy loam soil

## Geographical Area Water Needs

A plant's water need is affected by the following three factors:

1. Type of plant
2. Location in sun or shade
3. Proximity to trees and tree roots

### Type of Plant

In the chapter on precipitation rates, you saw how different plants have different water needs. Some plants need over 2 in (51 mm) of water per week, and some plants can do with 0.5 in (13 mm) of water per week. The list from Chapter 5 is repeated in Table 6.1 for your convenience.

### Sun or Shade

Plants get water from their roots, use it, and then release it through their leaves. This process, called transpiration, is the way that plants breathe. Plants that are located in the sun have to give off more water to stay cool, so they use more water. Similarly, water will evaporate more rapidly from soils located in the sun than from soils in the shade. This is one of the reasons why designers and managers of landscapes need to develop good mulching habits; mulch slows evaporation from the soil. By contrast, a plant located in the shade does not get as hot as one located in the sun and therefore does not need to transpire as much water. You must be aware, though, that some shade-tolerant plants have adapted to the increased moisture available to them in the shady environment and need a moderate amount of water to survive. These plants tend to have larger and thicker leaves, which are suitable for catching as much light as possible and turning it into nourishment by photosynthesis. Just because plants are in the shade does not always mean that they need less water than those in the sun.

*TABLE 6.1* **General Peak Plant Water Demand**

| PLANT TYPE | WATER DEMAND PER WEEK |
|---|---|
| Lawn grasses | 1.5–2 in (38–51 mm) |
| Ground covers | 0.5–1 in (13–25 mm) |
| Shrubs | 1–1.5 in (25–38 mm) |
| Trees | 1–1.5 in (25–38 mm) |
| Roses | 2 in (51 mm) |
| Perennials and annuals | 1.5–2 in (38–51 mm) |
| Vegetables | 2 in (51 mm) |

### Proximity to Trees and Tree Roots

It comes as a surprise to many that it is difficult to fulfill the water needs of plants that have been planted either near or under trees. Tree roots are opportunistic; they go where the water is. To adequately water newly planted, shade-loving plants located near and among tree roots, you must satisfy the water needs of both the tree and the new plants, which can mean watering excessively. To combat this watering problem, you could plant new plants in containers in the ground. Be sure to include good drainage in your containers, as many shade-loving plants will not tolerate wet feet. Be careful how much water you apply to the landscape around existing trees. Some trees cannot tolerate the increased moisture and will become stressed. Large, old trees are like old people; they do no react well to extreme changes.

## Soil Permeability Rates

There are two considerations that affect the soil's ability to absorb water. They are the composition of the soil and the slope of the soil. As was mentioned in Chapter 5, some soils practically drink water in big gulps, and some soils take little sips. There are three basic soil types: sandy loam soils, silty loam soils, and

clay soils. Their permeability rates, that is, their ability to absorb water as measured in inches (millimeters) per hour, are listed in Table 5.2 and duplicated in the second column of Table 6.2.

*TABLE 6.2* **Maximum Water Application Rates**

| SOIL TYPE | 0% SLOPE | 10% SLOPE |
|---|---|---|
| Sandy Loam | 1.7 in/hr (43 mm/hr) | 1.0 in/hr (25 mm/hr) |
| Silty Loam | 1.0 in/hr (25 mm/hr) | 0.6 in/hr (15 mm/hr) |
| Clay | 0.2 in/hr (5 mm/hr) | 0.1 in/hr (3 mm/hr) |

In flat areas, water can be absorbed by the soil without running downhill. Water that is placed on sloped areas does not have as much a chance to soak in as it does on flat areas. Table 6.2 contains data from the Soil Conservation Service and shows maximum water application rates for soils in a flat area and soils in an area with a 10% gradient.

You can conclude from Table 6.2 that water application rates on 10% slopes are nearly half of those for flat areas. Table 6.3A helps to organize the relationship between soil types and slopes.

Being able to separate a site into geographical areas is essential to being able to provide plants the amount of water they need at an application rate the soil can take. When developing a geographical area watering plan, be sure to consider the criteria that we discussed:

- Plant water needs

  -Plant type

  -Sun/shade location

  -Near tree roots

- Soil permeability rate

  -Soil type

  -Slope of soil

These criteria need to be considered before you define your geographical areas and begin your sprinkler head layout.

Let us apply what we have learned so far. We are going to consider the small, residential landscape shown in Figure 6.1 and do the following:

### *TABLE 6.3A* **Application Rate of Water**

| **SLOPES** | **SOIL TYPE** | | |
|---|---|---|---|
| | **Clay** | **Silty Loam** | **Sandy Loam** |
| Flat (0%) | Slow | Moderate | Fast |
| Sloped (10%) | Very slow | Slow | Moderate |

*TABLE 6.3B* ***Average Permeability Rates by Slope***

| **SOIL TEXTURE TYPE** | **PERCENT OF SLOPE** | | | | |
|---|---|---|---|---|---|
| | **0–4%** | **5–8%** | **8–12%** | **12–16%** | **Over 16%** |
| Coarse Sand | 1.25 in/hr<br>32 mm/hr | 1.00 in/hr<br>25 mm/hr | 0.75 in/hr<br>19 mm/hr | 0.50 in/hr<br>13 mm/hr | 0.31 in/hr<br>8 mm/hr |
| Fine Sand | 0.94 in/hr<br>24 mm/hr | 0.75 in/hr<br>18 mm/hr | 0.56 in/hr<br>13 mm/hr | 0.38 in/hr<br>9 mm/hr | 0.24 in/hr<br>6 mm/hr |
| Sandy Loam | 0.75 in/hr<br>19 mm/hr | 0.60 in/hr<br>15 mm/hr | 0.45 in/hr<br>11 mm/hr | 0.30 in/hr<br>8 mm/hr | 0.19 in/hr<br>5 mm/hr |
| Very Fine Sandy Loam | 0.59 in/hr<br>15 mm/hr | 0.47 in/hr<br>12 mm/hr | 0.35 in/hr<br>9 mm/hr | 0.24 in/hr<br>6 mm/hr | 0.15 in/hr<br>4 mm/hr |
| Silt Loam | 0.50 in/hr<br>13 mm/hr | 0.40 in/hr<br>10 mm/hr | 0.30 in/hr<br>8 mm/hr | 0.20 in/hr<br>5 mm/hr | 0.13 in/hr<br>3 mm/hr |
| Sandy Clay | 0.31 in/hr<br>8 mm/hr | 0.25 in/hr<br>6 mm/hr | 0.19 in/hr<br>5 mm/hr | 0.12 in/hr<br>3 mm/hr | 0.08 in/hr<br>2 mm/hr |
| Silty Clay | 0.19 in/hr<br>5 mm/hr | 0.15 in/hr<br>4 mm/hr | 0.11 in/hr<br>3 mm/hr | 0.08 in/hr<br>2 mm/hr | 0.05 in/hr<br>1 mm/hr |
| Clay | 0.13 in/hr<br>3 mm/hr | 0.10 in/hr<br>3 mm/hr | 0.08 in/hr<br>2 mm/hr | 0.05 in/hr<br>1 mm/hr | 0.03 in/hr<br>0.8 mm/hr |

Note: Rates based on full cover. These figures decrease with time and percent of cover. Derived from USDA information.

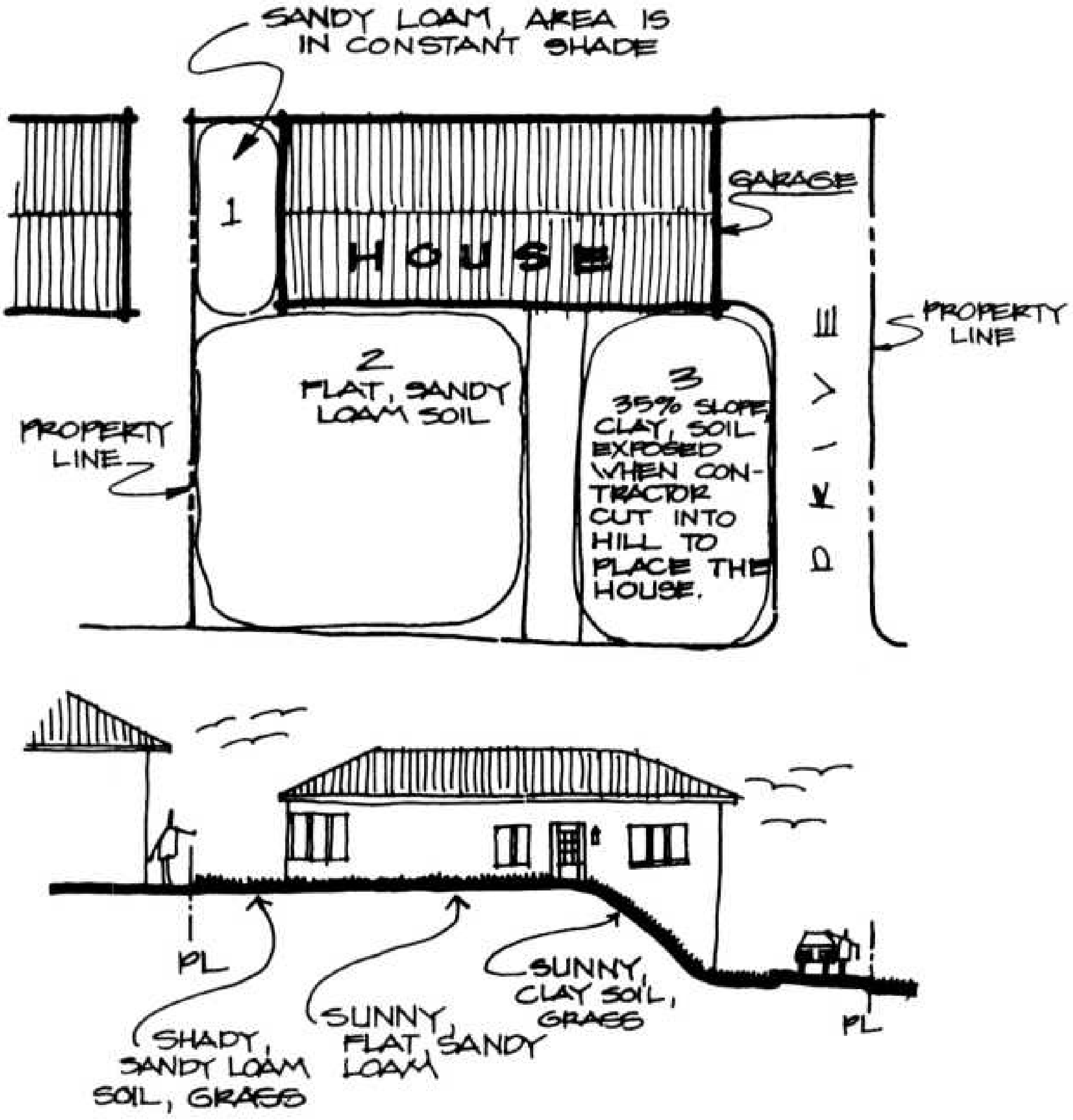


FIGURE 6. 1 Defined geographical areas.

1. Determine the geographical areas
2. Select the type of sprinkler heads we will use in each area
3. Develop a sprinkler head layout

**Determining Geographical Areas**

Our residential landscape features a one-story house with a garage on the basement level. The house is surrounded by turf that can be divided into three distinct geographical areas based on soil type, slope, and sun/shade conditions. The only area not in the sun all day long is the area between our house and another on the adjacent lot; this area is in the shade most of the day. The soil is sandy loam with a 1.7-in/hr (43mm/hr) permeability rate. The 35% sloped area used to be sandy loam soil as well, but when the contractor who built the house graded the property, he had to cut into the existing gently sloping hill to make way for access to the basement-level garage, thereby exposing a clay soil with a very slow permeability rate of 0.2 in/hr (5 mm/hr).

Based on this site information, we can define the three district geographical areas as follows:

1. The property on the side of the house is in constant shade. It is composed of sandy loam soils on a flat slope, and the plant cover is grass.

2. The front yard is in sun all day long. The soil is a sandy loam soil on a flat slope, and the plant cover is grass.

3. The area that slopes toward the drive is in sun all day and is covered with grass. The soil is clay, and the slope is 35%.

### Select the Sprinkler Head for Area 1

Now let us begin selecting irrigation heads for our three geographical areas of like watering needs. When we select a sprinkler head for an area, we are most concerned with answering these questions:

1. Does the radius of the sprinkler head fit the size of the area?

2. What is the largest radius head we can use in order to reduce the number of sprinkler heads and thus reduce the installed cost of the job?

3. Does the soil absorption rate or steep slopes require a sprinkler head that applies water very slowly?

Let us select sprinkler heads for geographical area 1, which is flat, covered in turf, shady all day long, and

composed of sandy loam soils that absorb water quickly. The area is 13 ft wide and 30 ft long (4 m X 9.1 m). We would like to find a sprinkler with a 13-ft (4 m) radius to fit the size of the small side yard. Figure 6.2 shows that although such a sprinkler head would fit the width of the space, we would have to stretch our water coverage a bit beyond head-to-head spacing lengthwise. This trial head location sketch, at least, gives us an idea of what radius we really want.

We need a head that not only fits the size of the site but also relates to the soil's ability to absorb water. Our soils are sandy loam in composition and they have a permeability rate of 1.7 in/hr (43 mm/hr) on a flat slope.

Now let us consider selection of a sprinkler head. In Table 6.4 we see that the nozzle for a spray head throws water from 13 ft to 16 ft, depending on water pressure. For full-circle (360°) heads, note how increased water pressure (measured in pounds per square inch [psi] or kilograms per square centimeter [kg/cm2]) will not only throw the water farther but will also push more of it through the sprinkler heads. On most irrigation jobs we have all the water pressure we need. So let us forget about water pressure and select a sprinkler head that works with our area's irrigation requirements. Before we forget about it, though, remember that water pressure is simply the power pushing the water through the pipes. We will thoroughly discuss the subject later, but for now you do not have to be concerned with it to select and lay out the sprinkler heads.

Looking at the page from a manufacturer's catalog reproduced in Figure 6.3, note the Specifications section of the 570 MPR nozzles data. We see that the radius is adjustable by a maximum of 25%, so the spray pattern can fit a space precisely. The radius is adjusted by a screw on top of the spray head, as shown in Figure 6.4. This allows the irrigation designer to water only the target area and not throw water onto sidewalks, walls, signs, and so on. Figure 6.5 shows the 570 spray heads in action.

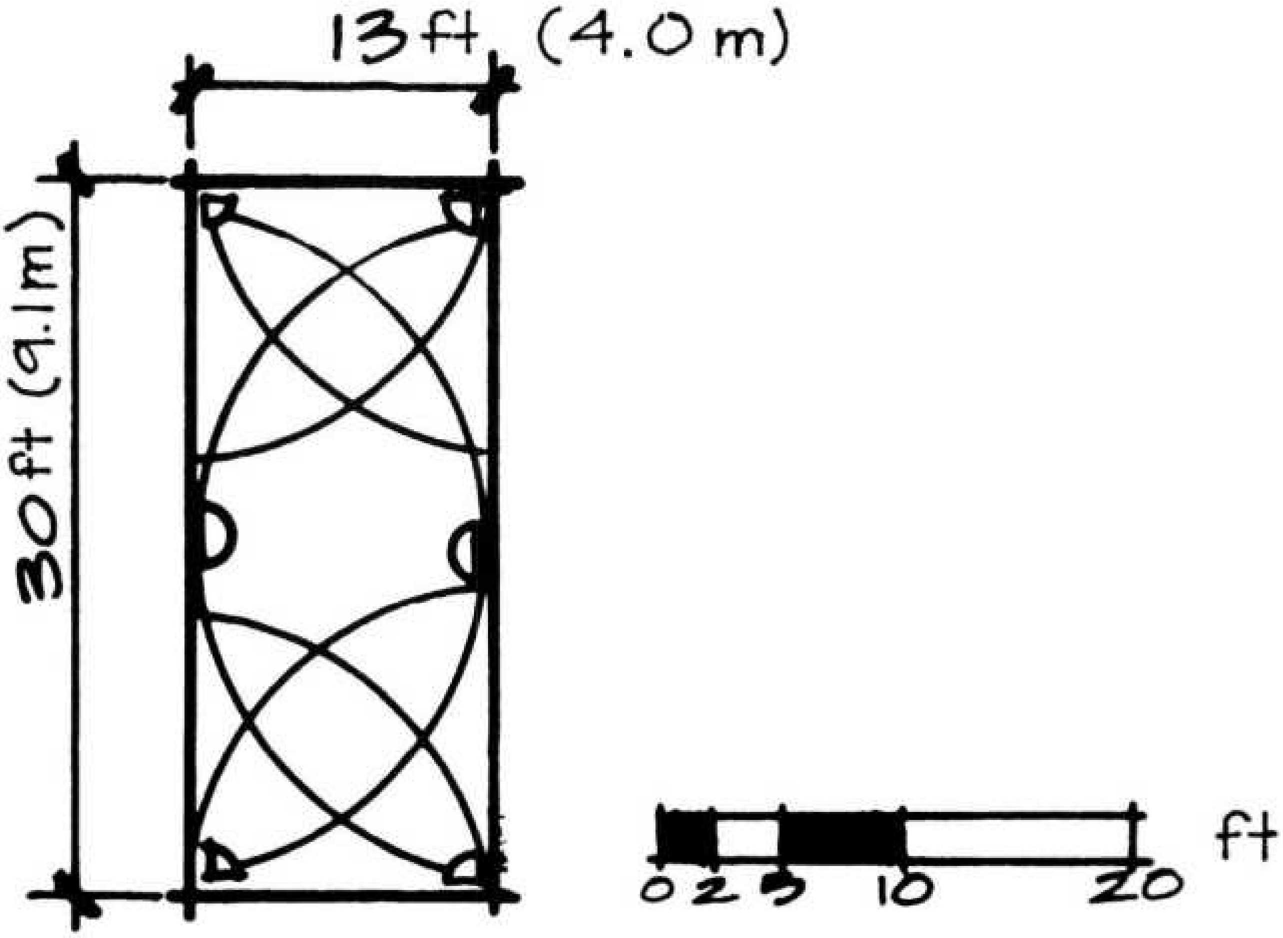


FIGURE 6.2 Geographical area 1-ideal head layout.

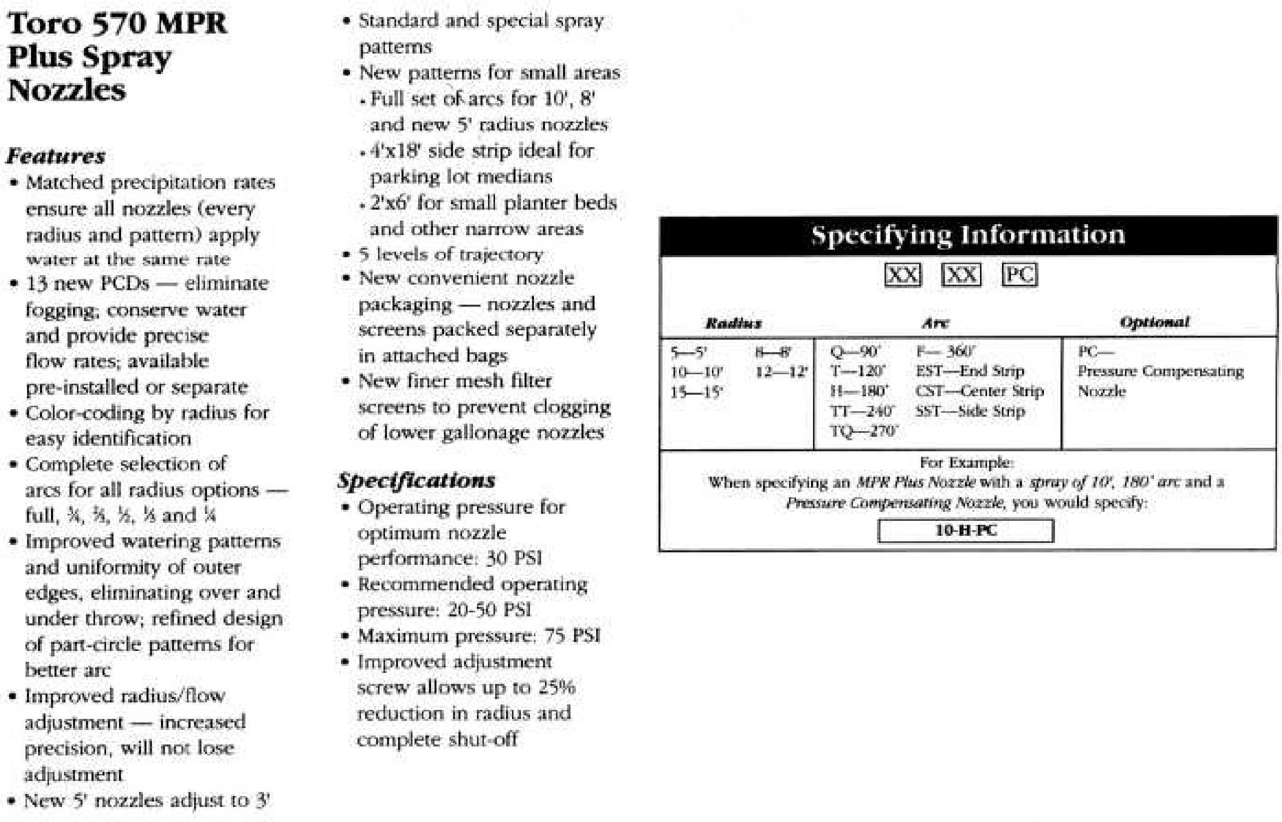
### TABLE 6.4 **Performance of a Full Circle 15 Foot Series 570 MPR Nozzle**

| **WATER PRESSURE** | | **WATER FLOW** | | **RADIUS OF THROW** | |
|---|---|---|---|---|---|
| **psi** | **kg/cm²** | **gpm** | **L/min** | **ft** | **m** |
| 20 | 1.41 | 2.85 | 10.79 | 13 | 4 |
| 30 | 2.11 | 3.6 | 13.63 | 15 | 4.6 |
| 40 | 2.81 | 4.2 | 15.9 | 16 | 4.9 |
| 50 | 3.52 | 4.58 | 17.34 | 16 | 4.9 |

Knowing that this spray head can be adjusted to fit our area, let us lay out our heads for the shady site. We begin by placing 15-ft (4.6-m) series quarter-circle heads in the four corners as shown in Figure 6.6.

We set the radius on our drawing at 13 feet (4 m), knowing that we can adjust the screw on top of the nozzle to fit any radius. Next, we look at the length of

the area to he watered and decide how we can space our 15-ft (4.6 m) Series heads along the 30-ft (9.1-m) stretch. The adjusted 13-ft (4-m) radius head throws water in a 26-ft (7.9-m) diameter, so it appears as though one half-circle head on either side of the 13 ft X 30 ft (4 m X 9.1 m) strip will adequately water the area. Note in Figure 6.7 that we do not have head-tohead coverage, but the arrangement is close enough to water our area. A large radius would throw water on the building and onto the neighbor's land. If we were to place two half-circle heads on either side, clearly the space would be overwatered in spots. It is best to go with one half-circle head on either side, even if it stretches our head-to-head coverage a bit. So our head layout for this area is the same as the ideal head layout that we developed in Figure 6.2. Because our grass is in constant shade, we will not water this area as much as if it were in full sun.



**Toro 570 MPR Plus Spray Nozzles**

***Features***

- Matched precipitation rates ensure all nozzles (every radius and pattern) apply water at the same rate
- 13 new PCDs — eliminate fogging; conserve water and provide precise flow rates; available pre-installed or separate
- Color-coding by radius for easy identification
- Complete selection of arcs for all radius options — full, ¾, ⅔, ½, ⅓ and ¼
- Improved watering patterns and uniformity of outer edges, eliminating over and under throw; refined design of part-circle patterns for better arc
- Improved radius/flow adjustment — increased precision, will not lose adjustment
- New 5' nozzles adjust to 3'
- Standard and special spray patterns
- New patterns for small areas
  - Full set of arcs for 10', 8' and new 5' radius nozzles
  - 4'x18' side strip ideal for parking lot medians
  - 2'x6' for small planter beds and other narrow areas
- 5 levels of trajectory
- New convenient nozzle packaging — nozzles and screens packed separately in attached bags
- New finer mesh filter screens to prevent clogging of lower gallonage nozzles

***Specifications***

- Operating pressure for optimum nozzle performance: 30 PSI
- Recommended operating pressure: 20-50 PSI
- Maximum pressure: 75 PSI
- Improved adjustment screw allows up to 25% reduction in radius and complete shut-off

**Specifying Information**

XX XX PC

| ***Radius*** | | ***Arc*** | | ***Optional*** |
|---|---|---|---|---|
| 5—5'<br>10—10'<br>15—15' | 8—8'<br>12—12' | Q—90°<br>T—120°<br>H—180°<br>TT—240°<br>TQ—270° | F— 360°<br>EST—End Strip<br>CST—Center Strip<br>SST—Side Strip | PC—<br>Pressure Compensating Nozzle |

For Example:
When specifying an *MPR Plus Nozzle* with a *spray of 10', 180° arc* and a *Pressure Compensating Nozzle*, you would specify:

**10-H-PC**

FIGURE 6.3 Page from a manufacturer's catalog. (Source: The Toro Company. Used with permission.)

**Select the Sprinkler Head for Area 2**

Now let us select sprinkler heads for geographical area 2. The area is flat, covered in turf, sunny all day, and composed of sandy loam soils that absorb water quickly. The area is 50 ft X 50 ft (15.2 m X 15.2 m), so we would like to find a sprinkler head with a radius of 50 ft (15.2 m). We see in Figure 6.8 that we could put a quarter-circle head in each corner and achieve headto-head coverage.

# Nozzle Performance Information

### 5' Series with 0° Trajectory

| Nozzle Radius | Pressure | GPM | Radius | Prec. Rate* | |
|---|---|---|---|---|---|
| | | | | ☐ | △ |
| 5-Q | 20 | 0.05 | 4 | 1.21 | 1.40 |
| ¼ | 30 | 0.09 | 5 | 1.40 | 1.61 |
| | 40 | 0.12 | 6 | 1.54 | 1.78 |
| | 50 | 0.15 | 6 | 1.62 | 1.86 |
| 5-Q-PC | 30-40 | 0.09 | 5 | 1.40 | 1.61 |
| | 40-75 | 0.10 | 5 | 1.55 | 1.79 |
| 5-T | 20 | 0.07 | 4 | 1.27 | 1.47 |
| ⅓ | 30 | 0.12 | 5 | 1.40 | 1.61 |
| | 40 | 0.16 | 6 | 1.54 | 1.78 |
| | 50 | 0.20 | 6 | 1.62 | 1.86 |
| 5-T-PC | 30-40 | 0.12 | 5 | 1.40 | 1.61 |
| | 40-75 | 0.13 | 5 | 1.55 | 1.79 |
| 5-H | 20 | 0.10 | 4 | 1.21 | 1.40 |
| ½ | 30 | 0.19 | 5 | 1.47 | 1.70 |
| | 40 | 0.23 | 6 | 1.47 | 1.70 |
| | 50 | 0.27 | 6 | 1.45 | 1.68 |
| 5-H-PC | 30-40 | 0.18 | 5 | 1.40 | 1.61 |
| | 40-75 | 0.20 | 5 | 1.55 | 1.79 |
| 5-TT | 20 | 0.15 | 4 | 1.36 | 1.57 |
| ⅔ | 30 | 0.25 | 5 | 1.45 | 1.68 |
| | 40 | 0.30 | 6 | 1.44 | 1.66 |
| | 50 | 0.35 | 6 | 1.41 | 1.63 |
| 5-TT-PC | 30-40 | 0.23 | 5 | 1.34 | 1.54 |
| | 40-75 | 0.27 | 5 | 1.57 | 1.81 |
| 5-TQ | 20 | 0.20 | 4 | 1.61 | 1.86 |
| ¾ | 30 | 0.29 | 5 | 1.50 | 1.73 |
| | 40 | 0.34 | 6 | 1.45 | 1.68 |
| | 50 | 0.40 | 6 | 1.44 | 1.66 |
| 5-TQ-PC | 30-40 | 0.26 | 5 | 1.34 | 1.55 |
| | 40-75 | 0.29 | 5 | 1.50 | 1.73 |
| 5-F | 20 | 0.25 | 4 | 1.51 | 1.75 |
| | 30 | 0.38 | 5 | 1.47 | 1.70 |
| ● | 40 | 0.45 | 6 | 1.44 | 1.66 |
| | 50 | 0.53 | 6 | 1.43 | 1.65 |
| 5-F-PC | 30-40 | 0.35 | 5 | 1.36 | 1.57 |
| | 40-75 | 0.39 | 5 | 1.51 | 1.75 |

### 8' Series with 5° Trajectory

| Nozzle Radius | Pressure | GPM | Radius | Prec. Rate* | |
|---|---|---|---|---|---|
| | | | | ☐ | △ |
| 8-Q | 20 | 0.17 | 7 | 1.34 | 1.55 |
| ¼ | 30 | 0.24 | 8 | 1.45 | 1.68 |
| | 40 | 0.26 | 9 | 1.39 | 1.61 |
| | 50 | 0.29 | 9 | 1.39 | 1.60 |
| 8-Q-PC | 30-40 | 0.22 | 8 | 1.33 | 1.54 |
| | 40-75 | 0.25 | 8 | 1.51 | 1.75 |
| 8-T | 20 | 0.23 | 7 | 1.36 | 1.58 |
| ⅓ | 30 | 0.30 | 8 | 1.36 | 1.57 |
| | 40 | 0.36 | 9 | 1.45 | 1.67 |
| | 50 | 0.40 | 9 | 1.44 | 1.66 |
| 8-T-PC | 30-40 | 0.29 | 8 | 1.32 | 1.52 |
| | 40-75 | 0.35 | 8 | 1.59 | 1.84 |
| 8-H | 20 | 0.37 | 8 | 1.27 | 1.47 |
| ½ | 30 | 0.50 | 8 | 1.51 | 1.75 |
| | 40 | 0.58 | 9 | 1.56 | 1.80 |
| | 50 | 0.65 | 9 | 1.56 | 1.80 |
| 8-H-PC | 30-40 | 0.44 | 8 | 1.33 | 1.54 |
| | 40-75 | 0.50 | 8 | 1.51 | 1.75 |
| 8-TT | 20 | 0.56 | 7 | 1.66 | 1.92 |
| ⅔ | 30 | 0.70 | 8 | 1.59 | 1.84 |
| | 40 | 0.80 | 9 | 1.61 | 1.86 |
| | 50 | 0.88 | 9 | 1.58 | 1.82 |
| 8-TT-PC | 30-40 | 0.59 | 8 | 1.34 | 1.55 |
| | 40-75 | 0.70 | 8 | 1.59 | 1.84 |
| 8-TQ | 20 | 0.63 | 7 | 1.66 | 1.92 |
| ¾ | 30 | 0.76 | 8 | 1.53 | 1.77 |
| | 40 | 0.86 | 9 | 1.54 | 1.78 |
| | 50 | 0.93 | 9 | 1.48 | 1.71 |
| 8-TQ-PC | 30-40 | 0.64 | 8 | 1.29 | 1.49 |
| | 40-75 | 0.70 | 8 | 1.41 | 1.63 |
| 8-F | 20 | 0.74 | 7 | 1.46 | 1.69 |
| | 30 | 1.00 | 8 | 1.51 | 1.75 |
| ● | 40 | 1.16 | 9 | 1.56 | 1.80 |
| | 50 | 1.30 | 9 | 1.56 | 1.80 |
| 8-F-PC | 30-40 | 0.85 | 8 | 1.29 | 1.49 |
| | 40-75 | 1.00 | 8 | 1.51 | 1.75 |

### 10' Series with 12° Trajectory

| Nozzle Radius | Pressure | GPM | Radius | Prec. Rate* | |
|---|---|---|---|---|---|
| | | | | ☐ | △ |
| 10-Q | 20 | 0.30 | 9 | 1.44 | 1.66 |
| ¼ | 30 | 0.40 | 10 | 1.55 | 1.79 |
| | 40 | 0.50 | 11 | 1.60 | 1.85 |
| | 50 | 0.60 | 12 | 1.62 | 1.86 |
| 10-Q-PC | 30-40 | 0.33 | 10 | 1.28 | 1.48 |
| | 40-75 | 0.37 | 10 | 1.43 | 1.66 |
| 10-T | 20 | 0.42 | 9 | 1.51 | 1.74 |
| ⅓ | 30 | 0.52 | 10 | 1.51 | 1.75 |
| | 40 | 0.65 | 11 | 1.56 | 1.80 |
| | 50 | 0.75 | 12 | 1.51 | 1.75 |
| 10-T-PC | 30-40 | 0.44 | 10 | 1.28 | 1.48 |
| | 40-75 | 0.50 | 10 | 1.45 | 1.68 |
| 10-H | 20 | 0.60 | 9 | 1.44 | 1.66 |
| ½ | 30 | 0.71 | 10 | 1.38 | 1.59 |
| | 40 | 0.85 | 11 | 1.36 | 1.57 |
| | 50 | 0.99 | 12 | 1.43 | 1.65 |
| 10-H-PC | 30-40 | 0.66 | 10 | 1.28 | 1.48 |
| | 40-75 | 0.75 | 10 | 1.45 | 1.68 |
| 10-TT | 20 | 0.71 | 9 | 1.27 | 1.47 |
| ⅔ | 30 | 0.97 | 10 | 1.41 | 1.63 |
| | 40 | 1.10 | 11 | 1.45 | 1.67 |
| | 50 | 1.19 | 11 | 1.43 | 1.65 |
| 10-TT-PC | 30-40 | 0.89 | 10 | 1.29 | 1.49 |
| | 40-75 | 1.00 | 10 | 1.45 | 1.68 |
| 10-TQ | 20 | 0.82 | 9 | 1.31 | 1.51 |
| ¾ | 30 | 1.04 | 10 | 1.34 | 1.55 |
| | 40 | 1.20 | 11 | 1.41 | 1.62 |
| | 50 | 1.35 | 11 | 1.44 | 1.66 |
| 10-TQ-PC | 30-40 | 0.99 | 10 | 1.28 | 1.48 |
| | 40-75 | 1.09 | 10 | 1.41 | 1.63 |
| 10-F | 20 | 1.11 | 9 | 1.49 | 1.72 |
| | 30 | 1.49 | 10 | 1.44 | 1.67 |
| ● | 40 | 1.61 | 11 | 1.42 | 1.63 |
| | 50 | 1.85 | 11 | 1.48 | 1.71 |
| 10-F-PC | 30-40 | 1.33 | 10 | 1.29 | 1.49 |
| | 40-75 | 1.51 | 10 | 1.46 | 1.69 |

### 12' Series with 23° Trajectory

| Nozzle Radius | Pressure | GPM | Radius | Prec. Rate* | |
|---|---|---|---|---|---|
| | | | | ☐ | △ |
| 12-Q | 20 | 0.40 | 11 | 1.28 | 1.48 |
| ¼ | 30 | 0.50 | 12 | 1.35 | 1.55 |
| | 40 | 0.60 | 13 | 1.42 | 1.64 |
| | 50 | 0.63 | 13 | 1.44 | 1.67 |
| 12-Q-PC | 30-40 | 0.48 | 12 | 1.29 | 1.49 |
| | 40-75 | 0.53 | 12 | 1.43 | 1.65 |
| 12-T | 20 | 0.57 | 11 | 1.37 | 1.58 |
| ⅓ | 30 | 0.72 | 12 | 1.45 | 1.68 |
| | 40 | 0.87 | 13 | 1.62 | 1.87 |
| | 50 | 0.97 | 13 | 1.67 | 1.93 |
| 12-T-PC | 30-40 | 0.64 | 12 | 1.29 | 1.49 |
| | 40-75 | 0.70 | 12 | 1.41 | 1.63 |
| 12-H | 20 | 0.95 | 11 | 1.52 | 1.76 |
| ½ | 30 | 1.09 | 12 | 1.47 | 1.69 |
| | 40 | 1.30 | 13 | 1.49 | 1.72 |
| | 50 | 1.55 | 14 | 1.53 | 1.77 |
| 12-H-PC | 30-40 | 0.96 | 12 | 1.29 | 1.49 |
| | 40-75 | 1.05 | 12 | 1.41 | 1.63 |
| 12-TT | 20 | 1.12 | 11 | 1.35 | 1.55 |
| ⅔ | 30 | 1.45 | 12 | 1.46 | 1.69 |
| | 40 | 1.63 | 13 | 1.52 | 1.75 |
| | 50 | 1.80 | 13 | 1.55 | 1.79 |
| 12-TT-PC | 30-40 | 1.28 | 12 | 1.29 | 1.49 |
| | 40-75 | 1.40 | 12 | 1.41 | 1.63 |
| 12-TQ | 20 | 1.05 | 11 | 1.23 | 1.42 |
| ¾ | 30 | 1.55 | 12 | 1.39 | 1.61 |
| | 40 | 1.65 | 13 | 1.36 | 1.58 |
| | 50 | 1.80 | 13 | 1.38 | 1.59 |
| 12-TQ-PC | 30-40 | 1.44 | 12 | 1.29 | 1.49 |
| | 40-75 | 1.60 | 12 | 1.44 | 1.66 |
| 12-F | 20 | 1.67 | 11 | 1.34 | 1.54 |
| | 30 | 2.19 | 12 | 1.47 | 1.70 |
| ● | 40 | 2.35 | 13 | 1.46 | 1.68 |
| | 50 | 2.70 | 13 | 1.55 | 1.79 |
| 12-F-PC | 30-40 | 1.92 | 12 | 1.29 | 1.49 |
| | 40-75 | 2.10 | 12 | 1.41 | 1.63 |

### 15' Series with 27° Trajectory

| Nozzle Radius | Pressure | GPM | Radius | Prec. Rate* | |
|---|---|---|---|---|---|
| | | | | ☐ | △ |
| 15-Q | 20 | 0.68 | 14 | 1.34 | 1.55 |
| ¼ | 30 | 0.85 | 15 | 1.46 | 1.69 |
| | 40 | 1.04 | 16 | 1.57 | 1.82 |
| | 50 | 1.23 | 16 | 1.86 | 2.15 |
| 15-Q-PC | 30-40 | 0.75 | 15 | 1.29 | 1.49 |
| | 40-75 | 0.81 | 15 | 1.40 | 1.61 |
| 15-T | 20 | 0.95 | 14 | 1.52 | 1.75 |
| ⅓ | 30 | 1.10 | 15 | 1.42 | 1.64 |
| | 40 | 1.30 | 16 | 1.57 | 1.82 |
| | 50 | 1.45 | 16 | 1.75 | 2.03 |
| 15-T-PC | 30-40 | 1.00 | 15 | 1.29 | 1.49 |
| | 40-75 | 1.10 | 15 | 1.42 | 1.64 |
| 15-H | 20 | 1.37 | 13 | 1.55 | 1.79 |
| ½ | 30 | 1.65 | 15 | 1.44 | 1.66 |
| | 40 | 2.02 | 16 | 1.53 | 1.77 |
| | 50 | 2.14 | 16 | 1.62 | 1.87 |
| 15-H-PC | 30-40 | 1.50 | 15 | 1.29 | 1.49 |
| | 40-75 | 1.65 | 15 | 1.42 | 1.64 |
| 15-TT | 20 | 1.78 | 14 | 1.38 | 1.59 |
| ⅔ | 30 | 2.20 | 15 | 1.42 | 1.64 |
| | 40 | 2.66 | 16 | 1.51 | 1.74 |
| | 50 | 2.84 | 16 | 1.61 | 1.86 |
| 15-TT-PC | 30-40 | 2.00 | 15 | 1.29 | 1.49 |
| | 40-75 | 2.20 | 15 | 1.42 | 1.64 |
| 15-TQ | 20 | 2.10 | 13 | 1.61 | 1.85 |
| ¾ | 30 | 2.60 | 15 | 1.49 | 1.72 |
| | 40 | 3.00 | 16 | 1.61 | 1.86 |
| | 50 | 3.40 | 16 | 1.72 | 1.98 |
| 15-TQ-PC | 30-40 | 2.30 | 15 | 1.32 | 1.53 |
| | 40-75 | 2.50 | 15 | 1.44 | 1.66 |
| 15-F | 20 | 2.85 | 13 | 1.63 | 1.89 |
| | 30 | 3.60 | 15 | 1.55 | 1.79 |
| ● | 40 | 4.20 | 16 | 1.59 | 1.84 |
| | 50 | 4.58 | 16 | 1.73 | 2.00 |
| 15-F-PC | 30-40 | 3.00 | 15 | 1.29 | 1.49 |
| | 40-75 | 3.30 | 15 | 1.42 | 1.64 |

### Special Patterns

| Nozzle Radius | Pressure | GPM | Special Patterns | | | Prec. Rate* |
|---|---|---|---|---|---|---|
| | | | Width | | Length | |
| 4-EST | 20 | 0.38 | 3' | x | 12' | 2.03 |
| | 30 | 0.45 | 4' | x | 15' | 1.44 |
| | 40 | 0.53 | 5' | x | 18' | 1.13 |
| | 50 | 0.60 | 6' | x | 20' | 0.96 |
| 4-EST-PC | 30-40 | 0.43 | 4' | x | 15' | 1.38 |
| | 40-75 | 0.50 | 4' | x | 15' | 1.61 |
| 4-CST | 20 | 0.75 | 3' | x | 24' | 2.01 |
| | 30 | 0.90 | 4' | x | 30' | 1.44 |
| | 40 | 1.04 | 4' | x | 30' | 1.67 |
| | 50 | 1.16 | 4' | x | 31' | 1.80 |
| 4-CST-PC | 30-40 | 0.86 | 4' | x | 30' | 1.38 |
| | 40-75 | 1.00 | 4' | x | 30' | 1.61 |
| 9-SST | 20 | 1.00 | 9' | x | 18' | 1.19 |
| | 30 | 1.20 | 9' | x | 18' | 1.43 |
| | 40 | 1.38 | 9' | x | 20' | 1.48 |
| | 50 | 1.55 | 10' | x | 22' | 1.36 |
| 9-SST-PC | 30-40 | 1.10 | 9' | x | 18' | 1.31 |
| | 40-75 | 1.20 | 9' | x | 18' | 1.43 |
| 4-SST | 20 | 0.65 | 4' | x | 24' | 1.30 |
| | 30 | 0.90 | 4' | x | 30' | 1.44 |
| | 40 | 1.04 | 4' | x | 32' | 1.56 |
| | 50 | 1.16 | 5' | x | 33' | 1.35 |
| 4-SST-PC | 30-40 | 0.88 | 4' | x | 30' | 1.41 |
| | 40-75 | 1.00 | 4' | x | 30' | 1.61 |
| 2-SST | 20 | 0.08 | 2' | x | 5' | 1.54 |
| | 30 | 0.09 | 2' | x | 6' | 1.44 |
| | 40 | 0.10 | 2' | x | 7' | 1.38 |
| | 50 | 0.12 | 3' | x | 7' | 1.10 |
| 2-SST-PC | 30-40 | 0.09 | 2' | x | 6' | 1.44 |
| | 40-75 | 0.10 | 2' | x | 6' | 1.61 |
| 4S-SST | 20 | 0.46 | 4' | x | 17' | 1.30 |
| | 30 | 0.55 | 4' | x | 18' | 1.47 |
| | 40 | 0.63 | 4' | x | 19' | 1.60 |
| | 50 | 0.71 | 5' | x | 19' | 1.44 |
| 4S-SST-PC | 30-40 | 0.50 | 4' | x | 18' | 1.34 |
| | 40-75 | 0.59 | 4' | x | 18' | 1.58 |

* △ Precipitation rates are for triangular spacing, shown in inches per hour calculated at 50% of diameter.
☐ Precipitation rates are for square spacing, shown in inches per hour, calculated at 50% of diameter.
All performance specifications are based on the stated working pressure available at the base of the sprinkler head.

FIGURE 6.3 (continued)

Looking back at Table 2.1, our sprinkler head radius chart, we see that the Super 600 Rotary Sprinkler that has a 35 ft-50 ft (10.7 m-15.2 m) radius might be the one to use to cover our front yard. To find out, let us examine our manufacturer's sprinkler performance chart in Figure 6.9. We have a choice of three nozzles to use (the maximum radii listed are based on 50 psi):

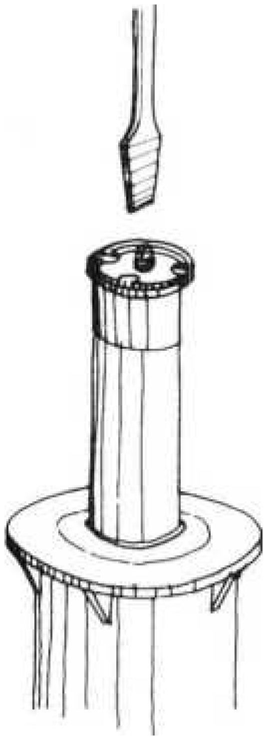


FIGURE 6.4 579 head with adjustment screw.

FIGURE 6.5 570 spray heads.

1. The 1.3 nozzle (approximately 1.3 gpm, 4.92 L/min) throws a quarter-circle pattern and has up to a 40-ft (12.2-m) radius.

2. The 2.5 nozzle throws a quarter-circle and a half-circle pattern and has a 45-ft (13.9-m) radius.

3. The 5.0 nozzle throws a quarter-circle, halfcircle, and full-circle pattern and has a radius of 50 ft (15.2 m).

Be sure to note that the 1.3 nozzle size only works in a quarter-circle pattern and that the 2.5 nozzle works in both a quarter-circle and half-circle pattern. If you were going to use quarter-circle and half-circle heads together in the same irrigation area, you would want to use the 1.3 quarter-circle nozzle with the 2.5 half-circle nozzle so that your resulting precipitation would be balanced, or evenly distributed throughout the irrigation area. Remember, a half-circle head covers twice as much area as a quarter-circle head, so the half-circle nozzle should put out approximately twice the gpm (L/min) flow as the quarter-circle nozzle. This occurs with balanced precipitation.

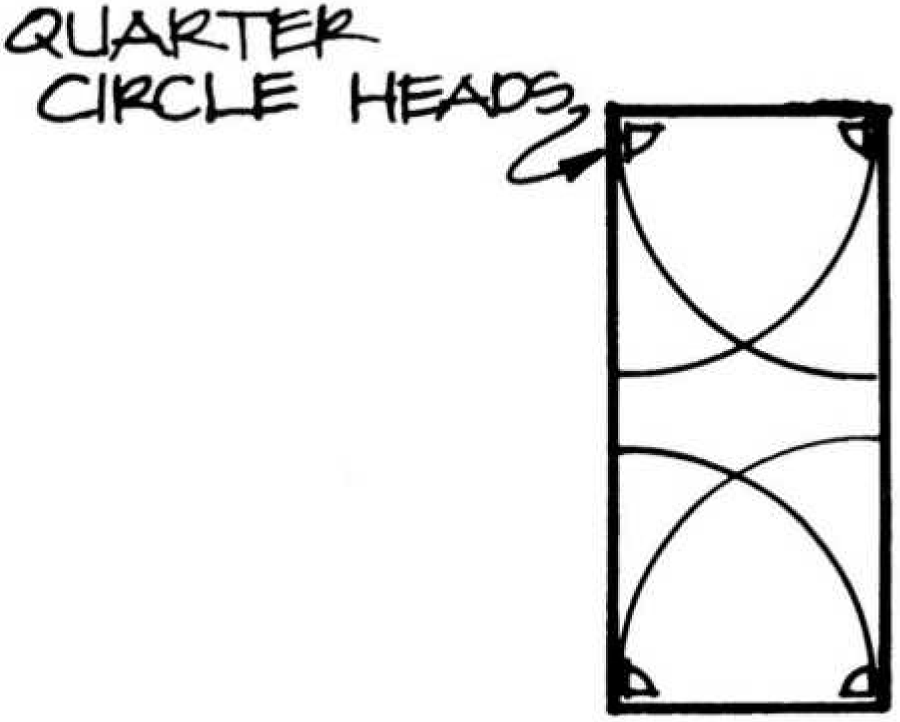


FIGURE 6.6 Irrigation area 1.

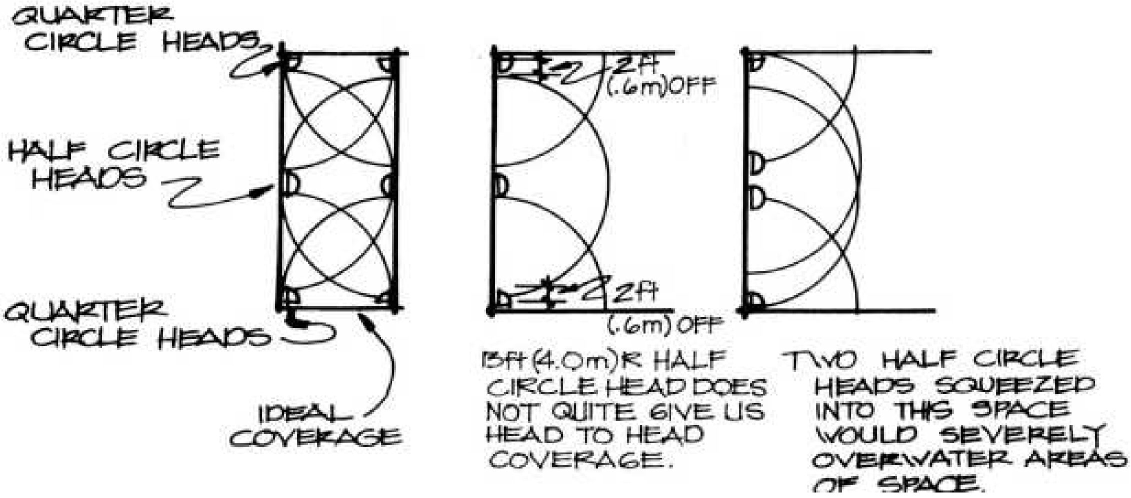


FIGURE 6.7 Spacing spray heads.

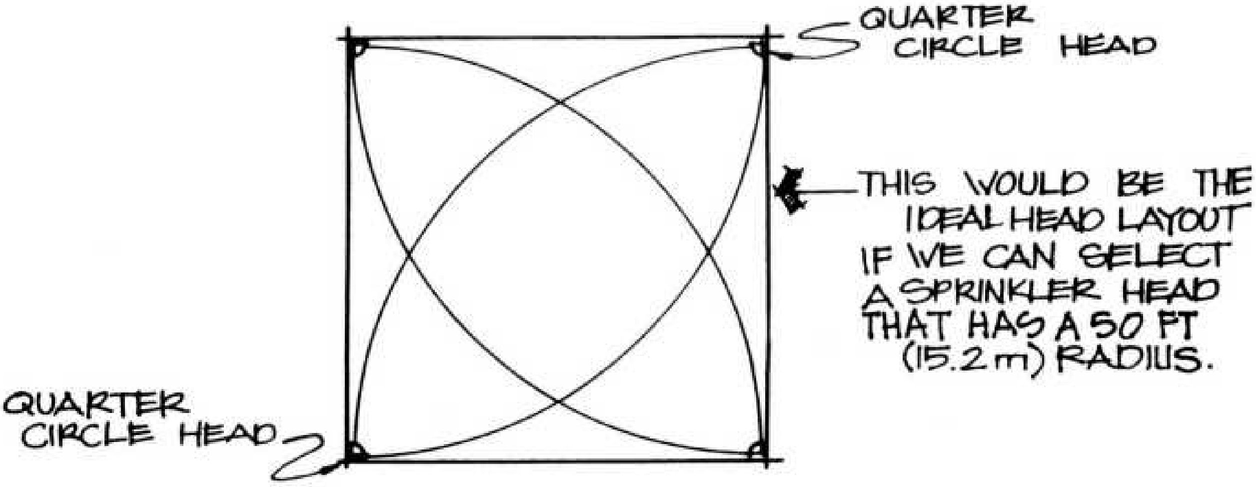
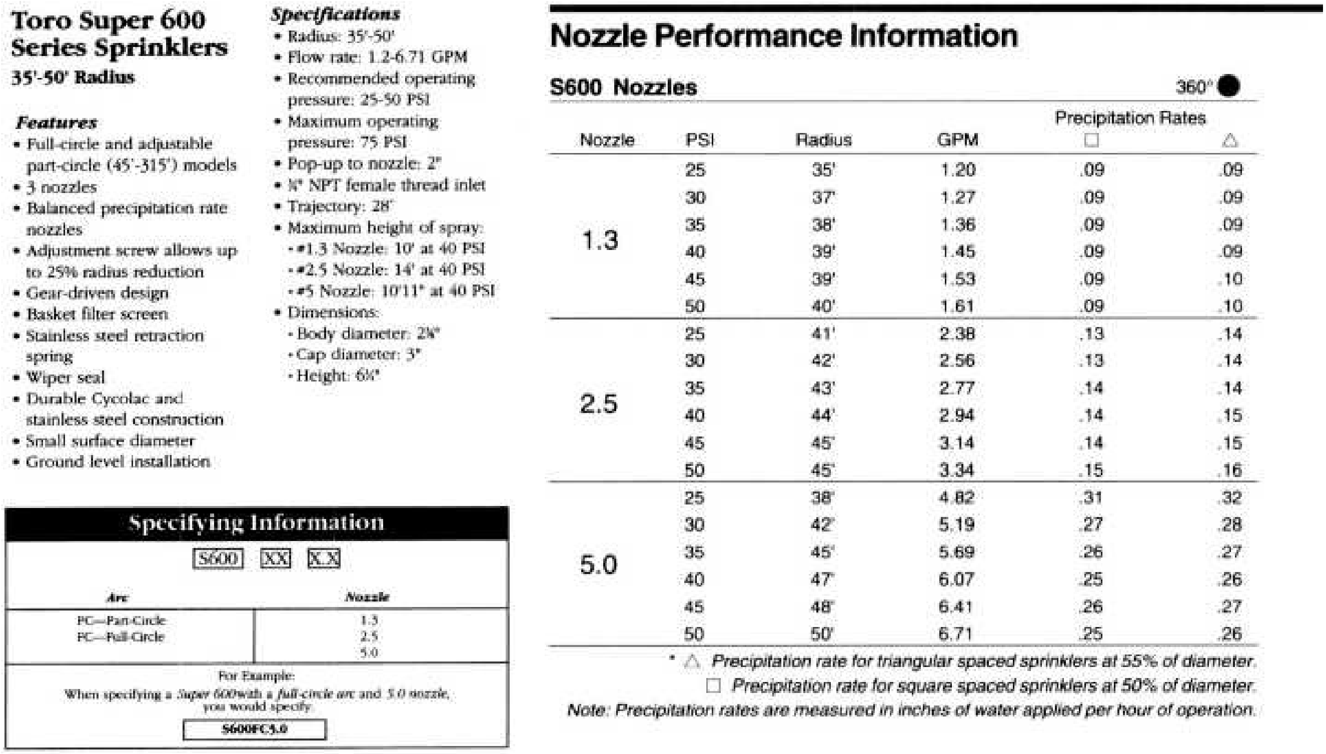


FIGURE 6.8 Geographical area 2-ideal head layout.



**Toro Super 600 Series Sprinklers**
**35'-50' Radius**

***Features***

- Full-circle and adjustable part-circle (45'-315') models
- 3 nozzles
- Balanced precipitation rate nozzles
- Adjustment screw allows up to 25% radius reduction
- Gear-driven design
- Basket filter screen
- Stainless steel retraction spring
- Wiper seal
- Durable Cycolac and stainless steel construction
- Small surface diameter
- Ground level installation

***Specifications***

- Radius: 35'-50'
- Flow rate: 1.2-6.71 GPM
- Recommended operating pressure: 25-50 PSI
- Maximum operating pressure: 75 PSI
- Pop-up to nozzle: 2"
- ¾" NPT female thread inlet
- Trajectory: 28°
- Maximum height of spray:
  - #1.3 Nozzle: 10' at 40 PSI
  - #2.5 Nozzle: 14' at 40 PSI
  - #5 Nozzle: 10'11" at 40 PSI
- Dimensions:
  - Body diameter: 2⅜"
  - Cap diameter: 3"
  - Height: 6¼"

**Specifying Information**

S600 XX X.X

| *Arc* | *Nozzle* |
|---|---|
| PC—Part-Circle<br>PC—Full-Circle | 1.3<br>2.5<br>5.0 |

For Example:
When specifying a *Super 600* with a *full-circle arc* and *5.0 nozzle*, you would specify:
**S600FC5.0**

**Nozzle Performance Information**

**S600 Nozzles** 360° ●

| Nozzle | PSI | Radius | GPM | Precipitation Rates ☐ | △ |
|---|---|---|---|---|---|
| 1.3 | 25 | 35' | 1.20 | .09 | .09 |
| | 30 | 37' | 1.27 | .09 | .09 |
| | 35 | 38' | 1.36 | .09 | .09 |
| | 40 | 39' | 1.45 | .09 | .09 |
| | 45 | 39' | 1.53 | .09 | .10 |
| | 50 | 40' | 1.61 | .09 | .10 |
| 2.5 | 25 | 41' | 2.38 | .13 | .14 |
| | 30 | 42' | 2.56 | .13 | .14 |
| | 35 | 43' | 2.77 | .14 | .14 |
| | 40 | 44' | 2.94 | .14 | .15 |
| | 45 | 45' | 3.14 | .14 | .15 |
| | 50 | 45' | 3.34 | .15 | .16 |
| 5.0 | 25 | 38' | 4.82 | .31 | .32 |
| | 30 | 42' | 5.19 | .27 | .28 |
| | 35 | 45' | 5.69 | .26 | .27 |
| | 40 | 47' | 6.07 | .25 | .26 |
| | 45 | 48' | 6.41 | .26 | .27 |
| | 50 | 50' | 6.71 | .25 | .26 |

** △ Precipitation rate for triangular spaced sprinklers at 55% of diameter.*
*☐ Precipitation rate for square spaced sprinklers at 50% of diameter.*
*Note: Precipitation rates are measured in inches of water applied per hour of operation.*

FIGURE 6.9 Super 600 Sprinkler performance chart. (Source: The Toro Company. Used with permission.)

Note that you can use the 5.0 nozzle in the quarter, half-, and full-ciircle patterns, but in order for it to be balanced for use with a quarter- and half-circle pattern, you need to use the 5.0 nozzle only in a full-circle pattern. The 5.0 nozzle throws a quarter-circle radius of 50 ft (15.2 ni), so it fits our ideal head layout perfectly! Because we are not mixing quarter-circle heads with half- and full-circle heads in this irrigation area, it is acceptable to use the 5.0 nozzle with a quarter-circle pattern to better fit the size of the space. If our space had been 42 ft or 47 ft (12.8 in or 14.3 m) square, the Super 600 Series head would still have worked because its radius can be reduced by 25%, or down to 37.5 ft (11.4 m).

50 ft (15.2 m) × 0.25 = 12.5 ft (3.8 m)
(25% is 0.25 when you multiply)
50 ft (15.2 m) – 12.5 ft (3.8 m) = 37.5 ft (11.4 m)

**Select the Sprinkler Head for Area 3**

This irrigation area has a 35% slope and is covered in turf, sunny all day long, and composed of clay soils that absorb water very slowly. The area is 28 ft X 50 ft (8.5m X 15.2 m).

We would like to find a sprinkler head with a radius of 28 ft (8.5 m) to fit the width of the sloped lawn area. This head should also have a low precipitation rate be

cause of the slow absorption rate of the clay soils and the steep slope. We want to avoid water runoff. Trying the 28-ft (8.5-m) ideal radius, as shown in Figure 6.10, we use quarter-circle heads in the four corners and find that they work well.

For our half-circle heads, again trying to achieve head-to-head coverage, we see that the 28-ft (8.5-m) radius will throw water onto the house and into the street. Overthrow onto the house will probably discolor the building material over time, and overthrow into the road will not only waste water but also create a slick spot that could be hazardous to drivers. So we need to reduce the 28-ft (8.5-m) radius on our halfcircle patterns to 25 ft (7.6 m), which will fit the 50-ft (15.2-m) length of the sloped area. We would like to find a sprinkler head that has a 28-ft (8.5-m) radius for our quarter-circle situation and whose radius can be adjusted to fit our half-circle situation. Let us see if what would be ideal is available.

Looking back at Table 2.1, our sprinkler head radius chart, we see that either a Steam Rotor with a radius of 15 ft to 30 ft (4.6 in to 9.1 m) or an XP-300 with a radius of 28 ft to 43 ft (8.5 in to 13.1 m) might work on our slope. We can see that even the Super 600 or 700 could work.

Let us first examine the Nozzle Performance section of the Stream Rotor's sprinkler performance data in Figure 6.11. We see that there are fixed-radius and adjustable-radius nozzles. Looking at the fixed-radius nozzles performance chart, we see that the radius varies according to the nozzle size and the water pressure. The precipitation rates in the chart are low for the -63 and -93 nozzles, which is good for our slope. However, the radius does not fit our space, so we need to look further for another sprinkler head whose radius and precipitation rate more ideally fits our site. The adjustable-radius nozzles will work, but note that the precipitation rates are high, especially on sloped lawn areas. So let us see if the XP-300 Rotor might fit our needs better.

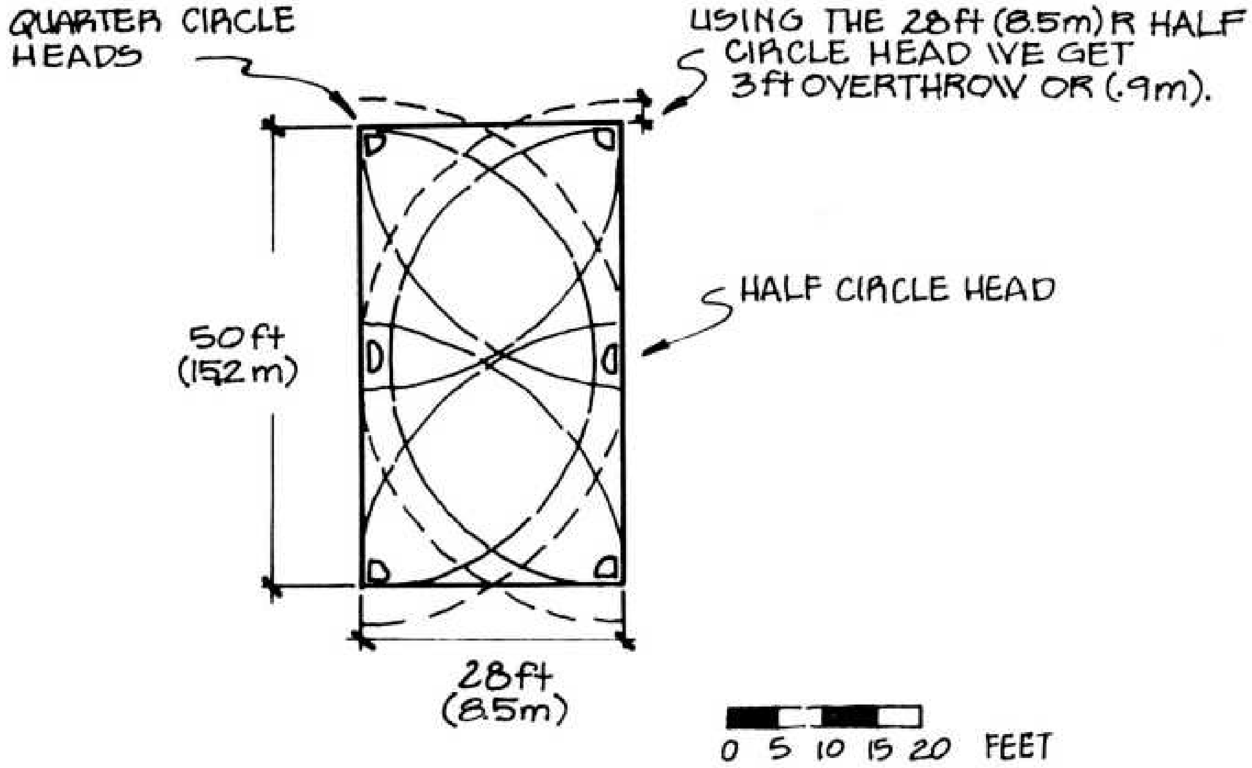


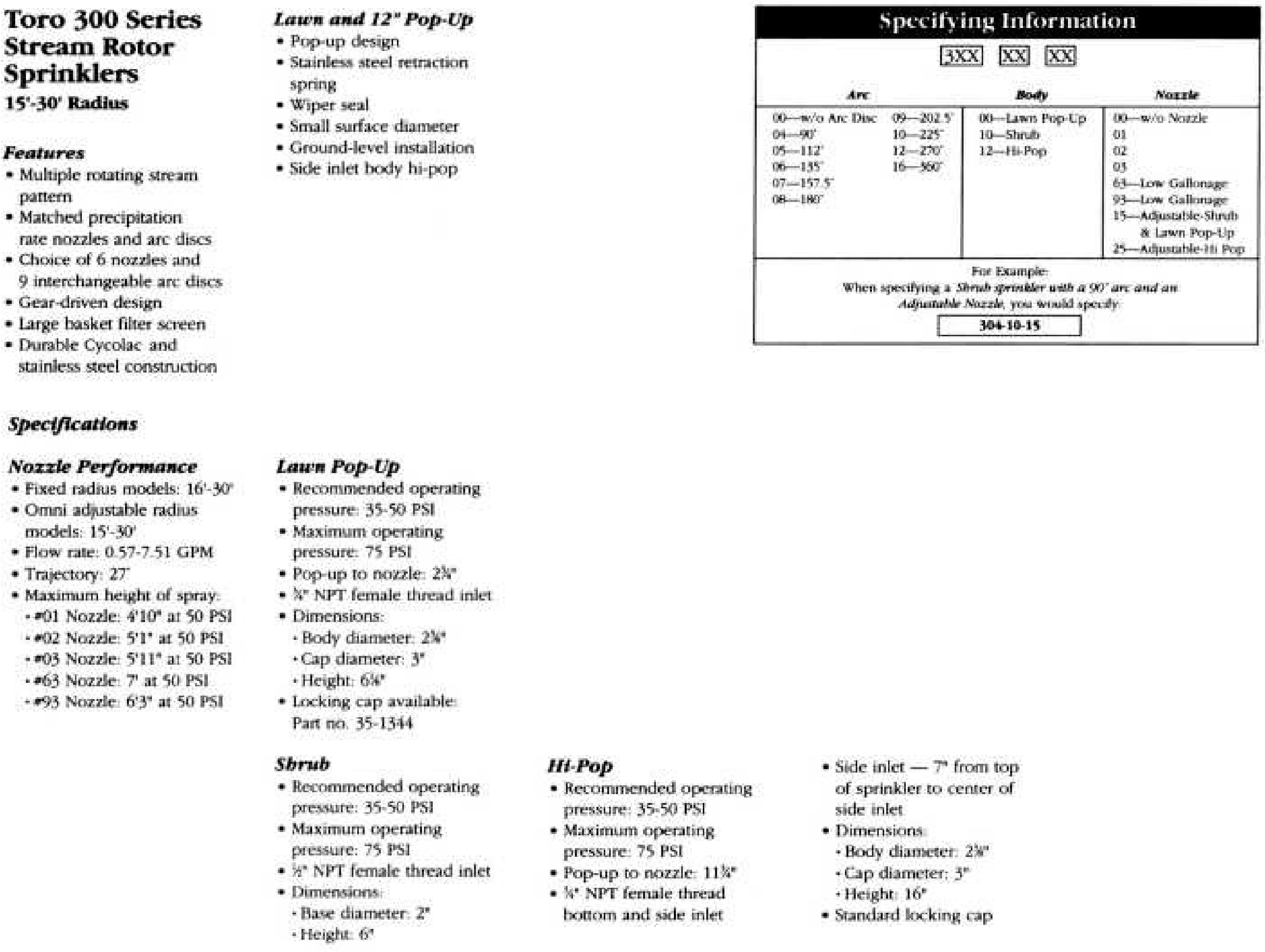
FIGURE 6. 10 Area 3-ideal head layout.

Looking at the XP-300 Rotor in Figure 6.12, we see that the head features a watering radius that is reducible up to 25%. This will provide some versatility in fitting the head to our site. The precipitation rates appear low, too.

The radius varies according to the nozzles used and the pressure at which the sprinkler head is operated. The -05 nozzle in the sprinkler performance chart has a 28-ft (8.5-m) radius at 35 psi (2.46 kg/cm2). The precipitation rate is 0.5 in/hr (13 mm/hr). The sprinkler radius can be reduced up to 25%, so we can cut our 28-ft (8.5-m) radius down to 25 ft (7.6 m) in order for our half-circle heads to fit the space. Using the XP-300 Rotor, we are then able to

achieve an ideal sprinkler head layout, as shown in Figure 6.13.

However, since area 3 is on a slope, we need to consider dividing the sprinkler heads into two zones, with the heads along the hilltop on one valve and the heads at the bottom of the hill on another. The problem with irrigating hillsides is that the water is always running downhill, often resulting in too much water at the bottom and not enough at the top. By placing the heads on two zones, the hilltop heads can be run more frequently at shorter run times. The heads at the bottom of the slope can be run longer than the hilltop heads. Trajectory of throw becomes important here, too. Flat or low-angle nozzles should be selected for the top of the hill, and standard or 25° trajectory heads would work best at the bottom of the hill (see Figure 6.13). Looking at the specifications for the XP-300, we see it is only available in a 28° trajectory. The Super 700 rotor (Figure 5.4) is available in flat (7°) , low (15°) , and standard (25°) trajectories. So to fit the slope conditions of this third area, we will use the Super 700 head. Because its radius is reducible up to 25%, we can use the 1.5 nozzle for our quarter-circle arcs and the 3.0 nozzle for our half-circle arcs. We will use flat-angle nozzles operated at 45 psi (3.16 kg/cm2) at the top of the hill and standard-angle nozzles operated at 25 psi (1.76 kg/cm2) along the bottom. Of interest is that the Super 700's precipitation rates are less than half of those for the XP'-300 nozzles. Looking at the half-circle, standard-angle 3.0 nozzle operated at 25 psi (1.76 kg/cm2), we see it will have a 38-ft (11.6-m) radius. When reduced by 25%, the radius would still be 28.5 ft (8.7 m), resulting in a 3.5-ft (1.1-m) overspray on either end of area 3. To fit the 50-ft (15.2-m) length of area 3, a contractor would adjust the radius reduction screw beyond the manufacturer's suggested limits, thereby bringing the nozzle radius to 25 ft (7.6 m).



**Toro 300 Series Stream Rotor Sprinklers**

**15'-30' Radius**

***Features***

- Multiple rotating stream pattern
- Matched precipitation rate nozzles and arc discs
- Choice of 6 nozzles and 9 interchangeable arc discs
- Gear-driven design
- Large basket filter screen
- Durable Cycolac and stainless steel construction

***Lawn and 12" Pop-Up***

- Pop-up design
- Stainless steel retraction spring
- Wiper seal
- Small surface diameter
- Ground-level installation
- Side inlet body hi-pop

**Specifying Information**

3XX XX XX

| Arc | | Body | Nozzle |
|---|---|---|---|
| 00—w/o Arc Disc | 09—202.5° | 00—Lawn Pop-Up | 00—w/o Nozzle |
| 04—90° | 10—225° | 10—Shrub | 01 |
| 05—112° | 12—270° | 12—Hi-Pop | 02 |
| 06—135° | 16—360° | | 03 |
| 07—157.5° | | | 63—Low Gallonage |
| 08—180° | | | 93—Low Gallonage |
| | | | 15—Adjustable-Shrub & Lawn Pop-Up |
| | | | 25—Adjustable-Hi Pop |

For Example:
When specifying a *Shrub sprinkler with a 90° arc and an Adjustable Nozzle, you would specify:*

**304-10-15**

***Specifications***

***Nozzle Performance***

- Fixed radius models: 16'-30'
- Omni adjustable radius models: 15'-30'
- Flow rate: 0.57-7.51 GPM
- Trajectory: 27°
- Maximum height of spray:
  - #01 Nozzle: 4'10" at 50 PSI
  - #02 Nozzle: 5'1" at 50 PSI
  - #03 Nozzle: 5'11" at 50 PSI
  - #63 Nozzle: 7' at 50 PSI
  - #93 Nozzle: 6'3" at 50 PSI

***Lawn Pop-Up***

- Recommended operating pressure: 35-50 PSI
- Maximum operating pressure: 75 PSI
- Pop-up to nozzle: 2¾"
- ¾" NPT female thread inlet
- Dimensions:
  - Body diameter: 2¾"
  - Cap diameter: 3"
  - Height: 6¾"
- Locking cap available: Part no. 35-1344

***Shrub***

- Recommended operating pressure: 35-50 PSI
- Maximum operating pressure: 75 PSI
- ½" NPT female thread inlet
- Dimensions:
  - Base diameter: 2"
  - Height: 6"

***Hi-Pop***

- Recommended operating pressure: 35-50 PSI
- Maximum operating pressure: 75 PSI
- Pop-up to nozzle: 11¾"
- ¾" NPT female thread bottom and side inlet
- Side inlet — 7" from top of sprinkler to center of side inlet
- Dimensions:
  - Body diameter: 2¾"
  - Cap diameter: 3"
  - Height: 16"
- Standard locking cap

FIGURE 6. 11 Stream Rotor sprinkler performance chart. (Source: The Toro Company. Used with permission.)

Looking at our completed head layout plan in Figure 6.14, we can plainly see that we are watering three distinct geographical areas. Because each area has its own set of sprinkler heads ideally suited to its size, plant water needs, and soil permeability restrictions, we can deliver the proper amount of water to it. Table 6.5 shows the material schedule for our irrigation design.

## Comparing Sprinkler Demand Flows with Available GPM Flow

Now, we need to total the gpm (L/min) flows demanded by the sprinkler heads in each geographical area and compare those figures to the flow we have available to use. If you are connecting an irrigation system to an existing water meter, your available flow will be limited by the size of the water meter and service line, which connects the meter to the city main. If you plan on having a new meter and service line installed for your irrigation system, then you can size the meter and service line to meet the flow of your largest irrigation area. Of course, meter costs will be an important consideration. The larger the water meter size, the more expensive a meter will be.

(continued on page 32)

# Performance Information

## Friction Loss — all 252 Models *

| Size | Type | | 5 | 10 | 20 | 25 | 30 | 40 | 50 | 60 | 70 | 80 | 100 | 120 | 150 | 170 | 180 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1½" | Hydraulic | Angle | | | | 1.0 | 1.0 | 1.5 | 1.5 | 3.0 | 4.0 | 5.0 | 7.0 | 11.0 | | | |
| | | Globe | | | | 1.0 | 1.0 | 2.0 | 30 | 4.0 | 5.5 | 6.5 | 10.5 | 13.5 | | | |
| 2" | Hydraulic | Angle | | | | | | | | 1.0 | 1.0 | 1.5 | 2.0 | 3.0 | 5.0 | 6.0 | 6.0 |
| | | Globe | | | | | | | | 1.5 | 2.0 | 2.0 | 3.5 | 5.0 | 8.0 | 10.0 | 11.0 |
| 1" | Electric | Angle | 2.0 | 3.5 | 4.5 | 4.5 | 5.0 | 7.5 | | | | | | | | | |
| | | Globe | 3.0 | 4.0 | 5.0 | 6.0 | 7.0 | 9.5 | | | | | | | | | |
| 1½" | Electric | Angle | | | | 1.5 | 1.0 | 1.5 | 2.0 | 3.0 | 3.0 | 5.0 | 7.0 | 9.0 | | | |
| | | Globe | | | | 1.5 | 1.5 | 2.0 | 3.0 | 4.0 | 5.0 | 7.0 | 11.0 | 15.0 | | | |
| 2" | Electric | Angle | | | | | | | | 1.0 | 1.0 | 2.0 | 3.0 | 4.0 | 5.0 | 6.0 | 7.0 |
| | | Globe | | | | | | | | 2.0 | 2.0 | 2.5 | 3.5 | 5.5 | 8.0 | 10.0 | 11.0 |

* Contamination resistant valves are electric only.

Note: When desigining a system,be sure to calculate total friction loss to ensure sufficient downstream pressure for optimum sprinkler performance.

# Nozzle Performance Information

## 300-15 and 300-25 Omni Adjustable Radius Nozzles

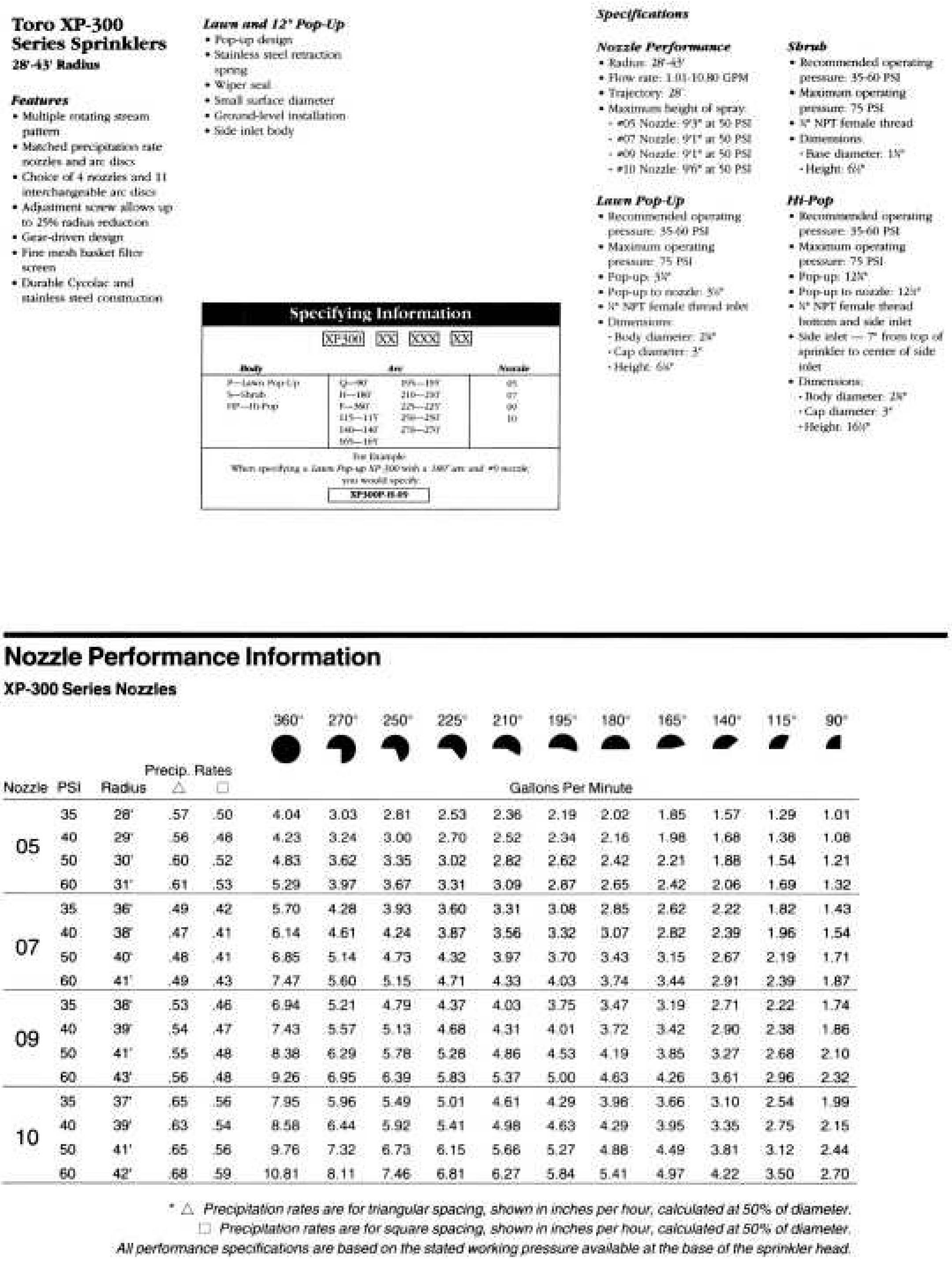
| Nozzle | PSI | Radius | Precip. Rates △ | Precip. Rates ☐ | 360° | 270° | 225° | 202.5° | 180° | 157.7° | 135° | 112° | 90° |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Gallons Per Minute | | | | | | | | |
| | 35 | 15' | 1.69 | 1.46 | 3.41 | 2.55 | 2.13 | 1.91 | 1.70 | 1.49 | 1.28 | 1.06 | 0.85 |
| | 35 | 18' | 1.37 | 1.19 | 4.00 | 3.00 | 2.50 | 2.25 | 2.00 | 1.75 | 1.50 | 1.24 | 1.00 |
| | 35 | 21' | 1.15 | 1.00 | 4.58 | 3.44 | 2.86 | 2.58 | 2.29 | 2.01 | 1.72 | 1.42 | 1.15 |
| | 35 | 24' | 0.99 | 0.86 | 5.17 | 3.88 | 3.23 | 2.91 | 2.58 | 2.26 | 1.94 | 1.60 | 1.29 |
| 300-15-ADJ | 35 | 26' | 0.95 | 0.82 | 5.76 | 4.32 | 3.60 | 3.24 | 2.88 | 2.52 | 2.16 | 1.79 | 1.44 |
| 300-25-ADJ | 50 | 18' | 1.60 | 1.38 | 4.65 | 3.49 | 2.91 | 2.62 | 2.33 | 2.04 | 1.74 | 1.44 | 1.16 |
| | 50 | 21' | 1.35 | 1.17 | 5.36 | 4.02 | 3.35 | 3.02 | 2.68 | 2.35 | 2.01 | 1.66 | 1.34 |
| | 50 | 24' | 1.17 | 1.02 | 6.08 | 4.56 | 3.80 | 3.42 | 3.04 | 2.66 | 2.28 | 1.88 | 1.52 |
| | 50 | 27' | 1.04 | 0.90 | 6.79 | 5.09 | 4.24 | 3.82 | 3.40 | 2.97 | 2.55 | 2.10 | 1.70 |
| | 50 | 30' | 0.93 | 0.80 | 7.51 | 5.63 | 4.69 | 4.23 | 3.75 | 3.29 | 2.82 | 2.33 | 1.88 |

## 300 Series Fixed Radius Nozzles

| Nozzle | PSI | Radius | Precip. Rates △ | Precip. Rates ☐ | 360° | 270° | 225° | 202.5° | 180° | 157.7° | 135° | 112° | 90° |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Gallons Per Minute | | | | | | | | |
| 01 | 35 | 16' | 0.99 | 0.86 | 2.28 | 1.71 | 1.43 | 1.28 | 1.14 | 1.00 | 0.86 | 0.71 | 0.57 |
| | 50 | 18' | 0.99 | 0.86 | 2.88 | 2.16 | 1.80 | 1.62 | 1.44 | 1.26 | 1.08 | 0.90 | 0.72 |
| 02 | 35 | 21' | 0.73 | 0.63 | 2.88 | 2.16 | 1.80 | 1.62 | 1.44 | 1.26 | 1.08 | 0.90 | 0.72 |
| | 50 | 24' | 0.66 | 0.57 | 3.41 | 2.56 | 2.13 | 1.92 | 1.71 | 1.49 | 1.28 | 1.06 | 0.85 |
| 03 | 35 | 28' | 0.77 | 0.67 | 5.43 | 4.07 | 3.39 | 3.05 | 2.72 | 2.38 | 2.04 | 1.69 | 1.36 |
| | 50 | 30' | 0.80 | 0.69 | 6.45 | 4.84 | 4.03 | 3.63 | 3.23 | 2.82 | 2.42 | 2.01 | 1.61 |
| 63 Low Gallonage | 35 | 28' | 0.39 | 0.33 | 2.72 | 2.04 | 1.70 | 1.53 | 1.36 | 1.19 | 1.02 | 0.85 | 0.68 |
| | 50 | 30' | 0.40 | 0.35 | 3.23 | 2.42 | 2.02 | 1.82 | 1.62 | 1.41 | 1.21 | 1.00 | 0.81 |
| 93 Low Gallonage | 35 | 28' | 0.58 | 0.50 | 4.07 | 3.05 | 2.54 | 2.29 | 2.04 | 1.78 | 1.53 | 1.27 | 1.02 |
| | 50 | 30' | 0.60 | 0.52 | 4.84 | 3.63 | 3.03 | 2.72 | 2.42 | 2.12 | 1.82 | 1.51 | 1.21 |

*△ Precipitation rates are for triangular spacing, shown in inches per hour, calculated at 50% of diameter.*
*☐ Precipitation rates are for square spacing, shown in inches per hour, calculated at 50% of diameter.*
*All performance specifications are based on the stated working pressure available at the base of the sprinkler head.*

FIGURE 6. 11 (continued)



**Toro XP-300 Series Sprinklers**
**28'-43' Radius**

***Features***
- Multiple rotating stream pattern
- Matched precipitation rate nozzles and arc discs
- Choice of 4 nozzles and 11 interchangeable arc discs
- Adjustment screw allows up to 25% radius reduction
- Gear-driven design
- Fine mesh basket filter screen
- Durable Cycolac and stainless steel construction

***Lawn and 12" Pop-Up***
- Pop-up design
- Stainless steel retraction spring
- Wiper seal
- Small surface diameter
- Ground-level installation
- Side inlet body

**Specifying Information**

XP300 XX XXX XX

| Body | Arc | | Nozzle |
|---|---|---|---|
| P—Lawn Pop-Up<br>S—Shrub<br>HP—Hi-Pop | Q—90°<br>H—180°<br>F—360°<br>115—115°<br>140—140°<br>165—165° | 195—195°<br>210—210°<br>225—225°<br>250—250°<br>270—270° | 05<br>07<br>09<br>10 |

For Example
When specifying a *Lawn Pop-up XP-300* with a 180° arc and #9 nozzle, you would specify:
XP300P-H-09

***Specifications***

***Nozzle Performance***
- Radius: 28'-43'
- Flow rate: 1.01-10.80 GPM
- Trajectory: 28°
- Maximum height of spray:
  - #05 Nozzle: 9'3" at 50 PSI
  - #07 Nozzle: 9'1" at 50 PSI
  - #09 Nozzle: 9'1" at 50 PSI
  - #10 Nozzle: 9'6" at 50 PSI

***Lawn Pop-Up***
- Recommended operating pressure: 35-60 PSI
- Maximum operating pressure: 75 PSI
- Pop-up: 3⅜"
- Pop-up to nozzle: 3⅝"
- ¾" NPT female thread inlet
- Dimensions:
  - Body diameter: 2⅞"
  - Cap diameter: 3"
  - Height: 6¾"

***Shrub***
- Recommended operating pressure: 35-60 PSI
- Maximum operating pressure: 75 PSI
- ¾" NPT female thread
- Dimensions
  - Base diameter: 1⅞"
  - Height: 6¼"

***Hi-Pop***
- Recommended operating pressure: 35-60 PSI
- Maximum operating pressure: 75 PSI
- Pop-up: 12⅜"
- Pop-up to nozzle: 12⅝"
- ¾" NPT female thread bottom and side inlet
- Side inlet — 7" from top of sprinkler to center of side inlet
- Dimensions:
  - Body diameter: 2⅞"
  - Cap diameter: 3"
  - Height: 16¼"

## Nozzle Performance Information

### XP-300 Series Nozzles

| Nozzle | PSI | Radius | Precip. Rates △ | Precip. Rates □ | 360° | 270° | 250° | 225° | 210° | 195° | 180° | 165° | 140° | 115° | 90° |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Gallons Per Minute | | | | | | | | | | |
| 05 | 35 | 28' | .57 | .50 | 4.04 | 3.03 | 2.81 | 2.53 | 2.36 | 2.19 | 2.02 | 1.85 | 1.57 | 1.29 | 1.01 |
| | 40 | 29' | .56 | .48 | 4.23 | 3.24 | 3.00 | 2.70 | 2.52 | 2.34 | 2.16 | 1.98 | 1.68 | 1.38 | 1.08 |
| | 50 | 30' | .60 | .52 | 4.83 | 3.62 | 3.35 | 3.02 | 2.82 | 2.62 | 2.42 | 2.21 | 1.88 | 1.54 | 1.21 |
| | 60 | 31' | .61 | .53 | 5.29 | 3.97 | 3.67 | 3.31 | 3.09 | 2.87 | 2.65 | 2.42 | 2.06 | 1.69 | 1.32 |
| 07 | 35 | 36' | .49 | .42 | 5.70 | 4.28 | 3.93 | 3.60 | 3.31 | 3.08 | 2.85 | 2.62 | 2.22 | 1.82 | 1.43 |
| | 40 | 38' | .47 | .41 | 6.14 | 4.61 | 4.24 | 3.87 | 3.56 | 3.32 | 3.07 | 2.82 | 2.39 | 1.96 | 1.54 |
| | 50 | 40' | .48 | .41 | 6.85 | 5.14 | 4.73 | 4.32 | 3.97 | 3.70 | 3.43 | 3.15 | 2.67 | 2.19 | 1.71 |
| | 60 | 41' | .49 | .43 | 7.47 | 5.60 | 5.15 | 4.71 | 4.33 | 4.03 | 3.74 | 3.44 | 2.91 | 2.39 | 1.87 |
| 09 | 35 | 38' | .53 | .46 | 6.94 | 5.21 | 4.79 | 4.37 | 4.03 | 3.75 | 3.47 | 3.19 | 2.71 | 2.22 | 1.74 |
| | 40 | 39' | .54 | .47 | 7.43 | 5.57 | 5.13 | 4.68 | 4.31 | 4.01 | 3.72 | 3.42 | 2.90 | 2.38 | 1.86 |
| | 50 | 41' | .55 | .48 | 8.38 | 6.29 | 5.78 | 5.28 | 4.86 | 4.53 | 4.19 | 3.85 | 3.27 | 2.68 | 2.10 |
| | 60 | 43' | .56 | .48 | 9.26 | 6.95 | 6.39 | 5.83 | 5.37 | 5.00 | 4.63 | 4.26 | 3.61 | 2.96 | 2.32 |
| 10 | 35 | 37' | .65 | .56 | 7.95 | 5.96 | 5.49 | 5.01 | 4.61 | 4.29 | 3.98 | 3.66 | 3.10 | 2.54 | 1.99 |
| | 40 | 39' | .63 | .54 | 8.58 | 6.44 | 5.92 | 5.41 | 4.98 | 4.63 | 4.29 | 3.95 | 3.35 | 2.75 | 2.15 |
| | 50 | 41' | .65 | .56 | 9.76 | 7.32 | 6.73 | 6.15 | 5.66 | 5.27 | 4.88 | 4.49 | 3.81 | 3.12 | 2.44 |
| | 60 | 42' | .68 | .59 | 10.81 | 8.11 | 7.46 | 6.81 | 6.27 | 5.84 | 5.41 | 4.97 | 4.22 | 3.50 | 2.70 |

** △ Precipitation rates are for triangular spacing, shown in inches per hour, calculated at 50% of diameter.*
*□ Precipitation rates are for square spacing, shown in inches per hour, calculated at 50% of diameter.*
*All performance specifications are based on the stated working pressure available at the base of the sprinkler head.*

FIGURE 6.12 Sprinkler performance chart. (Source: The Toro Company. Used with permission.)

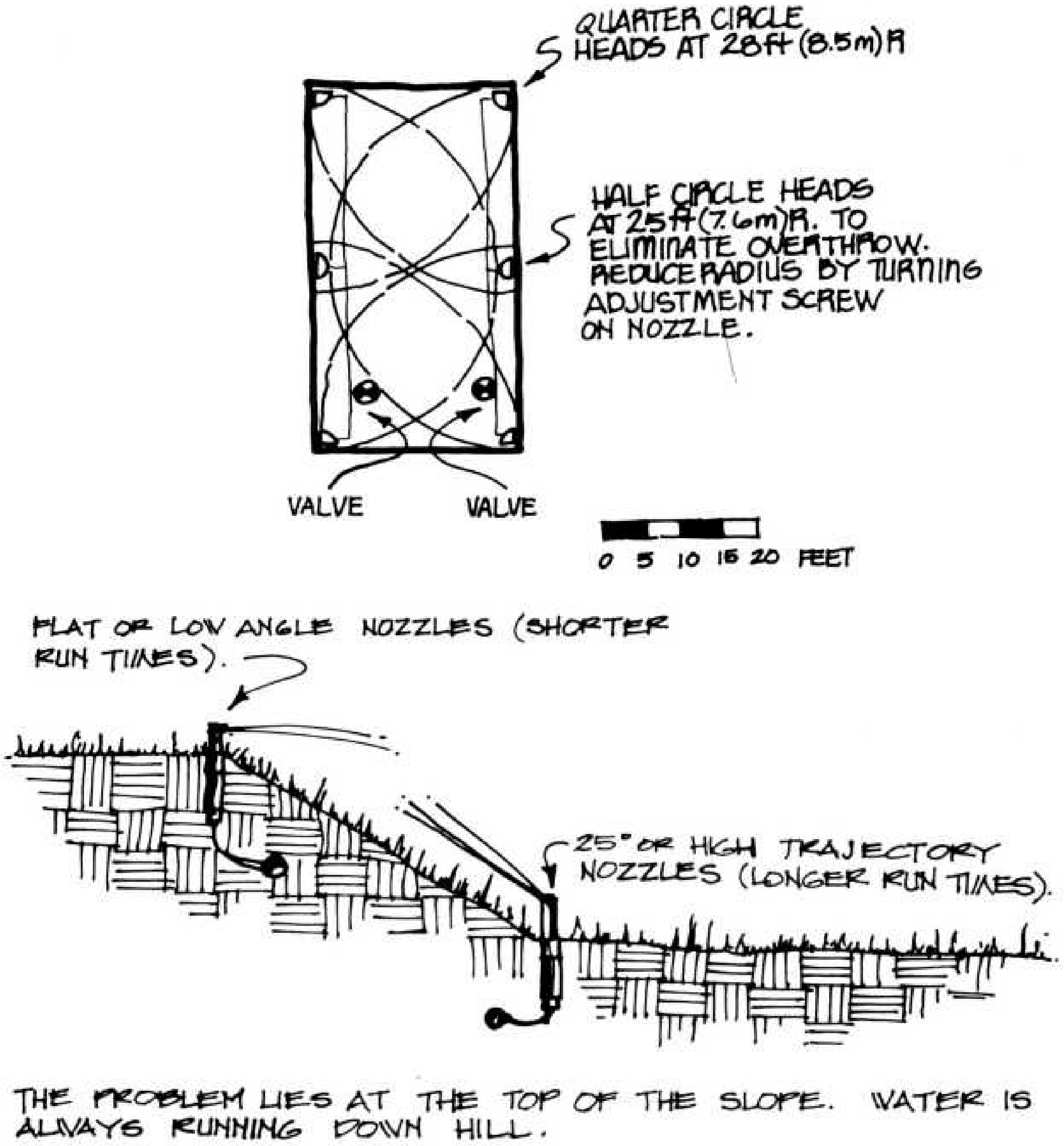


FIGURE 6.13 Area 3-layout of Super 700 Rotor heads.

Let us look at our three geographical areas and figure the total flows based on the heads we selected. Look at the gpm (L/min) and radius columns in Figure 6.3 under 15-ft (4.57-m) Series for the spray heads used in area 1:

4 quarter-circle heads at approximately 0.68 gpm (2.57 L/min)
flow each = 2.72 gpm (10.3 L/min)

2 half-circle heads at approximately 1.37 gpm (5.19 L/min)
flow each = 2.74 gpm (10.37 L/min)

FLOW TOTAL = 5.46 gpm (20.67 L/min)

For area 2, look at the gpm and radius columns for the 5.0 nozzle in Figure 6.9:

4 quarter-circle heads at 6.71 gpm (25.4 L/min) each
= 26.84 gpm (101.59 L/min)

FLOW TOTAL = 26.84 gpm (101.59 L/min)

For area 3, look at the gpm and radius columns for the 1.5 and 3.0 nozzles in Figure 5.4:

**Hilltop**

2 flat-angle, quarter-circle heads (1.5 nozzle) at 1.55 gpm
(5.87 L/min) flow each = 3.1 gpm (11.73 L/min)

1 flat-angle, half-circle head (3.0 nozzle) at 3.32 gpm
(12.57 L/min) flow each = 3.32 gpm (12.57 L/min)

**Bottom of Hill**

2 standard-angle, quarter-circle heads (1.5 nozzle) at 1.11 gpm
(4.20 L/min) flow each = 2.22 gpm (8.4 L/min)

1 standard-angle, half-circle head (3.0 nozzle) at 2.4 gpm
(9.08 L/min) = 2.4 gpm (9.08 L/min)

HILLTOP FLOW TOTAL = 6.42 gpm (24.3 L/min)

BOTTOM-OF-HILL FLOW TOTAL = 4.62 gpm (17.49 L/min)

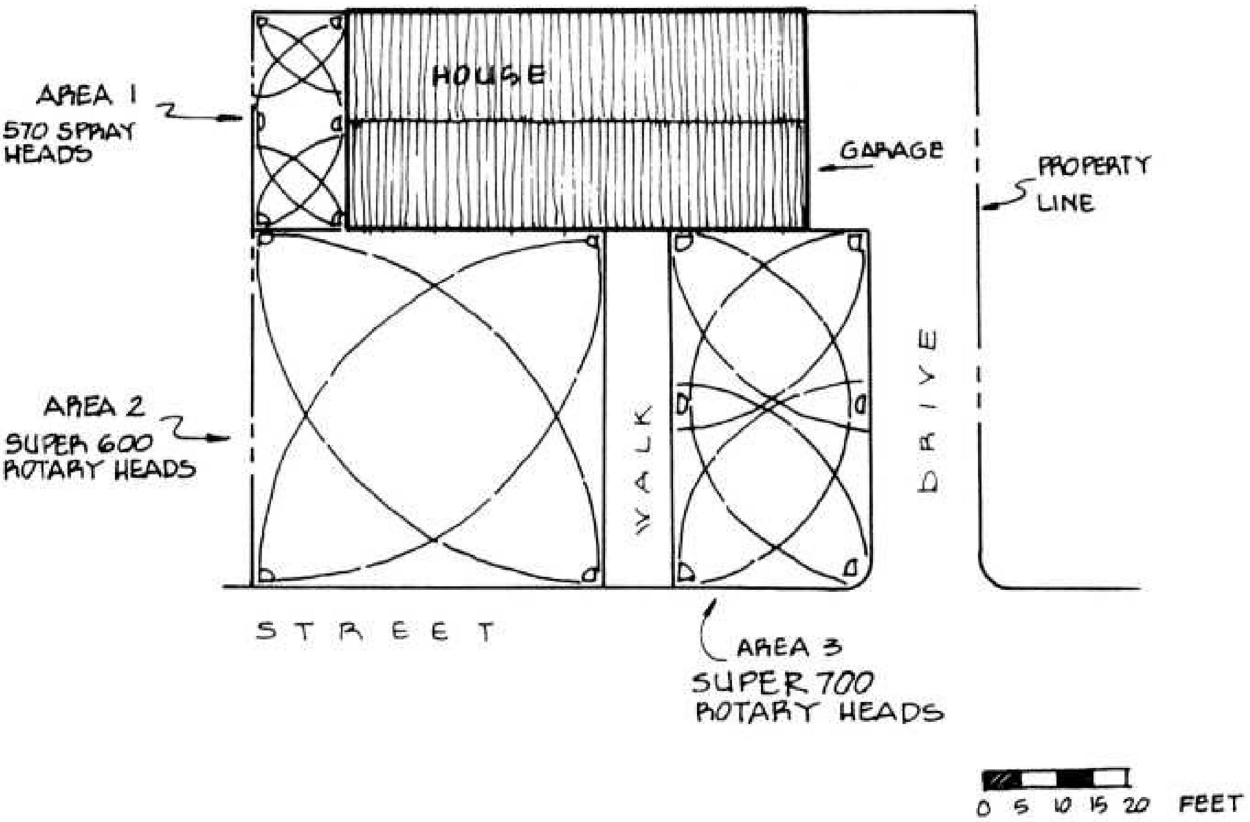


FIGURE 6. 14 Head layout-landscape with three watering areas.

Let us assume our water meter and service line restrict us to a maximum flow at any one time of 18 gpm (68.13 L/min). Area 1 demands 8 gpm (30.28 L/min), and area 3 demands 6.42 gpm and 4.62 gpm (24.30 L/min and 17.41) L/min), so the available flow is more than adequate.

Area 2, on the other hand, demands 26.84 gpm (101.59 L/min) of water to run all the heads at one time, and this amount exceeds the 18 gpm (68.13 L/min) that is available for use. Therefore, we have to divide area 2 into two watering circuits, or zones of heads, with a flow demand of approximately 13.42 gpm (50.3 L/min) for each circuit. By doing this, we do not demand more water than is available. When you design a circuit for more water than is available, the sprinkler heads will not perform correctly.

Once you divide your geographical areas according to your available flow, you create what we call circuits or zones that can be watered either by manual or automatic valves. A geographical area, remember, has generally the same plant water needs, sunlight exposure, and soil permeability rate. There can be multiple circuits within a geographical area. The limiting factor as to how many circuits you can have in a geographical area is your available gpm (L/min) flow. Our next step in developing an irrigation plan is to show the location of pipe and to size the pipe.

TABLE 6.5 **Materials Schedule**

**SPRINKLER HEAD SCHEDULE**

| Head Type | Model Number | Quantity |
|---|---|---|
| 570 spray nozzles | 15-Q-PC (pressure compensating) | 4 |
| Operates at 20–30 psi (1.41–2.11 kg/cm$^2$) | 15-H-PC | 2 |
| Super 600 Rotary Sprinkler | S600 PC 5.0 | 4 |
| Operates at 50 psi (3.52 kg/cm$^2$) | | |
| Quarter-circle patterns | | |
| Super 700 Rotary Sprinkler | S700-PC-1.5 FA | 2 |
| Operates hilltop sprinklers at 45 psi (3.16 kg/cm$^2$) and | S700-PC-3.0 FA | 1 |
| bottom-of-hill sprinklers at 25 psi (1.76 kg/cm$^2$) | S700-PC-1.5 SA | 2 |
| | S700-PC-3.0 SA | 1 |

# 7

# Pipe Routing

## Introduction

After we have determined our geographical areas, selected our sprinkler heads based on the areas' needs, laid out the heads, and divided the geographical areas into circuits or zones, we are then ready to develop a pipe routing, or pipe placement, plan. We need to connect our sprinkler heads to the water source in a manner that supplies the amount of water and pressure the heads need. We also need to consider how easy (or not) it will be to install the system.

## Pipe Installation

Let us first look at the process that contractors use to install pipe. Based on the drawings developed by the irrigation designer, the contractor installs polyvinyl chloride (PVC) pipe in this manner:

1. Trenches are machine-dug to the depth specified by the designer. A trenching machine can dig 5 ft to 30 ft (1.5 m to 9.1 m) of trench per minute. Some trenches adjacent to buildings, utility lines, and existing plants have to be dug by hand (see Figure 7.1A-C ).

FIGURE 7.1 A Trench dug by hand next to a building.

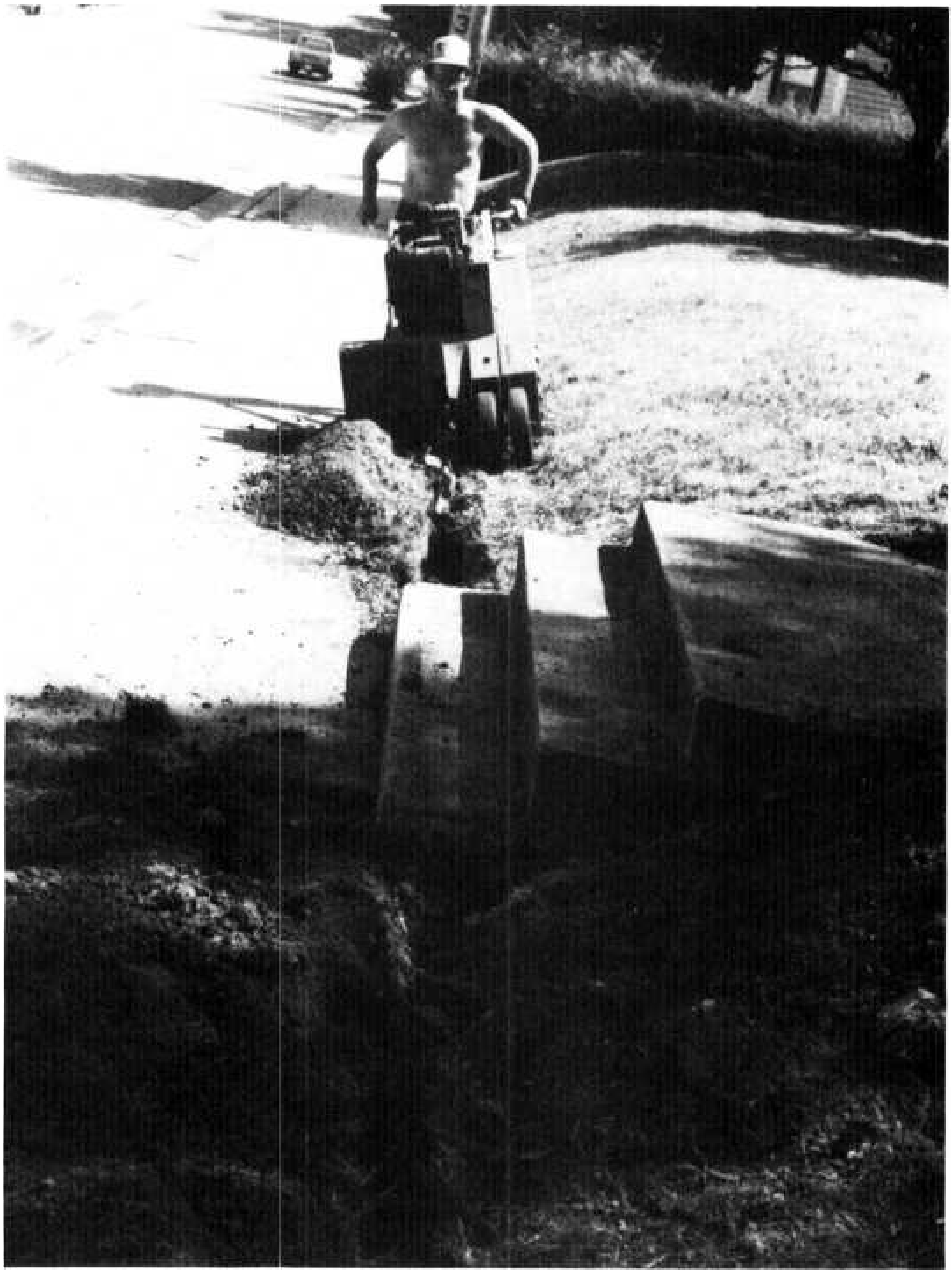


FIGURE 7.1 B Trenching machine.

FIGURE 7.1 C Trench in a shrub bed dug by hand.

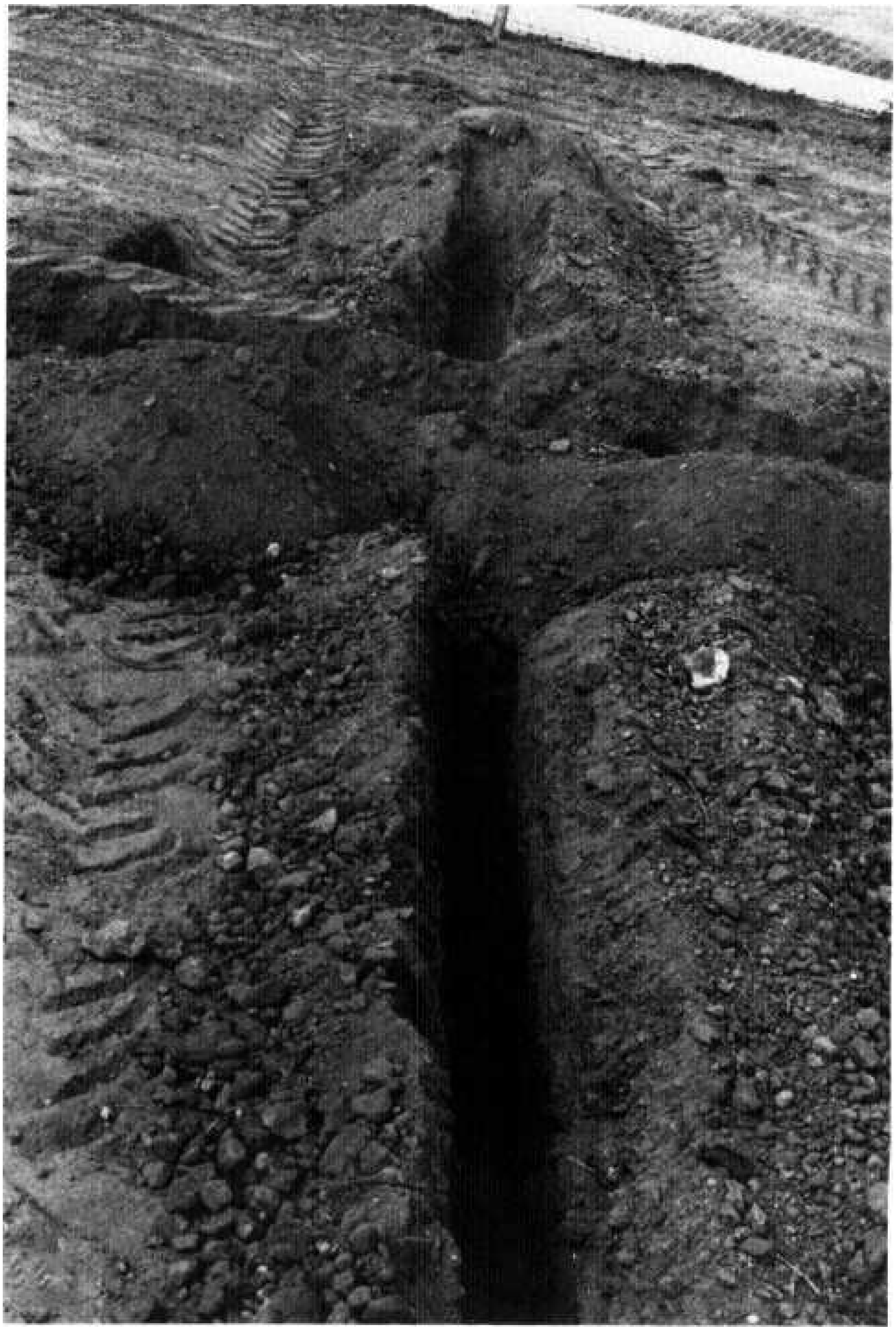


FIGURE 7.2 Soil in a crossed trench.

2. Once trenches are dug and cross-trenches are emptied of soil thrown into them by the trenching machine, the contractor lays the pipe in sizes specified by the designer, beside the trenches. Generally, all trenches must be cleaned out to make the trench level and smooth (see Figure 7.2).

3. The pipe sections and sprinkler assemblies

are attached and then placed into the trenches, as shown in Figure 7.3. The lines are flushed to eliminate any soil in the lines, as shown in Figure 7.4 The sprinkler heads can be capped at this point and the system put under pressure to check for leaks at joints, if testing is required.

4. Nozzles are attached to the sprinkler bodies.

5. The soil is then placed back in the trench 4 in (102 mm) at a time and tamped. Figure 7.5 shows a trench ready for backfilling, and Figure 7.6A shows a trench being tamped. Tamping eliminates any slumping of trenches- and the necessity of having the contractor return to the job site to add soil to a settled trench. Returning to the site, once a project is completed, is very expensive for a contracting company to do.

In most northern climate areas, contractors install polyethylene (PE) pipe with a tractor and vibratory plow. Also called a "pipe puller," the tractor and plow pull pipe below grade at a specific depth (Figure 7.6B). The value of this installation method is that it does very little damage to turf. The PE pipe is installed in this manner:

1. Small holes are dug where the sprinkler heads will be installed on the site.

2. The contractor then hooks the pipe to the plow (Figure 7.6C) and pulls the various runs of pipe. This leaves no trench to fill (Figure 7.61)).

3. After the pipe runs are complete, all the fittings are installed to link the zones together.

4. Finally, the heads are installed and nozzled.

## Pipe-Routing Considerations

Now that we have an idea about how the pipes and heads are installed, let us look at some guidelines for laying out or routing pipe to the sprinkler heads.

1. Avoid placing pipe where there are many tree roots. In particular, avoid placing pipe at right angles to tree roots because of the increased expense in getting the trench dug-and more important, the possibility of severely damaging or killing the tree (see Figures 7.7 and 7.8).

FIGURE 7.3 Sprinkler bodies are attached to the pipe.

FIGURE 7.4 Flushing pipe lines.

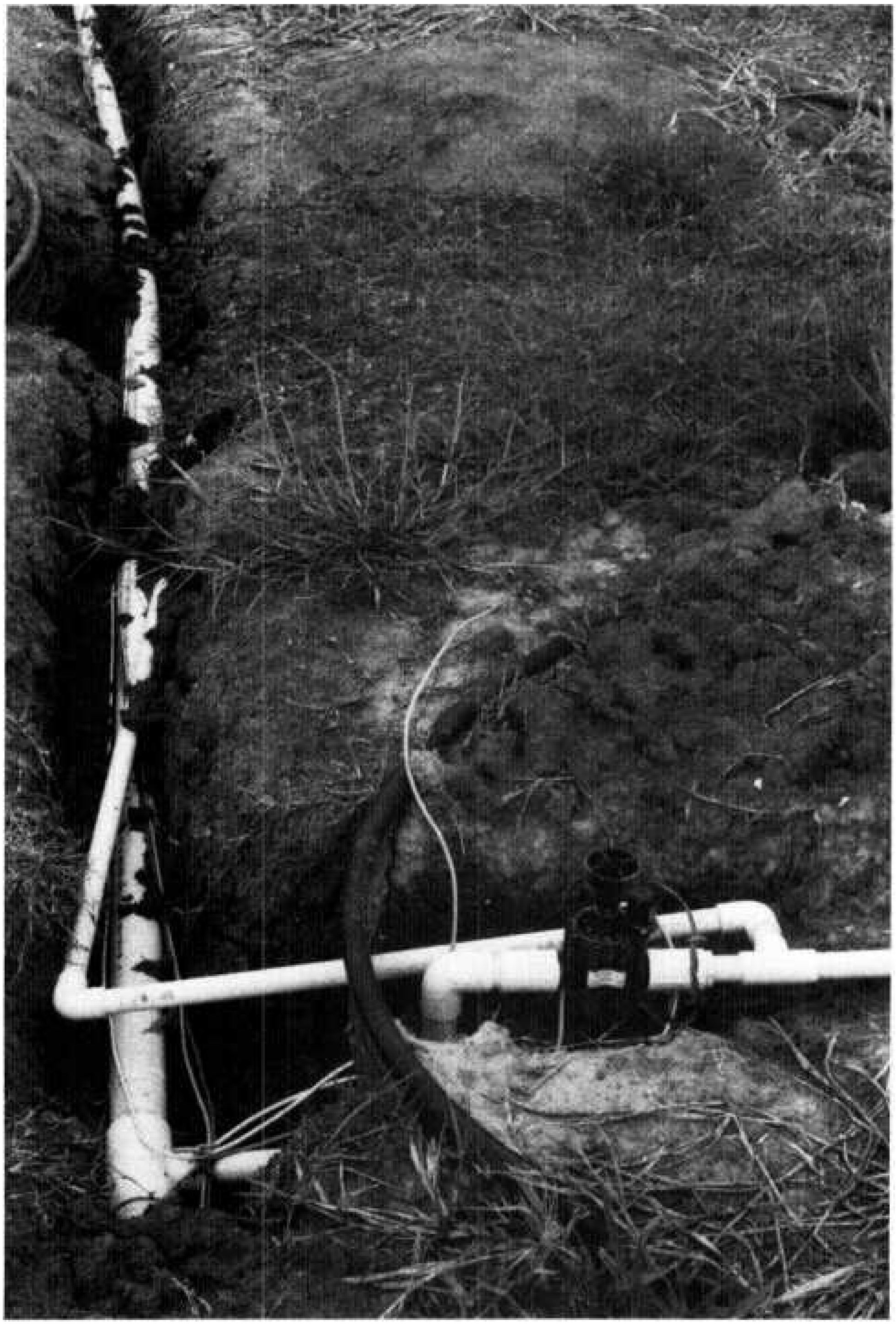


FIGURE 7.5 Pipe in trench ready to be covered.

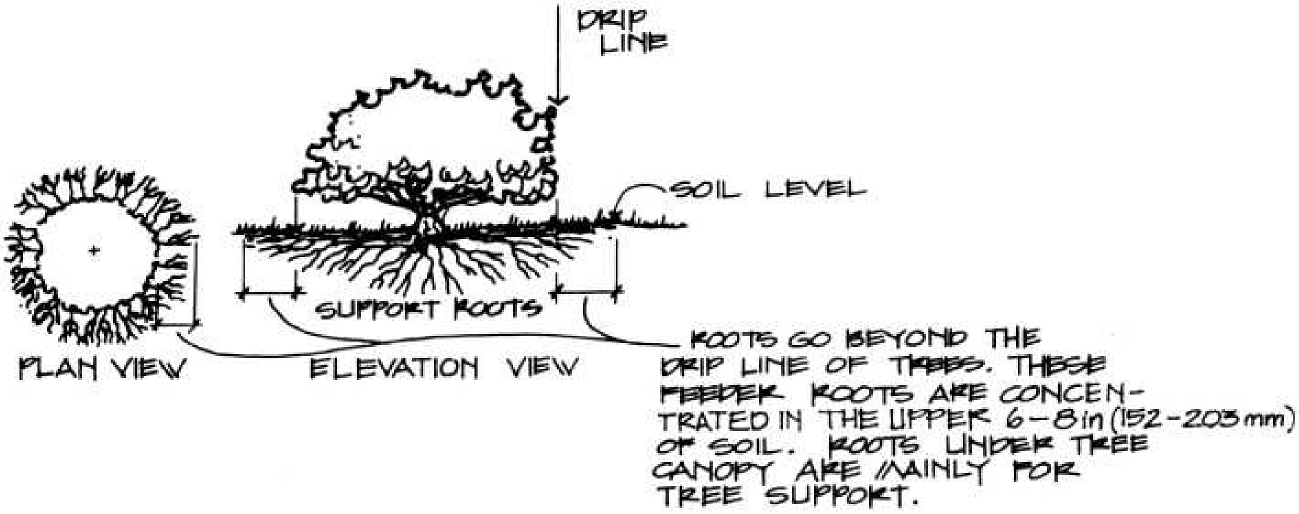
FIGURE 7.6A Tamping soil in a trench.

FIGURE 7.6B Tractor and vibratory plow pulling PE pipe.

2. Avoid placing pipe within established shrub and ground cover areas, as shown in Figure 7.9. If you do locate pipe within such areas, the trenches will have to be dug by hand to avoid excessive damage to the plants. An alternative method is to avoid the plant bed by machinedigging a trench 2 ft (0.6 m) beyond the plant bed and bringing short sections of pipe into the bed, as shown in Figure 7.10.

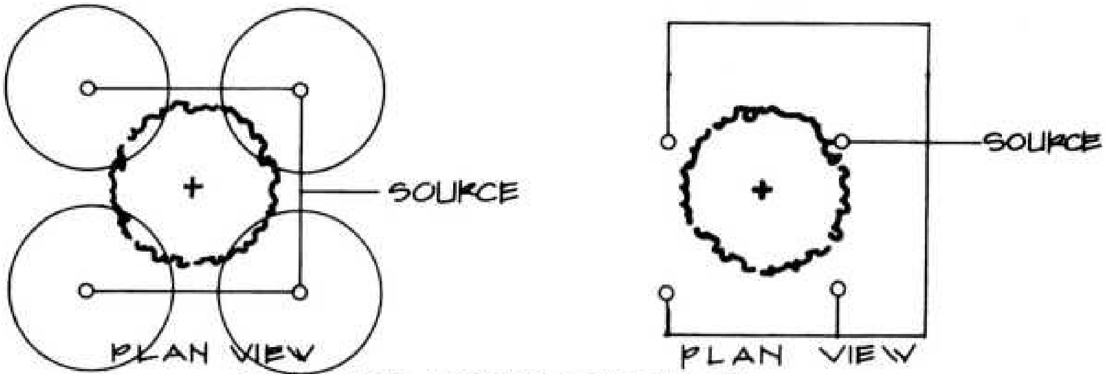
FIGURE 7.6C Attaching PE pipe to plow.

FIGURE 7.6D Pipe-pulling method leaves no trench to fill.



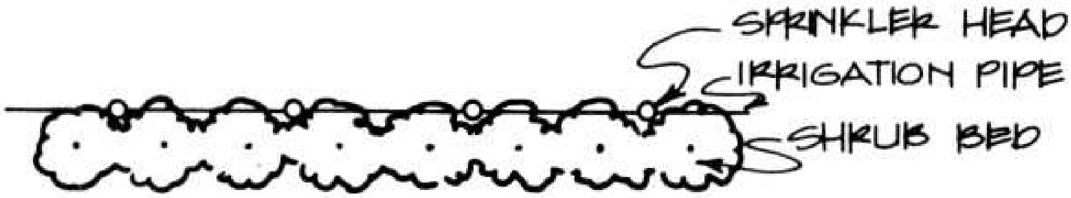
ROOTS GO BEYOND THE DRIP LINE OF TREES. THESE FEEDER ROOTS ARE CONCENTRATED IN THE UPPER 6–8 in (152–203 mm) OF SOIL. ROOTS UNDER TREE CANOPY ARE MAINLY FOR TREE SUPPORT.

FIGURE 7.7 Location of tree roots.



THE PIPE LAYOUT SCHEME ON THE LEFT CUTS MANY OF THE TREE'S FEEDER ROOTS. THE PIPE LAYOUT ON THE RIGHT LOCATES PIPE PARALLEL WITH TREE ROOTS & MINIMIZES DAMAGE.

FIGURE 7.8 Avoid cutting tree roots.



AVOID PLACING PIPE IN SHRUB AND GROUND COVER BEDS. TRENCHING WILL BE DIFFICULT AND MANY PLANT ROOTS WILL BE CUT.

FIGURE 7.9 Shrub bed with irrigation pipe.

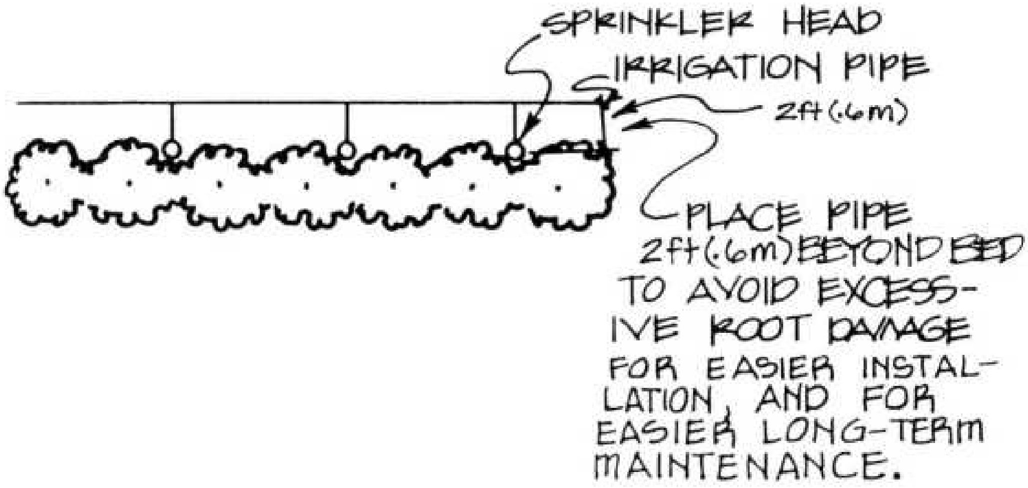


FIGURE 7. 10 Shrub bed with ideal pipe layout.

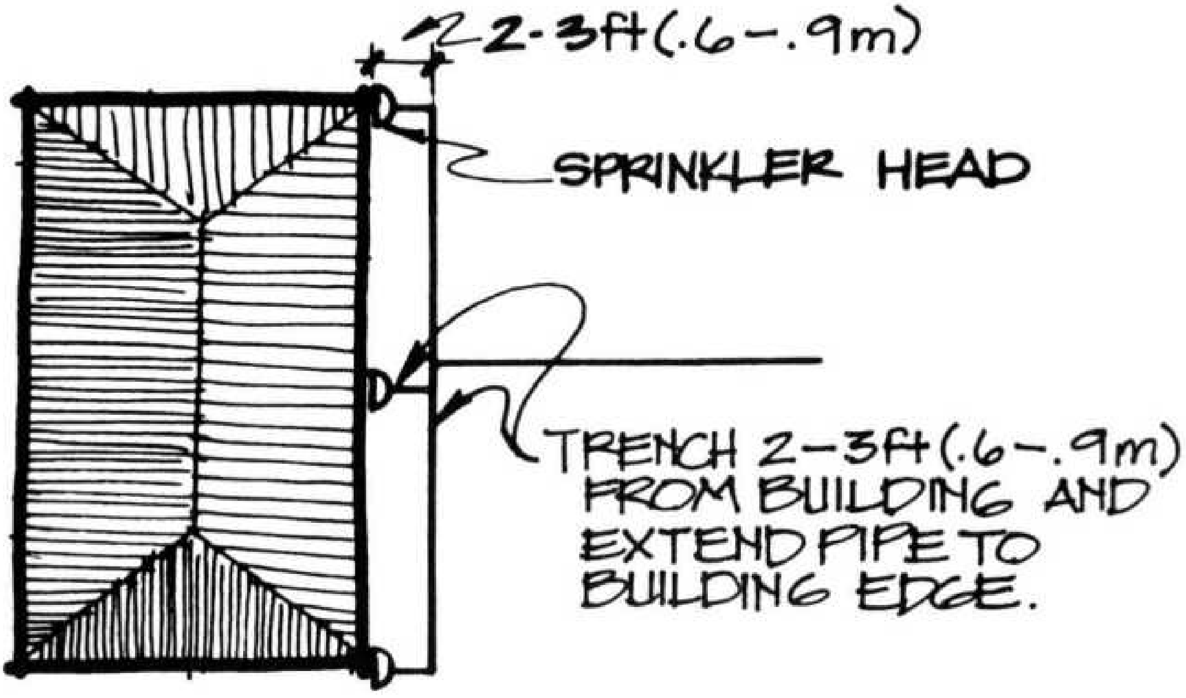


FIGURE 7. 11 Trenching near a building.

3. Pipe placed immediately adjacent to buildings will actually be about 2 ft (0.6 m) from the building because the trencher cannot get any closer. A short, hand-dug trench will be required for each head. Most trenching machines need at least 2 feet (0.6 m) on either side to dig a trench (see Figure 7.11).

4. Avoid placing pipe so as to cause excessive

cross-trenching. When you dig across an existing trench, the trenching machine throws soil into it. Removing this soil from the trench is laborious and increases installation costs (see Figure 7.12).

FIGURE 7.12 Cross-trenching.

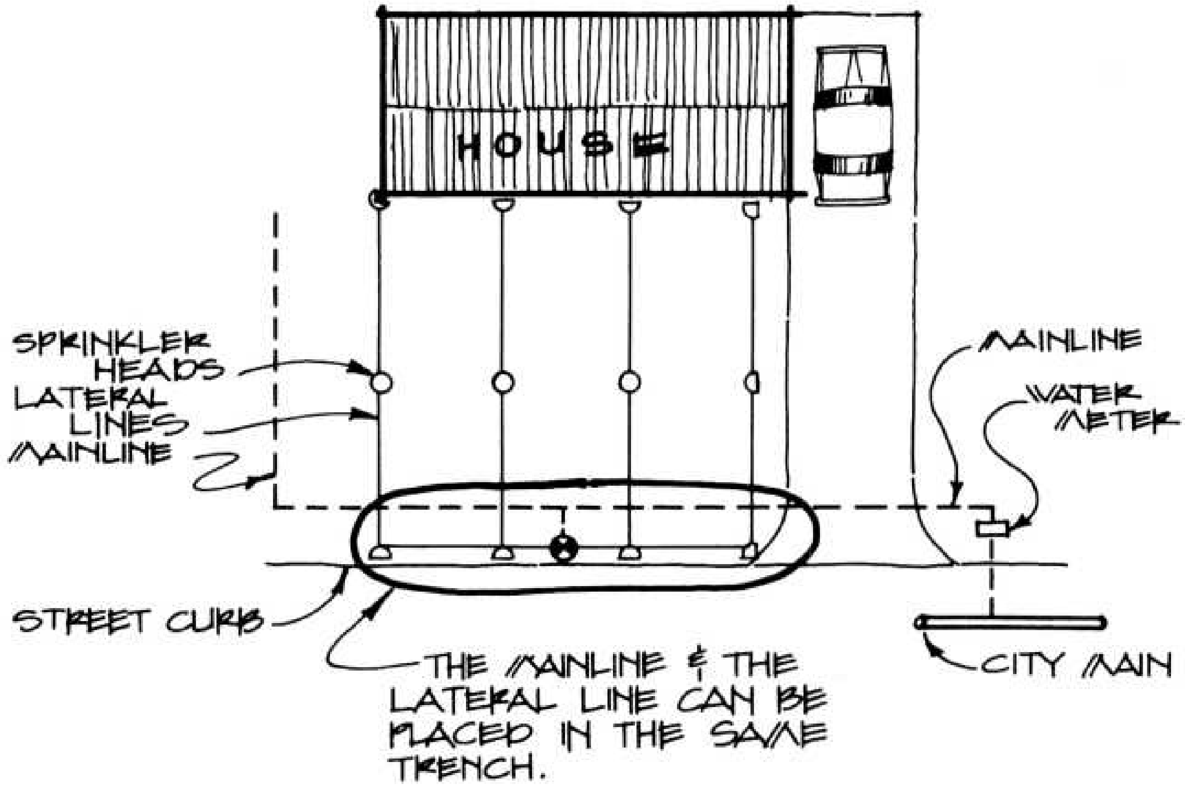


FIGURE 7.13 Parallel lines in the some trench.

5. When possible, place parallel lines in the same trench, as shown in Figure 7.13, to reduce costs. This works in many cases where you can place a mainline beside one of the lateral lines in a circuit.

6. Place the main water line so that it intersects near the center of the heads in each irrigation circuit, as. shown in Figure 7.14. This is called the "H" pattern of piping. The layout will provide equal pressure to all heads within a circuit, creating a balanced-irrigation circuit. As water travels through the pipe, pressure is lost due to the roughness of the inside of the pipe slowing down the water molecules. We can say that pressure loss accumulates as water travels through pipe, as illustrated in Figure 7.15. Note the estimated pressure difference between sprinklers A and B. This means that these heads will not throw the same radius and deliver the same amount of water. To combat this pressure difference, let us relocate our mainline to intersect nearer the center of the sprinkler heads. Now, as shown in Figure 7.16, the pressure at the two extreme heads on either side of the mainline intersection will be equal. The contractor will be able to give the client a better price if the variety of pipe sizes and fittings is reduced.

7. Try to lay out pipe symmetrically in your circuits. The symmetrical layout in Figure 7.17 duplicates pipe sizes, which reduces installation costs.

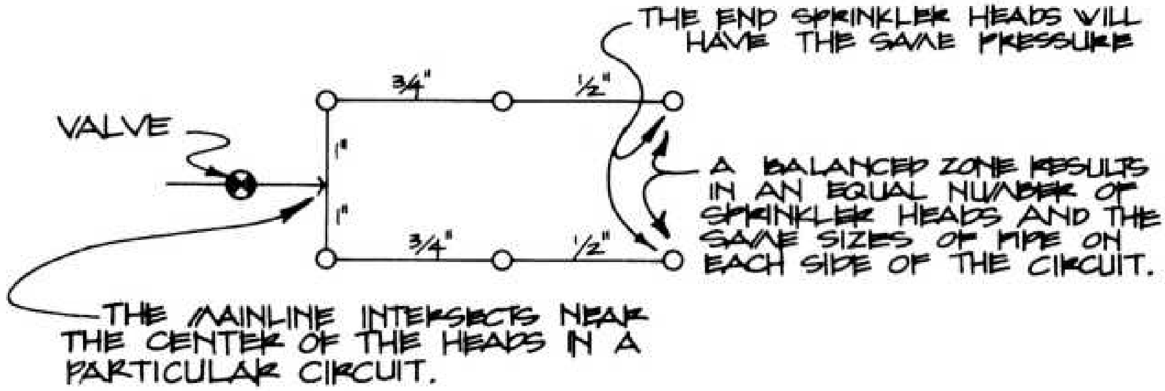


FIGURE 7.14 Balanced circuit.

