Student Workbook

Electrical Troubleshooting for Landscape Irrigation Systems

By
Donald Franklin, CID, CLIA

Edited by
Robert D. von Bernuth, PhD, PE, CID, CLWM, CIC

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Irrigation ASSOCIATION®

8280 Willow Oaks Corporate Drive
Suite 400
Fairfax, VA 22031-4507
Tel: 703.536.7080
Fax: 703.536.7019
info@irrigation.org
www.irrigation.org

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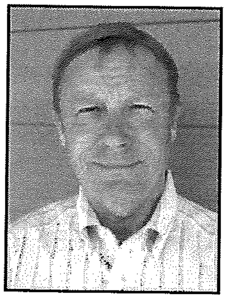
About the Author



Donald D. Franklin, CID, CLIA

Don Franklin has more than 40 years of experience in the landscape and irrigation industry. His background is in horticulture, plant propagation, and soil science, but his passion and expertise have been in the technical aspects of irrigation systems. He owned a landscape contracting and maintenance company and later established a technical service company specializing in irrigation controller repair, underground wire locating, and field troubleshooting. For more than 30 years Franklin has been associated with different computerized central control irrigation systems including product development, proper installation, and applications as water management tools.

Since the early 1990s, Franklin has served as a volunteer instructor for the Irrigation Association sharing his experience and knowledge by training industry professionals. He helped develop the popular "Electrical Troubleshooting" class including hands-on simulators to train students to diagnose field wiring problems using multimeters and different types of wire tracking equipment. He is respected throughout the irrigation industry for his ability to improve the skills and effectiveness of others through teaching and training. Always future-oriented, he contributed his training expertise to the creation of an online version of teaching electrical troubleshooting skills. The class, "Electrical Troubleshooting of Landscape Irrigation Systems," is hosted on the Irrigation Association website.

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Introduction

Notes

Electricity is one of the most misunderstood components in an irrigation system, yet it is critical to the operation of today's systems. This module will discuss the basics of electrical troubleshooting with an emphasis on basic electrical theory. Like irrigation design, having an understanding of how electricity "flows" makes it easier to successfully troubleshoot the various components in a system. Most people are comfortable working with water: we can see it, feel it, and, therefore, control it. Electricity, on the other hand, is invisible, but its presence can be felt, usually with some discomfort. However, water and electricity share some similar characteristics.

To better understand some basic electrical principles, this module draws some analogies between water and electricity. To help simplify the troubleshooting process, remember that there are only three electrical components to consider: the controller, the wire, and the valve. A problem may exist in one or more of these components. With a basic knowledge of electricity and through the process of elimination, nearly 100 percent of the problems commonly found in irrigation systems can be solved.

Definitions and Terms

Before discussing the different electrical components in an irrigation system, a few basic terms must be defined:

voltage — [V] An electrical unit of measurement. It is the force or potential available to push electricity through the wire. In water systems, this potential is like the pressure or pounds per square inch available to push water through the pipes. There are two types of electricity: alternating current and direct current.

> **alternating current** — [ac] Supplied by utility companies. It is called "alternating" because it oscillates between positive and negative. In the United States it oscillates 60 times a second, which is called 60-hertz. An irrigation controller may require a voltage potential of 240 or 120 volts ac, or 240/120 Vac, while the irrigation valve requires 24 Vac. A transformer, discussed later in this module, is used to reduce the voltage potential.
>
> **direct current** — [dc] Usually supplied by batteries or solar panels, or it is converted from ac. It does not oscillate between positive or negative; it is either positive or negative. It is usually used with latching-type solenoids and is an alternative power source when ac is not available.

ampere — [A] An electrical unit of measurement, also known as "amps" or "current." It is a measurement of the speed at which electrons move through the wire. In water systems, it is the velocity (or speed) at which water moves through the pipes. Just as high speed may cause damage to the hydraulic components in the irrigation system, high current may damage electrical components. **Important note:** Only one-quarter of an amp is needed to kill an individual.

✍ Notes

ohms — An electrical unit of measurement. It is a numeric value to measure the amount of resistance (see following definition) in a circuit.

resistance — [R] The "loss" of voltage and current in an electrical system. In water systems, it is the same as friction loss in pipe. As voltage and current move down a wire there is an opposition to the flow, which is a junction of the wire diameter and length. This opposition to flow is expressed in ohms.

PRACTICE PROBLEMS #1

Definition of Terms

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

Name______________________________

Date______________________________

1. Which of the following terms is ac the acronym for?

   A. alternating voltage.
   B. alternating current.
   C. alternating resistance.

2. What is the most common voltage used when turning on a sprinkler valve?

   A. 24 volts dc
   B. ac volts
   C. 24 volts ac

3. Ohms is measurement of

   A. volts.
   B. resistance.
   C. amps.

4. There are two types of electrical current.

   A. true
   B. false

Basic Meters and Their Use

A meter is an essential tool used to perform tests that will help identify potential problems in the electrical components of the control system. There are two main categories: analog and digital. Within these two categories are several types of meters: voltage, ohm, amp, and multimeter. Although the first three are useful, the multimeter combines the first three and is the most practical.

Analog Multimeter

This type of multimeter (see fig. 1) is still used today in a wide range of applications. The display consists of several scales and a red needle, which moves from left to right indicating the amount of resistance, voltage or current being measured. It may be used to determine if a cable or copper wire is making contact with the soil.

Digital Multimeter

Shortly after its introduction into the market, the digital multimeter (see fig. 2) replaced the analog multimeter because of its versatility and ease to read. Most digital multimeters have an auto-range feature allowing them to automatically adjust to a wide range of inputs.

Figure 1. Analog multimeter

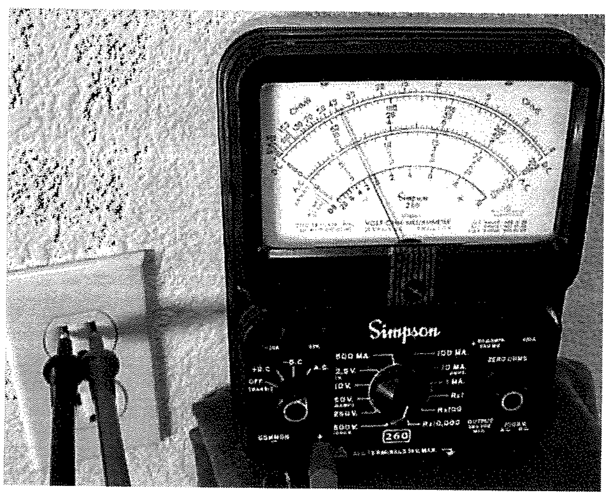
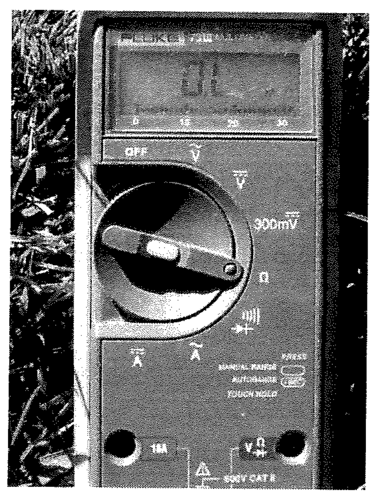


Figure 2. Digital multimeter



Basic Electrical Measurements

There are three basic measurements used in electrical troubleshooting, and all three measurements, or tests, can be performed at the irrigation controller.

