IRRIGATION SYSTEM INSTALLATION AND MAINTENANCE

THE IRRIGATION ASSOCIATION

www.irrigation.org

Irrigation System Installation and Maintenance

The Irrigation Association

October 2002

The Irrigation Association

The Irrigation Association is a non-profit trade organization representing the irrigation industry at the national and international level. Its primary purpose is to provide members with comprehensive programs and services to help them keep pace with the rapidly changing technology of the industry. The IA is dedicated to serving the needs of its members and to helping shape the future of irrigation.

Since 1949, the Irrigation Association has led the way in providing professional assistance in all aspects of irrigation. Members include manufacturers, distributors, dealers, contractors, manufacturers' representatives, professional irrigation consultants, and individuals representing all segments of the industry in the agricultural and landscape/turf fields.

For further information about the Irrigation Association or any of its educational and certification programs, please contact the IA. At:

The Irrigation Association
6540 Arlington Boulevard
Falls Church, VA 22042-6638
(703) 536-7080
web site: www.irrigation.org
email: education@irrigation.org

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Introduction

Thank you for using Irrigation Association (IA) educational material in your quest for greater professionalism. We hope this book will help in your efforts. There are a few points to keep in mind, however. This manual is not intended to be an all-inclusive book on all aspects of landscape irrigation installation and maintenance. It is meant to be a workbook used in conjunction with the IA Irrigation System Installation and Maintenance classes. However, even if you don't take the class, there is plenty of good, relevant information in this manual for you to use in real-life applications. Please keep in mind that your local area may use slightly different methods in regard to system installation techniques. In addition, local codes and ordinances will always take precedence in when, where and how you install your systems.

We hope this workbook will be useful in your irrigation system challenges.

Good Luck,

Tim Wilson
Education Director
The Irrigation Association

Acknowledgments

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Chapter 1: System Overview

Installation Procedures

The following manual is for your use and study during and after class. The chapters in the book are arranged in the same order that a system is normally installed.

Depending upon the complexity of the design/installation situation, some of these steps may have to be completed in different order.

Types of Landscape/Turf Systems

Irrigation Systems

A landscape/turf irrigation system consists of a network of pipes and valves, which carry water to various types of sprinklers for distribution over the surface of the soil. Except for an occasional portable surface system used simply to start and establish a newly seeded area, which will not be under permanent irrigation, or to grow turf for rapid harvesting by commercial sod producers, virtually all systems for landscape/turf are permanently installed. While there are many types of sprinklers utilized, these systems are much the same in basic design, varying primarily in the size and type of equipment and piping used, the spacings of the sprinklers, and the method of controlling their operation. These variances are often intermixed within a single system to accommodate different types of areas on a given property. Because of this, classification is necessarily somewhat vague and often overlapping as in the case of manual or automatic control options, which are applicable to most system types.

Sprinkler System Overview

Please refer to the following diagrams. The following bulleted paragraphs refer to the diagram and its various components.

1. **The City Main.** This is where your typical city system gets its water. They are buried quite deep and can be from 2" – 36" or bigger.
2. **The Water Meter.** This is how the city tracks your water use. They range from 5/8 – 4" or bigger. We tie in for our water after the meter.
3. **Backflow Preventer.** This is a special valve that stops water from flowing backwards from the sprinkler system into the house and city potable water lines. This is required by code.
4. **The Sprinkler Main.** This is the main line It is usually under pressure 24 hours a day. It is typically the largest pipe on the system. If you break it you will get very wet!
5. **Electric Zone Valve.** This stops the mainline water from shooting out of the heads all day long. The electric zone valve only allows water to a select group of heads when energized by the controller. All piping *up-stream* of the electric valve is called mainline and all piping *down-stream* of the valve is called lateral piping.
6. **Lateral Piping.** This piping carries the water from the electric valve to the heads it is of varying sizes and is only under pressure while the valve is energized.
7. **The Sprinkler Head.** This is what waters the lawn. There are sprays, micro-sprays, rotors, bubblers and other types available. Groups of heads assigned to one electric valve are called a "zone" or "station" or "circuit."
8. **The "Hot" Wire.** All Alternating Current electric valves have 2 wires attached from the controller, a "hot" and a "common." There is a separate hot wire that goes to each individual valve. It is usually red but can be any color other than white.
9. **The Common Wire.** This is the other wire that goes to the electric valve. This wire is "common" to all the valves. There is typically only one white wire that leaves the controller and all of the valves are tied together with the one common. It is always white.
10. **The Irrigation Controller.** This is the brain of the system. Controllers can be mechanical or solid state. They can be as simple as an on and off switch or a sophisticated as a central control system using PCs, cell phones, sensors, radio or comm cables, and weather stations.

There are many other things that can be part of an irrigation system, such as:

a. Sensors
b. Drain valves
c. Rain switches
d. Manual valves
e. Air-vents
f. Fittings
g. Pumps
h. Pressure regulators
i. Filters
j. Master valves

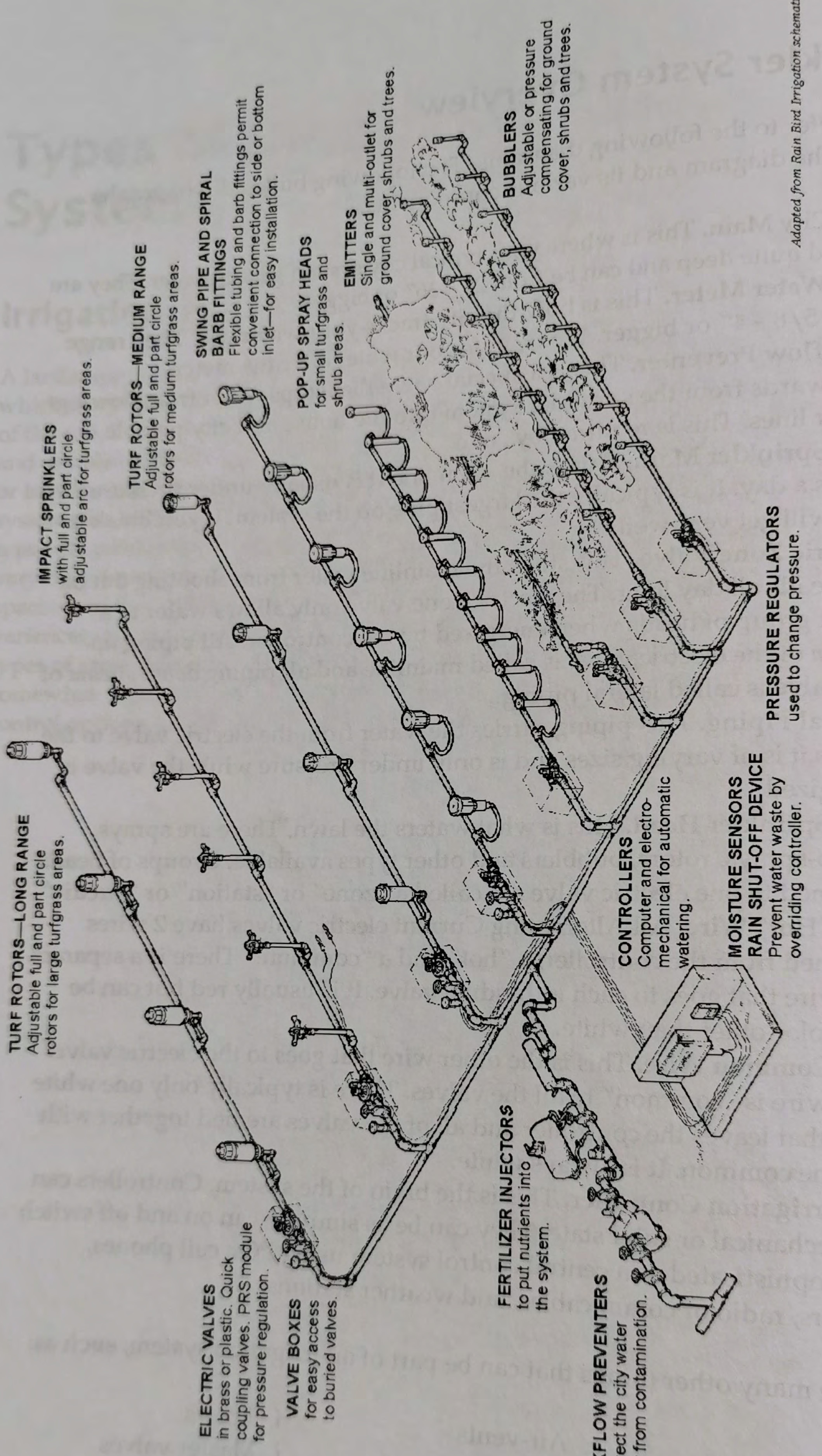


Figure 1-1: Diagram courtesy of Rainbird, Inc.

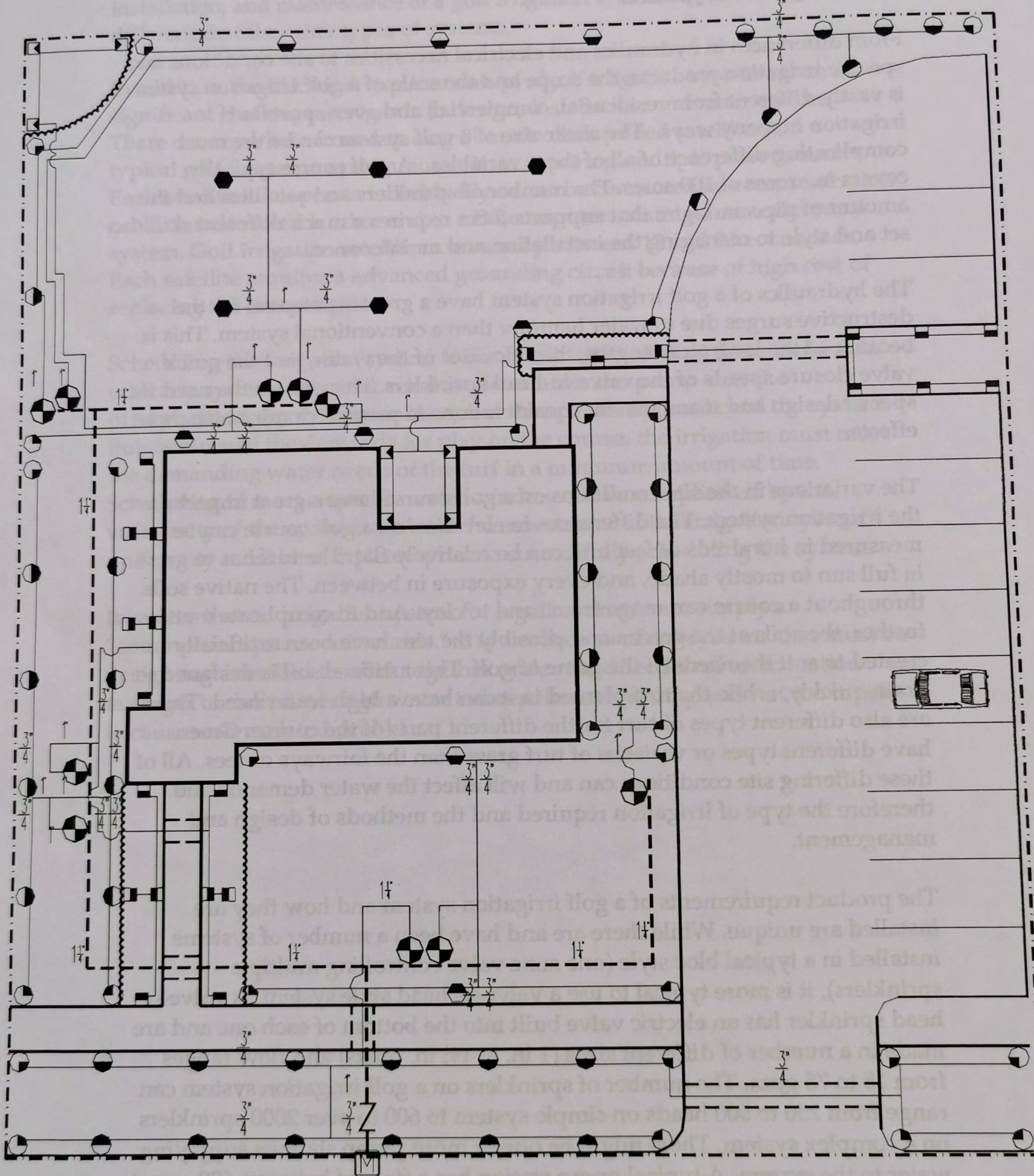


Figure 1-2: Sample irrigation plan

Golf Irrigation Systems

From differences in hydraulics and electrical necessities to site conditions and specific irrigation products, the scope and the scale of a golf irrigation system is vastly different from residential, commercial, and even sports turf irrigation in many ways. The shear size of a golf system can be the most complicating difference of all of these variables. A golf course typically covers in excess of 100 acres. The number of sprinklers and satellites and the amount of pipe and wire that supports them requires a much different skill set and style to managing the installation and maintenance.

The hydraulics of a golf irrigation system have a greater potential for the destructive surges due to water hammer than a conventional system. This is because of the long pipe lengths, the velocities of the water, and the quick valve closure speeds of the valve-in-head sprinklers. This creates the need for special design and management considerations to prevent or minimize these effects.

The variations in the site conditions on a golf course have a great impact on the irrigation system. The differences in elevation on a golf course can be measured in hundreds of feet or it can be relatively flat. The turf has to grow in full sun to mostly shade, and every exposure in between. The native soils throughout a course can range from sand to clay. And to complicate matters further, the soils at the greens and possibly the tees have been artificially created to suit the needs of the game of golf. This artificial soil is designed to drain quickly, while the turf planted in it can have a high water need. There are also different types of turf for the different parts of the course. Greens have different types or varieties of turf grass than the fairways or tees. All of these differing site conditions can and will affect the water demands and therefore the type of irrigation required and the methods of design and management.

The product requirements of a golf irrigation system and how they are installed are unique. While there are and have been a number of systems installed in a typical bloc style (one zone valve controlling multiple sprinklers), it is more typical to use a valve-in-head style system. A valve-in-head sprinkler has an electric valve built into the bottom of each one and are made in a number of different sizes (1 in. to 1½ in. inlets) and flow ranges from 15 to 75 gpm. The number of sprinklers on a golf irrigation system can range from 250 to 500 heads on simple system to 600 to over 2000 sprinklers on a complex system. There might be one or more pump stations supplying water to the system. A typical pump station has a flow of between 600 gpm to over 2500 gpm! Pipe sizes range from 2 in. to 12 in. and larger. These product differences, combined with the hydraulic differences, make the design, installation, and maintenance of a golf irrigation system significantly different that the other types of systems.

In addition, the electrical requirements of a golf irrigation system create a significant challenge in regards to design, installation, and maintenance. There are anywhere from 4 to over 30 controllers (called satellites) on a typical golf irrigation system, sometimes requiring multiple power sources. Each satellite can operate individually or can be connected by communication cable or radio to each other and to a PC computer creating a central control system. Golf irrigation satellites are usually between 12 and 96 zones each. Each satellite requires a advanced grounding circuit because of high cost of replacing the components.

Scheduling the irrigation system is the culmination of all of these factors. As with any system, the water window determines the pump size, the precipitation rate of the sprinklers, and the specific hydraulics of the system. But, because of the demands for play on the course, the irrigation must meet the demanding water needs of the turf in a minimum amount of time. Scheduling to meet a specific water window can be complicated by the uniformity of the sprinklers. A careful assessment of the irrigation system's uniformity must be completed prior to successfully scheduling the system.

It is clear that an irrigation system for a golf course is not simply a "commercial system on steroids." It is a collection of subsystems that must be design and installed to work together under the direction of an irrigation manager to deliver enough water to keep the turf healthy and not too much to cause water related problems.

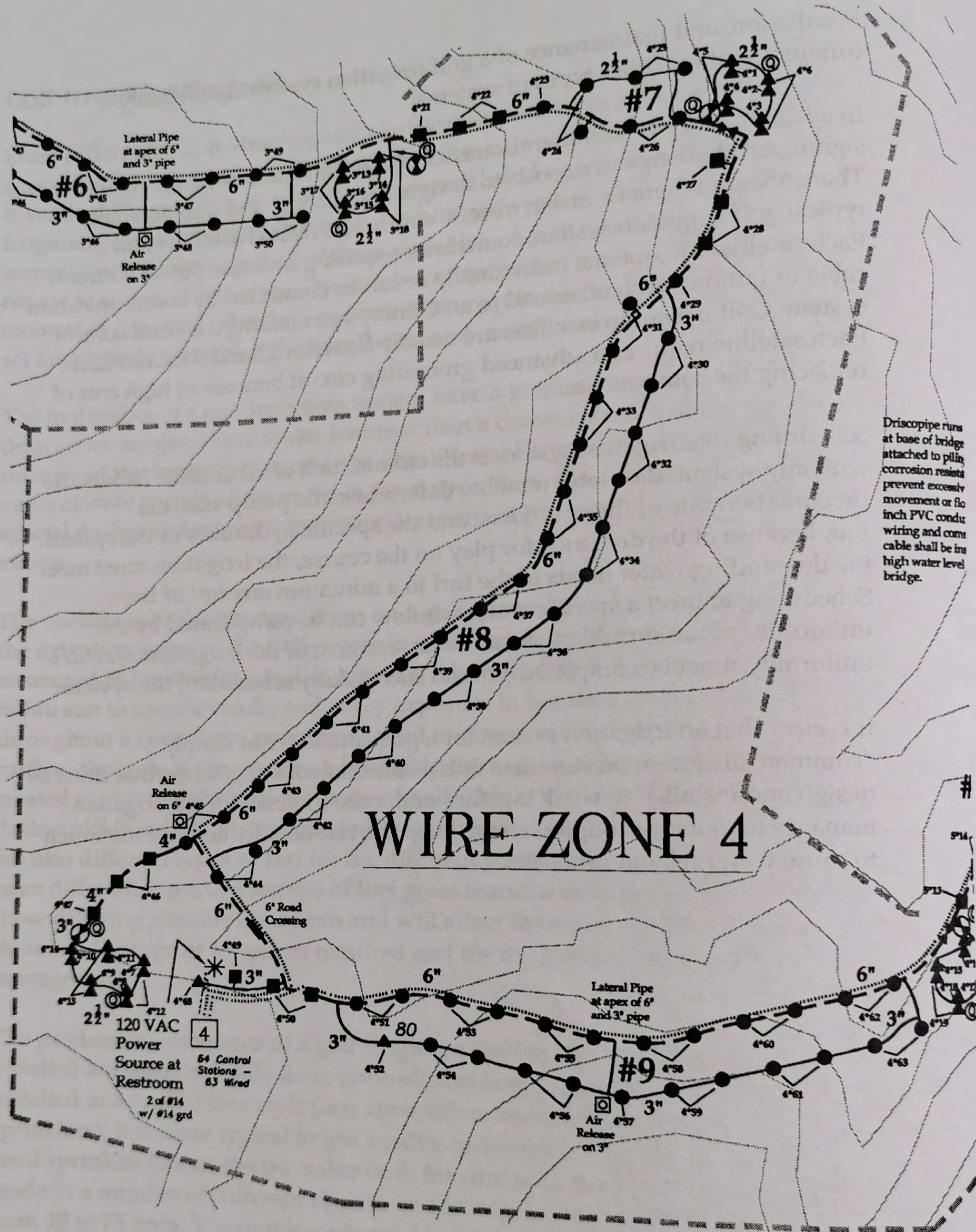


Figure 1-3: Sample golf design

Chapter 2: Select Proper Tools

Steps of Installation

1. **Select Proper Tools**
2. Perform Site Inspection
3. Read Blueprints
4. Install POC
5. Install Mainline
6. Install Field Wiring
7. Install Valves
8. Install Lateral Piping
9. Install Sprinkler Heads
10. Mount and Wire Controllers

Installation of an underground sprinkler system requires proper tools to perform a safe, quality installation. Some tools are very specific to the irrigation industry while others are more general. No matter what type of tools are required, having proper tools that are properly maintained is very important to a good installation.

Install Tools

Flat shovel
Trenching shovel
Steel Rake
Spring Rake
Pick
Rock Bar
Quick cuts (1 Inch)
Small Hacksaw
Small Screwdriver
2 pair Pipe Wrenches
Flags (Marking Heads)
Standard water key
Long standard water key
S & W key
Channel Locks
Wire Cutter/Strippers
Outlet Tester (with ground fault circuit)
Numbered Stickers
Wet/Dry Glue
Primer
Teflon Tape
Pipe Dope
Silicone Plumbers Grease (O-Rings)
Propane Torch
Solder (flux, emery cloth)
Rotor Hammer/Drill (Cordless best)
Masonry Bits (hanging controller on brick or concrete)
Long Masonry Bit (going through walls)
Extension Cord
Marking Paint
Safety Glasses
Ear Plugs
Neon Safety Tape (for taping off holes Liability)
Wet/Dry Glue
Primer
Teflon Tape
Pipe Dope
Broom
Drill & Bits
Broom
Wire Brush
Extension Cord (50 ft)
WD-40 spray
Electric clean spray
O-Rings Kit (for lost O-Rings)

Service Tools

Pitch Fork
Flat shovel
Trenching shovel
Trowel (tight spots)
Hard Rake
Soft Rake
Hammer
Calfs Paw (pulling nails)
Bilge pump
5 Gal Bucket
Head Trimmer small (18805)
Head Trimmer Large (Maxi Birds)

Pick
Come Out tool
Cut Out tools (2", 4", 6")
Driver-Drill Bits, Driver Bits
Rock Bar & Small Claw
Quick Cuts (1 inch)
Small Hacksaw
Nipple Extractor
Multi Bit Screw Driver
Screw Drivers (all sizes & types)
2 Pair Pliers
2 Pair Pipe Wrenches
Open End Wrench set
Crescent Wrench
1 Vise Grips small (broken valve handles)
Pipe Cutter (copper)
Hunter Key
Toro Key
Standard water key
Long Standard water key
Sprinkler Keys (long & short)
Street Key
Star Key
S & W Key
Hose Bib Key
Set Control Box Master Keys
Probe (finding boxes)
Garden Hose (100 ft)
Brass Hose to pipe swivel
Brass hose to hose swivel
Brass nozzle (water drill)
Channel Locks
Socket Set

Electrical Box

Multimeter
Wire cutter/Strippers
Outlet Tester (with ground fault circuit)
Numbered Stickers (for changing out controllers)
Torpedo level
Sawz ALL (Cordless best)
Saws (Hand, Hack, Wood, with Blades)
Rotor Hammer/Drill (Cordless best)
Masonry Bits (Hanging Controller on brick or concrete)
Long Masonry Bit (going through walls)
Square Headed Screw Driver Bits (you run into them)
Flashlight
Remote Unit
Locator
Marking Paint
Propane Torch
Solder (flux, emery cloth)

Safety

Safety Glasses
Ear Plugs
Dust Mask
Neon Safety Tape (for taping off holes Liability)
Flags (Marking Heads)
Hard hat
Gloves

Chapter 3: Perform Site Inspection

Steps of Installation

1. Select Proper Tools
2. **Perform Site Inspection**
3. Read Blueprints
4. Install POC
5. Install Mainline
6. Install Field Wiring
7. Install Valves
8. Install Lateral Piping
9. Install Sprinkler Heads
10. Mount and Wire Controllers

Installation Procedures

Installation of an underground sprinkler system involves arranging sprinklers, piping and controls in a system that best fits the conditions of the area to be watered; therefore, it is very important to secure complete and accurate field information of the actual site.

Obtain Site Information

Site Data Worksheet

Date
Job Number

❶ Site Information

Name ____________
Address ____________
City ______ State ____ ZIP ______
Day Phone ______ Eve. Phone ______
Storage area location ____________
Specs on File? ☐ Yes ☐ No
Permits Required? ☐ Yes ☐ No
Cost ____________

❷ Water Source

☐ City Water
☐ Well: ☐ Sub ☐ Centrifugal
HP___ psi___ gpm___
☐ Surface Water ☐ Effluent
Water Quality: ☐ Good ☐ Fair ☐ Poor
Water Purveyor ____________
Contact ____________
Phone ____________
Meter Location ____________
Meter size (in.) ____________
Service Line Type & Size ____________
Static pressure (PSI at meter) ____________
Elevation change (± feet) ____________
Backflow Regulations ____________
Water available? ☐

❸ Soil Information

☐ Sand ☐ Rock removal from site
☐ Sandy Loam ☐ Rock teeth required
☐ Loam ☐ Steep slopes
☐ Clay Loam ☐ Hard pan over shallow topsoil
☐ Clay ☐ Additional grading required

❹ Site Measurement Discrepancies

❺ Electrical Source

Type ____________
Location ____________
Voltage ____________

Notes

❻ Key Subcontractors

Company Name	Contact Name	Phone

Figure 3-1: Site Data Worksheet

Perform Pre-installation Inspection

Every job, no matter how small or large, requires an inspection before work can begin. This is especially true of new construction. The following items need to be checked before work can begin:

- **Grade:** Unless you also have the contract for grading and landscaping, it is usually someone else's job to bring the site to either rough or finished grade. Whatever your contract states, you are responsible for verifying that the site is properly graded before you begin your work. Failure to do so can result in pipe that is not installed at the correct depth, heads that are installed at the incorrect height, and numerous other problems that you will have to fix, at your own expense, later.
- **Other subcontractor's work:** Many times other subcontractors are working before you and are behind schedule. This can affect your access to the site. This can cause many job delays, safety risks and compromise installation quality. Trying to work around another subcontractor by working piece-meal in the areas that are ready can cause many problems later, when the system is eventually tied together.
- **Soil:** Not verifying soil conditions has cost many a contractor thousands of dollars. Don't guess or listen to others. Go out to the job, with a shovel, and verify soil conditions yourself. This can help you choose the correct size and type of trenching equipment, and the correct number of laborers to hand dig.
- **Point of connection (POC):** Quite often, on larger installations, someone else is responsible for the POC from which you will be getting your water. It is important to verify the POC location, size, and pressure, and to make sure there is water available for your use during installation. If the permanent POC is not available at the time you begin work, arrange for a temporary POC through the job site superintendent.
- **Site measurements:** Walk the site with a measuring wheel, tape measure and the blueprints. Verify dimensions and distances, and bring any inconsistencies to the attention of the owner's representative.
- **Talk with other subcontractors:** This is a good time to become acquainted and friendly with subcontractors with whom you will have to work closely, such as plumbers and electricians. It is also a good time to get a feel for the morale of the job and a sense of whether or not the job is on schedule. Also, you can find out from the other subcontractors the best way to get along with the jobsite superintendent and what his particular likes and dislikes may be.

- **Material and equipment storage:** Work with the superintendent to locate an area where job materials and equipment may be safely and securely stored out of the way of other subcontractors.

Special Conditions

Determine local codes that regulate the type of materials, equipment, and methods of installation. Determine what type of backflow prevention devices are required by local code, if one per system or one per circuit is required, and how they must be installed.

Chapter 4:
Reading Blueprints

Steps of Installation

1. Select Proper Tools
2. Perform Site Inspection
3. **Read Blueprints**
4. Install POC
5. Install Mainline
6. Install Field Wiring
7. Install Valves
8. Install Lateral Piping
9. Install Sprinkler Heads
10. Mount and Wire Controllers

Reading Blueprints

Reading blueprints is an important part of any irrigation installation. Understanding what the blueprint requires is imperative for any job site supervisor and foreman. Understanding a blueprint is not difficult but can be confusing for large systems with any components.

On any blueprint, there is a scale that tells you the relation between distances on the plan and distances on the project. This is very important to find and understand before moving on to any other part of the blueprint. In most cases, the irrigation plans drawn today are done with an engineering scale.

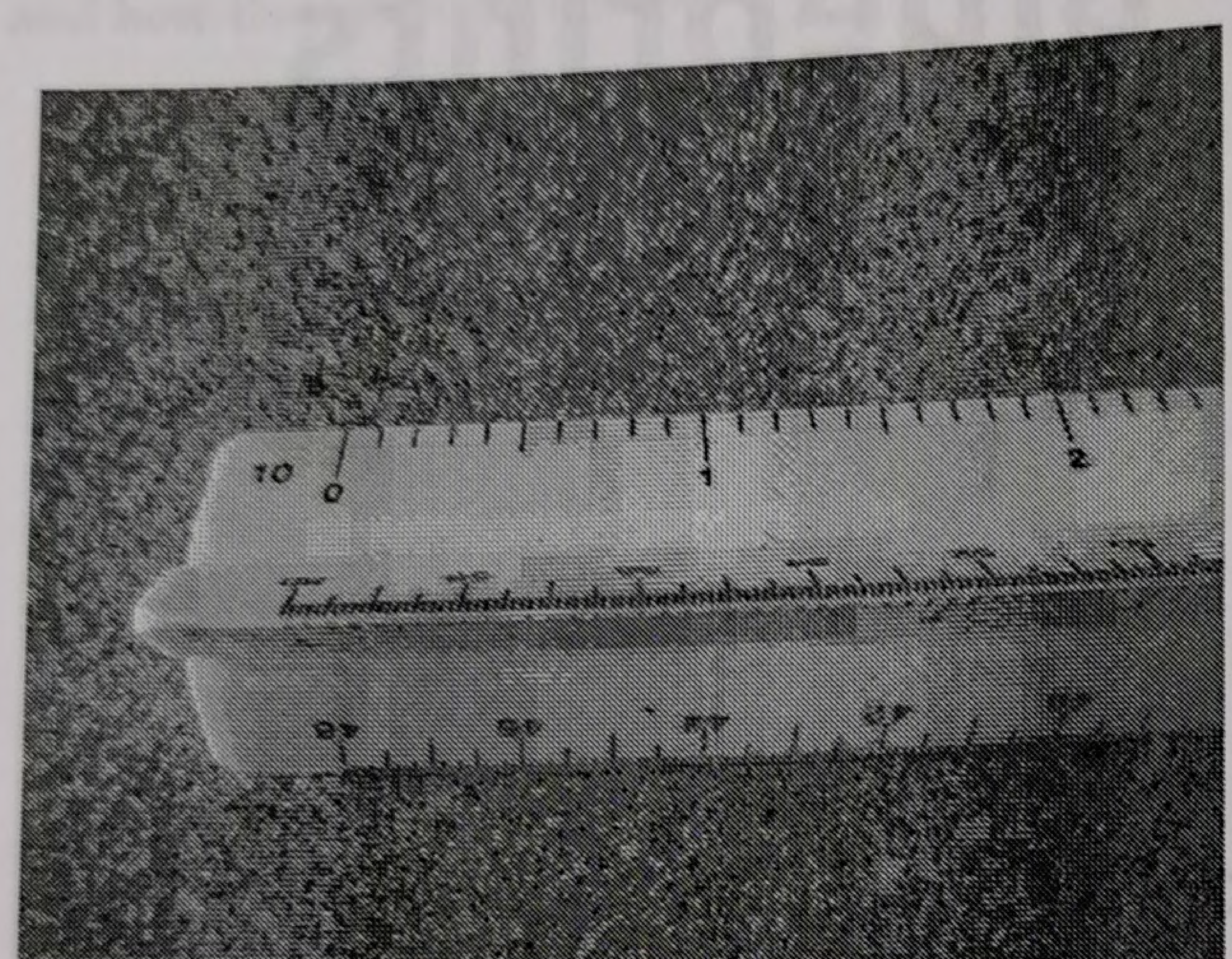


Figure 4-1: Engineer's Scale (1:20)

Engineering scales use ratios of tens to one inch. What this means is the scales used are 1 in. on the blueprint is equal to 10 ft, 20 ft, 30 ft, 40 ft or 50 on the job site. Which one of these is used will be shown on the blueprint. A blueprint will have only one scale for each sheet unless otherwise noted. Also near the scale will be the compass showing the direction of true North.

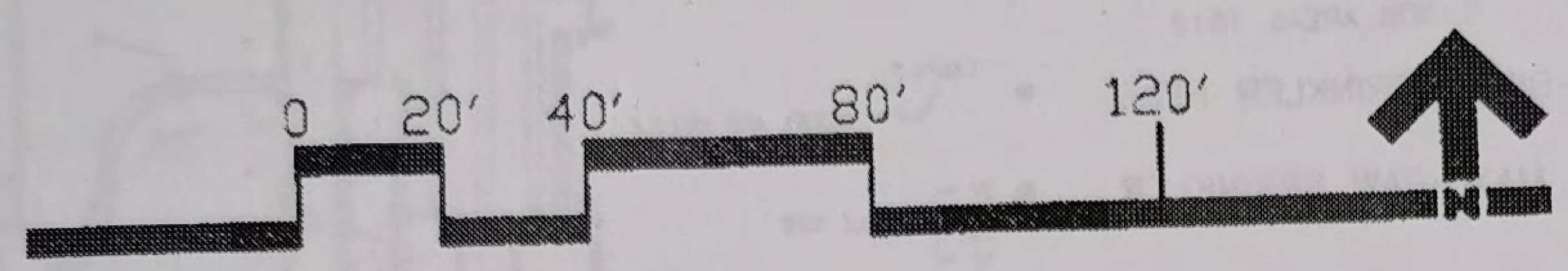


Figure 4-2: Scale on blueprint with direction indicator

The legend on a blueprint is the first place to look for details about the project. The legend will show you what each symbol on the irrigation blueprint represents. A solid circle may represent a full circle rotor while a circle with an "X" in it may represent a valve. This will be found in the legend.

The blueprint will show the reader the locations of all site improvements of importance to the subject matter shown. On an irrigation plan, the location of the buildings, sidewalks, driveways, parking lots and other hardscape items are normally shown. Some irrigation blueprints will have topography lines or large tree locations. Others may have the actual landscape areas shown. Many blueprints have the location of existing utilities such as water, sewer, gas or telephone lines. Be sure you understand what each item or notation on the plan means.

The actual irrigation system will also be shown. This includes valves, sprinkler heads and controllers. All piping will be shown in most cases but may not be in the actual location that the pipe will be installed. Main lines and lateral lines are most commonly shown. Wiring is usually not shown.

There will be comments on how the wiring is to be installed but the actual location of the wire is up to the installer. Valves and controllers will have additional markings showing more information about each component such as valve size and flow. Controller numbers and the number of stations actually used will also be shown.

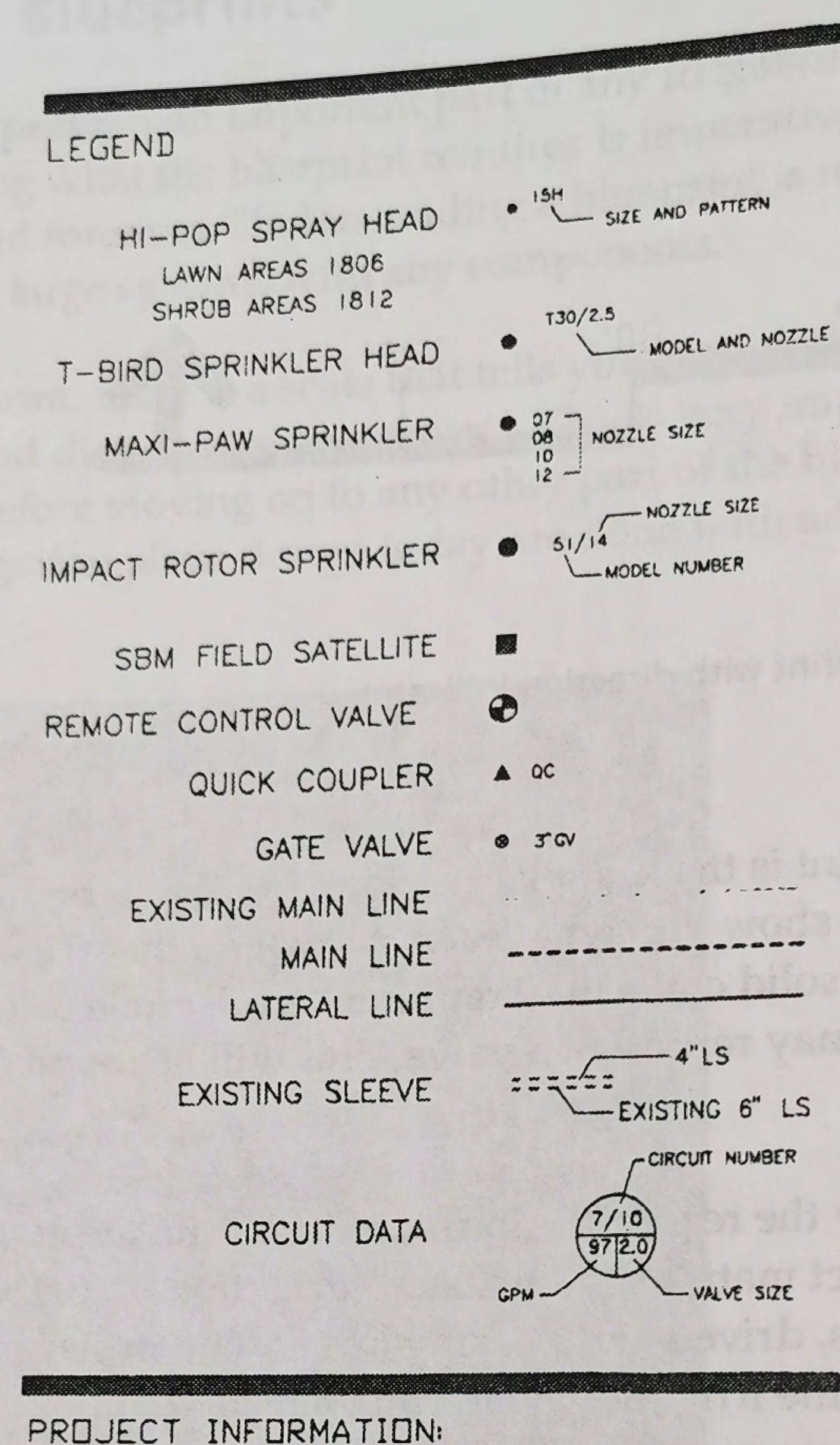


Figure 4-3: Blueprint legend

On larger systems, a detail page may be included with a drawing of how certain components are to be installed. Details are very important and should never be ignored. Some typical details are shown below.

Along with any blueprint are a set of specifications that explain in writing what the blueprint is showing you. Be careful to read them carefully as they may spell out many details not shown on the blueprint itself.

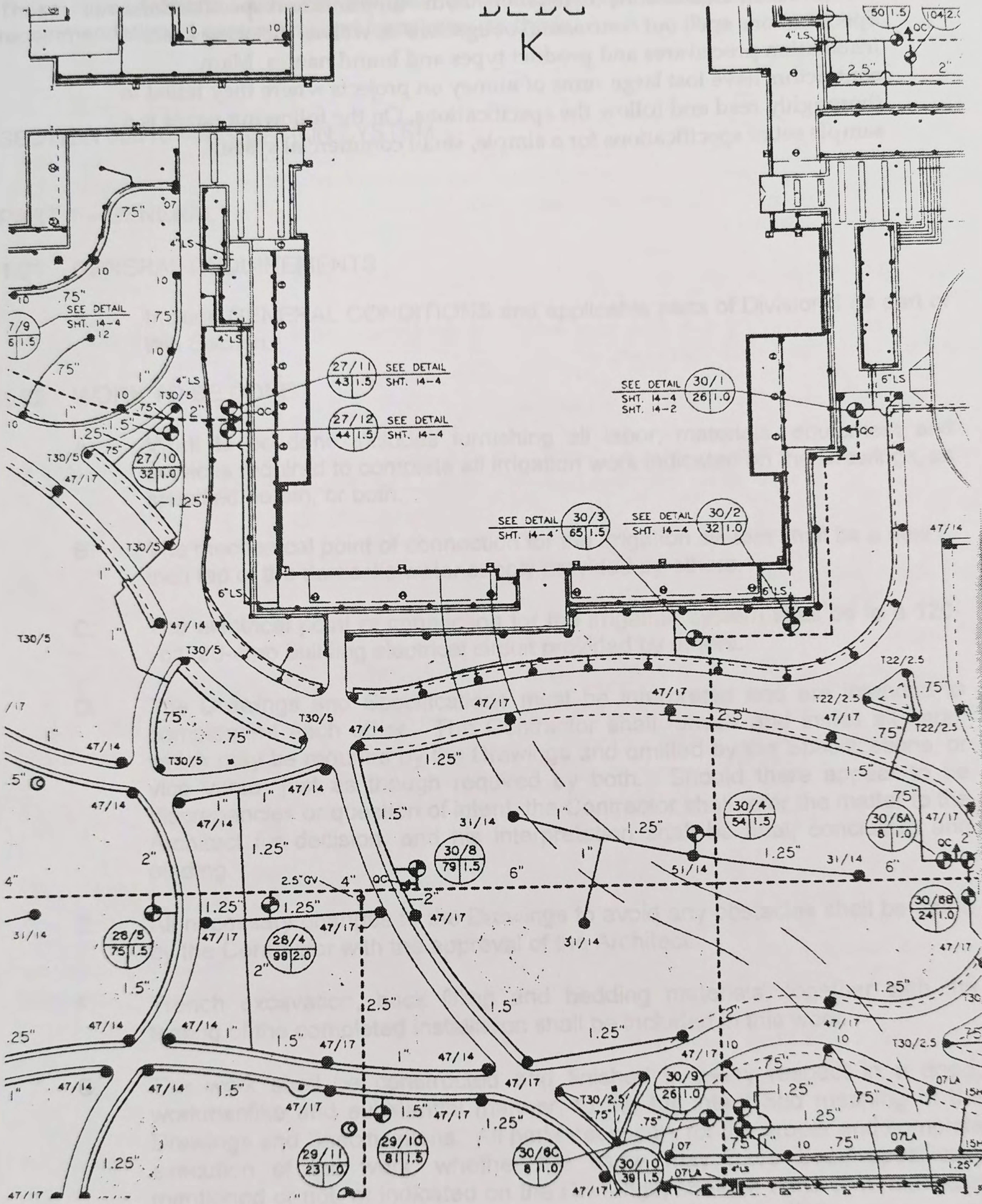


Figure 4-4: Blueprint showing buildings, hardscape items, irrigation valves, heads and piping

On almost all installations there will be both blueprints and specifications. Specifications spell out contractual obligations as well as dictating exact installation procedures and product types and brand names. Many contractors have lost large sums of money on projects where they failed to thoroughly read and follow the specifications. On the following pages is a sample set of specifications for a simple, small commercial systsm.

These specifications are for **sample purposes only** and do not represent a recommendation of contracting and installation methods.

SECTION 02810 – IRRIGATION SYSTEM

PART 1 – GENERAL

1.01 GENERAL REQUIREMENTS

A. Include GENERAL CONDITIONS and applicable parts of Division 1 as part of this Section.

1.02 WORK TO BE DONE

A. Work to be done includes furnishing all labor, materials, equipment and services required to complete all irrigation work indicated on the Drawings, as specified herein, or both.

B. The mechanical point of connection for the irrigation system shall be a new 2-inch tap of the domestic water supply provided by others.

C. The electrical point of connection for the irrigation system shall be to a 120-volt, 20-amp building electrical circuit provided by others.

D. The Drawings and Specifications must be interpreted and are intended to complement each other. The Contractor shall furnish and install all parts, which may be required by the Drawings and omitted by the Specifications, or vice versa, just as though required by both. Should there appear to be discrepancies or question of intent, the Contractor shall refer the matter to the Architect for decision, and his interpretation shall be final, conclusive and binding.

E. All necessary changes to the Drawings to avoid any obstacles shall be made by the Contractor with the approval of the Architect.

F. Trench excavation, back filling and bedding materials, together with the testing of the completed installation shall be included in this work.

G. The work shall be constructed and finished in every respect in a good, workmanlike and substantial manner, to the full intent and meaning of the Drawings and Specifications. All parts necessary for the proper and complete execution of the work, whether the same may have been specifically mentioned or not, or indicated on the Drawings, shall be done or furnished in a manner corresponding with the rest of the work as if the same were specifically herein described.

H. Record Drawing as well as Operating & Maintenance Manual generation, in accordance to these specifications shall also be included in this work.

1.03 SCOPE

A. The irrigation system shown on the Drawings and described within these Specifications represents a single controller, athletic field irrigation system supplied from municipal water. The system is designed for 65 gallons per minute. Minimum 80-psi static pressure is required from the point of connection.

1.04 RELATED WORK

A. Carefully examine all of the Contract Documents for requirements that affect the Work of this Section.

1.05 ORDINANCES, PERMITS AND FEES

A. The Work under this Section shall comply with all ordinances and regulations of authorities having jurisdiction.

B. The Contractor shall obtain and pay for any and all permits, tests and certifications required for the execution of Work under this Section, including water supply tap fee.

C. Furnish copies of Permits, Certifications and Approval Notices to the Owner's Representative prior to requesting payment.

D. The Contractor shall include in their bid any charges by the Water Department, Utility Company, or other authorities for work done by them and charged to the Contractor.

1.06 EXAMINATION OF CONDITIONS

A. The Contractor shall fully inform himself of existing conditions on the site before submitting his bid, and shall be fully responsible for carrying out all work required to fully and properly execute the work of the Contract, regardless of the conditions encountered in the actual Work. No claim for extra compensation or extension of time will be allowed on account of actual conditions inconsistent with those assumed, except those conditions described in the GENERAL CONDITIONS.

1.07 QUALITY ASSURANCE

A. Installer: A firm which has at least five (5) years experience in work of the type and size required by this Section and which is acceptable to the Owner's Representative.

B. References: The Contractor must supply three references for work of this type and size with their bid including names and phone numbers of contact person(s).

C. Applicable requirements of accepted Standards and Codes shall apply to the Work of this Section and shall be so labeled or listed:

1. American Society for Testing & Materials (ASTM)
2. National Plumbing Code (NPC)
3. National Electric Code (NEC)
4. National Sanitary Foundation (NSF)
5. American Society of Agricultural Engineers (ASAE)
6. Underwriters Laboratories, Inc. (UL)
7. Occupational Safety and Health Regulations (OSHA)

1.08 TESTS

A. Observation: The Owner's Representative will be on site at various times to insure the system is being installed according to the Specifications and Drawings.

B. Operational Test: After completion of the system, test the operation of entire system and adjust sprinklers as directed by the Owner's Representative. Demonstrate to the Owner's Representative that all irrigated areas are being adequately covered (See Part 3 - Execution).

1.09 SHOP DRAWINGS

A. The Contractor shall provide copies of product specification sheets on all proposed equipment to be installed to the Owner's Representative for approval prior to the start of work, in accordance with the parameters of Division-1. Work on the irrigation system may not commence until product sheets are submitted and approved. Submittals shall be marked up to show proper nozzles, sizes, flows, etc. Equipment to be included:

1. Sprinkler Heads
2. Valves: Manual and Automatic
3. Controller
4. Valve Boxes
5. Pipe and Fittings

6. Wire and Connectors
7. Quick Coupling Valves
8. Rain Sensor
9. Miscellaneous Materials

B. The Contractor shall maintain complete Record Drawings of the system as the project proceeds. Record Drawings shall specify sprinkler type; pop up height and nozzle for each sprinkler installed. Each valve box location to be referenced by distance from a minimum of two permanent locations. Controller(s), rain sensor(s), quick coupling valves, water meters, back flow prevention device and all other equipment shall be indicated on the drawings. All wire routing, wire size and splices shall be indicated. Main line pipe and wire route shall have two (2) distinctly different graphic symbols (line types).

1.10 DELIVERY, STORAGE AND HANDLING

A. Store and handle all materials in compliance with manufacturer instructions and recommendations. Protect from all possible damage. Minimize on-site storage.

1.11 GUARANTEE

A. The Contractor shall obtain in the Owner's name the standard written manufacturer's guarantee of all materials furnished under this Section where such guarantees are offered in the manufacturer's published product data. All these guarantees shall be in addition to, and not in lieu of, other liabilities that the Contractor may have by law.

B. In addition to the manufacturers guarantees the Contractor shall warrant the entire irrigation system, both parts and labor for a period of one (1) year from the date of acceptance by the Owner.

C. As part of the one-year warranty the Contractor shall perform the first year-end winterization and spring start-up for the irrigation system.

1.12 COORDINATION

A. The Contractor shall at all times coordinate his work closely with the Architect to avoid misunderstandings and to efficiently bring the project to completion. The Architect shall be notified as to the start of work, progression and completion, as well as any changes to the drawings before the change is made. The Contractor shall also coordinate his work with that of his sub-contractors.

B. The Contractor shall be held responsible for and shall pay for all damage to other work caused by his work, workmen or sub-contractors. Repairing of such damage shall be done by the Contractor who installed the work, as directed by the Architect.

1.13 MAINTENANCE AND OPERATING INSTRUCTIONS

A. Contractor shall include in their Bid an allowance for four (4) hours of instruction of Owner and/or Owner's personnel upon completion of check/test/start-up/adjust operations by a competent operator (The Architect's office shall be notified at least one (1) week in advance of check/test/start-up/adjust operations).

B. Upon completion of work and prior to application for acceptance and final payment, a minimum of three (3) three ring, hard cover binders titled MAINTENANCE AND OPERATING INSTRUCTIONS FOR THE FIELD IRRIGATION SYSTEM, shall be submitted to the Landscape Architect's office. After review and approval, the copies will be forwarded to the Owner. Included in the Maintenance and Operating binders shall be:

1. Table of Contents

2. Written description of Irrigation System.

3. System drawings:

   a. One (1) copy of the original irrigation plan;
   b. One (1) copy of the Record Drawing;
   c. One (1) reproducible of the Record Drawing;
   d. One (1) copy of the controller valve system wiring diagram

4. Listing of Manufacturers.

5. Manufacturers' data where multiple model, type and size listings are included; clearly and conspicuously indicating those that are pertinent to this installation.

   a. "APPROVED" submittals of all irrigation equipment;
   b. Operation:
   c. Maintenance: including complete troubleshooting charts.
   d. Parts list.
   e. Names, addresses and telephone numbers of recommended repair and service companies. A copy of the suggested "System Operating Schedule" which shall call out the controller program required (zone run time in minutes per day and days per week) in order to provide the desired amount of water to each area under "no-rain" conditions.

6. Winterization and spring start-up procedures.

7. Guarantee data.

1.14 PROCEDURE

A. Notify all city departments and/or public utility owners concerned, of the time and location of any work that may affect them. Cooperate and coordinate with them in the protection and/or repairs of any utilities.

B. Provide temporary support, adequate protection and maintenance of all structures, drains, sewers, and other obstructions encountered. Where grade or alignment is obstructed, the obstruction shall be permanently supported, relocated, removed or reconstructed as directed by the Architect.

PART 2 – PRODUCTS

2.01 GENERAL

A. All materials to be incorporated in this system shall be new and without flaws or defects and of quality and performance as specified and meeting the requirements of the system. All material overages at the completion of the installation are the property of the Contractor and shall be removed from the site.

B. No material substitutions from the irrigation products described in these specifications and shown on the drawings shall be made without prior approval and acceptance from the Owner's Representative.

2.02 PVC IRRIGATION PIPE

A. All pipe shall be PVC, Class 200, Type 1120, SDR 21, Solvent-Weld PVC, conforming to ASTM No. D2241 and D3036.

2.03 PVC PIPE SLEEVES

A. All pipe sleeves beneath non-soil areas shall be PVC, Class 160 water pipe. Minimum sleeve size to be 3-inch.

2.04 WIRE CONDUIT

A. Conduit for wiring beneath non-soil areas shall be PVC, SCH-80 conduit.

B. Conduit for above ground wiring to rain sensors or controllers shall be galvanized, rigid metallic conduit.

2.05 PVC IRRIGATION FITTINGS

A. Fittings for solvent weld PVC pipe, shall be Schedule 40 solvent weld PVC fittings.

B. All PVC threaded connections in and out of valves shall be made using Schedule 80 toe nipples and Schedule 40 couplers or socket fittings. Schedule 40 male threads will not be approved for installation.

C. PVC solvent shall be NSF approved, for Type I and Type II PVC pipe, and Schedule 40 fittings. Cement is to meet ASTM D2564 and FF493 for potable water pipes. PVC solvent cement shall be used in conjunction with the appropriate primer.