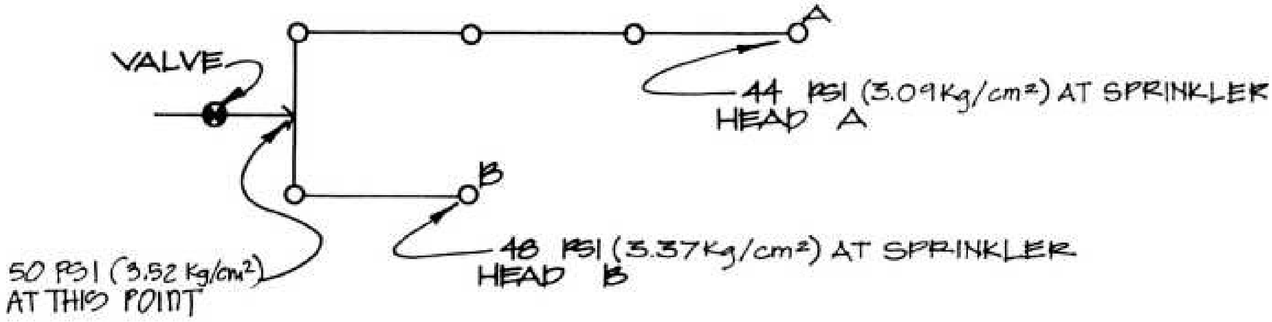


FIGURE 7.15 Unbalanced circuit.

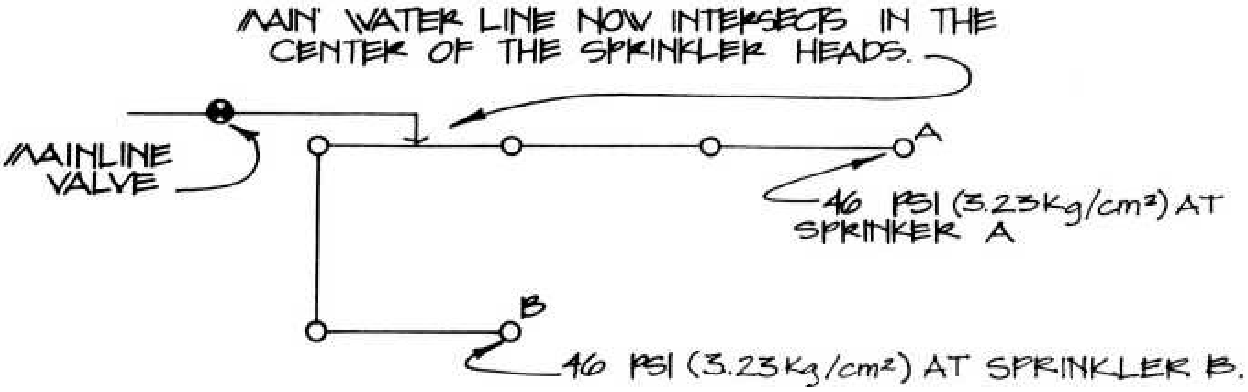


FIGURE 7.16 Balanced circuit.

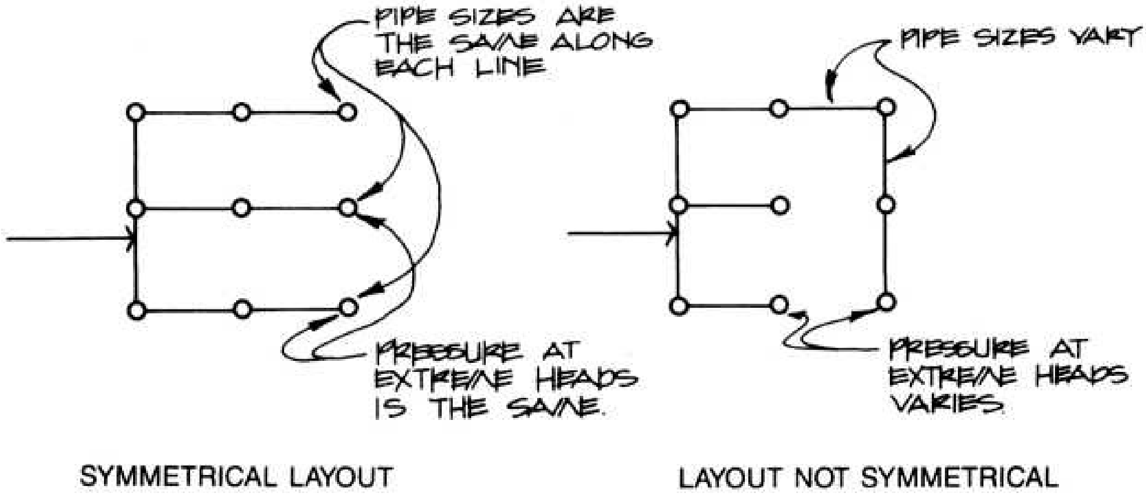


FIGURE 7.17 Pipe layout.

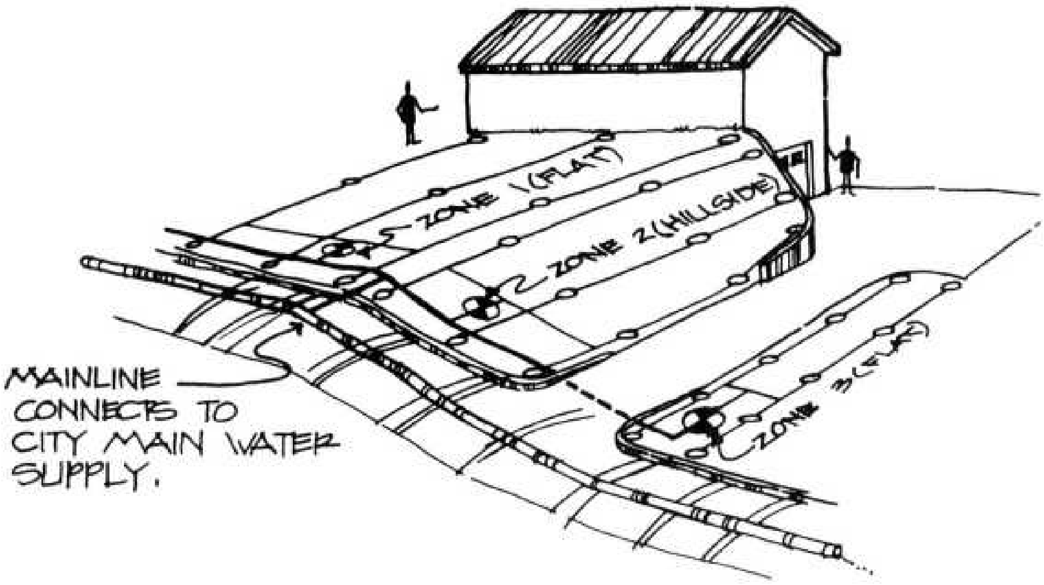


FIGURE 7.18 Route pipe with landforms.

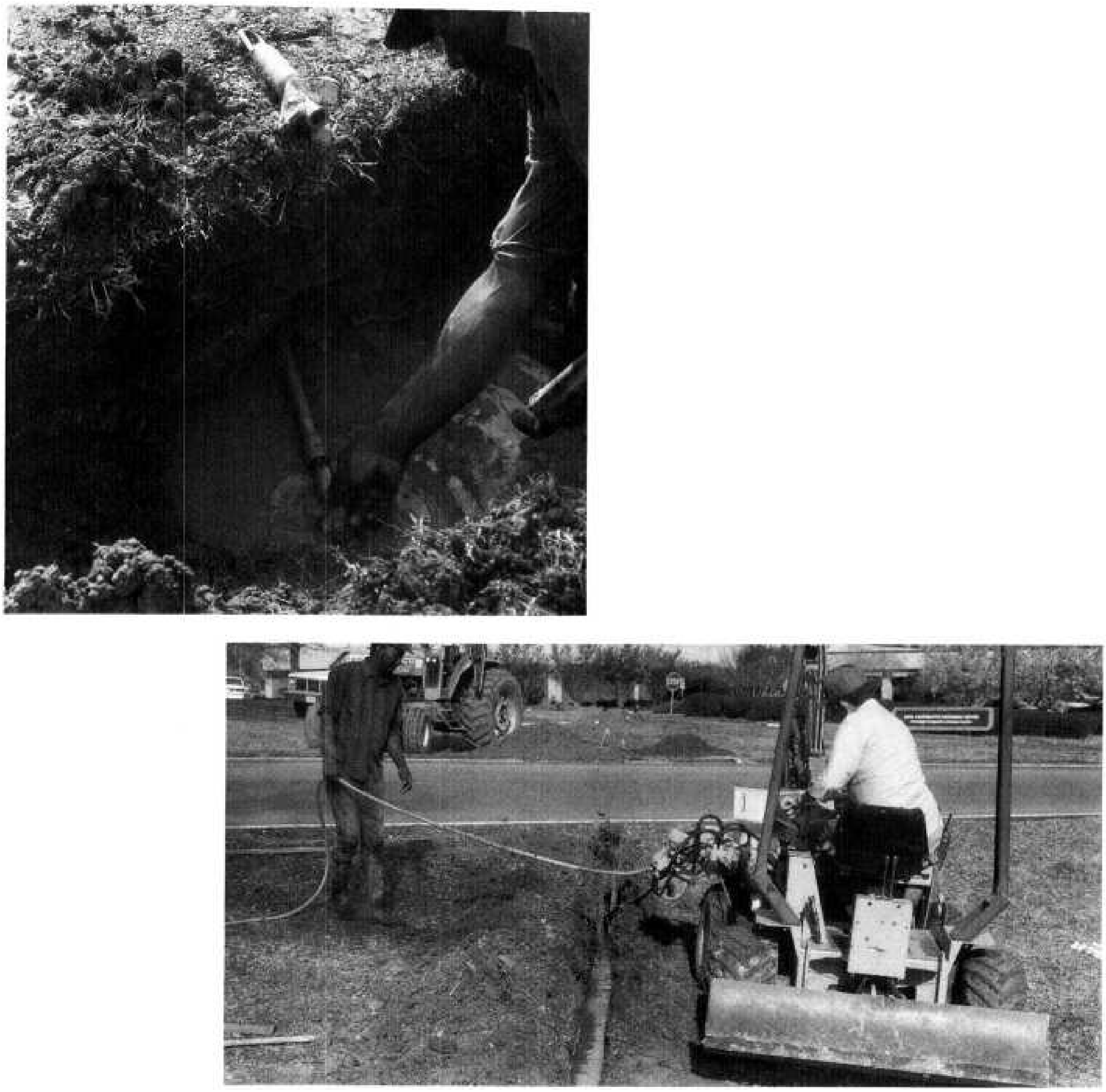


FIGURE 7.19 Boring beneath roadways.

8. Route pipe in your irrigation circuits with the contours of the land, as shown in Figure 7.18. This keeps pipes at, the same elevation and thus at the same pressure. For each elevation rise or fall of 1 ft (0.3 m), there is a 0.433 psi (0.03 kg/cm2) pressure change.

9. When laying out pipe, keep in mind that the longer and straighter the runs, the more time you'll save and the more productive the trenching machine will be. Each run or trench takes time to set up, and reducing setup time

saves money.

# 8

# Sizing Irrigation Pipe

## General Considerations

We have built up our confidence to the point where we are comfortable with defining geographical areas, laying out sprinkler heads, dividing geographical areas into circuits or zones, and even laying out pipe. Now, let us size that pipe. There are some general considerations we will first review before getting into actual sizing problems.

1. Pipe is sized according to how much water can go through it. The interior surface of pipe is rough; this causes friction loss, which diminishes the amount of pressure or force available to operate the heads. By controlling the speed or velocity of water, friction loss can also be controlled. Pipe sizes are selected based on flow at a velocity of 5 fps (1.5 mps). See Figure 8.1.

2. Why size pipe? Why not always use pipe that is big enough to carry the largest flow? The reason for sizing pipe is cost, a major factor in any irrigation installation. Looking at Table 8.1, we can see that larger pipe sizes are more expensive than the smaller sizes. This is why contractors use the smallest pipe size they can to accommodate the flow. Some designers will specify one or two pipe sizes on a job. This will increase the cost of the job but will simplify the contractor's task; installing only two sizes of pipe and fittings is much easier than installing lots of different sizes. Many good contractors never use pipe smaller than 1 in (25 mm).

3. The amount of water flowing through pipe at one time is based on how much water is demanded by the sprinkler heads downstream from that pipe section. The pipe gets smaller as it delivers water to irrigation heads (see Figure 8.2). Write the sprinkler head gpm (L/min) demand above each pipe section on your design to show required flow.

4. The bigger the flow the pipe must carry, the bigger the pipe must be. Table 8.2 depicts various pipe sizes and how much flow they can handle.

## TABLE 8.1 **Cost of Irrigation Pipe**

| SIZE | PIPE CLASS | COST PER FOOT (¢) |
|---|---|---|
| ½-in | 200 | 6.7 |
| ¾-in | 200 | 8 |
| 1-in | 200 | 10.6 |
| 1¼-in | 200 | 16.2 |
| 1½-in | 200 | 23.3 |
| 2-in | 200 | 37 |
| 3-in | 200 | 76 |
| 4-in | SCH 40 | 115 |

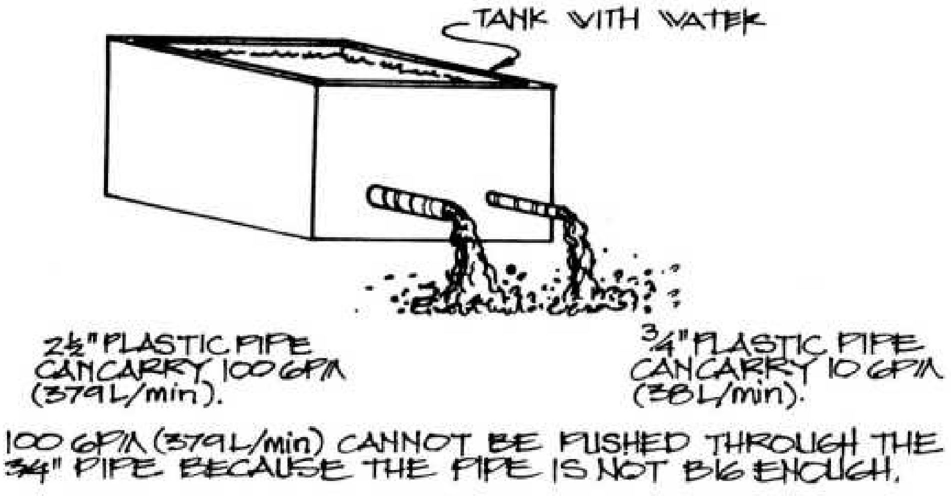


FIGURE 8. 1 Pipe size is based on flow.

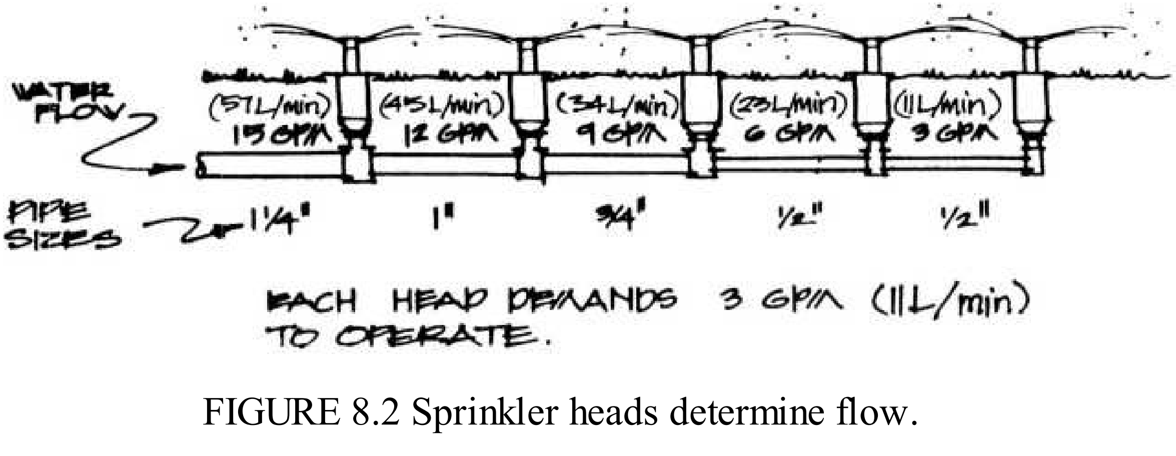


FIGURE 8.2 Sprinkler heads determine flow.

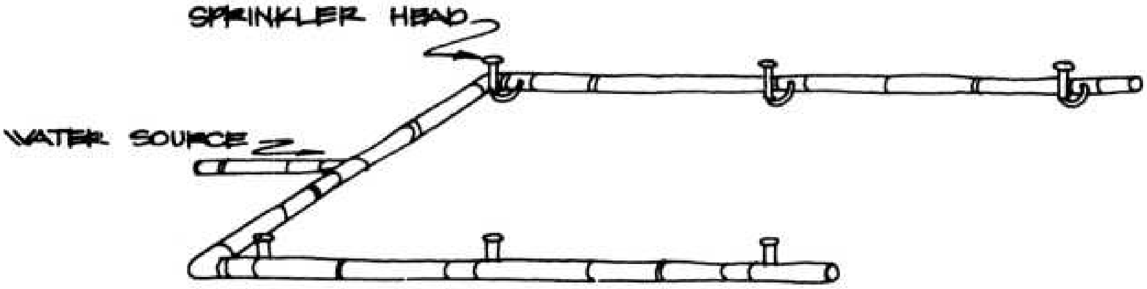


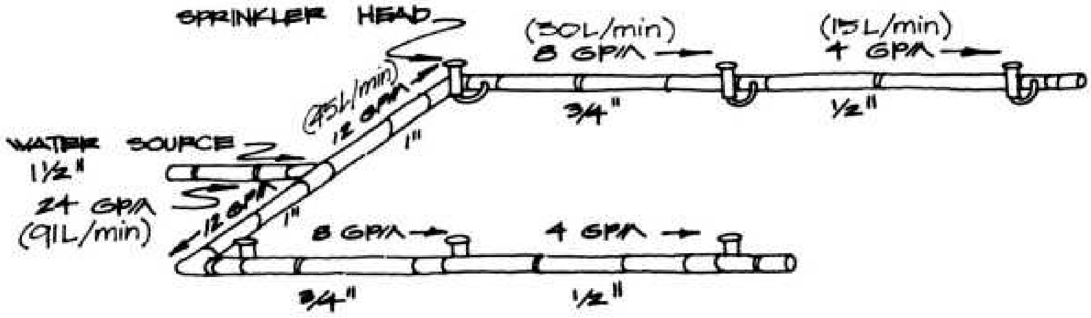
FIGURE 8.3 Pipe circuit with 6 sprinkler heads.

## TABLE 8.2 **Pipe Size and Flow Table**

| **PIPE SIZE** | **IDEAL FLOW** |
|---|---|
| **(Class 200-PVC)** | |
| ½-in | up to 6 gpm (23 L/min) |
| ¾-in | up to 10 gpm (38 L/min) |
| 1-in | up to 16 gpm (61 L/min) |
| 1¼-in | up to 26 gpm (98 L/min) |
| 1½-in | up to 35 gpm (133 L/min) |
| 2-in | up to 55 gpm (208 L/min) |

### Calculating Flow and Pipe Sizes

Now let us look at some examples of pipe circuits or zones to help you learn about calculating flow and pipe sizes. Remember, the size of pipe you choose should be based on how many gallons (liters) per minutes of water are flowing through it. You are given a layout in Figure 8.3 of six sprinkler heads connected with pipe. On this circuit, each head demands 4 gpm (15.14 L/min) of water in order to operate correctly. We would like you to:



EACH HEAD DEMANDS 4 GPM (15 L/min) TO OPERATE.

FIGURE 8.4 Flow and pipe sizes.

1. Calculate the number of gallons (liters) per minute of water going through each section of pipe.

2. Size the pipe based on your calculations.

Figure 8.4 illustrates the gpm (L/min) levels in various sections of pipe and how different pipe sizes are used to accommodate them.

Let us look at one more circuit, which will be more complex. Figure 8.5 shows a circuit with 13 sprinkler heads, each of which demands 2 gpm (7.57 L/min) of water flow. As in the preceding example, we would like you to

1 Calculate the number of gallons (liters) per minute of water going through each section of pipe.

2. Size the pipe based on your calculations.

Choose the smallest pipe possible for the given flow. Refer back to Table 8.2 for pipe sizing. The correct solution to this problem is illustrated in Figure 8.6.

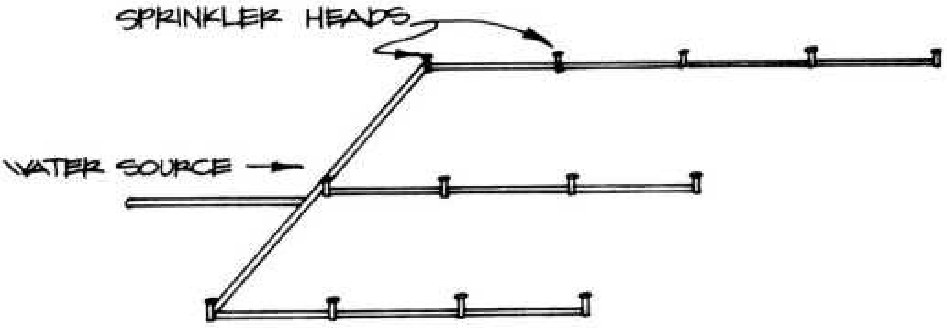


FIGURE 8.5 Pipe circuit with 13 sprinkler heads.

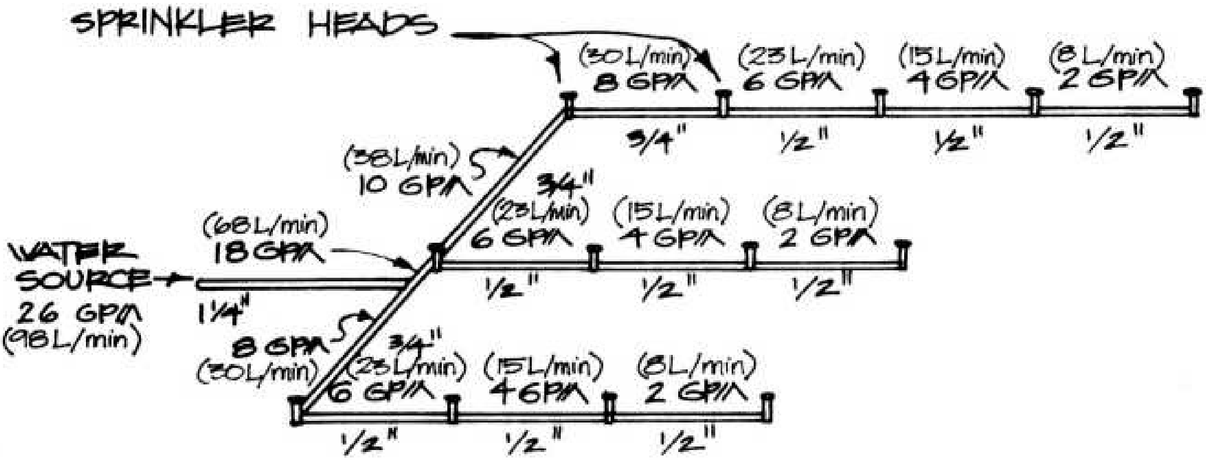


FIGURE 8.6 Flow and pipe size for each section.

# 9

# Basic Hydraulics

## Introduction

Now that we have explored the sprinkler head, its performance, and its placement, we are ready to extend our knowledge into the area of basic hydraulics.

As a designer, you must know where water for the system you are designing comes from and how to get it. You need to find out how much water is available to you and how much pressure will propel it through the pipe to the heads in the system. That pressure must be sufficient to push the heads out of the ground and distribute the water in the pattern you selected.

It can be a surprising experience for irrigation system designers to discover that they have not accurately determined existing water pressure and flow available and thus have incorrectly calculated the required pipe sizes. The author recently observed and photographed such a system in, which the heads would not operate properly.

## Hydraulic Terms

In order to understand and solve problems like the one we just described, we need to establish a thorough understanding of hydraulics. Hydraulics is the study of

the behavior of water both at rest and in motion. Water not moving through pipes has different characteristics than water that is moving. We will look at the following terms in detail:

1. Water pressure -static pressure

-working pressure (dynamic pressure)

2. Flow characteristics, including -friction loss

-velocity

-surge pressure

### Water Pressure

Pressure is what forces water to flow through the pipes to the sprinklers. This pressure is often created by the water's own weight. Water towers serve as examples of how this pressure caused by weight is influenced by elevation-the taller the column or pipe full of water, the more pressure you will have. We can, therefore, say that water pressure is a force at a particular location, caused by the weight of the water above that location.

The weight of water, which is the force, is directly related to the height of the column of water. A 1-ft (0.30481 m) column of water exerts 0.433 psi (0.0304399 kg/cm2) at the bottom of that column. The size of the column's base does not matter; the pressure per square inch (centimeter) at the bottom of the column is still 0.433 psi (0.0304399 kg/cm2) if the column is 1 ft (0.30481 m) long (see Figure 9.1) .

If we take the distance from the top of the water in a water tower to where it begins to run horizontally in the ground-let us say, 100 ft (30.5 m)-and multiply that figure by 0.433 psi (0.03 kg/cm2), we will get the amount of pressure that exists at the bottom of that column of water. In this case, the water pressure is 43.3 psi (3.04 kg/cm2), as is illustrated in Figure 9.2. The same process could be applied to a water tower that is 150 ft (45.72 m) above the ground. We take the height of the column of water, multiply it by 0.433 psi (0.0304399 kg/cm2), and come up with 65 pounds of pressure per square inch (4.57 kg/cm2) at the bottom of that column of water.

In addition to being created by elevation, water pressure can also be created mechanically by means of an electric motor and a pump with blades or impellers. Oftentimes, a steel tank is used to store water under pressure. As the pump forces water into the tank, pressure builds in it to a predesignated level. Then the pump shuts off. The pressurized tank will provide water at a range of pressure, for example, between 40 and 60 psi (2.81 kg/cm2-4.22 kg/cm2), which helps to reduce pump starting and stopping and thus extends the equipment's life. In this example, the pump would start at 40 psi (2.81 kg/cm2) and cut off at 60 psi (4.22 kg/cm2). Pump and pressure tank systems are available in a wide range of sizes and pressurization options, depending on your needs.

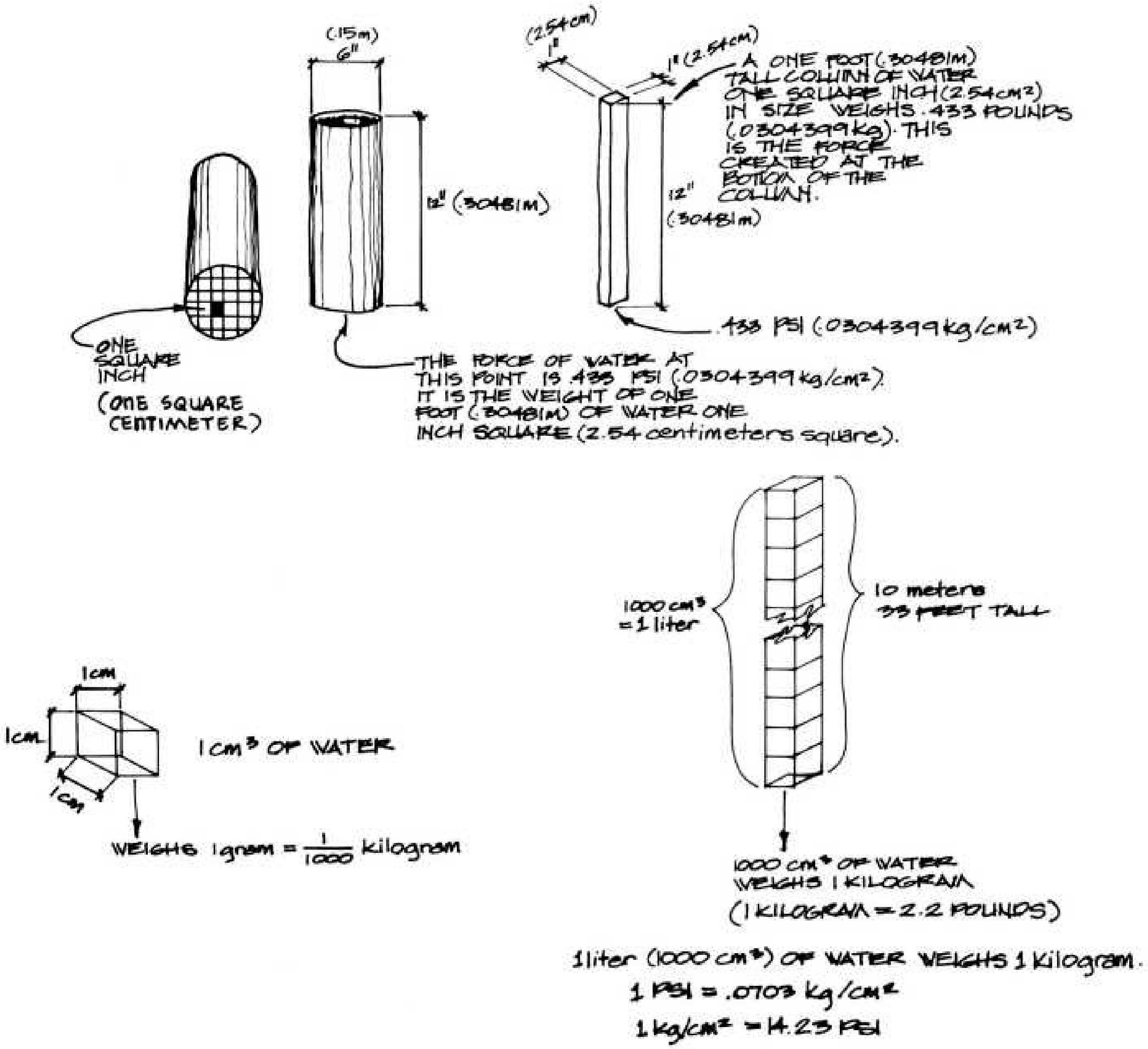


FIGURE 9.1 One pound per square inch of water (0.0304399 kilograms per square centimeter).

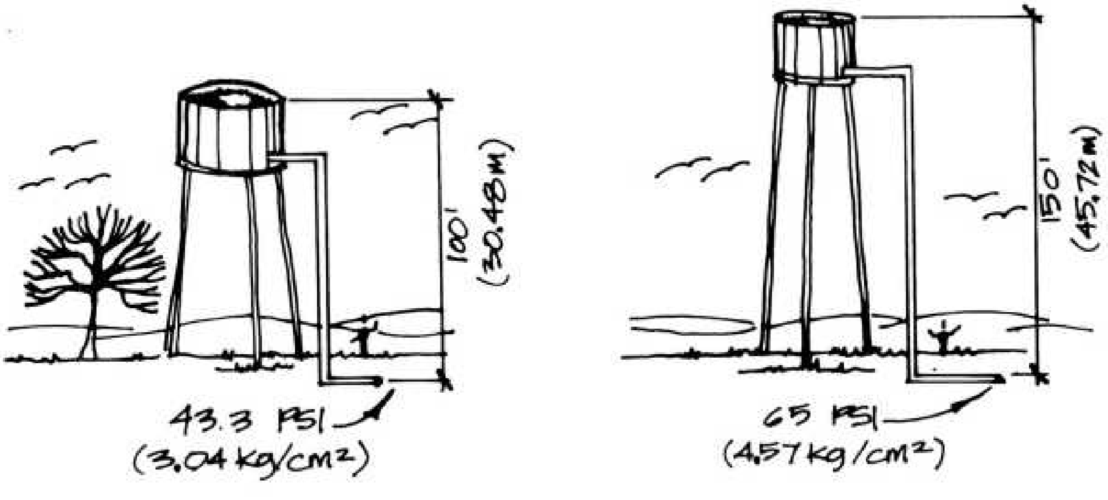


FIGURE 9.2 Water towers create pressure.

You might need a pump and pressure tank system when you are using pond water, well water, or even city-supplied water that does not have enough pressure and available flow for your needs. I have a client in a rural part of the county who had only 35 psi (2.46 kg/cm2) available to him at the roadside. (A typical pressure available in cities is 65 psi [4.57 kg/cm2].) This client had a 300-gal (1,136 L) tank and pump system, which builds water pressure up to a range of 60 psi to 80 psi (4.22 kg/cm2-5.62 kg/cm2), installed under his house. All of his water needs, from his bathrooms and kitchen to his irrigation system, are tied into this pressurized tank. He now has plenty of pressure to supply all of his water needs properly.

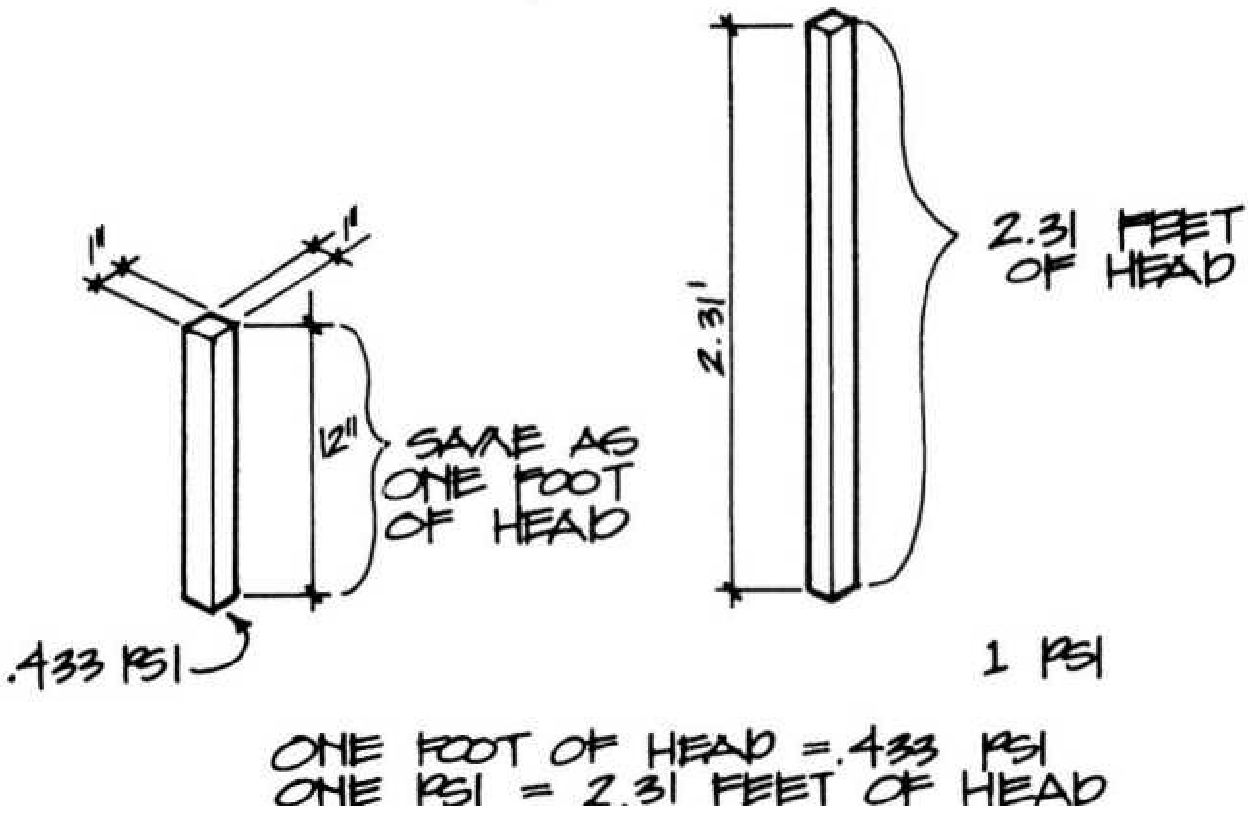


FIGURE 9.3 One foot of head.

Mechanical engineers refer to water pressure in terms of feet of head (meters of head) instead of pounds per square inch or kilograms per square centimeter. As we have said, a 12-in column of water exerts 0.433 psi of pressure (see Figure 9.3). This is the same as 1 ft of head. One psi, therefore, equals 2.31 ft of head (1.00 = 0.433 = 2.31). If you are going to be working with any kind of fountains or pumps, you need to be aware of this terminology. If an engineer asks you about the head-feet of a situation, know that you are being asked about the water pressure.

Static water pressure. The word static comes from the Greek word statikos, which means "causing to stand." As you might guess, therefore, static water pressure is calculated when water is standing still. When water is not moving, you need only to calculate the pressure in the pipe caused by elevation or by a pump. The static water pressure provided by many municipalities is around 65 psi (4.57 kg/cm2) in the city main (see Figure 9.4).

Working (dynamic) water pressure. Working water pressure is the pressure exerted by water moving and flowing. When water starts moving through a pipe, it begins to lose power, or pressure. The roughness of the pipe walls slows the molecules of water as they rush by. Therefore, when calculating working water pressure, you have to take into consideration this loss of pressure as water moves through the pipes.

### Flow Characteristics

When we use the term flow, we are talking about water moving. The terms friction loss, velocity, and surge pressure refer to the results of water moving. Irrigation designers must be aware of them.

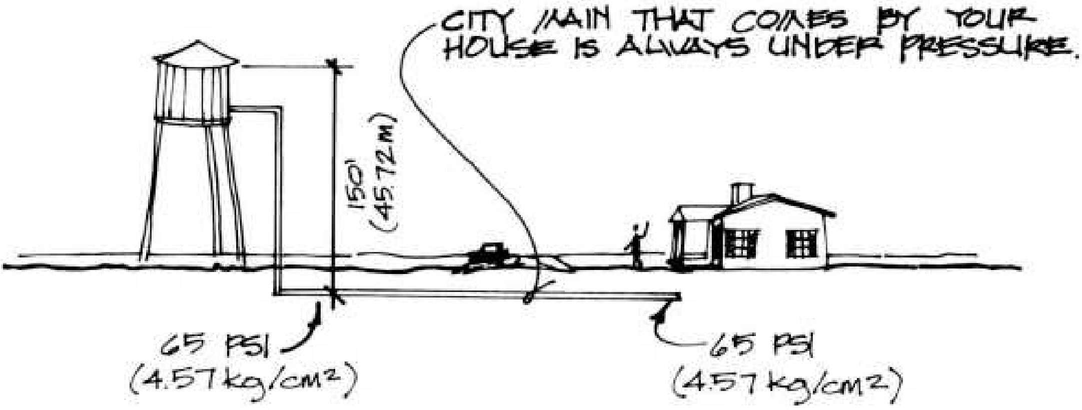


FIGURE 9.4 Static water pressure.

Friction loss. Friction loss is essentially the loss of pressure as water moves. It is expressed in pounds per square inch or kilograms per square centimeter. What causes friction loss? As water flows through the inside of a pipe, the roughness of the pipe wall slows the water, especially over long runs of pipe or when water is traveling very fast. This is an important point, so we will restate it. Friction loss occurs when:

1. The length of the pipe increases
2. The roughness of the inside of the pipe increases
3. The speed of water flow increases

Velocity. This term defines the rate at which water is moving and is expressed in feet (meters) per second. The maximum recommended velocity of water traveling through a pipe for irrigation use is 5 ft (1.52 m) per second. When water moves faster than that, turbulence in the pipe increases. When you try to stop water moving that fast, you will encounter shock wave problems. Consider the difference between a car hitting a wall at 10 mph (1.61 km/h) and a car hitting a wall at 70 mph (112.7 km/h). Water moving too fast through a pipe will cause major problems.

Surge pressure. This is pressure caused by water stopping suddenly in a pipe; it is the shock waves we just mentioned. Water hammer is another word for it. Velocities of 5 ft (1.52 m) per second and under will not produce excessive surge or water hammer. The valves that allow water to flow into your sprinkler system are engineered to open and close slowly enough so that water hammer is reduced. A valve that snaps shut in less than 1 second is going to cause shock waves, which have a tendency to run one way down the pipe until they get to the end and then reverse themselves, running back the other way until they dissipate-or until the pipe and its joints succumb to the force of the water hammer. If the system you are designing has valves that your clients turn on by hand, be sure to tell them about water hammer. Instruct your clients to open and close valves slowly. (A valve, by the way, is a device that turns water on and off either automatically or by hand. When you turn the bath water on, you are operating a valve.)

## Applying Hydraulic Terms

Now that we have reviewed our hydraulic terms, let us apply them to irrigation situations.

### Static Water Pressure

We will begin by looking at an example of static water pressure computation. Figure 9.5 depicts an underground sprinkler system with a mainline, a valve, and two sprinkler heads. The mainline down to the valve maintains a constant water pressure of 43 psi (3.02 kg/cm2). The pressure at the valve will be higher because of the difference in elevation. The 43 psi (3.02 kg/cm2) is a given pressure for this example; static pressures in mainlines vary from 30 psi (2.11 kg/cm2) to over 125 psi (8.79 kg/cm2) for residential and small commercial systems.

As we calculate the static pressure at the valve, be sure to note the change in elevation. There is a 20-ft (6.1-m) drop from the mainline to the valve.

Remember, static water pressure is the pressure when water is not moving. The drop in elevation from the mainline to the valve will increase the static pressure at the valve owing to the weight of the 20-ft (6.1-m) column of water in the pipe. So we take the 20 ft (6.1 m) and multiply it by 0.433 psi (0.0304399 kg/cm2), which is the weight (force) of a 1-ft (0.3 m) column of water, and we get 8.66 psi (0.6088 kg/cm2). We add this extra water weight (force) to the 43 psi (3.02 kg/cm2) static pressure in the mainline, and we end up with 51.66 psi (3.63 kg/cm2) static water pressure at the valve (43 + 8.66 = 51.66). Note that our static pressure increases just because of the 20-ft (6.1-m) drop. As a designer, you must consider elevation differences greater than 7 ft (2.13 m), because 7 ft (2.13 m) will cause a 3 psi (0.21 kg/cm2) rise or drop in your water pressure. Elevations less than that tend to be unimportant to a project's success.

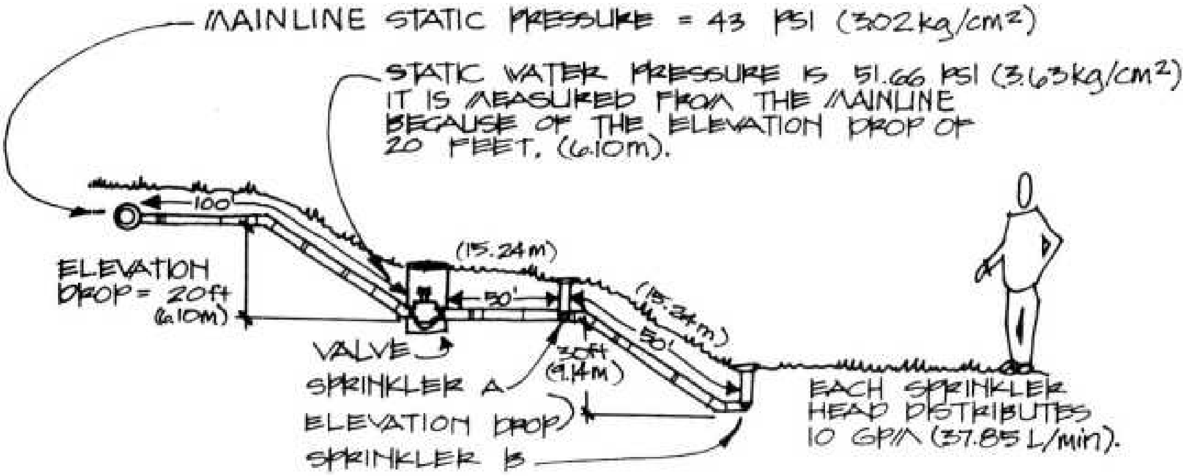


FIGURE 9.5 Static pressure.

We are not yet working with water that is moving! In a static pressure situation, the valve is closed, so

there is no water under pressure beyond the valve in the sprinkler heads. Figure 9.6 depicts a mainline and automatic valve.

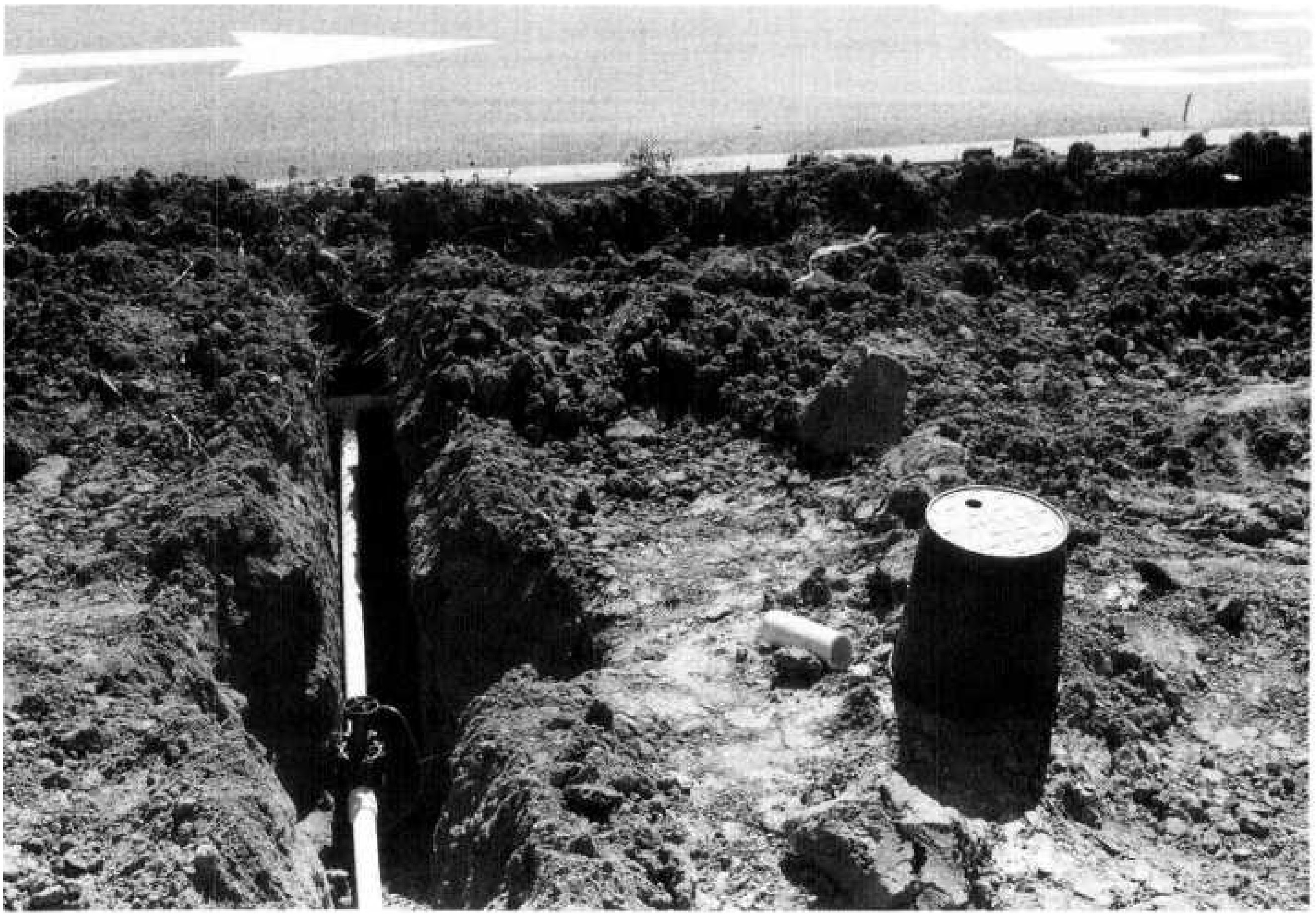


FIGURE 9.6 Mainline and automatic valve.

### Working Water Pressure

When the valve is turned on by hand (manually) or opened automatically by a controller, the water begins to move through the system to the sprinkler heads. This, now, is water in motion, so we will now calculate working water pressure. You might wonder at this point, Why do we calculate static pressure and then working pressure? The reason is that we must begin with a given or determined pressure, which includes elevation differences, before we can calculate the pressure resulting from water flowing.

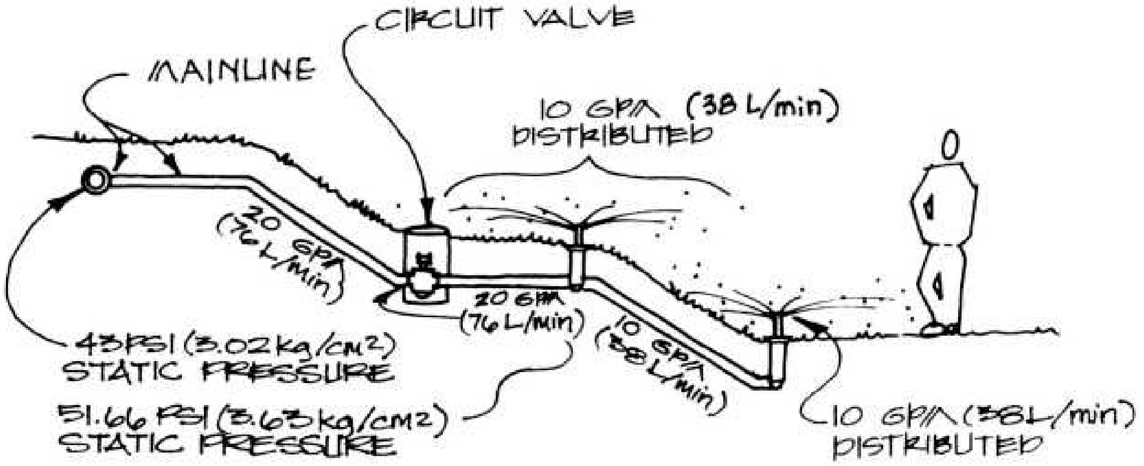


FIGURE 9.7 Gallons (liters) per minute of water going through pipe sections.

Consider the irrigation system depicted in Figure 9.7. As the valve opens, 20 gpm (75.7 L/min) of water flows through the pipes from the mainline to the first sprinkler head. Ten gpm (37.85 L/min) of water goes through this head and is sprayed on the lawn. From the first sprinkler to the second, only 10 gpm (37.85 L/min) of water flows through the pipe, and it, too, goes through a sprinkler head and onto the lawn. Remember, each sprinkler head needed 10 gpm (37.85 L/min) to operate properly. Therefore, 20 gpm (37.85 L/min) was called for when the valve was opened. In order to calculate working water pressure, we need to calculate the following:

1. The loss of pressure as water flows through pipe-remember, the roughness of the inside of the pipe slows the water

2. The loss of pressure as water flows through valves

3. How changes of elevation affect water pressure

We even have to go back to the service line and water meter and calculate the loss of pressure there.

Friction loss pipe charts. To avoid getting bogged down in too many calculations, for this example we are going to skip figuring pressure loss as water flows through the service line and water meter. We will calculate our pressure losses based on 43 psi (3.02 kg/cm2) static pressure at the mainline. Before we are able to calculate the loss of pressure as water flows through the pipes, we need to get acquainted with how to use pipe friction loss charts. There is a friction loss chart for every type of pipe. The charts help us to do two things:

1. Calculate the friction loss as water flows through pipes

2. Calculate the size of pipe needed based on the amount of water flowing through the pipe section

Table 9.1 shows the friction loss of water flowing through different sizes of Class 200 plastic pipe, a commonly used grade of irrigation pipe. On the left side of the chart, the GPM column indicates the flow, or the number of gallons of water traveling through the pipe each minute. The next column to the right indicates the velocity of the water in feet per second. On the right side of the chart, the flow is repeated for convenience, and the pipe sizes are listed as well, with the actual inside diameter sizes listed beneath them. The friction loss calculations within the chart are given for different lengths of pipe. The different pipe lengths are noted across the top of the chart. To convert from gallons to liters, multiply the number of gallons by 3.785. One U.S. gallon equals 3.785 liters. The time interval stays the same, so 1 gpm in U.S. (imperial) measurement is the same as 3.785 L/min in metric measurement.

This is a very convenient chart that allows us to find the friction loss in any size and length of pipe for any amount of flow. The corresponding velocities are also given, so we can be sure to select pipe sizes to keep the velocity at 5 ft (1.52 m) per second or lower in order to prevent water hammer in the pipes. As an example of pressure loss, let us say we have 30 gpm (113.55 L/min) of water going through a 2-in pipe. What is the friction loss per 100 ft of that water moving through the pipe? If you said 0.56 psi (0.04 kg/cm2), you were correct. What about 30 gpm (113.55 L/min) moving through a 1 4-in pipe? You were correct with 1.64 psi (0.12 kg/cm2) loss per 100 ft (30.48 in) of pipe. You can see that as you call for more water through a pipe, you need to go to larger pipe sizes to reduce pressure loss and keep velocity at or below 5 ft (1.52 m) per second.

*TABLE 9.1* ***Class 200 Friction Loss Chart***

| | | PSI LOSS PER PIPE LENGTH (FT) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **GPM** | **Velocity (ft/sec)** | **5** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** | **90** | **100** | **GPM** | **Pipe Size** |
| 1 | 0.8 | 0.01 | 0.02 | 0.04 | 0.06 | 0.08 | 0.10 | 0.12 | 0.14 | 0.16 | 0.18 | 0.20 | 1 | ½″ (0.720″ inside diameter) |
| 2 | 1.6 | 0.04 | 0.07 | 0.15 | 0.22 | 0.30 | 0.37 | 0.44 | 0.52 | 0.59 | 0.67 | 0.74 | 2 | |
| 3 | 2.4 | 0.08 | 0.16 | 0.31 | 0.47 | 0.62 | 0.78 | 0.94 | 1.09 | 1.25 | 1.40 | 1.56 | 3 | |
| 4 | 3.2 | 0.13 | 0.27 | 0.54 | 0.80 | 1.07 | 1.34 | 1.61 | 1.88 | 2.14 | 2.41 | 2.68 | 4 | |
| 5 | 4.0 | 0.20 | 0.40 | 0.81 | 1.21 | 1.62 | 2.02 | 2.42 | 2.83 | 3.23 | 3.64 | 4.04 | 5 | |
| 6 | 4.8 | 0.29 | 0.58 | 1.15 | 1.73 | 2.30 | 2.88 | 3.46 | 4.03 | 4.61 | 5.18 | 5.76 | 6 | |
| 7 | 5.6 | 0.38 | 0.77 | 1.53 | 2.30 | 3.06 | 3.83 | 4.60 | 5.36 | 6.13 | 6.89 | 7.66 | 7 | |
| 8 | 6.4 | 0.49 | 0.98 | 1.96 | 2.93 | 3.91 | 4.89 | 5.87 | 6.85 | 7.82 | 8.80 | 9.78 | 8 | |
| 2 | 0.9 | 0.01 | 0.02 | 0.04 | 0.07 | 0.09 | 0.11 | 0.13 | 0.15 | 0.18 | 0.20 | 0.22 | 2 | ¾″ (0.930″ inside diameter) |
| 4 | 1.9 | 0.04 | 0.08 | 0.16 | 0.23 | 0.31 | 0.39 | 0.47 | 0.55 | 0.63 | 0.70 | 0.78 | 4 | |
| 6 | 2.8 | 0.09 | 0.17 | 0.34 | 0.50 | 0.66 | 0.83 | 1.00 | 1.16 | 1.34 | 1.49 | 1.66 | 6 | |
| 8 | 3.8 | 0.14 | 0.28 | 0.56 | 0.85 | 1.14 | 1.42 | 1.70 | 1.99 | 2.27 | 2.56 | 2.84 | 8 | |
| 10 | 4.7 | 0.22 | 0.43 | 0.86 | 1.29 | 1.72 | 2.15 | 2.58 | 3.01 | 3.45 | 3.87 | 4.30 | 10 | |
| 12 | 5.7 | 0.30 | 0.60 | 1.20 | 1.80 | 2.40 | 3.00 | 3.60 | 4.20 | 4.80 | 5.40 | 6.00 | 12 | |
| 14 | 6.6 | 0.40 | 0.80 | 1.60 | 2.40 | 3.20 | 4.00 | 4.80 | 5.60 | 6.40 | 7.20 | 8.00 | 14 | |
| 6 | 1.7 | 0.03 | 0.05 | 0.10 | 0.15 | 0.20 | 0.25 | 0.30 | 0.35 | 0.40 | 0.45 | 0.50 | 6 | **1″** (1.189″ inside diameter) |
| 8 | 2.3 | 0.05 | 0.09 | 0.17 | 0.26 | 0.34 | 0.43 | 0.52 | 0.60 | 0.69 | 0.77 | 0.86 | 8 | |
| 10 | 2.9 | 0.07 | 0.13 | 0.26 | 0.39 | 0.52 | 0.65 | 0.78 | 0.91 | 1.04 | 1.17 | 1.30 | 10 | |
| 12 | 3.5 | 0.09 | 0.18 | 0.37 | 0.55 | 0.74 | 0.92 | 1.10 | 1.29 | 1.47 | 1.66 | 1.84 | 12 | |
| 14 | 4.1 | 0.12 | 0.24 | 0.48 | 0.73 | 0.97 | 1.21 | 1.45 | 1.69 | 1.94 | 2.18 | 2.42 | 14 | |
| 16 | 4.7 | 0.16 | 0.31 | 0.62 | 0.93 | 1.24 | 1.55 | 1.86 | 2.17 | 2.48 | 2.79 | 3.10 | 16 | |
| 18 | 5.2 | 0.20 | 0.39 | 0.77 | 1.16 | 1.54 | 1.93 | 2.32 | 2.70 | 3.09 | 3.47 | 3.86 | 18 | |
| 20 | 5.8 | 0.24 | 0.47 | 0.94 | 1.40 | 1.87 | 2.34 | 2.81 | 3.28 | 3.74 | 4.21 | 4.68 | 20 | |
| 22 | 6.4 | 0.29 | 0.57 | 1.13 | 1.70 | 2.26 | 2.83 | 3.40 | 3.96 | 4.53 | 5.09 | 5.66 | 22 | |
| 24 | 6.9 | 0.33 | 0.66 | 1.32 | 1.99 | 2.65 | 3.31 | 3.97 | 4.63 | 5.30 | 5.96 | 6.62 | 24 | |
| 10 | 1.8 | 0.02 | 0.04 | 0.08 | 0.13 | 0.17 | 0.21 | 0.25 | 0.29 | 0.34 | 0.38 | 0.42 | 10 | **1¼″** (1.502″ inside diameter) |
| 12 | 2.2 | 0.03 | 0.06 | 0.12 | 0.17 | 0.23 | 0.29 | 0.35 | 0.41 | 0.46 | 0.52 | 0.58 | 12 | |
| 14 | 2.6 | 0.04 | 0.08 | 0.16 | 0.23 | 0.31 | 0.39 | 0.47 | 0.55 | 0.62 | 0.70 | 0.78 | 14 | |
| 16 | 2.9 | 0.05 | 0.10 | 0.20 | 0.30 | 0.40 | 0.50 | 0.60 | 0.70 | 0.80 | 0.90 | 1.00 | 16 | |
| 18 | 3.3 | 0.06 | 0.12 | 0.25 | 0.37 | 0.50 | 0.62 | 0.74 | 0.87 | 0.99 | 1.12 | 1.24 | 18 | |
| 20 | 3.6 | 0.08 | 0.15 | 0.30 | 0.45 | 0.60 | 0.75 | 0.90 | 1.05 | 1.20 | 1.35 | 1.50 | 20 | |
| 22 | 4.0 | 0.09 | 0.18 | 0.36 | 0.54 | 0.72 | 0.90 | 1.08 | 1.26 | 1.44 | 1.62 | 1.80 | 22 | |
| 24 | 4.3 | 0.11 | 0.21 | 0.42 | 0.63 | 0.84 | 1.05 | 1.26 | 1.47 | 1.68 | 1.89 | 2.10 | 24 | |
| 26 | 4.7 | 0.12 | 0.24 | 0.49 | 0.73 | 0.98 | 1.22 | 1.46 | 1.71 | 1.95 | 2.20 | 2.44 | 26 | |
| 28 | 5.1 | 0.14 | 0.28 | 0.56 | 0.84 | 1.12 | 1.40 | 1.68 | 1.96 | 2.24 | 2.52 | 2.80 | 28 | |
| 30 | 5.5 | 0.16 | 0.32 | 0.64 | 0.95 | 1.27 | 1.59 | 1.91 | 2.23 | 2.54 | 2.86 | 3.18 | 30 | |
| 32 | 5.8 | 0.18 | 0.36 | 0.72 | 1.07 | 1.43 | 1.79 | 2.15 | 2.51 | 2.86 | 3.22 | 3.58 | 32 | |
| 34 | 6.2 | 0.20 | 0.40 | 0.80 | 1.20 | 1.60 | 2.00 | 2.40 | 2.80 | 3.20 | 3.60 | 4.00 | 34 | |
| 36 | 6.6 | 0.22 | 0.45 | 0.89 | 1.33 | 1.78 | 2.22 | 2.66 | 3.11 | 3.55 | 4.00 | 4.44 | 36 | |
| 15 | 2.2 | 0.03 | 0.05 | 0.09 | 0.14 | 0.18 | 0.23 | 0.28 | 0.32 | 0.37 | 0.41 | 0.46 | 15 | **1½″** (1.720″ inside diameter) |
| 20 | 2.8 | 0.04 | 0.08 | 0.16 | 0.23 | 0.31 | 0.39 | 0.47 | 0.55 | 0.62 | 0.70 | 0.78 | 20 | |
| 25 | 3.5 | 0.06 | 0.12 | 0.24 | 0.35 | 0.47 | 0.59 | 0.71 | 0.83 | 0.94 | 1.06 | 1.18 | 25 | |
| 30 | 4.1 | 0.08 | 0.16 | 0.33 | 0.49 | 0.66 | 0.82 | 0.98 | 1.15 | 1.31 | 1.48 | 1.64 | 30 | |
| 35 | 4.8 | 0.11 | 0.22 | 0.44 | 0.65 | 0.87 | 1.09 | 1.31 | 1.53 | 1.74 | 1.96 | 2.18 | 35 | |
| 40 | 5.5 | 0.14 | 0.28 | 0.56 | 0.84 | 1.12 | 1.40 | 1.68 | 1.96 | 2.24 | 2.52 | 2.80 | 40 | |
| 45 | 6.2 | 0.18 | 0.35 | 0.70 | 1.04 | 1.39 | 1.74 | 2.09 | 2.44 | 2.78 | 3.13 | 3.48 | 45 | |
| 50 | 6.9 | 0.21 | 0.42 | 0.85 | 1.27 | 1.70 | 2.12 | 2.54 | 2.97 | 3.39 | 3.82 | 4.24 | 50 | |

Now let us apply this friction loss chart to our sample problem, determine the pipe sizes to use, and calculate our working water pressure. From the main water supply line to the valve, we have a 100-ft (30.48-m) section of pipe with 20 gpm (75.7 L/min) going through it. Looking at the friction loss chart at 20 gpm (75.7 L/min) of flow, we see that a 1.25-in pipe will work. It is the smallest pipe we can choose and still maintain a velocity at or below 5 ft (1.52 m) per second. To be exact, the chart tells us that using this pipe would result in 3.6 ft (1.1 m) per second velocity. The friction loss for 20 gpm (75.7 L/min) of water going through the 1

Y4-in pipe is 1.5 psi (0.11 kg/cm2) loss per 100 ft (30.48 m). Going back to the static pressure at the valve of 51.66 psi (3.63 kg/cm2), we subtract the 1.5 psi (0.11 kg/cm2), and our working water pressure at the valve is 50.16 psi (3.53 kg/cm2).

Our 20 gpm (75.7 L/min) of water flowing through the valve loses 5 psi (0.35 kg/cm2). Valves will cause a pressure loss of roughly 1 to 7 psi (0.07 kg/cm2 to 0.49 kg/cm2) and higher, depending on the amount of water going through the valve. (See Table 9.2 to determine the friction loss for valves.) We are using a 1-in electrically actuated globe valve, which opens upon receiving an electric impulse from the automatic controller. The basic difference between angle and globe valves is shown in Figure 9.8.

From the valve to the first sprinkler head is 50 ft (15.24 m). We have 20 gpm (75.7 L/min) of water going through the pipe. Looking at our pipe chart, we see that with a 1%-in pipe, the friction loss will be 0.75 psi (0.05 kg/cm2). We now subtract the 0.75 psi (0.05 kg/cm2) friction loss from the 45.16 psi (3.18 kg/cm2) at the valve, and we get 44.4 psi (3.13 kg/cm2) working pressure at the first sprinkler. The working pressure calculation is important because sprinkler heads operate at a variety of pressure ranges.

Let us assume the pressure range for our nozzle is between 35 and 60 psi (2.46 kg/cm2 to 4.22 kg/cm2).

We see that the working pressure of 44.4 psi (3.12 kg/cm2) at the first sprinkler head is within its pressure operating range. If we had less than 35 psi (2.46 kg/cm2), the pressure would not pop the riser out of the ground and distribute the water in the pattern needed. If we had more than 60 psi (4.22 kg/cm2), the sprinkler head would be under too much pressure; the water pattern would be broken up, and misting would occur. The pattern could become distorted in the most gentle of winds.

## *TABLE 9.2* ***Valve Pressure Loss Table***

| TYPE | GPM | | | | | | |
|---|---|---|---|---|---|---|---|
| | 5 | 10 | 15 | 20 | 25 | 30 | 40 |
| 1-in HYDRAULIC | <1 | 1 | 2 | 3 | 4 | 6 | 9.5 |
| 1-in ELECTRIC | 3 | 4.4 | 4.5 | 5 | 5 | 7 | 9.5 |

The first sprinkler head then distributes 10 gpm (37.85 L/min) of water at 44.4 psi (3.12 kg/cm2). The remaining 10 gpm (37.85 L/min) goes to the second sprinkler head through a 50-ft (15.24 m) section of pipe. Checking the friction loss chart in Table 9.1, we first look at the 10-gpm (37.85 L/min) flow column and then over to the smallest pipe that will accommodate that flow. We see that a %}-in pipe will accommodate the 10-gpm (37.85-L/min) flow, with 2.15 psi (0.15 kg/cm2) of friction loss for the 50-ft (15.24 m) pipe section. Now, a word of advice to you. As a designer you can do something inexpensively to reduce the amount of pressure you have on your lines, like add a pressure regulator. But in general, you cannot do something inexpensively to increase your pressure. Therefore, we designers tend to be somewhat stingy with our pressure; we try to conserve it if we can.

Although 10 gpm (37.85 L/min) of water will go through the X4-in pipe and lose 2.15 psi (0.15 kg/cm2) per 50 ft (15.24 m) of pipe, if we use 1-in pipe, the friction loss will be only 0.65 psi (0.05 kg/cm2) per 50 ft (15.24 m) of pipe. So let us be conservative (and safe) and use that 1-in pipe size. Our working water pressure at the second sprinkler head, then, is 43.75 psi (3.08 kg/cm2), but this does not take into consideration the pressure increase due to the 30-ft (9.14-m) elevation drop (see Figure 9.9). Therefore, we take 0.433 psi (0.0304399 kg/cm2), multiply it by 30 ft (9.14 m), and get an increase of 12.99 psi (0.91 kg/cm2). We add this calculation to the 43.75 psi (3.08 kg/cm2) and get a working water pressure at the second sprinkler head of 56.73 psi (3.99 kg/cm2). This pressure is still within the sprinkler pressure operating range, so the head will operate correctly.

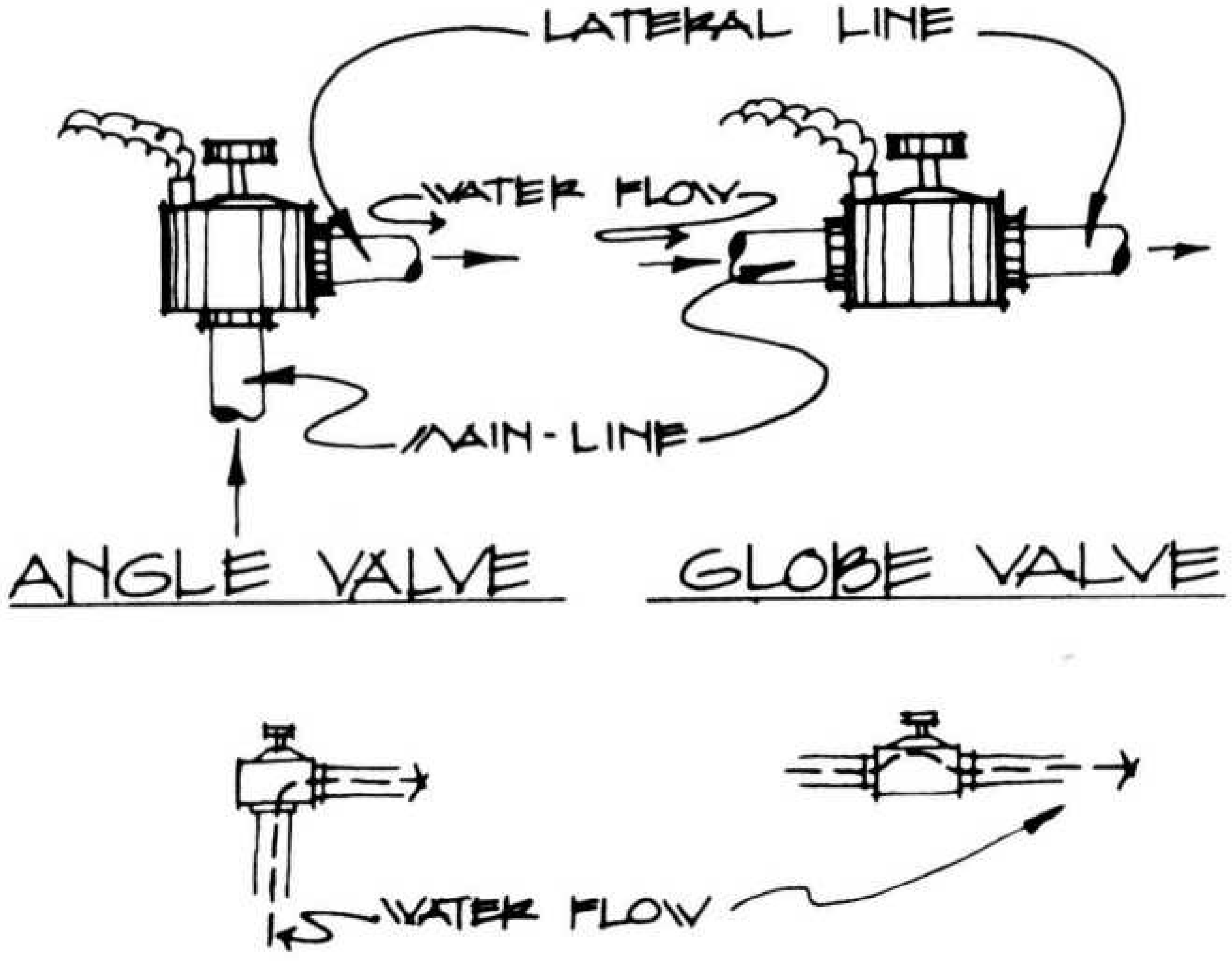


FIGURE 9.8 How water flows through angle and globe valves.

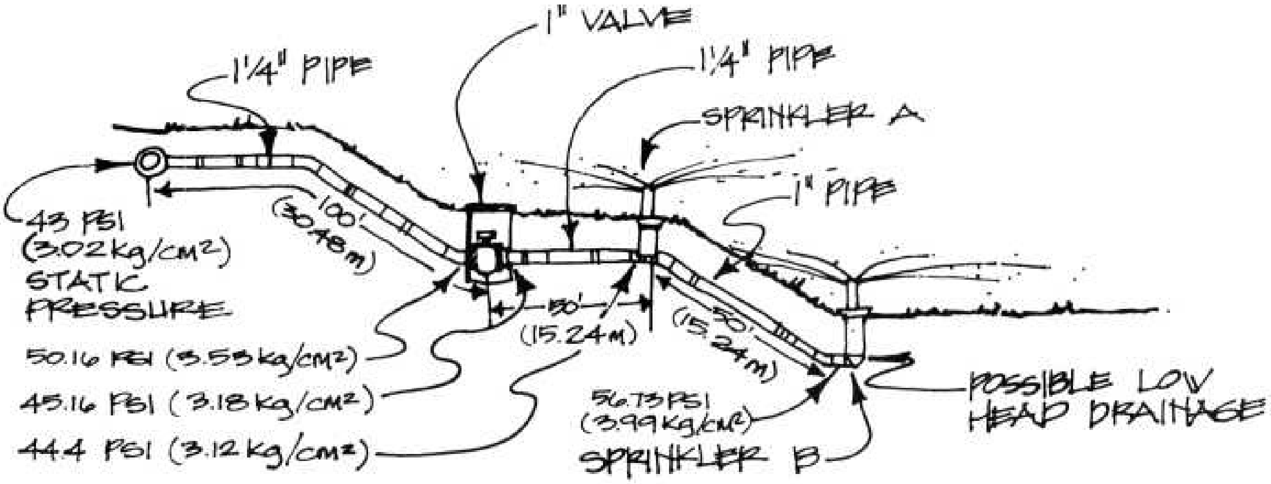


FIGURE 9.9 Working water pressure.

If we had gone slightly over the pressure operating range of our sprinkler head, which was 35 psi to 60 psi (2.46 kg/cm2 to 4.2 kg/cm2), we could have used a device called a pressure regulator, which causes friction loss as water goes through it. The pressure regulator, as shown in Figure 9.10, would have been placed between the first and second sprinkler heads to combat the increased pressure created by the 30-ft (9.14-m) drop in elevation. Pressure regulators are adjusted to the pressure you desire.

In many landscape situations, the low head drains the water from all the pipes in the circuit when the water pressure is turned off by the valve. Gravity causes this to occur. This may not sound like a big problem or a lot of water, but if you look at Figure 9.11, you will see what low head drainage can do to a landscape. You can select heads that have a special check valve in them that will not allow low head drainage. The valve will also keep the water in the circuit pipes and help prevent water hammer problems. When a valve opens and water rushes into an empty pipe, the air can compress and escape from the sprinklers about five times as fast as the water. Therefore, when the water reaches the sprinkler heads, water hammer occurs. Using check valves also supports water conservation.

FIGURE 9. 10 Valve and pressure regulator.

## Further Pipe Sizing

We now understand a little about basic hydraulics and, in particular, water pressure, whether it be static water pressure or working water pressure. We know how to calculate the water pressure of a given amount of water at certain points along a water line and how to determine the proper pipe sizes. Let us get involved in another pipe-sizing and pressure exercise to further sharpen our skills.

Looking at a more complex irrigation head layout in Figure 9.12, we see that each sprinkler head demands 2 gpm (7.57 L/min). I ask you, What is the total water demand of this sprinkler circuit? What you need to do is count the number of heads and multiply them by 2 gpm (7.57 L/min) of flow; you get 18 gpm (68.13 L/min) of flow demand for this circuit. Now, size the pipe according to the amount of water flowing through each section of pipe. I find that it helps to put the number of gallons (liters) flowing through the pipe right above each section of pipe on my design. Then, look at the pipe-sizing chart in Table 9.1 and select a pipe that allows the amount of gallons flowing through it to be accommodated without exceeding a velocity of 5 ft per second. In Figure 9.13 you will see the number of gallons (liters) per minute going

through each section of pipe written above or to the side of that section of pipe.

Once you have determined the amount of gallons (liters) flowing through each pipe section, you are ready to look at the GPM column in the pipe-sizing chart. Pick out the amount of flow for each pipe section, and then look to the right and pick the size of pipe needed to accommodate that flow.

The process of sizing pipe, as we have discussed, is basically a function of how much water is going to flow through that pipe. Once you have selected the sprinkler heads you are going to use and laid out the pipe in the most economical manner, you size the pipe according to the flow demand for each sprinkler head. At this point some of you are probably asking, What about water pressure? Do we need to know what the water pressure is in order to size the pipe? Remember from our previous discussion of pipe sizing that the answer is no, we do not need to know what the water pressure is in order to size the pipe. We do, however, need to know what the water pressure is for these reasons:

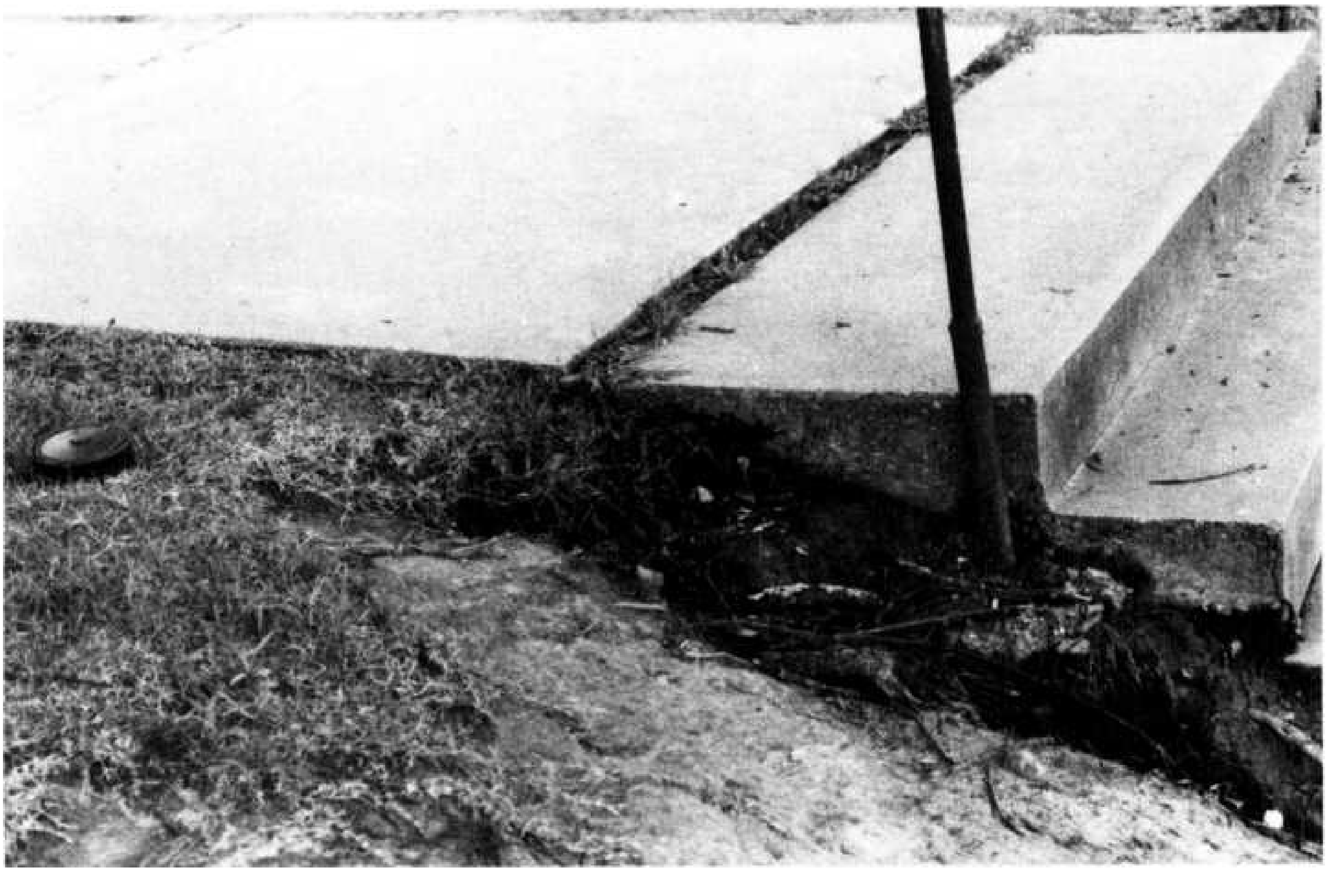


FIGURE 9. 11 Low head drainage.

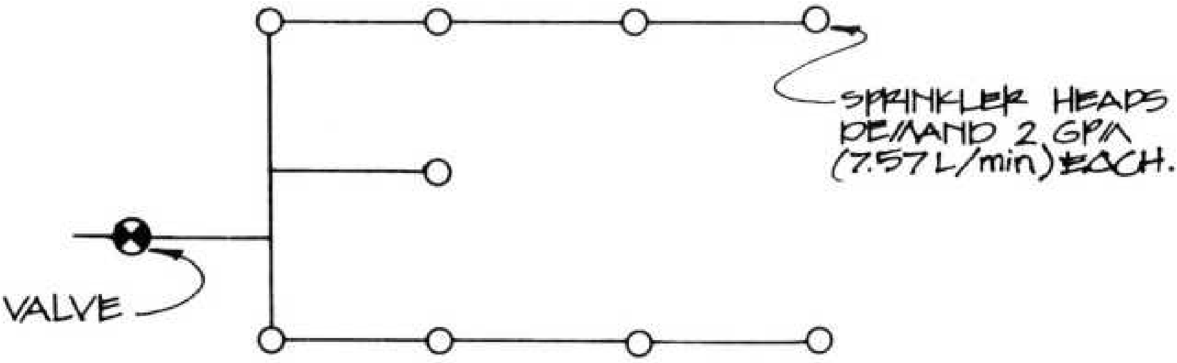


FIGURE 9.12 Head layout.

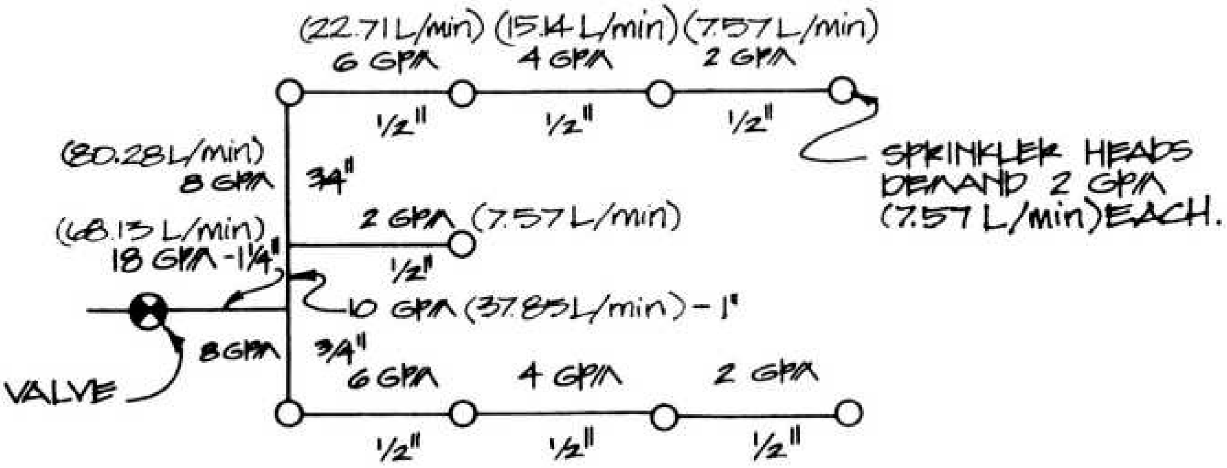


FIGURE 9.13 Flow and pipe sizes.

1. We choose irrigation heads on the basis of whether they can operate with the amount of pressure that is available.

2. If we do not have an ample amount of water pressure to work with, then we know to size our pipes larger than indicated by the pipe-sizing chart to reduce the friction loss of the water going through the pipe. This saves the pressure that we would lose through friction loss for proper operation of the sprinkler heads.

3. If we have too much water pressure, we will know to use certain kinds of valves or pressureregulating devices to reduce it.

Now let us calculate the pressure loss in the circuit for which we have just sized the pipe. The mainline just to the left of the valve is at a constant pressure of

50 psi (3.52 kg/cm2). When the valve is opened (either manually or automatically), how many gpm (L/min) of water will go through that valve? You are correct-the same flow that is needed by the nine sprinkler heads, 18 gpm (68.13 L/min). Let us look at the valve-sizing chart in Table 9.2 to see what size of globe valve we should use and what the pressure loss of the water moving through that valve will be.

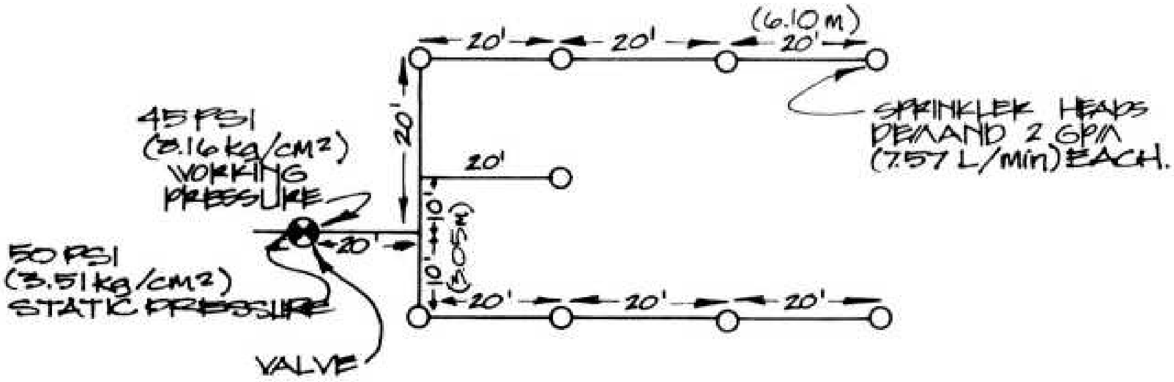


FIGURE 9.14 Pressure and pipe lengths.

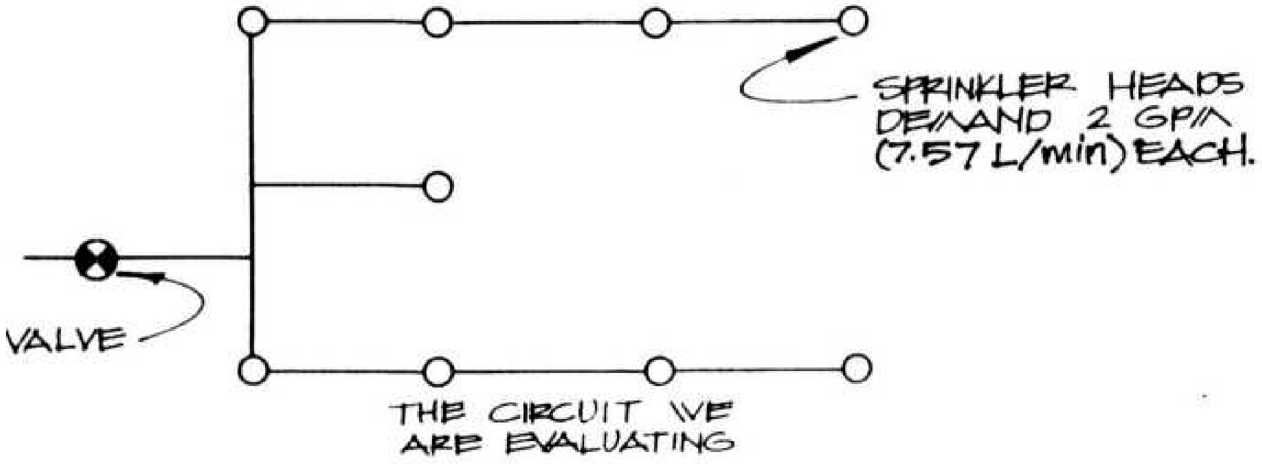


FIGURE 9. 15 The circuit we are evaluating.

We see that the 1-in electrically actuated valve will easily accommodate our 18-gpm (68.13 L/min) flow with an approximate loss of 5 psi (0.35 kg/cm2). So just behind the valve, we have a working pressure of 45 psi (3.16 kg/cm2) (see Figure 9.14). We will break the pipe into sections as shown in Figure 9.14 and compute pressure loss calculations to find the pressure at each head (see Figures 9.15, 9.16, and 9.17). As you re view this process, refer to Table 9.1 for calculating your pipe friction loss.

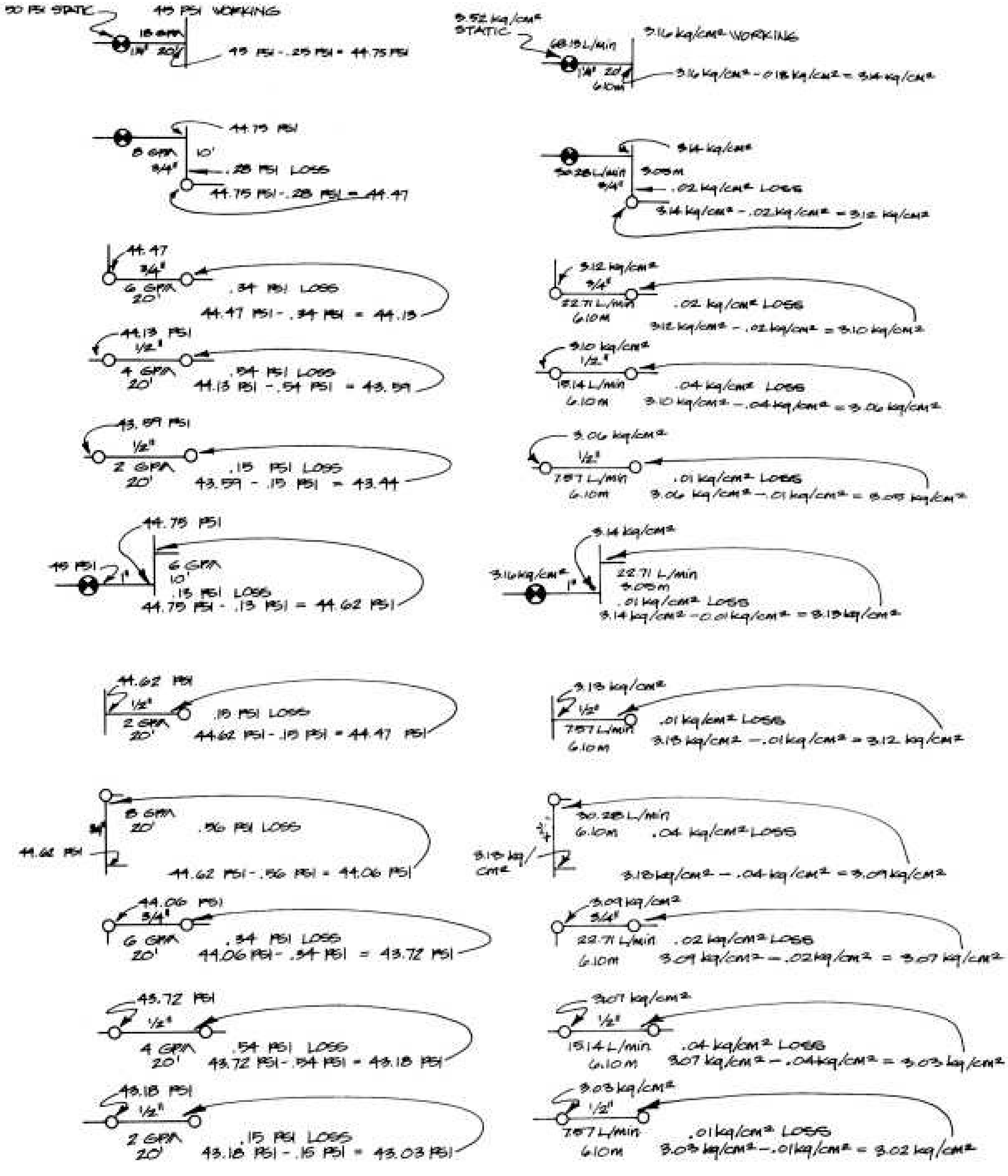


FIGURE 9.16 Figuring water pressure.

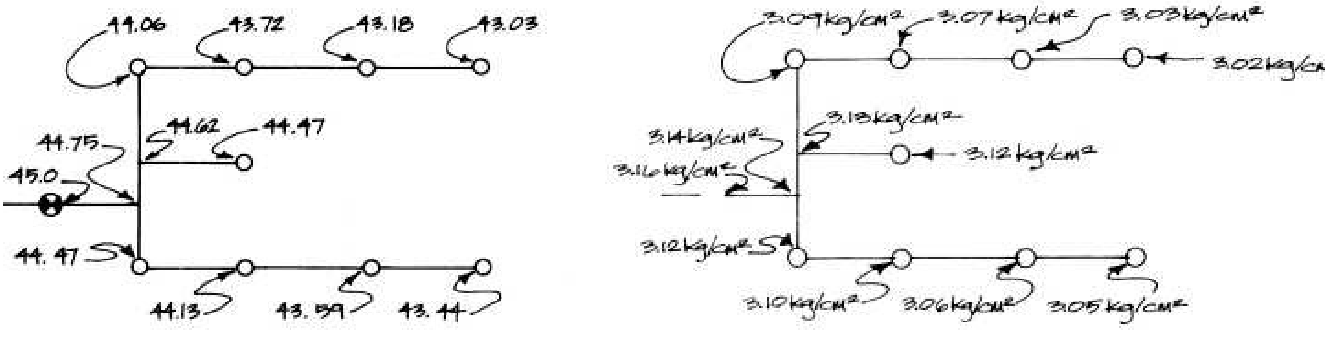
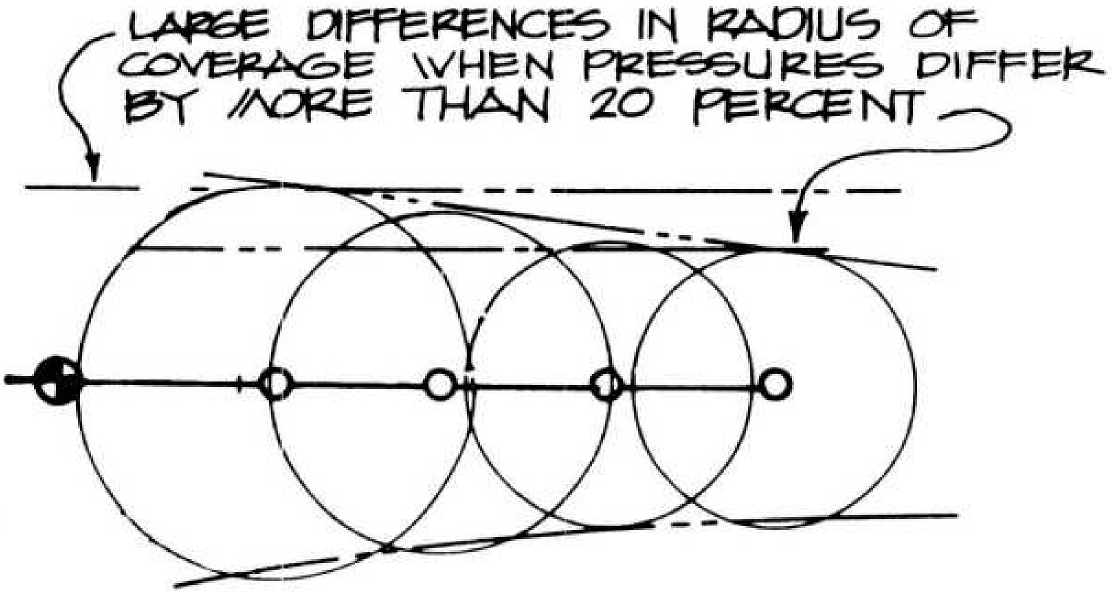
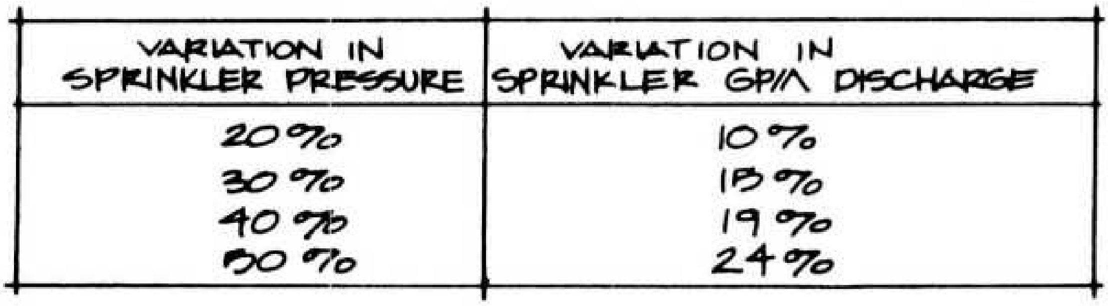


FIGURE 9.17 Water pressure at each head.





| VARIATION IN SPRINKLER PRESSURE | VARIATION IN SPRINKLER GPM DISCHARGE |
|---|---|
| 20% | 10% |
| 30% | 15% |
| 40% | 19% |
| 50% | 24% |

FIGURE 9.18 Pressure variation between the first and last head.

We will not always calculate pressure loss for each head on a circuit. Instead, we will calculate the first head and the farthest head on a circuit in order to

1. Make sure that the psi (kg/cm2) difference between the first and farthest head on a circuit is less than 20%. If the difference is greater than 20%, then the first sprinkler head's output of water (and the distance the water is thrown) will not match that of the other heads in the circuit. If the difference is under 20%, then the gpm (L/min) output and throw radii will be very close (see Figure 9.18).

2. Check to make sure that the pressure at the sprinkler head is within the operating pressure range for which it was designed (see Table

9.3).

*TABLE 9.3* ***Operating Range for 570 MPR Spray Nozzles***

## Nozzle Performance Information

### 5' Series with 0° Trajectory

| Nozzle Radius | Pressure | GPM | Radius | Prec. Rate* | |
|---|---|---|---|---|---|
| | | | | □ | △ |
| 5-Q | 20 | 0.05 | 4 | 1.21 | 1.40 |
| ¼ | 30 | 0.09 | 5 | 1.40 | 1.61 |
| | 40 | 0.12 | 6 | 1.54 | 1.78 |
| | 50 | 0.15 | 6 | 1.62 | 1.86 |
| 5-Q-PC | 30-40 | 0.09 | 5 | 1.40 | 1.61 |
| | 40-75 | 0.10 | 5 | 1.55 | 1.79 |
| 5-T | 20 | 0.07 | 4 | 1.27 | 1.47 |
| ⅓ | 30 | 0.12 | 5 | 1.40 | 1.61 |
| | 40 | 0.16 | 6 | 1.54 | 1.78 |
| | 50 | 0.20 | 6 | 1.62 | 1.86 |
| 5-T-PC | 30-40 | 0.12 | 5 | 1.40 | 1.61 |
| | 40-75 | 0.13 | 5 | 1.55 | 1.79 |
| 5-H | 20 | 0.10 | 4 | 1.21 | 1.40 |
| ½ | 30 | 0.19 | 5 | 1.47 | 1.70 |
| | 40 | 0.23 | 6 | 1.47 | 1.70 |
| | 50 | 0.27 | 6 | 1.45 | 1.68 |
| 5-H-PC | 30-40 | 0.18 | 5 | 1.40 | 1.61 |
| | 40-75 | 0.20 | 5 | 1.55 | 1.79 |
| 5-TT | 20 | 0.15 | 4 | 1.36 | 1.57 |
| ⅔ | 30 | 0.25 | 5 | 1.45 | 1.68 |
| | 40 | 0.30 | 6 | 1.44 | 1.66 |
| | 50 | 0.35 | 6 | 1.41 | 1.63 |
| 5-TT-PC | 30-40 | 0.23 | 5 | 1.34 | 1.54 |
| | 40-75 | 0.27 | 5 | 1.57 | 1.81 |
| 5-TQ | 20 | 0.20 | 4 | 1.61 | 1.86 |
| ¾ | 30 | 0.29 | 5 | 1.50 | 1.73 |
| | 40 | 0.34 | 6 | 1.45 | 1.68 |
| | 50 | 0.40 | 6 | 1.44 | 1.66 |
| 5-TQ-PC | 30-40 | 0.26 | 5 | 1.34 | 1.55 |
| | 40-75 | 0.29 | 5 | 1.50 | 1.73 |
| 5-F | 20 | 0.25 | 4 | 1.51 | 1.75 |
| | 30 | 0.38 | 5 | 1.47 | 1.70 |
| ● | 40 | 0.45 | 6 | 1.44 | 1.66 |
| | 50 | 0.53 | 6 | 1.43 | 1.65 |
| 5-F-PC | 30-40 | 0.35 | 5 | 1.36 | 1.57 |
| | 40-75 | 0.39 | 5 | 1.51 | 1.75 |

### 8' Series with 5° Trajectory

| Nozzle Radius | Pressure | GPM | Radius | Prec. Rate* | |
|---|---|---|---|---|---|
| | | | | □ | △ |
| 8-Q | 20 | 0.17 | 7 | 1.34 | 1.55 |
| ¼ | 30 | 0.24 | 8 | 1.45 | 1.68 |
| | 40 | 0.26 | 9 | 1.39 | 1.61 |
| | 50 | 0.29 | 9 | 1.39 | 1.60 |
| 8-Q-PC | 30-40 | 0.22 | 8 | 1.33 | 1.54 |
| | 40-75 | 0.25 | 8 | 1.51 | 1.75 |
| 8-T | 20 | 0.23 | 7 | 1.36 | 1.58 |
| ⅓ | 30 | 0.30 | 8 | 1.36 | 1.57 |
| | 40 | 0.36 | 9 | 1.45 | 1.67 |
| | 50 | 0.40 | 9 | 1.44 | 1.66 |
| 8-T-PC | 30-40 | 0.29 | 8 | 1.32 | 1.52 |
| | 40-75 | 0.35 | 8 | 1.59 | 1.84 |
| 8-H | 20 | 0.37 | 8 | 1.27 | 1.47 |
| ½ | 30 | 0.50 | 8 | 1.51 | 1.75 |
| | 40 | 0.58 | 9 | 1.56 | 1.80 |
| | 50 | 0.65 | 9 | 1.56 | 1.80 |
| 8-H-PC | 30-40 | 0.44 | 8 | 1.33 | 1.54 |
| | 40-75 | 0.50 | 8 | 1.51 | 1.75 |
| 8-TT | 20 | 0.56 | 7 | 1.66 | 1.92 |
| ⅔ | 30 | 0.70 | 8 | 1.59 | 1.84 |
| | 40 | 0.80 | 9 | 1.61 | 1.86 |
| | 50 | 0.88 | 9 | 1.58 | 1.82 |
| 8-TT-PC | 30-40 | 0.59 | 8 | 1.34 | 1.55 |
| | 40-75 | 0.70 | 8 | 1.59 | 1.84 |
| 8-TQ | 20 | 0.63 | 7 | 1.66 | 1.92 |
| ¾ | 30 | 0.76 | 8 | 1.53 | 1.77 |
| | 40 | 0.86 | 9 | 1.54 | 1.78 |
| | 50 | 0.93 | 9 | 1.48 | 1.71 |
| 8-TQ-PC | 30-40 | 0.64 | 8 | 1.29 | 1.49 |
| | 40-75 | 0.70 | 8 | 1.41 | 1.63 |
| 8-F | 20 | 0.74 | 7 | 1.46 | 1.69 |
| | 30 | 1.00 | 8 | 1.51 | 1.75 |
| ● | 40 | 1.16 | 9 | 1.56 | 1.80 |
| | 50 | 1.30 | 9 | 1.56 | 1.80 |
| 8-F-PC | 30-40 | 0.85 | 8 | 1.29 | 1.49 |
| | 40-75 | 1.00 | 8 | 1.51 | 1.75 |

### 10' Series with 12° Trajectory

| Nozzle Radius | Pressure | GPM | Radius | Prec. Rate* | |
|---|---|---|---|---|---|
| | | | | □ | △ |
| 10-Q | 20 | 0.30 | 9 | 1.44 | 1.66 |
| ¼ | 30 | 0.40 | 10 | 1.55 | 1.79 |
| | 40 | 0.50 | 11 | 1.60 | 1.85 |
| | 50 | 0.60 | 12 | 1.62 | 1.86 |
| 10-Q-PC | 30-40 | 0.33 | 10 | 1.28 | 1.48 |
| | 40-75 | 0.37 | 10 | 1.43 | 1.66 |
| 10-T | 20 | 0.42 | 9 | 1.51 | 1.74 |
| ⅓ | 30 | 0.52 | 10 | 1.51 | 1.75 |
| | 40 | 0.65 | 11 | 1.56 | 1.80 |
| | 50 | 0.75 | 12 | 1.51 | 1.75 |
| 10-T-PC | 30-40 | 0.44 | 10 | 1.28 | 1.48 |
| | 40-75 | 0.50 | 10 | 1.45 | 1.68 |
| 10-H | 20 | 0.60 | 9 | 1.44 | 1.66 |
| ½ | 30 | 0.71 | 10 | 1.38 | 1.59 |
| | 40 | 0.85 | 11 | 1.36 | 1.57 |
| | 50 | 0.99 | 12 | 1.43 | 1.65 |
| 10-H-PC | 30-40 | 0.66 | 10 | 1.28 | 1.48 |
| | 40-75 | 0.75 | 10 | 1.45 | 1.68 |
| 10-TT | 20 | 0.71 | 9 | 1.27 | 1.47 |
| ⅔ | 30 | 0.97 | 10 | 1.41 | 1.63 |
| | 40 | 1.10 | 11 | 1.45 | 1.67 |
| | 50 | 1.19 | 11 | 1.43 | 1.65 |
| 10-TT-PC | 30-40 | 0.89 | 10 | 1.29 | 1.49 |
| | 40-75 | 1.00 | 10 | 1.45 | 1.68 |
| 10-TQ | 20 | 0.82 | 9 | 1.31 | 1.51 |
| ¾ | 30 | 1.04 | 10 | 1.34 | 1.55 |
| | 40 | 1.20 | 11 | 1.41 | 1.62 |
| | 50 | 1.35 | 11 | 1.44 | 1.66 |
| 10-TQ-PC | 30-40 | 0.99 | 10 | 1.28 | 1.48 |
| | 40-75 | 1.09 | 10 | 1.41 | 1.63 |
| 10-F | 20 | 1.11 | 9 | 1.49 | 1.72 |
| | 30 | 1.49 | 10 | 1.44 | 1.67 |
| ● | 40 | 1.61 | 11 | 1.42 | 1.63 |
| | 50 | 1.85 | 11 | 1.48 | 1.71 |
| 10-F-PC | 30-40 | 1.33 | 10 | 1.29 | 1.49 |
| | 40-75 | 1.51 | 10 | 1.46 | 1.69 |

### 12' Series with 23° Trajectory

| Nozzle Radius | Pressure | GPM | Radius | Prec. Rate* | |
|---|---|---|---|---|---|
| | | | | □ | △ |
| 12-Q | 20 | 0.40 | 11 | 1.28 | 1.48 |
| ¼ | 30 | 0.50 | 12 | 1.35 | 1.55 |
| | 40 | 0.60 | 13 | 1.42 | 1.64 |
| | 50 | 0.63 | 13 | 1.44 | 1.67 |
| 12-Q-PC | 30-40 | 0.48 | 12 | 1.29 | 1.49 |
| | 40-75 | 0.53 | 12 | 1.43 | 1.65 |
| 12-T | 20 | 0.57 | 11 | 1.37 | 1.58 |
| ⅓ | 30 | 0.72 | 12 | 1.45 | 1.68 |
| | 40 | 0.87 | 13 | 1.62 | 1.87 |
| | 50 | 0.97 | 13 | 1.67 | 1.93 |
| 12-T-PC | 30-40 | 0.64 | 12 | 1.29 | 1.49 |
| | 40-75 | 0.70 | 12 | 1.41 | 1.63 |
| 12-H | 20 | 0.95 | 11 | 1.52 | 1.76 |
| ½ | 30 | 1.09 | 12 | 1.47 | 1.69 |
| | 40 | 1.30 | 13 | 1.49 | 1.72 |
| | 50 | 1.55 | 14 | 1.53 | 1.77 |
| 12-H-PC | 30-40 | 0.96 | 12 | 1.29 | 1.49 |
| | 40-75 | 1.05 | 12 | 1.41 | 1.63 |
| 12-TT | 20 | 1.12 | 11 | 1.35 | 1.55 |
| ⅔ | 30 | 1.45 | 12 | 1.46 | 1.69 |
| | 40 | 1.63 | 13 | 1.52 | 1.75 |
| | 50 | 1.80 | 13 | 1.55 | 1.79 |
| 12-TT-PC | 30-40 | 1.28 | 12 | 1.29 | 1.49 |
| | 40-75 | 1.40 | 12 | 1.41 | 1.63 |
| 12-TQ | 20 | 1.05 | 11 | 1.23 | 1.42 |
| ¾ | 30 | 1.55 | 12 | 1.39 | 1.61 |
| | 40 | 1.65 | 13 | 1.36 | 1.58 |
| | 50 | 1.80 | 13 | 1.38 | 1.59 |
| 12-TQ-PC | 30-40 | 1.44 | 12 | 1.29 | 1.49 |
| | 40-75 | 1.60 | 12 | 1.44 | 1.66 |
| 12-F | 20 | 1.67 | 11 | 1.34 | 1.54 |
| | 30 | 2.19 | 12 | 1.47 | 1.70 |
| ● | 40 | 2.35 | 13 | 1.46 | 1.68 |
| | 50 | 2.70 | 13 | 1.55 | 1.79 |
| 12-F-PC | 30-40 | 1.92 | 12 | 1.29 | 1.49 |
| | 40-75 | 2.10 | 12 | 1.41 | 1.63 |

### 15' Series with 27° Trajectory

| Nozzle Radius | Pressure | GPM | Radius | Prec. Rate* | |
|---|---|---|---|---|---|
| | | | | □ | △ |
| 15-Q | 20 | 0.68 | 14 | 1.34 | 1.55 |
| ¼ | 30 | 0.85 | 15 | 1.46 | 1.69 |
| | 40 | 1.04 | 16 | 1.57 | 1.82 |
| | 50 | 1.23 | 16 | 1.86 | 2.15 |
| 15-Q-PC | 30-40 | 0.75 | 15 | 1.29 | 1.49 |
| | 40-75 | 0.81 | 15 | 1.40 | 1.61 |
| 15-T | 20 | 0.95 | 14 | 1.52 | 1.75 |
| ⅓ | 30 | 1.10 | 15 | 1.42 | 1.64 |
| | 40 | 1.30 | 16 | 1.57 | 1.82 |
| | 50 | 1.45 | 16 | 1.75 | 2.03 |
| 15-T-PC | 30-40 | 1.00 | 15 | 1.29 | 1.49 |
| | 40-75 | 1.10 | 15 | 1.42 | 1.64 |
| 15-H | 20 | 1.37 | 13 | 1.55 | 1.79 |
| ½ | 30 | 1.65 | 15 | 1.44 | 1.66 |
| | 40 | 2.02 | 16 | 1.53 | 1.77 |
| | 50 | 2.14 | 16 | 1.62 | 1.87 |
| 15-H-PC | 30-40 | 1.50 | 15 | 1.29 | 1.49 |
| | 40-75 | 1.65 | 15 | 1.42 | 1.64 |
| 15-TT | 20 | 1.78 | 14 | 1.38 | 1.59 |
| ⅔ | 30 | 2.20 | 15 | 1.42 | 1.64 |
| | 40 | 2.66 | 16 | 1.51 | 1.74 |
| | 50 | 2.84 | 16 | 1.61 | 1.86 |
| 15-TT-PC | 30-40 | 2.00 | 15 | 1.29 | 1.49 |
| | 40-75 | 2.20 | 15 | 1.42 | 1.64 |
| 15-TQ | 20 | 2.10 | 13 | 1.61 | 1.85 |
| ¾ | 30 | 2.60 | 15 | 1.49 | 1.72 |
| | 40 | 3.00 | 16 | 1.61 | 1.86 |
| | 50 | 3.40 | 16 | 1.72 | 1.98 |
| 15-TQ-PC | 30-40 | 2.30 | 15 | 1.32 | 1.53 |
| | 40-75 | 2.50 | 15 | 1.44 | 1.66 |
| 15-F | 20 | 2.85 | 13 | 1.63 | 1.89 |
| | 30 | 3.60 | 15 | 1.55 | 1.79 |
| ● | 40 | 4.20 | 16 | 1.59 | 1.84 |
| | 50 | 4.58 | 16 | 1.73 | 2.00 |
| 15-F-PC | 30-40 | 3.00 | 15 | 1.29 | 1.49 |
| | 40-75 | 3.30 | 15 | 1.42 | 1.64 |

### Special Patterns

| Nozzle Radius | Pressure | GPM | Special Patterns | | | Prec. Rate* |
|---|---|---|---|---|---|---|
| | | | Width | | Length | |
| 4-EST | 20 | 0.38 | 3' | x | 12' | 2.03 |
| | 30 | 0.45 | 4' | x | 15' | 1.44 |
| | 40 | 0.53 | 5' | x | 18' | 1.13 |
| | 50 | 0.60 | 6' | x | 20' | 0.96 |
| 4-EST-PC | 30-40 | 0.43 | 4' | x | 15' | 1.38 |
| | 40-75 | 0.50 | 4' | x | 15' | 1.61 |
| 4-CST | 20 | 0.75 | 3' | x | 24' | 2.01 |
| | 30 | 0.90 | 4' | x | 30' | 1.44 |
| | 40 | 1.04 | 4' | x | 30' | 1.67 |
| | 50 | 1.16 | 4' | x | 31' | 1.80 |
| 4-CST-PC | 30-40 | 0.86 | 4' | x | 30' | 1.38 |
| | 40-75 | 1.00 | 4' | x | 30' | 1.61 |
| 9-SST | 20 | 1.00 | 9' | x | 18' | 1.19 |
| | 30 | 1.20 | 9' | x | 18' | 1.43 |
| | 40 | 1.38 | 9' | x | 20' | 1.48 |
| | 50 | 1.55 | 10' | x | 22' | 1.36 |
| 9-SST-PC | 30-40 | 1.10 | 9' | x | 18' | 1.31 |
| | 40-75 | 1.20 | 9' | x | 18' | 1.43 |
| 4-SST | 20 | 0.65 | 4' | x | 24' | 1.30 |
| | 30 | 0.90 | 4' | x | 30' | 1.44 |
| | 40 | 1.04 | 4' | x | 32' | 1.56 |
| | 50 | 1.16 | 5' | x | 33' | 1.35 |
| 4-SST-PC | 30-40 | 0.88 | 4' | x | 30' | 1.41 |
| | 40-75 | 1.00 | 4' | x | 30' | 1.61 |
| 2-SST | 20 | 0.08 | 2' | x | 5' | 1.54 |
| | 30 | 0.09 | 2' | x | 6' | 1.44 |
| | 40 | 0.10 | 2' | x | 7' | 1.38 |
| | 50 | 0.12 | 3' | x | 7' | 1.10 |
| 2-SST-PC | 30-40 | 0.09 | 2' | x | 6' | 1.44 |
| | 40-75 | 0.10 | 2' | x | 6' | 1.61 |
| 4S-SST | 20 | 0.46 | 4' | x | 17' | 1.30 |
| | 30 | 0.55 | 4' | x | 18' | 1.47 |
| | 40 | 0.63 | 4' | x | 19' | 1.60 |
| | 50 | 0.71 | 5' | x | 19' | 1.44 |
| 4S-SST-PC | 30-40 | 0.50 | 4' | x | 18' | 1.34 |
| | 40-75 | 0.59 | 4' | x | 18' | 1.58 |

* △ Precipitation rates are for triangular spacing, shown in inches per hour calculated at 50% of diameter.
□ Precipitation rates are for square spacing, shown in inches per hour, calculated at 50% of diameter.
All performance specifications are based on the stated working pressure available at the base of the sprinkler head.

Source: The Toro Company. Used with permission.

# 10

# Calculating Water Supply and Pressure

## Introduction

When you are designing an irrigation system that will use water supplied by a city or rural water system, you need to base your design on the gpm flow and pressure that are available. The available flow will restrict the maximum gpm size of your circuits, and the available pressure will determine the sizes of pipe and types of sprinkler heads you will use.

## City Water System Components

The components of the public water delivery system include the city main, a water meter, and a service line that connects the city main to the water meter. The city main is usually a cast-iron pipe, but in some communities it is made of plastic. The service line is usually a soft, bendable copper tube that is connected to a tap in the city main. The water meter is usually made of brass. Figure 10.1 illustrates typical city water system components from the city main to the water meter. Figure 10.2 shows an actual service line and water meter; the person in the photo is holding a water meter wrench used to shut off the water supply. Construction of the irrigation system begins downstream from the water meter.

## Available Static Water Pressure

Static water pressure in an area of a city can be determined by calling the water supplier, fire department, or utility company. Suppliers have reliable estimates on static pressure within their system. If you prefer to double-check their information, you can get a simple pressure gauge, attach it to a hose bib, turn on the faucet, and read the static pressure, as shown in Figure 10.3. This reading needs to be made when there is no other flow occurring in your system. If someone is taking a shower or your dishwasher is running, your pressure reading will be lower because you will be measuring working water pressure instead of static pressure.

## Available Flow and Working Water Pressure

To design our irrigation system, we need to know the flow and working water pressure, which will depend on the size of the water meter and the size and length of the service line. Of course, the elevation difference between the city main and the water meter must also be computed because it will affect working pressure.

The local water supplier will know the size of the service line and water meter. It will also know the location of the city main. So, now that we know how to find the sizes of our water system components, let us take a sample problem and calculate the flow and working pressure.

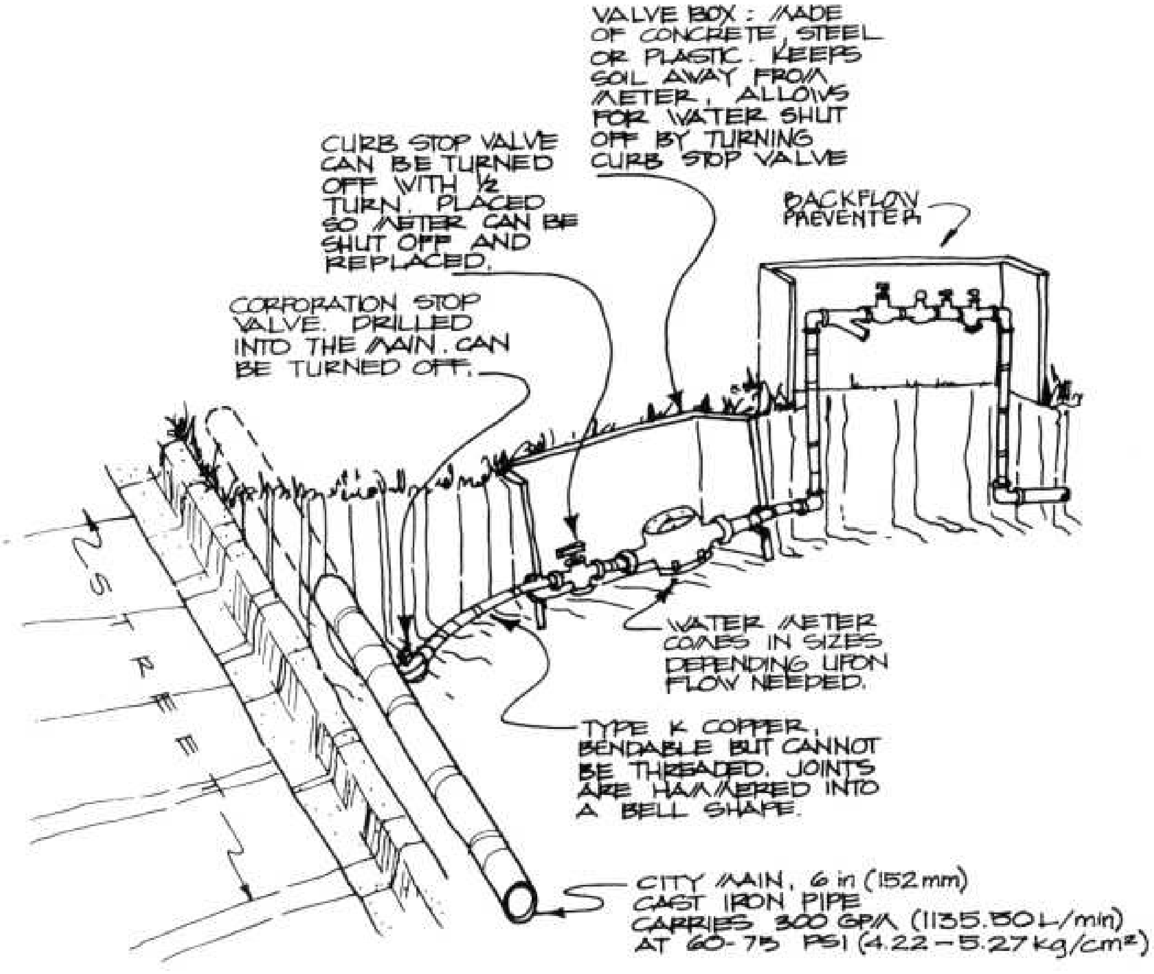


FIGURE 10. 1 City water system components.

FIGURE 10.2 Water meter, meter wrench, and service line.

### Flow and Working Pressure Example

For our sample problem, we will assume that we have the following conditions:

70 psi (4.92 kg/cm2) static pressure

1 V4-in Type K copper tube service line

-in water meter

20 ft (6.1 m) of service line

5 ft (1.5 m) elevation difference between the city main and the water meter

There are three rules we must follow when calculating our flow and working pressure. When we apply these rules, they will make more sense to you.

1. Do not go beyond 75% of the maximum safe flow capacity for the water meter.

2. Do not exceed 10% of the static water pressure as a pressure drop through the water meter.

3. Do not go beyond velocities of 5 to 6 feet (1.5 m to 1.8 m) per second in the service line.

Let us first consult our water meter chart in Table 10.1 to determine the maximum safe flow through a Y,in meter. We see that the maximum flow is 30 gpm (113.55 L/min). Now, applying rule number one, we take 75% of 30 gpm (113.55 L/min) and get 22.5 gpm (85.16 L/min). So at this point in our calculations, we know that the available flow we have to use in our irrigation system is 22.5 gpm (85.16 L/min). When we apply our other rules, the flow might be further reduced.

FIGURE 10.3 Reading static pressure.

The second rule says that we should not have a pressure drop through the water meter that exceeds 10% of the static pressure. Looking at the water meter chart, you can see that when 22.5 gpm (85.16 L/min) flows through a %-in meter, an approximately 8-psi (0.56 kg/cm2) water pressure loss in the meter will result. Now let us compare this pressure drop in the meter with the maximum allowable pressure drop, which was 10% of the static pressure. Our static pressure was 70 psi (4.92 kg/cm2), so the maximum allowable pressure drop is 7 psi (0.49 kg/cm2). Because the 22.5 gpm of water flowing through the meter lost 8 psi (0.56 kg/cm2), we need to reduce our flow through the meter to a calculation that will have a 7-psi (0.49- kg/cm2) loss. Look at the pressure loss column for X,in meters in Table 10.1. A flow of approximately 21 gpm (79.49 L/min) will loose our 7 psi (0.49 kg/cm2).

### *TABLE 10.1* ***Water Meter Chart***

| | **PRESSURE LOSS THROUGH WATER METERS (PSI)** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **METER SIZE** | | | | | | | |
| **GPM** | **5/8″** | **3/4″** | **1″** | **1 1/2″** | **2″** | **3″** | **4″** | **GPM** |
| 6 | 1.3 | 0.7 | | | | | | 6 |
| 8 | 2.3 | 1.0 | | | | | | 8 |
| 10 | 3.7 | 1.6 | 0.7 | | | | | 10 |
| 12 | 5.1 | 2.2 | 0.9 | | | | | 12 |
| 14 | 7.2 | 3.1 | 1.1 | | | | | 14 |
| 16 | 9.4 | 4.1 | 1.4 | | | | | 16 |
| 18 | 12.0 | 5.2 | 1.8 | | | | | 18 |
| 20 | 15.0 | 6.5 | 2.2 | 0.8 | | | | 20 |
| 22 | | 7.9 | 2.8 | 1.0 | | | | 22 |
| 24 | | 9.5 | 3.4 | 1.2 | | | | 24 |
| 26 | | 11.2 | 4.0 | 1.4 | | | | 26 |
| 28 | | 13.0 | 4.6 | 1.6 | | | | 28 |
| 30 | | 15.0 | 5.3 | 1.8 | 0.7 | | | 30 |
| 35 | | | 7.4 | 2.6 | 1.0 | | | 35 |
| 40 | | | 9.6 | 3.3 | 1.3 | | | 40 |
| 45 | | | 12.3 | 4.1 | 1.6 | | | 45 |
| 50 | | | 15.0 | 4.9 | 1.9 | 0.7 | | 50 |
| 60 | | | | 7.2 | 2.7 | 1.0 | | 60 |
| 70 | | | | 9.8 | 3.7 | 1.3 | | 70 |
| 80 | | | | 12.8 | 4.9 | 1.6 | 0.7 | 80 |
| 90 | | | | 16.1 | 6.2 | 2.0 | 0.8 | 90 |
| 100 | | | | 20.0 | 7.8 | 2.5 | 0.9 | 100 |
| 120 | | | | | 11.3 | 3.4 | 1.2 | 120 |
| 140 | | | | | 14.5 | 4.5 | 1.6 | 140 |
| 160 | | | | | 20.0 | 5.8 | 2.1 | 160 |
| 180 | | | | | | 7.2 | 2.7 | 180 |
| 200 | | | | | | 9.0 | 3.2 | 200 |
| 250 | | | | | | 14.0 | 5.0 | 250 |
| 300 | | | | | | 20.0 | 7.2 | 300 |
| 350 | | | | | | | 10.0 | 350 |
| 400 | | | | | | | 13.0 | 400 |
| 450 | | | | | | | 16.2 | 450 |
| 500 | | | | | | | 20.0 | 500 |

*TABLE 10.2* ***Type K Copper Friction Loss Chart***

| | | PSI LOSS PER PIPE LENGTH (FT) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **GPM** | **Velocity (ft/sec)** | **5** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** | **90** | **100** | **GPM** | **Pipe Size** |
| 1 | 1.5 | 0.06 | 0.12 | 0.24 | 0.36 | 0.48 | 0.60 | 0.72 | 0.84 | 0.96 | 1.08 | 1.20 | 1 | **½″** (0.527″ inside diameter) |
| 2 | 2.9 | 0.22 | 0.43 | 0.87 | 1.30 | 1.74 | 2.17 | 2.60 | 3.04 | 3.47 | 3.91 | 4.34 | 2 | |
| 3 | 4.4 | 0.46 | 0.92 | 1.83 | 2.75 | 3.66 | 4.58 | 5.50 | 6.41 | 7.33 | 8.24 | 9.16 | 3 | |
| 4 | 5.9 | 0.79 | 1.57 | 3.14 | 4.70 | 6.27 | 7.84 | 9.41 | 10.98 | 12.54 | 14.11 | 15.68 | 4 | |
| 1 | 0.7 | 0.01 | 0.02 | 0.04 | 0.06 | 0.08 | 0.10 | 0.12 | 0.14 | 0.16 | 0.18 | 0.20 | 1 | **¾″** (0.745″ inside diameter) |
| 2 | 1.5 | 0.04 | 0.08 | 0.15 | 0.23 | 0.30 | 0.38 | 0.46 | 0.53 | 0.61 | 0.68 | 0.76 | 2 | |
| 3 | 2.2 | 0.08 | 0.16 | 0.33 | 0.49 | 0.66 | 0.82 | 0.98 | 1.15 | 1.31 | 1.48 | 1.64 | 3 | |
| 4 | 2.9 | 0.14 | 0.28 | 0.56 | 0.83 | 1.11 | 1.39 | 1.67 | 1.95 | 2.22 | 2.50 | 2.78 | 4 | |
| 5 | 3.7 | 0.21 | 0.42 | 0.84 | 1.26 | 1.68 | 2.10 | 2.52 | 2.94 | 3.36 | 3.78 | 4.20 | 5 | |
| 6 | 4.4 | 0.30 | 0.59 | 1.18 | 1.77 | 2.36 | 2.95 | 3.54 | 4.13 | 4.72 | 5.31 | 5.90 | 6 | |
| 7 | 5.2 | 0.39 | 0.78 | 1.57 | 2.35 | 3.14 | 3.92 | 4.70 | 5.49 | 6.27 | 7.06 | 7.84 | 7 | |
| 8 | 5.9 | 0.50 | 1.00 | 2.01 | 3.01 | 4.02 | 5.02 | 6.02 | 7.03 | 8.03 | 9.04 | 10.04 | 8 | |
| 9 | 6.6 | 0.63 | 1.25 | 2.50 | 3.75 | 5.00 | 6.25 | 7.50 | 8.75 | 10.00 | 11.25 | 12.50 | 9 | |
| 4 | 1.7 | 0.04 | 0.07 | 0.14 | 0.20 | 0.27 | 0.34 | 0.41 | 0.48 | 0.54 | 0.61 | 0.68 | 4 | **1″** (0.995″ inside diameter) |
| 5 | 2.1 | 0.05 | 0.10 | 0.20 | 0.31 | 0.41 | 0.51 | 0.61 | 0.71 | 0.82 | 0.92 | 1.02 | 5 | |
| 6 | 2.5 | 0.07 | 0.14 | 0.29 | 0.43 | 0.58 | 0.72 | 0.86 | 1.01 | 1.15 | 1.30 | 1.44 | 6 | |
| 7 | 2.9 | 0.10 | 0.19 | 0.38 | 0.58 | 0.77 | 0.96 | 1.15 | 1.34 | 1.54 | 1.73 | 1.92 | 7 | |
| 8 | 3.3 | 0.12 | 0.24 | 0.49 | 0.73 | 0.98 | 1.22 | 1.46 | 1.71 | 1.95 | 2.20 | 2.44 | 8 | |
| 9 | 3.7 | 0.15 | 0.30 | 0.61 | 0.91 | 1.22 | 1.52 | 1.82 | 2.13 | 2.43 | 2.74 | 3.04 | 9 | |
| 10 | 4.1 | 0.19 | 0.37 | 0.74 | 1.11 | 1.48 | 1.85 | 2.22 | 2.59 | 2.96 | 3.33 | 3.70 | 10 | |
| 11 | 4.5 | 0.22 | 0.44 | 0.88 | 1.32 | 1.76 | 2.20 | 2.64 | 3.08 | 3.52 | 3.96 | 4.40 | 11 | |
| 12 | 5.0 | 0.26 | 0.52 | 1.03 | 1.55 | 2.06 | 2.58 | 3.10 | 3.61 | 4.13 | 4.64 | 5.16 | 12 | |
| 13 | 5.4 | 0.30 | 0.60 | 1.20 | 1.79 | 2.39 | 2.99 | 3.59 | 4.19 | 4.78 | 5.38 | 5.98 | 13 | |
| 14 | 5.8 | 0.35 | 0.69 | 1.38 | 2.06 | 2.75 | 3.44 | 4.13 | 4.82 | 5.50 | 6.19 | 6.88 | 14 | |
| 15 | 6.2 | 0.39 | 0.78 | 1.56 | 2.34 | 3.12 | 3.90 | 4.68 | 5.46 | 6.24 | 7.02 | 7.80 | 15 | |
| 16 | 6.6 | 0.44 | 0.88 | 1.76 | 2.63 | 3.51 | 4.39 | 5.27 | 6.15 | 7.02 | 7.90 | 8.78 | 16 | |
| 8 | 2.1 | 0.04 | 0.07 | 0.15 | 0.22 | 0.30 | 0.37 | 0.44 | 0.52 | 0.59 | 0.67 | 0.74 | 8 | **1¼″** (1.245″ inside diameter) |
| 10 | 2.6 | 0.06 | 0.11 | 0.22 | 0.34 | 0.45 | 0.56 | 0.67 | 0.78 | 0.90 | 1.01 | 1.12 | 10 | |
| 12 | 3.2 | 0.08 | 0.16 | 0.32 | 0.47 | 0.63 | 0.79 | 0.95 | 1.11 | 1.26 | 1.42 | 1.58 | 12 | |
| 14 | 3.7 | 0.11 | 0.21 | 0.41 | 0.62 | 0.82 | 1.03 | 1.24 | 1.44 | 1.65 | 1.85 | 2.06 | 14 | |
| 16 | 4.3 | 0.14 | 0.27 | 0.53 | 0.80 | 1.06 | 1.33 | 1.60 | 1.86 | 2.13 | 2.39 | 2.66 | 16 | |
| 18 | 4.8 | 0.17 | 0.33 | 0.66 | 0.99 | 1.32 | 1.65 | 1.98 | 2.31 | 2.64 | 2.97 | 3.30 | 18 | |
| 20 | 5.3 | 0.21 | 0.41 | 0.81 | 1.22 | 1.62 | 2.03 | 2.44 | 2.84 | 3.25 | 3.65 | 4.06 | 20 | |
| 22 | 5.8 | 0.24 | 0.48 | 0.97 | 1.45 | 1.94 | 2.42 | 2.90 | 3.39 | 3.87 | 4.36 | 4.84 | 22 | |
| 24 | 6.4 | 0.29 | 0.57 | 1.14 | 1.70 | 2.27 | 2.84 | 3.41 | 3.98 | 4.54 | 5.11 | 5.68 | 24 | |
| 26 | 6.9 | 0.33 | 0.66 | 1.32 | 1.98 | 2.64 | 3.30 | 3.96 | 4.62 | 5.28 | 5.94 | 6.60 | 26 | |
| 12 | 2.2 | 0.04 | 0.08 | 0.15 | 0.23 | 0.30 | 0.38 | 0.46 | 0.53 | 0.61 | 0.68 | 0.76 | 12 | **1½″** (1.481″ inside diameter) |
| 14 | 2.6 | 0.05 | 0.10 | 0.20 | 0.30 | 0.40 | 0.50 | 0.60 | 0.70 | 0.80 | 0.90 | 1.00 | 14 | |
| 16 | 3.0 | 0.06 | 0.12 | 0.25 | 0.37 | 0.50 | 0.62 | 0.74 | 0.87 | 0.99 | 1.12 | 1.24 | 16 | |
| 18 | 3.4 | 0.08 | 0.16 | 0.31 | 0.47 | 0.62 | 0.78 | 0.94 | 1.09 | 1.25 | 1.40 | 1.56 | 18 | |
| 20 | 3.7 | 0.10 | 0.19 | 0.38 | 0.58 | 0.77 | 0.96 | 1.15 | 1.34 | 1.54 | 1.73 | 1.92 | 20 | |
| 22 | 4.1 | 0.12 | 0.23 | 0.46 | 0.69 | 0.92 | 1.15 | 1.38 | 1.61 | 1.84 | 2.07 | 2.30 | 22 | |
| 24 | 4.5 | 0.14 | 0.27 | 0.54 | 0.80 | 1.07 | 1.34 | 1.61 | 1.88 | 2.14 | 2.41 | 2.68 | 24 | |
| 26 | 4.8 | 0.16 | 0.31 | 0.62 | 0.94 | 1.25 | 1.56 | 1.87 | 2.18 | 2.50 | 2.81 | 3.12 | 26 | |
| 28 | 5.2 | 0.18 | 0.35 | 0.71 | 1.06 | 1.42 | 1.77 | 2.12 | 2.48 | 2.83 | 3.19 | 3.54 | 28 | |
| 30 | 5.6 | 0.22 | 0.41 | 0.81 | 1.22 | 1.62 | 2.03 | 2.44 | 2.84 | 3.25 | 3.65 | 4.06 | 30 | |
| 32 | 6.0 | 0.23 | 0.45 | 0.91 | 1.36 | 1.82 | 2.27 | 2.72 | 3.18 | 3.63 | 4.09 | 4.54 | 32 | |
| 34 | 6.4 | 0.26 | 0.51 | 1.01 | 1.52 | 2.02 | 2.53 | 3.04 | 3.54 | 4.05 | 4.55 | 5.06 | 34 | |
| 36 | 6.8 | 0.28 | 0.56 | 1.12 | 1.69 | 2.25 | 2.81 | 3.37 | 3.93 | 4.50 | 5.06 | 5.62 | 36 | |
| 20 | 2.1 | 0.03 | 0.05 | 0.10 | 0.15 | 0.20 | 0.25 | 0.30 | 0.35 | 0.40 | 0.45 | 0.50 | 20 | **2″** (1.959″ inside diameter) |
| 25 | 2.7 | 0.04 | 0.07 | 0.15 | 0.22 | 0.30 | 0.37 | 0.44 | 0.52 | 0.59 | 0.67 | 0.74 | 25 | |
| 30 | 3.2 | 0.05 | 0.10 | 0.21 | 0.31 | 0.42 | 0.52 | 0.62 | 0.73 | 0.83 | 0.94 | 1.04 | 30 | |
| 35 | 3.7 | 0.07 | 0.14 | 0.28 | 0.41 | 0.55 | 0.69 | 0.83 | 0.97 | 1.10 | 1.24 | 1.38 | 35 | |
| 40 | 4.3 | 0.09 | 0.18 | 0.35 | 0.53 | 0.70 | 0.88 | 1.06 | 1.23 | 1.41 | 1.58 | 1.76 | 40 | |
| 45 | 4.8 | 0.11 | 0.22 | 0.44 | 0.65 | 0.87 | 1.09 | 1.31 | 1.53 | 1.74 | 1.96 | 2.18 | 45 | |
| 50 | 5.3 | 0.14 | 0.27 | 0.53 | 0.80 | 1.06 | 1.33 | 1.60 | 1.86 | 2.13 | 2.39 | 2.66 | 50 | |
| 55 | 5.8 | 0.16 | 0.32 | 0.63 | 0.95 | 1.26 | 1.58 | 1.90 | 2.21 | 2.53 | 2.84 | 3.16 | 55 | |

| | | PSI LOSS PER PIPE LENGTH (FT) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **GPM** | **Velocity (ft/sec)** | **5** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** | **90** | **100** | **GPM** | **Pipe Size** |
| 60 | 6.3 | 0.19 | 0.37 | 0.74 | 1.12 | 1.49 | 1.86 | 2.23 | 2.60 | 2.98 | 3.35 | 3.72 | 60 | |
| 65 | 6.8 | 0.22 | 0.43 | 0.86 | 1.28 | 1.71 | 2.14 | 2.57 | 3.00 | 3.42 | 3.85 | 4.28 | 65 | |
| 30 | 2.1 | 0.02 | 0.04 | 0.07 | 0.11 | 0.14 | 0.18 | 0.22 | 0.25 | 0.29 | 0.32 | 0.36 | 30 | **2½″**<br>(2.435″<br>inside<br>diameter |
| 40 | 2.8 | 0.03 | 0.06 | 0.12 | 0.19 | 0.25 | 0.31 | 0.37 | 0.43 | 0.50 | 0.56 | 0.62 | 40 | |
| 50 | 3.5 | 0.05 | 0.09 | 0.19 | 0.28 | 0.38 | 0.47 | 0.56 | 0.66 | 0.75 | 0.85 | 0.94 | 50 | |
| 60 | 4.1 | 0.07 | 0.13 | 0.26 | 0.39 | 0.52 | 0.65 | 0.78 | 0.91 | 1.04 | 1.17 | 1.30 | 60 | |
| 70 | 4.8 | 0.09 | 0.17 | 0.35 | 0.52 | 0.70 | 0.87 | 1.04 | 1.22 | 1.39 | 1.57 | 1.74 | 70 | |
| 80 | 5.5 | 0.11 | 0.22 | 0.44 | 0.66 | 0.88 | 1.10 | 1.32 | 1.54 | 1.76 | 1.98 | 2.20 | 80 | |
| 90 | 6.2 | 0.14 | 0.28 | 0.55 | 0.83 | 1.10 | 1.38 | 1.66 | 1.93 | 2.21 | 2.48 | 2.76 | 90 | |
| 100 | 6.9 | 0.17 | 0.33 | 0.67 | 1.00 | 1.34 | 1.67 | 2.00 | 2.34 | 2.67 | 3.01 | 3.34 | 100 | |
| 60 | 2.9 | 0.03 | 0.06 | 0.11 | 0.17 | 0.22 | 0.28 | 0.33 | 0.39 | 0.44 | 0.50 | 0.55 | 60 | **3″**<br>(2.907″<br>inside<br>diameter) |
| 70 | 3.4 | 0.04 | 0.07 | 0.15 | 0.22 | 0.30 | 0.37 | 0.44 | 0.52 | 0.59 | 0.67 | 0.74 | 70 | |
| 80 | 3.9 | 0.05 | 0.09 | 0.19 | 0.28 | 0.38 | 0.47 | 0.56 | 0.66 | 0.75 | 0.85 | 0.94 | 80 | |
| 90 | 4.4 | 0.06 | 0.12 | 0.23 | 0.35 | 0.46 | 0.58 | 0.70 | 0.81 | 0.93 | 1.04 | 1.16 | 90 | |
| 100 | 4.8 | 0.07 | 0.14 | 0.28 | 0.42 | 0.56 | 0.70 | 0.84 | 0.98 | 1.12 | 1.26 | 1.40 | 100 | |
| 110 | 5.3 | 0.09 | 0.17 | 0.34 | 0.50 | 0.67 | 0.84 | 1.01 | 1.18 | 1.34 | 1.51 | 1.68 | 110 | |
| 120 | 5.8 | 0.10 | 0.20 | 0.40 | 0.59 | 0.79 | 0.99 | 1.19 | 1.39 | 1.58 | 1.78 | 1.98 | 120 | |
| 130 | 6.3 | 0.12 | 0.23 | 0.46 | 0.69 | 0.92 | 1.15 | 1.38 | 1.61 | 1.84 | 2.07 | 2.30 | 130 | |

Now, let us apply rule number three, which says that our flow through the service line should not exceed 5 to 6 ft (1.5 m to 1.8 m) per second. Look at Table 10.2 to see what the velocity would be with 21- gpm (79.49-L/min) flow through 1%-in Type K copper pipe. The answer is 5.6 ft per second, and this velocity does not exceed the maximum specified in the third rule. So we will have a maximum flow of 21 gpm (79.49 L/min) to work with in our irrigation design.