- **resistance** — must be done without the presence of voltage. The symbol found on most meters is the "Ω."
- **voltage** — performed while voltage is present. The symbol for this function is "V."
- **amp (current)** — performed while voltage is present. The symbol found on most meters is the letter "A."

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Resistance Measurements

Measuring resistance of the valve circuit at the controller checks the integrity of the wire and the health of the solenoid. While performing the test it's always advisable to remove one of the wires from the controller to isolate the test and assure there isn't any voltage present. The resistance of the valve circuit is measured in ohms. In most situations a normal ohm measurement is anywhere from 20 to 60 ohms for a single solenoid (see fig. 3).

Carefully read the display. The number displayed may appear to be within the range of normal unless there is a "K" or an "M" in the lower right corner (see fig. 4). If one of these letters appears, then the number shown must be multiplied by 1,000 (for "K") or 1,000,000 (for "M"). For example, if the number displayed is 20 and a "K" appears in the lower right corner, then multiply 20 by 1,000 (20 × 1,000 = 20,000). This measurement indicates a different problem discussed later in this module.

Figure 3. Ohms measurement of a solenoid

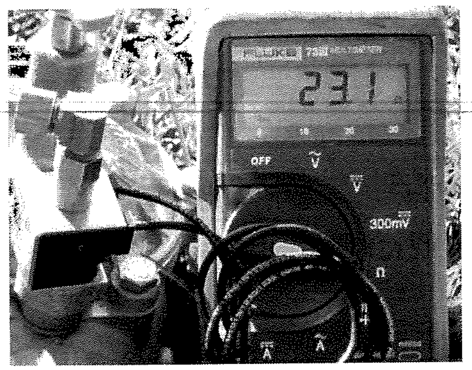
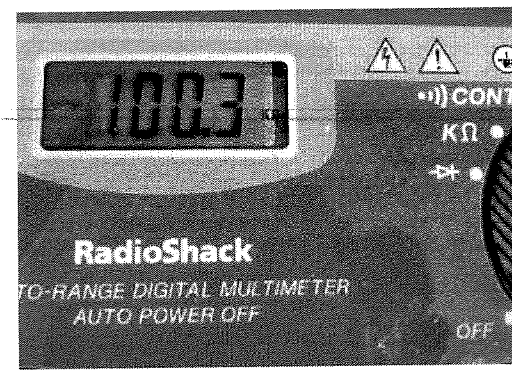


Figure 4. Measurement reading with letter indicators



Voltage Measurements

Voltage measurements are used to determine whether the 120 Vac is present at the controller and if the controller is sending 24 Vac to the valve. *Always be careful when performing this measurement.* The normal supply voltage should fall within +/–10 percent of the manufacturer's specifications. With a supply of 120 Vac, the nominal voltage should be within 108–132 Vac, as shown in figure 5. For a supply of 240 Vac the nominal voltage should be within 216–264 Vac.

The controller's output to a valve is commonly 24 volts ac. Today, some of the high-end controllers supply a little more than 24 Vac. The normal output voltage from the controller to the valve should be approximately 24–28 Vac, as indicated in figure 6. Also observe the upper right corner of the display. A "V," "Vac," or "VAC" in the display indicates volt; an "mV" in the display indicates millivolt, or thousandths of a volt. For example in figure 7, if the number displayed is 28 and an "mV" is in the lower right corner, then divide 28 by 1,000 (28 ÷ 1,000 = 0.028). Because 0.028 is less than half a volt, it is not enough voltage for the application.

Figure 5. Voltage reading for outlet power source

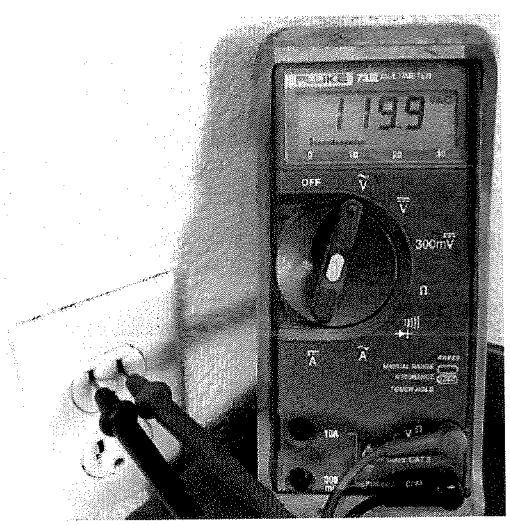


Figure 6. Voltage reading at terminal strip

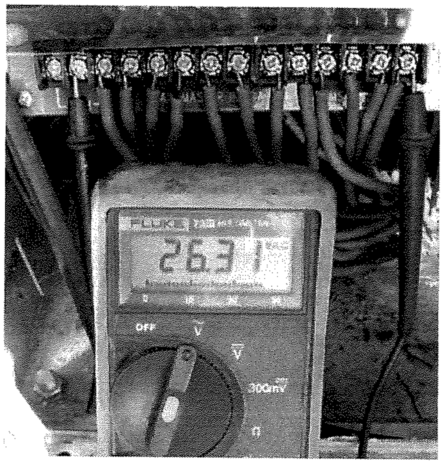
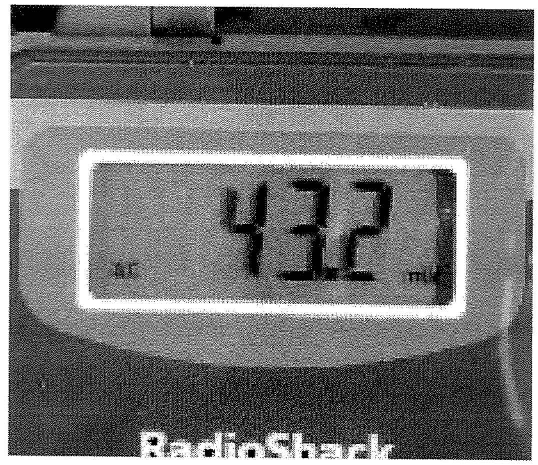


Figure 7. Millivolt reading (see lower right hand corner for mV)



Solar and battery operated controllers send a short Vdc (volts direct current) pulse to turn valves on and off. These controllers are separately covered later in this workbook.