D. All nipples to be schedule 80 PVC.

2.06 POLYETHYLENE IRRIGATION PIPE (ALTERNATE)

A. Piping 1-1/4 inch and smaller in size as indicated on the drawings may also be installed with polyethylene (PE3408) pipe, SDR 15, Class 100, Type III, Grade 3, Class C conforming to ASTM D2239, with a minimum pressure rating of 100 psi. Polyethylene pipe shall only be used in landscape areas.

2.07 POLYETHYLENE IRRIGATION FITTINGS (ALTERNATE)

A. Fittings for polyethylene pipe shall be insert PVC or Nylon type fittings. Fittings shall conform to NSF standards and be attached with two (2) dog-eared stainless steel clamps. Fittings shall be per ASTM D2609.

B. Supply only pipes and fittings that are marked by the manufacturer with the appropriate ASTM designations and pressure ratings and are free from cracks, wrinkles, blisters, dents or other damage.

2.08 SMALL ROTARY SPRINKLERS

A. Small rotary sprinklers shall be gear-driven, rotary type heads, designed for in-ground installation with integral check valves. Sprinkler shall be capable of covering a 34-48 foot radius and flow range of 1.6-7.0 gpm at 50-55 pounds per square inch of pressure. Sprinklers shall have a one hundred percent warranty for two years minimum against defects in workmanship.

B. The nozzle assembly shall elevate minimum four inches when in operation and retraction shall be achieved by a stainless steel spring. Riser assembly shall be plastic. A nozzle wiper seal shall be included in the sprinkler for continuous operation under the presence of sand and other foreign material.

C. All sprinkler parts shall be removable through the top of the unit through the removal of a heavy-duty threaded cap. The sprinkler shall have a three quarter-inch (3/4") IPS water connection on the bottom of the sprinkler.

2.09 LARGE ROTARY SPRINKLERS

A. Large rotary sprinklers shall be gear-driven, rotary type with drain check for in-ground installation. The nozzle assembly shall elevate three inches when in operation and retraction shall be achieved by a stainless steel spring.

Check valve shall be capable of holding up to 10 feet of elevation. Sprinkler shall be capable of covering a 47-60 foot radius and flow range of 7.0 to 16.8 gpm at 50 pounds per square inch of pressure.

B. All sprinkler parts shall be removable through the top of the unit by removing a heavy-duty threaded cap. The sprinkler shall have a one-inch (1") IPS water connection on the bottom of the sprinkler.

2.10 ELECTRIC CONTROL VALVES

A. Electric control valves shall be one, one and one half and two-inch remote control, diaphragm type, fiberglass or reinforced nylon body plastic valves with manual flow control, manual bleed screw and 150 psi pressure rating. Valves shall be globe/angle combination configuration.

2.11 VALVE BOXES

A. Valve boxes for single electric valves, isolation valves and quick coupling valves shall be 10-inch round valve boxes with metal detection and bolt down covers

B. Valve boxes for dual electric valves shall be 12-inch standard valve boxes with metal detection and bolt down covers.

C. Valve box extensions shall be provided as required for proper box depth.

2.12 AUTOMATIC CONTROLLER

A. Controller shall be electronic in construction with capability of up to 10 hour run times per zone in increments of 1 or 10 minutes. Controllers to have minimum two independent programs, auto/off switch and be capable of manual, semi-automatic and automatic operation. Controller shall have water budgeting feature, sensor input terminal, locking, weather resistant plastic cabinet and internal transformer. Terminal strip connection shall be easily accessible. The controller shall be U.L. listed, 120 volt, 60 Hertz, A.C. type.

B. Station quantity shall be minimum of 24.

2.13 QUICK COUPLING VALVES

A. The valve body shall be of cast brass construction with a working pressure of 125 psi. The valve seat disc plunger body shall be spring loaded so that the valve is normally closed under all conditions when the key is not inserted.

B. The top of the valve body receiving the key shall be equipped with a single slot and smooth face to allow the key to open and close the valve slowly with a one-half turn. The quick coupling valve shall be equipped with a locking vinyl cover.

C. The valve body construction shall be such that the coupler seal washer may be removed from the top for cleaning or replacement without disassembling any other parts of the valve.

D. Keys shall be single lug with 1-inch male thread and 3/4 inch female thread at the top.

E. Contractor shall provide two (2) keys for quick couplers, two (2) 1 inch x 1 inch swivel hose ells and two (2) cover keys for quick coupling valves.

2.14 WIRE

A. All valve control wire shall be minimum #14-awg, common #12-awg, single strand, solid copper, 600v, direct burial (UF) and shall meet all state and local codes for this service. Individual wires must be used for each zone valve. Common wire shall be white in color, control wire shall be red in color and spare wires, installed where indicated on the drawings shall be blue. White color shall be used for common wire only.

B. In ground wire connections shall be UL listed, manufactured by 3M, model DBY-6 splice kits. All wire splices shall be made in valve boxes, at controller, or at valves.

C. Wire type and method of installation shall be in accordance with local codes for NEC Class II circuits of 30-volt A.C. or less.

2.15 ISOLATION VALVES

A. Isolation valves shall be gate type, of bronze construction, US Manufacture, 600 WOG with steel cross handle and 200 psi rating.

2.16 SWING JOINTS

A. Small rotary sprinklers shall be installed on swing pipe assemblies, minimum length 6 inches, maximum 18 inches.

B. Large rotary sprinklers shall be installed on 1-inch prefabricated PVC unitized swing joint assemblies with integral o-rings, minimum length 12 inches.

C. Quick coupling valves to be installed on one-inch brass swing joint, minimum 12-inches in length with stabilizer (unless stabilizer is an integral part of the quick coupling valve).

2.17 AUTOMATIC RAIN SENSOR

A. Rain sensor shall be plastic in construction with adjustable interruption point, ½" IPS threads and stainless steel vandal resistant guard.

2.18 CRUSHED STONE

A. Crushed stone shall be as specified in SECTION: EARTHWORK. Crushed stone shall be used under valve boxes and below all sprinklers.

2.19 SAND

A. Sand used for backfilling of trenches; under, around and over PVC lines shall be as specified in SECTION: EARTHWORK.

PART 3 – EXECUTION

3.01 GENERAL

A. Examine all contract documents applying to this Section noting any discrepancies and bringing the same to the attention of the Owner's Representative for timely resolution.

B. Make all field measurements necessary for the work noting the relationship of the irrigation work to the other trades. Coordinate with other trades (landscaping and other site work trades). Project shall be laid out essentially as indicated on the Irrigation Plans, making minor adjustments for variations in the planting arrangement. Major changes shall be reviewed with the Architect prior to proceeding.

C. At all times, protect existing irrigation, landscaping, paving, structures, walls, footings, etc. from damage. Any inadvertent damage to the work of another trade shall be reported at once.

3.02 PIPE AND FITTINGS INSTALLATION

A. Using proper width trencher chain, excavate a straight and true trench to a depth of 2-inch of pipe invert elevation.

B. Loam encountered within the limits of trench excavation for irrigation mains and branch lines shall be carefully removed to the lines and depths as shown on the Drawings and stockpiled for subsequent replacement in the upper 6 inches of the trench from which it is excavated. Such removal and replacement of the quantities of loam shall be considered incidental to the irrigation system and no additional compensation will be allowed therefore.

C. Pipe shall be laid on undisturbed trench bottom provided suitable base is available - no rock larger than 1 inch or sharp edges; if not, excavate to 2 inch below pipe invert and provide sand base or crushed stone upon which to lay pipe.

D. Back filling shall be accomplished as follows: the first 10-inch of backfill material shall contain no foreign matter and no rock larger than 1 inch in diameter. Carefully place material around pipe and wire and tamp in place.

Remainder of backfill shall be laid-up in 6-inch (maximum) lifts and tamped to compaction with mechanical equipment matching adjacent undisturbed area. Frozen material shall not be used for backfill.

E. Make all solvent-weld joints in strict accordance with manufacturer's recommendations, making certain not to apply an excess of primer or solvent, and wiping off excess solvent from each connection. Allow connections to set minimum 24 hours before pulling or pressure is applied to the system. Provide for expansion and contraction as recommended. Wire shall be laid in same trench as mainline and at pipe invert (see Wire Installation).

F. Mainline pipe shall have minimum 22 inches of COVER (excavate to invert as required by pipe size). Lateral pipe shall have minimum 16 inches of COVER for PVC and 12 inches of cover for Polyethylene (excavate to invert as required by pipe size).

G. Cut plastic pipe with handsaw or pipe-cutting tool, removing all burrs at cut ends. All pipe cuts are to be square and true. Bevel cut end as required to conform to Manufacturer's Specifications.

H. Every precaution shall be taken to prevent foreign material from entering the pipe while it is being placed in the trench. At times, when installation of the piping is not in progress, the open end(s) of the pipe shall be closed by a watertight plug or other means. All piping, which cannot temporarily be joined, shall be sealed to make as watertight as possible. This provision shall apply during the lunch hour as well as overnight. Pipe not to be installed that day shall not be laid out. Should water enter the trench during or after installation of the piping, no additional piping may be installed or back filled until all water is removed from the trench. Pipe shall not be installed when water is in the trench, when precipitation is occurring, or when the ambient temperature is at 35º F or below. PVC pipe shall be snaked in the trench to accommodate for expansion and contraction due to changes in temperature.

I. In installing irrigation pipe the Contractor shall route the pipe as necessary to prevent damage to tree roots. Where trenching must occur near trees, the Contractor shall provide proper root pruning and sealing methods to all roots 1 inch and larger.

J. Throughout the guarantee period it will be the responsibility of the Contractor to refill any trenches that have settled due to incomplete compaction.

K. Pulling of pipe will be allowed provided soil is suitable and specified depth of bury can be maintained.

3.03 ELECTRICAL WIRE CONDUIT INSTALLATION

A. Electrical conduit shall be installed in all non-soil areas, as well as for all above ground wiring to controllers and rain sensor.

3.04 PIPE SLEEVING INSTALLATION

A. Sleeving shall be installed wherever piping is going under a non-soil area, generally where indicated on the Drawings. Minimum cover over all sleeving pipe shall be 24 inches as shown on the detail.

3.05 ISOLATION VALVE INSTALLATION

A. Install isolation valves per detail where indicated on the Drawings. Install all isolation valves on a level crushed stone base so that they can be easily opened or closed with the appropriate valve wrench. Install specified valve box over each isolation valve.

3.06 VALVE BOX INSTALLATION

A. Furnish and install a valve access box for each electric valve, quick coupling valve, isolation valve and wire splice.

B. All valve access boxes shall be installed on a minimum 4-inch crushed stone base. Finish elevation of all boxes shall be at grade. All crushed stone to be supplied by the Contractor and installed before valve box. Crushed stone shall not be poured into previously installed valve boxes.

3.07 24 VOLT CONTROL VALVE INSTALLATION

A. Control valves shall be installed on a level crushed stone base. Grade of bases shall be consistent throughout the project so that finish grades fall within the limits of work. Valves shall be set plumb with adjusting handle and all bolts, screws and wiring accessible through the valve box opening.

B. Adjust zone valve operation after installation using flow control device on valve.

3.08 WIRING INSTALLATION

A. Wiring shall be installed along with the main line. Multiple wire bundles shall be cinched together at maximum 12-foot centers using plastic cable cinches and shall be laid beside, and at the same invert as, the irrigation lines. Sufficient slack for expansion and contraction shall be maintained and wiring shall at no point be installed tightly. Provide an additional 8 inches to 12 inches slack at all changes of direction. Wiring in valve boxes shall be a sufficient length to allow the valve solenoid, splice, and all connections to be brought above grade for servicing. This additional slack shall be coiled for neatness in the valve box. Each valve shall have a separate wire back to the controller.

B. All wire shall be laid in trenches and shall be carefully back-filled to avoid any damage to the wire insulation or wire conductors themselves. In areas of unsuitable material, the trench shall have a 2 inches layer of sand or stone dust on the bottom before the wires are laid into the trench and back-filled.

The wires shall have a minimum of 12 inches of cover. Wire not to be installed that day shall not be laid out.

C. An expansion curl shall be provided within 6 inches of each wire connection to a solenoid and at least every 100 feet of wire length on runs more than 100 feet in length. Expansion curls can be formed by wrapping five (5) turns of wire around a 1-inch diameter or larger pipe and then withdrawing the pipe.

D. Provide a common ground wire of white color. No white color shall be used for power wire. Control wire shall be red and spare wiring shall be blue in color.

E. Service wiring in connection with Drawings and local codes for 24-volt service. All in-ground wire connections shall be waterproofed with 3M DBY splice kits. All splices shall be made in valve boxes (wire runs requiring splices between valve locations shall be provided in splice box--valve box shall be used). Splice locations shall be shown on the Record Drawings.

F. Contractor shall provide a complete wiring diagram showing wire routing for the connections between the controller and valves. See section one for the inclusion of wiring diagram in operation and maintenance manuals.

3.09 CONTROLLER INSTALLATION

A. Contractor to install controller on wall in maintenance building, generally where shown on the drawings. Contractor to wire valves and rain sensor into controller and set proper program.

B. Wire controller to 120-volt electrical supply provided to the controller locations by OTHERS.

C. Keys shall be turned over to Owner's Representative.

3.10 RAIN SENSOR INSTALLATION

A. Install rain sensor on exterior building wall, generally where indicated on the drawings. Coordinate final location of rain sensor with Architect. Rain sensor shall be in direct contact with the weather and not in contact with the irrigation spray.

B. Install rain sensor wiring within ½ inch conduit where exposed. All above ground wires shall be installed in conduits.

3.11 SPRINKLER INSTALLATION

A. Small rotary sprinklers shall be installed flush to grade on swing pipe assemblies, minimum length 6 inches, maximum 18 inches.

B. Large rotary sprinklers shall be installed flush to grade on 1-inch prefabricated PVC unitized swing joint assemblies with integral o-rings, minimum length 12 inches.

C. Adjust sprinkler zone pressure with flow control on valve.

3.12 QUICK COUPLING VALVE INSTALLATION

A. Provide quick coupling valves where indicated on the Drawings.

B. Quick coupling valves to be mounted on 1-inch brass swing joint with stabilizer as per details.

3.13 CHECK/TEST/START-UP/ADJUST

A. Flushing:

1. After all piping, valves and sprinkler bodies are in place and connected, but prior to installation of sprinkler internals, flush piping under a full head of water

B. Testing:

1. Leakage test: test all lines for leaks under operating pressure. Repair all leaks and re-test.

2. Coverage test: perform a coverage test in the presence of the Owner's Representative (notify Architect at least seven (7) days in advance of scheduled coverage test). Representative will determine if the water coverage is complete and adequate. Readjust heads and/or head locations as necessary or directed to achieve proper coverage.

3. All testing shall be at the expense of the Contractor.

3.14 CLEANING AND ADJUSTING

A. At the completion of the work, all parts of the installation shall be thoroughly cleaned. All equipment, pipe, valves and fittings shall be cleaned of grease, metal cuttings and sludge which may have accumulated by the operation of the system for testing.

B. Adjust sprinkler heads, valve boxes, and quick coupling valves to grade as required, so that they will not be damaged by mowing operations.

C. Continue sprinkler coverage adjustment as required by settlement, etc., throughout the guarantee period.

D. Each control zone shall be operated for a minimum of 5 minutes and all heads checked for consistency of delivering water. Adjustments shall be made to sprinklers that are not consistent to the point that they match the manufacturer's standards. All sprinklers, valves, timing devices or other mechanical or electrical components, which fail to meet these standards, shall be rejected, replaced and tested until they meet the manufacturer's standards.

3.15 ACCEPTANCE AND OPERATION BY OWNER

A. Upon completion of the work and acceptance by the Owner, the Contractor shall be responsible for the training of the Owner's Representative(s) in the operation of the system (provide minimum 48 hours written notice in advance of test). The Contractor shall furnish, in addition to the Record Drawings and operational manuals, copies of all available specification sheets and catalog sheets to the Owner's personnel responsible for the operation of the irrigation system. The Contractor shall guarantee all parts and labor for a minimum period of one (1) year from date of acceptance.

3.16 CLEAN UP

A. Upon completion of all installation work, Contractor shall remove all leftover materials and equipment from the site in a safe and legal manner.

3.17 WINTERIZATION

A. Winterization: The irrigation system is designed to be completely drained to protect pipe from bursting prior to freezing temperatures. To adequately drain the system the following procedure must be followed:

1. Air blow-out

    a. Set automatic controller stations to 2-1/2 minutes timing.

    b. Attach hose from portable air compressor to 1 inch air inlet installed on main line at back flow preventer.

    c. Operate compressor at 100 cubic feet per second at 60-80 psi.

2. Manual drain valves: Open manual drain valves located at low points on the main line to drain main completely after air blow-out has been completed.

3. Backflow Preventer: Rotate backflow unit at unions and open petcocks and drain. Reverse operation and tighten unions to resume irrigation.

END OF SECTION

Chapter 5: Install a Point of Connection (POC)

Steps of Installation

1. Select Proper Tools
2. Perform Site Inspection
3. Read Blueprints
4. **Install POC**
5. Install Mainline
6. Install Field Wiring
7. Install Valves
8. Install Lateral Piping
9. Install Sprinkler Heads
10. Mount and Wire Controllers

Important Note: The selection and installation of backflow preventers is governed by strict local codes. Please consult the local governing agency for information regarding who can install backflows and how they are to be installed.

Point of Connection (POC) work requires permits and licenses. Failure to hold the proper license or pull the correct permit can result in fines and endanger the health of the public. Make sure to consult your local regulatory agency before attempting any POC work. Quite often, this work can be subcontracted out to a licensed plumber.

Installing a POC requires knowledge of a number of different components and processes. There are many different types of valves, backflow preventers, pipe and installation methods of which only some will be covered here.

We will refer to POC as more than just where you connect the main line to for your water supply. We also include any backflow prevention required by local codes, master valves, flow sensors and other devices that are usually installed near the water source. The POC can also include where you connect your mainline to a pump station or booster pump. We will not discuss pumps here, only the components that are installed after the pump.

Most water sources including pumps are usually provided at or near a valve to allow for the irrigation system to be shut off in its entirety when necessary. This may be at a water meter, booster pump or a simple gate valve provided by the installing plumbing contractor that did the water supply for the property. We will assume a valve has been provided for many of these examples. On occasion, it may be required of you to install your own valve in another water supply line such as the water supply to a home or building. This requires you to shut off the water supply and tap into the line with the appropriate pipe tapping method. Be careful if you are working with any pipe type other than PVC if you are not familiar with that type of pipe installation procedures.

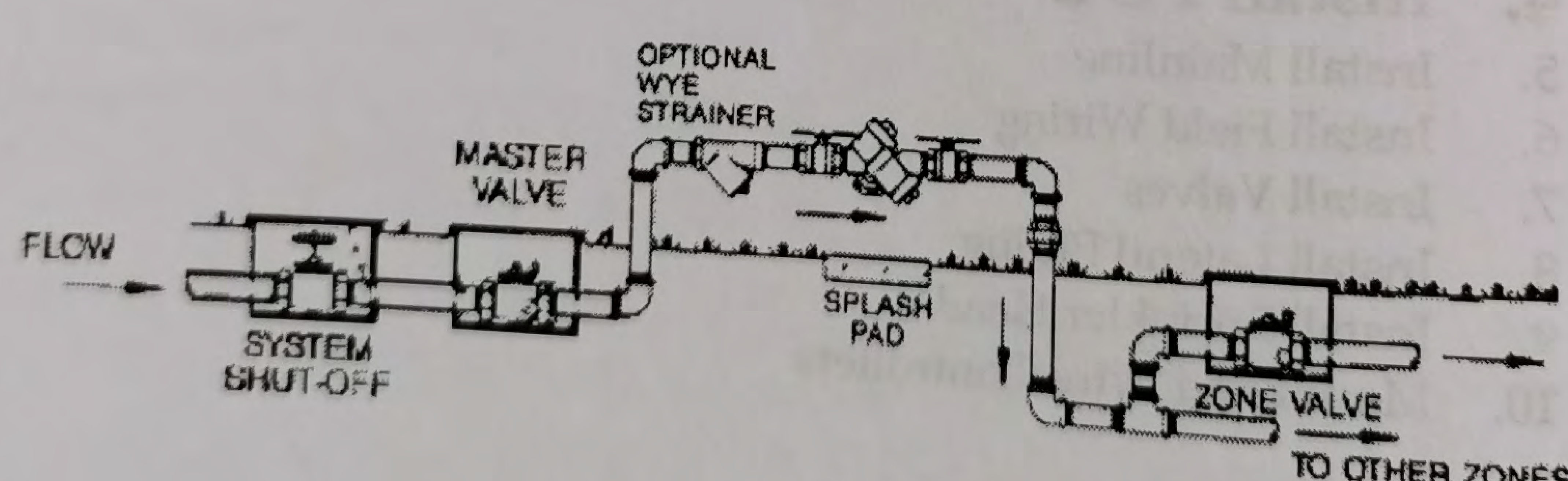


Figure 5-1: Typical POC including gate valve for system shut-off, master valve, backflow preventer and wye strainer

Below are photos of POC and backflow installations.

Figure 5-2: Pressure vacuum breaker

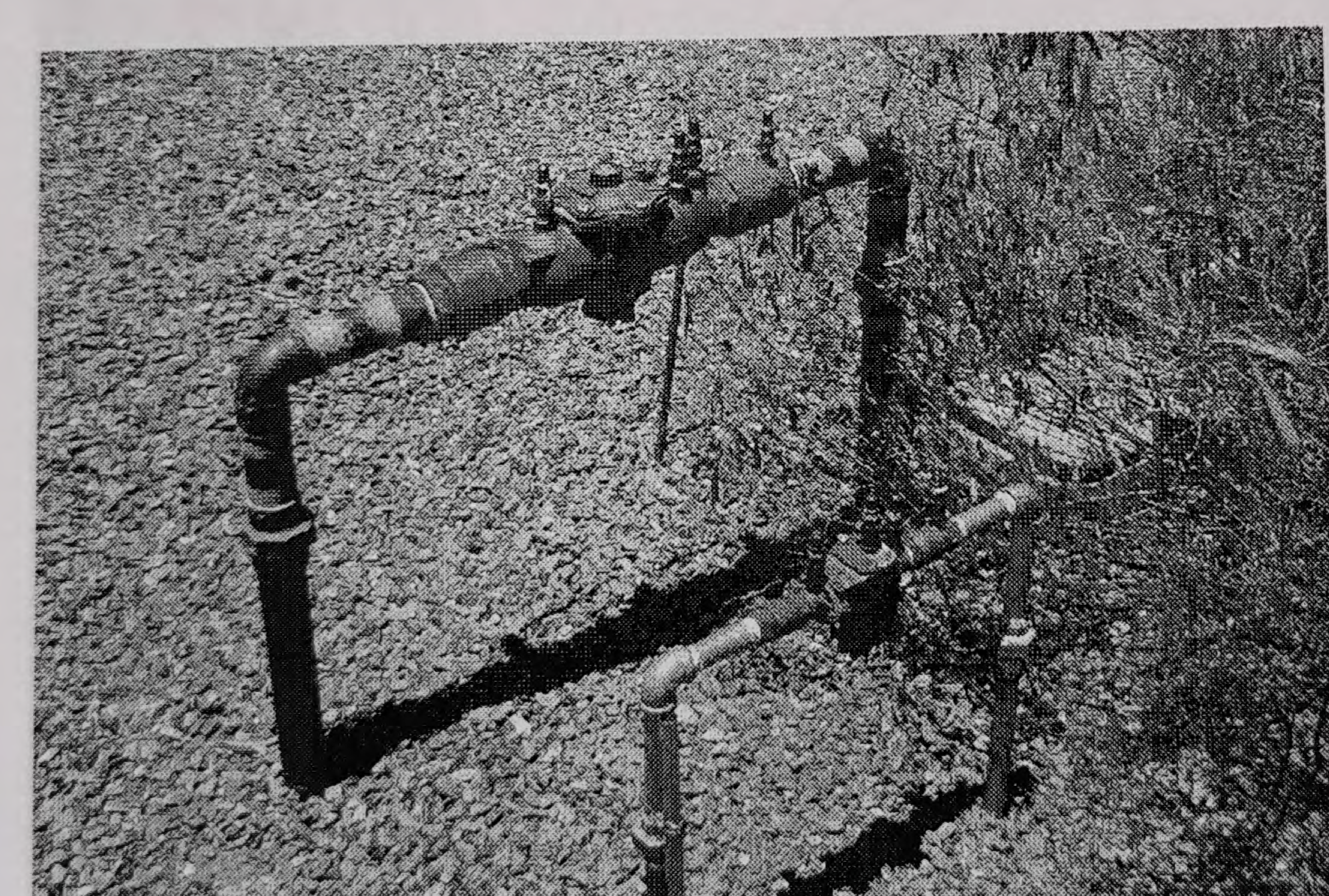


Figure 5-3: Reduced pressure assembly

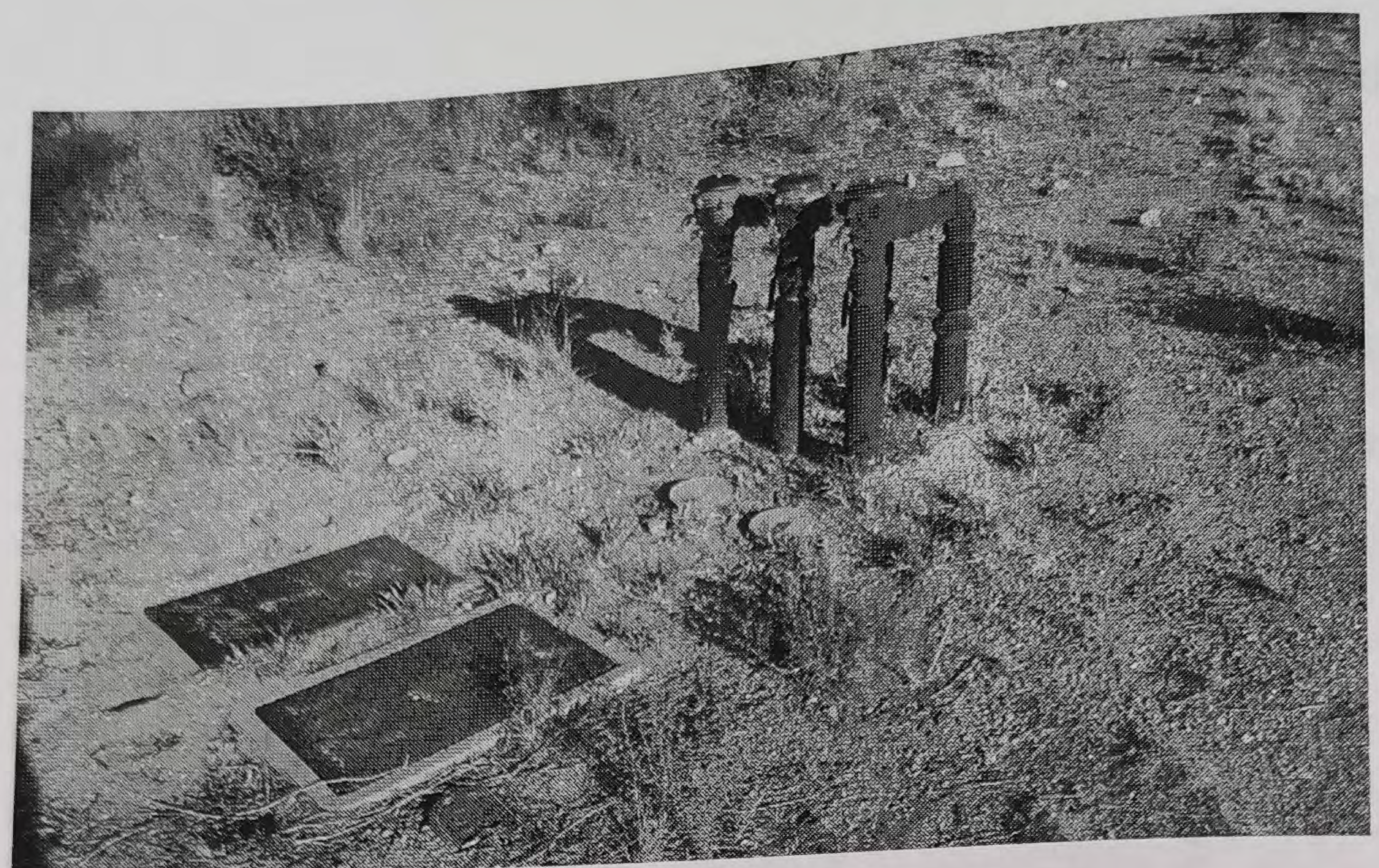


Figure 5-4: Atmospheric vacuum breaker

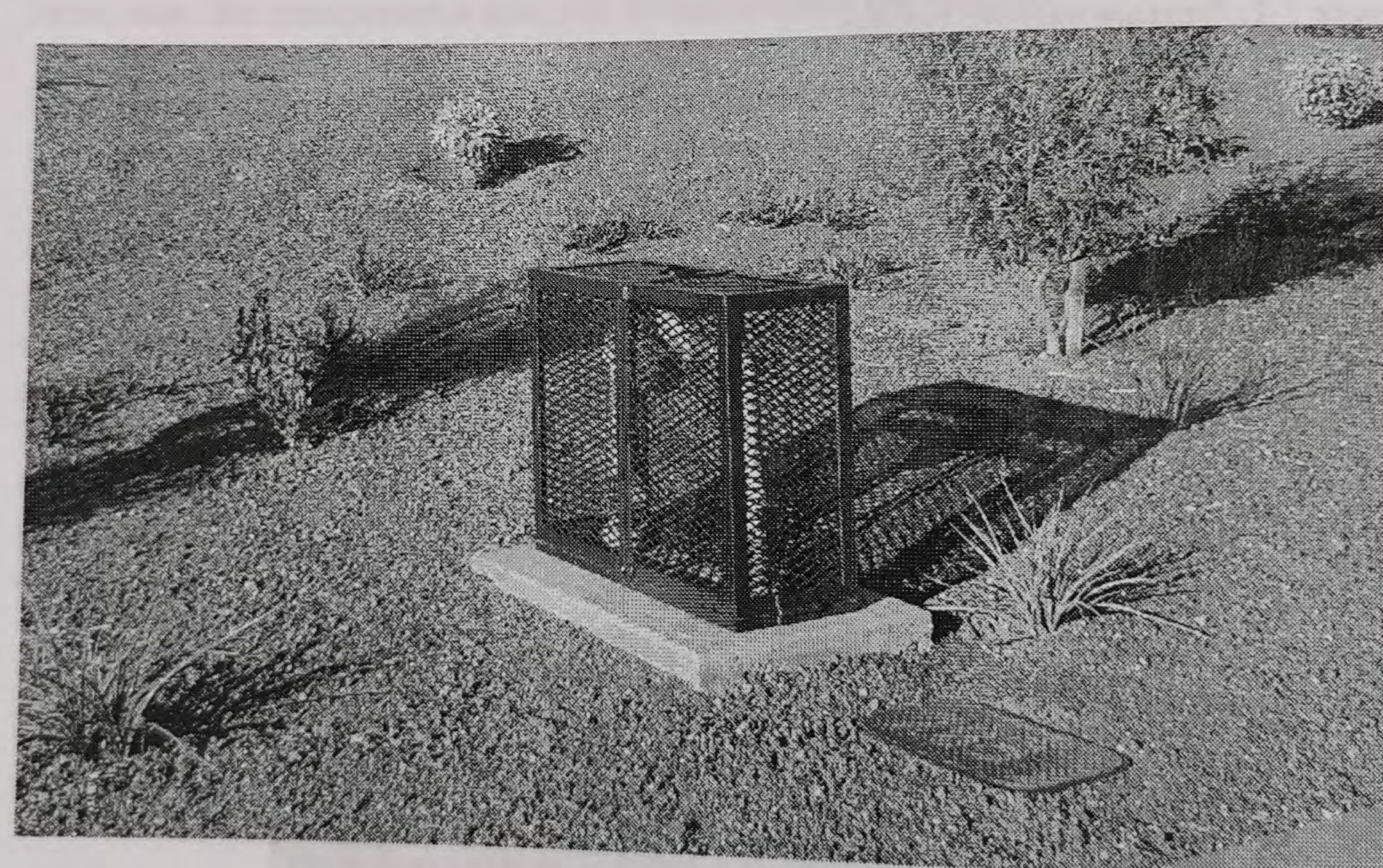


Figure 5-5: Backflow enclosure

Figure 5-6: Backflow enclosure

Figure 5-7: Pressure vacuum breaker

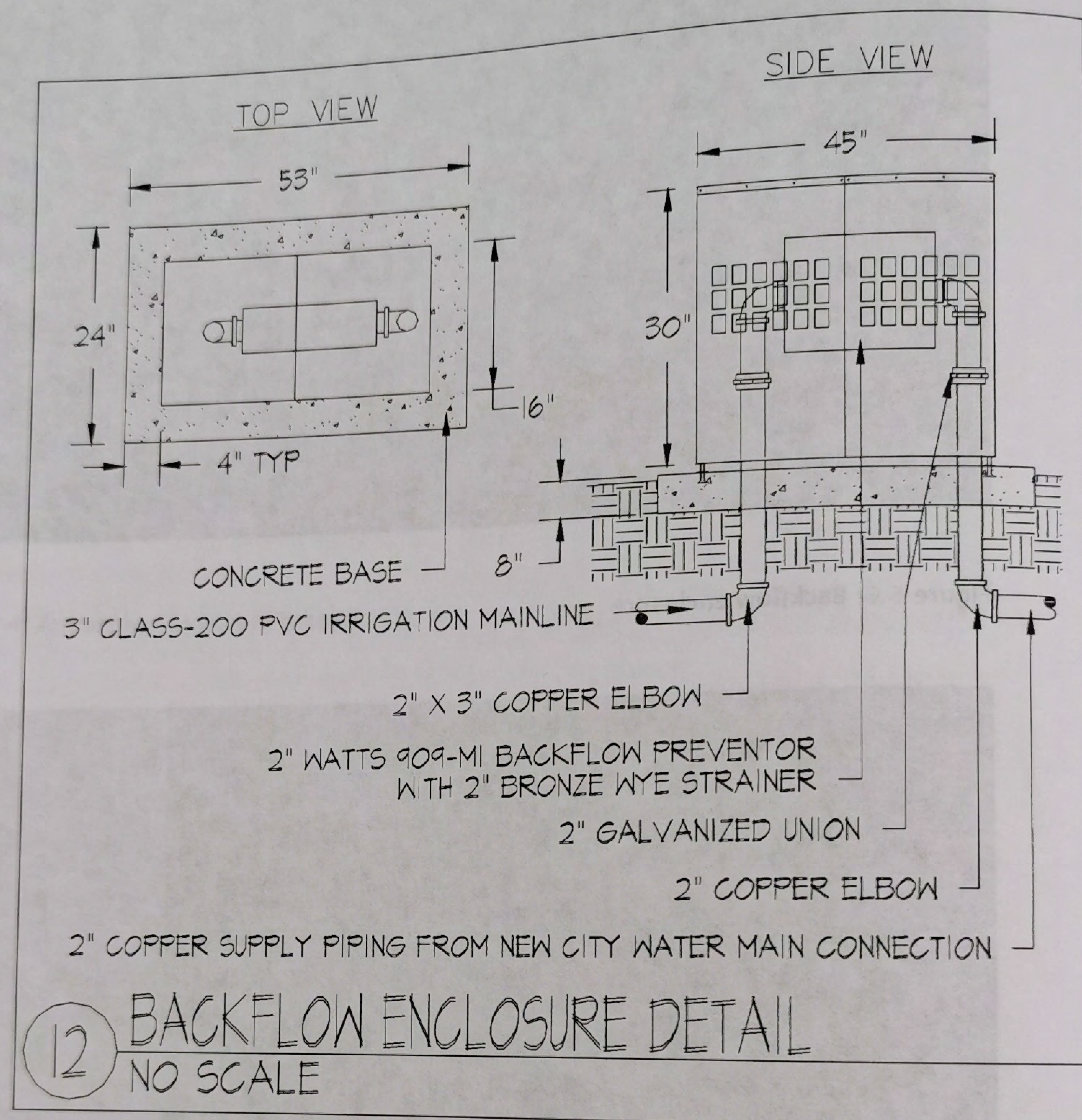


Figure 5-8: Backflow detail

Chapter 6: Install Mainline

Steps of Installation

1. Select Proper Tools
2. Perform Site Inspection
3. Read Blueprints
4. Install POC
5. **Install Mainline**
6. Install Field Wiring
7. Install Valves
8. Install Lateral Piping
9. Install Sprinkler Heads
10. Mount and Wire Controllers

The next step in the installation process is to install the main line, now that you have water from your POC. Mainline is defined as that pipe which is upstream of the remote control zone valve. It is typically under constant, 24-hour pressure and is normally the largest pipe on the job.

To begin our discussion, we will first look at different types of pipe used in the irrigation industry. This discussion on types of pipe is valid whether you are working with main line or lateral piping.

Thermoplastic Pipe for Irrigation Systems

Introduction

Two kinds of thermoplastic pipe are used in almost all turf, landscape and agricultural irrigation systems today. They are:

- Polyvinyl chloride (PVC)
- Polyethylene (PE)

PVC is usually manufactured as rigid pipe in 20-foot lengths, but it is also manufactured as flexible pipe in long coils, when plasticizers are added during the manufacturing process. PVC has high tensile strength and is resistant to nearly all types of deterioration (except UV).

Pipe Identification

How pipe is identified is described in ASTM A-53 Standard, which requires the following information:

1. Each length of pipe shall be legibly marked by rolling, stamping, or stenciling to show the name or brand of the manufacturers; the kind of pipe, that is continuous-welded, electric-resistance-welded A, electric-resistance-welded B; seamless; or seamless B; XS for extra strong, XXS for double extra strong; the specification number; and the length. Length shall be marked in feet and tenths of a foot, or meters to two decimal places, depending on the units to which the material was ordered, or other marking subject to agreement.
2. For pipe NPS 1½ inches (38.1mm) and smaller, which is bundled, this information may be marked on a tag securely attached to each bundle.
3. When pipe sections are cut into shorter lengths by a subsequent processor for resale as material, the processor shall transfer complete identification including the name or brand of the manufacturer, to

each unmarked cut length, or to metal tags securely attached to unmarked pipe bundled in accordance with the requirement of 2. The same material designation shall be included with the information transferred, and the processor's name, trademark or brand shall be added.

PE Pipe

PE is flexible, has less tensile strength and is more subject to creep; that is, when stretched and released it does not return completely to its original dimensions. It cannot be solvent welded, and in many cases requires the use of *pressure-losing* insert fittings.

Standard Dimensional Ratio's (SDR) are also used to classify flexible polyethylene pipe and tube. However, the formula for calculating the Design Working Pressure differs from that used with PVC pipe.

This difference is caused by the fact that PVC is an outside diameter rated pipe while polyethylene (PE) pipe is classified on the basis of inside diameter (SIDR). Therefore:

Design Working Pressure (PE)
= (2) (Design Tensile Strength)/(SDR + 1)

The following chart depicts the relationship between SIDR and the pressure ratings of the different PE pipes.

Table 6-1: PE Pipe Materials

	DESIGN WORKING PRESSURE RATINGS (psi)		
SIDR	ASTM PE 3306 PE 3406	ASTM PE 2306	ASTM PE 2305
15	80	80	-
11.5	100	100	80
9	125	125	100
7	160	160	125
5.3	200	200	160
DESIGN TENSILE STRENGTH	630 psi	630 psi	500 psi

Standard Dimension Ratio (SDR)

All plastic pipes have pressure ratings, but pipe manufactured with a *standard dimension ratio* (SDR-PR) has the same pressure rating for all diameters of pipe. This pipe is given a *pressure class* designation that is usually listed in friction-loss table titles. The *pressure class* provides for a safety factor of about 2:1 over the hydrostatic pressure test. This, however, may not be adequate in irrigation systems with long pipe runs, quick-closing valves, or pipeline temperatures greater than 73.4°F. To compensate for these situations, it is usually recommended that pipe be selected having a pressure rating somewhat higher than the maximum *design working pressure.*

By comparison, plastic pipe manufactured with *"schedule"* dimensions, such as Schedule 40 or Schedule 80, has different pressure ratings for all diameters of pipe even when they are of the same material. Some comparisons are shown in Table 6-2.

Table 6-2: Comparisons of wall thickness and pressure ratings for Class 160 and Schedule 40 ASTM 1120 pipe

Nominal Pipe Diameter	ASTM 1120 Press Class 160		ASTM 1120 Schedule 40	
	Wall Thickness	Press Rating	Wall Thickness	Press Rating
inches	Inches	psi	inches	psi
2	0.091	160	0.154	315
4	0.173	160	0.237	270
8	0.332	160	0.322	170
10	0.413	160	0.365	145

Observe the following:

- The wall thickness of SDR-PR pipe increases faster than schedule pipe as the pipe diameter increases.
- The pressure rating of SDR-PR pipe does not change with pipe diameter; the pressure rating of schedule pipe does.
- The pressure ratings of the two 8-inch diameter pipes are almost the same. If the comparison were made between 2-inch class 315 IPS plastic pipe (with a wall thickness of 0.176 inches) and schedule 40 pipe, they would have about the same pressure rating. Remember their *actual* ID and OD dimensions are different although their *nominal* diameters are the same.

Schedule Pipe Dimensions

Standard dimensions of ductile iron and steel pipe are called *dimension schedules*. Schedules do not relate to the internal pressure those pipes can withstand.

Wall thickness of PVC pipe is shown in Table 6-3. Greater wall thickness is sometimes needed in pipe diameters of less than 2 inches to provide compression strength, adequate material for threading nipples, and tensile strength. One-half inch and ¾-inch PVC pipe is often not manufactured or listed in friction tables under pressure classes of 315 psi and lower for this reason.

Table 6-3: Wall thickness comparison of SDR-PR and Schedule PVC pipe designated 1120 or 1220.

	Wall Thickness				
Nominal Diam	SDR 26 Cl 160	SDR 21 Cl 200	SDR 13.5 Cl 315	Sched 40	Sched 80
inches	inches	inches	inches	inches	inches
¾			0.078	0.113	0.154
1	0.060	0.063	0.097	0.133	1.154
1½	0.073	0.900	0.141	0.145	0.200
2	0.091	0.113	0.176	0.154	0.218
3	0.135	0.167	0.259	0.216	0.300
4	0.173	0.214	0.333	0.237	0.337

On some installations, Schedule 80 is recommended for threaded fittings and nipples to help avoid fitting-fractures, thread-stripping from over-tightening, and physical damage. All these hazards are present in swing riser assemblies. Schedule 40 fittings, however, are often used instead of Schedule 80 fittings because they are less expensive.

Since all the pipe listed in Table 6-2 is of the same formulation, thicker walls associated with schedule pipe provide greater strength and higher pressure ratings than might be needed for the job.

Main Line Pipe

Rigid PVC, Class 160, 200, or 315, is usually used for main lines. When pipe with thicker wall is preferred, schedule 40 pipe is usually selected, particularly in diameters of less than 2 inches.

When conditions are present that increase the likelihood of surge pressures, pipe selections should provide for an adequate safety factor by using pipe with higher pressure ratings.

Solvent Welding PVC

More short-term and long-term warranty repairs are caused by incorrect PVC solvent welding than any other failure in the system. The primary cause of this is inappropriate shortcuts. Below is a comprehensive checklist of steps to take in solvent welding PVC pipe.

1. Read these steps and follow directions found on solvent cement cans even if you have installed PVC pipe before!
2. Assemble materials needed
   PVC saw or cutter
   Clean rags
   Primer
   Knife
   Right cement for the kind and size of PVC you are installing
   Right size applicator for specific size of pipe being used
3. Cut pipe square
   One good way is with a saw and miter box
   A wheel cutter designed for plastic may also be used
   If you use a wheel cutter, be sure to remove the burrs it makes with a file
4. Remove burrs
   Inside and out
5. Clean pipe with rag
   To remove dirt and moisture
6. Check dry fit
   The pipe must enter at least 1/3 of the way into the socket without forcing it!
   A good fit can be assured of by using pipe and fittings that meet applicable ASTM standards and code approvals
7. Apply primer. If you skip this step the cost of fixing the leaks will be much greater than the money saved.

8. While primer is still wet… apply cement
   Flow cement on pipe with proper applicator, then a thin coat in the fitting, then pipe again… keep applicator in cement between application… keep can closed when not in use.
   Use a brush at least ½ the size of the pipe.
9. Work quickly while applying cement
   But, do not puddle the cement inside the fitting nor let cement run down inside of pipe.
10. Assemble immediately
    Be sure to bottom pipe in socket while both surfaces are still wet.
    While pushing the pipe and fitting together, rotate one-quarter turn.
11. Hold for about a minute
    Get help on large sizes or use mechanical helpers!
12. Wipe off excel cement
    Especially the bead… but don't disturb the joint.
13. Wait before disturbing, 30 minutes to 6 hours depending on temperature
14. Put in ditch carefully
    … and carefully means DON'T KICK IT IN!
15. Snake pipe in ditch
    From side to side!
16. Shade pipe with backfill
    Leaving joints exposed for inspection!
17. Set period will depend on
    1. type of cement
    2. size of pipe
    3. air temperature/humidity
    4. dry joint tightness

    for most cases 24-48 hours is considered to be a safe period for the piping system to be allowed to stand vented to the atmosphere before pressure testing!
    Shorter periods may be satisfactory for high air temperatures, small sizes of pipe, quick-drying cement, and tight dry fit joints.
    Longer periods are required for low air temperatures, high humidity, large sizes of pipe, slow-drying cements, and loose dry fit joints.
18. Bring pipe to about its operating temperature before testing and backfilling
    This can be done by…
    1. shade back filling
    2. filling with water at about operating temperature
    3. letting it stand overnight
19. Pressure test

Joining Plastic Pipe in Hot Weather

There are many occasions when solvent cementing plastic pipe in 95°F temperatures and above cannot be avoided. If special precautions are taken, problems can be avoided.

Solvent cements for plastic pipe contain high strength solvents which evaporate faster at elevated temperatures. This is especially true when there is a hot wind blowing. If the pipe is stored in direct sunlight, the pipe surface temperatures may be 20°F to 30°F higher than the ambient temperature. Solvents attack these hot surfaces faster and deeper, especially inside a joint. Therefore, it is very important to avoid puddling the cement inside the fitting socket and to wipe off any excess cement outside the joint.

By following standard instructions and using a little extra care, as outlined below, successful solvent cemented joints can be made in even the most extreme hot weather conditions.

Tips to follow when solvent cementing in high temperatures:

1. Store solvent cements and primers in a cool or shaded area prior to use.
2. If possible, store fittings and pipe or at least the ends to be solvent welded, in shady area before cementing.
3. Cool surfaces to be joined by wiping with a damp rag. Be sure that surface is dry prior to applying solvent cement.
4. Try to do the solvent cementing in cooler morning hours.
5. Make sure that both surfaces to be joined are still wet with cement when putting them together. With large size pipe, more people on the crew may be necessary.
6. Using a primer and a heavier, high viscosity cement will provide a little more working time.

During hot weather there can be a greater expansion-contraction factor. Follow the advice of the pipe manufacturer regarding this condition.

Joining Plastic Pipe in Cold Weather

Working in freezing temperatures is never easy. But sometimes the job is necessary, if that unavoidable job includes solvent cementing plastic pipe.

By following instructions and using a little extra care and patience, successful solvent cemented joints can be made at temperatures even as low as -15°F. In cold weather, solvents penetrate and soften the plastic pipe and fitting surfaces more slowly than in warm weather. Also the plastic is more resistant to solvent attack. Therefore, it becomes even more important to pre-soften surfaces with an aggressive primer. And, because of slower evaporation, a longer cure time is necessary. Cure schedules allow a margin for safety, but for colder weather more time should be allowed.

Tips to follow in solvent cementing during colder weather:

1. Prefabricate as much of the system as is possible in a heated work area.
2. Store cements and primers in a warmer area when not in use and make sure they remain fluid.
3. Take special care to remove moisture including ice and snow from the surfaces to be joined.
4. Use a primer to soften the joining surfaces before applying cement. More than one application may be necessary.
5. Allow a longer cure period before the system is used. A heat blanket may be used to speed up the set and cure times.
6. Read and follow all directions carefully before installation.

Helpful Hints

A properly cemented joint is a most critical part of the installation of plastic pipe and fittings. And no matter how many times joining pipe and fittings is done, it's still very easy to over look something. Here are some helpful hints:

1. Have all of the instructions on the cement container label been reviewed?
2. Is the proper cement for the job being used...for the type and size of pipe and fittings being joined?
3. Do special precautions need to be taken because of unusual weather conditions?
4. Has sufficient manpower been arranged? Is more help needed to maintain proper alignment and to bottom pipe in fitting?
5. Are the proper tools and sufficient quantities of cements and primer available, and is cement in good condition?
6. Remember, primer is NOT to be used on ABS pipe or fittings.
7. Be sure to use a large enough applicator to quickly spread cement generously on pipe and fittings. Then assemble immediately.
8. Avoid puddling excess cement inside the socket, especially on thin wall, bell end PVC pipe and ABS in any schedule.
9. Be aware at all times of good safety practices. Solvent cements for pipe and fittings are flammable, so there should be no smoking or other sources of heat or flame in working or storage areas. Be sure to work only in a well-ventilated space and avoid unnecessary skin contact with all solvents.

Joining Poly (PE) Pipe

Poly pipe is very prone to damage while in the ground, due to its soft composition. Pitchforks, cultivating tools and shovels can easily damage poly pipe, necessitating repairs. Below is a list of instructions for a typical poly pipe connection between any two fittings.

1. Assemble the materials necessary for the connection
   Pipe cutter
   Clamps
   Clamp tightening tool
   Rags for cleaning
2. Expose and clean pipe and fitting ends.
3. Cut end of pipe square. The best way to do this is to use a slicing type of pipe cutter; DO NOT use a hack saw (the PE filings will get inside the pipe are are impossible to remove, even with flushing the lines)
4. Clean the INSIDE of the pipe. The **inside** of the pipe must be clean of dirt, debris and clay that may be deposited there; the exterior of the pipe is less important.
5. Check dry fit. Slide the insert fitting halfway inside the pipe to check for fit; it should meet with resistance all the way in. This resistance can be lessened by wetting the pipe and fitting with water or some type of lubricant (soap solution works well)
6. Remove fitting from pipe and slide clamp over the pipe end.
7. Slide and work the fitting into pipe, ensuring that the pipe "bottoms" onto the fitting.
8. Slide the clamp on the pipe back over the insert fitting.
9. Tighten clamp.
10. Repeat this process for the other side of the fitting.
11. Fittings are ready for use as soon as they are fully tightened.
12. Put pipe into ditch or trench
13. Snake the pipe from side to side to ensure levelness.
14. Leave pipe and joints exposed for inspection, if required.
15. Pressure test

Safety Precautions

For over 40 years, millions of solvent-cemented joints have been made with only rare cases of mishap. However, since flammable and toxic solvents are a part of these products, appropriate safety precautions should be used.

All solvent cements and primers for plastic pipe are flammable and should not be used or stored near heat, spark, open flames and other sources of ignition. Vapors may ignite explosively. Keep containers closed when not in use and covered as much as possible when in use. Use in well ventilated area. If confined or partially enclosed, use forced ventilation or NIOSH approved respirator. Avoid breathing vapors. Atmospheric levels should be maintained below established exposure limits contained in the product's Material Safety Data Sheet. If airborne concentrations exceed those limits, use of a NIOSH approved organic vapor cartridge with full face piece is recommended. The effectiveness of an air purifying respirator is limited. Use it only for a single, short-term exposure. For emergency and other conditions where short-term exposure guidelines may be exceeded, use an approved positive pressure self-contained breathing apparatus. Do not smoke, eat or drink while using these products. Avoid contact with skin, eyes and clothing. Wash clothing if contaminated before reuse. May cause eye injury. Protective equipment such as gloves, goggles and impervious apron should be used. Keep out of reach of children. Carefully read our Material Safety Data Sheets and follow all precautions.

First Aid

Inhalation: If ill effects result from inhalation, remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Call physician immediately.
Eye Contact: Flush with plenty of water for 15 minutes and call a physician.
Skin Contact: Wash with plenty of soap and water for at least 15 minutes. If irritation develops, get medical attention.
Ingestion: If swallowed, drink 1 or 2 glasses of water or milk.
DO NOT INDUCE VOMITING! Contact physician immediately.

