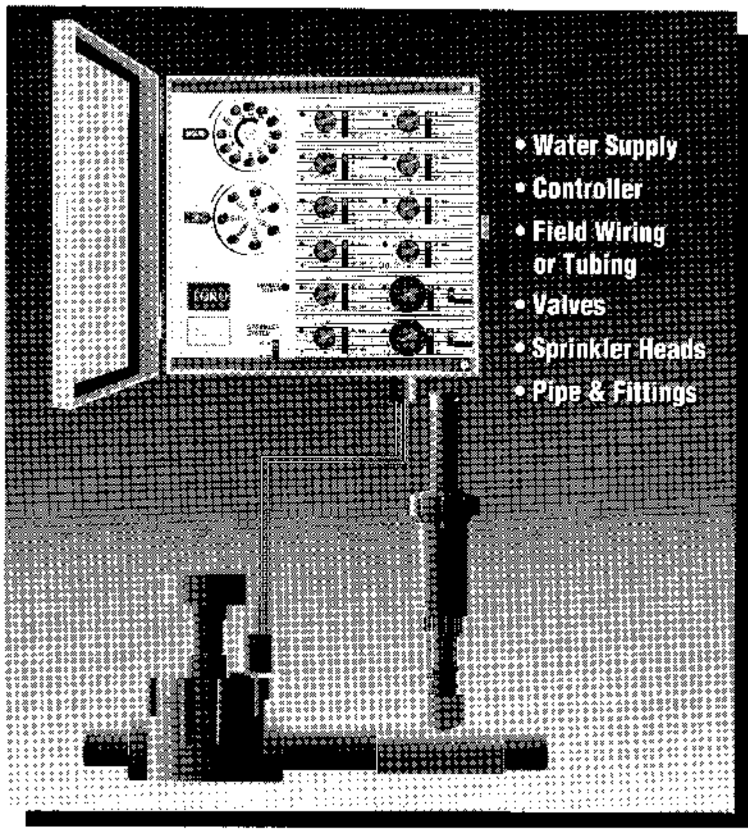
*A Guide to*

# *Troubleshooting*

## *Automatic Sprinkler Systems*

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# Troubleshooting Automatic Sprinkler Systems

## Introduction

The following discussion takes you through the basic steps in troubleshooting typical residential or commercial automatic sprinkler systems. The methodology presented is based on a block style system, i.e., a group of sprinkler heads downstream of a valve, but many aspects of the methodology are equally valid for valve-in-head, electric or hydraulic sprinkler systems.

This guide is based on Toro's video, "Troubleshooting Automatic Sprinkler Systems", order number 490-2371.

## Who is this program for?

This program is designed as a tool to improve the *efficiency* of *landscape personnel* and *irrigation specialists* or any others who maintain and repair sprinkler systems. This program will also be useful in *educating* students of *landscape/irrigation design* and *irrigation construction personnel* or any others who want to be more familiar with the components that comprise an automatic sprinkler system.

## How to use this program:

Keys to success in troubleshooting automatic sprinkler systems are:

1) an understanding of basic electricity, and 2) familiarity with the system's hydraulic components. These subjects are covered in Appendix A and B. We suggest you start the program with these appendices if you're not familiar with the subjects or if you want a quick review.

The methodology systematically guides the troubleshooting process through all the system components, starting with the components with the greatest probability of a problem and working to the components with the least probability of a problem. *In actual practice*, you'd modify this sequence to the extent you were familiar with the system. As an example, let's say you regularly maintain a particular site. When you come to work one morning you notice a turf area that is unusually wet. Mentally you check off the fact that you have water pressure, the controller did start and stop a cycle so it is functioning (maybe not correctly though), and that the valve did open and eventually close. In an instant, you've mentally gone through the first four troubleshooting steps. To finish our story, you go to the controller and initiate a manual start for the effected station. The sprinklers start operating (confirming the first four troubleshooting steps) and after a few moments you notice one sprinkler is not rotating. Now you know where the problem is and where to start the repair. In a situation where you're not familiar with the site, you'd actually check and confirm operation of each component as the methodology directs.

Appendix E is a suggested format for using this guide and the video program, "Troubleshooting Automatic Sprinkler Systems" (490-2371) in a training situation.

# Troubleshooting Methodology

In order to develop a troubleshooting methodology, we must visualize the six major components of any automatic sprinkler system and how they relate to each other.

Every automatic sprinkler system has:

- A pressurized water supply.
- An automatic controller.
- Field wiring between the controller and valves–or tubing, if the system is hydraulically controlled.
- Automatic zone control valves.
- Sprinklers to distribute the water.
- The pipe and fittings necessary to complete the system.

The usual field conditions experienced when one of the system's components fail are very often signs of plant stress or death. These symptoms might be localized or they might be system wide. Other clues are dry pavement when you'd expect to see signs of earlier scheduled watering, or soggy, even eroded areas that indicate excessive watering.

### Step One - Confirm Water Supply

* The first step is to verify that the system is pressurized. Locate a zone control valve that does not respond to a start cycle from the controller. All automatic valves have some means of manual operation. Find this "bleed" device and open it. This will relieve the hydraulic pressure on top of the valve's diaphragm or piston and allow the upstream water pressure to open the valve.
* If the sprinklers aren't activated, check the flow control handle. The flow control limits the amount of valve opening and is used to "fine tune" the system by adjusting the downstream pressure. It may have been cranked down so the valve can't open.
* If the valve operates manually, move on to the second step since you know the system is pressurized. However, if it doesn't operate manually, backtrack to find where the water supply has been interrupted.
* Check the backflow prevention device next. Since this equipment is above grade, it may have been tampered with and someone may have turned it off.
* If there is water at the backflow device, but not at the zone control valve, there is probably a master valve between the two. Track it down and repeat the manual bleeding process.
* If there isn't water at the backflow prevention device, move upstream and verify that the isolation valve and/or water meter are open.

### Step Two - Automatic Controller

* The next step is to verify that the controller is operating properly. It's been estimated that 90% of system failures can be traced to the controller, and that 90% of controller problems are programming errors. This means that there is an 81% chance that the system failure is the result of HUMAN ERROR in programming the controller correctly.

This being the case, first check the controller program.

- Rain or system switch on?
- Time set on individual stations?
- Station switches in an "on" or "auto" position?
- Start cycle times set?
- Correct day and hour set?

* A manual start should now activate the system. If not, confirm that there is power to the controller. Check to see that fuses are good and reset any circuit breakers.
* If the circuit breaker kicks out during an irrigation cycle, disconnect the field wires at the controller. Reset the circuit breaker and start another cycle. If it doesn't kick out now, the problem (probably a short) is in the field wiring; but if it does kick out, the problem is definitely in the controller. Isolate and repair or replace the defective part.

* *A Volt/Ohm multimeter is an inexpensive must for troubleshooting.*
  Set to the resistance scales, you can verify the integrity of coils, motors, relays, fuses and simple circuits by testing for continuity or a low ohms resistance reading.

  To check voltage you must set the meter to the voltage scale. Always set the meter to a higher scale than you expect to read. Set to a lower scale if the needle moves so little that the reading is difficult to interpret. Reading voltage on any other scale will cause damage to the meter and maybe you!!

**WARNING**

**ASSURE 120 VAC POWER SOURCE IS DISCONNECTED PRIOR TO MAKING WIRE CONNECTIONS. FAILURE TO COMPLY MAY RESULT IN SERIOUS INJURY AND/OR EQUIPMENT DAMAGE DUE TO ELECTRIC SHOCK HAZARD.**

**ALL ELECTRICAL COMPONENTS AND INSTALLATION PROCEDURES MUST COMPLY WITH THE NATIONAL ELECTRICAL CODE AND LOCAL CODES AS THEY APPLY.**

* Most controllers operate on 120 VAC. Carefully reading the input voltage, you should read between 105 and 130 VAC. If not, determine where the power has been interrupted. When you check after the transformer, you will read between 21 and 26 VAC if the transformer is functioning properly. Power specifications are usually found on the controller cabinet or door.
* Satisfied that you have input voltage, check for output voltage. Set time on a station, activate a manual start and read output from the terminal strip. A valve must be hooked up so there is a load on the circuit or you may get a false reading.
* If your check shows no continuity, determine if there are rain or freeze gauges in the system before you move onto step three and troubleshoot the field wiring. Rain and freeze gauges are devices that interrupt the 24 VAC output to the field by breaking the common wire leg of the 24 VAC circuit. If such a device is activated, you won't have continuity through the field wiring.

## Step Three - Field Wiring

* The next component to verify operation is the field wiring. Program a valve to run and go to that valve location. Remove the wire connection, twist the field and solenoid wire together so there is a load on the circuit, and read the voltage on the AC scale of your multimeter. If the wiring is intact, you will read between 19 and. 28 Volts, depending on the amount of input voltage to the controller.
* A low reading or a zero reading means a break in the field wiring, a partial open, undersized wires or, very often, poor or failed wire splices.
* Cable fault locators can be used to find the electrical fault in the wire. These devices connect to the field wires at the controller or the valve and transmit a pulse to the fault location that you can track with the aid of a receiver and earphones. Cable fault locators can be purchased, rented or sometimes borrowed from irrigation distributors.

## Step Four - Valves

* Check the valve solenoid first by untwisting the field wires to remove the solenoid from the system. With your multimeter set on the resistance scale, a good solenoid will read between 20 and 60 ohms. A defective solenoid will read over this.
* With power to the valve and a good solenoid, the system is functioning to this point. This means that if the system still isn't operating, the problem is an internal valve problem.

* These are the reasons valves will not open. Our troubleshooting methodology has already eliminated all the non-internal reasons for valves not opening.

1. No water pressure–First item we checked.
2. Flow control closed–Already checked.
3. Controller malfunction–Confirmed operation.
4. Faulty field wiring–Checked integrity.
5. Faulty solenoid–Also checked.
6. Plugged discharge path–The most common INTERNAL reason for the valve not opening.

* First partially disassemble the valve by removing the solenoid after turning off the water supply. Be careful not to lose the O-ring, solenoid plunger and plunger spring. The blockage may be found at this point. If the valve still does not operate after reassembly, completely disassemble and clean all internal passageways.

**CAUTION**

**Avoid using any tool that may enlarge the internal passageways of the valve. Their sizes are engineered, and changing them can cause the valve not to operate properly.**

* Let's consider the reasons why valves will not close:

1. Controller malfunction–check for power and programming errors!
2. Debris between diaphragm and seat–common reason not to close.
3. Plugged discharge path–disassemble and repair.
4. Ruptured diaphragm–disassemble and repair.

**CAUTION**

**If debris is holding the diaphragm open, cranking down on the flow control to close the valve could ruin the valve seat and require a complete valve replacement, or you might end up with a slowly weeping valve. If you need to shut the system down, use the shut off valve at the backflow device or the system isolation valve.**

## Step Five - Sprinkler Heads

* Because of the great diversity of sprinklers, our troubleshooting methodology will only consider problems common to all sprinklers. Check with your distributor for service information on the particular sprinklers on your project.
* Sprinklers should be operated and visually checked. Many landscaping dollars are lost each year, and a terrible amount of water is wasted because sprinklers aren't serviced on a regular basis.
* One of the most common problems is a sprinkler whose nozzle or rotor is clogged with debris. These sprinklers need to be disassembled, usually from the top, cleaned and reassembled. Most sprinklers either come with, or have available, plastic nozzle screens. Sometimes these do not get installed. Having them on hand is helpful so you can install them when sprinkler disassembly is necessary. If clogged nozzles are a recurring problem, a filter installed near the point of connection will prevent debris from reaching the sprinklers and save many hours of labor.
* Too much pressure, or not enough pressure, at the sprinkler are also common sprinkler problems. Each type of sprinkler is designed to operate within a range of pressures (detailed in the manufacturer's catalog). Too much pressure at the nozzle causes misting which reduces the radius of the sprinkler, makes the pattern prone to wind disturbance and distorts the sprinkler's distribution.

* A valve with flow control can be adjusted to dissipate constant excess pressure. A pressure-regulating valve will maintain a constant downstream pressure even with fluctuating high pressures.
* Not having the minimum operating pressure at the sprinkler causes dry spots around the head or midway within the radius, because the water stream isn't atomized sufficiently for efficient distribution.
* System pressure might be increased by opening up any pressure regulators and valve flow controls or reprogramming the controller to start earlier in the morning to take advantage of higher mainline pressures.
* If sprinklers are over-spaced, or the pipe undersized, there aren't any simple solutions. You might consider a booster pump to bring the pressure up to the high end of the nozzle specifications as a means of improving performance. The system must be analyzed prior to adding a pump to insure that damage won't result to any of the system's components.

**Step Six - Pipe and Fittings**

* Problems with this component of the system usually involve a break and require a repair. There are several devices available that simplify this operation. A plastic suction or bilge-type pump available through an irrigation supply store is very valuable in getting rid of water and mud at the site of a break. Ratchet or tubing type pipe cutters eliminate the small pipe particles produced by saws that do such a good job of plugging valves and sprinkler nozzles.
* Riser assemblies make the connection between the piping and the sprinkler. Flexible riser assemblies allow the sprinkler to be positioned easily and protect the piping from breakage. Flexible hose like Toro Funny Pipe™, make excellent risers and make sprinkler installation in tight locations easy.

# Troubleshooting Hydraulic Systems

* Review Hydraulics in appendix.
* The troubleshooting sequence is the same for a hydraulic system as it is for an electric system:
  1. Confirm supply water is available at adequate pressure.
  2. Confirm that controller is programmed and functioning correctly.
  3. Control tubing intact.
  4. Valve operating correctly.
* The main troubleshooting difference in our hydraulic system is confirming the integrity of the control tubing. Blocked control tubing, either at the valve or the controller, is often the cause of valves not opening. Valve failure to close is very often due to leaking control tubing or leaks at the valve body. Check the tubing at all connections and look to see if any cultivation or digging has severed the control tubing.

This systematic troubleshooting approach takes us step by step through each of the system components, starting with the system component with the highest probability of being the source of our system's non-operation and working to the component with the lowest probability of being the problem.

Today's landscaping investments demand irrigation professionals who can efficiently troubleshoot problems and effectively manage the irrigation system.

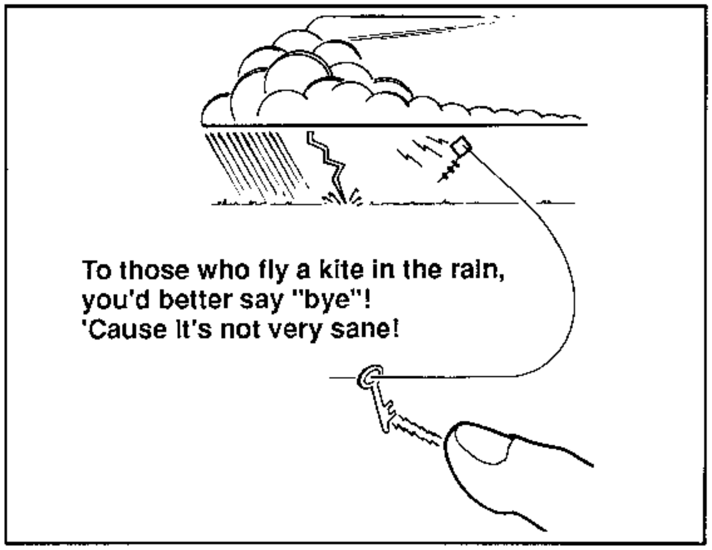
With a systematic approach, you can quickly diagnose the problem, its location, and quickly get the system up and running.

# Appendix A - Basic Electricity

The material in this section has been adapted from "Getting Started In Electronics" a Radio Shack book by Forrest M. Mims, III (Copyright 1983). Used with permission.

## Electricity

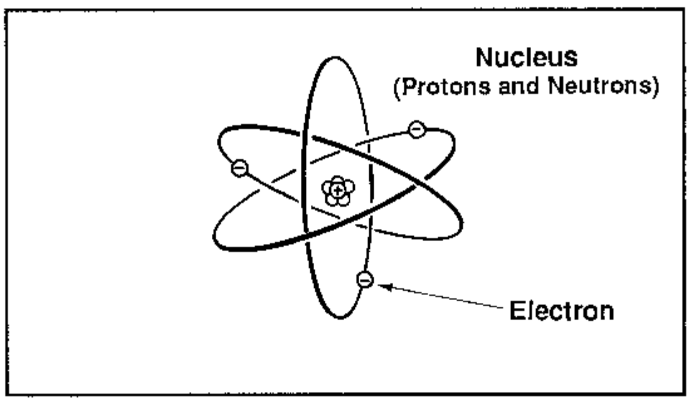
The only difference between a bolt of lightning and the spark between your finger and a doorknob on a dry day is **quantity,** *both are electricity.*
Benjamin Franklin first confirmed this with his famous kite experiment.




- ❑ **Putting Electricity to Work**
  *All* matter has electrical properties. That's why scientists over the past few centuries have been able to invent *hundreds* of gadgets that generate, store, control and switch electricity.

### Back to Basics

Electricity is an essential ingredient of matter. The best way to understand the nature of electricity is to examine the smallest component of every element, the atom.

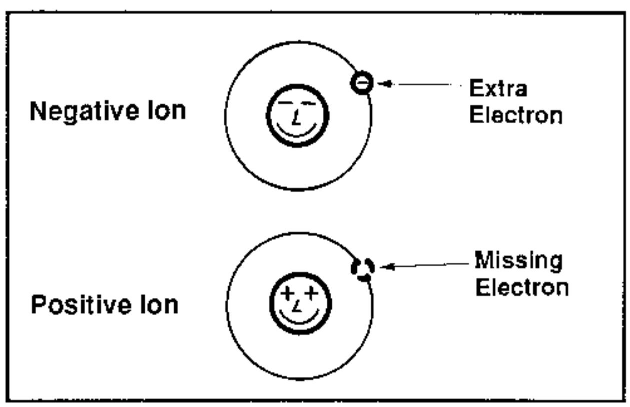



Lithium Atom

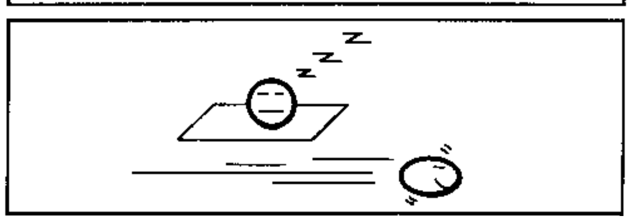
This is a lithium atom. The third simplest atom after hydrogen and helium, lithium atoms have 3 **electrons** that encircle a nucleus of 3 **protons** and 4 **neutrons**.

⊖ Electrons have a **negative** electrical charge.
⊕ Protons have a **positive** electrical charge.
O Neutrons have **no** electrical charge.