Amp (Current) Measurements

Amp, or current, measurements (see fig. 8) are used to determine the "health" of the valve circuit. At a glance, this test appears to duplicate the resistance test mentioned earlier. Both check if the valve circuit is complete and both can be done at the controller, but unlike the resistance test, a current test measures the circuit under a dynamic condition. Although it rarely occurs, it is possible for the resistance to show that a valve circuit is good (20–60 ohms) and the controller is sending 24 volts to the valve, yet the voltage measurement at the valve is not enough to turn the valve on. Unlike the voltage and resistance test, the ampere test is performed with the meter as part of the valve circuit. The meter is said to be "in series" with the valve. Electricity is actually passing through the meter, as illustrated in figure 9. As with the voltage test, electricity must be present. Always be careful when performing this measurement.

Figure 8. Amp measurement

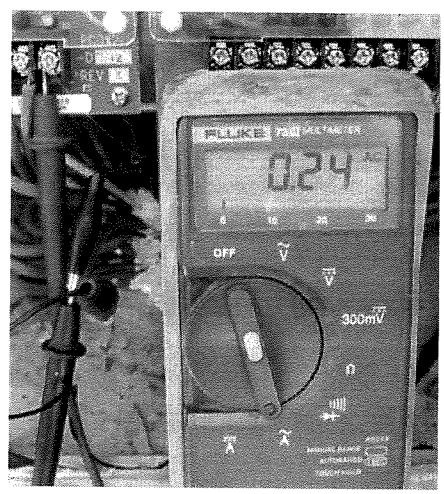


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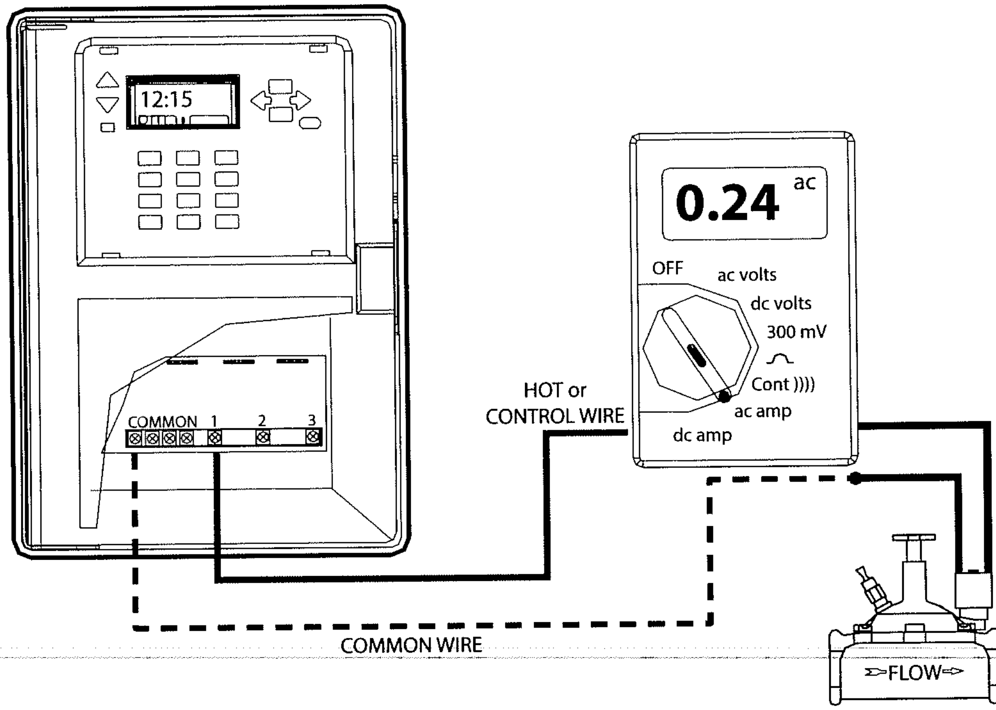
Figure 9. Meter used in ampere test



PRACTICE PROBLEMS #2

Basic Meter

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

Name____________________________

Date____________________________

1. What setting should a multimeter be set to when measuring 24 Vac?

   A. ac amps
   B. dc volts
   C. ac volts

2. When measuring current, the meter should be in __________ in the circuit.

   A. parallel
   B. series
   C. series or parallel

3. What is 25.5M ohms?

   A. 25.5 ohms
   B. 25,500 ohms
   C. 25,500,000 ohms

4. What is 25.5mV?

   A. 25.5 volts
   B. 25.5 megavolts
   C. 25.5 millivolts

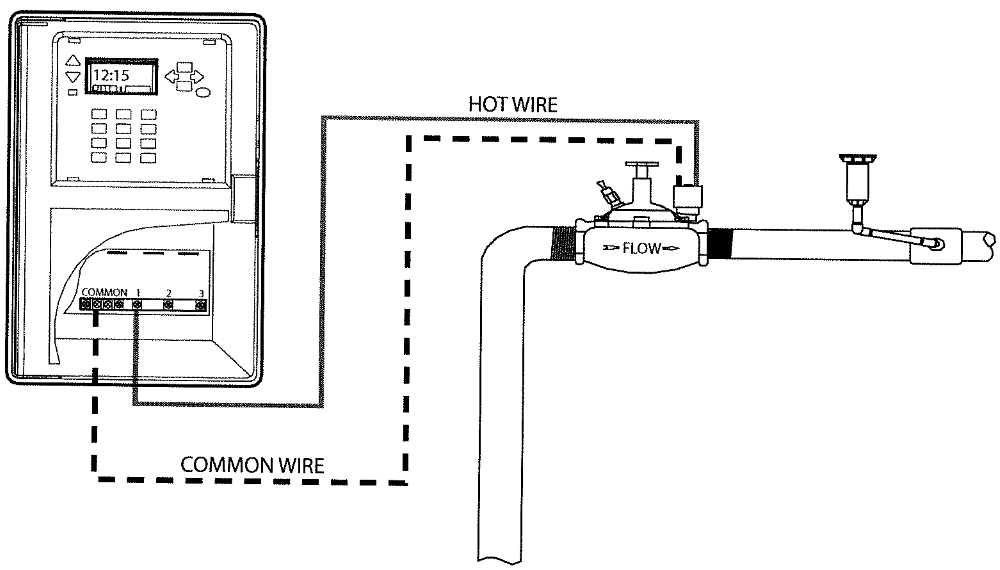
System Wiring

To accurately troubleshoot the electrical system, it is extremely important to understand how the valve circuit operates. Having a thorough understanding of proper valve circuitry makes it possible to troubleshoot and correct problems caused by improper installation or poor troubleshooting and repairs by others. (Notice the ohm measurement between common and hot in each example.)

Single Valve System

A circuit consists of one "hot" or control wire and one common or neutral wire. The controller sends 24 volts through the hot wire to the solenoid. The electricity travels through the solenoid creating an electromagnetic field and returns through the common wire back to the controller. The normal resistance measurement between common and hot should be approximately 20–60 ohms. It is not very common to find an irrigation system with only one valve, but for purposes of understanding a simple circuit, one is shown below.