Special Precautions

SOLVENT CEMENTS MUST NEVER BE USED IN A SYSTEM USING OR BEING TESTED BY COMPRESSED AIR OR GASES.
Do not use a dry granular calcium hypochlorite as a disinfecting material for water purification in potable water piping systems. The introduction of granules or pellets of calcium hypochlorite with PVC and CPVC solvent

cements and primers (including their vapors) may result in a violent chemical reaction if a water solution is not used. It is advisable to purify lines by pumping chlorinated water into the piping system - this solution will be nonvolatile. Furthermore, dry granular calcium hypochlorite should not be stored or used near solvent cements and primers. All systems should be flushed before start-up to remove excess fumes from piping system.

New or repaired potable water systems shall be purged of deleterious matter and disinfected prior to utilization. The method to be followed shall be that prescribed by the health authority having jurisdiction or, in the absence of a prescribed method, the procedure described in either AWWA C651 or AWWA C652.

Use Caution With Welding Torches

At construction sites where plastic pipe is being installed or has recently been solvent welded, extreme caution should be taken when using welding torches or other equipment where sparks may be involved. Flammable vapors from cemented joints sometimes linger within or around a piping system for some time.

Special care must be taken when using a welding torch in these installations:

A. Well casing, elevator shafts and other confined areas.

B. Installing pumps in irrigation water lines.

C. Plastic pipe systems in industrial plant areas with little or no air circulation. In all cases, solvent vapors must be removed by air circulation, purging, or other means prior to the use of welding torches, or other spark or flame generating equipment or procedures.

An additional note in regard to using propane torches: Quite often where poly pipe use is prevalent, contractors will use torches to soften the pipe so that fittings insert easier. While this technique may be widespread, we would like to point out that pipe manufacturers recommend against it. In addition, if you were to have widespread fitting blowouts or leaks on a project, the pipe manufacturer can determine whether or not torches were used on the pipe and if so, this would void any manufacturer's warranty.

Main Line Details

As seen in the following details, mainline pipe is installed deeper than other piping to offer increased protection from elements and overhead traffic. When dealing with gasketed mainline piping, as seen in Figure 6-1, cement thrust blocks are poured to keep the pipe from shifting.

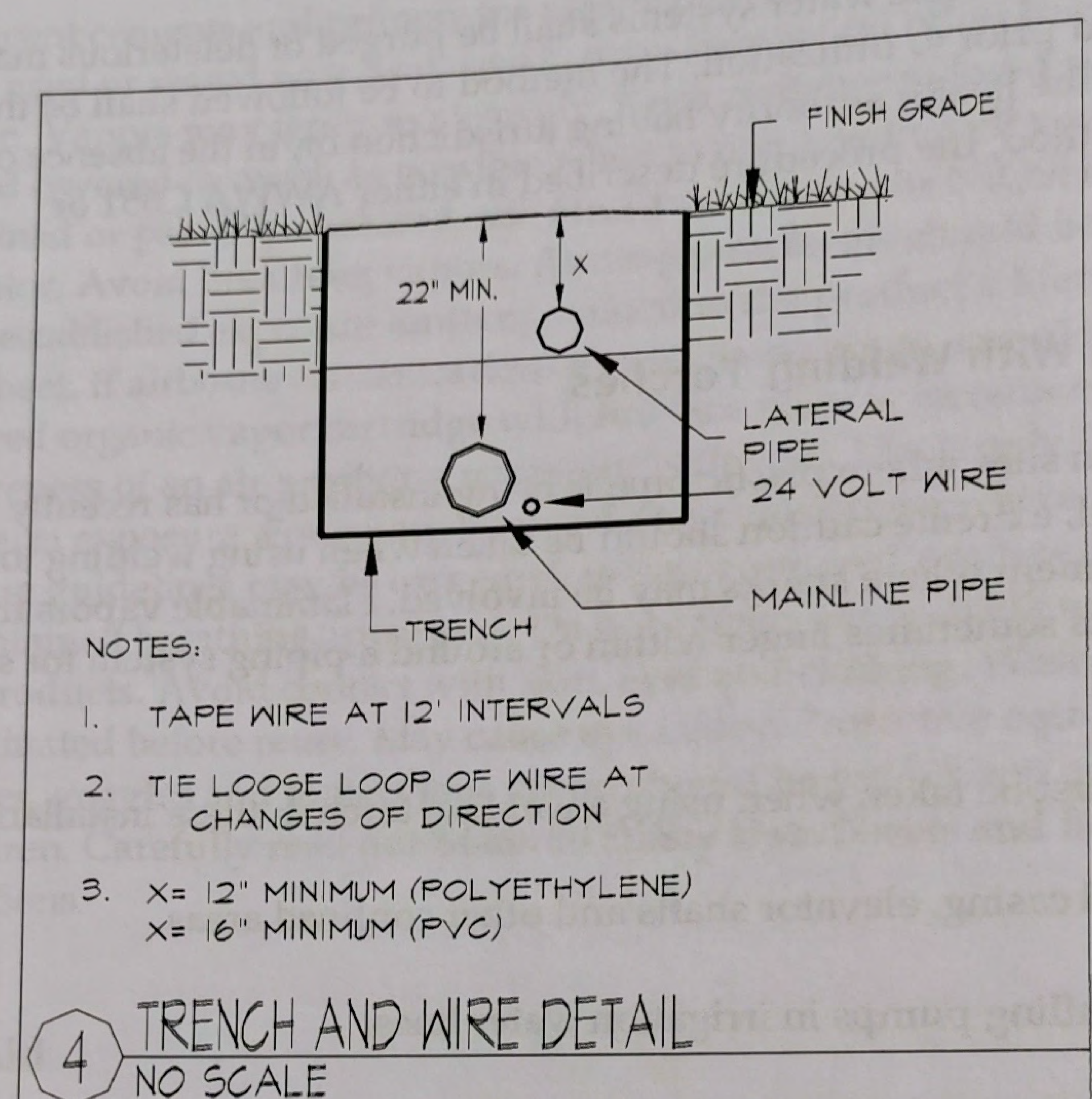


Figure 6-1

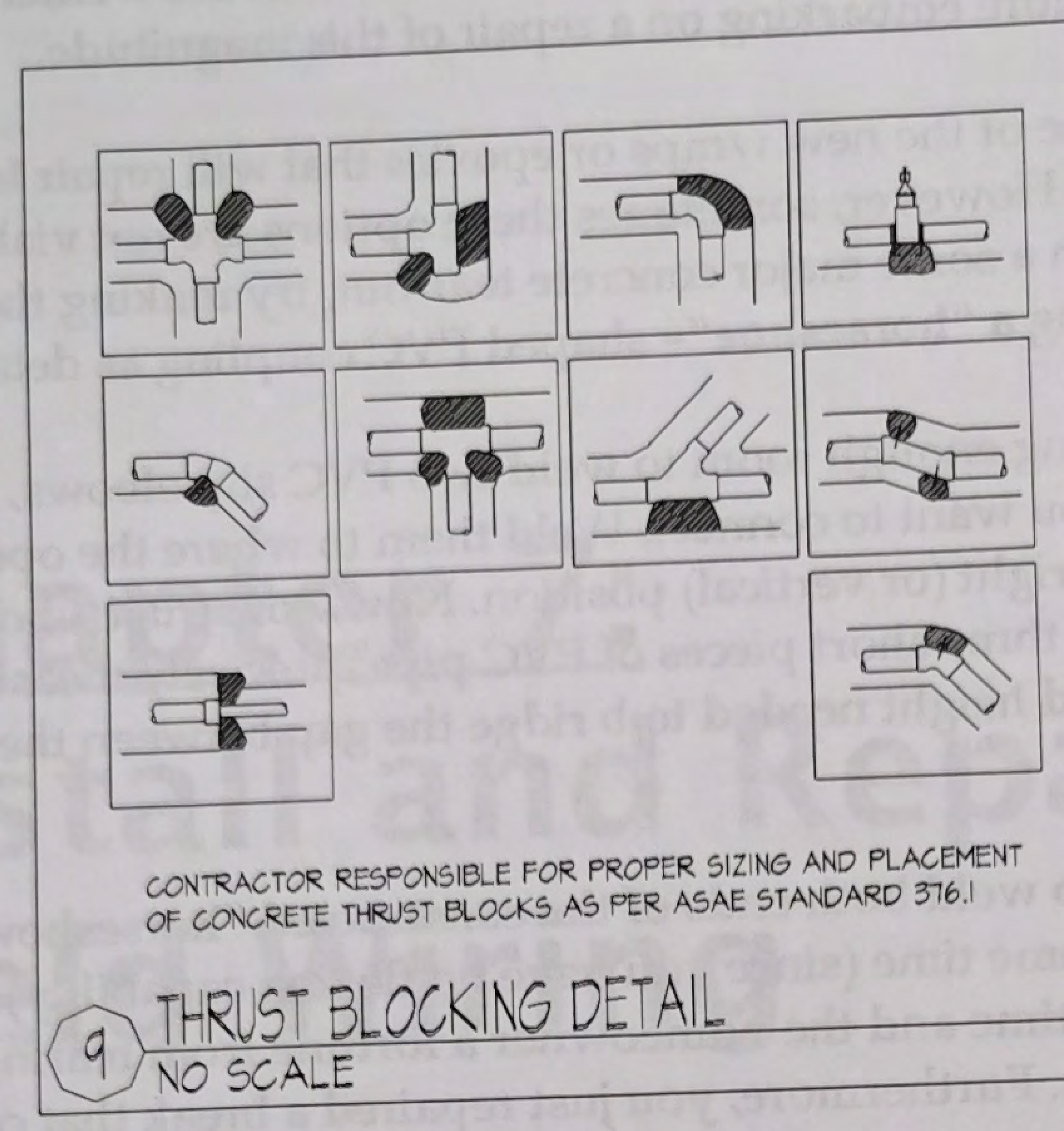


Figure 6-2

PVC Pipe Repairs

While repairing any pipe break, be aware of what might have caused this situation. It might be that too much pressure has created this problem. If so, then fixing the leak will only prolong the real problem. Next time it will be the next weakest joint or pipe. It would be best to correct the root of the problem by installing a pressure regulator.

Repairing broken PVC pipe is easier with the new telescoping and compression couplings, especially in tight quarters. As mentioned above, PVC pipe is not very flexible, requiring considerable digging on either side of the joint to repair it using the old conventional way of flexing (or bending) the pipe. For example, to repair a ¾″ PVC pipe with solvent in a conventional way, you need several feet of exposed pipe on each side of the joint. When applicable, spend a couple of extra dollars and use a telescoping or compression coupling. You will save on labor and make the job much easier.

Pipe breaks in places that are practically inaccessible present a real problem. For instance, take a pipe break on or near a manifold that is completely surrounded by concrete that was poured long after the system was installed. If there is not enough room to flex the pipe or use a telescoping or compression coupling, you may have no other option but to tear out concrete. Consult with, and secure written consent with the property owner before embarking on a repair of this magnitude.

First consider using one of the new wraps or epoxies that will repair leaks (check with your distributor). However, sometimes these options are not viable. Before going to extremes, such a some major concrete tear-out, try making the repair (on smaller pipe sizes) using a "**horseshoe**"– shaped PVC coupling as detailed below:

Cut the breakout, leaving enough room to weld two PVC slip elbows, one on each end of the two pipes you want to connect. Weld them to where the open socket is pointing in an exact upright (or vertical) position. Now, construct a horseshoe-shaped coupling out of three short pieces of PVC pipe, precisely measured and cut exactly to the length and height needed to b ridge the gap between the two vertical elbows.

The final procedure is to weld both ends of the constructed "horseshow" coupling into the sockets at the same time (since you have no flexing capability). Done! Now you just saved yourself time and the homeowner a fortune from tearing out their beautiful concrete porch. Furthermore, you just repaired a break that could not be repaired with one of the newer wraps, compression or telescoping couplings.

To successfully complete this procedure, remember to use a marker and measure precisely (no room for error), use plenty of solvent, be sure both pipes go in far enough and wipe off the excess solvent. (Note: You will be welding both ends of the coupling at the same time, which means that you will not b e able to give the pipe a quarter twist as normally recommended in ideal conditions).

Some irrigators might debate this procedure from a business standpoint. They may opt for the concrete tear-out in order to gain more business. However, years of experience and common sense indicate that your best option is to make the repair, if possible, without major concrete excavation. The time you saved can be better utilized on several easier repairs that will make you the same (or more) revenue. Furthermore, saving the customer this great expense will earn their loyalty toward your business for years to come.

PVC pipe, broken off inside the joint of a fitting, sometimes present difficult and timely repairs (especially on valve manifolds). Before replacing the fitting (and possibly rebuilding the entire manifold), consider several other options. First, drill attachments are available that allow you to drill the unwanted PVC out of the socket, then wells another piece of pipe in (ask your local distributor). Second, depending on the fitting manufacturer, some couplings (one size larger) will wend perfectly over the outside of a smaller fitting. This procedure should only be used with smaller pipe sizes (properly prepared) and if unable to use the first option.

Chapter 7: Install and Repair Field Wiring

Steps of Installation

1. Select Proper Tools
2. Perform Site Inspection
3. Read Blueprints
4. Install POC
5. Install Mainline
6. **Install Field Wiring**
7. Install Valves
8. Install Lateral Piping
9. Install Sprinkler Heads
10. Mount and Wire Controllers

Electrical Connections

Communication between automatic controllers and irrigation valves and heads has become critical to the success of any irrigation system. Like the nerves that carry messages from our brain to our body parts, if the message is corrupted between the two, so will the body's response to the signal. In irrigation system management, this corrupted message could result in sprinklers turning on and off when they aren't supposed to or not performing at all.

Improper wire can disrupt a message sent from a controller to a valve or sprinkler in the field. Even when all the other components in an irrigation system are functioning properly, wire can destroy the operation of the overall system. Properly selected wire ensures clear, crisp communication between components of a system. Improperly selected wire will result in faulty communication or will cause embarrassing and costly mistakes.

Basic Layout

Irrigation systems require a single copper control wire which connects each control valve's solenoid to the controller. This is the wire which carries a signal for the valve to open and close and that is why it is called the Control wire. Control wires are normally color coded and come in variety of colors. A Common or ground wire connects all the solenoids in the system to each other and to the controller. This is called the Common wire and is normally always white in color.

Insulation

Irrigation control wire must be insulated in order to carry an electric current; the current is the "message to open" for the control valve solenoid. The insulation is used to protect the wire during installation and settling and to prevent the loss of current during operation. Insulation is commonly made of a flexible PVC material which protects against moisture and resists chemical breakdown. Insulation coatings on wire must be continuous and undamaged. Any break or crack in the insulation can allow electrical current to dissipate or "ground" out the signal. Insulation is sometimes damaged during system installation and can be a common problem on control wires that are installed by vibratory ploughs.

When laying out the field wires to your controller there are a few issues to consider. The length of wire from the controller to the valve determines, for the most part, the gauge of wire necessary to use. One of the hardest tasks to undergo after an installation is to replace a valve wire that was not the correct gauge wire. It is the same as having to changing the sprinkler lateral line that was too small.

There is a formula that can be used to calculate the best wire gauge to use. This formula uses water pressure, solenoid current, minimum voltage needed to operate a solenoid, and one-way distance to the valve. However you can use the chart listed below as a guide, or for a good "rule-of-thumb" distance that can be expected by using a given wire gauge. For exact, reliable information, one should calculate wire sizes with the proper formulas or consult specific manufacturer's tables. This chart is one-way distance from the controller to the valve, figuring 150 psi static pressure and .30 amp inrush current.

Table 7-1

Maximum Allowable Length For Each Of Two Wires / Valve[1]					
AWG* Size	**Maximum Static Water Pressure not exceeding**				
	50 psi	**75 psi**	**100 psi**	**125 psi**	**150 psi**
#18	2,750'	2,070'	1,480'	970'	530'
#16	4,380'	3,290'	2,360'	1,550'	840'
#14	6,990'	5,250'	3,760'	2,470'	1,340'
#12	11,080'	8,330'	5,970'	3,930'	2,140'
#10	17,640'	13,260'	9,500'	6,250'	3,400'
#8	28,050'	21,090'	15,120'	9,940'	5,420'
#6	44,590'	33,520'	24,030'	15,810'	8,610'
#4	70,920'	53,310'	38,220'	25,140'	13,700'

[1] The two wires (control and common of same gauge) may be of unequal length if the total is not more than twice the table length

* AWG = American Wire Gauge

Commonly 14, 16 or 18 gauge are the most often used wires for field wiring. The industry standard for the common wire is white in color. The field "Hot" wire can be may other colors. When using 16, or 14 gauge wire, black tends to be used more than any other color wire for the "hot" wire. It is best to use separate colors for each station as this helps in identifying stations in the field when performing field wiring troubleshooting (on large installations this may be impractical).

There are several types of "multi-strand" wire on the market. Typically the black-jacked wire is 18gauge and is considered direct burial. There is a brown jacked wire known as "thermostat, or Bell wire" this is normally 20 or 22 gauge wire, but is referred to as 18 gauge wire. Be very cautious when using this type wire. At all times avoid using speaker wire, lamp cord wire, cut-off extension cord or raw copper wire. This can greatly impact the integrity of the system. By no means use the solenoid wire as field wire as to do so would require either the controller to be mounted too close to the ground, or the solenoid valves to be mounted too high off the ground.

Now that we have correctly chosen the size wire it is time to lay this system out. By now we should have picked the location for the valves and chosen the best path to run the sprinkler piping. It is best to run the valve wire in the same trench as the pipe. Home grown tip here is to put the wire below the pipe in the trench. Because there is no difference between tree roots and valve wires to a shovel.

When running the wire it is best to not try to use short pieces of wire. There is a little voltage loss at each connection. Also each wire splice is a potential wiring issue later on, from corrosion, or shorting out from a flooded splice. Lay the wire loose in the trench, do not stretch the wire in an attempt to save having to buy a few extra feet of wire, as this could damage, or crack the insulation, not to mention breaking the copper wire inside. Run the wire through a "Sleeve" whenever the path takes you under any walkway, driveway, or concrete pavement of any kind. This can be very tricky, and when pulling the wire through the sleeve it is very easy to rip the insulation as it is pulled. For future ease of repair place a small valve box at each and every wire splice. If there is room, place one at the beginning of each large sleeve, as well.

Making the wire connection is very important. Tying the wire is not considered a good connection. Soldering the wire is strong but really not practical. The very best connection is one that is water resistant, or proof, and made for wire connections. This would mean that placing a small amount of PVC pipe glue, car grease, Vaseline, toothpaste, or bubble gum in a wire nut is not a good idea. Simply putting black electrical tape around a pair twisted wires is really not a good idea as most valve boxes fill up with water after a short amount of time. Water and electricity do not mix. Think bathtub and hair dryer. Two common types of water resistant connectors are pictured below, (see Figure 7-1). When using wire nuts it is best to not try to stuff too many wires into one nut. Also try to not mix many sizes into one nut as well.

The number one common field related failure is in the wiring connector, or lack there of. Typically a standard yellow wire nut can reasonably hold up to three 14 gauge wire and a solenoid wire. Like wise the same yellow wire can hold up to four solenoid wires along with two 14 gauge wires. There is no reward for putting the most wires into a single wire nut. There are great numbers on plastic cards that are extremely helpful in identifying which wire goes to which valve. Consider that normally there more than one valve in a valve box and when you have three to four in a box it can be quite confusing which wire goes to which valve. It is a good practice to coil about one to two feet of wire tightly around a half inch piece of PVC pipe, both each at the controller and at the valve box. (See Figure 7-14.)

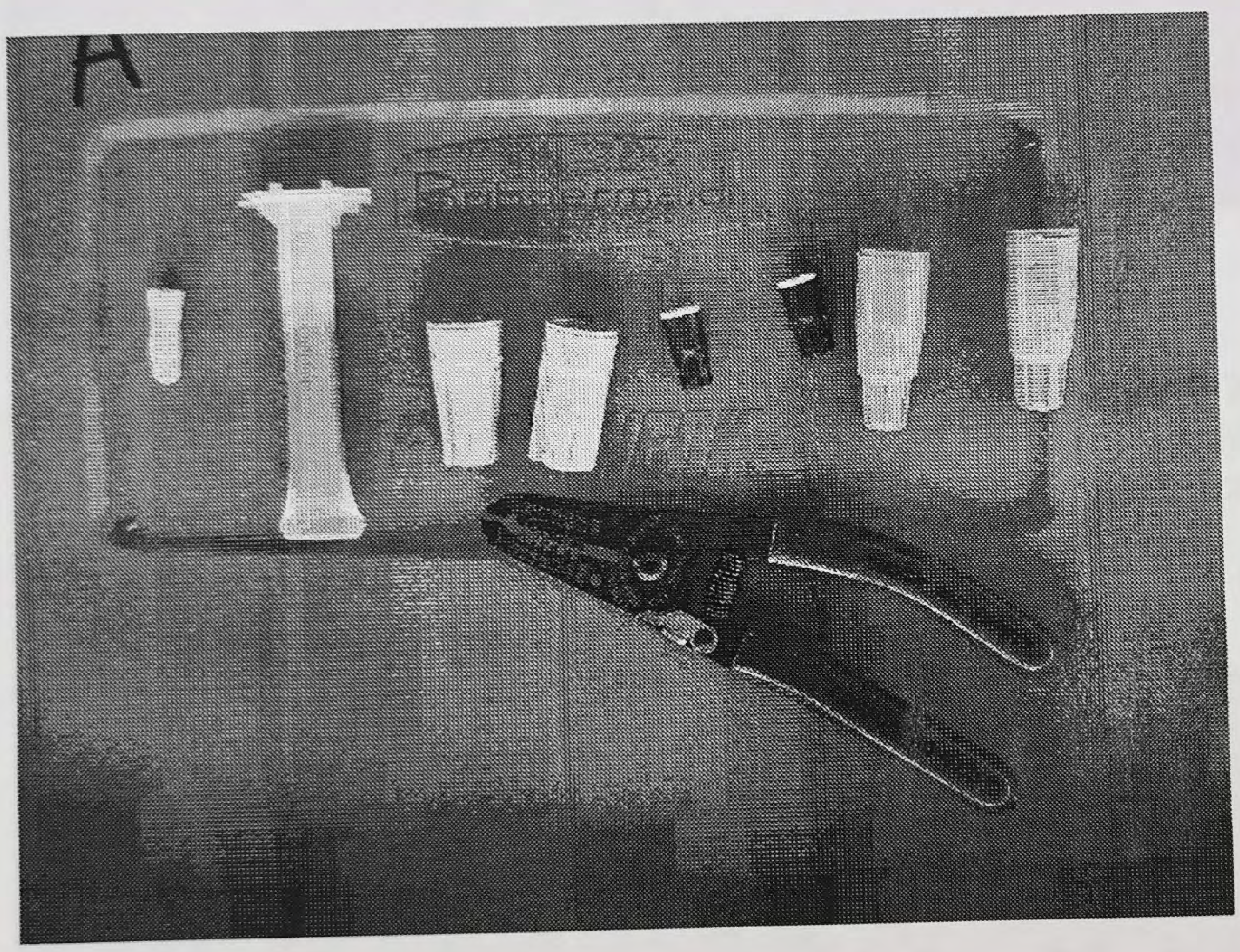


Figure 7-1: Wire splice kits

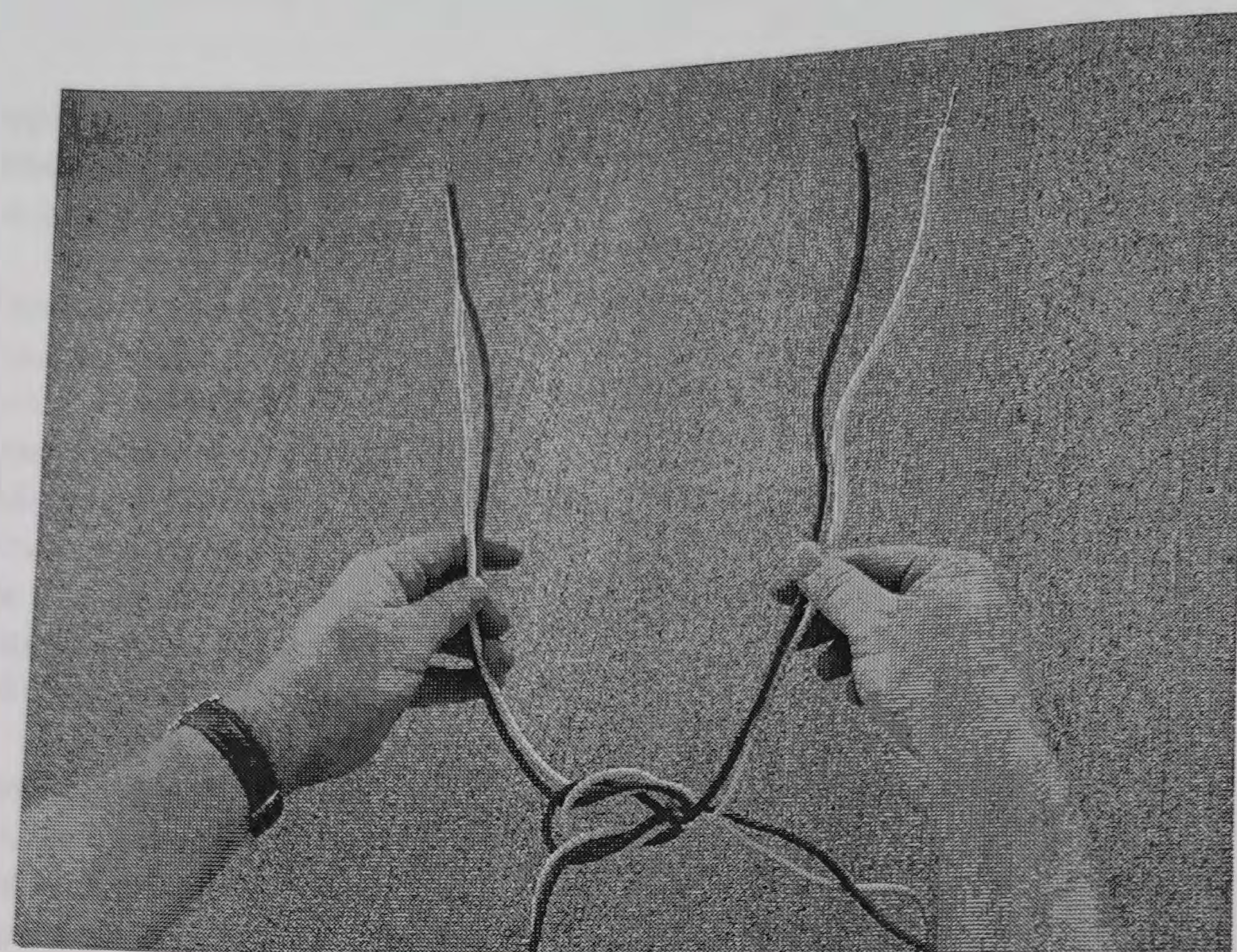


Figure 7-2

When making splices in the trench (not at the valve), it is a good idea to "knot" your wire. This helps prevent the splices from being pulled apart by temperature contraction or the wire accidentally being dug up.