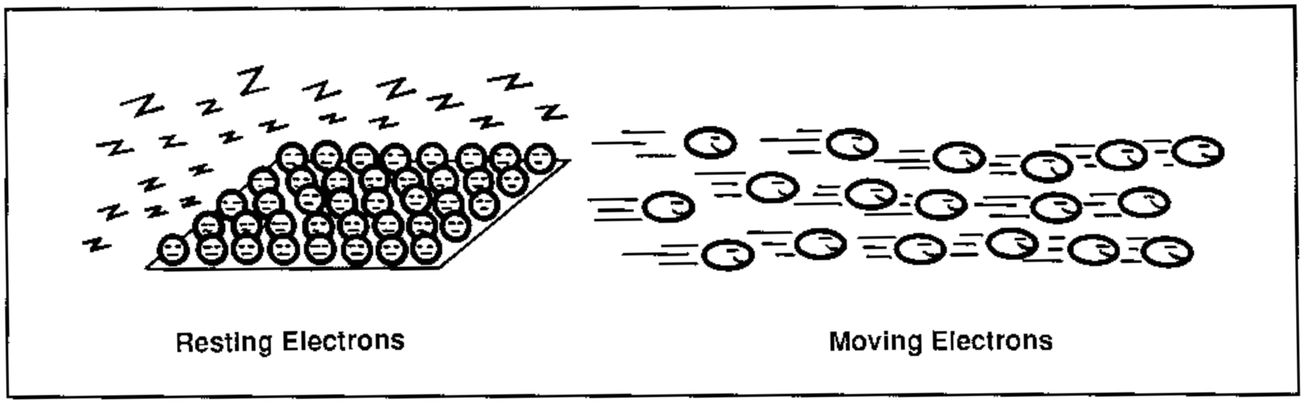
- ❑ **Ions** - Normally an atom has an equal number of electrons and protons. The charges cancel to give the atom **no** net electrical charge. It's possible to dislodge one or more electrons from most atoms. This causes the atom to have a net positive charge. It's then called a **positive ion**. If a stray electron combines with a normal atom, the atom has a negative charge and is called a **negative ion.**




- ❑ **Electrons** - **Free** electrons can move at high speed through metals, gases and a vacuum; or they can rest on a surface.

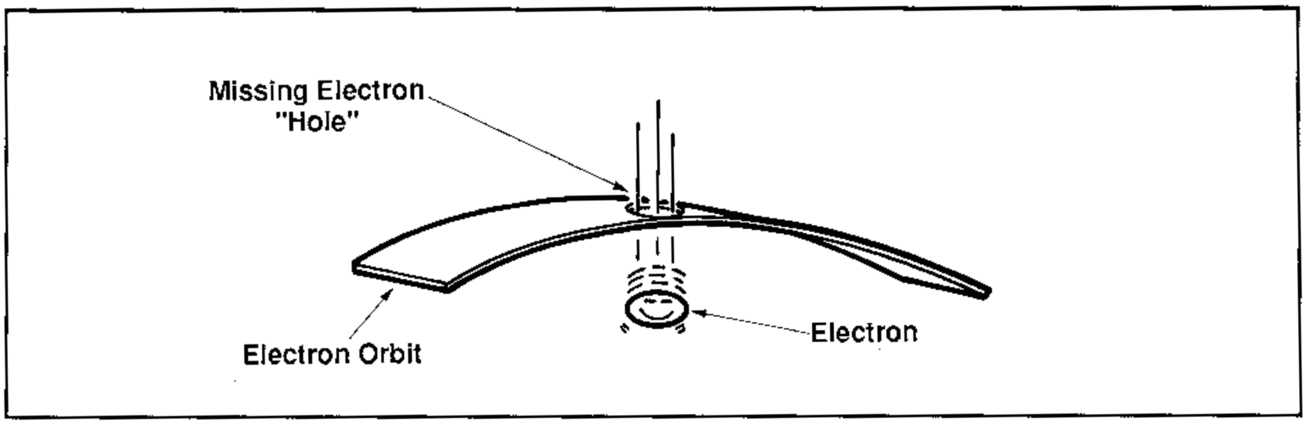


- **More About Free Electrons** - Many trillions of electrons can rest on a surface or travel through space or matter at near the speed of light (186,000 miles per second).

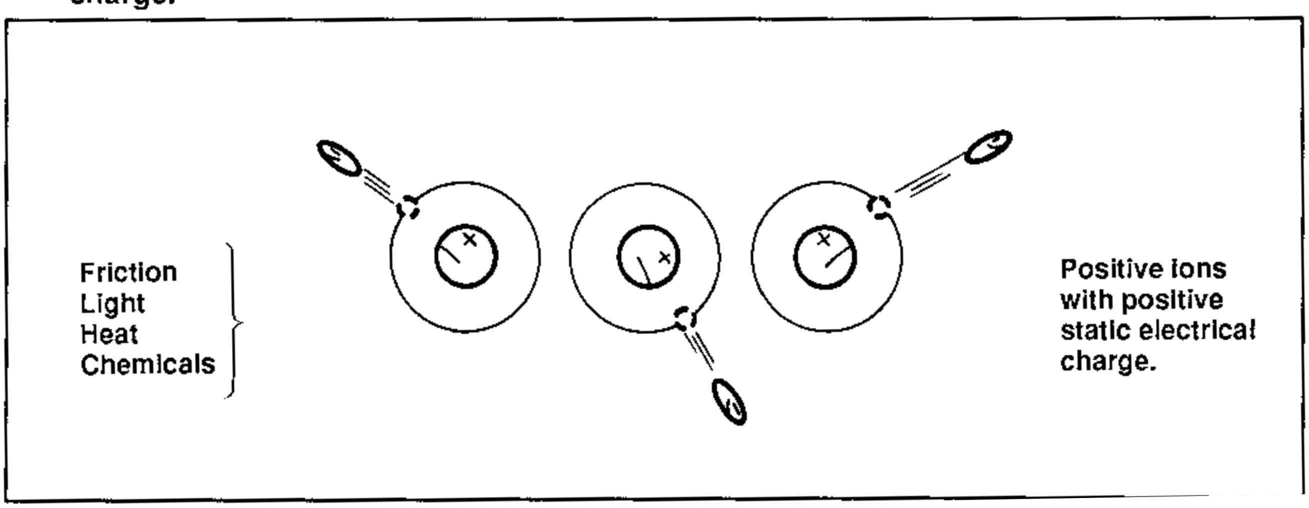



- **Resting Electrons** - A group of negative electrons on a surface causes the surface to be negatively charged. Since the electrons are not moving, the surface can be said to have a **negative static electrical charge.**

- **Moving Electrons** - A stream of moving electrons is called an **electrical current.** Resting electrons can quickly form an electrical current if placed near a cluster of positive ions. The positively charged ions will attract the electrons which will rush in to fill the "holes" or voids left by the missing electrons.



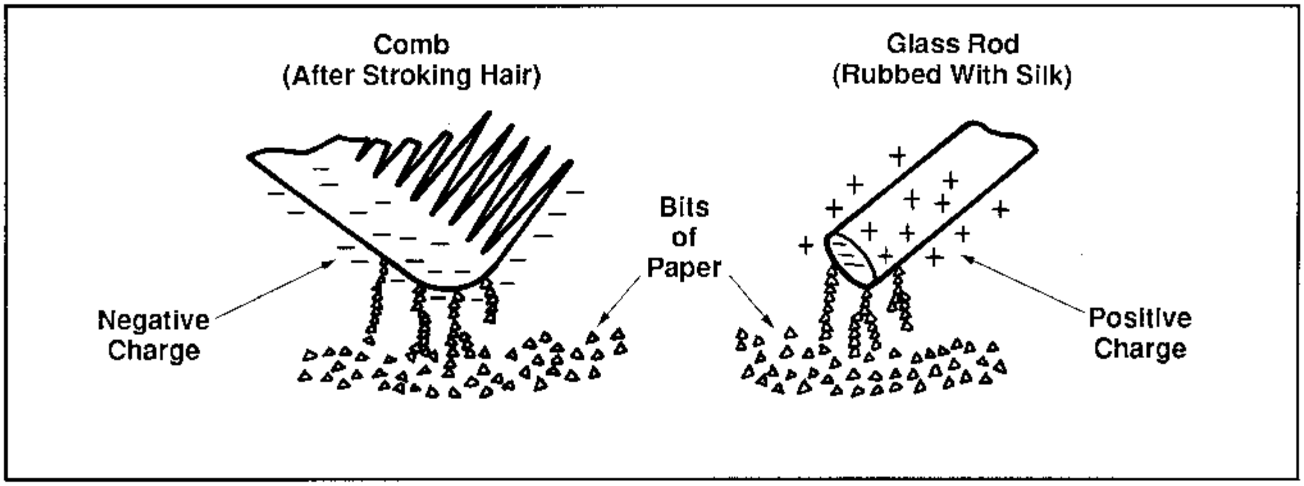

- **Missing Electrons** - Mechanical friction, light, heat or a chemical reaction may remove electrons from a surface. This causes the surface to be positively charged. Since the positively charged atoms are at rest, the surface can be said to have a **positive static electrical charge.**



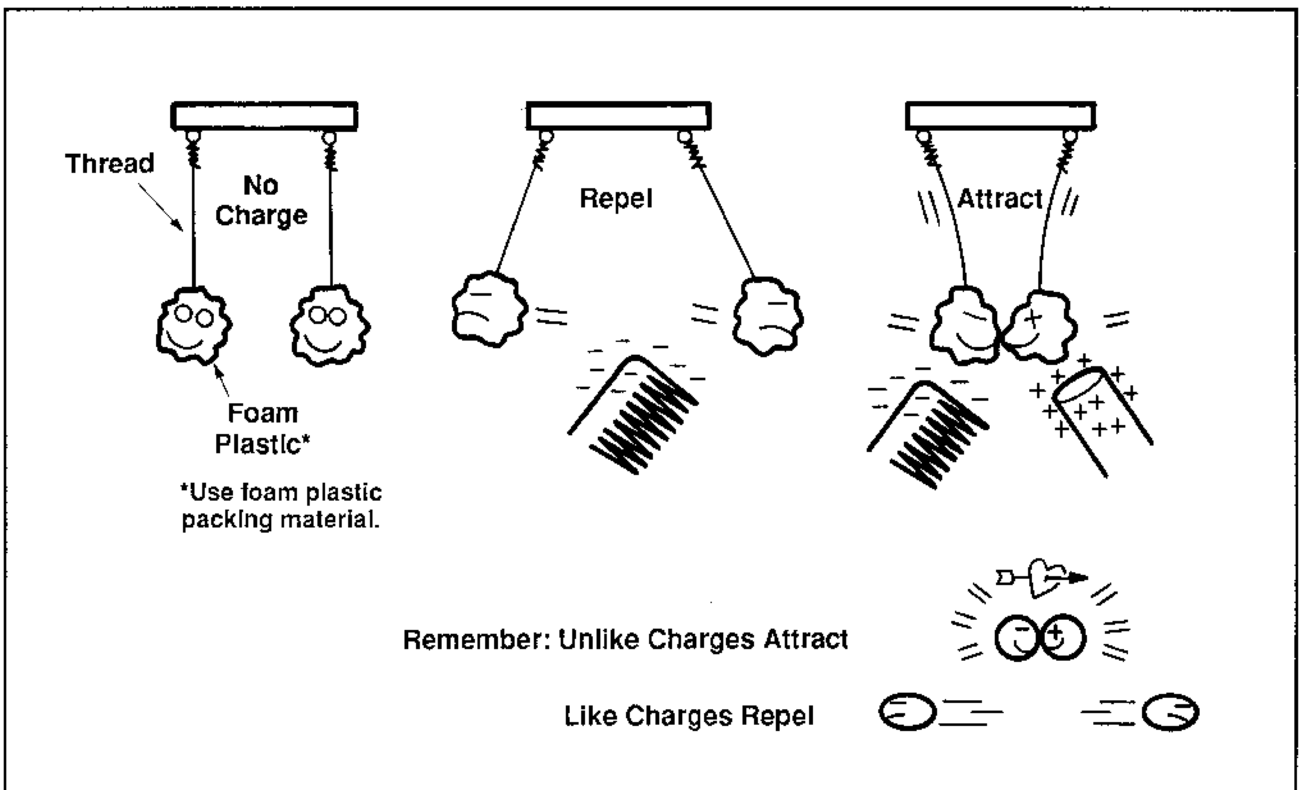
## Static Electricity

You generate static electricity every time you walk across a carpet, pull tape from a roll, remove your clothing or dry clothes in a dryer. Much of the time you don't even realize it unless the air is dry and the static charge suddenly crackles, pops and flashes its way to a new home. These static charges are caused by **mechanical friction.** Back in 600 B.C., Thales of Greece experimented with the static electricity produced when amber is rubbed with wool.

- ❑ **Electrified Plastic and Glass** - Run a plastic comb through your hair on a dry day and you'll transfer electrons from your hair to the comb. Rub a glass rod with silk or the synthetic fibers of a paint brush and you'll remove electrons from the glass. Both the negatively charged comb and the positively charged glass rod will, like amber, attract bits of paper. You can electrify or charge many materials by rubbing them with fur, wool, etc. Metal? No, the charge leaks away.



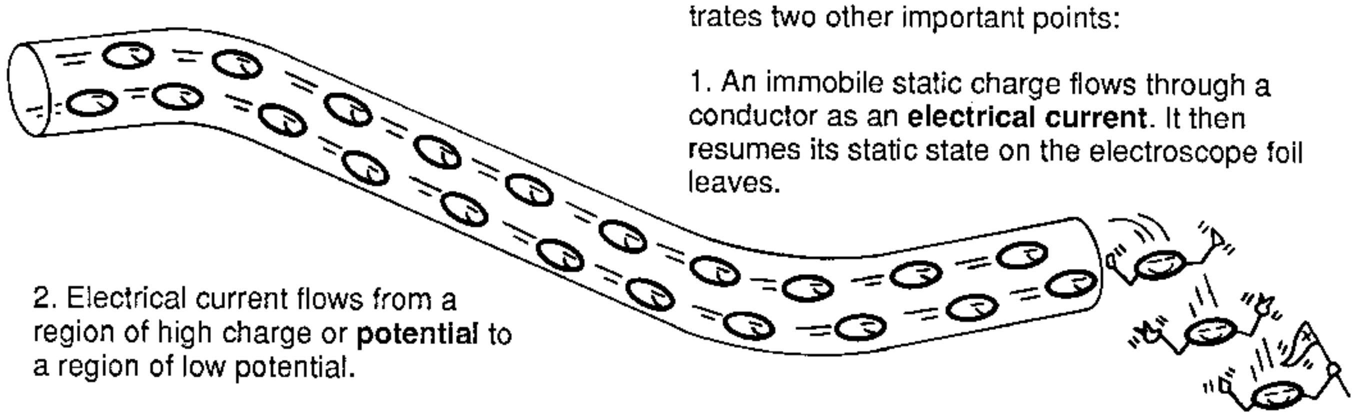

- ❑ **Opposite and Like Charges** - How do we know the comb and glass rod have opposite charges? A fundamental rule of electricity is **like charges repel** and **unlike charges attract.** Here's an experiment that proves the rule and answers the question:



## Electrical Current

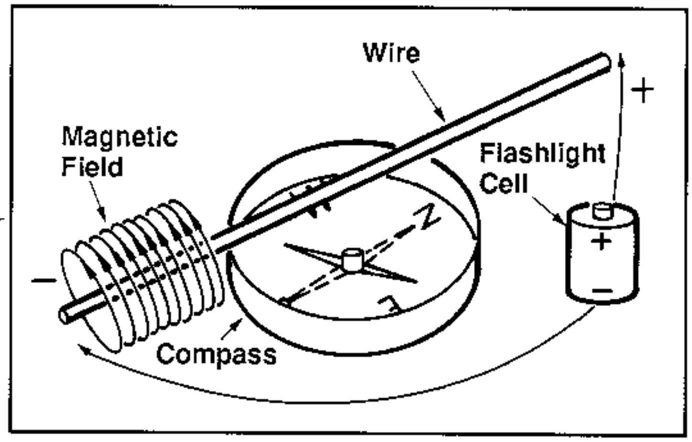
The conductor - insulator demonstration illustrates two other important points:

1. An immobile static charge flows through a conductor as an **electrical current**. It then resumes its static state on the electroscope foil leaves.

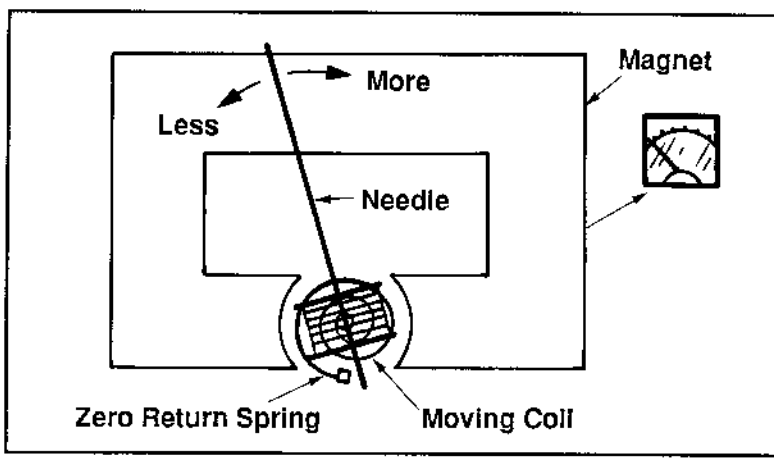


2. Electrical current flows from a region of high charge or **potential** to a region of low potential.

- ❑ **The Magnetic Connection** - A current flowing through a wire creates a **magnetic field** around the wire. You cannot see the field, but you can observe its effect. Orient a compass so its needle points to the north (N) mark. Place a copper wire over and parallel to the needle. Then connect a flashlight cell across the wire and the needle will move away from its north-south orientation. (Leave the wire connected for only an instant to prevent the cell from overheating.)




- ❑ **Measure Current Electricity** - The physical (or mechanical) motion of a magnetic compass needle in a magnetic field provides a convenient way to measure the quantity of current flowing in a wire. This is the basis of the **moving coil current meter** used in the analog multimeter. To provide high sensitivity, the wire is wrapped as a coil.




## Direct Current Electricity

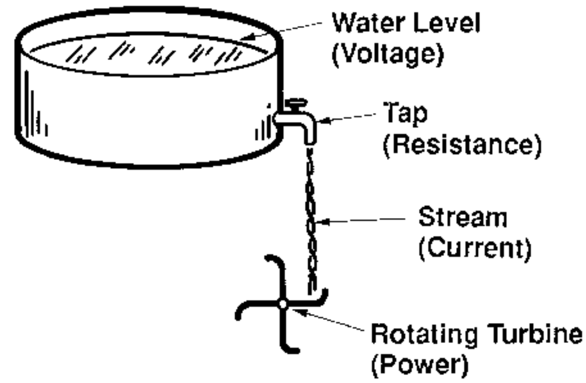
An electrical current can flow in either of two directions through a conductor. If it flows in only one direction, whether steadily or in pulses, it's called **direct current** (DC). It's important to be able to specify the quantity and power of a direct current. Here are the key terms:

- ❑ **Current (I)** - Current is the quantity of electrons passing a given point. The unit of current is the **ampere.** One ampere is 6,250,000,000,000,000,000 ($6.25 \times 10^{18}$) electrons passing a point in one second.
- ❑ **Voltage (V or E)** - Voltage is electrical pressure or force. Voltage is sometimes referred to as **potential. Voltage Drop** is the difference in voltage between the two ends of a conductor through which current is flowing. If we compare current to water flowing through a pipe, then voltage is the water pressure.