Figure 10. Single valve system



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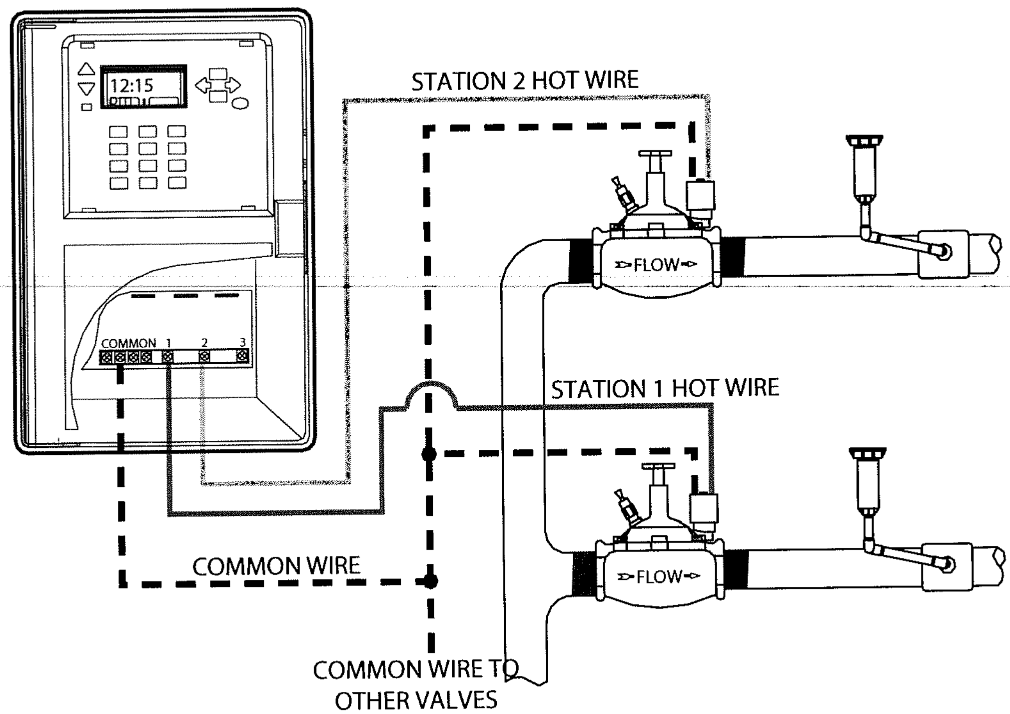
Multiple Valves with a Single Common

Multiple valves with a single common is the typical wiring installation, especially for residential or small commercial projects. Notice there is only one common or neutral wire and two hot wires (see fig. 11). When installing valve wiring, a single common wire can be used with several valves. That is why it's called the "common" wire; it is common to all valves. It is not a ground wire; a ground wire serves a different purpose. The electrical operation is the same in this configuration as in the single valve system. The normal resistance measurement between common and any hot wire should be approximately 20–60 ohms.

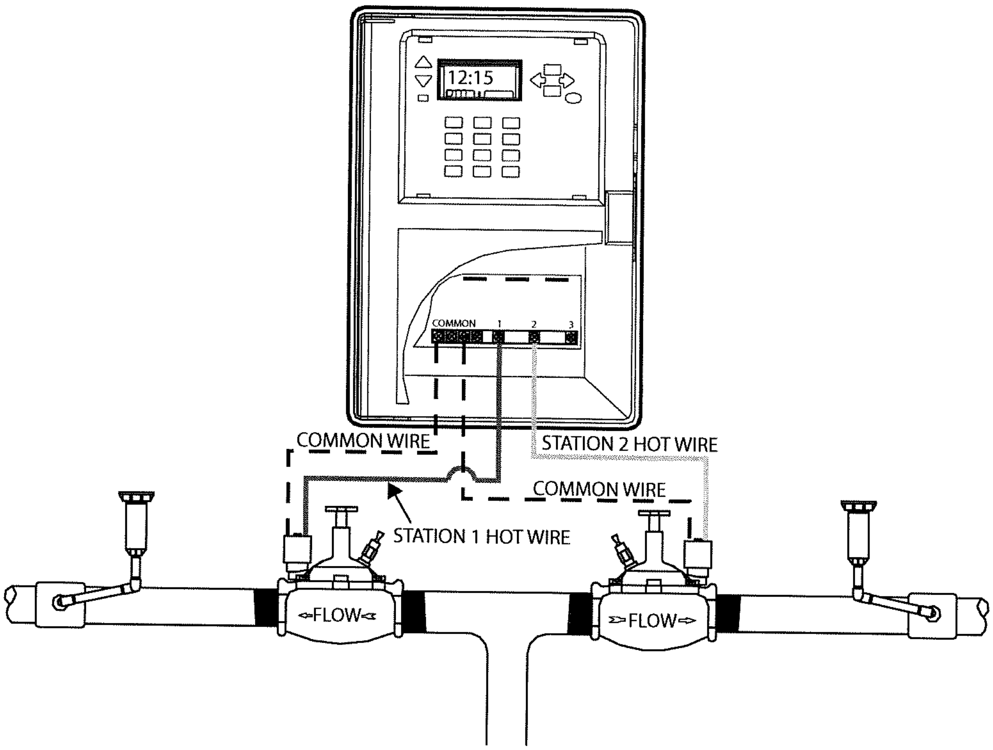
Figure 11. Multiple valves with a single common



Multiple Valves and Multiple Commons

The following drawing shows a multiple valve installation but with two common wires: one going to the valve on the left and the other to the valve on the right. The electrical operation is the same in this configuration as in the single valve system. The normal resistance measurement between any common and hot should be approximately 20–60 ohms.