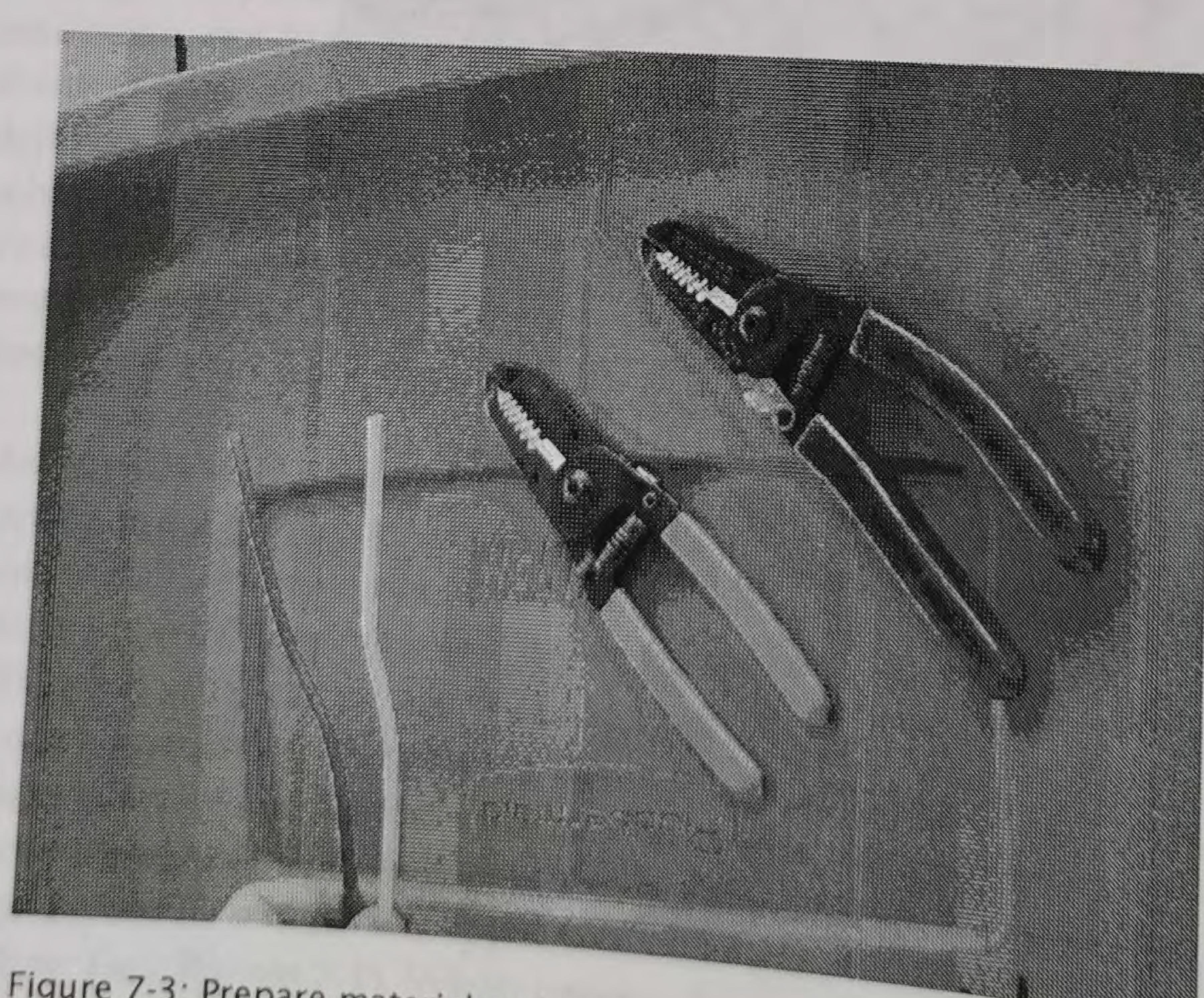


Figure 7-3: Prepare material and tools

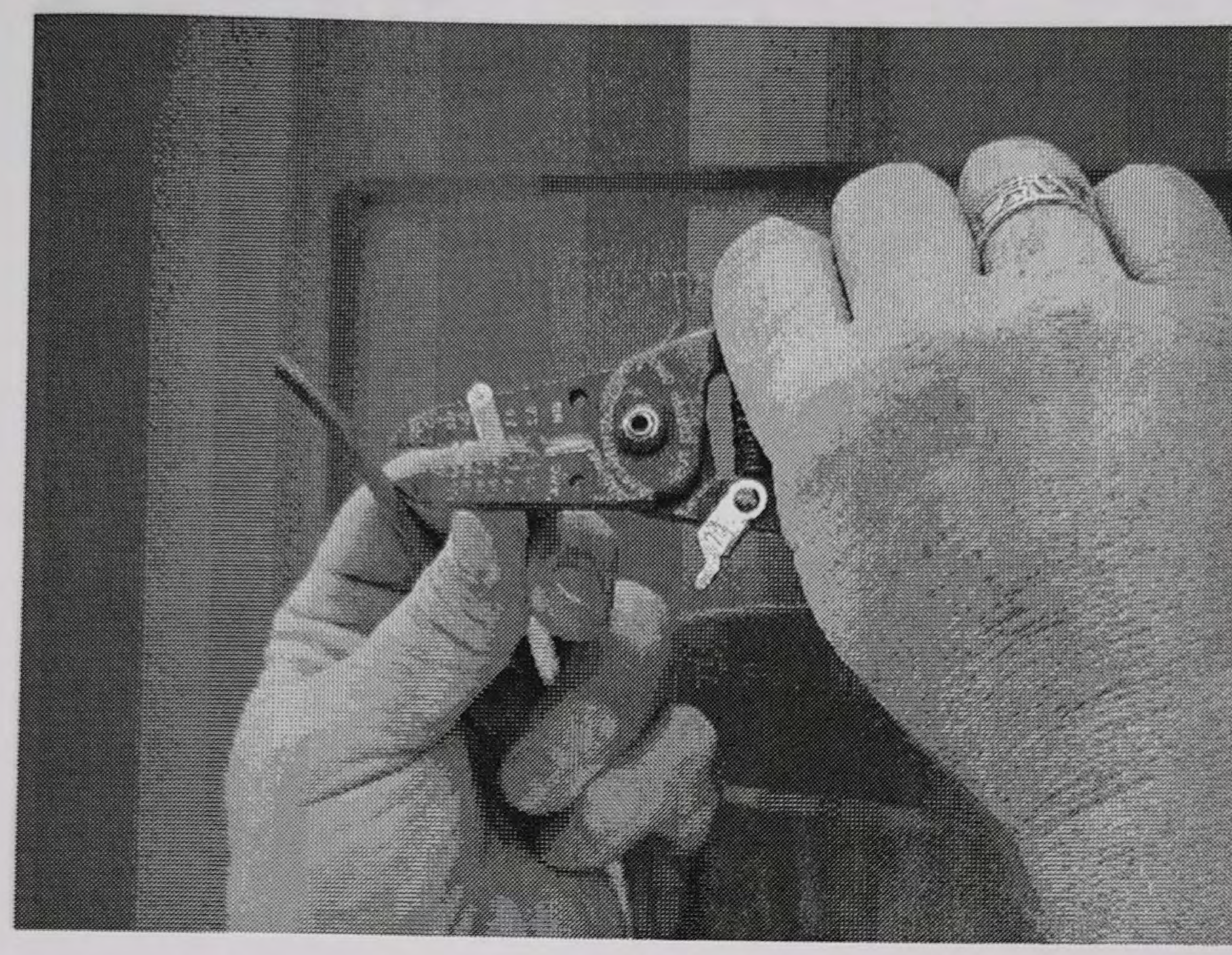


Figure 7-4: Stripping the wire insulation

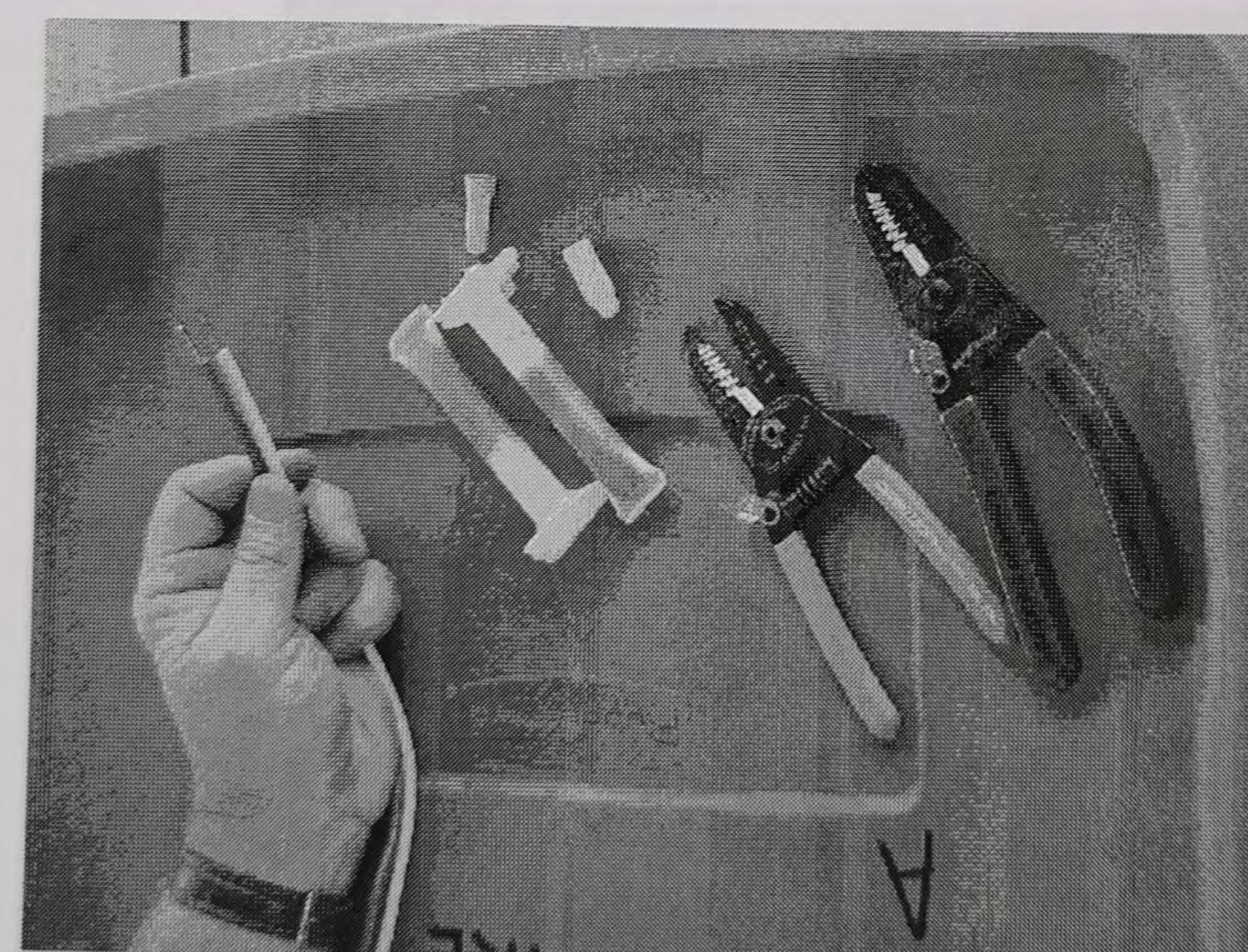


Figure 7-5: Hold wires together for splicing

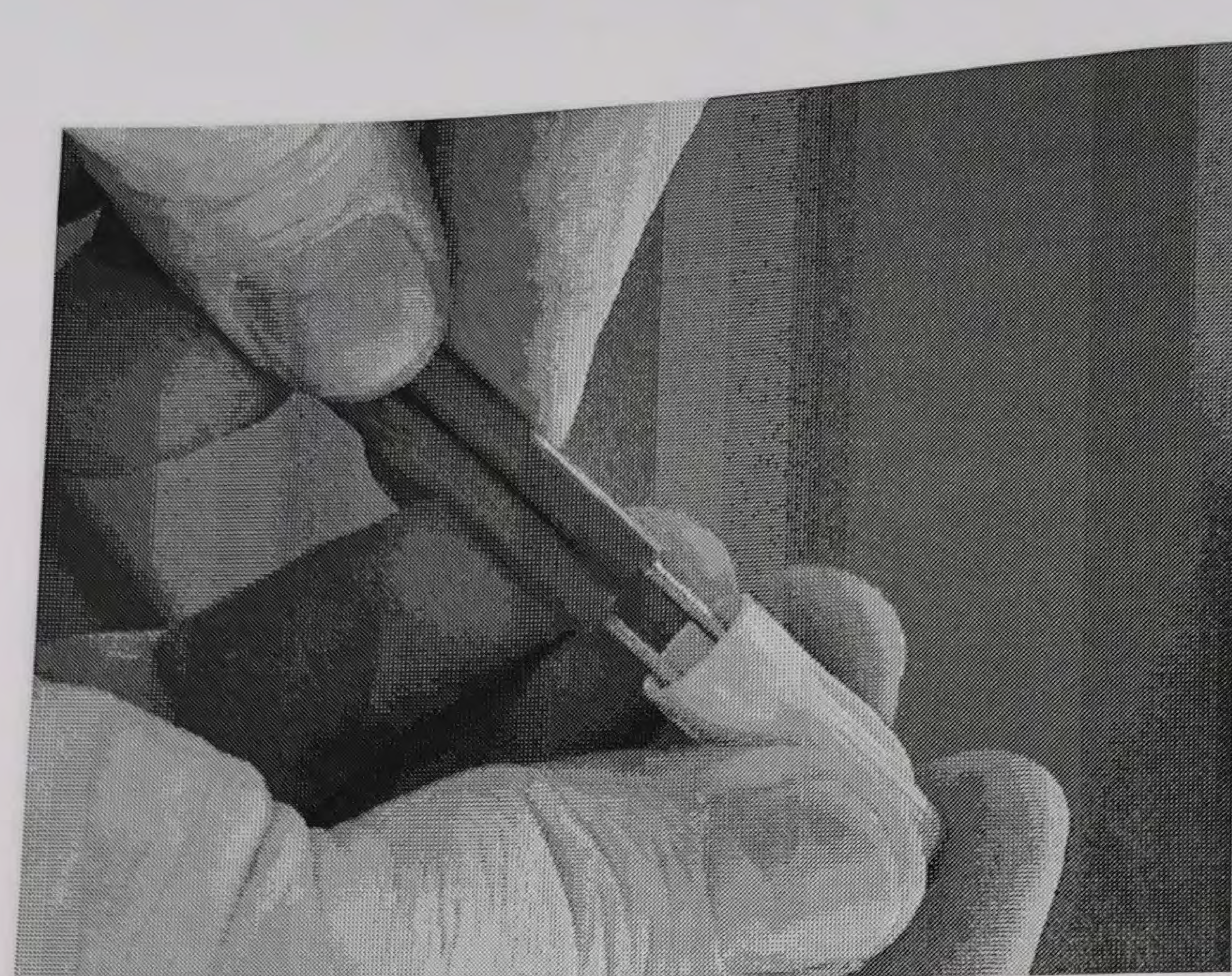


Figure 7-6: Install wire nut

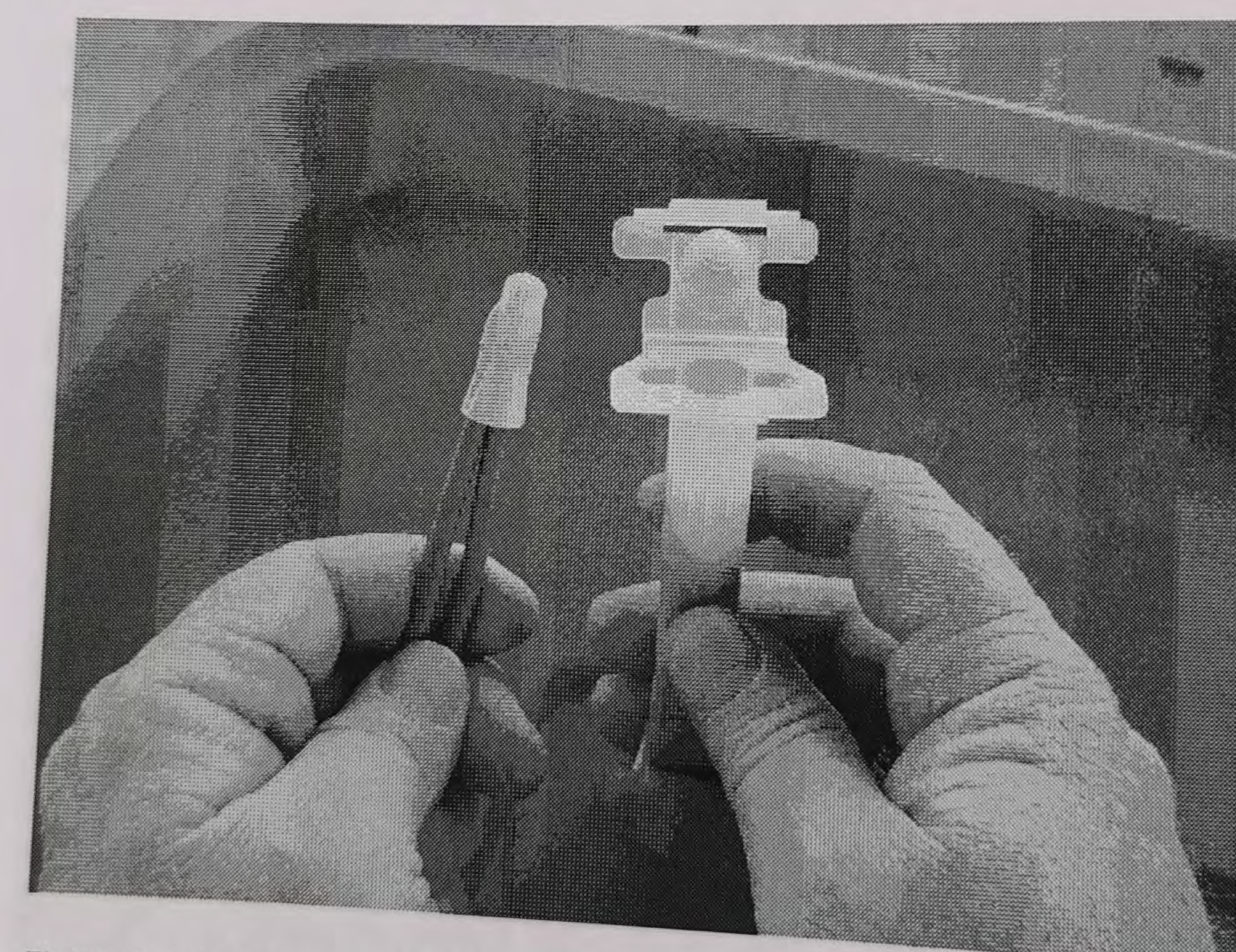


Figure 7-7: Prepare waterproof connector

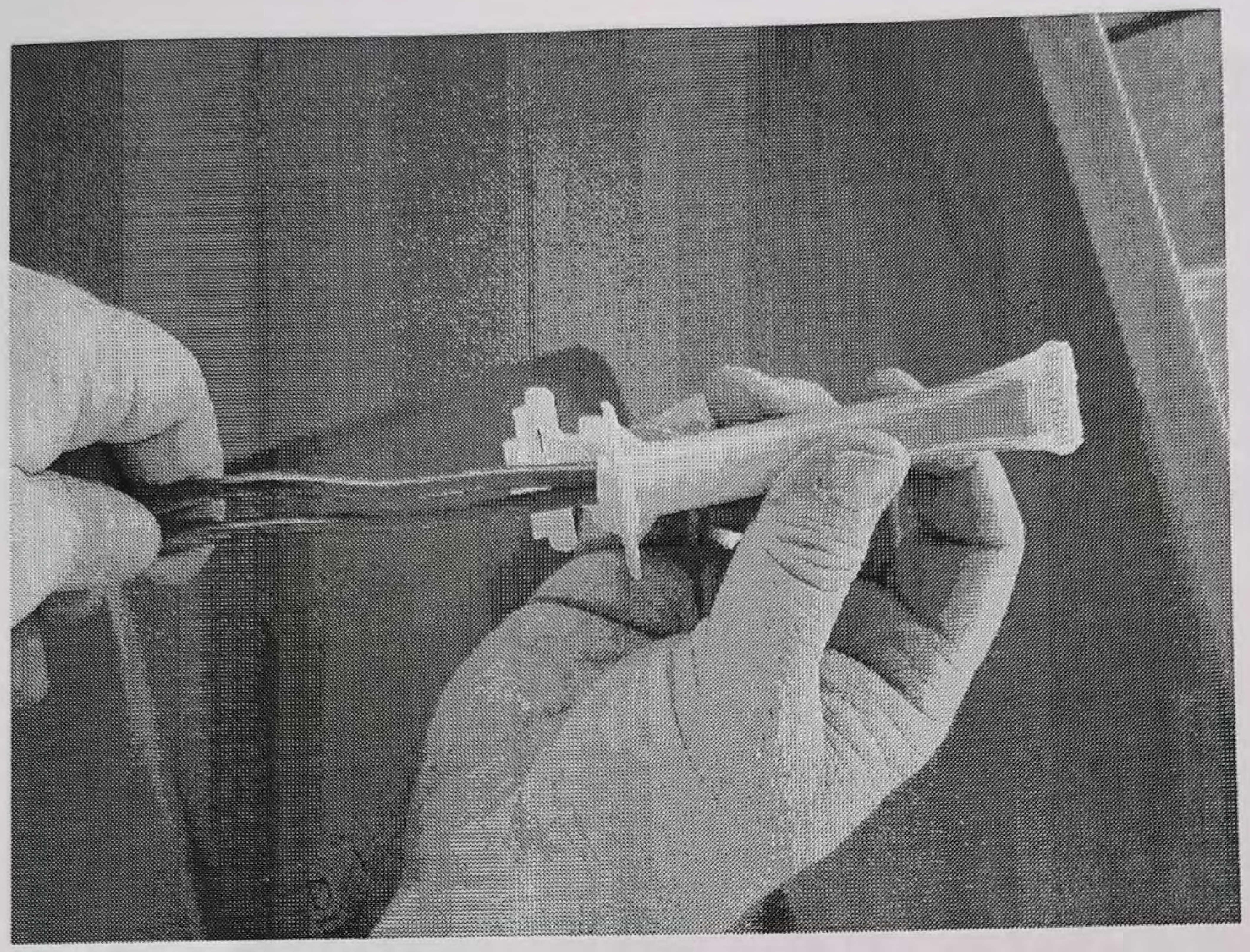


Figure 7-8: Insert wires into connector

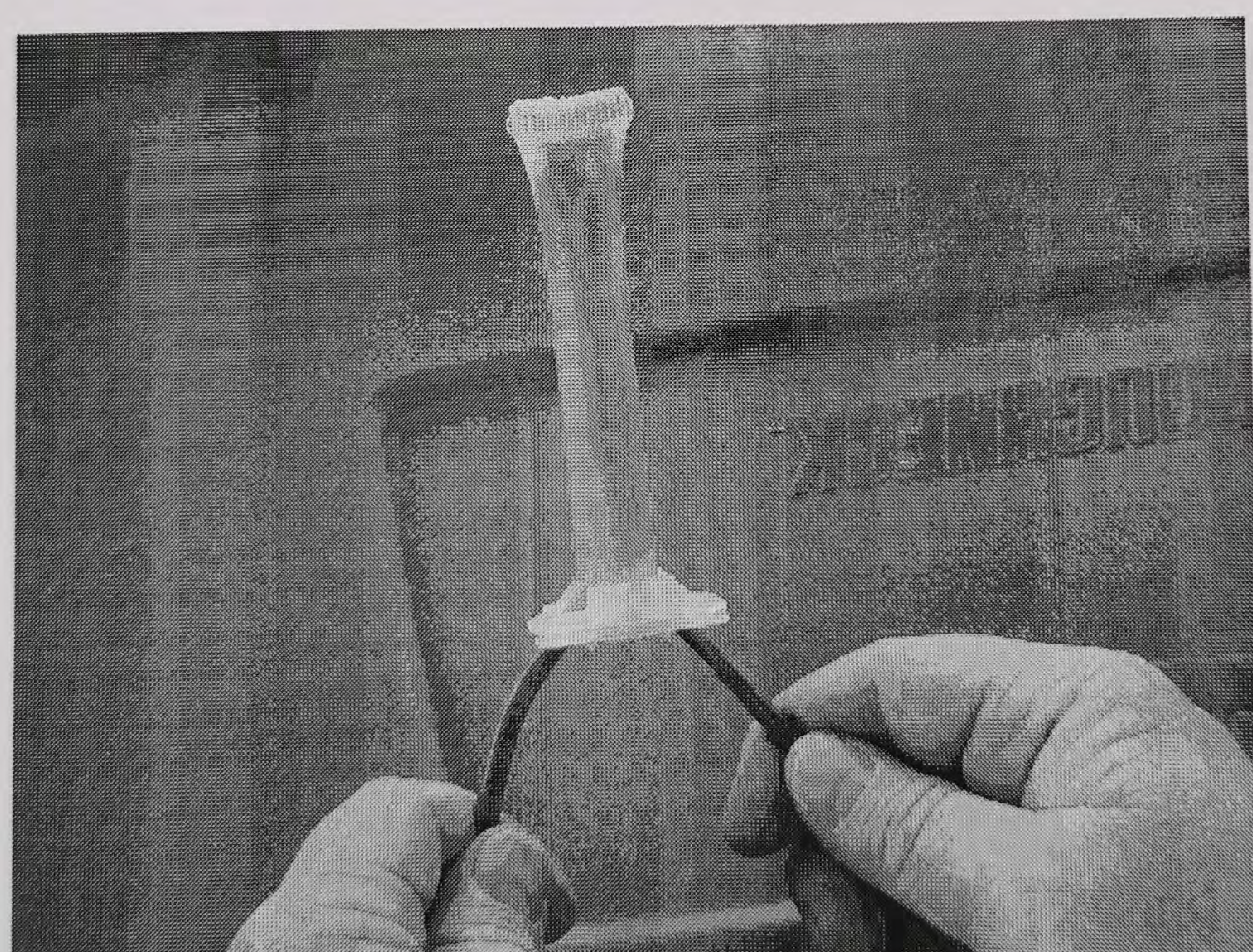


Figure 7-9: Finished splice

Figure 7-10: Splicing with waterproof filled wire nuts

Figure 7-11: Insert wires

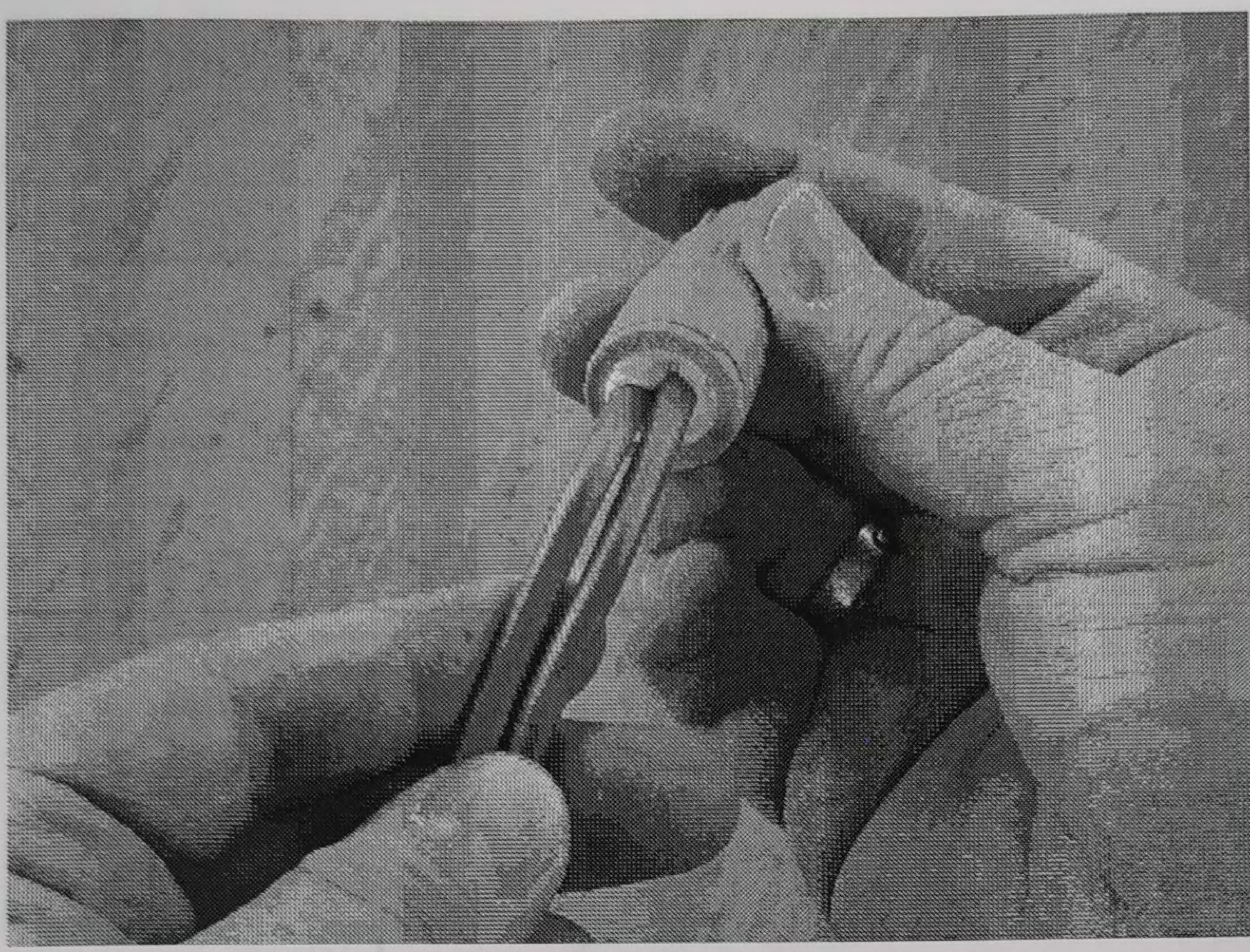
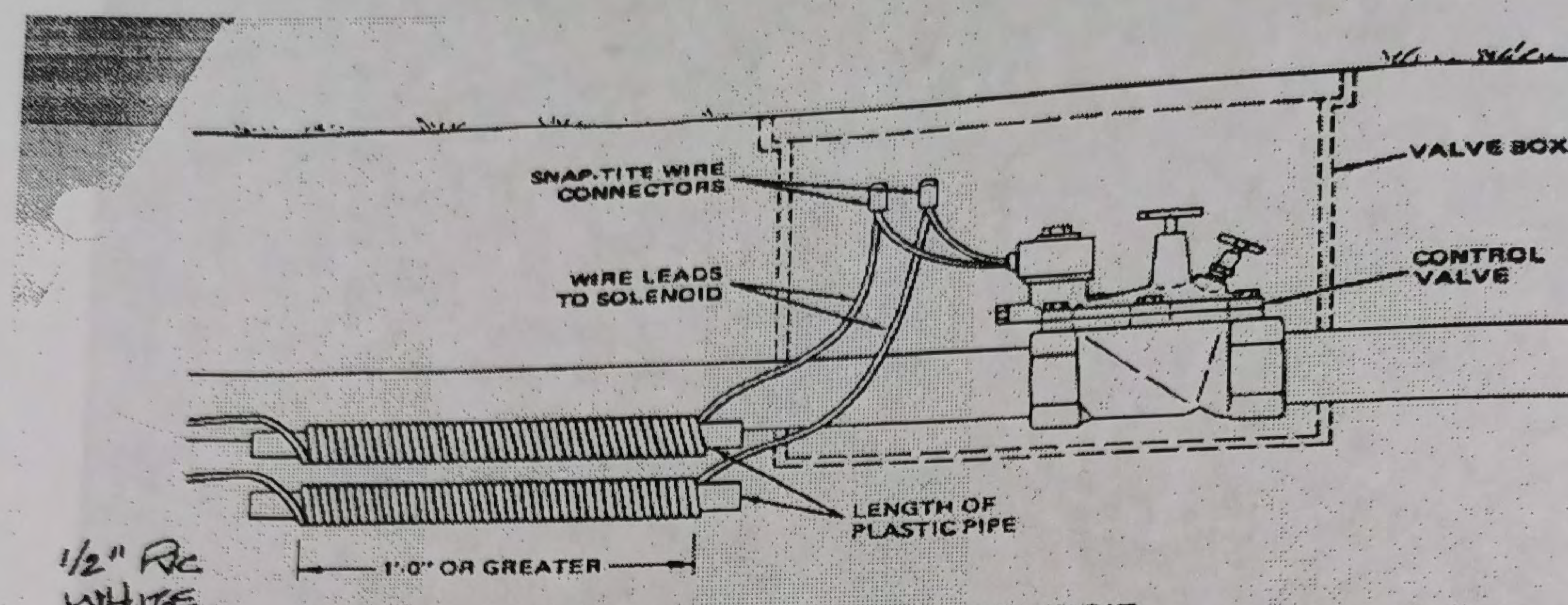
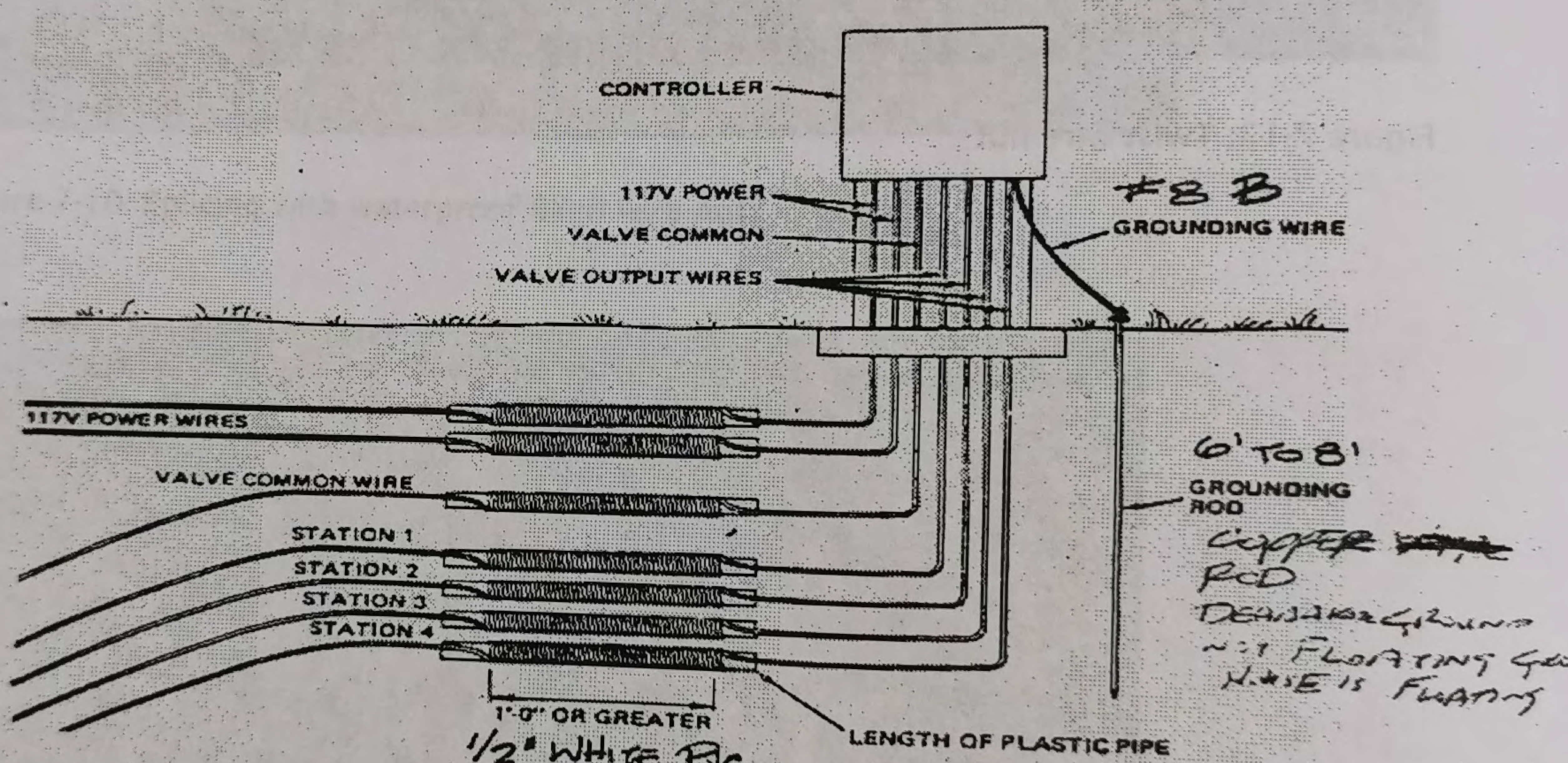


Figure 7-12: Twist wire nut



PROTECTION TO VALVE SOLENOID



ADDITIONAL PROTECTION TO THE CONTROLLER

SURGE PROTECTION METHODS

Figure 35

70

Figure 7-13

Chapter 8: Install and Repair Valves

Steps of Installation

1. Select Proper Tools
2. Perform Site Inspection
3. Read Blueprints
4. Install POC
5. Install Mainline
6. Install Field Wiring
7. **Install Valves**
8. Install Lateral Piping
9. Install Sprinkler Heads
10. Mount and Wire Controllers

Solenoid Valve Function – Installation, Troubleshooting & Repair

Fundamental Valve Hydraulics

The solenoid-actuated diaphragm valve employs some very simple physics as it operates. The valve utilizes line water pressure and a series of chambers to alternately create a force over the diaphragm surfaces to regulate the flow of water to the sprinklers. When the valve is closed and the diaphragm seated, the pressure in all chambers of the valve remains fairly constant. Figure 8-1 illustrates the various chambers or cavities of the valve. The inlet port channels pressurized water to the bonnet cavity. The pressure in the bonnet cavity may be relieved by opening either the outlet or the bleed ports. When this occurs, the diaphragm is forced upward and the water flows over the seat into the outlet cavity, providing water to the sprinklers.

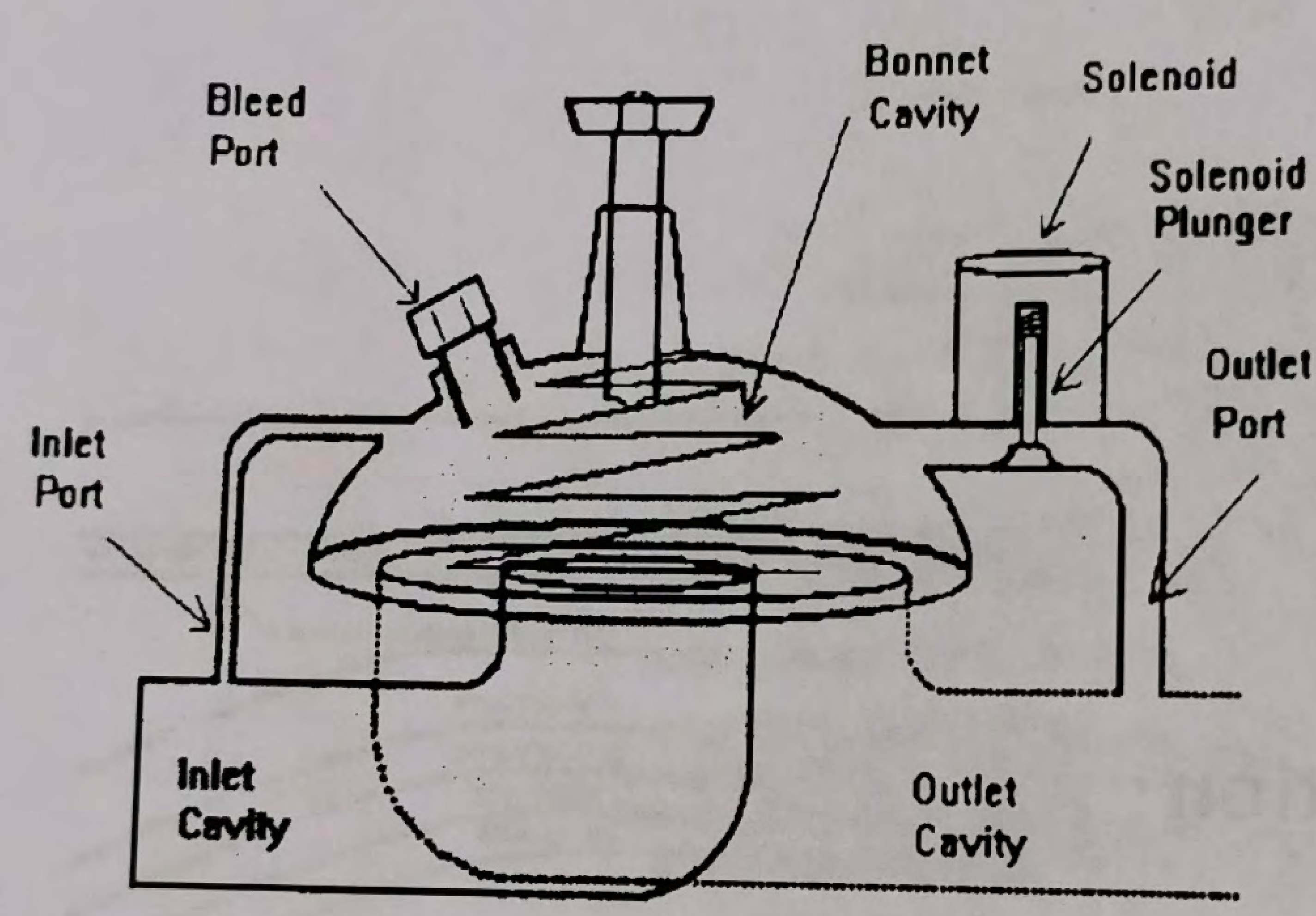


Figure 8-1: The cavities of the solenoid valve showing the position of the valve diaphragm and the inlet and outlet ports.

Water pressure, however, is just one aspect to consider with regard to the physics involved in the operation of the valve. Figure 8-2 represents the basic cavities of a solenoid valve in the closed position and displays the forces on the diaphragm. In this case, there is an inlet pressure of 50 psi pressurizing a 4.91 square inch area. Together, these two conditions yield a force over the diaphragm of 245.5 in/lbs. Conversely, the inlet pressure while also at 50 psi pressurizes only 1.23 square inches equaling 61.5 in/lbs. of force. The inlet or upward force in this case is only one quarter the downward force causing the valve to remain closed.

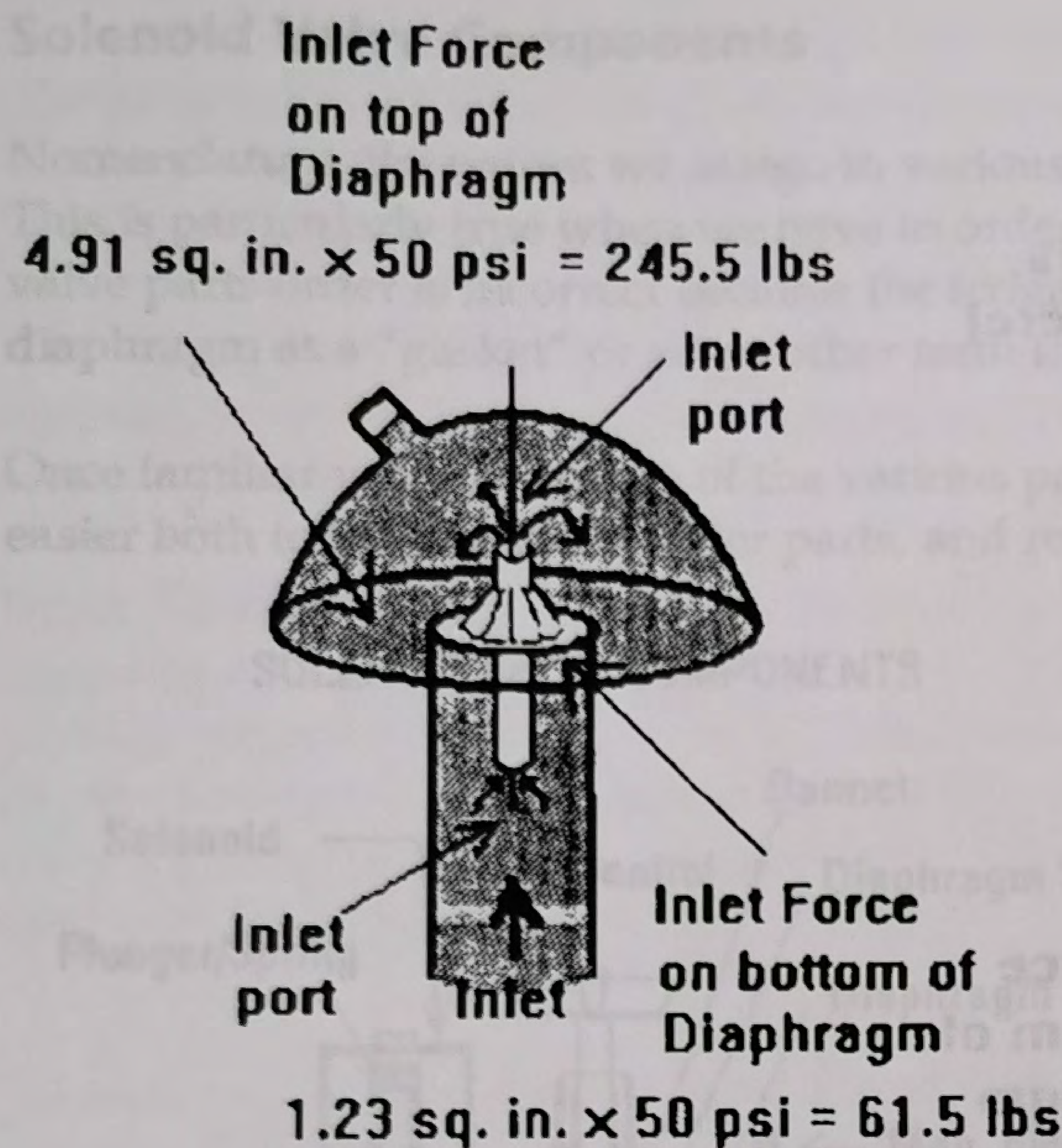


Figure 8-2: This diaphragm shows forces in the bonnet and inlet cavities with the valve in the normally closed position.

A reduction in bonnet cavity pressure changes the force over the diaphragm. In the case of the diaphragm as shown in Figure 8-3 the bonnet cavity pressure has been reduced to 5 psi. The pressurized surface area of 4.91 square inches now yields a force of only 24.55 lbs. (4.91 x 5 = 24.55). The inlet force of 61.5 lbs. is now nearly three times greater than the bonnet cavity pressure and the diaphragm is forced upward. When this occurs, the pressurized water flows into the outlet cavity through the lateral piping to the sprinklers.

Bonnet cavity pressure can be reduced to this threshold in a couple of ways. Bonnet cavity water can be discharged to the atmosphere through a manual bleed or to the nonpressurized outlet cavity through a port located under the solenoid. Either of these ports has a higher flow capacity than the inlet port. This allows water to evacuate the cavity faster than the inlet port can replenish it, so the pressure drops. Many valve manufacturers incorporate the manual bleed as an integral part of the solenoid assembly. This allows manually bled water to discharge into the outlet cavity.

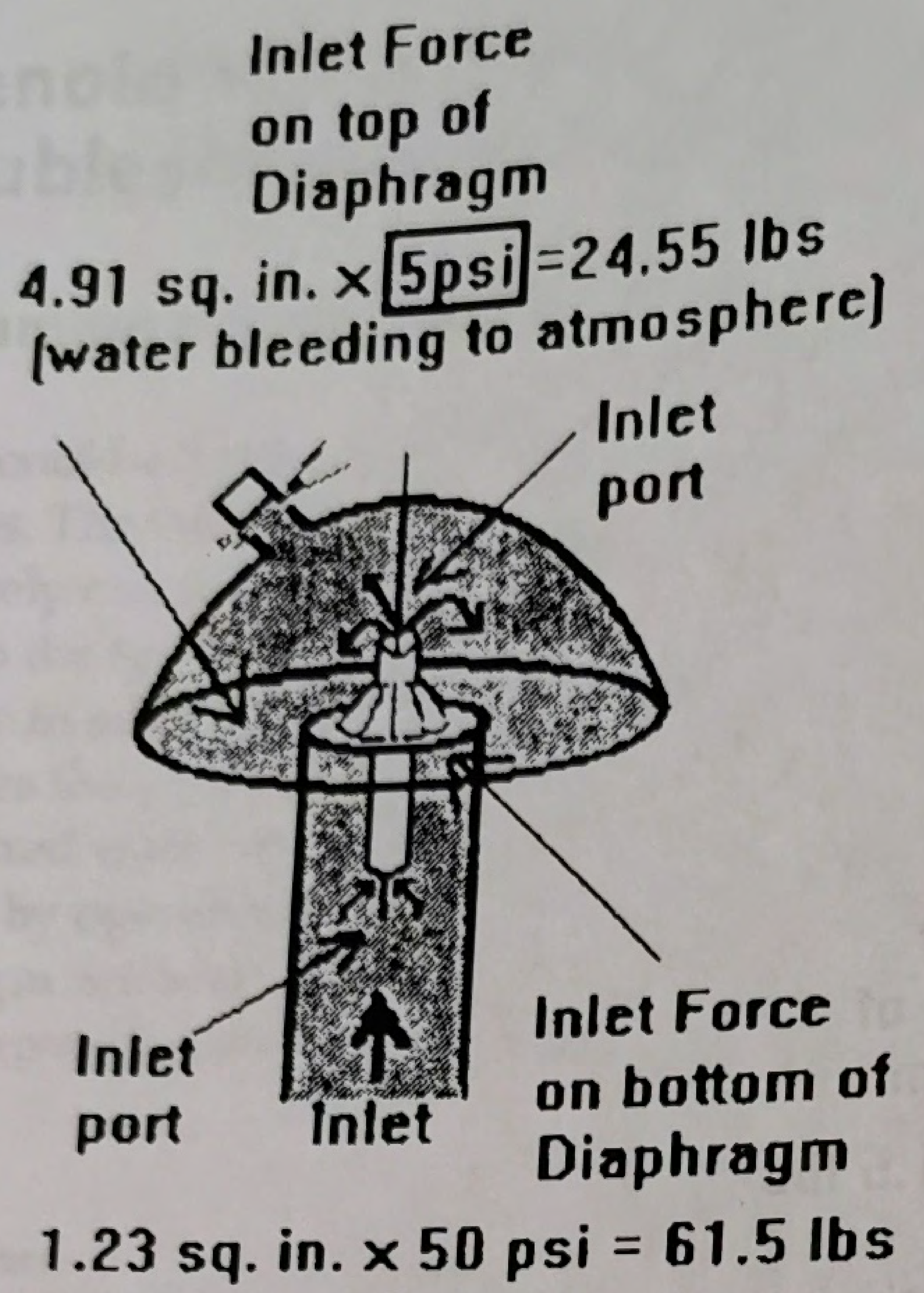


Figure 8-3: The forces in the valve bonnet and inlet cavities, and the change in force that occurs as the valve is manually bled.

Solenoid Valve Components

Nomenclature, the names we assign to various valve parts, is very important. This is particularly true when we have to order a replacement part. Quite often a valve parts order is incorrect because the irrigation technician referred to a valve diaphragm as a "gasket" or some other term that inadequately describes it.

Once familiar with the names of the various parts and their functions, it is much easier both to troubleshoot, order parts, and repair the valve.

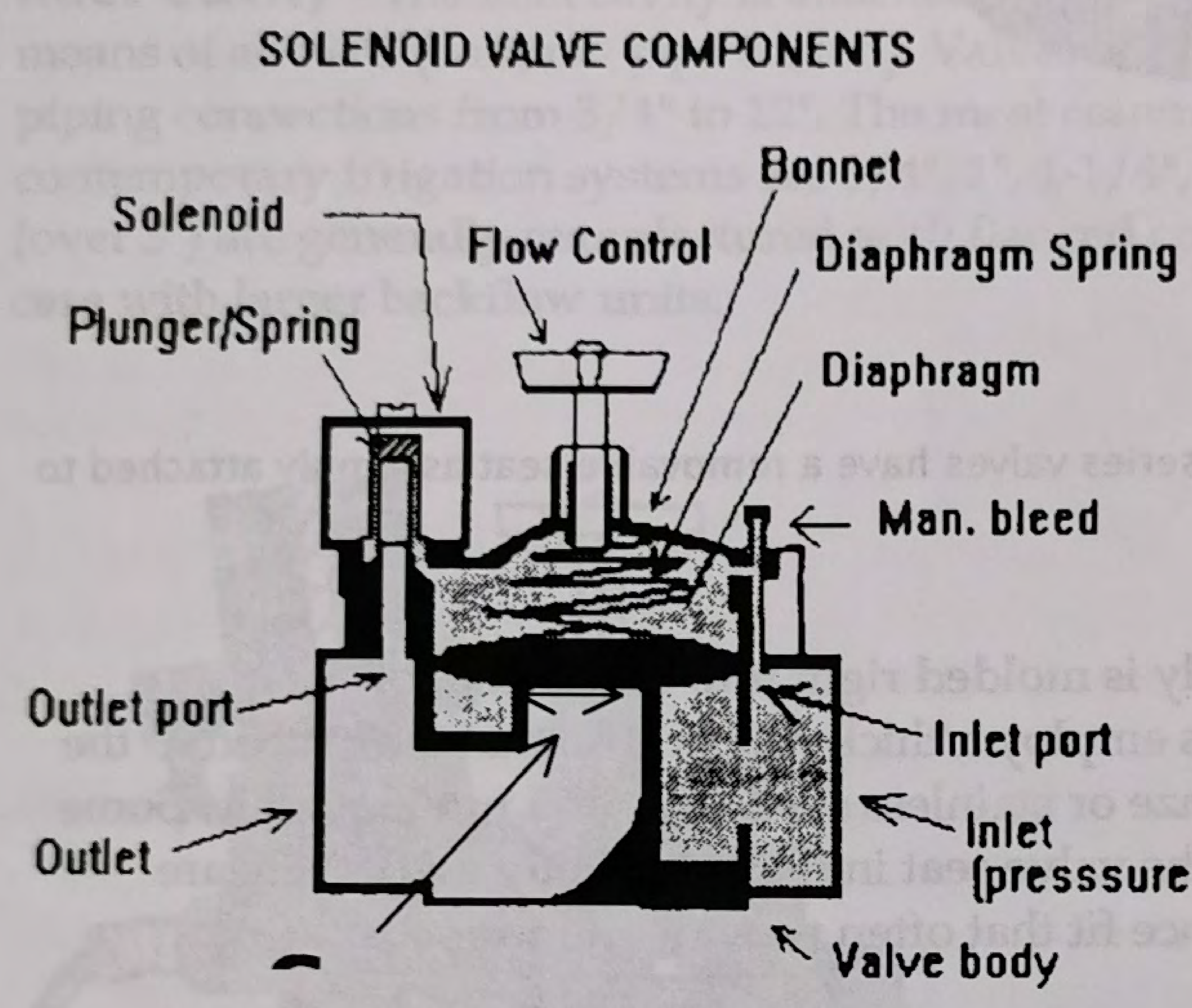


Figure 8-4: Components of the solenoid valve

Diaphragm – The diaphragm is a circular rubber space, "gasket-like" component that controls the opening and closing of the valve itself. The diaphragm is the device that regulates the flow of water through the valve. The diaphragm creates an impermeable membrane between the bonnet cavity and the two lower cavities; the inlet and outlet cavities. Valve opening and closing is modulated by pressurizing and depressurizing the bonnet cavity chamber. When the bonnet cavity is fully pressurized, the diaphragm is forced down, keeping the valve in a normally closed position.

Seat Assembly – The seat assembly is located directly underneath the diaphragm. While the diaphragm is the component that causes the valve to open and close, it is the circular rubber seat assembly that creates the watertight seal between the inlet and outlet cavities.

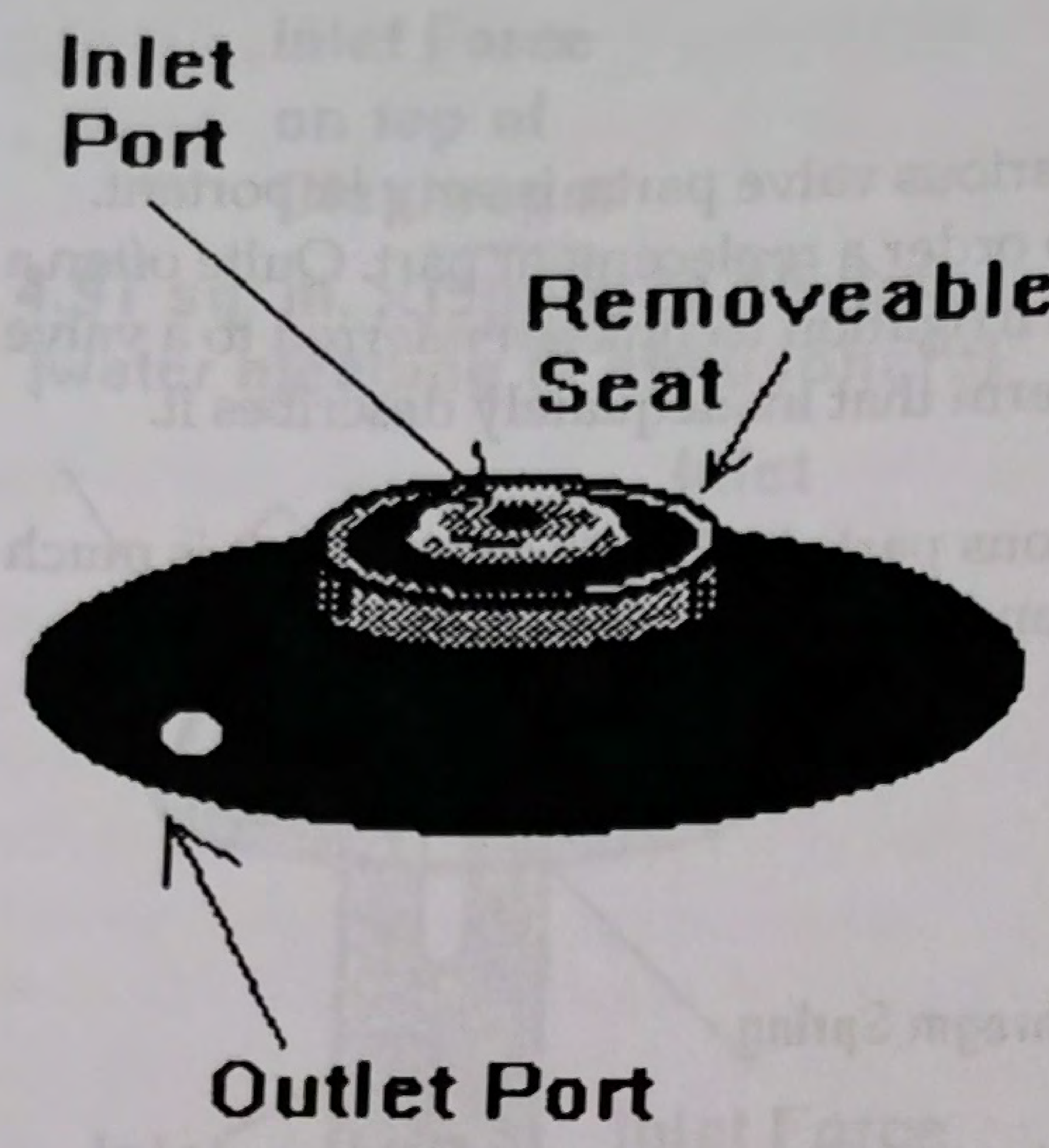


Figure 8-5: The Griswold™ 2000 series valves have a removable seat assembly attached to the diaphragm assembly.

In most cases, the seat assembly is molded right into the bottom of the diaphragm. Many diaphragms employ a thick rubber disc that is attached to the diaphragm by means of a bronze or stainless steel shaft and nut assembly. Some seat assemblies fit flatly onto the valve seat in the valve body and others are tapered and have an interference fit that often provides a more positive watertight seal.

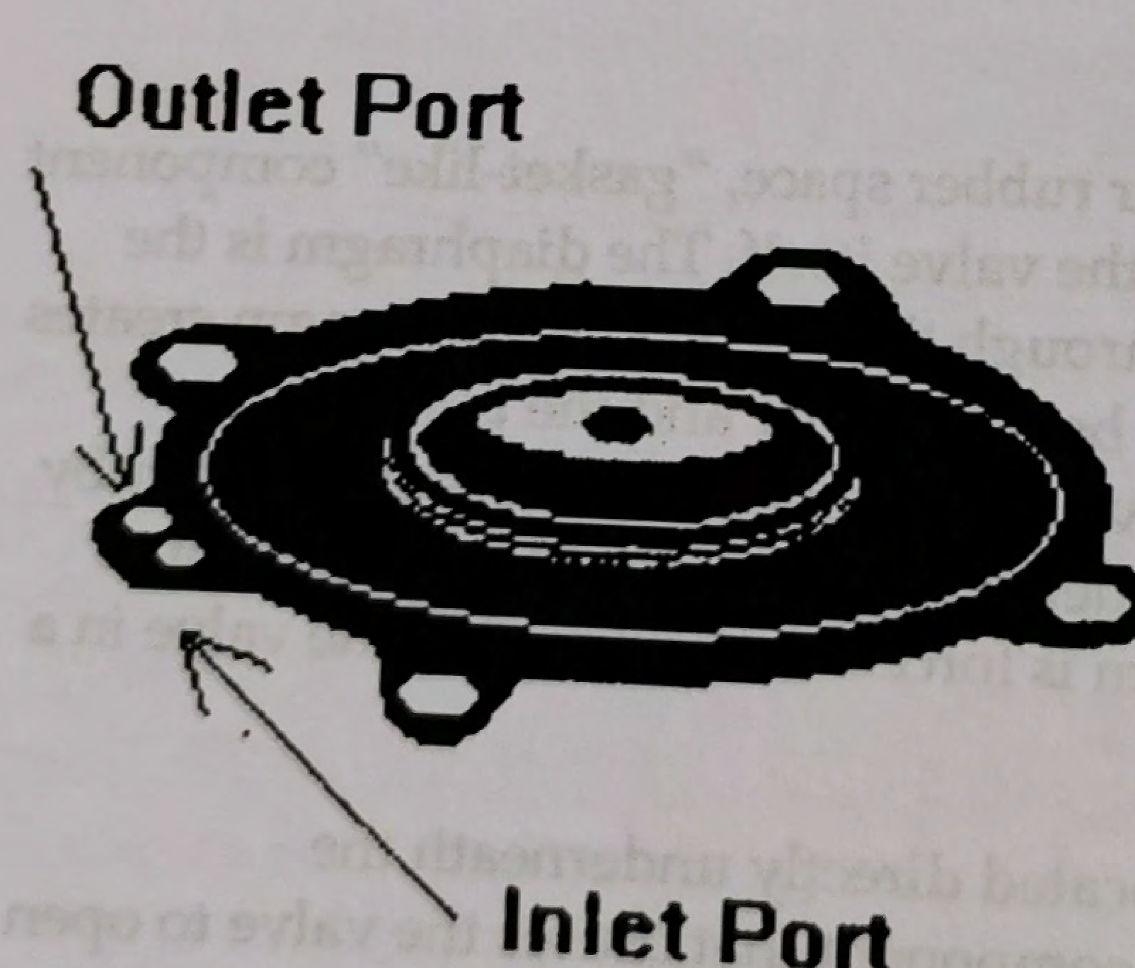


Figure 8-6: The Rainbird™ EF series valve has a seat assembly molded into the diaphragm assembly

Bonnet Cavity - The bonnet cavity is the chamber above the valve diaphragm. The diaphragm, when sandwiched between the valve bonnet and body, creates this large cavity. Pressure is then alternately applied to this cavity through the valve's inlet port, and relieved through either the valve's solenoid or bleed port.

Diaphragm Spring - The diaphragm spring is located directly over the diaphragm. The purpose of this spring is to help force the diaphragm back down into the closed position as the bonnet cavity builds pressure.

Inlet Cavity - The inlet cavity is attached to the pressurized main line by means of an NPT (national pipe thread). Valves are available to accommodate piping connections from 3/4" to 12". The most common sizes found in contemporary irrigation systems are 3/4", 1", 1-1/4", 1-1/2" and 2". Larger sizes (over 3") are generally manufactured with flanged connections, as would be the case with larger backflow units.

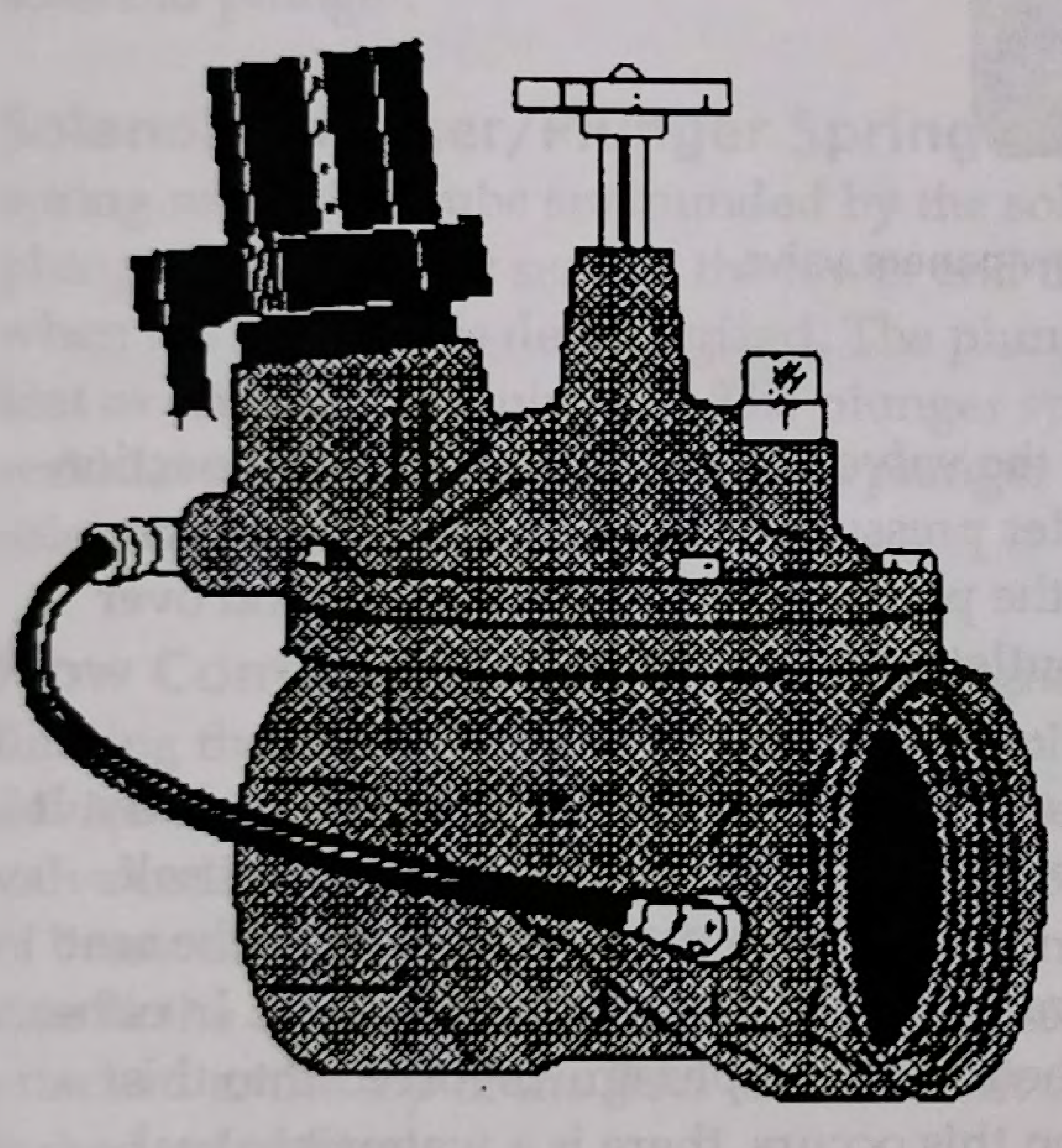


Figure 8-7: External inlet port tube of the Rain Bird EFB-CP series valve

Inlet Port - The inlet port channels pressurized water from the inlet cavity to the bonnet cavity. The inlet port may be machined into the valve body as is the case with the Rain Bird GB Series Valve or it may be externally plumbed like the Rain Bird EFB-CP series shown in Figure 8-7. These ports are difficult to mold or machine in plastic valves so the inlet port configuration is a bit different. Most plastic valves and some brass valves feature their inlet port in the very center of the diaphragm as part of the diaphragm/valve seat assembly. The Rain Bird EFA Series Valve utilizes such an assembly (as illustrated in Figure 8-8), but employs a metering pin to control the flow of water through the inlet port. Whatever the configuration of the inlet port, its flow capacity is less than either of the outlet ports. This allows bonnet cavity pressure to drop when either port is opened.

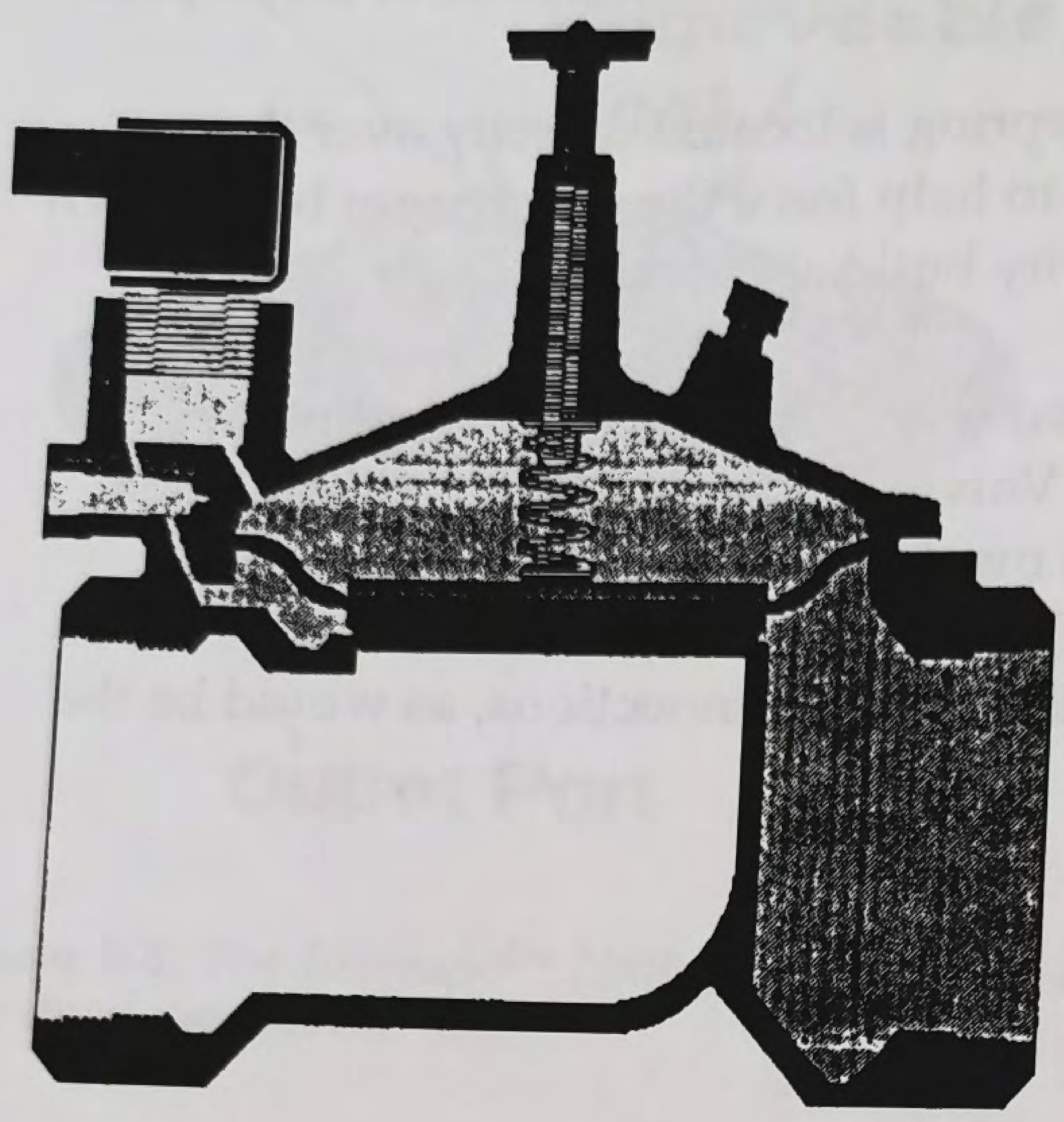


Figure 8-8: Rain Bird EFA Series reverse flow panem valve

Outlet Cavity - The outlet cavity of the valve makes the plumbing connection to the lateral piping. This cavity is under pressure only when the valve is open. As the valve opens, water flows from the pressurized inlet cavity, up and over the valve seat assembly, through the outlet cavity to the lateral piping.

Valve Seat Assembly - The valve seat is an integral part of the valve body. It is a nonmoving component that may be detachable from the valve body itself. Most plastic and low cost brass valves do not have a detachable seat, so the seat assembly is an area of the valve body rather than a separate component. In either event, the circular seat assembly attached to the diaphragm is forced into this concentric ring to close the valve. When this occurs, there is a watertight seal between the inlet and outlet cavities.

Bleed Port - The bleed port provides a means of manually relieving the main line water pressure from the bonnet cavity. The bleeder may be a hexagonal nut, knurled knob or petcock, that when opened, allows pressurized bonnet cavity water to flow to the atmosphere. The bonnet cavity is evacuated and the diaphragm lifts because the bleed port is much larger than the inlet port and when opened creates a pressure drop in the bonnet cavity.

A number of manufacturers now offer a manual bleed assembly that vents water into the unpressurized outlet cavity. These mechanisms do nothing more than manually open the outlet port under the solenoid.

The manual bleed is an important valve component because it allows the valve to be operated when the controller or wiring is disabled. This is particularly important if the controller panel is offsite being repaired.

Solenoid Outlet Port - The solenoid outlet port routes pressurized water from the bonnet cavity to the area directly under solenoid. This outlet port, while smaller than the bleed port is much smaller than the inlet port. The solenoid assembly is controlled electrically to regulate the flow of water through this port.

Solenoid - The valve solenoid is a low voltage electromagnetic coil. The coil is a cylindrical or square shaped device that houses a continuously wound copper wire no larger in diameter than a human hair. The windings are epoxy encapsulated to prevent moisture damage or short circuiting. Attached to the coil are two wires intended for connection to the controller field wiring. The coil operates at a level of 24 volts AC so that wiring may be directly buried without hazard. Within the solenoid is a hollow stainless steel tube, which houses the solenoid plunger.

Solenoid Plunger/Plunger Spring - The solenoid plunger and plunger spring reside in a tube surrounded by the solenoid coil. The stainless steel plunger has a rubber seat on the lower end that keeps the outlet port closed when the solenoid is de-energized. The plunger has a lightweight spring near the seat or on top of the plunger. The plunger spring is designed to overcome any residual magnetism and to hold the plunger seated on the outlet port when the solenoid is de-energized.

Flow Control - The flow control is designed to provide flow regulation by limiting the upward travel of the valve diaphragm. The primary purpose of this device, however, is to provide a positive emergency shutoff in the event of a valve or lateral malfunction. The flow control is usually a one piece round shaft of brass, stainless steel or PVC. The upper end of the shaft has male threads that ride in the threaded journal at the top and center of the bonnet. A cross handle is attached to the top of the flow control shaft to allow operation with the use of a forked valve key.

Hold Down Bolts/Screws – Most valves utilize fasteners of various styles to hold the removable bonnet in place with the valve body to provide a watertight seal. When the valve is reassembled, the fasteners should be tightened in an even sequence and gradually, just as would be done with the lug nuts on a wheel.

Normally Closed/Normally Open Configuration – Valves utilized in an irrigation system are typically of the normally closed configuration. This means that when pressurized from the inlet cavity, the bonnet cavity is immediately pressurized through the inlet port, and the valve remains normally closed. The valve will remain normally closed unless the manual bleed is opened or the solenoid activated. Quite often when a system is repressurized after being off for some time the valves will randomly come on momentarily until the inlet port repressurizes the bonnet cavity.

A normally open valve is often referred to as a specialty valve because of its limited applications in irrigation. Many older systems still utilize normally open valves so the distinction could be important. When water enters the inlet cavity of a normally open valve, the valve diaphragm lifts and the valve comes on. When the valve is activated, pressurized water is channeled to the bonnet cavity and the valve is turned off. Thus the normal condition is open rather than closed.

Forward and Reverse Flow Valves - The flow pattern through the valve represents the direction that the water travels from the pressurized inlet cavity to the outlet cavity. A forward flow configuration, most commonly found in plastic valves, is configured so the inlet cavity is in the center of the diaphragm.

Typically, the inlet port is a small journal in the center of the diaphragm through which flow is regulated by a metering pin. The inlet cavity is sealed off from the bonnet cavity by the diaphragm seat assembly and the diaphragm. All that separates the outlet cavity from the bonnet cavity is the diaphragm itself.