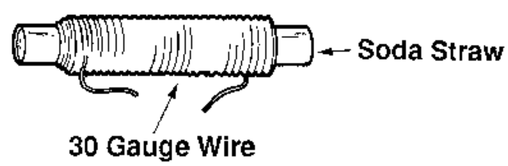
- **Power (P)** - The work performed by an electrical current is called power. The unit of power is the **Watt.** The power of a direct current is its voltage times its current. 1Watt = 1 Volt Amp.
- **Resistance (R)** - Conductors are not perfect. They resist to some degree the flow of current. The unit of resistance is the **Ohm** (Ω). A potential difference of one volt will force a current of one Ampere through a resistance of one Ohm. The resistance of a conductor is its voltage drop divided by the current flowing through the conductor.
- **Mr. Ohm's Law** - Given any two of the above, you can find the other two using these formulas known as **Ohm's Law**:

$$V = I \times R$$
$$I = V / R$$
$$R = V / I$$
$$P = V \times I \text{ (or) } I^2 \times R$$

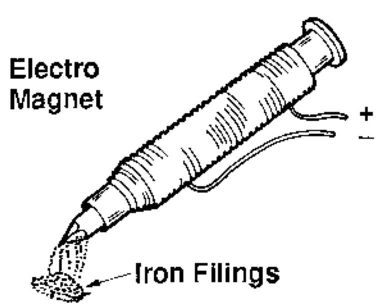
- **Summing Up** - This is the "Water Analogy":




There are so many uses for direct current electricity. Here's a page of several uses designed around a single wire coil you can easily make from a 1-1/2 to 3 inch section of a soda straw and at least 30 feet of 30 gauge, lacquer coated wire. Secure the coil in place with tape. Remove insulation from ends of coil with fine sand paper.

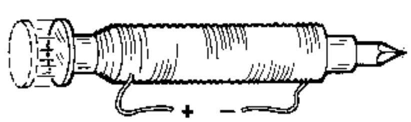



- **Electromagnet -** Insert a steel nail in the coil, connect the leads to a 9-volt battery, and the nail will become a magnet until the power is disconnected. (It may retain some magnetism.)

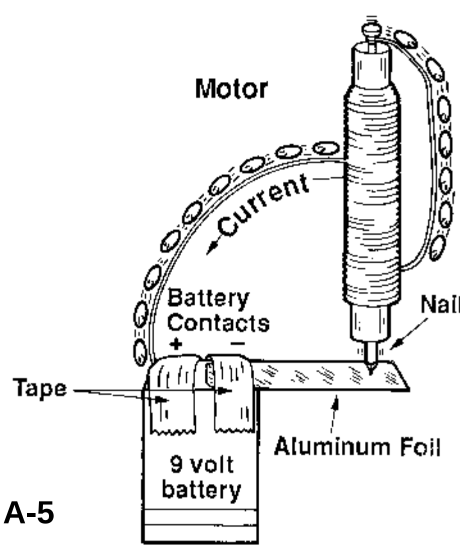



- **Solenoid** - This is a "sucking magnet". Apply power to coil and nail will be pulled rapidly inside.

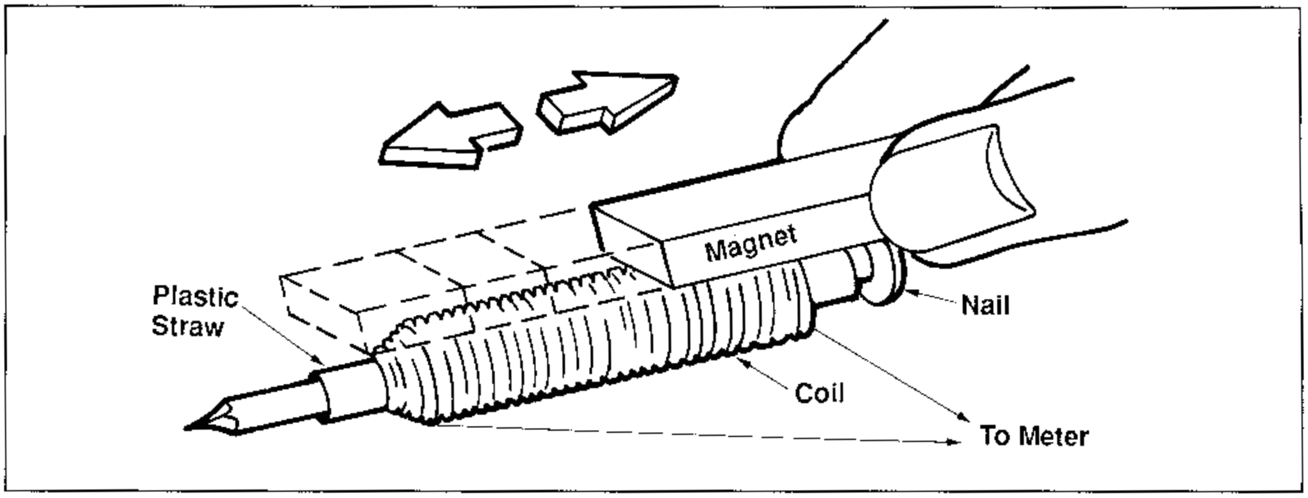
Solenoid



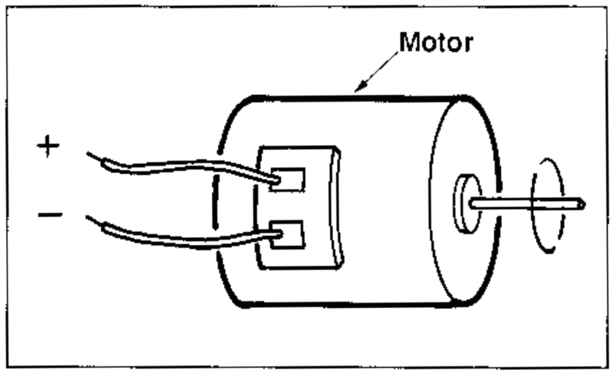

- **Motor** - A machine that converts electrical energy into mechanical energy by using the forces exerted by magnetic fields that are produced by current flow through a conductor. Use a *light weight* nail and adjust height of coil until nail jumps up and down!



- ☐ **Electromagnetic Generators** - A current flowing through a conductor establishes a magnetic field around the conductor. This effect works both ways so that a current will flow in a field. You can easily demonstrate electromagnetic current generation with a coil of wire and a small magnet. (The coil shown on page 11 works fine.) Connect the leads of the coil to a

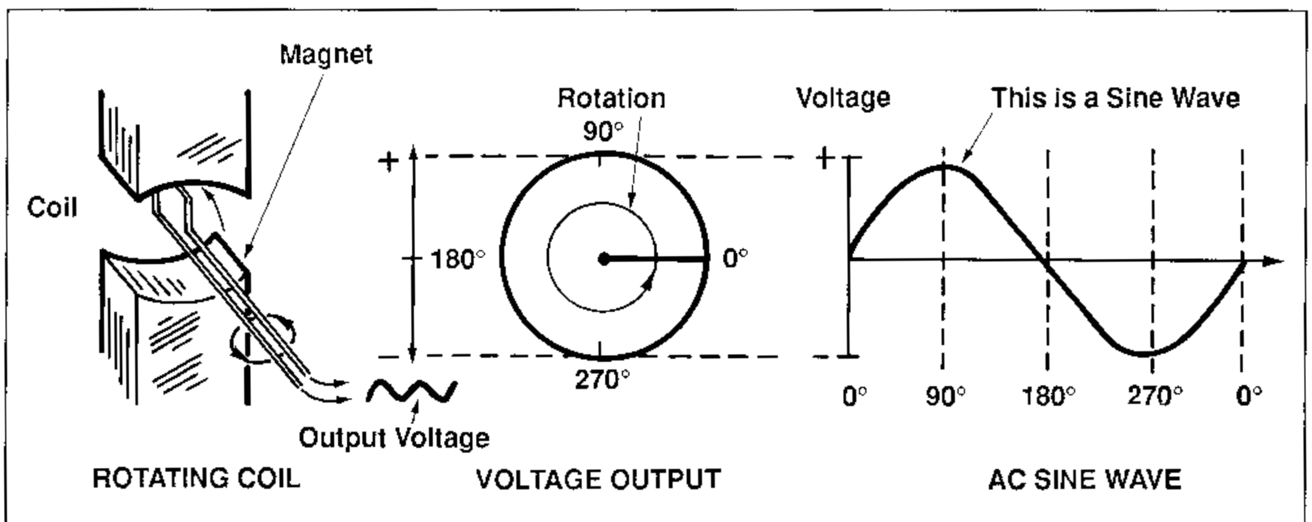



meter designed to sense microamperes. Insert a steel nail through the coil and stroke the magnet back and forth across the coil. The meter will indicate a few microamperes each stroke. The polarity (direction) of the current will **reverse** on the back strokes. Want a ready-made generator? Just rotate the shaft of a small DC motor. Most such motors will product potential difference of up to several volts! You can add a propeller to make a wind powered generator.

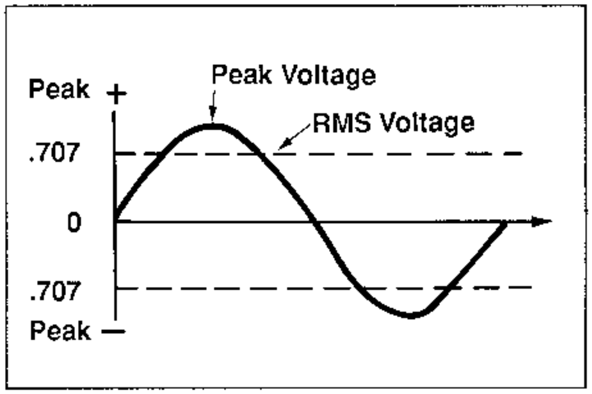



## Alternating Current Electricity

Look back at the home made coil and magnet "generator". When the magnet is stroked in one direction along the coil, electrons in the wire are moved in one direction and a **direct current** is produced. On the back stroke, unless the magnet is moved away from the coil, the direction of current flow is reversed. Therefore, if the magnet is stroked back and forth along the coil, a current which alternates in direction or **polarity** is produced. It's called an **alternating current**. Alternating current (AC) is usually produced by rotating a coil in a magnetic field.

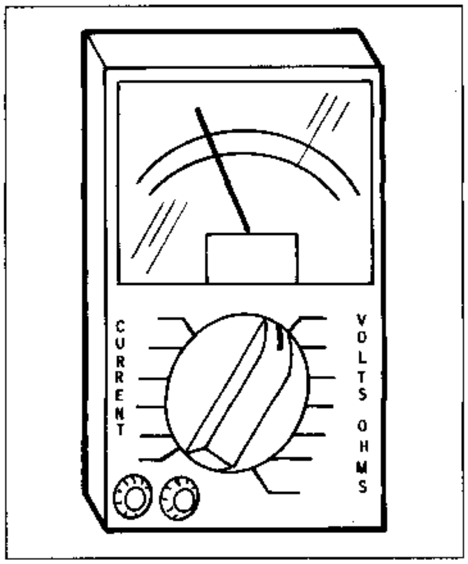


- **Sine Wave Measurement** - AC voltage is usually specified at a value equal to the DC voltage capable of doing the same work. For a sine wave this value is 0.707 times the peak voltage. It's called the **RMS** (Root-Mean-Square) voltage. The peak voltage (or current) is 1.41 times the RMS value. Household line voltage is specified according to its RMS value. Therefore, a household voltage of 120 volts corresponds to a peak voltage of 120 x 1.41 or 169.2 volts.

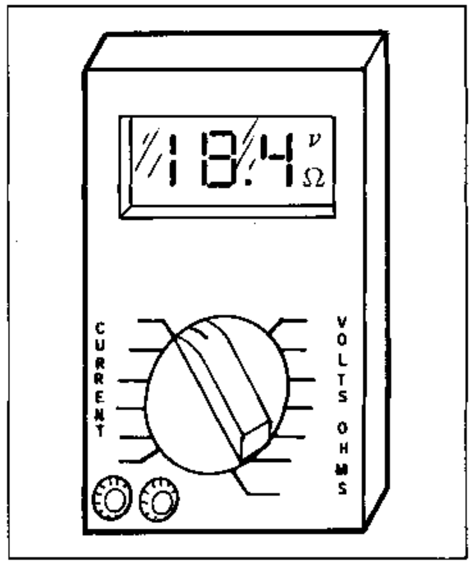





- **Why AC Is Used** - AC is better suited than DC for transmission through long distance power lines. A wire carrying AC will induce a current in a nearby wire. This is the principle behind the **transformer.**




You can easily measure AC and DC voltage and current with an instrument called the **multimeter**. Analog multimeters use a moving coil meter. Digital multimeters have a digital readout. The multimeter is the single most important electronic test instrument.



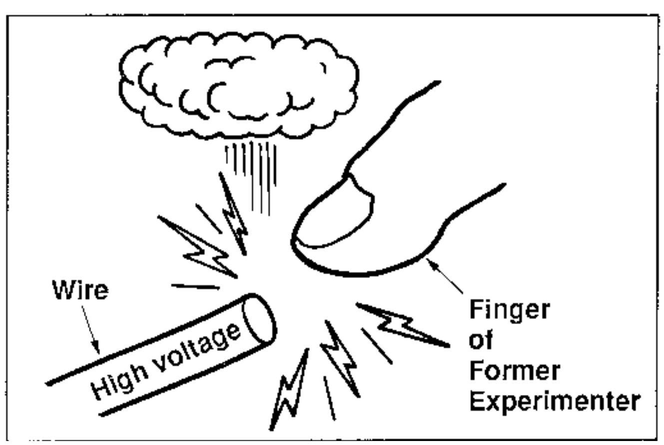

- **Analog Multimeter** - Less expensive, somewhat less precise than digital types. Best by far for observing the **trend** of a slowly changing voltage, current or resistance.

- **Digital Multimeter** - Highly accurate and easier to read than analog types. Best for finding the precise value of a voltage, current or resistance.

- **Summing Up Multimeters** - They're indispensable! Even if you have only a passing interest you should consider buying one because it has many uses in the home, on the job and when working with appliances and motor vehicles. If you're serious about electronics, consider buying a quality **high-impedance** multimeter that will have little or no effect on the device or circuit you're measuring. Ideally, you should have both the analog and digital types.

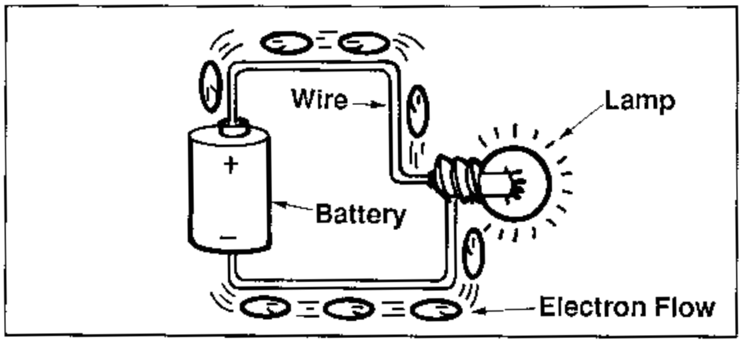
## Electrical Safety

**Electricity can kill!** If you want to be around long enough to enjoy experimenting with electronics, **always** treat electricity with the respect it deserves.

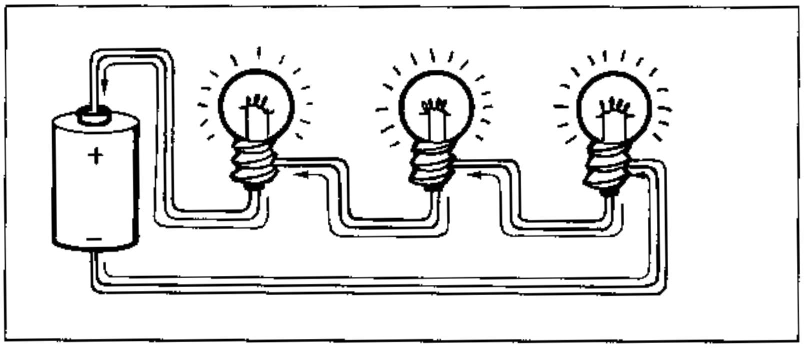


## Electrical Circuits

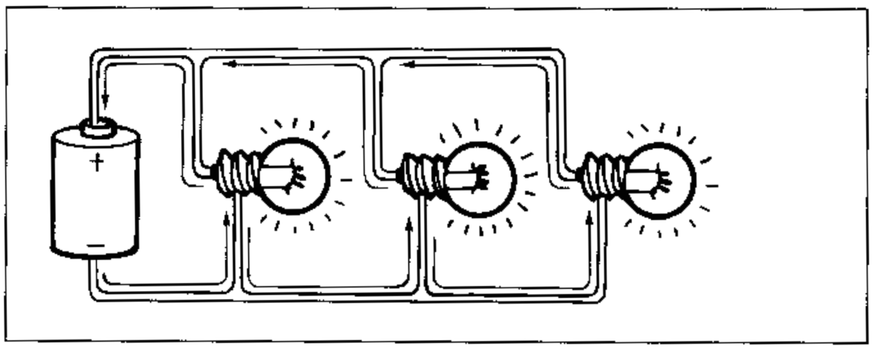
An **electrical circuit** is any arrangement that permits an electrical current to flow. A circuit can be as simple as a battery connected to a lamp or as complicated as a digital computer.



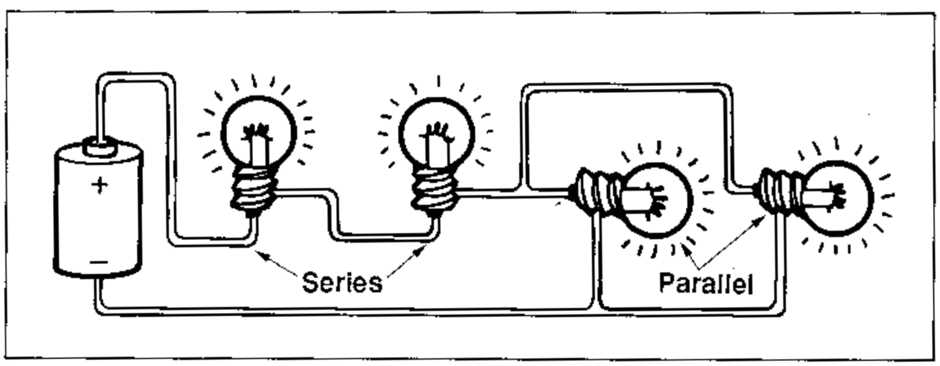

❑ **A Basic Circuit** - This basic circuit consists of a source of electrical current (a battery), a lamp and two connection wires. The part of a circuit which performs work is called the **load**. Here the load is the lamp. In other circuits the load can be a motor, a heating element, an electromagnet, etc.



❑ **A Series Circuit** - A circuit may include more than one **component** (switch, lamp, motor, etc.). A **series circuit** is formed when current flowing through one component first flows through another. (Arrows show direction of electron flow.)



❑ **A Parallel Circuit** - A **parallel circuit** is formed when two or more components are connected so current can flow through one component without having first to flow through another.

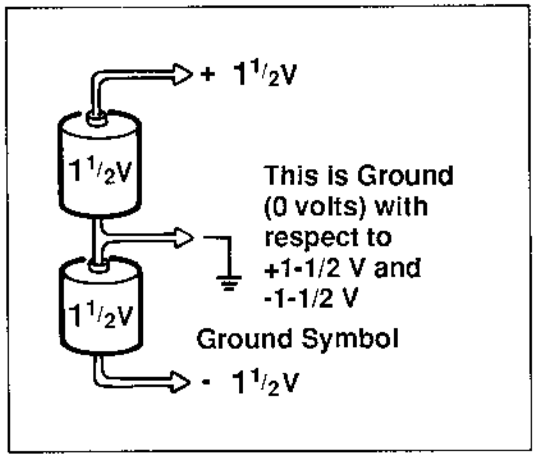



❑ **A Series - Parallel Circuit** - Many electrical circuits are both series **and** parallel. **All** provide a complete path between the circuit and its power supply.