Figure 12. Multiple valves and multiple commons



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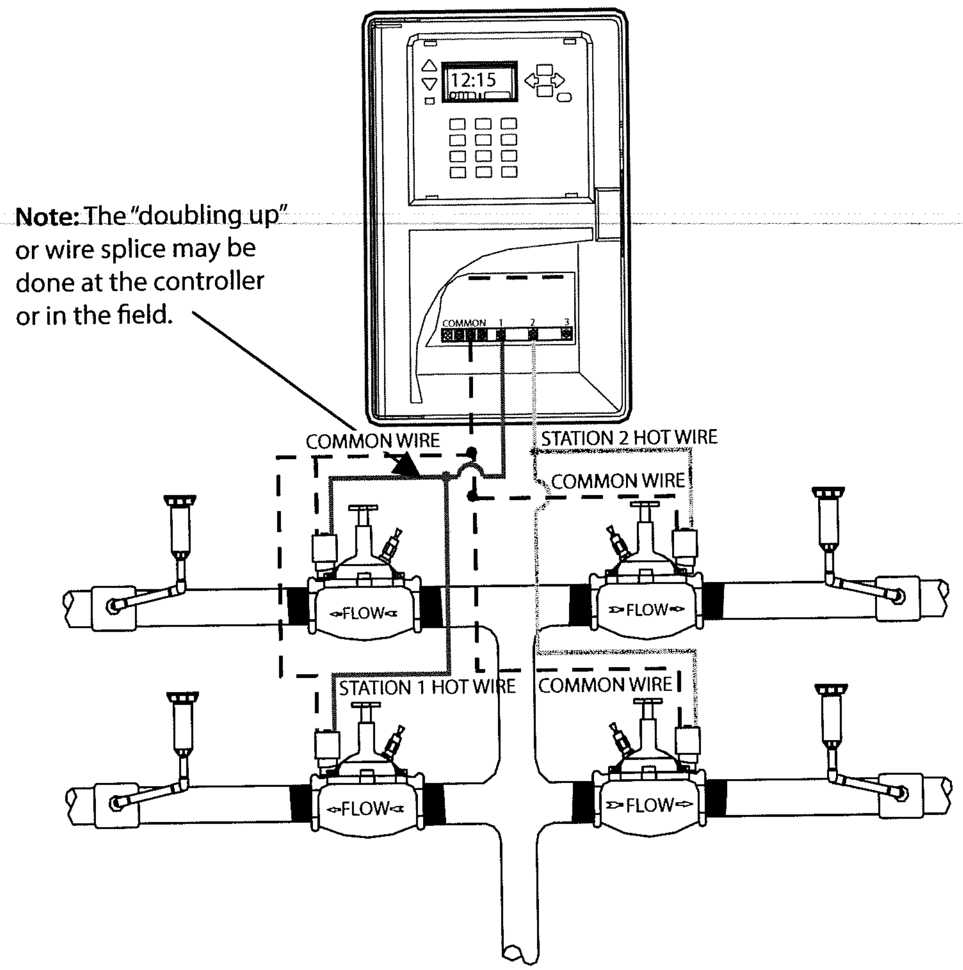
Multiple or Parallel Valve Wiring

A common practice on some large scale irrigation systems is to have multiple valves wired to the same station on the controller. This type of wiring is called a "parallel" circuit (see fig. 13). It is done on commercial projects, parks, and schools as part of the intention of the designer or where a wire may have been damaged causing the person troubleshooting the system to "double up" valves to one station. The controller sends 24 volts through the hot wire to both solenoids. The electricity travels through each solenoid creating an electromagnetic field and returns through the common wire back to the controller. It is interesting to notice the resistance measured between common and any hot is approximately *half* of a single valve. That is because the electricity is now divided between two valves.

Figure 13. Multiple or parallel valve wiring

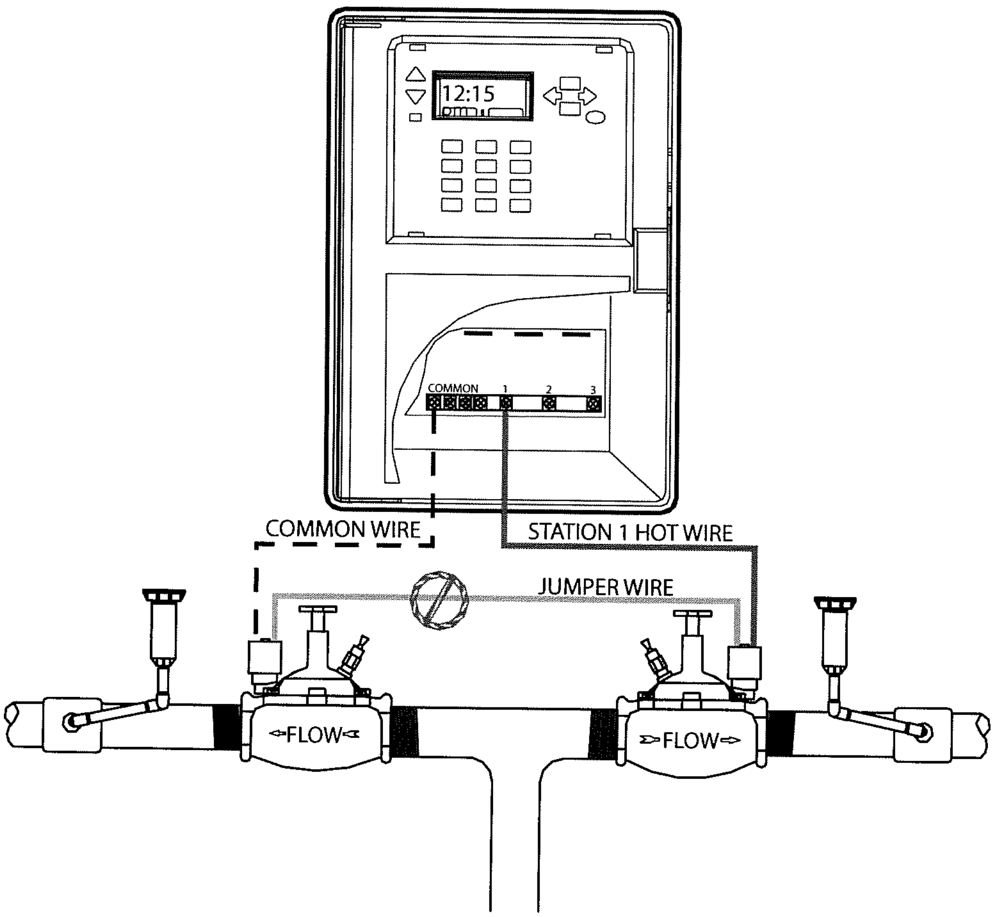


Note: If the resistance measured for a single valve is 30 ohms, then the resistance for two valves in parallel is approximately 15 ohms. If three valves were connected to a single station, the resistance is approximately 10 ohms. As the resistance drops, the amperage rises. If a single valve pulls 0.25 amps, then two valves on at the same time will pull 0.50 amps.

Multiple Valves in Series

Frequently, individuals not familiar with proper valve wiring procedures will wire valves in series, and the result is that the valves will not open. In figure 14, the controller sends 24 volts through the hot wire to the solenoid. The electricity travels through the first solenoid through the jumper wire to the second solenoid and returns through the common wire back to the controller. The voltage across each solenoid is insufficient to open the respective valves. The resistance measurement between common and hot in this circuit would be approximately double that of a single valve because the circuit is now doubled between two valves, and the voltage drop across each solenoid will be approximately half of the total voltage.

Figure 14. Multiple values in a series



Note: If the resistance measurement for a single valve is 30 ohms, then the resistance for two valves wired in series is approximately 60 ohms. As the resistance increases, the amperage decreases. If a single valve pulls 0.25 amps, then two valves wired in series pulls approximately 0.125 amps.