We are now ready to calculate the working water pressure. Pressure loss will be calculated as water flows through the service line and the water meter. The 5-ft (1.52-m) elevation difference between the city main and the meter will also influence our working water pressure.

We can see in Table 10.2 that as 21 gpm (79.49 L/min) of water flows through 20 ft (6.09 m) of 1 V-in Type K copper pipe, we will have a friction loss of approximately 0.9 psi (0.06 kg/cm2). As the 21 gpm (79.49 L/min) of water flows through the %-in water meter, we will have approximately 7 psi (0.49 kg/cm2) of friction loss. The 5-ft (1.52-m) elevation rise from the city main to the water meter will cause a 2.2 psi

(0.15 kg/cm2) pressure loss (5 X 0.433 = 2.2; 5 X 0.03 = 0.15).

Therefore, our total pressure loss and working water pressure is as follows:

Pressure loss in 1¼-in service line = 0.9 psi (0.06 kg/cm$^2$)
Pressure loss in ¾-in water meter = 7.0 psi (0.49 kg/cm$^2$)
Pressure loss caused by elevation rise = 2.2 psi (0.15 kg/cm$^2$)
TOTAL LOSS 10.1 psi (0.71 kg/cm$^2$)

Working pressure = 70 psi (4.92 kg/cm$^2$) –
10.1 psi (0.71 kg/cm$^2$) = 59.9 psi (4.21 kg/cm$^2$)

The water supply available for our irrigation design is 21 gpm (79.49 L/min), and the working pressure at the water meter is 59.9 psi (4.21 kg/cm2). Many irrigation designers assume that an average irrigation system will have a working water pressure loss of 15 psi to 20 psi (1.05 kg/cm2 to 1.41 kg/cm2) from the city main to the last or farthest irrigation head.

Calculation of water supply and working pressure is essential if you are going to connect to an existing water meter. Often, an irrigation designer will plan the ideal irrigation system and then specify a separate meter and service line for irrigation purposes. When this occurs, the service line and meter are sized according to the needs of the irrigation system.

# 11

# Selecting Valves

## Introduction

A valve is a device connected to a pipe that regulates the flow of water. When you turn on your bath water, you are turning on a valve. We have included an excerpt from our Webster's New World Dictionary in Figure 11.1 for your review.

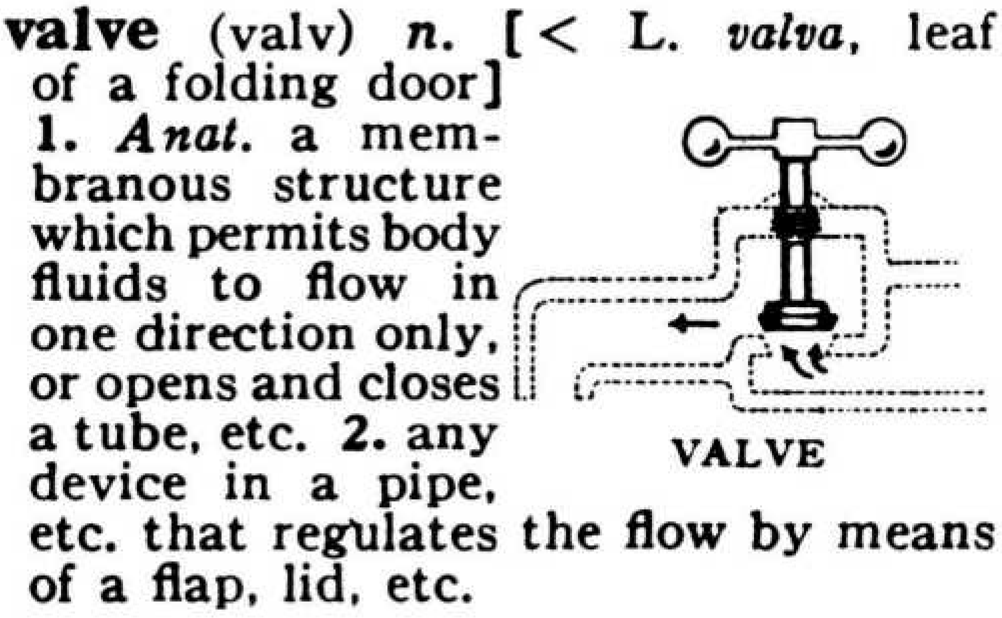
In an irrigation system, the function of a valve is to let the water flow into a circuit or zone, either automatically on command from the controller or manually. Recall that a circuit is a group of sprinkler heads interconnected with pipe and controlled by a valve. The automatic command from the controller is given to the valves either by an electric impulse or by water pressure. When the valves in your irrigation system are opened by an electric impulse, you have an electric system. When the valves are opened by a little tube of water under pressure, you have a hydraulic system.

## Electric Systems

Electric current in the United States is supplied at approximately 120 volts. Voltage is analogous to pressure. Water under high pressure is like electricity pushed by high voltage in that it is very dangerous. But enough of the minielectricity lesson. A transformer in the controller reduces the 120 volts to approximately 24 volts, a figure adopted by the irrigation industry for valves because this voltage level is not harmful to people. Wire can be buried directly in the ground instead of being placed in conduits or protective pipes. This low-voltage electricity is what turns the valve on and off.

The little device attached to the valve is called a solenoid (see Figure 11.2). When the solenoid receives current, it acts as a bar magnet and lifts a small plunger that allows the water to flow through the valve.

When the controller (see Figure 11.3), which is basically a fancy time clock, stops the flow of electric current to the solenoid, the magnetic effect ceases to exist, and the plunger falls back into place and slowly stops the flow of water through the valve. Electrically actuated valves are referred to as being normally closed; that is, in their normal state, they will not allow the passage of water. An electric charge must be sent to the solenoid to open the valve. There are also normally open electric valves that function the opposite way. Today, most irrigation installations are electric systems. However, in areas of frequent lightning strikes, the control wires buried in the ground can attract lightning strikes, which can damage the solenoid as well as the controller and valves.



**valve** (valv) *n.* [< L. *valva*, leaf of a folding door] 1. *Anat.* a membranous structure which permits body fluids to flow in one direction only, or opens and closes a tube, etc. 2. any device in a pipe, etc. that regulates the flow by means of a flap, lid, etc.

FIGURE 11. 1 Definition of a valve. (From Webster's New World International Dictionary, Pocket-Size Edition, 1975.)

FIGURE 11.2 Electric valve. (Source: The Toro Company. Used with permission.)

FIGURE 11.3 Automatic controller. (Source: The Toro Company. Used with permission.)

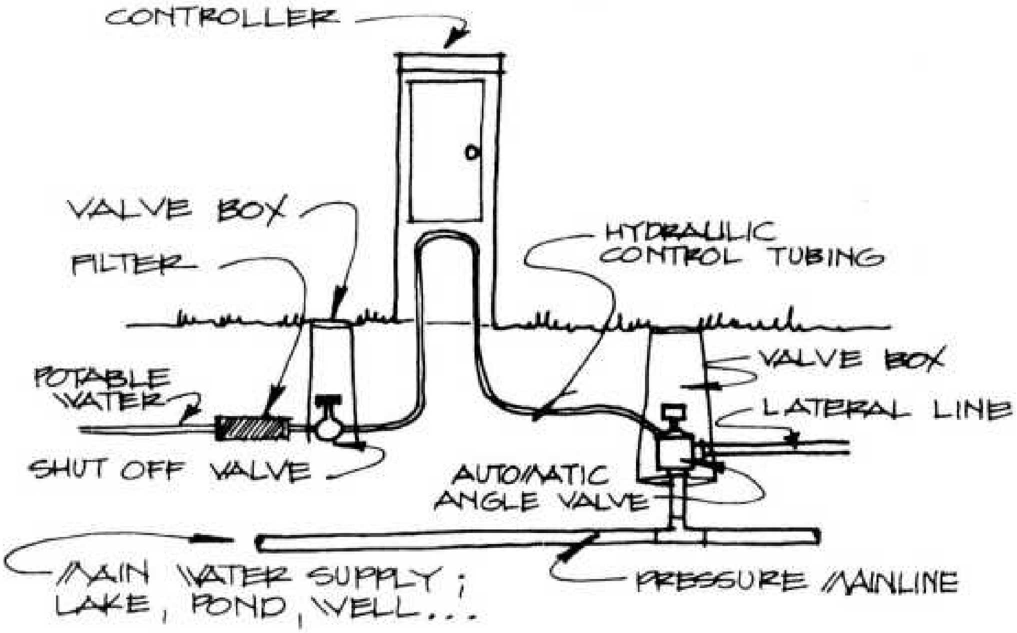


FIGURE 11.4 Hydraulic system.

## Hydraulic Systems

The hydraulically operated irrigation system uses water pressure to turn the valves on and off. Clean, potable (drinkable) water is usually supplied to the controller's signal tubing. Even though the water is clean, it should be filtered before using it in the small control tubes. See Figure 11.4 for a layout of hydraulic system components. Most hydraulically actuated valves are normally open valves. Recall the majority of electric valves are normally closed. In a normally open hydraulic valve system, the pressure is always on in the control tubes that are attached to each automatic circuit valve (see Figure 11.5). The pressure in the tubes keeps the valves shut. When the controller relieves the pressure in the tubing, the water flows through the valve and into the sprinkler circuit. Once the circuit has achieved its programmed watering time, the controller applies pressure to the signal tubing, which stops the flow of water through the valve. If the tubing is without water pressure, the valve will open and allow water to pass through. It is the starting and stopping of this water pressure that turns the valve on and off. There is also a normally closed hydraulic valve that works in the opposite way.

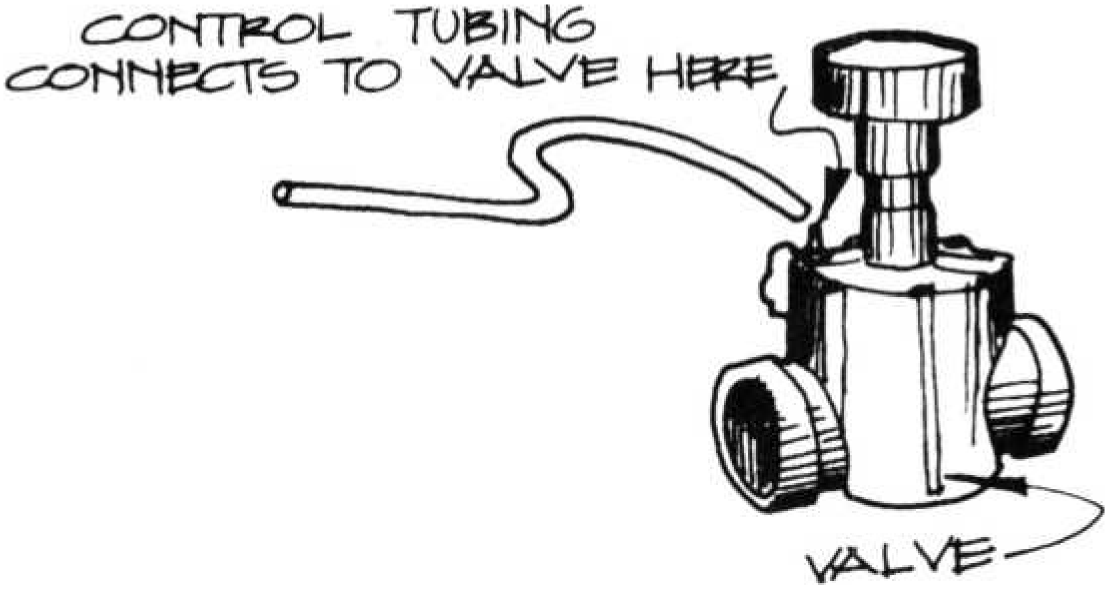


FIGURE 11.5 Control tubing and a hydraulic valve.

Hydraulic systems are a good choice for use on golf courses for several reasons. First, golf courses are often affected by lightning strikes. Second, when control tubing is accidentally cut, the system, being normally open, will come on. This way, on a 90- to 180-acre golf course that can have 5 miles of irrigation pipe, you can see where there is a system breakdown; the affected circuit will begin watering. With a normally closed electrical system, you could not detect a problem until browning of the turf began.

**Flow Controls**

Most valves have flow controls on top of the valve that can be turned manually to reduce the flow of water and create more friction loss (see Figure 11.6). These manual controls help to get the right amount of pressure to the heads on the circuit and may also assist in repair, because the maintenance person can turn the circuit on and off using the flow control without having to go back to the controller. On top of most valves, there is a small "bleed screw" that does the same thing as the automatic solenoid or hydraulic signal tubing. When you unscrew the bleed screw, water is allowed to pass through the valve and operate the sprinkler heads. Turn the bleed screw to a closed position to turn the circuit off.

## Angle Valve

There are two categories of valves: the angle valve and the globe valve. The angle valve is so named because the

water moves through the pipe and valve at a 90° angle, as depicted in Figure 11.7.

FIGURE 11.6 Automatic valves with flow controls (manifolded valve layout).

## Globe Valve

The globe valve is generally used when all of the irrigation pipe-that is, your main and lateral lines-is placed at the same depth. Water flows through the globe valve as shown in Figure 11.8. Because water has to turn in more directions in order to flow through a globe valve, more pressure is lost than is lost with the same amount of water flowing through an angle valve. When 25 gpm (94.63 L/min) of water flows through a 1-in (25.4-mm) electric valve, the angle valve loses 4.5 psi (0.32

kg/cm2), and the globe valve loses 6 psi (0.42 kg/cm2). An electric valve in a globe or angle configuration is shown in Figure 11.9.

## Selecting Valves

Now that we know a little bit about valves, how do we select them for our irrigation projects? Well, you select valves based on the following considerations:

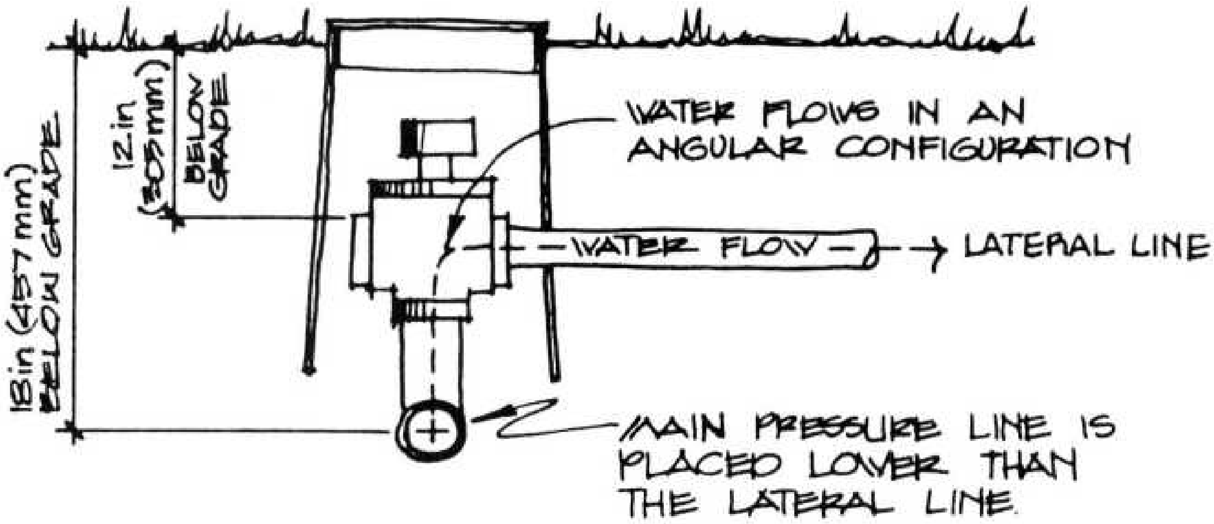


FIGURE 11.7 Angle valve.

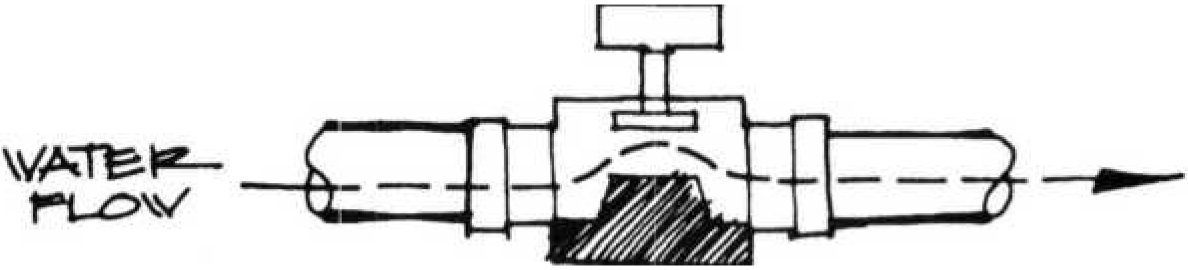


FIGURE 11.8 Globe valve.

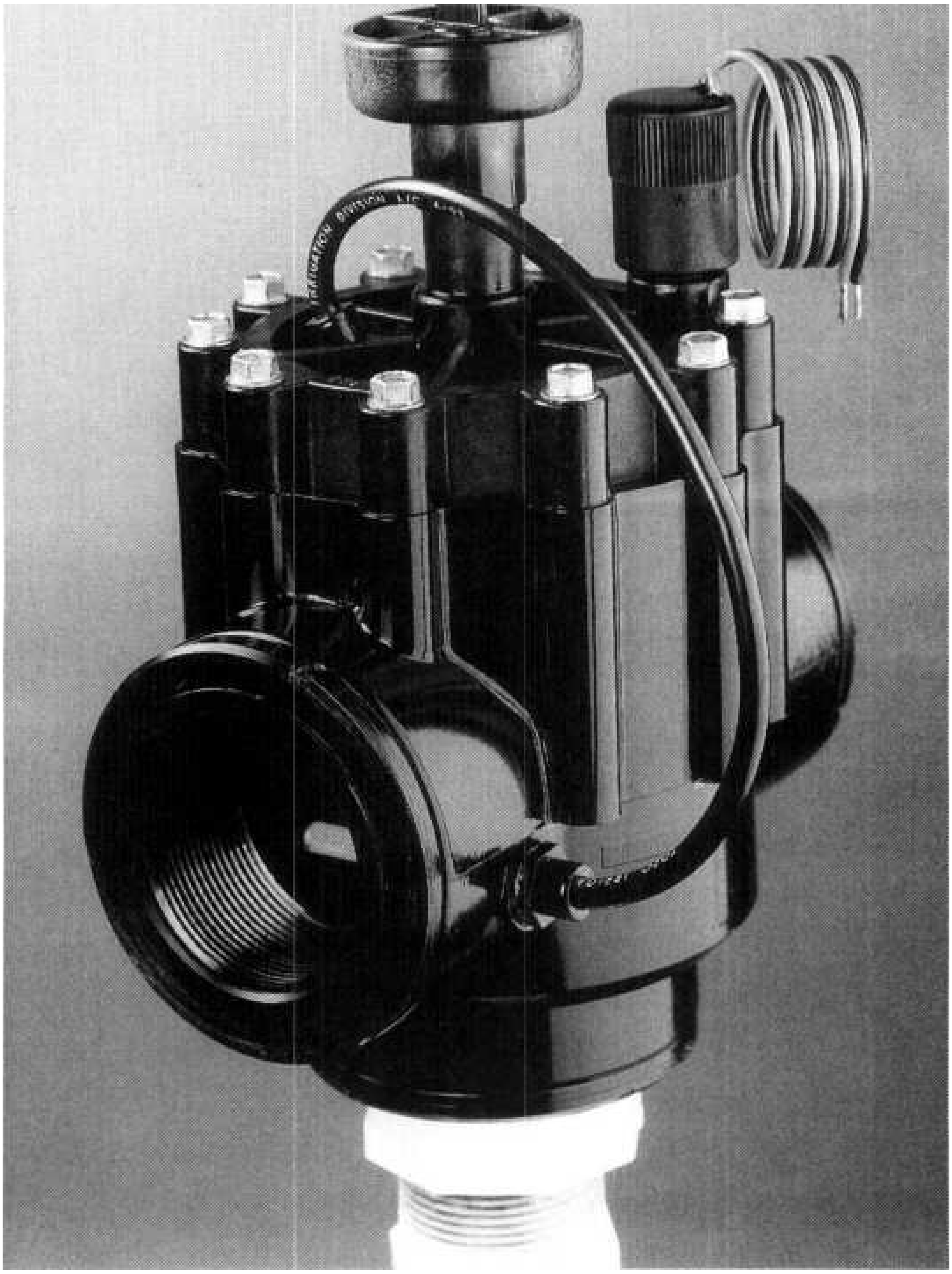


FIGURE 11.9 Electric valve in a globe or angle configuration. (Source: The Toro Company. Used with permission.)

1. How many gpm (L/min) of water is the circuit demanding?

2. How much pressure can you afford to lose?

3. Have you installed the main pressure line deeper than the lateral lines? If so, you will need to use an angle valve.

4. Are you using an electric or hydraulic system?

5. Is the area for which you are designing an irrigation system prone to lightning strikes?

Looking at a globe valve pressure loss chart in Table 11.1, you can see that the friction loss is given according to how many gpm (L/min) of water are going through the valve, whether it be an electric or hydraulic valve. Valves are selected according to the gpm (L/min) flow they must carry. More often than not, the valve opening will be smaller than the pipe with which it connects. Fittings are used to link the larger pipe size to the smaller valve connections. Table 11.2 shows friction losses for angle and globe configurations of both electric and hydraulic valves.

## Locating Valves

Locate valves near the center of the circuit they control. This way, valves split the circuit into equal parts, which results in duplicating pipe sizes and fittings on each half and also results in equal water pressure at the end heads in each circuit half.

Valves should be located so that you could turn on the valve by hand and see the circuit work, as opposed to the valve being located so that you cannot see the circuit work from the valve location when you turn the circuit on. It also helps if the valve can be located so that you do not get wet turning the circuit on manually.

*TABLE 11.1* **Globe Valve Pressure Loss Chart: Friction Loss in psi**

| TYPE | GPM | | | | | | |
|---|---|---|---|---|---|---|---|
| | 5 | 10 | 15 | 20 | 25 | 30 | 40 |
| 1-in Hydraulic | <1 | 1 | 2 | 3 | 4 | 6 | 9.5 |
| 1-in Electric | 3 | 4.4 | 4.5 | 5 | 5 | 7 | 9.5 |

Source: The Toro Company. Used with permission.

When you install a valve, locate a 4- or 6-in (102- or 152-mm) plastic pipe section over the valve from the ground level down to the valve, as shown in Figure 11.10. This allows for easy access. People with big hands have difficulty turning the valves on and off using the 4-in (102-mm) access pipe, so if you have a large client, you might want to consider using the 6-in (152-mm) size. Ten- and 12-in (254-mm and 305-mm) valve boxes and rectangular valve boxes are common on commercial work. The pipe is usually covered at ground level with a valve cover, which is usually green or black and inconspicuous looking. A valve box could trip someone walking through turf, so you need to locate your valves outside pedestrian areas. Many people like to locate their valves in ground cover beds so that they are unnoticed. At one time, valves were buried without the benefit of the access pipe and valve cover. They operated in that manner, but it was difficult to locate the valves for maintenance purposes.

TABLE 11.2 **Performance Information: Friction Loss—All 252 Models***

| SIZE | TYPE | | 5 | 10 | 20 | 25 | 30 | 40 | 50 | 60 | 70 | 80 | 100 | 120 | 150 | 170 | 180 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.5 in | Hydraulic | Angle | | | | 1 | 1 | 1.5 | 1.5 | 3 | 4 | 5 | 7 | 11 | | | |
| | | Globe | | | | 1 | 1 | 2 | 3 | 4 | 5.5 | 6.5 | 10.5 | 13.5 | | | |
| 2 in | Hydraulic | Angle | | | | | | | | 1 | 1 | 1.5 | 2 | 3 | 5 | 6 | 6 |
| | | Globe | | | | | | | | 1.5 | 2 | 2 | 3.5 | 5 | 8 | 10 | 11 |
| 1 in | Electric | Angle | 2 | 3.5 | 4.5 | 4.5 | 5 | 7.5 | | | | | | | | | |
| | | Globe | 3 | 4 | 5 | 6 | 7 | 9.5 | | | | | | | | | |
| 1.5 in | Electric | Angle | | | | 1.5 | 1 | 1.5 | 2 | 3 | 3 | 5 | 7 | 9 | | | |
| | | Globe | | | | 1.5 | 1.5 | 2 | 3 | 4 | 5 | 7 | 11 | 15 | | | |
| 2 in | Electric | Angle | | | | | | | | 1 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| | | Globe | | | | | | | | 2 | 2 | 2.5 | 3.5 | 5.5 | 8 | 10 | 11 |

**Contamination-resistant valves are electric only.*

*Note: When designing a system, be sure to calculate total friction loss to ensure sufficient downstream pressure for optimum sprinkler performance.*

Source: The Toro Company. Used with permission.

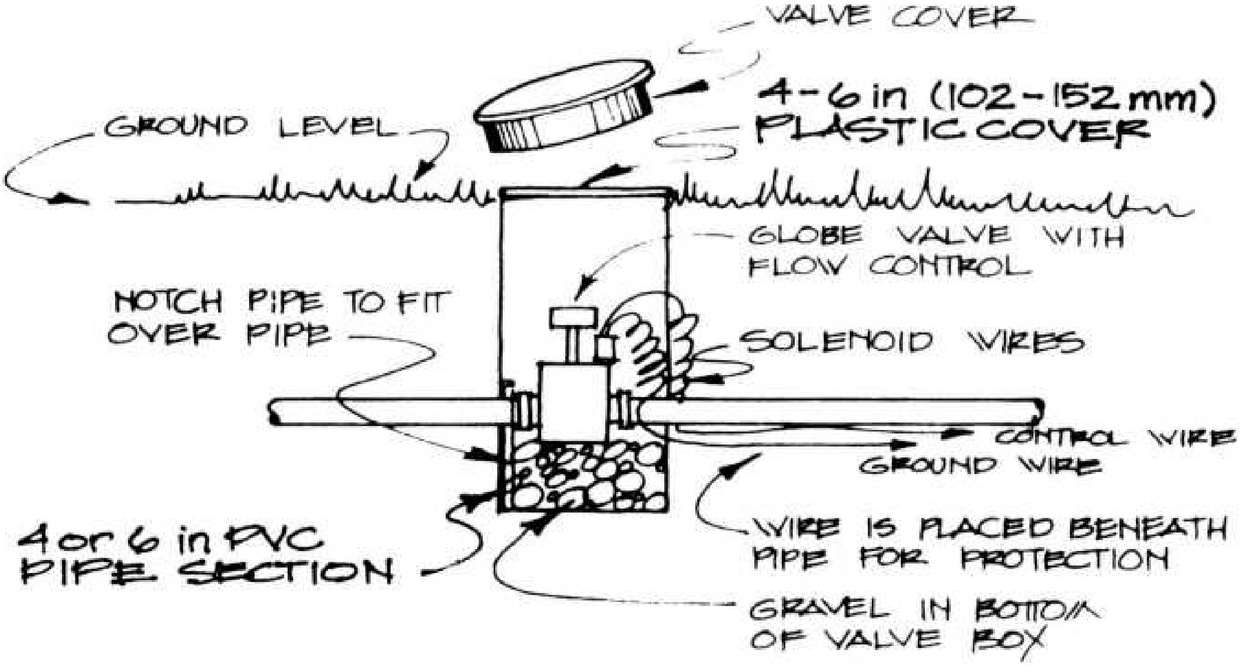


FIGURE 11. 10 Valve box.

# 12

# Sizing Wire to Electric Valves

## Introduction

When designing an electrically activated irrigation system, you need to calculate the size of the electrical wire that runs from the controller to each automatic circuit valve. This wire carries the electrical signal that opens and closes the circuit valves for the duration of time that you planned.

## Electrical Terms

Sizing the automatic valve wire is a relatively easy task that is similar to the process we use to size irrigation pipe. In order to grasp the meaning of pertinent electrical terms, let us compare them with irrigation terms:

Volt (V)-A volt is a unit of electrical pressure. Voltage is analogous to water pressure.

Amp (A)-An amp (or ampere, as it's more formally known) is a unit of measurement for the flow or quantity of electrons. Amps are analogous to the gpm (L/min) flow of water. Volts X amps = watts.

Watts (W)-Watts express power. If you take 120 volts and multiply by 10 amps, you get 1,200 watts of power. Electric power companies base their charges on the number of watts (amount of power) used.

Wire-Copper electrical wire is just like irrigation pipe-the smaller the wire or pipe, the smaller the flow of electrons or water they will carry, and vice versa. Just as water loses pressure as it goes through a pipe, voltage can be lost as it travels through wire. This is why we must minimize voltage loss. Just as a sprinkler head needs a certain pressure to pop up and operate properly, enough voltage pressure must be delivered to a valve in order to open it and keep it open until the watering cycle has concluded. Inrush current is the amount of amps that it takes to open the solenoid, and holding current is the amount of amps required to keep it open while irrigating. More amps are needed for the solenoid to open a valve than are needed to keep it open.

## Voltage and Electric Wire

In an electric irrigation system, the controller reduces voltage from 120 V to 24 V through a transformer that acts as a pressure regulator. Twenty-four V will not injure people if they accidentally cut into a buried wire. With this safety precaution in mind, the irrigation industry has designed electrically actuated valves to open with 24 V of pressure. Because 24 V is safe, electric wire is usually buried without being placed inside a protective pipe or conduit, as 120-V electric wire would be. Some federal government jobs require all irrigation wiring to be contained in plastic pipe (conduit) for protection of the wire. Always refer to local building codes to see if this is required.

## Electric Circuits

The controller sends the 24-V current through a wire that loops from the controller to the valve and back to the controller. This loop is also known as an electrical circuit, and a simple electrical circuit is shown in Figure 12.1. All electric circuits must have a complete loop to take electricity to the point of need and then return. As you learned in Chapter 11, the current traveling toward the valve actually arrives at a small device located on top of the valve called a solenoid, which is about 1 in (25 mm) tall and made of copper wire. The solenoid and waterproof wire splice caps are shown in Figure 12.2.

When the solenoid receives the electrical charge, it becomes magnetized and lifts a small plunger that activates the valve to open. The electricity, or flow of electrons, is transported by an individual wire, called a hot or control wire, to each valve. A common or neutral wire completes the circuit by returning to the controller (see Figure 12.3). The same hot or control wire should not be connected to each valve because all of the valves would come on at the same time when the electric charge was sent through the wire. A separate control wire is hooked from the controller to each valve. The common wire links all of the valves back to the controller. Figure 12.4 clearly illustrates electrical system components.

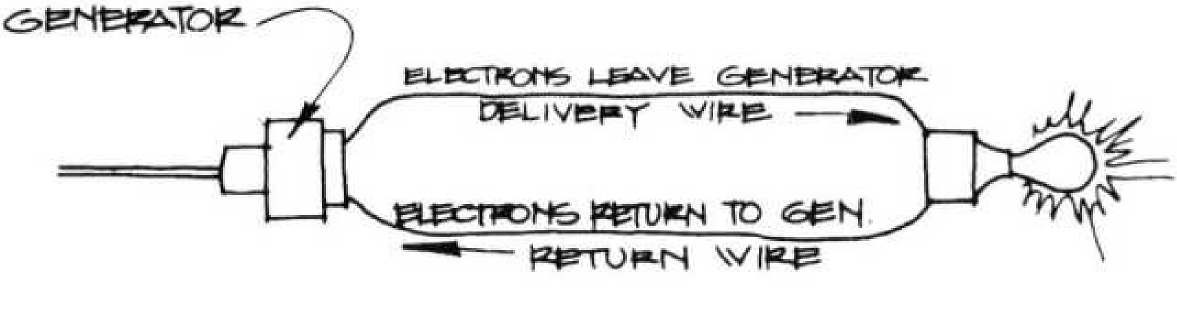


FIGURE 12. 1 Electrical circuit.

FIGURE 12.2 Valve with solenoid and wire splice caps. (Source: The Toro Company. Used with permission.)

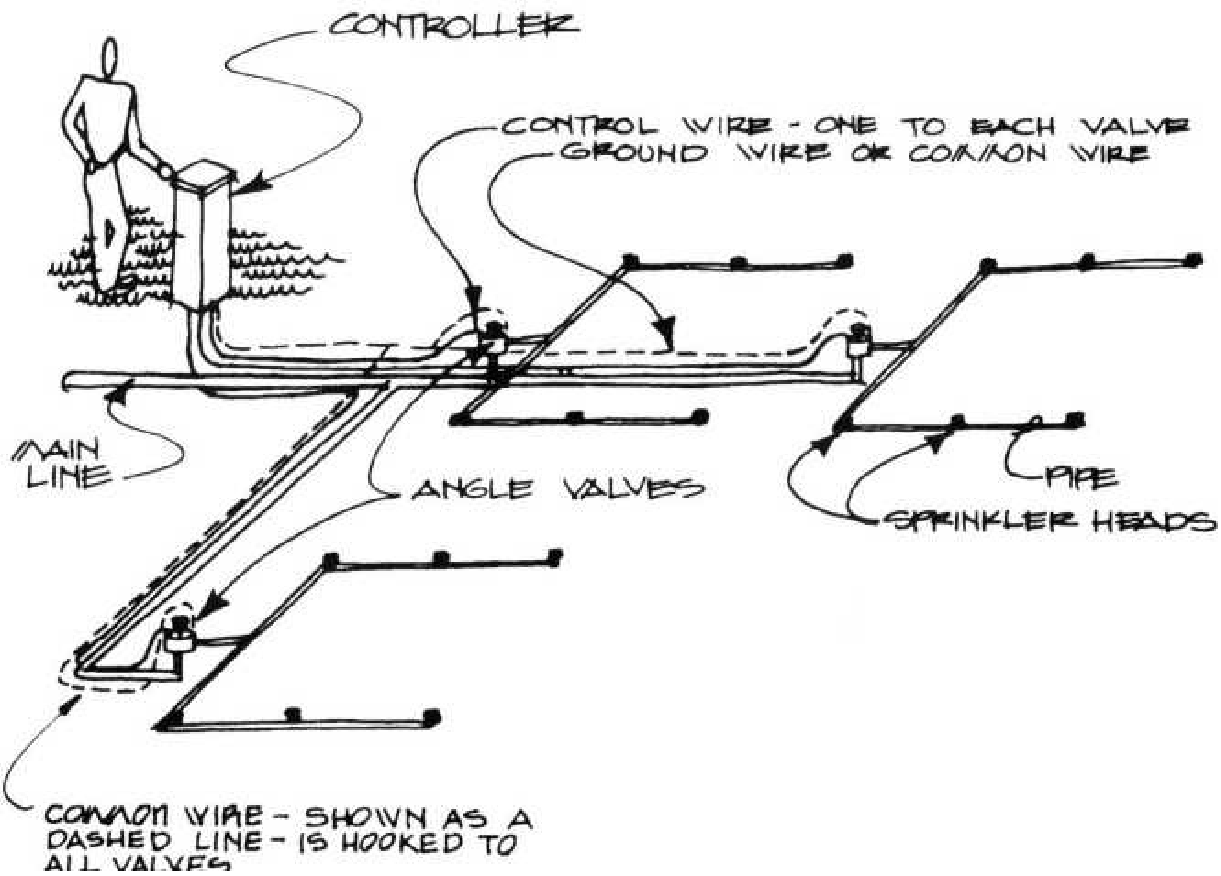


FIGURE 12.3 Wiring diagram for three separate valve circuits.

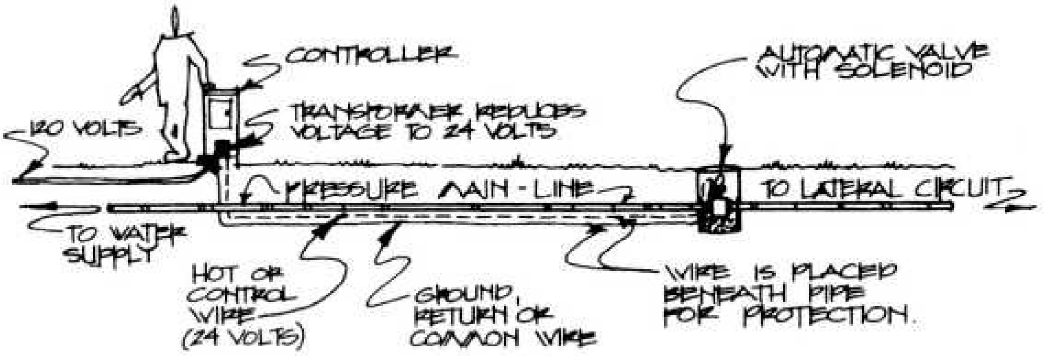


FIGURE 12.4 Electric system components.

**Wire Sizing**

Now that you have an idea of how to place wire to link valves to the controller, let us look at the criteria for sizing wire. There are three considerations you must keep in mind:

1. How far are the valves from the controller?

2. What is the static water pressure at the valves?

3. How many valves are on the same controller station?

The longer the wire is from the controller to the valve, the more likely voltage will drop as the electrical current travels. Just as we would use a larger pipe to reduce friction or pressure loss, we also use a larger wire to reduce voltage loss over long runs. Wire-sizing charts such as the one shown in Table 12.1 assist in selecting the correct wire to use. The table features the maximum length of wire run from the controller to the valve.

If we take a situation where we have 1,600 ft (487.7 m) from the controller to a single valve on a project, then we know we need a 1,600-ft (487.7-m) control wire run and a 1,600-ft (487.7-m) common or return wire to complete the circuit. Looking at the wire-sizing chart in Table 12.1 for a static water pressure of 80 psi (5.62 kg/cm2) or less, we see that we could use an 18gauge common wire and an 18-gauge control wire. In fact, we could have a control wire run up to 3,000 ft (914.4 m) long and still use 18-gauge wire.

Now let us look at what effect water pressure has on sizing wire. The greater the static water pressure (water not moving) at the valve, the more energy is required by the solenoid to overcome the static pressure and open the valve. The wire-sizing charts often break down the static pressure into categories such as:

| | |
|---|---|
| 80 psi (5.62 kg/cm$^2$) | |
| 100 psi (7.03 kg/cm$^2$) | Medium pressure |
| 125 psi (8.79 kg/cm$^2$) | |
| 150 psi (10.55 kg/cm$^2$) | High pressure |

In the wire-sizing problem we just completed, we used 80 psi (5.62 kg/cm2) as our maximum static pressure. Regarding the third consideration, the more valves you have linked together to come on at one time (which is the same thing as being connected to the same controller station), the larger your wire will need to be to carry the increased amps.

*TABLE 12.1* ***Wire Sizing Chart for 80 psi Water Pressure at Valve—Equivalent Circuit Length***

| **COMMON WIRE SIZE** | **CONTROL WIRE SIZE** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **18** | **16** | **14** | **12** | **10** | **8** | **6** | **4** |
| 18 | 3,000 | 3,700 | 4,300 | 4,800 | 5,200 | 5,500 | 5,200 | 5,800 |
| 16 | 3,700 | 4,800 | 5,900 | 6,900 | 7,700 | 8,300 | 8,800 | 9,100 |
| 14 | 4,300 | 5,900 | 7,700 | 9,400 | 11,000 | 12,300 | 13,300 | 14,000 |
| 12 | 4,800 | 6,900 | 9,400 | 12,200 | 15,000 | 17,500 | 19,600 | 21,100 |
| 10 | 5,200 | 7,700 | 11,000 | 15,000 | 19,400 | 23,900 | 27,800 | 31,100 |
| 8 | 5,500 | 8,300 | 12,300 | 17,500 | 23,900 | 30,900 | 38,000 | 44,300 |
| 6 | 5,700 | 8,800 | 13,300 | 19,600 | 27,800 | 38,000 | 49,200 | 60,400 |
| 4 | 5,800 | 9,100 | 14,000 | 21,100 | 31,100 | 44,300 | 60,400 | 78,200 |

## Wire Sizing for Multiple Valves

Again, the more valves you have linked together to come on at the same time, the larger the wire will need to be to accommodate the increase in amps flowing to the multiple valves. Remember, amps and gpm (L/min) are analogous units of measure. Both refer to the quantity of flow. To illustrate wire sizing for multiple valves, let us look at an irrigation circuit with three sprinkler heads that demand 3 gpm (11.36 L/min) each. We see in Figure 12.5 that the gpm (L/min) flow through the pipe decreases from left to right as the water demanded by the heads is delivered to each head.

Comparing water flow with electricity flow, we see that the flow of power decreases from left to right as the amps demanded by each valve solenoid are delivered. In our example in Figure 12.6, each valve solenoid demands 2 W of power. To accommodate the various flows of amps, we might need to use larger wire for the larger amp flows just as we would use larger pipe to accommodate higher gpm (L/min) flows. Some wire-sizing charts are set up to size wire for one, two, or three valves that are linked together. In some charts, you transpose the extra valves on a circuit into an equivalent length of wire to simplify figuring wire size. (See Figure 12.7 for an example of three valves wired so that they will all come on at one time.) Let us review a step-by-step method of sizing wire for valves that will all come on at the same time:

1. Measure the wire run from the controller to each valve on the circuit as shown in Figure 12.7.
2. Take the wire length from the controller to the first valve, from the first valve to the second valve, and so on, and multiply those wire lengths by the number of valves for which each wire section is supplying power. This will give you the equivalent length of wire needed for each wire section.

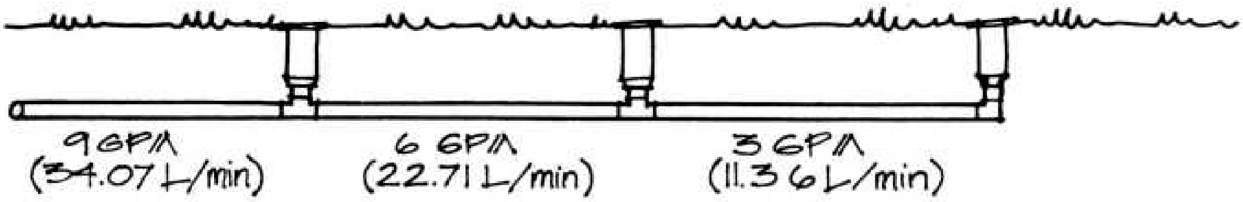


FIGURE 12.5 Gpm (L/min) flow through pipe sections.

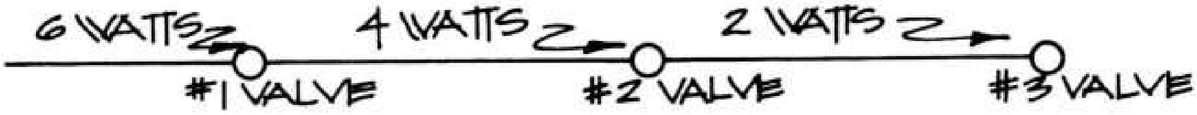


FIGURE 12.6 Electric power through copper wire sections.

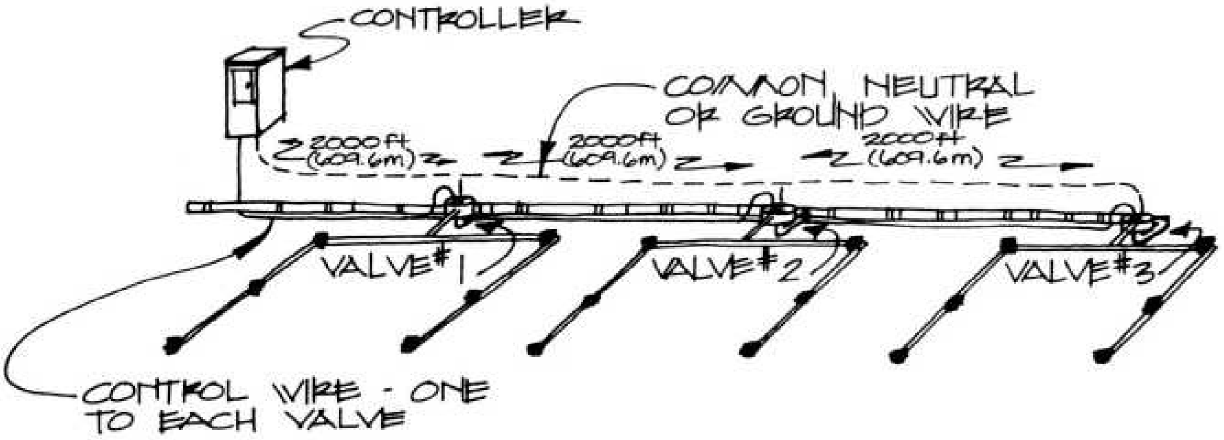


FIGURE 12.7 Three valves wired to operate together.

## TABLE 12.2 **Wire Costs**

| SIZE | RELATIVE COST |
|---|---|
| 18-gauge | *x* = Relative Cost |
| 16-gauge | 1.21*x*; cost is 21% more than that of 18-gauge wire |
| 14-gauge | 1.53*x*; cost is 53% more than that of 18-gauge wire |
| 12-gauge | 2.38*x*; cost is 138% more than that of 18-gauge wire |
| 10-gauge | 3.80*x*; cost is 280% more than that of 18-gauge wire |
| 8-gauge | 6.13*x*; cost is 513% more than that of 18-gauge wire |

3. Add all the equivalent-length-of-wire footage and you will get a length of wire that will serve the number of valves you have on the circuit.

4. Consult the wire-sizing chart that corresponds with your static water pressure and select your common wire and control wire sizes. We will use the wire-sizing chart for 80 psi in Table 12.1 in the following problem:

**Wire Section #1**

Wire section #1 serves 3 valves.

From controller to valve #1 = 2,000 ft (609.6 m).
2,000 ft (609.6 m) × 3 valves getting power from the wire section = 6,000 equivalent ft (1828.9 m).

**Wire Section #2**

Wire section #2 serves 2 valves.

From valve #1 to valve #2 = 2,000 ft (609.6 m).

2,000 ft (609.6 m) × 2 valves getting power from that wire section = 4,000 equivalent feet (1,219.2 m).

#### Wire Section #3

Wire section #3 serves 1 valve.

From valve #2 to valve #3 = 2,000 ft (609.6 m).

2,000 ft (609.6 m) × 1 valve getting power from that wire section = 2,000 ft (609.6 m).

Add all of the equivalent-length-of-wire footage:

6,000 ft (1,828.9 m)—controller to valve 1.
4,000 ft (1,219.2 m)—valve 1 to valve 2.
2,000 ft (609.6 m)—valve 2 to valve 3.
12,000 ft (3,657.7 m)—This is the control wire length from which you need to determine the wire size in the chart.

TABLE 12.3 **Wire Gauge and Amp Capacity**

| WIRE SIZE | CURRENT CARRYING CAPACITY (A) |
|---|---|
| 14-gauge | 15 |
| 12-gauge | 20 |
| 10-gauge | 30 |
| 6-gauge | 40 |
| 4-gauge | 70 |

The common wire must be as big as or one size bigger than the control wire because the common wire has to carry the return flow of the smaller circuits. The common wire must be able to carry the largest flow of electrons. This is analogous to sizing the mainline pipe in an irrigation system so that it's large enough to carry the gpm (L/min) flow demand from the largest irrigation circuit.

Looking at Table 12.1, we see that if we use an 18gauge common wire and a 4-gauge control wire, we can only run the control wire 5,800 ft (1,767.9 m). We need to have a 12,000-ft (3,657.7-m) control wire equivalent length to accommodate our three valves spaced 2,000 ft (609.6 m) apart. As the gauges get smaller, the wire is larger. So let us look at the larger 16-gauge common wire and see what the maximum control wire length would be. It is 9,100 ft (2,773.8 m) using a 4-gauge wire. Again, this is too short.

Let us look at cost for a minute before we solve our wire-solving problem. The chart in Table 12.2 shows the current cost relationship between wire sizes. We can see that the 8-gauge wire costs over five times what the 18-gauge wire costs (513% more, to be exact). We can therefore assume that cost is a significant factor in selecting wire sizes, and we should try to select the smallest wire size possible to reduce our material costs.

What we are looking for, then, is a common wire and control wire that are equal in size or a combination in which the common wire is one size larger. We should also try to select the smallest wire size possible in order to keep material costs down.

Looking for that ideal combination of sizes, we see that a 12-gauge common wire and 12-gauge control wire will accommodate our flow of electricity. The 12/12 combination will work on circuits with up to 12,200 ft (3,718.7 m) of wire. This length suffices for our three valves linked together, which, according to our calculations, need an equivalent length of 12,000 ft (3,657.7 m) of control wire.

In conclusion, many irrigation jobs do not require wire and pipe runs of 2,000 ft (609.6 m) or longer, so the calculations we have just worked out are larger than what an average residential scale project would call for. Also, many contractors use 14-gauge wire all the time for all occasions, although some contractors will switch the common wire to a larger size (12gauge) on long wire runs. Many contractors like to use the same wire size all the time so that their crews do not get different wire sizes mixed up during project construction. Using 14-gauge wire as a standard also eliminates costly wire replacement due to undersizing. Other contractors, though, prefer to size their wire exactly and reduce material costs.

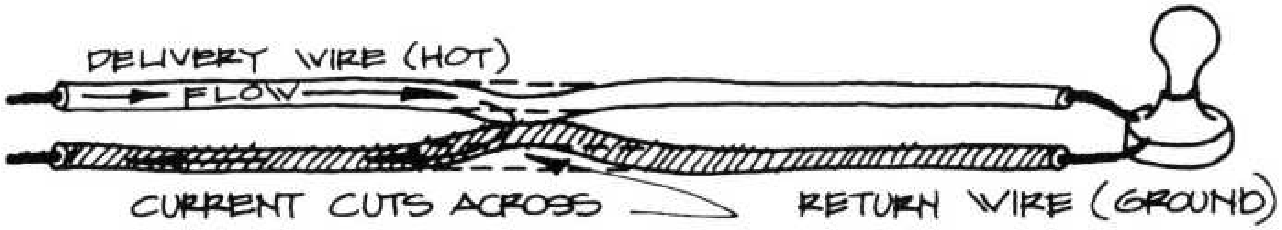


FIGURE 12.8 Short circuit stops flow of electricity.

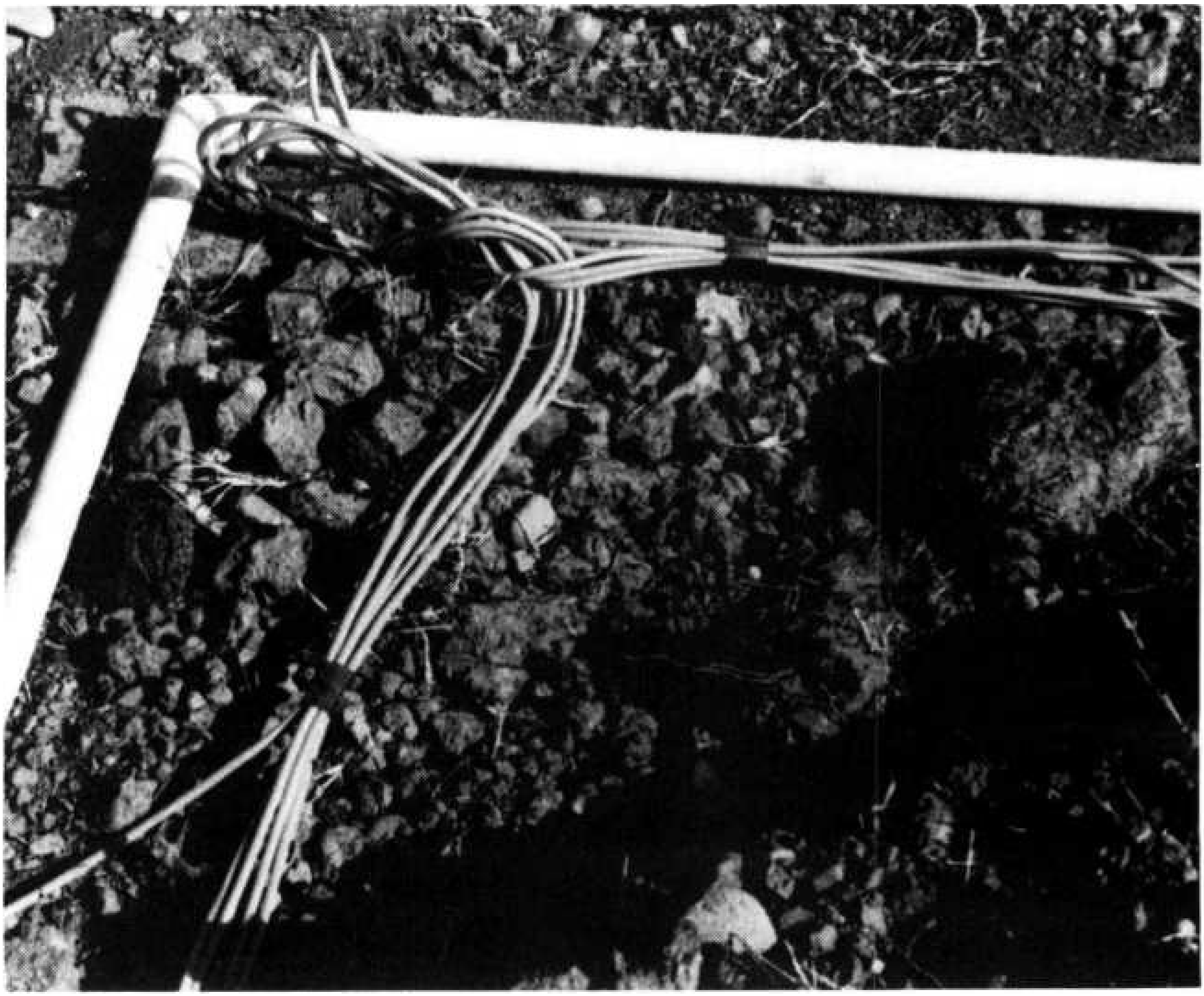


FIGURE 12.9 Loop of wire at corners.

## Wire Placement Techniques

When installing automatic valve wire, contractors place the wire beneath the pipe in the trench. If there is future digging in the area, the pipe will be hit before the wire. This placement protects the wire. Also, many contractors will run an extra length of wire along the

longest electrical circuit in case of wire malfunction. This precaution can save a great deal of effort in the future if a control or common wire fails for some reason. If the PVC insulation on a wire is nicked, the wire could spill its flow of electrons into the soil and short the circuit, as shown in Figure 12.8. The extra wire run could then be used.

Occasionally, the wire on the end of a spool will be wound tightly, and uncurling the wire will break the copper inside the insulation. The extra wire run will pay for itself in reducing installation costs. Another good construction practice is to snake the wire loosely in the trench to allow for its contracting in cool weather. Many contractors also make a 1-ft (0.3-m) loop of wire at all corners to allow for wire contraction and expansion. Others coil the wire six to eight times around a 1-in (25-mm) piece of PVC pipe. The coil can also dissipate power in case of a lightning strike. The wire loop, shown in Figure 12.9, comes in handy when you are splicing wire at a valve and need extra length. Because the wire is slick, you can tug on it and usually get enough length to make the splice. The wire loop is also useful when you are splicing in a tee fitting or repairing a leak in a mainline and you need to pull the wire out of the way so that you do not cut into it. It is also a good practice to allow 1.5 ft (0.5 m) of extra wire length at each valve, which makes future repair and maintenance easier.

The type of wire used for irrigation systems is known as "UF," or underground feeder wire. This is a low-voltage wire with thick insulation that allows the wire to be buried without being placed in conduit, and it has UF printed on its insulation. The wire comes in different colors, with the control wire typically being red. Common or ground wire is usually white or black, and extra or spare wire is any other color but often blue. Figure 12.10 shows splicing wire at an automatic valve.

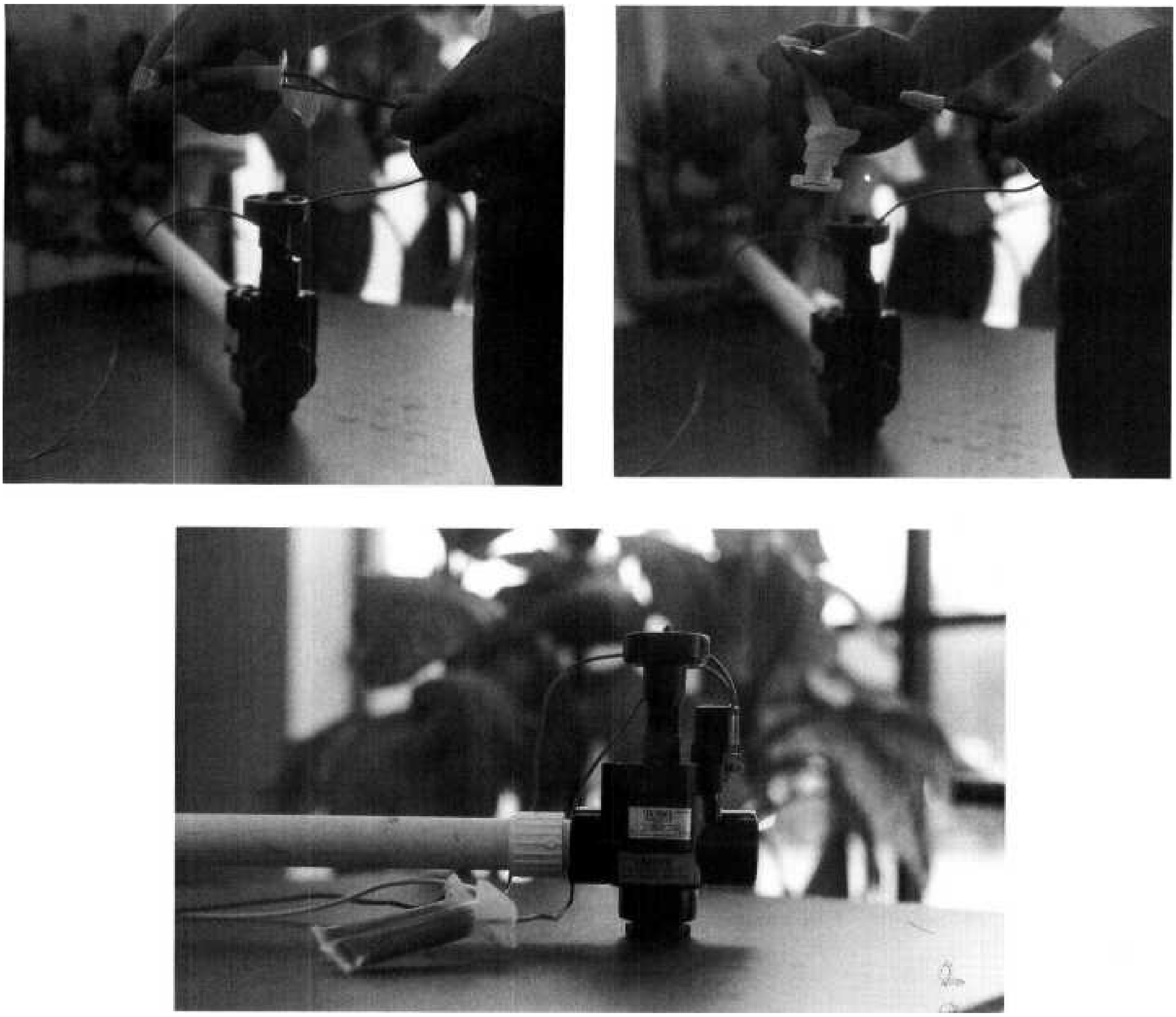


FIGURE 12. 10 Splicing wire at an automatic valve.

# 13

# Surge Pressure and Water Hammer

### Introduction

Water hammer is something you need to be aware of when designing an irrigation system. The term refers to the destructive forces, banging noises, and vibrations in a piping system that most commonly occur when the water flowing through that pipe is stopped by an automatic or manual circuit valve that closes too quickly.

### Surge Pressure

Surge pressure is the rise in pressure caused by the valve closing. The word surge comes from the Latin surgere, which means "to rise." Moving water slams against a valve when it is closed and causes a rise in water pressure proportionate to the water's velocity when the valve was shut off. Pressure that is created by the sudden closing of a valve may be up to four times the working water pressure. The high-pressure shock wave, or water hammer, moves back and forth through the pipe until its energy is expended through friction loss in the pipe. This surge pressure and resultant water hammer can weaken and damage an irrigation system over time by causing the pipe material to expand and causing joints to weaken. Surge pressure and water hammer are caused by

- Automatic valves that close too quickly
- Closing a manual valve too quickly
- Filling an empty pipe with water
- A water velocity in excess of 5 ft (1.5 m) per second

In most smaller irrigation projects, you will not have any problems with water hammer. Being aware of the problem, though, will enable you to design your irrigation systems cautiously to eliminate the possibility of excessive surge pressures. Figure 13.1 depicts the shock waves caused by a quickly closing valve.

### Calculating Surge Pressure

It is important to be able to compute surge pressures so that you can select a grade of plastic pipe that is strong enough to withstand the pressure rise. To calculate the total surge pressure, you first determine the surge pressure caused by the closing valve and then you add that calculation to the working pressure in the pipe line.

To determine the surge pressure caused by the closing valve, let us refer to the nomograph in Table 13.1, which contains all of the variables we need to consider:

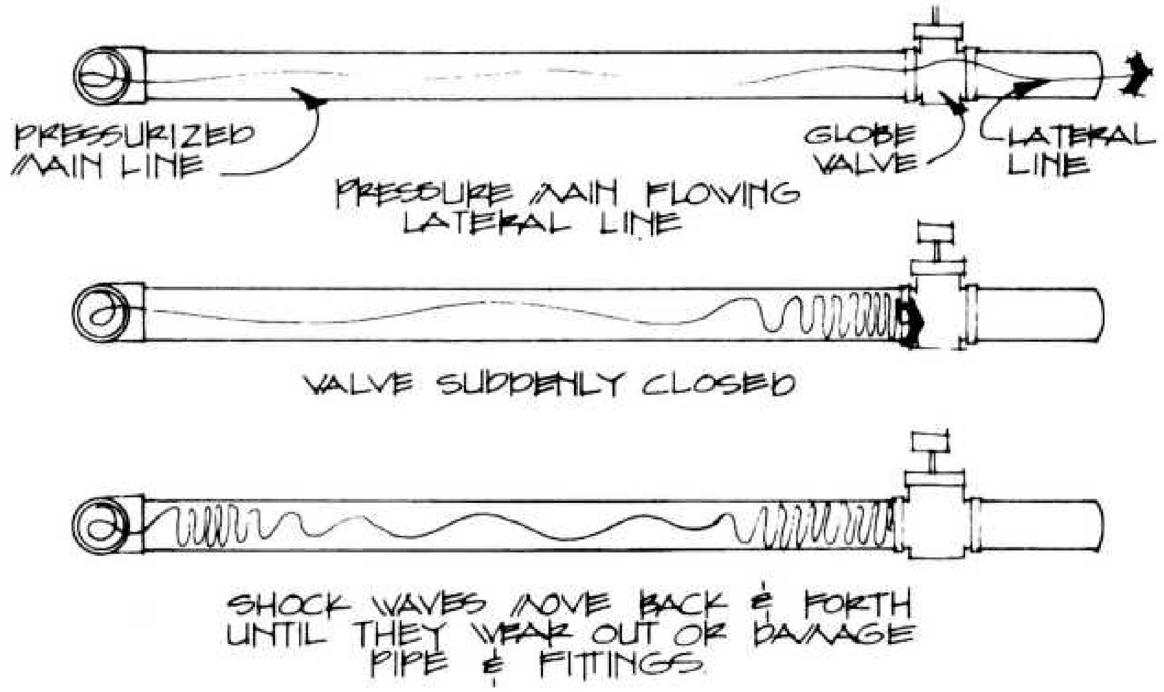
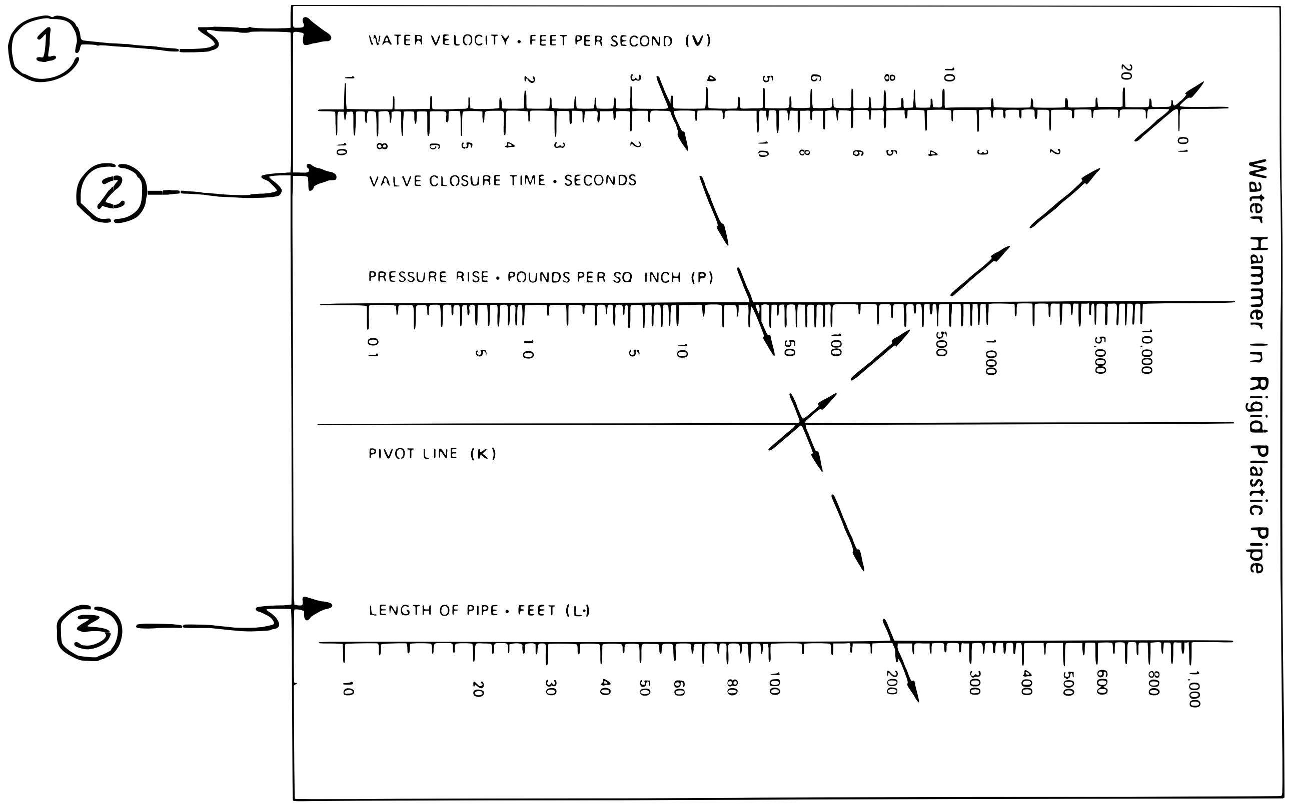


FIGURE 13. 1 Shock waves.

1. The water velocity in feet per second
2. Valve closure time in seconds and tenths of seconds
3. The length in feet of straight pipe that is affected by the water hammer.

The line entitled "pressure rise in pounds per square inch" will reveal the surge pressure we are trying to determine. Remember, this pressure rise is determined by the variables we just listed; water velocity, valve closure time, and length of pipe.

*TABLE 13.1* **Surge Pressure Nomograph**



Once we know the surge pressure, we add it to the working water pressure and determine the total rise in pressure caused by the sudden valve closure. The nomograph shows us that any time a valve is closed, there is going to be some amount of surge pressure. What affects that surge is how fast the valve closes, how long the affected pipe is, and how fast the water is moving. Let us review the step-by-step process for using the nomograph and computing surge pressure. Refer to Table 13.2 for calculations.

### Step-by-Step Surge Pressure Determination Process

1. Put a dot on the water velocity line for the pipe we are evaluating for surge. Let's say we have a 5 ft (1.5 m) /sec flow rate in our 2-in pipe.
2. Determine the pipe length and mark it on the length of pipe line. We will use a 50-ft (15.2-m) pipe.
3. Connect the two dots with a straight line.
4. Where our straight line crosses the pivot line, connect another straight line from the pivot point to the estimated valve closure time line. We will use 0.5 seconds for our valve closing time.

5. Where this straight line crosses the pressure rise line, we see that our surge pressure will be about 35 lb (2.46 kg/cm2) of extra pressure.

6. We add that 35 lb (2.46 kg/cm2) of extra pressure to our working pressure, which we will say is 50 psi (3.52 kg/cm2), and we get a total surge pressure of 85 psi (5.98 kg/cm2).

*TABLE 13.2* ***Surge Pressure Calculations***

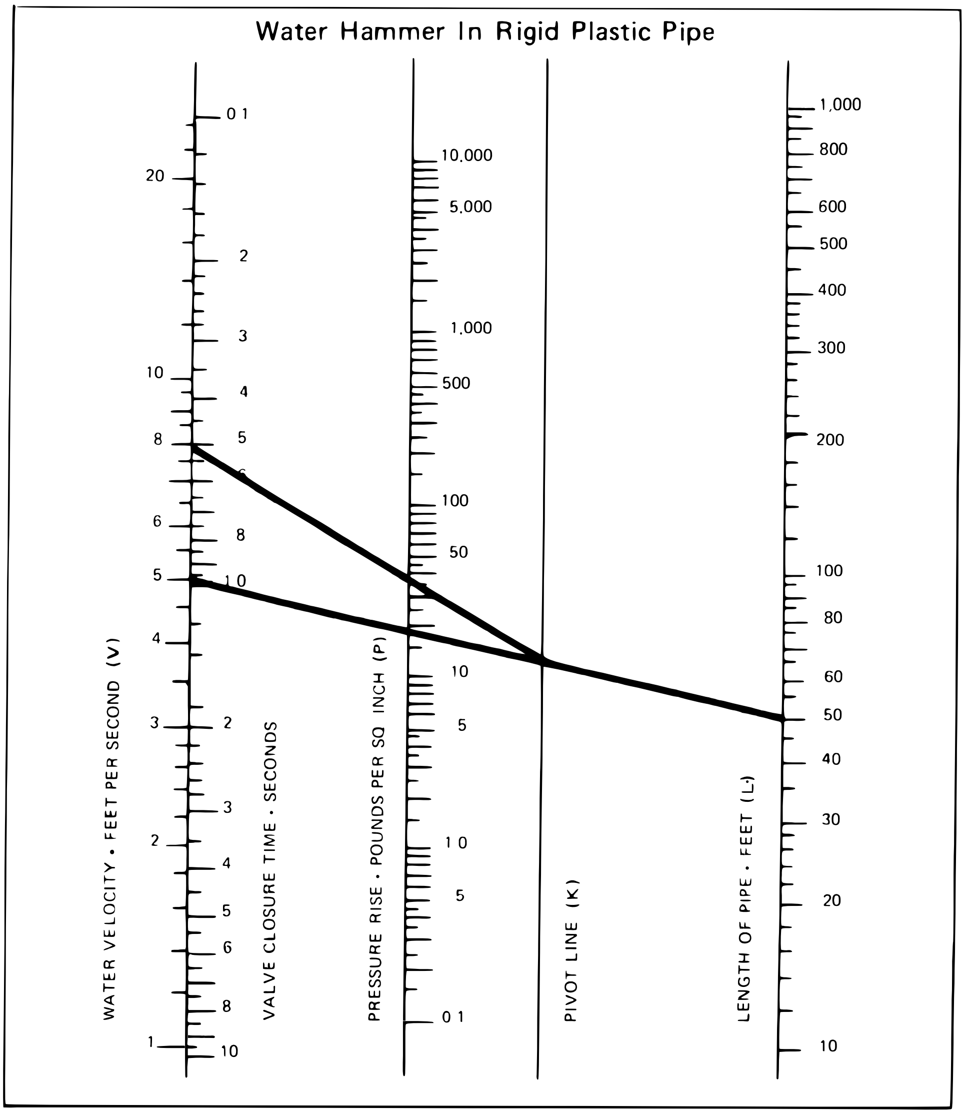


*TABLE 13.3* ***Valve Closure Times***

**1-IN ELECTRIC GLOBE VALVE—250 SERIES—PLASTIC**

| psi (kg/cm$^2$) | 10 gpm (37.9 L/min) | 20 gpm (75.7 L/min) | 30 gpm (113.6 L/min) | 40 gpm (151.4 L/min) |
|---|---|---|---|---|
| 30 (2.11) | 2 seconds | 3 seconds | 6 seconds | 5 seconds |
| 40 (2.81) | 3 seconds | 3 seconds | 6 seconds | 5 seconds |
| 50 (3.52) | 3 seconds | 4 seconds | 3 seconds | 5 seconds |

**3-IN ELECTRIC ANGLE VALVE—216 SERIES—BRASS**

| psi (kg/cm$^2$) | 60 gpm (227.1 L/min) | 100 gpm (378.5 L/min) |
|---|---|---|
| 80 (5.62) | 7 seconds | 6 seconds |

This is not an excessive amount of pressure, especially when you consider that the lowest pressure-rated plastic pipe is guaranteed to hold 160 psi (11.25 kg/cm2) of water pressure. We are specifically talking about class 160 PVC pipe; the 160 stands for the psi (11.25 kg/cm2) that the manufacturer guarantees the pipe to be able to withstand.

If we had a longer pipe run and a shorter valveclosing time, our pressure rise would have increased dramatically. The calculations we used reflected an average residential sprinkler system situation. Because valve closure times depend not only on the brand of the valve but also on water pressure and flow, we ran some tests on valves to determine specific valve closure times. The resulting valve closure times and the pressure and flow variables are listed in Table 13.3 for your

use. You can see from the tests that valves do not snap shut but instead close slowly, which helps to reduce surge pressures.

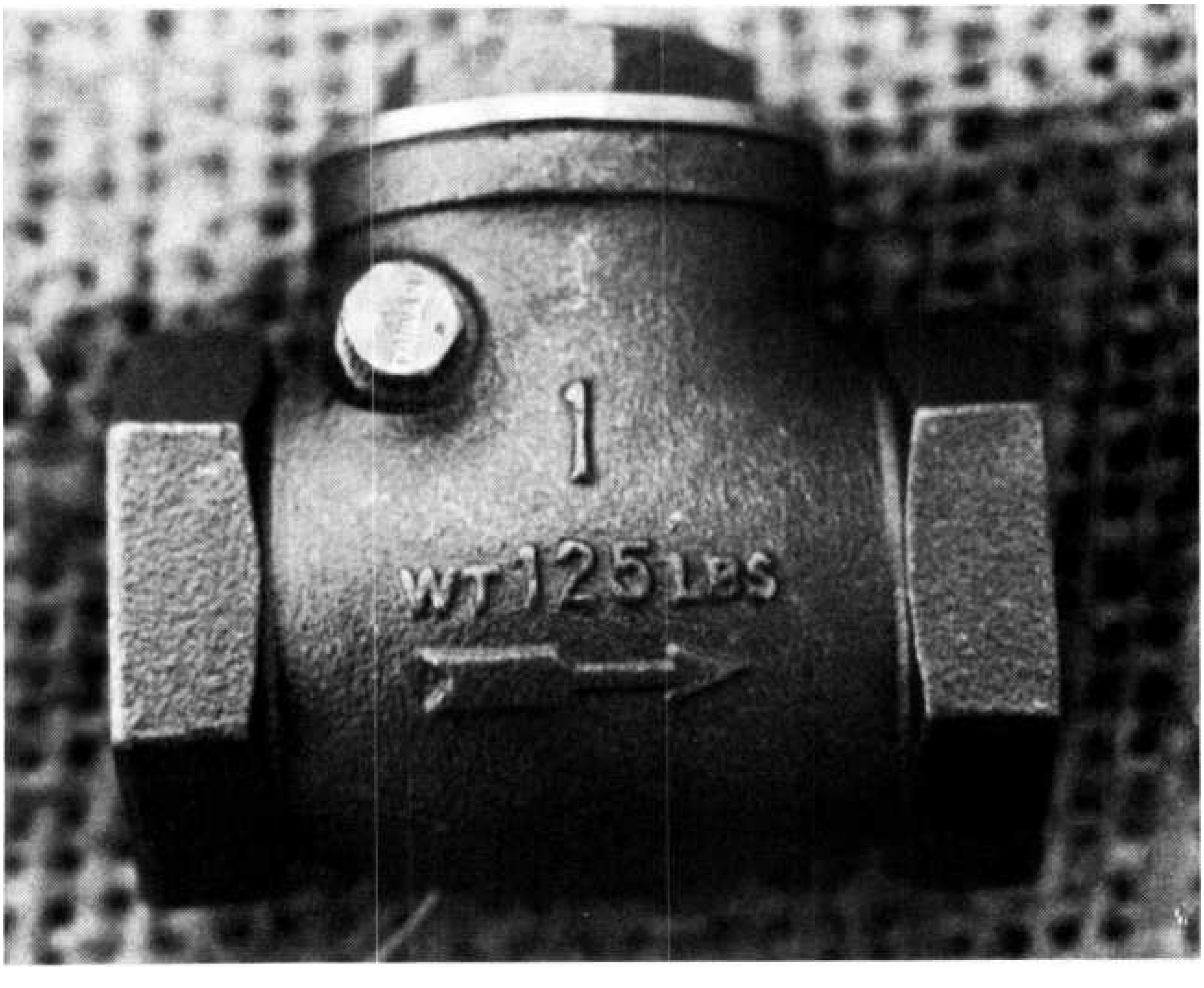


FIGURE 13.2 Check valve for use in a pipe line.

When calculating surge pressure for an irrigation job, it is best to be conservative so that you know your pipe will be strong enough. Remember, too, that the larger the irrigation system and the longer the pipes that will be subject to water hammer, the slower your valves will need to open and close. For manual systems, tell your clients to open their valves slowly, so as to prevent damaging water hammer!

## Water Hammer in Lateral Lines

There is one more point we would like to make. We have been talking about water hammer in pressurized mainlines, and this is where the biggest water hammer problems could occur. However, water hammer can occur in lateral lines, especially in those lines with automatic drain valves that empty the pipe of water after each irrigation cycle. Note, too, that water in lines in hilly areas could drain out of the lower sprinkler heads unless a head with a check valve is used or a check valve is placed in the lateral line to prevent drainage from occurring (see Figure 13.2). When the automatic circuit valve opens and water comes rushing into the empty lateral pipes, air in the line is compressed and blown out of the sprinkler heads. The heads help to act as a relief valve for the air and water surges in the lateral lines. Surge pressure does occur, though, and can be damaging to lateral systems that use the automatic drain valves. An alternative to draining the line after each cycle is to use manual drain valves, which can drain the lateral and pressurized mainlines in preparation for freezing weather.

# 14

# Winterizing the Irrigation System

## Introduction

PVC pipe is used throughout the irrigation industry, but if water freezes inside it, the pipe will crack. In areas where freezes occur at a 6-in (152-mm) or greater depth, provisions must be made to prepare the irrigation system for winter. This can be done by either blowing the water out of the irrigation lines or emptying the pipe line with drain valves placed at low points.

## Using an Air Compressor

Where freezes exceed 1 ft (0.3 m) in depth, it is desirable to blow all the water out of the irrigation system with an air compressor. Connect the air compressor to the mainline and open each circuit valve to empty the mainline and lateral lines. You can use the controller to open each valve, or you can do it manually. When you are making provisions for this end-of-the-year job, remember that large turf heads, like some of the golf course heads, need more pressure to blow the water out of the lines than do the smaller spray and rotary heads. Now here are some "don'ts" that will protect both the maintenance people and the irrigation system:

■ Don't exceed 80 psi (5.62 kg/cin2) of pressure for residential and commercial systems where

the heads run on less than 80 psi (5.62 kg/cm2) of water pressure.

■ Don't stand over the heads and valves when air is being pumped into the irrigation system. A malfunction could occur that would send an irrigation system component sky high and nearly into orbit.

■ Don't disassemble any equipment while it is under pressure.

## Using Drain Valves

Where freezes are less than 1 ft (0.3 m) in depth, it is sufficient to place drain valves at low points in the main and lateral lines to drain water. The two types of drain valves used are the automatic drain valve and the manual valve.

The automatic drain valve, shown in Figure 14.1 and Table 14.1, is a small appendage that is attached to low points on the lateral lines. When the line is pressurized, the valve closes. When the pressure is shut off or when a circuit has completed its watering cycle and the circuit valve closes, the automatic drain valve opens and drains the line (see Figure 14.2). It is best to build a gravel pit (also called a sump) 1 ft3 (0.3 m3) or larger in size around the automatic drain to collect the line water and prevent back-siphoning, or flow of water back into the pipe system. The size of the sump should be based on the volume of water in the pipes to be drained. All sumps should be lined with filter fabric to keep debris from moving into the sump. Sucking dirty water back into the pipe through the drain valve could bring grit and debris into a clean water system and ultimately cause sprinkler heads to fail. The gravel pit will at least keep the water relatively clean. Some automatic drain valves have a built-in filtering system to clean any water that may be pulled back into the pipe.

## TABLE 14.1 **Model 290–02 Automatic Drain Valve**

### Features

- Plastic body
- Protects sprinklers and pipes in freezing climates
- Valve drains pipe system at the end of each cycle
- May be installed horizontally or vertically
- Corrosion-resistant construction
- Flexible ethylene/propylene sealing washer lets piping system drain when pressure drops below 3 psi; is not position sensitive
- 0.5-in male pipe thread

### Specifications

- 0.5-in male threaded inlet
- Average opening pressure is 3 psi
- Average closing pressure is 5 psi

FIGURE 14. 1 Automatic drain valve.

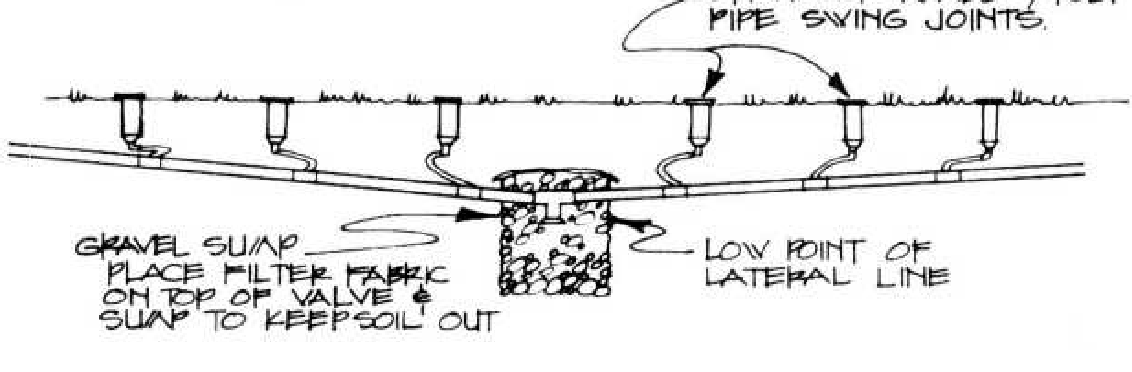


FIGURE 14.2 Automatic drain at circuit low point.

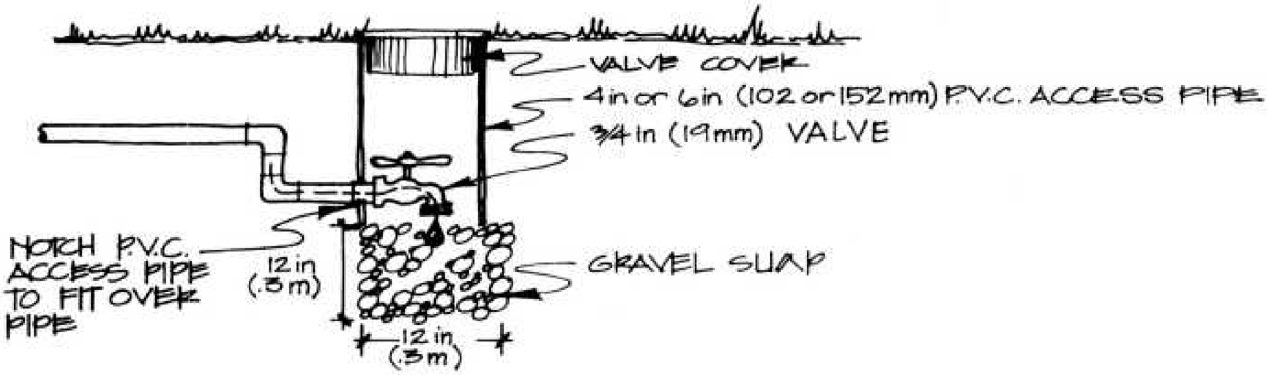


FIGURE 14.3 Manual valve-winterizing system.

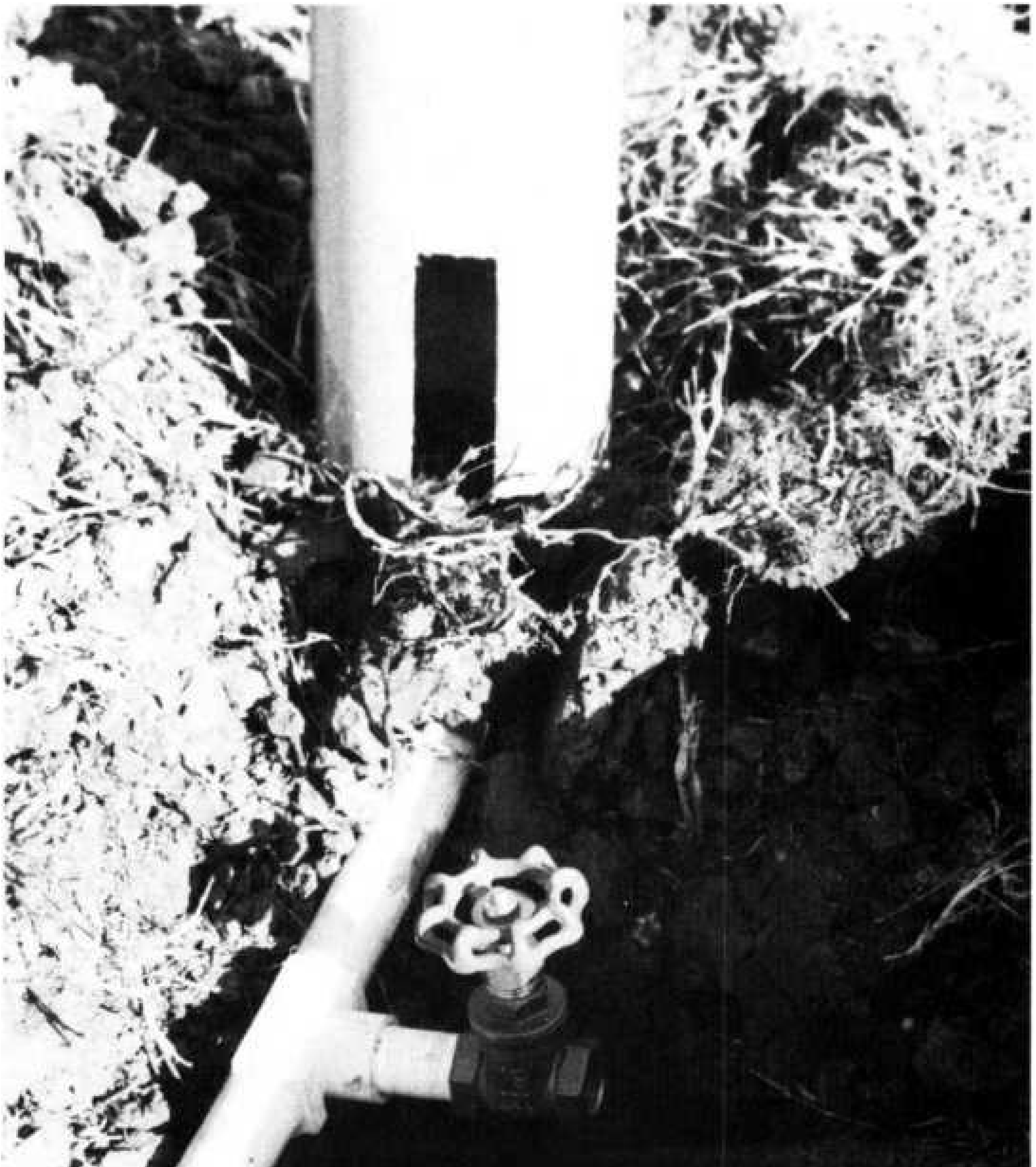


FIGURE 14.4 Gate valve and notched valve box.

Those who do not like to use automatic drain valves say they can get clogged, which could cause pipes to be full of water when the freezing season begins. Some experts also believe that water hammer can have a negative effect on the pipes and fittings when a drain valve empties the pipes after each watering cycle.

The alternative to the automatic drain valve is the manual drain valve, as illustrated in Figures 14.3 and 14.4. This valve is placed at the low point of each circuit and of the mainline. At the end of the irrigation season, if your climate is such that irrigation is not needed year-round, maintenance people will reach down into the valve box and open each valve to drain the lines. It is best to use a valve that has a rubber or plastic seat that will ensure a tight seal, such as an angle or globe valve. Some contractors like to use a ball valve. A gate valve is often used, but these develop leaks over time. A gate valve stops the flow of water by means of two flat surfaces that come together to form a seal (as shown in Figure 14.5). With frequent use, these hard, flat surfaces, which are usually made of brass, will wear and begin to leak.

Like the automatic drain valve, the manual drain valve empties into a gravel sump. It is necessary to

provide a valve box, as shown in Figure 14.6, for access to this valve. By contrast, the automatic drain valves are buried and forgotten. There is no ready access to them except through digging. Let us review the winterizing process step by step to ensure comprehension.

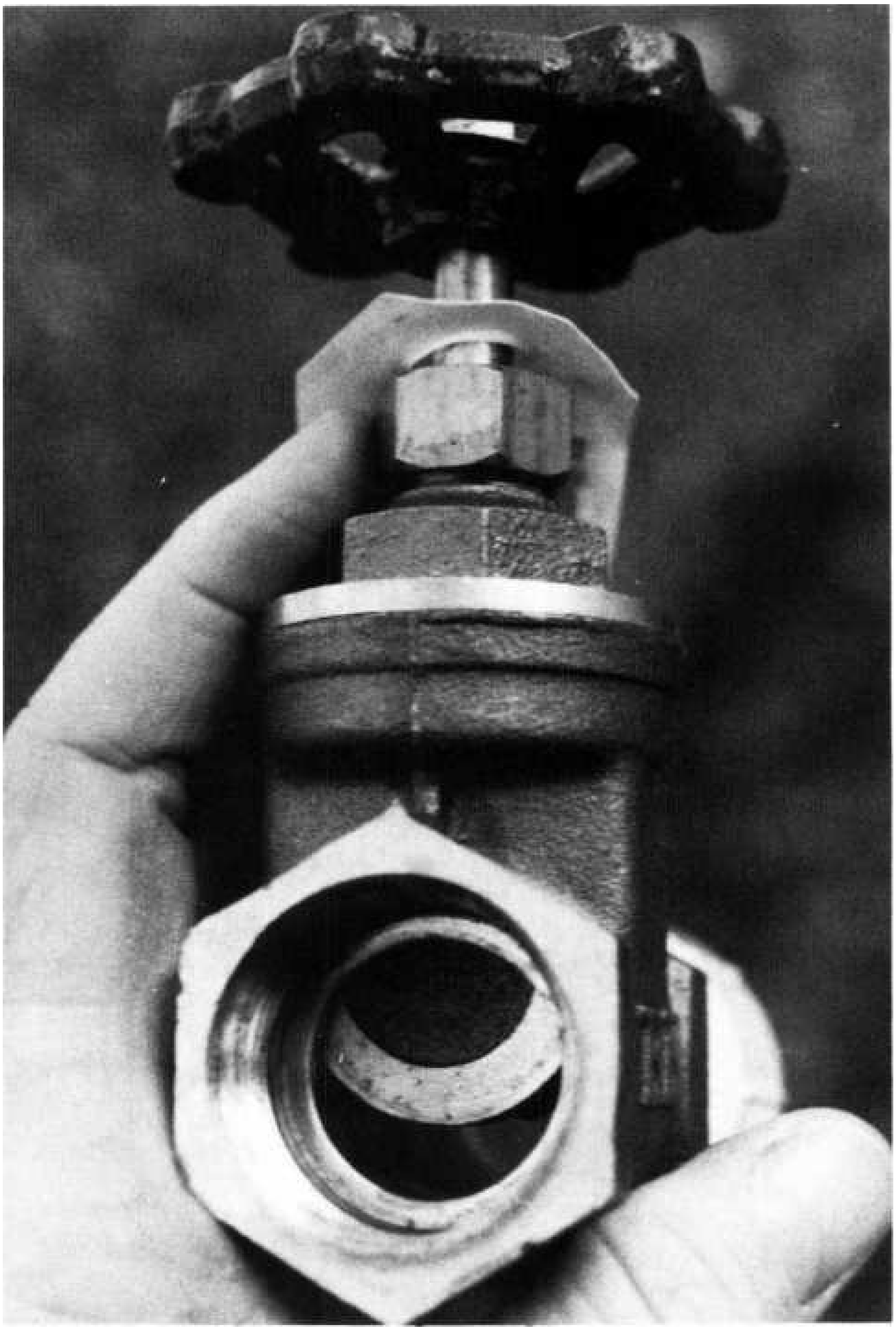


FIGURE 14.5 Gate valve.

1. Shut off the main water supply valve to the irrigation system.

2. Operate the controller to take the pressure off the mainline and each lateral circuit.

3. Blow the water out of the irrigation system. This is the preferred method when frost or freeze depth is at 1 ft (0.3 m) or deeper.

4. For freeze depths of less than 1 ft (0.3 m), open manual drain valves at each

circuit's low point and at the mainline's low point.

5. If you are winterizing a hydraulic irrigation system, you must also close and disconnect the potable water supply line to the V4-in (6-mm) signal control tubing and let the tubing drain. Signal control tubing made of polyethylene will expand slightly without injury if water freezes inside it. You can also use PVC control tubing, which will withstand the gnawing of ground rodents like gophers and moles if they are a problem. However, water that freezes in PVC control tubing will crack it.

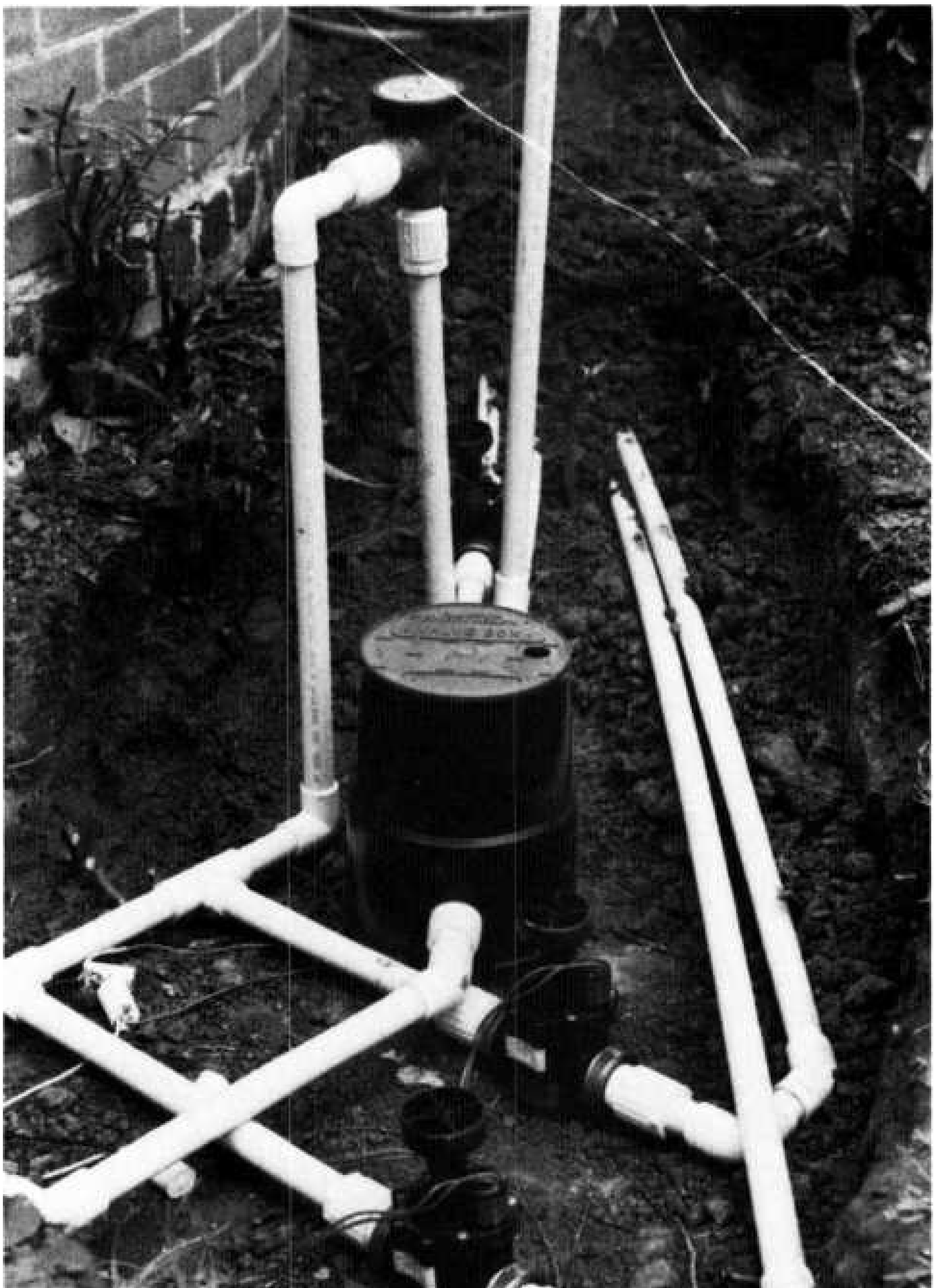


FIGURE 14.6 Valve box and valves.

# 15

# Controllers

## Controller Function

A controller is the brain of the irrigation system. It tells the valves when to come on and for how long so that the correct amount of watering can be carried out. Thinking of it in another way, the controller takes the place of the person who has to water a lawn or a shrub bed by hand. That person has to make a decision as to when there is enough water on an area and then move the hose. The controller does the same thing. You set the duration of time you want to water your areas and then schedule which areas get watered when. The controller takes this watering schedule and carries out your commands. To implement your watering schedule, the controller sends signals to the valves of each circuit. When a valve receives the signal, it slowly opens and allows water from the pressurized mainline to flow into the circuit and through the irrigation heads. When the duration of time you scheduled for a particular circuit has been expended, the controller sends another signal, and the valve slowly closes.

## Controller Features

There are many types of controllers and a large array of features from which to select. Usually, the more expensive a controller is, the more versatile it will be in meeting your irrigation needs.

### Controller Stations

A station within a controller is usually linked to one valve circuit or zone. If you have six circuits or zones, you will usually use a six-station controller. The station controls when and how long the watering at the valve circuit is carried out.

Although one station usually controls one valve, certain controllers could open two or more circuit valves if they were wired to do so and had the voltage capacity.

### Station Programs

A program is a set of watering instructions or a watering schedule for stations that will operate on the same days. When you program your controller, you are setting the days you want your stations to come on, the time of day you want to begin watering, and the duration of time you want to water. Some controllers have more than one program, which allows for more flexible watering. Because shrubs have more extensive root systems than grass, shrubs usually do not need to be watered as often. If a controller has dual programming, which is the same thing as two programs, the lawn can be watered every day on one program and the shrubs every other day on the second program. A single-program controller does not have this capability. With a single-program controller, you could water the grass circuits for 15 minutes each day of the week and water the shrubs for only 5 minutes, but watering would occur every day. This would apply less water to the shrubs, but you would also be encouraging roots to gather near the surface of the soil. You can water different stations on different days only if your controller has two or more programs.

When a controller implements a given program, it goes through the entire program before stopping or repeating the program. A typical program might start at 4 A.M, when the water pressure in the city main is good and strong. The controller will signal the various stations to come on, one after another. Each station will water for the amount of time you have specified.

If you have two or more programs and some stations are set for different days, when a program for watering turf is cycling, it will skip over those stations. How would you use a controller that had three independent programs? You could water your lawn every day on program A, water your shrubs every other day on program B, and run your outdoor lighting system or pool filter on program C.

The ultimate in programming flexibility is for each station on a controller to have its own independent program. This feature is called independent individual station programming.

### Start Times per Station per Day

Some controllers have just a few start times, and some have 45 or more start times per station in a 24-hour period. When we talk about start times, we are simply talking about how many times a controller cycle will signal its stations to water each day. If a controller has 11 start times, the stations can come on 11 times a day, if that is what you want.

Multiple start. times are good when you are establishing a newly seeded lawn or when you have just planted annuals. In these cases, you may want your stations for the lawn or annuals to come on three or four times a day to keep the seeds and plants moist. Multiple start times are also good when you have clay soils with very slow permeability rates. In this case, you may want to set your program to water the lawn circuits for 8 minutes and then repeat the same watering time in an hour to give the water time to soak into the dense clay soils. This prevents water runoff, water waste, and erosion. The way this multiple-start-time application works is that the lawn program cycles through each lawn station and waters the lawn circuits,

and then the controller turns off. In an hour the program cycles through each lawn station again. For most irrigation systems, you will need only one or two start times for your watering needs.

### Watering Cycle

Some controllers will water for 7 days and then repeat the cycle. This means that you have 7 days in which to schedule your watering instructions, and then the cycle will repeat your watering instructions or schedule. With a 7-day watering cycle, you can water every day but not every other day or every 3 days. A 7-day watering cycle is not very flexible because most numbers are not precisely divisible by 7.

Some controllers have 14-day or 15-day watering cycles. Both of these are more flexible than the 7-day cycle. With the 14-day cycle, you can water every day or every other day. With the 15-day cycle, you can water every third day or every fifth day. When you do an irrigation design, first decide upon your geographic area and select your heads and circuits, and then select the controller whose program capabilities and watering cycle fits your needs. Remember, the more days there are in the watering cycle, the more options for watering frequency you will have.

### Manual Control Switch

Most controllers have a switch that will allow you to interrupt the automatic cycling and give you manual control over the watering. On some controllers there is a manual switch for each station, and on other controllers the manual switch will give you control over all of the stations.

### System On/Off Switch

Almost all controllers have a switch that enables you to turn a controller off when you are doing repairs, when it starts to rain, and so on.

### Station Run Times

Controllers usually have the ability to run their stations from 1 to 60 minutes at a time. Some controllers have one or two stations that can be converted from I to 60 minutes to 0.5 to 18 hours of run time if you need to use those stations for drip irrigation, night lighting, or what have you. The most flexible controllers allow you to run each station in minutes or hours, depending on your needs.

### Pump/Master Valve Circuit

Controllers can be wired so that when they activate a station to water, they simultaneously activate a pump to come on or a master valve to open. Recall that a master valve is located in front of all your circuit valves and opens anytime a circuit valve is signaled.

I recently saw the need for an automatic master valve on a large irrigation system for a rose garden. Sometime late on a Friday night, a fitting came apart on the pressure mainline located between the water meter and the circuit valves. Water flowed freely out of a 1%-in (38-mm) line for over 12 hours before the problem was noticed and a manual valve for the entire system was finally closed. The automatic master valve would have prevented some of the water loss, depending on when the irrigation system was programmed to come on.

### Program Retention

When there is a power outage, some controllers can retain their program without batteries, and some controllers have a battery system that will save the program for a few hours. How long a battery will save a program depends on what kind of battery you are using and whether or not the battery is weak. Controllers use alkaline and nicad batteries. The nicad battery is best because it can be recharged by the controller. Remember, a battery only retains a program if the electrical service is down. The battery does not run the irrigation system. If the battery fails, most controllers have a "fail-safe" program built in and will reset to a specific program.

### Seasonal Adjustment Switch

This is also called a system water-budgeting switch. Some controllers have this valuable option, which allows you to increase or decrease the amount of water you have programmed for your circuits by a certain percentage (typically 0%-200%). All controller stations can have their watering time increased or decreased with only one entry. This helps you to conserve when less water is needed, like during cooler, wet weather. During dry cycles or drought periods, you can increase watering amounts, thereby protecting your client's valuable landscape. In most areas, irrigation programs need to be changed five to eight times during the watering season because the evapotranspiration rate (EVT) varies so dramatically, especially during spring, summer, and fall. There is usually a good deal of variance in evapotranspiration rates between the seasons, which dictates the need for differences in water application.

### Types of Controllers

There are basically two types of controllers in the irrigation industry: hydraulic and electric. All controllers need electricity to operate. The difference between the hydraulic and the electric controller is the type of signal they send to the valves.

### Hydraulic Controller

The hydraulic controller is connected to the circuit valves by means of small tubing about as big as a drinking straw. Hydraulic systems use normally open valves. Recall that in their normal state, these valves are open and will allow water to flow through them and that they close if water under pressure is applied to the top of the valve diaphragm. When the controller sends water under pressure through the small plastic or polyethylene tubes to the circuit valves, the valves close. When that water pressure in the small signal tubing is turned off, the valve opens, and there is irrigation. Figure 15.1 illustrates the hydraulic tubing being attached to a sprinkler head that has an automatic valve built into the bottom of the sprinkler body. The water that is sent through the %-in (6-mm) tubing is usually potable and has been filtered to keep particles from clogging the tubing. Water used for irrigating with hydraulic systems can be dirty water, which means water from a pond, lake, or well or treated effluent water.

Hydraulically actuated irrigation systems are not nearly as common as electrical systems, but they have some real advantages. In lightning-prone areas, an electrical irrigation system will have problems, whereas a hydraulic system will be largely unaffected. Some contractors say that hydraulic irrigation systems are easier to service and understand than electrical irrigation systems. Another advantage of hydraulic systems is that when the control or signal tubing is cut, pressure is taken off the valve, and water flows into the circuit. As we explained previously, if this happens, it is easy to notice where the problem is-the irrigation for that circuit comes on. If 'a signal wire failed in an electrical system, the valve would not come on, and you would probably not notice the problem until grass, shrubs, and trees started to brown. For this reason, many turf managers for golf courses and parks prefer a hydraulic irrigation system.

FIGURE 15. 1 Hydraulic tubing being connected to a valvein-head sprinkler.

**Electric Controller**

The electric controller is connected to the circuit valves by small wires. The controller sends electric charges to a solenoid attached to the valve. When the solenoid receives the electrical charge, it becomes magnetized and lifts a small plunger which opens the valve, thus allowing water to flow through to the valve circuit. If an electrical line is cut, the valve becomes lifeless. Most irrigation systems are electrical systems.

Types of electrical controllers. There are basically three types of electrical controllers on the market: electromechanical controllers, solid-state controllers, and hybrid controllers, which are both electromechanical and solid state. Each of these controllers sends an electrical impulse to a solenoid attached to a valve to operate the valve circuits.

Electromechanical Controller. This was the first type of controller to be developed, and it is all mechanical in its operation. That is to say, it is constructed of a motor, wheels, dials, gears, and pins (see Figure 15.2). The electromechanical controller is user-friendly. People can easily understand how to operate and program it. When there is an interruption of power, this controller does not lose its program. One of the drawbacks of an electromechanical controller is that it is not very accurate. If you set a station to run for 15 minutes, it might run for 11 or 19 minutes instead.

Solid-State Controller. Being of solid state design, this type of controller has a digital readout screen and buttons on a keyboard similar to that of many handheld calculators. It has no moving parts except the buttons. If there is an interruption of power, a battery will retain the program for a period of 3 to 9 hours. One of the advantages of solid-state controllers is that

they are accurate to within a minute. Solid-state controllers are thought to be more difficult to operate than the mechanical controllers, but if you follow directions they are easy to operate (see Figure 15.3).

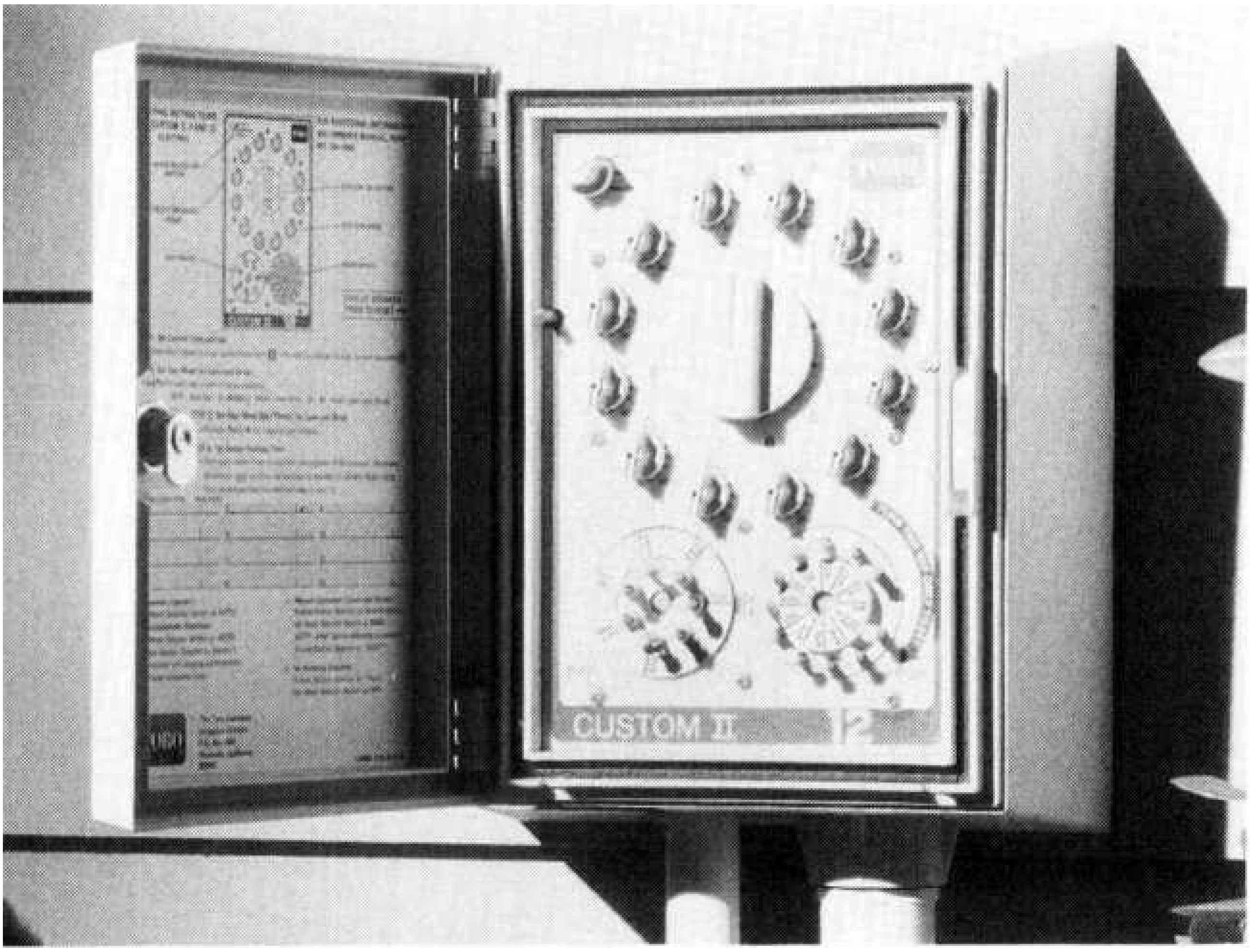


FIGURE 15.2 Electromechanical controller. (Source: The Toro Company. Used with permission.)

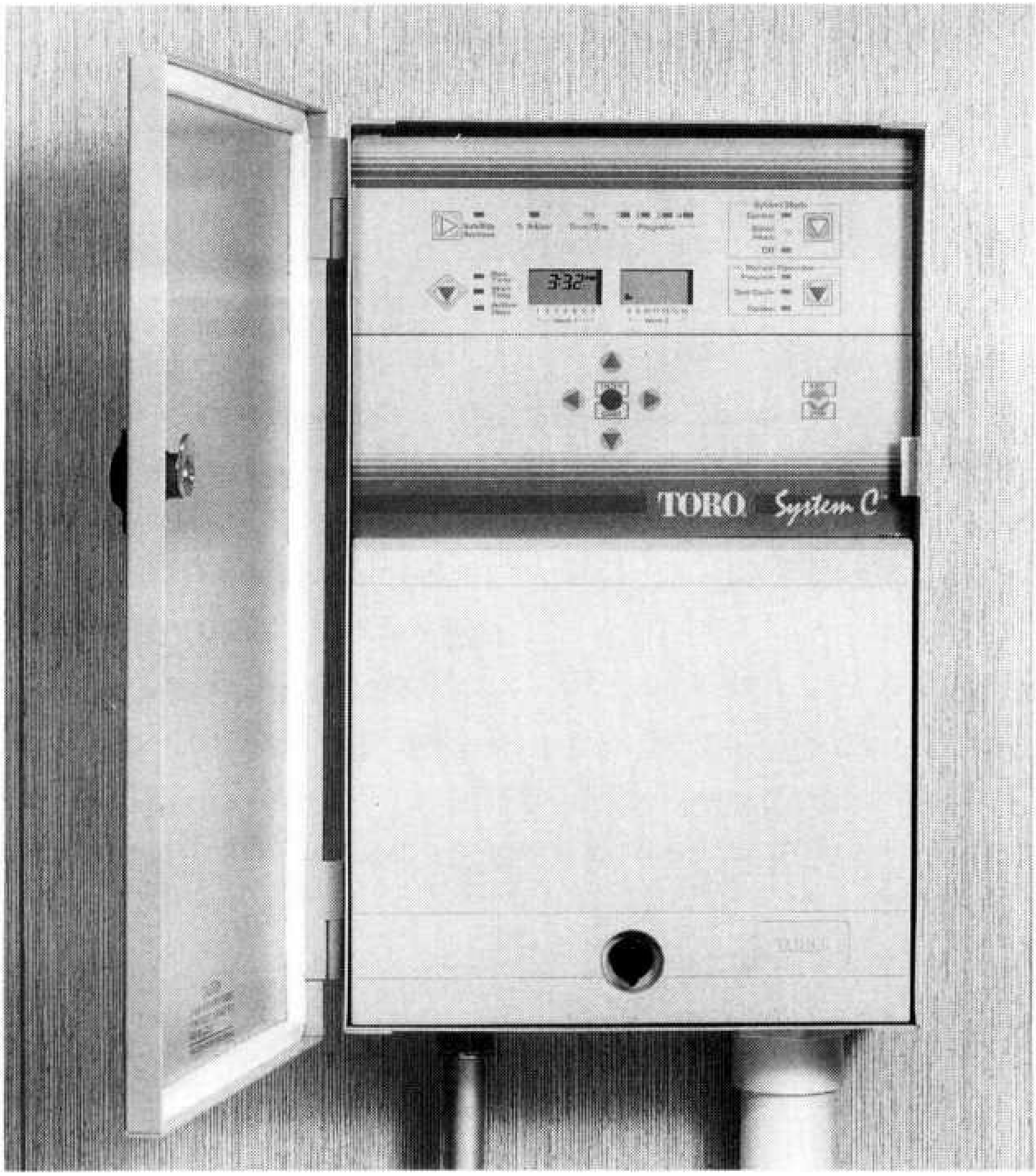


FIGURE 15.3 Solid-state controller. (Source: The Toro Company. Used with permission.)

Hybrid Controller. This type of controller, shown in Figure 15.4, has both solid-state circuitry and mechanical dials that help it to be more user-friendly. It is called a hybrid because it is a blend of electromechan ical and solid state design. "Hybrid" can also mean a solid-state clock with what appears to be an electromechanical interface for ease of use, but the controller is really all solid state.

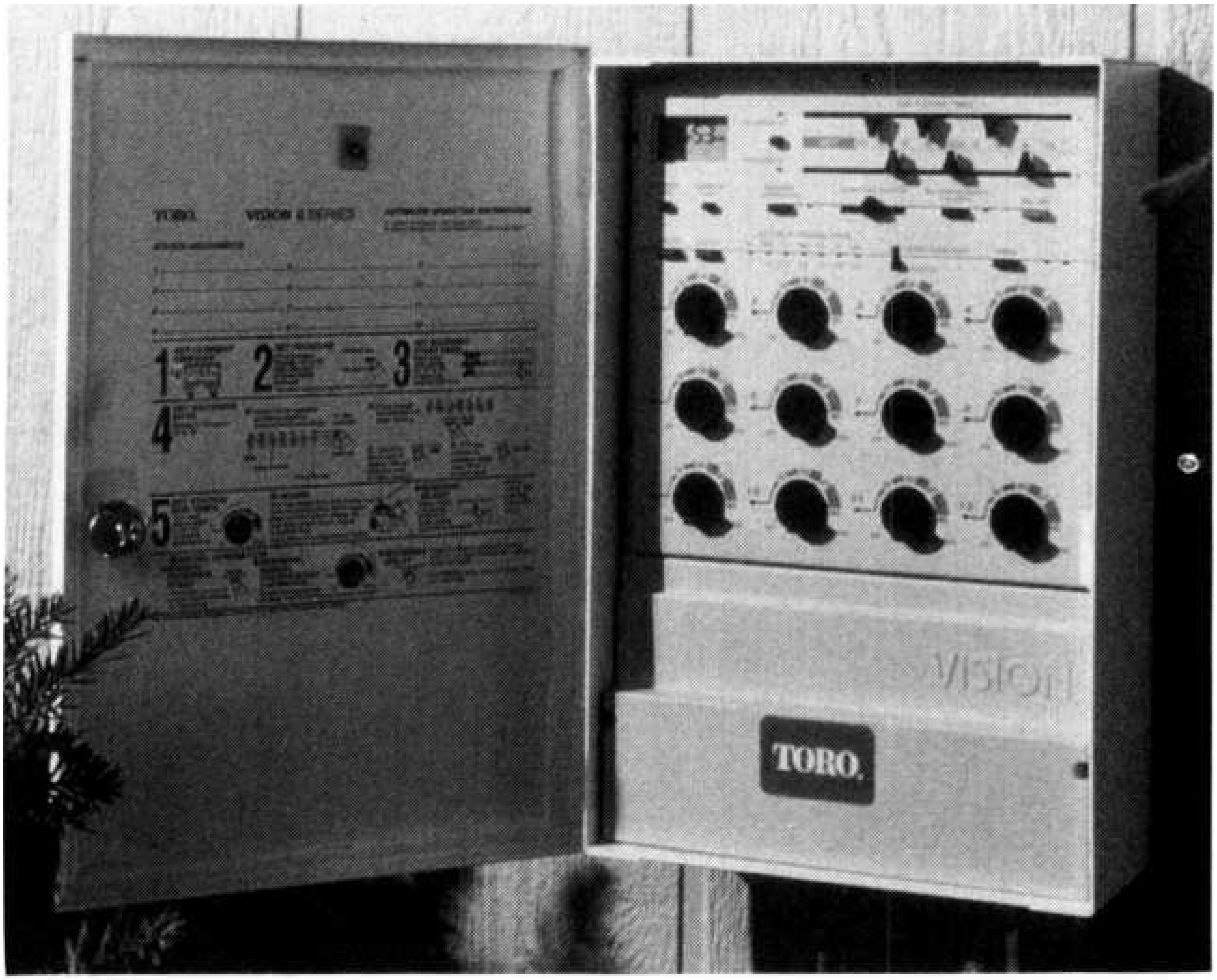


FIGURE 15.4 Hybrid controller. (Source: The Toro Company. Used with permission.)

## Water Conservation and Controllers

Our discussion of controllers thus far has dealt with the many ways they can help you apply water with precision. Although controllers can reduce the labor of watering, they can also result in overwatering if their schedules are not periodically adjusted to keep up with climatic changes throughout the growing season. Controllers of residential automatic irrigation systems can use up to 75% more water than hose-and-sprinkler systems, according to study done by Joe Henggeler in 1989 for the Texas Agricultural Extension Service. Irrigation designers and managers will have to become aware of this and work vigorously toward solving the problem. The study was based on residential systems, but the same water conservation concerns apply to commercial and sports turf systems.

Excessive watering often occurred when homeowners irrigated each zone or circuit for the same length of time regardless of different geographic conditions and because they used different heads with different precipitation rates in the same irrigation system. The length of time that different zones are watered is usually affected by the following factors:

- Changes in the climate throughout the growing season (different times of the year require different amounts of water to make up for soil water evaporation and water transpiration from plants)
- Soil permeability rates
- Sun or shade conditions
- Plant types (native trees and shrubs need less water than other plants)
- Flat or sloped areas
- Varying precipitation rates (for example, a zone of rotary heads might have a precipitation rate of 0.3 in [8 mm] per hour, and a zone of spray heads might have a precipitation rate of 1.5 in [38 mm] per hour)

The results indicate that most people (homeowners, in this study) don't know how to properly time their controllers and keep their watering schedules in sync with the climatic changes of the growing season. If systems are set to irrigate for the hottest and driest time of the year (usually July and August in the United States), they might need only 70% of that amount of water in May to prevent plant stress.

Controllers are simply water control tools. Competent management of the systems must occur for responsible watering to be carried out. Competent management demands that those who regularly operate the irrigation systems be knowledgeable about the precipitation rates for each zone, seasonal plant water demands, and figuring water needs for different geographic areas. Practicing water conservation while supplying sufficient water to the landscape will result in a win-win situation.

### Central/Satellite Control Systems

The central/satellite control system (Figure 15.5) features one centrally located controller that tells the satellite controllers when to begin their watering cycles. The satellite controller (see Figure 15.6) can either stand alone in its programming and operating capabilities or can be operated by electrical signals from the central controller. The central controller is basically a start mechanism for the satellite controllers, but it can also cancel all satellite controllers if it starts to rain or there are repairs to be made. Central controllers can be selected to manage a few or hundreds of satellite controllers. Some central controllers can also do water budgeting, where you increase or decrease watering time by selected percentages.

A golf course or large park are ideal places for a central/satellite system. A typical golf course might have 30 satellite controllers and one central controller. The satellites would be located at greens, tees, and along the fairways, whereas the central controller would be located in a maintenance shop or superintendent's office. The central/satellite system allows for labor-saving management of large irrigated areas.