❑ **Electrical "Short Circuit"** - When a wire or other conductor is placed across the connections of a component, some or all of any current in the circuit may take a **shortcut** through the conductor. "Short" circuits such as this are usually undesirable at best. They can cause batteries to rapidly lose their capacity. And they can cause damage to wiring and components. "Short" circuits can even cause enough heat to ignite the insulation on a wire!

**WARNING: The human body conducts electricity. Therefore, carelessly touching an electrical circuit may cause a "short" circuit. If the voltage and current are high enough, you may receive a dangerous or even lethal shock.**

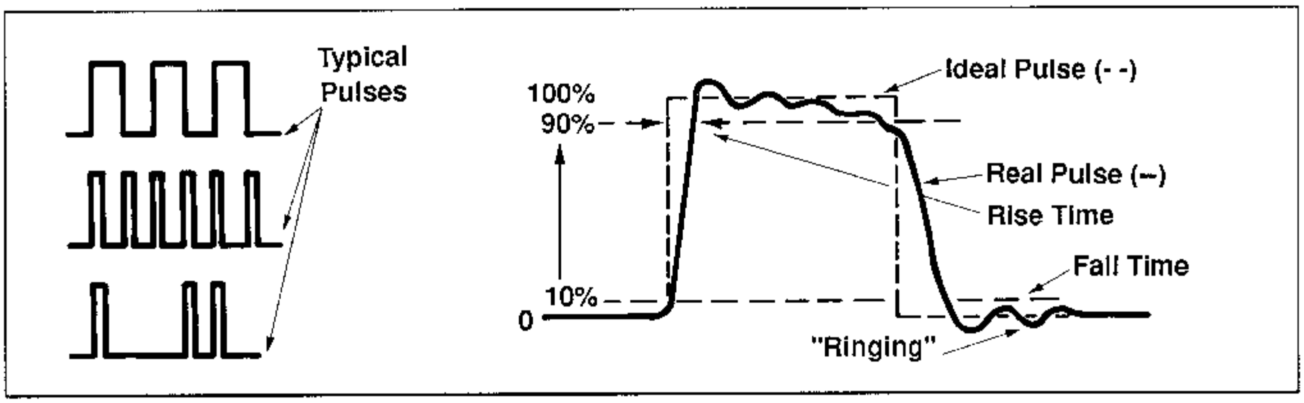
- **Electrical "Ground"** - One of the wires of the AC line is connected to earth by a metal rod. Metal enclosures of electrically powered devices are connected to this **ground** wire. This prevents a shock hazard should a non-grounded wire make contact with the metal enclosure. Without the ground connection, a person touching the device while standing on the ground or a wet floor might receive a dangerous shock. **Ground** also refers to the point in a circuit at **zero** voltage, whether or not it's connected to ground. For instance, the minus (-) side of the battery in the circuits above and on the preceding page can be considered ground.



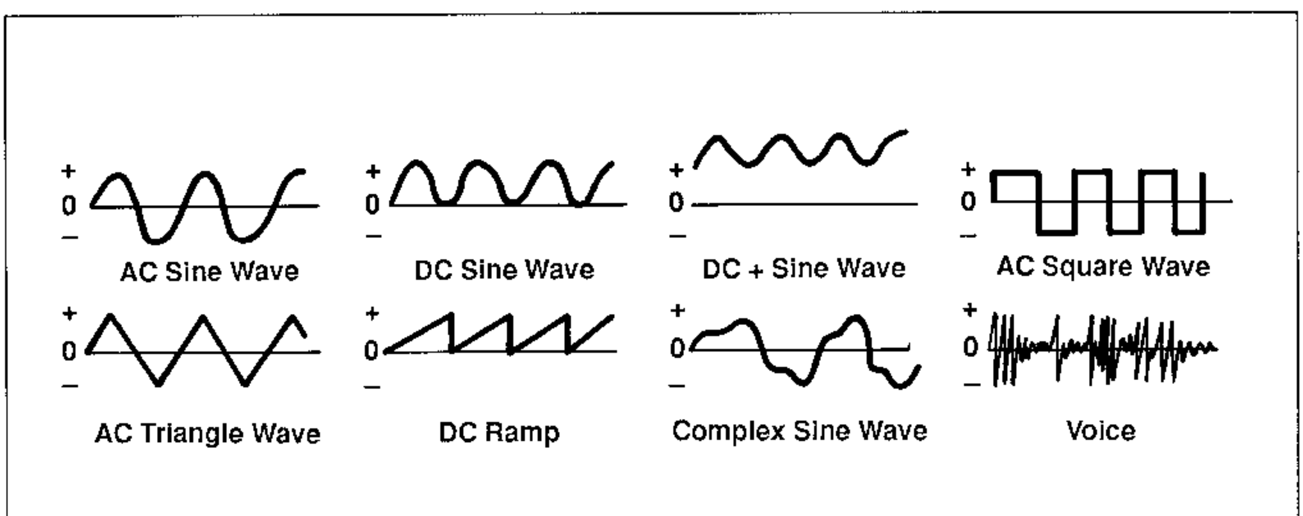

## Pulses, Waves, Signals and Noise

**Electronics** is the study and application of electrons, their behavior and their effects. The simplest applications for electrons are straightforward AC and DC circuits in which a current is used to power lamps, electromagnets, motors, solenoids and similar devices. What takes electronics far beyond these basic applications is the ease with which streams of electrons can be **controlled** and **manipulated.**

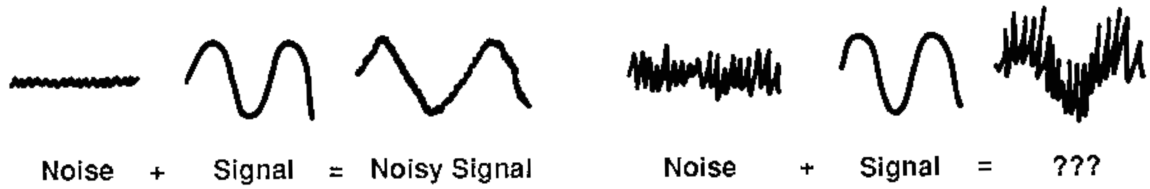
- **Pulses** - A pulse is a sudden, brief increase or decrease in a current flow. The ideal pulse would have an instantaneous rise and fall, but real pulses are not so ideal.




- **Waves** - A wave is a periodic fluctuation in a current or voltage. Waves may have a single polarity (DC) or both positive and negative components (AC). There are **many** kinds of waves. Here are a few:

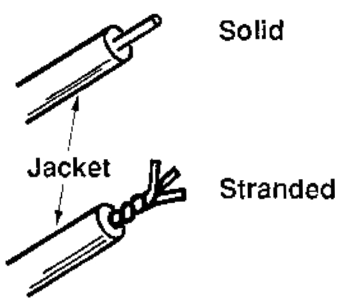


- **Signals** - A signal is a periodic waveform that conveys information. The process that generates the waveform is called **modulation**. Signals can be AC, DC or AC riding on a DC level. Their enemy is . . .
- **Noise** - **All** electronic devices and circuits generate small, random electrical currents. When these currents are unwanted, they're called **noise**. Noise can also enter electronic circuits by means of the electromagnetic waves generated by lightning, automobile ignition systems, electric motors and power lines. While noise may have a level of only a few millionths of a volt or ampere, it may easily obscure an equally low level signal.




## Wire and Cable

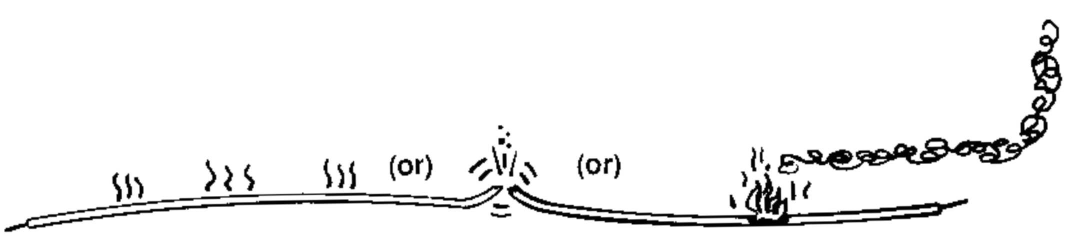
Used to carry an electrical current, most wire is made from a low resistance metal like copper. Solid wire is a single conductor. Stranded wire is two or more twisted or braided bare conductors. Most wire is protected by an insulating covering of plastic, rubber or lacquer.




| Gauge | Diameter (Inches) | Feet/Pound | Feet/Ohm |
|---|---|---|---|
| 15 | .05082 | 127.9 | 249.00 |
| 18 | .04030 | 203.4 | 156.50 |
| 20 | .03196 | 323.4 | 98.50 |
| 22 | .02535 | 514.2 | 61.96 |
| 24 | .02010 | 817.7 | 38.96 |
| 26 | .01594 | 1300.0 | 24.50 |
| 28 | .01264 | 2067.0 | 15.41 |
| 30 | .01003 | 3287.0 | 9.69 |

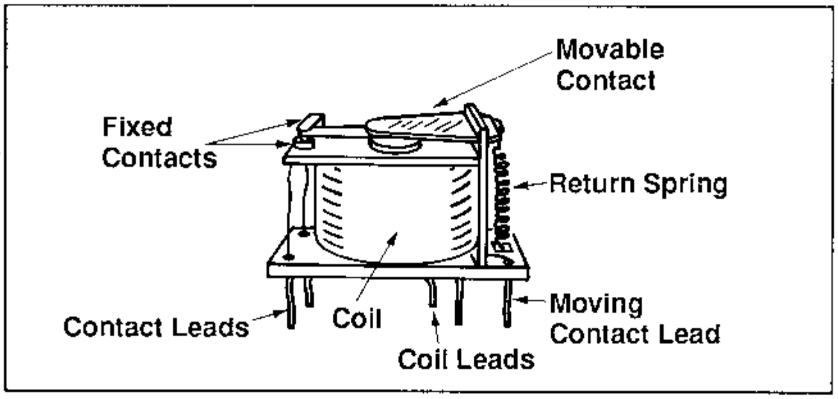
Cables have one or more conductors and more insulation than ordinary wire. Coaxial cable can carry high frequency signals (like television).

- **Caution!** - Always use wire rated for the current it is to carry. If a wire is hot to the touch, it's carrying too much current. Use a heavier gauge wire or reduce the current, otherwise:

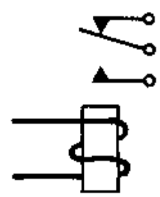


## Relays

A relay is an electromagnetic switch. A small current flowing through a coil in the relay creates a magnetic field that pulls one switch contact against or away from another.

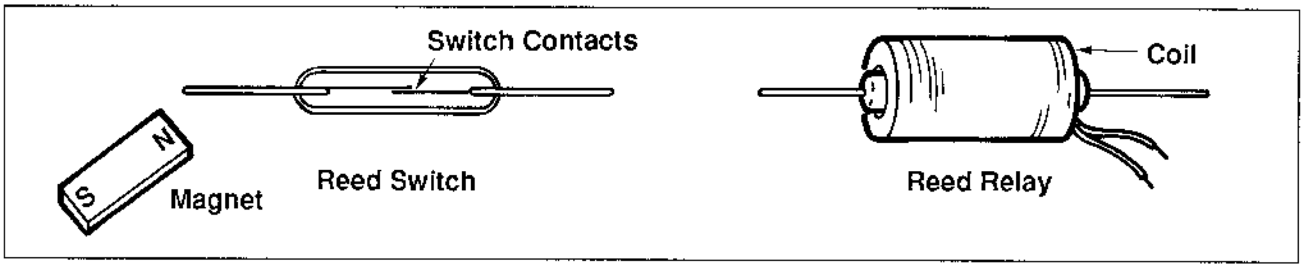



- **Relay Symbol** - The arrangement of contacts can provide SPST, SPDT, DPST, DPDT and other switch operations.



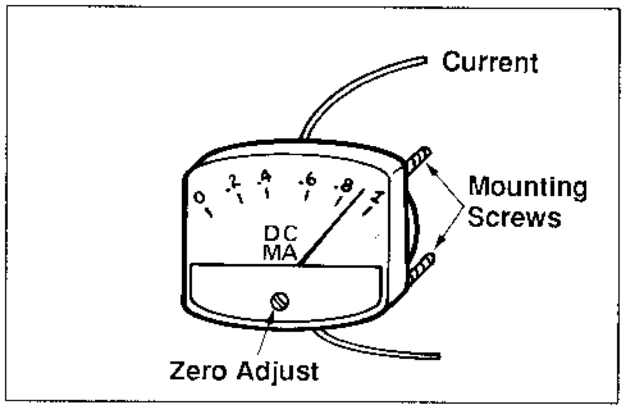
This is the symbol for a relay with spot contacts.

- **Reed Switch Relays** - An enclosed glass tube housing a pair of closely spaced switch contacts is a reed switch. A magnetic field will close the contacts. This makes possible a very simple SPST relay.




## Moving Coil Meter

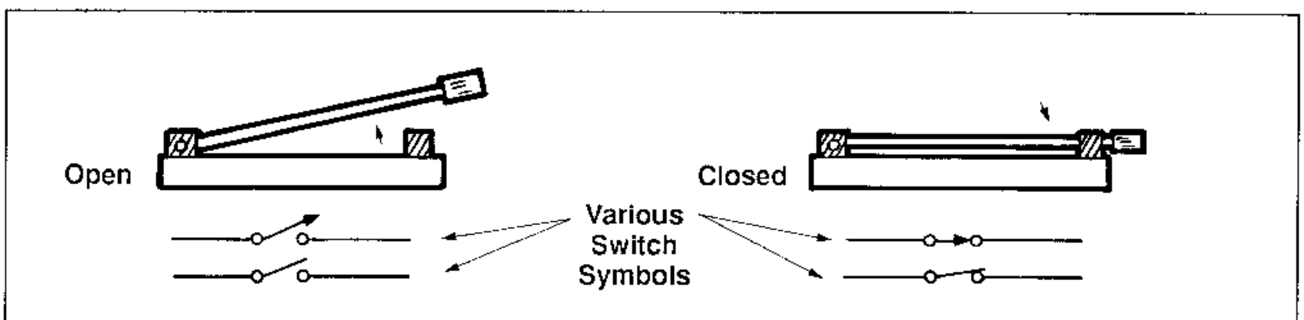
A coil on a pivot between the poles of a U-shaped magnet will rotate when a current is passed through the coil. This is the principle of the moving coil meter.




## Switches

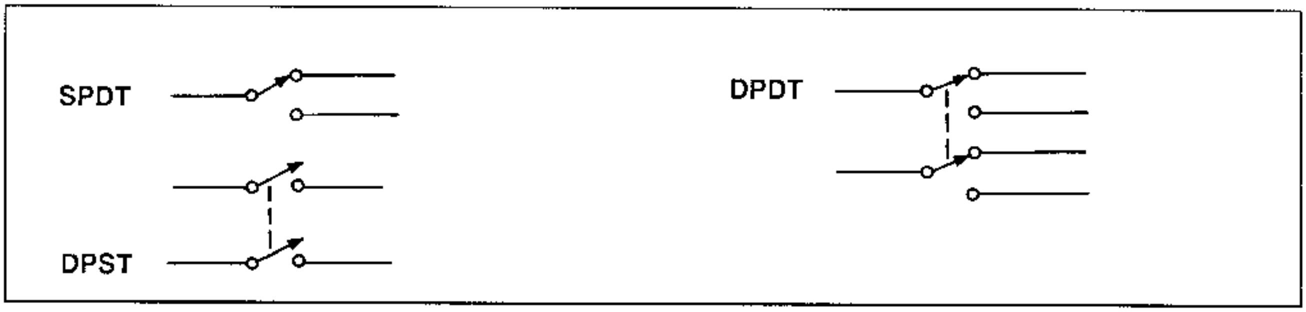
Mechanical switches permit or interrupt the flow of current. They are also used to direct current to various points.

- **The Basic Knife Switch** - The simplest switch . . .
This is called an SPST (single-pole, single-throw) switch.

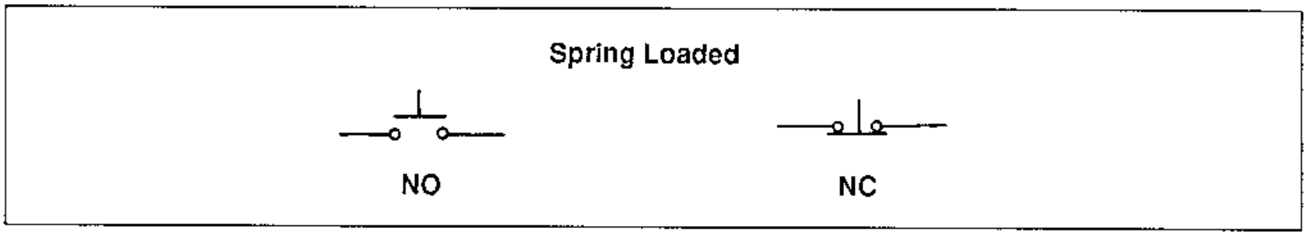


❑ **Multiple Contact Switches** - Here are symbols for the major kinds. (The dashed line means both sides move together):

SPDT - Single-Pole, Double Throw
DPST - Double-Pole, Single Throw
DPDT - Double-Pole, Double Throw




❑ **Other Switches** -
**Pushbutton.** Usually SPST, Normally Open (NO) or Normally Closed (NC).




**Rotary.** Wafer-like with one pole and 2 or more contacts. Wafers can be stacked to provide more poles. **Many** variations are possible.

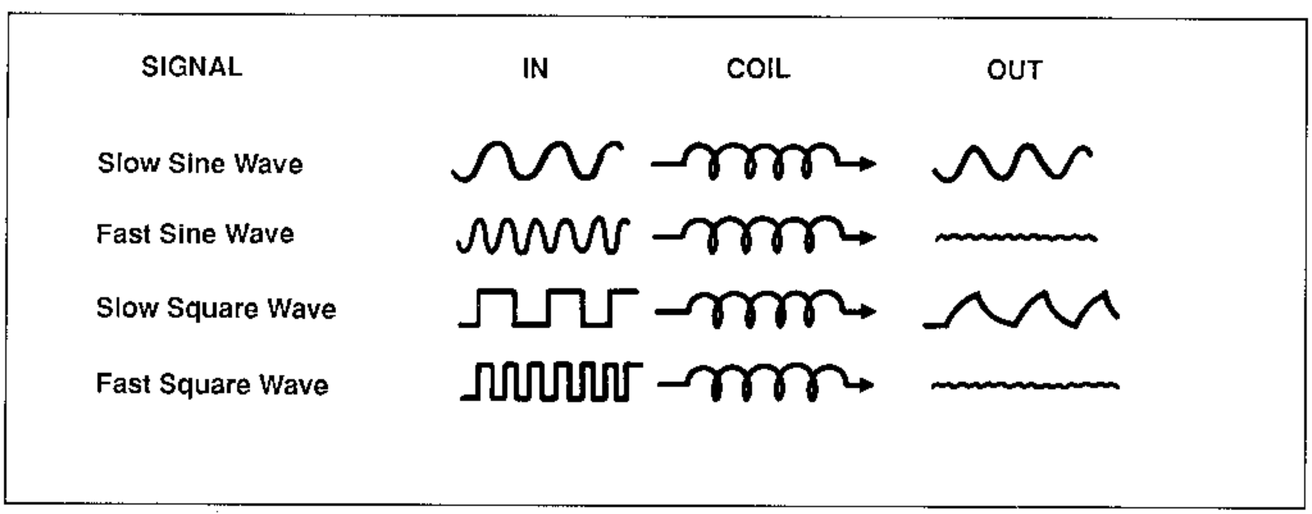
**Mercury.** Mercury blob closes switch. Position sensitive.