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PRACTICE PROBLEMS #3

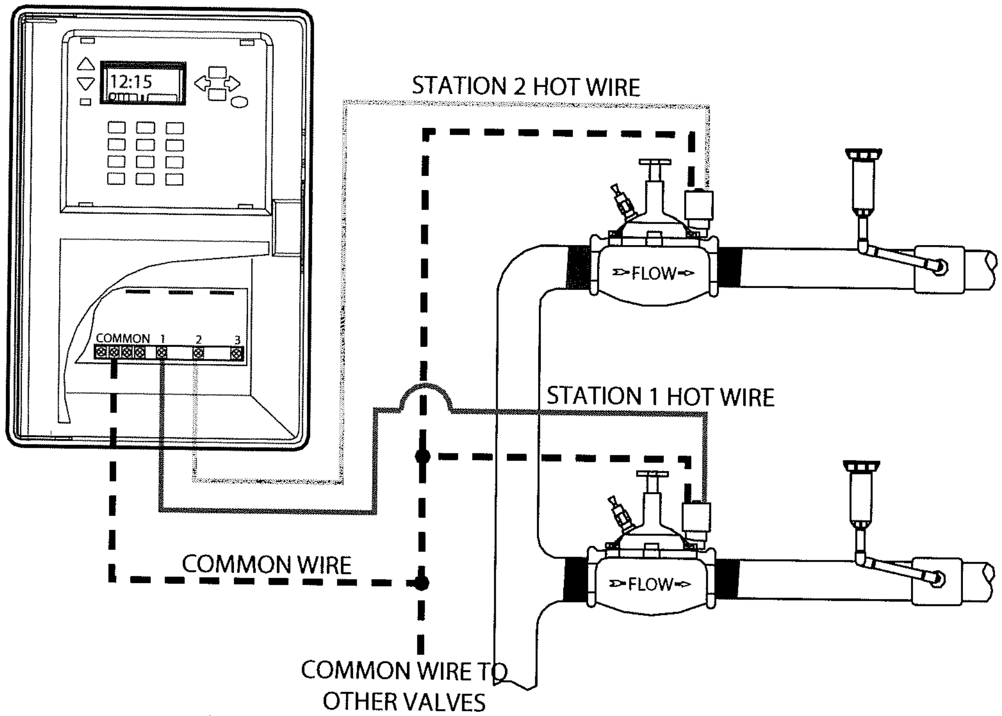
System Wiring

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

Name______________________________

Date______________________________

1. What type of wiring is shown below?



   A. single valve circuit
   B. multiple valve circuit
   C. single and multiple valve circuit

2. Two valves sharing one hot or control wire is what kind of circuit?

   A. single valve circuit
   B. single and multiple valve circuit
   C. multiple valve circuit

3. Two or more valves activated by a single station are what type of circuit?

   A. serial
   B. parallel
   C. serial and parallel

Electrical Faults

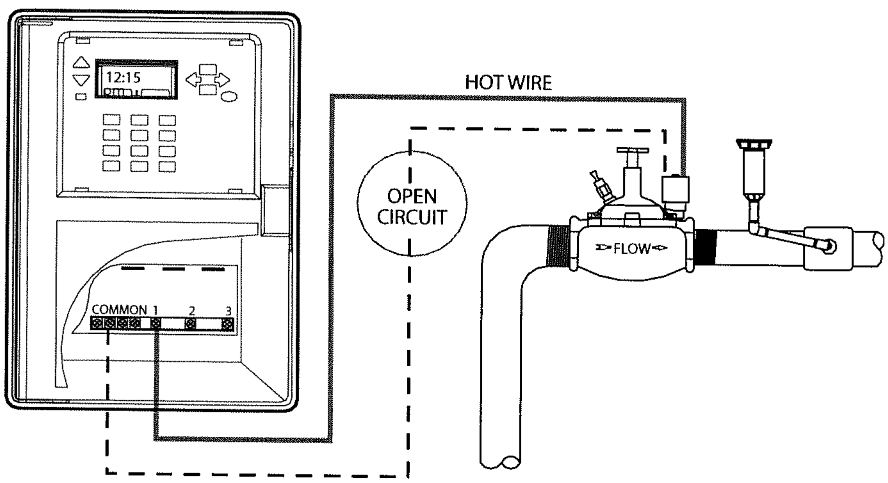
Notes

There are different types of faults that may occur in an irrigation electrical system. A clear understanding of each of these faults is critical to provide the proper response.

Open

This is an incomplete or broken circuit (see fig. 15). It may be caused by a broken wire, a broken splice, or a broken wire within the solenoid itself. The resistance measured on this type of circuit is very high, usually 1,000 ohms or higher.

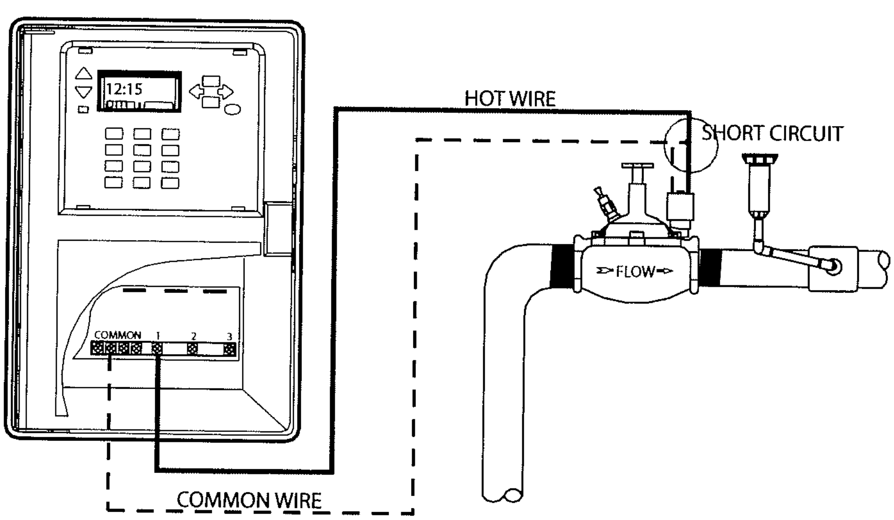
Figure 15. Open fault



Short

Unlike an open, the short is a complete circuit; however, the electricity is not traveling the desired path (see fig. 16). It is traveling a path *shorter* than normal. This may be caused by the hot and common wire touching or being spliced together. Splices that are not waterproof allow water to be used as a conductor between hot and common. Wire insulation within the solenoid that may have melted due to high heat will also cause a short circuit. The resistance measured on this type of circuit is low, usually from 0 to 9 ohms.