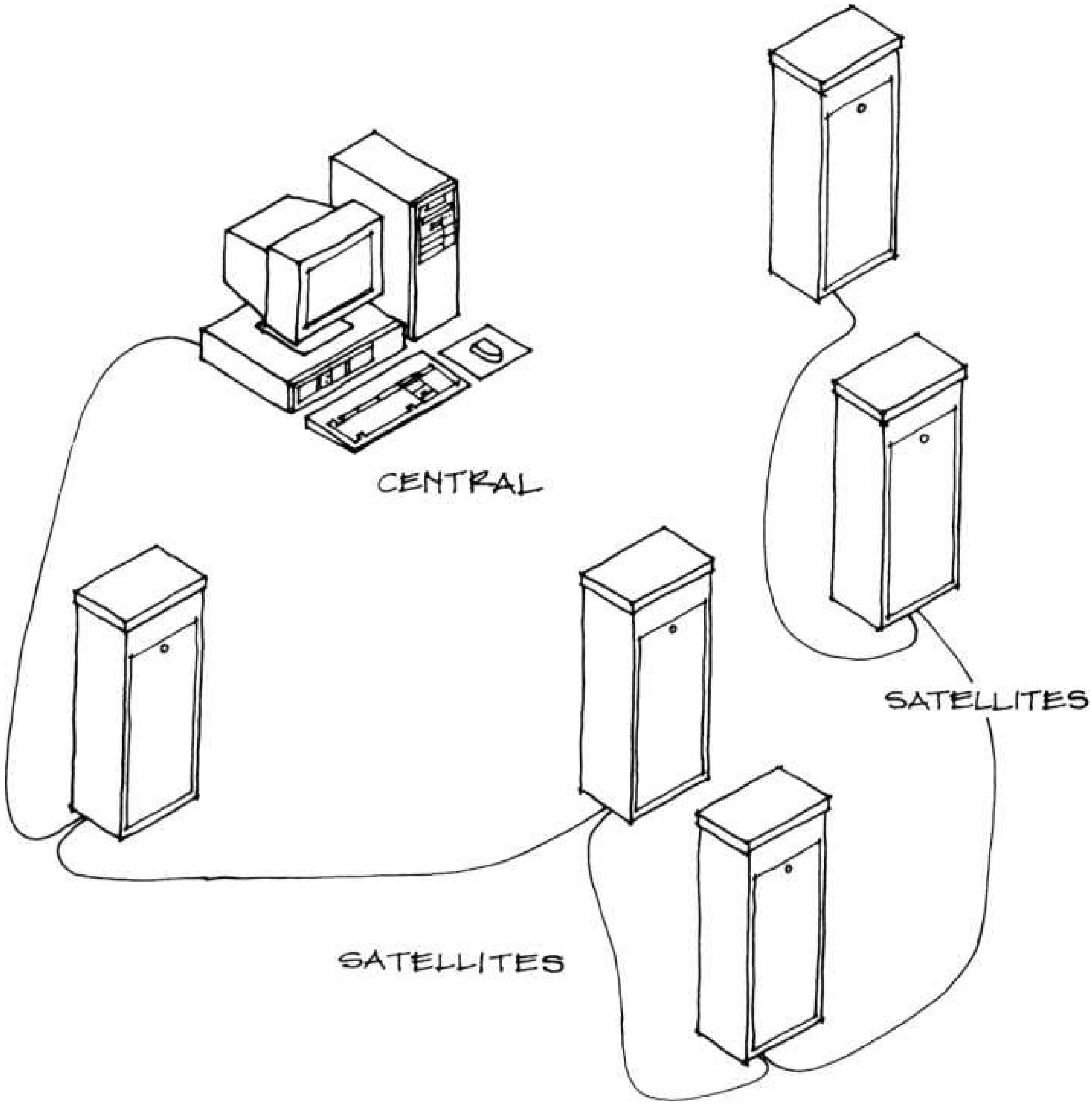


FIGURE 15.5 Central/satellite layout.

FIGURE 15.6 Satellite controller. (Source: The Toro Company. Used with permission.)

## Water Conservation Management Control Systems

A prominent newspaper garden columnist asked me what he could tell his readers about using their irrigation systems in a responsible manner. I suggested that homeowners should know to modify their station run times as the climate changed during the growing season. Additionally, they should also learn to recognize plant stress and irrigate just before it occurs. He responded that all of this was too complicated for the average reader. Nevertheless, responsible irrigation demands this kind of knowledge. Without it, water waste will continue to be a problem.

The irrigation industry has recognized the need for water-conserving irrigation systems. In addition to efforts to disseminate design and programming information, the industry has created incredible tools that save water, electricity (when using pump stations), and labor expenses. The following discussion of features relates to control systems generally used for large sites such as campuses and golf courses and to municipal irrigation systems located on multiple sites.

### Central Computer for Water Conservation Management

Figure 15.7 shows a central computer used for water conservation management. Software and hardware take climatic data and compute daily water needs for irrigated sites. The computer-controlled irrigation management system allows a large irrigated site or multiple sites, in the case of a city parks department, to be watered as conservatively as the irrigation manager desires. Results of using computer-controlled water conservation and management systems include a reduction in water use, reduced electrical costs when using pump stations, reduced labor costs, and more attractive landscapes.

When the city of Boca Raton, Florida, switched to using a computer-managed system, lower water bills and tighter control over their use of water was the result. The central computer, a Toro/Motorola MIR 5000c, displays daily flow rates for use by the irrigation manager. Gallons (liters) of water applied to each zone are read from flow meters that measure the gallons (liters) used at each source of water. The results of managing water use by computer were impressive. Workers no longer had to manually operate irrigation controllers and could instead work on repair tasks.

Managing 140 controllers at 18 sites throughout the city required one person a full day to shut down all of the city's controllers when it was raining. On Mondays, five two-person crews would check systems for blowouts, stuck valves, and broken heads. With the computer-managed irrigation system, a simple command on the computer will shut down all the satellite controllers. Figure 15.8 shows a computer-controlled satellite. Flow control meters at each water source are checked on the computer every morning by the irrigation manager to see if there are abnormal flows indicting stuck valves, blowouts, or broken heads. Crews are then sent out to specific sites for repairs. Because all satellite controllers are radio controlled, one person with a hand-held radio can do the job that once took two people to do. When alarms signal, the computer will even page the irrigation mechanic or manager when that level of control is desired.

FIGURE 15.7 Central computer. (Source: The Toro Company. Used with permission.)

FIGURE 15.8 Computer-controlled satellite.

By managing water with a computer for the 36-hole golf course at Glen Eagles Country Club in Delray Beach, Florida, watering time was reduced from 14 to 11 hours, thereby saving $15,000 in yearly electrical pumping costs. The increased playing time was applauded by many happy golfers. Additionally, the amount of water used was reduced. Figure 15.9 shows radio-operated satellite controllers at Glen Eagles Country Club.

It is projected by irrigation companies that water conservation management systems will pay for them selves in savings of electricity, water, and labor costs in three to five years. In addition to this benefit, better management resulting in more attractive landscapes and the conservation of water will occur.

FIGURE 15.9 Radio-operated satellite controller.

**Flow Meters**

Water can be delivered to a landscape by scheduling a certain amount of irrigation time for each zone (timebased) or by computing the gallons (liters) of water needed per zone based on plant need, soil permeability rates, and climate (flow-based). A flow meter (see Figure 15.10) located at the water source, like a well, lake, or city water main, computes the gallons (liters) flowing from the source. Computation of zone or circuit needs then allows the central computer to turn off the water at the valve when the required number of gallons (liters) for a zone have been applied. The advantage of using a flow meter is precise water application control. A time-based electromechanical controller scheduled to cut off after 15 minutes might actually run for 18 or 20 minutes, thus applying more water than is needed. A solid state controller is more precise with its run times. The advantage of flow-based control is exact water placement for each zone. With a record of the gallons (liters) used for each zone, the irrigation manager can compare water bills to exact flow figures.

FIGURE 15. 10 Flow meter at wellwater source.

Another advantage of using a flow meter is that when the zone cuts on but no water is registered at the central computer, an alarm will register, signaling a stuck or cut-off valve. Alarms signal as well when flows are above or below the amount scheduled. A higher flow than what is scheduled could indicate a broken head or a pipe blowout. The computer can shut the valve off at a selected amount of gallons above the predicted flow to prevent wasted water when a blowout occurs. Lower flows indicate stuck heads or even low pressure to the area. You don't have to wait for brown turf or dead trees and shrubs to know the valve is not working.

### Weather Station

Although a facility like the one depicted in Figure 15.11 might sound elaborate, a weather station will provide the central computer at a golf course, for example, with wind, humidity, temperature, and precipitation data that allow software to compute daily EVT (evapotranspiration) rates. Recall that EVT is the amount of water evaporating from the soil and transpiring from the plant. See Tables 15.1A and 15.1B for a 50-year average of monthly rainfall, EVT, and the difference between the two for the Fort Lauderdale area. After receiving climatic data, the central computer then signals (downloads) water needs, which are modified daily, to the satellite controllers by radio or by wire if hardwired to the central computer like at a golf course. The central controller will increase and decrease precipitation amounts as plant water needs change with climatic conditions.

FIGURE 15. 11 Weather station.

**Rainbuckets**

These sophisticated gauges measure precise amounts of rainfall at specific sites. When rainfall meets the amount of water scheduled to be irrigated that day, the rainbucket relays this information to the satellite controller, which then shuts down all irrigation (see Figure 15.12). When rainfall is less than the day's complete irrigation needs, the rainbucket relays precipitation amounts to the satellite controller, which will reduce the amount of water to be irrigated accordingly. The irrigation manager sets the conditions, or instructions, to the smart satellite controller in order to reduce watering when it rains. Conditions set by the irrigation manager at the central computer might tell the satellite controller to reduce watering by 25% when the rainbucket measures 25% of the daily water need and to reduce watering by 50% when 50% of the water needed is supplied by rainfall. All reductions or interruptions in the regular irrigation schedule are sent to the central computer for the irrigation manager's information. While I was observing such a system in Boca Raton, Florida, a morning rain in certain parts of the city provided 58% of the daily water requirement, and the system provided the remaining 42% where needed. In other parts of the city where no rain was recorded, the full amount of water was irrigated. The Boca Raton weather station and rainbuckets at each site have reduced water used in irrigation by more than 40%. This was well received by the local government and concerned citizens as well.

### Radio-Operated Satellite Controllers

An operator can turn satellite controllers on and off with a hand-held radio. This saves time and reduces the number of people needed to check stations or water specific zones. Existing field satellites can be converted to respond to radio control or new satellite controllers with this feature built in can be bought.

### Pump Station Flow Management

When using a pump station to provide water, less electricity will be used and the life of the pumps will be increased if the pumps can be scheduled to run continuously at the same flow, rather than starting and stopping throughout the day and having varying flow rates. Computer management can schedule irrigation programs to maximize the efficiency of the pump station and the watering window, which is the time you have available for watering. The results of computer management of pump stations include saving electrical power consumption, increasing pump life, and reducing the amount of water used.

### Electrical Storm Identification Device

Short-range thunderstorm sensors will detect lightning, activate warnings to landscape users like golfers or ball players, and automatically isolate irrigation equipment. The device can reduce deaths and injuries and protect equipment from electrical damage due to lightning strikes. Figure 15.13 shows a sensor on top of a lifeguard shack along a section of beach in Delray Beach, Florida. Able to accurately detect thunder storms within a 25-mile (40-km) radius, the device can shut power off to all satellite controllers and open a gap in the system to prevent damaging power surges.

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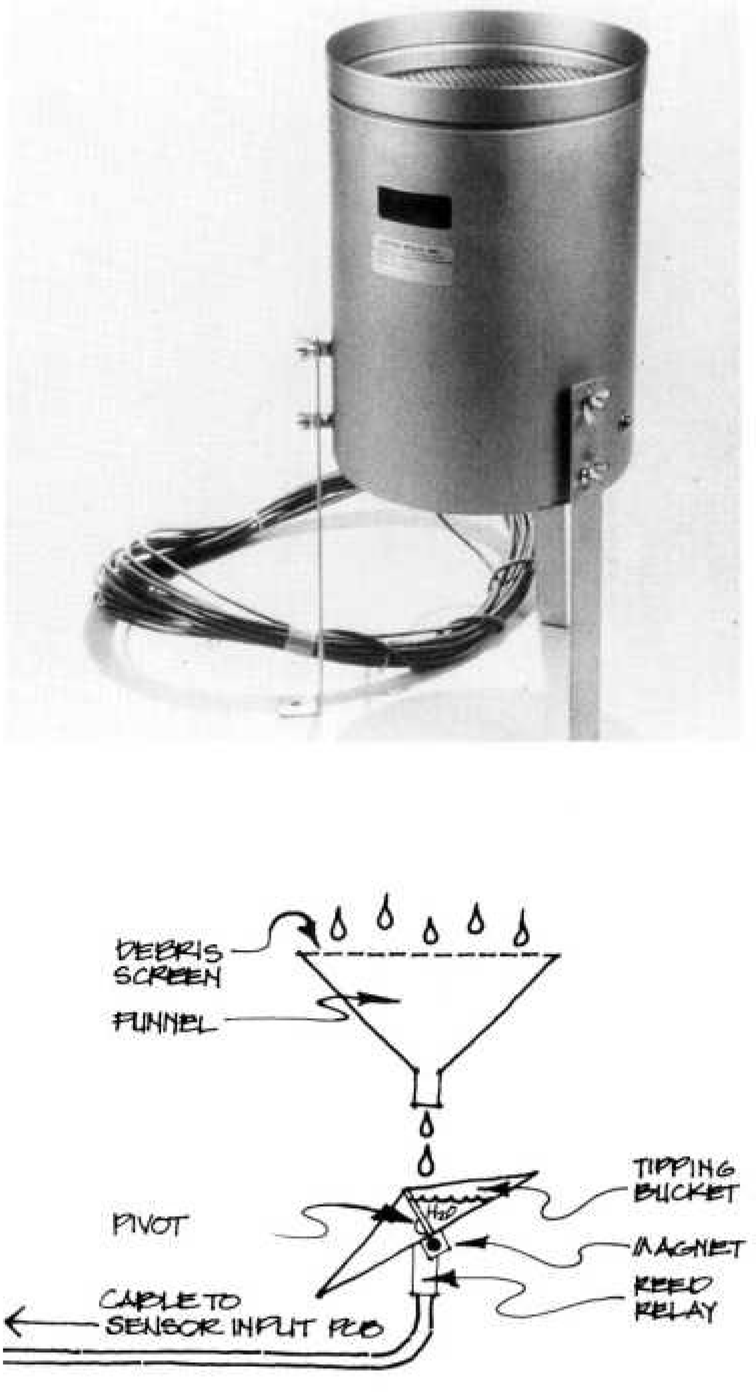


FIGURE 15. 12 Tipping rain bucket. (Source: The Toro Company. Used with permission.)

FIGURE 15.13 Electrical storm identification device.

## Conclusion

To conclude this chapter, let us say that there is a lot of information to know in order to fully understand how to work with controllers. Gradually, as you work with controllers, your knowledge about them will grow. Remember, be sure to design your irrigation system and know how much moisture your landscape will require before you select a controller. Once you have defined your watering schedule, then select the controller that works best for you.

# 16

# Backflow Prevention

## Backflow of Water

An irrigation system needs a device that will keep water from flowing back into the potable water supply. These devices are called backflow preventers, and they prevent the reverse flow of water.

## How Backflow Occurs

Why would water ever backflow into the potable water system (or city main)? Let us look at one exemplary instance where this could occur. If a fire truck connects to the city main, near to where your irrigation system is connected, and begins spraying water or flushing the city main, the pressure in the main might be reduced to the point of creating a vacuum, or 0 psi (kg/cm2). Without a backflow preventer, all of the water in the irrigation system-including any water puddled around irrigation heads-could be sucked into the city main. The harm comes from the fact that there may be grit and other debris in your irrigation system; even worse, the water that has puddled around your irrigation 'heads might be contaminated with lawn fertilizer, weed-killing chemicals, or bacteria from animal feces. Now wouldn't it be great to get a glass of that out of your kitchen sink faucet? That could happen to you or a neighbor when a Backflow into the city main occurs.

There are other ways water can be made to backflow through an irrigation system into the potable water supply, and it may be of interest to you to do further study on the subject. Manufacturers of backflow preventers generously supply educational material about backflow prevention.

## Backflow Prevention Devices

The types of backflow preventers used for irrigation systems include the following devices.

### Atmospheric Vacuum Breaker (AVB)

This device is installed between the circuit valve and the sprinklers (see Figures 16.1 and 16.2). When the circuit is turned on, water pushes up a small float in the AVB and flows to the irrigation heads. When the circuit valve closes, the flow of water stops, and the float falls to seal the line to the valve and potable water supply. Should any back-siphoning of water occur, for example, because of a fire truck using the water in the city main, the water in the circuit could not flow back into the city main because of the rubberized float that seals the circuit line. The AVB must be installed 12 in (305 mm) above the highest head so that water from the circuit does not drain by gravity flow back to the AVB and out the atmospheric vent, causing a large puddle of water around the backflow preventer. One AVB is needed per circuit.

### Pressure Vacuum Breaker (PVB)

This backflow preventer is installed after the water meter and before any valves (as shown in Figure 16.3). It is an economical backflow preventer in that you only need one for an entire project, as opposed to one AVB per circuit. There are one or two check valves (depending on what you buy) in the PVB that prevent a reverse flow of water. The PVB must be installed 12 in (305 mm) above the highest sprinkler head so that water does not flow back by gravity and come out the atmospheric vent on top of the device, causing a puddle to form around it. The purpose of the shutoff valves before and after the PVB is to seal the main and lateral lines when testing the backflow preventer. Many building codes require yearly tests to ensure proper operation of backflow preventers.

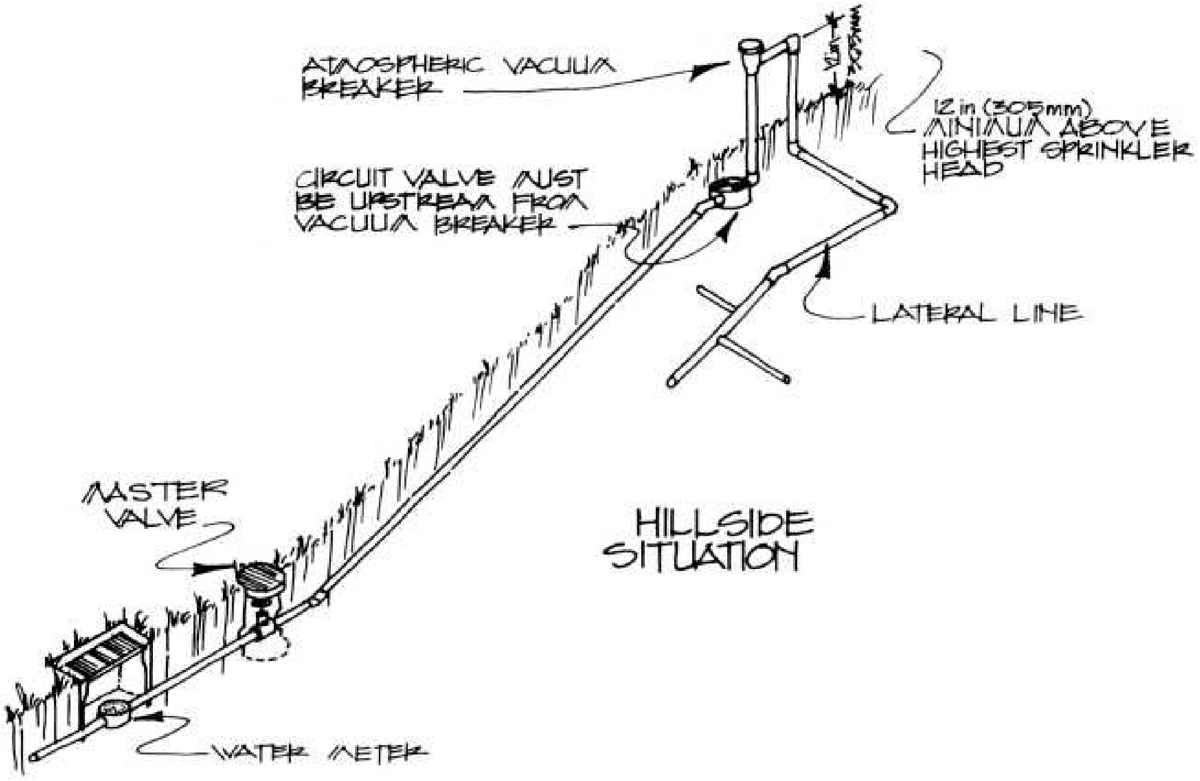


FIGURE 16. 1 Atmospheric vacuum breaker-hillside location.

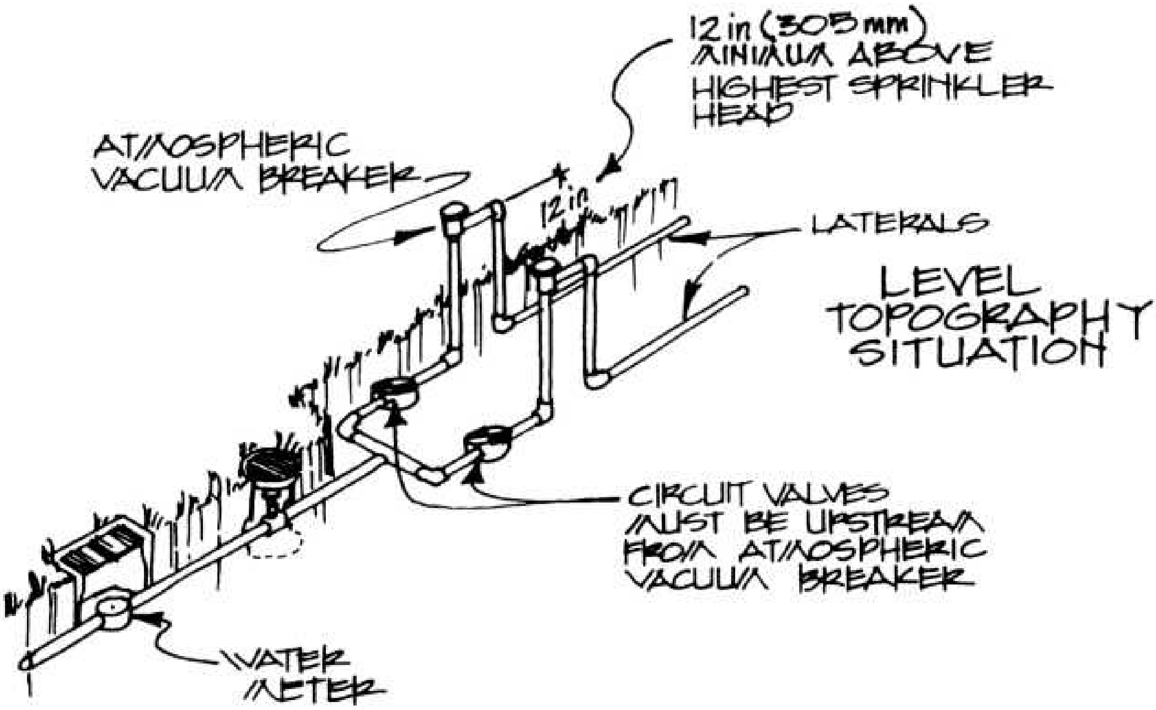


FIGURE 16.2 Atmospheric vacuum breaker-level terrain location.

On a hillside system, as shown in Figure 16.4, where the water meter is at the bottom of the hill, using a PVB device would require running the main pressurized line to the top of the hill and connecting the backflow preventer at that point. All of the sprinkler heads and valves would then be located downhill from the PVB. If you are considering using a PVB on a hillside, make sure you calculate the extra cost of running the mainline pipe to the top of the hill and connecting valve circuits from that point.

,Just as with the AVB, should there be a very low pressure or vacuum in the city main, the PVB check valve will prevent reverse flow or back-siphoning of irrigation system water back into the city main.

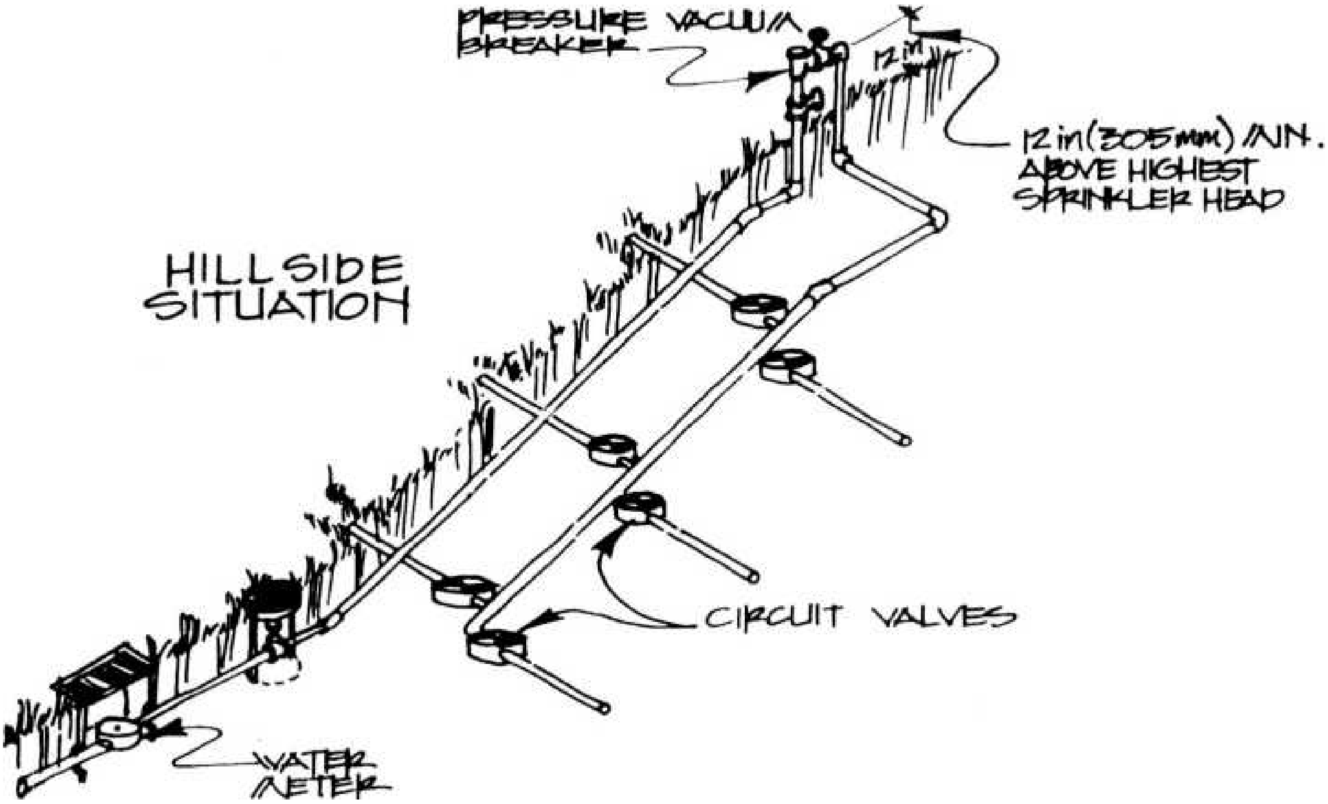


FIGURE 16.4 Pressure vacuum breaker-hillside location.

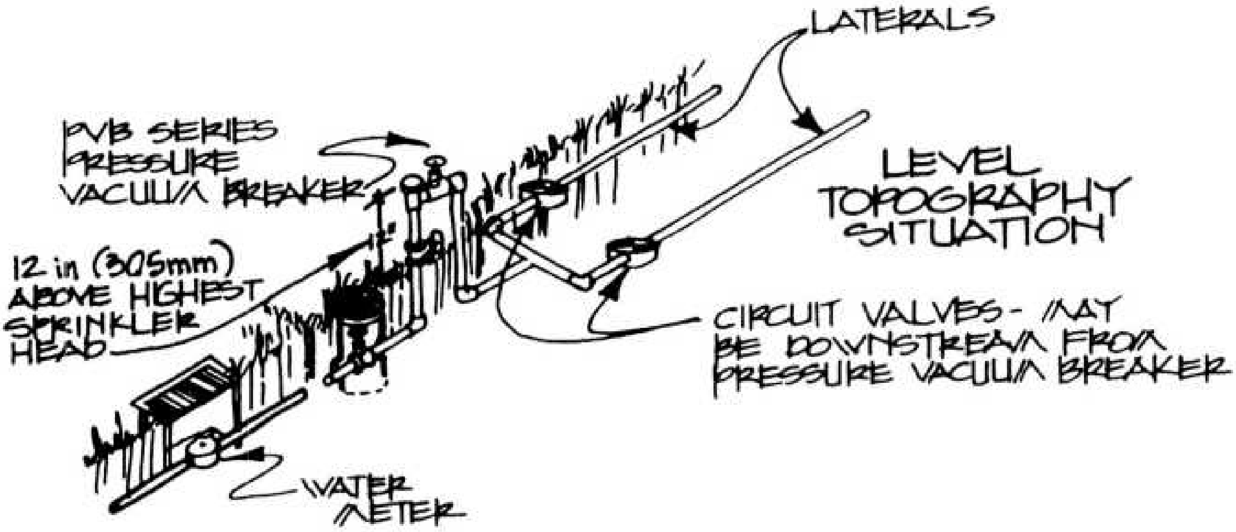


FIGURE 16.3 Pressure vacuum breaker-level terrain location.

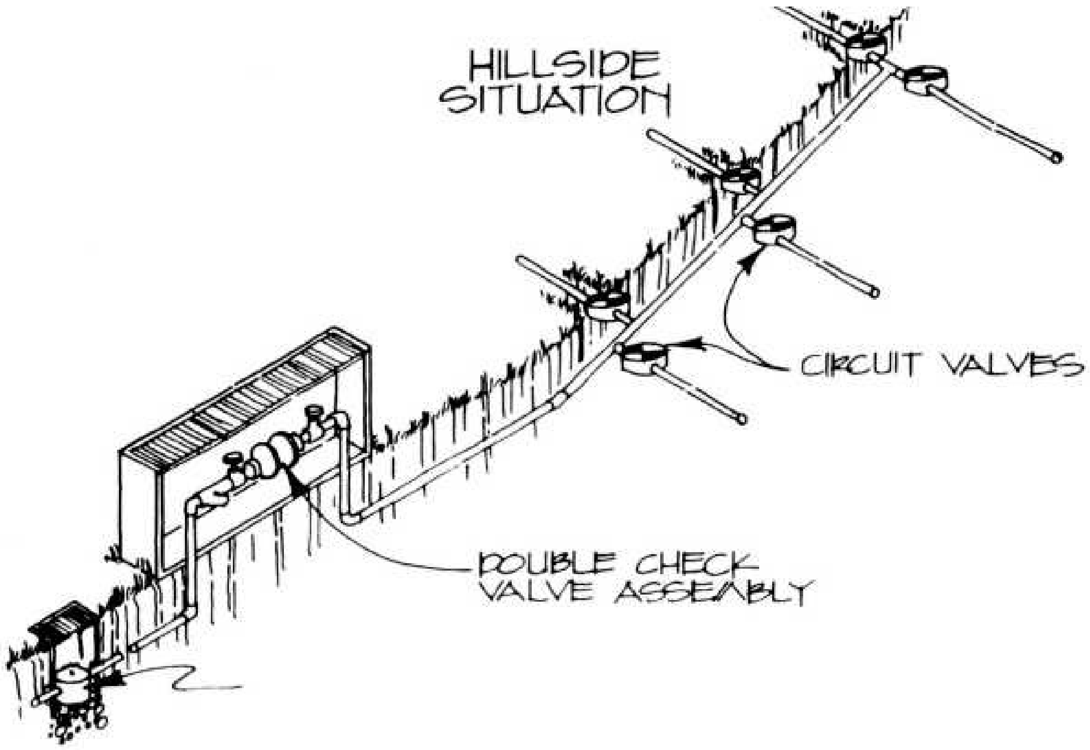


FIGURE 16.5 Double check valve assembly.

### Double Check Valve Assembly

This is a much more sophisticated and expensive backflow preventer than the AVB and PVB. Plumbing codes in many municipalities across the country require the DCVA backflow preventer. The device is usually installed just after the water meter and before any circuit valves (see Figure 16.5). Only one DCVA is needed per irrigation project.

The DCVA has two check valves that will prevent the backflow of water. The purpose of the two check valves is that if one fails because of grit in the valve, for example, then the other check valve will still prevent reverse water flow. The shutoff valves before and after the DCVA are used to seal the irrigation lines when testing the backflow preventer. One additional advantage the DCVA has over the AVB and PVB is that it can be used in a situation where you might have, at times, a greater pressure within the irrigation system than in the city main. This greater pressure (or back pressure) within the irrigation system could push irrigation water and its impurities back into the city main. Back pressure within an irrigation system can be caused by a pump, such as a booster pump or fertilizer injection pump, that may not have a functioning backflow preventer or check valve to prevent reverse waterflow. Another way back pressure is formed is when a large difference in elevation exists that may, when the pressure in the potable water system drops, force a reverse flow of water.

You might ask, why not use the AVB or PVB on a system where you have the possibility of reverse water flow due to back pressure? The answer is that the AVB and PVB are made to seal tightly only when there is a back-siphoning situation, such as when low pressure is created in the city main. The AVB and PVB are not effective in a back-pressure situation.

The DCVA should be installed so that it can be visually inspected and serviced.

**Reduced Pressure Principle Backflow Preventer (RPP)**

This is the most sophisticated and expensive backflow device, and it is used where irrigation water could be very hazardous to human life. An example of such a hazardous situation is when you are irrigating with effluent (treated sewage) water or where toxic chemicals are injected into the irrigation system. The RPP can stop backflow either in a back-siphoning or a backpressure situation.

The RPP has two check valves, two shutoff valves, test cocks, and a relief valve vent. When there is backflow, the RPP vents the water through the relief valve, which is beneath the unit. This audible and visible signal calls attention to a hazardous situation. When the backflow occurs, both shutoff valves should be closed to further ensure that a reverse flow of water into the potable water system does not occur. The RPP should be installed 12 in (305 mm) above grade level (see Figure 16.6).

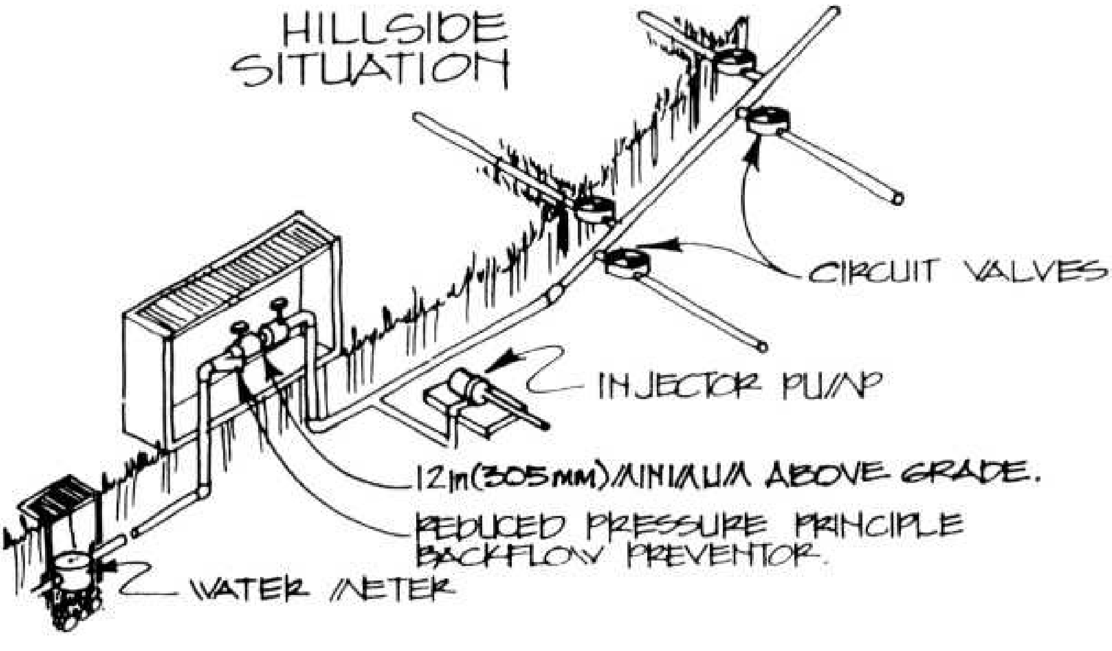


FIGURE 16.6 Reduced pressure principle backflow preventer.

### Hose Connection Vacuum Breaker (HCVB)

This device, shown in Figure 16.7, is a mini-backflow preventer for use with garden hoses. The unit is devised to be effective against back siphonage.

When a vacuum occurs in the city main, all water beyond the water meter, including that which is in the garden hose, could be sucked back into the potable water system. This could occur when, for example, a chemical sprayer connected to the water hose is in use. Depending on the chemical being used, you can see how dangerous this situation could be.

The HCVB has a check valve that prevents reverse water flow. The unit needs to be installed a minimum of 6 in (152 mm) above grade. It is a smart policy to recommend your clients to get a HCVB for each hose bib for safety reasons.

## Installation Guidelines

Installation instructions for each of the backflow preventers are summarized for easy use. Of course, city codes will also influence installation techniques.

### AVB-Atmospheric Vacuum Breaker

Install AVBs downstream from the automatic circuit valve, that is, between the valve and sprinkler heads. The AVB prevents only back-siphonage and should not be used when toxic chemicals could contaminate the potable water supply.

Install AVBs 12 in (305 mm) above the highest sprinkler head. Each circuit will need an AVB; if you have 12 circuits, you will have 12 AVB devices. Do not use an AVB where it will be under continuous pressure for more than 12 hours at a time because the disc float assembly could stick or become dented and thus become inoperable.

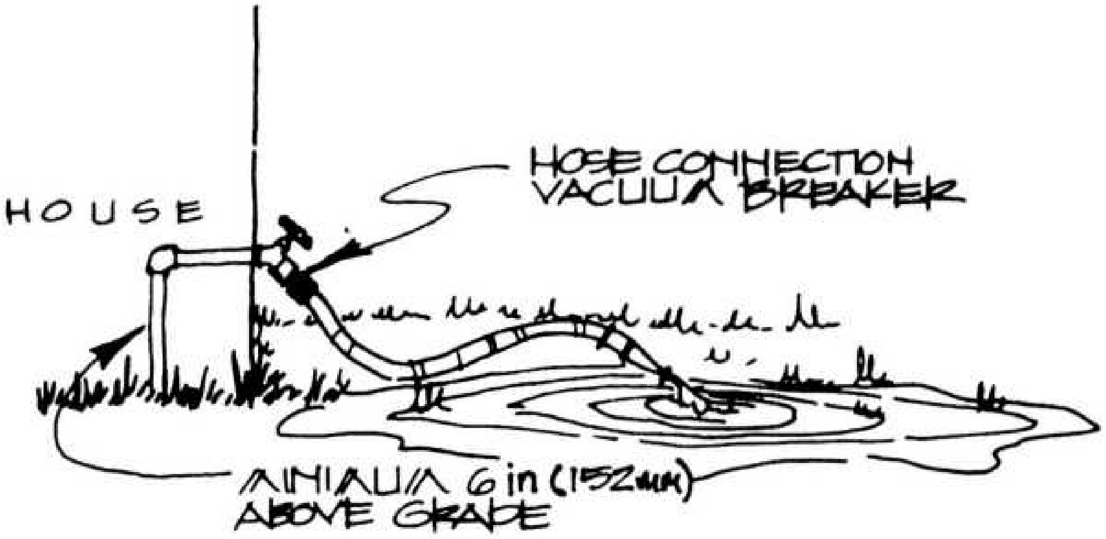


FIGURE 16.7 Hose connection vacuum breaker.

**PVB-Pressure Vacuum Breaker**

Install PVBs between the water meter and your circuit valves. Usually a project needs only one PVB. When the pressure within the PVB drops to 1 psi (0.07 kg/cm2) or lower, the disk float assembly drops and allows air into the system to stop back-siphonage. The system is not good for backflow due to back pressure and is not for use where toxic chemicals could contaminate the potable water supply.

A PVB should be installed 12 in (305 mm) above the highest sprinkler head on a site. A site that slopes upward from the meter is not usually economical for use with the PVB because of the extra mainline pipe (and trenching) needed to locate the PVB 12 in (305 mm) above the highest sprinkler head.

**DCVA-Double Check Valve Assembly**

The DCVA is used to prevent both back-siphonage and back pressure. The backflow preventer should not be used where the irrigation water could be toxic. When using a DCVA, install it downstream from the water meter and before any circuit valves, regardless of the terrain. With a DCVA, circuit valves can be located anywhere. The DCVA unit can be installed below ground in a valve box, but the assembly must have good drainage. It does need freeze protection or draining before winter months.

**RPP-Reduced Pressure Principle Backflow Preventer**

The RPP is accepted for use where toxic chemicals or effluent is used in the irrigation system.

Install the device a minimum of 12 in (305 mm) above grade so that the device cannot become submerged in any way. The RPP must be protected from freezing. It would be ideal to install the backflow preventer where it can be noticed if it vents water during a backflow situation.

## Considerations for Selecting a Backflow Preventer

Here are some considerations that may help you to select the correct backflow preventer for your project:

1. What do the plumbing codes require?

2. Is there a potential for back pressure in your system? If you are not injecting toxic chemicals into your system or using effluent water, a DCVA would probably be best to use because it is suitable for both back-siphonage and back pressure.

3. The number of valve circuits can affect the backflow preventer you select. Although the AVB is the least expensive of the backflow preventers, it may not be cost-effective to use the AVB if you have many circuits. It might be best to use a PVB or a DCVA.

4. Can the backflow preventer be installed 12 in (305 mm) above grade so that it will not be unsightly? Can it be tucked away in a shrub or ground cover bed?

5. Uphill terrain affects the location of vacuum breakers. Both the AVB and the PVB have to be installed 12 in (305 mm) above the highest sprinkler head. The extra cost of pipe and trenching might offset the cost of using one DCVA on a project.

6. For level landscapes with only a few circuits and in which the irrigation water is not hazardous, an AVB will usually be less expensive than either a PVB or a DCVA.

7. Where you have irrigation water that is toxic or potentially dangerous to people if it were to get into the potable water supply, use the RPP backflow preventer.

8. If you have a situation where back pressure could occur, use-either the DCVA or the RPP backflow preventer, depending on the water quality.

## Conclusion

To conclude this chapter, let us define three terms that are often used when discussing backflow prevention. We did not use these terms because we felt they were confusing and that we could explain backflow prevention using less technical jargon.

A cross connection is any connection between the irrigation system and the potable water supply. When you have a cross connection, you have the potential for backflow.

A low-hazard condition is where you have a cross connection but the water in the irrigation system is not hazardous to human health.

A high-hazard condition is where the water in the irrigation system is toxic and could cause illness or death to people. The degree of hazard helps to determine which backflow preventer to use.

# 17

# Using Plastic Pipe

## Introduction

The type of pipe used for irrigation projects has changed over the years from metal to plastic. It is our intention to discuss the varieties of plastic pipe available and how they fit specific jobs. There was a time when galvanized steel pipe and copper tubing were used almost exclusively in irrigation projects. The steel pipe was heavy, and after being in use for 10 to 15 years, its insides would clog up nearly 50% of the original volume due to corrosion. Steel and copper pipe were both expensive, and joining pipe together was tedious. Plastic pipe was first developed in the 1940s and has been refined over the years. Today, there are two kinds of plastic pipe primarily used in the irrigation industry, PVC (polyvinyl chloride) and PE (polyethylene) pipe.

PVC pipe is one of the most used plastic pipes in the irrigation industry. It is produced in two categories; schedule rated pipe and pressure-rated pipe. Schedule-rated pipe is used primarily under walls and drives as a sleeve to protect more thinly walled pipe (see Figure 17.1). Pressure-rated pipe is produced according to a uniform water pressure for each class of pipe, regardless of pipe size, and is used for pressure mainlines and lateral lines in irrigation projects.

## Schedule-Rated Pipe

Schedule-rated plastic pipe is a thick-walled pipe that is produced in the same dimensions as the iron pipe that preceded it. Schedule-rated pipe comes in three categories of wall thickness, with the thickest pipe having the highest schedule rating. The three categories are Schedule 40, Schedule 80, and Schedule 120. Table 17.1 compares the wall thickness and interior diameter for Schedule 40 and 80 pipe. Schedule 120 pipe is used mainly in industrial situations and will not be discussed in depth.

You can see from the charts that the nominal pipe size is not an actual size figure for the inside or outside diameter of the pipe. Nominal comes from the Latin word nomen, which means "name"; we use the word nominal to mean "in name only." I suppose you have also noticed that the outside diameters are the same for both Schedule 40 and 80 pipe. It is only the inside diameter and the wall thickness that change. Both schedule- and pressure-rated pipe are produced in the same outside dimensions as iron pipe and are designated IPS, which refers to iron pipe size. This method of sizing makes plastic pipe more compatible for use with the old iron pipe or the newer galvanized steel pipe that replaced iron pipe. The galvanized steel pipe is produced in the same dimensions as the iron pipe. Steel has more carbon in it than iron, which makes it stronger. The galvanization helps keep the steel from rusting.

FIGURE 17. 1 Schedule 40 pipe sleeve beneath walk.

**ASTM Standards**

In order to get a uniform, standard product in the marketplace, most pipe manufacturers produce plastic pipe according to standards developed by the American Society for Testing and Materials (ASTM). This respected testing organization sets forth material standards and testing procedures to ensure the manufacture of a uniform product. Any company producing pipe under the guidelines of ASTM can stamp their pipe with ASTM and the specification number under which the pipe was produced. PVC schedulerated pipe is produced under the specification ASTM D-1785, and PVC pressure-rated pipe is produced under ASTM D-2241. Irrigation designers specify PVC pipe that has been produced under the strict ASTM standards.

### ASTM Tests

During production, schedule-rated plastic pipe is subjected to a number of technical tests developed by ASTM, including the following:

TABLE 17.1 ***Schedule Pipe Wall Comparison in Inches***

**SCHEDULE 40**

| Nominal Pipe Size | Wall Thickness | Outside Diameter | Inside Diameter |
|---|---|---|---|
| ½ | 0.109 | 0.84 | 0.622 |
| ¾ | 0.113 | 1.05 | 0.824 |
| 1 | 0.133 | 1.315 | 1.049 |
| 1¼ | 0.14 | 1.66 | 1.38 |
| 1½ | 0.145 | 1.9 | 1.61 |
| 2 | 0.154 | 2.375 | 2.067 |
| 2½ | 0.203 | 2.875 | 2.469 |
| 3 | 0.216 | 3.5 | 3.068 |
| 4 | 0.237 | 4.5 | 4.026 |
| 6 | 0.28 | 6.675 | 6.065 |

**SCHEDULE 80**

| Nominal Pipe Size | Wall Thickness | Outside Diameter | Inside Diameter |
|---|---|---|---|
| ½ | 0.147 | 0.84 | 0.546 |
| ¾ | 0.154 | 1.05 | 0.742 |
| 1 | 0.179 | 1.315 | 0.957 |
| 1¼ | 0.191 | 1.66 | 1.278 |
| 1½ | 0.2 | 1.9 | 1.5 |
| 2 | 0.218 | 2.375 | 1.939 |
| 2½ | 0.276 | 2.875 | 2.323 |
| 3 | 0.3 | 3.5 | 2.9 |
| 4 | 0.337 | 4.5 | 3.826 |
| 6 | 0.432 | 6.675 | 5.761 |

The sustained pressure test. Six pipe specimens of one size are maintained at a certain test pressure for 1,000 hours. The pressure under which a pipe is tested depends on the size of the pipe. Remember, the wall thickness of schedule-rated pipe changes with each pipe size, so the pressures the pipe can withstand will also change. For example, 1-in (25-mm) Schedule 40 pipe is tested under 950 psi (67 kg/cm2) for 1,000 hours at 73° F (23°C). If one of the six specimens fails, six new specimens are tested. If one of the six specimens fails in the retest, the pipe is considered unfit to carry the ASTM stamp. This test relates to the constant water pressure conditions found in irrigation systems.

The Burst Pressure Test. For 60 to 70 seconds, five specimens of pipe are filled with water at a certain maximum pressure, depending on the pipe size. For example, 1-in (25 mm) Schedule 40 pipe should be able to hold 1,440 psi (101 kg/cm2), which is the minimum burst pressure it should be able to withstand according to ASTM. This test relates to pressure surges and water hammer that pipes must be able to withstand.

Flattening. Three pipe specimens are placed in a uniform press and flattened until the distance between the press plates is 40% of the outside diameter of the pipe. This means that a 2-in (51-mm) pipe is flattened almost 1 in. This occurs within a 2-to-5-minutes period, and afterwards the pipe should not show evidence of splitting, cracking, or breaking. This test relates to compressive pressure placed on pipe, for example, as when :heavy trucks drive over pipe trenches or when pipe is accidentally spilled or dumped from a truck. The impact on pipe from falling out of a truck causes extreme material stress.

### Guaranteed Pressure Rating

Table 17.2 shows the sizes, schedules, and pressure rating for PVC schedule-rated pipe. The pressure-rating figure, also called PR, is the estimated maximum water pressure a pipe can be expected to withstand "with a high degree of certainty, the failure of the pipe will not occur." This paraphrase from the ASTM D-1785 specification is what pipe manufacturers base their guarantee on; they guarantee the PR figure. The PR figure is usually stamped on the different sizes of PVC schedule pipe. Remember, with schedule pipe, PR changes for each pipe size.

The sustained pressure figure is used to test the six pipe specimens for 1,000 hours. A manufacturer will not guarantee this figure. The burst pressure figure is the minimum pressure the pipe must be able to contain for a 60-to-70-second period without bursting. Again, a manufacturer will not guarantee this figure. The minimum burst pressure figures, like the sustained pressure figures, are for testing to get uniform standard pipe production.

As we have already discussed, schedule-rated pipe is not often used for irrigation pipe. Designers would rather select pipe with standard pressure ratings for all the sizes in which the pipe is produced.

## Pressure-Rated Pipe

Pressure-rated pipe is manufactured in four classes, or pressure categories, that are used by the irrigation industry:

Class 125-guaranteed to hold 125 psi (8.79 kg/cm2)

Class 160-guaranteed to hold 160 psi (11.25 kg/cm2)

Class 200-guaranteed to hold 200 psi (14.06 kg/cm2)

Class 315-guaranteed to hold 315 psi (22.15 kg/cm2)

TABLE 17.2 **Guaranteed Pressure Rating for Schedule-Rated Pipe 1120, 1220, 2120**

| PIPE SIZE (IN) | SCHEDULE 40 (PSI) | SCHEDULE 80 (PSI) | SCHEDULE 120 (PSI) |
|---|---|---|---|
| ½ | 600 | 850 | 1,010 |
| ¾ | 480 | 690 | 770 |
| 1 | 450 | 630 | 720 |
| 1¼ | 370 | 520 | 600 |
| 1½ | 330 | 470 | 540 |
| 2 | 280 | 400 | 470 |
| 2½ | 300 | 420 | 470 |
| 3 | 260 | 370 | 440 |
| 3½ | 240 | 350 | 380 |
| 4 | 220 | 320 | 430 |
| 5 | 190 | 290 | 400 |
| 6 | 180 | 280 | 370 |

TABLE 17.3 **PVC Class 160 IPS Plastic Pipe**

| | | | |
|---|---|---|---|
| Nominal pipe size | 1.5 in | 2 in | 3 in |
| Outside diameter | 1.9 in | 2.375 in | 3.50 in |
| Wall thickness | 0.073 in | 0.091 in | 0.135 in |
| Ratio of wall to outside diameter | | | |
| 0.073 ÷ 1.9 | 26.02 ratio | | |
| 0.091 ÷ 2.375 | 26.09 ratio | | |
| 0.135 ÷ 3.5 | 25.92 ratio | | |

### Standard Dimension Ratio

In each class category, the ratio of wall thickness to the outside diameter of the pipe is the same. As a point of interest, the word ratio means "a relationship between two things." We are talking about a relationship between the wall thickness to the outside pipe diameter. It does not matter if you are examining a 1-in (25-mm) pipe or a 3-in (76-mm) pipe; the wall thickness compared to the outside diameter of the pipe size will be the same (see Table 17.3).

To find the ratio of wall thickness to outside diameter, divide the outside diameter by the wall thickness. A 2-in (51-mm) pipe actually has a 2.375-in (60-mm) outside diameter and a 2.193-in (56-mm) inside diameter. The 2 in (51 mm), therefore, is a nominal (in name only) dimension. The wall thickness is 0.09 in (2 mm). Divide the wall thickness into 2.375 in (60 mm), and you get a ratio of 26.09.

This ratio of wall thickness to outside pipe diameter is what gives pressure-rated pipe its ability to withstand a certain pressure for all the pipe sizes that have the same ratio of wall thickness to outside diameter. This is called the standard dimension ratio. It is usually abbreviated SDR-PR, which means Standard Dimension Ratio-Pressure Rated. Irrigation designers like to use SDR pipe because they can count on a certain design pressure regardless of the pipe size with which they are working. Remember that Schedule 40 pipe had a different PR (pressure rating) for each pipe size. With pressure-rated pipe, designers know that all pipe sizes rated Class 200, for example, will be guaranteed to hold 200 psi (14 kg/cm2).

#### Guaranteed Pressure Rating

Table 17.4 compares the various pressures under which PR pipe is held in order to pass inspection as an ASTM-conforming pipe. Remember, only the pressure rating is guaranteed by the pipe manufacturer. The other pressure tests make sure the pipe can handle the stress of being under constant pressure and pressure surges.

Most designers and contractors use Class 200 PVC pipe on projects where the static pressure in the system is below 80 psi (5.62 kg/cm2). For systems where larger pipe and higher pressures are being used, designers specify Class 315 pipe.

### Explanation of Quality Stamp

When you look at PVC pipe, you will see a continuous string of numbers and letters on the pipe that looks impressive and yet confusing (see Figure 17.2). Let us look at an example of the string of numbers and letters for schedule- and pressure-rated pipe and explain the different codes.

#### Schedule 40 Pipe

2" SCH 40 PVC 1120 280PSI @ 23 degrees C ASTM D1785 USPI NSF-PW STSSR

2"-This is the nominal size of the pipe. The pipe is actually 2.375 in (60 mm) in outside diameter and 2.067 in (53 mm) in inside diameter.

SCH4(-This stands for "schedule" and refers to the sizing system for plastic pipe. Schedule pipe has thicker walls than class-rated pipe. Schedule 80 pipe has thicker walls than Schedule 40 pipe.

PVC 1120-PVC stands for polyvinyl chloride, of which the pipe is made. The numbers stand for the raw material and stress the pipe can handle. The first two numbers stand for the type and grade of material-Type 1, Grade 1, which is the best for irrigation pipe. Type 1, grade 2, is best for drainage systems and industrial applications. The "20" stands for the material tensile design stress, given in 100s. That means that the material will hold up to 2,000 psi (141 kg/cm2) in a tensile or pulling stress.

TABLE 17.4 **Comparison of Pressure-Rated Pipe**

| PR (THE GUARANTEED PSI FIGURE) | SDR (STANDARD DIMENSION RATIO) | SUSTAINED PRESSURE | MINIMUM BURST PRESSURE |
|---|---|---|---|
| Class 125—SDR | 32.5 | 260 psi | 400 psi |
| Class 160—SDR | 26 | 340 psi | 500 psi |
| Class 200—SDR | 21 | 420 psi | 630 psi |
| Class 315—SDR | 13.5 | 670 psi | 1,000 psi |

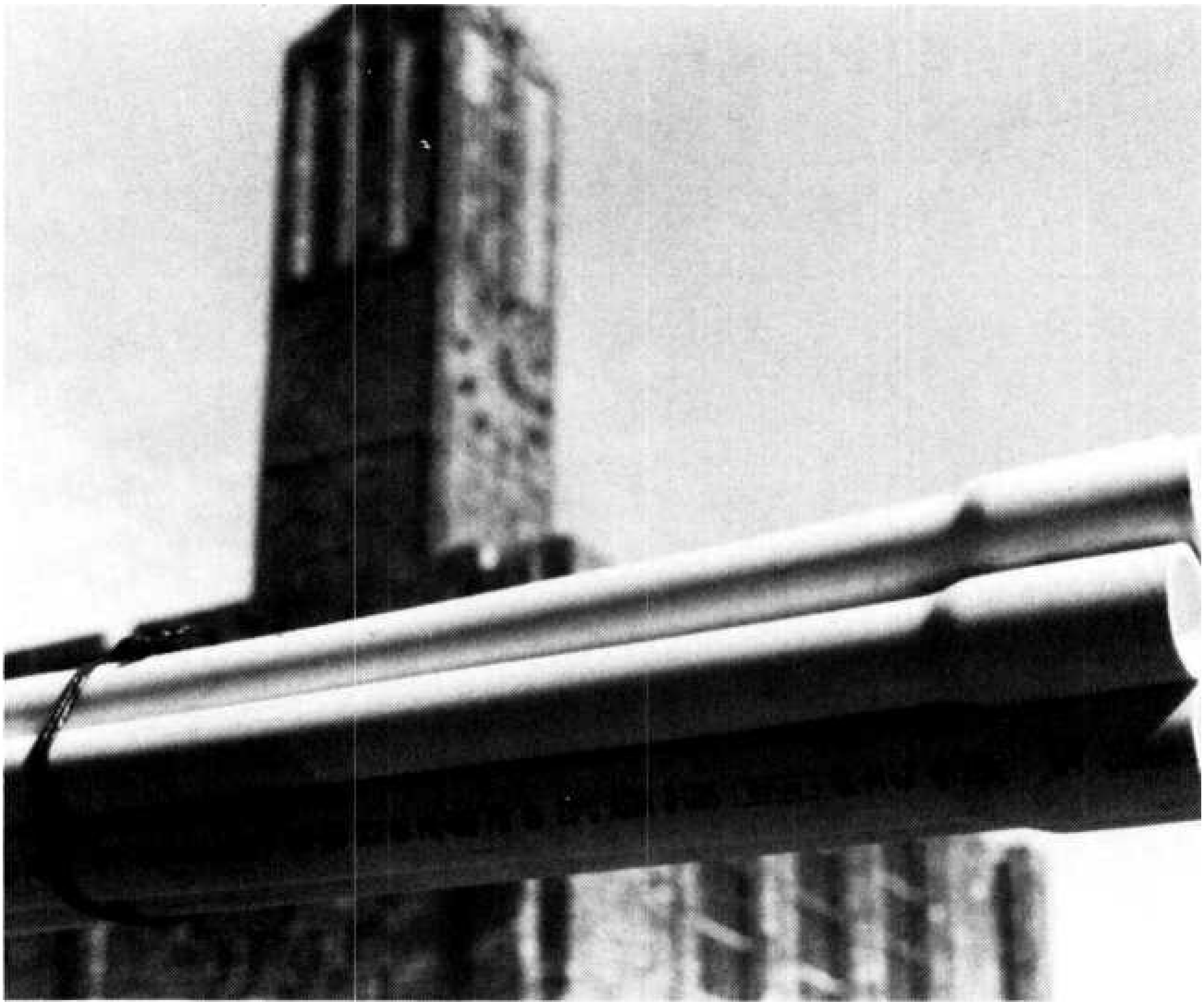


FIGURE 17.2 Schedule 40 quality stamp.

280 PSI-This is the pressure rating of 2 in (51mm) Schedule 40 pipe that is guaranteed by the manufacturer (280 psi = 19.68 kg/cm2).

23°C-The 280-psi pressure rating is tested at 23°C (Celsius) or 73°F (Fahrenheit). At higher temperatures, the pipe becomes soft and loses its strength. When temperatures are lower than 73°F, (23°C), the pipe also loses strength because it becomes brittle and less elastic.

ASTM D-1785-ASTM stands for the American Society for Testing and Materials, which develops product standards. Manufacturers produce their products according to the material definitions and testing methods developed by ASTM.

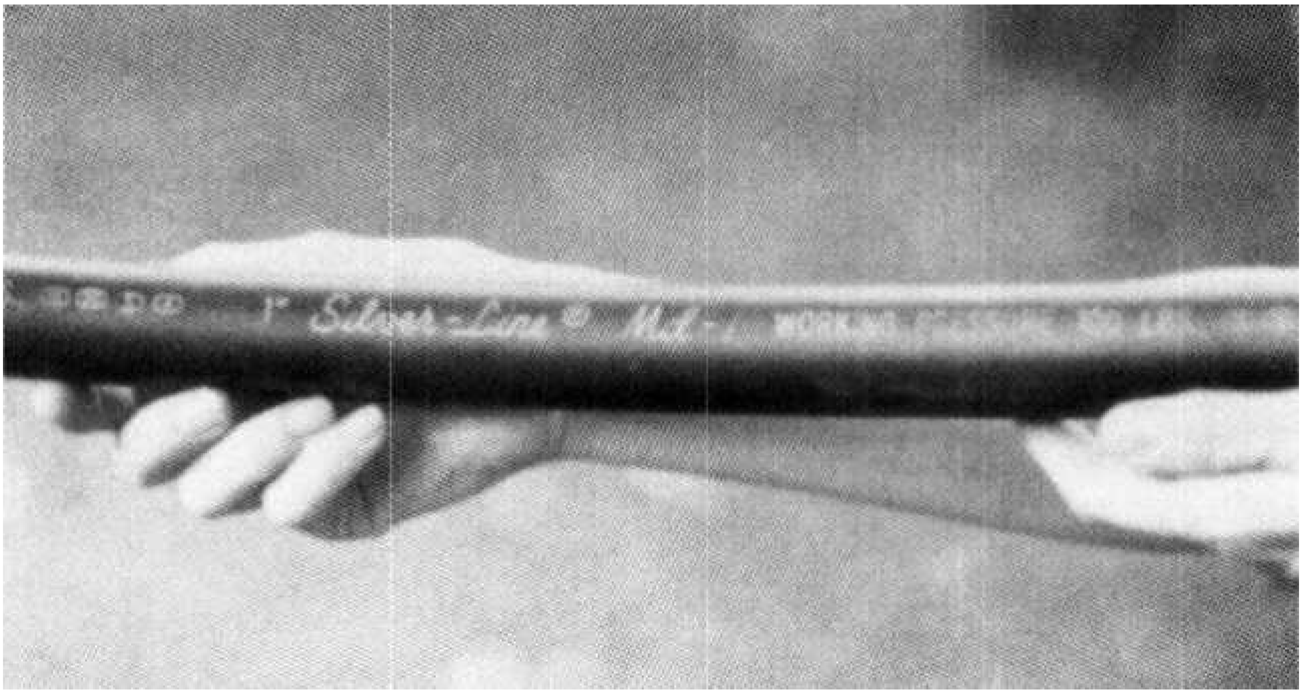


FIGURE 17.3 Utility-grade PE pipe stamp.

D- 1 785-This refers to the standard specification for producing PVC Schedule 40, 80, and 120 plastic pipe. You can find these specifications either in the ASTM Annual Book of Standards or by referring to the microfilm version of the book of standards, which is usually found in university libraries.

USPI-USPI is the trademark and name of the company that produces the pipe. In this case it is U.S. Plastics, Incorporated.

NSF-PW-NSF is the trademark for the National Sanitation Foundation. PW stands for "potable water" and indicates that the pipe is suitable for drinking water use. The presence of the NSF seal means the pipe meets NSF manufacturing standards.

STSSR-This is the date code, which defines the day and time of year the pipe was made.

### Class 160 Pipe

1 %," Silver Line PVC 1120 SDR-26 PRA 60 PSI at 23 degrees C ASTM D-2241 NSF-PW SL-M-2

1'/4"-Nominal size of pipe. Actual size is 1.66 in (42 mm) outside diameter and 1.532 in (39 mm) inside diameter.

Silver Line-This is the registered trademark of the manufacturer.

PVC 1 120-As you know, PVC stands for polyvinyl chloride. The "11" is the type and grade of material composition: type 1, grade 1. The "20" is the stress of the material given in 100s; the pipe is made to withstand a 2,000 psi (141 kg/cm2) material design stress. What this actually means is the material can withstand up to 2,000 psi (141 kg/cm2) tensile or pulling stress before it fails.

SDR-26-The SDR, as you recall, stands for Standard Dimension Ratio. We are talking about the ratio between the wall thickness and the outside pipe diameter. The 26 is the ratio of the wall and the outside diameter of the pipe for pipe that is produced to be guaranteed to withstand water pressures of 160 psi (11.25 kg/cm2). Regardless of the pipe size, if the ratio between the wall thickness and the outside diameter is SDR-26, the pipe will be guaranteed by the manufacturer to withstand 160 psi (11.25 kg/cm2) of water pressure.

PR- 160 PSI-PR stands for pressure rating. 160 PSI stands for 160 pounds per square inch (11.25 kg/cm2). This is the water pressure that the manufacturer guarantees the pipe will withstand.

At 23°C-This means that the ability to handle 160 psi (11.25 kg/cm2) of water pressure is guaranteed at 23°C (73°F). At higher temperatures, the pipe becomes soft and loses its strength. At lower temperatures, the pipe will become brittle and less elastic.

ASTM D-2241-This is the standard specification for PVC pressure-rated pipe.

NSF-PW-NSF is the trademark for the National Sanitation Foundation, and the "PW" means the pipe is suitable for potable water use. The presence of the NSF seal means the pipe meets its manufacturing standards.

SL-M-2-This is the code that identifies the date the pipe was produced. Some manufacturer codes also identify a particular plant and even the machine that produced the pipe.

## Polyethylene Pipe

Polyethylene (PE) pipe is a black, flexible plastic pipe that is used in irrigation systems, primarily for lateral lines. The pipe was produced before PVC pipe and was one of the first plastic pipes used for irrigation. Figure 17.3 depicts utility-grade PE pipe.

### Advantages

Polyethylene pipe has several advantages for use in irrigation systems. The pipe comes in 100-ft (30.48-m) rolls rather than in 20-ft (6-m), rigid lengths like PVC pipe. The pipe is flexible, which allows the contractor some flexibility in making turns without using 90° elbow fittings. Because PE pipe has ultraviolet stabilizers mixed with the plastic material, it is less susceptible to the deteriorating effects of sunlight than PVC pipe. Finally, one of the biggest advantages of PE pipe is that it resists cracking and bursting caused by freezing water. This is probably the biggest advantage of using PE pipe, especially in areas like Denver, Colorado, where freezes extend 2.5 ft (0.76 m) deep. In the Denver area, some contractors use PE pipe for lateral lines because of the flexibility of the pipe if water freezes in it. When winterizing irrigation systems, some water will remain in the pipe. The PE pipe can tolerate the freezing effects of the water. In Denver, mainlines are usually constructed of PVC and placed 24 in (610 mm) deep. Lateral lines are often constructed of PE pipe, and they are placed 12 in to 18 in (305 mm to 457 mm) deep.

*TABLE 17.5* **SIDR and Pressure Ratings for PE Plastic Pipe**

| SIDR | PSI | |
|---|---|---|
| **PE 3408** | **PE 3306** | **PE 3406** |
| 5.3 | 250 | 200 |
| 7 | 200 | 160 |
| 9 | 160 | 125 |
| 11.5 | 125 | 100 |
| 15 | 100 | 80 |
| 19 | 80 | — |

### Pressure Ratings

Like class-rated PVC pipe, PE pipe is produced according to a standard pipe dimension ratio. The ratio, abbreviated SIDR, is between the inside pipe diameter and the wall thickness. Producing PE pipe with an SIDR ensures that any size of pipe with the same SIDR ratio will have the same pressure rating. See Table 17.5 for SIDR ratios and guaranteed pressure ratings for PE pipe. Irrigation designers usually specify either SIDR 15 or 19 for use as lateral lines. SIDR 15 is guaranteed to hold 100 psi (7 kg/cm2), and SIDR 19 is guaranteed to hold 80 psi (5.62 kg/cm2). PE pipe that carries the SIDR ratio is produced according to ASTM specification D-2239. This grade of pipe is also stamped with the NSF seal, which enables the pipe to be used to carry water for human consumption.

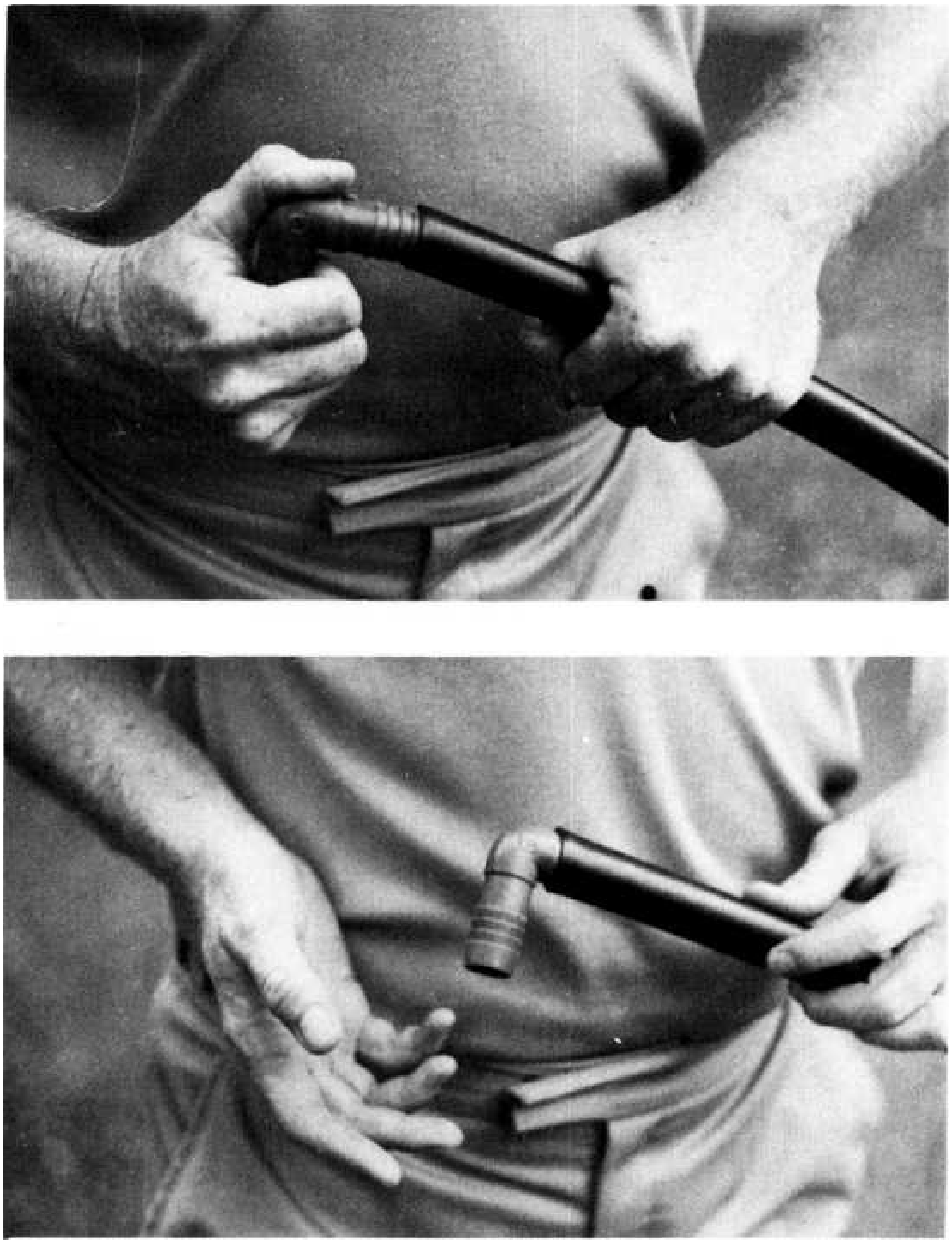


FIGURE 17.4 Barbed fitting and PE pipe.

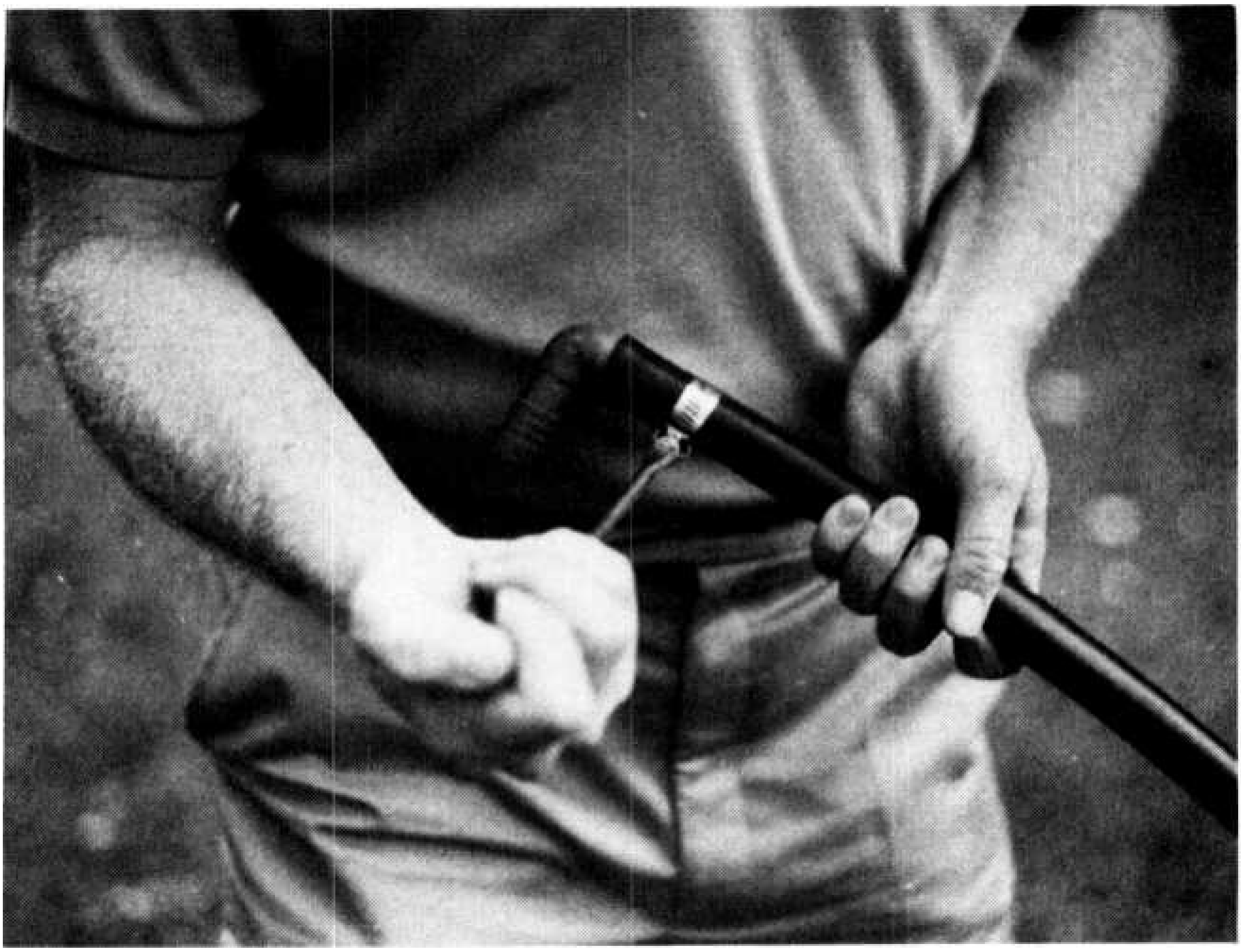


FIGURE 17.5 Attaching stainless steel clamp.

PE pipe is also produced in a utility grade and stamped with a pressure rating that is guaranteed by the manufacturer. The utility-grade PE pipe is used for irrigation pipe more often than the SIDR pipe because it is less expensive. Utility-grade PE pipe production standards vary from one manufacturer to another; however, all manufacturers produce the pipe to a standard inside diameter so that the pipe can be used with standard pipe fittings.

### Installation

PE pipe is connected with barbed fittings that are pushed into the pipe and clamped with a stainless steel clamp, as shown in Figure 17.4. The steel clamp should be placed over the barbed portion of the fitting, as shown in Figure 17.5. For pipes 1% in (38 mm) and larger, two stainless steel clamps should be used.

# 18

# Triangular Spacing of Sprinkler Heads

## Introduction

The goal of a good sprinkler head layout is to provide uniform water distribution without water waste. We have already learned how to lay out sprinkler heads in a square pattern. We are now going to explore the methods of laying out sprinkler heads in a triangular pattern and why triangular spacing is more desirable than square spacing. Figure 18.1 shows equilateral triangular spacing.

## Why Use Triangular Spacing?

Let us first convince you why triangular spacing is better than square spacing.

1. Equilateral triangular spacing produces a more uniform water distribution pattern. With square layout, the sprinkler heads have to be closer to get adequate coverage in the center of the square (see Figure 18.2).

2. Because the water distribution pattern is more uniform with triangular spacing, there is less water waste, which is a major consideration in areas of the country where water is precious.

3. Sprinkler heads are spaced further apart in triangular spacing, thus resulting in the use of fewer heads on a project.

4. Triangular spacing fits irregularly shaped sites better than square spacing.

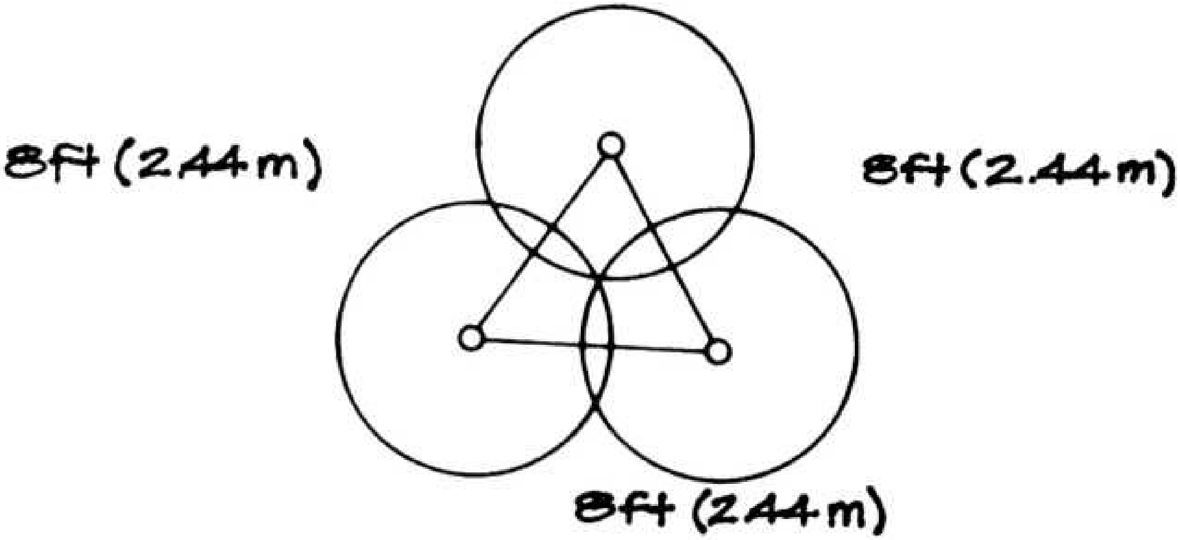


FIGURE 18. 1 Equilateral triangle spacing.

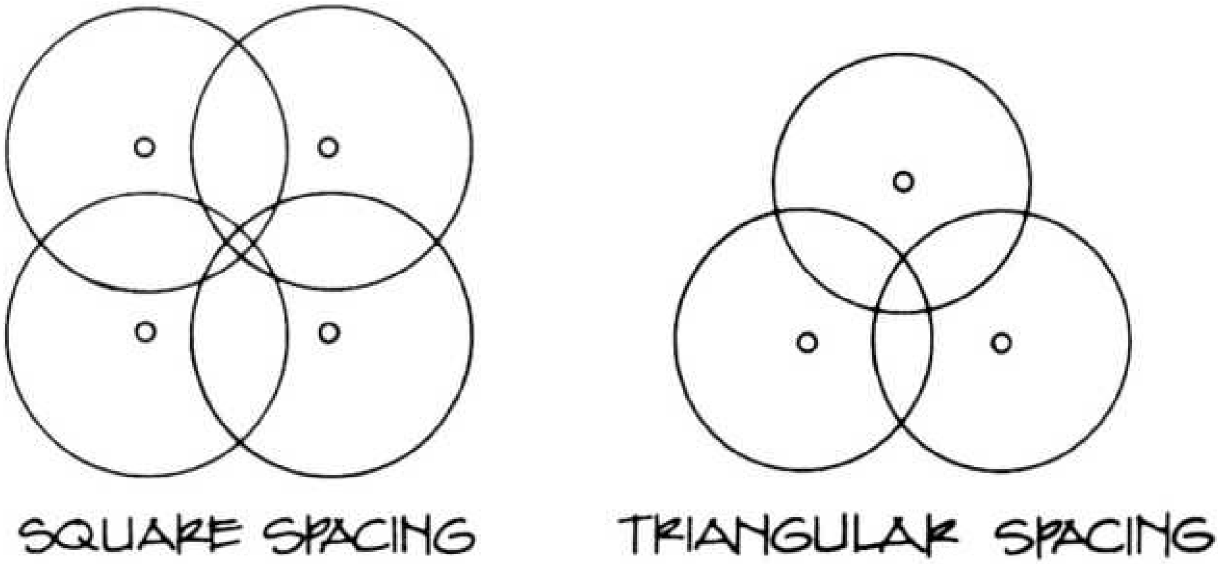


FIGURE 18.2 Square and triangular spacing.

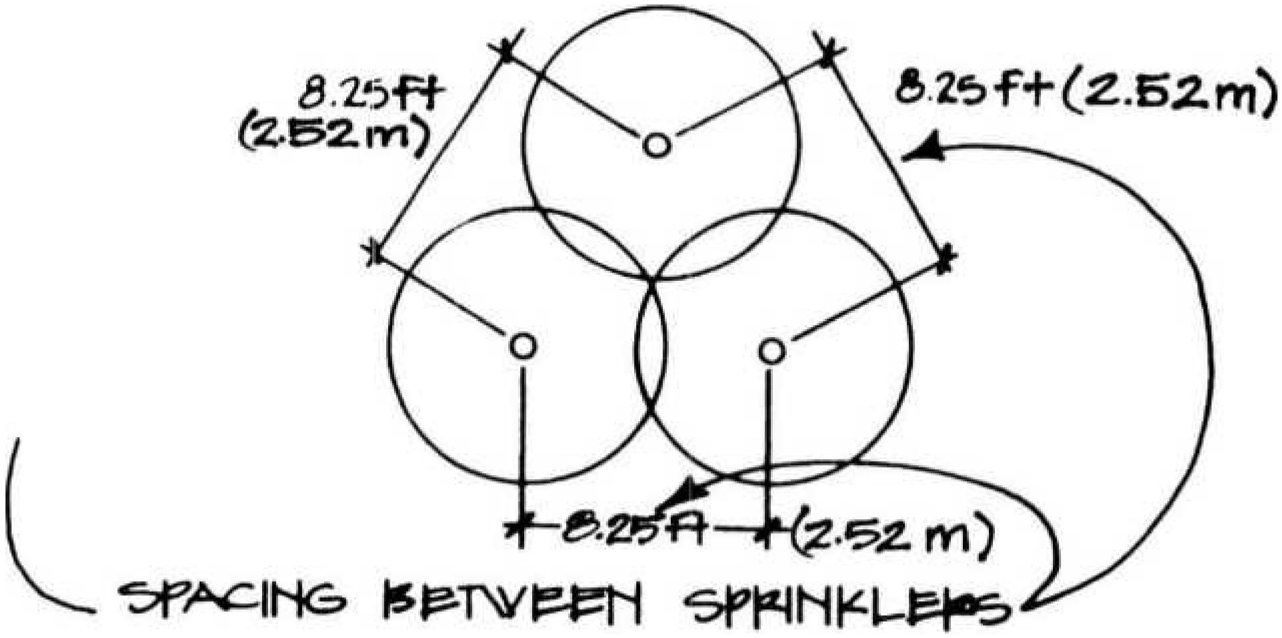


FIGURE 18.3 Equilateral triangle.

### How to Locate Heads Using Triangular Layout

An equilateral triangle is one in which all the sides of the triangle are the same size, as shown in Figure 18.3. That is the same as saying that all of the heads in your layout will be the same distance apart. To construct an equilateral triangle, locate two corners (two heads), set your compass at the distance between the two corners, and then swing an arc from each corner. Where the arcs intersect, that is your third corner (head) of the equilateral triangle. Figure 18.4 shows the construction of an equilateral triangle. Let us review the process for constructing an equilateral triangle:

1. Locate two heads.
2. Set your compass at the distance between the two heads.
3. Swing an arc from each head.
4. Where the arcs intersect is the third corner, or head, of the equilateral triangle.

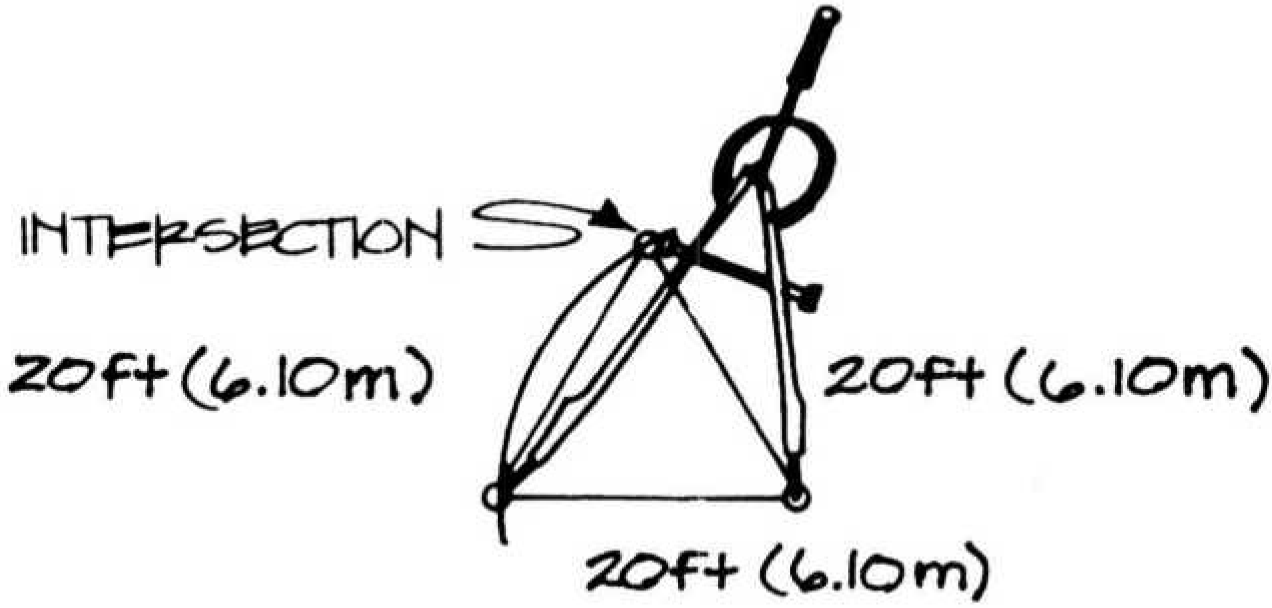


FIGURE 18.4 Construction of an equilateral triangle.

## Consider Winds When Laying Out Your Sprinkler Heads

Let us look at how far apart you must space your sprinkler heads to allow for wind conditions. Remember, winds distort water patterns, especially fine spray patterns. The stronger the wind that exists when you turn on your irrigation system, the closer you need to space your heads in order that water from the sprinkler head will get to the planted area. Manufacturers give us triangular layout head spacings for three wind conditions:

1. No wind-Space heads 60% of the sprinkler throw diameter

2. 4 mph (6.4 km/h) wind-Space heads 55% of the sprinkler throw diameter

3. 8 mph (12.9 km/h) wind-Space heads 50% of the sprinkler throw diameter

How can you recognize the speed of winds? Maybe a description of how they are described in the Beaufort Scale of Winds will help. The Beaufort Scale is accepted and used by meteorologists.

- A 4-mph-to-7-mph (6.4-km/h-to-11.3-km/h) wind is felt on your face and causes the leaves on the trees to rustle. It is called a light breeze.

- An 8-mph-to-12-mph (12.9-km/h-to-19.3-km/h) wind causes leaves and twigs to be in constant motion, and the wind will extend a light flag. This wind is called a gentle breeze.

The description of winds should enable you to estimate how strong winds are and whether or not you are dealing with a constant 4-mph (6.4-km/h) or 8-mph (12.9-km/h) wind. In many parts of the country, when sprinklers are turned on in the early morning hours, the winds are still. Some coastal areas and areas near mountains have prevailing winds nearly all the time, so you must space your irrigation heads according to the speed of the wind in order to get even precipitation of water.

Going back to our spacing recommendations according to wind speed, you can see that the head spacings are given as a percentage of the diameter of the throw of the sprinkler head. For example, if you are using a spray head that throws a 32-ft (9.8-m) diameter water pattern, you need to space your sprinkler heads the following distances apart according to wind speed:

For no wind, (32-ft [9.8-m] diameter X 0.60) = 19.2 ft (5.9 m) apart

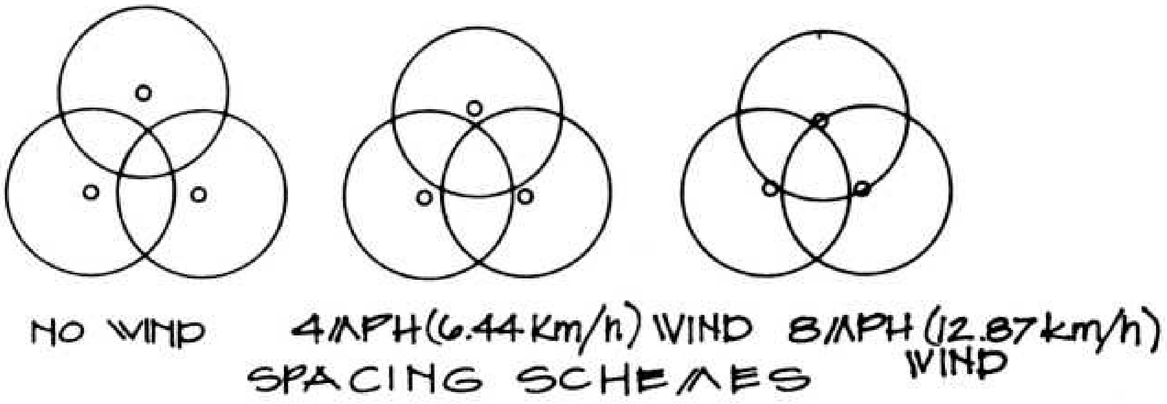


FIGURE 18.5 Wind spacing schemes.

For 4-mph (6.4-km/h) wind, (32-ft [9.8 m] diameter X 0.55) = 17.6 ft (5.4 m) apart

For 8-mph (12.9-km/h) wind situation, (32-ft [9.8 m] diameter X 0.50) = 16 ft (4.9 m) apart

(See Figure 18.5 for the different sprinkler head wind spacing schemes.)

### Triangular Spacing in Freeform Lawn Areas

Now that we see what an equilateral triangle is and we understand what its advantages are, let us become familiar with how to lay out sprinkler heads using triangular spacing in an irregularly shaped lawn area. Let us say right off that you will hardly ever find a freeform landscape situation where the equilateral triangle will work perfectly; that just never happens. You must re member, though, that the ideal head spacing is where the three heads, or corners of the triangle, are an equal distance apart. Try always to space the heads as close to the equilateral triangle as possible. In some areas you will get more overlap, and in some areas you will get less. But with heads an equal distance apart, you will be achieving as close to uniform water coverage as "humanly" possible. Only Mother Nature can do it better!

Our challenge in Figure 18.6 is a lawn area adjacent to a home on a wooded lot. Let us begin by calculating our ideal head spacing based on the 4-mph (6.4-km/h) winds at the site. We will use a spray head with a radius of 16 ft (4.9 m) for our lawn area.

Spray head 16-ft (4.9-m) radius 32-ft (9.8-m) diameter

4-mph (6.4-km/h) wind 55%, or 0.55, × spray diameter
0.55 × 32 ft = 17.6 ft (5.4 m)
head spacing

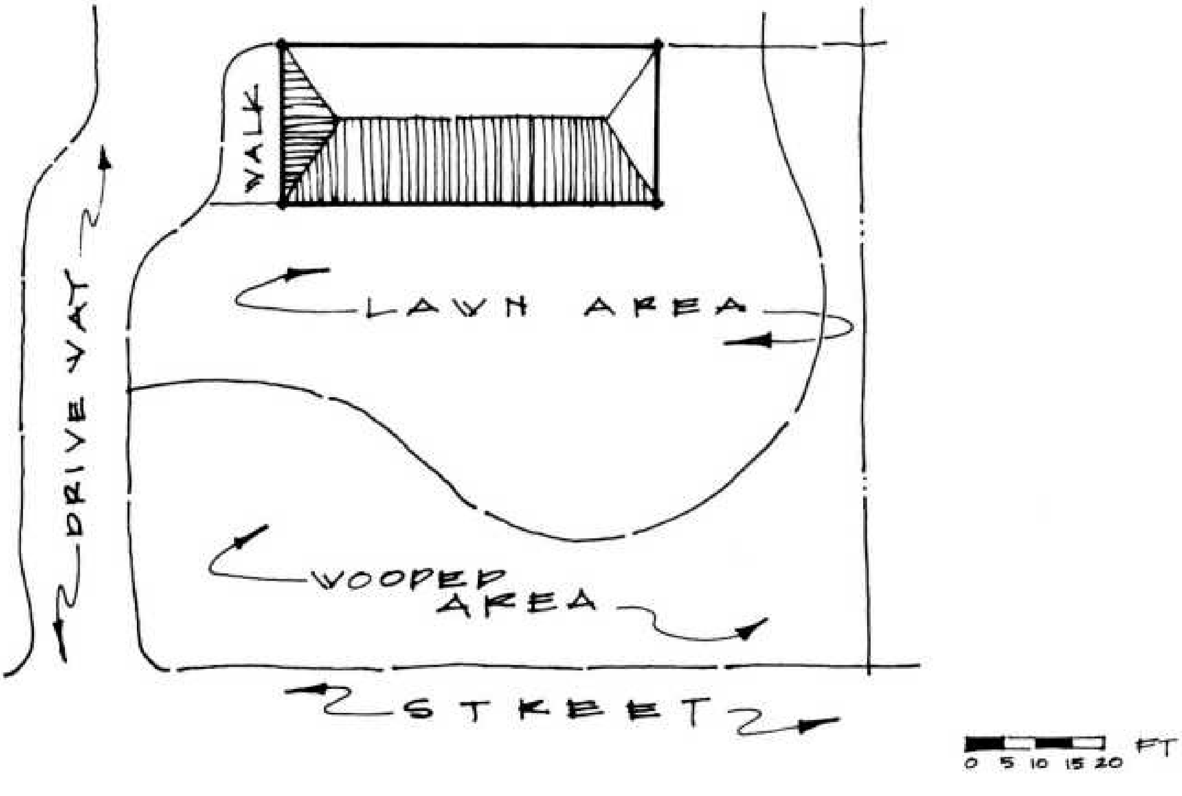


FIGURE 18.6 Lawn area to be irrigated.

Begin by laying out your sprinkler heads along the border where you need the most even spray control; we call this the control border. Continue laying out your heads along the other borders where control of spray patterns may not be so critical. Remember, we are spacing our heads 17.6 ft (5.4 m) apart, which was the ideal triangular head spacing according to a 4-mph (6.4-km/h) wind speed.

Next, swing your intersecting arcs with a compass spaced at 17.6 Ft (5.4 m) to find the third head location between the control borders and the wooded area border. Then, in the remaining area, lay out equilateral triangles to get a logical head layout that is as close to equilateral triangle spacing as you can get. Step back and look at your completed head layout. Does it look close to the equilateral triangle spacing in Figure 18.7? If not, adjust it.

Do not worry if your heads are not in a geometric grid pattern or if they appear difficult to connect to lateral pipe lines with PVC and PE swing joint pipe. Your major concern is to design a head layout that provides even precipitation and does not waste water. Your contractor will have no trouble connecting heads to lateral pipe lines. Let's review the process for laying out heads in a freeform space:

1. Select the sprinkler head and calculate the ideal head spacing based on wind conditions.

2. Lay out heads along the control border first and then along other borders.

3. Fill in head locations by swinging arcs with your compass to construct equilateral triangles.

4. Adjust equilateral triangles to fit the spaces.

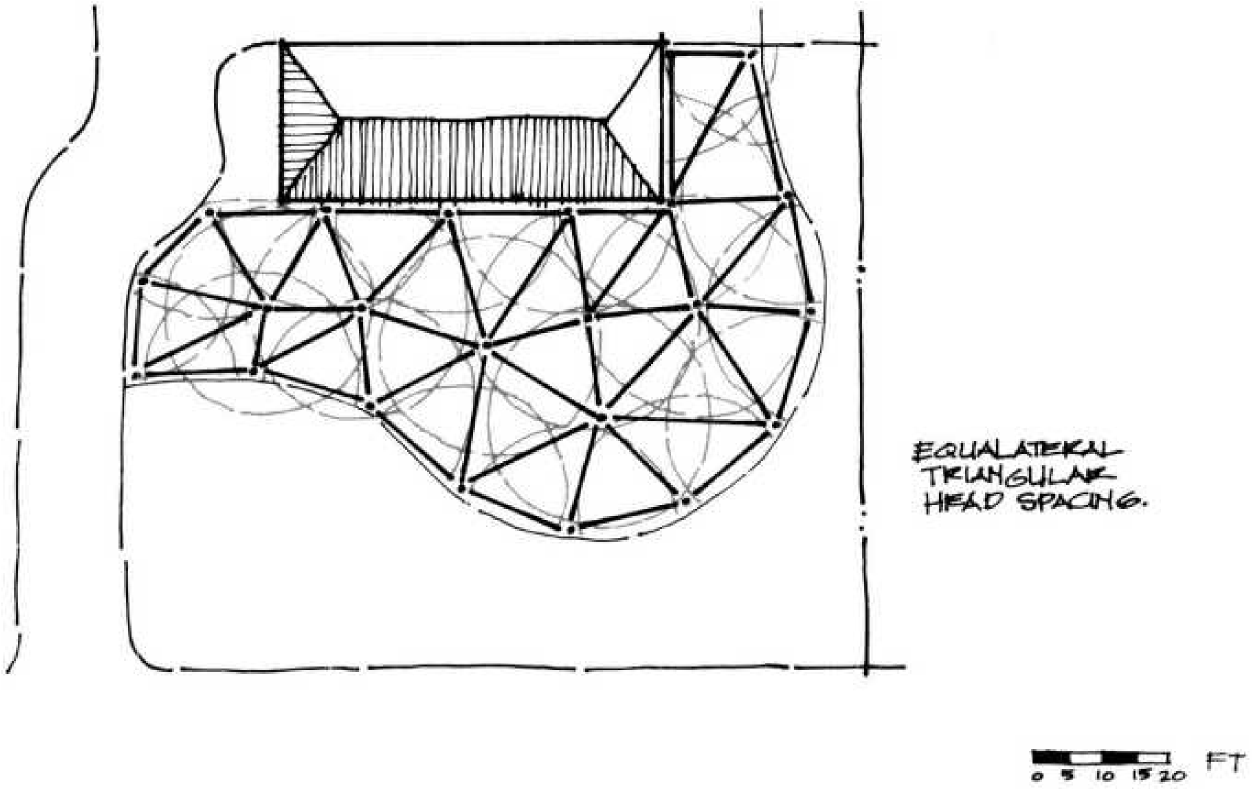


FIGURE 18.7 Equilateral triangle head layout.

### Triangular Spacing in Square and Rectilinear Spaces

Now that you have seen how triangular spacing works with irregular or freeform spaces, let us look at the application to square and rectilinear spaces. Our challenge is a rectilinear lawn area (Figure 18.8) with a building along one border. Winds are 4 mph (6.4 km/h). When you lay out your heads, do not stretch them beyond what the manufacturer recommends according to the different wind speeds. Compress the head spacing if you have to, but do not stretch the heads beyond what is recommended. You want to make sure your plants get enough water in even amounts.

First, select the sprinkler head you will use based on the size of the space, and then determine the ideal head spacing. In our example, we are using 15-ft (4.6- m) radius spray heads, which means they have a 30-ft (9.1-m) diameter. For our 4-mph (6.4-km/h) winds, we see that our recommended spacing is 55% of the diameter of the sprinkler head (0.55 X 30 ft [9.1 m] = 16.5 ft [5 in]. Therefore our ideal head spacing for a 4 mph (6.4 km/h) wind situation is 16.5 ft [5 m].

Next, let us locate heads along the side that cannot have an overspray. This is our control border. Control borders can be where a building is located or where there is a busy sidewalk or street. We do not want to throw water on a building because the water will discolor the building material over time, and water can cause slick sidewalks and streets that can endanger the public's health, not to mention waste water! Determine how many times the 16.5-ft (5-m) ideal head spacing will fit along the control border. Divide the length of the control border by the ideal head spacing calculation.

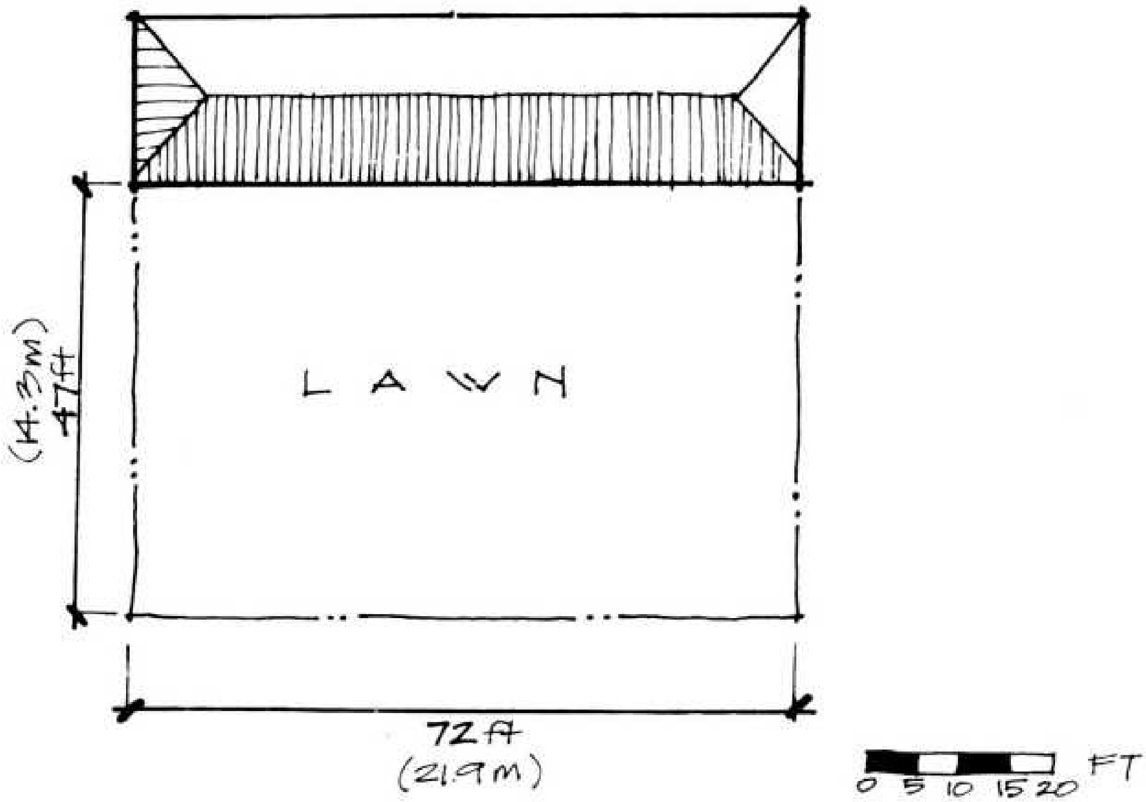


FIGURE 18.8 Rectilinear lawn area.

$$\frac{\text{Control border length—72 ft (22 m)}}{\text{Ideal head spacing—16.5 ft (5 m)}} = 4.36$$

The ideal head spacing will fit in the control border length 4.36 times. This calculation needs to be a whole number to give us an even number of times the ideal sprinkler head spacing will fit along the control border, so reduce the 4.36 to 4 times. You will see by doing this we are stretching our head spacing beyond what we should.

To find the distance at which to space our heads along the control border, divide the control side length by the number of times the ideal head spacing length fits along the control border.

$$\frac{\text{Control border length—72 ft (22 m)}}{\text{Number of times the ideal spacing will fit into the control border length—4}} = \text{18 ft (5.5 m). This is the head spacing along the control border.}$$

(See Figure 18.9 for the spacing of sprinkler heads 18 ft [5.5 m] apart along the control border.)

Recall that the ideal sprinkler head spacing for a 4mph (6.4-km/h) wind was 16.5 ft (5 m) using a 15-ft (4.6-m) radius spray head. Note that we are spacing our heads 18 ft (5.5 m), or 1.5 ft (0.46 m) greater than the ideal head spacing. Let us see what kind of spacing we will have if we expand the number of times a sprinkler head will fit along the control border to 5 instead of 4. By doing this, we are spacing our heads closer together instead of stretching them.

$$\frac{\text{Control border length—72 ft (22 m)}}{\text{Number of times the ideal head spacing will fit along the control border—5}} = \text{14.4-ft (4.4-m) sprinkler head spacing}$$

By using the 14.4-ft (4.4-m) head spacing, we will be compressing our heads instead of stretching them, as we did with the 18-ft (5.5-m) head layout. It is generally better to compress your head spacing to ensure adequate water coverage than to stretch head spacing and get dry spots. (See Figure 18.10 for the head layout using the 14.4-ft [4.4-m] head spacing.)

Now let us determine the sprinkler head spacing along the side adjacent to the control border. Follow the same process that we used to determine the head spacing along the control border.

$$\frac{\text{Noncontrol border length—47 ft (14.3 m)}}{\text{Ideal head spacing—16.5 ft (5 m), based on wind conditions}} = \text{2.84. This is the number of times the ideal head spacing will fit in our noncontrol border length}$$

We need a whole number to lay out heads evenly, so round the 2.84 to 3 times.

$$\frac{\text{Noncontrol border length—47 ft (14.3 m)}}{\text{the number of times the ideal head spacing will fit into the noncontrol border length—3 times}} = 15.7 \text{ ft head spacing}$$

Now we have head spacing along two sides from which to locate the other heads for our equilateral triangles. Draw a grid of squares or rectangles based on spacing to locate all sprinkler heads in a triangular manner (see Figure 18.11). Measuring our triangles, we see that we do not have exact equilateral triangles, but they are as close as we can get. The head spacing will give us good sprinkler coverage.

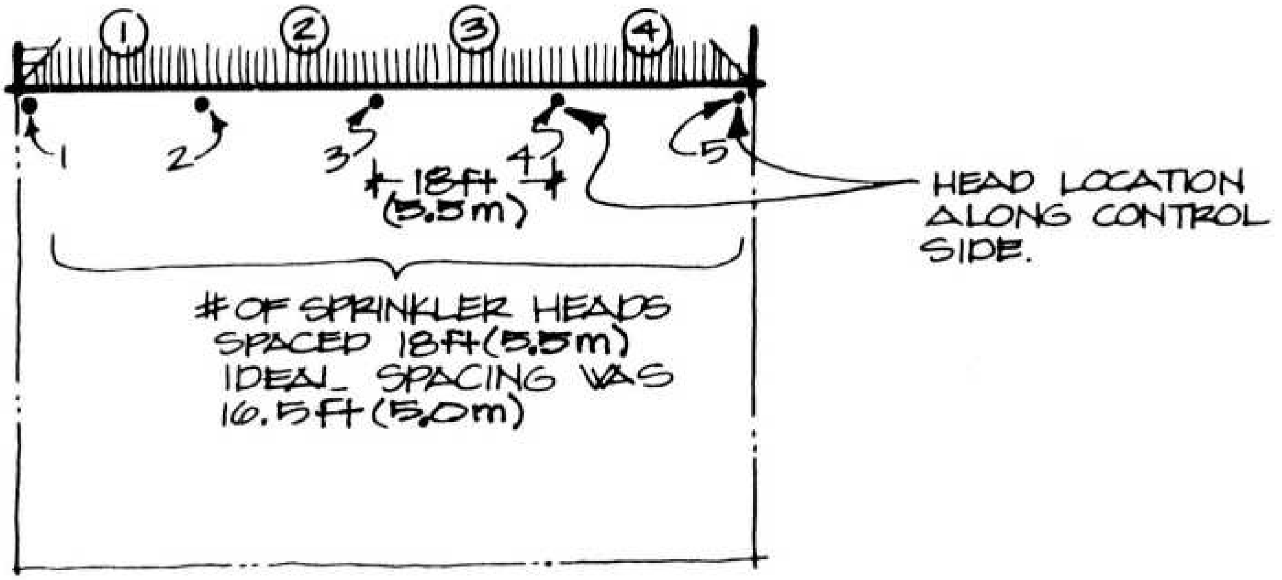


FIGURE 18.9 Control border head spacing.

Note that there is some overspray along two sides. When you use spray heads, there will always be some overspray caused by even the gentlest of winds. If the overspray is offensive, you could reduce the spray radius of the overspraying head in question and put a half-circle head at the border, as shown in Figure 18.12. If there is a prevailing wind, you may only have to reduce the spray radius and fill in half-circle heads on the side with the wind overspray.

As a matter of interest, let us look at the same rectangular area and determine how many sprinkler heads we would use by laying out our heads in a square spacing pattern (see Figure 18.13). Recall that we are using 15-ft radius (4.6-m) heads in a 4-mph (6.4- km/h) wind. We take 50% X 30 ft (9.1 m) in diameter and get 15-ft (4.6-m) head spacing for our square head layout. Do not get confused; remember, the 4-mph (6.4-km/h) head spacing requirement for triangular spacing was 55% of the diameter, but it is 50% of the diameter for square spacing. Let us review our design process for head layout.

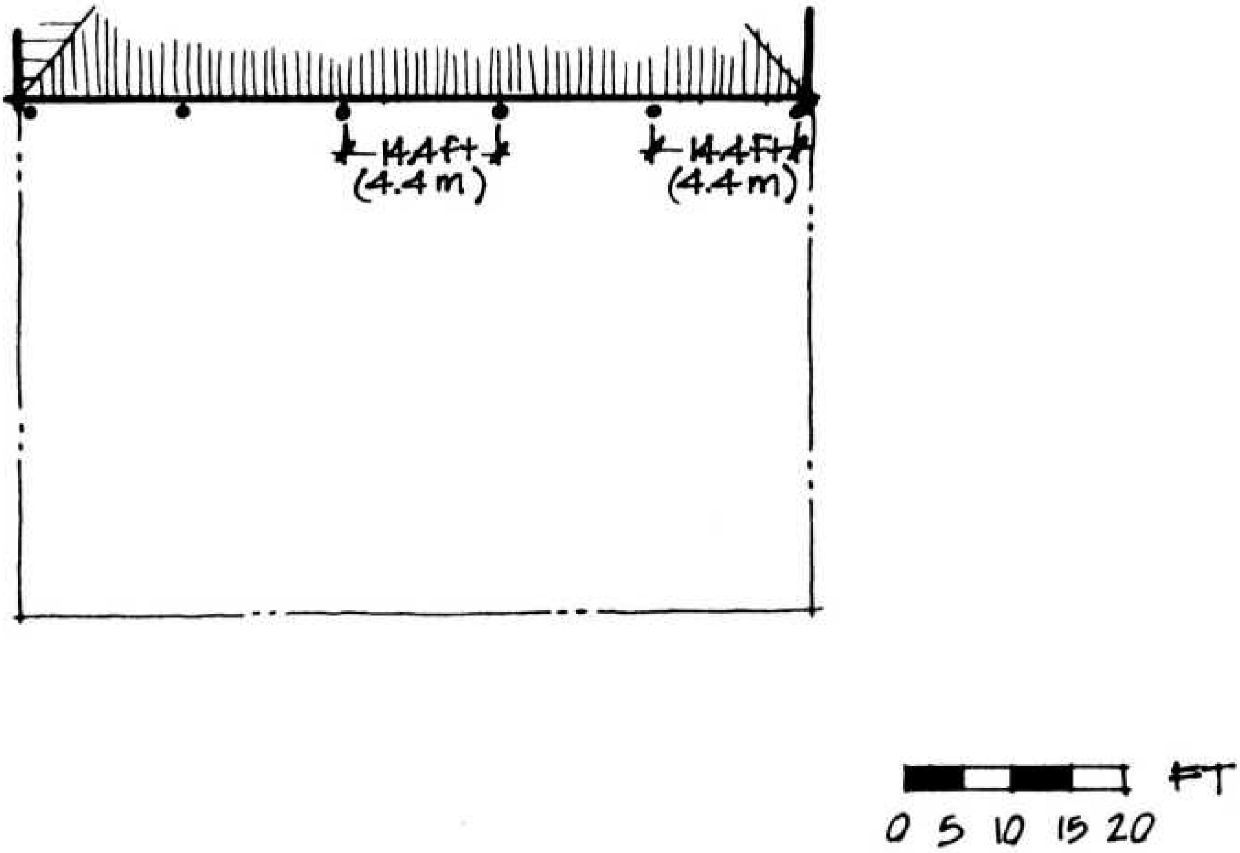


FIGURE 18.10 Revised head spacing.

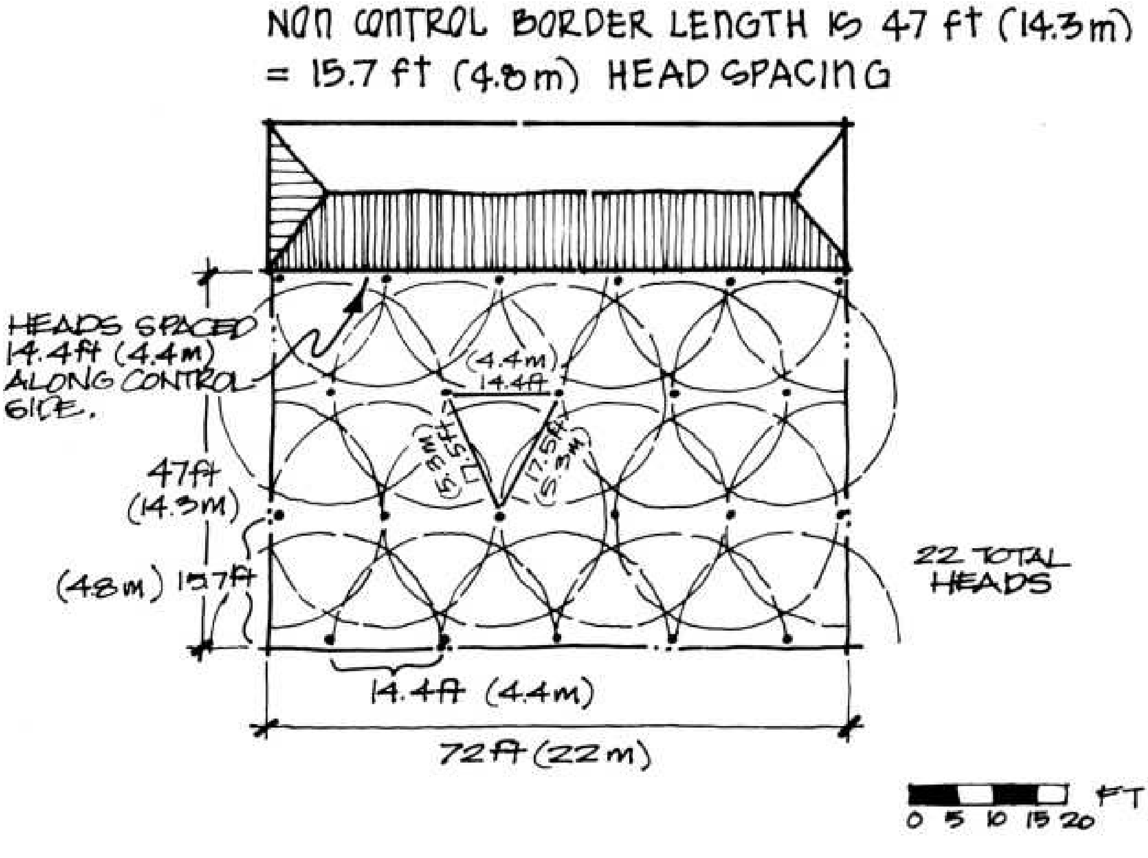


FIGURE 18. 11 Final triangular head layout.

1. Divide control border by ideal head spacing and round off to the nearest whole number:

$$\frac{72\text{ ft (22 m)}}{15\text{ ft (4.6 m)}} = 4.8\text{, or }5$$

2. Divide the control border length by the result to get the head spacing:

$$\frac{72\text{ ft (22 m)}}{5} = 14.4\text{ ft (4.4 m)}$$

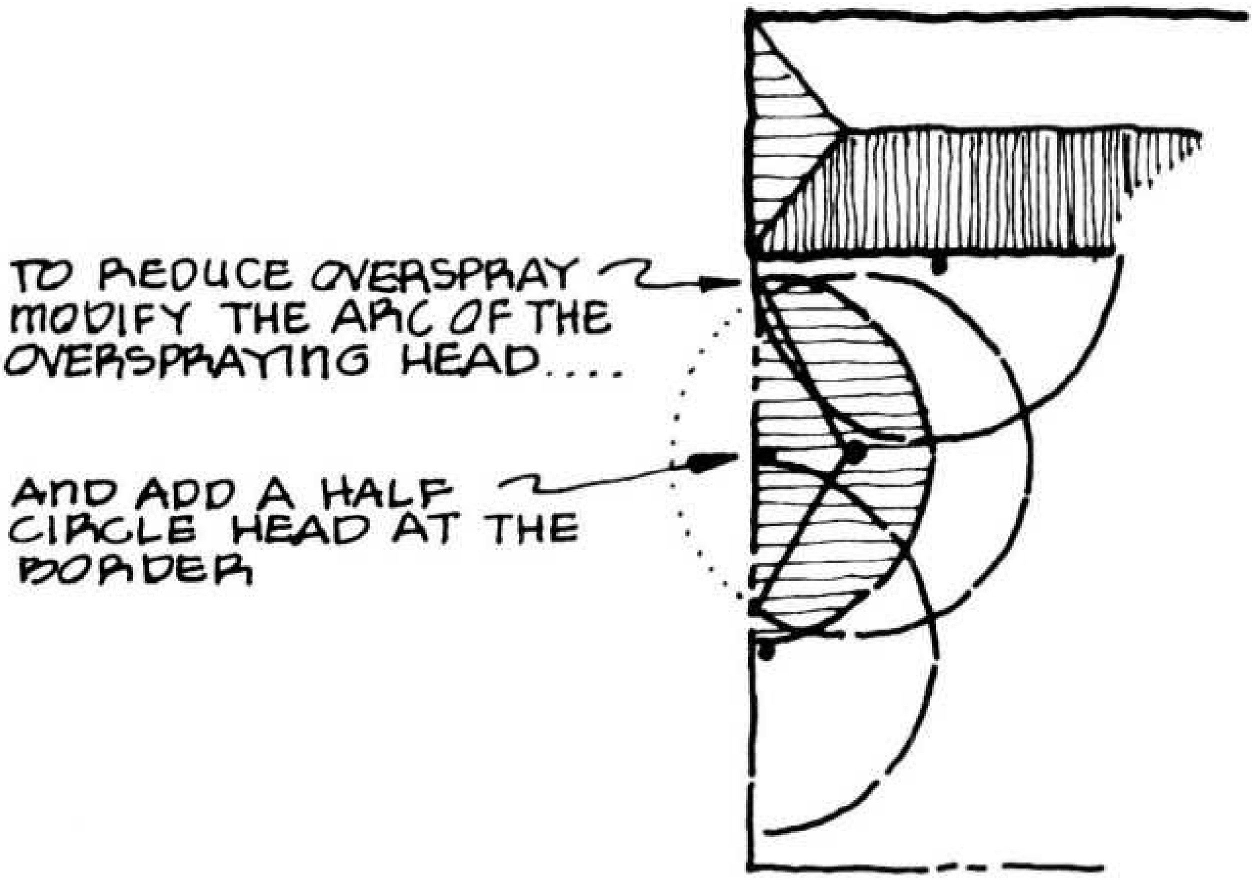


FIGURE 18.12 Reducing overspray.

3. Lay out heads along control border.

4. Divide the adjacent side by ideal head spacing:

$$\frac{47 \text{ ft } (14.3 \text{ m})}{15 \text{ ft } (4.6 \text{ m})} = 3.13, \text{ or } 3$$

5. Divide the control border length by the result to get the head spacing:

$$\frac{47 \text{ ft } (14.3 \text{ m})}{3} = 15.6 \text{ ft } (4.8 \text{ m})$$

6. Now draw a grid and locate heads at grid intersections.

You can see Figure 18.13 that we are using two more heads for square spacing than for triangular spacing, and we are not getting the uniform coverage that triangular spacing gives us!

## Triangular Spacing in Narrow Spaces

Triangular spacing works in narrow spaces such as medians, boulevards, and that space between the sidewalk and curb. Strip-pattern spray heads that put out water in rectilinear patterns are also useful for watering narrow spaces. The only drawback to the strip spray is that its pattern is easily disrupted by any kind of wind, so it is best to use triangular head spacing.

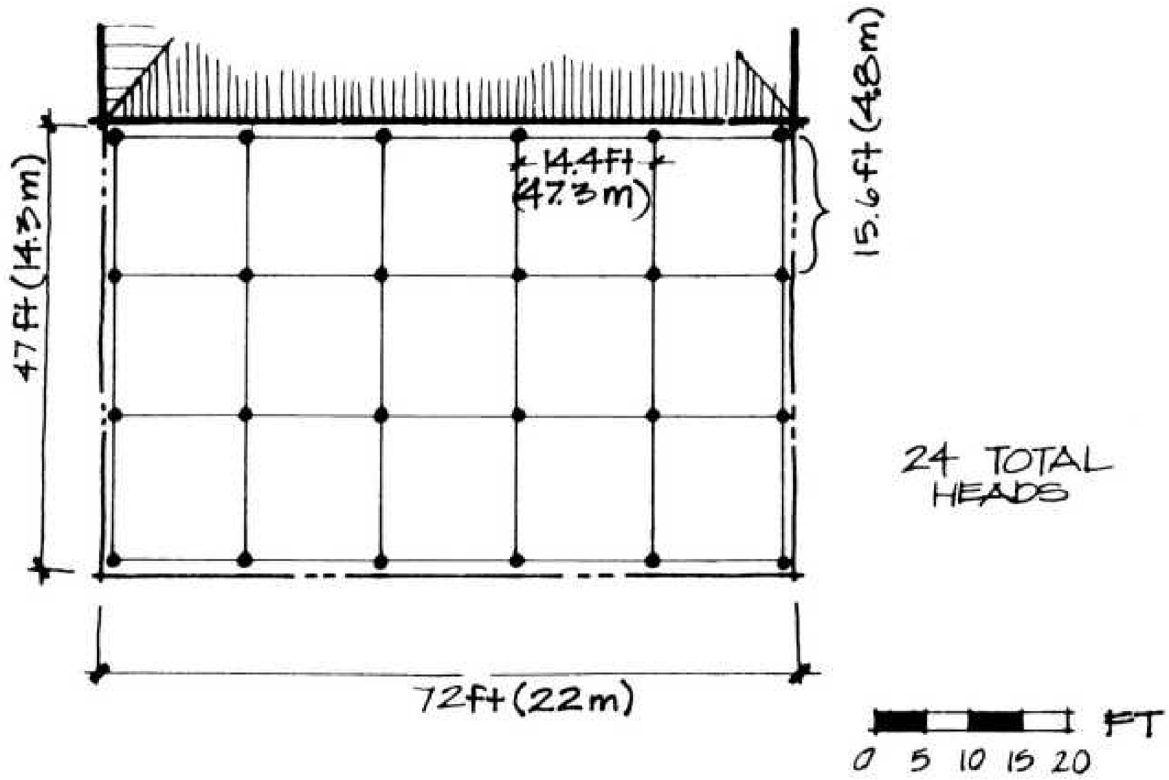


FIGURE 18.13 Square spacing.

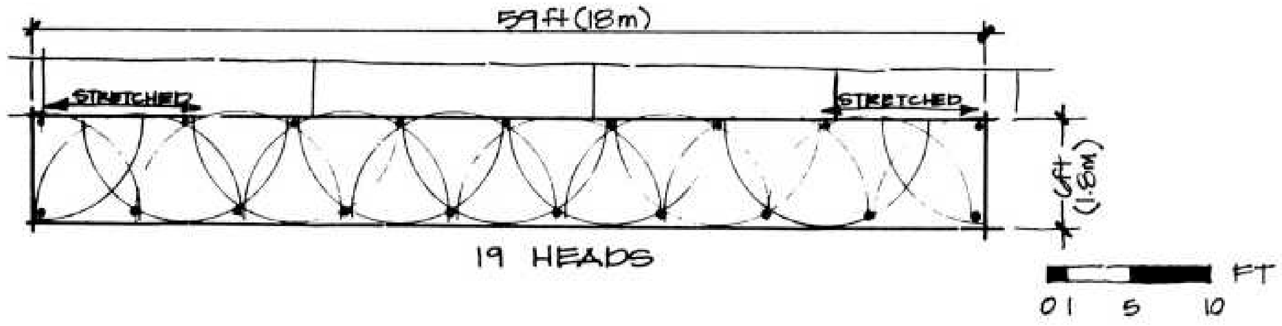
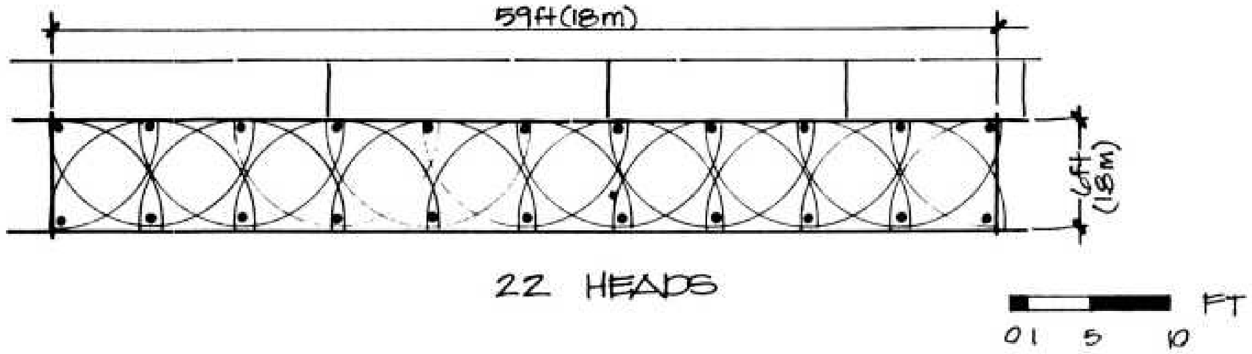


FIGURE 18.14 Narrow space triangular head layout.



4MPH (6.4km/h) WIND = 50% DIAMETER
.50 X 12ft (3.7m) DIAM. = 6ft (1.8m) IDEAL HEAD
SPACING FOR SQUARE LAYOUT.

FIGURE 18.15 Narrow space square head layout.

Let us look at a 6-ft (1.8-m) wide by 59-ft (18-m) long space. We will use a spray head with a radius that we can reduce to 6-ft (1.8-m), or a 12-ft (3.7-m) diameter. In a 4-mph (6.4-km/h) wind, we space our heads 55% of the spray head diameter (0.55 X 12 ft [3.7 m] = 6.6 ft [2 m]). The 6.6 ft (2 m) is our ideal head spacing. Now let us lay out our heads. We see in Figure 18.14 that we will use 19 heads. We will have a little overspray on each end, but it is so little as to be insignificant.

Now let us compare our triangular head layout with square head layout. To irrigate the same space,

you can see in Figure 18.15 that we use three more heads and do not get the ideal coverage that triangular spacing gives us. In fact, we waste water with square spacing.

In conclusion, try to use triangular spacing whenever possible because of its uniform watering capability. Most designers and contractors use triangular spacing whenever they can. Some designers save triangular spacing for irregular shapes and larger turf areas. As a designer, you must become familiar with triangular head layout and, through your experiences, decide for yourself where triangular spacing can best be used.

# 19

# Soils and Irrigation

## Introduction

It is plain and simple: If you do not understand at least a little about the nature of soils and how they act as an environment for plant roots, then you will be incapable of doing accurate irrigation design.

## Soil Water-Holding Abilities

Soil provides three essential things to plants:

1. A firm foothold

2. Food

3. Water

Let us explore in detail how soils hold water. The capacity of a soil to hold water long enough for plants to use it and not dry out too quickly is of prime concern. Water is held in the soil in two ways. The organic matter in the soil, for example, ground-up leaves or shredded bark, will soak up water and act in much the same way as a sponge. Organic matter, or humus, is essential for good soil.

The second way water is held in the soil is by mineral particles. When the mineral particles get wet, they hold on to a thin coating of water by surface tension. This is true whether we are talking about sandy soils or clay soils. Sandy soils are composed of big particles and therefore do not hold a large amount of surface tension water. Because clay soils are composed of so many microscopic particles, they hold significantly more tension water than the sandy soils. In fact, clay soils will actually expand when they get wet because of water held by surface tension on the mineral particles. When clay soils dry out, they shrink and crack.

We can conclude that soils with clay in them will hold more water than soils that are predominantly sandy in nature. Clay soils will also hold water longer than sandy soils. If you apply 1 in (25 mm) of water to a sandy soil, the top 12 in (305 mm) will be dry in only five days. Apply 1 in (25 mm) of water to a clay soil, and the top 12 in (305 mm) will take about 15 days to dry. Clay soils take over three times as long to dry out as do the sandy soils. When a clay soil does dry out, it usually cracks severely and requires slow soaking to become full of water again.

The drying out and cracking of clay soils can be devastating to plant roots.

## Ideal Soil Composition

An ideal garden soil is composed of the following five elements:

1. Rock and minerals (sand and clay)
2. Organic material (leaves and animal matter)
3. Living organisms (bacteria, fungi, worms)
4. Air
5. Water

These five elements are usually found in the top 6 in to 12 in (152 mm to 305 mm) of soil, which is called topsoil. Undisturbed soils found in nature usually conform to a typical soil profile, which reflects how the soils have developed over time. If you were to dig a 5-ft (1.52-m) pit and examine the layers of a typical soil, you would see something like the profile in Figure 19.1.

The topsoil is where the greatest amount of organic matter and biological activity is to be found. This is where the most oxygen is located and where the greatest amount of plant roots are found. Good topsoil is half air. It is an open soil where roots proliferate. The topsoil, simply, is where the action is! Because plant roots concentrate their feeding and drinking activities in the topsoil, this is the soil layer with which we need to be most concerned. Thus, we have the opportunity to influence the root environment either by modifying existing topsoil or creating a new topsoil layer.

So, when we are talking about an ideal soil, we are talking about that 6 in to 12 inch (152 mm to 305 mm)

topsoil level. Not all soils have well-composed topsoil or even topsoil at all. A good gardener will evaluate the topsoil and modify it to create an ideal root environment.

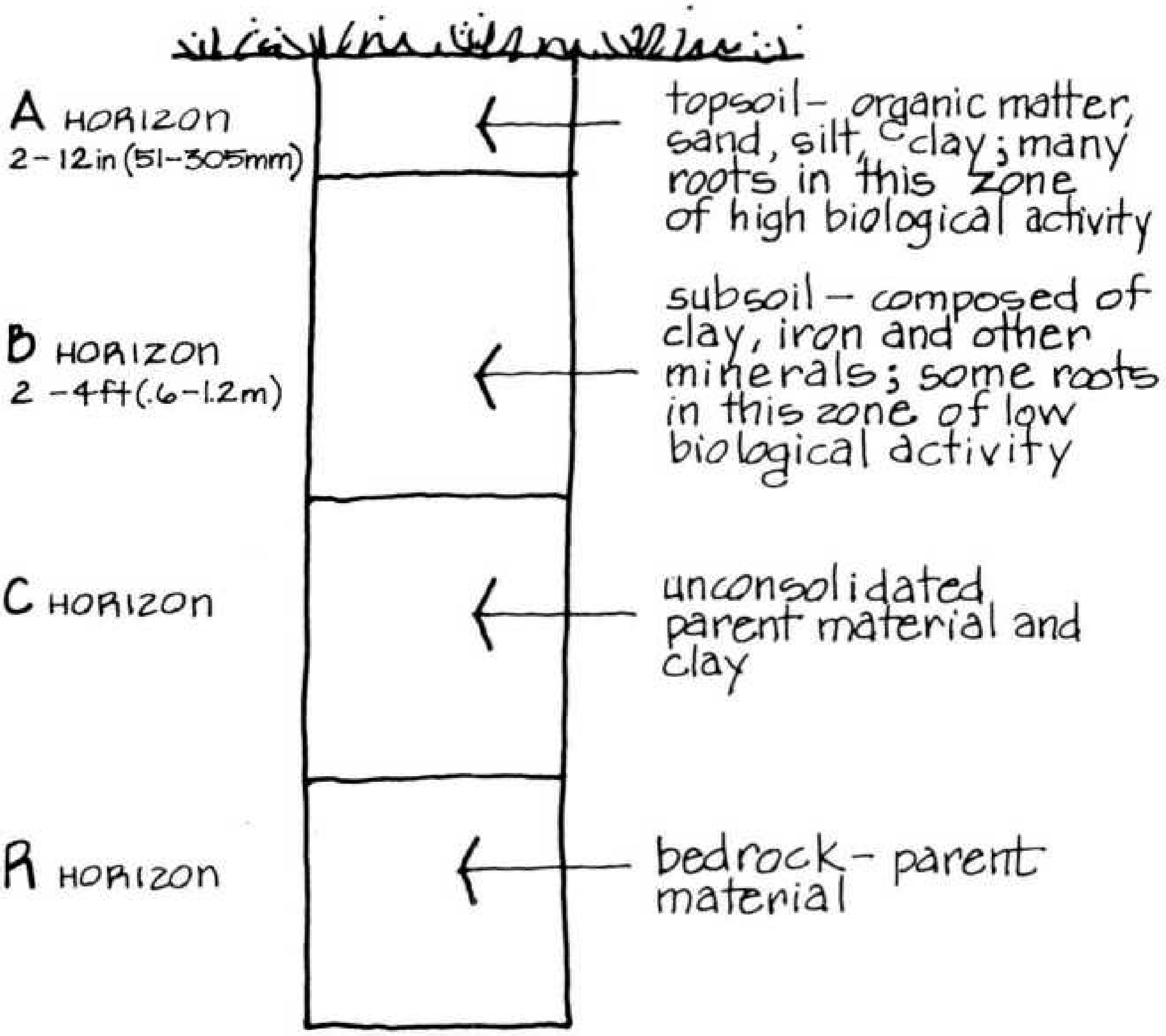


FIGURE 19. 1 Soil profile.