**Other.** Many kinds of toggle, rocker, lever, slide, push-on/push-off, illuminated and other switches are available.

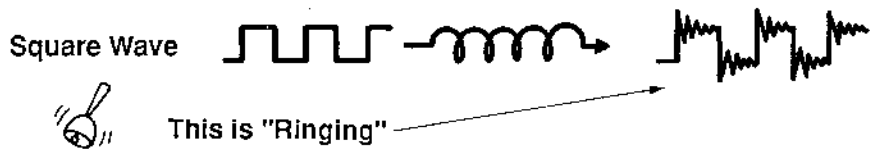
## Coils

Electrons moving through a wire cause an **electromagnetic field** to encircle the wire. As you have seen, passing a current through a wire that's been wrapped as a coil creates an even stronger field. This field makes possible solenoids, motors and electromagnets. Coils have other important roles, too:

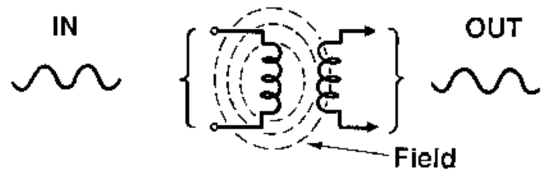
1. Coils resist **rapid** changes in the current flowing through them while freely passing steady (DC) current. Here are some examples:



Sometimes a coil will add **ringing** to a square wave passing through it. This can happen when the resistance of the external current path that connect the ends of the coil is high.



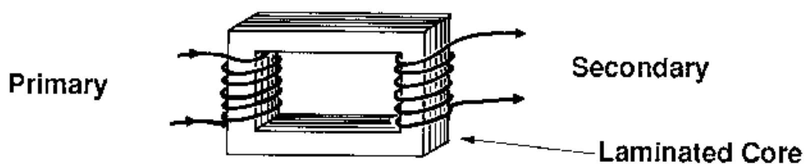

2. Some of the energy in the field around a coil can be **induced** (transferred) into a second, nearby coil. This is the principle of the **transformer**:




The input side of the transformer is called the **primary**. The output side is called the **secondary**.

## Transformers

Transformers are a major class of coils having two or more windings usually wrapped around a common core made from laminated iron sheets. Here's a simple transformer:




If the current flowing through the primary coil is fluctuating, then a current will be induced into the secondary winding. A steady (DC) current will *not* be transferred from one coil to the other.

- ❑ **How They Work** - Transformers have the ability to transform voltage and current to higher or lower levels. They do *not* of course, create power from nothing. Therefore, if a transformer boosts the voltage of a signal, it reduces its current. And if it cuts the voltage of a signal, it raises its current. In other words . . . the power flowing from a transformer *cannot* exceed the incoming power!

- ❑ **Turns Ratio** - The ratio of primary to secondary turns determines a transformer's voltage ratio . . .

 **1:1 Ratio** — The primary voltage and current are transferred unaltered to the secondary. Often called an **isolation transformer**.

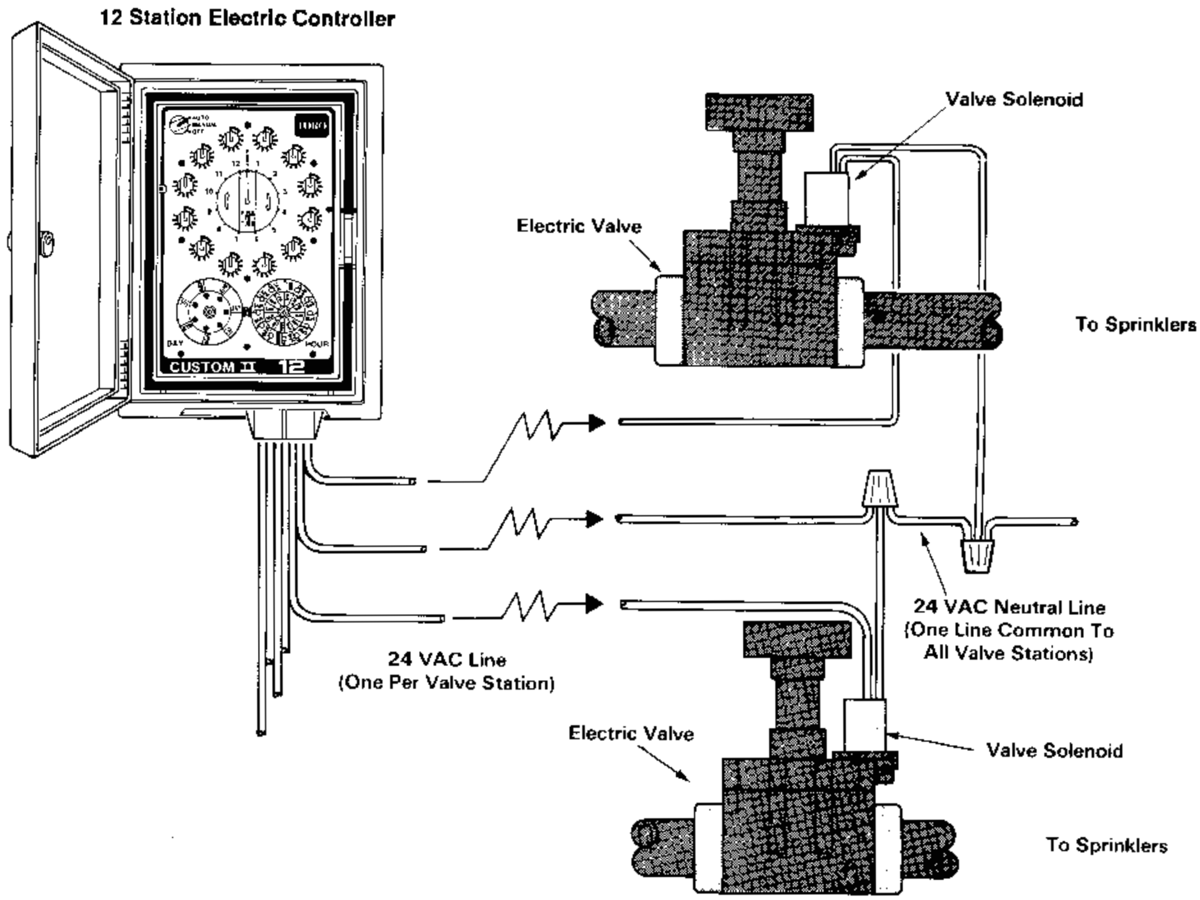
 **Step Up** — The voltage is increased by the turns ratio. Thus a 1:5 turns ratio will boost 5-volts at the primary into 25 volts at the secondary.

 **Step Down** — The voltage is reduced by the turns ratio. Thus a 5:1 turns ratio will drop 25 volts at the primary to 5 volts at the secondary

# Appendix B - Control Systems

This section contains the basic operations of electric and hydraulic control systems along with explanations of automatic valve operation. This is intended as a basic primer. Toro's "Product Application Guide, Valves and Actuators", publication 362-0046, is recommended for further detailed study.

## The Electric Control System



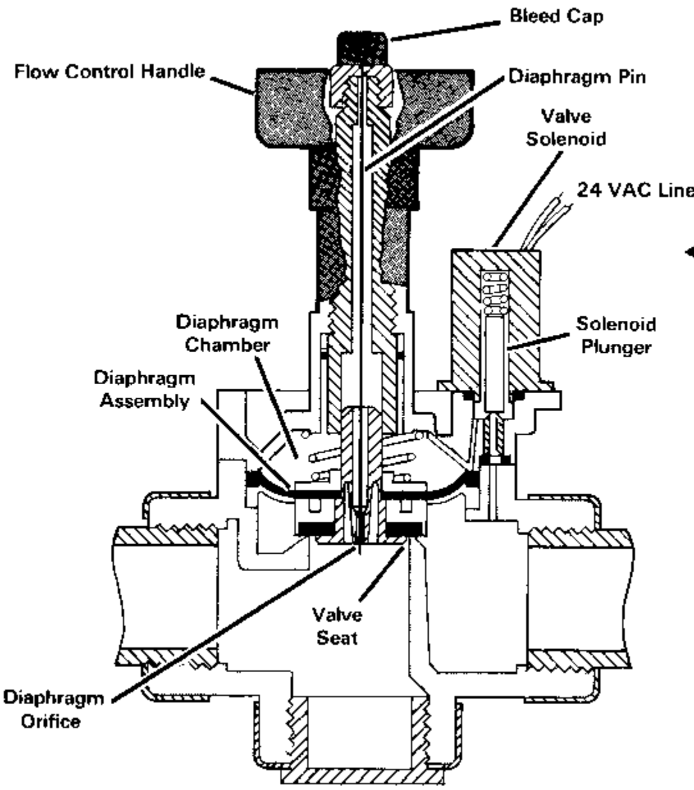

The controller sends 24 VAC to the control valve, energizing an actuation solenoid. The valve opens, allowing irrigation water to flow to the sprinklers. The valve will remain open until the controller discontinues its 24 VAC output.

### *Wire Size Note*

*Valve wire size is very important in an electric control system and must be correct to insure proper valve operation. If undersize wire is used on long runs between the controller and the valve, actuator or valve-in-head sprinkler, a voltage drop will occur causing erratic operation. To avoid this problem, refer to wire sizing charts found in the Toro Technical Data Manual (Form No. 490-1737) or Appendix III. Proper wire connections are also very important in an electric system. All connections must be made securely and waterproofed to prevent short circuiting.*

## Plastic Diaphragm Valve (Electric)

The electric models of Toro's plastic 250/260 Series valves are solenoid actuated and held in the normally closed position by internal water pressure. The electric valves in this Series are designed for clean water systems.



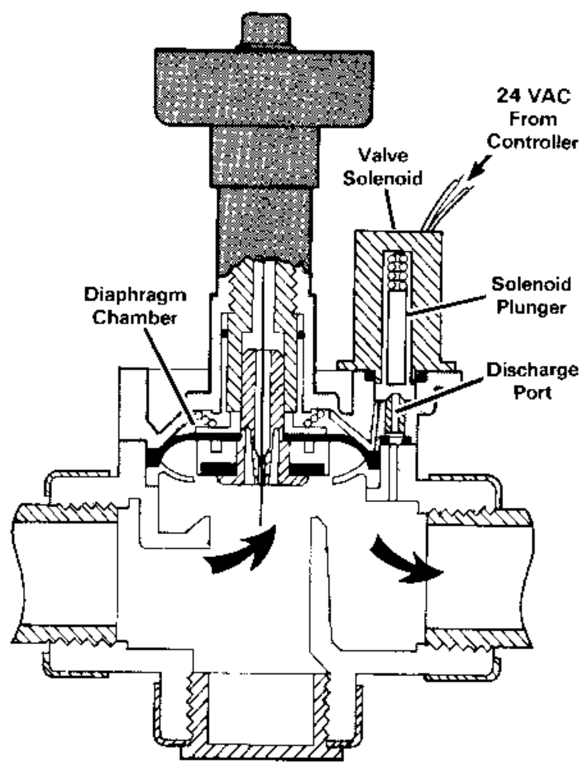

### ◀Closed Position

Irrigation water, metered through the diaphragm orifice, fills the diaphragm chamber causing internal pressure to build. The pressure exerted within the chamber holds the diaphragm assembly firmly against the valve seat preventing water flow through the valve. The diaphragm pin helps prevent debris from clogging the orifice as the diaphragm moves to open and closed positions.

Control Systems

### Open Position ▶

The valve solenoid, when activated by 24 VAC from the controller, draws the solenoid plunger away from the discharge port, relieving water pressure from the diaphragm chamber. The irrigation water pushes the diaphragm assembly away from the valve seat allowing water to flow through the valve. The valve will remain open until the controller discontinues.



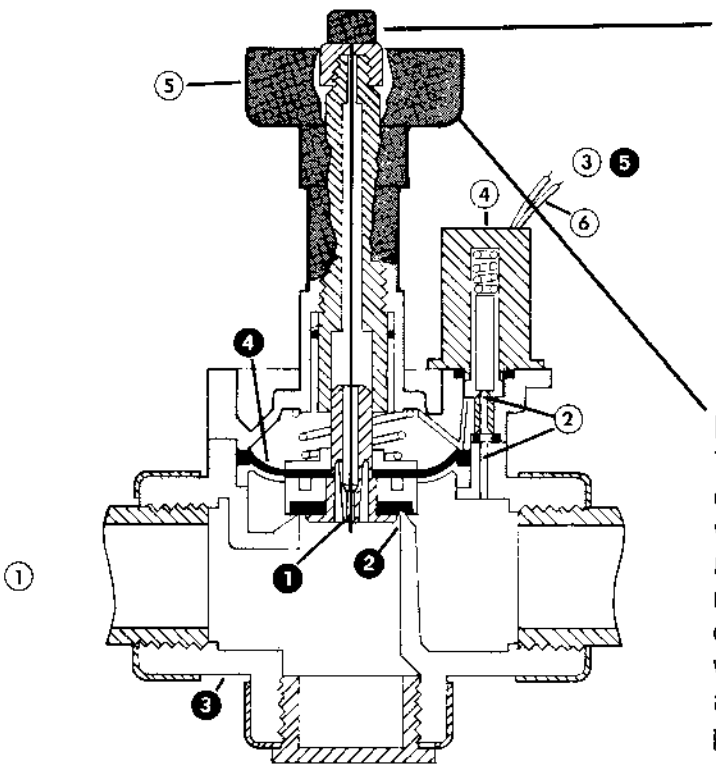
# Troubleshooting

**Valve Will Not Close ●**

1. Blocked orifice - remove debris by cleaning.
2. Debris between diaphragm assembly and seat - clean out.
3. Leak in valve body - repair or replace.
4. Damaged diaphragm assembly - replace.
5. Controller malfunction - see Controller Service Manual.

**Valve Will Not Open ○**

1. No water pressure - isolate and correct situation.
2. Plugged communication tube - clean out.
3. Controller malfunction - see Controller Service Manual.
4. Faulty solenoid - replace.
5. Flow control closed - open flow control.
6. Faulty or severed control wiring - repair wiring using an approved splicing method.




**Manual Bleed**

A manual bleed port is provided on all diaphragm valves (except Series 260) to limit water flow through the valve. **It is not a pressure regulating device.** Clockwise rotation of the handle limits travel of the diaphragm assembly away from the valve seat which restricts water flow. Full clockwise adjustment will hold the valve in the closed position.

**Flow Control**

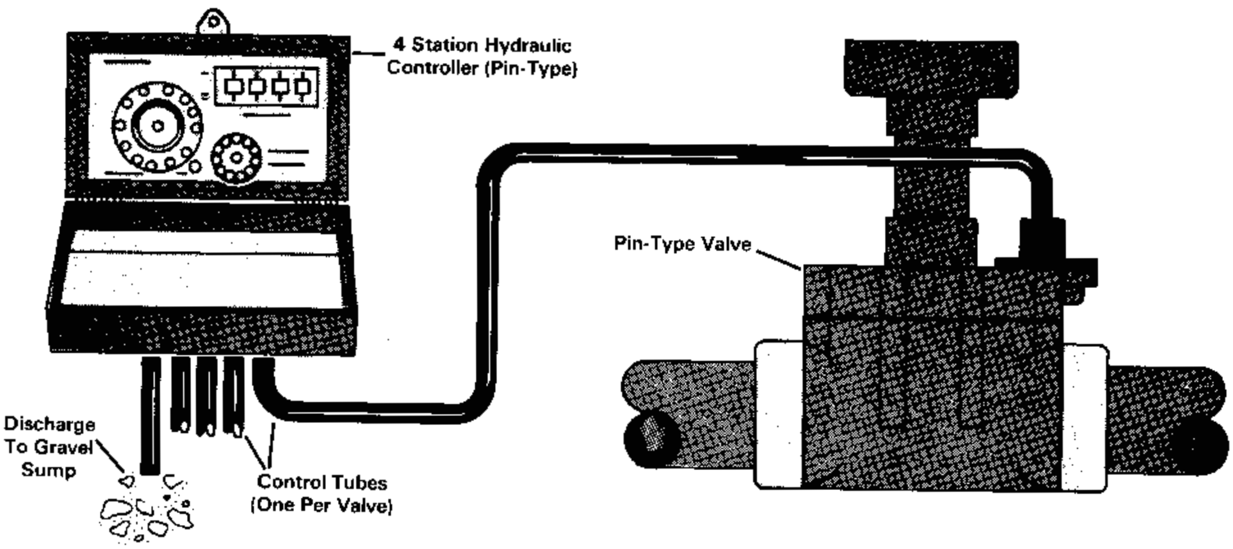
The flow control mechanism, standard on all diaphragm valves (except Series 260) is provided to limit water flow through the valve. **It is not a pressure regulating device.** Clockwise rotation of the handle limits travel of the diaphragm assembly away from the valve seat which restricts water flow. Full clockwise adjustment will hold the valve in the closed position.

***Note***

*The diaphragm orifice, used for metering supply water to the diaphragm chamber, is engineered to control a specific volume of water flow. Therefore, to prevent erratic valve operation, the orifice MUST NOT be enlarged or damaged in any way.*

## The Pin-Type Hydraulic Control System

The illustration below shows the basic Pin-Type system. Supply water fills the actuation mechanism within the valve and holds it in the closed position. A control tube, filled with water, links the valve to the controller where a selector valve is opened automatically by the controller timing mechanism, allowing water in the control tube to discharge, releasing pressure from the valve and allowing it to open.