Figure 16. Short fault



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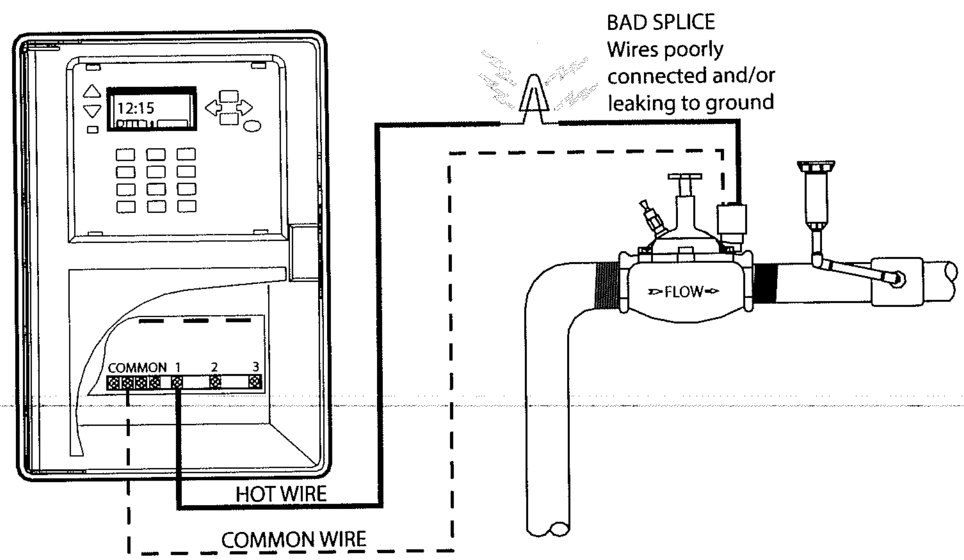
Partial

This type of fault can be one of the more difficult problems to identify because the problem may be intermittent (see fig. 17). The circuit is *almost* complete. It may be caused by a splice that is not waterproof or a wire exposed to soil for a period and is partially corroded. The resistance measured on this type of circuit is higher than a normal circuit but lower than an open circuit, usually between 70 and 200 ohms.

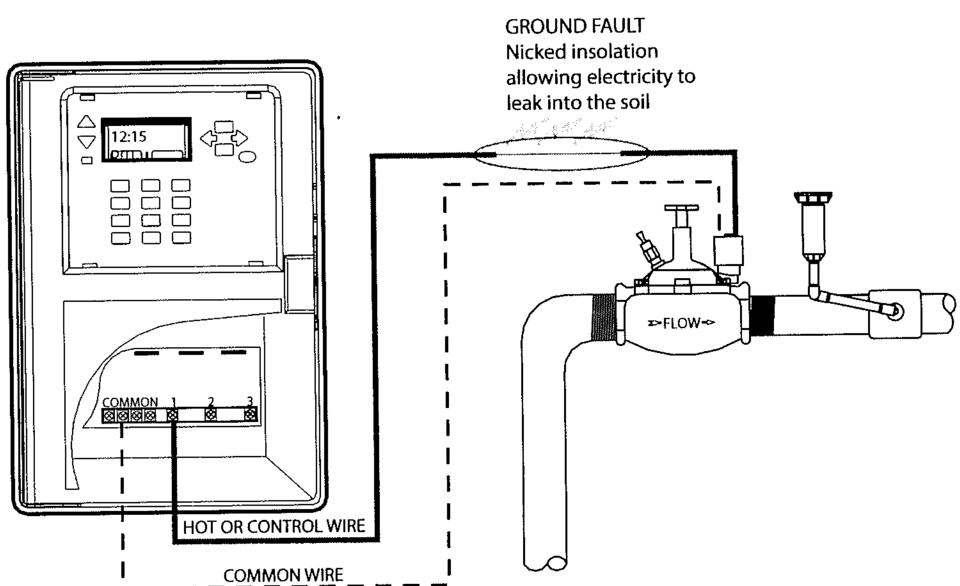
Figure 17. Partial fault



Ground

The conductor exposed to the soil causes this type of fault (see fig. 18). It may be a complete circuit, but as time passes, the conductor begins to corrode, resulting in a partial fault and eventually becoming an open fault. The resistance test may reveal ohm readings ranging from a normal circuit to an open circuit. A more detailed troubleshooting approach is discussed later in this module.

Figure 18. Ground fault



PRACTICE PROBLEMS #4
Electrical Fault

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

Name________________________________

Date________________________________

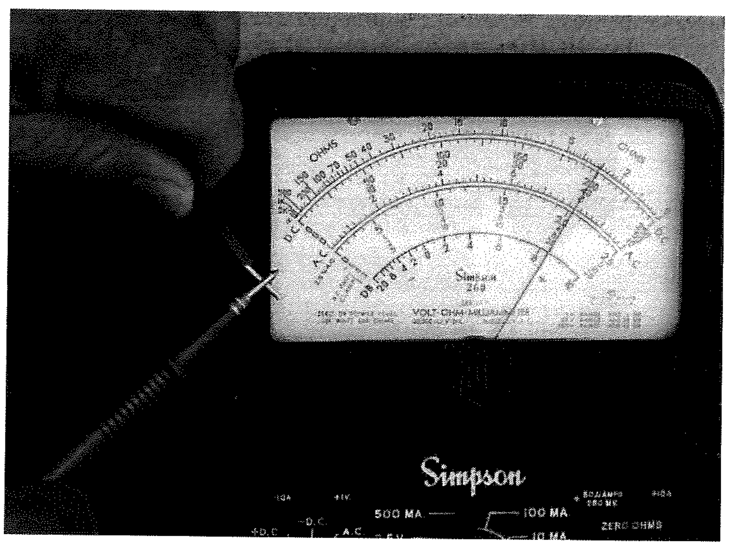
1. An ohm measurement across common and station 5 of 200k Ω is a