**Clay Soils**

In some areas you might have a topsoil layer composed of mostly clay with a little organic matter. In my landscape, I have clay soils with poor drainage. Clays, recall, are composed of microscopic particles and are usually so dense that rainfall moves very slowly into the soil. I recently dug a 12-in (305-mm) pit in my lawn area and filled it with water. I wanted to know the permeability rate, or how many inches of water per hour would move into the soil. After letting the water set for 24 hours, the water level dropped less than 1 in (25 mm), which indicates a very slow permeability rate. Many clay soils have a permeability rate of from 0.2 in to 0.6 in (5 mm to 15 mm) per hour. In order to create an ideal soil for plant roots, I would have to make some major changes.

## Sandy Soils

In contrast to clay soil, let us say we are working with a sandy soil. Remember, water moves very easily into a sandy soil. Some sandy soils have a permeability rate of from 2 in to 6 in (51 mm to 152 mm) per hour, which is a high rate. A golf green, which is mostly sand, is constructed to have an ideal permeability rate of 4 in to 6 in (102 mm to 152 mm) per hour. Recall that even though a sandy soil is an easy, airy place for roots to grow, it dries out very quickly. In addition, because water moves so quickly through the soil, nutrients tend to get washed through the soil beyond the grasp of plant roots. This is known as leaching. Sandy soils have the reputation of being low in fertility because of this leaching problem.

The ideal soil, therefore, is a combination of both clay and sandy soils with the addition of organic matter. We will call this ideal soil a loam soil.

## Loam Soils

A good loam soil is sandy enough to drain well and has enough clay to hold water reserves. Humus improves the soil texture. Add peat moss, leaf compost, manure, or straw to a sandy soil, and it clogs the soil pores, thereby slowing drainage. Add humus to clay, and it opens the soil and creates soil pores, thereby allowing water and air into the soil. The humus creates an environment that is conducive to plant root growth.

The loam soil you will create will be dark in color, easy to dig, and will be an ideal root growth medium; it will also smell good. The soil will also be an adequate water-holding medium. Recall that when 1 in (25 mm) of water was placed on sandy and clay soil, the top 12 in (305 mm) of the sandy soil dried out in 5 days, whereas the clay soil dried out in 15 days. When 1 in (25 mm) of water is placed on a loam soil, it will take 10 days for the top 12 in (305 mm) of that soil to dry out. The loam soil is the ideal garden soil we should try to create for optimum plant growth.

## Mulching

Just as it was important for you to know about soils and their water-holding abilities, it is important for you to know the benefits of mulching your plant beds. Mulching is an important part of managing a landscape. A 4 in to f in (102 mm to 152 mm) layer of organic mulch will prevent evaporation of water from the soil, suppress growth of weeds, and gradually add humus to the soil as the mulch decomposes. Mulch can also impart a soft, freeform curve to a flower bed and impart the effect the designer wants to convey.

Be careful not to put more than 4 in to 6 in (102 mm to 152 mm) of mulch on a plant bed. If the mulch

is too thick, plant roots will grow into the mulch, and when drought, irrigation system breakdown, or a bad winter freeze occurs, the plants will not be able to survive. Mulching is an important method of water conservation.

## Water Availability

The last subject we will discuss relates to soils and water availability. Let us begin the discussion with a question. Would it be best to have a constant source of water either as a constantly high water table or through repeated irrigation so that plants can have water anytime they want it? The answer is no. Roots need air as much as they need water. Waterlogged soils have no air in them. A consistently high water table or constant irrigation restricts plant roots to the area just below the soil's surface where the roots become subject to damage caused by changing weather, droughts, and malfunctions in the irrigation system.

It is a fatal mistake to water plants a small amount on a frequent basis. This causes roots to concentrate at the surface where the water is available. The golden rule of watering is to water plants as infrequently as possible, but to water them thoroughly when you do. In other words, water deep and long. This causes roots to go deeper for water and enables the plant to be more tolerant of droughts.

# 20

# Pipe Loops

## Introduction

There are two ways to lay out pipe in an irrigation design, the in-line method and the loop method. The piperouting technique we have reviewed thus far is the in-line method. Figure 20.1 illustrates an in-line piperouting example.

The pipe loop is used when you need to reduce your friction losses or your pipe sizes. If you are designing an irrigation plan for a client and the static water pressure available is not very high, you might want to use a loop to reduce friction loss. In another situation you might be designing an irrigation plan with circuits that have high flow demands. Of course, the higher the gpm (L/min) flow you have, the larger the pipe you will need to carry the flow. A pipe loop will

usually cut required pipe sizes in half, which can save your client money.

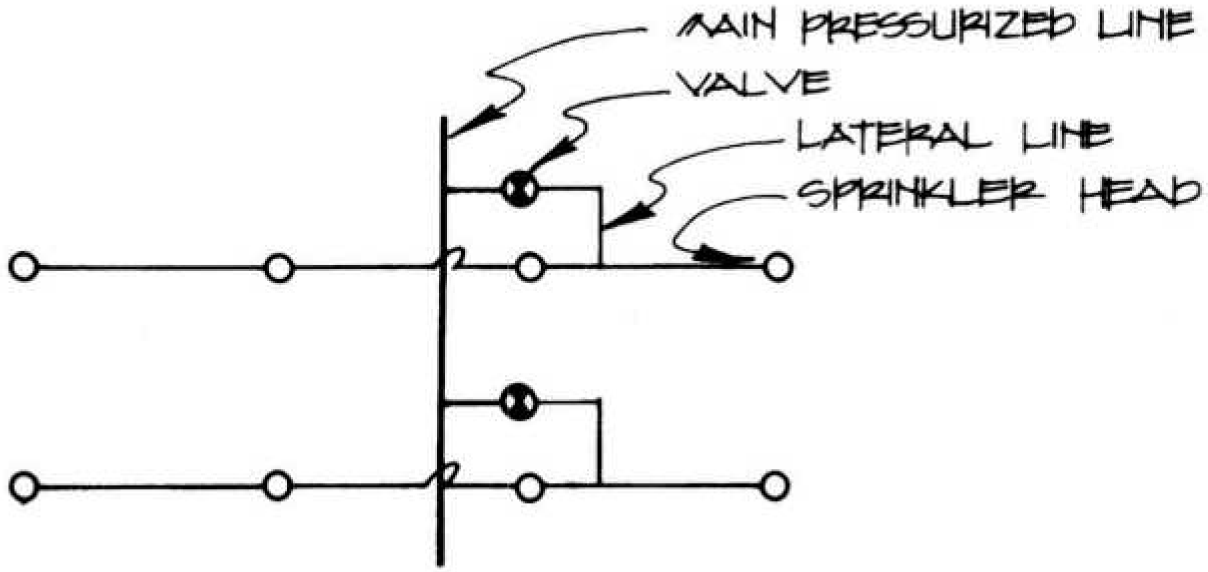


FIGURE 20. 1 In-line pipe routing.

## In-Line Friction Loss

Let us look at an in-line pipe layout and calculate friction loss. Figure 20.2 shows a pipe with a valve at one end and a sprinkler head that demands 20 gpm (75.7 L/min) at the other end. For our example we will use a 400-ft (121.9-m) long, 1%-in (32-mm) Class 200 PVC pipe. Looking at the friction loss chart in Appendix I, we see that we have 1.5 psi (0.11 kg/cm2) loss per 100 ft (30.5 m) of pipe at 20 gpm (75.7 L/min) flow. Our total friction loss along the 400-ft (121.9-m) length of pipe is therefore 6 psi (0.42 kg/cm2). Now let us compare this in-line friction loss with loop friction loss.

## Loop Friction Loss

Our loop has the same flow and pipe length as our inline system. You can see in Figure 20.3 that each side of the loop is 400 ft (121.9 m) long. The sprinkler head at the opposite end of the valve demands 20 gpm (75.7 L/min). You can see in the illustration that when the valve opens, the flow to the sprinkler head divides into 10 gpm (37.9 L/min) along each side of the loop. Looking at the friction loss charts for a 10 gpm (37.9 L/min) flow, we can use either 1-in (25-mm) pipe or 1 '/4-in (32-mm) pipe. Let us compute the friction loss for both sizes.

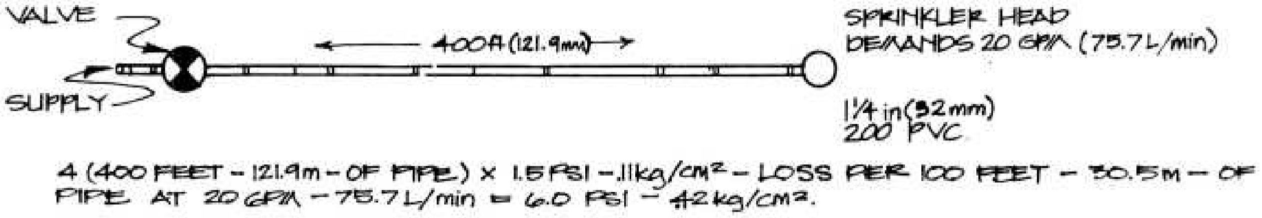


FIGURE 20.2 In-line pipe layout.

10 gpm (37.9 L/min) flowing through 1-in (25-mm) pipe =
1.3 psi (0.09 kg/cm$^2$) loss per 100 feet (30.5 m) of pipe.

4 (400 ft [121.9 m] of pipe) × 1.3 =
5.2 psi (0.37 kg/cm$^2$) total friction loss.

10 gpm (37.9 L/min) flowing through 1¼-in (32-mm) pipe =
0.42 psi (0.03 kg/cm$^2$) loss per 100 ft (30.5 m) of pipe

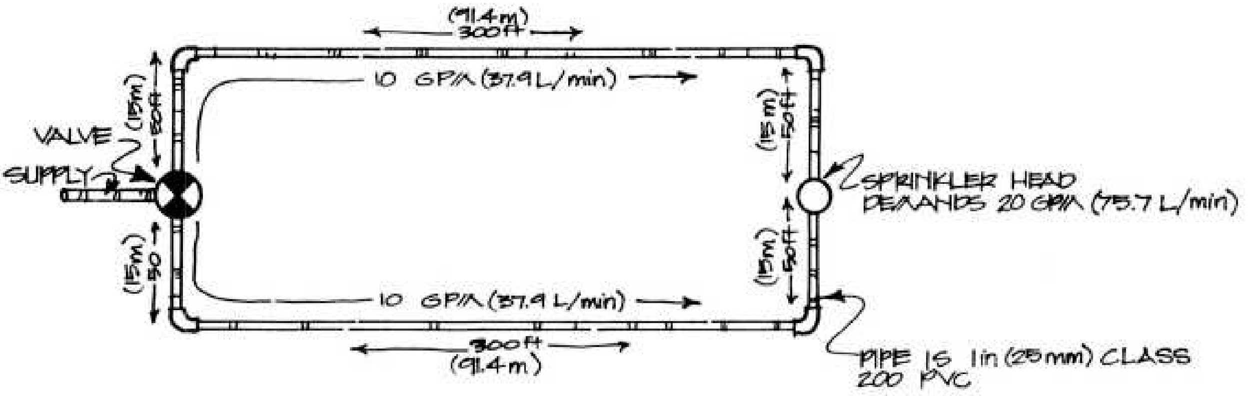
4 (400 ft [121.9 m] of pipe) × 0.42 =
1.68 psi (0.12 kg/cm$^2$) total friction loss.

If the water pressure had been low, we would have used the 1 4-in (32-mm) pipe. Because we had plenty of water pressure to work with, we used the 1-in (25-mm) pipe to save on material costs. Note that by using the 1-in (25-mm) pipe, we not only use smaller pipe than in the in-line example but we also have a lower friction loss figure as well.

In our loop example, where the distance from the valve to the sprinkler head is equal on both sides, the water flow splits into two equal parts.

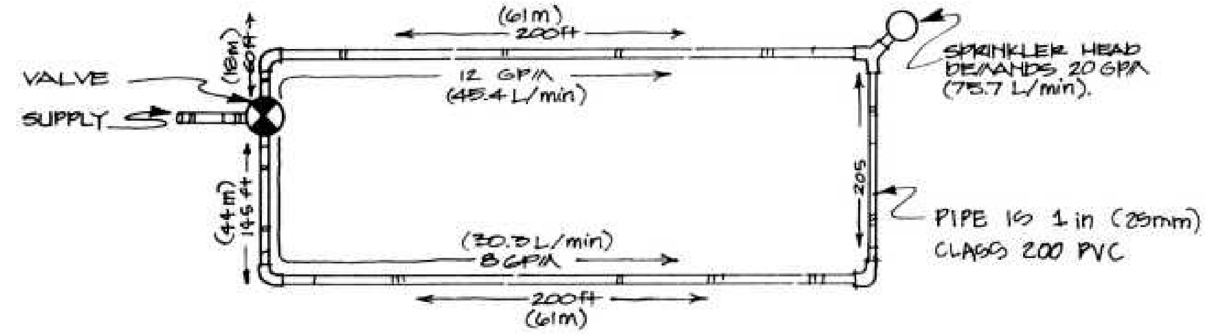
## Unbalanced Loop

Now let us look at a loop where the length of paths from the valve to the sprinkler head are not equal. In Figure 20.4 we have 260 ft (79.3 m) from the valve to the sprinkler head on one side and 550 ft (167.7 m) on the other side. Note that we are using the same 1-in (25-mm) pipe size throughout the loop. You can see that more gallons (liters) per minute of water flow through the shorter leg of the loop than through the longer leg. This is what happens to the flow in an unbalanced loop. Even though the flows are different along the legs of an unbalanced loop, the friction loss balances on both sides, as you can see in the friction loss computations in Figure 20.4. Here's a rule, or axiom, concerning the use of loops:



4 (400 FEET - 121.9m - OF PIPE) × 1.3 PSI - .09kg/cm² - LOSS PER 100 FEET - 30.5m - OF PIPE AT 10 GPM - 37.9L/min - = 5.2 PSI - .37kg/cm² LOSS.

FIGURE 20.3 Loop pipe layout.



TOP LEG - 2.6 (260 FEET - 79.3m - OF PIPE) × 1.84 PSI - .13kg/cm² - LOSS PER 100 FEET - 30.5m OF PIPE AT 12 GPM - 45.4 L/min - FLOW = 4.78 PSI - .37kg/cm² - LOSS.

BOTTOM LEG - 5.5 (550 FEET - 167.7m - OF PIPE) × .86 PSI - .06kg/cm² - LOSS PER 100 FEET - 30.5m OF PIPE AT 8 GPM - 30.3 L/min - FLOW = 4.73 PSI - .33kg/cm² - LOSS.

FIGURE 20.4 Unbalanced loop.

Where there is more than one path for water to flow to the demand point, the friction loss will be equal or nearly equal along both paths.

## Friction Loss Calculation

If you want to calculate your friction loss in an unbalanced loop where the pipe is all the same size, base your calculations on one-half of the gpm (L/min) flow of the largest circuit and one-half the total length of the loop. This is a rule-of-thumb technique that includes a safety factor of approximately 10%.

Let us apply this method to the unbalanced loop in Figure 20.4. Our total flow was 20 gpm (75.7 L/min), and the total length of the loop was 810 ft (247 m). Therefore, when we take one-half of the flow and pipe length, the result is a flow of 10 gpm (37.9 L/min) and a pipe length of 405 ft (123.5 m) on which to base our friction loss computations. Looking at the Class 200 friction loss chart, we see that we have a friction loss of 1.3 psi (0.09 kg/cm2 per 100 ft (30.5 m) of pipe at 10 gpm (37.9 L/min) flow using 1-in (25-mm) pipe. Now let us multiply:

1.3 psi [0.09 kg/cm$^2$] (loss per 100 ft [30.5 m]) × 4.05 (405 ft [123.5 m] of pipe) = 5.3 psi (0.37 kg/cm$^2$) loss in the loop.

Recall that in Figure 20.4 we had a friction loss of 4.78 psi (0.37 kg/cm2) along the top leg of the loop and 4.73 psi (0.33 kg/cm2) along the bottom leg of the loop. After completing complicated engineering calculations, we knew how the flow would split in the unbalanced loop. Therefore, our calculation of friction loss for each leg of the loop was nearly exact. The rule-of-thumb method, which divides the total flow and pipe length in half, computed it to be 5.3 psi (0.37 kg/cm2). This figure has a 0.53 psi (0.04 kg/cm2) (5.3 psi - 4.73 psi = 0.53 psi; 0.37 kg/cm2 - 0.33 kg/cm2 = 0.037 kg/cm2) safety factor built in. If you knew exactly how your flow would divide, you could precisely figure friction loss along a loop. Using the rule-ofthumb method is an easy, fast, and sufficiently accurate way to figure friction loss in an unbalanced loop.

## Comparison of In-Line and Loop Pipe Routing

In Figures 20.5 and 20.6, we are illustrating an in-line and loop layout for a large residence. The valve circuits are the same in each example; only the configuration of the mainline pipe changes. The largest circuit demands 40 gpm (151.4 L/min). You can see in the in-line example that the mainline pipe has to be sized large enough to carry the 40 gpm (151.4 L/min). We selected a 2-in (51-mm) Class 200 pipe to carry the 40 gpm (151.4 L/min) flow at 0.94 psi loss per 100 ft (30.5 m) of pipe.

If a loop were used instead of the in-line layout, we would size the entire loop based on one-half the flow of the largest valve circuit. In this example, for a 20-gpm (75.7-L/min) flow (one-half of 40 gpm [ 151.4 L/min] ), the best pipe size to use would be 1% inch (32 mm), and our friction loss for the 20 gpm (75.7 L/min) flow would be 1.5 psi (0.11 kg/cm2) per 100 ft (30.5 m) of pipe. You can see that by using the loop, we have re duced our pipe size from 2 in (51 mm) to 1%-in (32 mm). Because 2-in (51-mm) pipe costs almost twice as much as the 1%-in (32-mm) pipe, we will save money. Our friction loss will be slightly higher using 1%-in (32mm) pipe. We could have selected 1! -in (38-mm) pipe, which has a friction loss of 0.78 psi (0.06 kg/cm2) per 100 ft (30.5 m), and our friction loss would have been lower than with the 2-in (51-mm) pipe.

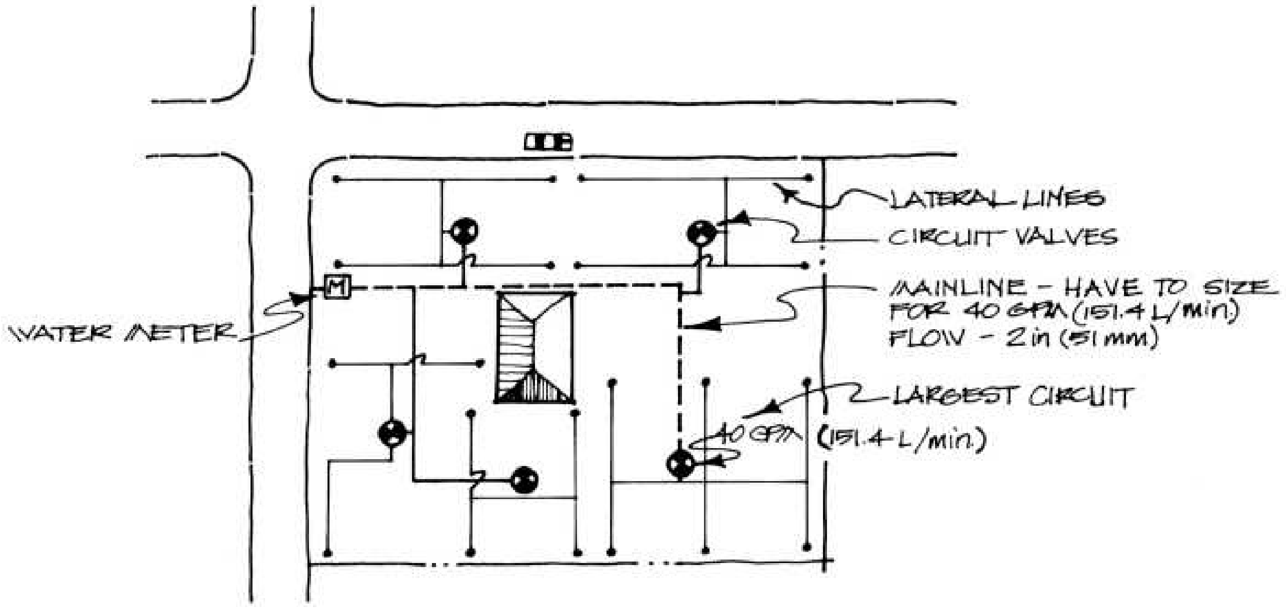


FIGURE 20.5 In-line pipe layout-residential landscape.

## Summary

Remember, when you use a loop, the friction loss will be the same or nearly the same along both its legs. The flow to your demand points splits along both legs of the loop. This reduced flow allows you to use smaller pipe and have less friction loss.

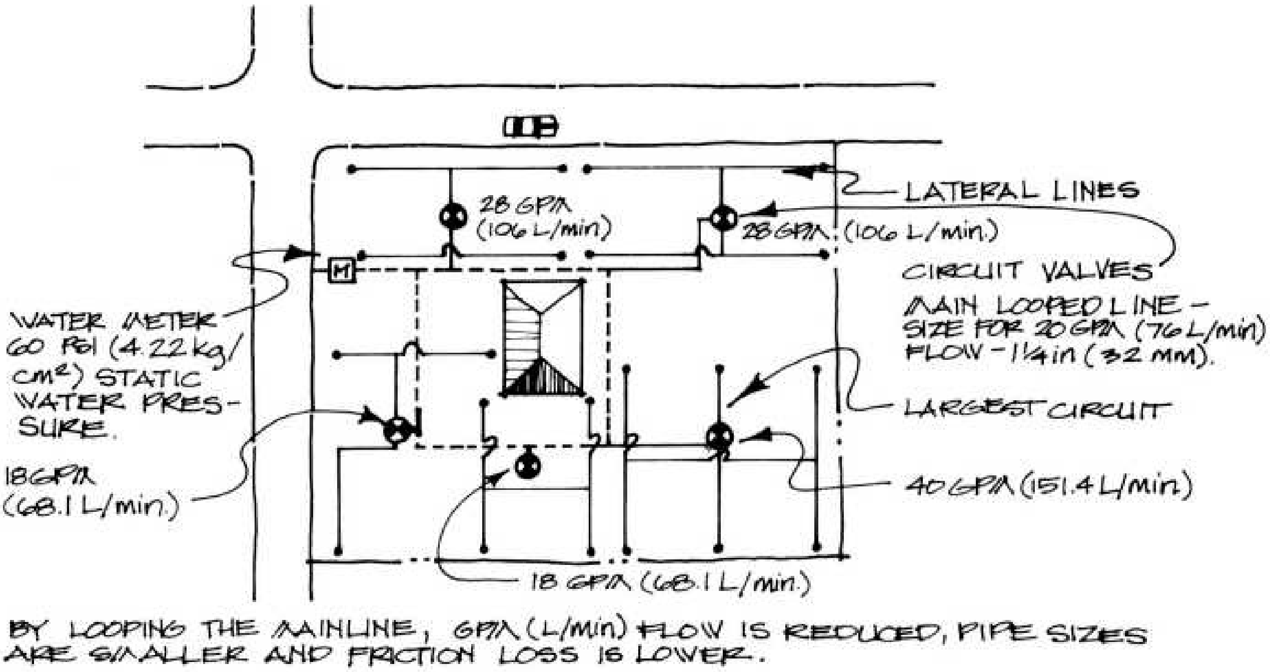


FIGURE 20.6 Loop pipe layout residential landscape.

# 21

# Fittings for the Irrigation System

## Introduction

Fittings are to an irrigation system what mortar is to a brick wall. Both hold the whole works together! Fittings connect irrigation pipe and allow for the addition of valves and sprinkler heads. Some fittings are made with slip joints where pipe is slipped into the fitting and glued, and others have threaded joints where pipe is screwed together. Some fittings are a combination of slip and threaded joints. Although this may initially sound confusing, we hope to slay the dragon of ignorance about fittings in this chapter.

## Description of Fittings

Fittings are used to turn corners, change vertical directions, reduce pipe sizes, cap pipes, repair pipes, and connect sprinkler heads and valves to pipe. PVC fittings are made either to be glued or screwed into PVC pipe. Before we get into a specific review of fittings and their uses, let us look at four- terms that you need to know in order to understand fittings and how they are connected.

1. Slip fittings-With slip fittings, PVC is slipped into a fitting socket and glued. The fittings are designated by the word slip.
2. Threaded fittings-These are PVC fittings that are threaded and designated either MPT or FPT. See the following terms for further understanding.
3. Male pipe threads (MPT)-These fittings have threads that will screw into another fitting (see Figure 21.1) .
4. Female pipe threads (FPT)-This term relates to the position of the threads; the female threads are inside a pipe (see Figure 21.2).

Now we are going to review a variety of fittings and how they are used. In the explanation of fittings, we are going to convey ways in which irrigation contractors use different fittings.

90° Slip Elbow. This fitting is used for changing directions with pipe either vertically or horizontally (see Figure 21.3). It is used for connecting lateral and main pipe lines at different depths and for turning corners. A 90° slip elbow could be used to connect a 2ft (0.6-m) deep pipe under a drive with a 12-in (0.3-m) deep pipe in a lawn area. Pipe is inserted in each end of the fitting and glued. The photograph in Figure 21.4 shows a slip elbow and other fittings in use.

90° Threaded Elbow. This fitting is good for attaching the last sprinkler head on a pipe run to a flexible swing joint (see Figure 21.5). To attach the swing joint, turn the threaded part of the elbow up and screw a barbed male adapter or a barbed male elbow into the female pipe threads (FPT). Next, attach flexible PE pipe to the barbed portion of the male adapter and then attach another barbed male elbow to the flexible pipe. The swing joint is then ready to screw into the bottom of a sprinkler head. The slip portion of the 90° threaded elbow is slipped onto the pipe section and glued. Figure 21.6 shows a barbed male elbow screwed into a saddle fitting.

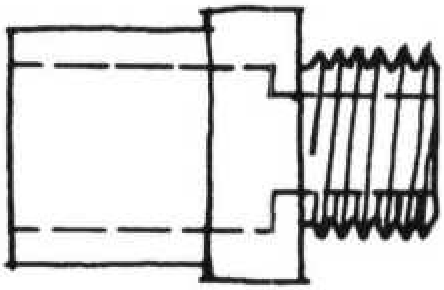


FIGURE 21.1 Male pipe threads.

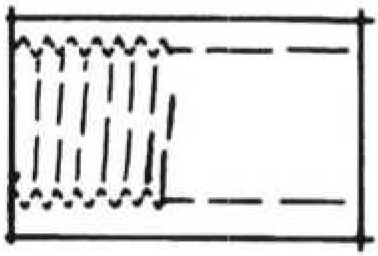


FIGURE 21.2 Ferrule pipe threads.

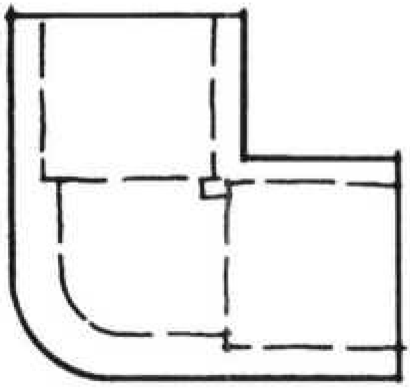


FIGURE 21.3 90° slip elbow.

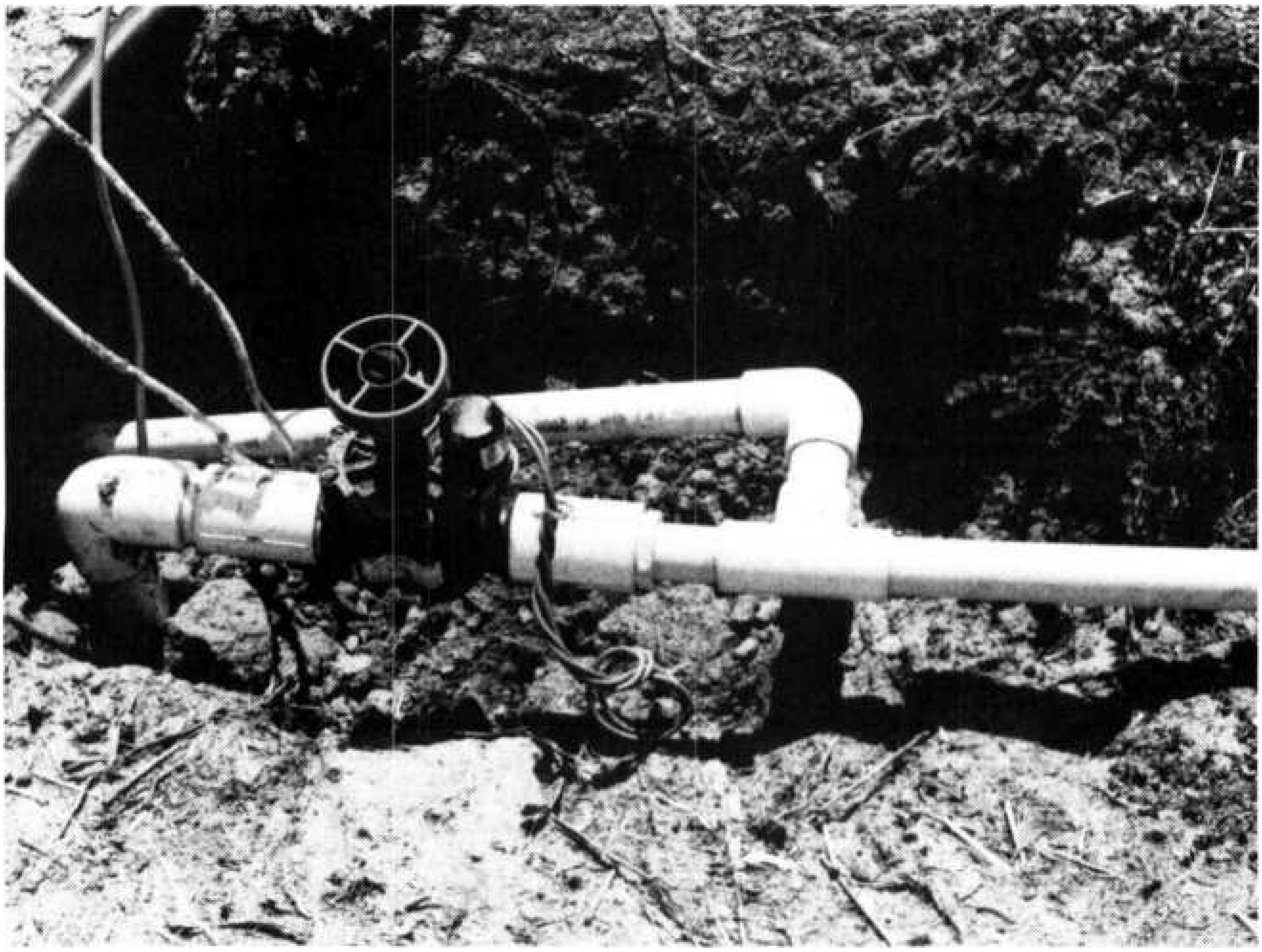


FIGURE 21.4 Various fittings in use.

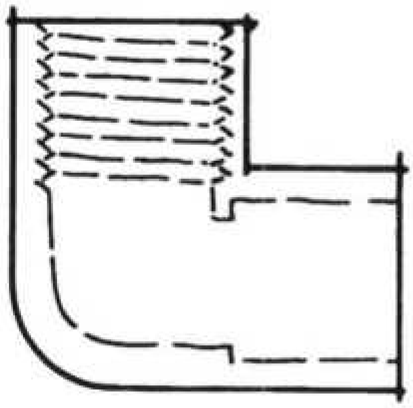


FIGURE 21.5 90° threaded elbow.

Rigid Nipples. A nipple is defined as a "small protuberance or extension." They are used as an extension in the construction of swing joints, where the nipple connects two threaded street elbows (see Figure 21.7). Nipples are also used to raise a sprinkler head that has been set too deep.

Flexible Riser. The flexible riser is a PE fitting that is used a great deal on lateral lines (see Figure 21.8). The flexible riser is used like a rigid nipple is used, but it has an additional feature in that it can be cut off to fit the size of extension needed. The flexible fitting is used to connect to bubblers and fixed spray heads. Flexible risers will bend and pop back to their original shape when stepped on. Figure 21.9 shows flexible risers attached to saddle fittings on a lateral line.

Barbed Male Adapter. This is a PE fitting that is used to connect flexible polyethylene pipe to PVC pipe (see Figure 21.10). The barbed male adapter is used when you want to put a sprinkler head at the end of a pipe run. The fitting is screwed into the end of a PVC reducing threaded elbow, and the PE pipe is inserted over the fitting barbs. The PE pipe then connects to another barbed male adapter or elbow. The barbed male fitting is then screwed into a sprinkler head.

FIGURE 21.6 Barbed male elbow screwed into a saddle.

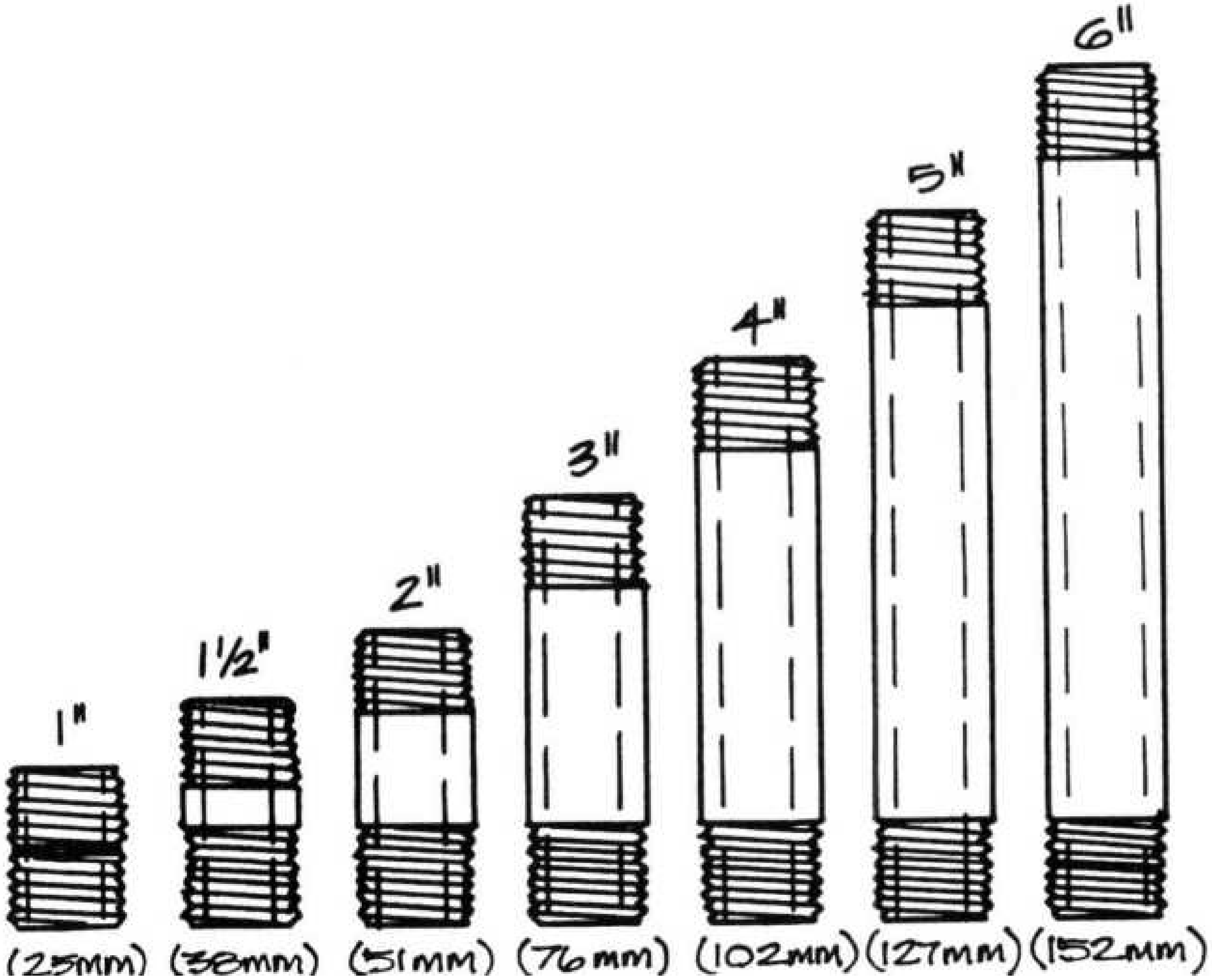


FIGURE 21.7 Rigid nipples.

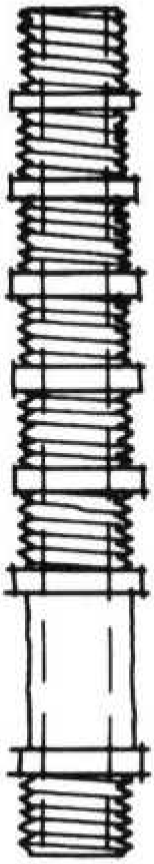


FIGURE 21.8 Flexible riser.

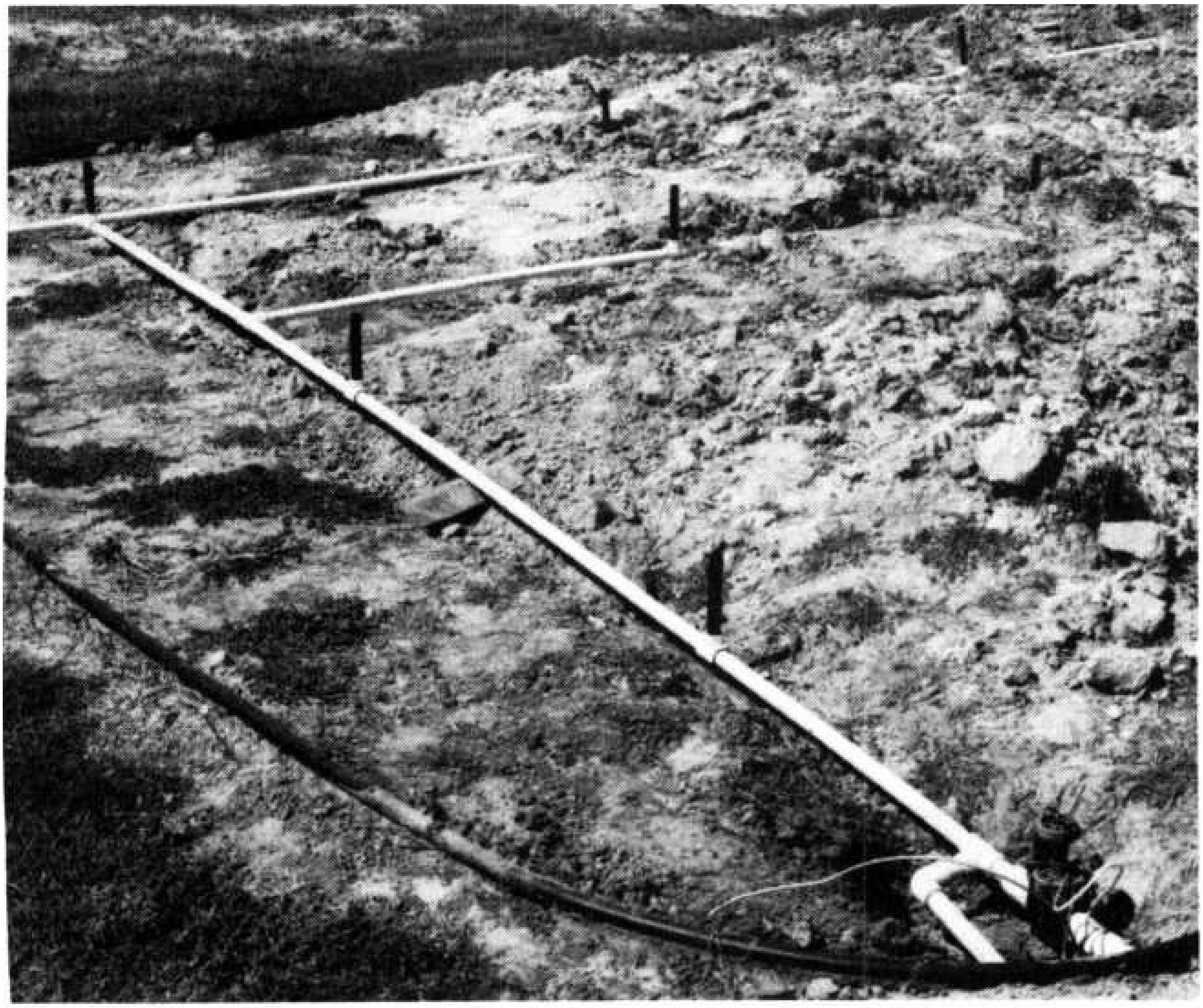


FIGURE 2 1.9 Flexible risers screwed into saddles.

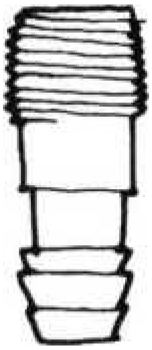


FIGURE 21.10 Barbed male adapter.

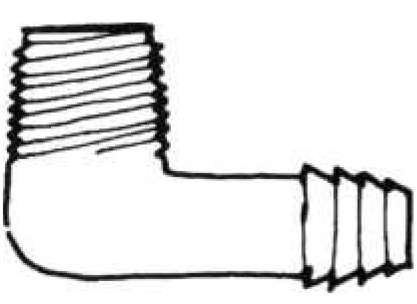


FIGURE 21.11 Barbed male elbow.

Barbed Male Elbow. Also a PE fitting, the barbed male elbow (Figure 21.11) is used to attach PE flexible swing pipe to a PVC threaded tee. The elbow screws into the threaded tee, and the PE pipe is pushed onto the barbed fitting. The barbs hold the pipe in place without leaking. Figure 21.12 shows a barbed male elbow and flexible pipe swing joint.

Reducing 90° Threaded Elbow. The slip side is the larger side of this fitting, and the female pipe threads are on the smaller side (see Figure 21.13). The fitting is good for adding a sprinkler head on the end of a pipe run. Slip the elbow on the pipe and glue it. Screw a barbed male adapter with MPT into the FPT side of the fitting. Do not use Teflon tape for this connection. The barbed portion of the male adapter is for PE flexible pipe attachment.

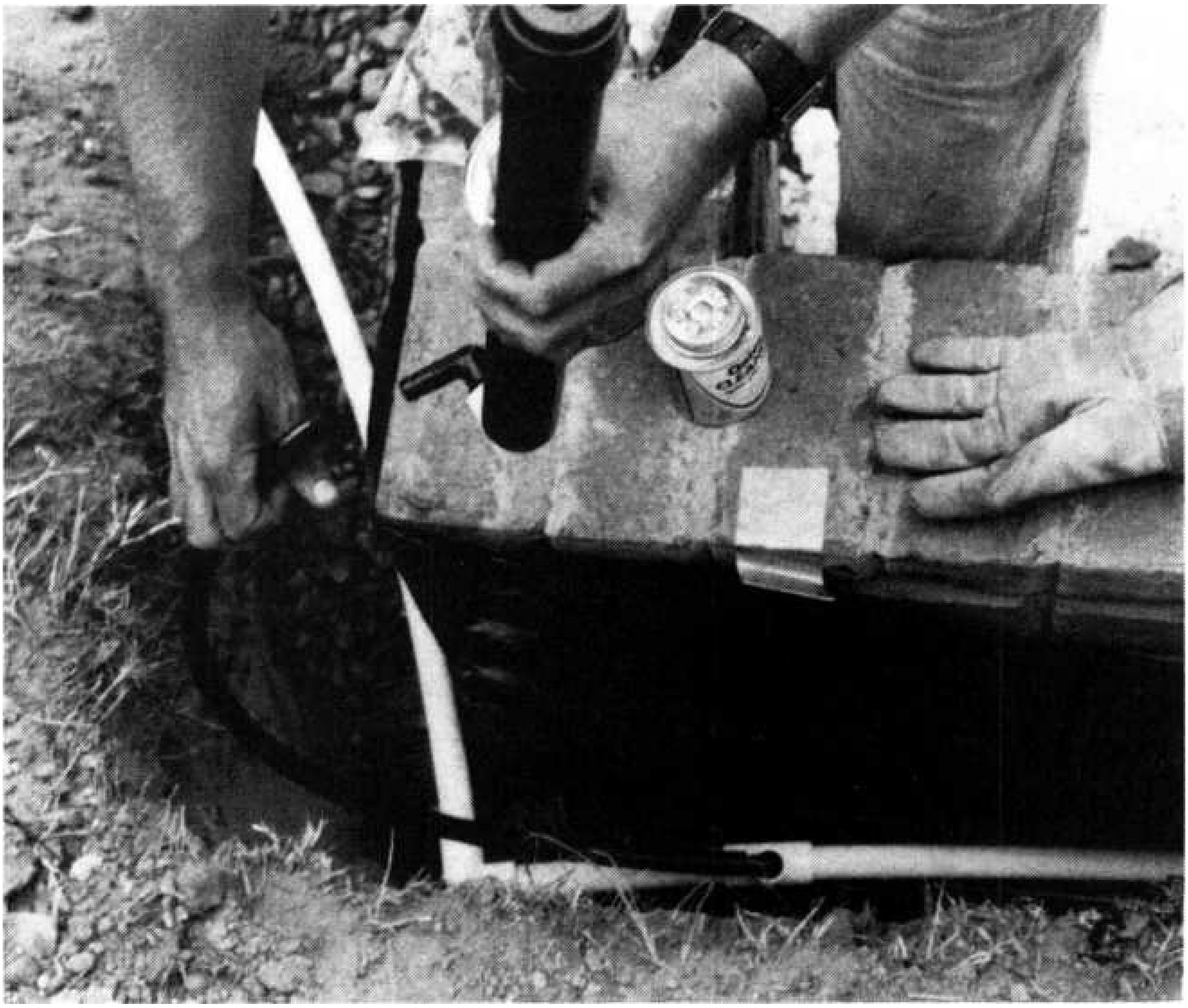


FIGURE 21.12 Barbed male elbow and flexible pipe swing joint.

Slip Reducing Tee. This fitting is good for connecting the mainline to a lateral line when you are reducing line size (Figure 21.14).

Reducing Threaded Tee. This threaded tee (Figure 21.15) is best used for adding a sprinkler head on a lateral line where you would use the barbed male elbow connection. Glue PVC pipe to the slip joints and screw the male elbow into the threaded portion of the tee.

Slip Coupling. This is a basic fitting used to attach two pieces of pipe together (Figure 21.16).

Female Adapter. The female adapter (Figure 21.17) is mainly used to connect a valve or backflow preventer that has male pipe threads to a pipe line. It is also useful when you have threaded galvanized or brass pipe and you want to switch to PVC pipe.

Male Adapter. This fitting (Figure 21.18) is used to attach a sprinkler body to PVC pipe. Most sprinkler bodies have FPT, into which the male adapter can be screwed. You then glue the adapter to PVC pipe. The male adapter is also used on automatic valves. Most automatic valves have FPT. Where there is a constant pressure condition, use Teflon tape on threaded connections. Be careful when threading brass to PVC fittings; cross threading will ruin the plastic fitting. Brass is stronger than the PVC fitting, and it will strip the threads.

Threaded Plug. This fitting (Figure 21.19) is good for plugging a reducing threaded tee to which you might want to add a sprinkler head at a later date. Anytime you want to seal a threaded hole, the threaded plug is what is used.

Slip Plug. The slip plug is used where you have a tee, cross, or elbow fitting you want to seal (Figure 21.20).

Slip Cap. Slip caps (Figure 21.21) are used for capping the end of a line. They are also good for emergencies; if you have a problem, you can cap it and fix it later.

Slip Tee Reducing. This fitting (Figure 21.22) is similar to other reducing tees. Its use depends on which direction you want your reduced pipe line to run. It is used where your mainline makes a 90° turn and you also need to go straight with a smaller pipe line. The fitting is seldom used because of having to stock four or five sizes. It is easier to stock slip tees and use a reducing bushing fitting.

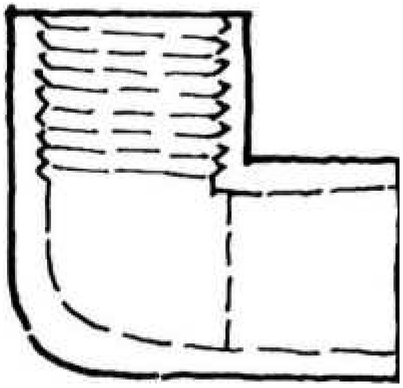


FIGURE 21.13 Reducing 90° threaded elbow.

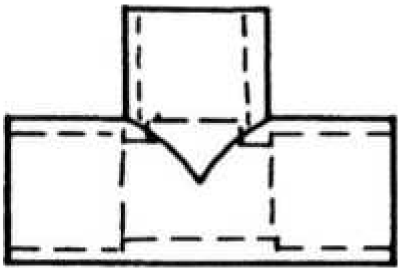


FIGURE 21.14 Slip reducing tee.

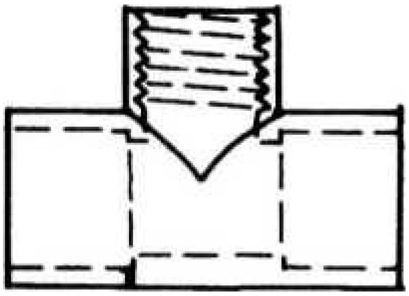


FIGURE 21.15 Reducing threaded tee.

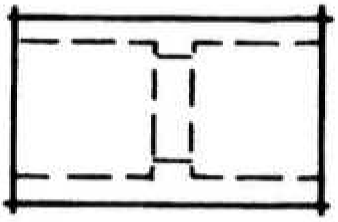


FIGURE 21.16 Slip coupling.

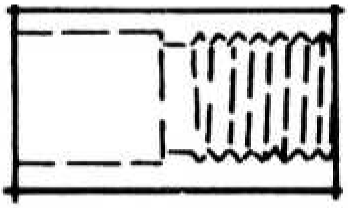


FIGURE 21.17 Female adapter.

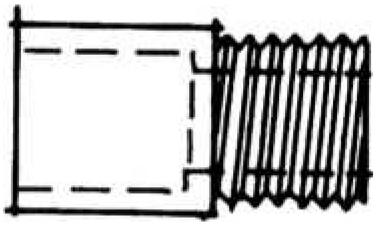


FIGURE 21.18 Male adapter.

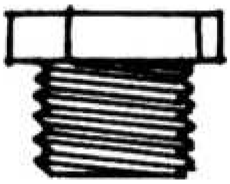


FIGURE 21.19 Threaded plug.

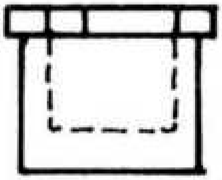


FIGURE 21.20 Slip plug.

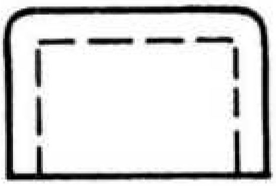


FIGURE 21.21 Slip cap.

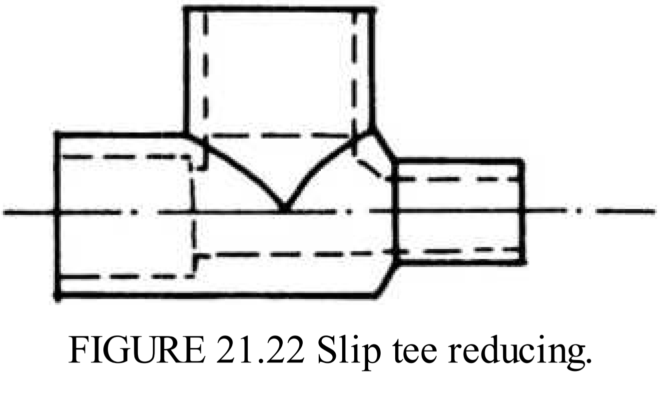


FIGURE 21.22 Slip tee reducing.

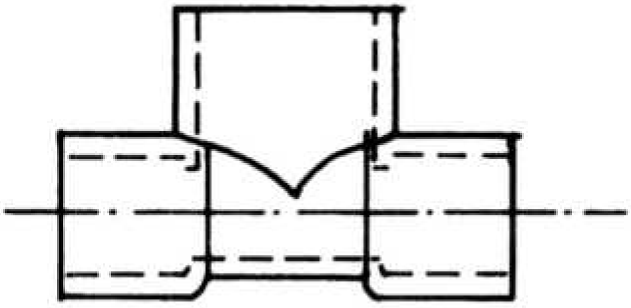


FIGURE 21.23 Bull head tee (slip).

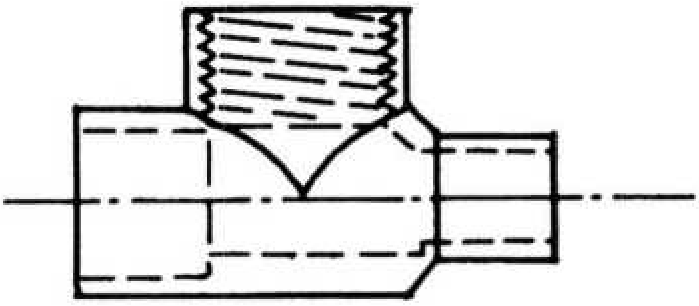


FIGURE 21.24 Combination tee reducing.

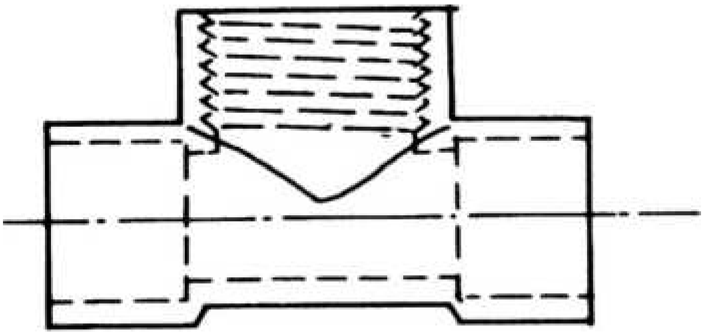


FIGURE 21.25 Bull head tee (slip x threaded).

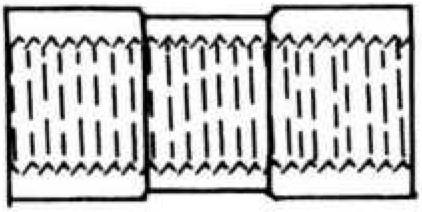


FIGURE 21.26 Threaded coupling.

Bull Head Tee (Slip). The bull head tee (Figure 21.23) is often used where you have a lateral line that tees at the end with a sprinkler head attached on either side.

Combination Tee Reducing. This fitting (Figure 21.24) is very specialized and not used very often. It is useful when you need to have a threaded joint and reduce your pipe size at the same time.

Bull Head Tee (Slip X Threaded). There are not a lot of irrigation applications for this tee (Figure 21.25). It is useful if you have a threaded mainline that is galvanized and you want to tee off with two smaller PVC lines and attach automatic valves and lateral lines.

Threaded Coupling. This fitting (Figure 21.26) is very useful when you have two nipples that are not long enough and you need to extend them. Just screw a nipple into each side of the threaded coupling. If your pipe line is 12 in. (0.3 m) deep and you need to attach a bubbler, use two 5-in nipples and connect them with the threaded coupling to get the needed height. Also, threaded couplings are useful for making swing joints.

Adapter Reducing Coupling. This fitting (Figure 21.27) reduces a pipe run from one pipe size to a smaller size by gluing pipe into each side of the coupling.

Reducing Bushing (Slip x Slip). Anytime you want to change pipe sizes, use this fitting (Figure 21.28). It works with a coupling or tee fitting and pipe. The outside of the bushing is a slip male fitting, and the inside is a slip female fitting. The outside slips into a coupling or tee, and the smaller pipe fits into the bushing. This fitting is useful for going from %,}-in (19-mm) pipe to %-in (13-mm) pipe.

Reducing Bushing (Slip x FPT). This reducing bushing (Figure 21.29) is often used with slip reducing tees when you want to add a sprinkler head and you need a V'-in (13-mm) threaded fitting to attach a barbed male elbow and PE pipe for a flexible swing joint. The bushing plugs into the tee and is glued.

Male Adapter Reducing. On occasion, this fitting (Figure 21.30) is useful where you are connecting an automatic valve to a smaller pipe line. The male part of this fitting is larger than the reduced slip portion. This fitting is also used when you have a sprinkler head with %-in (19-mm) FPT. You can screw it into the sprin kler head and then attach the head to V,2-in (13-mm) pipe.

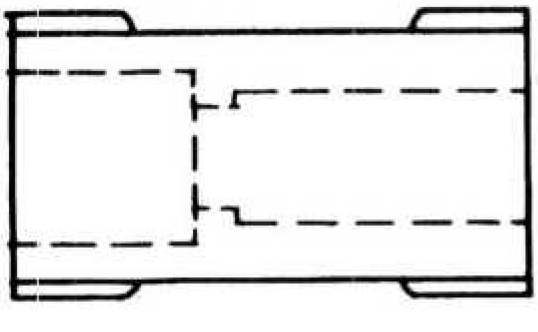


FIGURE 21.27 Adapter reducing coupling.

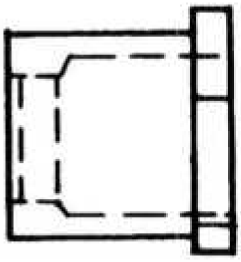


FIGURE 21.28 Reducing bushing (slip x slip).

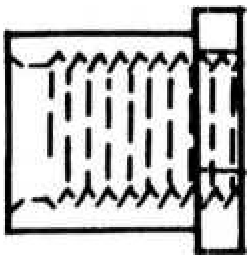


FIGURE 21.29 Reducing bushing (slip x FPT).

Female Adapter Reducing. This is a limited-use fitting (Figure 21.31) that works well when you have larger galvanized pipe that connects to smaller PVC pipe.

Threaded Cap. Threaded caps (Figure 21.32) are used when you have a male adapter glued to a PVC riser on which you decided not to use a shrub nozzle. The male adapter's threaded fittings can be easily capped with this fitting.

Reducing Bushing. Reducing bushings (Figure 21.33) are used when you want to switch pipe sizes. They are handy for attaching to sprinkler heads with

4-in (19-mm) FPT where you screw the bushing into the bottom of the sprinkler and then screw a barbed male elbow into the bushing for attachment to a PE flexible swing joint.

Side Outlet 910° Elbow. This fitting (Figure 21.34) is used when you are making a 90° turn and you want a sprinkler head located at the turn. Screw a barbed male elbow or adapter into the FPT and attach PE pipe for a flexible swing joint.

Male Adapter Reducing. The slip portion of this adapter (Figure 21.35) is larger than the threaded portion. This fitting is useful for attaching sprinkler heads or shrub heads to a larger pipe size. Screw the fitting into the sprinkler head and glue the pipe into the slip side of the adapter.

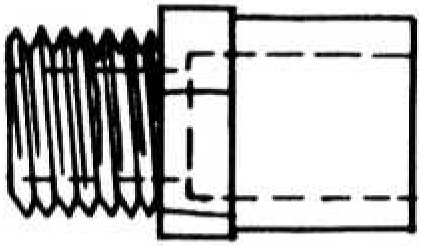


FIGURE 21.30 Male adapter reducing.

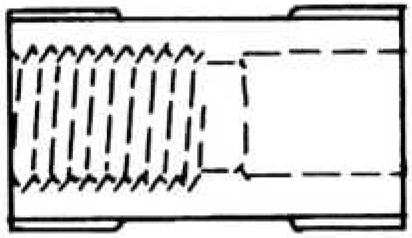


FIGURE 21.31 Female adapter reducing.

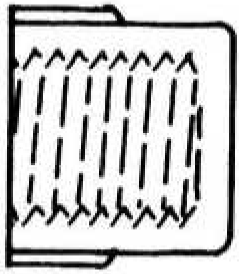


FIGURE 21.32 Threaded cap.

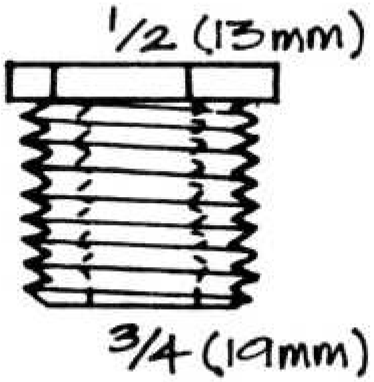


FIGURE 21.33 Reducing bushing.

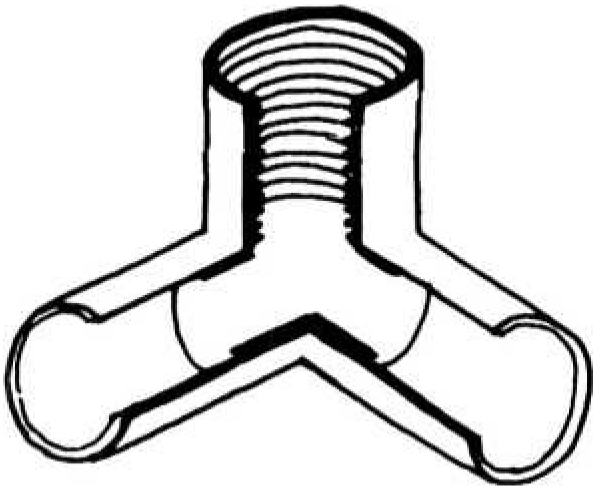


FIGURE 21.34 Side outlet 90° elbow.

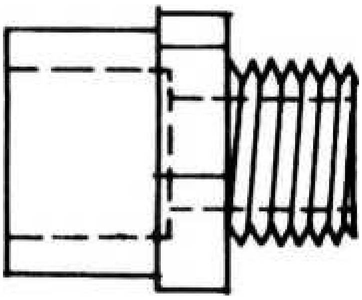


FIGURE 21.35 Male adapter reducing.

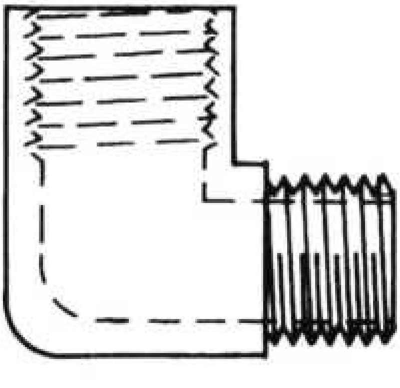


FIGURE 21.36 90° threaded street elbow.

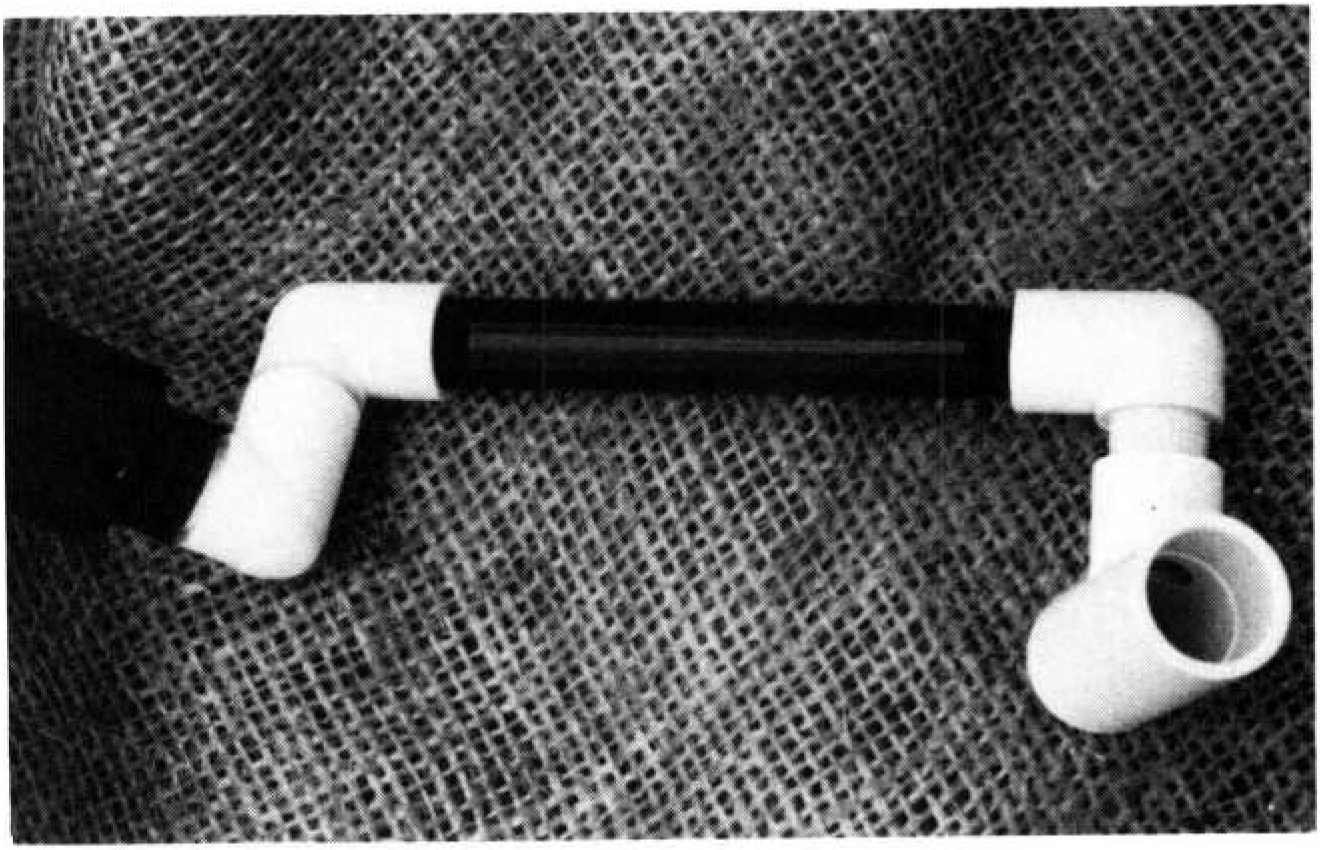


FIGURE 21.37 Triple swing joint.

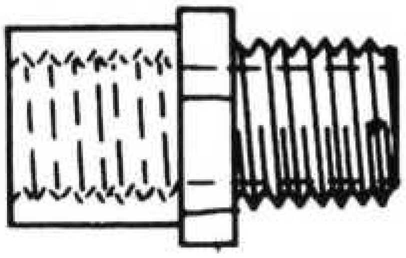


FIGURE 21.38 Male adapter.

90° Threaded Street Elbow. This fitting (Figure 21.36) is used for constructing swing joints. It is also called a "street ell." Once assembled, joints will move, allowing flexibility in the sprinkler head if it is run over by a tractor tire. (See Figure 21.37 for a photograph of a triple-swing joint constructed of street elbows and a rigid nipple.) The swing joint is screwed into a reducing thread tee.

Male Adapter (MPT x FPT). This male adapter (Figure 21.38) is used for attaching a galvanized pipe riser to a sprinkler head that has 4-in (13-mm) FPT.

Compression Tees (Slip). These are used when you have an existing line under pressure and you need to come back and tie in a tee to add a new pipe line. If you were to use a regular PVC tee fitting (slip x slip), you would have to dig up 5 ft to 6 ft (1.5 in to 1.8 m) of pipe on either side where you want the tee to lift the pipe up to insert it. With the compression tee (Figure 21.39), you cut out a small section of pipe, loosen the caps on the tee, slide the pipe into either end of the tee, and then tighten the caps. A rubber gasket inside the cap, as shown in Figure 21.40, compresses and seals against the pipe. To install a compression tee, you have to dig up only 12 in to 18 in (0.3 in to 0.5 m) of soil along the pipe. No pipe flexibility is needed to install the compression tee. This is a slip pipe fitting.

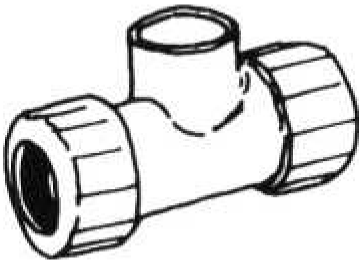


FIGURE 21.39 Compression tees (slip).

FIGURE 21.40 Rubber gasket in compression tee (threaded).

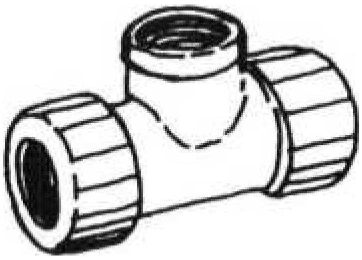


FIGURE 21.4 1 Compression tee (threaded).

Compression Tee (Threaded). This tee (Figure 21.41) is used with a threaded connection. With the slip compression tee, you would glue the pipe in the slip opening. The threaded opening is popular, especially when you have a wet situation where it would be hard to dry the slip opening enough to glue pipe. With the threaded opening, you can glue the male adapter to your new pipe and then screw the male adapter into the threaded fitting using Teflon tape to get a good seal.

Quick-FixTM Coupling. Quick-Fix is a trade name for a very popular coupling (Figure 21.42). The QuickFix coupling allows for repair of broken or "trenchedthrough" pipe without having to unearth 5 ft to 8 ft (1.5 m to 2.4 m) of pipe. Cut out the section of broken pipe, loosen the compression caps on the fittings, and extend and glue the ends of the coupling up to 8 in (203 mm) over the existing pipe (see Figure 21.43). Tighten the caps to seal the coupling unit. If you have trenched through existing pipe, be sure to remove the sprinkler head nozzles and flush the soil particles out of the system. With the regular compression coupling, you have to dig up enough pipe to lift the pipe slightly in order to fit the coupling on the existing pipe.

Compression Coupling. If you cannot get your pipe dry enough to glue it to the Quick-Fix coupling, then the regular compression coupling is best to use (Figure 21.44).

Union. The union (Figure 21.45) is a good fitting for repair and replacement of a valve in a tight or rigid situation. The big collar or cap on the union backs up so the joint comes loose and allows you to slip the valve out and put it back in without. moving any of the pipe. The collar essentially holds two halves together. The unit is a compression union.

Ball Valve. This valve (Figure 21.46) is available in slip x slip and FPT x FPT. The ball valve is used for manual valves and as a master cut off valve to shut off the entire water system. When used as a manual valve, be aware that rapid turn off and on can cause severe water surge pressures.

Spring Check Valve. Spring check valves (Figure 21.47) come in both PVC and galvanized materials, and they are available in both slip x slip and FPT x FPT models. A small spring in this valve seals it shut when the water line pressure is off and allows water to flow only in one direction. In low head drainage situations where water in lateral lines drains downhill to the lowest sprinkler head when the line pressure is off, use a check valve in the line to stop the flow. Remember, when the line is not under pressure, the spring in the valve seals the valve shut.

Saddle. The saddle (Figure 21.48) is a laborsaving fitting that is glued to PVC pipe. Once the glue has set, a hole can be drilled through the top of the fitting into the pipe. Do not forget to flush your system to prevent plastic particles from clogging sprinkler nozzles. Once in place, the saddle is ready to receive either a flexible PE riser for shrub bubbler heads or a barbed male elbow for attachment of a flexible, PE pipe swing joint.

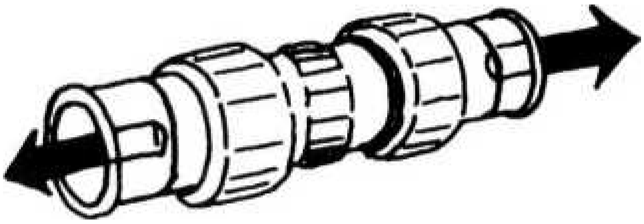


FIGURE 21.42 Quick-FixTM coupling.

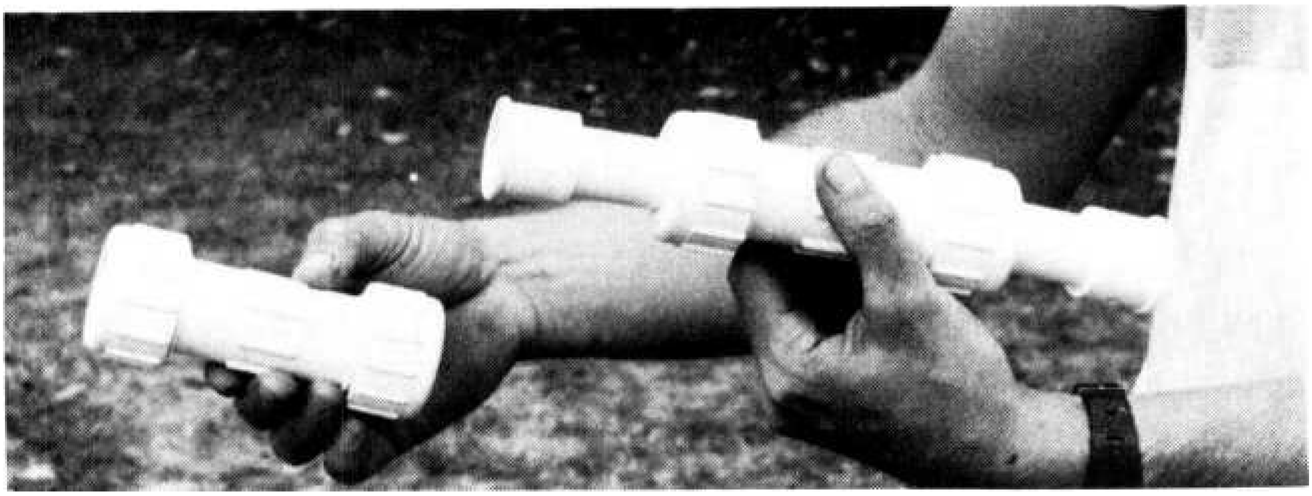


FIGURE 21.43 Compression and Quick-FixTM coupling.

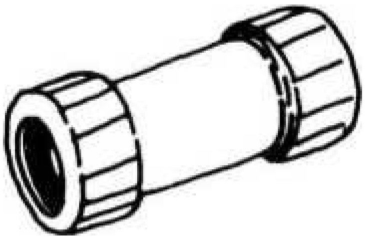


FIGURE 21.44 Compression coupling.

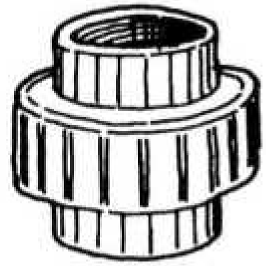


FIGURE 21.45 Union.

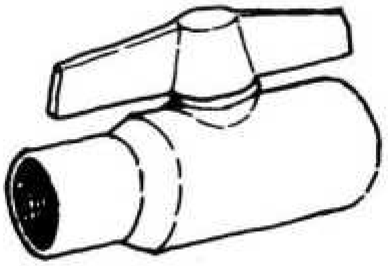


FIGURE 21.46 Ball valve.

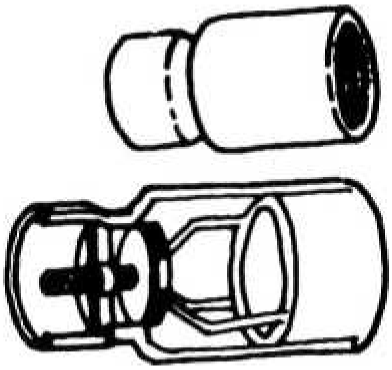


FIGURE 21.47 Spring check valve.

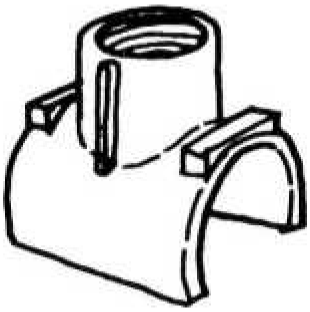


FIGURE 21.48 Saddle.

# 22

# Installation Details

The purpose of this chapter is to illustrate typical construction details for irrigation systems. The installation details will show the size, form, location, and arrangement of elements. By contrast, the written specifications define the quality of materials and specific installation techniques for a particular job. You do not need to repeat information in the technical specifications on the installation details.

The more experience you have in designing, inspecting, and/or installing irrigation systems, the

more knowledge you will gain and the better you will become in designing irrigation details. If there is a specific way you want your construction elements to be assembled, then develop a construction detail to communicate your ideas to the irrigation contractor. Figures 22.1 through 22.4 will give you an idea of some appropriate details for irrigation systems and show you what installation details should communicate.

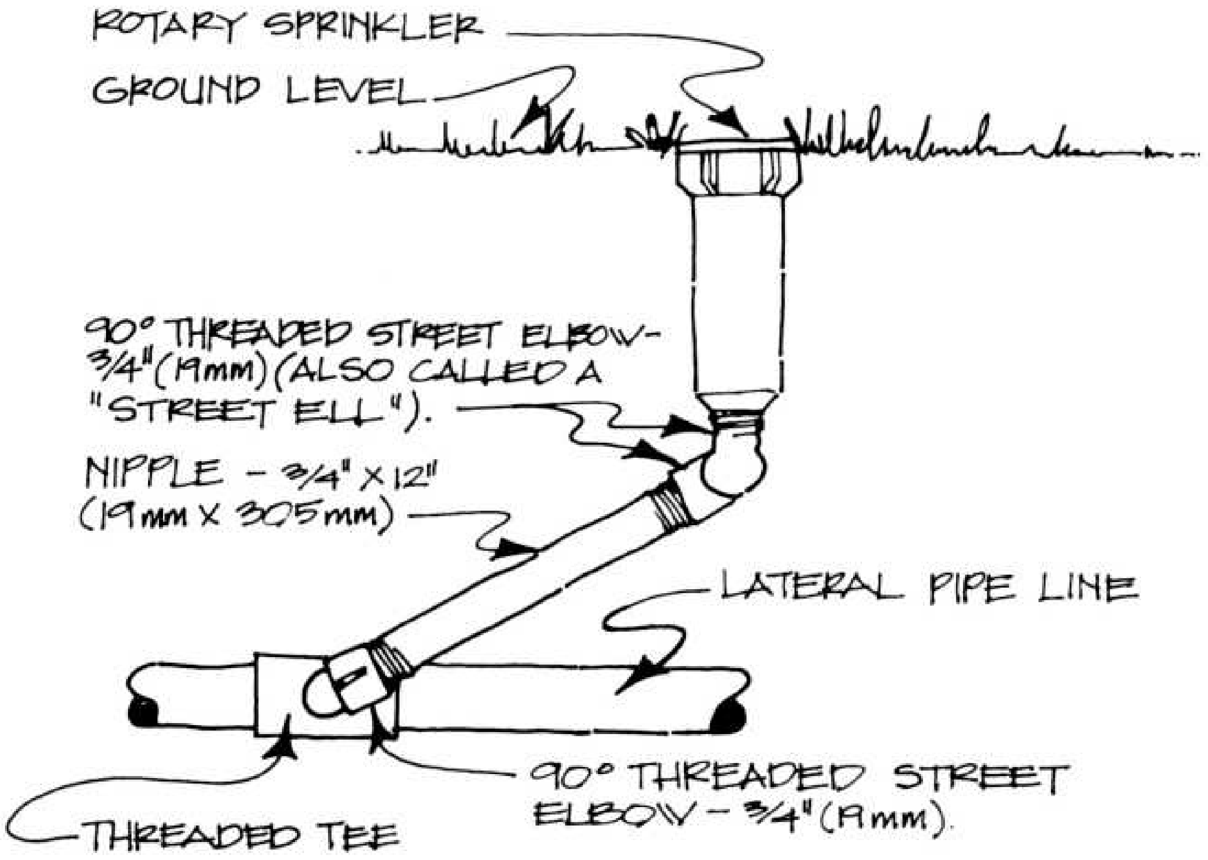


FIGURE 22. 1 Triple swing joint and sprinkler head installation.

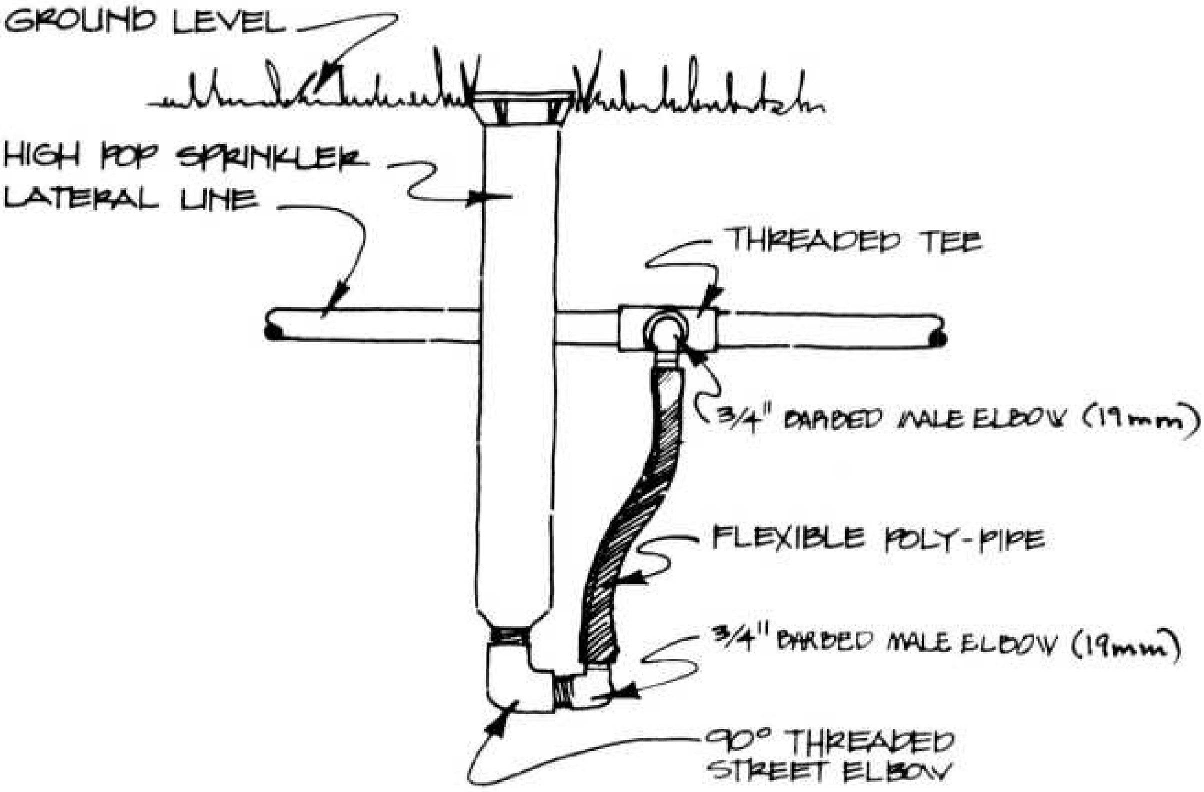


FIGURE 22.2 Sprinkler head and flexible swing joint.

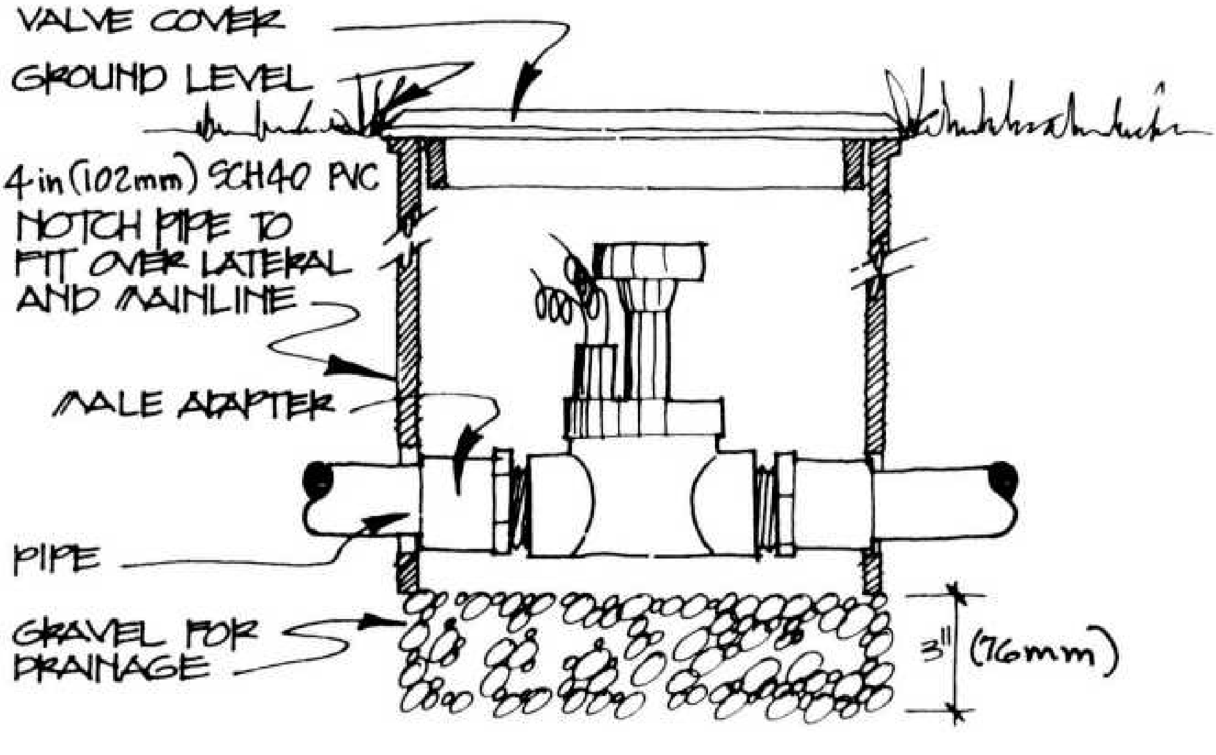


FIGURE 22.3 Electric valve and valve box installation.

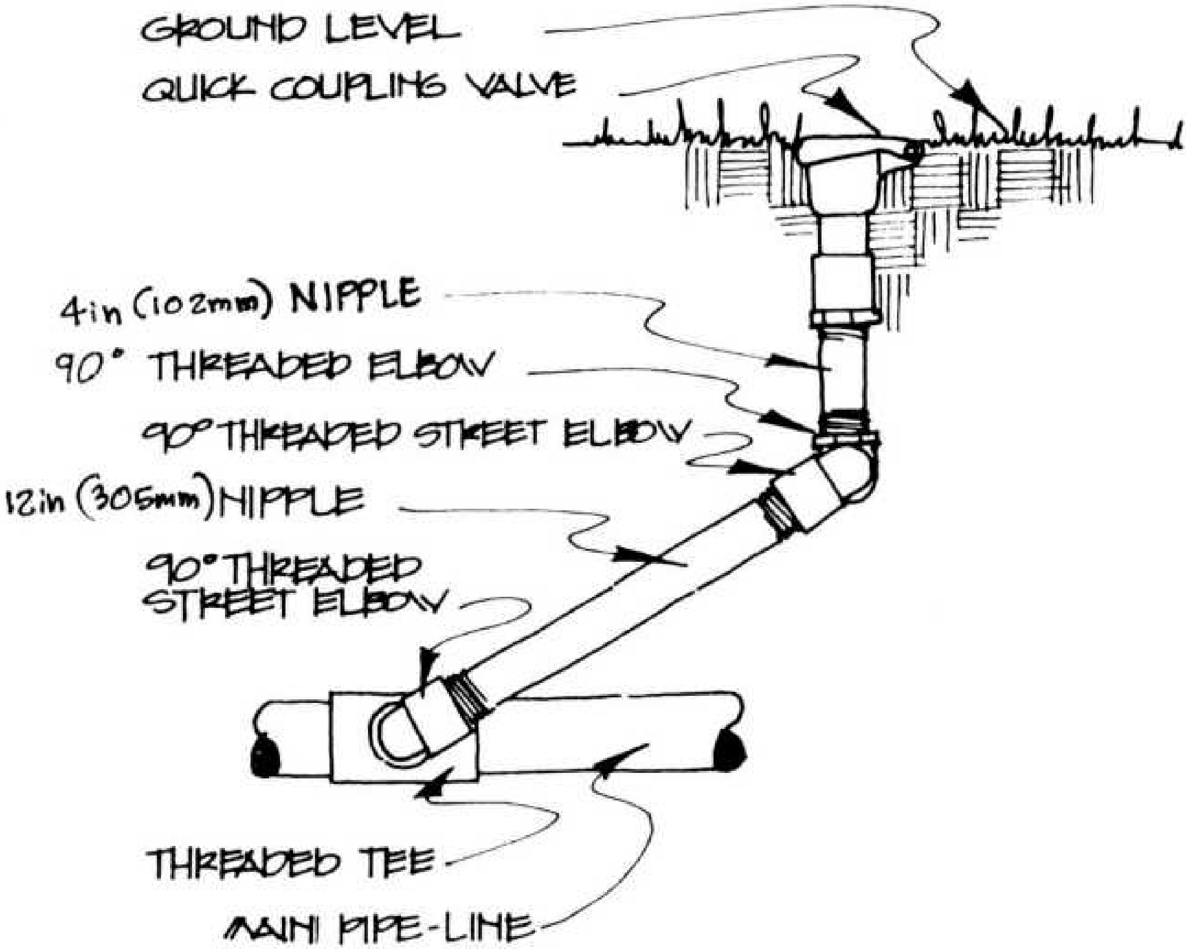


FIGURE 22.4 Quick coupling valve.

# 23

# Irrigation Design Graphics

## Introduction

Once you have designed your irrigation system, you are then ready to develop your final drawings so that they can be reproduced and contractors can bid on the project. In order for a contractor to develop a bid and accurately install the design you created, he or she must be able to read your design drawings. Therefore, you need to develop a method by which you can graphically convey your ideas clearly and simply. If your irrigation design drawing is confusing, the project could be installed incorrectly, or you might have to spend many hours answering questions and interpreting your graphic fiasco. This expenditure of time will be aggravating and cost money.

## Graphic Symbols

Use simple graphic symbols in your irrigation design so as to aid in rapid recognition of the irrigation components you are specifying. Clear graphic symbols will enhance the irrigation installation process.

We are illustrating four different graphic techniques of conveying irrigation components for your review. When you develop your own graphics for irrigation designs, remember that you are communicating ideas. Keep your graphics clear and simple.

The graphic symbols in our illustrations are defined in a legend. Legend comes from the Latin word legere, which means "to read." Therefore, we will read about what the graphic symbols are representing in our legends. It is best to place a legend of all graphic symbols you are using in the lower right-hand corner of your drawing for easy reference.

The first graphic legend we will review is from a U.S. Army Corps of Engineers project. You can see in Table 23.1 that the legend is divided into four parts: the symbol, the item, the manufacturer of the item, and the specific model number of the item. Specific information about sprinkler head radii and pressure at the heads is in the technical specifications. Figure 23.1 illustrates these graphic symbols along an entry drive to a visitor's center.

In our second legend, Table 23.2, you can see that the irrigation designer chose to identify the location and type of sprinkler heads and valves with symbols and letters. He then placed a letter beside each sprinkler head on the irrigation plan (see Figure 23.2) to identify the manufacturer of the head, the model number, and the radius of throw for the head. This graphic approach was provided by the firm Bishop and Walker, landscape architects in Houston, Texas.

TABLE 23.1 **U.S. Army Corps of Engineers Legend**

LEGEND

| SYMBOL | ITEM | MANUFACTURER | MODEL NO. |
|---|---|---|---|
| ⬢ | PRESSURE VACUUM BREAKER BACKFLOW PREVENTER | RAINBIRD | PVB-200 |
| ▲ | DOUBLE CHECK VALVE ASSEMBLY " " | RAINBIRD | DCA-200 |
| ■ | QUICK COUPLING VALVE | NELSON | 7651 |
| ◕ | PVC ELECTRIC CONTROL VALVE W/VALVE BOX | NELSON | 7928 |
| ◉ | FULL OR PART CIRCLE IMPACT ROTOR POP-UP SPRINKLER | RAINBIRD | 15111 B |
| ∘ | POP-UP SPRAY SPRINKLER | RAINBIRD | 1804/1806/1812 |
| ⟶ | STUB-OUT FOR FUTURE CONNECTION | | |
| ═ | SLEEVE | | |
| ▣ | ELECTRONIC CONTROLLER | NELSON | 8412 |
| —⊛— | WATER METER | | |
| ○ | STREAM BUBBLER | RAINBIRD | 2200 CST |

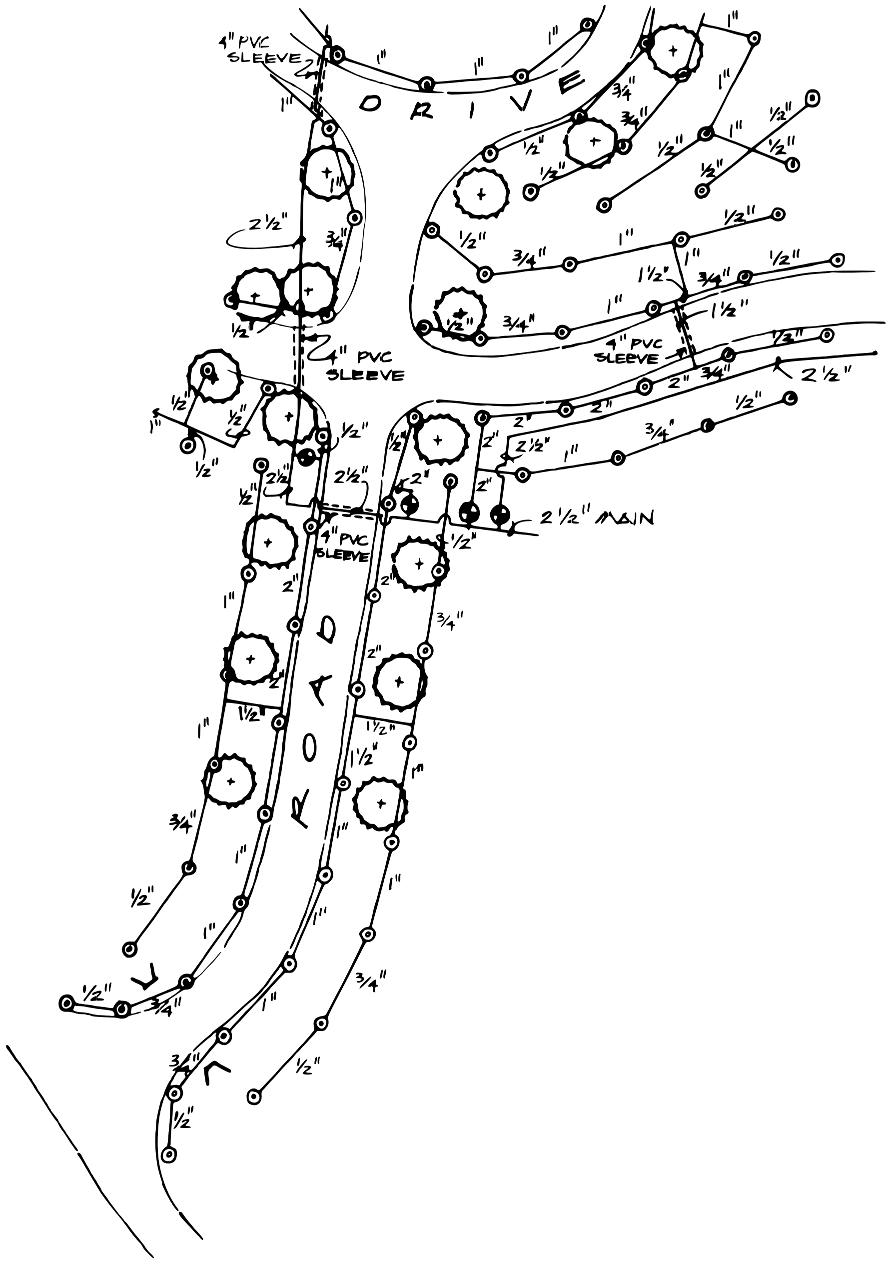
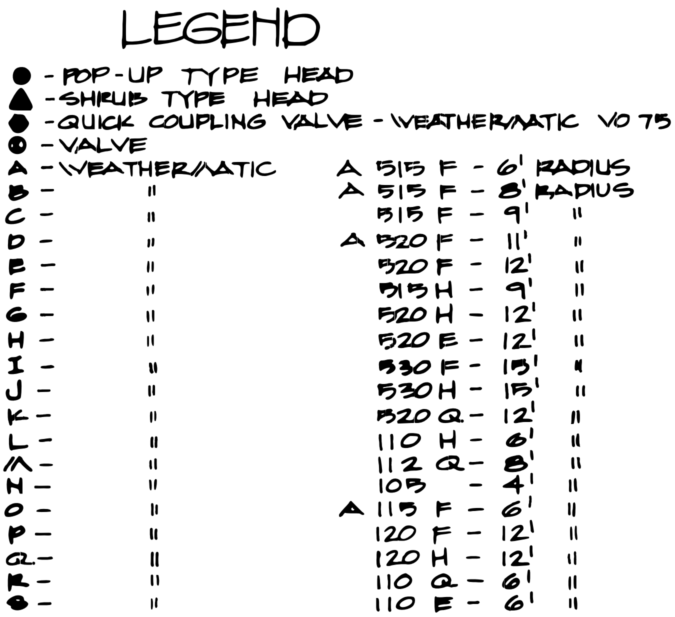


FIGURE 23. 1 Entry drive irrigation plan.

TABLE 23.2 **Bishop and Walker Legend**



LEGEND

● - POP-UP TYPE HEAD
▲ - SHRUB TYPE HEAD
⬢ - QUICK COUPLING VALVE - WEATHERMATIC VO 75
⊙ - VALVE
A - WEATHERMATIC ▲ 515 F - 6' RADIUS
B - " ▲ 515 F - 8' RADIUS
C - " 515 F - 9' "
D - " ▲ 520 F - 11' "
E - " 520 F - 12' "
F - " 515 H - 9' "
G - " 520 H - 12' "
H - " 520 E - 12' "
I - " 530 F - 15' "
J - " 530 H - 15' "
K - " 520 Q - 12' "
L - " 110 H - 6' "
M - " 112 Q - 8' "
N - " 105 - 4' "
O - " ▲ 115 F - 6' "
P - " 120 F - 12' "
Q - " 120 H - 12' "
R - " 110 Q - 6' "
S - " 110 E - 6' "

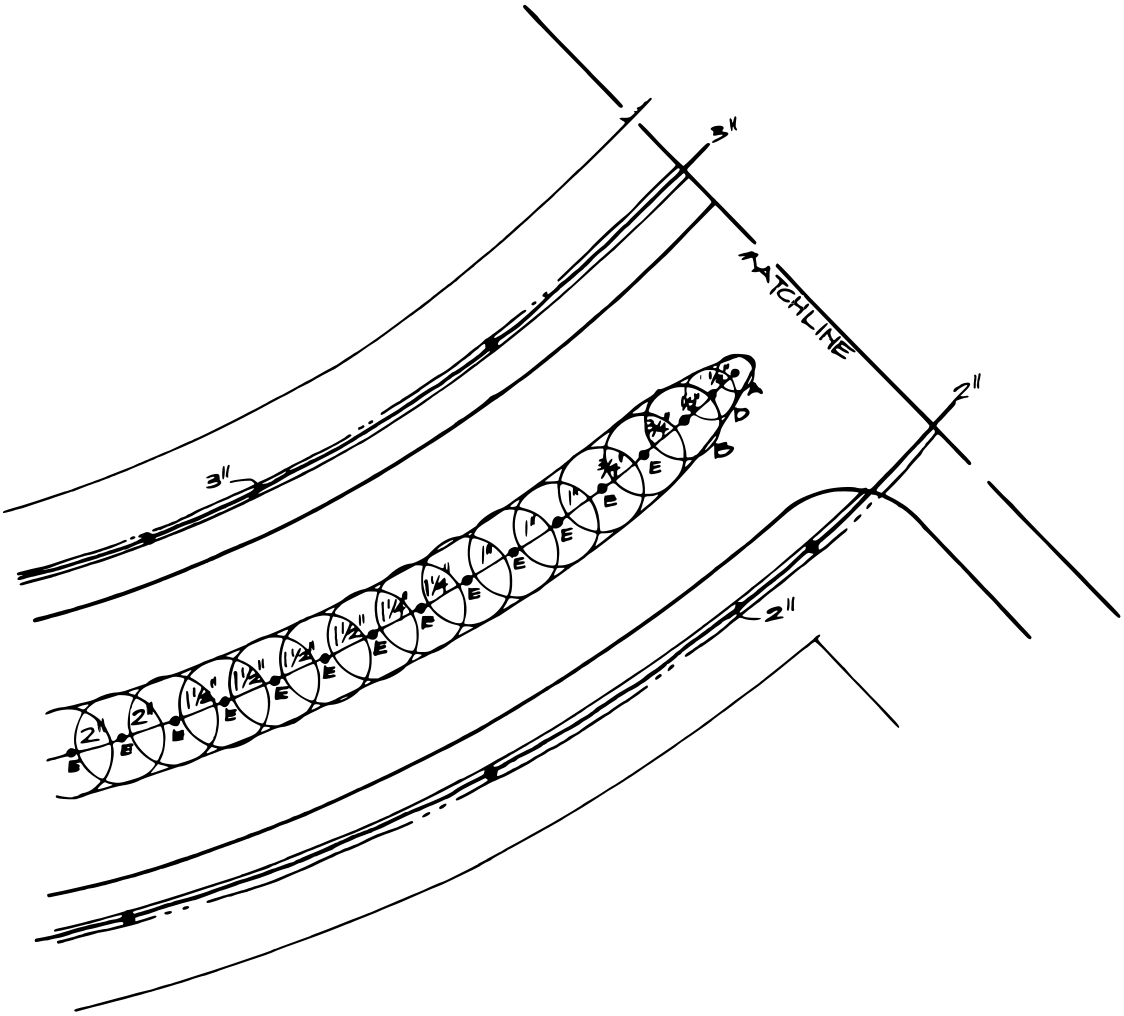
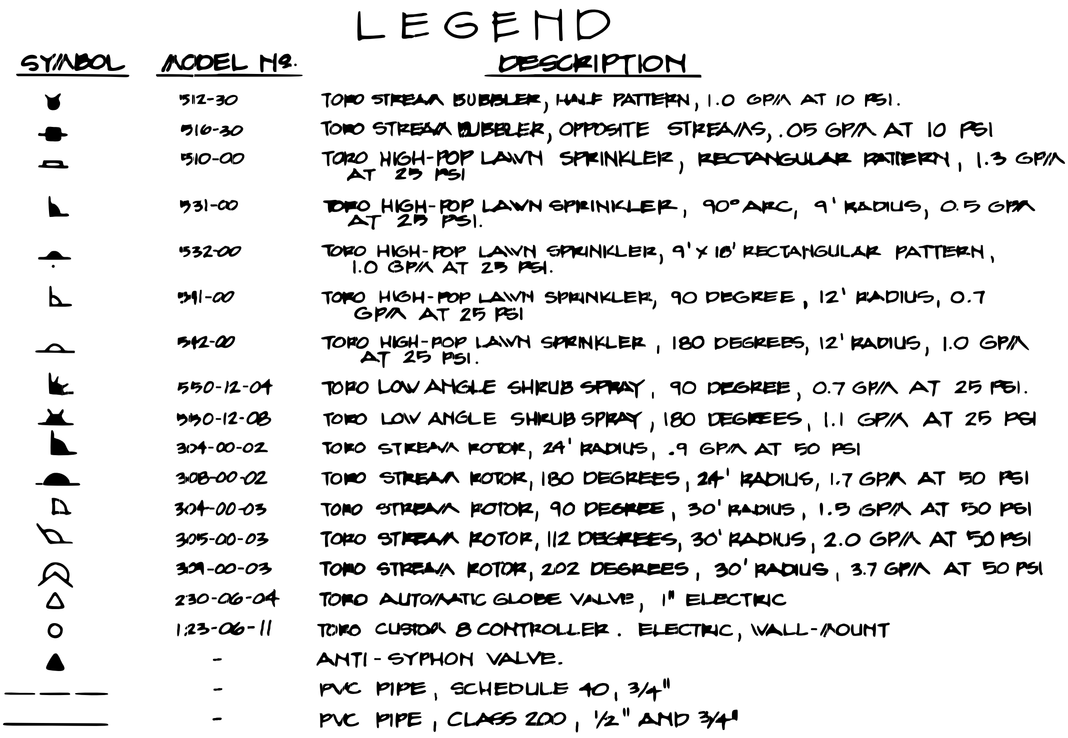


FIGURE 23.2 Bishop and Walker Plan graphics.

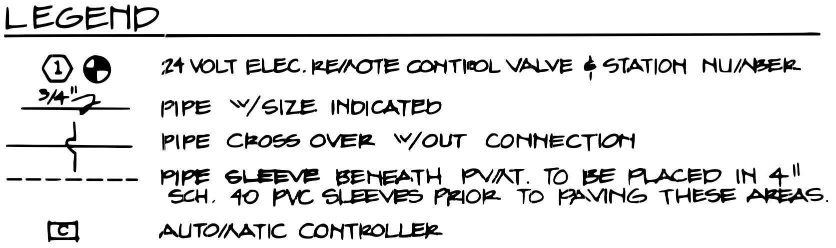
## TABLE 23.3 **Toro Company Legend**



LEGEND

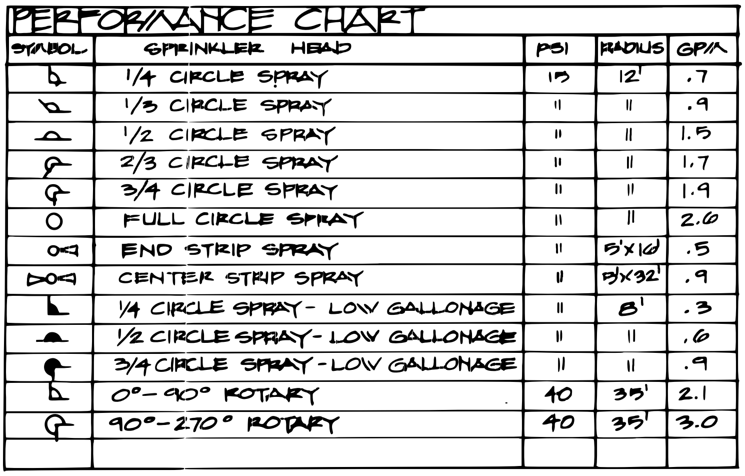
| SYMBOL | MODEL Nº. | DESCRIPTION |
|---|---|---|
|  | 512-30 | TORO STREAM BUBBLER, HALF PATTERN, 1.0 GPM AT 10 PSI. |
|  | 516-30 | TORO STREAM BUBBLER, OPPOSITE STREAMS, .05 GPM AT 10 PSI |
|  | 510-00 | TORO HIGH-POP LAWN SPRINKLER, RECTANGULAR PATTERN, 1.3 GPM AT 25 PSI |
|  | 531-00 | TORO HIGH-POP LAWN SPRINKLER, 90° ARC, 9' RADIUS, 0.5 GPM AT 25 PSI. |
|  | 532-00 | TORO HIGH-POP LAWN SPRINKLER, 9' x 18' RECTANGULAR PATTERN, 1.0 GPM AT 25 PSI. |
|  | 541-00 | TORO HIGH-POP LAWN SPRINKLER, 90 DEGREE, 12' RADIUS, 0.7 GPM AT 25 PSI |
|  | 542-00 | TORO HIGH-POP LAWN SPRINKLER, 180 DEGREES, 12' RADIUS, 1.0 GPM AT 25 PSI. |
|  | 550-12-04 | TORO LOW ANGLE SHRUB SPRAY, 90 DEGREE, 0.7 GPM AT 25 PSI. |
|  | 550-12-08 | TORO LOW ANGLE SHRUB SPRAY, 180 DEGREES, 1.1 GPM AT 25 PSI |
|  | 304-00-02 | TORO STREAM ROTOR, 24' RADIUS, .9 GPM AT 50 PSI |
|  | 308-00-02 | TORO STREAM ROTOR, 180 DEGREES, 24' RADIUS, 1.7 GPM AT 50 PSI |
|  | 304-00-03 | TORO STREAM ROTOR, 90 DEGREE, 30' RADIUS, 1.5 GPM AT 50 PSI |
|  | 305-00-03 | TORO STREAM ROTOR, 112 DEGREES, 30' RADIUS, 2.0 GPM AT 50 PSI |
|  | 309-00-03 | TORO STREAM ROTOR, 202 DEGREES, 30' RADIUS, 3.7 GPM AT 50 PSI |
| △ | 230-06-04 | TORO AUTOMATIC GLOBE VALVE, 1" ELECTRIC |
| ○ | 123-06-11 | TORO CUSTOM 8 CONTROLLER. ELECTRIC, WALL-MOUNT |
| ▲ | - | ANTI-SYPHON VALVE. |
| — — — | - | PVC PIPE, SCHEDULE 40, 3/4" |
| ——— | - | PVC PIPE, CLASS 200, 1/2" AND 3/4" |

## TABLE 23.4 **U.S. Army Corps of Engineers Legend and Valve Schedule**



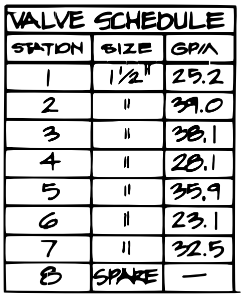
LEGEND

| | |
|---|---|
| ① | 24 VOLT ELEC. REMOTE CONTROL VALVE & STATION NUMBER |
| 3/4" | PIPE W/SIZE INDICATED |
|  | PIPE CROSS OVER W/OUT CONNECTION |
| - - - - - - - - | PIPE SLEEVE BENEATH PVMT. TO BE PLACED IN 4" SCH. 40 PVC SLEEVES PRIOR TO PAVING THESE AREAS. |
| C | AUTOMATIC CONTROLLER |



PERFORMANCE CHART

| SYMBOL | SPRINKLER HEAD | PSI | RADIUS | GPM |
|---|---|---|---|---|
|  | 1/4 CIRCLE SPRAY | 15 | 12' | .7 |
|  | 1/3 CIRCLE SPRAY | " | " | .9 |
|  | 1/2 CIRCLE SPRAY | " | " | 1.5 |
|  | 2/3 CIRCLE SPRAY | " | " | 1.7 |
|  | 3/4 CIRCLE SPRAY | " | " | 1.9 |
| ○ | FULL CIRCLE SPRAY | " | " | 2.6 |
|  | END STRIP SPRAY | " | 5'x16' | .5 |
|  | CENTER STRIP SPRAY | " | 5'x32' | .9 |
|  | 1/4 CIRCLE SPRAY - LOW GALLONAGE | " | 8' | .3 |
|  | 1/2 CIRCLE SPRAY - LOW GALLONAGE | " | " | .6 |
|  | 3/4 CIRCLE SPRAY - LOW GALLONAGE | " | " | .9 |
|  | 0°-90° ROTARY | 40 | 35' | 2.1 |
|  | 90°-270° ROTARY | 40 | 35' | 3.0 |
|  |  |  |  |  |



VALVE SCHEDULE

| STATION | SIZE | GPM |
|---|---|---|
| 1 | 1½" | 25.2 |
| 2 | " | 39.0 |
| 3 | " | 38.1 |
| 4 | " | 28.1 |
| 5 | " | 35.9 |
| 6 | " | 23.1 |
| 7 | " | 32.5 |
| 8 | SPARE | — |

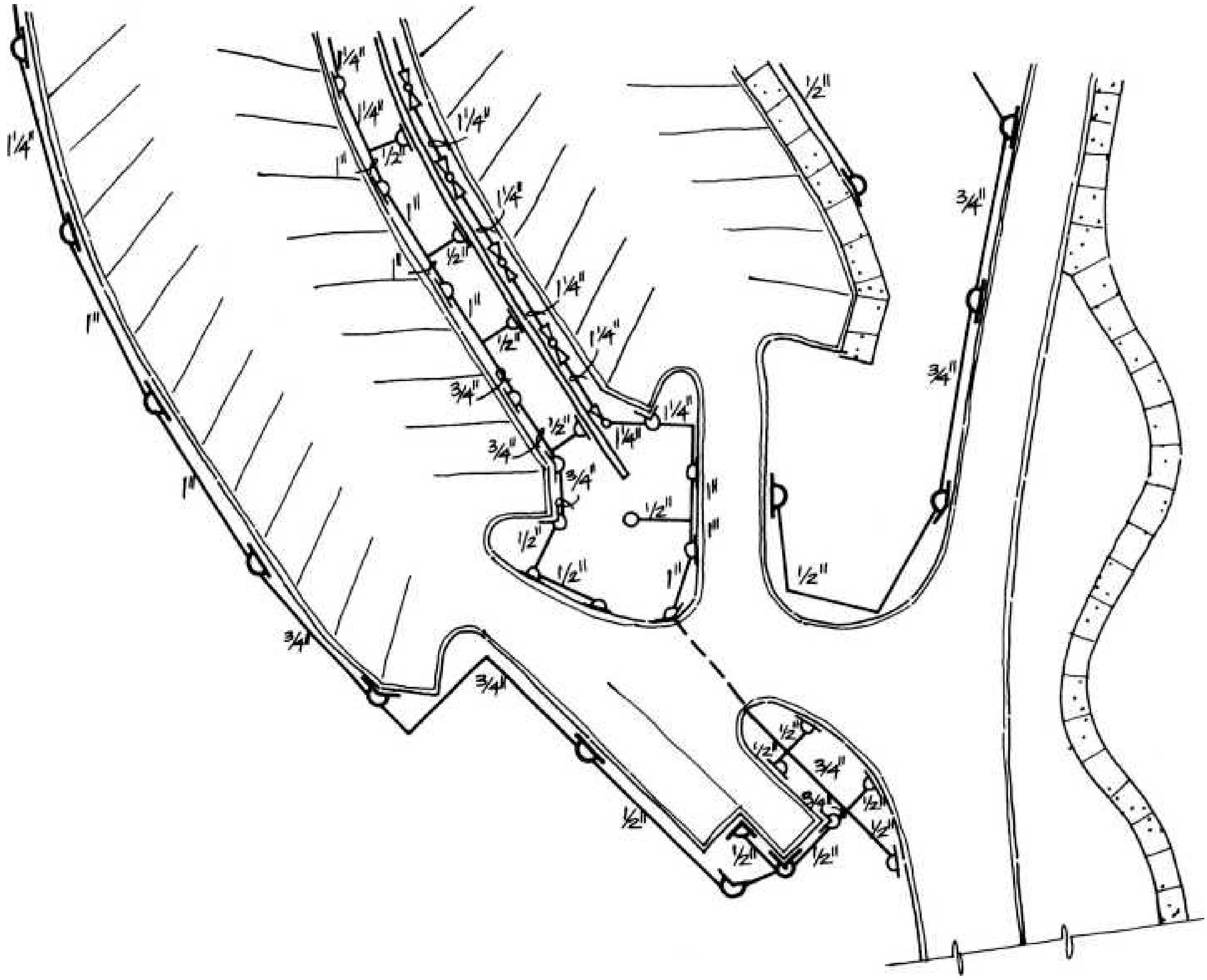


FIGURE 23.3 U.S. Army Corps of Engineers irrigation plan.

The third set of graphics, Table 23.3, is provided by the Toro Company. Their legend is divided into symbols, the model number of the equipment specified, and the description of the equipment.

Our fourth legend, Table 23.4, is from the U.S. Army Corps of Engineers, and it conveys clear and concise graphics, as seen in Figure 23.3. The manufacturer of the irrigation equipment is defined in the technical specifications. This legend, with its complete set of symbols, also includes a valve schedule, in which the size and gpm flow through each valve is given.

Graphics are an important part of irrigation design. Create your graphics to communicate clearly to the client and the contractor.

# 24

# Cost Estimating

## Introduction

How successful you are in business will depend on how you calculate the cost of materials and service. We will discuss four methods used to develop cost estimates. Within these various methods, there are various levels of precision. The more time you spend on estimating costs, the more precise you will be. The following methods are for installed irrigation costs.

## Methods of Cost Estimating

### Cost Based on the Square Foot of Irrigated Area

This is the most generalized way of computing costs. If your company has been keeping current with irrigation costs on projects, the cost-per-square-foot method can be accurate.

There is a difference in costs between small irrigated areas, which usually have more heads and valves, and larger irrigated areas, which have more pipe and fewer heads and valves. Be aware of this when using square-foot cost calculations.

Irrigation costs vary between different regions of the country for two reasons: the appreciation of landscapes and climatic conditions. Landscape design is

more sophisticated and appreciated in the Southwest, especially in California. In terms of climate, southern California and the Southwest in general are nearly and landscapes and need irrigation all year long. In the southeast part of the country, for example, Georgia, irrigation is mainly needed in the three or four dry summer months.

California and the Southwest have the highest square-foot installed irrigation costs because of these factors:

1. There is a greater appreciation of landscape design in this region.

2. The irrigation contractors are experienced and know their costs.

3. Everything is watered all year long, including turf, shrubs, and trees.

The Florida market area has one of the lowest costs per square foot of installed irrigation systems because of the intense competition among contractors.

The Southeast has a middle range of irrigation cost per square foot because irrigation is primarily used for turf and not for shrubs and trees. Although rainfall is high and varies in this region from 40 in to 60 in (1,016 mm to 1,524 mm) per year, there is a seasonal drought during the summer.

To find out the square-foot prices of irrigation installation in your region, call experienced contractors, landscape architects, or irrigation manufacturing representatives. Use this method cautiously.

### Cost Based on Doubling the List Price of Materials

A manufacturer publishes a list price of materials it sells. A contractor usually pays 40% off the list price. To calculate the installed cost of irrigation using this method, take the list price of materials and multiply it by a factor that will cover your costs and make you a profit. The factor you set, multiplied against the list price, depends on your costs and what kind of profit you want to make. A small contracting company that specializes in irrigation installation may make money by doubling the list price. If materials for the job cost $500 and you use a factor of two, you will charge $1,000 to install the job and make a profit. You might need to take the list price of materials multiplied by more than a factor of two to meet your company's needs.

Doubling the list price is a good method for small jobs, and it is used by a number of contractors. The process does not take a lot of time to calculate. If you have a $2,000 irrigation job that a crew can install in one day, you can not afford to spend more than an hour or so to estimate costs.

### Major Irrigation Component Cost Estimate

This cost-estimating method is based on the number of irrigation components and their unit cost, which includes the cost of the component, pipe, labor, and profit. The major irrigation components are the sprinkler heads, valves, and controller. This cost-estimating method can be developed quickly from the material schedule, and it tends to be more precise than the previous two methods. Like all the cost-estimating methods discussed in this chapter, the component method includes the labor to install the project, the materials, and all other costs, including profit. Components and exemplary unit costs include the following:

$100 per rotary head-This includes pipe, fittings, and installation.

$50 per spray head-This includes pipe, fittings, and installation.

List cost of valves plus $50-This includes pipe, fittings, and installation.

List cost of controller plus $250-This includes pipe, fittings, wire, and installation.

Of course, costs will change. The calculations we used show proportional differences in unit costs. Contact a reliable contractor, irrigation designer, or irrigation manufacturer's representative for current costs using this method.

### Material, Labor, Overhead, and Profit Method

Without a doubt, this is the most accurate method to determine what a job will cost to install, plus profit. This process is the most time-consuming method by which to develop a cost estimate, but once it is developed, then you will know how much money you will spend and make on a job. Contractors use this method to be able to accurately schedule installation crews and evaluate their efficiency.

You start with calculating or assembling the list price of materials you will use on a job. If the job is very large, you had better not forget even the smallest fittings, like adapters and bushings, as they can add significant cost if very many of them are used.

Once you have an accurate assessment of material needs, then you can estimate how long it will take your crew to do a job. The only way to do this accurately is through experience. Always keep accurate records as to how long it takes to install irrigation components and systems. Some contractors really know their costs. They know, for example, that it is going to take 1.2 minutes to install a male adapter, 4.5 minutes per foot (305 mm) to install a 1%-in (38 mm) PVC mainline, 8.4 minutes per foot (305 mm) to bore under a slab less than 4 ft (1.2 m) deep, and 69 minutes to install a double check backflow preventer. With this kind of accuracy, the contractor can develop precise cost estimates and have a good handle on managing the construction crews. After you have estimated the time it will take to install a job, multiply those hours by your labor cost, and you will have your total cost of labor.

Let us look at labor costs for just a moment. If you pay a laborer $5 per hour, it may actually cost you $15 per hour to get him or her on the job. Besides the $5 per hour you pay to the laborer as a wage, the federal government requires you to pay

- Half of the FICA or Social Security tax (the laborer pays the other half)
- Worker's compensation

- Unemployment compensation

You may also pay liability insurance and health insurance for the employee, which increases your cost of having that laborer in the field. Some accountants call these costs labor burden, and they call the $5 per hour wage direct labor costs. Labor burden is the cost in addition to the hourly wage. Both the direct labor cost and the labor burden can be charged directly to a job.

You must now calculate your overhead cost. Overhead is those expenses that you cannot directly charge to a particular job. Overhead is also called indirect cost because you are not able to charge the cost to a specific job. Overhead, or your indirect cost, includes

Administrative costs: boss, secretary

Accountant fees

Vehicles

Irrigation installation equipment

Tools

Gas and oil

Vehicle and equipment maintenance and repair

Uniforms

Building to house business

Office equipment

Advertising

Office supplies

Telephone

Utility costs

Bad debts

Insurance

You can see that overhead is the support needed for running a business. Although overhead is an indirect cost that cannot. be charged to a specific job like material and labor costs, overhead has to be charged somehow.

Most businesses follow their costs very carefully and eventually know what their overhead cost is. A business may know that for every $100 of direct costs (materials and labor) it incurs, it will also have an in

direct cost that is 55% of the direct cost. That is to say, for every $100 of direct costs, it will spend $55 as overhead or support to do the work. Overhead is a necessary part of doing business that must be charged to your jobs.

Once you have computed your material costs, labor costs, and overhead, then you have your final calculation, the amount it will cost you as the business owner to install the work and break even. If you were in a nonprofit business, this is where you would compute your final cost.

However, most businesses want to grow and improve, and want to make money on their investment, so they calculate profit on their investment. You can make 6% to 12% interest on your money at the bank, depending on economic times. So to make the effort of running a company worthwhile, many contractors like to calculate from 15% to 35% profit on their jobs. This percentage of profit is computed on both the direct and indirect costs, since that is their investment. The total cost then includes

Material

Direct labor

Labor burden

Overhead

Profit

As a safety factor, many wise contractors like to add a 2% to 5% contingency factor to the total cost to cover unforeseen problems, which always seem to arise.

The material, labor, overhead, and profit method of calculating irrigation costs is time consuming, but it is the most accurate way to estimate costs.

NOTE: Prices shown in this chapter are for 1995. Adjust for subsequent years according to your local inflation factor. Prices also vary by region, and these prices may be higher or lower than those in your region.

# 25

# Pumps for Irrigation

## Introduction

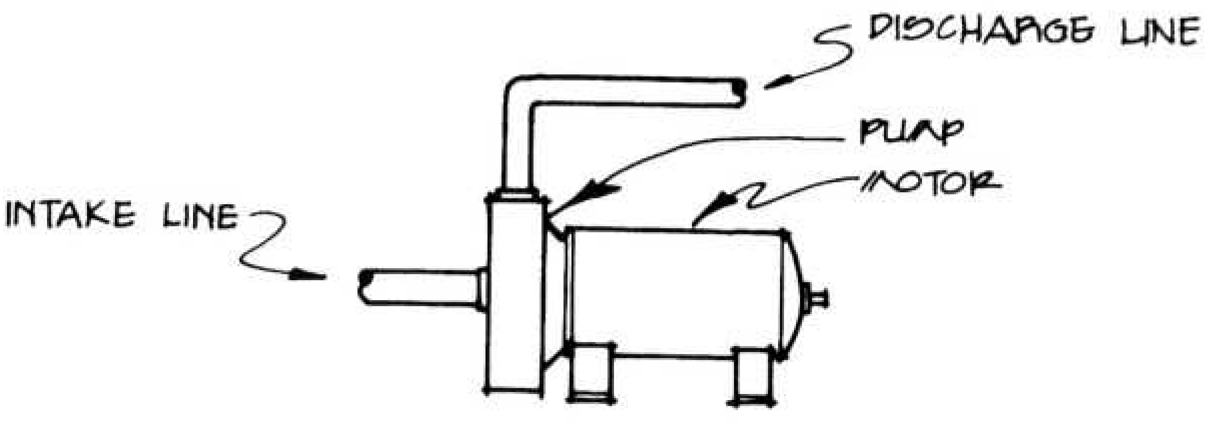
As an irrigation designer, you need to be aware of the various types of pumps as well as which pumps are used to perform certain tasks. Actual selection of the pump should be left to an expert, as there are many variables that need to be considered in selecting the right type and size of pump.

## When Are Pumps Used?

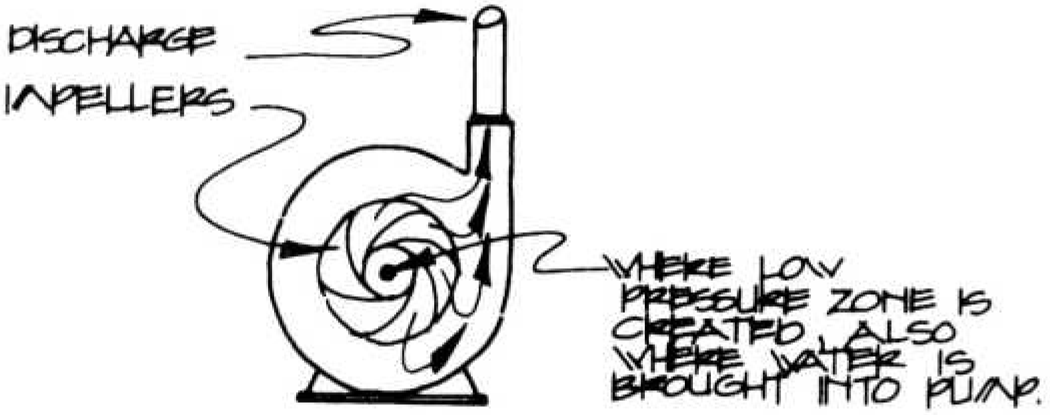
Pumps are used to bring well or lake water to the irrigation system. In many irrigation situations, municipalities provide water for large irrigation projects such as a golf course, but the pressure at which the water is provided is not high enough to run large irrigation heads. In such cases, a pump is used to increase the water pressure. Pumps are also used to increase pressure for projects that have elevation extremes and for projects located in districts that provide water at relatively low pressures.

## How Pumps Work

A pump is composed of blades or an impeller inside a housing or case (see Figure 25.1) . The case is also called a volute. The pump has an intake and a discharge line so that it can draw and expel water. A motor is connected to the pump blades or impeller by a shaft. When the motor turns the impeller, a vacuum or low-pressure zone is crated. (A vacuum is zero pressure.) The air pressure at sea level is 14.7 psi (1.03 kg/cm2). Most pumps do not create a true vacuum, but they do create a zone with pressure that is lower than air pressure. When the low-pressure zone is created in the pump, air pressure actually pushes the water from the well or lake up to the pump. When you suck liquid through a straw, you are actually creating the same type of low-pressure zone that the pump creates. Once the water is inside the pump, the impellers throw the water to the outside of the impeller case. This centrifugal action is what creates the pressure that allows the water to be pushed or pumped to the irrigation heads.



SIDE VIEW



END VIEW OF VOLUTE & IMPELLERS

FIGURE 25. 1 Centrifugal pump-volute and impellers.

As an irrigation designer, you need to tell the pump expert the maximum gpm (L/min) flow rate and pressure you need to make your most extreme circuit operate. You also need to tell the pump designer whether or not you will be pumping from a lake, well, or stream and what. phase power is available in your area. Power is supplied as single-phase and three-phase service. Single-phase power is usually supplied to residences, and three-phase power is supplied to facilities needing large quantities of power for such things as large air conditioners, industrial machines, and some pumps. Three-phase power is much more powerful than single-phase power. Contact your local electricity supplier to find out if you can get threephase power where you are planning to pump water. Once you have communicated all the variables to your pump station designer, he or she will then design your complete pumping station.

## Types of Pumps

There are two types of pumps used for irrigation pumping. They are the horizontal centrifugal pump and the vertical turbine pump.

### Horizontal Centrifugal Pump

Horizontal centrifugal pumps are less costly and less efficient than vertical turbine pumps. They have to be primed to work, so they are generally placed below the water source, unless you are willing to pay the extra cost of a self-priming unit. Figure 25.2 illustrates a horizontal centrifugal pump that is used on a golf course to pump water from a lake to an irrigation storage pond.

Centrifugal pumps can be used in shallow wells where the distance from the pump to the water source is less than 20 ft (6.1 m). If the distance is greater than that, you must use a vertical turbine pump. You have to use a self-priming pump if the pump is above the water level. One of the best uses for a centrifugal pump is to increase water pressure, for example, when inadequate water pressure is provided by a municipality or you are going up a hillside with irrigation lines. In such cases, you place the pump "in-line," or along the pressure mainline where you need to increase the water pressure.

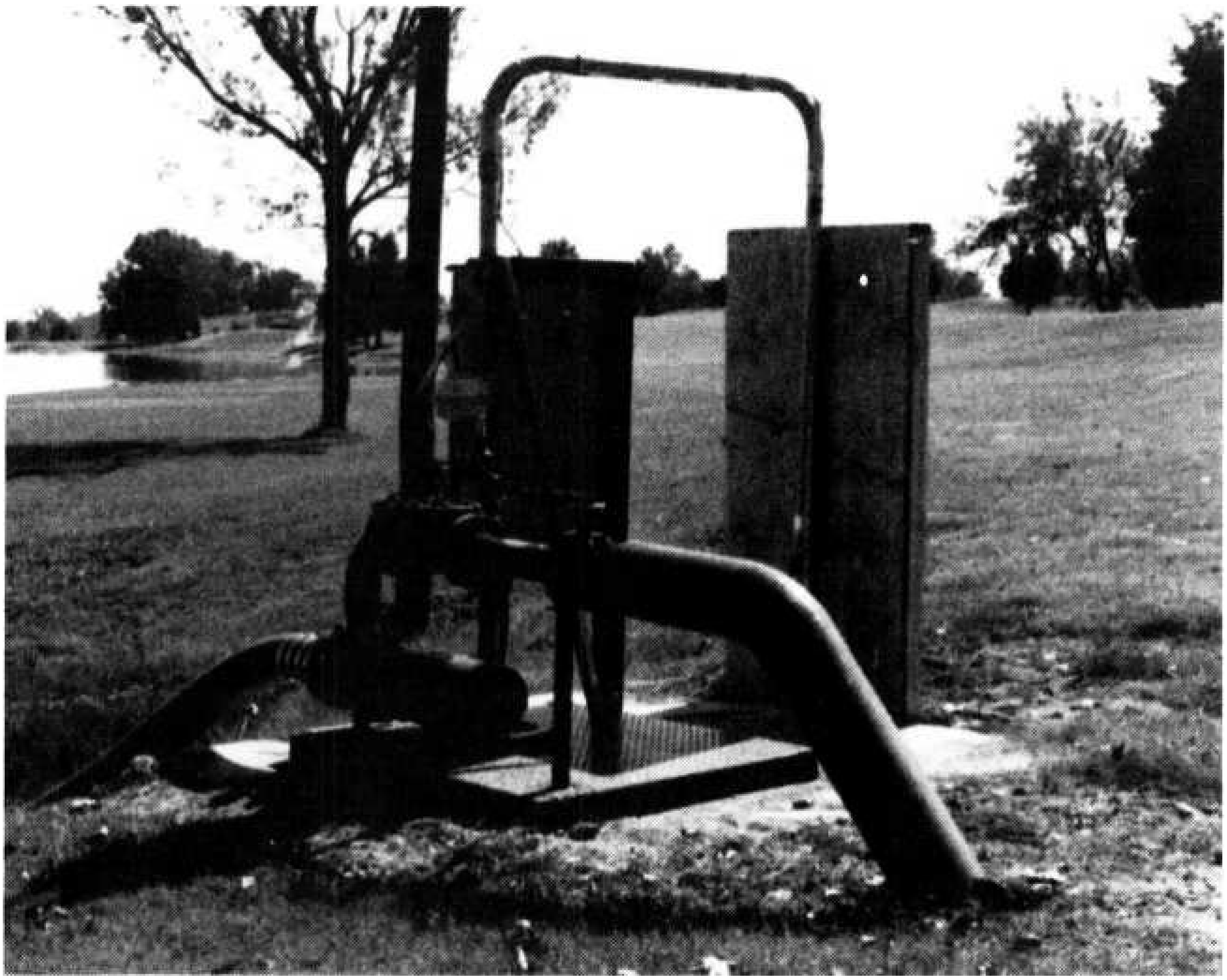


FIGURE 25.2 Horizontal centrifugal pump-self-priming.