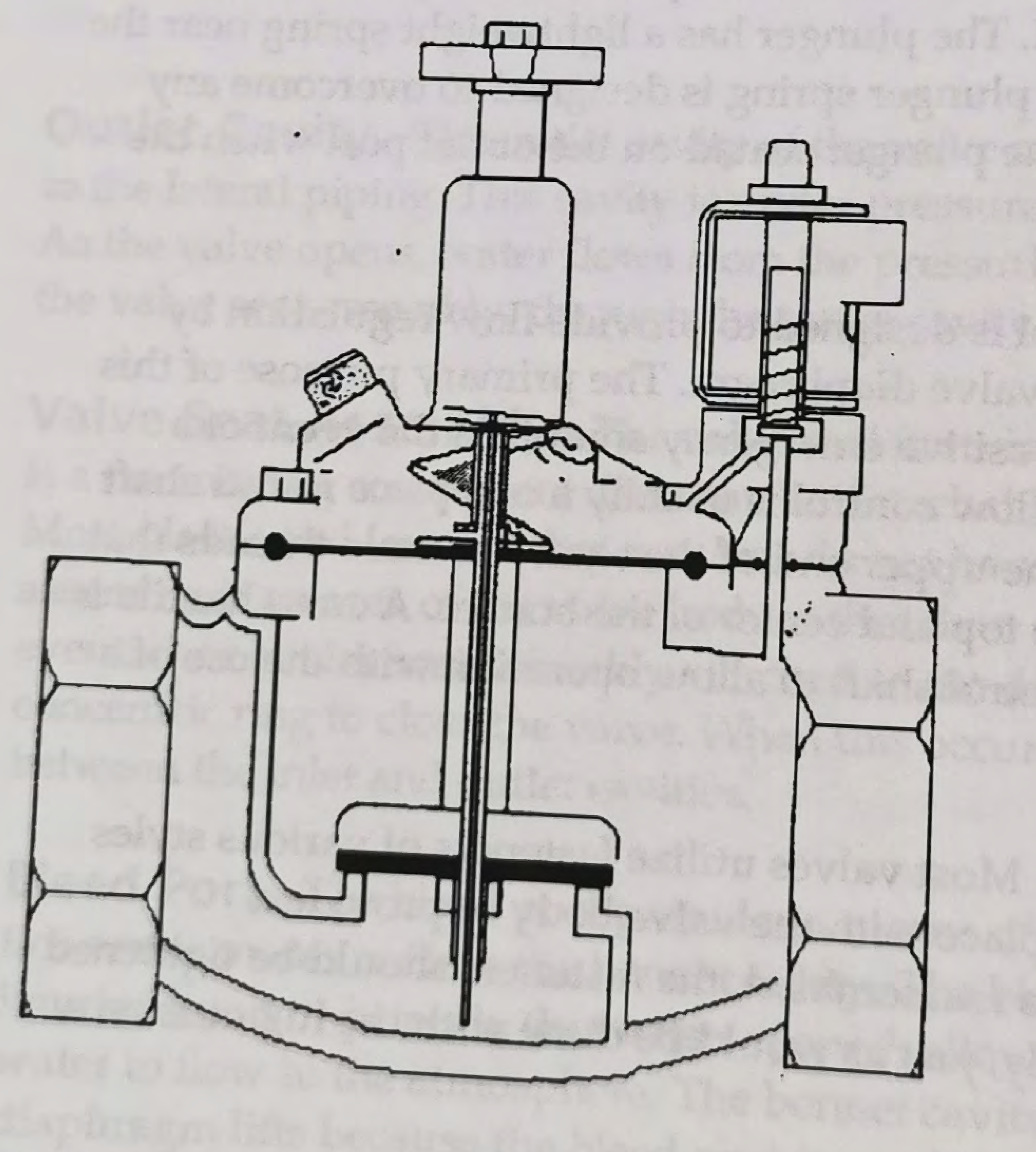


Figure 8-9: Superior 950 series valve, forward flow pattern

A tear in the diaphragm in this area would allow water to leak from the bonnet cavity to the outlet cavity. In such a situation, it is likely that pressure would be reduced in the bonnet cavity, and the valve would either come on or fail to close. This can be an advantage in terms of system reliability.

The reverse flow valve has an outlet cavity that is in the center of the diaphragm. (See Figure 8-10.) This is exactly the opposite or reversed from the forward flow pattern. The diaphragm seat assembly and the diaphragm separate the bonnet cavity from the nonpressurized outlet port. If the diaphragm is torn in the outer margin, the leak allows water to flow from the pressurized inlet cavity to the bonnet cavity and the valve does not come on or fails in the open position.

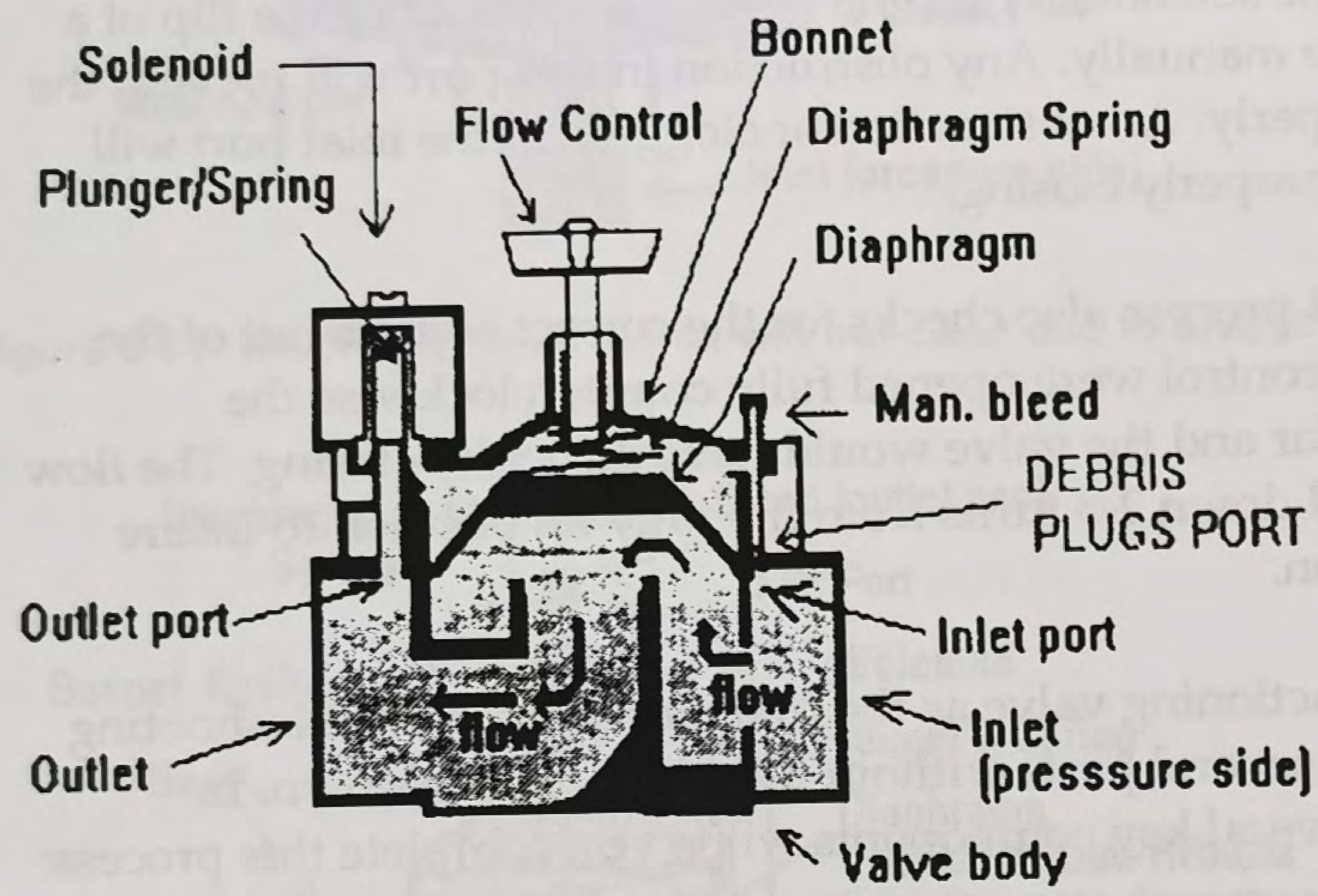


Figure 8-10: Remote control valve being manually bled to troubleshoot, checking condition of inlet port, diaphragm flow control and diaphragm spring.

Troubleshooting the Valve – The very first step in valve troubleshooting is to narrow down the nature of the problem. In fact, this is what troubleshooting is all about -- spending adequate time accurately determining the problem before starting the repair. Begin the valve troubleshooting process by resisting the temptation to tear the valve down!

Start the troubleshooting process by adjusting the flow control on the top of the valve. Next, open the manual bleed port, allowing the pressurized bonnet cavity water to flow to atmosphere. Most older valves have a bleed plug on the bonnet itself to facilitate manual operation. Some newer valves have a mechanism near the solenoid which, when activated, lifts the solenoid plunger off of the outlet port. In this case, the bonnet cavity water is evacuated to the downstream side of the valve just as it would be if the valve were activated electrically. Once the valve has achieved full flow to the sprinklers, the manual bleed is closed and the valve should close.

This manual operation of the valve verifies the operation of many key components. First and most importantly it checks the condition of the diaphragm. If the diaphragm was seriously torn it would be difficult for the valve to close, particularly with forward flow valves. Furthermore, if the diaphragm spring were absent, the valve would likely not close so this test checks for the presence of this spring.

The next area of concern is the condition of the inlet, bleed and outlet ports. In the case of a bonnet bleed plug, port flow can be visually verified. Solenoid bleed mechanisms can be verified for flow and this will check flow in the outlet port located directly under the solenoid. A simple twist of a solenoid or the flip of a lever will open the valve manually. Any obstruction in this port will prevent the valve from opening properly. An obstruction or clogging in the inlet port will prevent the valve from properly closing.

Finally the manual bleed process also checks for the correct adjustment of the flow control. If the flow control were opened fully counterclockwise the diaphragm may lift too far and the valve would have difficulty closing. The flow control should be backed down 2-3 turns from the fully on position to insure consistent valve operation.

Manually bleed a malfunctioning valve as the first stage of the troubleshooting process and you'll check several parts without tearing the valve down. In summary you'll check several key components when you complete this process:

- Valve Diaphragm
- Valve Diaphragm Spring
- Valve Bleed Port (in the case of the bonnet bleed plug)
- Solenoid Outlet Port (manual bleed) (when the manual bleed is part of the solenoid assembly)
- Flow Control Adjustment
- Valve Inlet Port

Common Valve Problems

When solenoid valves fail to close or stick open, significant water and pressure loss can occur. If the valve sticks on in the fully open condition, then there are a number of possible causes:

- Inlet port plugged
- Improperly adjusted flow control
- Torn diaphragm
- Missing diaphragm spring
- Missing plunger spring
- Continuous voltage on valve wires, due to a controller or wiring problem (rare)

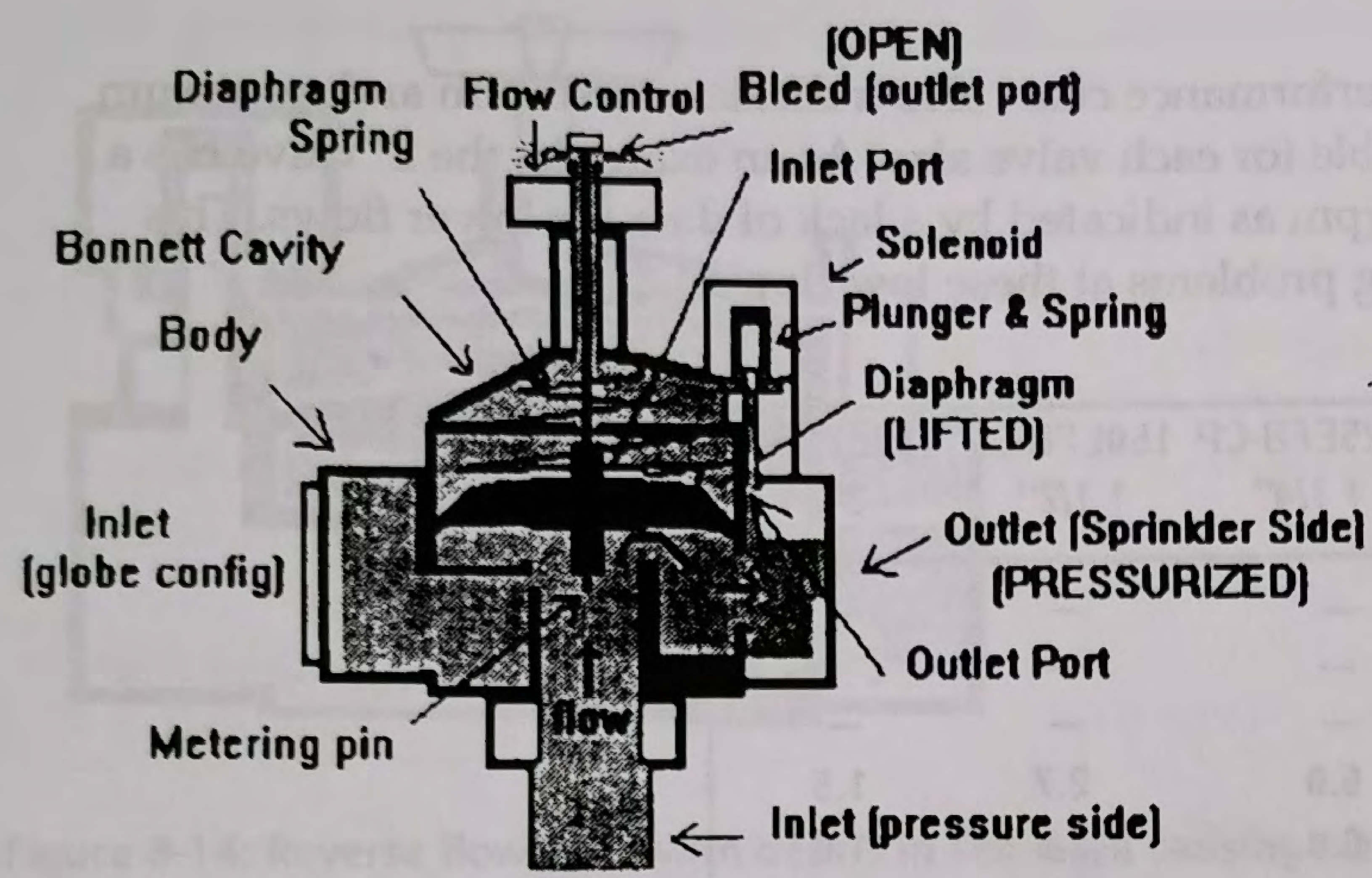


Figure 8-11: Reverse Flow valve that will not close due to plugged inlet port

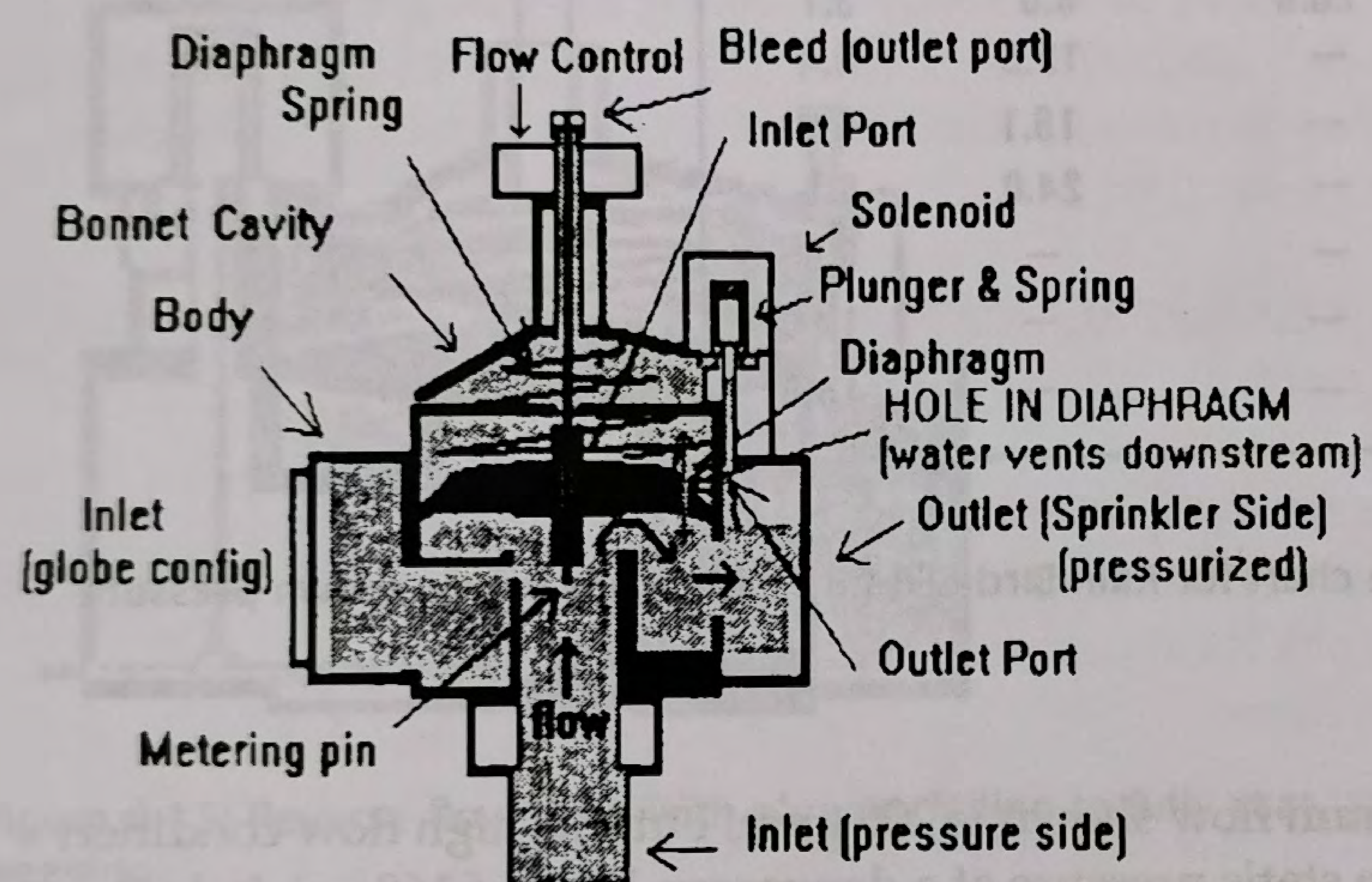


Figure 8-12: Forward Flow valve with a hole in the diaphragm, which drops bonnet cavity pressure to the outlet cavity and causes valve to stick on

Valves may also have sticking problems that relate to improper flow conditions. Manufacturer's recommendations for flow and pressure must be carefully observed to insure proper operation. A general rule of thumb is to limit pressure loss through the valve to 10% of the static pressure available. As an example, consider the case of the Rain Bird EFB-CP. Assume a hypothetical flow requirement of 80 gallons per minute and a static pressure of 60 psi. Our maximum allowable valve pressure loss would be 6 psi. The 1 ½ " valve would have a pressure loss of 8.0 psi, which is excessive. This valve is too small so we would upsize to the 2" which has a loss of only 3.1 psi. Keeping the pressure loss to a controlled percentage reserves vital water pressure for sprinklers and maintains velocities below 7.5 feet per second.

The manufacturer's performance chart also indicates maximum and minimum flows that are acceptable for each valve size. As an example, the 2" valve has a minimum flow of 20 gpm as indicated by a lack of data for lower flows. This valve will have closing problems at these low flows.

Flow (GPM)	100EFB-CP 1"	125EFB-CP 1 1/4"	150EFB-CP 1 1/2"	200EFB-CP 2"
5	3.0	—	—	—
10	3.5	—	—	—
15	4.0	—	—	—
20	5.0	5.0	2.7	1.5
30	9.0	6.0	2.9	1.6
40	13.0	8.0	3.2	1.8
50	20.0	10.0	3.7	2.0
60	—	13.0	4.5	2.3
80	—	20.0	8.0	3.1
100	—	—	12.9	4.4
120	—	—	18.1	6.2
140	—	—	24.0	8.5
160	—	—	—	8.5
180	—	—	—	14.0
200	—	—	—	16.8

Figure 8-13: Performance chart for Rain Bird EFB-CP series brass valves shown pressure losses at various flows.

Conversely, the maximum flow shown is 200 gpm, but this high flow condition would require a system static pressure at a dangerous level of 168 psi. In both cases, the valve would have problems closing. Flow conditions are also critical when dealing with the low flows associated with drip/micro irrigation. Carefully observe the minimum flows in the valve specifications. Remember to convert the gph (gallons per hour) flow of drip micro zones into gpm when sizing valves.

Static pressure also indicates the types of valves that may be acceptable for a particular application. Observe the manufacturer's recommendations and remember that a system that has experienced a drop in static pressure may have intermittent valve closure problems.

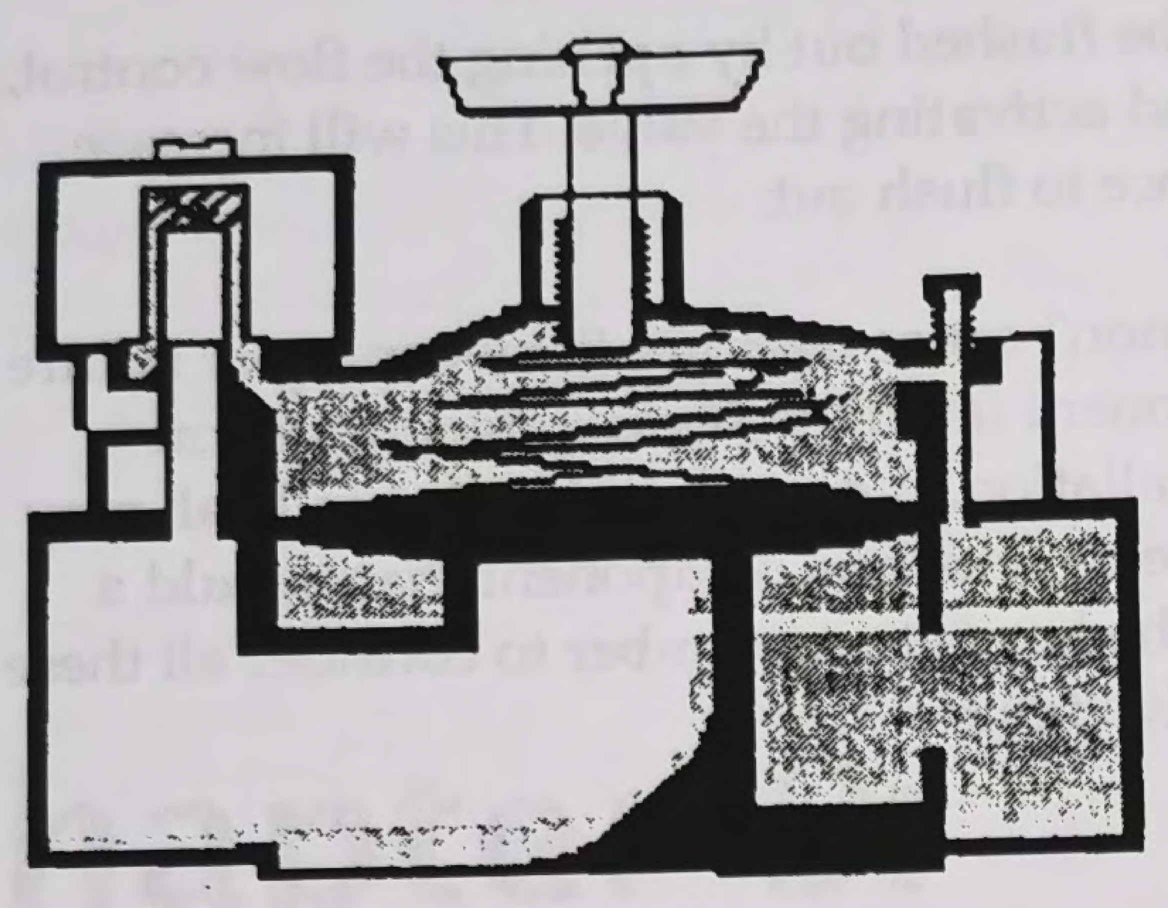


Figure 8-14: Reverse flow valve with debris in seat area causing weeping.

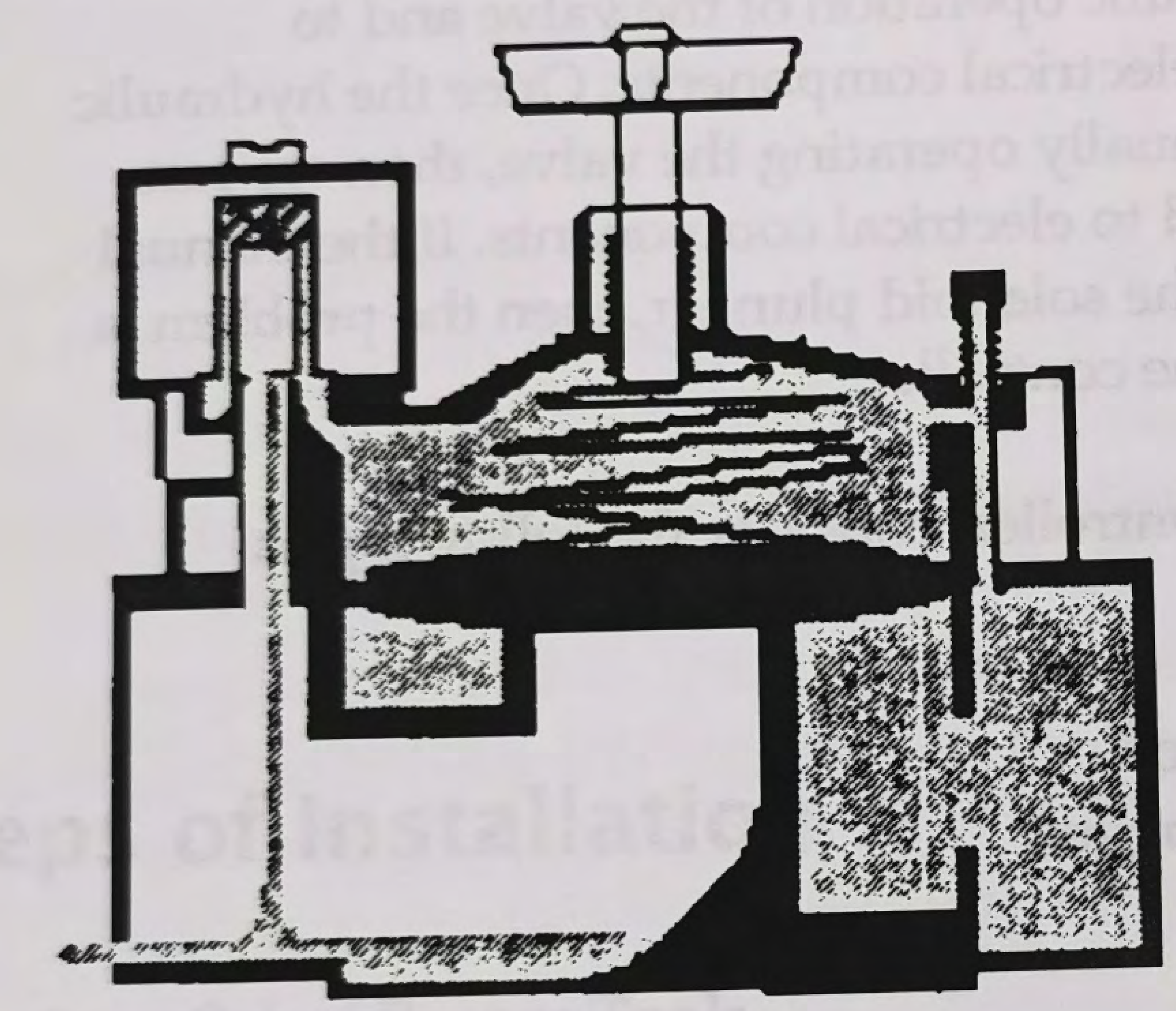


Figure 8-15: Reverse flow valve with plunger failing to fully seat, and as a result valve is weeping

Frequently, valves stick on, but not in the fully open position. The first indication of this problem would be water collecting at low sprinklers in the zone. Further diagnosis is usually necessary because this problem could be low head drainage or damaged check valves in the sprinklers. Go to a problem sprinkler and stir the water up that has puddled around the head until it is muddy. Observe the water, looking for a clearwater plume. If the valve has been off for a period of hours and the plume is present, then the valve is probably sticking partially open. When the valve is weeping, consider the following as likely causes of the problem:

- Debris wedged between the valve seat assembly and the rubber seat that is connected to the bottom of the diaphragm.
- Defective plunger seat or debris in this area that allows a slight weepage into the outlet cavity
- A very slight hole in the diaphragm (forward flow valves only)

Very often debris in the seat area can be flushed out by opening the flow control, removing several sprinkler nozzles and activating the valve. This will increase the velocity and give the debris a chance to flush out.

Unfortunately, there is no "most common" cause to either the weeping or failure to close problems. Frequency of component failure will vary, depending on water quality, pressure, and valve installation. A service technician in Utah may find a much higher frequency of problems with one component than would a tech in Texas or southern California. The key is to remember to consider all these components as a possible source of valve failure.

Valve Fails to Open – Causes

Quite often, when a valve fails to open, electrical components come into the picture and can be suspected as a source of the problem. This is why we always bleed the valve to assure proper hydraulic operation of the valve and to determine if the problem is related to electrical components. Once the hydraulic possibility has been eliminated by manually operating the valve, then we can assume the problem is probably related to electrical components. If the manual bleed mechanism is the type that lifts the solenoid plunger, then the problem is definitely electrical – no output from the controller.

If the valve fails to come on from the controller, consider the following as possible causes of the problem:

- flow control turned completely off
- solenoid outlet port partially plugged
- solenoid has an electrical defect
- valve wiring defective

If the solenoid outlet port is the suspected source of the problem, then flow through this internal port must be verified. Removal of the bonnet is not necessary for this check! Turn off the water to the valve and bleed off all residual main line pressure. Next, remove the solenoid coil and plunger tube from the valve bonnet and remove the solenoid plunger and spring. Reinstall the solenoid, less the plunger assembly, and turn the water on. If the solenoid outlet port is clear, the valve should come on and stay on.

Perhaps 80% of solenoid valve problems may be traced to the hydraulic components of the valve. System start-up typically reveals a higher incidence of electrical problems rather than hydraulic.

Chapter 9: Install Lateral Piping

Steps of Installation

1. Select Proper Tools
2. Perform Site Inspection
3. Read Blueprints
4. Install POC
5. Install Mainline
6. Install Field Wiring
7. Install Valves
8. **Install Lateral Piping**
9. Install Sprinkler Heads
10. Mount and Wire Controllers

Pipe selection for laterals depends somewhat on the type of irrigation system being installed, that is, whether it is drip/micro, spray pop-ups, or rotor pop-ups. Other factors that influence pipe selection are water volume, soil condition, installation technique, hydraulic conditions, and regional preferences.

In some areas, PE pipe with pressure ratings of either 80 or 100 psi is preferred for lateral lines. This preference is based on prior experiences, flexibility of PE pipe, and deep frost lines.

PE pipe friction tables do not include losses caused by insert fittings. Losses can be significant if a large number of insert fittings are used. However, increasing the pipe friction losses about 10 % is usually adequate to cover these losses if flow velocities are kept below 5 feet per second.

Pipe Installation

There are two main methods of installing irrigation pipe underground; trenching or using a "vibratory plough." Trenching involves cutting a trench through the ground using a specialized piece of digging equipment; a spinning chain of metal teeth cuts the trench. Trenching is commonly used when pipe sizes exceed 2" to 2.5"; smaller pipe sizes allow the use of vibratory ploughs. Vibratory ploughs pull the pipe in behind a vibrating "bullet"; the vibrating steel shank moves vertically through the ground, shattering any resistance. The pipe is attached behind the bullet and is pulled underground through the newly broken up soil. There are advantages and disadvantages of each type of installation method.

Trenching

Advantages

- allows larger pipe sizes to be installed
- allows the trench to leveled before the pipe is installed; → better grading
- gives more room for pipe connections, installing valves, sprinklers, etc.
- allows control wiring to be installed simultaneously; expansion coils are then possible to install
- can use solvent weld or bell + spigot pipe

Disadvantages:

- disruptive of the site surface; open holes, lines etc.
- settling creates problems; easy to see for years afterwards
- slower overall process; requires significant clean up

Vibratory Plow

Advantages

- quick to install; pipe installation times drop by 50% to 75%
- minimal disruption to the site; disturbed ground heals nicely

Disadvantages:

- cannot level pipe (unless a laser transit is used to control plough depth) during the installation
- cannot install expansion coils when "pulling in" control wires
- limited to smaller pipe sizes; generally less than 2.5 in.

Facts About Water

Definitions

1. **HYDRAULICS** – The study of the behavior of fluids both at rest and in motion.
2. **HYDROSTATICS** – The specific study of the behavior of water at rest. Often referred to as static water pressure.
3. **HYDRODYNAMICS (working or dynamic psi)** – The specific study of the behavior of water in motion. Often referred to as dynamic water pressure.
4. **FLOW** – The amount of water in motion expressed as gallons per minute (gpm).
5. **VELOCITY** – The time rate at which water moves through the components of an irrigation system. Expressed in feet per second (fps).
6. **PRESSURE** – The force exerted on a given area expressed in pounds per square inch (psi).
7. **HEAD** – A measure of pressure in terms of an equivalent height of water column that would create that pressure (feet of head).

Characteristics

1. Water takes the shape of its containers.
2. Water is relatively incompressible compared to air.
3. Water will seek its own level.
4. Water is relatively heavy, weighing 62.4 lb/ft^3 (specific weight).
5. One U.S. gallon weighs 8.34 lb.

Static Water Pressure (Hydrostatics)

1. Static water pressure is an indication of the potential pressure energy available in a closed hydraulic network, such as an irrigation main line. A "closed" system is one in which there exists water at rest.
2. Static water pressure is created by either raising the water to an elevation above where it is to be used or by imparting energy to the water through a pump.
3. Static water pressure is measured in terms of the weight of a vertical column of water exerting a pressure on the bottom of the column. Static pressure is dependent only upon the vertical height of the column and not on the surface area subject to the pressure.
4. Elevation is the major influence on static water pressure. Thus one (1) foot of elevation change is equated to 0.43 psi pressure change, or one (1) psi is equated to 2.31 feet of elevation change.

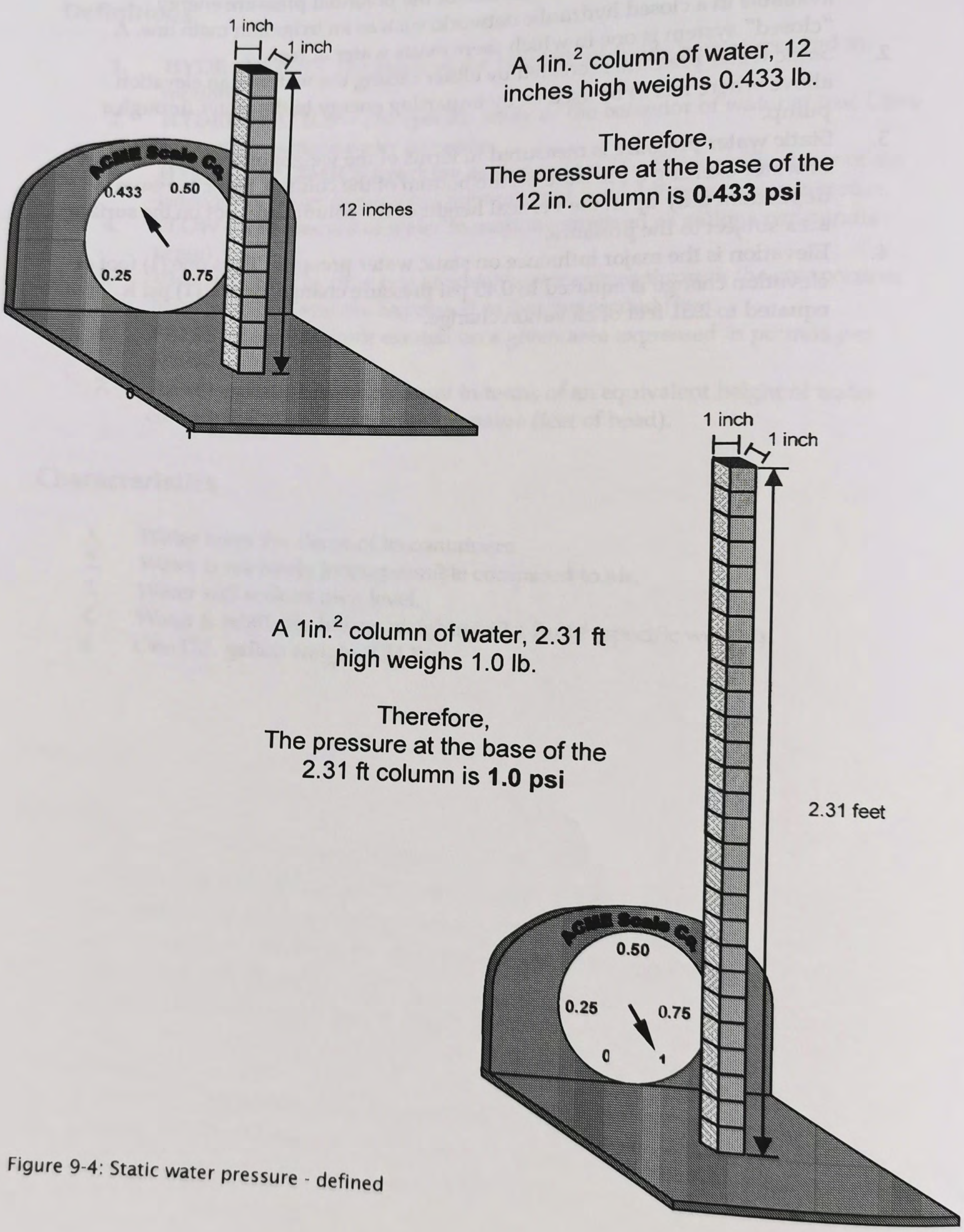
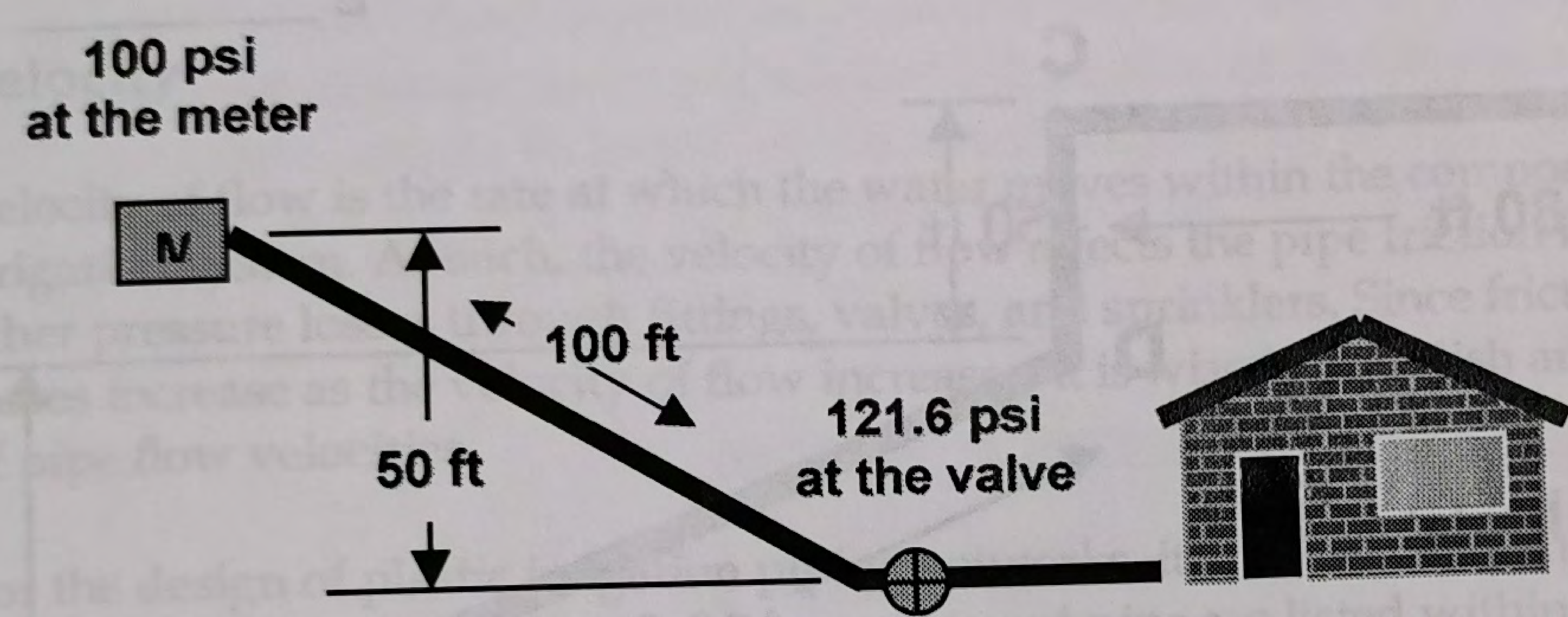


Figure 9-4: Static water pressure - defined

Facts to Memorize

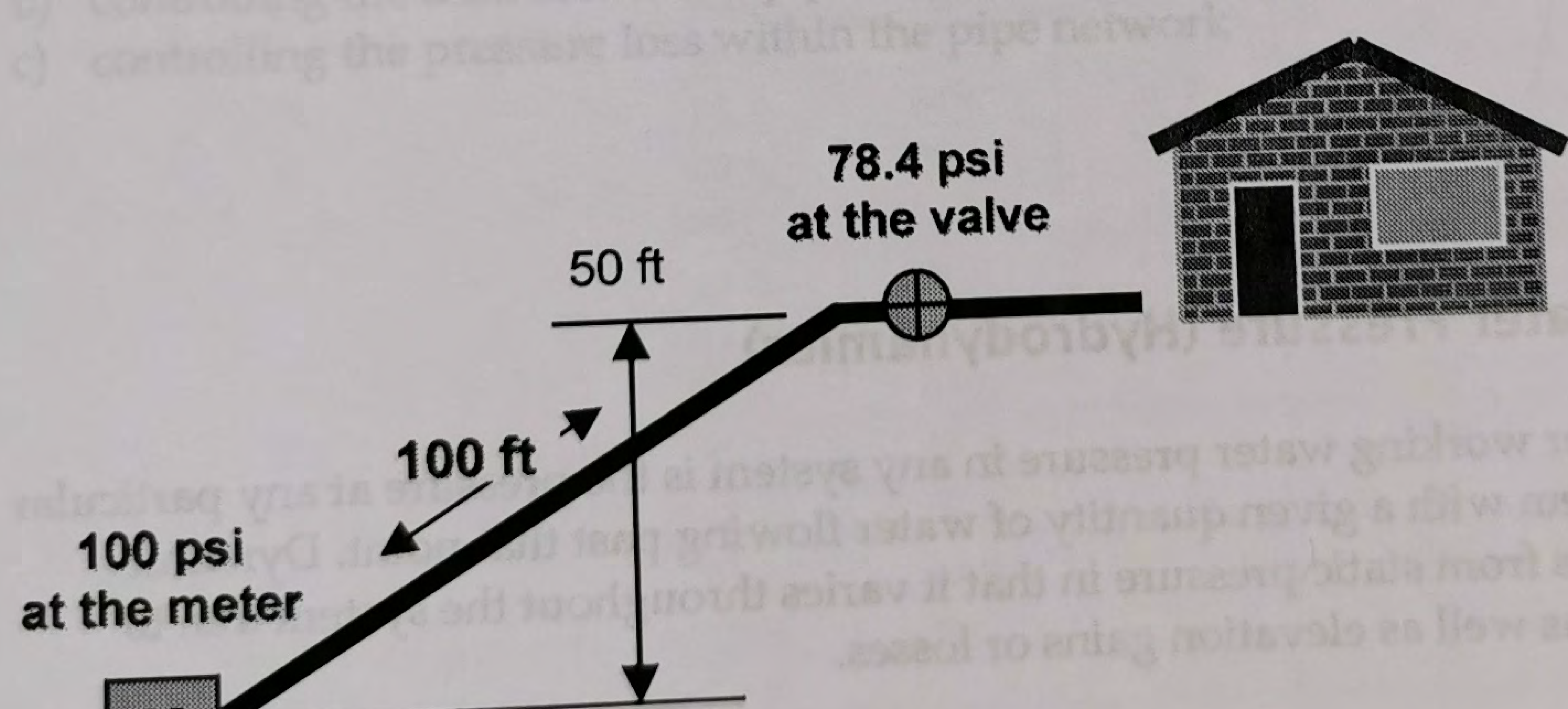
1. A column of water one foot high = one foot of head = 0.433
2. 1.0 psi = a column of water 2.31 feet high
   - OR -
   1.0 psi = 2.31 feet of head
3. A column of water 1 foot high will create 0.433 psi at the bottom
   - OR -
   1 foot of head = 0.433

Static Water Pressure Example



Example 1: In the figure above, the example shows a water source above the control valve. In this case the static water pressure is calculated as:

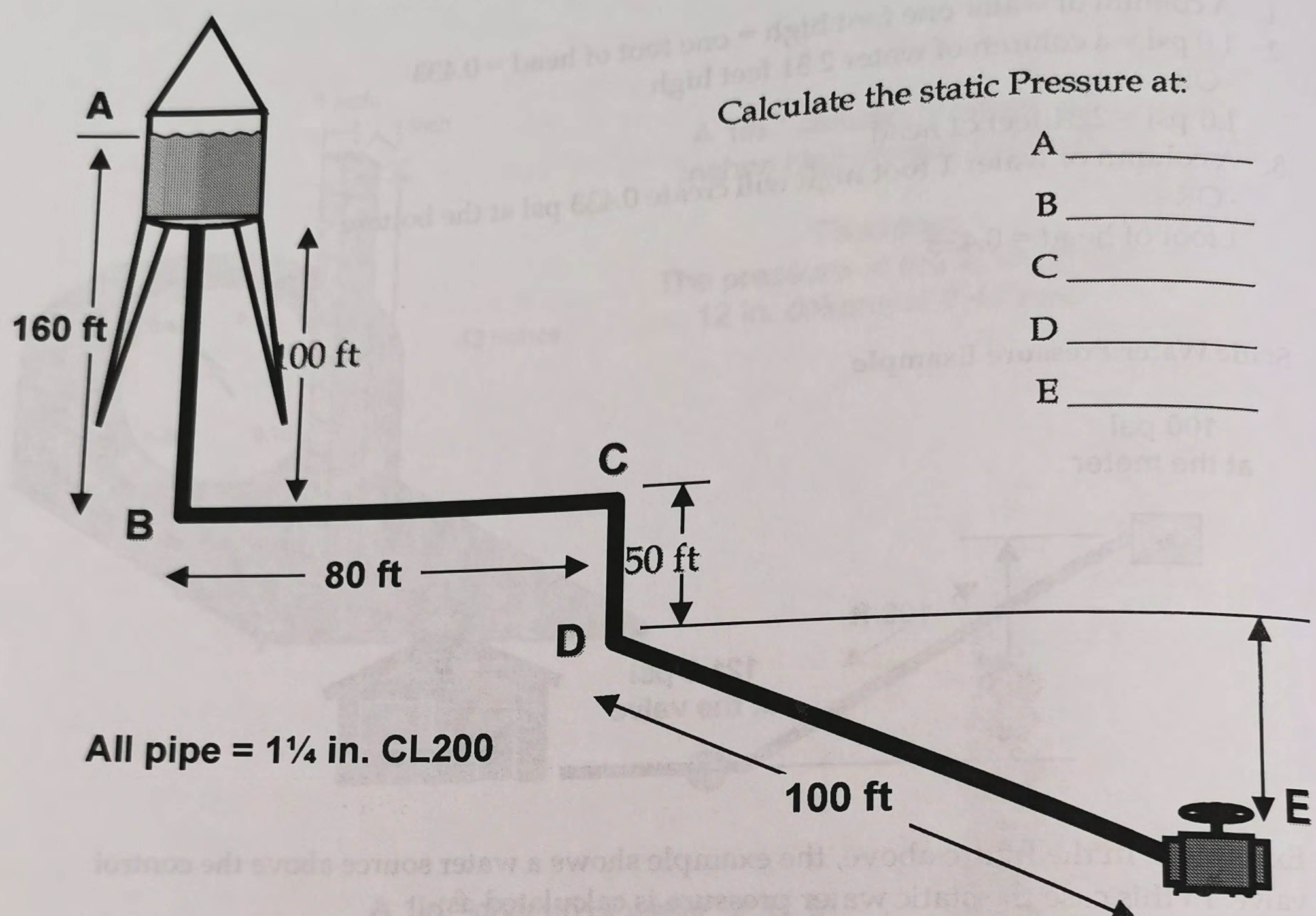
100 psi + (50 ft x 0.433 psi per foot) = (100 + 21.6) = 121.6 psi static



Example 2: In the second example, the water source is below the control valve, the static water pressure is calculated as:

100 psi - (50 ft x 0.433 psi per foot) = (100 – 21.6) = 78.4 psi static

Practice Problem – Static Pressure Loss



Calculate the static Pressure at:

A ________

B ________

C ________

D ________

E ________

Dynamic Water Pressure (Hydrodynamics)

The dynamic or working water pressure in any system is the pressure at any particular point in a system with a given quantity of water flowing past that point. Dynamic pressure differs from static pressure in that it varies throughout the system due to friction losses as well as elevation gains or losses.

Friction loss is the loss of pressure energy caused by water flowing against the surface of a pipe flow passage. The type of pipe material, size of pipe and length of pipe, as well as quantity of water flowing, determines the total amount of friction loss. Friction loss charts are listed in psi loss per 100 feet of pipe. Friction loss charts can be found in Appendix A.

Other types of pressure losses occur within fittings, valves, and sprinklers. These losses of pressure energy are NOT classified as friction loss because there is relatively little surface area within a fitting or valve or sprinkler against which friction can occur. The major loss of pressure within fittings and valves is caused by turbulence. Change in elevation affects dynamic pressure the same way it affects static pressure.

Pipe Sizing and Basic Hydraulics

There are two common methods for pipe sizing: the velocity limit technique and the friction factor method. Both use the information found in standard friction loss charts. In this manual we will only look at the velocity method.

Velocity

Velocity of flow is the rate at which the water moves within the components of the irrigation system. As such, the velocity of flow affects the pipe friction losses and the other pressure losses through fittings, valves, and sprinklers. Since frictional pressure losses increase as the velocity of flow increases, it is wise to establish an acceptable range of pipe flow velocities.

For the design of plastic irrigation piping networks, it is desirable to maintain a velocity of 5 fps maximum Velocities for commonly used pipe are listed within the friction loss charts located in Appendix A.

Velocity may be controlled in a pipe network by:

a) controlling the quantity of water flowing through the pipe;
b) controlling the diameter of the pipe through which the water flows;
c) controlling the pressure loss within the pipe network

Pipe Sizing

The simplest method of sizing pipe is called the velocity method. To size pipe using this method, you only need a friction loss/velocity chart for the pipe you are using. Make sure that at no point are you exceeding 5 fps velocity in the pipe, based on the gpm required. For example, in a 1 in. PVC SDR 21 (class 200) pipe, we can safely flow 15 gpm at 4.34 fps, which is under our limit of 5 fps. (See velocity charts in Appendix A.)

Using Charts to Size Pipe

The most important thing to remember when using a chart to size pipe is to be sure the chart is for the type of pipe that you intend to use in your plan. Some charts have both friction loss and velocity in one. In this manual there are separate charts found in Appendix A. The type of pipe can be found on the top of all charts. The information needed to size pipe is described below.