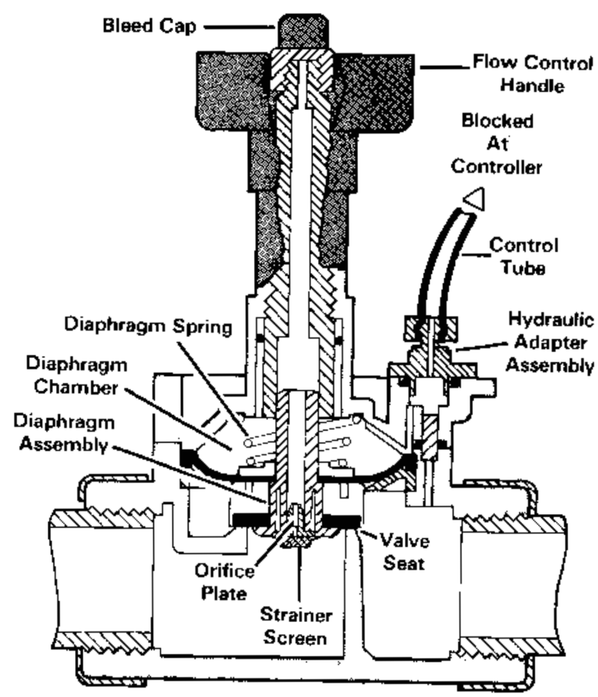

> ***Note***
>
> *To assure proper operation of Pin-Type valves, discharge water must flow with minimum restriction through the control tubing, therefore, the control tubing length between the valve and controller should not exceed 200 feet. Control tubing runs that exceed 200 feet will result in added flow restriction and may cause improper valve operation.*

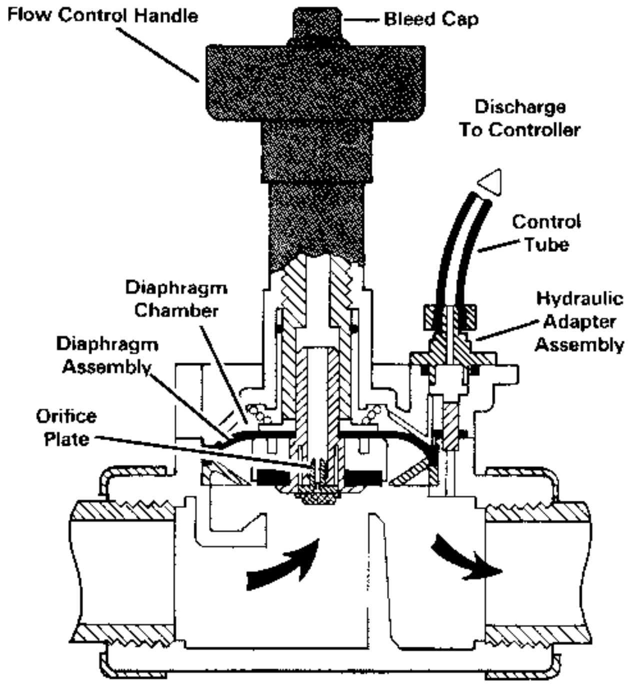
### Hydraulic Diaphragm Valve (Pin-Type)

The Series 250/260 Diaphragm Valves (Pin-Type) are hydraulically actuated and are held closed by internal water pressure. **These 250/260 Pin-Type valves are designed for clean water systems only.**

### Closed Position

Supply water, metered through the orifice plate, fills the diaphragm chamber and control tube. The controller selector valve blocks the discharge from the control tube allowing pressure to build in the control tube and diaphragm chamber. The pressure exerted within the chamber holds diaphragm assembly firmly against the valve seat, restricting water flow through the valve.






## ◀Open Position

The selector valve in the controller allows water to discharge through the control tube, relieving water pressure from the diaphragm chamber. The irrigation water pushes the diaphragm assembly away from the valve seat allowing water to flow through the valve. The valve will remain open until the selector valve blocks the discharge water metered through the control tube.

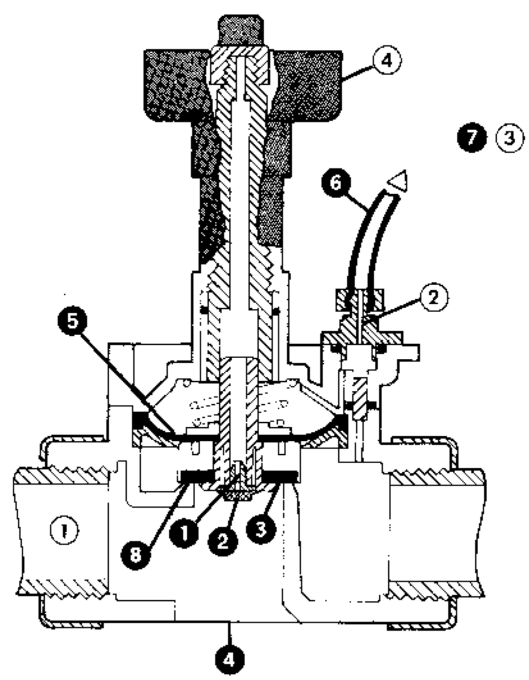
## Troubleshooting

### Valve Will Not Close ●

1. Blocked orifice plate - remove debris by cleaning.
2. Strainer screen blocked - flush out.
3. Debris between diaphragm assembly and valve seat - flush out.
4. Leak in valve body - repair or replace.
5. Damaged diaphragm assembly - repair or replace.
6. Control tube leak - isolate and repair or replace.
7. Controller selector malfunction - see Controller Service Manual.
8. Damaged valve seat - replace valve body.

### Valve Will Not Open ○

1. No water pressure - isolate and correct situation.
2. Hydraulic adapter assembly plugged - clean out.
3. Controller selector malfunction - see Controller Service Manual.
4. Flow control closed - open flow control.

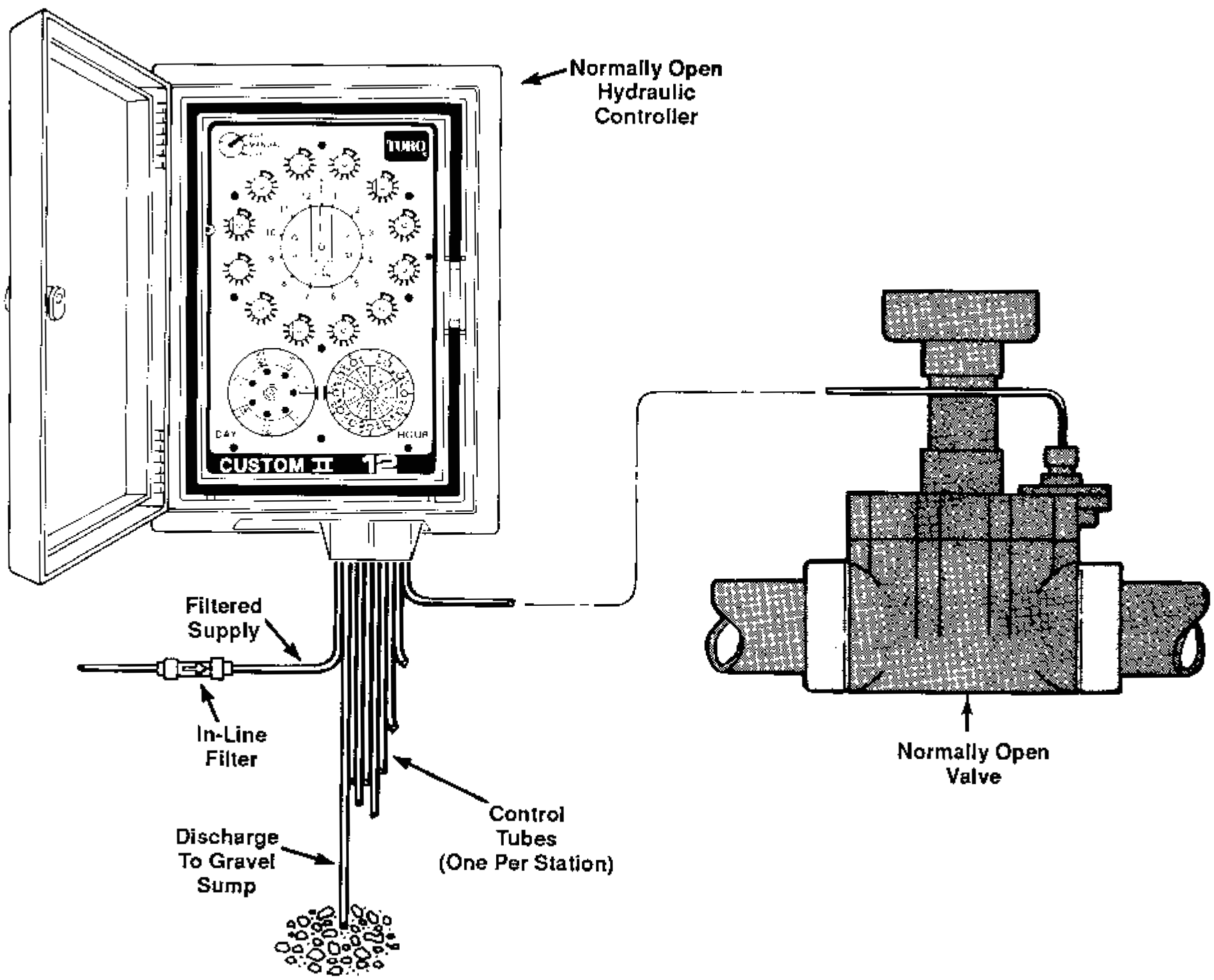


# Normally Open Hydraulic Control System

The illustration below shows the basic components of a Normally Open control system. The controller supplies and discharges filtered water to and from the valve diaphragm/piston chamber for operation. **The Normally Open Valve diaphragm/piston chamber is isolated from the irrigation water and receives only filtered water from the controller, which enables this valve to be used in dirty water systems.**

> ***Note***
> *For proper valve operation, the filtered water supplied to the controller must be obtained from the highest pressure point in the system, usually at the source or pump station.*



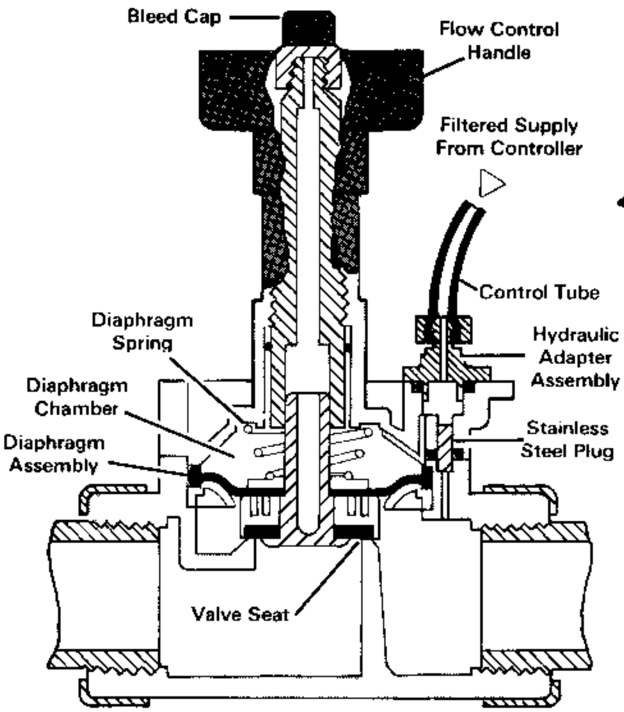



> ***Normally Open Control Tube Note***
> *In Normally Open valve systems, control tube length between the valve and controller is not as critical as in Pin-Type systems. Only the amount of water requried to open and close the valve is moved through the tube. The recommended maximum tubing length is 1,000 feet. Tubing length over 1,000 feet may cause erratic valve operation.*

# Normally Open Hydraulic Diaphragm Valve

The Series 250/260 Hydraulic Diaphragm Valve (Normally Open) is hydraulically actuated and held closed by a filtered external water source. **It is designed for use in dirty water systems.**

> ***Note***
> *Filtered water pressure from the controller must be equal to or greater than the supply water pressure to the valve.*

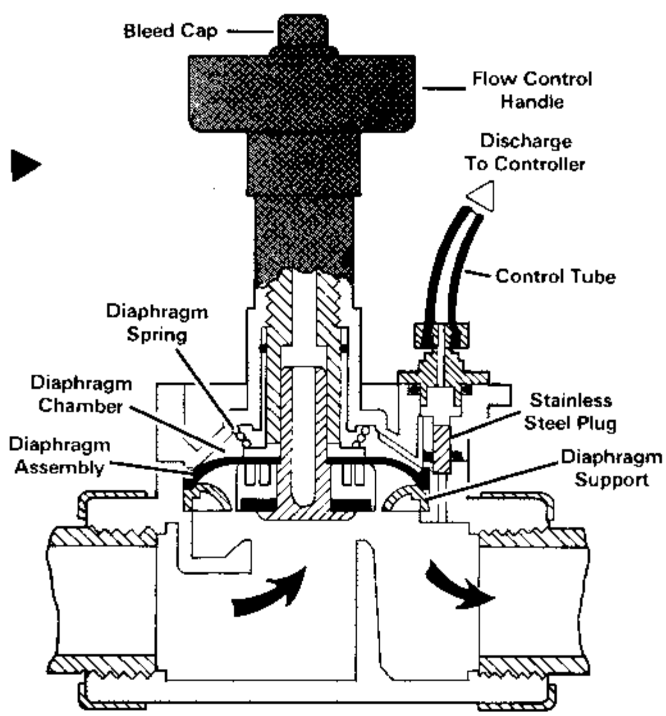



## ◀ Closed Position

Filtered water from the controller fills and pressurizes the diaphragm assembly firmly against the valve seat, restricting water flow through the valve.

## Open Position ▶

The selector valve in the controller opens and allows water to discharge through the control tube, relieving water pressure from the diaphragm assembly away from the valve seat allowing water to flow through the valve.



## Troubleshooting

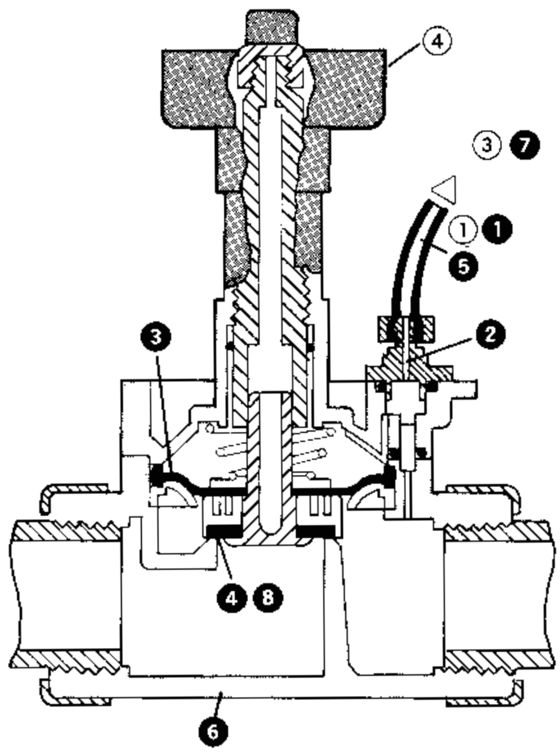
### Valve Will Not Close ●

1. Leak in control tube - isolate and repair or replace.
2. Blocked hydraulic adapter assembly - clean out.
3. Damaged diaphragm assembly - replace.
4. Debris between diaphragm assembly and seat - clean out.
5. Low pressure in control tube - isolate and repair.
6. Leak in valve body - repair or replace.
7. Controller selector malfunction - see Controller Service Manual.
8. Damaged valve seat - replace valve body.

### Valve Will Not Open ○

1. Blocked control tube - isolate and repair.
2. No supply water pressure - isolate and correct situation.
3. Controller selector malfunction - see Controller Service Manual.
4. Flow control closed - open flow control.

Control Systems



> ***Note***
>
> *The Series 216 Hydraulic (Normally Open) Valve has not been illustrated in open and closed positions as it operates in the same manner as the Series 250/260 (Normally Open) Valve. However, it is important to note that with their brass and stainless steel construction the Series 216 valves make an ideal choice for the most severe dirty water systems.*

# Appendix C - Controller Troubleshooting Guide

This section contains a basic troubleshooting guide for Toro hybrid-electronic controllers. This is a basic primer that is also applicable to other manufacturer's electronic controllers. Operation and service literature should be obtained from your distributor for the specific product model at your site.

**WARNING**

**MANY OF THE PROCEDURES WITHIN THIS GUIDE REQUIRE MAKING ELECTRICAL MEASUREMENTS. THESE SHOULD BE PERFORMED BY QUALIFIED PERSONNEL ADHERING TO STRICT SAFETY STANDARDS.**

## Basic Checklist

First check on the following items:

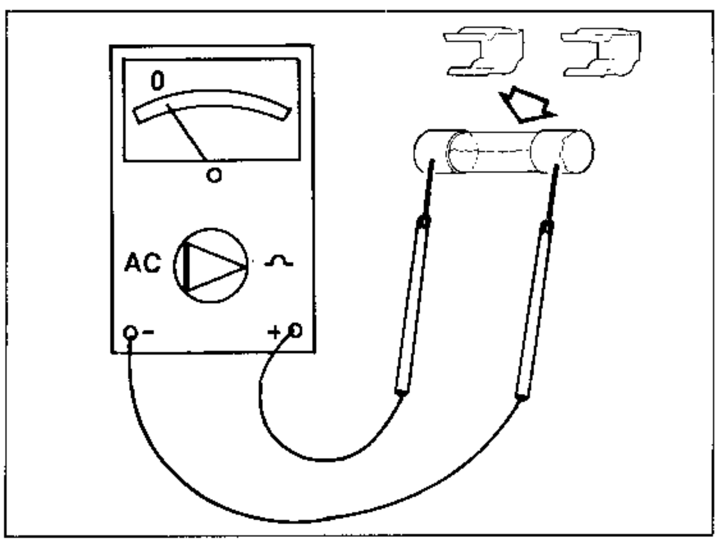
Confirm that a pressurized water supply exists. Verify that all sprinkler valve flow control knobs are open. Manually bleed the valve to insure that water is being supplied and the valve is operating correctly. Now go to the remaining Basic Checklist steps.

1. **Sprinkler System Switch Position** - Verify that the sprinkler system switch is in the "ON" position.
2. **Reset Controller** - The electronics of the controller can be reset by placing the Sprinkler System Switch in the "OFF" position for 60 seconds and then returning it to the "ON" position.
3. **Controller Program** - Check the following and refer to the Owner's Manual.
   - Hour wheel pin fully depressed for desired start time.
   - Day wheel pin depressed for desired active days and aligned with the day indicator. Pin depressed halfway activates "A" program only. Pin fully depressed activates "A" and "B" programs.
   - Station Operation Switch is set in "A" or "B" program position.
4. **Controller Fuse** - Check the condition of the controller fuse. (See Fuse Check section of this guide.)
5. **Incoming Power** - Verify that incoming power, 105 to 130 VAC, is being supplied to the controller transformer.
6. **Field Wiring Connections** - Verify that all valve wire connections are securely attached at the controller. Check for proper operation of any Rain Gauge device that may be installed.

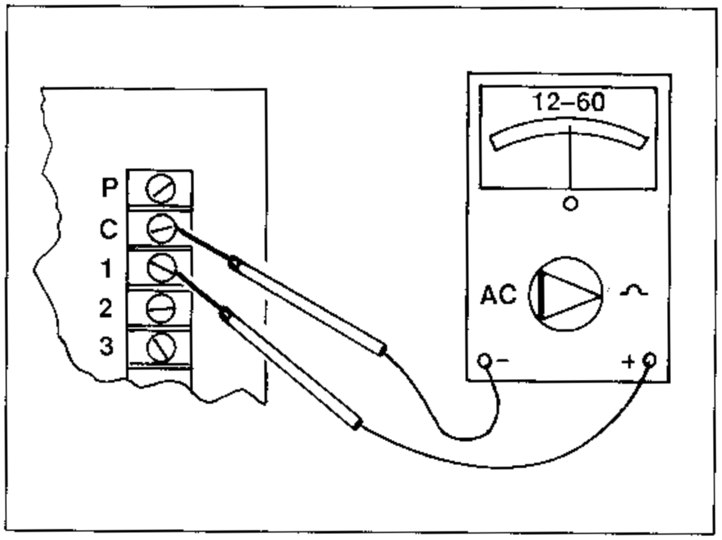
## Fuse Checks

1. Disconnect power to the controller.
2. Open controller's timing mechanism front plate and remove the fuse from the retaining clip.
3. Using an ohmmeter or continuity tester, perform the following test:

***Note:** A good fuse will indicate continuity or a zero ohms resistance reading.*



If the fuse has blown, perform the following tests prior to replacement:




1. Leave power to the controller "OFF".
2. Using an ohmmeter, place one meter lead (black) on the **Common** terminal and the other meter lead (red) on the **Station 1** terminal as shown. Note the resistance reading.
3. Move the meter lead (red) to each station terminal and the pump terminal noting the resistance of each.