When a horizontal centrifugal pump operates, a motor rotates an impeller or blade that is surrounded by water. The impeller and water are contained in a casing or volute. Water from a well, pond, or municipal supply enters by pipe into the center of the impeller and is forced at high speed to the outside of the casing by centrifugal force. The water, now under pressure, enters the mainline of your irrigation system.

Your pump will be selected based on the irrigation circuit with the highest flow and pressure demand. This way, your pump will meet the demands of the worst irrigation circuit. Remember, horizontal centrifugal pumps will not operate until the casing or volute is full of water, or primed.

### Vertical Turbine Pump

These pumps are used in both shallow and deep wells. A motor is installed aboveground on a concrete platform, and the pump is placed underground in the water (see Figures 25.3-25.6). There is a drive shaft that extends into the well and links the motor to the pump. The motor turns the drive shaft, which turns the impeller in the pump. Vertical turbine pumps can be used in wells over 1,000 ft (304.8 m) deep.

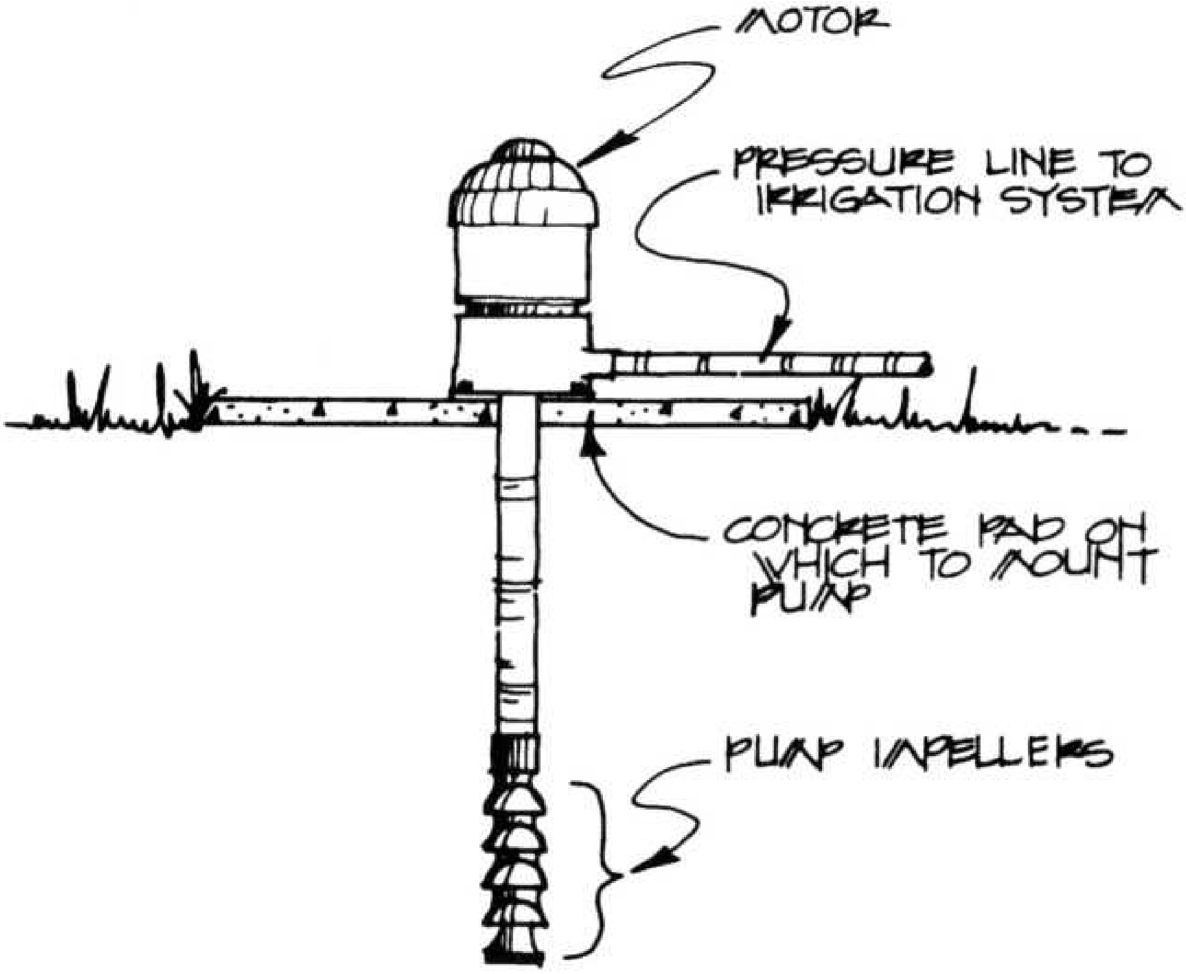


FIGURE 25.3 Vertical turbine pump.

Oftentimes, the flow rate and/or water pressure that is needed is more than can be pumped from a deep well, so a storage pond is constructed, and the turbine pump in the well keeps the pond full of water. When irrigation water is needed, another vertical turbine pump stationed beside the pond lifts water from the pond and pushes it into the irrigation system at the required pressure and flow rate (see Figures 25.4 and 25.5). Vertical turbine pumps are used a great deal in irrigation systems because of their efficiency and the high water pressure they are able to generate.

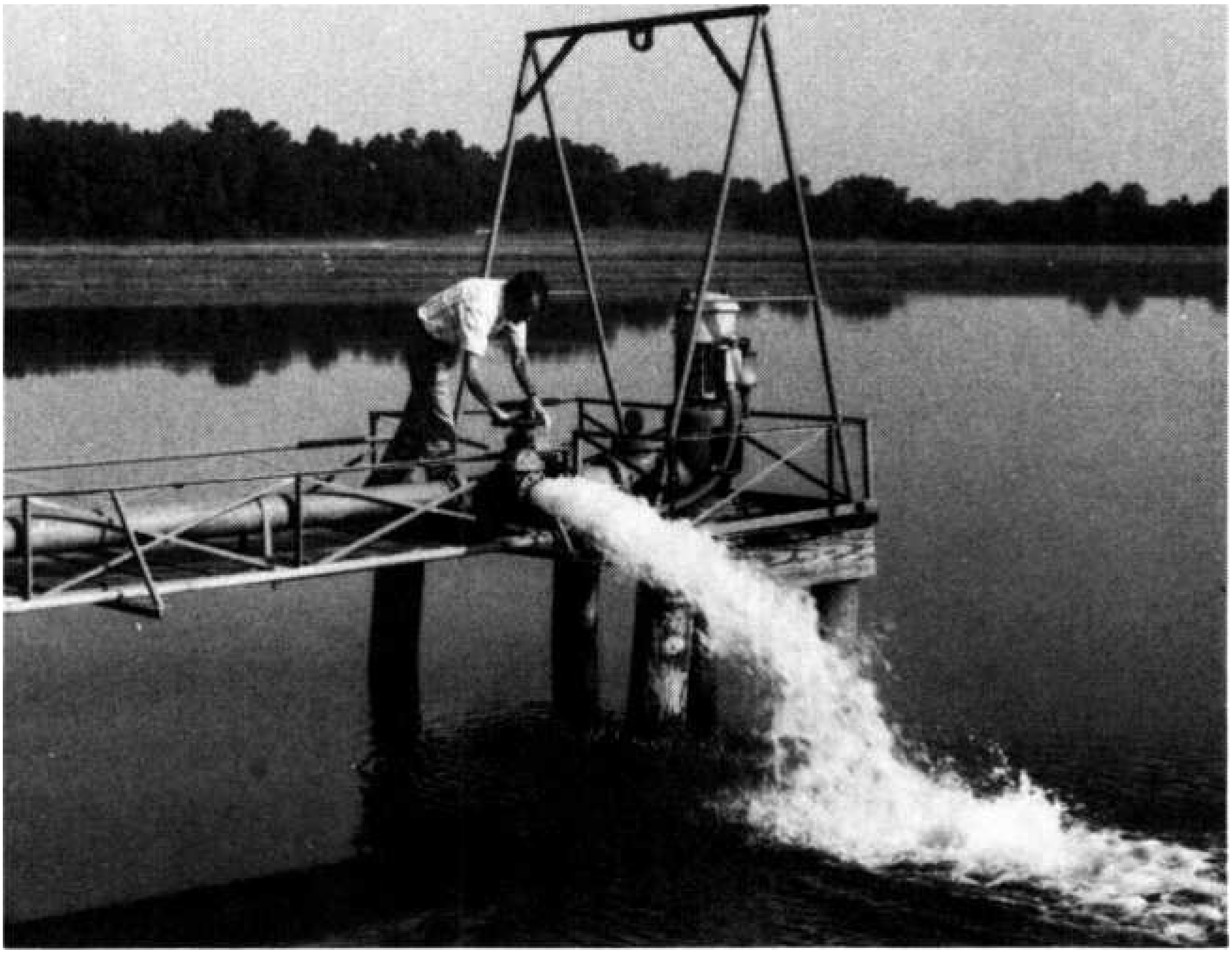


FIGURE 25.5 Deep well pumping into storage pond.

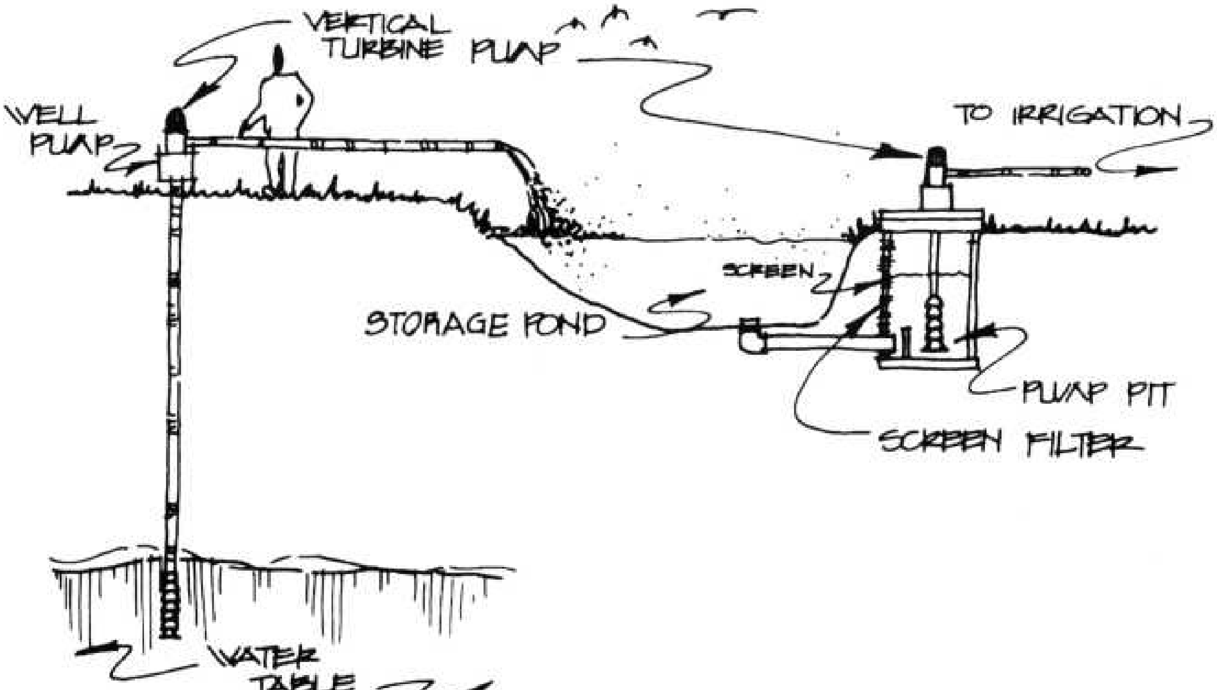


FIGURE 25.4 Deep well and storage pond pumping system.

## Creating Pressure and Flow with Pumps

### Pumping in Series

Let us say that your project demands 25 gpm (94.6 L/min) flow at 60 psi (4.2 kg/cm2). You could select a single pump that would deliver that flow and pressure, but let us assume the electrical service available might restrict you to using several smaller pumps, which you place behind one another. As each pump's impeller turns, water is pushed from one pump to another, and each pump adds greater pressure to the water. When you are using centrifugal pumps, this arrangement is called "pumps in series." After water has been forced through the last pump, we end up with our original flow of 25 gpm (94.6 L/min), but we now have a water pressure of 60 psi (4.2 kg/cm2) (see Figure 25.7).

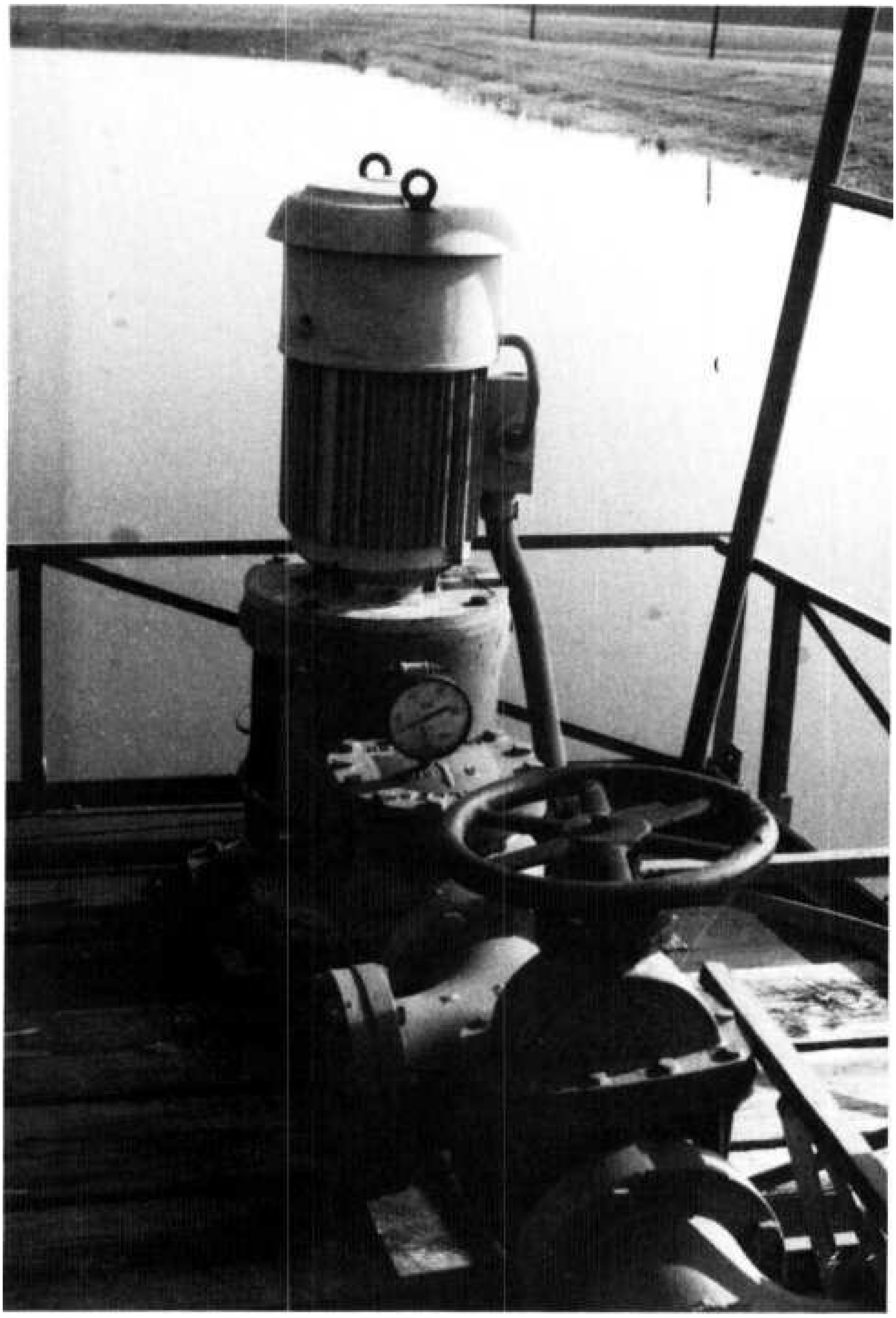


FIGURE 25.6 Vertical turbine pump at storage pond.

#### Multistage Pump

With a vertical turbine pump you can have several impellers that are arranged so that the flow from one impeller flows into the center of the other, thus building water pressure in the same way as does pumping in series. When you stack impellers in a vertical turbine pump, you have what is called a multistage pump (see Figure 25.3).

#### Pumping in Parallel

On most irrigation projects you need to provide different flow rates for different circuits while keeping the pressure the same; it is common for the flow rates for different circuits to vary. Providing different flow rates is accomplished by arranging your pumps beside one another, as shown in Figure 25.8. As the flow rate demand increases, each pump will come on to provide the extra flow. If all three pumps are on, as shown in Figure 25.8, a total of 75 gpm (283.9 L/min) flow at 25 psi (1.76 kg/cm2), for example, can be provided. If two pumps are on, 50 gpm (189.3 L/min) at 25 psi (1.76 kg/cm2) is provided. If the flow demand is for 25 gpm (94.6 L/min) or less, only one pump comes on and provides the 25 gpm (94.6 L/min) flow at 25 psi (1.76 kg/cm2). This arrangement of pumps is called "pumps in parallel," and it is often used for large turfwatering projects.

**Booster Pump**

In many irrigation instances, you may not have enough water pressure because of elevation extremes or the limitations of your water supply. Many municipal water companies supply water to golf courses at 70 psi (4.92 kg/cm2), and the pressure demand for the large turf irrigation heads needed for a golf course exceeds 100 psi (7.03 kg/cm2).

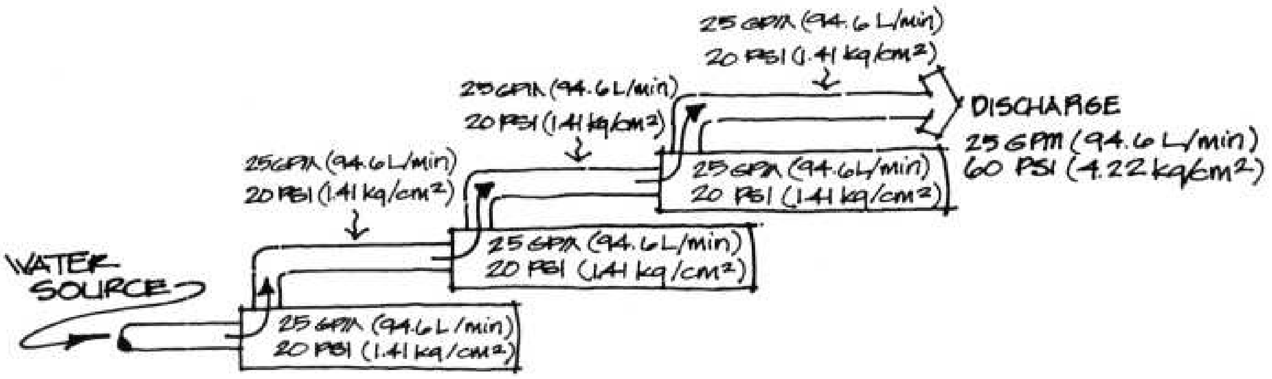


FIGURE 25.7 Pumping in series.

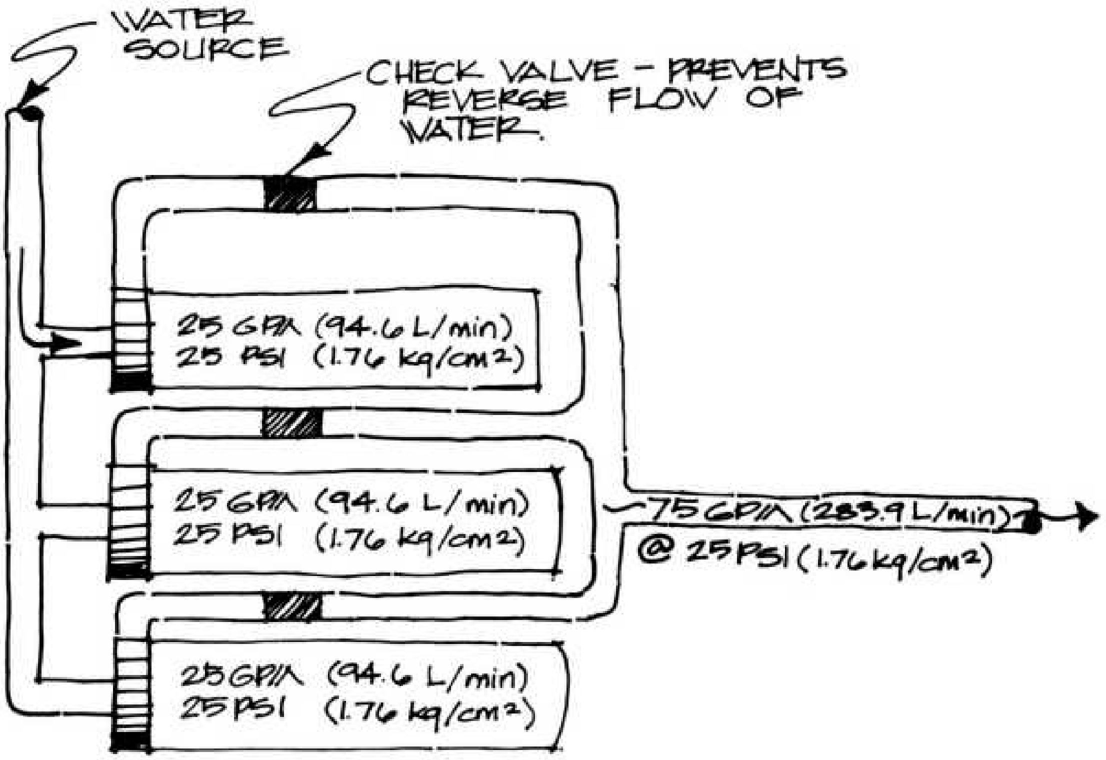


FIGURE 25.8 Pumping in parallel.

If you only have 40 psi (2.81 kg/cm2) at a 25 gpm (94.6 L/min) flow and you need 70 psi (4.92 kg/cm2) at a 25 gpm flow, you can get a booster pump rated to boost the water pressure 30 extra psi (2.11 kg/cm2). The pump takes the water at 40 psi (2.81 kg/cm2) and boosts it 30 more psi (2.11 kg/cm2) to give you 70 psi (4.92 kg/cm2). Horizontal centrifugal pumps are used to boost pressure, and you can install them along the pressurized mainline near the location where you want to boost the pressure (see Figure 25.9).

#### Pressurized Tanks

Using a pressurized tank, or hydropneumatic tank as it is also called, is another method of supplying irrigation water when you have varied discharge demands. The pressure tank contains water under pressure that can be delivered to the demand area. When the pressure and quantity of water in the tank drops below a certain point, pumps turn on automatically to replenish water and rebuild water pressure. Pressurized water tanks help to keep pumps from coming on too frequently, thus maintaining longer pump life. Additionally, the pressure tank takes up the surge when the pumps turn on. In any large irrigation system, there are going to be leaks along the pressurized lines. The pressure tank helps to keep constant pressure water in the irrigation lines at all times, thus reducing water hammer problems when pumps are turned on. Figure 25.10 illustrates a pressure tank and vertical turbine pumps.

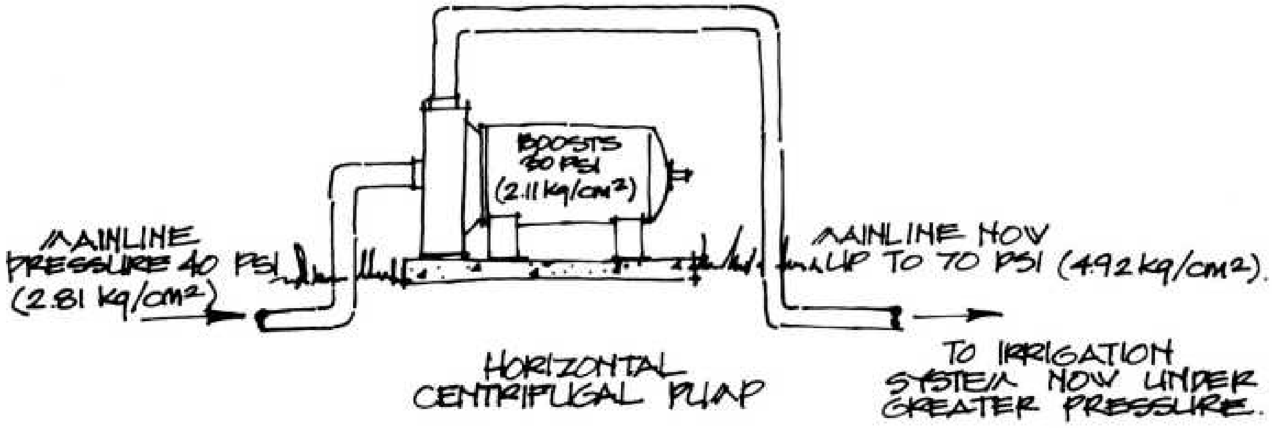


FIGURE 25.9 Booster pump.

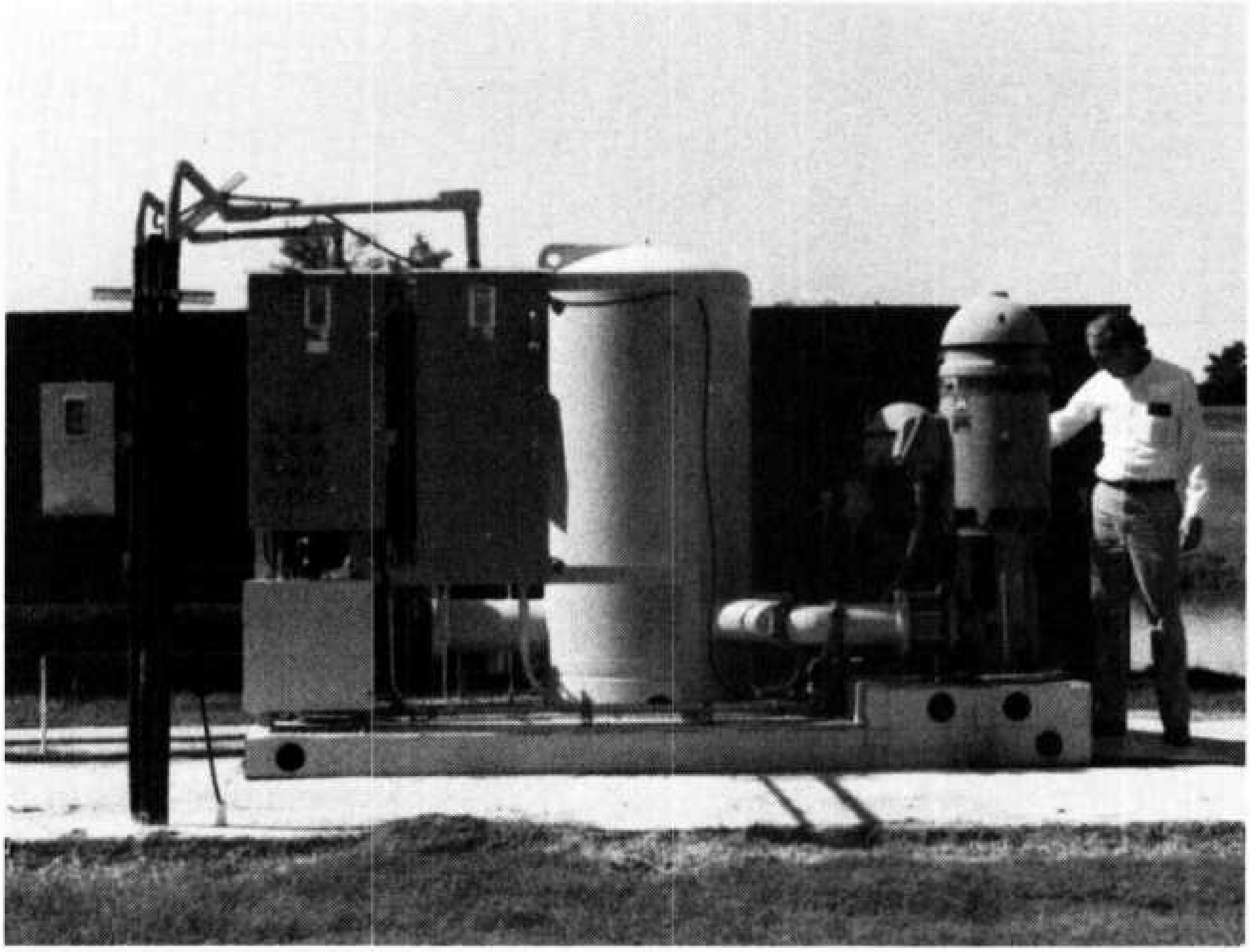


FIGURE 25. 10 Pressure tank and vertical turbine pump.

**Jockey Pump**

In many large irrigation projects, you have vertical turbine or centrifugal pumps that supply irrigation water. Usually, there is a pressurized tank that helps to reduce pump starting and keep pressurized water lines full. To further reduce the amount of times the large pumps come on, you can use a small pump called a jockey pump. Figure 25.11 shows a large pump, a jockey pump, and a pressure tank beside the jockey pump. This small vertical turbine jockey pump will restore water and pressure in the pressurized tank as small amounts of water are used. When a circuit is turned on, the jockey pump will come on. When the pressure in the tank is reduced to a certain point, the larger pump is signaled to provide water supply needs. When the large pump comes on, the jockey pump is turned off. When the water demand surpasses the ability of the big pump, the jockey pump comes back on to help the large pump meet the demand. On larger pumping systems, if the water demand by the irrigation circuit is still not met, a second large pump comes on, and the jockey pump is signaled to turn off.

FIGURE 25. 11 Large pump, jockey pump, and pressure tank.

# 26

# Making Solvent-Cemented Joints with PVC Pipe and Fittings

## Introduction

Because making solvent-cemented joints is one of the most important aspects of installing an irrigation system, we are going to thoroughly discuss the subject in this chapter. This chapter will help you to develop performance specifications and to know the correct method of gluing pipe as you inspect projects being installed.

Repair of broken lines and leaking pipe is very labor-intensive and results in a big cost either to you or your client. It is easy to solvent-cement joints, if you know the correct technique.

## PVC Joint Assembly Objective

Our objective is to produce strong, pressure-tight joints between PVC pipe and fittings. We are talking about pipe-to-pipe and pipe-to-fittings connections. There exists a good deal of variation in the industry regarding correct procedures for creating good joints. But there is only one approved way to produce the best joints and that process is set forth by the American Society for Testing and Materials (ASTM) in their specification ASTM D 2855-83, entitled "The Standard Practice for Making Solvent-Cemented Joints With Poly(Vinyl Chloride) (PVC) Pipe and Fittings." Throughout this chapter we will be discussing the content of this specification and even paraphrasing it at times.

## PVC Solvent-Cemented Joint

PVC solvent-cemented joints are made between pipe and fittings. Essentially, a primer is placed on the inside of the fitting and on the outside of the pipe, which dissolves their surfaces. A thin coat of cement, which is also called glue, is placed on both the pipe and fitting; when they are pressed together, a pressuretight joint is created. A solvent-cemented joint is also called a solvent-welded joint, and some folks call the procedure just plain old "gluing pipe."

## Principles for Making Joints

There are some excellent guiding principles you need to remember when making PVC solvent-cemented joints:

1. The joining surfaces must be softened and made semifluid.
2. Enough cement must be applied to fill the gap between the pipe and the fitting.
3. Pipe and fitting assembly must be made while the surfaces are still wet and fluid.
4. In the part of the joint where pipe and fitting are tight, their surfaces fuse together. Cement bonds the other surfaces that are not as tight.
5. When you solvent-weld a joint, you first apply a primer to the surfaces of the joint and then you apply the cement. Although the cement alone will penetrate and dissolve the surfaces, using a primer will :penetrate and dissolve the plastic surfaces more quickly.
6. When you apply cement, apply more than you need to fill the loose part of a joint. Cement layers will penetrate both surfaces and remain wet until the joint is assembled. Fluid coatings on the pipe and fitting will ensure that the two cement coatings will become one cement layer and eventually a stronger joint.
7. As the solvent in the cement evaporates, the cement layer and dissolved surfaces will harden, and the joint will become stronger. A well-made joint will be able to withstand water pressure before it is fully dry. Completed joints should not be handled until they have sufficiently set.
8. Use only solvent cements that are fresh and have been stored in a cool place. While on a lob site, keep your solvent cements in the shade if possible. Solvent cement has a limited shelf life when not stored in airtight containers. Notice the viscosity of the cement when you use it. Become aware of the correct fluid thickness of solvent cement.

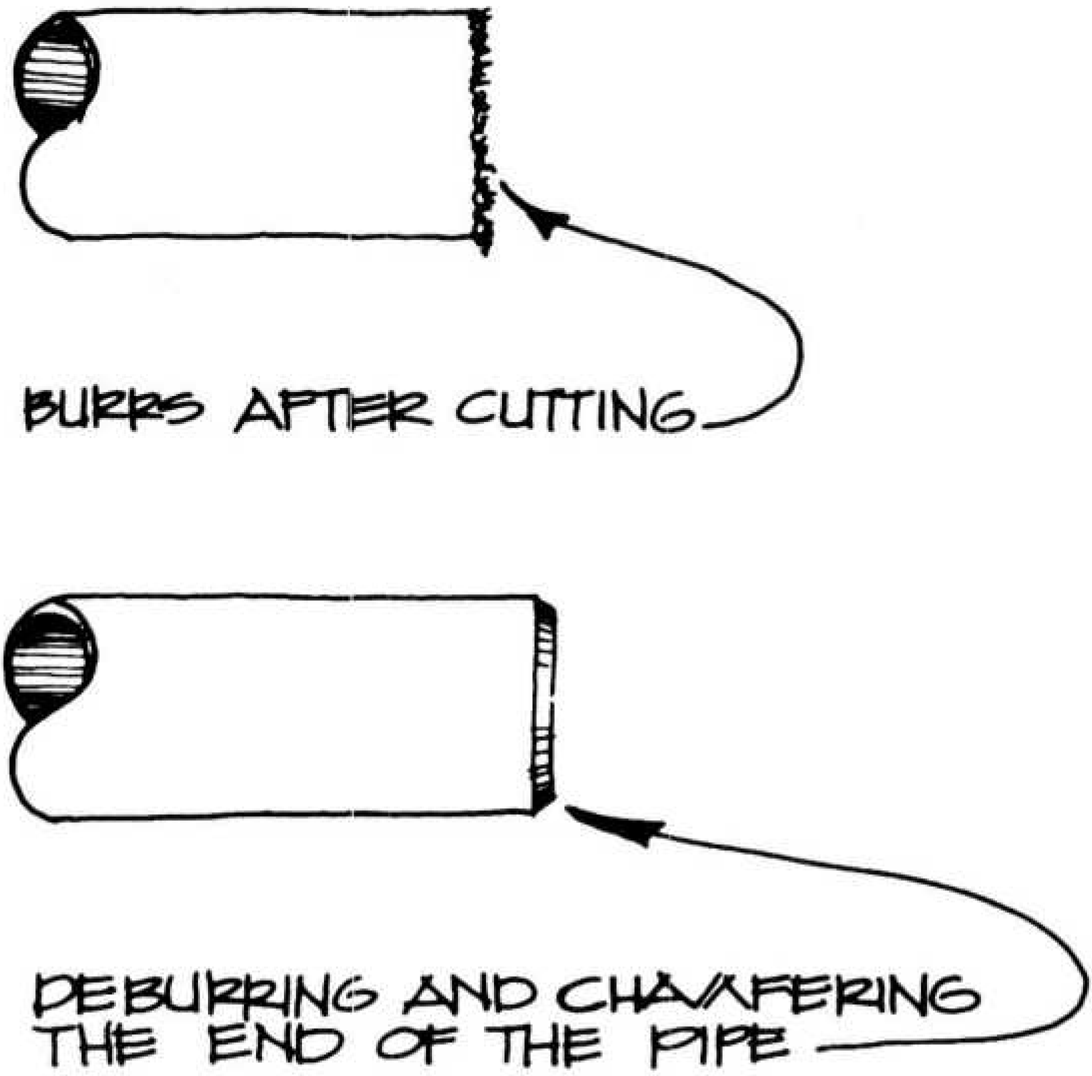


FIGURE 26. 1 Cutting pipe.

## Making a Solvent-Cemented Joint

### Cutting Your Pipe

Cut the pipe square with a fine-tooth saw. When you saw PVC, you will have burrs at the pipe end. Remove these with a deburring cone, knife, or abrasive paper (see Figure 26.1) . If any burrs remain, the burrs could scrape cement from the socket surface when you push your cemented joint together. This could produce a weak welded joint that would leak. When you deburr, you are not only eliminating the burrs but also chamfering the end of the pipe so that when you push the cement-coated pipe into a fitting, it does not remove the cement and softened plastic material from the fitting socket (see Figure 26.2).

### Test Joint for Fit Before Gluing

Pipe and fittings have been designed so that when you insert a pipe into a fitting, the pipe wall and fitting will become snug before the pipe reaches the bottom of the fitting socket. In fact, interference occurs about one-third to two-thirds of the socket depth. This snug fit helps to make for a strong, leak-free joint. If the pipe goes all the way to the bottom of the fitting socket, be sure to apply enough cement to fill the gap between the joint and the fitting.

### Cleaning the Pipe and Fitting

Make sure the surfaces to be joined are free of grit, moisture, oil, and whatever else. Wipe these surfaces with a clean, dry cloth to prepare them for solventwelding.

### Considerations Affecting Solvent-Welding

Because solvent cement dries quickly, apply the cement and make your joints as quickly as good work manship will allow. With large pipe, two people may need to work together to solvent-weld.

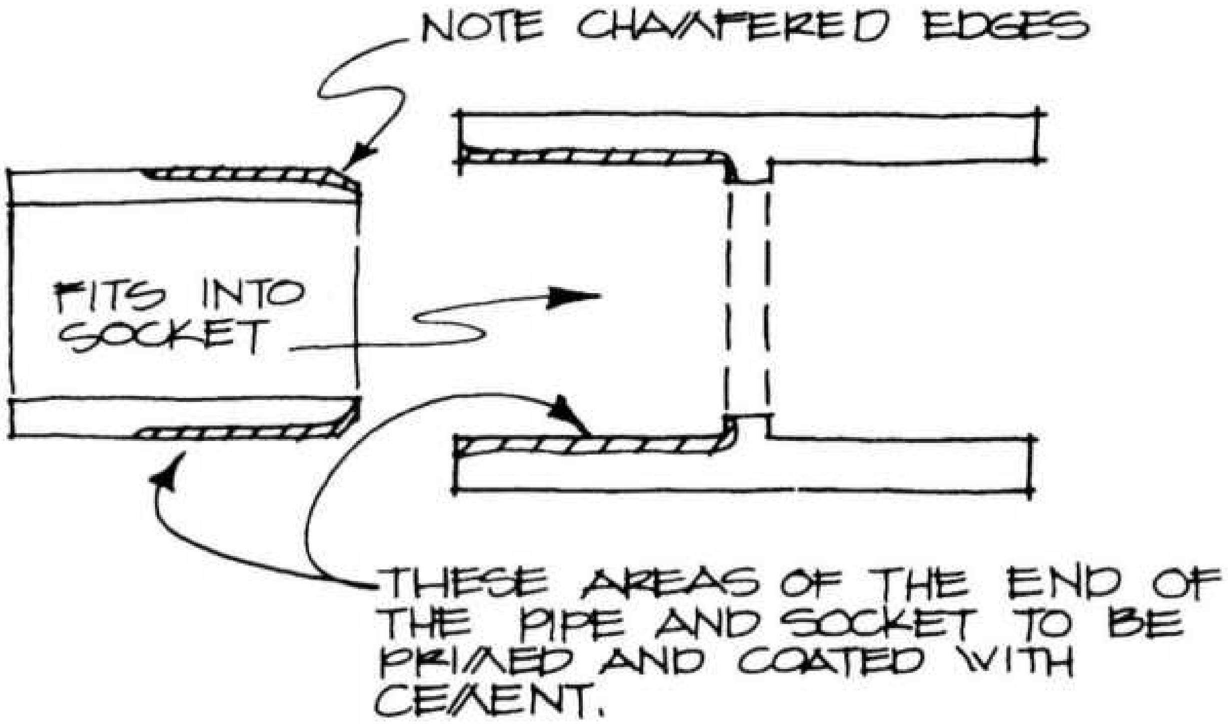


FIGURE 26.2 Solvent cemented joint preparation.

When you are working in an area of high humidity, it is important to be able to make your solvent-welded joints quickly because moisture in the air condenses on the surface of the cement. Also, be aware of air temperature extremes. Do not glue pipe when the air temperature is above 110°F (43.3°C) or when the pipe is in the direct sun and the pipe surface is hotter than 110°F (43.3°C). You can reduce the temperature of the pipe by wetting it with clean cloths. Be sure to thoroughly remove all moisture on the pipe before making your welding joints.

When the air temperature is below 32°F (0°C), solvents soften the PVC much more slowly than in warm weather. You can glue pipe at these temperatures, but it is recommended that you make a test with scrap pipe and primer to see if the solvent is able to penetrate the PVC in the cold weather. To do this, apply primer to the pipe, wait two or three minutes, and then check to see if the primer has penetrated into the pipe surface. Scrape the area with your knife. If the solvent has made the plastic surface soft enough to be removed, then a suitable joint will result. If the solvent has not penetrated sufficiently into the pipe, then a good, strong joint will not likely develop. Your alternatives, then, are to make your joints indoors where the temperatures are more suitable or wait until another day to glue pipe. It is a cautious practice to make your penetration test on several different pieces of pipe, especially if you have material from different manufacturers. Pipe formulas and surfaces may vary, and the penetration test results may vary as well.

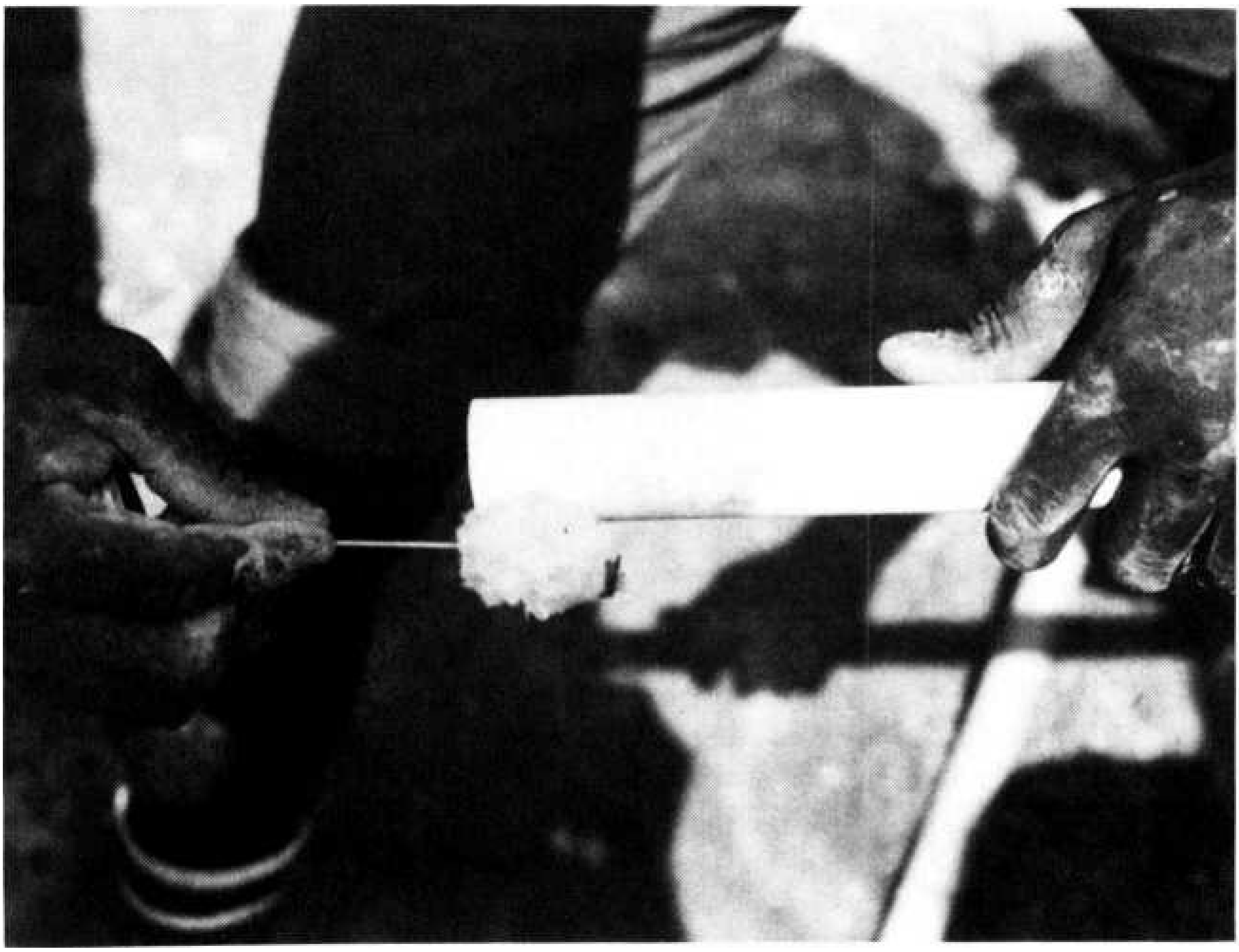


FIGURE 26.3 Application of primer to pipe.

**Application of Primer and Cement to the Joint**

You first apply primer in a scrubbing motion to the inside of the fitting socket. The back-and-forth scrubbing motion of the application brush ensures penetration of the primer. Next, you do the same thing to the male end of the pipe that is to be inserted into the socket (see Figure 26.3). Of course, only apply primer to the depth of the fitting socket. You want to be sure the surface of the pipe to be solvent-welded is well dissolved. Before you apply the cement to the pipe, be sure to brush the fitting socket again with primer to make sure the surface is dissolved.

Now, quickly apply cement with the brush (see Figure 26.4) in a light coating to the male end of the pipe while it is still wet with primer. Next, apply cement lightly to the inside of the fitting, taking care to keep excess cement from building up in the socket. The excess cement could weaken the PVC by dissolving through the pipe. Finally, apply a second light coat of cement to the pipe, and while both the fitting socket and the pipe end are soft and wet with cement, force the pipe into the socket all the way to the bottom of the fitting socket (see Figure 26.5). Be sure to turn the pipe or fitting % turn while you are forcing them into one another to evenly distribute the cement. Also, if a piece of sand or grit were to get on the primed areas, twisting the pipe helps to seal the grit into the joint without leakage. While pushing the pipe into the fitting socket, be sure to use a steady, twisting force. Do not beat on the end of the joint to force the pieces together, as this will make a weak joint.

Once the joint is together, hold it in place for one minute after assembly so that the cement can set in the joint. If you do not hold the two pieces together, the pipe could back out of the fitting socket. The ASTM specification says that assembly of the joint should take less than 20 seconds after the last coat of cement has been applied to the pipe.

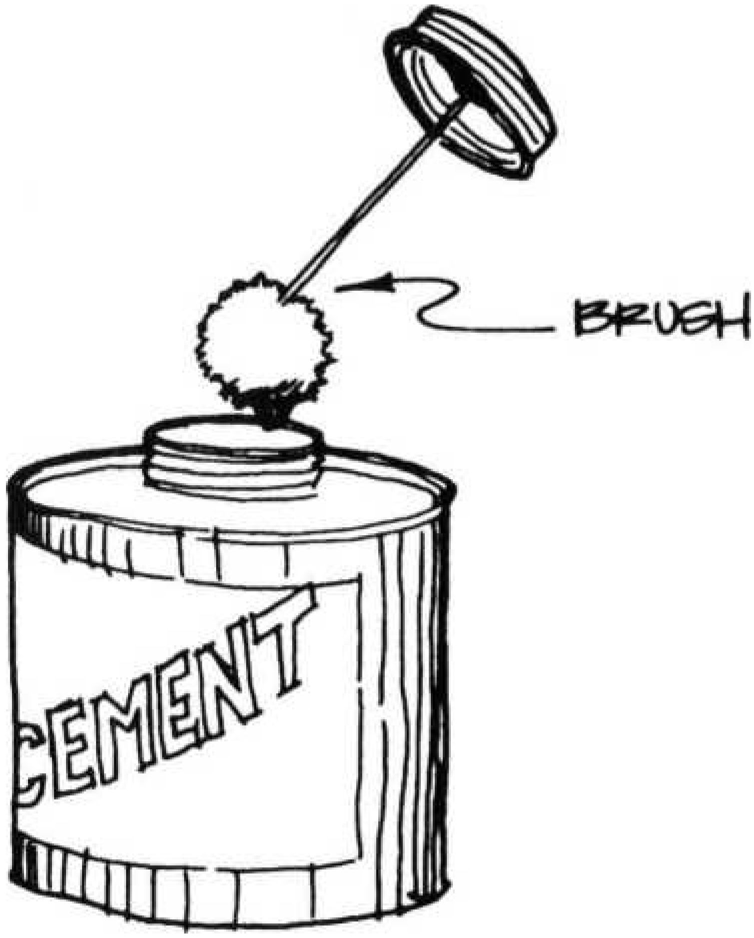


FIGURE 26.4 Can of cement and brush.

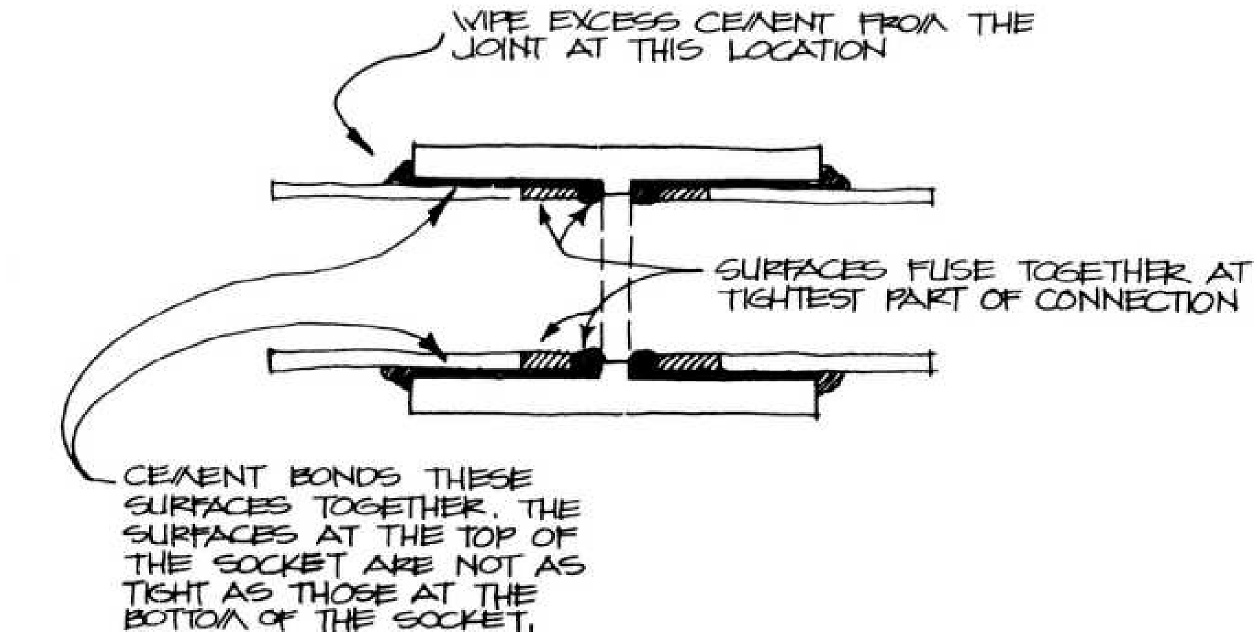


FIGURE 26.5 Characteristics of the solvent weld joint.

After assembling the joint, wipe any excess cement from around the pipe at the fitting socket. This will ensure that your cement does not continue to dissolve into the pipe and weaken the assembly. You know you have made a good joint when you can see a continuous bead of cement around the fitting socket without any gaps. Gaps might mean the cement was not fully placed on the PVC parts to be joined, and this would indicate a defective or weak joint.

### Curing Time for the Solvent-Cemented Joint

After holding the joint assembly together for one minute (in order for the cement to set), you can handle the pipe and new joint, but only if you do it gently and carefully. Dropping or jarring the pipe can weaken and even break the curing joints. After the cement has set, it takes a certain amount of time for the joint to cure, depending on the air temperature. The following minimum cure times are recommended by ASTM for PVC joints.

30 minutes if the air temperature is 60°F to 100°F (16°C to 38°C)

1 hour if the air temperature is 40°F to 60°F (4°C to 16°C)

2 hours if the air temperature is 20°F to 40°F (-7°C to 4°C)

4 hours if the air temperature is 0°F to 20°F (-18°C to -7°C)

### Pipe Installation and Testing of New Joints

After the pipe joints have cured, the pipe can be carefully placed in a trench. When placing the pipe, be sure to snake it from side to side in the trench, as plastic pipe can expand and contract 0.33 in (8 mm) per 100 ft (31 m), depending on temperature fluctuations. By snaking the pipe, you will not only be providing for this change of lengths but also making sure to protect your joints from excessive stresses.

Before backfilling the trench, the pipe should be brought near to the temperature at which it will operate to prevent expansion and contraction stresses. If you assembled pipe in the sun or on a hot day, it will need to cool before placing it underground and running cool water through it. To bring the pipe to its operating temperature, you could let it stand overnight, you could place a small amount of soil over the pipe to shield it from the sun, or you could fill the pipe with water and let it. stand. All of these methods will help to cool the pipe.

Many contractors like to pressure-test pipe before they backfill their trenches. If you bring the pipe to operational temperature by placing soil over the pipe to shade the pipe from the sun, be sure to leave all joints exposed so that they can he examined during pressure tests. ASTM suggests that you test your irrigation system with 150% of the water pressure you plan to use in your system. If you plan to run your system at 50 psi (3.52 kg/cm2), test if for leaks at 75 psi (5.27 kg/cm2). Test pressures are held until the pipe joints are checked for leaks.

# 27

# Irrigation Specifications

## Introduction

We will first discuss the generalities of specifications (such as what a specification is and how it is used) and then we will discuss how specifications relate to contract documents. We will conclude with the difference between specifications and working drawings. We have compiled a sample irrigation specification for your review in Appendix II.

According to Webster's Third New International Dictionary (1986), a specification is "a part of a contract [that describes] qualities of materials and methods of construction."

Specifications are used by the contractor, estimator, purchasing agent, inspector, owner, subcontractor, and material manufacturers. The estimator uses specifications to define materials on which to estimate a bid. Specifications tell the contractor how to construct a project and inform the client as to what he or she is buying. Because the overall format of organizing specifications is broken down into the various trades, subcontractors use specifications to determine their scope of work.

## Contract Document

We have been talking about technical specifications thus far in our discussion. Let us now look at the components that comprise a set of contract documents, or contract specifications, to see where technical specifications are located (see Table 27.1). A brief description of the five components that comprise a legal contract will help you to understand the nature of a complete contract and the role of the technical specification.

The bidding documents describe the work to be done and the qualifications a contractor must have in order to bid on the work. This first section of the contract tells how the bid should be developed and when it will be opened. A bid bond is usually required in this section, which ensures that the contractor who makes the selected bid will perform the work.

The contract forms component contains the actual agreement between the client and the contractor. This section usually contains a proof-of-insurance form that protects the client from liability insurance claims. Proof that the contractor has bonds to ensure payment for materials and labor is also contained in this section of the contract.

The general requirements part of the contract is, basically, the ground rules for doing the work. The ground rules cover the client and contractor rights, the responsibilities of the landscape architect, the due date of the contract, payment schedule, changes needed to be made, and inspection of work.

The technical specifications section is usually the most voluminous part of the contract. Technical specifications describe the quality of the materials and the construction techniques that the contractor will use on the project.

### *TABLE 27.1* **Contract Documents**

1. Bidding documents
   Invitation to bid
   Instructions to bidders
   Bid forms
   Bid bond
2. Contractual forms
   Agreement
   Proof of bond form
   Proof of insurance form
3. General requirements of the contract
   Summary of work
   Payment schedule
   Submittals
   Quality control
   Project closeout
4. Technical specifications
5. Working drawings

The working drawings section of the contract is comprised of all working drawings developed for a particular project. Even though the drawings may not he bound together in an 8.5-in X 11-in (216 mm X 279 mm) format with the specifications, the drawings are still an integral part of the contract document.

### Types of Technical Specifications

The four kinds of technical specifications are the descriptive, performance, proprietary and reference specifications. The descriptive specification defines in detail the materials the client wants used on the project and the workmanship he or she expects. A performance specification requires a contractor to match an existing condition or situation, such as paving color and texture. The proprietary specification states the actual model, make, and number of a product. This specification could tell a contractor to use a specific sprinkler head or controller. And finally, the reference specification makes reference to a standard established for a material or test method like an ASTM specification.

### Working Drawings and Specifications

Working drawings make no attempt at segregating work of the various trades, whereas the technical specifications do. If the working drawings and specifications are in conflict with one another, the courts have adjudged that the technical specifications have greater importance than the working drawings.

Let us look further at the relationship between working drawings and specifications. The drawings you develop show size, form, location, and arrangement of elements. In particular, drawings show

1. Location of materials and equipment
2. Details of construction and dimensions
3. Interrelationship of materials, equipment, and space
4. Schedules, such as a listing of circuit valves and their gpm (L/min) flow rates

A specification is a device for organizing the information on drawings. Technical specifications break down information into units of work done by various trades. In partictilar, technical specifications include

1. Type and quality of materials, equipment, and fixtures
2. Quality of workmanship
3. Methods of fabrication, installation, and erection

4. Test requirements

**Conclusion**

The irrigation installation specifications in Appendix II have been developed for your review. The specifications contain the general requirements and technical specifications of a contract. If you plan to use this specification or parts of it, be sure to make it applicable to the irrigation materials you are going to use and to construction practices in your part of the country.

# 28

# As-Built Drawings

## Introduction

An irrigation system is not often built according to the original layout plan. When a revision occurs, the contractor should draw a revised layout plan that records all changes. This revised layout plan is an as-built drawing and is an invaluable tool for future maintenance and development.

An as-built drawing has many uses. Because the drawing records all the changes from the original irrigation plan, it serves as a tool for finding and repairing pipe. All additions to the irrigation system must be in concert with the pipe layout on the as-built plans. Pipes are frequently cut into by a trenching machine or cracked by a shovel because the location of existing facilities was unknown.

## Why Changes Occur

Changes in the original drawings occur because of various unpredictable circumstances. A contractor may hit rock or buried concrete while trenching and may have to alter the pipe location. Existing utilities that were not considered in the original plan may dictate changes from the original drawing. Many times, a contractor may know a less expensive and more efficient way to route pipe while maintaining the same sprinkler coverage as designed in the original irrigation plan.

## Example of an As-Built Drawing

Figure 28.1 illustrates a portion of the original irrigation plan for a park visitor center. In the original plan, the pipe mainline was laid out to go beneath an existing retaining wall. Because the contractor did not know how deep the footing was for the wall, he got permission to route the mainline around the end of the wall. Once the irrigation design was installed, the contractor developed an as-built drawing, as shown in Figure 28.1, to record the changes from the original plan.

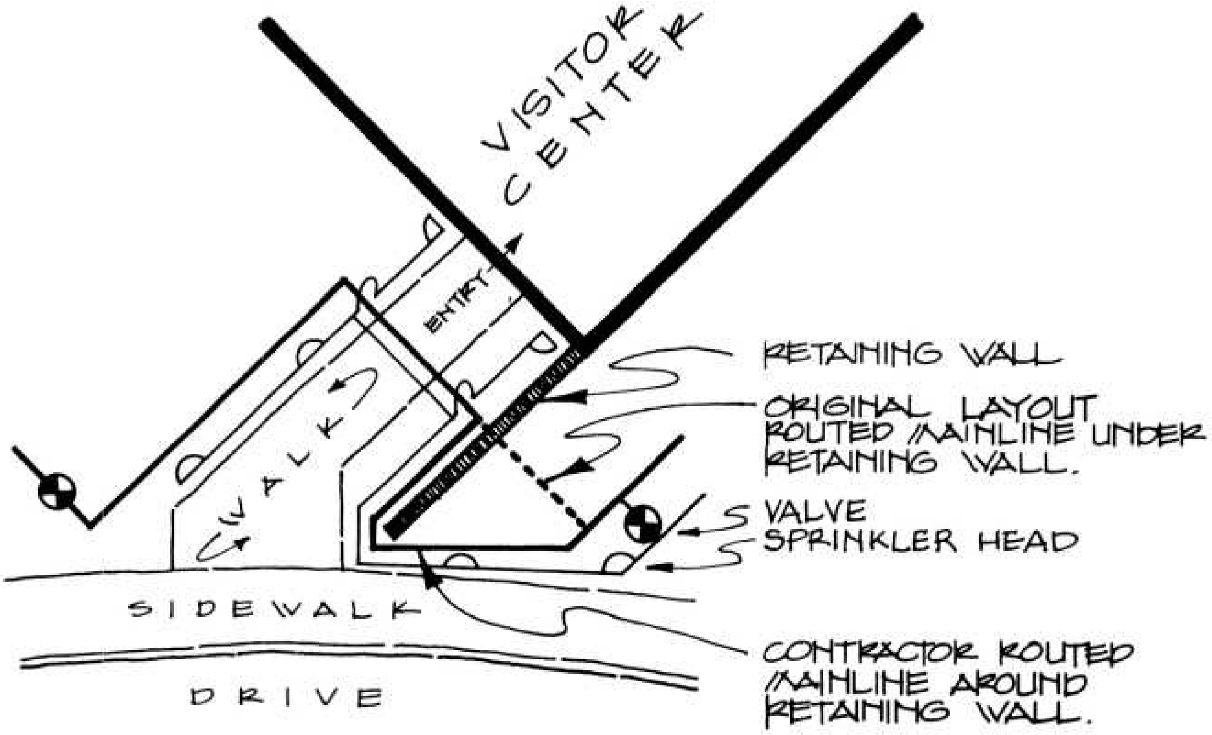


FIGURE 28. 1 As-built drawing.

# 29

# Athletic Field Irrigation Design

## Introduction

When you water an athletic field, you are watering large, open expanses of turf. This situation demands the use of irrigation heads that throw water long distances. Irrigation heads used on athletic fields have at least a 50-ft (15-m) radius. The large turf heads use a lot of water, from 6 gpm (22.7 L/min) to over 30 gpm (113.6 L/min). Be aware that if you use very many high-gpm (-L/min) heads on the same circuit, you are going to have to use large pipe to handle the flow.

Heads used on athletic fields must not impede the play of the game. The better athletic turf heads recede up to 0.5 in (13 mm) below the surface of the ground. This not only makes the heads practically invisible, but it also makes it nearly impossible for an athlete to become injured by falling on an irrigation head.

## Circuiting Heads

There are two techniques for circuiting or zoning large turf irrigation heads: the block system and the valve-in-head system.

### Block System

The block system is the method in which we link groups of sprinkler heads to valves (see Figure 29.1).

We have already learned about this method. The block system works best where many diverse watering areas need to be controlled by separate circuits.

With athletic fields, the entire field has the same general water need. However, the areas of a field that get the most use, such as the center of a football field, do need more water than the edges.

### Valve-in-Head System

The valve-in-head (VIH) system uses sprinkler heads that have a valve built into their bottom. Some sprinklers are called valve-under-head (VUH), and these have a valve attached either to one side of the head or on the swing joint. Both the VIH and VUH sprinklers are individually controlled. The valve in the sprinkler head acts just like the circuit valves. When the valve receives a signal from the controller, it opens and allows water to pass through the sprinkler head. Valve-inhead sprinklers are hydraulically actuated; they are part of a hydraulic sprinkler system rather than an electric system. Valve-under-head sprinklers are usually electrically controlled.

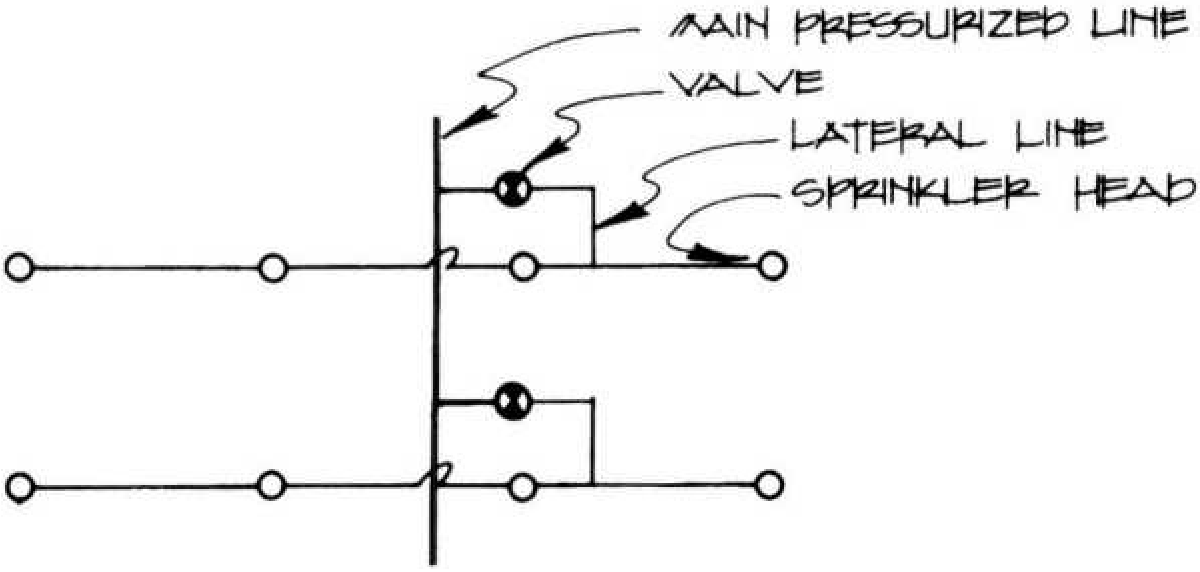


FIGURE 29. 1 Block system.

For large-scale turf irrigation, there are advantages to using the valve-in-head system over the block system. Those advantages include the following:

1. The VIH system uses smaller pipe than block systems.

2. Fewer pipe sizes are used, which means there is more duplication of pipe and fittings. This can mean lower costs to the contractor.

3. Because there are not main and lateral lines, all lines are trenched at the same depth.

4. All valves are accessed through the top of the head for maintenance, so there are no valve boxes on the play field.

5. Because each head has its own valve, there is no low-head drainage. When the valves close, the line connecting the sprinkler head and valve is under static pressure.

6. Surge pressure is practically eliminated because all lines are full of water and under pressure at all times.

7. Any of the sprinkler heads can be linked together to run on the same station. For example, the heads in the center of a football field, which need to be run longer than those on the side of the field, could be run together on the same stations.

## Athletic Field Design

Figure 29.2 illustrates how to lay out heads for a football field. We have used 22 VIH sprinklers laid out using triangular spacing. At times there will be 8-mph (12.9-km/h) winds during watering, so we will use 50% overlap for our irrigation heads. In this situation we are not intending to water the area beyond the field, although some water will be sprinkled in this area. You can see that the heads are located to provide even coverage in the center of the playing field. Less water is delivered along the edges of the field, but there is usually less stress placed on the turf in that area.

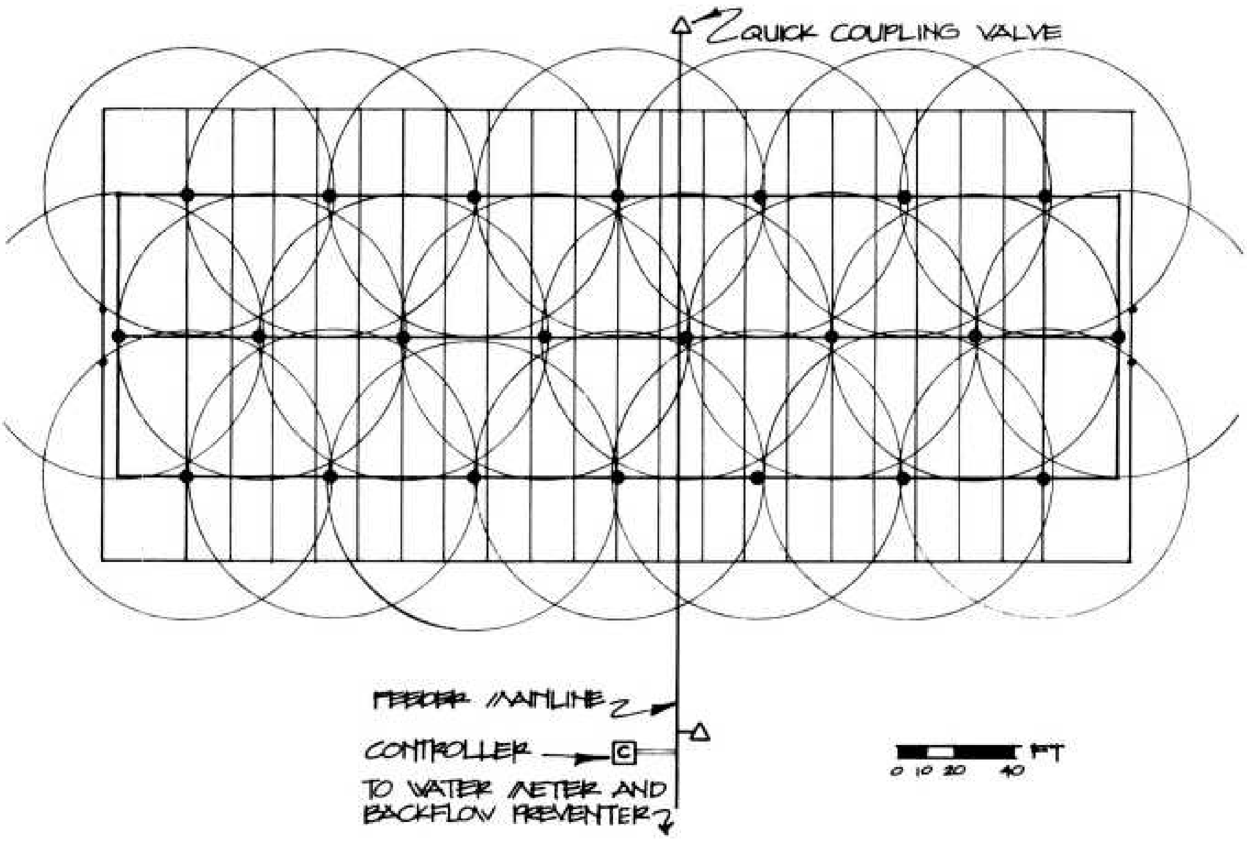


FIGURE 29.2 Head layout for a football field.

FIGURE 29.3 Valve-in-head sprinkler and swing joint.

The head we used was a Toro 640 Series head (see Figure 29.3), which recedes 0.5 in (13 mm) below ground when not sprinkling. We selected a -41 nozzle and a full-circle arc. At 60 psi (4.22 kg/cm2), the nozzle has a 54-ft (16.5-m) radius and delivers 11 gpm (41.6 L/min) of flow.

The piping is looped so as to reduce the size of pipe we have to use and to minimize friction losses. Because our heads need 60 psi (4.22 kg/cm2) to operate properly and many municipal suppliers provide static water pressure at around 70 psi (4.92 kg/cm2), water pressure is precious. If we find that we do not have enough water pressure after calculating our losses through the water meter, backflow preventer, and pipe lines, then we will have to use a small horizontal centrifugal booster pump to increase operating pressure.

To save money on pipe costs, we are going to link two heads together per controller station as shown in our example. Each head demands 11 gpm (41.6 L/min) of flow, so our pipe must accommodate a maximum of 22 gpm (83.3 L/min) of flow at one time. Looking at Class 200 pipe-sizing charts for 22-gpm (83.3-L/min) flow, we see that we can use 1'/4-1 n or I in (32 mm or 38 mm) pipe. To reduce our friction losses, it might be best to bring the water into the field with a 1 6-in (38-mm) pipe and then use 1 V-in (32mm) pipe on the field.

You can see in Figure 29.4 that we decided to link the 8 heads down the middle of the field on four stations and then the 14 heads along both sides of the field to seven stations. Recall that with a hydraulic system, the valves are opened by a release of water pressure in the Vi-in (6-mm) control tubing. When the controller applies water pressure, the valves close. The valves in the VIH sprinkler are normally open.

There are many ways to arrange sprinkler heads to water a football field, but this 22 VIH method is one of the most popular (Figure 29.5).

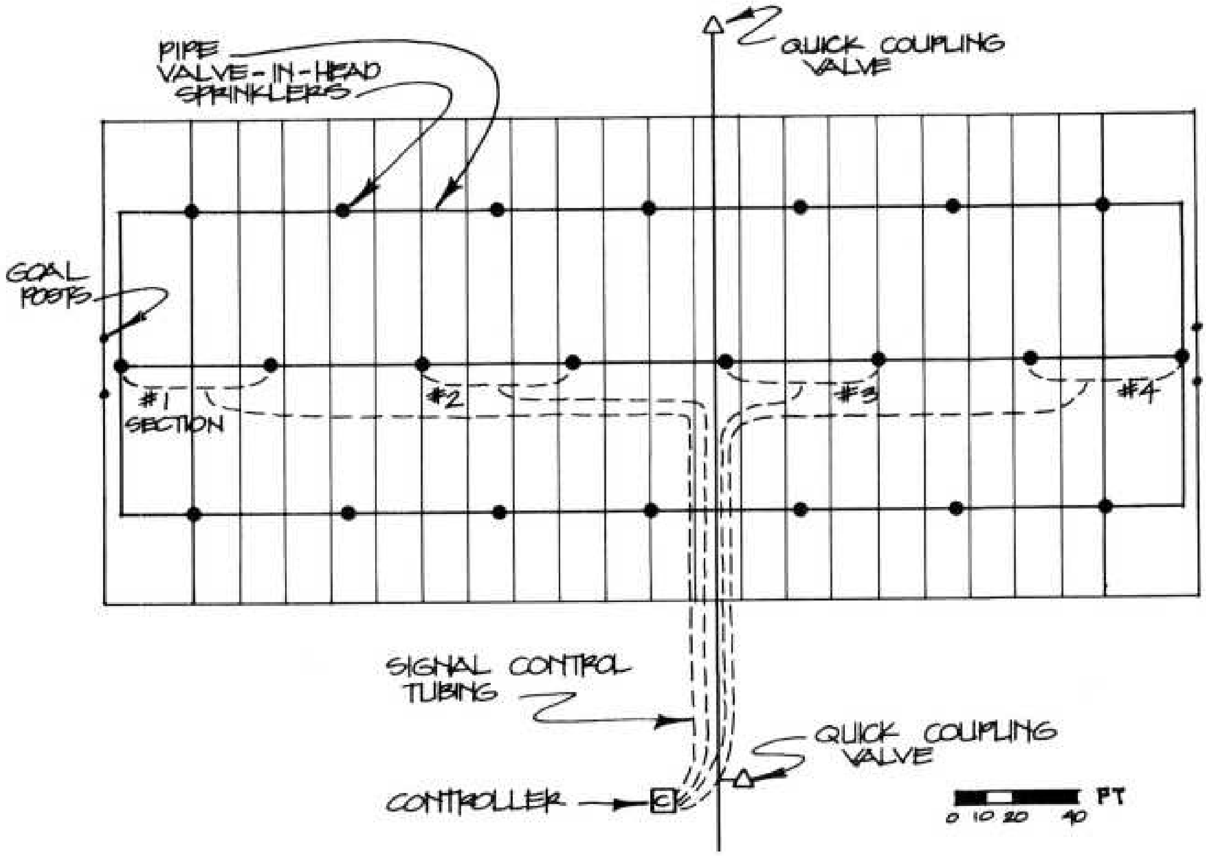


FIGURE 29.4 Connecting heads to controller stations.

FIGURE 29.5 Vlhl sprinklers watering the center of a football field.

# 30

# Getting Acquainted with Drip Irrigation

## Introduction

Drip irrigation is defined as the slow application of water to the root zone of a plant by means of a very small sprinkler head called an emitter. The emitter delivers water very slowly, drop by drop, to the soil. Drip irrigation has a proven record for watering trees, shrubs, ground cover, flowers, and vegetable gardens. It can also be used for irrigating small turf areas. Why consider drip application when a sprinkler system will do the same job? The advantages of drip irrigation for a landscape design include the following:

- Drip irrigation components are not very expensive, so money can be saved.
- Drip irrigation puts the water at the plant's root zone where it is needed.
- There is no water runoff with drip irrigation because of the slow application; nearly all water soaks into the soil.
- Water is not thrown into the air as it is in a sprinkler system, so there is no evaporation in the air and from plant leaves.
- There is less weed growth with drip irrigation because the water is placed only at the plant's roots, in contrast to covering a larger area with sprinkler heads.

With drip irrigation, you can deliver ideal plant water needs and thereby achieve optimum plant growth.

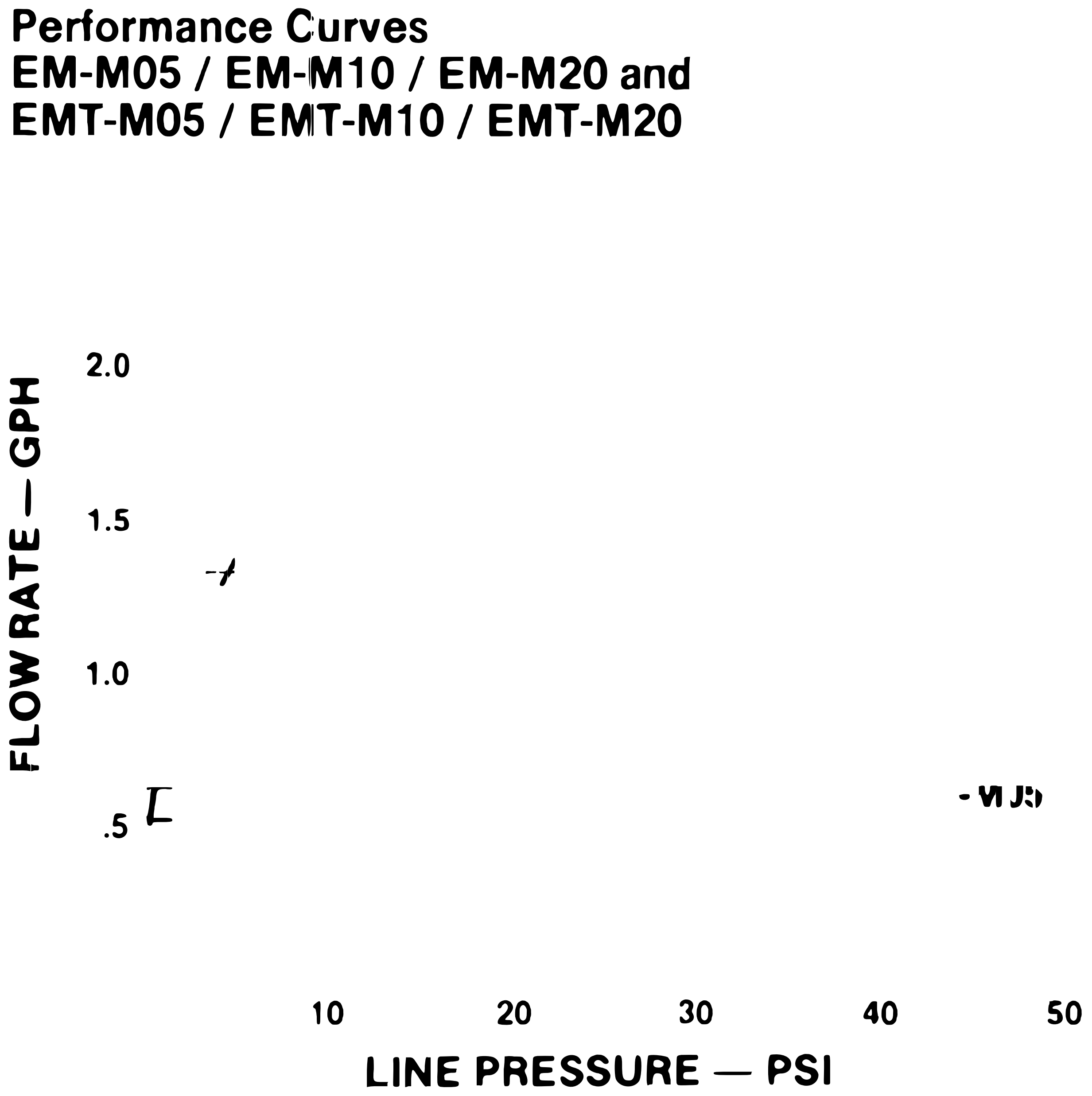
## Evolution of Drip Irrigation

Drip irrigation is called trickle irrigation by many because of the way that water is distributed by the emitter. According to our Webster's New World Dictionary (1975), trickle means "to flow slowly in a thin stream or fall in drops." Regardless of what it is called, this method of slowly applying water has proven itself all over the world. Drip irrigation was pioneered in Israel during that country's efforts to grow crops in the desert on a very limited water budget, and it proved to be a success. Now drip irrigation is used on row crops and in vineyards, orchards, and greenhouses nearly everywhere. More recently, drip irrigation has proven to be effective on ornamental plants in the landscape. To further our knowledge, let us examine the emitters, those devices used to deliver that trickle of water to plants.

## Emitters

The emitter acts as the sprinkler head in the drip method of watering. Water is sent under pressure through a plastic or polyethylene pipe or tube, and the emitter delivers the water in a precise amount each hour. Notice that we said a "precise amount of water each hour." Emitters are rated on how many gallons or liters per hour (gph, L/hr) they discharge, as opposed to the gallons or liters per minute (gpm, L/min) measurement we use on our sprinkler systems. The discharge of water from the emitter is so slow that we must rate it in terms of hours rather than minutes.

*TABLE 30.1* ***Rain Bug and Shrub Bug Performance Curves***



Emitters are rated according to the pressure in psi (kg/cm2) and the flow in gph (L/hr) they will discharge. Most emitters are manufactured to work at 10 psi, 15 psi, or 20 psi (0.7 kg/cm2, 1 kg/cm2, or 1.4 kg/cm2) and will deliver either 0.5 gph, 1 gph, 2 gph, or 4 gph (2 L/hr, 4 L/hr, 8 L/hr, or 15 L/hr). A single emitter will deliver only one of the flows listed. Usually, emitters with the lower flow rates have the smallest drip opening and are more susceptible to clogging.

### Pressure-Compensating Emitters

Pressure-compensating emitters will deliver the same gph output over a wide range of pressure. For example, some emitters will deliver 1.5 gph (6 L/hr) over a range of pressure from 15 psi to 50 psi (1.1 kg/cm2 to 3.5 kg/cm2). Look at the performance curves for the Rain Bug and Shrub Bug emitters in Table 30.1.* The emitters are produced in 0.5-gph, 1-gph, and 2-gph (2-L/hr, 4-L/hr, 8-L/hr) models. The 1-gph (4-L/hr) emitter

will deliver approximately 1 gph (4 L/hr) whether the pressure is 15 psi (1.1 kg/cm2) or 50 psi (3.5 kg/cm2). The features of these emitters are listed in Figure 30.1.

*Lady Bug, Rain Bug, and Shrub Bug are trademarks of Rainbird Irrigation.

The pressure-compensating emitters cost two to three times as much as those that are not pressure compensating. They are best used where there is going to be a wide range of pressure in one project due to topography changes. Recall that the water pressure in a section of pipe at the top of a hill will be less than the water pressure down the hill.

RAIN BUG`M EMITTERS EM-M05 / EM-M10 / EM-M20

**SHRUB BUG TM EMITTERS EMT-M05 / EMT-M10 EMT-M20**

Single Outlet Pressure

Compensating Emitters

Operating Range

Flow: .35 to 1.9 gph

Pressure:

10 to 50 psi (EM-M05/EMT-M05)

15 to 50 psi (EM-M10/EMT-M10)

15 to 50 psi (EM-M20/EMT-M20)

Features

• Requires 200 mesh filtration

(EMT-M05/EM-M05); all others 140 mesh

- Durable and heat resistant plastic construction
- Highly inert silicone elastomer diaphragm
- Barbed inlet (EM models)
- Self cleaning

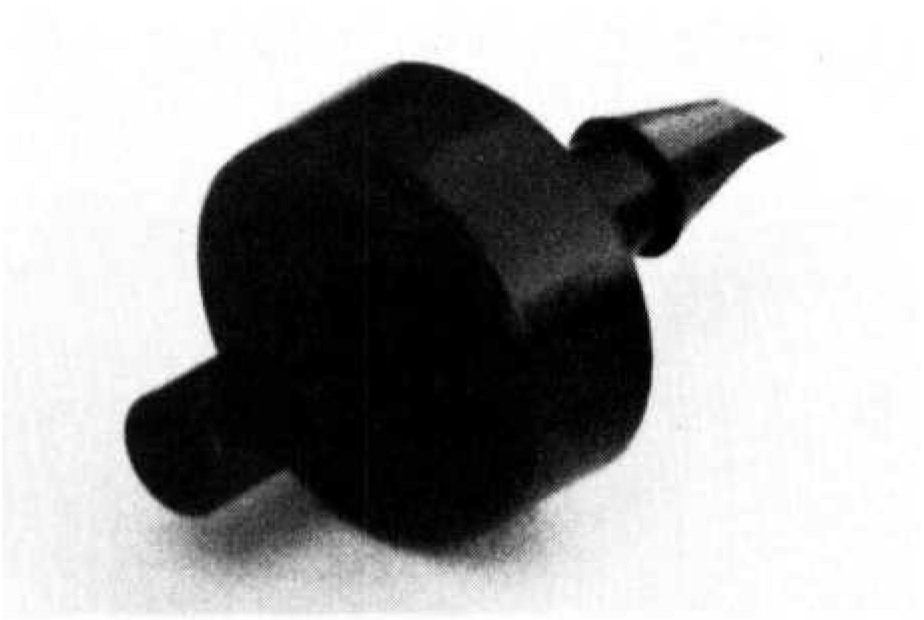


FIGURE 30.1 Features-Rain Bug, Shrub Bug.

In some pressure compensating emitters, increases in pressure force a small, flexible tube to close slightly, thus creating friction loss and reducing the gph flow. Research has shown that pressure-compensating emitters that have been installed in the field for 10 years are still reliable, and the flexible tube still works accurately. However, it is generally agreed that pressurecompensating emitters will not last as long as nonpressure-compensating emitters because of the life span of the flexible pressure control tube.

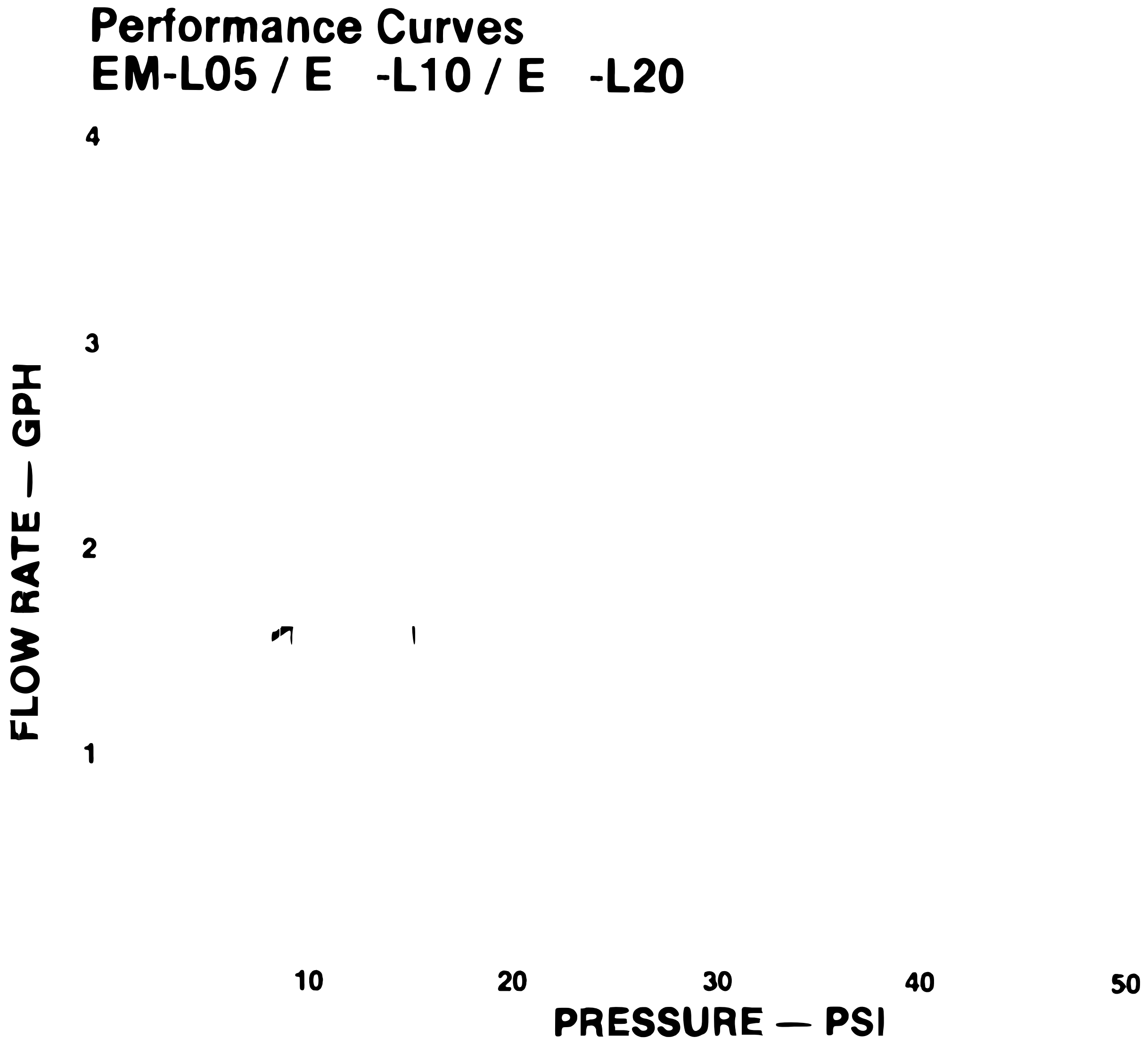
### Non-Pressure-Compensating Emitters

Most people call non-pressure-compensating emitters ... emitters. They are produced without the pressurecompensating device. Non-pressure-compensating emitters are designed to deliver a certain flow, like 0.5 gph or 2 gph (1.9 L/hr or 7.6 L/hr) at a certain pressure, for example, 15 psi (1.1 kg/cm2). Looking at the performance curve of the 1-gph (4-L/hr) Lady Bug emitter in Table 30.2, we see that it delivers more water as the water pressure increases. (See Figure 30.2 for a list of its features.) The flow rates for the Lady Bug emitter at various water pressures are as follows:

The Lady Bug emitter is guaranteed to discharge 1 gph (4 L/hr) at 15 psi (1.06 kg/cm2). At 50 psi (3.52 kg/cm2), the flow being discharged by the emitter is nearly doubled. We can conclude that non-pressurecompensating emitters will probably need a pressureregulating device to reduce the water pressure to the level for which the emitter is rated. Remember, emitters are rated to perform at a specific water pressure. By using a pressure regulator, as shown in Figure 30.3, we will be ensured of a specific flow rate from our non-pressure-compensating emitters.

0.6 gph 5 psi (0.35 kg/cm2) 0.8 gph 10 psi (0.70 kg/cm2) 1.1 gph 20 psi (1.41 kg/cm2) 1.3 gph 30 psi (2.11 kg/cm2) 1.55 gph 40 psi (2.81 kg/cm2) 1.8 gph 50 psi (3.52 kg/cm2) (2.3 L/hr) (3.0 L/hr) (4.2 L/hr) (4.9 L/hr) (5.9 L/hr) (6.8 L/hr)

## *TABLE 30.2* ***Lady Bug Performance Curves***



We can also conclude that a series of non-pressurecompensating emitters cannot be placed up and down hills on the same line and be expected to deliver the same flow. As the pressure rises owing to the weight of the column of water at the bottom of a hill, the gph (L/hr) flow increases. In Figure 30.4, we see that at the top of the hill we have less water pressure due to the pull of gravity, and thus we have less pressure in the line and less flow being discharged by the emitter. If you need to lay out your emitters up and down hills, you probably need to use pressure-compensating emitters. Non-pressure-compensating emitters need a constant pressure to deliver a constant gph flow. So, in a

hilly area, we should lay out pipe and emitters parallel to the slope so that the pipe is at a constant level of elevation, as shown in Figure 30.5.

**LADY BUG... EMITTERS EM-L05/EM-L1 O/EM-L20**

Single Outlet Emitters

Operating Range

Flow, .35 to 3.7 gph

Pressure: 5 to 50 psi

Features

- "Tortuous Path" design utilizes

large water passages to flush out debris, resist clogging

- Special outlet accepts B-220

distribution tubing

- Color-coded red inlet barb and

black outlet barb provide visual check for proper installation

- No moving parts
- Durable, ultra violet-resistant

polypropylene construction

Specifications

- Three (3) models available:

Nominal Flow Model No. (@ 15 psi) EM-L05 0.5 gph 1.0 gph EM-L10 2.0 gph EM-L20 Filtration Required 140 mesh 100 mesh 100 mesh

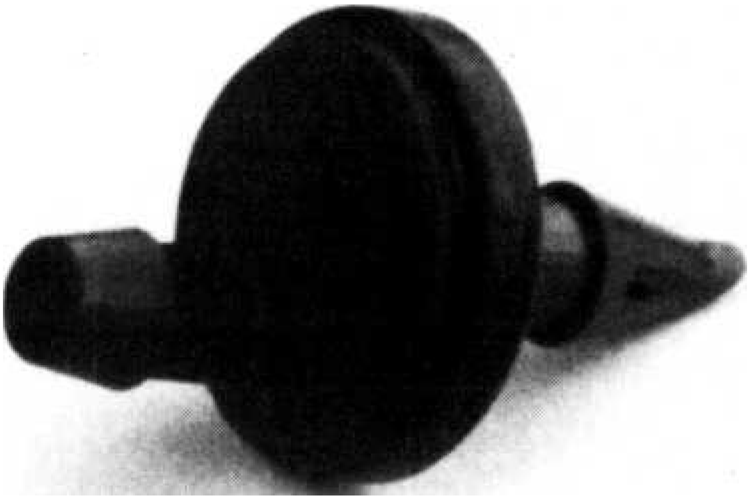


FIGURE 30.2 Features-Lady Bug.

FIGURE 30.3 Pressure regulator. (Source: The Toro Company. Used with permission.)

FIGURE 30.4 Elevation affects emitter flow.

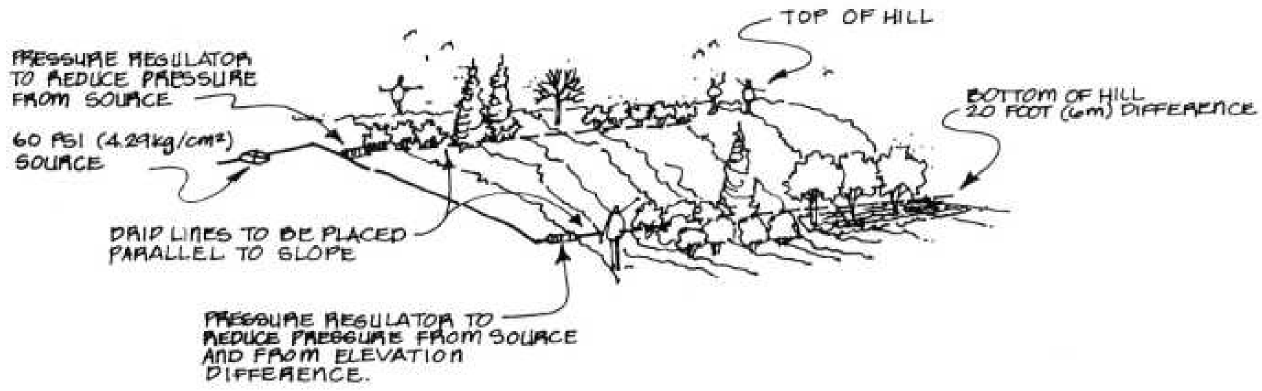


FIGURE 30.5 Lay out drip lines parallel to the slope.

In this figure, all trees and shrubs can be watered at the same time using non-pressure-compensating emitters. Pressure regulators are necessary to reduce the water pressure to 15 psi (1.06 kg/cm2) to allow the Lady Bug emitter to produce 0.5 gph, 1 gph, or 2 gph (2 L/hr, 4 L/hr, or 8 L/hr), depending on the model number we select.

FIGURE 30.6A Micro-spray adapter and nozzle caps.

FIGURE 30.6C Drip manifold and micro-spray stake assemblies.

FIGURE 30.6B Micro-spray adapter and nozzle cap attached to 570 body.

**Drip System Spray Heads**

Yes, there are even micro-spray heads with low gph (L/hr) flow rates and low pressure rates that are suitable for use on ground cover, annuals and perennials, and even small turf areas. Examine the micro-spray units shown in Figure 30.6. They will either adapt to a 570 pop-up body or can be attached to a stake assembly that sticks into the ground. There is usually less opportunity for vandalism when the micro-sprays that attach to the 570 body are used because the unit retracts to ground level and is out of view when the water pressure is cut off. The unit is then very difficult to spot for the casual vandal. Stake assemblies are more visible and vulnerable, but they are easy to place and move around. Poly-tubing or microtubing can be attached to the stake assembly and linked to a multiple outlet emitter like the DM-9 drip manifold. Stake assemblies and microtubing can also be attached directly to polyethylene drip tubing with a barbed x barbed coupler.

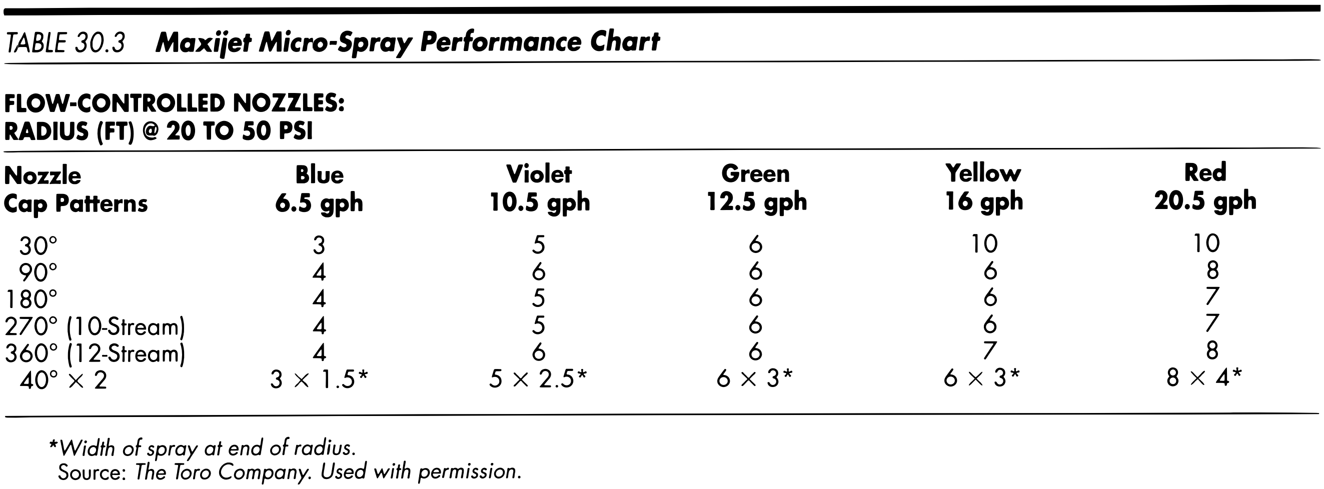


TABLE 30.3 **Maxijet Micro-Spray Performance Chart**

**FLOW-CONTROLLED NOZZLES: RADIUS (FT) @ 20 TO 50 PSI**

| **Nozzle Cap Patterns** | **Blue 6.5 gph** | **Violet 10.5 gph** | **Green 12.5 gph** | **Yellow 16 gph** | **Red 20.5 gph** |
|---|---|---|---|---|---|
| 30° | 3 | 5 | 6 | 10 | 10 |
| 90° | 4 | 6 | 6 | 6 | 8 |
| 180° | 4 | 5 | 6 | 6 | 7 |
| 270° (10-Stream) | 4 | 5 | 6 | 6 | 7 |
| 360° (12-Stream) | 4 | 6 | 6 | 7 | 8 |
| 40° × 2 | 3 × 1.5* | 5 × 2.5* | 6 × 3* | 6 × 3* | 8 × 4* |

*Width of spray at end of radius.
Source: *The Toro Company. Used with permission.*

**Micro Spray Irrigation**

**Features**

- Retrofits 570Z bodies for low application rate spray
- Pressure compensation provides uniform application over elevation changes and long runs
- Low precipitation rate reduces runoff in compacted soils
- Six nozzle patterns and radius choices, from 3' to 10', 300 to 360°
- Easy snap-on, snap-off nozzle cap installation
- Flush mount micro sprays retrofit to any 570 body or shrub adapter
- Bases are color-coded to GPH for easy identification
- Fine, 149-micron screen reduces lateral line contamination
- Vandal-resistant
- Adapter flushed debris on pop-up

**Specifications**

- Minimum 100-mesh system

filtration recommended

- Recommended operating

range: 20 to 50 PSI

- Maximum operating pressure:

75 PSI

- 6.50 to 20.50 GPH flow control
- Micro Spray Adapter flush rate

of 0.30 GPM does not exceed 570 flush rate

FIGURE 30.7A Maxijet features and specifications. (Source: The Toro Company. Used with permission.)

**Accessories**

**Flow-Controlled Spray Fan and Stream Nozzle Caps**

- 30° Fan Nozzle Cap

MJ30NC

Can be used as end strip with

40° Center Strip

- 40° Fan Center Strip

MJ40NC

- 90° Fan Nozzle Cap

MJ90NC

- 180° Fan Nozzle Cap

MJ180NC

- 270° x 10 Stream Spray Cap

MJ270NC

- 360° x 12 Stream Spray Cap

MJ36ONC

Note that the color-coded spray bases will distribute from 6.5 gph to 20.5 gph (25 L/hr to 78 L/hr). Table 30.3 shows the accompanying Maxijet MicroSpray Performance Chart. Note that the throw radius varies from 3 ft to 10 ft (0.9 m to 3.0 m), depending on the flow control nozzle selected. Patterns vary from part-circle sprays to full-circle stream sprays. There is also a stream spray that will water narrow strips from 1.5 ft to 4 ft (0.5 m to 1.2 m) wide and 3 ft to 8 ft (0.9 in to 2.4 m) long. The Maxijet's features and specifications are shown in Figure 30.7.

FIGURE 30.7B Micro-Spray stake assembly.

## Subsurface Drip

An addition to the arsenal of water-conserving irrigation components is subsurface drip irrigation. Used successfully in agricultural production for over 15 years, subsurface drip is now enjoying a wider variety of landscape uses. The product is ideal for use in narrow medians and boulevard plantings. Where there are high winds or intense foot traffic, subsurface drip eliminates wind drifting of atomized spray and accident liability. Subsurface drip is being used on larger turf areas like athletic fields and urban park areas. Trees, shrubs, flowers, and grass at residences are being watered successfully as well.

Subsurface drip tubing is placed 4 in to 8 in (102 mm to 203 mm) below ground. Emitters are spaced within the flexible tubing from 12 in to 36 in (305 mm to 914 mm) apart. Spacing between lines (also called laterals) is generally recommended to be from 12 in to 36 in (305 mm to 914 mm) apart. Some manufacturers offer pressure-compensating tubing that will deliver a set gph (L/hr) flow from 7 psi to 70 psi (0.49 kg/cm2 to 4.9 kg/cm2). A leading manufacturer's drip tube flow rates are available at 0.6 gph or 0.9 gph (2.3 L/hr to 3.4 L/hr). The precipitation rate for 36-in (914-mm) spacing between lines varies from 0.32 in per hr (8. mm/hr), with emitters spaced 12 in (305 mm) apart, to 0.11 in per hr (3 mm/hr), with emitters spaced 36 in (914 mm) apart.

Although installation costs for subsurface drip irrigation are more than those for sprinkler irrigation, its advantages can be impressive. There is no runoff, erosion, overspray, evaporation, and accident liability associated with projecting irrigation equipment. Water savings from 20% to 50% result, owing to elimination of evaporation and wind losses from atomization of spray and drifting. Because the equipment is below ground, there is no opportunity for vandalism. Through elimination of the surface moist zone, soil and grass remain dry, resulting in fewer fungi problems and weed seed germination. When used on athletic fields, soils are reported to be "spongier," which reduces injury possibilities.

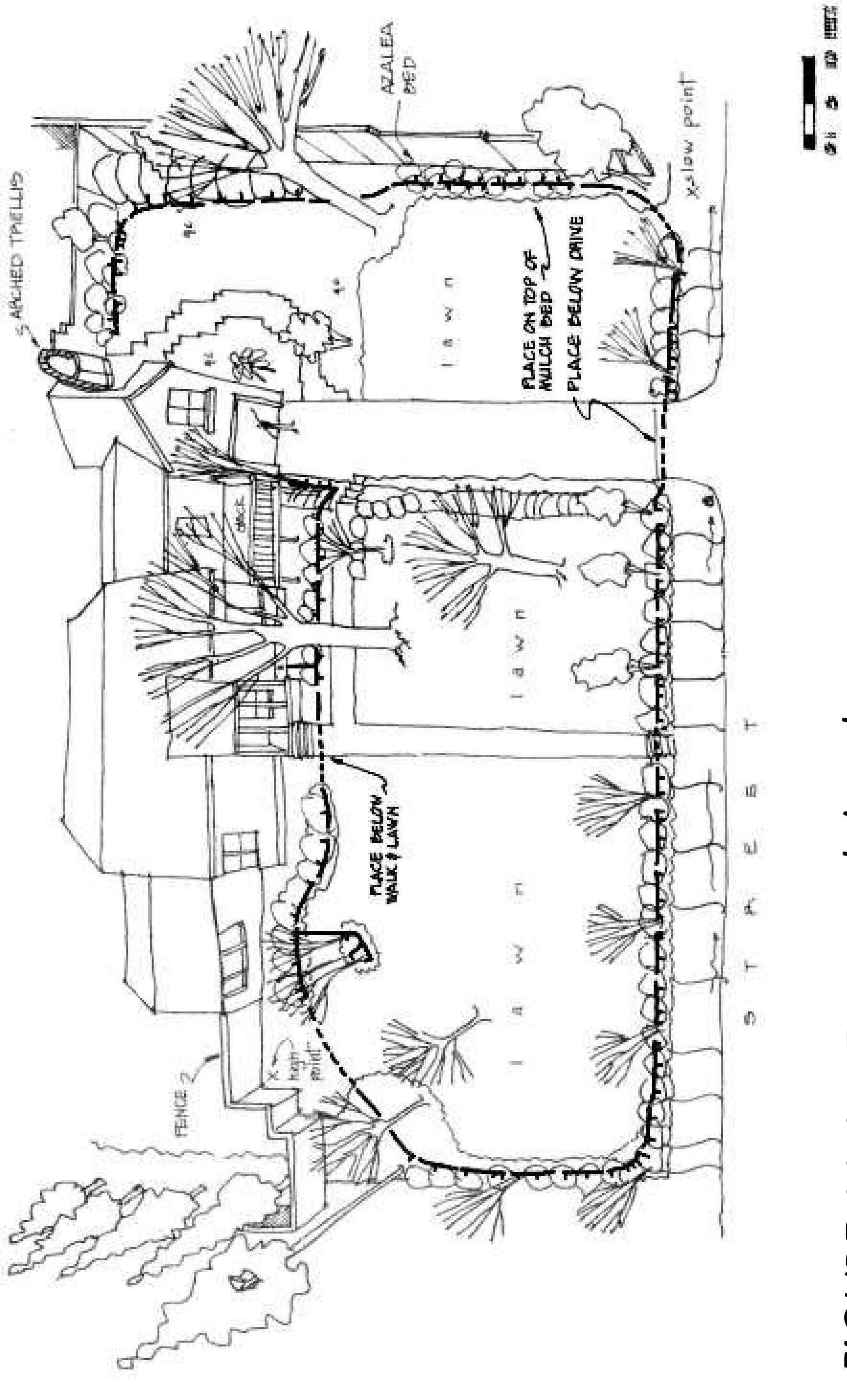


FIGURE 30.8 *Front yard drip design.*

Disadvantages include the need for regular maintenance. Lines have to be flushed regularly (one study says monthly). Filters have to be cleaned monthly. Systems have to be checked regularly for wet spots and leaks. Timed irrigation schedules have to be regular and precise so that roots do not seek to enter an emitter and thus clog it. With regular, daily irrigation, roots will not notice the difference between moist and dry soil and will not seek the emitter opening. Ideally, soils should be amended to create an acceptable level for capillary movement of water.

**Example of a Drip Design**

In order to better understand drip design, let us examine a drip system that has been in successful operation for over 15 years. A tilt-up perspective view (Figure 30.8) of this residence's front yard has been drawn to acquaint you with the landscape's design and topography. The land slopes from the left to the right, with the low point being noted in the lower right corner of the drawing. The upper left part of the yard near the fence is 6 ft (1.8 m) higher in elevation than the low point. To the right of the garage, there is a steep slope that goes up to an arched trellis. The difference in elevation from the bottom of the garage door to the trellis is 10 ft (3.1 m). You can see that the site is anything but flat! Some large trees on the site were doing well without irrigation, so we decided not to include them on our drip system.

For our drip design, 15-mm (0.5-in) polyethylene drip tubing was placed beside new trees and shrubs that we wanted to water. Where the tubing crossed the lawn area, we buried it 4 in (102 mm) below the lawn surface. We decided to use pressure-compensating emitters that would deliver 1 gph (4 L/hr) at any pressure between 15 psi and 50 psi (1.1 kg/cm2 and 3.5 kg/cm2) because of the elevation differences. We attached our drip hose to the hose bib, which is just to the right of the front door and just to the left of the deck. Because we had 75 psi (5.3 kg/cm2) at the hose bib (we measured the pressure with a pressure gauge), we decided to use a 20-psi (1.4-kg/cm2) pressure regulator, which reduced the 75 psi to 20 psi (5.3 kg/cm2 to 1.4 kg/cm2) as water entered the drip tubing.

Because of the uneven topography, the pressure at the emitters will be between 15 psi and 50 psi (1.1 kg/cm2 and 3.5 kg/cm2), at which the pressure-compensating emitters are rated to deliver 1 gph (4 L/hr). At each shrub, we attached a 1-gph (4-L/hr) emitter to the drip tubing. At each small tree, we attached two 1-gph (4-L/hr) emitters, one on either side of the tree. The drip tubing was placed about 12 in (305 mm) from the base of the shrubs and trees. Where there was a slope, we placed the drip tubing uphill from the plant root zone to make sure water got to the roots instead of flowing downhill beyond the root zone. A total of 85 1gph (4-L/hr) emitters and 402 linear ft (122.5 m) of PE drip tube was used for this drip system.

Except for the soils in a specially prepared azalea bed on the far right side of the yard next to the fence, the site is characterized by clay soils with slow internal drainage. The soil in the azalea bed is very sandy and has good drainage. Azaleas do best in sandy soil because they do not like to have wet feet and water moves through sandy soils faster than clay soils (the soil pores are bigger). However, the sandy soils dry out more quickly than the clay soils. The azalea bed thus needs more water than the adjacent clay soil beds, and this has posed a problem.

To correct the problem, we had two choices. We could either run a new drip tube to apply water more frequently to this one bed or try to mix the sandy soils with organic matter such as rotted sawdust or leaves so that internal drainage would be slowed without adversely affecting the azaleas. We chose the latter option. We amended the soils and also mulched the azaleas to reduce any evaporation that could occur from the soil.

You might ask, Why not just add another emitter to each azalea? That would only waste water. The water is still going to move through the sandy soil at a brisk pace, as compared to the pace at which it would move through the clay soils. The sandy soil will not store any more water with another drip emitter, and the azaleas would not receive any extra benefit. We feel confident the soil amendment and mulching process will help to eliminate our underwatering of the azaleas.

During the growing season, at the hottest and driest part of the year, the drip system is turned on for three to five hours, twice a week. This achieves deep and thorough watering and encourages plant roots to grow deep down into the soil. This drip system provides ideal plant growth conditions, and the plants have responded enthusiastically! The drip system has also saved the homeowners from spending hours on weekly hand-watering, which was previously necessary for survival of the trees and shrubs.

# 31

# Specific Drip Design Considerations

Now that you have been exposed to the basic ideas behind drip irrigation, let us explore specific considerations that will enable you to develop an accurate drip irrigation design. Two major factors that affect drip design are soils and the water requirement of plants. The nature of an area's soils determines the placement of emitters and the frequency and duration of watering. Determining how much water to apply to plants is based on four variables that are combined to create a water need chart. Included in this chapter are charts for each regional climate that will allow you to quickly determine how many gallons (liters) of water to apply to a plant each day.

## Soils and Emitter Location

Let us begin our look at soils with an examination of how water moves through different soil types. Drip emitters create different subsurface wetting patterns in different soil types. To illustrate water movement, we will divide soils into three categories:

Sandy soil-Coarse textured; larger pockets or pores in soil

Loamy soil-Medium textured; rich soils composed of clay, silt, sand, and often organic matter

Clay soil-Fine textured; very small pores in the soil, so there's very little air.

The size of the open spaces (pores) in the soils determines how far and how fast water will move vertically (that is, down) and horizontally in the soil. The smaller the pores in the soil, the easier water can move horizontally. Larger soil pores impede the horizontal movement of water through soil. Thus, we can conclude that water in clay soils will spread more horizontally than it will in sandy soils.

The sketches in Figure 31.1 show soil wetting patterns created by a single drip emitter in the three soil types. If you were to operate a 1-gph (4-L/hr) emitter for three to five hours and then dig a trench with a backhoe at the emitter location, you would see these wetting patterns.

These illustrations of soil wetting patterns apply to uniform soils. If your soil has various layers, as many soils do, the wetting pattern will be different and hard to predict. You might have to experiment with emitter spacing and length of watering periods if the soil is layered.

So what do these soil wetting patterns tell us? First, you need to know what kinds of soils you are working with. Then you must space your emitters according to the soil type. On sandy soils, you need to space emitters closer together because the large pore spaces in these soils are more conducive to vertical movement (moving downward) of water than to horizontal movement. On clay soils, you need to space emitters further apart because of the great horizontal movement of water.

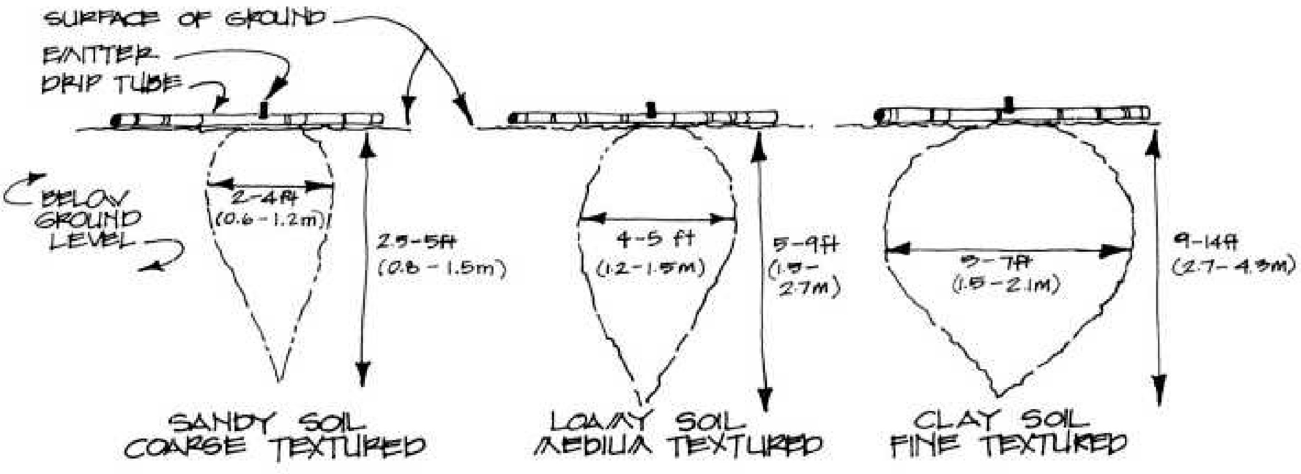


FIGURE 3 1. 1 Soil wetting patterns.

A more thorough discussion of soil types, provided by the U.S. Department of Agriculture, is listed in Table 31.1 for your reference.

## Plant Water Needs

How do you determine how much water to deliver to a plant? Four variables must be taken into consideration to find the answer: the plant's type, the plant's size, the climate region in which the plant is located, and the efficiency level of the drip system in that climate region. These four variables are combined to develop a water need chart that speeds the process along considerably. Let us begin by defining plant types and their water needs.

### Plant Type

Some plants have high water needs, and some plants have low water needs. We can group plant types into three categories based on water needs, as seen in Table 31.2.

### Size of Plant

The larger the plant, the more water it will need. Roots take moisture from the soil and carry it to the plant's trunk, stems, and leaves. Water is an essential part of plant subsistence and growth. Moisture is con stantly given off by a plant as part of its breathing process. This process is called transpiration, which means to give off moisture through pores. When water is not available, as in a drought, the living and growth process of the plant is slowed. Plant pores on the leaves close and sometimes, depending on the severity of a drought, a plant may lose all of its leaves in an effort to save itself by directing all possible water toward its woody structure.

## *TABLE 31.1* **Definition of Soil Types**

SAND: Sand is loose and single-grained. The individual grains can be seen or felt. Squeezed in the hand when dry, it will fall apart when pressure is released. Squeezed when moist, it will form a cast but will crumble.

SANDY LOAM: A sandy loam is a soil containing mostly sand but that has enough silt and clay to make it somewhat coherent. Squeezed when dry, it will form a cast that will fall apart, but if squeezed when moist, a cast can be formed that will bear careful handling without crumbling.

LOAM: A loam is a soil having a mixture of the different grades of sand, silt, and clay in such proportion that the characteristics of no one ingredient predominate. Squeezed when dry, it will form a cast that will bear careful handling, whereas the cast formed by squeezing the moist soil can be handled quite freely without crumbling.

SILT LOAM: A silt loam is a soil having a moderate amount of the fine grades of sand and only a small amount of clay. Over half of the particles are of the size called "silt." When dry, it may appear quite cloddy, but the lumps can be readily broken; when pulverized, it feels smooth, soft, and floury. When wet, the soil readily runs together. Either dry or moist, it will form casts that can be freely handled without breaking.

CLAY LOAM: A clay loam is a fine textured soil that usually breaks into clods or lumps that are hard when dry. When the moist soil is pinched between the thumb and finger, it will form a thin "ribbon" that will break, barely sustaining its own weight. The moist soil is plastic and will form a cast that will bear much handling. When kneaded in the hand, it does not crumble easily.

CLAY: A clay is a fine textured soil that usually forms very hard lumps or clods when dry and is quite plastic and usually sticky when wet. When the moist soil is pinched between the thumb and finger, it will form a long, flexible "ribbon."

*TABLE 31.2* ***General Plant Water Needs***

| HIGH WATER NEEDS | MODERATE WATER NEEDS | LOW WATER NEEDS |
|---|---|---|
| Evergreen trees<br>Fruit trees<br>Small shrubs<br>Vines<br>Perennials<br>Roses<br>Vegetable gardens<br>Lush ground covers | New plantings of native plants<br>Ornamental trees<br>Shade trees<br>Shrubs | Established plants native to the area |

### Climate in the Region

We need to understand the basics of how climate affects plant water needs. As water is being applied to the soil near a plant, a certain amount of moisture will evaporate. The hotter and drier a climate, the more water will be lost through evaporation. The evaporation of water from soils and the transpiration of water from plants is known as evapotranspiration, or EVT, which has been calculated on a monthly water loss basis for different climate regions. Table 31.3 shows the amount of rainfall (RF), evapotranspiration (EVT), and the difference between the two on a monthly basis. One part of the table contains data for various regions within California, and the other part is for regions within Georgia. Rainfall and evapotranspiration data are available from universities and weather stations nearly everywhere. Table 31.4 summarizes regions, climate types, and average EVT rate for each climate region.

### Efficiency Level of Drip Irrigation

How efficient drip irrigation becomes in delivering water to your plants is dependent on the general climate in which the system operates. More water evaporates from the soil in hot, dry, desert-type environments than in the cool, humid environments. The following list gives you an idea of how various climates affect the efficiency level of drip irrigation.

Cool climates-only 5% of water is lost to evaporation

Moderate and hot climates-10% of water is lost to evaporation

Hot, dry desert climates-15% of water is lost to evaporation

As with the climate zones and their different evapotranspiration rates, the efficiency level of drip irrigation systems in the various climatic zones has been incorporated into the plant water need chart.

### Plant Water Need Chart

To determine the water needed by a given plant, we will use Tables 31.5 through 31.10, which give us a good estimate related to the diameter of the plant canopy. Each of these tables focuses on a specific type of climate and its relationship to plant type, plant size, and required efficiency levels of the irrigation system.

Let us calculate the water needs for a small flowering tree like a crape myrtle, whose canopy is 6 ft (1.8 m) in diameter. The crape myrtle, which is native to the mountains of China, has almost become naturalized in the southern part of the United States. Knowing how the tree performs in various climates, we can say that it has low water needs. For a hot climate, we can see from Table 31.8 that a tree 6 ft (1.8 m) in canopy diameter with low water needs will require 2.7 gallons of water per day (2.7 gpd; 10 L/d) in the most stressful part of the growing season-usually July and August, when the EVT rates are the highest. On a weekly basis, that tree will need 18.9 gallons (71.5 L) of water (2.7 gpd need x 7 days). During other months, the water demand will not be as high as in July and August.

In the same hot climate with high humidity, let us calculate the water need for ivy ground cover. We base our water need calculations for plants like ivy on square feet (meters) of ground covered instead of on a single plant's diameter (see Figure 31.2). Looking at Table 31.8 for ivy, which we know by experience needs a moderate amount of water to look its best, we can see that the ground cover will need 0.16 gal (0.6 L) of water per day or 1.12 gal (4.2 L) per week per 1 ft2 (0.09 m2). After installing your drip system and evaluating

its effectiveness for a few weeks, if you perceive that your ground cover may need more water than you scheduled, either add more emitters or run the system longer. Drip design for landscapes is very flexible and requires that the designer monitor a landscape's response to the amount of water being applied.

TABLE 31.3 **Climate Data for California and Georgia**

| CALIFORNIA | JAN | FEB | MAR | APR | MAY | JUNE | JULY | AUG | SEPT | OCT | NOV | DEC | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| North Coast Drainage (Eureka) | | | | | | | | | | | | | |
| RF | 7.73 | 6.35 | 4.89 | 2.60 | 1.68 | .72 | .15 | .15 | .53 | 2.67 | 4.42 | 7.43 | 39.32 |
| EVT | .59 | .85 | 1.60 | 2.44 | 3.59 | 4.51 | 5.32 | 4.75 | 3.68 | 2.38 | 1.18 | .71 | 31.60 |
| DIFF | 7.14 | 5.50 | 3.29 | .16 | -1.91 | -3.79 | -5.17 | -4.60 | -3.15 | .29 | 3.24 | 6.72 | 7.72 |
| Sacramento Drainage (Sacramento) | | | | | | | | | | | | | |
| RF | 6.80 | 6.21 | 4.85 | 2.88 | 1.69 | .68 | .10 | .09 | .46 | 2.08 | 3.58 | 6.43 | 35.85 |
| EVT | .49 | .71 | 1.43 | 2.43 | 3.78 | 5.09 | 6.51 | 5.65 | 4.13 | 2.48 | 1.12 | .62 | 34.44 |
| DIFF | 6.31 | 5.50 | 3.42 | .45 | -2.09 | -4.41 | -6.41 | -5.56 | -3.67 | -.40 | 2.46 | 5.81 | 1.41 |
| Northeast Interior Basin (Squaw Valley Lodge) | | | | | | | | | | | | | |
| RF | 3.43 | 3.11 | 2.36 | 1.31 | 1.05 | .67 | .37 | .26 | .42 | 1.28 | 1.89 | 3.35 | 19.40 |
| EVT | 0.00 | 0.00 | .68 | 1.48 | 2.50 | 3.58 | 5.11 | 4.42 | 2.90 | 1.54 | .58 | .25 | 23.04 |
| DIFF | 3.43 | 3.11 | 1.58 | -.17 | -1.45 | -2.91 | -4.75 | -4.16 | -2.48 | -.26 | 1.31 | 3.10 | -3.64 |
| Central Coast Drainage (San Francisco) | | | | | | | | | | | | | |
| RF | 4.14 | 3.75 | 2.84 | 1.51 | .59 | .13 | .02 | .03 | .18 | .82 | 1.73 | 4.02 | 19.76 |
| EVT | .83 | 1.08 | 1.94 | 2.75 | 3.70 | 4.41 | 4.99 | 4.52 | 3.84 | 2.76 | 1.56 | 1.02 | 33.40 |
| DIFF | 3.31 | 2.67 | .90 | -1.24 | -3.11 | -4.28 | -4.97 | -4.49 | -3.66 | -1.94 | .17 | 3.00 | -13.64 |
| San Joaquin Drainage (Fresno) | | | | | | | | | | | | | |
| RF | 3.61 | 3.60 | 3.00 | 1.88 | .81 | .20 | .04 | .02 | .22 | .92 | 1.73 | 3.58 | 19.61 |
| EVT | .62 | .91 | 1.77 | 2.88 | 4.34 | 5.69 | 7.22 | 6.34 | 4.71 | 2.94 | 1.40 | .78 | 39.60 |
| DIFF | 2.99 | 2.69 | 1.23 | -1.00 | -3.53 | -5.49 | -7.18 | -6.32 | -4.49 | -2.02 | .33 | 2.80 | -19.99 |
| South Coast Drainage (Los Angeles) | | | | | | | | | | | | | |
| RF | 3.25 | 3.55 | 2.63 | 1.47 | .32 | .08 | .07 | .15 | .25 | .69 | 1.27 | 3.17 | 16.90 |
| EVT | .97 | 1.19 | 2.12 | 3.01 | 4.13 | 4.94 | 6.13 | 5.71 | 4.56 | 3.16 | 1.84 | 1.20 | 38.96 |
| DIFF | 2.28 | 2.36 | .51 | -1.54 | -3.81 | -4.86 | -6.06 | -5.56 | -4.31 | -2.47 | -.57 | 1.97 | -22.06 |
| Southeast Desert Basins (Palm Springs) | | | | | | | | | | | | | |
| RF | 1.36 | 1.49 | 1.03 | .57 | .15 | .07 | .20 | .36 | .32 | .34 | .58 | 1.43 | 8.01 |
| EVT | .75 | 1.03 | 2.12 | 3.53 | 5.34 | 7.01 | 8.90 | 7.90 | 5.72 | 3.46 | 1.58 | .94 | 48.28 |
| DIFF | .61 | .46 | -1.09 | -2.96 | -5.19 | -6.94 | -8.70 | -7.54 | -5.40 | -3.01 | -1.00 | .49 | -40.27 |

TABLE 31.3 **(continued)**

| GEORGIA | JAN | FEB | MAR | APR | MAY | JUNE | JULY | AUG | SEPT | OCT | NOV | DEC | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Northwest (Rome) | | | | | | | | | | | | | |
| RF | 5.28 | 5.31 | 5.76 | 4.57 | 3.70 | 3.75 | 4.66 | 4.24 | 3.23 | 2.86 | 3.43 | 4.99 | 51.78 |
| EVT | .67 | .87 | 1.85 | 3.39 | 5.46 | 7.00 | 7.72 | 7.04 | 5.06 | 2.99 | 1.36 | .75 | 44.16 |
| DIFF | 4.61 | 4.44 | 3.91 | 1.18 | -1.76 | -3.25 | -3.06 | -2.80 | -1.83 | -.13 | 2.07 | 4.24 | 7.62 |
| North Central (Atlanta) | | | | | | | | | | | | | |
| RF | 5.07 | 5.07 | 5.57 | 4.65 | 3.66 | 3.75 | 5.10 | 4.00 | 3.23 | 2.99 | 3.26 | 4.96 | 51.31 |
| EVT | .67 | .83 | 1.78 | 3.27 | 5.27 | 6.77 | 7.33 | 6.68 | 4.88 | 2.96 | 1.36 | .75 | 42.55 |
| DIFF | 4.40 | 4.24 | 3.79 | 1.38 | -1.61 | -3.02 | -2.23 | -2.68 | -1.65 | .03 | 1.90 | 4.21 | 8.76 |
| Northeast (Elberton) | | | | | | | | | | | | | |
| RF | 5.22 | 5.15 | 5.76 | 4.63 | 3.71 | 4.02 | 5.42 | 4.67 | 3.68 | 3.27 | 3.57 | 5.11 | 54.21 |
| EVT | .68 | .87 | 1.78 | 3.35 | 5.28 | 6.80 | 7.36 | 6.81 | 4.90 | 2.97 | 1.37 | .75 | 42.92 |
| DIFF | 4.54 | 4.28 | 3.98 | 1.28 | -1.57 | -2.78 | -1.94 | -2.14 | -1.22 | .30 | 2.20 | 4.36 | 11.29 |
| West Central (LaGrange) | | | | | | | | | | | | | |
| RF | 4.44 | 4.69 | 5.91 | 4.67 | 3.42 | 3.90 | 5.58 | 4.24 | 3.33 | 2.22 | 2.84 | 4.56 | 49.80 |
| EVT | .82 | 1.04 | 2.13 | 3.64 | 5.65 | 7.13 | 7.67 | 7.04 | 5.21 | 3.24 | 1.54 | .91 | 46.02 |
| DIFF | 3.62 | 3.65 | 3.78 | 1.03 | -2.23 | -3.23 | -2.09 | -2.80 | -1.88 | -1.02 | 1.30 | 3.65 | 3.78 |
| Central (Macon) | | | | | | | | | | | | | |
| RF | 3.93 | 4.31 | 5.13 | 4.11 | 3.55 | 3.71 | 5.34 | 4.15 | 3.37 | 2.36 | 2.51 | 4.10 | 46.57 |
| EVT | .89 | 1.10 | 2.23 | 3.79 | 5.85 | 7.37 | 7.90 | 7.27 | 5.50 | 3.44 | 1.67 | .97 | 47.98 |
| DIFF | 3.04 | 3.21 | 2.90 | .32 | -2.30 | -3.66 | -2.56 | -3.12 | -2.13 | -1.08 | .84 | 3.13 | -1.41 |
| East Central (Augusta) | | | | | | | | | | | | | |
| RF | 3.17 | 3.87 | 4.34 | 3.65 | 3.36 | 3.76 | 4.88 | 4.48 | 3.80 | 2.46 | 2.20 | 3.46 | 43.43 |
| EVT | .95 | 1.20 | 2.34 | 3.93 | 6.02 | 7.54 | 8.10 | 7.43 | 5.54 | 3.48 | 1.75 | 1.02 | 49.30 |
| DIFF | 2.22 | 2.67 | 2.00 | -.28 | -2.66 | -3.78 | -3.22 | -2.95 | -1.74 | -1.02 | .45 | 2.44 | -5.87 |
| Southwest (Albany) | | | | | | | | | | | | | |
| RE | 5.25 | 5.42 | 5.94 | 6.67 | 7.44 | 8.04 | 8.14 | 8.12 | 7.75 | 6.85 | 5.80 | 5.25 | 80.67 |
| EVT | .45 | .74 | 1.96 | 1.75 | 1.05 | 1.75 | 4.41 | 2.70 | 1.33 | 0.00 | 0.00 | .59 | 16.73 |
| DIF | 4.80 | 4.68 | 3.98 | 4.92 | 6.39 | 6.29 | 3.73 | 5.42 | 6.42 | 6.85 | 5.80 | 4.66 | 63.94 |
| South Central (Valdosta) | | | | | | | | | | | | | |
| RF | 3.19 | 3.83 | 4.67 | 4.09 | 3.54 | 4.48 | 6.28 | 5.39 | 4.14 | 2.30 | 1.97 | 3.18 | 47.06 |
| EVT | 1.10 | 1.34 | 2.56 | 4.19 | 6.22 | 6.57 | 7.95 | 7.45 | 5.71 | 3.74 | 1.92 | 1.23 | 50.98 |
| DIFF | 2.09 | 2.49 | 2.11 | -.10 | -2.68 | -3.09 | -1.67 | -2.06 | -1.57 | -1.44 | .05 | 1.95 | -3.92 |
| Southeast (Savannah) | | | | | | | | | | | | | |
| RF | 2.50 | 3.13 | 3.84 | 3.19 | 3.36 | 5.12 | 6.83 | 6.13 | 6.49 | 3.25 | 1.75 | 2.65 | 48.24 |
| EVT | 1.11 | 1.39 | 2.63 | 4.19 | 6.20 | 7.54 | 7.95 | 7.46 | 5.72 | 3.84 | 1.99 | 1.24 | 51.26 |
| DIFF | 1.39 | 1.74 | 1.21 | -1.00 | -2.84 | -2.42 | -1.12 | -1.33 | .77 | -.59 | -.24 | 1.41 | -2.02 |

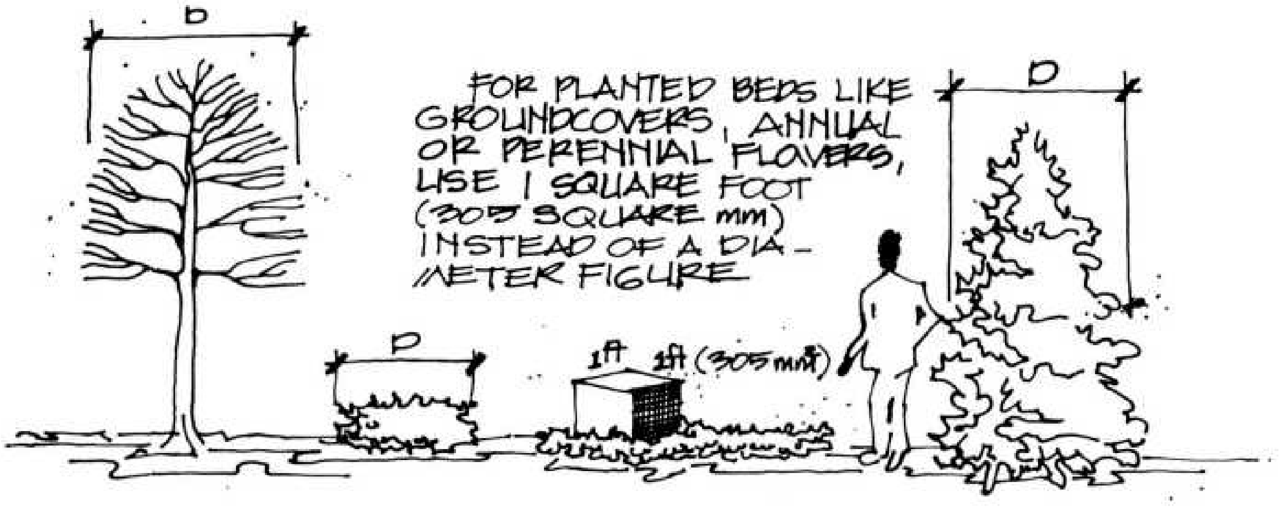


FIGURE 31.2 Diameter and square foot measurements.