Velocity of Flow – SDR21 / Class 200 Plastic

Flow (gpm)	½"	¾"	1"
1	.80	.47	
2	1.59	.94	
3	2.39	1.42	
4	3.19	1.89	1.16
5	3.98	2.36	1.45
6	4.78	2.83	1.73
7	5.58	3.30	2.02
8	6.38	3.78	2.31
9	7.17	4.25	2.60
10	7.97	4.72	2.89
11	8.77	5.19	3.18
12	9.56	5.66	3.47
13		6.14	3.76
14		6.61	4.05
15		7.08	4.34
20		9.44	5.78
25		11.80	7.23
30			8.67
35			10.12
40			11.46
50			14.45

Figure 9-1

1. The nominal pipe size can be found along the top row.
2. The flow, expressed in gallons per minute, is found in the outside column.
3. Under each nominal pipe size, there is velocity, expressed in feet per second.

To size pipe:

1. Determine flow in length of pipe
2. Read down from column to locate flow
3. Read across to locate value just less than 5 fps
4. Read up the column to find pipe size

Pipe Sizing Example

Pipe sizing using the velocity method is relatively easy. Below find the steps along with a worked out example on the following page:

- Go to the furthest head on the zone away from the valve (if there is more than one "furthest head," then just pick one).

- Find the gpm for that head. For our example on the next page that would be 8 gpm.

- Go to the velocity/friction loss charts in Appendix C. For our example find the SDR 21/Class 200 chart.

- Read along the left side of the chart down to 8 gpm. Now read across to the right, making sure to be looking in the velocity column. As you read over you are looking for a number that is less than 5 ft per second. In this case, the first number we read is 3.77. Look up at the top of the column, and you can see that the pipe size is ¾ in. That becomes the pipe size for the first leg.

- Now go to the next head up stream from the first head. Look at the pipe just upstream from the second head. This is the pipe we are sizing now. Because flow is cumulative, we now have the gpm from TWO heads in this section of pipe: 2 x 8 gpm = 16 gpm.

- We now go back to the chart in the back of the book again. We look down the left to 16 gpm and then read over to the right, looking for a number less than 5. Again make sure you are reading the velocity column. The first number under 5 is 4.62. Now read up the column and we see that the pipe size is 1 in. We now have sized the 2nd leg of pipe.

- Now if we look at the zone layout we see ten other segments that look just like the two we have just sized. Same number of heads, same gpm per head. They can all be sized at ¾ in. and 1 in.

- As we work back towards the valve we see the section of pipe that connects the second and third rows of heads. We will now size this. This section of pipe has to carry water for 4 heads: 4 x 8 gpm = 32 gpm. We will look at the chart for 32 gpm and as we read over to the right the first number we see under 5 is 4.41. If we look up we see that the pipe is 1 ½ in.

- We now continue on back toward the valve using the same procedures. (See the example on the following page.)

After you feel comfortable with this example, go to the practice problem at the end of the chapter and complete the pipe sizing example.

Pipe Sizing Example

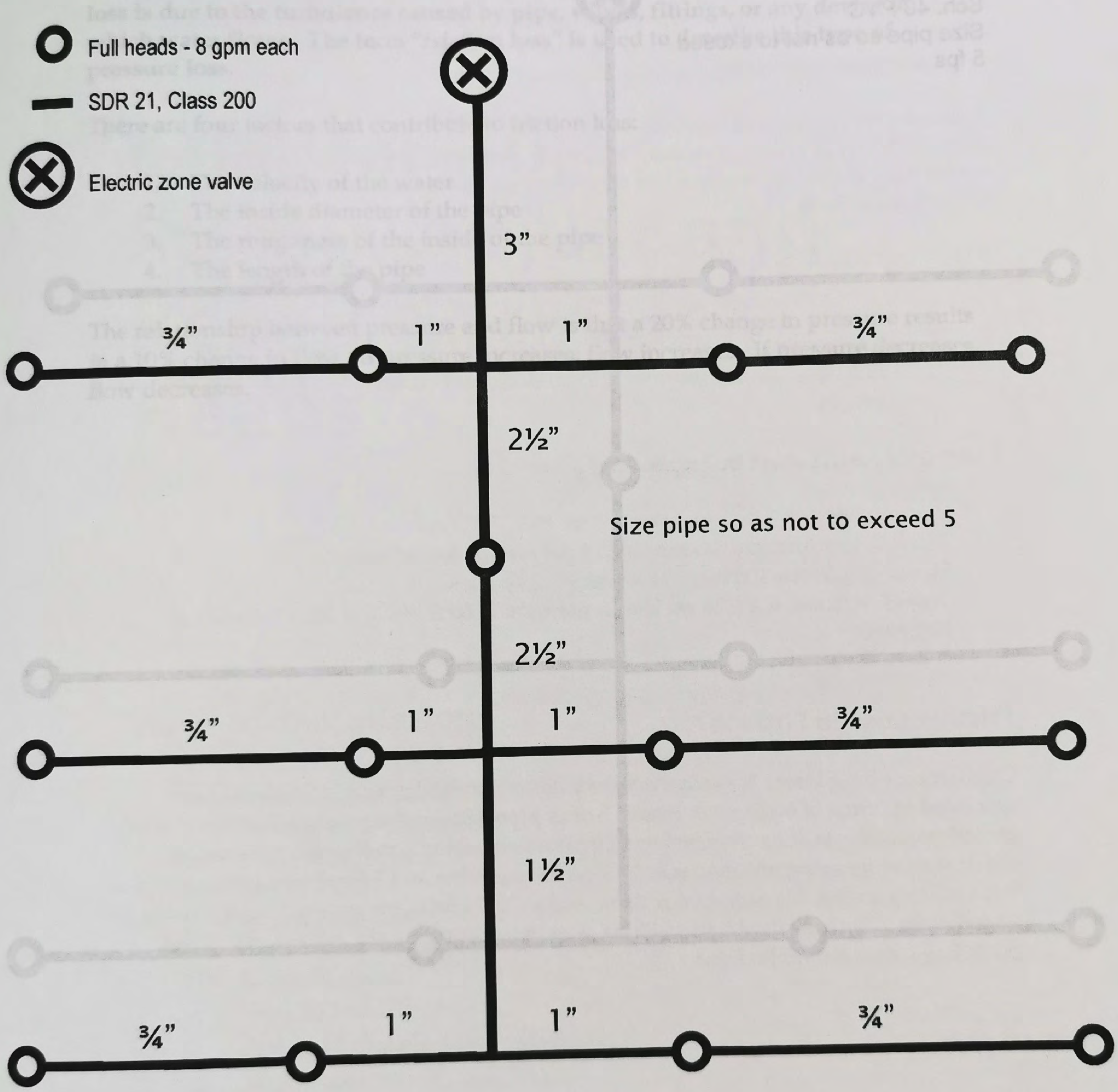


Figure 9-2

Pipe Sizing Practice Problem #1

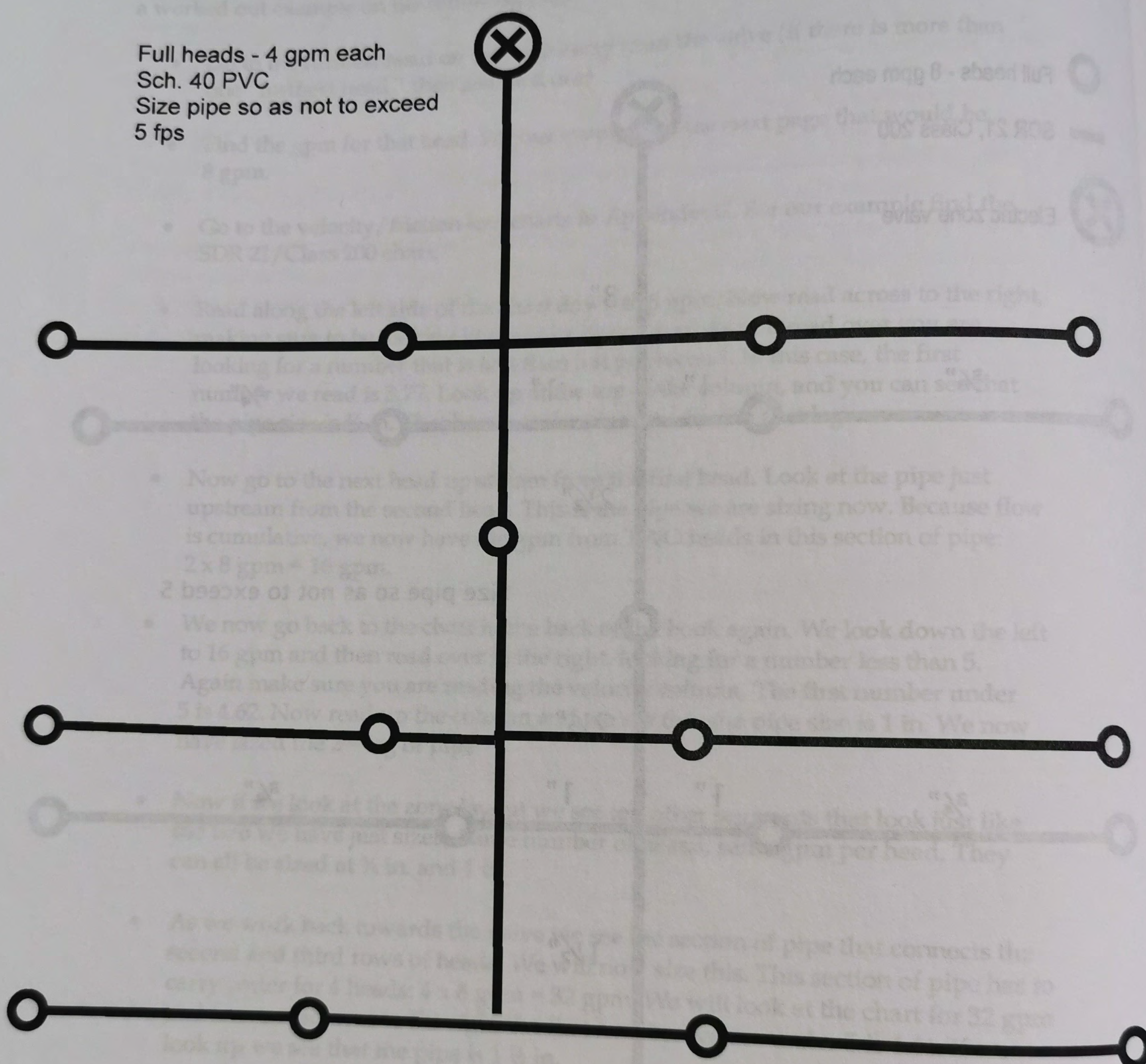


Figure 9-3

Fundamental Principles of Hydrodynamics

Pressure and Flow

Pressure is lost any time water moves through an irrigation system. This pressure loss is due to the turbulence caused by pipe, valves, fittings, or any device in which water flows. The term "friction loss" is used to describe this type of pressure loss.

There are four factors that contribute to friction loss:

1. The velocity of the water
2. The inside diameter of the pipe
3. The roughness of the inside of the pipe
4. The length of the pipe

The relationship between pressure and flow is that a 20% change in pressure results in a 10% change in flow. If pressure increases, flow increases. If pressure decreases, flow decreases.

Calculating Pressure Losses

Using Friction Loss Charts to Calculate Pressure Loss

Most pipe friction loss charts today are based upon the Hazen-Williams formula and verified by testing. Each pipe type is categorized by a "C" value, which indicates its relative roughness or smoothness, as the case may be. Friction loss charts are then organized (generally) along the following format.

Pipe sizes are categorized opposite flow rate in gallons per minute (gpm). Friction loss is psi per 100 feet of pipe and velocity in feet per second (fps) are compiled opposite flow versus pipe size. There is also a line or shading on most charts that indicates where the velocity goes above 5 fps.

To find any pipe friction loss:

1. Determine flow rate of the pipe section (gpm).
2. Read across to the column under the desired pipe size.
3. Multiply the friction loss rate by decimal equivalent of pipe section length.

Example: **(using chart in Appendix A)**

Find the friction loss for 60 feet of 1 in. PVC CL 200 flowing 12 gpm.
From charts: Friction loss rate is 2.14 psi per 100 feet of pipe
$H_f = 2.14 \times 60 \text{ ft} \div 100 \text{ ft} = 2.14 \times 0.60 = 1.28$ psi loss
Therefore, there is a 1.28 psi loss in pressure in 60 ft of Class 200 PVC pipe at 12 gpm.

Friction Loss in Fittings

Calculating fitting losses is rarely necessary since standard fitting losses have been cataloged in terms of equivalent loss in feet of pipe. If your fitting manufacturer doesn't provide such charts, they may be found in most plumbing handbooks. A common shortcut used by designers is to take 10% of the mainline and lateral pipe losses and use this as fitting losses. For example, if there was a 6 psi loss in my mainline and 4 psi in the lateral piping, that is a total loss of 10 psi. Ten percent of that would be 1 psi. Therefore, the fitting losses would be 1 psi.

Chapter 10: Install, Adjust and Repair Sprinkler Heads

Steps of Installation

1. Select Proper Tools
2. Perform Site Inspection
3. Read Blueprints
4. Install POC
5. Install Mainline
6. Install Field Wiring
7. Install Valves
8. Install Lateral Piping
9. **Install Sprinkler Heads**
10. Mount and Wire Controllers

General Characteristics of Sprinklers

Many types of sprinkler heads are available on the market. They are classified according to their construction, performance, and applications:

- Fixed or Rotary
- Drive Type: impact, gear, and ball
- Range of Throw: short, medium, and long
- Pattern of Spray: spray and stream, sprinkling, and bubbling
- Horizontal Arc of Spray: full and part circle
- Height: pop-up and non pop-up
- Nozzle: adjustable, non-adjustable, and special
- Precipitation: matched and non matched
- Low Head Drainage: check valve and non-check valve
- Pressure Regulating: regulating and non-regulating

The primary classification of sprinklers is determined by the way the sprinklers move to distribute water. A fixed or stationary head does not rotate and a rotary head does rotate. A fixed head typically distributes water in a fan-like pattern (spray heads) or multiple streams (stream sprays) that do not move. A rotary head distributes water through one or more nozzles and rotates to move the stream(s) of water.

Fixed or Rotary

Fixed Heads

1. Operate at low pressures: 15 to 30 psi range.
2. Cover small area: 5 to 18 ft radius.
3. Apply water at a varied rate of application from 0.75 to 6 in./h.
4. Most economical for small areas or irregularly shaped areas.

Rotary Heads

1. Operate at higher pressures: 30 to 70 psi range.
2. Cover larger areas: 18 ft to 100 ft radius.
3. Apply water at a low rate: generally from 0.20 to 0.60 in./h.
4. Most economical for medium to large open areas.

Spray Systems

This terminology is generally applied to those sprinkler systems, or portions of systems, which distribute water through sprinklers having a fixed nozzle orifice and resultant pattern of water distribution in the form of a fine spray. This type of sprinkler may actually be one of a number of different varieties, most of which are similar or identical in performance, but designed for different applications.

Spray Heads

- fixed spray heads commonly used in the residential landscape market
- low pressure, 15-50 psi
- patterns can vary widely, from full to part circle, from square to rectangular
- well suited to inside and outside curves and narrow strips
- coverage diameter varies from 5' to 30'
- high precipitation rates; from 0.85 in./h to 1.85 in./h

Lawn Sprays fall into two categories, both of which are designed to be used in lawn areas and are installed flush with the surface of the soil to be out of sight and to eliminate obstruction to mowers and pedestrian traffic.

1. Stationary or surface lawn sprays are short, mushroom-shaped sprinklers with no moving parts. They incorporate a spray nozzle within a grass flange, usually about 2 in. in diameter, from which the spray pattern is discharged at ground level.
2. Pop-up spray heads have a longer body or housing which contains a sliding inner tube with a spray nozzle attached to the top and a water seal at the bottom. Water pressure forces this unit up when in operation to project the nozzle from 1 in. to as much as 12 in. above the soil surface to prevent interference of the spray pattern by surrounding turf or relatively low ground covers.

Shrub Sprays utilize the same basic nozzle types as lawn sprays in a small stationary housing for placement above ground level in cultivated bed areas. Actual placement is determined by the plantings to be watered, with the nozzle placed on a riser high enough for the spray to clear the top of the foliage if watering is to be over the plants. They are commonly referred to as bed spray heads.

Also falling into this general category are the so-called bubbler heads, which are further classified as flood type if the heads simply flow a small metered amount from the nozzle or as spider or stream type if it emits small streams to disperse the water over a slightly larger area. These are normally installed just above ground level in extremely small areas or areas where spray of any sort would be objectionable.

Stream Sprays fall into either the lawn or shrub categories but are different in that they disperse the water through a serrated type nozzle. This results in a pattern of many slim streams of water rather than the solid fan or cone spray emitted by the conventional spray nozzle.

The common denominator, which brings all of these various types of sprinklers together under the spray system category, is the relatively small area of coverage plus versatility for maximum control of water application. The normal range of most spray heads is from a few ft up to about an 18 ft throw, or up to about 22 ft in the case of the stream spray. Normal spacings are on an equilateral triangular pattern with about 15 to 22 ft between sprinklers for the average lawn area.

The wide range of patterns available, particularly in the part circle nozzles, offers extreme versatility. In addition to the full circle and square or rectangular patterns, part circle sprays with arcs covering such portions of a circle as 1/4, 1/3, 1/2, 2/3, and 3/4 are relatively standard and some manufacturers will supply part circle patterns in 100 increments to fit any special requirements. Strip patterns are also available for long narrow areas such as parkway strips.

Relatively close spacing and versatility of nozzle use with resultant control of the spray makes the spray system ideal for use in irrigating small and confined areas. This type of system is therefore used primarily on landscaped areas of residential and smaller commercial properties. It is also often incorporated as a part of larger systems to water certain smaller areas such as those found around entranceways or a building. Spray systems have high water application rates.

Rotary Systems

The rotary system derives its name from the type of sprinkler used. The rotary sprinkler is so named because one or more nozzles, attached to a sprinkler with a rotating mechanism, discharge a relatively long, narrow stream of water that covers a circular area as it turns. Part circle patterns are obtained by reversing the rotation at given points. The non-retracting impact-drive sprinklers are primarily agricultural in application, but are sometimes incorporated into the turf irrigation system to irrigate certain areas such as broad expanses of ground cover where the sprinkler must be elevated above the foliage to perform properly. They are used in quick-coupling systems, which will be explained later. Impacts are also used when water is drawn from dirty water sources, i.e. ponds, lakes, canals.

Rotary Heads

- most common sprinkler type in commercial landscapes, parks and golf courses
- medium to high pressure, 30 - 100 psi
- patterns are fully adjustable
- well suited to larger applications and areas
- coverage diameter varies from 30' to +100'
- low precipitation rates; from .15" / hr to .55" / hr
- two basic types used today - gear drive and impact

Gear Drive sprinklers

- most common today
- a water driven rotor gradually turns the sprinkler through a series of reduction gears

Impact sprinklers

- was very common prior to gear drive designs
- a spring loaded arm taps the water stream sideways, gradually turning the sprinkler
- usually made of metal, they wear out and are expensive to maintain

Pop-up rotary sprinklers are used almost exclusively in turf applications. There are some types that do not pop up but discharge the water through nozzles set in a rotating cover plate, which remains at ground level. The top of the pop-up rotary sprinkler housing is installed flush with the level of the soil. Water pressure raises the nozzle above ground level during operation.

The variety of pop-up rotary sprinklers is extremely wide, both in terms of areas of coverage and types of drive mechanisms. While a few offer coverage patterns from a 35 to 50 ft diameter, most begin at about the 50 ft diameter and range upward to 250 ft diameter. The mid range performance from a diameter of about 70 to 170 ft is most commonly used. Rotating mechanisms include not only the impact-drive sprinklers placed in a pop-up housing, but also gear, cam, and ball drives plus combinations and variations of these.

Rotary systems are basically designed in much the same manner as the spray systems except that the spacings are much greater, with the majority ranging from 40 feet upward. Pipe sizes must be increased because of the greater volume of flow, and higher pressures are required for operation, especially in the larger sprinklers that may require as much as 100 psi at the sprinkler for operation as opposed to a general 15-30 psi range for spray heads.

The primary design exception is found in golf course systems, which are often designed to water only the fairways, tees, and greens. In this case, the width of the fairway and the quality of coverage required determines whether a single row of larger rotary sprinklers down the center will provide adequate water or whether two, three, or more rows will be necessary. Turf irrigation terminology names these as single-row, double-row, three-row, etc. systems. When the entire course, including the roughs, is covered, this is usually referred to as a "wall-to-wall" system.

Quick-Coupler System

A variation of the rotary system, the quick-coupler system has declined in favor as a primary method of irrigating turf because of the amount of labor required. This system still fits those areas where normal rainfall is such that only occasional supplemental watering is required to maintain the turf.

The name is derived from the quick coupling valve. This valve is installed on piping which remains under pressure. It is placed with the top at ground level, and has a hinged or removable cap to allow access to the valve. Inside is a valve seat and a disc that is held closed by a spring and water pressure. The top inside portion has a spiral keyway cut into the wall. A matching coupler fits into the top opening and one or two lugs projecting from the coupler fit into the spiral keyway. By engaging the lug and turning the coupler with a side handle, the coupler is forced into the valve, opening it and allowing water to flow through the coupler. A sprinkler head may be attached to the threaded top of the coupler to operate at that location, or a swivel hose ell and hose may be connected. When used as a total quick-coupling system for turf irrigation, the valves are placed on suitable spacing for the sprinkler to be used, or in the case of some golf course fairways, in single or multiple rows down the fairways. Each individual sprinkler, attached to a coupler, must then be inserted by hand, its operation timed, then manually removed.

In an attempt to eliminate the night labor required for this operation in most public locations and the water waste from timing errors, some existing quick-coupler systems have added a time clock to control the pump or pressure supply to these systems. In this way the sprinklers to be operated on a given night can be inserted in the evening, the pressure will be applied to operate them during the timed night interval, and they can be removed manually in the morning. This arrangement is often referred to as a "semi-automatic quick-coupler system."

Even for an automatic irrigation system for golf courses there are quick coupling valves at each green and often at each tee to provide manual irrigation capabilities. Quick coupling valves are also used on sports turf, athletic fields, and parks and recreation.

Valve Under Head or Valve In Head

A special technique has been developed and used primarily in golf course irrigation, which originated with the placement of a remote control valve in the riser assembly below each large rotary sprinkler to allow individual automatic control. Several manufacturers have now incorporated the valve directly into the bottom of the sprinkler head housing as an integral unit. This technique has been successful in converting existing quick-coupling systems to automatic operation and has also come into wide acceptance as a means of splitting the hydraulic loading of rotary system piping by simultaneously operating single heads in different areas of the system. The ability to operate any single sprinkler in the system as desired also provides increased versatility to the turf manager.

Installing Sprinklers

When installing sprinkler heads, there are a variety of methods and guidelines to follow, based on the type of head you are working with.

General Guidelines for Installation

Always protect your sprinkler and piping system from vehicle damage by attaching it to a swing joint or some type of flexible piping. ("funny" pipe, etc.). Maintenance equipment, delivery vehicles, etc. will invariably drive over the top of recessed irrigation heads. As well, vandals enjoy smacking heads which destroy them or damage underground pipe connections. To protect these excessive forces from damaging both the sprinkler head itself and the piping that it is connected to, you need to create some "flex" in the piping to absorb these tremendous weight loads and potential blows.

Always seal up the threaded connections with Teflon tape or paste. Threading plastic irrigation connections tightly together is no guarantee that there will be no leaks! Plastic threads are manufactured with some degree of tolerance and plastic is a very soft material. Therefore, two plastic threads together require some type of sealant to prevent leaks. Teflon tape or paste is most commonly recommended – DO NOT USE GRAY PIPE DOPE ON PLASTIC THREADS. The Gray pipe dope is designed for use on metal fittings; it acts as a sealant and work very effectively as such – on metal! The chemical makeup of metal pipe thread sealers will eat away at plastic threads; when this occurs, your only recourse to solve a leaky head is to replace the entire sprinkler body or casing.

When placing heads alongside curbs, roadsides or sidewalks, it is best to actually locate the head a little bit back from the concrete edge. The sprinkler should be somewhere between 3″ and 6″ in from the edge of the concrete, depending upon the size of the sprinkler (the bigger the head, the greater the setback). This helps to minimize damage to the head from passersby and trimming equipment as well as to reduce water runoff onto the curb or sidewalk area.

Installing Spray Heads

Spray heads are small and fairly quick to install. Assuming that the piping has been installed at the correct depth with a suitable connecting fitting, it is relatively easy to quickly attach a swing joint and then attach this assembly to the piping. When you are installing the swing joints, you want to pay particular attention to the actual flagged location of the head. You should align your swing joint so as to place the sprinkler head as close as possible to the original flagged location.

Many manufacturers of sprayheads sell their heads with "flush caps" installed. These are soft plastic fittings that will allow water to run through the end of the sprinkler riser and are ideal for flushing the piping. It is best to remove all screens from the head, hook up the head to the swing joint and then run the zone or head, "flushing" the line through the "flush caps", before you place the head in the ground and backfill. This will allow any debris, bits of tape or garbage in the piping to run out through the head. This greatly simplifies sprinkler adjustments later on in the installation process. After flushing, you are then ready to install the screens and nozzles.

Ensure that the sprayhead filter or screen is correctly installed before screwing on the nozzle. When using pressure regulating screens, it is imperative to ensure that the right colored screen is used to maintain correct operating pressure for the head. Also ensure nozzle uniformity when

Figure 10-1

putting the nozzles in. Thread the nozzles onto the sprayhead risers, being careful not to "cross thread" the riser. **Do not use teflon tape on nozzle threads!** After threading the nozzles onto the sprinkler risers, if possible, set the nozzle to the correct arc or pattern before backfilling the head.

When your hole is significantly deeper than required, tamp the soil beneath the head very firmly; this will prevent or at least lessen any settling that will occur after the head is activated. When backfilling around a sprayhead, pay particular attention to keeping the head perfectly upright. Backfilling is when you set the head's tilt; if the head is not at the correct tilt, it will negatively affect the heads coverage and performance. You can backfill around the heads initially for the purposes of testing; the piping trenches can be filled in later.

When installing sprayheads on a slope, it is best to tilt the head perpendicular to the slope, unless the slope is greater than 3:1 (rise : run). With sprayheads, you are sometimes dealing with fairly large water droplets and gravity will negatively affect the water distribution on slopes. On steeper slopes (i.e. greater than 3:1), it is best to install the head at an angle halfway between the existing slope and a level grade. On steeper slopes, there may well be a better way to irrigate than sprayheads!

Once the heads are all installed flush with the finish grade, turn the zone on and check sprayhead performance. If you were not able to set the sprayhead arc or pattern earlier, now is the time to set the arcs to the correct angle. You may also want to do some fine adjusting on the sprayheads to limit overthrow or to adjust for specific factors on site. Keep in mind that substantially reducing spray coverage by screwing in the adjustment screw IS NOT an acceptable substitute for using the wrong sized head or nozzle!

Installing Fixed Riser Heads

Fixed heads (sprayhead or rotary) are established in place and therefore require slightly different installation techniques. Generally, vandalism or damage to the riser is your biggest concern. Therefore, you need to install some type of flexible polynipple or poly fitting to provide some degree of movement in the event that a blow or damage occurs. This flexible connection can occur at the base of the riser, where it connects to the piping or it may be above ground on the riser itself. Another method of protecting the riser is to attach it to something, i.e. a retaining wall behind it, a building surface, etc. If the site does lend itself to this, sometimes additional staking materials may help (wooden or steel stakes, bamboo stakes, etc.) The riser itself needs to be firmly placed and backfilled so it will not move or be prone to movement once the sprinklers come on.

Once the riser is protected and in place, you can proceed with flushing out through the tops of the risers before installing the heads or nozzles. Head adjustment can occur after the head or the nozzle is in place.

Installing Rotary Heads

Many of the principles described above apply to the installation of rotary heads as well. When you are connecting swing joints to the supply pipe, you want to pay particular attention to the actual flagged location of the head. You should align your swing joint so as to place the sprinkler head as close as possible to the original flagged location for the head

Swing joints for rotary heads can be either "home made" or "prefab." The advantage of "prefab" swing joints is that they are commonly made using "Acme" threads. An "Acme" thread is actually different from conventional threads on plastic fittings; they are conical shaped threads and utilize rubber "O" rings to seal the connection. "Acme" threaded swing joints are substantially more expensive than "homemade" swing joints but they provide a greater degree of flexibility without leaking. The larger the head, the more recommended it is to use "Acme" threaded swing joints.

Swing Joint Information

To protect lateral lines from being damaged when sprinkler heads are moved, a swing joint is used to provide flexibility to the head to pipe joint. Swing joints come in a number of varieties. Some are prefabricated of PVC fitting and pipe while others are field built of PE flex pipe and slip joint fittings. For smaller heads, "funny pipe" is used to provide this flexibility. It consists of small diameter PE pipe with slip fittings that thread into the lateral line. For larger heads, a pre-made swing joint is used. See Figures on the following pages. These are usually made of PVC and rubber gasket fittings. They come in sizes up to 2 in.

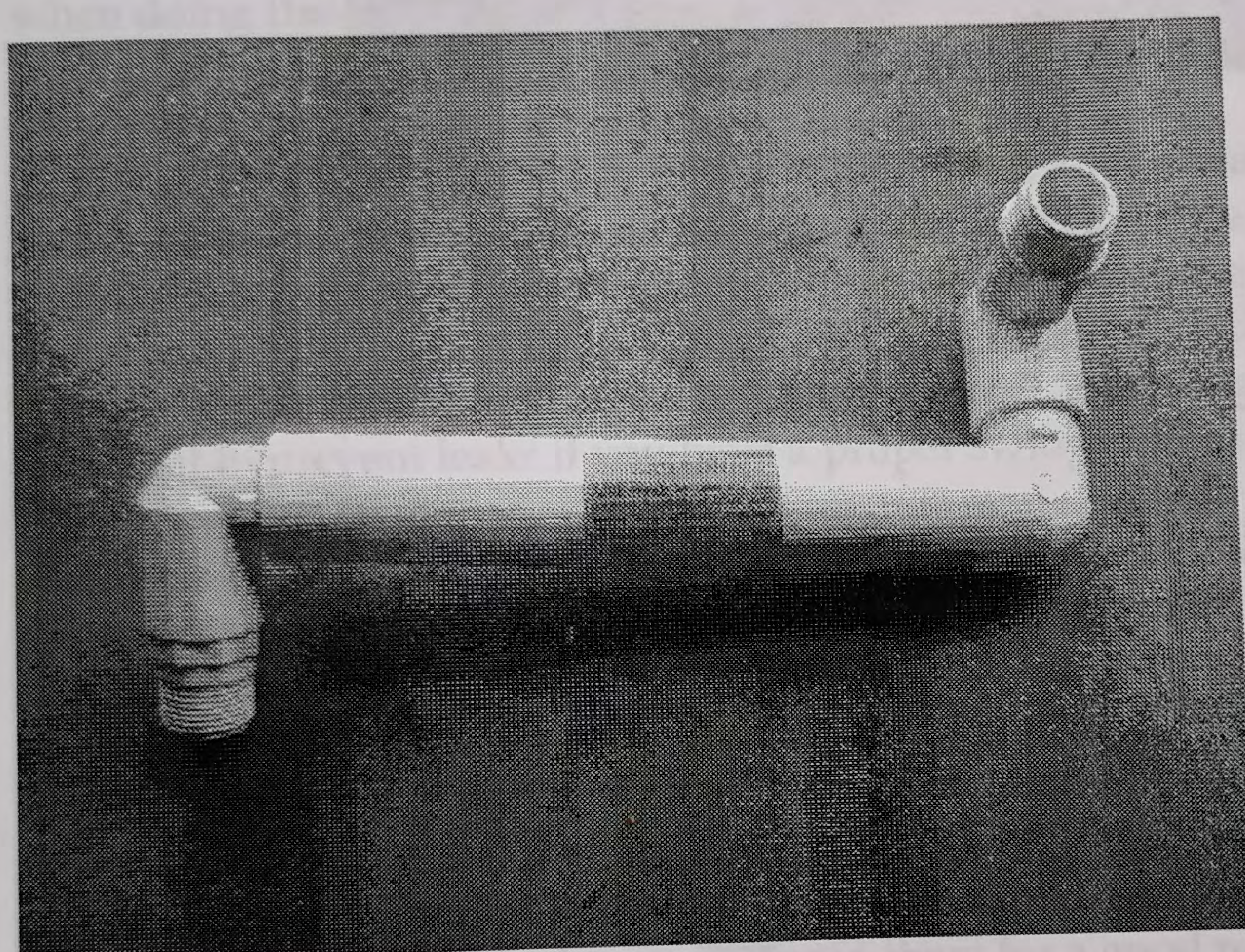


Figure 10-2

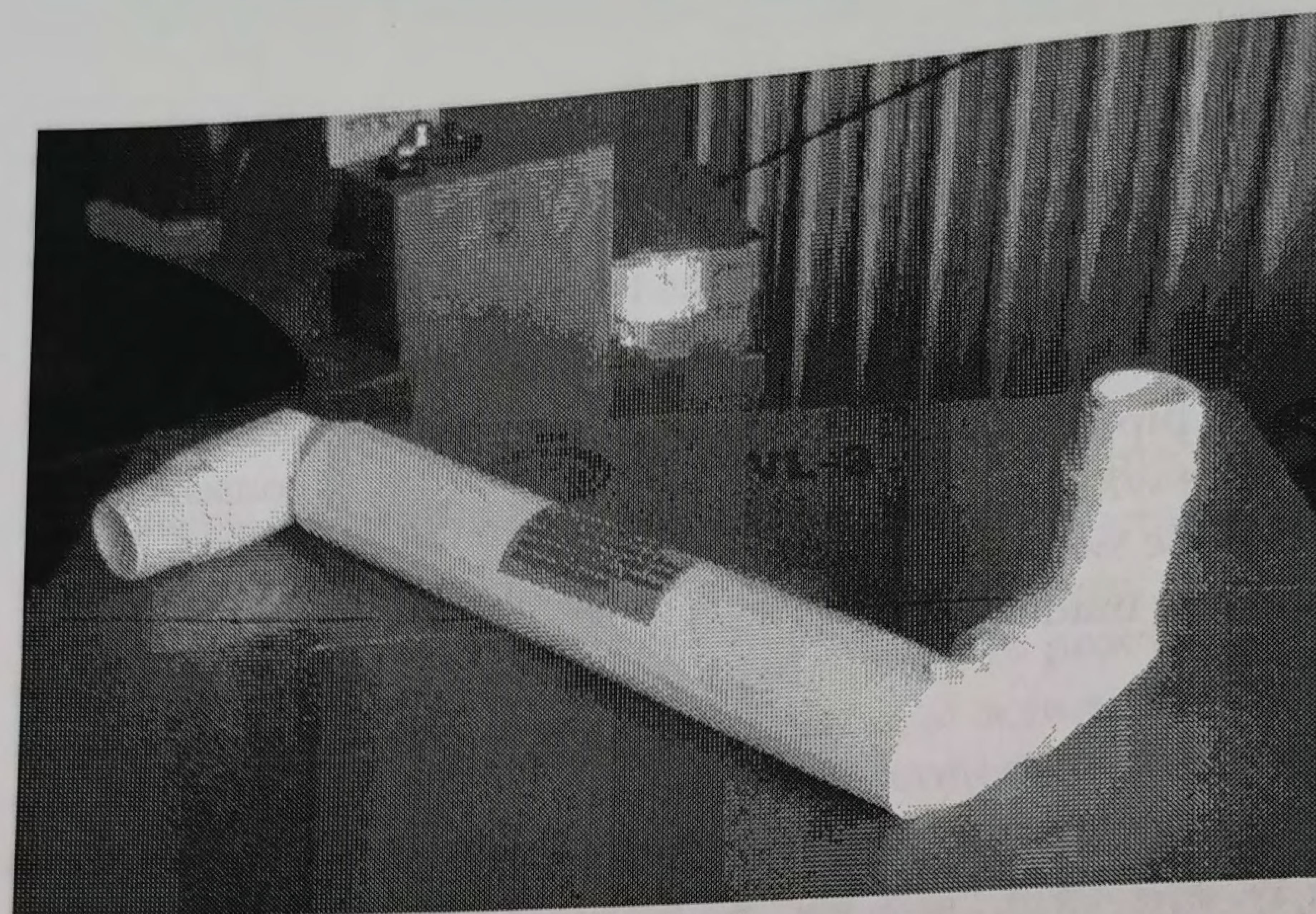


Figure 10-3

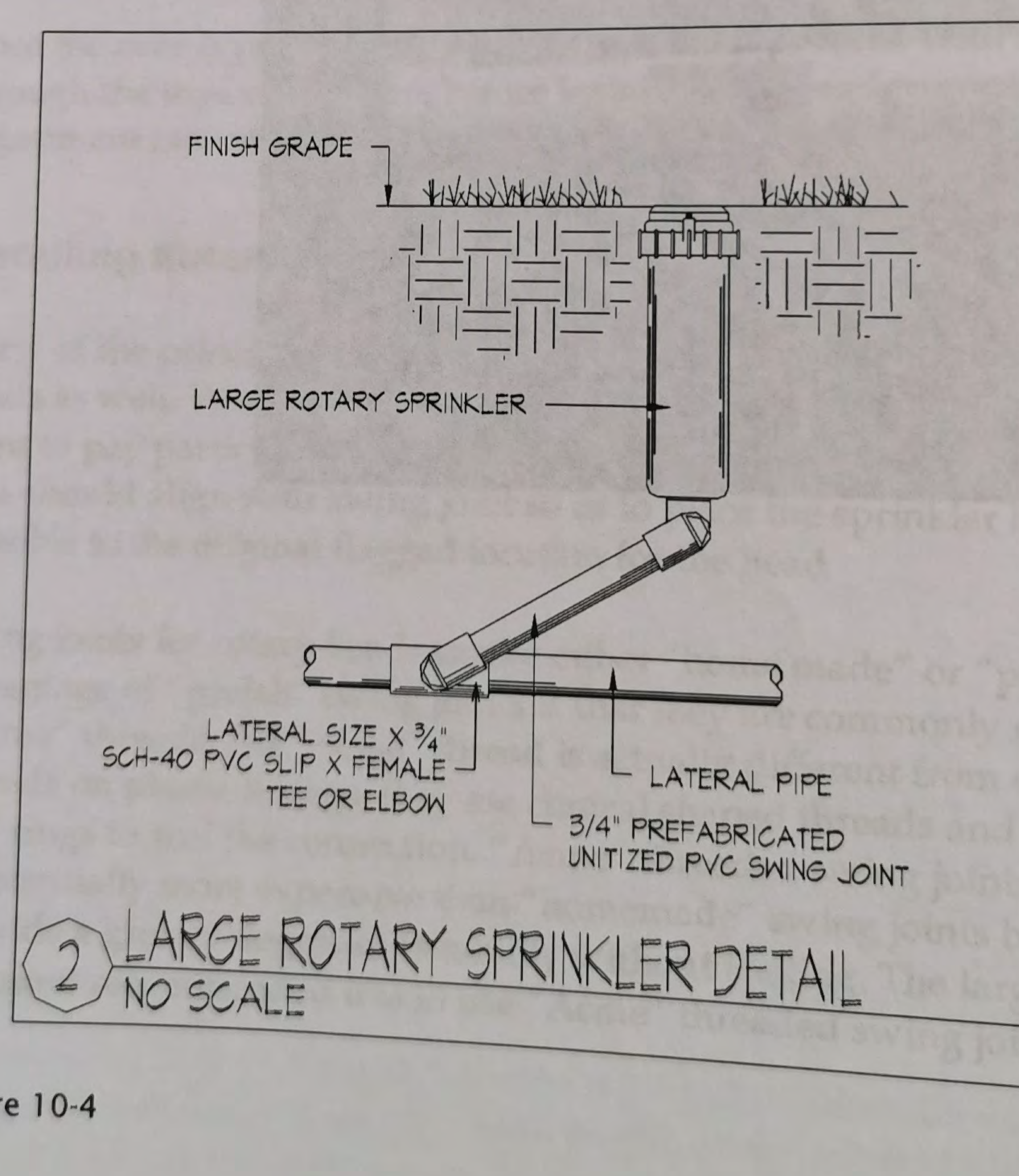


Figure 10-4

Also, ensure that the swing joints have not been undersized. The swing joint should always be at least the size of the threaded inlet on the underside of the sprinkler. On large commercial projects, it is not uncommon to see contractors or developers undersize the swing joint in an effort to reduce costs. An undersized swing joint can dramatically reduce pressure just below the head and compromise sprinkler performance.

Larger rotary heads do not normally have "flush caps" so "flushing" has to occur before you install the head. Typically, you will connect your swing joints to the piping, raise them up out of the ground and then "flush" water through the lines to clean them out. On larger commercial or even golf systems, it is a good idea to leave the end of the supply or lateral pipe open when doing flushing. It truly is remarkable how much debris can get inside piping even when a conscientious crew has installed the pipe!

After the lines have been flushed, you can now thread the heads onto the swing joints. Sprinkler heads should always have Teflon tape on the threads to seal the connection. Never tighten a sprinkler onto a swing joint tighter than "hand tight," i.e. as tight as you can with your hands – **do not use a pipe wrench or channel lock pliers to tighten the head!** "Hand tight" will be sufficient to prevent leaks if you have a proper swing joint in place.

On larger commercial and golf course installations, some contractors remove the screens on the bottom of the sprinkler casing to aid in letting debris pass through the sprinkler. The thinking is that this reduces sprinkler clogging – which, in actual fact, it does on larger heads. The problem is, it also creates abnormally high levels of wear and damage inside the sprinkler's internal workings – this, in turn, shortens the life of these workings! **It is not recommended to remove sprinkler screens during installation.** These screens were designed and manufactured there for a good reason – to protect the internal workings of the head and to extend the life of the sprinkler.

On golf course installations where Valve in Head (VIH) sprinklers are used almost exclusively, you will then need to make your wiring connections, prior to backfilling around the head. When installing VIH sprinklers, it is a good idea to tape extra wire and the electrical connections to the sprinkler body itself, using electricians tape. This will safeguard the electrical connections should you ever have to dig the head up

Rotary heads should be installed flush with the finished grade. For newly seeded areas, you need to raise the head slightly to account for the turf growing up in around the head. Typically, heads on new construction jobs are set approximately 1/2" to 2" above grade and then relevelled after the turf becomes established. Soils underneath and around the head should be firmly tamped in place after backfilling to prevent the head from changing its tilt. This is critically important to the success of the sprinkler's long term performance, especially on unstable soils such as sand and sandy loam. A poor job of setting the head in place will result in sprinkler heads shifting and a guaranteed call back to the job to correct the problem.

Again, on slopes, keep the rotary head perpendicular to the slope on all slopes up to 3:1 (rise:run). On steeper ground, install the head at an angle approximately halfway between the existing sloped grade and a level grade.

When installing rotary heads, it is important to check for nozzle uniformity. It is not uncommon on larger commercial jobs to have the sprinklers all ordered from the manufacturer with a specific nozzle already installed and preset at the factory. Check these nozzles again during installation – never assume that out of 200+ heads, that all the nozzles are the correct nozzles!

You are now ready for a system performance check to see how the heads work. Most rotary heads today use "through the top" adjustment – you adjust arc, spray pattern, trajectory, etc. through the top of the sprinkler head using a specific adjustment tool. Once the system is running, you can "fine tune" your heads to ensure you are receiving the correct coverage patterns. Always obtain and follow sprinkler manufacturers' recommendations for sprinkler adjustments. Again, major adjustment to a sprinkler's performance will not correct the wrong sprinkler or nozzle choice.

Adjusting Sprinklers

When maintaining an irrigation system, sprinkler performance is often compromised because no adjustments have been made over time. Common changes occur to irrigation systems after they have been installed and any irrigation system will require periodic adjustment. In this section we will discuss a few common problems that require routine maintenance adjustments.

Spray Heads

The most common spray head problem is that they change their tilt. Trimming and maintenance equipment often bump or jostle a spray head riser and change the sprinkler's tilt. A simple hand trowel can often be used to partially dig up the head, where you can reset the sprinkler to the correct tilt. If the bump has been severe, not only is the head tilting but it may also have a cracked riser or sprinkler casing and now is causing flooding whenever the head comes on. Sprinkler replacement and/or fitting repair will be required.

Another adjustment that commonly is required on spray heads is that of the mysterious changed arc – people sometimes go over to the spray head and turn the whole sprinkler body so the arc is no longer a problem for them. Resetting the arc of coverage can be troublesome especially if the head has been over-tightened on the swing joint fitting; this often results in cracked fittings or sprinkler body casings and will require the same expensive repair mentioned above. If not cracked, it may be best to dig the head up, reattach it to the swing joint and then just reset the arc. For this adjustment, it would be a good idea to find out why people keep turning the head in the first place – is it watering somewhere it shouldn't?

When adjusting the spray head, learn the particular adjustment techniques for that particular head from manufacturer's brochures. Some heads use a right click stop adjustment while other heads use a left stop – using the wrong technique can strip the internal workings of the head in some cases.

Another common problem with spray heads is clogged or partially clogged nozzles. This can cause tremendous problems with spray heads and they are prone to it due to their very fine orifices. Simply removing the filter screen underneath the nozzle is the easiest quickest solution but provides only short tern relief from the problem. If many nozzles are clogged on a site, it may be best to remove all the nozzles and screens, "flush" the lines, then clean all the screens and reinstall the screens and nozzles. This is a common occurrence after repairs to an irrigation system.

If spray heads routinely clog up, you need to check the water involved with the irrigation system's source. Poor water quality may require the use of some type of filtering system. With poor water quality, you may need to treat the water itself at source, you may need to install a centralized filtration system for the entire irrigation system or you may need to install some smaller filters (one / zone). The cost and frequency of cleaning heads will determine which option you choose.

If you are dealing with sandy or silty water at source, you will also see premature seal failure on the riser seals. The dirt and sand will increase wear on the plastic seals, allowing water to "blow by" the seal. Sprinklers which show a lot of water erupting around the base of the riser have faulty riser seals. Some manufacturers supply replacement seals while others require you to replace the entire lower sprinkler casing. In either case, you can usually repair a faulty riser seal by removing the sprinklers internal workings and not having to dig the head up.

An occasional problem for spray heads is sprinkler settling. Over time, a sprinkler commonly settles into place; if insufficient tamping occurred when the head was first installed, you will see significantly settling around the head and it will not work effectively. The head should be dug up retamped and properly reset flush to grade.

Rotary Heads

The adjustment and maintenance problems associated with rotary heads are substantially less than with spray heads. Rotary heads use greater pressures and generally have larger orifices – therefore their adjustment problems are far less and their maintenance somewhat simpler.

The greatest problem with rotary sprinklers is their tilt and settling problems. Due to their larger size and bigger excavation holes, the amount of settling is often greater with rotary heads. This settling, in turn, increases the likelihood that sprinklers will change their placement and start to tilt. Settling problems compound as rotary heads with bigger covers will be subjected to greater amounts of vehicular traffic from mowers and maintenance equipment. To fix this problem, the head needs to be dug up and the head reset to grade.

Occasionally, larger rotary heads will have clogged nozzles or clogged screens at the base of the head. Most rotary heads allow you to clean these screens by removing the head cover and then removing the internal workings of the sprinkler. If screens are routinely clogging up, you may need to address the problem from the water source as contaminants are getting into the system somehow. With rotary heads, nozzles can be quickly removed, cleaned and re-inserted into the head without ever having to dig the head up. Nozzles that are used in dirty water situations where there is a lot of sand or grit will see premature wear on the nozzle's orifice. Nozzles should be changed out in these specific situations on a routine basis.

On rare occasions, you will see a clogged or partially clogged swing joint elbow. Chips or shavings from pipe, small stones, gravel, etc. can all build up and clog an elbow within the swing joint assembly. This typically happens on the top street elbow of the swing joint. In this case, you need to dig up the head and expose the end of the swing joint above ground. The problem can be remedied by removing the sprinkler (ensuring that it is not clogged) and then 'flushing" the line – you will usually see the debris blow out; you can then reattach the head and reset it to grade.

Another problem with rotary heads is the faulty riser seal, again caused by sand or silt wearing away the riser seal. When a rotary head has major water flooding out from the base of the riser, the seal is defective and will require replacement. Most rotary sprinkler manufacturers supply individual replacement seals; they are a must for any maintenance toolbox.

Another problem with rotary heads, particularly in colder climates where systems are winterized, is differing rotation times. It is a good idea from a maintenance perspective to annually check and time (using a stop watch) all sprinkler rotation times. Plastic gear drive assemblies are prone to damage from excessive rotation speeds during typical "blow out" procedures. This can result in burned out gear drive assemblies and very irregular and slow rotation times. There are no adjustments on rotary heads for rotation speed therefore your only recourse is to replace the entire gear drive assembly.

Sprinkler Head Maintenance

Nozzles

- different materials will wear differently; brass will last longer than plastic in "dirty" water conditions
- the edge of the nozzle's opening or orifice will expand with wear
- worn nozzles will increase the water flowing through them, increasing PR
- nozzles should be checked and replaced on a regular basis; more often in "dirty" water applications

Drive Mechanisms

- on gear drive heads, the gears may be stripped, due to vandalism or clogging; the head will not rotate effectively, increasing PR or causing puddling
- on impact heads, the recoil springs will deteriorate over time due to metal fatigue; the turning action slows, increasing PR rates
- for either case, it is usually most cost effective to replace the whole head than repair it

Delivery Patterns

- may be affected by too much pressure (lush green centre around head surrounded by outer halo of brown) or too little pressure (brown spot at head with outer lush green ring)
- sprinkler spacing has to be exact; too much overlap will cause puddling while too little overlap will cause "browning"
- nozzles should be periodically checked to ensure that all the nozzles are the same size and deliver the same GPM
- wind may disrupt the sprinkler's pattern; water at night to minimize the effect of wind

Misfire and Malfunction

Five problems that can develop... and how.

Even obvious problems, such as broken heads, sometimes go unnoticed because the system is on an automatic timer that waters early in the morning.

Problem 1: Head bubbles or squirts at base. (Tap nozzle to clear debris from stem. If it still doesn't seal, remove head and clean). Replace head if rubber wiper seal on end of sprinkler stem is missing or damaged.

Problem 2: Grass blocks spray of stationary head. (Change head to pop-up, fill dangerous hole around it with soil, seed with grass). If spray still hits grass, dig out lawn and add a 1/2-inch or 1-inch riser.

Problem 3: Head doesn't spray enough lawn area, (Change head to wider-angle pop-up to cover more lawn and clear height of grass).

Problem 4: Clogged sprinkler sprays erratically. (Run knife blade through slit, if it doesn't clear, remove head and clean or replace it).

Problem 5: Brand-new head sprays erratically. (Remove nozzle with wrench, turn on the system, and flush dirt from line).

Most Common Sprinkler Non-Uniformity Problems

Mixed Sprinkler Types: The mixing of different types of sprinklers on the same line. Especially the mixing of sprayheads and rotary heads.

Improper Nozzle Selection: Sprayheads – Mixing nozzles with different trajectories. The flat spray (5 degrees), the low-angle spray (12 degrees), or standard angle spray (30 degrees).

Rotary Sprinklers Only: The mismatched precipitation rate. The use of quarter-, half- and full-circle sprinklers within the same irrigation station, each with the same size *gpm* nozzle, nor taking into account that the half-circle is covering twice the area of the quarter-circle sprinkler and only half the area of the full-circle sprinkler. Many sprinkler manufacturers now routinely offer a selection of matched precipitation rate (MPR) sprinkler nozzles.

Spacing Irregularities: Clustered, gappy or open-perimeter coverage. We are looking for head-to-head, closed-perimeter coverage for best uniformity.

Chapter 11: Mount and Wire Controllers

Steps of Installation

1. Select Proper Tools
2. Perform Site Inspection
3. Read Blueprints
4. Install POC
5. Install Mainline
6. Install Field Wiring
7. Install Valves
8. Install Lateral Piping
9. Install Sprinkler Heads
10. **Mount and Wire Controllers**

Important Note: When installing controllers, this sometimes involves working with high voltage (110/120V or higher). In almost all cases local codes will require that this work be done by a licensed electrician. The information regarding working with high voltage wiring in this chapter is for information purposes only. A licensed electrician should always do this work.