   ***Note:*** *The lower the resistance the higher the amperage. If the resistance becomes low enough to allow an amperage greater than the rating of the fuse, the fuse will blow.*
4. If any station exhibits a much lower resistance than expected, (see Coil Resistance Chart) remove the station wire and investigate possible wire damage and/or defective valve coil.
5. Install a fuse into the controller.

   **CAUTION**

   **Never install a fuse with a higher rating. Controller damage and/or personal injury may result.**
6. Close the timing mechanism's front plate.

   **CAUTION**

   **The timing mechanism should be installed as protection against flying debris should an electronic component burst abruptly when power is applied.**
7. Place all Station Operation Switches and the Sprinkler System Switch into the "OFF" position.
8. Turn power to the controller "ON".
9. Place the Sprinkler System Switch "ON". If the fuse blows immediately after the sprinkler system switch is placed "ON", the controller circuit board is defective and requires replacement. If not, go on to Step 10.
10. Place each individual station operation switch into the "ON" and then "OFF" positions. Verify the correct operation of each station. If the fuse blows when a station is activated, investigate for damage to the field wiring and/or valve coil for that station and repair as required.

    ***Note:*** *Much of this procedure is applicable to circuit breakers as well.*

**Controller Troubleshooting**

## Coil Resistance Chart

The following coil resistance chart illustrates the approximate resistance expected for Toro valve coils. All resistance readings are in ohms.

***Note:*** *The values listed in this chart are for reference only!!! Actual readings will vary depending on distances of valve wiring.*

| Valve/Coil | Resistance (Ω) 1 Valve | 2 Valves |
|---|---|---|
| 3/4" and 1" Plastic (2 per station maximum) | 55 | 28 |
| 1-1/2" and 2" Plastic / All Brass - Hexagon Shaped Coil - (2 per station maximum) | 24 | 12 |
| 1-1/2" and 2" Plastic / All Brass 1980-85 - Toro Heavy Duty Coil - (1 per station maximum) | 12 | |
| 1-1/2" and 2" Plastic / All Brass pre-1980 - ITT Coil - (1 per station maximum) | 14 | |
| Large Turf Coil - (1 per station maximum) | 16 | |

***Note:*** *If the pump is used, no more than 1 valve of any type is recommended per station.*

### No Functions At All

1. Perform the "Basic Checklist" procedures.
2. With controller power "ON", open the front plate and swing out the timing mechanism.
3. Set your volt meter to read AC volts in a range above 50 VAC. Place the meter leads directly onto the output terminals of the transformer. You should read 24 VAC. If ok, go to Step 5. If not, go to Step 4.
4. Reset meter scale to 200 VAC and verify 115 VAC at the transformer input. If ok, replace transformer. If not, re-establish power source.
5. Place meter leads between the wires from the transformer at the cable connector. You should read 24 VAC. If ok, go to Step 6. If not, repair wires between the transformer and the cable connector.
6. Verify proper placement of the cable connector to the PCB (Printed Circuit Board) connector. If ok, go to Step 7. If not, reinsert cable connector properly.
7. Place meter leads between one wire from the 24 VAC transformer at the cable connector and the hot wire to the "B" program switch of the station output cable connector while it's attached to the controller PCB. You should read 24 VAC. If ok, go to Step 9. If not, go to Step 8.
8. Check all solder connections for the station output connector and power connector on the controller PCB. Repair or replace the controller PCB as required.
9. Place meter leads between one wire from the 24 VAC transformer at the cable connector and the hot wire to the "B" program switch of the station output cable connector attached to the station output PCB. You should read 24 VAC. If ok, go to Step 10. If not, replace station output cable.
10. Place meter leads between one wire from the 24 VAC transformer at the cable connector and the hot wire to start switch from the station output cable connector attached to the station output PCB. You should read 24 VAC. If ok, go to Step 11. If not, recheck the fuse. If ok, repair or replace the station output PCB. If not, see "Fuse Checks" section of this guide.
11. Place meter leads between one wire from the 24 VAC transformer at the cable connector and the hot wire to start switch from the station output cable connector attached to the controller PCB. You should read 24 VAC. If not, replace station output cable connector. If ok, check station output connector solder connections. Repair or replace controller PCB as required.

### Controller Will Not Keep Time

1. With controller power "OFF", swing out the timing mechanism. Turn controller power "ON".
2. Are the exposed hour motor gears turning? If not, go the Step 3. If ok, go to Step 4.
3. Verify the proper alignment and insertion of the cable connector to the PCB connector, then perform the following voltage checks.

   A. Place metor leads between motor input leads. You should read 24 VAC. If ok, replace motor. If not, go to Step B.
   B. Place meter leads between wires to the Day/Hour wheel motor at the cable connector. You should read 24 VAC. If ok, repair the wires between the connector and the motor. If not go to Step C.
   C. Place meter leads between wires from the 24 VAC transformer at the cable connector. You should read 24 VAC. If ok, check and repair the PCB and/or cable connector terminations. If not, go to Step D.
   D. Place meter leads between output terminals of the transformer. You should read 24 VAC. If ok, repair the wires from the transformer to the cable connector. If not, go to Step E.
   E. Change meter to AC scale above 120 VAC. Place meter leads between transformer input terminals. You should read 115 VAC. If ok, replace the transformer. If not, check the electrical power source.
4. Are there any physical restrictions to the clockwise movement of the hour wheel? If this restriction occurred at the midnight day change point, go to Step 5. If there is no restriction or if the restriction occurred other than at midnight, go to Step 6.

5. If midnight restriction occurred, check:

   A. Do the gears between the hour wheel, idler gear and day wheel mesh properly? If not, replace defective part(s). If ok, go to Step B.
   B. Does the tension of the index lever to the day wheel appear excessive? If yes, replace defective part(s) and/or adjust as necessary. If not, go to Step C.
   C. Turn the day wheel to check for any restrictions. Repair as required.

6. If no restriction other than at midnight occurred check:

   A. Does the hour wheel motor mesh properly with the drive gear? If not, replace defective part(s). If ok, go to Step B.
   B. Remove the motor and rotate the drive wheel counterclockwise. If the restriction continues, remove the drive wheel, hour wheel and ratchet components from the frame. Inspect and repair as required.

### No Automatic Starts

1. Does the controller keep time? If ok, go to Step 2. If not, see guide section "Controller Will Not Keep Time".
2. Is the controller programmed properly? Check the following, if ok, go to Step 3. If not, reprogram.
   A. Is the Sprinkler System Switch in the "ON" position?
   B. Is a pin fully depressed in the hour wheel?
   C. Does the day wheel pin line up with the day pointer?
   D. Is a pin depressed in the day wheel? A pin depressed halfway will only operate valves assigned to the "A" program.
   E. Are the Station Operation Switches in a program position ("A" or "B")?
3. With power to the controller "OFF", swing out the timing mechanism.
4. Set your volt meter to read DC Volts in a range above 10 VDC. Turn controller power "ON".
5. Verify that the micro "Start" switch button is not depressed.
6. Place one meter lead on each tab of the microswitch. You should read 4.5-5 VDC. If ok, go to Step 10. If not, go to Step 7.
7. Verify that the cable connector is properly aligned and inserted onto the PCB connector. If ok, go to Step 8. If not, realign and insert.
8. Check for 4.5-5 VDC between wires to the microswitch at the cable connector. If ok, repair the wires between the microswitch and the cable connector. If not, go to Step 9.
9. Check all connections on the PCB connector and the cable connector. If ok, replace PCB. If not, repair as required.
10. Depress a day wheel pin and align it with the day pointer. Depress an hour wheel pin and slowly rotate the hour wheel to the trip point.
11. Does the actuator link fully depress the microswitch button? If ok, go to Step 12. If not, adjust or replace defective parts.
12. With the microswitch button depressed, place the meter leads onto the microswitch tabs. Do you read 0 VDC? If ok, replace PCB. If not, replace microswitch.

## Controller Runs Multiple Cycles

The controller is capable of repeating a cycle if the manual start button is depressed more than once (see Manual Operation section of the owner's manual) or if an hour wheel pin is depressed and passes the trip point while an irrigation cycle is in progress.

If the above mentioned factors are not creating this condition please check the following:

1. Perform the "Reset" procedure. If the condition continues, go to Step 2.
2. With controller power "OFF", swing out the timing mechanism.
3. Verify that clearance exists between the manual start button and the manual start switch on the PCB. If ok, go to Step 4. If not, repair as required.
4. Place the meter leads of an ohmmeter between the tabs of the auto start microswitch and depress the microswitch button. The meter should read zero resistance. If it does, go to Step 5. If not, replace the microswitch.
5. Place the meter leads between the wires to the microswitch at the cable connector. When the microswitch button is depressed the meter should read zero resistance. If ok, replace PCB. If not, repair the wires between the cable connector and the auto start microswitch.

## Verifying Station Output Common

Prior to making any station output checks it is advisable to verify that the station output common remains intact.

1. Set your volt meter to read AC volts in a scale above 50 VAC. Swing out timing mechanism.
2. Place the meter leads directly onto the output terminals of the transformer. You should read 24 VAC. If ok, go to Step 4. If not, go to Step 3.
3. Verify 115 VAC at transformer input. Be sure to select proper scale on ohmmeter. If ok, replace transformer. If not, re-establish power source.
4. Place the meter leads between the wires from the 24 VAC transformer at the cable connector. You should read 24 VAC. If ok, go to Step 5. If not, repair the wires between the transformer and the cable connector.
5. Place the meter leads between the load wire from the 24 VAC transformer connector and the station output common. You should read 24 VAC. If ok, **common has been verified!!!** If not, go to Step 6.
6. Place the meter leads between the hot wire from the 24 VAC transformer connector and the right end of the fuse. You should read 24 VAC. If ok, repair or replace the station output PCB as required. If not, go to Step 7.
7. Place the meter leads between the hot wire from the 24 VAC transformer at the cable connector and the left end of the fuse. You should read 24 VAC. If ok, replace fuse. Ensure proper contact to fuse clip. If not, go to Step 8.
8. Place the meter leads between the hot wire from the 24 VAC transformer at the cable connector and the load wire to the "B" program switch at the station output cable connector attached to the station output PCB. You should read 24 VAC. If ok, repair or replace station output PCB as required. If not, go to Step 9.
9. Place the meter leads between the hot wire from the 24 VAC transformer at connector and the hot wire to the "B" program switch at the station output PCB attached to the controller PCB. You should read 24 VAC. If ok, replace station output cable. If not, go to Step 10.
10. Check all solder connections for the station output cable connector and the power cable connector. Repair or replace the controller PCB as required.

## No Station Output

1. Perform all "Basic Checklist" and "Verifying Station Output Common" tests.
2. With controller power "OFF", swing out the timing mechanism.
3. Verify proper placement of all valve wires and common.
4. With an ohmmeter, verify proper valve coil resistance for each station. See "Fuse Checks" and the "Coil Resistance Chart". A very high resistance reading indicates a broken or disconnected wire or a defective valve coil.
5. Set volt meter to read AC volts in a range above 50 VAC. Turn controller power "ON".
6. Place the Station 1 Operation Switch into the "MAN" position. Place the meter leads between common and the Station 1 output terminal. You should read 24 VAC. If ok, repeat for all stations. If all stations are ok, reconfirm wiring and valve operation. If not, go to Step 7.
7. Place the meter leads between common and the station one position of the station output cable connector attached to the station output PCB. You should read 24 VAC. If ok, repair or replace the station output PCB. If not, go to Step 8.
8. Place the meter leads between common and the station one position of the station output cable connector attached to the controller PCB. You should read 24 VAC. If ok, replace the station output cable. If not, go to Step 9.
9. Check solder connections on the controller PCB for the station output cable connector. Repair or replace controller PCB as required.



## No "B" Program Station Output

1. Verify the correct setting of the day wheel. Pin depressed halfway activates "A" program stations only. Pin depressed fully activates both "A" and "B" program stations.
2. With controller power "OFF", swing out the timing mechanism. Verify proper placement of all valve wires and commons. If ok, go to Step 3. If not, arrange and replace wires.
3. Verify that with a day wheel pin fully depressed and aligned at the day indicator and that the "B" program microswitch is activated. If ok, go to Step 4. If not, repair trip lever linkage as required.
4. With an ohmmeter, verify proper valve coil resistance for each valve assigned to "B" program. See "Fuse Checks" and the "Coil Resistance Chart". A very high resistance reading indicates a broken or disconnected wire or a defective valve coil. If ok, go to Step 5. If not, repair wires or coil as required.
5. Set your volt meter to read DC volts in a range above 10 VDC. Place all day wheel pins in their outermost position. Turn controller power "ON". Place the meter leads as stated and perform the following tests:
   A. Meter leads between the "B" program microswitch tabs. You should read 4.5-5 VDC. If ok, go to Step B. If not, go to Step C.
   B. Meter leads between the "B" program microswitch tabs, depress the microswitch button. You should read 0 VDC. If ok, replace controller PCB. If not, replace microswitch.
   C. Meter leads between wires to "B" program microswitch at the cable connector. You should read 4.5-5 VDC. If ok, repair wires between the cable connector and the microswitch. If not, check solder connections for the cable connector on the controller PCB. Repair or replace controller PCB as required.

## Station On Continuously

***Note:*** *When making voltage checks at the station output terminal, 24 VAC will be measured continuously unless a valve is wired to that station. This is characteristic of the triac in the station output circuit and poses no problem.*

1. Verify proper placement of the Station Operation Switch by placing it "OFF" and then returning it to its program position. If the valve remains on, go to Step 2.
2. Place the Sprinkler System Switch into the "OFF" position. If the valve remains on, the valve has malfunctioned and requires repair. If not, go to Step 3.
3. Verify all valve wire connections. If ok, replace controller PCB.

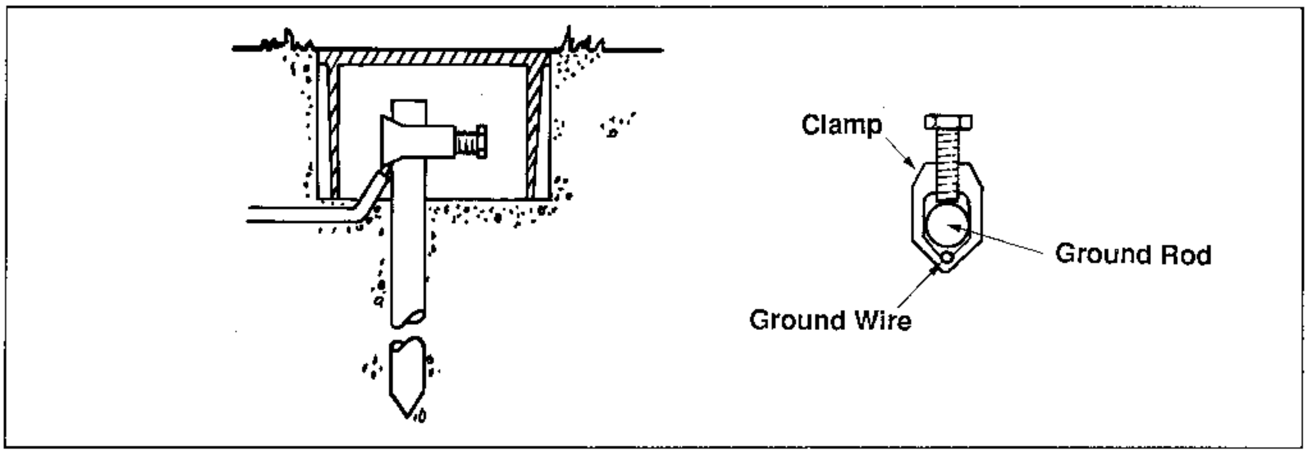
# Appendix D - Electrical Grounding and Wire Sizing

This section contains basic information on electric control system grounding and detailed information on sizing primary or high voltage wiring and secondary or low voltage wiring. Toro's "Electrical Wiring and Grounding of Automatic Control Systems", publication 366-0052, is recommended for further study.

### Minimum Grounding Standards

The recommendations listed below are minimum standards. Equipment manufacturers may require specific equipment to be installed exceeding these recommendations. Please refer to equipment installation instructions prior to installing grounding materials.

1. **Grounding Electrode** - A copper clad steel grounding electrode, 5/8" diameter and a minimum of 8' long should be driven into moist ground at each controller location.
2. **Grounding Clamp** - A one piece brass clamp with single tightening bolt should be used for each wire being attached to the rod.
3. **Ground Wire** - Used to connect the controller to the grounding rod, it must be at least equal in size to the smallest gauge wire entering the controller, 12 gauge minimum. This wire must be as short and as straight as possible to effectively shunt a lightning strike to ground. A lightning strike is a high frequency, high amptitude current and the magnetic field that surrounds a wire with a current flowing through it can act as a choke to the current path. In essence, it can create resistance to the energy flow. The longer the wire to earth ground and the more bends it contains, the more resistance it will develop to a high frequency strike. This can cause the load (circuit) to have less resistance than the ground and the energy will always take the path of least resistance.




**Typical Ground Rod Installation**

Since electrical currents flow through the path of least resistance, for surge protection to be effective, ground must be at the lowest possible resistance level. Earth ground resistance, as measured by an earth resistance testing instrument, such as a Megger 63220, is classified as:

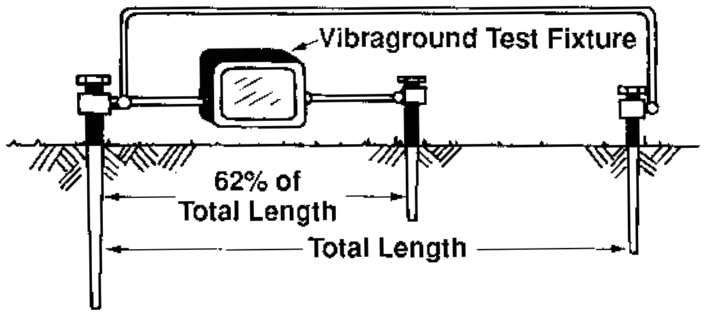
| | |
|---|---|
| Excellent | 5 Ohms or Less |
| Good | 6-10 Ohms |
| Marginal | 10-20 Ohms |
| Inadequate | Above 20 Ohms |

***Note:*** *Any resistance above 10 ohms will most likely result in an undesirable level of protection and should be corrected!*

In extreme cases where a 10 ohm reading proves elusive, several grounding techniques can be combined to achieve a satisfactory ground resistance reading. Remember, the ground is an essential part of the surge protection of your control system. Without it, the surge protection built into the control system will fail and you will not have the program reliability the manufacturer has designed into the system.

Grounds change! Measure their resistance at least twice a year and re-establish as necessary.