*TABLE 31.4* ***Average Worst EVT Rates for Climate—Regions***

| **REGION** | **TYPE OF CLIMATE** | **EVT** |
|---|---|---|
| HIGHLANDS<br>Mountainous areas on the West Coast and the Great Plains | VERY COOL<br>50–60° F (10–16° C) average peak temperature<br>Humid | 0.1 in (3 mm)/day |
| NORTHEAST, NORTHWEST, NORTH COASTAL CALIFORNIA<br>Oregon, Washington, Los Angeles Area, Wyoming, Montana, Colorado, Wisconsin, Minnesota, Massachusetts, New York, Vermont, Maine | COOL<br>70–80° F (21–27° C) average peak temperature<br>Medium humidity | 0.2 in (5 mm)/day |
| MIDWEST, EAST-CENTRAL U.S., MID-SOUTH<br>Michigan, Illinois, Iowa, Missouri, Ohio, Kansas, Pennsylvania, North Carolina, Virginia, Kentucky, Maryland, Tennessee | MODERATE<br>80–90° F (27–32° C) average peak temperature<br>Medium-to-high humidity | 0.25 in (6 mm)/day |
| DEEP SOUTH<br>Mississippi, Arkansas, Alabama, Florida, Georgia, South Carolina, Louisiana, Oklahoma, Texas | HOT<br>90–100° F (27–38° C) average peak temperature<br>Medium to high humidity | 0.3 in (8 mm)/day |
| SOUTHWEST<br>Arizona, Palm Springs Area, Nevada | HIGH DESERT<br>90–100° F (27–38° C) average peak temperature<br>Dry | 0.35 in (9 mm)/day |
| SOUTHWEST<br>ARIZONA | LOW DESERT<br>100° F (38° C) + average peak temperature<br>Dry | 0.4 in (10 mm)/day |

TABLE 31.5A ***Very Cool Climate—Plant Water Needs***

| | | CANOPY DIAMETER OF PLANT IN FEET | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **USE EITHER 1 FT$^2$ OR 1 FT DIAMETER** | **1.5** | **2** | **2.5** | **3** | **4** | **5** | **6** | **8** | **10** | **12** | **14** |
| **PLANT WATER NEED** | **GALLONS OF WATER REQUIRED PER DAY** | | | | | | | | | | | |
| **High**<br>Evergreen and fruit trees, small shrubs, ground cover and flowers | 0.08 | 0.2 | 0.3 | 0.4 | 0.6 | 1 | 1.5 | 2.2 | 3.9 | 6.1 | 9.0 | 12 |
| **Moderate**<br>New plantings of native plants, trees and shrubs native to humid climate zones | 0.05 | 0.1 | 0.2 | 0.3 | 0.4 | 0.7 | 1.1 | 1.6 | 2.8 | 4.3 | 6.2 | 9 |
| **Low**<br>Established native plants; some native plants do not need to be irrigated | 0.03 | 0.1 | 0.1 | 0.2 | 0.2 | 0.4 | 0.6 | 0.9 | 1.6 | 2.5 | 3.5 | 4.8 |

***Climate: Very Cool*** *50–60° F average peak temperature; humid*

***Region: Highlands*** *Mountainous areas on the West Coast and in the Great Plains*

TABLE 31.5B ***Very Cool Climate—Plant Water Needs (Metric)***

| | | CANOPY DIAMETER OF PLANT IN METERS | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **USE EITHER 305 MM$^2$ OR 305 MM DIAMETER** | **0.5** | **0.6** | **0.8** | **0.9** | **1.2** | **1.5** | **1.8** | **2.4** | **3.1** | **3.7** | **4.3** |
| **PLANT WATER NEED** | **LITERS OF WATER REQUIRED PER DAY** | | | | | | | | | | | |
| **High**<br>Evergreen and fruit trees, small shrubs, ground cover and flowers | 0.3 | 0.8 | 1.1 | 1.5 | 2.3 | 3.8 | 5.7 | 8.3 | 14.8 | 23.0 | 34.0 | 45.4 |
| **Moderate**<br>New plantings of native plants, trees and shrubs native to humid climate zones | 0.2 | 0.4 | 0.8 | 1.1 | 1.5 | 2.7 | 4.2 | 6.1 | 10.6 | 16.3 | 23.5 | 34.0 |
| **Low**<br>Established native plants; some native plants do not need to be irrigated | 0.1 | 0.4 | 0.4 | 0.8 | 0.8 | 1.5 | 2.3 | 3.4 | 6.1 | 9.5 | 13.3 | 18.2 |

***Climate:* Very Cool** 10–16° C average peak temperature

***Region: Highlands*** Mountainous areas on the West Coast and in the Great Plains

TABLE 31.6A **Cool Climate—Plant Water Needs**

| PLANT WATER NEED | USE EITHER 1 FT$^2$ OR 1 FT DIAMETER | CANOPY DIAMETER OF PLANT IN FEET | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **1.5** | **2** | **2.5** | **3** | **4** | **5** | **6** | **8** | **10** | **12** | **14** |
| | **GALLONS OF WATER REQUIRED PER DAY** | | | | | | | | | | | |
| **High**<br>Evergreen and fruit trees, small shrubs, ground cover and flowers | 0.15 | 0.3 | 0.5 | 0.8 | 1.1 | 2 | 3.1 | 4.4 | 8 | 12 | 18 | 24 |
| **Moderate**<br>New plantings of native plants, trees and shrubs native to humid climate zones | 0.11 | 0.2 | 0.4 | 0.6 | 0.8 | 1.4 | 2.2 | 3.1 | 5.5 | 9 | 13 | 17 |
| **Low**<br>Established native plants, some native plants do not need to be irrigated | 0.06 | 0.1 | 0.2 | 0.3 | 0.5 | 0.8 | 1.2 | 1.8 | 3.1 | 4.9 | 7 | 10 |

***Climate: Cool*** *70–80° F average peak temperature; medium humidity*

***Region: Northeast, Northwest, North Coastal California*** *Oregon, Washington, Los Angeles, Wyoming, Colorado, Montana, Wisconsin, Minnesota, Massachusetts, New York, Vermont, Maine*

TABLE 31.6B **Cool Climate—Plant Water Needs (Metric)**

| PLANT WATER NEED | USE EITHER 305 MM$^2$ OR 305 MM DIAMETER | CANOPY DIAMETER OF PLANT IN METERS | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **0.5** | **0.6** | **0.8** | **0.9** | **1.2** | **1.5** | **1.8** | **2.4** | **3.1** | **3.7** | **4.3** |
| | **LITERS OF WATER REQUIRED PER DAY** | | | | | | | | | | | |
| **High**<br>Evergreen and fruit trees, small shrubs, ground cover and flowers | 0.6 | 1.1 | 1.9 | 3.0 | 4.2 | 7.6 | 11.7 | 16.7 | 30.3 | 45.4 | 68.1 | 91.0 |
| **Moderate**<br>New plantings of native plants, trees and shrubs native to humid climate zones | 0.4 | 0.8 | 1.5 | 2.3 | 3.0 | 5.3 | 8.3 | 11.7 | 20.8 | 34.1 | 49.2 | 64.3 |
| **Low**<br>Established native plants, some native plants do not need to be irrigated | 0.2 | 0.4 | 0.8 | 1.1 | 1.9 | 3.0 | 4.5 | 6.8 | 11.7 | 18.6 | 26.5 | 37.9 |

***Climate: Cool*** *21–27° C average peak temperature; medium humidity*

***Region: Northeast, Northwest, North Coastal California*** *Oregon, Washington, Los Angeles, Wyoming, Colorado, Montana, Wisconsin, Minnesota, Massachusetts, New York, Vermont, Maine*

*TABLE 31.7A* **Moderate Climate—Plant Water Needs**

| | | CANOPY DIAMETER OF PLANT IN FEET | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **PLANT WATER NEED** | **USE EITHER 1 FT$^2$ OR 1 FT DIAMETER** | **1.5** | **2** | **2.5** | **3** | **4** | **5** | **6** | **8** | **10** | **12** | **14** |
| | | **GALLONS OF WATER REQUIRED PER DAY** | | | | | | | | | | |
| **High**<br>Evergreen and fruit trees, small shrubs, ground cover and flowers | 0.19 | 0.4 | 0.7 | 1 | 1.4 | 2.5 | 3.9 | 5.5 | 10 | 16 | 22 | 30 |
| **Moderate**<br>New plantings of native plants, trees and shrubs native to humid climate zones | 0.13 | 0.3 | 0.5 | 0.7 | 1 | 1.7 | 2.7 | 3.9 | 7 | 11 | 16 | 21 |
| **Low**<br>Established native plants; some native plants do not need to be irrigated | 0.08 | 0.2 | 0.3 | 0.4 | 0.6 | 1 | 1.5 | 2.2 | 3.9 | 6.1 | 9 | 12 |

***Climate: Moderate*** 80–90° F average peak temperature; medium-to-high humidity

***Region: Midwest, East Central U.S., Mid-South*** Michigan, Illinois, Iowa, Missouri, Ohio, Kansas, Pennsylvania, North Carolina, Virginia, Kentucky, Maryland, Tennessee

*TABLE 31.7B* **Moderate Climate—Plant Water Needs (Metric)**

| | | CANOPY DIAMETER OF PLANT IN METERS | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **PLANT WATER NEED** | **USE EITHER 305 MM$^2$ OR 305 MM DIAMETER** | **0.5** | **0.6** | **0.8** | **0.9** | **1.2** | **1.5** | **1.8** | **2.4** | **3.1** | **3.7** | **4.3** |
| | | **LITERS OF WATER REQUIRED PER DAY** | | | | | | | | | | |
| **High**<br>vergreen and fruit trees, small shrubs, ground cover and flowers | 0.7 | 1.5 | 2.7 | 3.8 | 5.3 | 9.5 | 14.8 | 20.8 | 37.9 | 60.6 | 83.3 | 113.6 |
| **Moderate**<br>New plantings of native lants, trees and shrubs native to humid climate zones | 0.5 | 1.1 | 1.9 | 2.7 | 3.8 | 6.4 | 10.2 | 14.8 | 26.5 | 41.6 | 60.6 | 79.5 |
| **ow**<br>stablished native plants; some native plants do not need to be irrigated | 0.3 | 0.8 | 1.1 | 1.5 | 2.3 | 3.8 | 5.7 | 8.3 | 14.8 | 23.0 | 34.1 | 45.4 |

***Climate: Moderate*** 27–32° C average peak temperature; medium-to-high humidity

***Region: Midwest, East Central U.S., Mid-South*** Michigan, Illinois, Iowa, Missouri, Ohio, Kansas, Pennsylvania, North Carolina, Virginia, Kentucky, Maryland, Tennessee

*TABLE 31.8A* **Hot Climate—Plant Water Needs**

| PLANT WATER NEED | USE EITHER 1 FT$^2$ OR 1 FT DIAMETER | CANOPY DIAMETER OF PLANT IN FEET | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1.5 | 2 | 2.5 | 3 | 4 | 5 | 6 | 8 | 10 | 12 | 14 |
| | GALLONS OF WATER REQUIRED PER DAY | | | | | | | | | | | |
| **High**<br>Evergreen and fruit trees, small shrubs, ground cover and flowers | 0.23 | 0.5 | 0.8 | 1.2 | 1.7 | 3 | 4.6 | 7 | 12 | 19 | 27 | 36 |
| **Moderate**<br>New plantings of native plants, trees, shrubs native to humid climate zones | 0.16 | 0.3 | 0.5 | 0.8 | 1.2 | 2.1 | 3.2 | 4.7 | 8 | 13 | 19 | 25 |
| **Low**<br>Established native plants; some native plants do not need to be irrigated | 0.09 | 0.2 | 0.3 | 0.5 | 0.7 | 1.2 | 1.9 | 2.7 | 4.7 | 8 | 11 | 15 |

***Climate: Hot*** 90–100° F average peak temperature; medium-to-high humidity

***Region: Deep South*** Mississippi, Arkansas, Alabama, Florida, Georgia, South Carolina, Louisiana, Oklahoma, Texas

*TABLE 31.8B* **Hot Climate—Plant Water Needs (Metric)**

| PLANT WATER NEED | USE EITHER 305 MM$^2$ OR 305 MM DIAMETER | CANOPY DIAMETER OF PLANT IN METERS | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 0.5 | 0.6 | 0.8 | 0.9 | 1.2 | 1.5 | 1.8 | 2.4 | 3.1 | 3.7 | 4.3 |
| | LITERS OF WATER REQUIRED PER DAY | | | | | | | | | | | |
| **High**<br>Evergreen and fruit trees, small shrubs, ground cover and flowers | 0.9 | 1.9 | 3.0 | 4.5 | 6.4 | 11.3 | 17.4 | 26.5 | 45.4 | 71.9 | 102.2 | 136.3 |
| **Moderate**<br>New plantings of native plants, trees and shrubs native to humid climate zones | 0.6 | 1.1 | 1.9 | 3.0 | 4.5 | 7.9 | 12.1 | 17.8 | 30.3 | 49.2 | 71.9 | 94.6 |
| **Low**<br>Established native plants; some native plants do not need to be irrigated | 0.3 | 0.8 | 1.1 | 1.9 | 2.7 | 4.5 | 7.2 | 10.2 | 17.8 | 30.3 | 41.6 | 56.8 |

***Climate: Hot*** 27–38° C average peak temperature; medium-to-high humidity

***Region: Deep South*** Mississippi, Arkansas, Alabama, Florida, Georgia, South Carolina, Louisiana, Oklahoma, Texas

## TABLE 31.9A **High-Desert Climate—Plant Water Needs**

| PLANT WATER NEED | USE EITHER 1 $FT^2$ OR 1 FT DIAMETER | CANOPY DIAMETER OF PLANT IN FEET | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **1.5** | **2** | **2.5** | **3** | **4** | **5** | **6** | **8** | **10** | **12** | **14** |
| | GALLONS OF WATER REQUIRED PER DAY | | | | | | | | | | | |
| **High**<br>Evergreen and fruit trees, small shrubs, ground cover and flowers | 0.27 | 0.5 | 0.9 | 1.4 | 2 | 3.5 | 5.4 | 8 | 14 | 22 | 31 | 42 |
| **Moderate**<br>New plantings of native plants, trees, and shrubs native to humid climate zones | 0.19 | 0.4 | 0.6 | 1 | 1.4 | 2.4 | 3.8 | 5.4 | 10 | 15 | 22 | 30 |
| **Low**<br>Established native plants; some native plants do not need to be irrigated | 0.11 | 0.2 | 0.4 | 0.6 | 0.8 | 1.4 | 2.2 | 3.1 | 5.5 | 9 | 13 | 17 |

***Climate: High Desert*** 90–100° F average peak temperature; dry

***Region: Southwest*** Arizona, Palm Springs Area, Nevada

## TABLE 31.9B **High-Desert Climate—Plant Water Needs (Metric)**

| PLANT WATER NEED | USE EITHER 305 $MM^2$ OR 305 MM DIAMETER | CANOPY DIAMETER OF PLANT IN METERS | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **0.5** | **0.6** | **0.8** | **0.9** | **1.2** | **1.5** | **1.8** | **2.4** | **3.1** | **3.7** | **4.3** |
| | LITERS OF WATER REQUIRED PER DAY | | | | | | | | | | | |
| **High**<br>Evergreen and fruit trees, small shrubs, ground cover and flowers | 1.0 | 1.9 | 3.4 | 5.3 | 7.6 | 13.2 | 20.4 | 30.3 | 53.0 | 83.3 | 117.3 | 159.0 |
| **Moderate**<br>New plantings of native plants, trees and shrubs native to humid climate zones | 0.7 | 1.5 | 2.3 | 3.8 | 5.3 | 9.1 | 14.4 | 20.4 | 37.9 | 56.8 | 83.3 | 113.6 |
| **Low**<br>Established native plants; some native plants do not need to be irrigated | 0.4 | 0.8 | 1.5 | 2.3 | 3.0 | 5.3 | 8.3 | 11.7 | 20.8 | 34.1 | 49.2 | 64.3 |

***Climate: High Desert*** 27–38° C average peak temperature; dry

***Region: Southwest*** Arizona, Palm Springs Areas, Nevada

*TABLE 31.10A* ***Low-Desert Climate—Plant Water Needs***

| | | CANOPY DIAMETER OF PLANT IN FEET | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | USE EITHER 1 FT$^2$ OR 1 FT DIAMETER | 1.5 | 2 | 2.5 | 3 | 4 | 5 | 6 | 8 | 10 | 12 | 14 |
| PLANT WATER NEED | | GALLONS OF WATER REQUIRED PER DAY | | | | | | | | | | |
| **High**<br>Evergreen and fruit trees, small shrubs, ground cover and flowers | 0.31 | 0.6 | 1 | 1.6 | 2.3 | 4 | 6.2 | 9 | 16 | 25 | 36 | 48 |
| **Moderate**<br>New plantings of native plants, trees, and shrubs native to humid climate zones | 0.21 | 0.4 | 0.7 | 1.1 | 1.6 | 2.8 | 4.3 | 6.2 | 11 | 17 | 25 | 34 |
| **Low**<br>Established native plants; some native plants do not need to be irrigated | 0.12 | 0.2 | 0.4 | 0.6 | 0.9 | 1.6 | 2.5 | 3.5 | 6.3 | 10 | 14 | 19 |

***Climate: Low Desert*** 100° F + average peak temperature; peak temperature

***Region: Southwest*** Arizona

*TABLE 31.10B* ***Low-Desert Climate—Plant Water Needs (Metric)***

| | | CANOPY DIAMETER OF PLANT IN METERS | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | USE EITHER 305 MM$^2$ OR 305 MM DIAMETER | 0.5 | 0.6 | 0.8 | 0.9 | 1.2 | 1.5 | 1.8 | 2.4 | 3.1 | 3.7 | 4.3 |
| PLANT WATER NEED | | LITERS OF WATER REQUIRED PER DAY | | | | | | | | | | |
| **High**<br>Evergreen and fruit trees, small shrubs, ground cover and flowers | 1.2 | 2.3 | 3.8 | 6.1 | 8.7 | 15.1 | 23.5 | 34.1 | 60.6 | 94.6 | 136.3 | 181.7 |
| **Moderate**<br>New plantings of native plants, trees, and shrubs native to humid climate zones | 0.8 | 1.5 | 2.7 | 4.2 | 6.1 | 10.6 | 16.3 | 23.5 | 41.6 | 64.3 | 94.6 | 128.7 |
| **Low**<br>Established native plants; some native plants do not need to be irrigated | 0.5 | 0.8 | 1.5 | 2.3 | 3.4 | 6.1 | 9.5 | 13.2 | 23.8 | 37.9 | 53.0 | 71.9 |

***Climate: Low Desert*** 38° C + average peak temperature

***Region: Southwest*** Arizona

# 32

# Drip Tube and Emitter Layout

## Introduction

Now that we know how much water our plants need during the most stressful part of a growing season and we know how the emitter works to deliver water to the plants, let us look at how to place drip tubing and emitters in the landscape.

## Drip Tube Placement

Most drip tubing is black and inconspicuous and can either be placed directly on top of a mulch bed or buried. The tubing is composed of polyethylene, carbon, and ultraviolet stabilizers, which help to resist the destructive effect the sun has on plastic (and especially PVC) pipe. So placing the tubing on top of a plant bed and covering it with mulch will protect it from the sun and reduce its unattractiveness.

## Emitter Placement

Most designers like to run their drip tubing along the path where their emitters are to be located (Figure 32.1). This way, you can attach an emitter and let it drip. If your drip tube is too far from an emitter location, you have to connect microtubing, or "spaghetti tubing," to the emitter and run it to where you want the drip. If you can run your drip tube to the plant root zones and eliminate the need to rely on microtubing, you will reduce labor costs and the maintenance of constantly shifting the drip tube when it gets slightly out of alignment.

FIGURE 32.1 Drip tube and emitter.

Most microtube runs will need a tubing stake to keep the microtubing off the mulch so that it can be easily inspected for proper operation at the point of dripping. An insect cap, which fits over the microtubing, will keep insects from setting up housekeeping there (see Figure 32.2).

If you have closely planted shrub areas where more than one emitter is needed, multiple-outlet drip manifolds, such as the one shown in Figure 32.3, are available. The pressure-regulating drip manifold connects to a 1/2-in (13-mm) threaded PVC riser. When using multiple-emitter manifolds, the riser is connected to PVC pipe instead of PE tubing. Microtubing is then connected to the outlets, and either emitters or microsprays are attached to the microtubing. If all outlets are not needed, there are caps that slip over the barbed outlet to seal them. (The word manifold is derived from the Old English manig (many) and feald (fold), meaning a device that has many parts or outlets.)

The DM-9 drip manifold has nine pressure-regulated outlets per unit. Each unit will deliver a maximum flow of 210 gph (795 L/hr) at a pressure range from 20 psi to 100 psi (1.4 kg/cm2 to 7 kg/cm2). The multiple-outlet drip manifold is designed to attach micro-sprays or emitters at the end of microtubing that connects to the drip manifold outlets. The DM-9 has a maximum flow of 23 gph (87 L/hr) per outlet (see Figure 32.4).

FIGURE 32.2 Mic-rotube stake and insect cap.

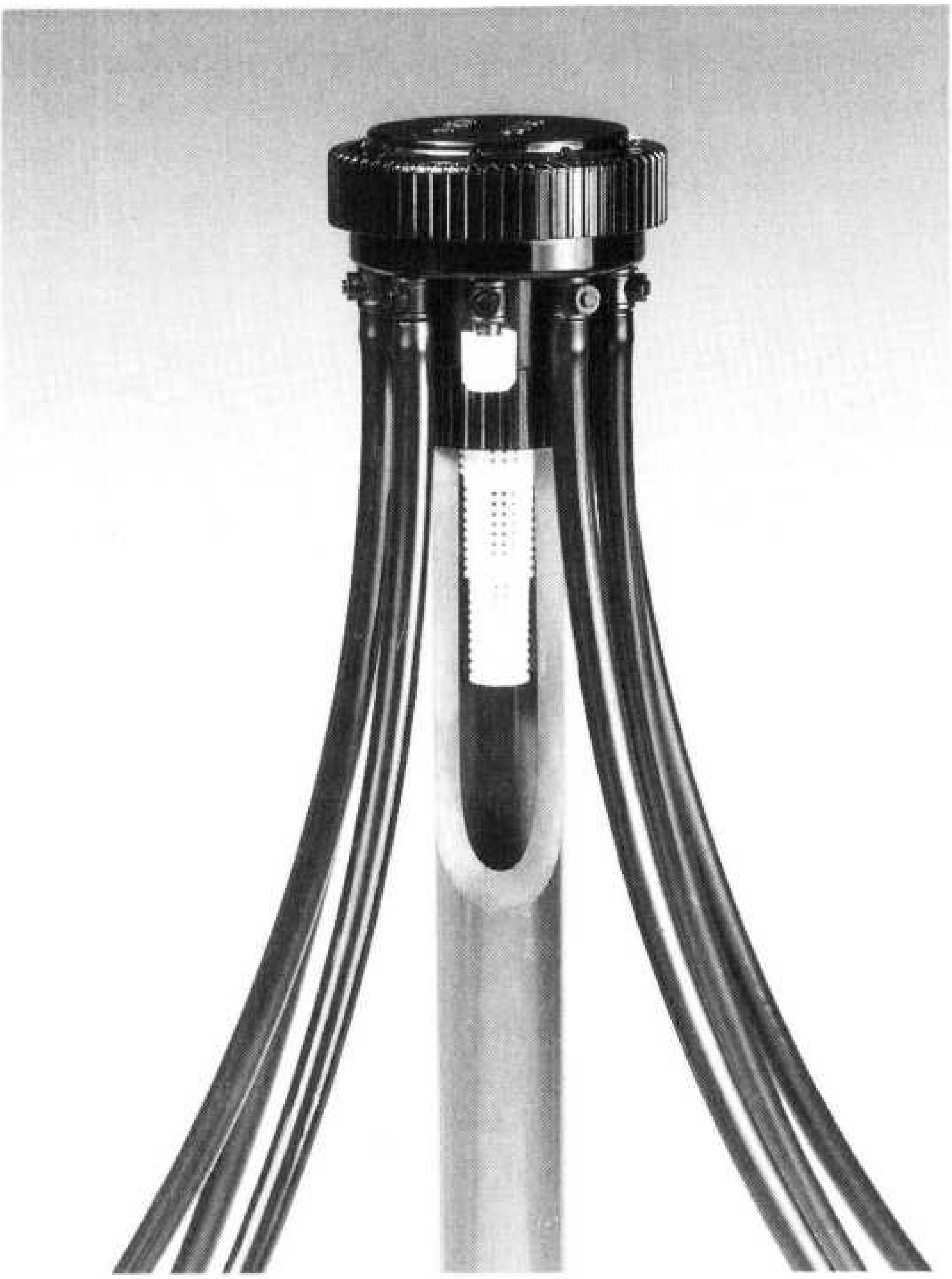


FIGURE 32.3 Drip manifold and microtubing. (Source: The Toro Company. Used with permission.)

### Emitters and the Root Zone

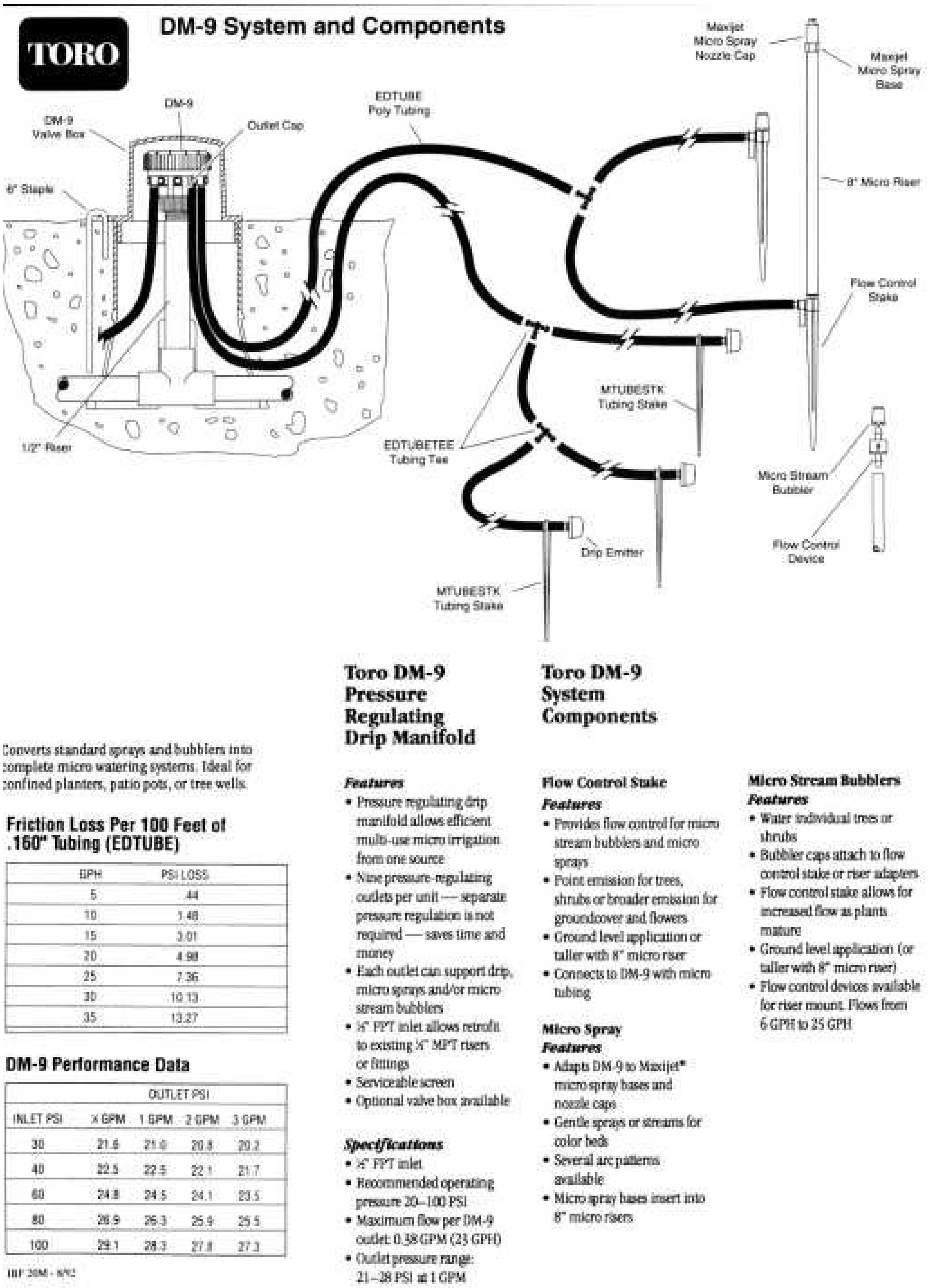
Emitters, or the microtubing connected to them, should be located so as to water at least 50% of a plant's root zone. Studies have shown that pecan trees in Georgia were as productive when 50% of their root zone was watered as when their entire root zone was watered. Keep in mind that for this experiment, the same amount of water was applied in each situation.

## Emitter Location Schemes

The following discussion illustrates methods of laying out drip tubing and emitters for various kinds of landscape plantings. Please note that we are trying to water a minimum of 50% of a plant's root system. Figure 32.5 shows connecting microtubing to emitters at drip tubing.

**Figure 32.6**

Ground cover and other mass plantings can be watered by laying out the drip tubing and emitters in a grid fashion. Spacing of tubing depends upon the soil type.



Converts standard sprays and bubblers into complete micro watering systems. Ideal for confined planters, patio pots, or tree wells.

**Friction Loss Per 100 Feet of .160" Tubing (EDTUBE)**

| GPH | PSI LOSS |
|---|---|
| 5 | 44 |
| 10 | 1.48 |
| 15 | 3.01 |
| 20 | 4.98 |
| 25 | 7.36 |
| 30 | 10.13 |
| 35 | 13.27 |

**DM-9 Performance Data**

| | OUTLET PSI | | | |
|---|---|---|---|---|
| INLET PSI | ½ GPM | 1 GPM | 2 GPM | 3 GPM |
| 30 | 21.6 | 21.0 | 20.8 | 20.2 |
| 40 | 22.5 | 22.5 | 22.1 | 21.7 |
| 60 | 24.8 | 24.5 | 24.1 | 23.5 |
| 80 | 26.9 | 26.3 | 25.9 | 25.5 |
| 100 | 29.1 | 28.3 | 27.8 | 27.3 |

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**Toro DM-9 Pressure Regulating Drip Manifold**

***Features***

- Pressure regulating drip manifold allows efficient multi-use micro irrigation from one source
- Nine pressure-regulating outlets per unit — separate pressure regulation is not required — saves time and money
- Each outlet can support drip, micro sprays and/or micro stream bubblers
- ½" FPT inlet allows retrofit to existing ½" MPT risers or fittings
- Serviceable screen
- Optional valve box available

***Specifications***

- ½" FPT inlet
- Recommended operating pressure 20–100 PSI
- Maximum flow per DM-9 outlet: 0.38 GPM (23 GPH)
- Outlet pressure range: 21–28 PSI at 1 GPM

**Toro DM-9 System Components**

**Flow Control Stake**

***Features***

- Provides flow control for micro stream bubblers and micro sprays
- Point emission for trees, shrubs or broader emission for groundcover and flowers
- Ground level application or taller with 8" micro riser
- Connects to DM-9 with micro tubing

**Micro Spray**

***Features***

- Adapts DM-9 to Maxijet® micro spray bases and nozzle caps
- Gentle sprays or streams for color beds
- Several arc patterns available
- Micro spray bases insert into 8" micro risers

**Micro Stream Bubblers**

***Features***

- Water individual trees or shrubs
- Bubbler caps attach to flow control stake or riser adapters
- Flow control stake allows for increased flow as plants mature
- Ground level application (or taller with 8" micro riser)
- Flow control devices available for riser mount. Flows from 6 GPH to 25 GPH

FIGURE 32.4 Drip manifold and components. (Source: The Toro Company. Used with permission.)

FIGURE 32.5 Microtubing and drip tube.

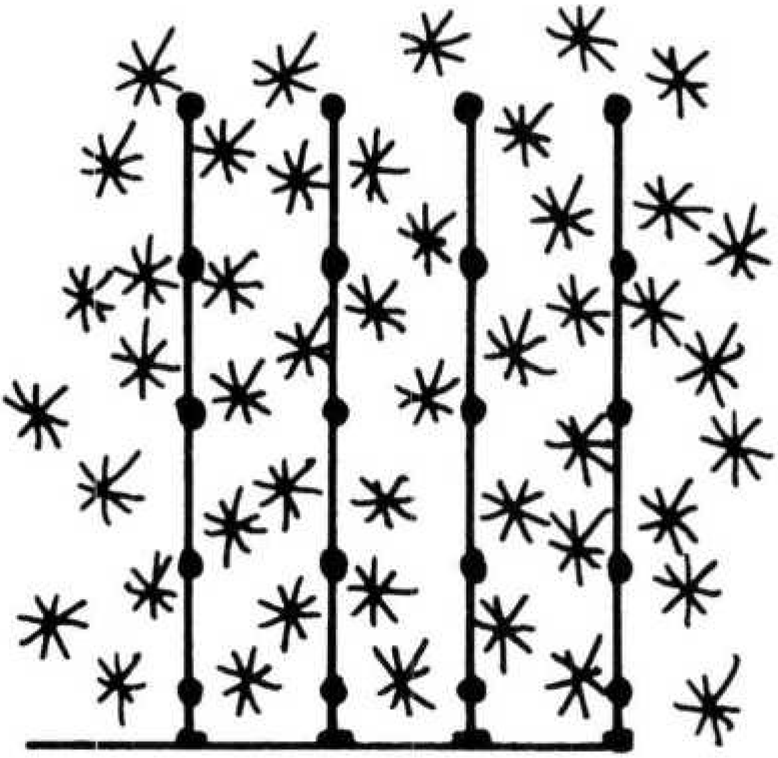


FIGURE 32.6 Ground cover bed.

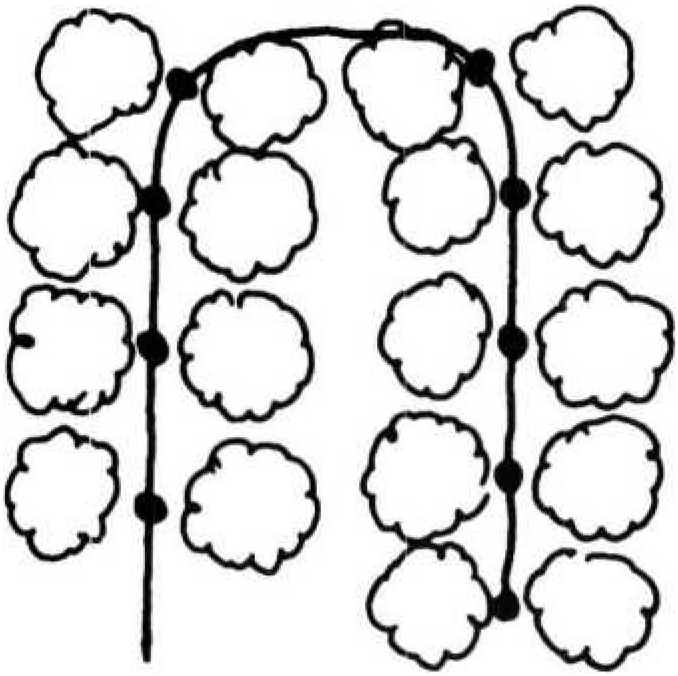


FIGURE 32.7 Perennial bed.

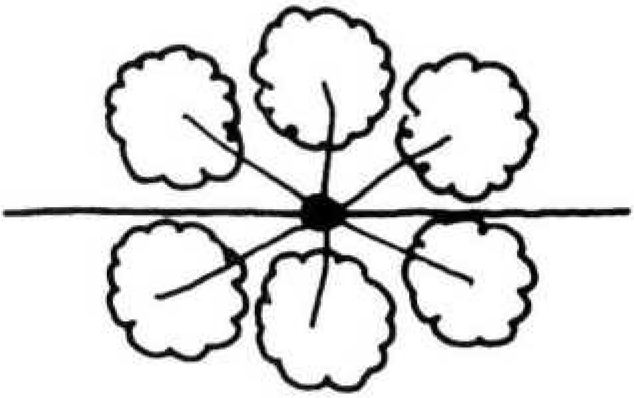


FIGURE 32.8 Shrub bed.

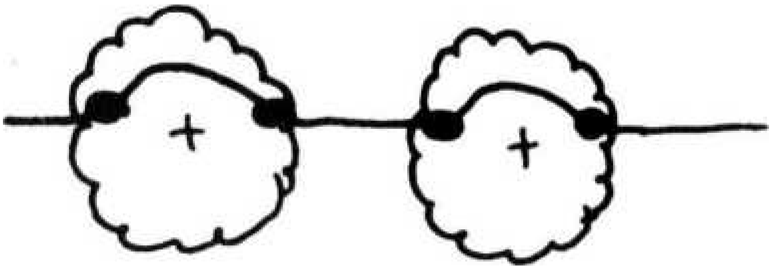


FIGURE 32.9 Large shrubs.

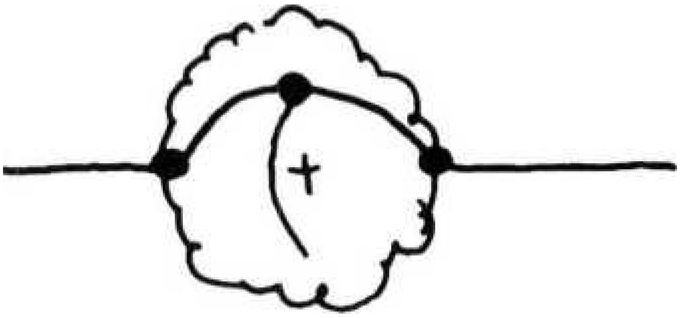


FIGURE 32. 10 Evergreen tree.

**Figure 32.7**

This could represent a bed of peonies or any other perennial. Drip tubing is looped so that each emitter serves the root zone of two plants.

**Figure 32.8**

For closely planted shrub areas, it may be ideal to use a multiple-outlet manifold with microtubing and emitters to deliver water to the root zone of each plant.

**Figure 32.9**

Large shrubs like winter honeysuckle or a large azalea might be best watered by emitters attached to drip tubing.

**Figure 32.10**

A straight line of drip tubing beside a large evergreen tree could have three emitters, one of which is connected to microtubing that waters at the edge of the tree drip line.

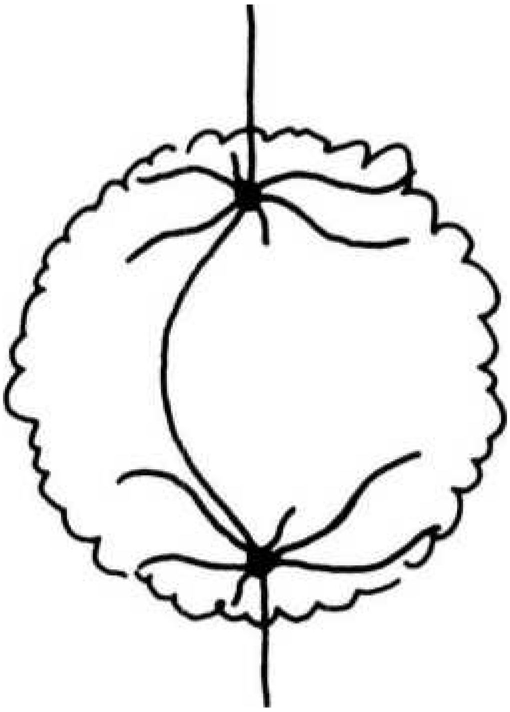


FIGURE 32. 11 Deciduous tree.

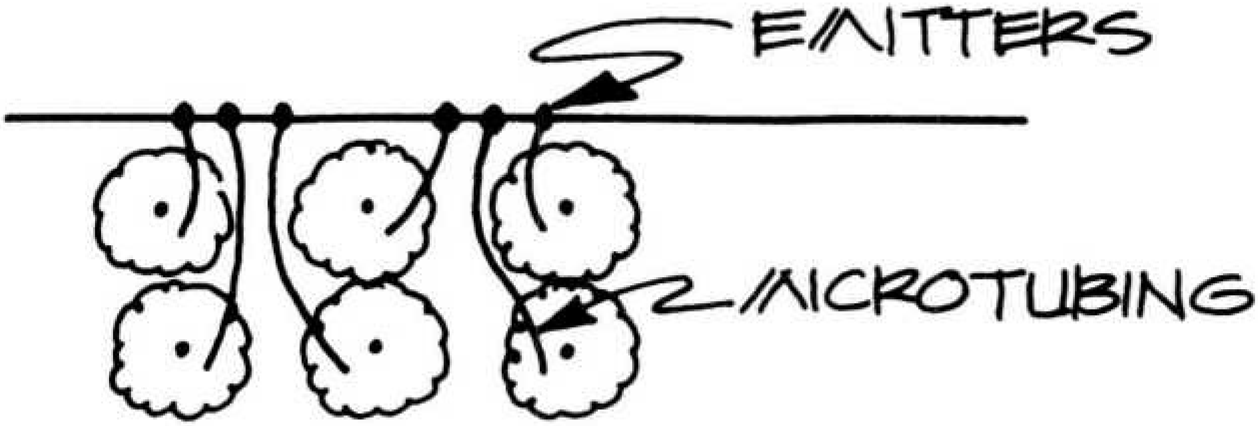


FIGURE 32.12 Shrubs planted on a hillside.

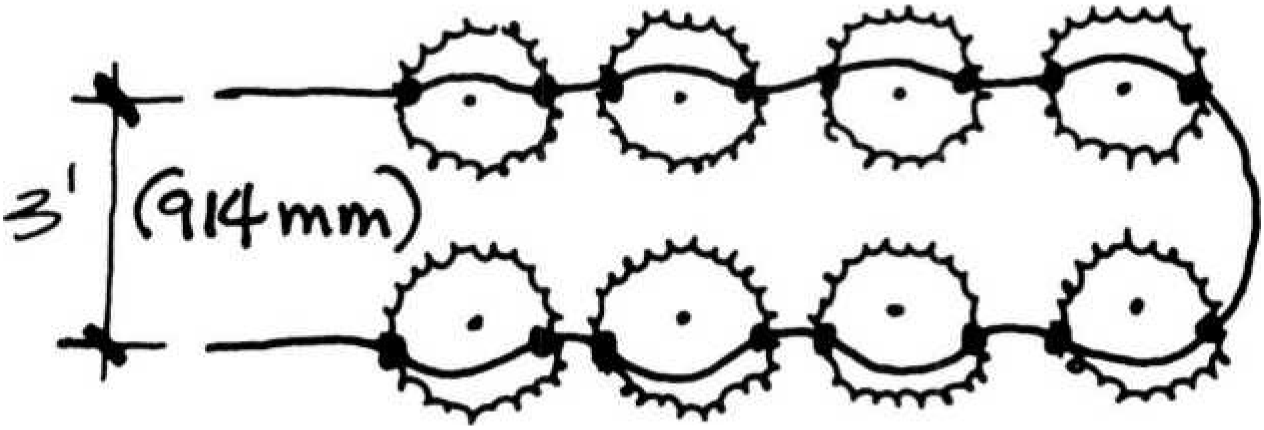


FIGURE 32.13 Rose bushes.

**Figure 32.11**

In order to fulfill the water needs of this larger deciduous tree, two multiple-outlet manifolds could be placed under the tree canopy and spaced to water the tree roots.

**Figure 32.12**

These shrubs on a 30% hillside slope are being effectively watered with single emitters and microtubing runs from the drip tubing to the root zones of the shrubs.

**Figure 32.13**

When watering rose bushes, it is best to loop the drip tubing near the base of the rose bush and allow for two 1-gph (4-L/hr) emitters for each plant. Two emitters are needed because roses are usually planted in sandy soils with good drainage. It takes two emitters per bush to water half of the plant's roots.

When placing your tubing, remember that you want to keep it out of sight not only for reasons of beauty but also to reduce vandalism. Placing bark mulch, pine straw, or even leaves over the tubing will safely conceal it and yet allow you easy access when you need to make changes. When using regular PVC pipe instead of polyethylene (PE) tubing, remember that it will deteriorate in sunlight. You must bury or fully mulch PVC pipe to protect it from the sun.

Your emitters will work if placed beneath a mulch; however, you cannot make periodic maintenance checks on them unless you can see them dripping. That is why we encourage you to locate your emitters so that they can be inspected visually while on a walking inspection.

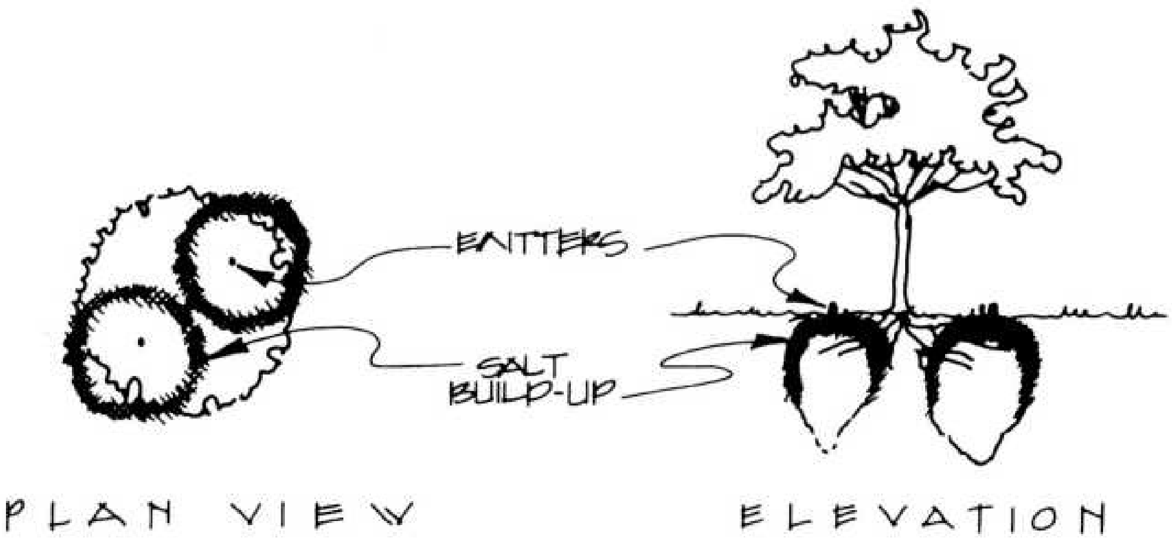


FIGURE 32.14 Salt buildup zones.

## Salt Buildup and Emitter Placement

Be aware of possible salt buildup in soils. In certain areas, for example, in and around Los Angeles, there are salts in the water that can damage a plant's roots, especially if only 50% of the roots are watered (see Figure 32.14). Soluble salts in the water and in the soils accumulate where evaporation and drying occur at the outer limits of the wetted areas.

Emitters can be located so as to prevent salt damage to plant roots, as shown in Figure 32.15. The emitters need to be placed so that they overlap in the wetted area and completely cover the plant root zone. This ensures that salt buildup will occur only beyond plant roots at the outer edges of the wetted area where drying occurs.

Salt buildup in soils is a problem in only a few areas of the country like the Southwest and parts of the Southeast. Most other areas of the country have no such problem, and thus the guideline of watering 50% of a plant's roots works.

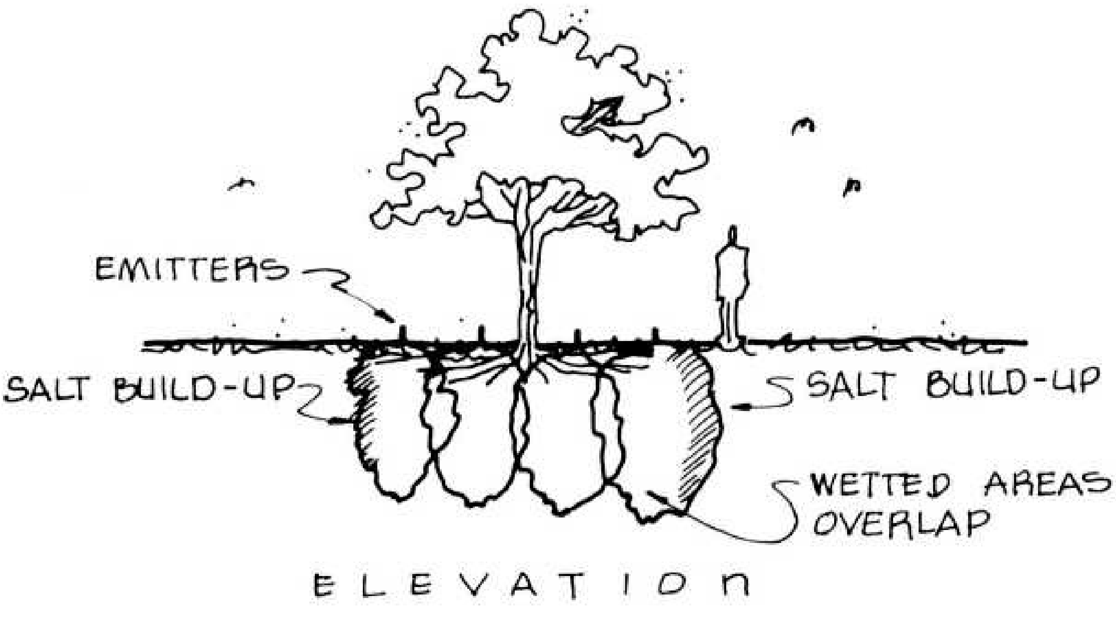


FIGURE 32.15 Salt buildup occurs beyond tree roots.

# 33

# Determining Pressure and Available Flow

## Introduction

You now understand the emitter and how to place it. You also know how to calculate plant water needs on a daily basis. Now let us see what kind of pressure and flow we have at the hose bib in our front yard drip irrigation example. Let us first say that you can install drip irrigation on its own metered water system, or you can hook it up to a hose bib connected to your household water supply. A drip system can have remote electric valves attached to an automatic controller, or it can be manually controlled with separate globe valves for each watering area (Figure 33.1). In our example, we are connecting the drip system to a hose bib connected to the household water supply. If your household sewer bill is charged as a portion of your water bill, you might save money by installing a separate, metered irrigation water line. Nevertheless, we are attaching our drip system to our household water system.

## Pressure and Flow Determination

To determine water pressure, we attach a pressure gauge to the hose bib (Figure 33.2) and see that we have a static pressure of 75 psi (5.3 kg/cm2); the average static pressure for a typical suburban neighbor hood might be around 60 psi (4.3 kg/cm2). When we turn the water on and measure the working water pressure on the flow gauge, the pressure is 65 psi (4.6 kg/cm2). To calculate the flow, we can do one of three things. We can read a flow meter attached to the hose bib, we can turn the hose bit) on full force and measure the gallons that will fill a bucket in 30 or 60 seconds (this will give us a gpm IL/min] calculation), or we can consult a chart for the amount of flow moving through the size of our hose bib.

FIGURE 33. 1 Drip system connected to gate valve.

FIGURE 33.2 Reading water pressure at hose bib.

Filling the bucket for 30 or 60 seconds and then measuring the amount of water in the bucket is the most accurate way to determine the flow. In our example, we have a flow from the hose bib of 4 gpm (15 L/min). If we take 4 gpm (15 L/min) and multiply it by 60 minutes, we will get the flow in gallons (liters) per hour, which in our situation is 240 gph (908 L/hr) maximum flow.

## Further Pressure Reduction

We now know our working pressure and flow at the hose bib. There are usually three more components needed in a drip system that affect the water pressure. They are the filter, pressure regulator, and the drip tubing itself. Let us review each of these vital components.

### Drip Irrigation Filters

All drip systems need a filter to keep small particles in the water from clogging the emitters (Figure 33.3). Whether your source is a lake, well, or municipal water system, you still need to use a filter. When your source of water is a lake or well, it is easy to see that small particles such as sand and algae could clog the emitters. In a city water supply, you might get scale from the inside of galvanized pipe or even mineral particles that build up on the inside of pipes.

FIGURE 33.3 Drip system filter.

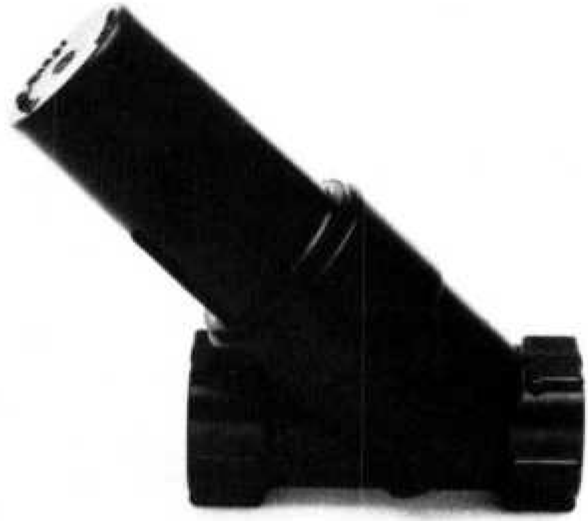
Some filters have a plastic mesh screen that filters the water (see Figure 33.4). The mesh is rated according to how many openings it has per linear inch; thus, a 200 mesh screen has 200 openings per linear inch and is finer than a 140 mesh screen. Many emitters are rated according to the size of mesh screen they need to keep from clogging. The 0.5-gph (2-L/hr) emitters need a finer mesh screen than the 1-gph and 2-gph (4L/hr and 8-L/hr) emitters because the opening on a 0.5-gph (2-L/hr) emitter is smaller. You can see from the pressure loss chart in Table 33.1 that the pressure loss through a 200 mesh filter for a 5-gpm or 300-gph (19-L/min or 1136-L/hr) flow is only 0.5 psi (0.04 kg/cm2), which is a very small amount.

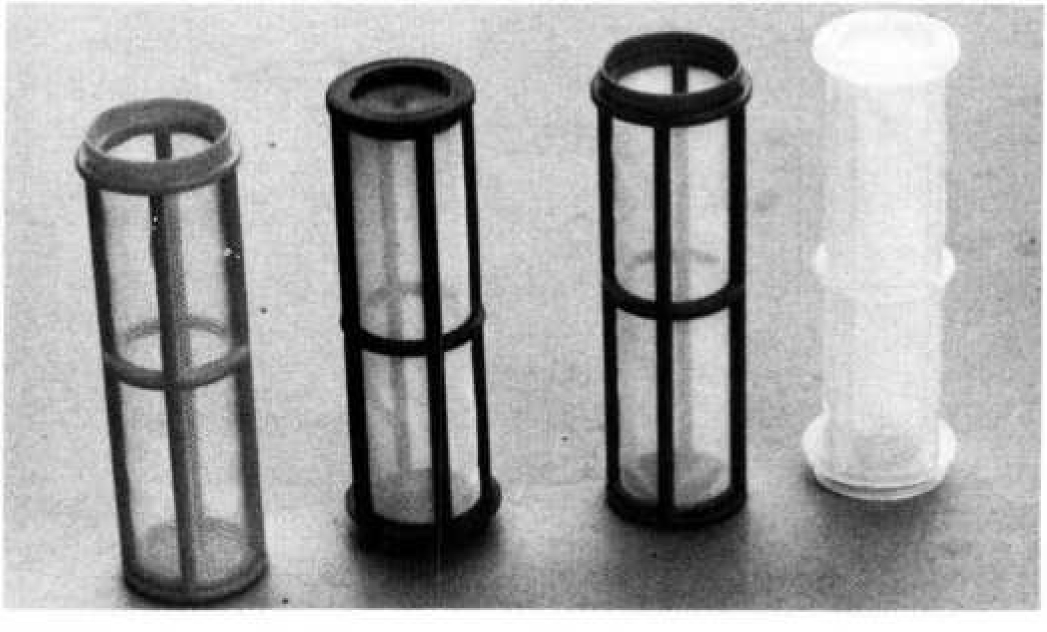
Filters need to be cleaned on a weekly basis if the source is a lake or well and on a monthly basis if the source is a city water supply. If you are in an area that freezes, you need to clean and drain the filter before freezing weather.

### Pressure Regulator

The function of a pressure regulator is to reduce the water pressure to the psi (kg/cm2) relative to the needs of the emitters you select. Remember, emitters are produced to deliver a certain gph (L/hr) flow at a specific water pressure. A pressure regulator is built to create pressure loss so as to reduce water pressure to a specific amount, depending on the psi (kg/cm2) rating of the pressure regulator selected.

**RBY-075**





30 Mesh (Yellow)

100 Mesh (Red)

150 Mesh (Blue)

200 Mesh (White)

FIGURE 33.4 Drip filter and mesh screens.

The pressure regulator in Figure 33.5 is available in 15 psi, 20 psi, and 25 psi (1.1 kg/cm2, 1.4 kg/cm2, and 1.8 kg/cm2) outlet pressures. The term outlet pressure refers to the pressure of the water coming out of the pressure regulator. The inlet is where the water comes into the pressure regulator.

## *TABLE 33.1* **Filter Pressure Loss Chart**

**DIMENSIONS**

- Height—4.5 in
- Length—5 in
- Width—1.9 in

**RBY-075/RBY-100**
**PRESSURE LOSS (PSI)**

| Flow Rate in GPM | 30 Mesh | 100 Mesh | 150 Mesh | 200 Mesh |
|---|---|---|---|---|
| 5 | 0 | 0 | 0 | 0.5 |
| 10 | 0 | 0.5 | 0.5 | 1.5 |
| 15 | 1.8 | 2.4 | 2.6 | 2.9 |
| 20 | 3.8 | 5.2 | 5.4 | 5.4 |
| 30 | 6.4 | 8.6 | 8.8 | 8.8 |

**PSI-HLB-15 / PSI-HLB-20 PSI- HLB-25 / PSI-HMB-20 PSI-HMB-25**

Drip Underground

Pressure Regulators

Operating Range

Flow: 6 to 300 gph

(PSI-HLB Series)

120 to 1320 gph

(PSI-HMB Series)

Pressure: 10 to 80 psi

Outlet Pressure:

15 psi (PSI-HLB-15)

20 psi (PSI-H LB-20/PSI-H M B-20)

25 psi (PSI-HLB-25/PSI-HMB-25)

Features

- Can be installed above or below ground
- Durable, heat-resistant plastic construction
- Pre-set outlet pressure - 15, 20 or 25 psi
- 3/4" female threaded inlet and outlet

FIGURE 33.5A Pressure regulator features.

FIGURE 33.5B Pressure regulator.

### Calculating Pressure Loss in Drip Tubes

Once you have determined where your emitters need to go and you have completed a preliminary pipe layout, you need to calculate your pressure loss in the length of drip tube for each circuit. We compute this pressure loss so that we can accurately estimate the amount of pressure available to the emitters. The pipe pressure loss compared to the pressure available tells us whether or not we need to use a pressure regulator. The pressure at the first and last emitters tells us if the pressure variation is less than 20%, which is the maximum variation allowable to get a uniform gph (L/hr) flow.

We will base our pressure loss calculation on the gallons (liters) per hour of water going through the pipe and on the length of the pipe. Recall that as the amount of water going through a pipe increases, so does the pressure loss due to friction.

The most accurate method you can use to calculate the pressure loss along the tubing run is to use pressure loss curves that have been developed for the size of drip tubing you select. These curves compute the pressure loss according to how much flow in gph (L/hr) you have going through the drip tubes and the length of the drip line.

To use the curves, first divide the total line flow by the total line length. You could also get the same answer by dividing the average emitter discharge by the average emitter spacing. In our front yard landscape example, we had a total line length of 402 linear ft (122.5 m) and 85 gph (322 L/hr) flow. Dividing the line flow by the ]line length, we get

$$\frac{85\text{ gph}}{402\text{ linear ft of tubing}} = 0.21\text{ gph/ft}$$

This gph/ft amount is also known as the specific discharge rate, which is abbreviated SDR. The SDR is equal to the rate of gph/per foot. Do not confuse this SDR for drip with the standard dimension ratio (also abbreviated SDR) we discussed when dealing with PVC pipe. That SDR relates to a standard pipe size.

Let us take our 0.21 gph,/ft amount and insert it into our pressure loss curve. Looking at the curve chart in Table 33.2 we see that to its left is the pressure loss in feet of head. (Recall from our chapter on basic hydraulics that feet of head is the unit mechanical engineers use to measure pressure). Irrigation designers prefer to work with psi, so to convert feet of head to psi, we divide the feet of head by 2.31. (1 foot of head = 0.433 psi; 1 psi = 2.31 feet of head.)

$$\frac{\text{feet of head}}{2.31} = \text{psi}$$

At the top of Table 33.2 is the SDR in gph per foot (or gph/ft). The length of PE hose or tubing we are using is at the bottom of the chart.

To use the chart, first plot the location of the SDR (0.21 gph/ft) along the top of the chart and then follow the curved line down to the point that reflects how many feet of drip hose we are using in our design. Move horizontally from this point of intersection to the left-hand side of the chart and read the pressure loss, which is approximately 4.7 feet of head. Convert that amount to psi by dividing by 2.31. The result gives us the pressure loss at the last emitter.

$\frac{4.7}{2.31}$ = 2.03 psi (0.14 kg/cm$^2$) pressure loss at the last emitter caused by the 85 gph (322 L/hr) moving through the 402 linear feet (122.5 m) of drip tubing.

Therefore, we will have a pressure loss along our 402 linear feet (122.5 m) of drip tube (delivering 85 gph, or 322 L/hr) of 2.03 psi (0.14 kg/cm2). If you feel that this is not a lot of pressure loss, you're right. The water is moving so slowly through the pipe that there is not going to be much friction loss caused by the water being slowed by the inside surface of the pipe. Note that the 2.03 psi (0.14 kg/cm2) pressure loss does not include losses and gains caused by elevation.

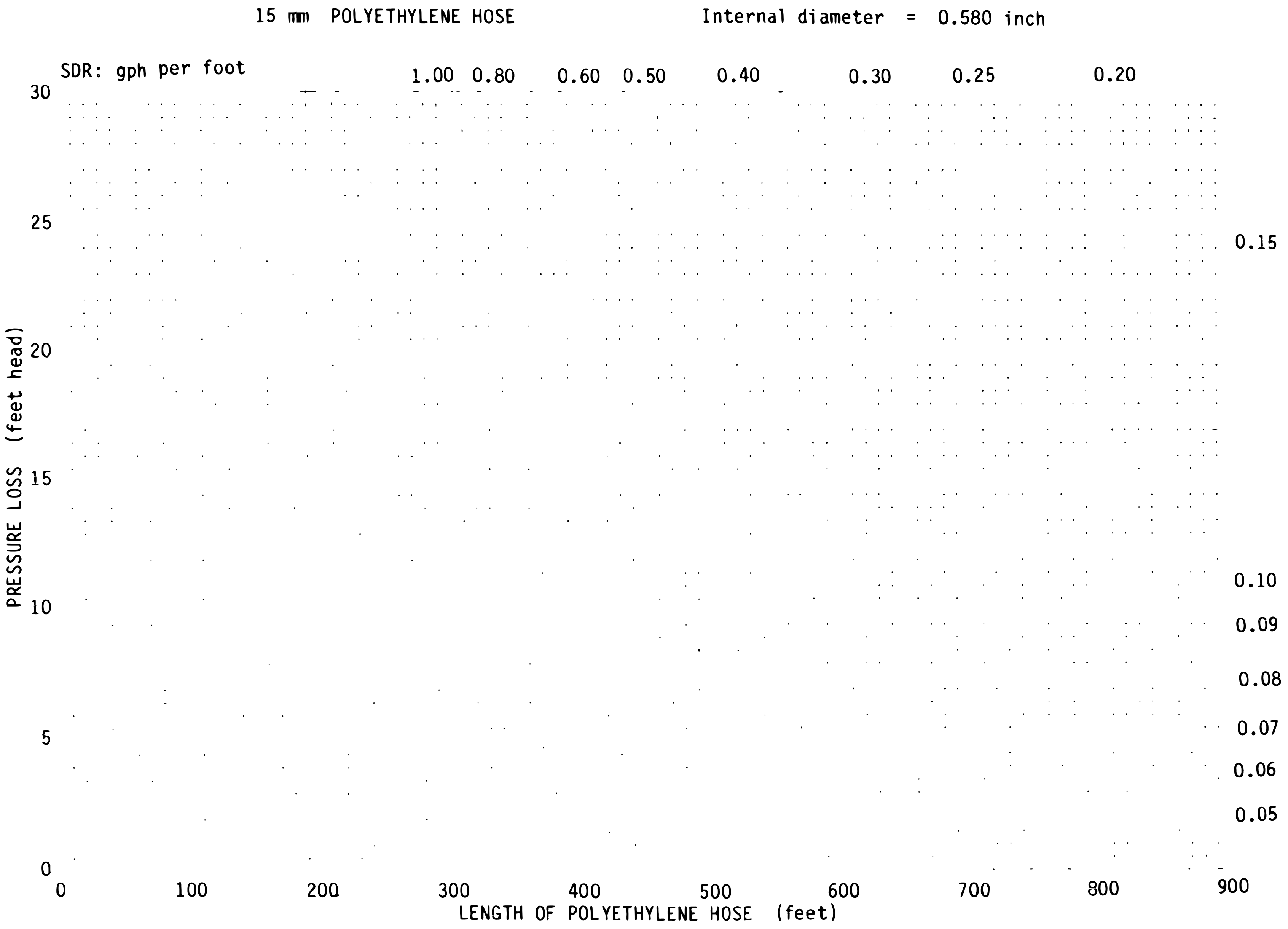
In our example we used 15-min PE hose or tubing. Many contractors prefer to use 16-mm hose and fittings. Remember, each size of PE drip tube will have its own design curve.

### Emitter Pressure Variation and Flow Changes

Let us compare the discharge of an emitter at different pressure variations. For a typical 1-gph (4-L/hr) non-pressure-compensating emitter, the discharge rate in gph (L/hr) will vary depending on the amount of pressure at the emitter. A typical 1-gph (4-L/hr) emitter is built to provide 1 gph (4 L/hr) at 15 psi (1.1 kg/cm2). As the pressure at the emitter rises, the discharge increases (see Table 33.3).

If the pressure at the first emitter on our 402 ft (122.5 m) drip line is 15 psi (1.1 kg/cm2), then with 2.03 psi (0.14 kg/cm2) loss in the line, the pressure at the last emitter on the line will be 12.97 psi (0.9 kg/cm2). The pressure variation (or loss) between the first and last emitter is 13.53%. We set up a proportional relationship to find the pressure variation, by figuring that 2.03 psi (0.14 kg/cm2) loss (or gain, if the line went downhill) is to 15 psi (1.1 kg/cm2) as xis to 100:

TABLE 33.2 **Drip Tubing Pressure Loss Curves**



### *TABLE 33.3* ***Pressure Variation and Flow—Changes—1-gph (4-L/hr) Emitter***

| PRESSURE INCREASE (%) | 15 PSI (1.1 KG/CM$^2$) | 1 GPH (4 L/HR) | WATER DISCHARGE INCREASE (%) |
|---|---|---|---|
| 33 | 20 (1.4) | 1.1 (4.2) | 10 |
| 100 | 30 (2.1) | 1.3 (4.9) | 30 |
| 166 | 40 (2.8) | 1.55 (5.9) | 55 |
| 233 | 50 (3.5) | 1.8 (6.8) | 80 |

$$\frac{2.03}{15} \times \frac{x}{100}$$

$$15x = 203$$

$$x = \frac{203}{15}$$

$$x = 13.53\%$$

An easier way to understand how to calculate the pressure variation by the proportion method is to use a simpler number. Let us say that we have a pressure difference between the first and last emitter of 8 psi (6.6 kg/cm2) and our pressure at the first emitter was 10 psi (6.7 kg/cm2). Thus, 8 psi is to 10 psi as xis to 100:

$$\frac{8}{10} \times \frac{x}{100}$$

$$10x = 800$$

$$x = \frac{800}{10}$$

$$x = 80\%$$

It is probably easier to see that 8/10 is the same as 80%. When working any math calculations, it is always best to think reasonably about your conclusions. Does a pressure loss of 2.03 psi (0.14 kg/cm2) from 15 psi (1.1 kg/cm2) logically equal 13.53%? Yes, it does; it is logical.

## Calculating Total System Pressure

We now know how to calculate pressure loss and pressure variation in our drip system, and we know that pressure variation will create flow rate changes in our emitters. Let us now calculate our total system pressure so that

1. We can adjust our water pressure to the pressure requested by the emitters
2. We can decide whether or not we will need a pressure regulator on our system
3. We can see if we are within a 20% pressure variance between the first and last emitter on the drip line

Referring back to our front yard example drip system, we determined that we had a working pressure of 65 psi (4.6 kg/cm2) and a flow of 240 gph (908 L/hr) at our hose bib (see Figure 33.6). Next, we calculated our psi loss through the filter, which was only 0.5 psi (0.04 kg/cm2). Our pressure regulator will reduce our pressure to whatever we want it to be. Our drip tube with the 85-gph (322-L/hr) flow lost 2.03 psi (0.14 kg/cm2) through friction loss over its 402-ft (122.5-m) length.

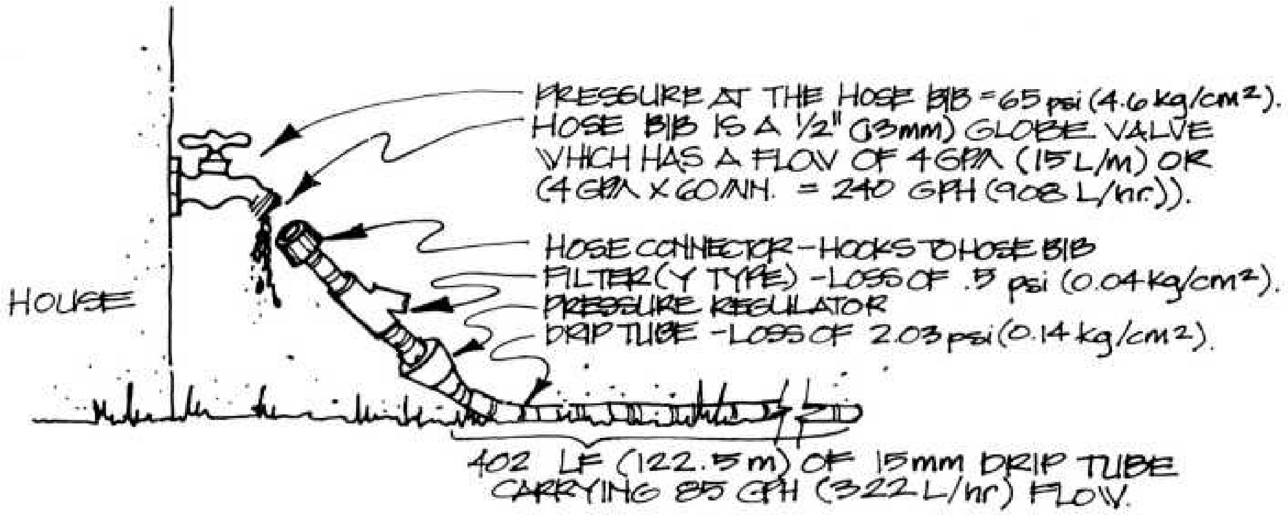


FIGURE 33.6 Pressure and flow available.

So, we can calculate our pressure loss at our last emitter as follows:

65.00 psi (4.6 kg/cm$^2$)—working pressure at hose bib

–0.50 psi (0.04 kg/cm$^2$)—filter
–2.03 psi (0.14 kg/cm$^2$)—loss through drip tube

62.47 psi (4.4 kg/cm$^2$)—the pressure at the last emitter, not including gains and losses due to changes in elevation

If we are using pressure-compensating emitters that will deliver 1 gph (4 L/hr) between 10 psi and 40 psi (0.7 kg/cm2 and 2.8 kg/cm2), we see that we have too much water pressure and therefore need to use a 25-psi (1.8-kg/cm2) pressure regulator, which will reduce water pressure to 25 psi (1.8 kg/cm2). Now at the last emitter we will have a water pressure of 22.97 psi (1.6 kg/cm2) (25 psi - 2.03 psi = 22.97 psi). We do not include the pressure loss through the filter because the pressure regulator is placed downstream from it.

Now let us calculate how elevation differences affect our water pressure. We have a 7-ft (2.1-m) drop in elevation from the hose bib to the lowest point in the landscape, which will cause a 3-psi (0.2-kg/cm2) increase in water pressure (7 ft X 0.433 psi = 3.03 psi). The total water pressure at the low point will still be within the 10 psi to 40 psi (0.7 kg/cm2 to 2.8 kg/cm2) operating range of our pressure-compensating emitter. From the low point to the high point near the trellis, there is a 10-ft (3-m) rise in elevation, which will cause a pressure loss of 4.33 psi (0.3 kg/cm2). Let us calculate our pressure from the pressure regulator to the trellis to see if we are still going to be within our pressure-compensating emitter's range.

25.00 psi (1.8 kg/cm$^2$)—the pressure of the water as it comes out of the pressure regulator
–2.03 psi (0.14 kg/cm$^2$)—the pressure lost as 85 gph moves through the 402-ft (122.5-m) drip tube
+3.03 psi (0.2 kg/cm$^2$)—the pressure gain by water flowing downhill at the front yard low point; 7 ft (2.1 m) × 0.433 psi (0.03 kg/cm$^2$) = 3.03 psi (0.21 kg/cm$^2$)
– 4.3 psi (0.3 kg/cm$^2$)—pressure loss as water is pushed uphill to the trellis; 10 ft (3 m) elevation × 0.433 psi (0.03 kg/cm$^2$)

21.70 psi (1.56 kg/cm$^2$)—pressure at end of system.

The remaining pressure at the end of our drip tube of 21.70 psi (1.56 kg/cm2) is still within our pressure-compensating emitter's range. Therefore, we have the correct water pressure for our emitters.

What if we had used non-pressure-compensating emitters? Remember, these emitters produce a given amount of water at a specific pressure. Let us examine the situation using the Lady Bug emitter, which discharged 1 gph (4 L/hr) at 15 psi (1.1 kg/cm2). At the hose bib we had 65 psi (4.6 kg/cm2) working pressure. Our loss through the filter will still be 0.5 psi (0.04 kg/cm2), and our pressure loss through 402 ft (122.5 m) of 15-mm drip tube will still be 2.03 psi (0.14 kg/cm2) (see Figure 33.7).

Let us look at our example landscape to determine the water pressure at the high and low points. Using a 15-psi (1.1-kg/cm2) rated pressure regulator, we will have 15 psi (1.1 kg/cm2) at the outlet of the pressure regulator. At the low point of the front yard, we have

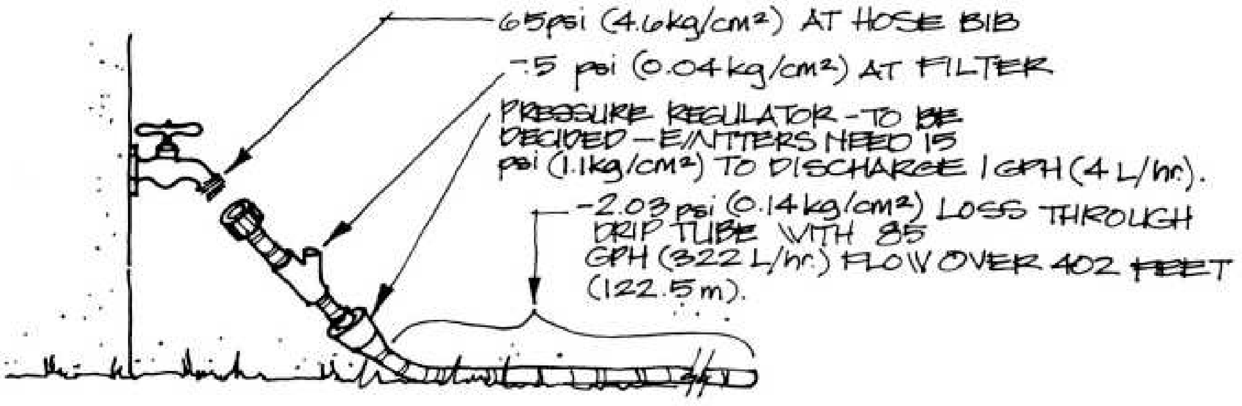


FIGURE 33.7 Pressure and flow.

15 psi (1.1 kg/cm$^2$)
–1.5 psi (0.11 kg/cm$^2$)—line loss in approximately 300 ft (91.4 m) of drip tubing (to the low point)
+ 3.03 psi (0.21 kg/cm$^2$)—pressure increase caused by drop in elevation from hose bib; 7 ft (2.1 m) elevation drop × 0.433 psi (0.03 kg/cm$^2$) = 3.03 psi (0.21 kg/cm$^2$)

---

16.53 psi (1.2 kg/cm$^2$)

From the low point, we travel 102 ft (31.1 m) uphill to the trellis and lose 0.53 psi (0.04 kg/cm2) in tube friction loss and 4.33 psi (0.3 kg/cm2) elevation loss in our 10 ft (3 m) climb.

16.53 psi (1.2 kg/cm$^2$)—working pressure at low point
– 0.53 psi (0.04 kg/cm$^2$)—tube friction loss
– 4.33 psi (0.3 kg/cm$^2$)—10 ft (3 m) climb in elevation

---

11.67 psi (0.82 kg/cm$^2$)—pressure at top of hill beside the trellis

We have 11.67 psi (0.82 kg/cm2) at our last emitter at the high point beside the trellis. Now let us evaluate the discharge of our 1-gph (4-L/hr) emitters, which are rated to work at 15 psi (1.1 kg/cm2). Looking at the performance chart of the Lady Bug 1-gph (4L/hr) emitter in Figure 30.2, we see that at 11.67 psi (0.82 kg/cm2) (the high point), the discharge = 0.88 gph (3 L/hr)

at 15.00 psi (1.1 kg/cm2) (the hose bib), the discharge = 1 gph (3.8 L/hr)

at 16.5 psi (1.2 kg/cm2) (the low point), the discharge = 1.02 gph (3.9 L/hr)

The variation in discharge between the 0.88 gph (3.8 L/hr) and the 1.02 gph (3.9 L/hr) is 13.7%, which is within our 20% variance rule. If you can live with the small variance in. gph (L/hr) output, then using the non-pressure-compensating emitters will work fine. The pressure-compensating emitters will be slightly more accurate in our example drip design. However,

do not forget that the non-compensating emitters will last longer than the pressure-compensating emitters and will also cost less. In this situation, we could have used the non-pressure-compensating emitters rather than the pressure-compensating emitters. Running drip tubing parallel to slopes as shown in Figure 33.8 keeps emitter pressures nearly the same, eliminating the need for pressure-compensating emitters.

FIGURE 33.8 Drip tubing running parallel with slope.

# 34

# Drip Design Components

It may be of value to illustrate a typical drip system at this point. We will depict an automated system because our last example was a manual system. Examine the sketch in Figure 34.1 for components and their placement.

You can see that an automated drip system is just like an automated sprinkler system, with the automatic electric valves located to turn circuits on and off. You should note as well that PVC pipe and PE drip tubing can be connected together with compression adapters. This allows drip systems constructed with PE tubing to be connected to sprinkler systems constructed with PVC pipe.

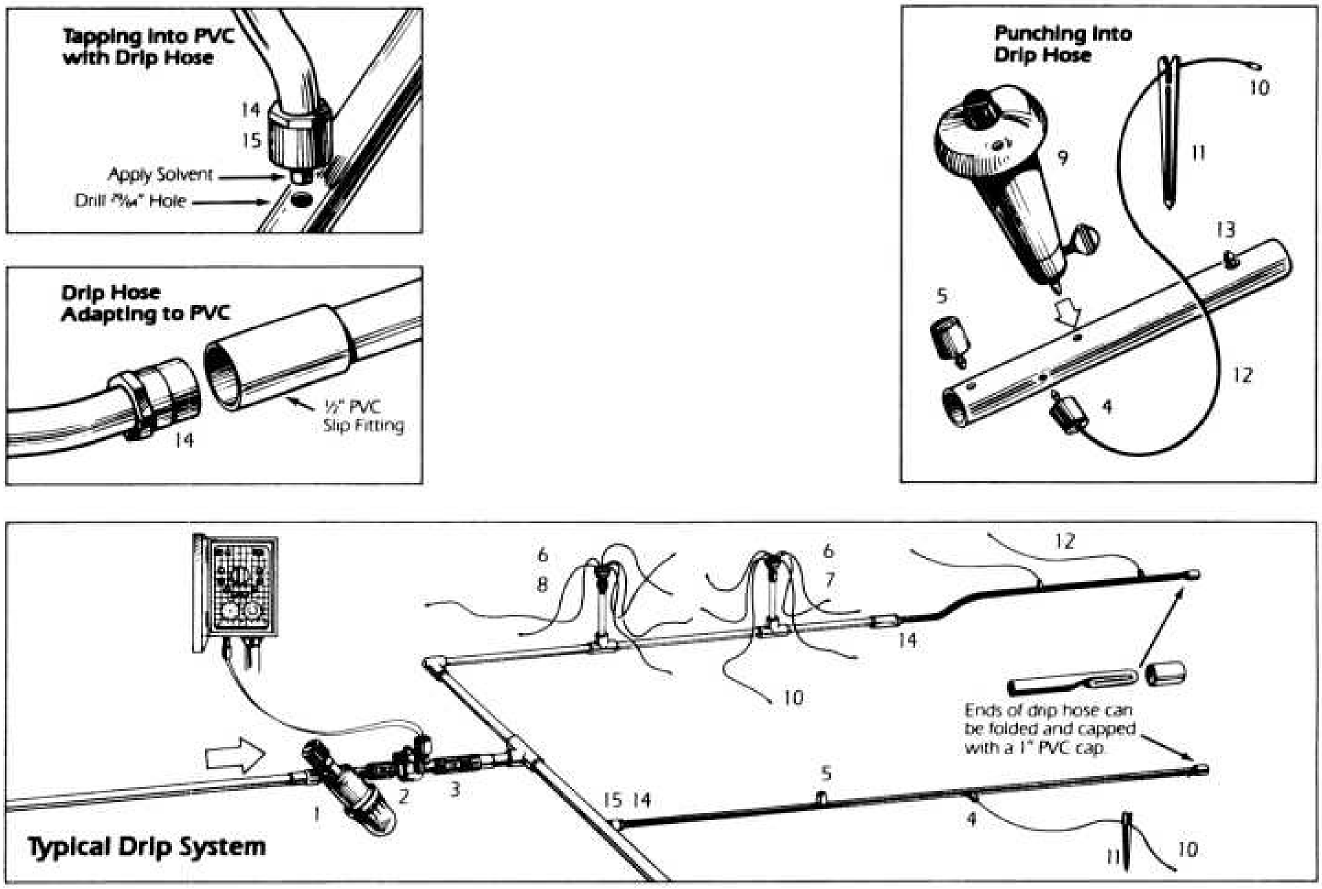


FIGURE 34.1 Typical drip system. 1. Filter 2. Automatic Valve 3. Pressure Regulator 4. Emitter 5. Emitter 6. Multiple Outlet Emitter or Drip Manifold 7. Microtubing 8. Microtubing 9. Hole Punch 10. Insect Cap 11. Microtube Stake 12. Microtubing 13. Mistake (or Goof) Plugs 14. Compression Adapter 15. Tapered Pipe Adapter

# 35

# Drip Design Process

## Introduction

Let us review a four-step process by which to design a drip irrigation system. We have discussed most of the terms and ideas in this process, so you should have no trouble applying the principles. This process will give you an educated guess as to your drip needs for landscape use. As with all drip systems, you need to monitor your system carefully. Look at your soil to see if it is getting water at the proper depth, and look at your plants to see if they are performing well.

## Four-Step Process

### 1. Determine Watering Frequency

Determine the number of times per week to activate your drip system based on soil types (see Table 35.1).

- If you have clay soils, water your landscape twice a week during the hottest and driest portion of the plant growth season. Clay soils hold moisture longer than loamy and sandy soils.
- If you have loamy soils, water three times a week. Pore spaces in loamy soils are larger than those in clay soils, so water moves through them at a faster rate. Therefore, the loamy soils dry out faster than the clay soils.
- If you have sandy soils, water every other day. The pore spaces in sandy soils are so large that the water moves very rapidly through them, and they dry out quickly.

We have estimated the number of hours that a 1-gph (4-L/hr) emitter should run in Table 35.2 based on the different rates at which water penetrates the three soil types. Our estimation of the length of the watering cycle is just that--an estimate-and the system should be closely monitored on each job site.

*TABLE 35.1* ***Watering Frequency Depends on Soil Types***

| SOIL | SU | M | T | W | TH | F | S | WATERING TIMES PER WEEK |
|---|---|---|---|---|---|---|---|---|
| Clay | X |  |  | X or | X |  |  | Twice |
| Loam | X |  |  | X |  |  | X | Three times |
| Sandy | X |  | X |  | X |  | X | Four times |

*TABLE 35.2* ***Hours per Watering Cycle for a 1-gph (4-L/hr) Emitter***

| SOIL TYPE | HOURS PER WATERING CYCLE |
|---|---|
| CLAY | 3–4 hours |
| LOAM | 2–3 hours |
| SANDY | 2–3 hours |

### 2. Determine Plant Water Need

This is done by referring to Tables 31.5-31.10, which give the irrigation required in gallons and liters per day by plant type and the diameter of the plant's canopy.

### 3. Determine the Number of Watering Circuits

Divide the landscape into watering circuits, depending on the kinds of plants you have and the soil types you are watering. Remember, do not mix soil types on the same circuit.

- Water remains in clay soils longer than in any other type of soil.
- Water drains most quickly from sandy soils.
- If clay and sandy soils are on the same circuit, either the sandy soils will dry out too quickly or the clay soils will be overwatered.

### 4. Determine the Number of Emitters

To determine the number of 1-gph (4-L/hr) emitters you will need, first take the gpd (L/day) water requirement for each plant (according to the water need chart) and multiply it by 7 to get the gallons or liters of required water per week. Next, divide the watering frequency (number of times you water per week) for your soil type into the gpw (L/wk) calculation. The result is the amount of water to be discharged per watering cycle.

Now, to get the number of 1-gph (4-L/hr) emitters needed per plant, divide the amount of water being discharged per watering cycle by the number of hours you will run your system per watering cycle.

Let us organize this process to determine the number of emitters needed per plant in a more concise way. The variables used to determine the number of 1 gph (4 L/hr) emitters are as follows:

gpd (L/day)--Water requirement of plant per day

gpw (L/wk)--Water requirement of plant per week

Watering frequency-Number of times per week plants need to be watered based on soil type

Gallons (liters) per watering cycle-Amount of water discharged each time the irrigation system is turned on

Hours per watering cycle-The number of hours to run the irrigation system per watering cycle

We can take these variables and put them into an equation that gives us the number of 1-gph (4-L/hr) emitters needed for each plant. We will follow the equation with an actual example.

$$\text{gpd (L/day)} \times 7 = \text{gpw (L/wk)}$$

$$\frac{\text{gpw (L/wk)}}{\text{watering frequency}} = \text{gallons (liters) per watering cycle}$$

$$\frac{\text{gallons (liters) per watering cycle}}{\text{hours per watering cycle}} = \begin{array}{c}\text{number of 1-gph (4-L/hr)} \\ \text{emitters needed}\end{array}$$

Now let us recall our front yard irrigation plan, in which we had evergreen shrubs and crape myrtle trees in clay soils. The evergreen shrubs are 3 ft (.9 m) in diameter and need lots of water, whereas the crape myrtles are 6 ft (1.8 m) in diameter and need much less water. Referring to the plant water need chart, we can see that in a hot climate, the evergreen (high-water need) shrubs will use 1.7 gpd (6.4 L/day), and the crape myrtles (low-water need) will use 2.7 gpd (10 L/day). Let its insert these gpd (L/day) computations into our equation to determine the number of 1-gph (4-L/hr) emitters needed per plant.

E.vercreen Shrubs

$$1.7\text{ gpd }(6.4\text{ L/day}) \times 7 = 11.9\text{ gpw }(44.8\text{ L/wk})$$

$$\frac{11.9\text{ gpw }(44.8\text{ L/wk})}{2\text{ (clay soils are watered twice a week)}} = \begin{array}{c}5.95\text{ gal }(22.4\text{ L})\text{ per}\\ \text{watering cycle}\end{array}$$

$$\frac{5.95\text{ gal }(22.4\text{ L})\text{ per watering cycle}}{4\text{ (hours per watering cycle)}} = \begin{array}{c}1.49\text{, or }1.5\text{, emitters per}\\ \text{shrub}\end{array}$$

We could use a 1.5-gph (6-L/hr) emitter, or we could see if the shrubs performed well with a 1-gph (4 L/hr) emitter, or we could use a 1-gph and a 0.5-gph (a 4L/hr and a 2-L./hr) emitter.

Crape Myrtle

$$2.7\text{ gpd }(10\text{ L/day}) \times 7 = 18.9\text{ gpw }(72\text{ L/wk})$$

$$\frac{18.9\text{ gpw }(72\text{ L/wk})}{2} = 9.45\text{ gal }(36\text{ L})$$

$$\frac{9.45\text{ gal }(36\text{ L})}{4\text{ hours}} = 2.36\text{, or }3\text{, emitters per tree}$$

You can see that we need 1.5 emitters on our shrubs and 3 emitters on our crape myrtles if we are going to run them twice a week on the same circuit for 4 hours per watering cycle.

# 36

# Final Drip Design Considerations

The following is a list of some basic considerations related to drip irrigation design, which serve as a summary of our discussion. These considerations will help to substantiate the basis for our drip design process.

1. Learn your soils. Monitor your watering schedule to see if the soils are getting too much water and becoming waterlogged. Look at plant performance to see if plants are getting enough water for optimum growth.

2. Clay soils hold more water than other soils, but the clays do not release the water as easily. This is because the pore spaces in clays are so small that water in the pores is held tightly.

3. When clay soils become saturated, most of the air is pushed out of the soil by water. If a clay soil remains saturated too long, the soil will become waterlogged, and the plant may suffocate from lack of oxygen.

4. Anything larger than a 2-gph (8-L/hr) emitter will cause runoff on tight, clay soils, resulting in wasted water.

5. Clay soils need a greater time interval between waterings to dry so that air can move back into the soil.

6. As the texture of soils becomes finer, the pores become smaller, and the water in those pores is held more tightly by the soil.

7. Because some of the water in clay soils is held tightly by the small soil pores, clay soils need more water than other soils to fulfill a plant's water needs.

8. Larger pore spaces in sandy and loamy soils allow water to move rapidly through the soils. Air follows the water that moves through these soils and quickly supplies needed air to plant roots.

9. Organic matter in loamy soils holds a great amount of water in its large pores and readily releases the water to plant roots. Remember, loamy soils are a rich blend of silt, clay, sand, and organic matter.

10. Examine your water depth. Soils can be checked for depth of water

penetration with a soil probe and the "feel method." When you squeeze soil, it is dry if it falls apart; if it holds together, there is moisture in it.

11. One inch (25 mm) of water will go deeper in a sandy soil than in a clay soil. Therefore, you can see that it takes longer for water to penetrate clay soils.

12. Water moves so quickly through sandy soils that it often moves beyond plant roots because of the pull of gravity.

13. The number of hours you water your plants and the number of times per week you water should be based on the time of year when the plants get the least moisture and the temperature is the hottest. For most of the United States, we are talking about the months ofJuly and August. This is also when the evapotranspiration (EVT) is the highest.

14. The EVJT rate for an area relates to plants growing in full sun.

15. Emitters with flow rates of 1 gph, 1.5 gph, and 2 gph (4 L/hr, 6 L/hr, and 8 L/hr) will adequately cover the watering needs of most landscape plants.

16. A 0.5-gph (2-L/hr) emitter is not often used because its orifice is so small as to be prone to clogging.

17. Although there are 4-gph (16-L/hr) emitters, there are few reasons to use them because landscape plants do not need to be watered too fast.

# 37

# Conserving Water

## Introduction

As an irrigation designer, installer, or manager, you must become responsible for conserving water. Although in some parts of the country it appears as though water supplies are inexhaustible, we are approaching or exceeding available water limits in many areas.

Many western states have imposed legal restrictions on water use. Water became so scarce in Santa Barbara, California, that sprinkler irrigation was banned. Beneath Mississippi State University's campus, the water table has dropped 40 ft (12.2 m) in the past 20 years. Atlanta, Georgia, periodically has to restrict the use of water because of shortages. In south Florida, where yearly rainfall is 60 in (1,524 mm), excessive pumping of water from wells has caused the pressure of freshwater in the ground to drop below the pressure of the saltwater surrounding the fragile Florida peninsula. Seawater has intruded into the mainland water table. This has resulted in the creation of water management districts to govern the use of water including private wells. Our increasing dependence on water is becoming a problem of which we must all become aware and work toward solving.

The problem will be solved when we determine the carrying capacity of regional landscapes for human use and then plan for the use of land based on these limits or carrying capacities. Until these limits are determined, however, we can implement immediate solutions for conserving water. Low-water need landscapes can be created, landscapes can be maintained in a manner requiring less water, water-conserving components can become a part of all irrigation systems, wastewater can be recycled, and runoff water can be retained for further use.

## Sustainability

A term to be aware of is sustainability, which denotes use of the land that doesn't wear out and deplete its natural resources; it is when we live in harmony with the environment. The natural ecosystem serves as a model for sustainability. An ecosystem is always taking care of its problems and renewing itself. In a sustainable landscape, resources are not overused, there is no pollution, and waste dumps do not exist; yard wastes and other organics are recycled back into the soil, thus feeding the abundant, nourishing life there. Dependence on nonrenewable resources like oil and minerals is reduced and replaced as much as possible through using renewable resources like the sun, wind, plants, soils, and water.

### Degeneration

We used to live in harmony with our environment. But during the industrial period of 1870 to 1990, engi neers and architects tried to overwhelm nature with concrete, steel, and fossil fuels, failing disastrously and not realizing the need to depend on nature's processes for their own existence. In this industrial era, our buildings, agriculture, solid waste, and sewage treatment systems contributed to pollution and the overuse of nonrenewable energy sources and materials. The methods of production employed during this era have proven unsustainable due to the overuse of raw materials that cannot be replaced and the production of by-products that cannot be recycled. Human support systems are currently using renewable resources faster than they can he renewed. Simply stated, we are not living in harmony with our environment; we are living beyond the means of the environment to continue to support our human population. Degeneration is the general term defining this relationship with the land that has resulted in high energy bills; water shortages; water, soil, and air pollution; infertile soils and the greater presence of disease.

### Regeneration

Regeneration, another term to understand and practice, is when renewable resources are relied upon for human life support systems and are treated as renewable. Regenerative technologies do not use up nonrenewable resources but rely more upon using continuously renewable resources. A constructed wetland or plantreed sewage treatment system that treats wastes biologically (with communities of microorganisms), without the concrete, steel, chemicals, and electrical energy of a high-tech treatment plant, is an example of regeneration. Methods of regeneration could also include collecting rainfall from roofs and paved areas for landscape irrigation and creating planting designs that result in cooler, more energy-efficient environments. This would result in less power usage and less demand for water. Regeneration, therefore, is continuing self-renewal. It is our challenge as designers and managers of landscapes to create regenerative landscapes that contribute to the sustaining processes of natural ecological systems.

Once again, sustainability is achieved when our life support systems are continually selfrenewing. One way to do this is to model life support systems after natural systems to create landscapes that are much like the indefinitely sustainable natural ecosystem. Let us look in more detail at a few regenerative techniques that relate to conserving water.

**Xeriscapes**

Creating and maintaining low-water need landscapes is generally called xeriscaping, derived from the Greek

xeros, meaning "dry." As a teacher of planting design for the past 15 years, I have come to realize that nearly anything can be planted from outside a native landscape and be successfully grown. But there is a price to growing nonnative plants. Soils have to be amended to provide the plants with their specific flavor of soil. Exotic selections will need extra maintenance like pruning, fertilizing, and mulching to survive, and they will also probably need precise amounts of regularly scheduled water. Without all the extra attention, these plants would not make it.

When applying xeriscaping techniques, it is best to select native plants from the local area. These plants can take the heat, the drought, or possibly all the extra water. By using these native plants, the need to irrigate can be reduced. Be aware, though, that while using native plants-including trees, shrubs, ground covers, grasses, and perennials-there will still exist the need to irrigate regularly until they become established. Some plants will need irrigation for a longer time to achieve optimum size in order for us to benefit from the function the plant is to perform. Functional uses like creating comfortable outdoor spaces that retain or block the sun's warmth or are shielded from winter winds (thereby reducing dependence on fossil fuels and reducing energy bills) are examples of arranging plants to perform regenerative tasks.

When creating xeriscapes, a designer should also consider the following for reducing water needs:

1. Consider whether a screen should be a row of' plants, or would a fence or wall perform as well.

2. Evaluate whether areas should be paved, covered with a mulch, or planted with grass.

3. Incorporate shade into the design. Shaded landscapes are up to 20° F (11 ° C) cooler than areas in the sun. Water loss through evaporation is greater in sunny areas. Shade can come from trees but can also be a result of using arbors and tall fences.

4. Plan for water need zones in a landscape. Highvisibility public areas might need the most water, whereas service and utility areas might need the least amount. The University of Georgia College of Agriculture and Environmental

Sciences recommends dividing a landscape into three water use zones: high use (regular watering), moderate use (occasional watering), and low use (relying on natural rainfall). Remember, though, that most newly planted landscapes require regular irrigation while becoming established. Ornamental plants and turf grass might need watering 8 to 10 weeks after planting for establishment. The street tree program in Starkville, Mississippi, calls for watering newly planted 5 ft to 6 ft (1.5 m to 1.8 m) street trees with 5 gal (18.9 L) of water each week during the dry summer months for two growing seasons. After that, the street trees are established enough to make it on their own.

5. Concentrate plantings with high water needs together (like annual flowers) rather than scattering them throughout the landscape.

6. Fit plant selections to the size of the space in which they will be located. Don't choose plants that need constant shearing or pruning. Not only does this take extra work, but cutting back a plant also stimulates growth, which increases water demand.

7. Regularly feed soil with composted yard waste and organic matter. The soil will then have abundant microorganisms that will consume and convert organic matter into a slowly released fertilizer for plants. This method of fertilizing naturally will reduce growth spurts, fertilizer needs, and water needs.

8. Use a natural, organic mulch to cover bare soil around plants. Mulch will slow evaporation from the soil and reduce heat stress to plant roots.

9. Mow turf grass so that no more than one-third of the leaf is removed. This practice reduces growth surges, which demand water. Raising mower blades during drought periods and at the end of the growing season encourages deeper rooting.

10. Irrigate just before plants become stressed. Learn to identify when plants need water. Grass will dull in color and not spring back when walked on. Tree leaves will begin to droop and shed. Shrubs will dull in color and begin to wilt. Keep plants healthy but don't encourage optimum growth all the time.

### Water Management Components

In addition to the watering strategies suggested as a part of creating and maintaining xeriscapes, begin to study and use water-conserving irrigation components. A rain shutoff device (Figure 37.1) mounted to catch water will shut down an irrigation system during rain. This sensible device is required on irrigation systems in some states. Moisture sensors located in the soil perform in a similar fashion, shutting off the irrigation system until the soil is dry enough to warrant watering.

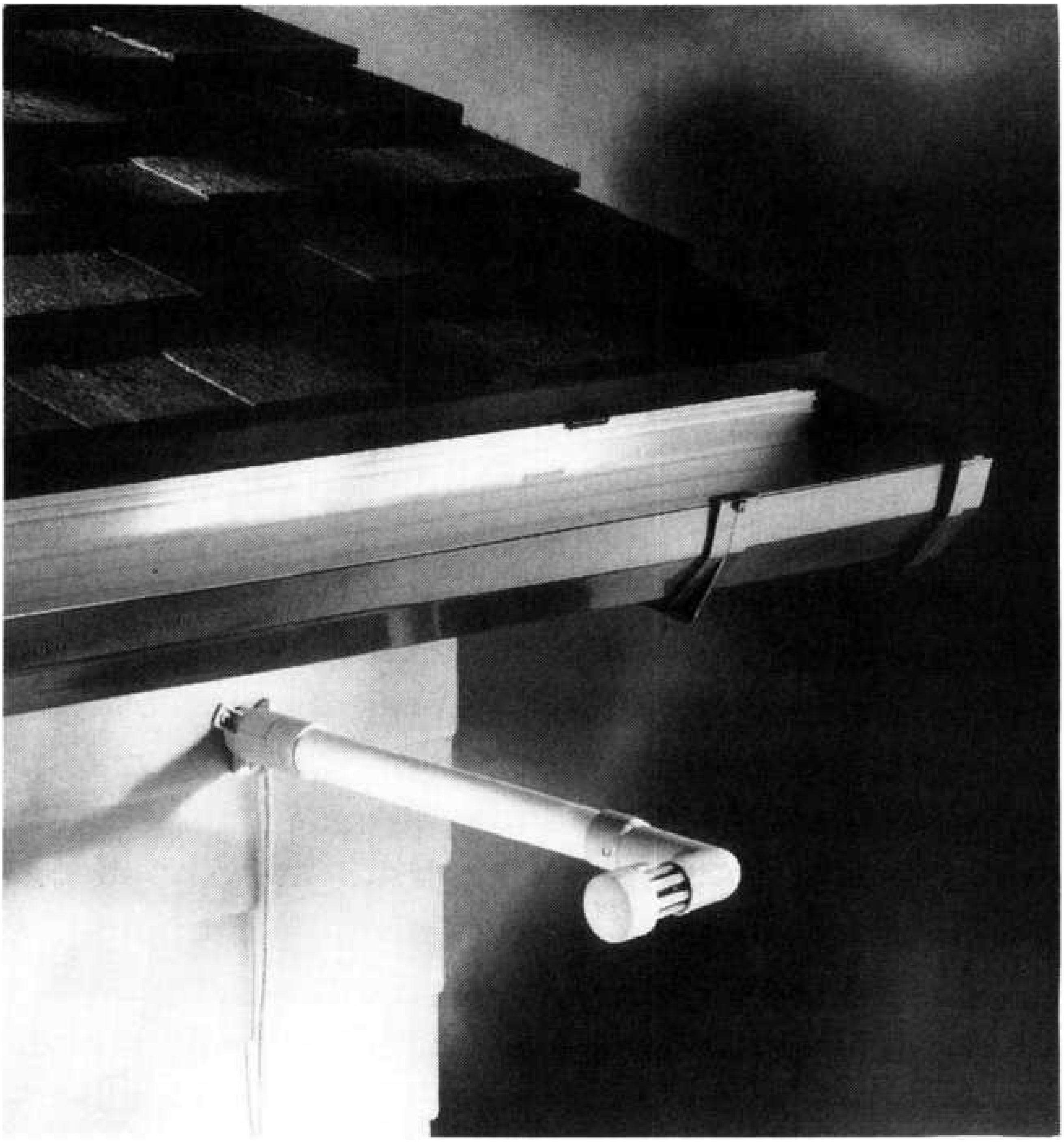


FIGURE 37. 1 Rain switch. (Source: The Toro Company. Used with permission.)

Water conservation management systems are available that will monitor environmental conditions like temperature, wind, and precipitation and develop daily water need schedules based on these conditions. A computer and software calculate daily water needs based on weather conditions and send revised daily watering schedules to satellite controllers that implement conservation minded watering schedules. Water conservation management systems save on water use, and they reduce labor costs.

### Reusing Wastewater

Wastewater from the treatment of sewage can be recycled for irrigation use. In a mechanical sewage treatment plant, which operates on a three-stage basis, primary sewage treatment removes the solids from sewage effluent. Secondary treatment is a biological process that works on reducing the suspended solids and harmful pathogens in the liquid effluent. Tertiary treatment is advanced treatment such as further filtration or the adding of chlorine to kill pathogens. The liquid effluent is aerated, thereby injecting oxygen into the watery mixture, which encourages aerobic bacteria (bacteria that need oxygen) to thrive. The bacteria consume most of the remaining solids in the effluent, including the harmful pathogens. Pathogens are disease-causing organisms such as protozoa, bacteria, and viruses that can cause dysentery, salmonellosis, and typhoid, among other diseases. Mechanical sewage treatment plants are very labor, chemical, and energy intensive. The initial cost of the concrete and steel municipal plants is a major community investment. Usually this water flows into a stream after treatment. Some cities take the treated water and sell it for irrigation use, on golf courses and so on. In Delray Beach, Florida, some golf courses are required to buy treated effluent for 28V per 1,000 gallons (3785 liters) rather than being allowed to pump water from wells.

An alternative to the energy-, chemical-, and laborintensive mechanical systems are artificial marshes that treat sewage biologically (Figure 37.2). In these natural treatment plants, also called rock-reed treatment systems, sewage is treated by first removing solids. In a small-scale system this is done with a septic tank. (The tank will usually need to be pumped out by a "honey wagon" every three to five years to prevent solids from getting into the marsh.) The liquid effluent then flows to a marsh or wetland where naturally occurring bacteria located on gravel, plant stems, and roots will consume the remaining solids, including the pathogens. After the effluent slowly flows through this contained biological treatment marsh for a set time, it can be collected and pumped for irrigation uses. Natural marsh sewage treatment systems can be built to service a single residence or a large municipality.

The sewage is treated as well as in most municipal plants, but it still needs to be handled with care as 100% treatment is never guaranteed in any sewage system. Applying this clear water to the landscape will further treat any remaining pathogens. Avoid human contact with the liquid. Do not eat fruits or vegetables that have been sprayed with the effluent to eliminate the remote possibility of contracting disease. This lowtech method of treating sewage water requires only nature's bacteria to do the purification. There are no moving mechanical parts to wear out, energy bills to pay, or chemicals needed to treat the water. The lowtech marsh-style treatment process is an example of a regenerative system.

### Collecting Runoff Water

Another regenerative technique is to catch rainfall and store it for irrigation use. Collection of water by cisterns used to be part of every home landscape. The cistern collected runoff from roof tops and stored it in underground or raised containers. Runoff from paved areas and low points of landscaped areas can also be stored in cisterns and used for irrigation when needed. Mississippi gets an average of 58 in (1,473 mm) of rain per year. The roof of my two-story home measures 2,000 ft2 (180 m2) in size. Over the course of the year, 72,500 gal (274,413 L) of water could be collected just from the roof for irrigation use. If my 0.25- acre (0.1-ha) landscape area consisted of just turf grass and I replaced the amount of water lost to evaporation and plant transpiration, the roof collection system could provide over two-thirds of my grass irrigation needs. For a landscape applying xeriscape principles, the 72,500 gal (274,413 L) provided on a yearly basis from my roof would more than likely meet my total irrigation needs.

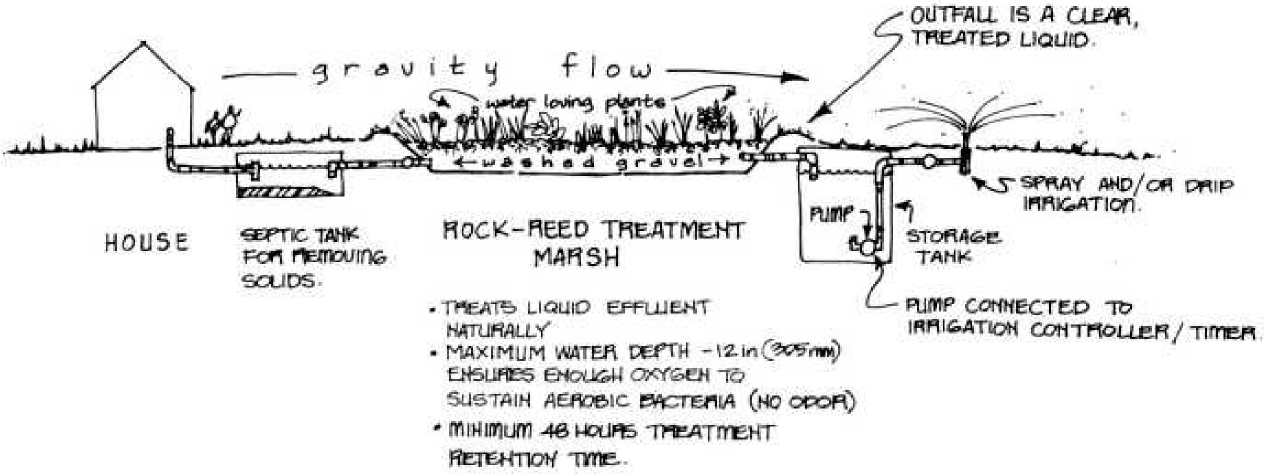


FIGURE 37.2 Reusing waste water.

# Appendix I

# Pipe Friction Loss Charts

*TABLE A1.1* ***PVC 1120-1220 Class 160 Friction Loss Chart C=150***

| | | **PSI LOSS PER PIPE LENGTH (FT)** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **GPM** | **Velocity (ft/sec)** | **5** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** | **90** | **100** | **GPM** | **Pipe Size** |
| 1 | 0.8 | 0.01 | 0.02 | 0.04 | 0.06 | 0.08 | 0.10 | 0.12 | 0.14 | 0.16 | 0.18 | 0.20 | 1 | **½″** |
| 2 | 1.6 | 0.04 | 0.07 | 0.15 | 0.22 | 0.30 | 0.37 | 0.44 | 0.52 | 0.59 | 0.67 | 0.74 | 2 | (0.720″ |
| 3 | 2.4 | 0.08 | 0.16 | 0.31 | 0.47 | 0.62 | 0.78 | 0.94 | 1.09 | 1.25 | 1.40 | 1.56 | 3 | inside |
| 4 | 3.2 | 0.13 | 0.27 | 0.54 | 0.80 | 1.07 | 1.34 | 1.61 | 1.88 | 2.14 | 2.41 | 2.68 | 4 | diameter) |
| 5 | 4.0 | 0.20 | 0.40 | 0.81 | 1.21 | 1.62 | 2.02 | 2.42 | 2.83 | 3.23 | 3.64 | 4.04 | 5 | |
| 6 | 4.8 | 0.29 | 0.58 | 1.15 | 1.73 | 2.30 | 2.88 | 3.46 | 4.03 | 4.61 | 5.18 | 5.76 | 6 | |
| 7 | 5.6 | 0.38 | 0.77 | 1.53 | 2.30 | 3.06 | 3.83 | 4.60 | 5.36 | 6.13 | 6.89 | 7.66 | 7 | |
| 8 | 6.4 | 0.49 | 0.98 | 1.96 | 2.93 | 3.91 | 4.89 | 5.87 | 6.85 | 7.82 | 8.80 | 9.78 | 8 | |
| 2 | 0.9 | 0.01 | 0.02 | 0.04 | 0.07 | 0.09 | 0.11 | 0.13 | 0.15 | 0.18 | 0.20 | 0.22 | 2 | **¾″** |
| 4 | 1.9 | 0.04 | 0.08 | 0.16 | 0.23 | 0.31 | 0.39 | 0.47 | 0.55 | 0.63 | 0.70 | 0.78 | 4 | (0.930″ |
| 6 | 2.8 | 0.09 | 0.17 | 0.34 | 0.50 | 0.66 | 0.83 | 1.00 | 1.16 | 1.34 | 1.49 | 1.66 | 6 | inside |
| 8 | 3.8 | 0.14 | 0.28 | 0.56 | 0.85 | 1.14 | 1.42 | 1.70 | 1.99 | 2.27 | 2.56 | 2.84 | 8 | diameter) |
| 10 | 4.7 | 0.22 | 0.43 | 0.86 | 1.29 | 1.72 | 2.15 | 2.58 | 3.01 | 3.45 | 3.87 | 4.30 | 10 | |
| 12 | 5.7 | 0.30 | 0.60 | 1.20 | 1.80 | 2.40 | 3.00 | 3.60 | 4.20 | 4.80 | 5.40 | 6.00 | 12 | |
| 14 | 6.6 | 0.40 | 0.80 | 1.60 | 2.40 | 3.20 | 4.00 | 4.80 | 5.60 | 6.40 | 7.20 | 8.00 | 14 | |
| 6 | 1.7 | 0.03 | 0.05 | 0.10 | 0.15 | 0.20 | 0.24 | 0.29 | 0.34 | 0.39 | 0.44 | 0.48 | 6 | **1″** |
| 8 | 2.3 | 0.04 | 0.08 | 0.16 | 0.25 | 0.34 | 0.42 | 0.50 | 0.59 | 0.67 | 0.76 | 0.84 | 8 | (1.195″ |
| 10 | 2.9 | 0.07 | 0.13 | 0.26 | 0.38 | 0.50 | 0.63 | 0.76 | 0.88 | 1.02 | 1.13 | 1.26 | 10 | inside |
| 12 | 3.4 | 0.09 | 0.18 | 0.36 | 0.53 | 0.71 | 0.89 | 1.07 | 1.25 | 1.43 | 1.60 | 1.78 | 12 | diameter) |
| 14 | 4.0 | 0.12 | 0.24 | 0.48 | 0.71 | 0.94 | 1.18 | 1.42 | 1.65 | 1.89 | 2.12 | 2.36 | 14 | |
| 16 | 4.5 | 0.15 | 0.30 | 0.60 | 0.91 | 1.21 | 1.52 | 1.82 | 2.12 | 2.43 | 2.73 | 3.04 | 16 | |
| 18 | 5.1 | 0.19 | 0.38 | 0.76 | 1.13 | 1.50 | 1.88 | 2.26 | 2.63 | 3.01 | 3.38 | 3.76 | 18 | |
| 20 | 5.7 | 0.23 | 0.46 | 0.92 | 1.37 | 1.82 | 2.28 | 2.74 | 3.19 | 3.65 | 4.10 | 4.56 | 20 | |
| 22 | 6.3 | 0.28 | 0.55 | 1.10 | 1.65 | 2.20 | 2.75 | 3.30 | 3.85 | 4.40 | 4.95 | 5.50 | 22 | |
| 24 | 6.8 | 0.38 | 0.65 | 1.30 | 1.94 | 2.58 | 3.23 | 3.88 | 4.52 | 5.23 | 5.81 | 6.46 | 24 | |

| | | PSI LOSS PER PIPE LENGTH (FT) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **GPM** | **Velocity (ft/sec)** | **5** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** | **90** | **100** | **GPM** | **Pipe Size** |
| 10 | 1.7 | 0.02 | 0.04 | 0.08 | 0.11 | 0.15 | 0.19 | 0.23 | 0.27 | 0.31 | 0.34 | 0.38 | 10 | **1¼″** (1.532″ inside diameter) |
| 12 | 2.1 | 0.03 | 0.05 | 0.10 | 0.16 | 0.21 | 0.26 | 0.32 | 0.37 | 0.42 | 0.47 | 0.52 | 12 | |
| 14 | 2.4 | 0.04 | 0.07 | 0.14 | 0.21 | 0.28 | 0.35 | 0.42 | 0.49 | 0.56 | 0.63 | 0.70 | 14 | |
| 16 | 2.8 | 0.05 | 0.09 | 0.18 | 0.27 | 0.36 | 0.45 | 0.54 | 0.63 | 0.72 | 0.81 | 0.90 | 16 | |
| 18 | 3.1 | 0.06 | 0.11 | 0.22 | 0.34 | 0.45 | 0.56 | 0.67 | 0.78 | 0.90 | 1.01 | 1.12 | 18 | |
| 20 | 3.5 | 0.07 | 0.14 | 0.28 | 0.41 | 0.54 | 0.68 | 0.82 | 0.95 | 1.09 | 1.22 | 1.36 | 20 | |
| 22 | 3.9 | 0.08 | 0.16 | 0.32 | 0.49 | 0.65 | 0.81 | 0.97 | 1.13 | 1.30 | 1.46 | 1.62 | 22 | |
| 24 | 4.2 | 0.10 | 0.19 | 0.38 | 0.57 | 0.76 | 0.95 | 1.14 | 1.33 | 1.53 | 1.71 | 1.90 | 24 | |
| 26 | 4.5 | 0.11 | 0.22 | 0.44 | 0.67 | 0.89 | 1.11 | 1.33 | 1.55 | 1.78 | 2.00 | 2.22 | 26 | |
| 28 | 4.9 | 0.13 | 0.25 | 0.50 | 0.76 | 1.02 | 1.27 | 1.52 | 1.78 | 2.04 | 2.29 | 2.54 | 28 | |
| 30 | 5.2 | 0.15 | 0.29 | 0.58 | 0.87 | 1.16 | 1.45 | 1.74 | 2.03 | 2.32 | 2.61 | 2.90 | 30 | |
| 32 | 5.6 | 0.17 | 0.33 | 0.66 | 0.98 | 1.30 | 1.63 | 1.96 | 2.28 | 2.62 | 2.93 | 3.26 | 32 | |
| 34 | 5.9 | 0.18 | 0.36 | 0.72 | 1.09 | 1.46 | 1.82 | 2.18 | 2.55 | 2.91 | 3.28 | 3.64 | 34 | |
| 36 | 6.2 | 0.20 | 0.40 | 0.80 | 1.21 | 1.62 | 2.02 | 2.42 | 2.83 | 3.23 | 3.64 | 4.04 | 36 | |
| 38 | 6.6 | 0.23 | 0.45 | 0.90 | 1.34 | 1.79 | 2.24 | 2.69 | 3.14 | 3.59 | 4.03 | 4.48 | 38 | |
| 20 | 2.7 | 0.04 | 0.07 | 0.14 | 0.21 | 0.28 | 0.35 | 0.42 | 0.49 | 0.56 | 0.63 | 0.70 | 20 | **1½″** (1.754″ inside diameter) |
| 25 | 3.3 | 0.06 | 0.11 | 0.22 | 0.32 | 0.42 | 0.53 | 0.64 | 0.74 | 0.86 | 0.95 | 1.06 | 25 | |
| 30 | 4.0 | 0.08 | 0.15 | 0.30 | 0.46 | 0.60 | 0.75 | 0.90 | 1.05 | 1.20 | 1.35 | 1.50 | 30 | |
| 35 | 4.7 | 0.10 | 0.20 | 0.40 | 0.59 | 0.79 | 0.99 | 1.19 | 1.39 | 1.59 | 1.78 | 1.98 | 35 | |
| 40 | 5.3 | 0.13 | 0.25 | 0.51 | 0.76 | 1.02 | 1.27 | 1.52 | 1.78 | 2.04 | 2.29 | 2.54 | 40 | |
| 45 | 6.0 | 0.16 | 0.32 | 0.64 | 0.95 | 1.26 | 1.58 | 1.90 | 2.21 | 2.53 | 2.84 | 3.16 | 45 | |
| 50 | 6.6 | 0.19 | 0.38 | 0.76 | 1.15 | 1.54 | 1.92 | 2.30 | 2.69 | 3.07 | 3.46 | 3.84 | 50 | |
| 30 | 2.6 | 0.03 | 0.05 | 0.10 | 0.15 | 0.20 | 0.25 | 0.30 | 0.35 | 0.40 | 0.45 | 0.50 | 30 | **2″** (2.193″ inside diameter) |
| 35 | 3.0 | 0.04 | 0.07 | 0.13 | 0.20 | 0.27 | 0.34 | 0.40 | 0.47 | 0.54 | 0.61 | 0.68 | 35 | |
| 40 | 3.4 | 0.05 | 0.09 | 0.17 | 0.26 | 0.34 | 0.43 | 0.52 | 0.60 | 0.69 | 0.77 | 0.86 | 40 | |
| 45 | 3.8 | 0.06 | 0.11 | 0.21 | 0.32 | 0.43 | 0.54 | 0.64 | 0.75 | 0.86 | 0.97 | 1.08 | 45 | |
| 50 | 4.3 | 0.07 | 0.13 | 0.26 | 0.39 | 0.52 | 0.65 | 0.78 | 0.91 | 1.04 | 1.17 | 1.30 | 50 | |
| 55 | 4.7 | 0.08 | 0.15 | 0.31 | 0.46 | 0.62 | 0.77 | 0.92 | 1.08 | 1.23 | 1.39 | 1.54 | 55 | |
| 60 | 5.1 | 0.09 | 0.18 | 0.36 | 0.54 | 0.72 | 0.90 | 1.08 | 1.26 | 1.44 | 1.62 | 1.80 | 60 | |
| 65 | 5.5 | 0.11 | 0.21 | 0.42 | 0.63 | 0.84 | 1.05 | 1.26 | 1.47 | 1.68 | 1.89 | 2.10 | 65 | |
| 70 | 6.0 | 0.12 | 0.24 | 0.48 | 0.72 | 0.96 | 1.20 | 1.44 | 1.68 | 1.92 | 2.16 | 2.40 | 70 | |
| 75 | 6.4 | 0.14 | 0.27 | 0.55 | 0.82 | 1.10 | 1.37 | 1.64 | 1.92 | 2.19 | 2.47 | 2.74 | 75 | |
| 80 | 6.8 | 0.16 | 0.31 | 0.62 | 0.93 | 1.24 | 1.55 | 1.86 | 2.17 | 2.48 | 2.79 | 3.10 | 80 | |
| 50 | 2.9 | 0.03 | 0.05 | 0.10 | 0.15 | 0.20 | 0.25 | 0.30 | 0.35 | 0.40 | 0.45 | 0.50 | 50 | **2½″** (2.655″ inside diameter) |
| 60 | 3.5 | 0.04 | 0.07 | 0.14 | 0.21 | 0.28 | 0.35 | 0.42 | 0.49 | 0.56 | 0.63 | 0.70 | 60 | |
| 70 | 4.1 | 0.05 | 0.10 | 0.19 | 0.29 | 0.38 | 0.48 | 0.58 | 0.67 | 0.77 | 0.86 | 0.96 | 70 | |
| 80 | 4.6 | 0.06 | 0.12 | 0.24 | 0.37 | 0.49 | 0.61 | 0.73 | 0.85 | 0.98 | 1.10 | 1.22 | 80 | |
| 90 | 5.2 | 0.08 | 0.15 | 0.30 | 0.46 | 0.61 | 0.76 | 0.91 | 1.06 | 1.22 | 1.37 | 1.52 | 90 | |
| 100 | 5.8 | 0.09 | 0.18 | 0.37 | 0.55 | 0.74 | 0.92 | 1.10 | 1.29 | 1.47 | 1.66 | 1.84 | 100 | |
| 110 | 6.4 | 0.11 | 0.22 | 0.44 | 0.66 | 0.88 | 1.10 | 1.32 | 1.54 | 1.76 | 1.98 | 2.20 | 110 | |
| 120 | 7.0 | 0.13 | 0.26 | 0.52 | 0.77 | 1.03 | 1.29 | 1.55 | 1.81 | 2.06 | 2.32 | 2.58 | 120 | |
| 80 | 3.1 | 0.02 | 0.05 | 0.09 | 0.14 | 0.18 | 0.23 | 0.28 | 0.32 | 0.37 | 0.41 | 0.46 | 80 | **3″** (3.230″ inside diameter) |
| 90 | 3.5 | 0.03 | 0.06 | 0.12 | 0.17 | 0.23 | 0.29 | 0.35 | 0.41 | 0.46 | 0.52 | 0.58 | 90 | |
| 100 | 3.9 | 0.04 | 0.07 | 0.14 | 0.21 | 0.28 | 0.35 | 0.42 | 0.49 | 0.56 | 0.63 | 0.70 | 100 | |
| 110 | 4.3 | 0.04 | 0.08 | 0.17 | 0.25 | 0.33 | 0.42 | 0.51 | 0.59 | 0.67 | 0.76 | 0.84 | 110 | |
| 120 | 4.7 | 0.05 | 0.10 | 0.20 | 0.29 | 0.39 | 0.49 | 0.59 | 0.69 | 0.78 | 0.88 | 0.98 | 120 | |
| 130 | 5.1 | 0.06 | 0.11 | 0.23 | 0.34 | 0.46 | 0.57 | 0.68 | 0.80 | 0.91 | 1.03 | 1.14 | 130 | |
| 140 | 5.5 | 0.07 | 0.13 | 0.26 | 0.39 | 0.52 | 0.66 | 0.79 | 0.92 | 1.05 | 1.18 | 1.32 | 140 | |
| 150 | 5.9 | 0.08 | 0.15 | 0.30 | 0.45 | 0.60 | 0.75 | 0.90 | 1.05 | 1.20 | 1.35 | 1.50 | 150 | |
| 160 | 6.3 | 0.09 | 0.17 | 0.34 | 0.50 | 0.67 | 0.84 | 1.01 | 1.18 | 1.34 | 1.51 | 1.68 | 160 | |
| 170 | 6.7 | 0.10 | 0.19 | 0.37 | 0.56 | 0.75 | 0.94 | 1.13 | 1.32 | 1.51 | 1.69 | 1.88 | 170 | |
| 150 | 3.6 | 0.02 | 0.04 | 0.09 | 0.13 | 0.17 | 0.22 | 0.26 | 0.31 | 0.35 | 0.39 | 0.44 | 150 | **4″** (4.154″ inside diameter) |
| 160 | 3.8 | 0.03 | 0.05 | 0.10 | 0.15 | 0.20 | 0.25 | 0.30 | 0.35 | 0.40 | 0.45 | 0.50 | 160 | |
| 170 | 4.0 | 0.03 | 0.06 | 0.11 | 0.17 | 0.22 | 0.28 | 0.33 | 0.39 | 0.44 | 0.51 | 0.56 | 170 | |
| 180 | 4.3 | 0.03 | 0.06 | 0.12 | 0.18 | 0.25 | 0.31 | 0.37 | 0.43 | 0.49 | 0.56 | 0.62 | 180 | |
| 190 | 4.5 | 0.04 | 0.07 | 0.14 | 0.21 | 0.28 | 0.34 | 0.41 | 0.48 | 0.55 | 0.62 | 0.68 | 190 | |
| 200 | 4.7 | 0.04 | 0.07 | 0.15 | 0.22 | 0.30 | 0.37 | 0.44 | 0.52 | 0.59 | 0.67 | 0.74 | 200 | |

*TABLE A1.1* ***(continued)***

| | | PSI LOSS PER PIPE LENGTH (FT) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **GPM** | **Velocity (ft/sec)** | **5** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** | **90** | **100** | **GPM** | **Pipe Size** |
| 210 | 4.9 | 0.04 | 0.08 | 0.16 | 0.24 | 0.32 | 0.40 | 0.48 | 0.56 | 0.64 | 0.72 | 0.80 | 210 | **4"**<br>(4.154″ inside diameter) |
| 220 | 5.2 | 0.05 | 0.09 | 0.18 | 0.27 | 0.36 | 0.44 | 0.53 | 0.62 | 0.71 | 0.80 | 0.88 | 220 | |
| 230 | 5.4 | 0.05 | 0.10 | 0.19 | 0.29 | 0.38 | 0.48 | 0.58 | 0.67 | 0.77 | 0.86 | 0.96 | 230 | |
| 240 | 5.7 | 0.05 | 0.10 | 0.21 | 0.31 | 0.42 | 0.52 | 0.62 | 0.73 | 0.83 | 0.94 | 1.04 | 240 | |
| 250 | 5.9 | 0.06 | 0.11 | 0.22 | 0.34 | 0.45 | 0.56 | 0.67 | 0.78 | 0.90 | 1.01 | 1.12 | 250 | |
| 260 | 6.2 | 0.06 | 0.12 | 0.24 | 0.36 | 0.48 | 0.60 | 0.72 | 0.84 | 0.96 | 1.08 | 1.20 | 260 | |
| 270 | 6.4 | 0.07 | 0.13 | 0.26 | 0.39 | 0.52 | 0.64 | 0.77 | 0.90 | 1.03 | 1.16 | 1.28 | 270 | |
| 280 | 6.6 | 0.07 | 0.14 | 0.28 | 0.41 | 0.55 | 0.69 | 0.83 | 0.97 | 1.10 | 1.24 | 1.38 | 280 | |