Controllers are the brains of the irrigation system. Controllers send the signals to individual valves turning them on and off causing the irrigation system to apply water according to your instructions. The choice of controller features increases almost daily providing the designer/specifier with almost unlimited opportunities. Controllers for larger commercial sites and golf courses feature computer control with remote satellites (controllers) to control hundreds of valves. Features include hand-held transmitters for on-site or off-site remote valve actuation. Perhaps the biggest challenge is to select the minimum configured controller to do the job without over-investing in unneeded features. Since our focus is residential and smaller commercial applications, we will discuss the less sophisticated controllers. The controllers used for residential and small commercial applications, however, are just as impressive as their bigger cousins.

Method of Control

Let's begin our discussion of controllers with the two primary methods of providing signals from the controller to the valves: hydraulic and electric. With hydraulic control, water pressure is used to control the valve and small-diameter tubing connects the controller to the valve. Voltage passing along electrical wires is used to control electric valves. Both systems offer some advantages. Hydraulic systems, for example, reduce the risks associated with damage caused by voltage surges. However, the much more commonly used electrically actuated systems will be the focus of our discussions.

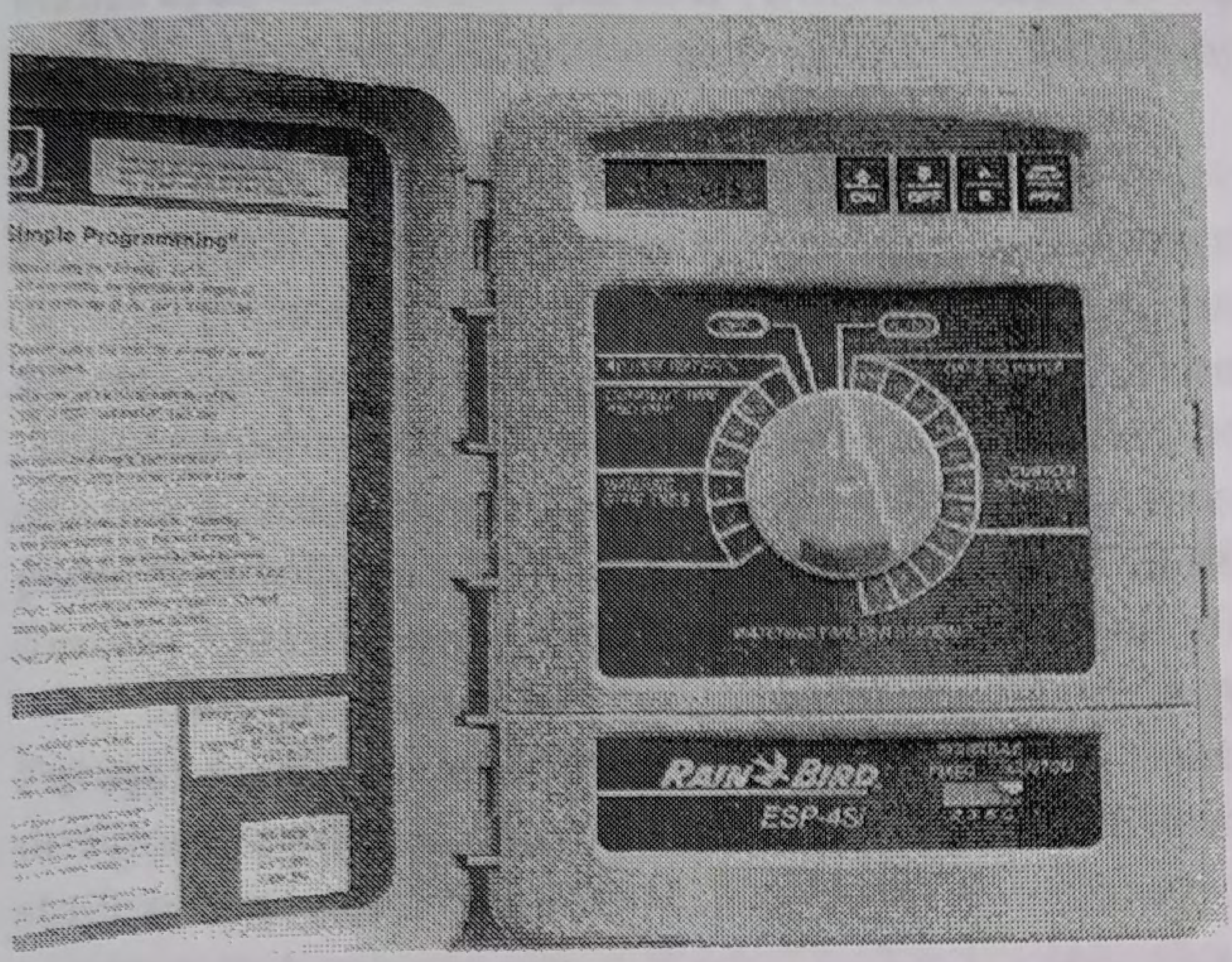


Figure 11-1: Four-station controller

Types of Controllers

Controllers can be categorized according to the way they are made: (1) electromechanical, (2) electronic/solid-state, and (3) hybrid. Initially, all controllers were electromechanical, that is, they were made of motors, mechanical switches, gears, and other mechanical parts. They have and continue to offer basic features of turning valves on and off in a reliable and understandable way. The advent of electronics, however, offered the opportunity to design totally solid-state controllers that could do much more. Unfortunately, early electronic controllers required programming by use of key pads, could loose their programming with power losses, and were difficult to understand and use.

To overcome these problems, many manufacturers combined the desirable features of the electromechanical and the electronic controllers to provide an easier-to-use "hybrid" controller. This controller utilizes mechanical knobs and displays in conjunction with electronic circuitry and readouts to provide an exceedingly user-friendly product.

A new type of controller that has gained popularity in recent years is called Central Control. Central Control allows the user to control a wide array of many different sites spread out over a large area from a personal computer. This type of control uses many different types of communication; cellular phone technology, radio, fiber optic, telephone wire, and pager technology. With a PC at the office and specially designed controllers out in the field serving as relays, an end user can monitor flow, weather, and other data and control irrigation systems one hundred miles away without leaving their office.

Another type of irrigation control that is relatively new is the two-wire system. A two-wire system allows a user, for example, at a golf course, to control hundreds of electric valves with just two wires. On a normal system, if one had one hundred electric valves, there would be at least one hundred power wires plus a common wire. With the two-wire system, a control message is encoded and embedded in the wires that carry the power for the valves. This system obviously has many benefits including lower cost. However, with the advantages are disadvantages and limitations as well. This book does not allow a detailed discussion of this type of system, but it is gaining in popularity and should be explored as an option on some sites.

Features and Options

As discussed earlier, there is an almost unlimited choice of features and options for today's controllers. Some are now standard on most controllers, while others are less available. Let's look at some of the more useful features.

Enclosure. Controllers are available in both plastic and metal enclosures and are rated for either inside or outside use. Some have locks. In deciding on the type of enclosure to use, consider who will need access to the controller. Would this person have access to the controller if placed inside? Does the controller need to be protected from unauthorized entry by vandals or children? Is there a location where the controller can be placed to easily view the various zones? Is that location outside?

Transformers. All electrical controllers have transformers. Transformers reduce the incoming voltage, usually 115 V (volts) to approximately 24 V, a much safer voltage for use in underground wiring. Usually, licensed electricians or contractors must install 115-V controllers, i.e., those that have built- in transformers. Some controllers can be obtained with external transformers, which plug directly into an electrical outlet. Only 24 V is supplied to the controller, thus eliminating the need for a licensed electrician, assuming an electrical outlet is available.

Number of Stations. Controllers are generally available with from 4 to 36 stations. Some common controllers include 4, 6, 8, 12, 18, 24, and 36 stations. Some newer controllers have modules to allow expansion. Naturally, the controller is selected near the end of the design process and after the number of zones required is known. You may want to have several unused stations to allow for expansion. There's always the possibility of a new flower bed or even an alternate use of controlling lights, etc.

Valves Per Station. Electric controllers are rated according to the amount of current that can be supplied to operate the electric diaphragm valves. Some operate only one, while others can operate two or more. Many designs require only one valve per zone or station. There are situations, though, where two or more isolated areas require the same treatment and should be operated at the same time. Under those conditions the controller must provide adequate current to operate those valves at the same time. We'll discuss this more later.

Pump/Master-valve Control. The individual stations on a controller are designed to activate one at a time. There are situations, however, where a station may need to be on all the time, or for a series of stations. Turning on a pump or a master valve would be such examples. Later we'll discuss another use for this type of station, which will provide some protection from electrical surges. Even though you may not need to turn on a pump, this still is a very useful feature.

Independent Programs. If an irrigation design includes different zones with shrubs, turf, and annuals or sprinklers and drip, there is likely a need to irrigate the different zones at different intervals. To accomplish this effectively, more than one program sequence is needed. Many controllers are now pro- viding two or more programming options. Thus, for example, turf could be sprinkler irrigated on Monday and Thursday, while shrubs could be drip-irrigated on Tuesday. All annual beds could be controlled by a third program and irrigated on Wednesday, and the system could be turned off when the annuals are removed from the beds.

Multi-start Times. There are times when it is necessary to start a zone more than one time during a day. Many controllers provide that option. This feature is sometimes used when the sprinkler application rate exceeds the soil intake rate. Dividing the application into two parts can reduce runoff. This feature might also be useful in establishing water-sensitive plants and newly seeded lawns.

Multi-timer Ranges. Many controllers have a variable on-time that is more appropriate for sprays and sprinklers, for example, 1 to 90 min. This time period may be too short for drip circuits. Some controllers allow one or more of the stations to be modified to provide a much longer time range, e.g., 10 min to 9 h. This allows an effective mixing of sprinkler and drip zones on the same controller.

Manual and Individual Start. Most controllers have a manual-start feature allowing the system to be initiated at any time. Another useful feature allows individual zones to be manually started independently.

Rain Delay. The rain-delay feature deactivates irrigation for a period of time. Usually a button can be depressed a number of times to provide several days of delay. Some visual indicator, such as a blinking light, is useful to indicate that the delay has been activated.

Percentage Adjustment. As the growing season advances, the amount of water applied may need to be increased or decreased. It's much easier to change all stations at the same time with a percentage adjustment than to readjust each individual station. When adjusting water application in excess of normal settings, some controllers make two applications rather than one longer application.

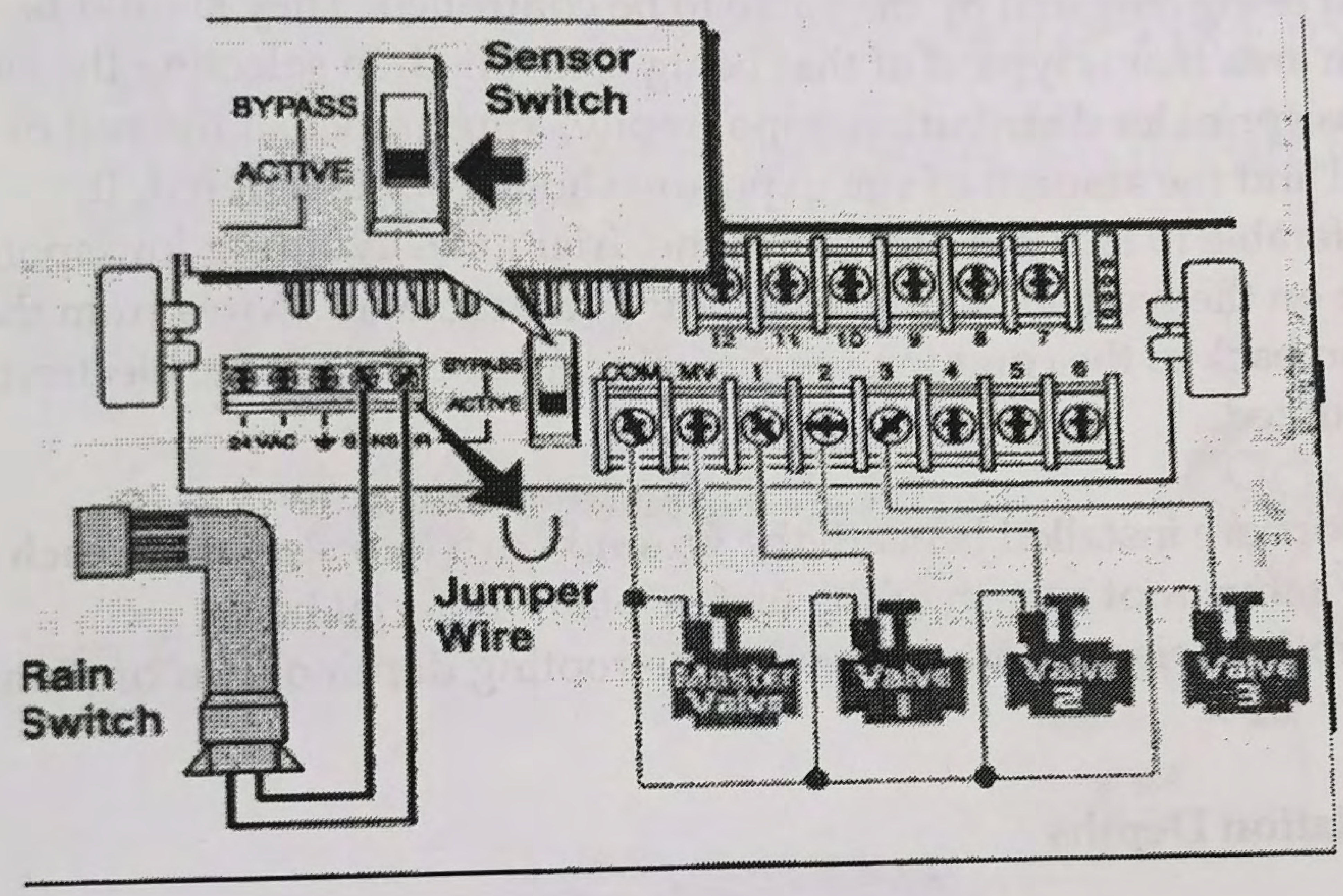
Cycle Options. All controllers provide a basic time period to schedule repeated irrigations. The minimum time period is usually seven days, but many controllers provide 14 or more days for scheduling. Additionally, some controllers provide interval programming, which allows irrigation one day in two, or every third day, etc. Providing water on a regular schedule more closely accommodates plant needs, but irrigating the same days each week may better accommodate service personnel.

Sensors

Rain Sensors

When connecting a rain sensor there are conflicting instructions, depending on which manufacture's product you combine together. Many Controller manufactures are building their product with a rain sensor terminal hook-up. Many of these manufactures are also providing software inside their controllers to work in conjunction with these rain sensors. While the manufactures of rain sensors give very little detail to how to connect their devices to controllers with these special terminal hook-ups, there is really not much to doing so. The best and easiest way to connect these devices is to first look at the terminal strip of your controller for a position dedicated for a "Rain Sensor." (See Figure 11-2 below.) Most of these sensors provide only two wires, connect either wire to either screw, however only one wire per screw please. If your sensor has three wires read their instruction very closely as this type sensor may require one of the wires to be connected to a power source. There are two popular and distinctly different types of rain sensors currently on the market; normally closed (most common) and normally open.

The normally closed type is called so because the contacts are a closed jumper. Now how this all works is when rain is collected by this device and measured to be over an operator determined amount the contact will be opened (or closed if it is a "Normally open" type). When this contact is opened the controller will discontinue the watering cycle. Some controllers will resume watering once the sensor dries out and the contacts close again, some may only water at the next scheduled start time. There are many Controllers that provide a "Bypass" switch that will allow you to over-rule the sensors' decision when running a manual program or station test. Always remember to return this switch to the "Active" position when you finish your system test.



'e 11-2

Soil Moisture Sensors

Soil moisture sensors are used in irrigation systems to monitor the soil moisture level to more accurately schedule the watering time. This allows the site manager to limit the under or over watering of a given area. They can be install "stand alone" to just provide readings and information to the site manager or they can be wired into the system to give automatic control. Soil moisture sensors wired to a an irrigation control system are used to automatically manage and schedule the amount of water being applied to a landscape. They typically cannot be wired directly to a sensor input on a controller, but have to be wired in line in the common wire.

They can be wired to control the operation of a single valve, a group of valves or the entire system. In essence they simple open the common wire to prevent a valve, group of valves, or the entire system from watering when scheduled.

They do not turn the system on when the soil is dry, they stop it from coming on if the soil is too wet. You still need an irrigation controller when using soil moisture sensors to control your watering.

Some soil moisture sensors are just wired in line in the common wire out in the field and that is all of the wiring needed. There are other soil moisture sensors that offer more detailed control, these are wired to an electronic module which is then wired to the common wire.

Installing Soil Moisture Sensors

Soil moisture sensors are installed in the active root system of the turf or plant material being irrigated by the valve to be controlled. They should be installed in an area that is typical of that being controlled. In selecting the site, factors such as sprinkler distribution, topography, appearance of the turf or plant material and the amount of sun exposure should be considered. It would be preferable to locate the sensor in the drier area, avoiding low spots, which may be on the wetter side due to runoff and drainage. Wires from the sensors are run back to the common wire or to a location where the electronic module is mounted.

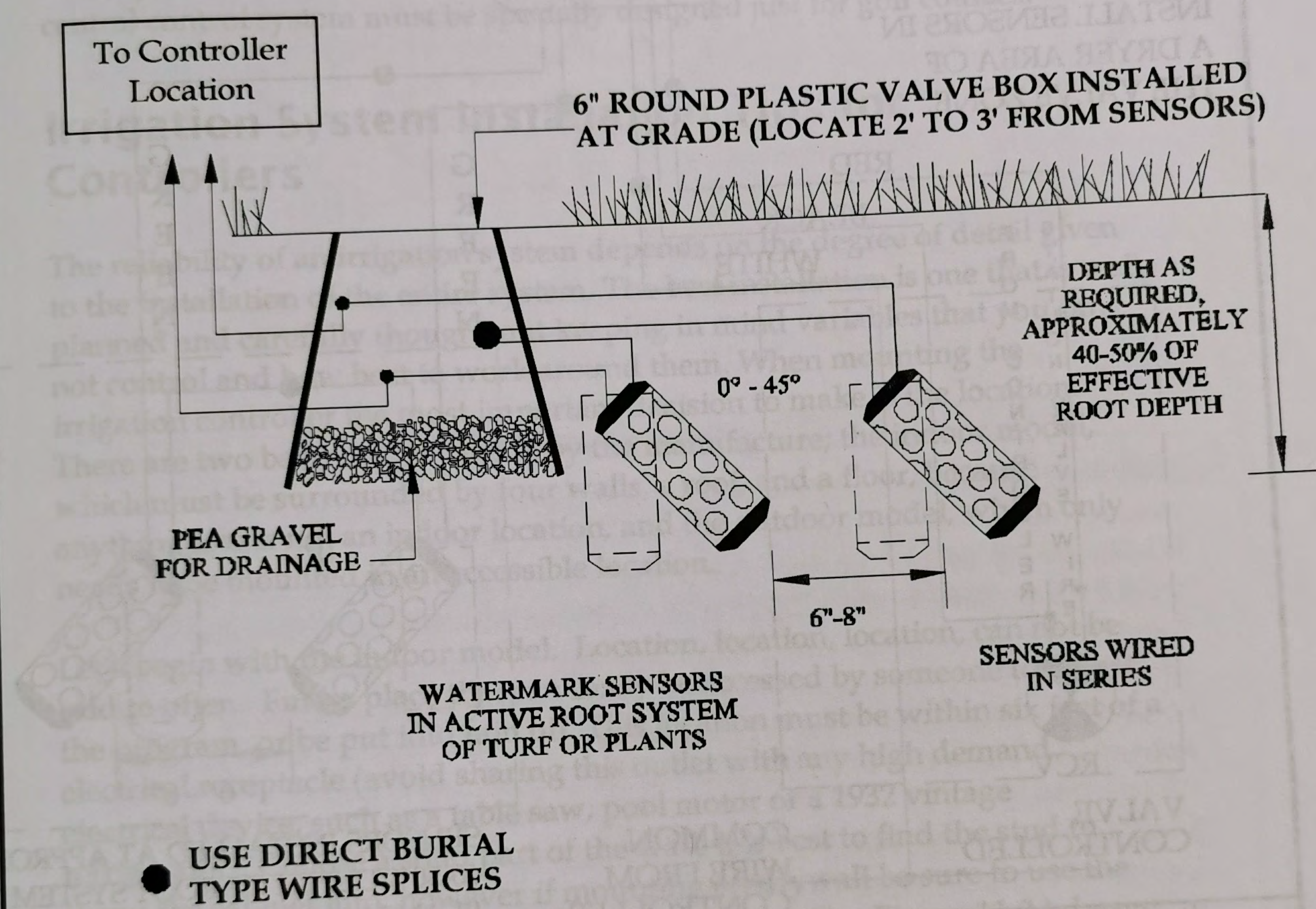
Typically sensors are installed beneath the ground with two sensors at each location in the active root system of the turf or plant material being monitored. Depth of placement varies with the rooting depth of turf or plant material.

Typical Installation Depths

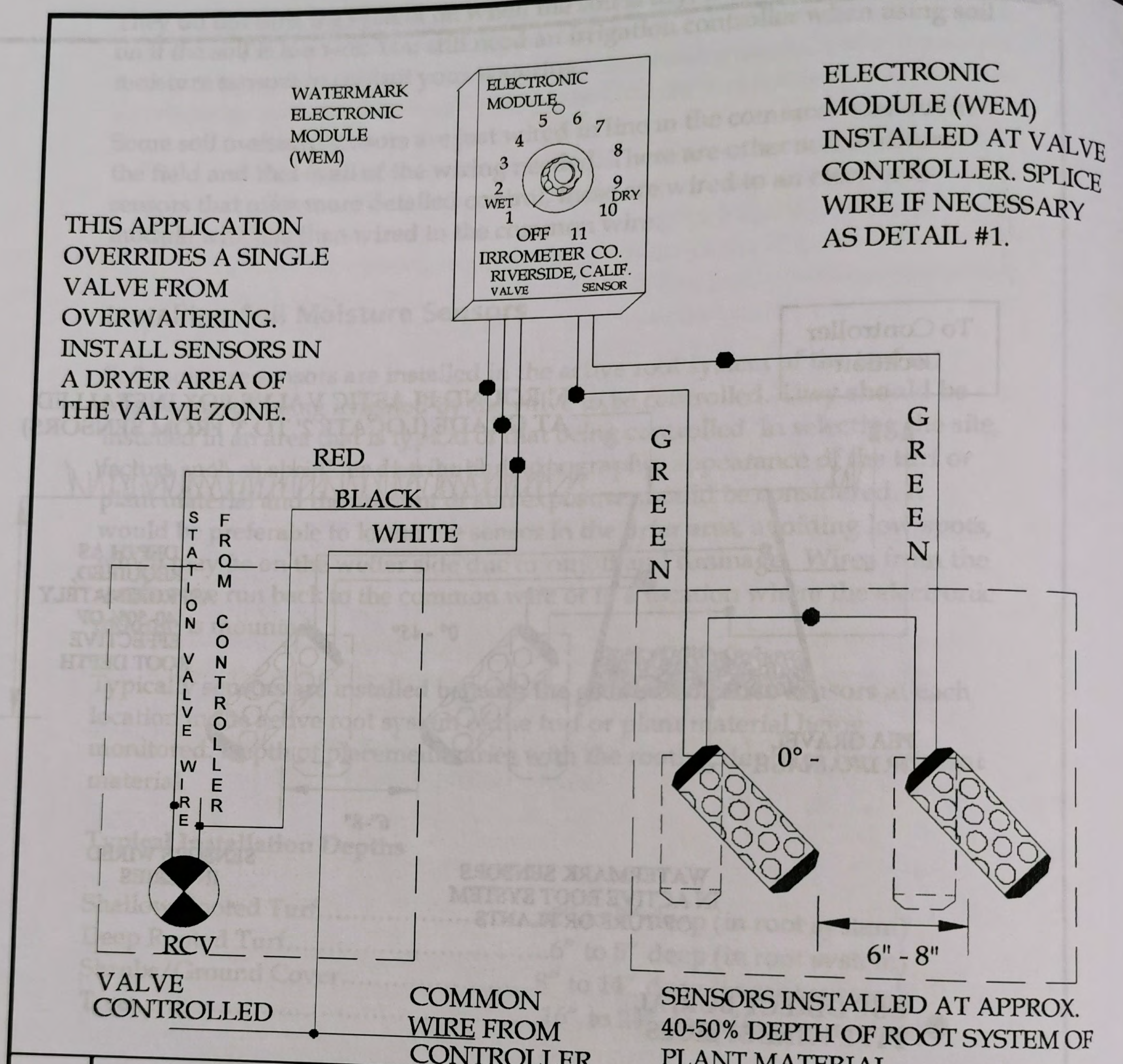
Shallow Rooted Turf..........................2″ to 5″ deep (in root system)
Deep Rooted Turf..............................6″ to 8″ deep (in root system)
Shrubs/Ground Cover.......................8″ to 14″ deep (in root system)
Trees..16″ to 24″ deep (in root system)

There are many different types and brands of quality soil moisture sensors available with varying levels of control, one should consult specific manufacturer instructions when using soil moisture sensors.

The following figures show some sample wiring and installation diagrams for a more sophisticated soil moisture control system:



1 Field Moisture Sensor



2 Individual Valve Wiring (WEM)

Golf Course Central Control

Because of the special needs of golf courses, central controllers used for golf are unique as well. They have to allow for the specific needs of greens. They also have to be able to handle a wide variety of flows. They need to be able to tie into weather stations and pump stations. Many times they are hook up to lightning detectors and liquid level sensors for ponds and lakes. Many of the newer systems are using 2 wire central control as well.

The key point here is that golf courses have such specialized needs that the central control system must be specially designed just for golf courses.

Irrigation System Installation Tips for Controllers

The reliability of an irrigation system depends on the degree of detail given to the installation of the entire system. The best installation is one that is well planned and carefully thought-out keeping in mind variables that you can not control and how best to work around them. When mounting the irrigation controller the most important decision to make is the location. There are two basic designs made by the manufacture; the indoor model, which must be surrounded by four walls, a roof, and a floor, because anything less is not an indoor location, and the outdoor model, which only needs to be mounted in an accessible location.

Let's begin with the indoor model. Location, location, location, can not be said to often. Find a place that can easily be accessed by someone to adjust the program, or be put into rain off. This location must be within six feet of a electrical receptacle (avoid sharing this outlet with any high demand electrical device, such as a table saw, pool motor or a 1932 vintage refrigerator). Choose a solid part of the wall, it is best to find the stud to screw the cabinet into, however if mounting on drywall be sure to use the appropriate anchor for reinforcement of the screw. (See Figure 11-3.) Leave the top of the screw out from the wall about ¼" to allow the keyhole to slide over the screw. (See Figure 11-3 letter A, and B.) Mount the controller securely using the lower hole. Eye level is the best height to mount the controller as placing it at ground level only causes trouble in the worst way. Always plug any unused hole to keep any unwanted crawling thing from relocating their home to the inside of your controller. Snails and slugs leave behind a material that will destroy a controller in a matter of days.

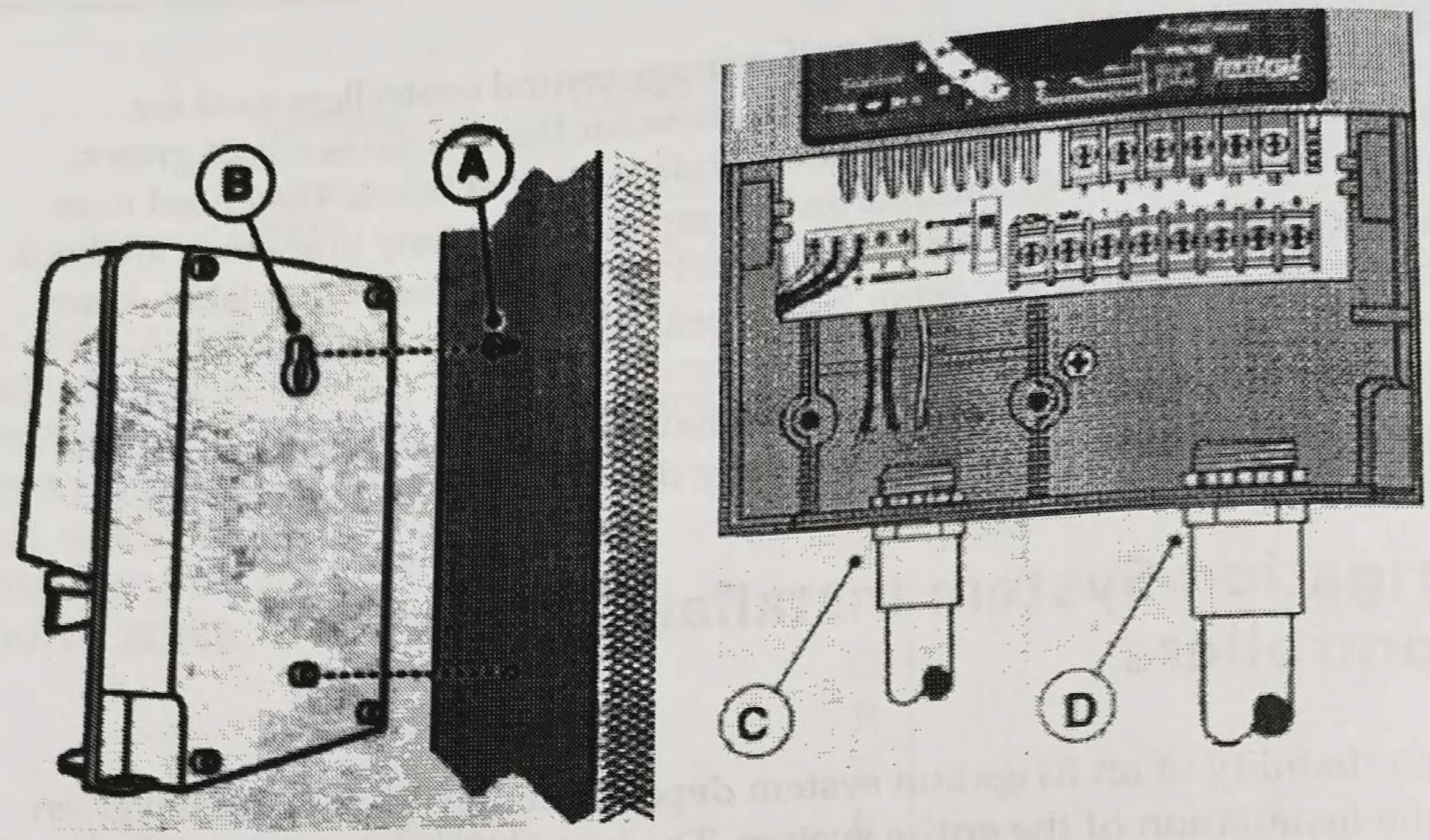


Figure 11-3

Now that the controller is mounted, carefully run the wire from the transformer to the controller using the small hole provided by the factory. (It is best to only use the transformer provided by the factory for this particular model controller.) When plugging in the transformer always hang the transformer down and never plug it into any style plug adapter, such as a three pin to a two pin connector. When routing the valve wires to the controller use conduit to protect the wires and fasten the conduit with the appropriate electrical lock nut. (See Figure 11-3, letters C and D.)

Now let's mount the outdoor style controller. As with the indoor type choose a suitable location that is easily accessible to adjust programs, run stations manually, or put into rain off. Ground level is not a suitable height for your controller as water and controllers do not mix. Remember to always plug any unused hole to keep any unwanted crawling thing from relocating their home to the inside of your controller. As mentioned above, snails and slugs leave behind a material that will destroy a controller in a matter of days. When connecting the power wires first consult an electrician, and follow local electrical codes. It is important that the wire be rated to handle the current required by the controller and must be run through weather proof conduit. Connect the wires as per local electrical code, normally the black wire is connected to the hot white is connected to the neutral and green is for ground. (See Figure 11-4 below.)

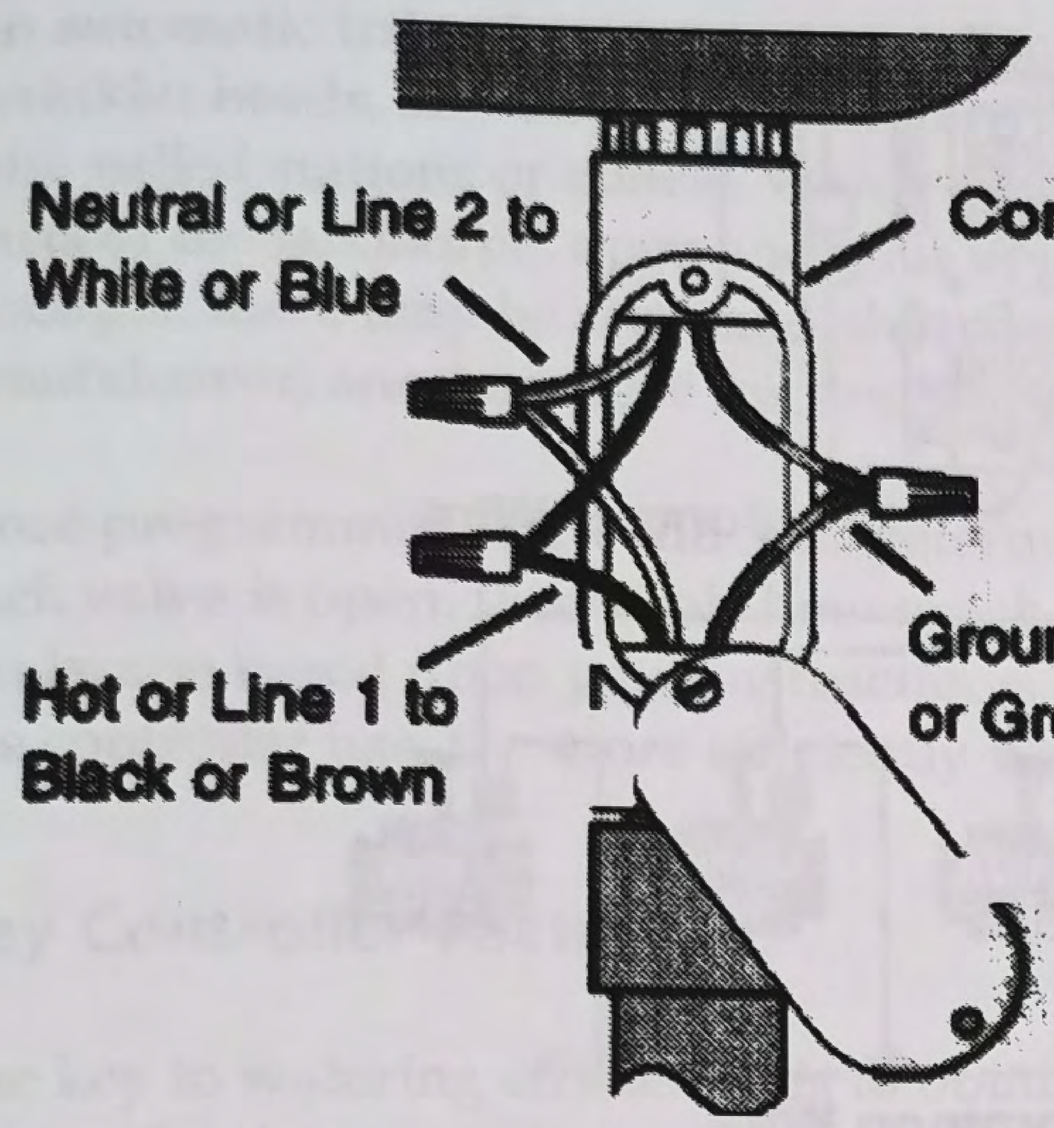


Figure 11-4: This work should only be done by a licensed electrician.

Some systems require the use of a pump. When connecting a pump often the use of a pump start relay is used. First consult a certified electrician and local authorities for proper installation and code requirements. Size the relay to be able to handle the current demand of the pump. Some are rated by horsepower, while some are only rated by amperages. Some controllers can handle pump start motors but it is best to use a relay to avoid any current overloads. Always check that the controller can handle the current of the relay. When connecting the relay follow the manufacture instructions of the relay. Typically there four wires for the power from the main breaker and to the pump. There are also two wires that go to the controller. One for the master valve terminal and the other connect to valve common. It is important to use a jumper wire to connect all unused stations on the controller to the last used station to avoid the pump from operating while no stations are in use. This can cause serious damage to the pump. (See Figure 11-5.)

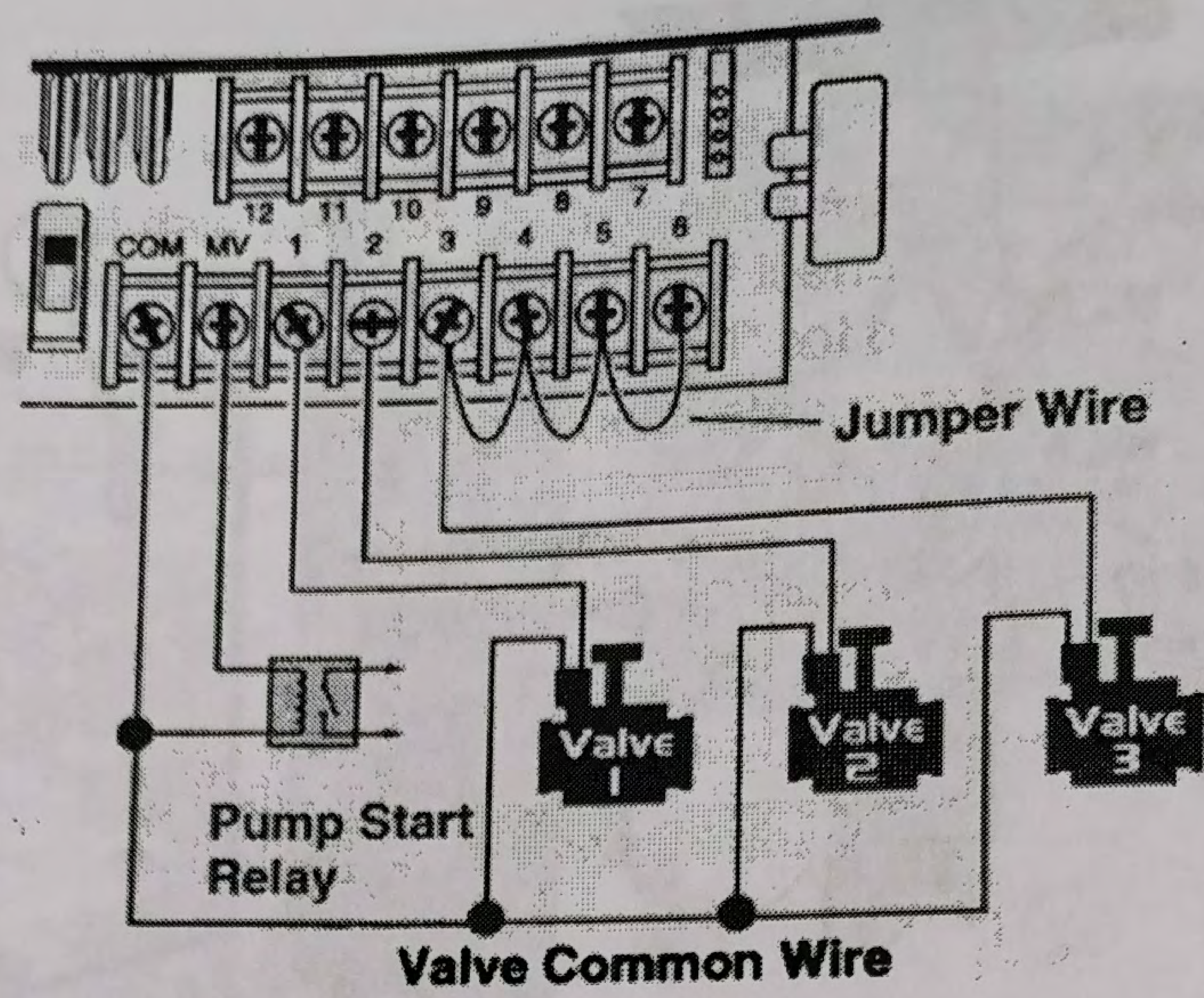


Figure 11-5

When connecting the field wires to your controller there are a few issues to consider. The length of wire from the controller to the valve determines, for the most part, the gauge of wire necessary to use. There is a formula that can be used to calculate the best wire gauge to use. This formula uses water pressure, solenoid current, minimum voltage needed to operate a solenoid, and one way distance to the valve. However you can use the chart listed below as a guide, or for a good "rule-of-thumb" distance that can be expected by using a given wire gauge. This chart is one-way distance from the controller to the valve, figuring 150psi static pressure and .30 amp inrush current.

Tips for Controller Programming

A large part of our household water use goes to watering our landscape and many households rely on automatic irrigation systems to accomplish this. One of the most important components of an automatic irrigation system is the irrigation controller (also called a timer or clock). The controller turns the irrigation system on and off at the times you select. In other words, the controller controls the irrigation system and you control the controller.

Having a controller with certain minimum performance capabilities is vital to efficient watering. The right controller, properly scheduled, can result in significant water savings and lower water bills.

An automatic irrigation system is a collection of pipes, tubing, valves, sprinkler heads, and circuitry used to irrigate a landscape. Automatic valves (also called stations or zones), which control the flow of water to different parts of the landscape, open and shut upon a signal from the controller. For example, there may be one valve that controls the water flow to some groundcover, another valve for some shrubs and another valve for the lawn.

Once programmed, the controller determines when, how often, and how long each valve is open. It controls how much water goes where and when in your landscape based upon your instructions. The more programming flexibility the controller has, the more efficiently water can be applied to the landscape.

Key Controller Features

The key to watering efficiently is to obtain a controller that can handle diverse landscape and weather situations and then to program it properly to meet your plants' water needs. Let's imagine you have a front yard with three valves that control the water flow to a sloped lawn area, to several trees, and to a groundcover area. You desire to water the lawn every third day for the entire month in three short time intervals of five minutes each and want a 30-minute break between watering to avoid runoff from the slope. You also desire to water the trees, which are on a drip system, once a month for two hours. Next, you want to water the groundcover once a week for 30 minutes. Finally, you don't want to water if it is raining. To accomplish this, your controller would need the following features: 1) three independent programs, 2) 120 minute station run times, 3) three start times per program, 4) interval program capability to 30 days, and 5) rain shut-off device capability (the actual rain shut-off device needs to be purchased separately).

Important Water Saving Features

The recommended minimum hardware features for a controller when water efficiency is a priority include:

- Three independent programs
- Station run times from one to 200 minutes 2
- Three start times per program
- Odd/even, weekly and interval program capability up to 30 days
- Water budgeting from 0-200%, in 10% increments, by program
- 365 day calendar, adjusted for leap year
- Non-volatile memory or battery back-up
- "Off," "Auto," and "Manual" operation modes without disturbing programming
- Rain shut-off device capability
- Diagnostic circuitry to notify homeowner when station is shorted or a power failure has occurred

The above features, discussed in more detail below, are important because they give you the ability to properly manage your landscape watering. Multiple independent programs allow watering different parts of the yard on different days. Station ran times determine the upper and lower limit on how long an area can be watered. While watering times are usually in minutes, a few controllers are capable of assigning run times in seconds (for potted plants) and hours for drip applications. Multiple start times allow for repeat watering in the same area on the same day. Odd/even weekly and interval program capability allows for flexibility in deciding what days to water. For example, a 30-day calendar would allow watering a large tree once a month.

Water budgeting (also known as a percent switch) allows for an increase or decrease in station run times by a certain percent. For example, during a cool spell, you may want to decrease watering time by 10% for all programs. This feature allows for the changing of all station run times within a given program in one easy step. 365-day calendar allows for the tracking of the number of days in each month throughout the year. Non-volatile memory retains the set program in case of a power failure. However, the set start watering times are still affected. For example, a four-hour power failure where the watering times are set to start at 6 a.m. would result in 10 a.m. start. A battery back-up is recommended to retain the 6 a.m. watering time.

Controllers with only volatile memories would both lose their set program and have the watering start time affected. For controllers with volatile memories, a battery back-up would retain both the set program and the set watering times. Rain shut-off device capability (and rain shut- off device) is used to automatically override the call for water during rain -events. (The actual rain shut-off device needs to be purchased separately since it is not included with the controller.) Diagnostic circuitry to notify homeowner when a station is shorted or a power failure has occurred is useful so that the controller can be checked for any changes or problems as soon as possible. In addition to the above hardware, programming instructions, technical support phone numbers, and irrigation scheduling information are important resource tools. Check with your local water utility, irrigation supply company, or landscape professional for local watering guidelines.

Besides the above mentioned recommended controller features, several desirable but optional features include "pause times" and "soak cycles." The "pause time" feature allows for some time to elapse before watering different stations within a program. This feature allows time for a control valve to completely close before the next valve opens ensuring more uniform pressure and thus better uniformity of coverage. For those on well water, this feature may allow time for the level in the well to recover before the next irrigation cycle. The "soak cycle" allows for short, multiple watering cycles. This feature can be used either before a normal irrigation cycle to wet the soil to break the soil surface tension to reduce runoff or for multiple, short watering of a given area. Ask about the warranty on any controller you are considering. The length of a product warranty is often linked to quality and many controller manufactures are offering warranties in the 2-5 year range: the longer, the better.

Besides obtaining an irrigation controller with the recommended features, there are other irrigation components that should be used with irrigation systems to save additional water. Control valves control the flow of water to different parts of the landscape and are used for the separate watering of plants with different watering needs. Check valves can be installed in sprinkler heads to prevent water from draining out of the irrigation line when the water is turned off and are most useful on sloped landscapes. Rain shutoff devices can be wired to a controller to shut off the system when it is raining. Moisture sensors can be wired to control valves to override the call for water if they "sense" that enough moisture is already present in the soil.

Moisture sensors, therefore, "monitor" the irrigation schedule for over watering. Drip or bubbler irrigation can be used to irrigate slowly and minimize or eliminate evaporation, runoff and overspray. Finally, low precipitation spray, stream, and sprinkler heads with matching precipitation rates can dramatically improve efficiency. It is important to note that automatic irrigation systems, if not properly managed, can waste a lot of water. Always be mindful that YOU are the "brains" behind your irrigation system scheduling and YOU control the controller. Plants require the most water during the summer and little or no water in the winter. After July, plants need less water each month, and by November, often little or no irrigation is required until March or April.

Setting Your Controller

Set Clock: Although there are a multitude of quality controllers on the market, the following procedures will set most of them. If there are features not covered in this section, please refer to your owner's manual. This sets the day & time. Usually press clock/time and move arrows up or down for hours & minutes. Day may be displayed or be printed on controller face. Enter until the desired day is displayed. Hit enter to set.

Set Start Time: Most clocks have 3 start times. But many less expensive ones will cycle all stations that have runtimes each time you set a start. Multi-programmable clocks can run stations on different start times. Look for set times or starts, this usually will show the number of the start (1,2,3, etc.). Hit enter to set how many start times that are needed.

Set Water Days: This sets how many days per week to water. Usually this is shown as an arrow over the printed face of the controller, or displayed as Mon., Tues., Wed., etc. Hit enter or on/off to select days. If you have 3 start times, the clock will water each day it's on, 3 times.

Set Station Runtime: This sets the amount of time each station will run, usually 1-99 minutes. Depending on your plant material, some may run only 10 minutes, while others like turf, may run 20 minutes every other day. Depending on how many stations your clock has, this will have to be done for each one. If you don't want a station to run, leave it at 0 or off by pressing arrow keys or up/down keys.

Auto Run: This usually is a switch that says runoff or run/rain. Set to on or run. If it rains ½ in. or more, turn your clock off.

Manual Run: This usually can be done by pressing the manual key, then the station you want to water. Sometimes the station will run indefinitely until you press off or stop. Otherwise the station will run the time you set back on station runtime. If your still having trouble, consult your owner's manual.

Chapter 12: System Winterization

Irrigation System Freeze Protection

Irrigation systems in northern climates must be "blown out" to protect them from freezing. The method of blowing compressed air through irrigation piping is most commonly used to achieve this end. How the Blow Out occurs and what type of equipment is involved will depend on the size and complexity of the irrigation.

Draining the System Saves Time and Money

The first step in winterizing a system is to try and drain the bulk of the water from the system's mainlines. By removing the majority of the water from supply lines, prior to "blow out," you will reduce the time and costs involved in winterizing your system. On a larger commercial system, draining the mainlines involves touring the site and opening all the manual drain valves a day or two ahead of when you want to "blow out." All main supply lines should have manual drains to facilitate this process. Once the main lines have had a chance to drain away their water, repeat the tour of the site but, this time, closing the drains. In a residential system, it is a good idea to physically disconnect the piping from the water source to facilitate some water draining away.

Blowing Out the Irrigation System

With most large commercial irrigation systems, the common method of removing the water from the lines is with high pressure - high volume air compressors. The water is literally blown from the pipes, zone after zone, until just clear air is whistling through the heads.

There are some inherent dangers in using compressed air to "blow out" pipelines. The velocities of the air created by the compressor can be very high and the surge potential is very high on the irrigation piping. If compressed air is to be used to evacuate pipelines, considerable care should be exercised. A high volume compressor should be used, but ***the output pressure should be limited to less than 50% of the system operating pressure***. If a sufficient volume of air can be developed at lower pressure, so much the better.

For residential systems, an air compressor that can generate approximately 50 cfm to 75 cfm would be adequate. Systems with 3" diameter pipe or less can be blown out with a 125 CFM compressor. Larger systems (4" diameter pipe and larger) may require 250 CFM or more. A pressure gauge should be installed on the pipeline near the compressor and monitored continuously during the operation. Pressure should be built up slowly to allow the water columns to begin moving gradually, avoiding any sudden pressure surges. If the line pressure gauge fluctuates dramatically, the air pressure should be reduced to lower the risk of pipe damage.

Before opening the valve on the compressor, ensure that one zone is on; activate the zone furthest from the source first. After the main is cleared of water, sequence through the other zones. This can be done by manually turning on each zone or cycling through the zones at the controller. Run through two short cycles rather than one long one. This allows for the removal of water that has drained from another zone. Cycling through the system twice also helps to avoid longer dry run times that could cause damage due to heat build up. **The most common cause of gear drive assembly failure in sprinkler heads is excessive heat buildup during blow out!!** The problem is, you won't discover it until the next hot dry period next summer, when you get browning out of the turf.

Also, be sure to blow out the zones at highest elevation first and work downward. Don't forget that water will run down hill into the main if you start at the bottom and work upward.

At lower temperatures there is a potential for ice to build up in the nozzle. If the nozzle opening freezes closed with ice, it is possible that the water will not be vacated from that area of the pipe and freeze damage may occur. This is always a problem if you wait too long before blowing out your system. Typical "blow out" dates are from mid to late October in northern climates.

On larger commercial systems, check the pipe closest to the compressor from time to time to ensure that it does not get hot to the touch. This is an indication that air velocity through the pipe is too great and should be reduced. Excess heat building up can cause damage to the pipe and other components in the system.

The time required to vacate a zone will be anywhere from five minutes up. When the water coming from the sprinkler nozzle is reduced to a fine mist, an adequate amount of water has been blown from the system. When you are satisfied that you are through, leave one zone on and shut down the compressor.