**Conductivity Test of Soil**

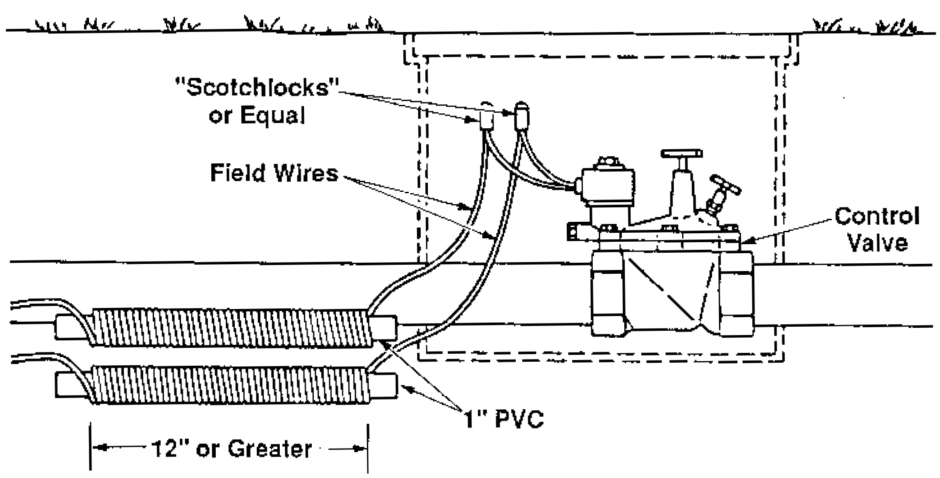



- Conductivity varies widely depending on:
  - Moisture of soil
  - Temperature of soil
  - Type of soil
- Correction techniques:
  - Longer rods
  - More rods
  - Adding salt walls

## Valve Surge Protection

In areas of high lightning activity, the designer can provide a system with significantly lower life-time operating costs by specifying a hydraulic system. The combination of a solid-state central controlling mechanical or hybrid field satellites and hydraulic valves is the best system to minimize system lightning damage.

If electric valves must be used in areas of high lightning activity, using the method shown in the illustration below will afford some surge protection and prolong the life expectancy of the valve solenoid. Having the current pass through the coiled wire will create a magnetic field and dissipate most of the high frequency, high amplitude current of a lightning strike.




**Valve Solenoid Surge Protection**

## Wire Sizing

Proper wire sizing for irrigation controllers and valves is vital for insuring that the correct operating voltage is provided. Voltage loss occurs at a rate based upon the length of wire, current flow (amperage) through the wire and the size of the wire. Therefore, proper wire sizing requires the following information:

1. **Voltage available at the source** - This must be established to determine the maximum allowable voltage loss. This information can be obtained through the local utility company or through actual site measurement. Most manufacturers recommend a minimum voltage of 115 VAC at the source.

   Power conditioning equipment may be a consideration at this point for providing a stable voltage source.

2. **Total Length of wire from source to load** - Once the controller and valve locations have been established, the total length of wire can be determined. The total length of wire is the length of the hot or line wire, plus the length of the common or neutral wire.

3. **Amperage** - After determining the number of controllers and valve programming sequence, the total amperage can be calculated. The highest amperage requirement, including valve inrush rating, must be used when calculating wire size to be certain that the valve will have adequate power to open under the worst conditions. If heat tapes are used their amperage load must be added to the controller's load.

4. **Minimum Operating Voltages** - Prior to calculating wire sizes, knowledge of the equipment's minimum operating voltage is required. Consult the manufacturer.

   Once these factors have been determined, the wire size can be calculated using the following formulas:

   For Voltage Drop, $E = \frac{KLI}{CM}$ or for circular mils, $CM = \frac{KLI}{E}$

   E = Voltage Drop. Total voltage lost from the source to the load. The voltage drop must never be such that the load voltage drops below the equipment's minimum operating voltage.

   K = Resistance in one foot of copper wire, one circular mil in cross section, or 10.4 ohms. K = 10.4 per foot for annealed copper wire.

   L = Total length of wire in the loop being circulated.

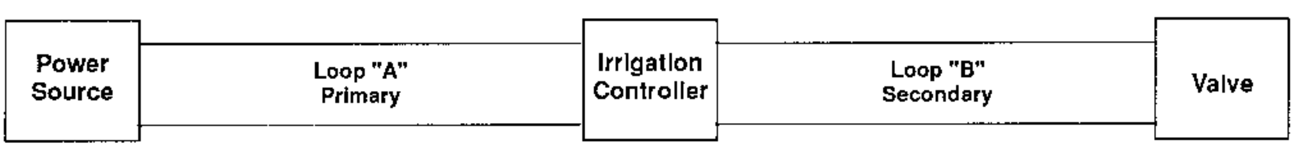
   I = Total amperage for the loop being calculated.

   CM = Circular Mils is the area of wire .001" in diameter and is a constant based upon the American wire gauges as follows:

   | | | |
   |---|---|---|
   | #0 - 106,000 | #8 - 16,500 | #16 - 2,580 |
   | #2 - 66,400 | #10 - 10,400 | #18 - 1,620 |
   | #4 - 41,700 | #12 - 6,530 | |
   | #6 - 26,300 | #14 - 4,100 | |

   AWG 14 is the smallest gauge single wire that is recommended for direct burial. This is based on the tensile strength of the wire. A smaller gauge wire is more likely to break or stretch during field installation operations.

There are actually two separate loops to consider when sizing wire:




**Loop "A"** - Consists of the wiring for the primary 120 VAC supplied to the controllers. When calculating wire size within this loop, the total amperage draw, including the maximum amperage from the secondary loop, must be considered. Total amperage is determined as follows:

$$\textbf{Total Amperage} = \textbf{Primary Amperage} + \frac{\textbf{Secondary Amperage}}{5.0}$$

**Loop "B"** - Consists of the secondary voltage provided to the valve solenoids. The voltage is reduced by a 5:1 ratio in the step down transformer for the secondary or field wiring loop. The secondary voltage at the controller can be determined by the primary voltage at the controller as follows:

**Primary Voltage ÷ 5 = Secondary Voltage**
**or**
**120 VAC ÷ 5 = 24 VAC**

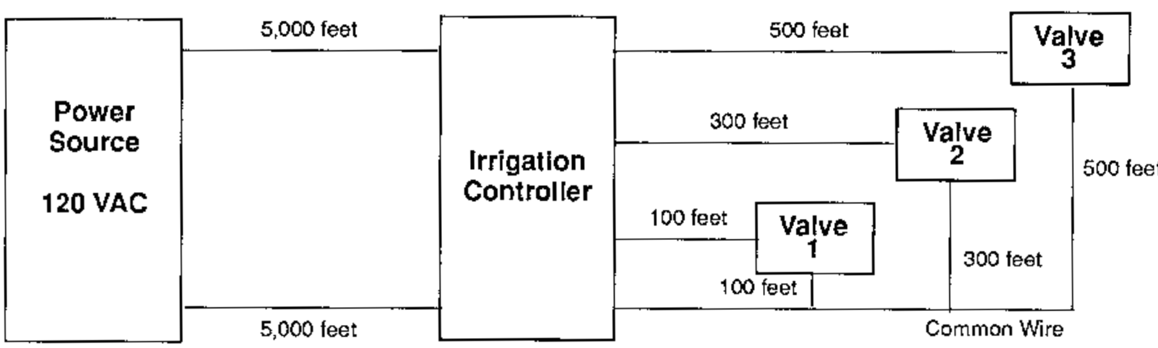
Wire sizing for Loop "B" only considers the highest amperage draw for the valve solenoids attached to that wire.

***Note:*** *When using hydraulically operated valves there is no secondary loop to consider and no additional amperage load to add to Loop "A".*

***Note:*** *The figures used in the example below are intended for reference only. Minimum operating voltage and amperage requirements must be substituted when calculating voltage drops and wire sizes.*

**Example:**

1. Power source provides 120 VAC.
2. Controller is 5,000 feet from the power source.
3. Controller draws 1 amp during operation.
4. Valves are located 1) 100', 2) 300', 3) 500' from controller.
5. Valve inrush is .5 amps.
6. One valve will operate at a time.
7. Valve wire will be sized to provide a minimum of 20 VAC to the valve solenoid.




## Calculating Voltage Drop in Loop "B"

**(Using #14 Gauge Wire)**

$$E = \frac{KLI}{CM}$$

- Valve 1: $E = \frac{10.4 \times 200' \times .5 \text{ amps}}{4100}$  $E = .25$ Volts

- Valve 2: $E = \frac{10.4 \times 600' \times .5 \text{ amps}}{4100}$  $E = .76$ Volts

- Valve 3: $E = \frac{10.4 \times 1{,}000' \times .5 \text{ amps}}{4100}$  $E = 1.27$ Volts

Valve 3, being furthest from the controller, has the largest voltage drop of 1.27 volts. If our minimum operating voltage is 20 VAC, we must have 21.27 VAC available at the controller. Given this, we can now determine the minimum primary voltage that will be required at the controller.

**Secondary Voltage x 5 = Primary Voltage**

**or**

**21.27 x 5 = 106.35**

From calculating Loop "B", the following has been determined:

1. Minimum primary voltage required at the controller is 106.35.
2. With only one valve operating at a time, there is a maximum of .5 amps drawn on the secondary side. To determine the total amperage draw on the primary side:

$$\text{Total Amperage} = \text{Primary Amperage} + \frac{\text{Secondary Amperage}}{5}$$

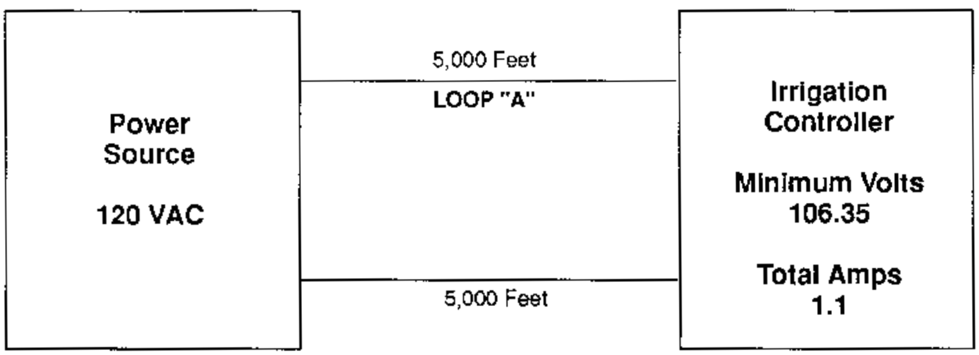
**or**

$$\text{Total Amperage} = 1.0\ (\text{Controller Amps}) + \frac{.5\ (\text{Valve Amperage})}{5}$$

**or**

**Total Amperage = 1.1 Amps**

After determining the total primary amperage, we can calculate the wire size for Loop "A".




From this we know that our maximum voltage drop from the power source to the irrigation controller will be: **120 - 106.35 = 13.65 Volts**

## Calculating Wire Size and Voltage Drop in Loop "A"

$$CM = \frac{K\,L\,I}{E} = \frac{10.4 \times 10{,}000' \times 1.1}{13.65} = \frac{114400}{13.65} \quad CM = 8381$$

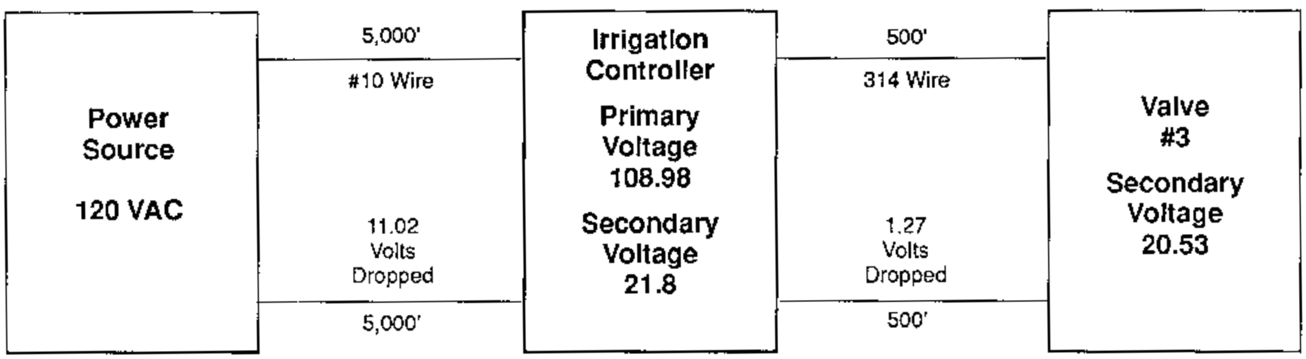
Referring back to the circular mil chart we find that 8381 falls between #10 (10380) and #12 (6530), therefore the wire size for Loop "A" will be #10.

Now that the wire sizes have been established, the exact voltage drops can be calculated to determine the actual primary and secondary voltages that can be expected at the controller and furthest valve.

Loop "A" $E = \frac{K\,L\,I}{CM}$ or $E = \frac{10.4 \times 10{,}000' \times 1.1}{10380 \text{ (\#10 wire)}}$ $E = 11.02$ Volts

| | |
|---|---|
| Primary Controller Voltage | 120 – 11.02 = 108.98 VAC |
| Secondary Controller Voltage | 108.98 ÷ 5.0 = 21.8 VAC |
| Voltage to Furthest Valve | 21.8 – 1.27 = 20.53 VAC |
| Voltage Needed to Operate | 20 VAC |

This proves our wire size selection is the smallest size possible that will carry adequate voltage to operate the furthest valve.






The chart below provides the voltage loss that will occur in an AWG single copper wire, 100 feet long, for wire gauges 2 through 14 at various amperages.

**Voltage Losses Per 100 Feet of Copper Wire**

| Gauge | 14 | 12 | 10 | 8 | 6 | 4 | 2 |
|---|---|---|---|---|---|---|---|
| **Amps** | | | | | | | |
| .1 | .0253 | .0159 | .0100 | .0060 | .0038 | .0024 | .0015 |
| .2 | .0506 | .0318 | .0205 | .0121 | .0076 | .0048 | .0030 |
| .3 | .0759 | .0478 | .0305 | .0182 | .0114 | .0072 | .0045 |
| .4 | .1013 | .0637 | .0405 | .0242 | .0152 | .0096 | .0060 |
| .5 | .1266 | .0796 | .0501 | .0303 | .0191 | .0120 | .0075 |
| .6 | .1514 | .0955 | .0601 | .0364 | .0229 | .0144 | .0090 |
| .7 | .1772 | .1114 | .0701 | .0424 | .0267 | .0168 | .0105 |
| .8 | .2025 | .1274 | .0801 | .0485 | .0305 | .0192 | .0121 |
| .9 | .2279 | .1433 | .0901 | .0546 | .0343 | .0216 | .0136 |
| 1.0 | .2532 | .1592 | .1001 | .0606 | .0381 | .0240 | .0151 |
| 1.5 | .3798 | .2389 | .1502 | .0910 | .0572 | .0361 | .0226 |
| 2.0 | .5064 | .3185 | .2003 | .1213 | .0763 | .0481 | .0302 |
| 2.5 | .6330 | .3981 | .2504 | .1516 | .0954 | .0601 | .0377 |
| 3.0 | .7576 | .4478 | .3005 | .1820 | .1145 | .0722 | .0453 |
| 3.5 | .8862 | .5574 | .3505 | .2123 | .1335 | .0842 | .0528 |
| 4.0 | 1.0128 | .6370 | .4006 | .2426 | .1526 | .0962 | .0604 |
| 4.5 | 1.1394 | .7166 | .4507 | .2729 | .1717 | .1082 | .0679 |
| 5.0 | 1.2660 | .7963 | .5007 | .3033 | .1908 | .1203 | .0755 |
| 5.5 | 1.3926 | .8759 | .5508 | .3336 | .2098 | .1323 | .0830 |
| 6.0 | 1.5192 | .9555 | .6009 | .3639 | .2289 | .1443 | .0906 |
| 6.5 | 1.6458 | 1.0351 | .6510 | .3942 | .2480 | .1563 | .0981 |
| 7.0 | 1.7724 | 1.1148 | .7011 | .4246 | .2671 | .1684 | .1057 |

# Appendix E - Training Others In Troubleshooting

The video program "Troubleshooting Automatic Sprinkler Systems" and this troubleshooting guide can be used in many ways for different types of audiences.

Start by looking at the video program at least two times. This will familiarize you with the basic program content and the pace of the program. Note the VCR counter location at each step for quick location later. Next read over the guide and make your own outline for your training session. You'll now have ownership in the material and, very likely, you'll also have a good idea of how you'll want to present it to your particular audience.

**Suggested format:**

1. Quickly outline the program so everyone knows what to expect.
2. Paraphrase the introduction. Make clear that the methodology is purposely broad to cover all situations. Explain or modify an example that would apply in your local area.
3. Run the video through Part I.
4. Use overhead TS-1 to review the major components. Review each step on the tape if necessary. This will depend on your audience.
5. Discuss Step One. Following this guide is an excellent way to direct the discussion. Solicit personal experiences, unusual conditions people have encountered or particular local situations for group discussion.
6. Review Step Two. Have controllers ready for participants to use. Use EL-6 or EL-12 controllers and explain the hybrid technology advantages. Outlet strips plugged into extension cords work well in distributing power around a meeting room. Also have the appropriate troubleshooting guides available for the controllers. Each participant should have a guide and two people can share a controller. Either provide analog and/or digital multi-meters or require participants to provide their own.
   * Review multimeter operation.
   * Make all the voltage checks described in the booklet or go through the controller troubleshooting guide.
   * Have a mechanical controller at the front of the room and demonstrate the checks to make on it as you go through the procedures. If mechanical controllers are the dominant controller in your area, you might use them and demonstrate the hybrid controller.
   * Discuss models available, their applications in your area and proper installation techniques.
7. Move into discussion about Step Three, the field wiring. Explain its purpose and installation. Discuss multi and single conductor UL rated, direct burial wire.
   * Demonstrate continuity checks on field wiring.
   * Stress importance of proper wire splices and have some available for participants to use.
   * Discuss proper controller grounding techniques.
   * Demonstrate, if you can secure the equipment, or discuss with the help of the overheads, earth resistance meters and cable fault locators.
8. Start discussion of Step Four with a review of diaphragm valve operation. Use overhead TS-4 for this review. Distribute a diaphragm valve to everyone and, with the help of TS-5, disassemble and go through the troubleshooting sequence. Check everyone on correct assembly.
9. TAKE A BREAK!

10. Run the video through Part II.
    * Distribute Pressure Compensating Devices and explain operation and advantage of regularly using them.
11. Have available sprinkler(s) common to your area or new models. Walk everyone through disassembly, cleaning, assembly and adjustment of at least one sprinkler.
    * Show flexible riser assemblies and discuss local practices for sprinkler installation. Stress importance of using riser assemblies that protect the lateral piping.
    * Discuss importance of sprinkler spacing to achieve a good distribution profile. Show how Funny Pipe™ can simplify sprinkler re-alignment.
    * Distribute Pressure Compensating Devices and explain operation and advantage of regularly using them.
12. Step Six activity will depend on the type of audience.
    * People new to the industry will benefit from seeing a slide program on correct PVC gluing techniques. This slide program is a available from Industrial Polychemical Service, Gardena, California 90248.
    * Demonstrate pipe cutters that do not leave PVC particles to clog sprinklers and valves.
13. Discuss hydraulic control system operation with the help of overheads TS-6, 7, & 8 if appropriate to your area.
14. TAKE A BREAK!
15. Play the entire video and administer exam.
    * Trade exams and grade.

**References:**

Videos
Automatic Sprinkler System Scheduling - VHS Video - 490-2448

Publications
Educator Series: Sprinkler Scheduling, 490-2235

Check with your local distributor for the owner's manual and installation instructions of your Toro controller. Customer Service in Riverside, California can provide the name and address of the Toro distributor nearest you. Call 1-800-FOR-TORO (California residents call, 1-800-255-TORO).

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