TABLE A1.2 **PVC 1120-1220 Class 200 Pipe Friction Loss Chart C=150**

| | | PSI LOSS PER PIPE LENGTH (FT) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **GPM** | **Velocity (ft/sec)** | **5** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** | **90** | **100** | **GPM** | **Pipe Size** |
| 1 | 0.8 | 0.01 | 0.02 | 0.04 | 0.06 | 0.08 | 0.10 | 0.12 | 0.14 | 0.16 | 0.18 | 0.20 | 1 | **½″** (0.720″ inside diameter) |
| 2 | 1.6 | 0.04 | 0.07 | 0.15 | 0.22 | 0.30 | 0.37 | 0.44 | 0.52 | 0.59 | 0.67 | 0.74 | 2 | |
| 3 | 2.4 | 0.08 | 0.16 | 0.31 | 0.47 | 0.62 | 0.78 | 0.94 | 1.09 | 1.25 | 1.40 | 1.56 | 3 | |
| 4 | 3.2 | 0.13 | 0.27 | 0.54 | 0.80 | 1.07 | 1.34 | 1.61 | 1.88 | 2.14 | 2.41 | 2.68 | 4 | |
| 5 | 4.0 | 0.20 | 0.40 | 0.81 | 1.21 | 1.62 | 2.02 | 2.42 | 2.83 | 3.23 | 3.64 | 4.04 | 5 | |
| 6 | 4.8 | 0.29 | 0.58 | 1.15 | 1.73 | 2.30 | 2.88 | 3.46 | 4.03 | 4.61 | 5.18 | 5.76 | 6 | |
| 7 | 5.6 | 0.38 | 0.77 | 1.53 | 2.30 | 3.06 | 3.83 | 4.60 | 5.36 | 6.13 | 6.89 | 7.66 | 7 | |
| 8 | 6.4 | 0.49 | 0.98 | 1.96 | 2.93 | 3.91 | 4.89 | 5.87 | 6.85 | 7.82 | 8.80 | 9.78 | 8 | |
| 2 | 0.9 | 0.01 | 0.02 | 0.04 | 0.07 | 0.09 | 0.11 | 0.13 | 0.15 | 0.18 | 0.20 | 0.22 | 2 | **¾″** (0.930″ inside diameter) |
| 4 | 1.9 | 0.04 | 0.08 | 0.16 | 0.23 | 0.31 | 0.39 | 0.47 | 0.55 | 0.63 | 0.70 | 0.78 | 4 | |
| 6 | 2.8 | 0.09 | 0.17 | 0.34 | 0.50 | 0.66 | 0.83 | 1.00 | 1.16 | 1.34 | 1.49 | 1.66 | 6 | |
| 8 | 3.8 | 0.14 | 0.28 | 0.56 | 0.85 | 1.14 | 1.42 | 1.70 | 1.99 | 2.27 | 2.56 | 2.84 | 8 | |
| 10 | 4.7 | 0.22 | 0.43 | 0.86 | 1.29 | 1.72 | 2.15 | 2.58 | 3.01 | 3.45 | 3.87 | 4.30 | 10 | |
| 12 | 5.7 | 0.30 | 0.60 | 1.20 | 1.80 | 2.40 | 3.00 | 3.60 | 4.20 | 4.80 | 5.40 | 6.00 | 12 | |
| 14 | 6.6 | 0.40 | 0.80 | 1.60 | 2.40 | 3.20 | 4.00 | 4.80 | 5.60 | 6.40 | 7.20 | 8.00 | 14 | |
| 6 | 1.7 | 0.03 | 0.05 | 0.10 | 0.15 | 0.20 | 0.25 | 0.30 | 0.35 | 0.40 | 0.45 | 0.50 | 6 | **1″** (1.189″ inside diameter) |
| 8 | 2.3 | 0.05 | 0.09 | 0.17 | 0.26 | 0.34 | 0.43 | 0.52 | 0.60 | 0.69 | 0.77 | 0.86 | 8 | |
| 10 | 2.9 | 0.07 | 0.13 | 0.26 | 0.39 | 0.52 | 0.65 | 0.78 | 0.91 | 1.04 | 1.17 | 1.30 | 10 | |
| 12 | 3.5 | 0.09 | 0.18 | 0.37 | 0.55 | 0.74 | 0.92 | 1.10 | 1.29 | 1.47 | 1.66 | 1.84 | 12 | |
| 14 | 4.1 | 0.12 | 0.24 | 0.48 | 0.73 | 0.97 | 1.21 | 1.45 | 1.69 | 1.94 | 2.18 | 2.42 | 14 | |
| 16 | 4.7 | 0.16 | 0.31 | 0.62 | 0.93 | 1.24 | 1.55 | 1.86 | 2.17 | 2.48 | 2.79 | 3.10 | 16 | |
| 18 | 5.2 | 0.20 | 0.39 | 0.77 | 1.16 | 1.54 | 1.93 | 2.32 | 2.70 | 3.09 | 3.47 | 3.86 | 18 | |
| 20 | 5.8 | 0.24 | 0.47 | 0.94 | 1.40 | 1.87 | 2.34 | 2.81 | 3.28 | 3.74 | 4.21 | 4.68 | 20 | |
| 22 | 6.4 | 0.29 | 0.57 | 1.13 | 1.70 | 2.26 | 2.83 | 3.40 | 3.96 | 4.53 | 5.09 | 5.66 | 22 | |
| 24 | 6.9 | 0.33 | 0.66 | 1.32 | 1.99 | 2.65 | 3.31 | 3.97 | 4.63 | 5.30 | 5.96 | 6.62 | 24 | |
| 10 | 1.8 | 0.02 | 0.04 | 0.08 | 0.13 | 0.17 | 0.21 | 0.25 | 0.29 | 0.34 | 0.38 | 0.42 | 10 | **1¼″** (1.502″ inside diameter) |
| 12 | 2.2 | 0.03 | 0.06 | 0.12 | 0.17 | 0.23 | 0.29 | 0.35 | 0.41 | 0.46 | 0.52 | 0.58 | 12 | |
| 14 | 2.6 | 0.04 | 0.08 | 0.16 | 0.23 | 0.31 | 0.39 | 0.47 | 0.55 | 0.62 | 0.70 | 0.78 | 14 | |
| 16 | 2.9 | 0.05 | 0.10 | 0.20 | 0.30 | 0.40 | 0.50 | 0.60 | 0.70 | 0.80 | 0.90 | 1.00 | 16 | |
| 18 | 3.3 | 0.06 | 0.12 | 0.25 | 0.37 | 0.50 | 0.62 | 0.74 | 0.87 | 0.99 | 1.12 | 1.24 | 18 | |
| 20 | 3.6 | 0.08 | 0.15 | 0.30 | 0.45 | 0.60 | 0.75 | 0.90 | 1.05 | 1.20 | 1.35 | 1.50 | 20 | |
| 22 | 4.0 | 0.09 | 0.18 | 0.36 | 0.54 | 0.72 | 0.90 | 1.08 | 1.26 | 1.44 | 1.62 | 1.80 | 22 | |
| 24 | 4.3 | 0.11 | 0.21 | 0.42 | 0.63 | 0.84 | 1.05 | 1.26 | 1.47 | 1.68 | 1.89 | 2.10 | 24 | |
| 26 | 4.7 | 0.12 | 0.24 | 0.49 | 0.73 | 0.98 | 1.22 | 1.46 | 1.71 | 1.95 | 2.20 | 2.44 | 26 | |
| 28 | 5.1 | 0.14 | 0.28 | 0.56 | 0.84 | 1.12 | 1.40 | 1.68 | 1.96 | 2.24 | 2.52 | 2.80 | 28 | |

|  |  | PSI LOSS PER PIPE LENGTH (FT) |  |  |  |  |  |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GPM | Velocity (ft/sec) | 5 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 | GPM | Pipe Size |
| 30 | 5.5 | 0.16 | 0.32 | 0.64 | 0.95 | 1.27 | 1.59 | 1.91 | 2.23 | 2.54 | 2.86 | 3.18 | 30 | **1¼″** (1.502″ inside diameter) |
| 32 | 5.8 | 0.18 | 0.36 | 0.72 | 1.07 | 1.43 | 1.79 | 2.15 | 2.51 | 2.86 | 3.22 | 3.58 | 32 |  |
| 34 | 6.2 | 0.20 | 0.40 | 0.80 | 1.20 | 1.60 | 2.00 | 2.40 | 2.80 | 3.20 | 3.60 | 4.00 | 34 |  |
| 36 | 6.6 | 0.22 | 0.45 | 0.89 | 1.33 | 1.78 | 2.22 | 2.66 | 3.11 | 3.55 | 4.00 | 4.44 | 36 |  |
| 15 | 2.2 | 0.03 | 0.05 | 0.09 | 0.14 | 0.18 | 0.23 | 0.28 | 0.32 | 0.37 | 0.41 | 0.46 | 15 | **1½″** (1.720″ inside diameter) |
| 20 | 2.8 | 0.04 | 0.08 | 0.16 | 0.23 | 0.31 | 0.39 | 0.47 | 0.55 | 0.62 | 0.70 | 0.78 | 20 |  |
| 25 | 3.5 | 0.06 | 0.12 | 0.24 | 0.35 | 0.47 | 0.59 | 0.71 | 0.83 | 0.94 | 1.06 | 1.18 | 25 |  |
| 30 | 4.1 | 0.08 | 0.16 | 0.33 | 0.49 | 0.66 | 0.82 | 0.98 | 1.15 | 1.31 | 1.48 | 1.64 | 30 |  |
| 35 | 4.8 | 0.11 | 0.22 | 0.44 | 0.65 | 0.87 | 1.09 | 1.31 | 1.53 | 1.74 | 1.96 | 2.18 | 35 |  |
| 40 | 5.5 | 0.14 | 0.28 | 0.56 | 0.84 | 1.12 | 1.40 | 1.68 | 1.96 | 2.24 | 2.52 | 2.80 | 40 |  |
| 45 | 6.2 | 0.18 | 0.35 | 0.70 | 1.04 | 1.39 | 1.74 | 2.09 | 2.44 | 2.78 | 3.13 | 3.48 | 45 |  |
| 50 | 6.9 | 0.21 | 0.42 | 0.85 | 1.27 | 1.70 | 2.12 | 2.54 | 2.97 | 3.39 | 3.82 | 4.24 | 50 |  |
| 30 | 2.7 | 0.03 | 0.06 | 0.11 | 0.17 | 0.22 | 0.28 | 0.34 | 0.39 | 0.45 | 0.50 | 0.56 | 30 | **2″** (2.149″ inside diameter) |
| 35 | 3.1 | 0.04 | 0.07 | 0.15 | 0.22 | 0.30 | 0.37 | 0.44 | 0.52 | 0.59 | 0.67 | 0.74 | 35 |  |
| 40 | 3.5 | 0.05 | 0.09 | 0.19 | 0.28 | 0.38 | 0.47 | 0.56 | 0.66 | 0.75 | 0.85 | 0.94 | 40 |  |
| 45 | 4.0 | 0.06 | 0.12 | 0.23 | 0.35 | 0.46 | 0.58 | 0.70 | 0.81 | 0.93 | 1.04 | 1.16 | 45 |  |
| 50 | 4.4 | 0.07 | 0.14 | 0.28 | 0.42 | 0.56 | 0.70 | 0.84 | 0.98 | 1.12 | 1.26 | 1.40 | 50 |  |
| 55 | 4.9 | 0.08 | 0.17 | 0.34 | 0.50 | 0.67 | 0.84 | 1.01 | 1.18 | 1.34 | 1.51 | 1.68 | 55 |  |
| 60 | 5.3 | 0.10 | 0.20 | 0.39 | 0.59 | 0.78 | 0.98 | 1.18 | 1.37 | 1.57 | 1.76 | 1.96 | 60 |  |
| 65 | 5.8 | 0.12 | 0.23 | 0.45 | 0.68 | 0.90 | 1.13 | 1.36 | 1.58 | 1.81 | 2.03 | 2.26 | 65 |  |
| 70 | 6.2 | 0.13 | 0.26 | 0.52 | 0.78 | 1.04 | 1.30 | 1.56 | 1.82 | 2.08 | 2.34 | 2.60 | 70 |  |
| 75 | 6.7 | 0.15 | 0.30 | 0.60 | 0.89 | 1.19 | 1.49 | 1.79 | 2.09 | 2.38 | 2.68 | 2.98 | 75 |  |
| 50 | 3.0 | 0.03 | 0.06 | 0.11 | 0.17 | 0.22 | 0.28 | 0.34 | 0.39 | 0.45 | 0.50 | 0.56 | 50 | **2½″** (2.601″ inside diameter) |
| 60 | 3.6 | 0.04 | 0.08 | 0.16 | 0.24 | 0.32 | 0.40 | 0.48 | 0.56 | 0.64 | 0.72 | 0.80 | 60 |  |
| 70 | 4.2 | 0.06 | 0.11 | 0.21 | 0.32 | 0.42 | 0.53 | 0.64 | 0.74 | 0.85 | 0.95 | 1.06 | 70 |  |
| 80 | 4.8 | 0.07 | 0.13 | 0.27 | 0.40 | 0.54 | 0.67 | 0.80 | 0.94 | 1.07 | 1.21 | 1.34 | 80 |  |
| 90 | 5.4 | 0.08 | 0.17 | 0.34 | 0.50 | 0.67 | 0.84 | 1.01 | 1.18 | 1.34 | 1.51 | 1.68 | 90 |  |
| 100 | 6.0 | 0.10 | 0.20 | 0.40 | 0.61 | 0.81 | 1.01 | 1.21 | 1.41 | 1.62 | 1.82 | 2.02 | 100 |  |
| 110 | 6.6 | 0.12 | 0.24 | 0.49 | 0.73 | 0.98 | 1.22 | 1.46 | 1.71 | 1.95 | 2.20 | 2.44 | 110 |  |
| 80 | 3.3 | 0.03 | 0.05 | 0.11 | 0.16 | 0.22 | 0.27 | 0.32 | 0.38 | 0.43 | 0.49 | 0.54 | 80 | **3″** (3.166″ inside diameter) |
| 90 | 3.7 | 0.04 | 0.07 | 0.13 | 0.20 | 0.26 | 0.33 | 0.40 | 0.46 | 0.53 | 0.59 | 0.66 | 90 |  |
| 100 | 4.1 | 0.04 | 0.08 | 0.16 | 0.24 | 0.32 | 0.40 | 0.48 | 0.56 | 0.64 | 0.72 | 0.80 | 100 |  |
| 110 | 4.5 | 0.05 | 0.10 | 0.19 | 0.29 | 0.38 | 0.48 | 0.58 | 0.67 | 0.77 | 0.86 | 0.96 | 110 |  |
| 120 | 4.9 | 0.06 | 0.11 | 0.22 | 0.34 | 0.45 | 0.56 | 0.67 | 0.78 | 0.90 | 1.01 | 1.12 | 120 |  |
| 130 | 5.3 | 0.07 | 0.13 | 0.26 | 0.40 | 0.53 | 0.66 | 0.79 | 0.92 | 1.06 | 1.19 | 1.32 | 130 |  |
| 140 | 5.7 | 0.08 | 0.15 | 0.30 | 0.45 | 0.60 | 0.75 | 0.90 | 1.05 | 1.20 | 1.35 | 1.50 | 140 |  |
| 150 | 6.1 | 0.09 | 0.17 | 0.34 | 0.51 | 0.68 | 0.85 | 1.02 | 1.19 | 1.36 | 1.53 | 1.70 | 150 |  |
| 160 | 6.5 | 0.10 | 0.19 | 0.38 | 0.58 | 0.77 | 0.96 | 1.15 | 1.34 | 1.54 | 1.73 | 1.92 | 160 |  |
| 170 | 6.9 | 0.11 | 0.22 | 0.43 | 0.65 | 0.86 | 1.08 | 1.30 | 1.51 | 1.73 | 1.94 | 2.16 | 170 |  |
| 150 | 3.7 | 0.03 | 0.05 | 0.10 | 0.15 | 0.20 | 0.25 | 0.30 | 0.35 | 0.40 | 0.45 | 0.50 | 150 | **4″** (4.072″ inside diameter) |
| 160 | 3.9 | 0.03 | 0.06 | 0.11 | 0.17 | 0.22 | 0.28 | 0.34 | 0.39 | 0.45 | 0.50 | 0.56 | 160 |  |
| 170 | 4.2 | 0.03 | 0.06 | 0.12 | 0.19 | 0.25 | 0.31 | 0.37 | 0.43 | 0.50 | 0.56 | 0.62 | 170 |  |
| 180 | 4.4 | 0.04 | 0.07 | 0.14 | 0.20 | 0.27 | 0.34 | 0.41 | 0.48 | 0.54 | 0.61 | 0.68 | 180 |  |
| 190 | 4.7 | 0.04 | 0.08 | 0.15 | 0.23 | 0.30 | 0.38 | 0.46 | 0.53 | 0.61 | 0.68 | 0.76 | 190 |  |
| 200 | 4.9 | 0.04 | 0.08 | 0.17 | 0.25 | 0.34 | 0.42 | 0.50 | 0.59 | 0.67 | 0.76 | 0.84 | 200 |  |
| 210 | 5.2 | 0.05 | 0.09 | 0.18 | 0.27 | 0.36 | 0.45 | 0.54 | 0.63 | 0.72 | 0.81 | 0.90 | 210 |  |
| 220 | 5.4 | 0.05 | 0.10 | 0.20 | 0.29 | 0.39 | 0.49 | 0.59 | 0.69 | 0.78 | 0.88 | 0.98 | 220 |  |
| 230 | 5.7 | 0.06 | 0.11 | 0.22 | 0.32 | 0.43 | 0.54 | 0.65 | 0.76 | 0.86 | 0.97 | 1.08 | 230 |  |
| 240 | 5.9 | 0.06 | 0.12 | 0.23 | 0.35 | 0.46 | 0.58 | 0.70 | 0.81 | 0.93 | 1.04 | 1.16 | 240 |  |
| 250 | 6.2 | 0.06 | 0.12 | 0.25 | 0.37 | 0.50 | 0.62 | 0.74 | 0.87 | 0.99 | 1.12 | 1.24 | 250 |  |
| 260 | 6.4 | 0.07 | 0.13 | 0.27 | 0.40 | 0.54 | 0.67 | 0.80 | 0.94 | 1.07 | 1.21 | 1.34 | 260 |  |
| 270 | 6.6 | 0.07 | 0.14 | 0.29 | 0.43 | 0.58 | 0.72 | 0.86 | 1.01 | 1.15 | 1.30 | 1.44 | 270 |  |
| 280 | 6.9 | 0.08 | 0.15 | 0.31 | 0.46 | 0.62 | 0.77 | 0.92 | 1.08 | 1.23 | 1.39 | 1.54 | 280 |  |
| 250 | 2.9 | 0.01 | 0.02 | 0.04 | 0.06 | 0.08 | 0.10 | 0.12 | 0.14 | 0.16 | 0.18 | 0.20 | 250 | **6″** (5.993″ inside diameter) |
| 275 | 3.2 | 0.01 | 0.02 | 0.04 | 0.07 | 0.09 | 0.11 | 0.13 | 0.15 | 0.18 | 0.20 | 0.22 | 275 |  |
| 300 | 3.5 | 0.02 | 0.03 | 0.06 | 0.08 | 0.11 | 0.14 | 0.17 | 0.20 | 0.22 | 0.25 | 0.28 | 300 |  |
| 325 | 3.7 | 0.02 | 0.03 | 0.06 | 0.10 | 0.13 | 0.16 | 0.19 | 0.22 | 0.26 | 0.29 | 0.32 | 325 |  |

*TABLE A1.2* ***(continued)***

| | | **PSI LOSS PER PIPE LENGTH (FT)** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **GPM** | **Velocity (ft/sec)** | **5** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** | **90** | **100** | **GPM** | **Pipe Size** |
| 350 | 4.0 | 0.02 | 0.04 | 0.07 | 0.11 | 0.14 | 0.18 | 0.22 | 0.25 | 0.29 | 0.32 | 0.36 | 350 | **6"** (5.993″ inside diameter) |
| 375 | 4.3 | 0.02 | 0.04 | 0.08 | 0.13 | 0.17 | 0.21 | 0.25 | 0.29 | 0.34 | 0.38 | 0.42 | 375 | |
| 400 | 4.6 | 0.03 | 0.05 | 0.09 | 0.14 | 0.18 | 0.23 | 0.28 | 0.32 | 0.37 | 0.41 | 0.46 | 400 | |
| 425 | 4.9 | 0.03 | 0.05 | 0.10 | 0.16 | 0.21 | 0.26 | 0.31 | 0.36 | 0.42 | 0.47 | 0.52 | 425 | |
| 450 | 5.2 | 0.03 | 0.06 | 0.12 | 0.17 | 0.23 | 0.29 | 0.35 | 0.41 | 0.46 | 0.52 | 0.58 | 450 | |
| 475 | 5.4 | 0.03 | 0.06 | 0.13 | 0.19 | 0.26 | 0.32 | 0.38 | 0.45 | 0.51 | 0.58 | 0.64 | 475 | |
| 500 | 5.7 | 0.04 | 0.07 | 0.14 | 0.21 | 0.28 | 0.35 | 0.42 | 0.49 | 0.56 | 0.63 | 0.70 | 500 | |
| 525 | 6.0 | 0.04 | 0.08 | 0.15 | 0.23 | 0.30 | 0.38 | 0.46 | 0.53 | 0.61 | 0.68 | 0.76 | 525 | |
| 550 | 6.3 | 0.04 | 0.08 | 0.16 | 0.25 | 0.33 | 0.41 | 0.49 | 0.57 | 0.66 | 0.74 | 0.82 | 550 | |
| 575 | 6.6 | 0.05 | 0.09 | 0.18 | 0.26 | 0.35 | 0.44 | 0.53 | 0.62 | 0.70 | 0.79 | 0.88 | 575 | |
| 600 | 6.9 | 0.05 | 0.10 | 0.19 | 0.29 | 0.38 | 0.48 | 0.58 | 0.67 | 0.77 | 0.86 | 0.96 | 600 | |

### *TABLE A1.3* ***PVC 1120-1220 Class 315 Pipe Friction Loss Chart C=150***

| | | **PSI LOSS PER PIPE LENGTH (FT)** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **GPM** | **Velocity (ft/sec)** | **5** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** | **90** | **100** | **GPM** | **Pipe Size** |
| 1 | 0.8 | 0.01 | 0.02 | 0.04 | 0.06 | 0.08 | 0.10 | 0.12 | 0.14 | 0.16 | 0.18 | 0.20 | 1 | **½″** (0.720″ inside diameter) |
| 2 | 1.6 | 0.04 | 0.07 | 0.15 | 0.22 | 0.30 | 0.37 | 0.44 | 0.52 | 0.59 | 0.67 | 0.74 | 2 | |
| 3 | 2.4 | 0.08 | 0.16 | 0.31 | 0.47 | 0.62 | 0.78 | 0.94 | 1.09 | 1.25 | 1.40 | 1.56 | 3 | |
| 4 | 3.2 | 0.13 | 0.27 | 0.54 | 0.80 | 1.07 | 1.34 | 1.61 | 1.88 | 2.14 | 2.41 | 2.68 | 4 | |
| 5 | 4.0 | 0.20 | 0.40 | 0.81 | 1.21 | 1.62 | 2.02 | 2.42 | 2.83 | 3.23 | 3.64 | 4.04 | 5 | |
| 6 | 4.8 | 0.29 | 0.58 | 1.15 | 1.73 | 2.30 | 2.88 | 3.46 | 4.03 | 4.61 | 5.18 | 5.76 | 6 | |
| 7 | 5.6 | 0.38 | 0.77 | 1.53 | 2.30 | 3.06 | 3.83 | 4.60 | 5.36 | 6.13 | 6.89 | 7.66 | 7 | |
| 8 | 6.4 | 0.49 | 0.98 | 1.96 | 2.93 | 3.91 | 4.89 | 5.87 | 6.85 | 7.82 | 8.80 | 9.78 | 8 | |
| 2 | 1.2 | 0.02 | 0.03 | 0.05 | 0.08 | 0.10 | 0.13 | 0.16 | 0.18 | 0.21 | 0.23 | 0.26 | 2 | **¾″** (0.894″ inside diameter) |
| 4 | 2.0 | 0.05 | 0.10 | 0.19 | 0.29 | 0.38 | 0.48 | 0.58 | 0.67 | 0.77 | 0.86 | 0.96 | 4 | |
| 6 | 3.1 | 0.10 | 0.20 | 0.40 | 0.61 | 0.81 | 1.01 | 1.21 | 1.41 | 1.62 | 1.82 | 2.02 | 6 | |
| 8 | 4.1 | 0.17 | 0.34 | 0.69 | 1.03 | 1.38 | 1.72 | 2.06 | 2.41 | 2.75 | 3.10 | 3.44 | 8 | |
| 10 | 5.1 | 0.26 | 0.52 | 1.04 | 1.56 | 2.08 | 2.60 | 3.12 | 3.64 | 4.16 | 4.68 | 5.20 | 10 | |
| 12 | 6.1 | 0.36 | 0.73 | 1.46 | 2.18 | 2.91 | 3.64 | 4.37 | 5.10 | 5.82 | 6.55 | 7.28 | 12 | |
| 14 | 7.2 | 0.49 | 0.97 | 1.94 | 2.91 | 3.88 | 4.85 | 5.82 | 6.79 | 7.76 | 8.73 | 9.70 | 14 | |
| 4 | 1.3 | 0.02 | 0.03 | 0.06 | 0.10 | 0.13 | 0.16 | 0.19 | 0.22 | 0.26 | 0.29 | 0.32 | 4 | **1″** (1.121″ inside diameter) |
| 6 | 1.9 | 0.04 | 0.07 | 0.14 | 0.20 | 0.27 | 0.34 | 0.41 | 0.48 | 0.54 | 0.61 | 0.68 | 6 | |
| 8 | 2.6 | 0.06 | 0.11 | 0.23 | 0.34 | 0.46 | 0.57 | 0.68 | 0.70 | 0.91 | 1.03 | 1.14 | 8 | |
| 10 | 3.2 | 0.09 | 0.17 | 0.34 | 0.51 | 0.68 | 0.85 | 1.02 | 1.19 | 1.36 | 1.53 | 1.70 | 10 | |
| 12 | 3.9 | 0.12 | 0.24 | 0.48 | 0.72 | 0.96 | 1.20 | 1.44 | 1.68 | 1.92 | 2.16 | 2.40 | 12 | |
| 14 | 4.5 | 0.16 | 0.32 | 0.64 | 0.97 | 1.29 | 1.61 | 1.93 | 2.25 | 2.58 | 2.90 | 3.22 | 14 | |
| 16 | 5.2 | 0.21 | 0.41 | 0.82 | 1.24 | 1.65 | 2.06 | 2.47 | 2.88 | 3.30 | 3.71 | 4.12 | 16 | |
| 18 | 5.8 | 0.26 | 0.51 | 1.03 | 1.54 | 2.06 | 2.57 | 3.08 | 3.60 | 4.11 | 4.63 | 5.14 | 18 | |
| 20 | 6.5 | 0.36 | 0.63 | 1.25 | 1.88 | 2.50 | 3.13 | 3.76 | 4.38 | 5.01 | 5.63 | 6.26 | 20 | |
| 8 | 1.6 | 0.02 | 0.04 | 0.08 | 0.11 | 0.15 | 0.19 | 0.23 | 0.27 | 0.30 | 0.34 | 0.38 | 8 | **1¼″** (1.414″ inside diameter) |
| 10 | 2.0 | 0.03 | 0.06 | 0.11 | 0.17 | 0.22 | 0.28 | 0.34 | 0.39 | 0.45 | 0.50 | 0.56 | 10 | |
| 12 | 2.4 | 0.04 | 0.08 | 0.16 | 0.23 | 0.31 | 0.39 | 0.47 | 0.55 | 0.62 | 0.70 | 0.78 | 12 | |
| 14 | 2.9 | 0.05 | 0.10 | 0.21 | 0.31 | 0.42 | 0.52 | 0.62 | 0.73 | 0.83 | 0.94 | 1.04 | 14 | |
| 16 | 3.3 | 0.07 | 0.13 | 0.27 | 0.40 | 0.54 | 0.67 | 0.80 | 0.94 | 1.07 | 1.21 | 1.34 | 16 | |
| 18 | 3.7 | 0.09 | 0.17 | 0.33 | 0.50 | 0.66 | 0.83 | 1.00 | 1.16 | 1.33 | 1.49 | 1.66 | 18 | |
| 20 | 4.1 | 0.10 | 0.20 | 0.40 | 0.60 | 0.80 | 1.00 | 1.20 | 1.40 | 1.60 | 1.80 | 2.00 | 20 | |

| | | PSI LOSS PER PIPE LENGTH (FT) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **GPM** | **Velocity (ft/sec)** | **5** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** | **90** | **100** | **GPM** | **Pipe Size** |
| 22 | 4.5 | 0.12 | 0.24 | 0.48 | 0.72 | 0.96 | 1.20 | 1.44 | 1.68 | 1.92 | 2.16 | 2.40 | 22 | **1¼″** (1.414″ inside diameter) |
| 24 | 4.9 | 0.14 | 0.28 | 0.56 | 0.85 | 1.13 | 1.41 | 1.69 | 1.97 | 2.26 | 2.54 | 2.82 | 24 | |
| 26 | 5.3 | 0.17 | 0.33 | 0.66 | 0.98 | 1.31 | 1.64 | 1.97 | 2.30 | 2.62 | 2.95 | 3.28 | 26 | |
| 28 | 5.7 | 0.19 | 0.38 | 0.75 | 1.13 | 1.50 | 1.88 | 2.26 | 2.63 | 3.01 | 3.38 | 3.76 | 28 | |
| 30 | 6.1 | 0.22 | 0.43 | 0.85 | 1.28 | 1.70 | 2.13 | 2.56 | 2.98 | 3.41 | 3.83 | 4.26 | 30 | |
| 32 | 6.5 | 0.24 | 0.48 | 0.96 | 1.44 | 1.92 | 2.40 | 2.88 | 3.36 | 3.84 | 4.32 | 4.80 | 32 | |
| 10 | 1.6 | 0.02 | 0.03 | 0.06 | 0.09 | 0.12 | 0.15 | 0.18 | 0.21 | 0.24 | 0.27 | 0.30 | 10 | **1½″** (1.618″ inside diameter) |
| 15 | 2.3 | 0.03 | 0.06 | 0.13 | 0.19 | 0.26 | 0.32 | 0.38 | 0.45 | 0.51 | 0.58 | 0.64 | 15 | |
| 20 | 3.1 | 0.05 | 0.10 | 0.21 | 0.31 | 0.42 | 0.52 | 0.62 | 0.73 | 0.83 | 0.94 | 1.04 | 20 | |
| 25 | 3.9 | 0.08 | 0.16 | 0.32 | 0.47 | 0.63 | 0.79 | 0.95 | 1.11 | 1.26 | 1.42 | 1.58 | 25 | |
| 30 | 4.7 | 0.11 | 0.22 | 0.44 | 0.67 | 0.89 | 1.11 | 1.33 | 1.55 | 1.78 | 2.00 | 2.22 | 30 | |
| 35 | 5.5 | 0.15 | 0.30 | 0.59 | 0.89 | 1.18 | 1.48 | 1.78 | 2.07 | 2.37 | 2.66 | 2.96 | 35 | |
| 40 | 6.2 | 0.19 | 0.38 | 0.76 | 1.13 | 1.51 | 1.89 | 2.27 | 2.65 | 3.02 | 3.40 | 3.78 | 40 | |
| 20 | 2.0 | 0.02 | 0.03 | 0.07 | 0.10 | 0.14 | 0.17 | 0.20 | 0.24 | 0.27 | 0.31 | 0.34 | 20 | **2″** (2.023″ inside diameter) |
| 25 | 2.5 | 0.03 | 0.06 | 0.11 | 0.17 | 0.22 | 0.28 | 0.34 | 0.39 | 0.45 | 0.50 | 0.56 | 25 | |
| 30 | 3.0 | 0.04 | 0.08 | 0.16 | 0.23 | 0.31 | 0.39 | 0.47 | 0.55 | 0.62 | 0.70 | 0.78 | 30 | |
| 35 | 3.5 | 0.05 | 0.10 | 0.20 | 0.31 | 0.41 | 0.51 | 0.61 | 0.71 | 0.82 | 0.92 | 1.02 | 35 | |
| 40 | 4.0 | 0.07 | 0.13 | 0.26 | 0.40 | 0.53 | 0.66 | 0.79 | 0.92 | 1.06 | 1.19 | 1.32 | 40 | |
| 45 | 4.5 | 0.08 | 0.16 | 0.32 | 0.49 | 0.65 | 0.81 | 0.97 | 1.13 | 1.30 | 1.46 | 1.62 | 45 | |
| 50 | 5.0 | 0.10 | 0.20 | 0.41 | 0.61 | 0.82 | 1.02 | 1.22 | 1.43 | 1.63 | 1.84 | 2.04 | 50 | |
| 55 | 5.5 | 0.12 | 0.24 | 0.48 | 0.72 | 0.96 | 1.20 | 1.44 | 1.68 | 1.92 | 2.16 | 2.40 | 55 | |
| 60 | 6.0 | 0.14 | 0.28 | 0.56 | 0.84 | 1.12 | 1.40 | 1.68 | 1.96 | 2.24 | 2.52 | 2.80 | 60 | |
| 65 | 6.5 | 0.16 | 0.32 | 0.64 | 0.97 | 1.29 | 1.61 | 1.93 | 2.25 | 2.58 | 2.90 | 3.22 | 65 | |
| 40 | 2.7 | 0.03 | 0.05 | 0.10 | 0.16 | 0.21 | 0.26 | 0.31 | 0.36 | 0.42 | 0.47 | 0.52 | 40 | **2½″** (2.449″ inside diameter) |
| 50 | 3.4 | 0.04 | 0.08 | 0.16 | 0.24 | 0.32 | 0.40 | 0.48 | 0.56 | 0.64 | 0.72 | 0.80 | 50 | |
| 60 | 4.1 | 0.06 | 0.11 | 0.22 | 0.33 | 0.44 | 0.55 | 0.66 | 0.77 | 0.88 | 0.99 | 1.10 | 60 | |
| 70 | 4.8 | 0.08 | 0.15 | 0.30 | 0.44 | 0.59 | 0.74 | 0.89 | 1.04 | 1.18 | 1.33 | 1.48 | 70 | |
| 80 | 5.5 | 0.09 | 0.18 | 0.36 | 0.55 | 0.73 | 0.91 | 1.09 | 1.27 | 1.46 | 1.64 | 1.82 | 80 | |
| 90 | 6.1 | 0.12 | 0.23 | 0.47 | 0.70 | 0.94 | 1.17 | 1.40 | 1.64 | 1.87 | 2.11 | 2.34 | 90 | |
| 100 | 6.8 | 0.15 | 0.29 | 0.58 | 0.86 | 1.15 | 1.44 | 1.73 | 2.02 | 2.30 | 2.59 | 2.88 | 100 | |
| 60 | 2.8 | 0.02 | 0.04 | 0.08 | 0.13 | 0.17 | 0.21 | 0.25 | 0.29 | 0.34 | 0.38 | 0.42 | 60 | **3″** (2.982″ inside diameter) |
| 70 | 3.2 | 0.03 | 0.06 | 0.11 | 0.17 | 0.22 | 0.28 | 0.34 | 0.39 | 0.45 | 0.50 | 0.56 | 70 | |
| 80 | 3.7 | 0.04 | 0.07 | 0.14 | 0.22 | 0.29 | 0.36 | 0.43 | 0.50 | 0.58 | 0.65 | 0.72 | 80 | |
| 90 | 4.1 | 0.05 | 0.09 | 0.18 | 0.27 | 0.36 | 0.45 | 0.54 | 0.63 | 0.72 | 0.81 | 0.90 | 90 | |
| 100 | 4.6 | 0.06 | 0.11 | 0.22 | 0.33 | 0.44 | 0.55 | 0.66 | 0.77 | 0.88 | 0.99 | 1.10 | 100 | |
| 110 | 5.1 | 0.07 | 0.13 | 0.26 | 0.40 | 0.53 | 0.66 | 0.79 | 0.92 | 1.06 | 1.19 | 1.32 | 110 | |
| 120 | 5.5 | 0.08 | 0.16 | 0.31 | 0.47 | 0.62 | 0.78 | 0.94 | 1.09 | 1.25 | 1.40 | 1.56 | 120 | |
| 130 | 6.0 | 0.09 | 0.18 | 0.36 | 0.54 | 0.72 | 0.90 | 1.08 | 1.26 | 1.44 | 1.62 | 1.80 | 130 | |
| 140 | 6.4 | 0.11 | 0.21 | 0.41 | 0.62 | 0.82 | 1.03 | 1.24 | 1.44 | 1.65 | 1.85 | 2.06 | 140 | |
| 150 | 6.9 | 0.12 | 0.23 | 0.47 | 0.70 | 0.94 | 1.17 | 1.40 | 1.64 | 1.87 | 2.11 | 2.34 | 150 | |
| 130 | 3.6 | 0.03 | 0.06 | 0.11 | 0.17 | 0.22 | 0.28 | 0.34 | 0.39 | 0.45 | 0.50 | 0.56 | 130 | **4″** (3.834″ inside diameter) |
| 140 | 3.9 | 0.03 | 0.06 | 0.13 | 0.19 | 0.26 | 0.32 | 0.38 | 0.45 | 0.51 | 0.58 | 0.64 | 140 | |
| 150 | 4.2 | 0.04 | 0.07 | 0.14 | 0.22 | 0.29 | 0.36 | 0.43 | 0.50 | 0.58 | 0.65 | 0.72 | 150 | |
| 160 | 4.5 | 0.04 | 0.08 | 0.16 | 0.24 | 0.32 | 0.40 | 0.48 | 0.56 | 0.64 | 0.72 | 0.80 | 160 | |
| 170 | 4.7 | 0.05 | 0.09 | 0.18 | 0.27 | 0.36 | 0.45 | 0.54 | 0.63 | 0.72 | 0.81 | 0.90 | 170 | |
| 180 | 5.0 | 0.05 | 0.10 | 0.20 | 0.30 | 0.40 | 0.50 | 0.60 | 0.70 | 0.80 | 0.90 | 1.00 | 180 | |
| 190 | 5.3 | 0.06 | 0.11 | 0.22 | 0.33 | 0.44 | 0.55 | 0.66 | 0.77 | 0.88 | 0.99 | 1.10 | 190 | |
| 200 | 5.6 | 0.06 | 0.12 | 0.24 | 0.36 | 0.48 | 0.60 | 0.72 | 0.84 | 0.96 | 1.08 | 1.20 | 200 | |
| 210 | 5.8 | 0.07 | 0.13 | 0.26 | 0.40 | 0.53 | 0.66 | 0.79 | 0.92 | 1.06 | 1.19 | 1.32 | 210 | |
| 220 | 6.1 | 0.07 | 0.14 | 0.29 | 0.43 | 0.58 | 0.72 | 0.86 | 1.01 | 1.15 | 1.30 | 1.44 | 220 | |
| 230 | 6.4 | 0.08 | 0.16 | 0.31 | 0.47 | 0.62 | 0.78 | 0.94 | 1.09 | 1.25 | 1.40 | 1.56 | 230 | |
| 240 | 6.7 | 0.09 | 0.17 | 0.34 | 0.51 | 0.68 | 0.85 | 1.02 | 1.19 | 1.36 | 1.53 | 1.70 | 240 | |

## *TABLE A1.4* ***PVC 1120-1220 Schedule 40 Pipe Friction Loss Chart C=150***

| | | **PSI LOSS PER PIPE LENGTH (FT)** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **GPM** | **Velocity (ft/sec)** | **5** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** | **90** | **100** | **GPM** | **Pipe Size** |
| 1 | 1.1 | 0.02 | 0.04 | 0.09 | 0.13 | 0.18 | 0.22 | 0.26 | 0.31 | 0.35 | 0.40 | 0.44 | 1 | **½″** (0.622″ inside diameter) |
| 2 | 2.1 | 0.08 | 0.15 | 0.31 | 0.46 | 0.62 | 0.77 | 0.92 | 1.08 | 1.23 | 1.39 | 1.54 | 2 | |
| 3 | 3.2 | 0.17 | 0.33 | 0.66 | 0.98 | 1.31 | 1.64 | 1.97 | 2.30 | 2.62 | 2.95 | 3.28 | 3 | |
| 4 | 4.2 | 0.28 | 0.55 | 1.10 | 1.66 | 2.21 | 2.76 | 3.31 | 3.86 | 4.42 | 4.97 | 5.52 | 4 | |
| 5 | 5.3 | 0.42 | 0.84 | 1.68 | 2.53 | 3.37 | 4.21 | 5.05 | 5.89 | 6.74 | 7.58 | 8.42 | 5 | |
| 6 | 6.3 | 0.59 | 1.17 | 2.34 | 3.51 | 4.68 | 5.85 | 7.02 | 8.19 | 9.36 | 10.53 | 11.70 | 6 | |
| 2 | 1.2 | 0.02 | 0.04 | 0.08 | 0.12 | 0.16 | 0.20 | 0.24 | 0.28 | 0.32 | 0.36 | 0.40 | 2 | **¾″** (0.824″ inside diameter) |
| 4 | 2.4 | 0.07 | 0.14 | 0.28 | 0.43 | 0.57 | 0.71 | 0.85 | 0.99 | 1.14 | 1.28 | 1.42 | 4 | |
| 6 | 3.6 | 0.15 | 0.30 | 0.60 | 0.89 | 1.19 | 1.49 | 1.79 | 2.09 | 2.38 | 2.68 | 2.98 | 6 | |
| 8 | 4.8 | 0.26 | 0.51 | 1.02 | 1.52 | 2.03 | 2.54 | 3.05 | 3.56 | 4.06 | 4.57 | 5.08 | 8 | |
| 10 | 6.0 | 0.39 | 0.77 | 1.53 | 2.30 | 3.06 | 3.83 | 4.60 | 5.36 | 6.13 | 6.89 | 7.66 | 10 | |
| 4 | 1.5 | 0.02 | 0.04 | 0.08 | 0.13 | 0.17 | 0.21 | 0.25 | 0.29 | 0.34 | 0.38 | 0.42 | 4 | **1″** (1.049″ inside diameter) |
| 6 | 2.2 | 0.05 | 0.09 | 0.18 | 0.26 | 0.35 | 0.44 | 0.53 | 0.62 | 0.70 | 0.79 | 0.88 | 6 | |
| 8 | 3.0 | 0.08 | 0.15 | 0.30 | 0.45 | 0.60 | 0.75 | 0.90 | 1.05 | 1.20 | 1.35 | 1.50 | 8 | |
| 10 | 3.7 | 0.12 | 0.23 | 0.45 | 0.68 | 0.90 | 1.13 | 1.36 | 1.58 | 1.81 | 2.03 | 2.26 | 10 | |
| 12 | 4.5 | 0.16 | 0.32 | 0.63 | 0.95 | 1.26 | 1.58 | 1.90 | 2.21 | 2.53 | 2.84 | 3.16 | 12 | |
| 14 | 5.2 | 0.21 | 0.42 | 0.84 | 1.27 | 1.69 | 2.11 | 2.53 | 2.95 | 3.38 | 3.80 | 4.22 | 14 | |
| 16 | 5.9 | 0.27 | 0.54 | 1.08 | 1.62 | 2.16 | 2.70 | 3.24 | 3.78 | 4.32 | 4.86 | 5.40 | 16 | |
| 18 | 6.7 | 0.34 | 0.67 | 1.34 | 2.01 | 2.68 | 3.35 | 4.02 | 4.69 | 5.36 | 6.03 | 6.70 | 18 | |
| 8 | 1.7 | 0.02 | 0.04 | 0.08 | 0.13 | 0.17 | 0.21 | 0.25 | 0.29 | 0.34 | 0.38 | 0.42 | 8 | **1¼″** (1.380″ inside diameter) |
| 10 | 2.2 | 0.03 | 0.06 | 0.12 | 0.19 | 0.25 | 0.31 | 0.37 | 0.43 | 0.50 | 0.56 | 0.62 | 10 | |
| 12 | 2.6 | 0.05 | 0.09 | 0.18 | 0.26 | 0.35 | 0.44 | 0.53 | 0.62 | 0.70 | 0.79 | 0.88 | 12 | |
| 14 | 3.0 | 0.06 | 0.12 | 0.23 | 0.35 | 0.46 | 0.58 | 0.70 | 0.81 | 0.93 | 1.04 | 1.16 | 14 | |
| 16 | 3.4 | 0.08 | 0.15 | 0.30 | 0.44 | 0.59 | 0.74 | 0.89 | 1.04 | 1.18 | 1.33 | 1.48 | 16 | |
| 18 | 3.8 | 0.09 | 0.18 | 0.37 | 0.55 | 0.74 | 0.92 | 1.10 | 1.29 | 1.47 | 1.66 | 1.84 | 18 | |
| 20 | 4.3 | 0.11 | 0.22 | 0.45 | 0.67 | 0.90 | 1.12 | 1.34 | 1.57 | 1.79 | 2.02 | 2.24 | 20 | |
| 22 | 4.7 | 0.14 | 0.27 | 0.54 | 0.80 | 1.07 | 1.34 | 1.61 | 1.88 | 2.14 | 2.41 | 2.68 | 22 | |
| 24 | 5.1 | 0.16 | 0.31 | 0.63 | 0.94 | 1.26 | 1.57 | 1.88 | 2.20 | 2.51 | 2.83 | 3.14 | 24 | |
| 26 | 5.6 | 0.18 | 0.36 | 0.73 | 1.09 | 1.46 | 1.82 | 2.18 | 2.55 | 2.91 | 3.28 | 3.64 | 26 | |
| 28 | 6.0 | 0.21 | 0.42 | 0.84 | 1.25 | 1.67 | 2.09 | 2.51 | 2.93 | 3.34 | 3.76 | 4.18 | 28 | |
| 30 | 6.4 | 0.24 | 0.48 | 0.95 | 1.43 | 1.90 | 2.38 | 2.86 | 3.33 | 3.81 | 4.28 | 4.76 | 30 | |
| 32 | 6.9 | 0.27 | 0.54 | 1.08 | 1.61 | 2.15 | 2.69 | 3.23 | 3.77 | 4.30 | 4.84 | 5.38 | 32 | |
| 10 | 1.6 | 0.01 | 0.02 | 0.04 | 0.07 | 0.09 | 0.11 | 0.13 | 0.15 | 0.18 | 0.20 | 0.22 | 10 | **1½″** (1.610″ inside diameter) |
| 15 | 2.4 | 0.03 | 0.05 | 0.10 | 0.14 | 0.19 | 0.24 | 0.29 | 0.34 | 0.38 | 0.43 | 0.48 | 15 | |
| 20 | 3.2 | 0.04 | 0.08 | 0.16 | 0.24 | 0.32 | 0.40 | 0.48 | 0.56 | 0.64 | 0.72 | 0.80 | 20 | |
| 25 | 3.9 | 0.06 | 0.12 | 0.24 | 0.37 | 0.49 | 0.61 | 0.73 | 0.85 | 0.98 | 1.10 | 1.22 | 25 | |
| 30 | 4.7 | 0.09 | 0.17 | 0.34 | 0.52 | 0.69 | 0.86 | 1.03 | 1.20 | 1.38 | 1.55 | 1.72 | 30 | |
| 35 | 5.5 | 0.12 | 0.23 | 0.46 | 0.69 | 0.92 | 1.15 | 1.38 | 1.61 | 1.84 | 2.07 | 2.30 | 35 | |
| 40 | 6.3 | 0.15 | 0.29 | 0.59 | 0.88 | 1.18 | 1.47 | 1.76 | 2.06 | 2.35 | 2.65 | 2.94 | 40 | |
| 20 | 1.9 | 0.02 | 0.03 | 0.06 | 0.10 | 0.13 | 0.16 | 0.19 | 0.22 | 0.26 | 0.29 | 0.32 | 20 | **2″** (2.067″ inside diameter) |
| 25 | 2.4 | 0.03 | 0.05 | 0.10 | 0.14 | 0.19 | 0.24 | 0.29 | 0.34 | 0.38 | 0.43 | 0.48 | 25 | |
| 30 | 2.9 | 0.04 | 0.07 | 0.14 | 0.20 | 0.27 | 0.34 | 0.41 | 0.48 | 0.54 | 0.61 | 0.68 | 30 | |
| 35 | 3.4 | 0.05 | 0.09 | 0.18 | 0.27 | 0.36 | 0.45 | 0.54 | 0.63 | 0.72 | 0.81 | 0.90 | 35 | |
| 40 | 3.8 | 0.06 | 0.11 | 0.23 | 0.34 | 0.46 | 0.57 | 0.68 | 0.80 | 0.91 | 1.03 | 1.14 | 40 | |
| 45 | 4.3 | 0.07 | 0.14 | 0.28 | 0.43 | 0.57 | 0.71 | 0.85 | 0.99 | 1.14 | 1.28 | 1.42 | 45 | |
| 50 | 4.8 | 0.09 | 0.17 | 0.34 | 0.52 | 0.69 | 0.86 | 1.03 | 1.20 | 1.38 | 1.55 | 1.72 | 50 | |

| | | PSI LOSS PER PIPE LENGTH (FT) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **GPM** | **Velocity (ft/sec)** | **5** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** | **90** | **100** | **GPM** | **Pipe Size** |
| 55 | 5.3 | 0.10 | 0.20 | 0.41 | 0.61 | 0.82 | 1.02 | 1.22 | 1.43 | 1.63 | 1.84 | 2.04 | 55 | **2″** (2.067″ inside diameter) |
| 60 | 5.7 | 0.12 | 0.24 | 0.48 | 0.72 | 0.96 | 1.20 | 1.44 | 1.68 | 1.92 | 2.16 | 2.40 | 60 | |
| 65 | 6.2 | 0.14 | 0.28 | 0.56 | 0.83 | 1.11 | 1.39 | 1.67 | 1.95 | 2.22 | 2.50 | 2.78 | 65 | |
| 70 | 6.7 | 0.16 | 0.32 | 0.64 | 0.96 | 1.28 | 1.60 | 1.92 | 2.24 | 2.56 | 2.88 | 3.20 | 70 | |
| 30 | 2.0 | 0.02 | 0.03 | 0.06 | 0.08 | 0.11 | 0.14 | 0.17 | 0.20 | 0.22 | 0.25 | 0.28 | 30 | **2½″** (2.469″ inside diameter) |
| 40 | 2.7 | 0.03 | 0.05 | 0.10 | 0.14 | 0.19 | 0.24 | 0.29 | 0.34 | 0.38 | 0.43 | 0.48 | 40 | |
| 50 | 3.4 | 0.04 | 0.07 | 0.14 | 0.22 | 0.29 | 0.36 | 0.43 | 0.50 | 0.58 | 0.65 | 0.72 | 50 | |
| 60 | 4.0 | 0.05 | 0.10 | 0.20 | 0.31 | 0.41 | 0.51 | 0.61 | 0.71 | 0.82 | 0.92 | 1.02 | 60 | |
| 70 | 4.7 | 0.07 | 0.13 | 0.27 | 0.40 | 0.54 | 0.67 | 0.80 | 0.94 | 1.07 | 1.21 | 1.34 | 70 | |
| 80 | 5.4 | 0.09 | 0.17 | 0.34 | 0.52 | 0.69 | 0.86 | 1.03 | 1.20 | 1.38 | 1.55 | 1.72 | 80 | |
| 90 | 6.0 | 0.11 | 0.21 | 0.43 | 0.64 | 0.86 | 1.07 | 1.28 | 1.50 | 1.71 | 1.93 | 2.14 | 90 | |
| 100 | 6.7 | 0.13 | 0.26 | 0.52 | 0.78 | 1.04 | 1.30 | 1.56 | 1.82 | 2.08 | 2.34 | 2.60 | 100 | |
| 70 | 3.0 | 0.03 | 0.05 | 0.09 | 0.14 | 0.18 | 0.23 | 0.28 | 0.32 | 0.37 | 0.41 | 0.46 | 70 | **3″** (3.068″ inside diameter) |
| 80 | 3.5 | 0.03 | 0.06 | 0.12 | 0.18 | 0.24 | 0.30 | 0.36 | 0.42 | 0.48 | 0.54 | 0.60 | 80 | |
| 90 | 3.9 | 0.04 | 0.07 | 0.15 | 0.22 | 0.30 | 0.37 | 0.44 | 0.52 | 0.59 | 0.67 | 0.74 | 90 | |
| 100 | 4.3 | 0.05 | 0.09 | 0.18 | 0.27 | 0.36 | 0.45 | 0.54 | 0.63 | 0.72 | 0.81 | 0.90 | 100 | |
| 110 | 4.8 | 0.06 | 0.11 | 0.22 | 0.32 | 0.43 | 0.54 | 0.65 | 0.76 | 0.86 | 0.97 | 1.08 | 110 | |
| 120 | 5.2 | 0.07 | 0.13 | 0.25 | 0.38 | 0.50 | 0.63 | 0.76 | 0.88 | 1.01 | 1.13 | 1.26 | 120 | |
| 130 | 5.6 | 0.08 | 0.15 | 0.29 | 0.44 | 0.58 | 0.73 | 0.88 | 1.02 | 1.17 | 1.31 | 1.46 | 130 | |
| 140 | 6.1 | 0.09 | 0.17 | 0.34 | 0.50 | 0.67 | 0.84 | 1.01 | 1.18 | 1.34 | 1.51 | 1.68 | 140 | |
| 150 | 6.5 | 0.10 | 0.19 | 0.38 | 0.57 | 0.76 | 0.95 | 1.14 | 1.33 | 1.52 | 1.71 | 1.90 | 150 | |
| 160 | 6.9 | 0.11 | 0.21 | 0.43 | 0.64 | 0.86 | 1.07 | 1.28 | 1.50 | 1.71 | 1.93 | 2.14 | 160 | |
| 140 | 3.5 | 0.03 | 0.05 | 0.09 | 0.14 | 0.18 | 0.23 | 0.28 | 0.32 | 0.37 | 0.41 | 0.46 | 140 | **4″** (4.026″ inside diameter) |
| 150 | 3.8 | 0.03 | 0.05 | 0.10 | 0.16 | 0.21 | 0.26 | 0.31 | 0.36 | 0.42 | 0.47 | 0.52 | 150 | |
| 160 | 4.0 | 0.03 | 0.06 | 0.12 | 0.17 | 0.23 | 0.29 | 0.35 | 0.41 | 0.46 | 0.52 | 0.58 | 160 | |
| 170 | 4.3 | 0.03 | 0.06 | 0.13 | 0.19 | 0.26 | 0.32 | 0.38 | 0.45 | 0.51 | 0.58 | 0.64 | 170 | |
| 180 | 4.5 | 0.04 | 0.07 | 0.14 | 0.22 | 0.29 | 0.36 | 0.43 | 0.50 | 0.58 | 0.65 | 0.72 | 180 | |
| 190 | 4.8 | 0.04 | 0.08 | 0.16 | 0.24 | 0.32 | 0.40 | 0.48 | 0.56 | 0.64 | 0.72 | 0.80 | 190 | |
| 200 | 5.0 | 0.05 | 0.09 | 0.18 | 0.26 | 0.35 | 0.44 | 0.53 | 0.62 | 0.70 | 0.79 | 0.88 | 200 | |
| 210 | 5.3 | 0.05 | 0.10 | 0.19 | 0.29 | 0.38 | 0.48 | 0.58 | 0.67 | 0.77 | 0.86 | 0.96 | 210 | |
| 220 | 5.5 | 0.05 | 0.10 | 0.21 | 0.31 | 0.42 | 0.52 | 0.62 | 0.73 | 0.83 | 0.94 | 1.04 | 220 | |
| 230 | 5.8 | 0.06 | 0.11 | 0.22 | 0.34 | 0.45 | 0.56 | 0.67 | 0.78 | 0.90 | 1.01 | 1.12 | 230 | |
| 240 | 6.1 | 0.06 | 0.12 | 0.24 | 0.37 | 0.49 | 0.61 | 0.73 | 0.85 | 0.98 | 1.10 | 1.22 | 240 | |
| 250 | 6.3 | 0.07 | 0.13 | 0.26 | 0.40 | 0.53 | 0.66 | 0.79 | 0.92 | 1.06 | 1.19 | 1.32 | 250 | |
| 260 | 6.6 | 0.07 | 0.14 | 0.28 | 0.43 | 0.57 | 0.71 | 0.85 | 0.99 | 1.14 | 1.28 | 1.42 | 260 | |
| 270 | 6.8 | 0.08 | 0.15 | 0.30 | 0.46 | 0.61 | 0.76 | 0.91 | 1.06 | 1.22 | 1.37 | 1.52 | 270 | |
| 275 | 3.1 | 0.01 | 0.02 | 0.04 | 0.07 | 0.09 | 0.11 | 0.13 | 0.15 | 0.18 | 0.20 | 0.22 | 275 | **6″** (6.065″ inside diameter) |
| 300 | 3.3 | 0.02 | 0.03 | 0.05 | 0.08 | 0.10 | 0.13 | 0.16 | 0.18 | 0.21 | 0.23 | 0.26 | 300 | |
| 325 | 3.6 | 0.02 | 0.03 | 0.06 | 0.09 | 0.12 | 0.15 | 0.18 | 0.21 | 0.24 | 0.27 | 0.30 | 325 | |
| 350 | 3.9 | 0.02 | 0.03 | 0.07 | 0.10 | 0.14 | 0.17 | 0.20 | 0.24 | 0.27 | 0.31 | 0.34 | 350 | |
| 375 | 4.2 | 0.02 | 0.04 | 0.08 | 0.11 | 0.15 | 0.19 | 0.23 | 0.27 | 0.30 | 0.34 | 0.38 | 375 | |
| 400 | 4.4 | 0.02 | 0.04 | 0.09 | 0.13 | 0.18 | 0.22 | 0.26 | 0.31 | 0.35 | 0.40 | 0.44 | 400 | |
| 425 | 4.7 | 0.03 | 0.05 | 0.10 | 0.14 | 0.19 | 0.24 | 0.29 | 0.34 | 0.38 | 0.43 | 0.48 | 425 | |
| 450 | 5.0 | 0.03 | 0.05 | 0.10 | 0.16 | 0.21 | 0.26 | 0.31 | 0.36 | 0.42 | 0.47 | 0.52 | 450 | |
| 475 | 5.3 | 0.03 | 0.06 | 0.12 | 0.17 | 0.23 | 0.29 | 0.35 | 0.41 | 0.46 | 0.52 | 0.58 | 475 | |
| 500 | 5.6 | 0.03 | 0.06 | 0.13 | 0.19 | 0.26 | 0.32 | 0.38 | 0.45 | 0.51 | 0.58 | 0.64 | 500 | |
| 525 | 5.8 | 0.04 | 0.07 | 0.14 | 0.21 | 0.28 | 0.35 | 0.42 | 0.49 | 0.56 | 0.63 | 0.70 | 525 | |
| 550 | 6.1 | 0.04 | 0.08 | 0.16 | 0.23 | 0.31 | 0.39 | 0.47 | 0.55 | 0.62 | 0.70 | 0.78 | 550 | |
| 575 | 6.4 | 0.05 | 0.09 | 0.17 | 0.26 | 0.34 | 0.43 | 0.52 | 0.60 | 0.69 | 0.77 | 0.86 | 575 | |

## *TABLE A1.5* **Pipe Friction Loss Chart: Polyethylene Pipe, Standard Size C=120***

| | | PSI LOSS PER PIPE LENGTH (FT) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **GPM** | **Velocity (ft/sec)** | **5** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** | **90** | **100** | **GPM** | **Pipe Size** |
| 1 | 1.1 | 0.03 | 0.06 | 0.12 | 0.17 | 0.23 | 0.29 | 0.35 | 0.41 | 0.46 | 0.52 | 0.58 | 1 | **½″** (0.622″ inside diameter) |
| 2 | 2.1 | 0.11 | 0.22 | 0.45 | 0.67 | 0.90 | 1.12 | 1.34 | 1.57 | 1.79 | 2.02 | 2.24 | 2 | |
| 3 | 3.2 | 0.24 | 0.48 | 0.97 | 1.45 | 1.94 | 2.42 | 2.90 | 3.39 | 3.87 | 4.36 | 4.84 | 3 | |
| 4 | 4.2 | 0.43 | 0.86 | 1.72 | 2.58 | 3.44 | 4.30 | 5.16 | 6.02 | 6.88 | 7.74 | 8.60 | 4 | |
| 5 | 5.3 | 0.68 | 1.35 | 2.70 | 4.05 | 5.40 | 6.75 | 8.10 | 9.45 | 10.80 | 12.15 | 13.50 | 5 | |
| 6 | 6.4 | 0.91 | 1.81 | 3.62 | 5.43 | 7.24 | 9.05 | 10.86 | 12.67 | 14.48 | 16.29 | 18.10 | 6 | |
| 1 | 0.6 | 0.01 | 0.02 | 0.03 | 0.05 | 0.06 | 0.08 | 0.10 | 0.11 | 0.13 | 0.14 | 0.16 | 1 | **¾″** (0.824″ inside diameter) |
| 2 | 1.2 | 0.03 | 0.06 | 0.11 | 0.17 | 0.22 | 0.28 | 0.34 | 0.39 | 0.45 | 0.50 | 0.56 | 2 | |
| 3 | 1.8 | 0.07 | 0.13 | 0.25 | 0.38 | 0.50 | 0.63 | 0.76 | 0.88 | 1.01 | 1.13 | 1.26 | 3 | |
| 4 | 2.4 | 0.11 | 0.21 | 0.42 | 0.64 | 0.85 | 1.06 | 1.27 | 1.48 | 1.70 | 1.91 | 2.12 | 4 | |
| 5 | 3.0 | 0.16 | 0.32 | 0.63 | 0.95 | 1.26 | 1.58 | 1.90 | 2.21 | 2.53 | 2.84 | 3.16 | 5 | |
| 6 | 3.6 | 0.23 | 0.45 | 0.91 | 1.36 | 1.82 | 2.27 | 2.72 | 3.18 | 3.63 | 4.09 | 4.54 | 6 | |
| 7 | 4.2 | 0.31 | 0.61 | 1.22 | 1.82 | 2.43 | 3.04 | 3.65 | 4.26 | 4.86 | 5.47 | 6.08 | 7 | |
| 8 | 4.8 | 0.39 | 0.78 | 1.56 | 2.35 | 3.13 | 3.91 | 4.69 | 5.47 | 6.26 | 7.04 | 7.82 | 8 | |
| 9 | 5.4 | 0.49 | 0.97 | 1.94 | 2.91 | 3.88 | 4.85 | 5.82 | 6.79 | 7.76 | 8.73 | 9.70 | 9 | |
| 10 | 6.0 | 0.59 | 1.17 | 2.34 | 3.51 | 4.68 | 5.85 | 7.02 | 8.19 | 9.36 | 10.53 | 11.70 | 10 | |
| 3 | 1.1 | 0.02 | 0.04 | 0.08 | 0.12 | 0.16 | 0.20 | 0.24 | 0.28 | 0.32 | 0.36 | 0.40 | 3 | **1″** (1.049″ inside diameter) |
| 4 | 1.5 | 0.04 | 0.07 | 0.14 | 0.21 | 0.28 | 0.35 | 0.42 | 0.49 | 0.56 | 0.63 | 0.70 | 4 | |
| 5 | 1.9 | 0.05 | 0.10 | 0.20 | 0.31 | 0.41 | 0.51 | 0.61 | 0.71 | 0.82 | 0.92 | 1.02 | 5 | |
| 6 | 2.2 | 0.07 | 0.14 | 0.29 | 0.43 | 0.58 | 0.72 | 0.86 | 1.01 | 1.15 | 1.30 | 1.44 | 6 | |
| 7 | 2.6 | 0.10 | 0.19 | 0.38 | 0.57 | 0.76 | 0.95 | 1.14 | 1.33 | 1.52 | 1.71 | 1.90 | 7 | |
| 8 | 3.0 | 0.12 | 0.24 | 0.48 | 0.72 | 0.96 | 1.20 | 1.44 | 1.68 | 1.92 | 2.16 | 2.40 | 8 | |
| 9 | 3.3 | 0.15 | 0.30 | 0.59 | 0.89 | 1.18 | 1.48 | 1.78 | 2.07 | 2.37 | 2.66 | 2.96 | 9 | |
| 10 | 3.7 | 0.18 | 0.36 | 0.72 | 1.07 | 1.43 | 1.79 | 2.15 | 2.51 | 2.86 | 3.22 | 3.58 | 10 | |
| 11 | 4.1 | 0.21 | 0.42 | 0.85 | 1.27 | 1.70 | 2.12 | 2.54 | 2.97 | 3.39 | 3.82 | 4.24 | 11 | |
| 12 | 4.5 | 0.25 | 0.50 | 1.00 | 1.49 | 1.99 | 2.49 | 2.99 | 3.49 | 3.98 | 4.48 | 4.98 | 12 | |
| 13 | 4.8 | 0.29 | 0.58 | 1.16 | 1.73 | 2.31 | 2.89 | 3.47 | 4.05 | 4.62 | 5.20 | 5.78 | 13 | |
| 14 | 5.2 | 0.33 | 0.66 | 1.33 | 1.99 | 2.66 | 3.32 | 3.98 | 4.65 | 5.31 | 5.98 | 6.64 | 14 | |
| 15 | 5.6 | 0.38 | 0.75 | 1.51 | 2.26 | 3.02 | 3.77 | 4.52 | 5.28 | 6.03 | 6.79 | 7.54 | 15 | |
| 16 | 6.0 | 0.43 | 0.85 | 1.70 | 2.54 | 3.39 | 4.24 | 5.09 | 5.94 | 6.78 | 7.63 | 8.48 | 16 | |
| 8 | 1.7 | 0.03 | 0.06 | 0.12 | 0.18 | 0.24 | 0.30 | 0.36 | 0.42 | 0.48 | 0.54 | 0.60 | 8 | **1¼″** (1.380″ inside diameter) |
| 10 | 2.2 | 0.05 | 0.09 | 0.18 | 0.28 | 0.37 | 0.46 | 0.55 | 0.64 | 0.74 | 0.83 | 0.92 | 10 | |
| 12 | 2.6 | 0.07 | 0.13 | 0.25 | 0.38 | 0.50 | 0.63 | 0.76 | 0.88 | 1.01 | 1.13 | 1.26 | 12 | |
| 14 | 3.0 | 0.09 | 0.17 | 0.34 | 0.52 | 0.69 | 0.86 | 1.03 | 1.20 | 1.38 | 1.55 | 1.72 | 14 | |
| 16 | 3.4 | 0.11 | 0.22 | 0.44 | 0.67 | 0.89 | 1.11 | 1.33 | 1.55 | 1.78 | 2.00 | 2.22 | 16 | |
| 18 | 3.9 | 0.14 | 0.28 | 0.55 | 0.83 | 1.10 | 1.38 | 1.66 | 1.93 | 2.21 | 2.48 | 2.76 | 18 | |
| 20 | 4.3 | 0.17 | 0.34 | 0.67 | 1.01 | 1.34 | 1.68 | 2.02 | 2.35 | 2.69 | 3.02 | 3.36 | 20 | |
| 22 | 4.7 | 0.20 | 0.40 | 0.80 | 1.21 | 1.61 | 2.01 | 2.41 | 2.81 | 3.22 | 3.62 | 4.02 | 22 | |
| 24 | 5.2 | 0.24 | 0.47 | 0.94 | 1.41 | 1.88 | 2.35 | 2.82 | 3.29 | 3.76 | 4.23 | 4.70 | 24 | |
| 26 | 5.6 | 0.28 | 0.55 | 1.09 | 1.64 | 2.18 | 2.73 | 3.28 | 3.82 | 4.37 | 4.91 | 5.46 | 26 | |
| 28 | 6.0 | 0.32 | 0.63 | 1.26 | 1.89 | 2.52 | 3.15 | 3.78 | 4.41 | 5.04 | 5.67 | 6.30 | 28 | |
| 30 | 6.4 | 0.36 | 0.71 | 1.43 | 2.14 | 2.86 | 3.57 | 4.28 | 5.00 | 5.71 | 6.43 | 7.14 | 30 | |
| 10 | 1.6 | 0.02 | 0.04 | 0.08 | 0.13 | 0.17 | 0.21 | 0.25 | 0.29 | 0.34 | 0.38 | 0.42 | 10 | **1½″** (1.610″ inside diameter) |
| 12 | 1.9 | 0.03 | 0.06 | 0.12 | 0.17 | 0.23 | 0.29 | 0.35 | 0.41 | 0.46 | 0.52 | 0.58 | 12 | |
| 14 | 2.2 | 0.04 | 0.08 | 0.16 | 0.23 | 0.31 | 0.39 | 0.47 | 0.55 | 0.62 | 0.70 | 0.78 | 14 | |
| 16 | 2.5 | 0.05 | 0.10 | 0.20 | 0.31 | 0.41 | 0.51 | 0.61 | 0.71 | 0.82 | 0.92 | 1.02 | 16 | |
| 18 | 2.9 | 0.07 | 0.13 | 0.25 | 0.38 | 0.50 | 0.63 | 0.76 | 0.88 | 1.01 | 1.13 | 1.26 | 18 | |
| 20 | 3.2 | 0.08 | 0.15 | 0.31 | 0.46 | 0.62 | 0.77 | 0.92 | 1.08 | 1.23 | 1.39 | 1.54 | 20 | |
| 22 | 3.5 | 0.10 | 0.19 | 0.37 | 0.56 | 0.74 | 0.93 | 1.12 | 1.30 | 1.49 | 1.67 | 1.86 | 22 | |
| 24 | 3.8 | 0.11 | 0.22 | 0.44 | 0.65 | 0.87 | 1.09 | 1.31 | 1.53 | 1.74 | 1.96 | 2.18 | 24 | |
| 26 | 4.1 | 0.13 | 0.25 | 0.51 | 0.76 | 1.02 | 1.27 | 1.52 | 1.78 | 2.03 | 2.29 | 2.54 | 26 | |
| 28 | 4.4 | 0.15 | 0.29 | 0.58 | 0.88 | 1.17 | 1.46 | 1.75 | 2.04 | 2.34 | 2.63 | 2.92 | 28 | |

*Constant is derated to compensate for insert fittings.

| GPM | Velocity (ft/sec) | 5 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 | GPM | Pipe Size |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  | PSI LOSS PER PIPE LENGTH (FT) |  |  |  |  |  |  |  |  |  |  |  |  |
| 30 | 4.7 | 0.17 | 0.33 | 0.67 | 1.00 | 1.34 | 1.67 | 2.00 | 2.34 | 2.67 | 3.01 | 3.34 | 30 | **1½″** (1.610″ inside diameter) |
| 32 | 5.0 | 0.19 | 0.38 | 0.75 | 1.13 | 1.50 | 1.88 | 2.26 | 2.63 | 3.01 | 3.38 | 3.76 | 32 |  |
| 34 | 5.3 | 0.21 | 0.42 | 0.85 | 1.27 | 1.70 | 2.12 | 2.54 | 2.97 | 3.39 | 3.82 | 4.24 | 34 |  |
| 36 | 5.6 | 0.24 | 0.47 | 0.94 | 1.42 | 1.89 | 2.36 | 2.83 | 3.30 | 3.78 | 4.25 | 4.72 | 36 |  |
| 38 | 6.0 | 0.26 | 0.52 | 1.04 | 1.57 | 2.09 | 2.61 | 3.13 | 3.65 | 4.18 | 4.70 | 5.22 | 38 |  |
| 40 | 6.3 | 0.29 | 0.57 | 1.15 | 1.72 | 2.30 | 2.87 | 3.44 | 4.02 | 4.59 | 5.17 | 5.74 | 40 |  |
| 20 | 1.9 | 0.03 | 0.05 | 0.11 | 0.16 | 0.22 | 0.27 | 0.32 | 0.38 | 0.43 | 0.49 | 0.54 | 20 | **2″** (2.067″ inside diameter) |
| 25 | 2.4 | 0.04 | 0.08 | 0.16 | 0.23 | 0.31 | 0.39 | 0.47 | 0.55 | 0.62 | 0.70 | 0.78 | 25 |  |
| 30 | 2.9 | 0.06 | 0.11 | 0.22 | 0.34 | 0.45 | 0.56 | 0.67 | 0.78 | 0.90 | 1.01 | 1.12 | 30 |  |
| 35 | 3.4 | 0.08 | 0.15 | 0.31 | 0.46 | 0.62 | 0.77 | 0.92 | 1.08 | 1.23 | 1.39 | 1.54 | 35 |  |
| 40 | 3.8 | 0.10 | 0.20 | 0.40 | 0.59 | 0.79 | 0.99 | 1.19 | 1.39 | 1.58 | 1.78 | 1.98 | 40 |  |
| 45 | 4.3 | 0.13 | 0.25 | 0.50 | 0.74 | 0.99 | 1.24 | 1.49 | 1.74 | 1.98 | 2.23 | 2.48 | 45 |  |
| 50 | 4.8 | 0.15 | 0.30 | 0.60 | 0.91 | 1.21 | 1.51 | 1.81 | 2.11 | 2.42 | 2.72 | 3.02 | 50 |  |
| 55 | 5.3 | 0.18 | 0.36 | 0.72 | 1.08 | 1.44 | 1.80 | 2.16 | 2.52 | 2.88 | 3.24 | 3.60 | 55 |  |
| 60 | 5.7 | 0.21 | 0.42 | 0.84 | 1.27 | 1.69 | 2.11 | 2.53 | 2.95 | 3.38 | 3.80 | 4.22 | 60 |  |
| 65 | 6.2 | 0.25 | 0.49 | 0.98 | 1.47 | 1.96 | 2.45 | 2.94 | 3.43 | 3.92 | 4.41 | 4.90 | 65 |  |
| 70 | 6.7 | 0.28 | 0.56 | 1.12 | 1.69 | 2.25 | 2.81 | 3.37 | 3.93 | 4.50 | 5.06 | 5.62 | 70 |  |
| 30 | 2.0 | 0.02 | 0.03 | 0.07 | 0.10 | 0.14 | 0.17 | 0.20 | 0.24 | 0.27 | 0.31 | 0.34 | 30 | **2½″** (2.469″ inside diameter) |
| 35 | 2.4 | 0.03 | 0.05 | 0.09 | 0.14 | 0.18 | 0.23 | 0.28 | 0.32 | 0.37 | 0.41 | 0.46 | 35 |  |
| 40 | 2.7 | 0.03 | 0.06 | 0.12 | 0.18 | 0.24 | 0.30 | 0.36 | 0.42 | 0.48 | 0.54 | 0.60 | 40 |  |
| 45 | 3.0 | 0.04 | 0.07 | 0.15 | 0.22 | 0.30 | 0.37 | 0.44 | 0.52 | 0.59 | 0.67 | 0.74 | 45 |  |
| 50 | 3.4 | 0.05 | 0.09 | 0.18 | 0.28 | 0.37 | 0.46 | 0.55 | 0.64 | 0.74 | 0.83 | 0.92 | 50 |  |
| 55 | 3.7 | 0.06 | 0.11 | 0.22 | 0.34 | 0.45 | 0.56 | 0.67 | 0.78 | 0.98 | 1.01 | 1.12 | 55 |  |
| 60 | 4.0 | 0.07 | 0.13 | 0.26 | 0.40 | 0.53 | 0.66 | 0.79 | 0.92 | 1.06 | 1.19 | 1.32 | 60 |  |
| 65 | 4.4 | 0.08 | 0.15 | 0.31 | 0.46 | 0.62 | 0.77 | 0.92 | 1.08 | 1.232 | 1.39 | 1.54 | 65 |  |
| 70 | 4.7 | 0.09 | 0.18 | 0.36 | 0.53 | 0.71 | 0.89 | 1.07 | 1.25 | 1.42 | 1.60 | 1.78 | 70 |  |
| 75 | 5.0 | 0.10 | 0.20 | 0.41 | 0.61 | 0.82 | 1.02 | 1.22 | 1.43 | 1.63 | 1.84 | 2.04 | 75 |  |
| 80 | 5.4 | 0.12 | 0.23 | 0.46 | 0.70 | 0.93 | 1.16 | 1.40 | 1.62 | 1.86 | 2.09 | 2.32 | 80 |  |
| 85 | 5.7 | 0.13 | 0.26 | 0.52 | 0.79 | 1.05 | 1.31 | 1.57 | 1.83 | 2.10 | 2.36 | 2.62 | 85 |  |
| 90 | 6.0 | 0.15 | 0.29 | 0.59 | 0.88 | 1.18 | 1.47 | 1.76 | 2.06 | 2.35 | 2.65 | 2.94 | 90 |  |
| 95 | 6.4 | 0.17 | 0.33 | 0.66 | 0.98 | 1.31 | 1.64 | 1.97 | 2.30 | 2.62 | 2.95 | 3.28 | 95 |  |
| 100 | 6.7 | 0.18 | 0.36 | 0.73 | 1.09 | 1.46 | 1.82 | 2.18 | 2.55 | 2.91 | 3.28 | 3.64 | 100 |  |

### *TABLE A1.6* ***Pipe Friction Loss Chart: Copper Pipe—Type K C=140***

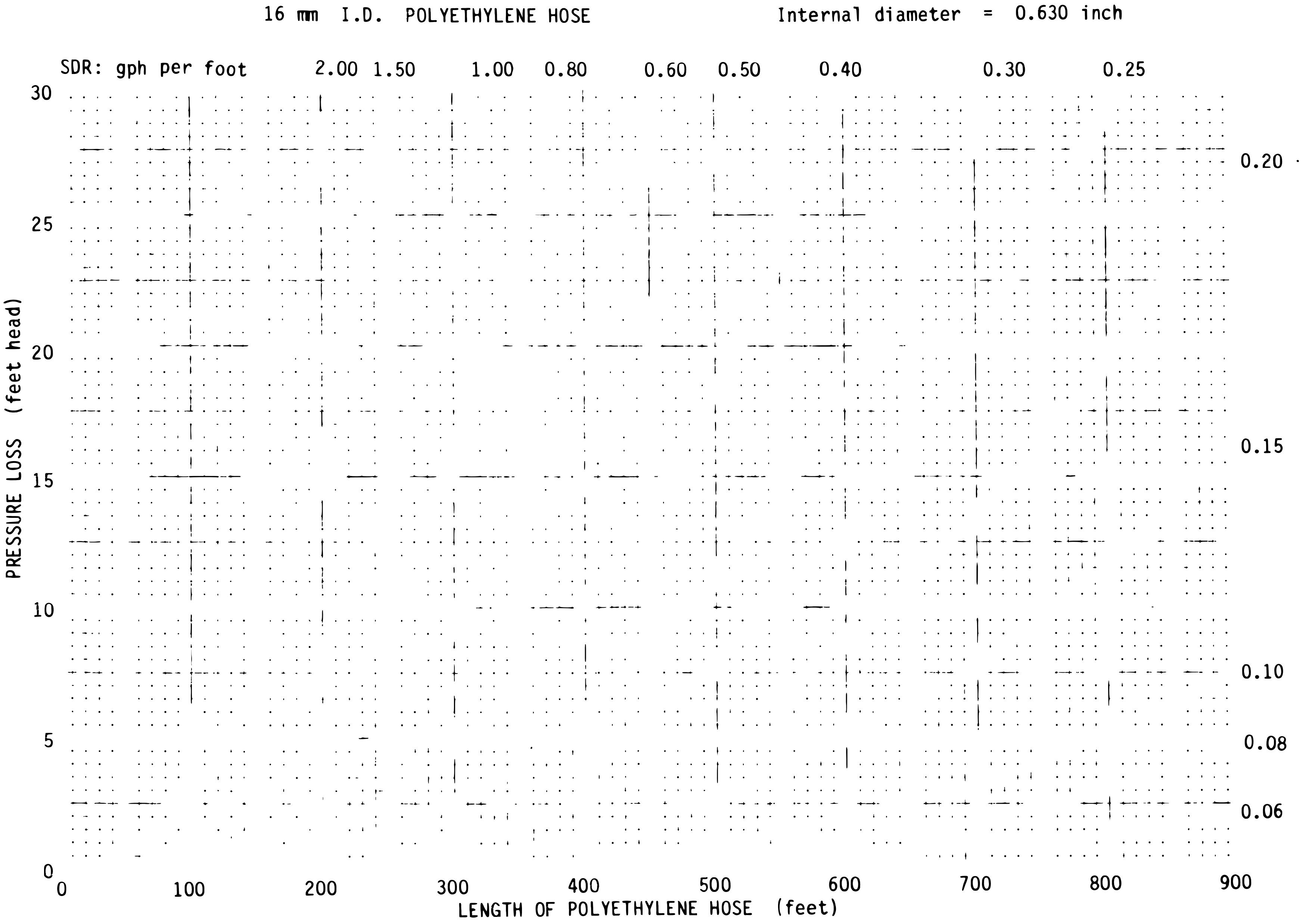
| GPM | Velocity (ft/sec) | 5 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 | GPM | Pipe Size |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  | PSI LOSS PER PIPE LENGTH (FT) |  |  |  |  |  |  |  |  |  |  |  |  |
| 1 | 1.5 | 0.06 | 0.12 | 0.24 | 0.36 | 0.48 | 0.60 | 0.72 | 0.84 | 0.96 | 1.08 | 1.20 | 1 | **½″** (0.527″ inside diameter) |
| 2 | 2.9 | 0.22 | 0.43 | 0.87 | 1.30 | 1.74 | 2.17 | 2.60 | 3.04 | 3.47 | 3.91 | 4.34 | 2 |  |
| 3 | 4.4 | 0.46 | 0.92 | 1.83 | 2.75 | 3.66 | 4.58 | 5.50 | 6.41 | 7.33 | 8.24 | 9.16 | 3 |  |
| 4 | 5.9 | 0.79 | 1.57 | 3.14 | 4.70 | 6.27 | 7.84 | 9.41 | 10.98 | 12.54 | 14.11 | 15.68 | 4 |  |
| 1 | 0.7 | 0.01 | 0.02 | 0.04 | 0.06 | 0.08 | 0.10 | 0.12 | 0.14 | 0.16 | 0.18 | 0.20 | 1 | **¾″** (0.745″ inside diameter) |
| 2 | 1.5 | 0.04 | 0.08 | 0.15 | 0.23 | 0.30 | 0.38 | 0.46 | 0.53 | 0.61 | 0.68 | 0.76 | 2 |  |
| 3 | 2.2 | 0.08 | 0.16 | 0.33 | 0.49 | 0.66 | 0.82 | 0.98 | 1.15 | 1.31 | 1.48 | 1.64 | 3 |  |
| 4 | 2.9 | 0.14 | 0.28 | 0.56 | 0.83 | 1.11 | 1.39 | 1.67 | 1.95 | 2.22 | 2.50 | 2.78 | 4 |  |
| 5 | 3.7 | 0.21 | 0.42 | 0.84 | 1.26 | 1.68 | 2.10 | 2.52 | 2.94 | 3.36 | 3.78 | 4.20 | 5 |  |
| 6 | 4.4 | 0.30 | 0.59 | 1.18 | 1.77 | 2.36 | 2.95 | 3.54 | 4.13 | 4.72 | 5.31 | 5.90 | 6 |  |
| 7 | 5.2 | 0.39 | 0.78 | 1.57 | 2.35 | 3.14 | 3.92 | 4.70 | 5.49 | 6.27 | 7.06 | 7.84 | 7 |  |
| 8 | 5.9 | 0.50 | 1.00 | 2.01 | 3.01 | 4.02 | 5.02 | 6.02 | 7.03 | 8.03 | 9.04 | 10.04 | 8 |  |
| 9 | 6.6 | 0.63 | 1.25 | 2.50 | 3.75 | 5.00 | 6.25 | 7.50 | 8.75 | 10.00 | 11.25 | 12.50 | 9 |  |

*TABLE A1.6* ***(continued)***

| | | PSI LOSS PER PIPE LENGTH (FT) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **GPM** | **Velocity (ft/sec)** | **5** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** | **90** | **100** | **GPM** | **Pipe Size** |
| 4 | 1.7 | 0.04 | 0.07 | 0.14 | 0.20 | 0.27 | 0.34 | 0.41 | 0.48 | 0.54 | 0.61 | 0.68 | 4 | **1″** (0.995″ inside diameter) |
| 5 | 2.1 | 0.05 | 0.10 | 0.20 | 0.31 | 0.41 | 0.51 | 0.61 | 0.71 | 0.82 | 0.92 | 1.02 | 5 | |
| 6 | 2.5 | 0.07 | 0.14 | 0.29 | 0.43 | 0.58 | 0.72 | 0.86 | 1.01 | 1.15 | 1.30 | 1.44 | 6 | |
| 7 | 2.9 | 0.10 | 0.19 | 0.38 | 0.58 | 0.77 | 0.96 | 1.15 | 1.34 | 1.54 | 1.73 | 1.92 | 7 | |
| 8 | 3.3 | 0.12 | 0.24 | 0.49 | 0.73 | 0.98 | 1.22 | 1.46 | 1.71 | 1.95 | 2.20 | 2.44 | 8 | |
| 9 | 3.7 | 0.15 | 0.30 | 0.61 | 0.91 | 1.22 | 1.52 | 1.82 | 2.13 | 2.43 | 2.74 | 3.04 | 9 | |
| 10 | 4.1 | 0.19 | 0.37 | 0.74 | 1.11 | 1.48 | 1.85 | 2.22 | 2.59 | 2.96 | 3.33 | 3.70 | 10 | |
| 11 | 4.5 | 0.22 | 0.44 | 0.88 | 1.32 | 1.76 | 2.20 | 2.64 | 3.08 | 3.52 | 3.96 | 4.40 | 11 | |
| 12 | 5.0 | 0.26 | 0.52 | 1.03 | 1.55 | 2.06 | 2.58 | 3.10 | 3.61 | 4.13 | 4.64 | 5.16 | 12 | |
| 13 | 5.4 | 0.30 | 0.60 | 1.20 | 1.79 | 2.39 | 2.99 | 3.59 | 4.19 | 4.78 | 5.38 | 5.98 | 13 | |
| 14 | 5.8 | 0.35 | 0.69 | 1.38 | 2.06 | 2.75 | 3.44 | 4.13 | 4.82 | 5.50 | 6.19 | 6.88 | 14 | |
| 15 | 6.2 | 0.39 | 0.78 | 1.56 | 2.34 | 3.12 | 3.90 | 4.68 | 5.46 | 6.24 | 7.02 | 7.80 | 15 | |
| 16 | 6.6 | 0.44 | 0.88 | 1.76 | 2.63 | 3.51 | 4.39 | 5.27 | 6.15 | 7.02 | 7.90 | 8.78 | 16 | |
| 8 | 2.1 | 0.04 | 0.07 | 0.15 | 0.22 | 0.30 | 0.37 | 0.44 | 0.52 | 0.59 | 0.67 | 0.74 | 8 | **1¼″** (1.245″ inside diameter) |
| 10 | 2.6 | 0.06 | 0.11 | 0.22 | 0.34 | 0.45 | 0.56 | 0.67 | 0.78 | 0.90 | 1.01 | 1.12 | 10 | |
| 12 | 3.2 | 0.08 | 0.16 | 0.32 | 0.47 | 0.63 | 0.79 | 0.95 | 1.11 | 1.26 | 1.42 | 1.58 | 12 | |
| 14 | 3.7 | 0.11 | 0.21 | 0.41 | 0.62 | 0.82 | 1.03 | 1.24 | 1.44 | 1.65 | 1.85 | 2.06 | 14 | |
| 16 | 4.3 | 0.14 | 0.27 | 0.53 | 0.80 | 1.06 | 1.33 | 1.60 | 1.86 | 2.13 | 2.39 | 2.66 | 16 | |
| 18 | 4.8 | 0.17 | 0.33 | 0.66 | 0.99 | 1.32 | 1.65 | 1.98 | 2.31 | 2.64 | 2.97 | 3.30 | 18 | |
| 20 | 5.3 | 0.21 | 0.41 | 0.81 | 1.22 | 1.62 | 2.03 | 2.44 | 2.84 | 3.25 | 3.65 | 4.06 | 20 | |
| 22 | 5.8 | 0.24 | 0.48 | 0.97 | 1.45 | 1.94 | 2.42 | 2.90 | 3.39 | 3.87 | 4.36 | 4.84 | 22 | |
| 24 | 6.4 | 0.29 | 0.57 | 1.14 | 1.70 | 2.27 | 2.84 | 3.41 | 3.98 | 4.54 | 5.11 | 5.68 | 24 | |
| 26 | 6.9 | 0.33 | 0.66 | 1.32 | 1.98 | 2.64 | 3.30 | 3.96 | 4.62 | 5.28 | 5.94 | 6.60 | 26 | |
| 12 | 2.2 | 0.04 | 0.08 | 0.15 | 0.23 | 0.30 | 0.38 | 0.46 | 0.53 | 0.61 | 0.68 | 0.76 | 12 | **1½″** (1.481″ inside diameter) |
| 14 | 2.6 | 0.05 | 0.10 | 0.20 | 0.30 | 0.40 | 0.50 | 0.60 | 0.70 | 0.80 | 0.90 | 1.00 | 14 | |
| 16 | 3.0 | 0.06 | 0.12 | 0.25 | 0.37 | 0.50 | 0.62 | 0.74 | 0.87 | 0.99 | 1.12 | 1.24 | 16 | |
| 18 | 3.4 | 0.08 | 0.16 | 0.31 | 0.47 | 0.62 | 0.78 | 0.94 | 1.09 | 1.25 | 1.40 | 1.56 | 18 | |
| 20 | 3.7 | 0.10 | 0.19 | 0.38 | 0.58 | 0.77 | 0.96 | 1.15 | 1.34 | 1.54 | 1.73 | 1.92 | 20 | |
| 22 | 4.1 | 0.12 | 0.23 | 0.46 | 0.69 | 0.92 | 1.15 | 1.38 | 1.61 | 1.84 | 2.07 | 2.30 | 22 | |
| 24 | 4.5 | 0.14 | 0.27 | 0.54 | 0.80 | 1.07 | 1.34 | 1.61 | 1.88 | 2.14 | 2.41 | 2.68 | 24 | |
| 26 | 4.8 | 0.16 | 0.31 | 0.62 | 0.94 | 1.25 | 1.56 | 1.87 | 2.18 | 2.50 | 2.81 | 3.12 | 26 | |
| 28 | 5.2 | 0.18 | 0.35 | 0.71 | 1.06 | 1.42 | 1.77 | 2.12 | 2.48 | 2.83 | 3.19 | 3.54 | 28 | |
| 30 | 5.6 | 0.22 | 0.41 | 0.81 | 1.22 | 1.62 | 2.03 | 2.44 | 2.84 | 3.25 | 3.65 | 4.06 | 30 | |
| 32 | 6.0 | 0.23 | 0.45 | 0.91 | 1.36 | 1.82 | 2.27 | 2.72 | 3.18 | 3.63 | 4.09 | 4.54 | 32 | |
| 34 | 6.4 | 0.26 | 0.51 | 1.01 | 1.52 | 2.02 | 2.53 | 3.04 | 3.54 | 4.05 | 4.55 | 5.06 | 34 | |
| 36 | 6.8 | 0.28 | 0.56 | 1.12 | 1.69 | 2.25 | 2.81 | 3.37 | 3.93 | 4.50 | 5.06 | 5.62 | 36 | |
| 20 | 2.1 | 0.03 | 0.05 | 0.10 | 0.15 | 0.20 | 0.25 | 0.30 | 0.35 | 0.40 | 0.45 | 0.50 | 20 | **2″** (1.959″ inside diameter) |
| 25 | 2.7 | 0.04 | 0.07 | 0.15 | 0.22 | 0.30 | 0.37 | 0.44 | 0.52 | 0.59 | 0.67 | 0.74 | 25 | |
| 30 | 3.2 | 0.05 | 0.10 | 0.21 | 0.31 | 0.42 | 0.52 | 0.62 | 0.73 | 0.83 | 0.94 | 1.04 | 30 | |
| 35 | 3.7 | 0.07 | 0.14 | 0.28 | 0.41 | 0.55 | 0.69 | 0.83 | 0.97 | 1.10 | 1.24 | 1.38 | 35 | |
| 40 | 4.3 | 0.09 | 0.18 | 0.35 | 0.53 | 0.70 | 0.88 | 1.06 | 1.23 | 1.41 | 1.58 | 1.76 | 40 | |
| 45 | 4.8 | 0.11 | 0.22 | 0.44 | 0.65 | 0.87 | 1.09 | 1.31 | 1.53 | 1.74 | 1.96 | 2.18 | 45 | |
| 50 | 5.3 | 0.14 | 0.27 | 0.53 | 0.80 | 1.06 | 1.33 | 1.60 | 1.86 | 2.13 | 2.39 | 2.66 | 50 | |
| 55 | 5.8 | 0.16 | 0.32 | 0.63 | 0.95 | 1.26 | 1.58 | 1.90 | 2.21 | 2.53 | 2.84 | 3.16 | 55 | |
| 60 | 6.3 | 0.19 | 0.37 | 0.74 | 1.12 | 1.49 | 1.86 | 2.23 | 2.60 | 2.98 | 3.35 | 3.72 | 60 | |
| 65 | 6.8 | 0.22 | 0.43 | 0.86 | 1.28 | 1.71 | 2.14 | 2.57 | 3.00 | 3.42 | 3.85 | 4.28 | 65 | |
| 30 | 2.1 | 0.02 | 0.04 | 0.07 | 0.11 | 0.14 | 0.18 | 0.22 | 0.25 | 0.29 | 0.32 | 0.36 | 30 | **2½″** (2.435″ inside diameter) |
| 40 | 2.8 | 0.03 | 0.06 | 0.12 | 0.19 | 0.25 | 0.31 | 0.37 | 0.43 | 0.50 | 0.56 | 0.62 | 40 | |
| 50 | 3.5 | 0.05 | 0.09 | 0.19 | 0.28 | 0.38 | 0.47 | 0.56 | 0.66 | 0.75 | 0.85 | 0.94 | 50 | |
| 60 | 4.1 | 0.07 | 0.13 | 0.26 | 0.39 | 0.52 | 0.65 | 0.78 | 0.91 | 1.04 | 1.17 | 1.30 | 60 | |
| 70 | 4.8 | 0.09 | 0.17 | 0.35 | 0.52 | 0.70 | 0.87 | 1.04 | 1.22 | 1.39 | 1.57 | 1.74 | 70 | |
| 80 | 5.5 | 0.11 | 0.22 | 0.44 | 0.66 | 0.88 | 1.10 | 1.32 | 1.54 | 1.76 | 1.98 | 2.20 | 80 | |
| 90 | 6.2 | 0.14 | 0.28 | 0.55 | 0.83 | 1.10 | 1.38 | 1.66 | 1.93 | 2.21 | 2.48 | 2.76 | 90 | |
| 100 | 6.9 | 0.17 | 0.33 | 0.67 | 1.00 | 1.34 | 1.67 | 2.00 | 2.34 | 2.67 | 3.01 | 3.34 | 100 | |

|  |  | **PSI LOSS PER PIPE LENGTH (FT)** |  |  |  |  |  |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **GPM** | **Velocity (ft/sec)** | **5** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** | **90** | **100** | **GPM** | **Pipe Size** |
| 60 | 2.9 | 0.03 | 0.06 | 0.11 | 0.17 | 0.22 | 0.28 | 0.33 | 0.39 | 0.44 | 0.50 | 0.55 | 60 | **3″** (2.907″ inside diameter) |
| 70 | 3.4 | 0.04 | 0.07 | 0.15 | 0.22 | 0.30 | 0.37 | 0.44 | 0.52 | 0.59 | 0.67 | 0.74 | 70 |  |
| 80 | 3.9 | 0.05 | 0.09 | 0.19 | 0.28 | 0.38 | 0.47 | 0.56 | 0.66 | 0.75 | 0.85 | 0.94 | 80 |  |
| 90 | 4.4 | 0.06 | 0.12 | 0.23 | 0.35 | 0.46 | 0.58 | 0.70 | 0.81 | 0.93 | 1.04 | 1.16 | 90 |  |
| 100 | 4.8 | 0.07 | 0.14 | 0.28 | 0.42 | 0.56 | 0.70 | 0.84 | 0.98 | 1.12 | 1.26 | 1.40 | 100 |  |
| 110 | 5.3 | 0.09 | 0.17 | 0.34 | 0.50 | 0.67 | 0.84 | 1.01 | 1.18 | 1.34 | 1.51 | 1.68 | 110 |  |
| 120 | 5.8 | 0.10 | 0.20 | 0.40 | 0.59 | 0.79 | 0.99 | 1.19 | 1.39 | 1.58 | 1.78 | 1.98 | 120 |  |
| 130 | 6.3 | 0.01 | 0.23 | 0.46 | 0.69 | 0.92 | 1.15 | 1.38 | 1.61 | 1.84 | 2.07 | 2.30 | 130 |  |
| 140 | 6.8 | 0.13 | 0.26 | 0.52 | 0.79 | 1.05 | 1.31 | 1.57 | 1.83 | 2.10 | 2.36 | 2.62 | 140 |  |
| 100 | 2.8 | 0.02 | 0.04 | 0.07 | 0.11 | 0.14 | 0.18 | 0.22 | 0.25 | 0.29 | 0.32 | 0.36 | 100 | **4″** (3.857″ inside diameter) |
| 110 | 3.0 | 0.02 | 0.04 | 0.08 | 0.12 | 0.16 | 0.21 | 0.25 | 0.29 | 0.33 | 0.37 | 0.41 | 110 |  |
| 120 | 3.3 | 0.03 | 0.05 | 0.10 | 0.14 | 0.19 | 0.24 | 0.29 | 0.34 | 0.38 | 0.43 | 0.48 | 120 |  |
| 130 | 3.6 | 0.03 | 0.06 | 0.11 | 0.17 | 0.22 | 0.28 | 0.34 | 0.39 | 0.45 | 0.50 | 0.56 | 130 |  |
| 140 | 3.9 | 0.04 | 0.07 | 0.13 | 0.20 | 0.26 | 0.33 | 0.40 | 0.46 | 0.53 | 0.59 | 0.66 | 140 |  |
| 150 | 4.1 | 0.04 | 0.07 | 0.15 | 0.22 | 0.30 | 0.37 | 0.44 | 0.52 | 0.59 | 0.67 | 0.74 | 150 |  |
| 160 | 4.4 | 0.04 | 0.08 | 0.17 | 0.25 | 0.34 | 0.42 | 0.50 | 0.59 | 0.67 | 0.76 | 0.84 | 160 |  |
| 170 | 4.7 | 0.05 | 0.09 | 0.19 | 0.28 | 0.38 | 0.47 | 0.56 | 0.66 | 0.75 | 0.85 | 0.94 | 170 |  |
| 180 | 4.9 | 0.05 | 0.10 | 0.21 | 0.31 | 0.42 | 0.52 | 0.62 | 0.73 | 0.83 | 0.94 | 1.04 | 180 |  |
| 190 | 5.2 | 0.06 | 0.11 | 0.23 | 0.34 | 0.46 | 0.57 | 0.68 | 0.80 | 0.91 | 1.03 | 1.14 | 190 |  |
| 200 | 5.5 | 0.07 | 0.13 | 0.25 | 0.38 | 0.50 | 0.63 | 0.76 | 0.88 | 1.01 | 1.13 | 1.26 | 200 |  |
| 210 | 5.8 | 0.07 | 0.14 | 0.28 | 0.41 | 0.55 | 0.69 | 0.83 | 0.97 | 1.10 | 1.24 | 1.38 | 210 |  |
| 220 | 6.1 | 0.08 | 0.15 | 0.30 | 0.45 | 0.60 | 0.75 | 0.90 | 1.05 | 1.20 | 1.35 | 1.50 | 220 |  |
| 230 | 6.3 | 0.08 | 0.16 | 0.32 | 0.49 | 0.65 | 0.81 | 0.97 | 1.13 | 1.30 | 1.46 | 1.62 | 230 |  |
| 240 | 6.6 | 0.09 | 0.17 | 0.35 | 0.52 | 0.70 | 0.87 | 1.04 | 1.22 | 1.39 | 1.57 | 1.74 | 240 |  |
| 250 | 6.9 | 0.10 | 0.19 | 0.38 | 0.56 | 0.75 | 0.94 | 1.13 | 1.32 | 1.50 | 1.69 | 1.88 | 250 |  |

TABLE A1.7 **Drip Tubing Pressure Loss Curves**



# Appendix II

## Irrigation Installation Specifications

### Division 1-General Requirements

1. CONTRACTOR QUALIFICATIONS: The system shall be installed by an experienced firm, regularly engaged in irrigation installation. Contractor shall have a minimum of three (3) years of successful experience with installations. The contractor can be asked to submit evidence of these qualifications. The Owner's Authorized Representative will reject contractors who cannot show evidence of these qualifications.

2. PROTECTION: The irrigation contractor shall protect all materials and work against injury from any cause and shall provide and maintain all necessary safeguards for the protection of the public. He shall be held responsible for any damage or injury to person or property that may occur as a result of his negligence in the prosecution of the work.

   The irrigation contractor shall exercise care in digging and other work so as not to damage existing work, including underground cables and pipes. Should such overhead or underground obstructions be encountered that interfere with his work, the Owner's Authorized Representative shall be consulted. The contractor shall be responsible for the immediate

   repair of any damage caused by his work. This also applies to lawn areas.

3. SUBMITTALS: The contractor shall be responsible for the following material and meeting.

3.1 AS-BUILT DRAWING-During the course of the installation, the irrigation contractor shall record all changes made to the irrigation system during installation. Changes shall be carefully drawn in red line on a print of the irrigation system drawing. Upon completion of the installation, this red line drawing shall be given to the Owner's Authorized Representative for use as an as-built irrigation drawing.

3.2 MANAGEMENT INSTRUCTIONS-After the irrigation system is installed and approved, the Owner's Authorized Representative shall be instructed in the complete operation and maintenance of the system by the contractor. The contractor shall furnish five (5) copies of an Irrigation System Management Manual prepared by the system installer.

4. PRECONSTRUCTION SITE REVIEW: The irrigation contractor shall schedule an on-site preconstruction conference with the owner and the owner's Authorized Representative prior to beginning the installation of the irriga tion system. The contractor shall be responsible for coordinating this work with all other parties involved with the job such as the general contractor, planting contractor, paving, electrical, and so on in order to eliminate unnecessary complication during the installation of his work.

## Division 2-Site Work

### Part 1: General

1.1 SCOPE OF WORK: The contractor shall provide all labor, materials, and equipment for a complete operating underground irrigation system as specified herein and as shown on the drawings. During construction and storage, the contractor shall protect materials from damage and prolonged exposure to sunlight and heat. Work and materials shall conform to all current state and local laws, rules, codes, or regulations as may be applicable to this work.

1.2 QUALITY CONTROL: The Owner's Authorized Representative shall have the right, at any stage of the operation, to inspect and reject any and all work and materials that, in his opinion, do not meet with the requirements of the contract. Such rejected material shall be removed from the site and approved material substituted in its place. The contractor shall maintain quality control for all materials, equipment, and construction operations. Inspections that help ensure quality control include the following:

A. Checking material conformance to requirements

B. Discussing methods of installation, operation, and maintenance, as well as items to be accomplished during installation, with the Owner's Authorized Representative

C. Coordinating sleeving installation with paving contractor

D. Coordinating work with landscape contractor

E. Coordinating work with schedules and commitments of owner

As work progresses, inspection shall be conducted on

A. Head and equipment locations

B. Trenching depth, width, and location

C. Proper solvent-welding of piping and fittings

D. Location and installation of valves E. Backfilling

F. Whether maintenance and cleanup is performed immediately after installation

G. Whether installation is coordinated with landscape contractor to ensure an adequate water supply beginning continuously within 3 days after plant installation

1.3 GUARANTY: Materials, equipment, and workmanship furnished under this contract shall be guaranteed for a period of one (1) year from the date of acceptance. The guaranty shall include but not be limited to the following:

A. Filling and repairing depressions and replacing plantings due to settlement of irrigation trenches for one (1) year following acceptance of project.

B. Ensuring that the irrigation system can be adequately drained to protect from freeze damage.

C. Ensuring that the system has been adjusted to supply proper water coverage of areas designed to receive water.

D. Existing sod or grass damaged as a result of irrigation system installation will be replaced.

Upon receipt of notice from the Owner or his Authorized Representative of failure of any part of the guaranteed equipment, material, or workmanship during the guaranty period, the affected part or parts shall be replaced promptly with new parts, by and at the expense of the contractor. The contractor shall acknowledge his responsibility under these guaranty provisions by letter, stating that the equipment, materials, and workmanship referred to herein are guaranteed and stating the inclusive dates of the guaranty period.

All work under this contract shall not be finally accepted until expiration of the guaranty period. During this period, the irrigation contractor is responsible for the work until final acceptance.

1.4 APPLICABLE SPECIFICATIONS: The specifications listed below are referred to in the text and define material quality as specified herein. American Society for Testing and Materials

| | |
|---|---|
| D 1785-83 | Poly(Vinyl Chloride) (PVC) Plastic Pipe, Schedules 40, 80, and 120 |
| D 2466-78 | Socket-Type Poly(Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 40 |
| D 2241-84 | Poly(Vinyl Chloride) (PVC) Pressure-Related Pipe |
| D 2885-83 | Making Solvent-Cemented Joints with Poly(Vinyl Chloride) (PVC) Pipe and Fittings |

### Part 2: Materials

2.1 PVC Pipe: Below-ground pipe shall be poly(vinyl chloride) (PVC) pipe conforming to ASTM Specification D 1785, Schedule 40, or it may be PVC pipe conforming to ASTM D 2241, Class 200.

2.2 PVC Fittings: All PVC fittings shall be Schedule 40, Type 1, NSF Approved conforming to the ASTM D 2466 requirements (except as noted on the drawing).

2.3 PVC Sleeves: All crossings under paved areas for water line and wire runs shall be Schedule 40 PVC pipe conforming to the ASTM-D 1785 requirements.

2.4 Sprinkler Heads: Sprinkler heads shall conform to requirements shown on drawings. Each type of head shall be the product of a single manufacturer. Contractor shall provide the appropriate nozzle for each sprinkler head.

2.5 Automatic Circuit Valves: All valves shall be as indicated on the working drawings.

2.6 Drain Valves: All drain valves shall be of a globe configuration and constructed of brass with a rubberized seat.

2.7 Controller: The controller shall have dual programs and shall be a microprocessorbased/ microelectronics solid-state type, capable of fully automatic or manual operation of the system. It shall be housed in a wall-mountable, heavy-duty molded plastic, weatherproof, lockable cabinet.

The controller shall operate on a minimum of 117 volts AC power input and be capable of operating 24-volt AC electric remote control valves. The controller shall have a reset circuit breaker to protect it from power overload. Each station shall have the capability of being programmed to operate for 1 to 99 minutes in 1-minute increments or 0.1 to 9.9 hours in 0.1-hour increments. The controller shall have two independent programs with three automatic starts per day for each station. Each station on the controller shall be assigned to either or both programs. The con

troller shall have 14-day programming for flexibility in programming day starts.

During operation, the controller shall provide a readout indicating station in operation and time remaining. The controller shall be capable of being operated manually at any time. A manual "single-station" operation for programmed time or new time setting shall be possible without affecting the original program.

The controller shall have a factory preset backup program for standby operation (in the event of a program loss) and a rechargeable battery backup to maintain program during a power loss.

**Part 3: Installation**

3.1 TRENCHING AND BACKFILLING: The contractor shall exercise caution when working near existing utilities and structures. Trenches shall be excavated to the required grades for pipe installation, and they shall be straight and uniformly graded. In any areas where rock or unyielding material larger than 3 inches (76 mm) is encountered during trench excavation, trenches shall be overexca- vated a minimum of 6 inches (152 mm) and backfilled to the required grade. Backfill material shall be soil free of rock, gravel larger than 2 inches (51 min), organic material, or debris. Backfill shall be compacted by uniformly tamping the backfill in loose lift thicknesses not exceeding 8 inches (203 mm) to a density approximately equal to the adjacent undisturbed soil. Do not cover pipe joints or fittings until inspected and approved by the Owner's Authorized Representative.

3.2 GRADING AND DRAINAGE OF PIPE: Piping shall be graded so it can be completely drained in preparation for freezing weather. Slope pipe to low points as shown on the working drawings and install a brass, globestyle drain valve. The valve shall be surrounded by a cubic foot (0.03 cubic meter) of graded gravel for drainage.

3.3 INSTALLATION OF PLASTIC PIPE: The contractor shall install plastic pipe as shown on the drawings and in a manner to provide for expansion and contraction as recommended by the manufacturer. Pipe shall be snaked from one side to the other in the trenches. Unless otherwise indicated on drawings the contractor shall install mainlines and lateral lines connecting rotor pop-up sprinklers with a minimum cover of 18 inches (457 mm) based on finished grade. Remaining lateral lines shall be installed with a minimum of 8 inches (203 mm) of cover based on finish grade. Pipe shall be installed under driveways or parking areas in Schedule 40 sleeves at least 12 inches (305 mm) below finish grade or as shown on drawings. No sprinkler head shall be located closer than 12 inches (305 mm) from a building foundation. Heads immediately adjacent to walks or curbs shall be

inch (3 mm) below top of walk or curb and have a 1-inch (25-mm) clearance between the head and the walk or curb.

3.4 MAKING SOLVENT-CEMENT JOINTS: Plastic pipe shall be cut square and burrs removed at cut ends prior to installation so unobstructed flow will result. Solvent-cemented joints shall be made in the following manner:

A. Clean each end of the pipe and fitting with a clean, dry cloth or paper towel.

B. Apply primer in a scrubbing motion to inside of the fitting socket.

C. Apply primer in the same manner to the male end of the pipe.

D. Again brush the fitting socket with primer to make sure the surface has dissolved.

E. Quickly apply cement in a light coating to the male end of the pipe.

F. Next, apply cement to the inside of the fitting.

G. Apply a second coat of cement to the pipe and while both the fitting socket and the pipe end are soft and wet with cement, force the pipe into the socket all the way to the bottom of the socket. While forcing the two pieces together, turn the pipe or fitting one-quarter turn to evenly distribute cement and seal any grit that might be on the surface.

H. Once the joint is together, hold it in place for one minute after assembly so the cement can set up in the joint.

1. After assembly, wipe excess cement from around the pipe at the fitting socket. Observe the minimum curing times for solvent-cemented joints. After curing, the pipe can be placed in trenches and pressure tested.

CURE TIMES

30 minutes if the air temperature is 60° to 100° F (16° to 38° C)

1 hour if the air temperature is 40° to 60° F (4° to 16° C)

2 hours if the air temperature is 20° to 40° F (-7° to 4° C)

4 hours if the air temperature is 0° to 20° F (-18° to -7° C)

3.5 TESTING IRRIGATION LINES: Prior to the installation of the sprinkler heads, the contractor shall flush all lines with the maximum water pressure available to remove dirt and grit. Lines shall be pressure-tested at 150% of their operating pressure for leaks, and all leaks shall be repaired. This is to be done before backfilling.

3.6 SPRINKLER HEADS: Set sprinkler heads and quick coupling valves perpendicular to finish grade. Set sprinkler heads adjacent to existing walks, curbs, and other paved areas to grade. Set sprinkler heads installed in lawn areas, where turf has not yet been established, 4 inches (102 mm) above proposed finish grade. Adjust heads to proper grade when turf is sufficiently established or when turf can be walked on without appreciable harm. Such lowering or raising of heads shall be part of the original contract with no additional cost to the owner. Adjust sprinkler head pattern and radius for proper distribution and coverage.

3.7 SPRINKLER HEADS ON RISERS: All sprinklers installed in the vicinity of buildings and signs shall be adjusted to prevent water from hitting these facilities. All sprinklers shall also be adjusted to minimize overspray onto paved surfaces. All sprinkler heads on risers of 12 inches (305 mm) or more shall be rigidly secured in a plumb position using a 30-inch (762 mm) angle iron stake or a number 4 (13mm diameter) steel reinforcing bar and stainless steel clamps. All stakes shall be painted, with color to be approved by the Owner's Authorized Representative.

3.8 AUTOMATIC CIRCUIT VALVES: Automatic circuit valves shall be in a valve box positioned over the valve so that all parts of the valve can be reached for service.

3.9 VALVE BOXES: Valves shall be installed in a plastic box with a reinforced heavy-duty plastic cover. Valve box covers shall be set even with the finish grade. Contractor shall install valve boxes over 3 inches (76 mm) of gravel for drainage. Gravel shall be reasonably free from dirt and debris.

4.0 CONTROL WIRE: Place the control wire below the pipe for protection of the wire. Use the waterproof wire connectors at all splices. Wire shall be placed loosely in the trenches to allow for contraction. A 1-foot (305 mm) loop of wire shall be constructed at all corners for future repair.

4.1 CLEANING: The Irrigation Contractor shall, at all times, keep the premises, including the paved areas, free from accumulations of waste materials or rubbish caused by his employees or work.

# Appendix III

# Using the Metric System

## Introduction

Through a series of meetings attended by representatives from countries around the world, including the United States, an agreement evolved in the 1970s on a uniform set of standards for all measurement. Today, most of the world's countries use this set of standards, the Systeme internationale d'unites, abbreviated as SI in all languages. SI is an updated and expanded version of the metric system. The basic SI units that relate to irrigation design and management include meter (m) for length, kilogram (kg) for mass or weight, second (s) for time, ampere (A) for electric current, and Kelvin (K) for temperature.

## Why Use Metric Measurement

Beginning in 1992, all federal work done by U.S. government employees and consultants for federal projects is to be carried out in the metric system. This is a result of a federal executive order. The U.S. government recognizes the need to use the metric system and has begun the process through this federal mandate.

The greatest pressure for using the metric system relates to the competitiveness of U.S. products and services. Because most countries in the world use the metric system and because U.S. products and services, including design services, must compete in a world market, it is essential that the people of the United States begin to understand the metric system and express products and services in it. If the United States does not become literate in the metric system, its competitiveness will diminish. Experts on the metric system and world markets predict that all U.S. products and services will be expressed in the metric system by the year 2015.

Simplified Irrigation Design has a very large international readership, which is why this second edition uses both the traditional Imperial (U.S.) units and the SI, or metric, system. Communications from readers in Europe, Africa, and Australia, coupled with support from the publisher, have reinforced our commitment to effectively communicate irrigation design on a worldwide basis.

## Understanding the Metric System

As we mentioned previously, the SI metric units that relate to irrigation design and management include the following:

Meter (m)

Kilogram (kg)

Second (s)

Ampere (A)

Kelvin (K)

These are called the Basic SI Units. Units not listed among the Basic SI Units, such as for pressure and volume, are derived from them and will be discussed later. The most logical thing about the metric system is that its units of measurement are based on 10. Prefixes are multiples of 10 and are used with a given root word to indicate larger and smaller quantities. The prefix milli equals one thousandth (.001), centi equals one hundredth (.01), and kilo equals one thousand (1,000). Regarding length, for example, a meter is composed of 100 centimeters, or 1,000 millimeters. A millimeter is 0.001 meter; a centimeter is 0.01 meter. One meter, 100 centimeters, and 1,000 millimeters all express the same length. The SI unit of area is the square meter. A. hectare (ha;), the unit for measuring land, is 10,000 square meters.

Weight is expressed as grams, milligrams, kilograms, and metric tonnes. It takes 1,000 milligrams to equal a gram. So a milligram is 0.001 grams, and 1,000 grams equals one kilogram. One metric tonne equals 1,000 kilograms.

The SI unit for temperature is Kelvin, but for everyday use the Celsius scale is acceptable. With the Celsius scale, the freezing point of water is set at 0° and the boiling point at 100°. The temperature on a nice day is about 25° C. This same scale used to be called the centigrade scale but was renamed in honor of Swedish-born inventor and astronomer Anders Celsius.

Derived SI units are combined from the basic units of meter, kilogram, second, ampere, and Kelvin. Pressure from derived units can be expressed in several ways. The standard SI pressure is the pascal (Pa), but pressure is also expressed in different countries as newtons per square meter, kilograms per square centimeter, and bars. The pressure unit we will use is kilograms per square centimeter because that is the unit of choice expressed in the user-friendly Toro Company international catalog. Volume as expressed by liters is not an approved measurement, but it is in common use. One cubic centimeter equals a milliliter, and one liter equals 1,000 milliliters, so 1,000 cubic centimeters equals one liter.

Many products produced in the United States have both Imperial and metric units of measurement listed on them so as to be acceptable in world markets. When measurements are changed in language only, this is called soft conversion. Hard conversion is when a product is redesigned using metric units.

### Learning Approach

The best way to learn the metric system is to acquire metric-scaled equipment like tape measures, drawing scales, weighing scales, and a Celsius thermometer. Then simply force yourself to switch to metric. After a few days of struggle, my students have no problem with their newly acquired "bilingual" ability. Although the measurements in this book give both the Imperial (U.S.) unit followed by the metric unit, learning the metric system through constantly converting figures is slow and confusing.

### Practical Metric Relationships

Conversion factors are provided in Table A3.1, but let us first share some practical comparisons in relation to metric measurements. The meter as the fundamental metric unit of length is a little longer than an adult's arm and about the distance from the floor to a doorknob. A millimeter is very small, about the width of a sesame seed. A square millimeter is close to the area of a sesame seed.

The liter is often the amount of wine served at a dinner for two people (too much for me and my wife ... ), and it is slightly larger than a quart. The gram is the unit of measurement for small masses, with a nickel weighing about five grams and a penny weighing about two grams. A cubic centimeter of water weighs one gram; a liter is composed of 1,000 cubic centimeters. The kilogram, the basic unit of mass (weight), is about the weight of an average hardback book, which is to say, slightly heavier than two pounds. A milliliter is a cubic centimeter in volume, or 0.2 teaspoon. It is a small unit of measure used in medicine. An average-sized automobile is 2 meters wide and weighs about 2 tonnes.

## *TABLE A3.1* **Common Conversions**

1 inch = 25.4 millimeters (mm)
1 inch = 2.54 centimeters (cm)
1 foot = 0.30481 meter (m)
1 yard = 0.91443 meter (m)
1 mile = 1.6093 kilometers (km)
1 meter = 3.281 feet (ft)

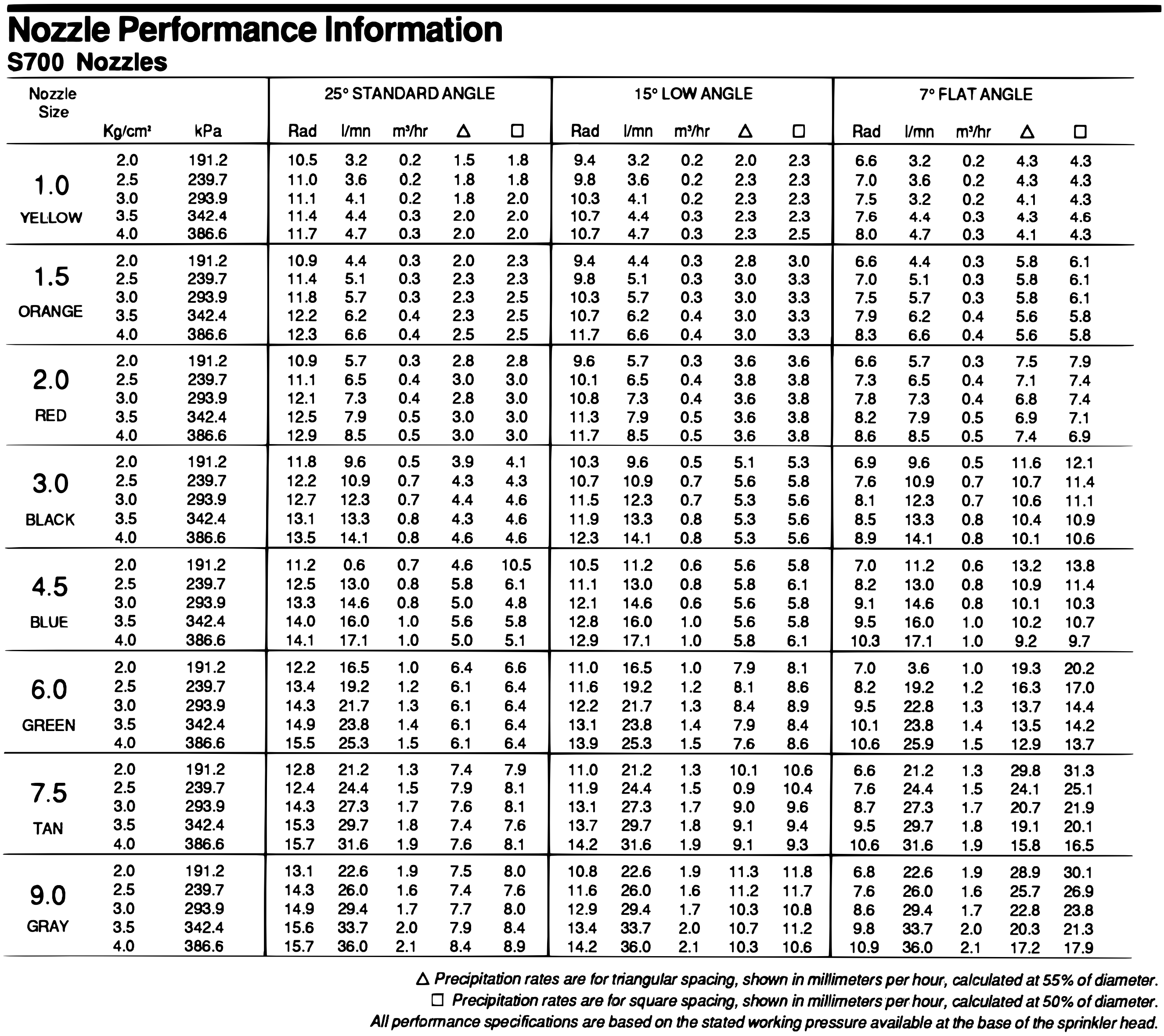
1 quart = 0.94625 liter (L)
1 gallon = 3.785 liters (L)
1 liter = 1.056 quarts (qt)
1 ounce = 28.35 grams (g)
1 gram = 0.035 ounces (oz)
1 pound = 0.45 kilogram (kg)
1 kilogram = 2.2 pounds (lb)

1 square inch = 6.5 square centimeters (cm$^2$)
1 square foot = 0.09 square meter (m$^2$)
1 psi = 0.0703 kilograms per square centimeter (kg/cm$^2$)
1 ft/sec = 0.3048 meters per second (mps)
1 hectare = 2.47 acres (ac)
1 acre = 0.405 hectares (ha)

The irrigation design process and metric explanation imparted in this second edition, coupled with a metric version of a sprinkler manufacturer's product

catalog, will enable irrigation designers to begin designing and specifying irrigation systems in metric. See Figure A3.1 for an example of a metric performance chart for a rotary irrigation head.

To convert Fahrenheit to Celsius: Take x° Fahrenheit minus 32° to get y. Multiply y by 5 and then divide the result by 9. For example, 75° Fahrenheit minus 32° equals 43°. Take 43° and multiply it by 5 to get 215 and divide 215 by 9 to get 25° Celsius ... the temperature considered to be quite pleasant.



## Nozzle Performance Information

### S700 Nozzles

| Nozzle Size | | | 25° STANDARD ANGLE | | | | | 15° LOW ANGLE | | | | | 7° FLAT ANGLE | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Kg/cm$^2$ | kPa | Rad | l/mn | m$^3$/hr | △ | □ | Rad | l/mn | m$^3$/hr | △ | □ | Rad | l/mn | m$^3$/hr | △ | □ |
| 1.0<br>YELLOW | 2.0 | 191.2 | 10.5 | 3.2 | 0.2 | 1.5 | 1.8 | 9.4 | 3.2 | 0.2 | 2.0 | 2.3 | 6.6 | 3.2 | 0.2 | 4.3 | 4.3 |
| | 2.5 | 239.7 | 11.0 | 3.6 | 0.2 | 1.8 | 1.8 | 9.8 | 3.6 | 0.2 | 2.3 | 2.3 | 7.0 | 3.6 | 0.2 | 4.3 | 4.3 |
| | 3.0 | 293.9 | 11.1 | 4.1 | 0.2 | 1.8 | 2.0 | 10.3 | 4.1 | 0.2 | 2.3 | 2.3 | 7.5 | 3.2 | 0.2 | 4.1 | 4.3 |
| | 3.5 | 342.4 | 11.4 | 4.4 | 0.3 | 2.0 | 2.0 | 10.7 | 4.4 | 0.3 | 2.3 | 2.3 | 7.6 | 4.4 | 0.3 | 4.3 | 4.6 |
| | 4.0 | 386.6 | 11.7 | 4.7 | 0.3 | 2.0 | 2.0 | 10.7 | 4.7 | 0.3 | 2.3 | 2.5 | 8.0 | 4.7 | 0.3 | 4.1 | 4.3 |
| 1.5<br>ORANGE | 2.0 | 191.2 | 10.9 | 4.4 | 0.3 | 2.0 | 2.3 | 9.4 | 4.4 | 0.3 | 2.8 | 3.0 | 6.6 | 4.4 | 0.3 | 5.8 | 6.1 |
| | 2.5 | 239.7 | 11.4 | 5.1 | 0.3 | 2.3 | 2.3 | 9.8 | 5.1 | 0.3 | 3.0 | 3.3 | 7.0 | 5.1 | 0.3 | 5.8 | 6.1 |
| | 3.0 | 293.9 | 11.8 | 5.7 | 0.3 | 2.3 | 2.5 | 10.3 | 5.7 | 0.3 | 3.0 | 3.3 | 7.5 | 5.7 | 0.3 | 5.8 | 6.1 |
| | 3.5 | 342.4 | 12.2 | 6.2 | 0.4 | 2.3 | 2.5 | 10.7 | 6.2 | 0.4 | 3.0 | 3.3 | 7.9 | 6.2 | 0.4 | 5.6 | 5.8 |
| | 4.0 | 386.6 | 12.3 | 6.6 | 0.4 | 2.5 | 2.5 | 11.7 | 6.6 | 0.4 | 3.0 | 3.3 | 8.3 | 6.6 | 0.4 | 5.6 | 5.8 |
| 2.0<br>RED | 2.0 | 191.2 | 10.9 | 5.7 | 0.3 | 2.8 | 2.8 | 9.6 | 5.7 | 0.3 | 3.6 | 3.6 | 6.6 | 5.7 | 0.3 | 7.5 | 7.9 |
| | 2.5 | 239.7 | 11.1 | 6.5 | 0.4 | 3.0 | 3.0 | 10.1 | 6.5 | 0.4 | 3.8 | 3.8 | 7.3 | 6.5 | 0.4 | 7.1 | 7.4 |
| | 3.0 | 293.9 | 12.1 | 7.3 | 0.4 | 2.8 | 3.0 | 10.8 | 7.3 | 0.4 | 3.6 | 3.8 | 7.8 | 7.3 | 0.4 | 6.8 | 7.4 |
| | 3.5 | 342.4 | 12.5 | 7.9 | 0.5 | 3.0 | 3.0 | 11.3 | 7.9 | 0.5 | 3.6 | 3.8 | 8.2 | 7.9 | 0.5 | 6.9 | 7.1 |
| | 4.0 | 386.6 | 12.9 | 8.5 | 0.5 | 3.0 | 3.0 | 11.7 | 8.5 | 0.5 | 3.6 | 3.8 | 8.6 | 8.5 | 0.5 | 7.4 | 6.9 |
| 3.0<br>BLACK | 2.0 | 191.2 | 11.8 | 9.6 | 0.5 | 3.9 | 4.1 | 10.3 | 9.6 | 0.5 | 5.1 | 5.3 | 6.9 | 9.6 | 0.5 | 11.6 | 12.1 |
| | 2.5 | 239.7 | 12.2 | 10.9 | 0.7 | 4.3 | 4.3 | 10.7 | 10.9 | 0.7 | 5.6 | 5.8 | 7.6 | 10.9 | 0.7 | 10.7 | 11.4 |
| | 3.0 | 293.9 | 12.7 | 12.3 | 0.7 | 4.4 | 4.6 | 11.5 | 12.3 | 0.7 | 5.3 | 5.6 | 8.1 | 12.3 | 0.7 | 10.6 | 11.1 |
| | 3.5 | 342.4 | 13.1 | 13.3 | 0.8 | 4.3 | 4.6 | 11.9 | 13.3 | 0.8 | 5.3 | 5.6 | 8.5 | 13.3 | 0.8 | 10.4 | 10.9 |
| | 4.0 | 386.6 | 13.5 | 14.1 | 0.8 | 4.6 | 4.6 | 12.3 | 14.1 | 0.8 | 5.3 | 5.6 | 8.9 | 14.1 | 0.8 | 10.1 | 10.6 |
| 4.5<br>BLUE | 2.0 | 191.2 | 11.2 | 0.6 | 0.7 | 4.6 | 10.5 | 10.5 | 11.2 | 0.6 | 5.6 | 5.8 | 7.0 | 11.2 | 0.6 | 13.2 | 13.8 |
| | 2.5 | 239.7 | 12.5 | 13.0 | 0.8 | 5.8 | 6.1 | 11.1 | 13.0 | 0.8 | 5.8 | 6.1 | 8.2 | 13.0 | 0.8 | 10.9 | 11.4 |
| | 3.0 | 293.9 | 13.3 | 14.6 | 0.8 | 5.0 | 4.8 | 12.1 | 14.6 | 0.6 | 5.6 | 5.8 | 9.1 | 14.6 | 0.8 | 10.1 | 10.3 |
| | 3.5 | 342.4 | 14.0 | 16.0 | 1.0 | 5.6 | 5.8 | 12.8 | 16.0 | 1.0 | 5.6 | 5.8 | 9.5 | 16.0 | 1.0 | 10.2 | 10.7 |
| | 4.0 | 386.6 | 14.1 | 17.1 | 1.0 | 5.0 | 5.1 | 12.9 | 17.1 | 1.0 | 5.8 | 6.1 | 10.3 | 17.1 | 1.0 | 9.2 | 9.7 |
| 6.0<br>GREEN | 2.0 | 191.2 | 12.2 | 16.5 | 1.0 | 6.4 | 6.6 | 11.0 | 16.5 | 1.0 | 7.9 | 8.1 | 7.0 | 3.6 | 1.0 | 19.3 | 20.2 |
| | 2.5 | 239.7 | 13.4 | 19.2 | 1.2 | 6.1 | 6.4 | 11.6 | 19.2 | 1.2 | 8.1 | 8.6 | 8.2 | 19.2 | 1.2 | 16.3 | 17.0 |
| | 3.0 | 293.9 | 14.3 | 21.7 | 1.3 | 6.1 | 6.4 | 12.2 | 21.7 | 1.3 | 8.4 | 8.9 | 9.5 | 22.8 | 1.3 | 13.7 | 14.4 |
| | 3.5 | 342.4 | 14.9 | 23.8 | 1.4 | 6.1 | 6.4 | 13.1 | 23.8 | 1.4 | 7.9 | 8.4 | 10.1 | 23.8 | 1.4 | 13.5 | 14.2 |
| | 4.0 | 386.6 | 15.5 | 25.3 | 1.5 | 6.1 | 6.4 | 13.9 | 25.3 | 1.5 | 7.6 | 8.6 | 10.6 | 25.9 | 1.5 | 12.9 | 13.7 |
| 7.5<br>TAN | 2.0 | 191.2 | 12.8 | 21.2 | 1.3 | 7.4 | 7.9 | 11.0 | 21.2 | 1.3 | 10.1 | 10.6 | 6.6 | 21.2 | 1.3 | 29.8 | 31.3 |
| | 2.5 | 239.7 | 12.4 | 24.4 | 1.5 | 7.9 | 8.1 | 11.9 | 24.4 | 1.5 | 0.9 | 10.4 | 7.6 | 24.4 | 1.5 | 24.1 | 25.1 |
| | 3.0 | 293.9 | 14.3 | 27.3 | 1.7 | 7.6 | 8.1 | 13.1 | 27.3 | 1.7 | 9.0 | 9.6 | 8.7 | 27.3 | 1.7 | 20.7 | 21.9 |
| | 3.5 | 342.4 | 15.3 | 29.7 | 1.8 | 7.4 | 7.6 | 13.7 | 29.7 | 1.8 | 9.1 | 9.4 | 9.5 | 29.7 | 1.8 | 19.1 | 20.1 |
| | 4.0 | 386.6 | 15.7 | 31.6 | 1.9 | 7.6 | 8.1 | 14.2 | 31.6 | 1.9 | 9.1 | 9.3 | 10.6 | 31.6 | 1.9 | 15.8 | 16.5 |
| 9.0<br>GRAY | 2.0 | 191.2 | 13.1 | 22.6 | 1.9 | 7.5 | 8.0 | 10.8 | 22.6 | 1.9 | 11.3 | 11.8 | 6.8 | 22.6 | 1.9 | 28.9 | 30.1 |
| | 2.5 | 239.7 | 14.3 | 26.0 | 1.6 | 7.4 | 7.6 | 11.6 | 26.0 | 1.6 | 11.2 | 11.7 | 7.6 | 26.0 | 1.6 | 25.7 | 26.9 |
| | 3.0 | 293.9 | 14.9 | 29.4 | 1.7 | 7.7 | 8.0 | 12.9 | 29.4 | 1.7 | 10.3 | 10.8 | 8.6 | 29.4 | 1.7 | 22.8 | 23.8 |
| | 3.5 | 342.4 | 15.6 | 33.7 | 2.0 | 7.9 | 8.4 | 13.4 | 33.7 | 2.0 | 10.7 | 11.2 | 9.8 | 33.7 | 2.0 | 20.3 | 21.3 |
| | 4.0 | 386.6 | 15.7 | 36.0 | 2.1 | 8.4 | 8.9 | 14.2 | 36.0 | 2.1 | 10.3 | 10.6 | 10.9 | 36.0 | 2.1 | 17.2 | 17.9 |

*△ Precipitation rates are for triangular spacing, shown in millimeters per hour, calculated at 55% of diameter.*
*□ Precipitation rates are for square spacing, shown in millimeters per hour, calculated at 50% of diameter.*
*All performance specifications are based on the stated working pressure available at the base of the sprinkler head.*

FIGURE A3.1 Rotary head performance information in metric. (Source: The Toro Company. Used with permission.)

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