Chapter 13: Final Review

Practice Questions

1. When sizing pipe, we use velocity charts. True or false?

2. When solvent welding PVC pipe, one uses:
   a. Cleaner & primer
   b. Cleaner & glue
   c. Primer & cement
   d. All of the above

3. A reading of 20-60 ohms would indicate a healthy valve. True or false?

4. The recommended maximum velocity of water in sprinkler systems is:
   a. 7 fps
   b. 5 gallons per second
   c. 5.0 friction loss per hundred
   d. 5 fps

5. When the plan scale indicates 1 = 10 it means:
   a. One inch equals 10 inches
   b. One inch equals 10 feet
   c. One inch equals one foot
   d. One inch equals 10 meters

6. To quickly and easily improve a sprinkler system's uniformity:
   a. Install an approved backflow device.
   b. Re-design the system
   c. Replace all of the heads
   d. Adjust heads, valves, etc., for proper performance

7. Electric valve control wires should be:
   a. All the same color
   b. 14-1
   c. UF/UL
   d. 12 gauge romex

8. The following parts: bonnet, plunger, diaphragm, spring, would be found in:
   a. A rotor head
   b. An impact head
   c. An electric valve
   d. A backflow device
   e. None of the above

9. When installing barbed fittings on ploy pipe the clamp should be:
    a. After the barbs
    b. Before the barbs
    c. On top of the barbs
    d. Doesn't matter

10. Correct pipe sizing:
    a. Is not needed on residential systems
    b. Minimizes friction loss
    c. Increases the flow
    d. Increases the velocity

11. A 1-inch square column of water 12 inches high weights 0.433 pounds. True or false?

12. The symbols on an irrigation plan indicate:
    a. The location of heads, valves and other components
    b. The types of hardware
    c. How the various components are connected
    d. All of the above

13. Controllers always put out exactly 24 VAC. True or false?

14. Class 200 PVC pipe has a thicker wall than Class 160 pipe. True or false?

15. Static pressure is measured when the water is at rest. True or false?

16. The pressure in a sprinkler system when it is spraying is called:
    a. Operating
    b. Dynamic
    c. Working
    d. All of the above
    e. None of the above

17. A sprinkler head with no rotating parts is usually called a:
    a. Spray head
    b. A rotor head
    c. An impact head
    d. All of the above

18. If a valve is stuck in the off position the pressure chamber is:
   a. Not holding pressure
   b. Not releasing pressure
   c. Not big enough
   d. None of the above

19. A typical reason that rotors stop turning is a clogged filter. True or false?

20. The best way to fix a broken head is to dig up the entire head and replace it. True or false?

Appendix A: Friction Loss Charts

Pressure Loss From Friction – Class 160 / SDR 26 PVC

Loss per 100 ft of pipe (1120, 1220) C=140 SDR 26

FLOW gpm	*½	*¾	1	1 ¼	1 ½	2	2 ½	3	4
1	0.26	0.07							
2	0.89	0.26							
3	1.86	0.52							
4	3.12	0.90	0.27						
5	4.76	1.37	0.40						
6	6.62	1.90	0.57						
7	8.82	2.52	0.76						
8	11.26	3.21	0.98	0.31					
9	14.10	4.05	1.19	0.41					
10	17.11	4.90	1.48	0.45	0.23				
11	20.37	5.82	1.77	0.55	0.29				
12	23.87	6.83	2.08	0.65	0.33				
13		7.94	2.42	0.75	0.39				
14		9.11	2.76	0.84	0.44				
15		10.36	3.17	0.95	0.50				
20		17.67	5.41	1.64	0.84	0.29			
25		26.70	8.28	2.45	1.28	0.42			
30			11.56	3.34	1.78	0.60	0.23		
35			15.47	4.45	2.37	0.81	0.20		
40			19.76	5.65	3.02	1.02	0.40		
50			30.55	8.74	4.67	1.59	0.63		
60				11.95	6.40	2.18	0.88		
70					8.52	2.91	1.16	0.46	
80					10.82	3.68	1.48	0.57	
90					13.47	4.57	1.84	0.72	
100					16.57	5.62	2.24	0.88	0.25
110						6.59	2.63	1.02	0.30
120						7.81	3.16	1.20	0.36
130						9.16	3.68	1.42	0.42
140						10.38	4.18	1.62	0.49
150						11.81	4.76	1.84	0.55
160						13.34	5.38	2.09	0.64
170						14.81	5.97	2.31	0.70
180						16.48	6.63	2.56	0.77
190						18.18	7.31	2.81	0.85
200						20.08	8.07	3.10	0.95
210							8.96	3.45	1.04
220							9.80	3.80	1.15
230							10.48	4.06	1.23
240							11.30	4.36	1.32
250							12.11	4.67	1.41
260							12.90	4.99	1.50
270							14.17	5.47	1.65
280							15.23	5.89	1.78
290							15.91	6.15	1.85
300							16.86	6.50	1.95
320								7.57	2.27
240								8.30	2.50
360								9.18	2.77
380								10.20	3.09
400								11.41	3.45

Velocity of Flow (ft/sec) – Class 160 / SDR 26 PVC

FLOW gpm	*½	*¾	1	1 ¼	1 ½	2	2 ½	3	4
1	0.80	0.47							
2	1.59	0.94							
3	2.39	1.42							
4	3.19	1.89	1.14						
5	3.98	2.36	1.43						
6	4.78	2.83	1.72						
7	5.58	3.30	2.00						
8	6.38	3.78	2.29	1.39					
9	7.17	4.25	2.57	1.57					
10	7.97	4.72	2.86	1.74	1.33				
11	8.77	5.19	3.15	1.91	1.46				
12	9.56	5.66	3.43	2.09	1.59				
13		6.14	3.72	2.26	1.73				
14		6.61	4.01	2.44	1.86				
15		7.08	4.29	2.61	1.99				
20		9.44	5.72	3.48	2.66	1.70			
25		11.80	7.15	4.35	3.32	2.12			
30			8.58	5.22	3.98	2.55	1.74		
35			10.01	6.09	4.65	2.97	2.03		
40			11.44	6.96	5.31	3.40	2.32		
50			14.30	8.70	6.64	4.25	2.90		
60				10.44	7.97	5.10	3.48		
70					9.29	5.95	4.06	2.74	
80					10.62	6.80	4.64	3.13	
90					11.95	7.64	5.22	3.52	
100					13.28	8.49	5.80	3.92	2.37
110						9.34	6.37	4.31	2.60
120						10.19	6.95	4.70	2.84
130						11.04	7.53	5.09	3.08
140						11.89	8.11	5.48	3.31
150						12.74	8.69	5.87	3.55
160						13.59	8.27	6.26	3.79
170						14.44	9.85	6.66	4.02
180						15.29	10.43	7.05	4.26
190						16.14	11.01	7.44	4.50
200						16.99	11.59	7.83	4.73
210							12.17	8.22	4.97
220							12.75	8.61	5.21
230							13.33	9.01	5.44
240							13.91	9.40	5.68
250							14.49	9.79	5.92
260							15.07	10.18	6.15
270							15.65	10.57	6.39
280							16.23	10.96	6.63
290							16.81	11.35	6.87
300							17.39	11.75	7.10
320								12.53	7.58
240								13.31	8.05
360								14.10	8.52
380								14.88	9.00
400								15.66	9.47

Pressure Loss From Friction – Class 200 / SDR 21 PVC

Loss per 100 ft of pipe (1120, 1220) C=140 SDR 21

FLOW gpm	*½	*¾	1	1 ¼	1 ½	2	2 ½	3	4
1	0.26	0.07							
2	0.89	0.26							
3	1.86	0.52							
4	3.12	0.90	0.28						
5	4.76	1.37	0.42						
6	6.62	1.90	0.59						
7	8.82	2.52	0.80						
8	11.26	3.21	1.02	0.31					
9	14.10	4.05	1.24	0.40					
10	17.11	4.90	1.52	0.50	0.26				
11	20.37	5.82	1.81	0.59	0.30				
12	23.87	6.83	2.14	0.69	0.36				
13		7.94	2.51	0.80	0.41				
14		9.11	2.86	0.90	0.48				
15		10.36	3.26	1.02	0.56				
20		17.67	5.53	1.76	0.90	0.31			
25		26.70	8.36	2.67	1.39	0.48			
30			11.66	3.72	1.93	0.66	0.27		
35			15.56	4.96	2.56	0.89	0.36		
40			19.87	6.33	3.28	1.16	0.46		
50			30.66	9.78	5.08	1.77	0.71		
60				13.41	6.97	2.42	0.98		
70				17.90	9.28	3.22	1.28	0.50	
80				22.70	11.79	4.10	1.62	0.63	
90					14.66	5.10	2.00	0.80	0.24
100					18.06	6.24	2.44	0.99	0.30
110						7.30	2.90	1.15	0.35
120						8.68	3.43	1.36	0.40
130						10.18	4.01	1.60	0.47
140						11.56	4.56	1.80	0.52
150						13.16	5.20	2.05	0.60
160						14.90	5.60	2.33	0.70
170						16.55	6.56	2.59	0.76
180						18.38	7.26	2.88	0.85
190						20.24	8.00	3.16	0.94
200						22.36	8.81	3.50	1.03
210							9.80	3.88	1.15
220							10.76	4.25	1.25
230							11.49	4.55	1.35
240							12.36	4.90	1.44
250							13.26	5.25	1.55
260							14.16	5.60	1.64
270							15.45	6.13	1.80
280							16.65	6.60	1.95
290							17.86	6.90	2.03
300							19.06	7.30	2.15
320								8.48	2.50
240								9.30	2.75
360								10.28	3.03
380								11.46	3.36
400								12.80	3.77

Velocity of Flow (ft/sec) - Class 200 / SDR 21 PVC

FLOW gpm	½	¾	1	1 ¼	1 ½	2	2 ½	3	4
1	0.80	0.47							
2	1.59	0.94							
3	2.39	1.42							
4	3.19	1.89	1.16						
5	3.98	2.36	1.45						
6	4.78	2.83	1.73						
7	5.58	3.30	2.02						
8	6.38	3.78	2.31	1.46					
9	7.17	4.25	2.60	1.64					
10	7.97	4.72	2.89	1.82	1.38				
11	8.77	5.19	3.18	2.00	1.52				
12	9.56	5.66	3.47	2.18	1.66				
13		6.14	3.76	2.37	1.79				
14		6.61	4.05	2.55	1.93				
15		7.08	4.34	2.73	2.07				
20		9.44	5.78	3.64	2.76	1.77			
25		11.80	7.23	4.55	3.45	2.21			
30			8.67	5.46	4.14	2.66	1.81		
35			10.12	6.37	4.83	3.10	2.11		
40			11.56	7.28	5.52	3.54	2.41		
50			14.45	9.10	6.90	4.43	3.02		
60				10.92	8.28	5.31	3.62		
70				12.74	9.66	6.20	4.22	2.86	
80				14.56	11.04	7.08	4.82	3.26	
90					12.42	7.97	5.43	3.67	2.21
100					13.80	8.85	6.03	4.08	2.46
110						9.74	6.63	4.49	2.71
120						10.62	7.24	4.90	2.95
130						11.51	7.84	5.30	3.20
140						12.39	8.44	5.71	3.44
150						13.28	9.05	6.12	3.69
160						14.16	9.65	6.53	3.94
170						15.05	10.25	6.94	4.18
180						15.93	10.85	7.34	4.43
190						16.82	11.46	7.75	4.66
200						17.70	12.06	8.16	4.92
210							12.66	8.57	5.17
220							13.27	8.98	5.41
230							13.87	9.38	5.66
240							14.47	9.79	5.90
250							15.08	10.20	6.15
260							15.68	10.61	6.40
270							16.28	11.02	6.64
280							16.88	11.42	6.89
290							17.49	11.83	7.13
300							18.09	12.24	7.38
320								13.06	7.87
240								13.87	8.36
360								14.69	8.86
380								15.50	9.35
400								16.32	9.84

Pressure Loss From Friction – Class 315 / SDR 13.5 PVC

Loss per 100 ft of pipe (1120, 1220) C=140 SDR 13.5

FLOW gpm	½	¾	1	1 ¼	1 ½	2	2 ½	3	4
1	0.26	0.08							
2	0.89	0.30							
3	1.86	0.63							
4	3.12	1.09	0.37						
5	4.76	1.66	0.56						
6	6.62	2.30	0.77						
7	8.82	3.06	1.01						
8	11.26	3.90	1.31	0.46					
9	14.10	4.88	1.63	0.56					
10	17.11	5.90	2.00	0.66	0.34				
11	20.37	7.03	2.36	0.79	0.41				
12	23.87	8.26	2.77	0.92	0.49				
13		9.67	3.24	1.09	0.56				
14		11.00	3.70	1.23	0.65				
15		12.50	4.20	1.40	0.76				
20		21.32	7.18	2.40	1.26	0.42			
25		32.21	10.86	3.61	1.89	0.64			
30			15.13	5.03	2.62	0.89	0.36		
35			20.16	6.70	3.50	1.18	0.47		
40			25.77	8.58	4.47	1.50	0.60		
50			39.76	13.26	6.90	2.34	0.93	0.36	
60				18.19	9.47	3.20	1.28	0.50	
70				24.26	12.61	4.24	1.71	0.66	
80					16.00	5.41	2.17	0.84	
90					19.90	6.76	2.70	1.05	0.32
100					24.50	8.32	3.31	1.30	0.39
110						9.71	3.88	1.50	0.46
120						11.53	4.60	1.80	0.54
130						13.50	5.39	2.10	0.64
140						15.30	6.15	2.38	0.72
150						17.46	6.97	2.70	0.82
160						19.76	7.89	3.06	0.93
170						21.90	8.76	3.40	1.03
180						24.36	9.73	3.77	1.15
190						26.81	10.70	4.17	1.26
200						29.60	11.80	4.60	1.40
210							13.04	5.10	1.55
220							14.24	5.59	1.70
230							15.36	5.97	1.83
240							16.53	6.44	1.97
250							17.64	6.90	2.10
260							18.88	7.34	2.24
270							20.64	8.05	2.45
280							22.34	8.67	2.65
290							23.96	9.05	2.75
300							25.66	9.60	2.93
320								11.15	3.40
240								12.25	3.72
360								13.52	4.12
380								15.05	4.59
400								16.85	5.14

Velocity of Flow (ft/sec) – Class 315 / SDR 13.5 PVC

FLOW gpm	½	¾	1	1 ¼	1 ½	2	2 ½	3	4
1	0.80	0.51							
2	1.59	1.02							
3	2.39	1.53							
4	3.19	2.04	1.30						
5	3.98	2.56	1.63						
6	4.78	3.07	1.95						
7	5.58	3.58	2.28	1.43					
8	6.38	4.09	2.60	1.63					
9	7.17	4.60	2.93	1.84					
10	7.97	5.11	3.25	2.04	1.56				
11	8.77	5.62	3.58	2.25	1.72				
12	9.56	6.13	3.90	2.45	1.87				
13		6.64	4.23	2.66	2.03				
14		7.16	4.55	2.86	2.18				
15		7.67	4.88	3.07	2.34				
20		10.22	6.50	4.09	3.12	2.00			
25		12.78	8.13	5.11	3.90	2.50			
30			9.75	6.13	4.68	2.99	2.04		
35			11.38	7.15	5.46	3.49	2.38		
40			13.00	8.17	6.24	3.99	2.72		
50			16.25	10.22	7.80	4.99	3.41	2.30	
60				12.26	9.36	5.99	4.09	2.76	
70					10.92	6.99	4.77	3.22	
80					12.48	7.99	5.45	3.68	
90					14.12	8.98	6.13	4.13	2.50
100					15.60	9.98	6.81	4.59	2.78
110						10.98	7.49	5.05	3.06
120						11.98	8.17	5.51	3.33
130						12.98	8.85	5.97	3.1
140						13.97	9.54	6.43	3.89
150						14.97	10.22	6.89	4.17
160						15.97	10.90	7.35	4.45
170						16.97	11.58	7.62	4.72
180						17.97	12.26	8.27	5.00
190						18.96	12.94	8.73	5.28
200						19.96	13.62	9.19	5.56
210							14.30	9.65	5.84
220							14.98	10.11	6.11
230							15.67	10.57	6.39
240							16.35	11.03	6.67
250							17.03	11.48	6.95
260							17.71	11.94	7.23
270							18.39	12.40	7.50
280							19.07	12.86	7.78
290							19.75	13.32	8.06
300							20.43	13.78	8.34
320								14.70	8.89
240								15.62	9.45
360								16.54	10.00
380								17.46	10.56
400								18.38	11.12

Pressure Loss From Friction – Schedule 40 PVC

Loss per 100 ft of pipe (1120, 1220) C=150

FLOW gpm	½	¾	1	1 ¼	1 ½	2	2 ½	3	4
1	0.49	0.13							
2	1.78	0.45							
3	3.75	0.95							
4	6.40	1.63	0.50						
5	9.64	2.46	0.75						
6	13.50	3.45	1.05						
7	18.00	4.59	1.38						
8	23.00	5.85	1.81	0.48					
9	28.60	7.28	2.23	0.60					
10	34.80	8.84	2.75	0.72	0.34				
11	41.50	10.60	3.26	0.86	0.40				
12	48.80	12.40	3.85	1.01	0.48				
13		14.40	4.44	1.17	0.55				
14		16.50	5.10	1.35	0.63				
15		18.70	5.79	1.52	0.72				
20		32.00	9.85	2.60	1.24	0.36			
25		48.30	14.90	3.92	1.85	0.55			
30			20.90	5.50	2.60	0.77	0.32		
35			27.70	7.30	3.45	1.02	0.43		
40				9.37	4.43	1.31	0.55		
50				14.10	6.67	1.98	0.84		
60				19.90	9.35	2.79	1.17		
70					12.40	3.70	1.55	0.54	
80					15.90	4.72	2.00	0.70	
90					19.80	5.88	2.49	0.87	
100					24.00	7.14	3.00	1.05	0.28
110						8.50	3.59	1.25	0.33
120						10.00	4.22	1.46	0.39
130						11.60	4.90	1.70	0.46
140						13.30	5.60	1.95	0.53
150						15.10	6.40	2.23	0.60
160						17.00	7.19	2.50	0.67
170						19.00	8.02	2.80	0.74
180						21.20	8.91	3.10	0.83
190						23.40	9.85	3.43	0.91
200						25.70	10.80	3.78	1.00
210							11.90	4.12	1.10
220							12.90	4.50	1.20
230							14.00	4.89	1.30
240							15.20	5.30	1.41
250							16.40	5.70	1.52
260							17.60	6.13	1.63
270							18.90	6.56	1.75
280							20.20	7.03	1.87
290							21.50	7.50	2.00
300							22.90	7.98	2.14
320								9.00	2.40
240								10.10	2.68
360								11.20	2.98
380								12.30	3.30
400								13.60	3.63

Velocity of Flow (ft/sec) - Schedule 40 PVC

FLOW gpm	½	¾	1	1 ¼	1 ½	2	2 ½	3	4
1	1.06	0.60							
2	2.11	1.20							
3	3.17	1.80							
4	4.22	2.41	1.48						
5	5.28	3.01	1.86						
6	6.33	3.63	2.23						
7	7.39	4.21	2.60						
8	8.45	4.81	2.97	1.72					
9	9.50	5.41	3.34	1.93					
10	10.56	6.02	3.71	2.15	1.58				
11	11.61	6.62	4.08	2.36	1.73				
12	12.67	7.22	4.45	2.57	1.89				
13		7.82	4.83	2.79	2.05				
14		8.42	5.20	3.00	2.21				
15		9.02	5.57	3.22	2.36				
20		12.03	7.42	4.29	3.15	1.91			
25		15.04	9.28	5.36	3.94	2.39			
30			11.14	6.44	4.73	2.87	2.01		
35			12.99	7.51	5.52	3.35	2.36		
40				8.58	6.30	3.82	2.68		
50				10.73	7.88	4.78	3.35		
60				12.87	7.46	5.74	4.02		
70					11.03	6.69	4.69	3.04	
80					12.61	7.65	5.36	3.47	
90					14.18	8.60	6.03	3.91	
100					15.76	8.56	6.70	4.34	2.52
110						10.52	7.37	4.77	2.77
120						11.47	8.04	5.21	3.02
130						12.43	8.71	5.64	3.28
140						13.38	9.38	6.08	3.53
150						14.34	10.05	6.51	3.78
160						15.30	10.72	6.94	4.03
170						16.25	11.39	7.38	4.28
180						17.21	12.06	7.81	4.54
190						18.16	12.73	8.25	4.79
200						19.12	13.40	8.68	5.04
210							14.07	9.11	5.29
220							14.74	9.55	5.54
230							15.41	9.98	5.80
240							16.08	10.42	6.05
250							16.75	10.85	6.30
260							17.42	11.28	6.55
270							18.09	11.72	6.80
280							18.76	12.15	7.06
290							19.43	12.59	7.31
300							20.10	13.02	7.56
320								13.89	8.06
240								14.76	8.57
360								15.62	9.07
380								16.49	9.58
400								17.36	10.08

Pressure Loss From Friction – Standard Polyethylene Pipe

Loss per 100 ft of pipe 125 psi PE 3205 C=140 SDR 7

FLOW gpm	½	¾	1	1 ¼	1 ½	2	2 ½
1	0.51	0.15					
2	1.79	0.48					
3	3.77	1.00					
4	6.43	1.64	0.46				
5	9.69	2.46	0.76				
6	1..50	3.45	1.06	0.29			
7	18.00	4.59	1.37	0.37			
8	23.00	5.85	1.80	0.46			
9		7.29	2.23	0.59			
10		8.85	2.76	0.70	0.33		
11		10.60	3.27	0.85	0.39		
12		12.40	3.85	1.01	0.46		
13		14.40	4.45	1.20	0.54		
14		16.50	5.10	1.37	0.65		
15		18.70	5.76	1.56	0.76	0.21	
20		31.90	9.90	2.56	1.18	0.36	
25			14.90	3.87	1.85	0.55	
30			20.90	5.46	2.56	0.75	0.33
35			27.70	7.30	3.45	0.97	0.44
40				9.40	4.38	1.28	0.56
50				14.10	6.70	1.97	0.83
60				19.90	9.40	2.76	1.18
70					12.40	3.70	1.57
80					15.90	4.70	2.00
90					19.80	5.90	2.50
100					24.00	7.10	3.00
110						8.50	2.60
120						10.00	4.20
130						11.60	4.90
140						13.30	5.60
150						15.10	6.40
160						17.00	7.20
170						19.00	8.00
180						21.20	8.90
190						23.40	9.90
200						25.70	10.90
210							11.90
220							12.90
230							14.00
240							15.20
250							16.40
260							17.60
270							18.90
280							20.20
290							21.50
300							22.90

Velocity of Flow (ft/sec) – Standard Polyethylene Pipe

FLOW gpm	½	¾	1	1 ¼	1 ½	2	2 ½
1	1.06	0.60					
2	2.11	1.20					
3	3.17	1.80					
4	4.22	2.41	1.48				
5	5.28	3.01	1.86				
6	6.33	3.61	2.23				
7	7.39	4.21	2.60				
8	8.45	4.81	2.97	1.72			
9	9.50	5.41	3.34	1.93			
10	10.56	6.02	3.71	2.15	1.58		
11	11.61	6.62	4.08	2.36	1.73		
12	12.67	7.22	4.45	2.57	1.89		
13		7.82	4.83	2.79	2.05		
14		8.42	5.20	3.00	2.21		
15		9.02	5.57	3.22	2.36		
20		12.03	7.42	4.29	3.15	1.91	
25		15.04	9.28	5.36	3.94	2.39	
30			11.14	6.44	4.73	2.87	2.01
35			12.99	7.51	5.52	3.35	2.35
40				8.58	6.30	3.82	2.68
50				10.73	7.88	4.78	3.35
60				12.87	9.46	5.74	4.02
70					11.03	6.69	4.69
80					12.61	7.65	5.36
90					14.18	8.60	6.03
100					15.76	8.56	6.70
110						10.52	7.37
120						11.47	8.04
130						12.43	8.71
140						13.38	9.38
150						14.34	10.05
160						15.30	10.72
170						16.25	11.39
180						17.21	12.06
190						18.16	12.73
200						19.12	13.40
210							14.07
220							14.74
230							15.41
240							16.08
250							16.75
260							17.42
270							18.09
280							18.76
290							19.43
300							20.10

Pressure Loss From Friction – Type M Copper Tube

C=140

FLOW gpm	½	¾	1	1 ¼	1 ½	2	2 ½	3	4
1	0.79	0.15							
2	2.85	0.51							
3	6.03	1.08							
4	10.31	1.83	0.51						
5	15.50	2.77	0.77						
6	21.70	3.88	1.08						
7	28.90	5.16	1.43						
8	37.00	6.60	1.85	0.63					
9		8.21	2.28	0.78					
10		9.97	2.77	0.95					
11		11.90	3.31	1.13					
12		14.00	3.89	1.33	0.65				
13		16.20	4.51	1.55	0.75				
14		18.60	5.17	1.77	0.86				
15		21.10	5.87	2.01	0.97				
20		36.00	10.00	3.42	1.65	0.45			
25			15.10	5.17	2.50	0.66			
30			21.20	7.25	3.50	0.92	0.32		
35			28.20	9.60	4.66	1.23	0.43		
40			36.10	12.30	5.96	1.57	0.55		
50			54.50	18.60	9.01	2.37	0.83		
60				26.10	12.60	3.32	1.16	0.49	
70					16.80	4.42	1.55	0.65	
80					21.50	5.66	1.97	0.83	
90					26.70	7.05	2.45	1.03	
100					32.50	8.55	2.98	1.25	0.32
110						10.20	3.56	1.50	0.37
120						12.00	4.18	1.76	0.43
130						13.90	4.85	2.05	0.50
140						15.90	5.56	2.34	0.58
150						18.10	6.31	2.66	0.66
160						20.40	7.11	2.99	0.74
170						22.80	7.95	3.35	0.83
180						25.40	8.82	3.72	0.92
190						28.00	9.77	4.11	1.02
200						30.80	10.81	4.52	1.12
210							11.80	4.95	1.22
220							12.80	5.40	1.33
230							13.90	5.85	1.45
240							15.10	6.33	1.57
250							16.20	5.83	1.69
260							17.50	7.34	1.82
270							18.70	7.88	1.95
280							20.00	8.42	2.08
290							21.40	8.99	2.22
300							22.80	9.57	2.37
320								10.80	2.67
240								12.10	2.98
360								13.40	3.32
380								14.80	3.50
400								16.30	3.68

Velocity of Flow (ft/sec) – Type M Copper Tube

FLOW gpm	½	¾	1	1 ¼	1 ½	2	2 ½	3	4
1	1.26	0.62							
2	2.52	1.24							
3	3.78	1.86							
4	5.05	2.48	1.47						
5	6.31	3.11	1.84						
6	7.57	3.73	2.20						
7	8.83	4.35	2.57						
8	10.09	4.97	2.94	1.96					
9		5.59	3.30	2.21					
10		6.21	3.67	2.45					
11		5.83	4.04	2.70					
12		7.45	4.40	2.94	2.10				
13		8.07	4.47	3.19	2.28				
14		8.70	5.14	3.43	2.45				
15		9.32	5.51	3.68	2.63				
20		12.42	7.34	4.90	3.50	2.02			
25			9.18	6.13	4.38	2.53			
30			11.01	7.35	5.26	3.04	1.97		
35			12.85	8.58	6.13	3.54	2.30		
40			14.68	9.80	7.01	4.05	2.62		
50			18.35	12.26	8.76	5.06	3.28		
60				14.71	10.51	6.07	3.94	2.76	
70					12.26	7.08	4.59	3.22	
80					14.02	8.10	5.25	3.68	
90					15.77	9.11	5.90	4.14	
100					17.52	10.12	6.56	4.60	2.61
110						11.13	7.21	5.06	2.87
120						12.14	7.87	5.52	3.13
130						13.16	8.53	5.98	3.39
140						14.17	9.18	6.44	3.65
150						15.18	9.84	6.90	3.92
160						16.19	10.50	7.36	4.18
170						17.20	11.15	7.82	4.44
180						18.22	11.81	8.28	4.70
190						19.23	12.46	8.74	4.96
200						20.24	13.12	9.20	5.22
210							13.78	9.66	5.48
220							14.43	10.12	5.74
230							15.09	10.58	6.00
240							15.74	11.04	6.26
250							16.40	11.50	5.53
260							17.06	11.96	6.79
270							17.71	12.42	7.05
280							18.37	12.88	7.31
290							19.02	13.34	7.57
300							19.68	13.80	7.83
320								14.72	8.35
240								15.64	8.87
360								16.56	9.40
380								17.48	9.92
400								18.40	10.44

Pressure Loss From Friction – Type L Copper Tube

C=140

FLOW gpm	½	¾	1	1 ¼	1 ½	2	2 ½	3	4
1	0.97	0.19							
2	3.51	0.60							
3	7.42	1.26							
4	12.68	2.15	0.59						
5	19.10	3.25	0.89						
6	26.70	4.55	1.25						
7	35.60	6.04	1.65						
8	45.50	7.72	2.13	0.69					
9		9.61	2.62	0.86					
10		11.66	3.19	1.05					
11		13.90	3.81	1.25					
12		16.40	4.47	1.46	0.70				
13		19.00	5.19	1.71	0.81				
14		21.80	5.95	1.95	0.93				
15		24.70	6.75	2.21	1.05				
20		42.10	11.50	3.76	1.78	0.48			
25			17.40	5.69	2.70	0.70			
30			24.40	7.98	3.78	0.98	0.35		
35			32.40	10.60	5.03	1.30	0.46		
40			41.50	13.50	6.44	1.66	0.58		
50			62.70	20.50	9.73	2.51	0.88		
60				28.70	13.40	3.54	1.25	0.52	
70					18.10	4.69	1.65	0.69	
80					23.20	6.00	2.09	0.88	
90					28.80	7.47	2.60	1.09	
100					35.10	9.06	3.16	1.33	0.34
110						10.00	3.77	1.59	0.39
120						12.70	4.43	1.87	0.46
130						14.70	5.14	2.17	0.53
140						16.90	5.89	2.48	0.61
150						19.20	6.69	2.82	0.70
160						21.60	7.54	3.17	0.78
170						24.20	8.43	3.55	0.88
180						26.90	9.40	3.94	0.98
190						29.70	10.40	4.36	1.08
200						32.60	11.50	4.79	1.19
210							12.50	5.25	1.29
220							13.60	5.72	1.41
230							14.70	6.20	1.54
240							16.00	6.71	1.66
250							17.20	7.24	1.79
260							18.60	7.50	1.93
270							19.80	8.40	2.07
280							21.20	8.90	2.20
290							22.70	9.50	2.35
300							24.20	10.10	2.51
320								11.40	2.83
240								12.80	3.16
360								14.20	3.52
380								15.70	3.71
400								17.30	3.90

Velocity of Flow (ft/sec) - Type L Copper Tube

FLOW gpm	½	¾	1	1 ¼	1 ½	2	2 ½	3	4
1	1.38	0.66							
2	2.75	1.33							
3	4.13	1.99							
4	5.50	2.65	1.56						
5	6.88	3.31	1.94						
6	8.25	3.98	2.33						
7	9.63	4.64	2.72						
8	11.00	5.30	3.11	2.04					
9		5.97	3.50	2.30					
10		6.63	3.89	2.55					
11		7.29	4.28	2.81					
12		7.95	4.67	3.06	2.16				
13		8.62	5.05	3.32	2.35				
14		9.28	5.44	3.57	2.53				
15		9.94	5.83	3.83	2.71				
20		13.26	7.78	5.11	3.61	2.07			
25			9.72	6.38	4.51	2.59			
30			11.66	7.66	5.41	3.11	2.02		
35			13.61	8.94	6.31	3.63	2.35		
40			15.55	10.21	7.22	4.15	2.69		
50			19.44	12.77	9.02	5.19	3.36		
60				15.32	10.82	6.22	4.03	2.83	
70					12.63	7.26	4.70	3.30	
80					14.43	8.30	5.38	3.77	
90					16.24	9.33	6.05	4.24	
100					18.04	10.37	6.72	4.71	2.68
110						11.41	7.39	5.18	4.05
120						12.44	8.06	5.65	4.42
130						13.48	8.74	6.12	4.78
140						14.52	9.41	6.59	5.15
150						15.56	10.08	7.07	5.52
160						16.59	10.75	7.54	5.89
170						17.63	11.42	8.01	6.26
180						18.67	12.10	8.48	6.62
190						19.70	12.77	8.95	6.69
200						20.74	13.44	9.42	7.36
210							14.11	9.89	7.73
220							14.78	10.36	8.10
230							15.46	10.83	8.46
240							16.13	11.30	8.83
250							16.80	11.78	9.20
260							17.47	12.25	9.57
270							18.14	12.72	9.94
280							18.82	13.19	10.30
290							19.49	13.66	10.67
300							20.16	14.13	11.04
320								15.07	11.78
240								16.01	12.51
360								16.96	13.25
380								17.90	13.98
400								18.84	14.72

Pressure Loss From Friction – Type K Copper Tube

C=140

FLOW gpm	½	¾	1	1 ¼	1 ½	2	2 ½	3	4
1	1.20	0.23							
2	4.33	0.77							
3	9.17	1.65							
4	15.67	2.78	0.68						
5	23.60	4.21	1.02						
6	33.00	5.90	1.44						
7	43.90	7.84	1.90						
8	56.20	10.03	2.46	0.75					
9		12.48	3.03	0.93					
10		15.15	3.68	1.13					
11		18.10	4.40	1.35					
12		21.30	5.17	1.58	0.75				
13		24.60	6.00	1.84	0.87				
14		28.30	6.88	2.11	1.00				
15		32.10	7.81	2.39	1.13				
20		54.70	13.30	4.07	1.91	0.50			
25			20.10	6.15	2.90	0.74			
30			28.20	8.63	4.06	1.03	0.36		
35			37.50	11.50	5.41	1.38	0.48		
40			48.00	14.60	6.91	1.76	0.62		
50			72.50	22.10	10.45	2.65	0.93		
60				31.10	14.60	3.72	1.30	0.55	
70					19.50	4.95	1.74	0.73	
80					25.00	6.34	2.21	0.93	
90					31.00	7.90	2.75	1.15	
100					37.70	9.58	3.34	1.40	0.36
110						11.40	4.00	1.68	0.41
120						13.50	4.68	1.97	0.48
130						15.60	5.43	2.30	0.56
140						17.80	6.23	2.62	0.65
150						20.30	7.07	2.98	0.74
160						22.91	7.96	3.35	0.83
170						25.50	8.90	3.75	0.93
180						31.40	9.90	4.17	1.03
190						34.50	11.00	4.60	1.14
200							12.10	5.06	1.25
210							13.20	5.54	1.37
220							14.30	6.05	1.49
230							15.60	6.55	1.62
240							16.90	7.09	1.76
250							18.20	7.65	1.89
260							19.60	8.22	2.04
270							21.00	8.83	2.18
280							22.40	9.43	2.33
290							24.00	10.07	2.49
300							25.50	10.72	2.65
320								12.10	2.99
240								13.55	3.34
360								15.01	3.72
380								16.58	3.92
400								18.26	4.12

Velocity of Flow (ft/sec) - Type K Copper Tube

FLOW gpm	½	¾	1	1 ¼	1 ½	2	2 ½	3	4
1	1.47	0.74							
2	2.94	1.47							
3	4.41	2.21							
4	5.88	2.94	1.65						
5	7.36	3.68	2.06						
6	8.83	4.42	2.48						
7	10.30	5.15	2.89						
8	11.77	5.89	3.30	2.11					
9		6.62	3.71	2.37					
10		7.36	4.13	2.64					
11		8.10	4.54	2.90					
12		8.83	4.95	3.16	2.23				
13		9.57	5.36	3.43	2.42				
14		10.30	5.78	3.69	2.61				
15		11.04	6.19	3.95	2.79				
20		14.72	8.25	5.27	3.72	2.13			
25			10.32	6.59	4.66	2.66			
30			12.38	7.91	5.59	3.19	2.07		
35			14.44	9.22	6.52	3.72	2.41		
40			16.50	10.54	7.45	4.26	2.76		
50			20.63	13.18	9.31	5.32	3.45		
60				15.81	11.17	6.38	4.13	2.90	
70					13.03	7.45	4.82	3.38	
80					14.90	8.51	5.51	3.86	
90					16.76	9.58	6.20	4.35	
100					18.62	10.64	6.89	4.83	2.75
110						11.70	7.58	5.31	3.03
120						12.77	8.27	5.80	3.30
130						13.83	8.96	6.28	3.58
140						14.90	9.65	6.76	3.85
150						15.96	10.34	7.25	4.13
160						17.02	11.02	7.73	4.40
170						18.09	11.71	8.21	4.68
180						19.15	12.40	8.69	4.95
190						20.22	13.09	9.18	5.23
200						21.28	13.78	9.66	5.50
210							14.47	10.14	5.78
220							15.16	10.63	6.05
230							15.85	11.11	6.33
240							16.54	11.59	6.60
250							17.23	12.08	6.88
260							17.91	12.56	7.15
270							18.60	13.04	7.43
280							19.29	13.52	7.70
290							19.98	14.01	7.98
300							20.67	14.49	8.25
320								15.46	8.80
240								16.42	9.35
360								17.39	9.90
380								18.35	10.45
400								19.32	11.00

Pressure Loss Through Standard Water Meters

Pounds per Square Inch

FLOW gpm	5/8	¾	1	1 ½	2	3	4
1	0.2	0.1					
2	0.3	0.2					
3	0.4	0.3					
4	0.6	0.5	0.1				
5	0.9	0.6	0.2				
6	1.3	0.7	0.3				
7	1.8	0.8	0.4				
8	2.3	1.0	0.5				
9	3.0	1.3	0.6				
10	3.7	1.6	0.7	0.1			
11	4.4	1.9	0.8	0.2			
12	5.1	2.2	0.9	0.2			
13	6.1	2.6	1.0	0.3			
14	7.2	3.1	1.1	0.3			
15	8.3	3.6	1.2	0.4			
16	9.5	4.1	1.4	0.4			
17	10.7	4.6	1.6	0.5			
18	12.0	5.2	1.8	0.6			
19	13.4	5.8	2.0	0.7			
20	15.0	6.5	2.2	0.8	0.4		
25		10.3	3.7	1.3	0.5		
30		15.0	5.3	1.8	0.7		
35			7.3	2.6	1.0		
40			9.6	3.3	1.3		
50			15.0	4.9	1.9	0.8	
60				7.2	2.7	1.0	
70				9.8	3.7	1.3	
80				12.8	4.9	1.6	0.7
90				16.1	6.2	2.0	0.8
100				20.0	7.8	2.4	0.9
110					9.5	2.9	1.0
120					11.3	3.4	1.2
130					13.1	3.9	1.4
140					15.0	4.5	1.6
150					17.3	5.1	1.8
160					20.0	5.8	2.1
170						6.5	2.4
180						7.2	2.7
190						8.0	3.0
200						9.0	3.2
220						11.0	3.9
240						13.0	4.7
260						15.0	5.5
280						17.3	6.3
300						20.0	7.2
320							8.1
340							9.0
360							11.0
380							12.0
400							13.0
450							16.2
500							20.0

Approximate Pressure Losses Through Pipe Fittings and Manual Valves

Listed in equivalent feet of pipe

	PIPE FITTINGS		
Pipe Size	Standard Elbow Or Tee Reduced by ½	Long Sweep Elbow Or Standard Tee	Side Outlet Or Standard Tee
½	0.9	0.4	1.8
¾	1.2	0.6	2.5
1	1.7	0.8	3.4
1 ¼	2.4	1.2	4.8
1 ½	3.0	1.4	5.8
2	4.0	2.0	7.9
2 ½	5.0	2.5	9.9
3	6.7	3.3	13.1
4	9.2	4.5	18.3
5	12.2	6.0	24.3
6	15.3	7.6	30.5
8	21.7	10.7	43.1
10	28.7	14.1	56.9

	MANUAL VALVES		
Valve Size	Gate Valves	Angle Valves	Globe Valves
½	0.3	1.2	2.7
¾	0.5	1.7	3.8
1	0.6	2.3	5.1
1 ¼	0.9	3.2	7.2
1 ½	1.1	4.0	8.7
2	1.5	5.4	11.9
2 ½	1.9	6.7	14.9
3	2.5	8.9	19.7
4	3.4	12.4	27.5
5	4.6	16.5	36.6
6	5.7	20.6	45.0
8	8.1	29.2	64.8
10	10.7	38.5	85.6

To use these charts:

1. Find the type of fittings for manual valves along the top of the chart.
2. Find the size along the left of the chart.
3. The value at the intersection is the equivalent feet of pipe value.
4. Go to the appropriate pipe sizing chart and find the loss per 100 ft for the flow through the fitting or manual valve.
5. Multiply the loss per 100 ft by the equivalent feet of pipe value, then divide by 100.

Pressure Loss through Typical Electric Globe Valves

(Loss in pounds per square inch)

Flow (gpm)	1 in.	1½ in.	2 in.
0-4	1.2		
6	1.4		
8	1.6		
10	1.7		
15	2.0		
20	2.3	1.3	
25	3.0	1.6	
30	4.3	1.9	
35	6.0	2.4	
40	7.7	3.0	2.3
45	9.5	3.8	2.4
50	11.5	4.6	2.6
55		5.6	2.7
60		6.7	2.9
70		9.5	3.3
80		10.0	3.4
90			4.2
100			5.2
110			6.7
120			7.7
130			8.8

Typical Pressure Loss in Backflow Prevention Devices

(Loss in pounds per square inch)

	Pressure Vacuum Breaker				
gpm	¾ in.	1 in.	1¼ in.	1 ½ in.	2 in.
5	3.5				
10	4.0				
15	4.6				
20	5.5	4.2			
25	6.5	4.5			
30	7.5	5.0	4.5		
35		5.5	--		
40		6.0	5.1	3.6	
45		6.6	--	--	
50		7.5	5.6	3.8	
60		8.5	6.2	4.0	4.5
70			6.8	4.2	5.0
80			7.5	4.6	5.1
90				4.8	5.3
100				5.0	5.6
110				5.5	5.8
120				5.9	5.9
130				6.9	6.0
140					6.1
150					6.2
160					6.5
170					6.8
180					7.0
190					7.2
200					7.5

Typical Pressure Loss in Backflow Prevention Devices

(Loss in pounds per square inch)

Double Check Assembly					
gpm	¾	1	1¼	1 ½	2
5	5.5				
10	6.0				
15	6.9				
20	8.0	5.5			
25	8.9	5.7			
30	9.5	6.0			
35	10.5	6.5			
40	11.5	7.1	6.7		
45		8.0	7.0		
50		8.9	7.5		
55		9.5	7.7		
60		10.0	8.0	6.8	
70		12.3	8.5	7.0	
80			9.1	7.2	
90			10.0	7.5	
100			10.9	7.9	6.5
110				8.1	6.8
120				8.5	7.0
130				9.0	7.2
140				9.5	7.8
150				10.5	8.1
160					8.5
170					9.0
180					9.4
190					9.9
200					10.2

Typical Pressure Loss in Backflow Prevention Devices

(Loss in pounds per square inch)

	Reduced Pressure Principle Assembly				
gpm	**¾**	**1**	**1¼**	**1 ½**	**2**
5	10.5				
10	11.2				
15	11.9				
20	12.7	12.0			
25	13.3	12.1			
30	14.0	12.2	13.8		
35	15.1	12.4	13.9		
40	16.9	12.8	14.1		
45		13.1	14.3		
50		13.7	14.5		
55		14.3	14.8		
60		15.0	15.0	13.7	
70		16.5	15.5	14.0	
80			16.0	14.2	13.1
90			16.8	14.8	13.3
100			17.5	15.0	13.5
110				15.2	13.7
120				15.8	13.9
130				16.1	14.1
140				16.9	14.4
150					14.9
160					15.1
170					15.8
180					16.5
190					17.1
200					18.0

Appendix B: Site Information Worksheet

Obtain Site Information

Site Data Worksheet

Date
Job Number

❶ Site Information

Name ______
Address ______
City ______ State ______ ZIP ______
Day Phone ______ Eve. Phone ______
Storage area location ______
Specs on File? ☐ Yes ☐ No
Permits Required? ☐ Yes ☐ No
Cost ______

❷ Water Source

☐ City Water
☐ Well: ☐ Sub ☐ Centrifugal
HP___ psi___ gpm___
☐ Surface Water ☐ Effluent
Water Quality: ☐ Good ☐ Fair ☐ Poor
Water Purveyor ______
Contact ______
Phone ______
Meter Location ______
Meter size (in.) ______
Service Line Type & Size ______
Static pressure (PSI at meter) ______
Elevation change (± feet) ______
Backflow Regulations ______
Water available? ☐

❸ Soil Information

☐ Sand
☐ Sandy Loam
☐ Loam
☐ Clay Loam
☐ Clay
☐ Rock removal from site
☐ Rock teeth required
☐ Steep slopes
☐ Hard pan over shallow topsoil
☐ Additional grading required

❹ Site Measurement Discrepancies

❺ Electrical Source

Type ______
Location ______
Voltage ______

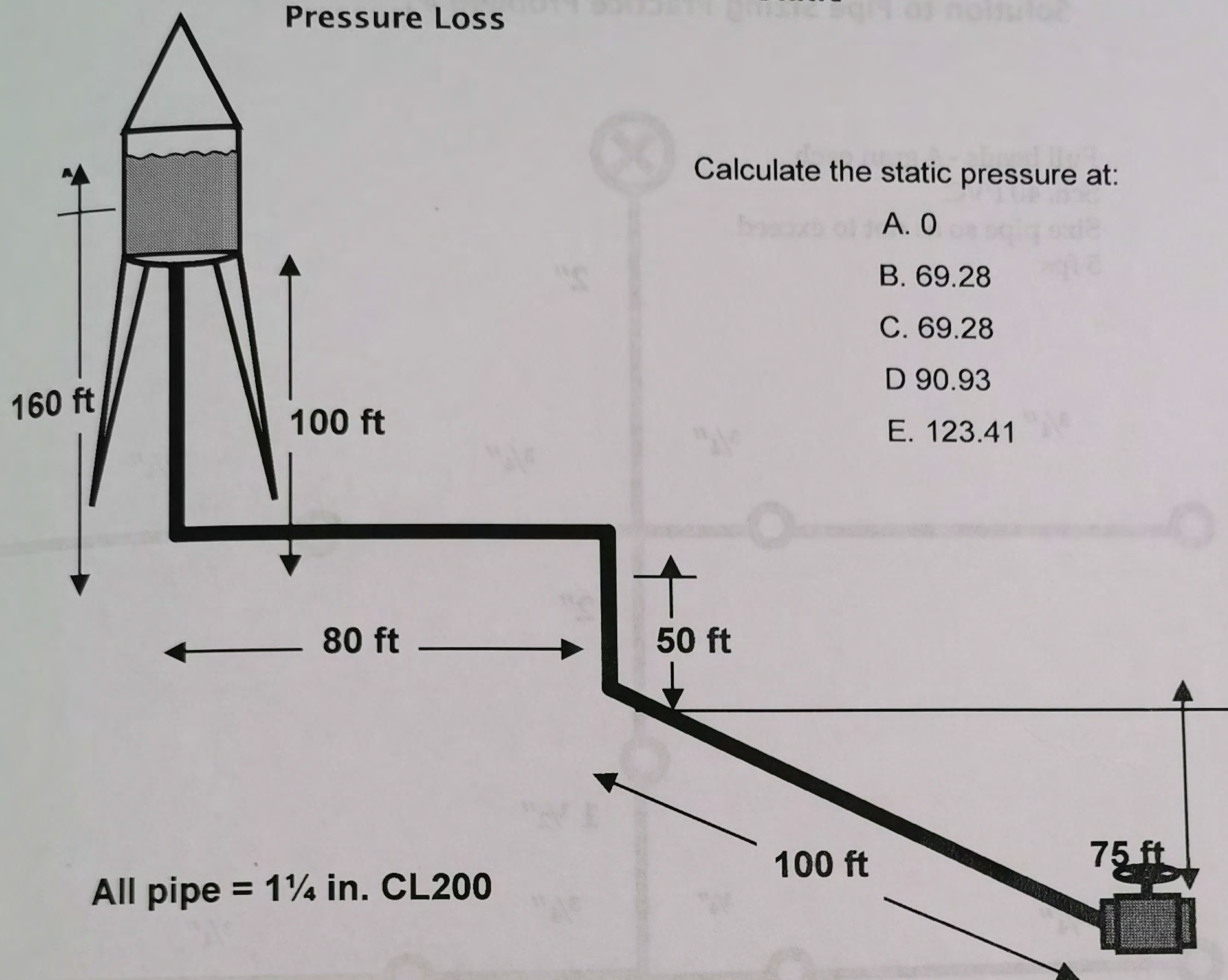
Notes

❻ Key Subcontractors

Company Name	Contact Name	Phone

Appendix C: Answers to Practice Questions

Answer to Practice Problem – Static Pressure Loss



Calculate the static pressure at:

A. 0

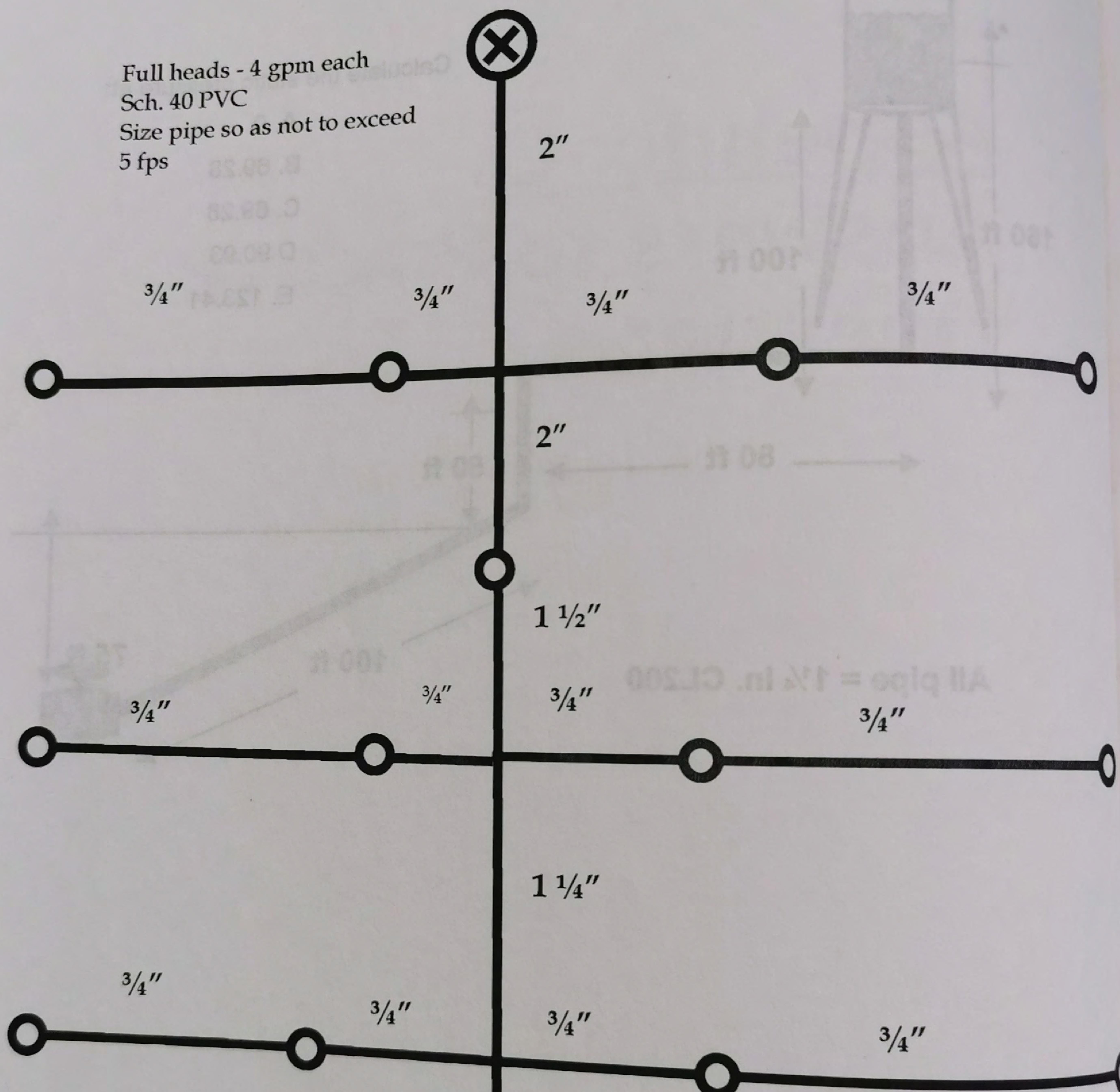
B. 69.28

C. 69.28

D 90.93

E. 123.41

Solution to Pipe Sizing Practice Problem #1



Chapter 13:

1. True
2. c
3. True
4. d
5. b
6. d
7. c
8. c
9. c
10. b
11. True
12. a
13. False
14. True
15. True
16. d
17. a
18. b
19. True
20. False