   A. short circuit.
   B. open circuit.
   C. partial circuit.

2. Which type of fault would cause a circuit to have a resistance measurement of greater than 1,000 ohms?

   A. open circuit
   B. partial circuit
   C. short circuit

3. What type of fault is shown below (R × 10,000 is selected)?



   A. open
   B. partial
   C. short

4. A nonwaterproof wire splice directly buried in the ground can cause what kind of fault?

   A. open
   B. partial
   C. ground

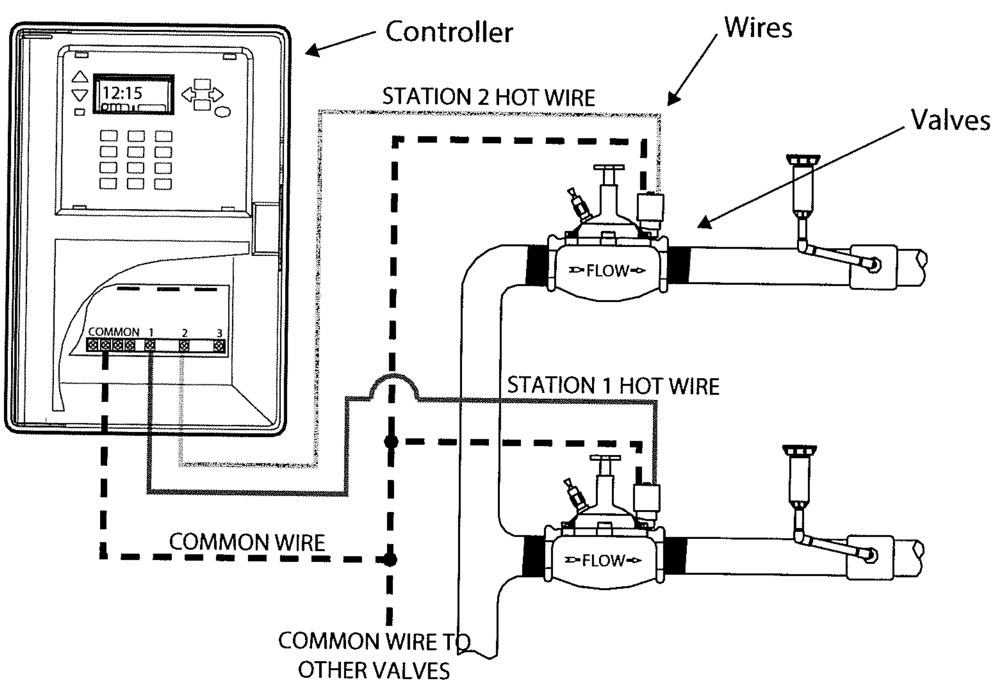
Troubleshooting

Electrical Components

Troubleshooting is a process of elimination. There are only three electrical components to be considered while troubleshooting (see fig. 19). Below is a list of electrical components in order of their importance:

1. Controller
   - A. Program
   - B. Sensors
     - (1) Rain
     - (2) Moisture
   - C. Station output
2. Wire
   - A. Faults
     - (1) Short
     - (2) Open
     - (3) Partial
3. Valve
   - A. Electrical
     - (1) Solenoid
   - B. Mechanical
     - (1) Diaphragm assembly
     - (2) Solenoid ports

Figure 19. Typical multi-valve wiring



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Steps to Troubleshooting

It is best to follow a systematic approach to troubleshooting. Following a logical path can reduce the risk of missing the cause of the problem. Successful troubleshooters are consistent in utilizing the sequential approach presented. Ninety percent of the tests performed will be done at the controller. Therefore, after checking the obvious, it makes sense to begin at the controller.

Basic Steps to Troubleshooting

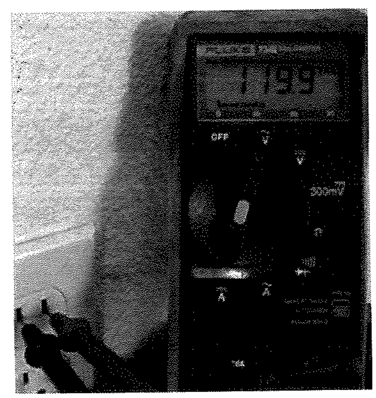
Step 1 — Check the obvious.

1. Is the water turned on?
   a. water meter
   b. backflow
   c. isolation valve
2. Check the flow control at the zone valve.
3. Is the controller programmed correctly?
4. Are sensors installed?
   a. rain
   b. moisture

Step 2 — Check the power supply. It should measure 110–120 volts ac (Vac) (see fig. 20).

- If the correct voltage IS present, go to step 3.
- If voltage is NOT present, check the following:
  1. the circuit breaker at the electrical panel
     - If the circuit breaker is in the OFF position, switch it ON. If the breaker immediately trips call an electrician to determine the cause of the problem.
     - If the circuit breaker is in the ON position, call an electrician to determine the cause of the problem.
  2. Is the controller connected to a ground fault interrupting circuit (GFIC) outlet?
     - If YES, reset the outlet by pressing RESET.
     - If NO, call an electrician to determine the cause of the problem.
- If voltage is less than 110 Vac, call an electrician to determine the cause of the problem.

Figure 20. Voltage check at power source



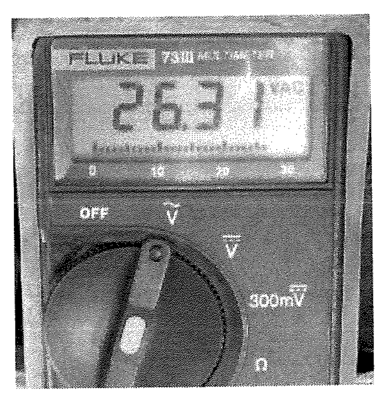
Step 3 — Check the transformer output. It should measure 24–30 Vac (see fig. 21).

- If the correct voltage IS present, go to step 4.
- If voltage is NOT present, replace the transformer.

Step 4 — Check the station output. It should measure 24–30 Vac.

- If the correct voltage IS present, go to step 5.
- If voltage is NOT present, repair or replace the controller.

Figure 21. Transformer output voltage reading



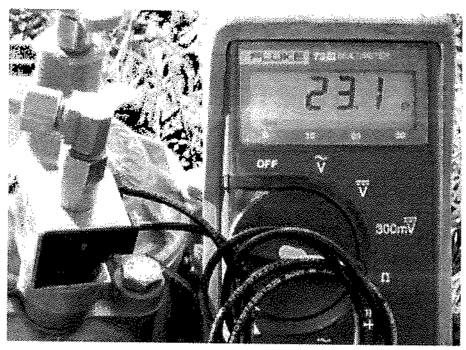
Step 5 — Check station resistance. It should measure 20–60 ohms.

- If the resistance measurement is between 0 and 9 ohms, the circuit is said to be a short circuit.
  1. Check all wire splices. Be sure bare wires are not touching. Make sure all splices are correct and waterproof.
  2. If all wire splices are correct, go to step 6.
- If the resistance measurement is between 70 and 200 ohms, the circuit is said to be a partial circuit.
  1. Check all wire splices. Be sure bare wires are not exposed to soil, water, or air. Make sure all splices are correct and waterproof.
  2. If all wire splices are correct, go to step 6.
- If the resistance measurement is 1,000 ohms or higher, the circuit is said to be an open circuit.
  1. Check all wire splices. Be sure bare wires are not exposed to soil, water, or air. Make sure all splices are correct and waterproof.
  2. If all wire splices are correct, go to step 6.

Step 6 — Check solenoid resistance. It should measure 20–60 ohms (see fig. 22).

- If the ohm reading is NOT between 20 and 60, replace the solenoid.
- If the ohm reading IS between 20 and 60, go back to step 5 and repeat the troubleshooting process.

Figure 22. Solenoid resistance reading in ohms



Troubleshooting Special Situations

The previous sections have provided a basic understanding of electrical circuits and how to troubleshoot them. This section discusses situations that may appear abnormal but, in fact, are normal and correct. Multiple valves connected to one station, as discussed earlier under "Multiple or Parallel Valve Wiring," may give a low ohm measurement appearing to be a short when it is actually a normal ohm reading for that particular circuit. On the other hand, valves wired in series, also discussed earlier, may render a normal ohm measurement, but the valve(s) in question are not turning on from the controller. Direct current will also be discussed. Troubleshooting these systems requires the same process; however, the measurements are different.

Parallel Circuits

As discussed earlier, parallel circuits occur frequently in our landscape. The circuit may be intentionally designed or an irrigation technician may have combined two valves to one controller station output to get emergency water on a specific area. Regardless, the ohm measurement for this type of circuit will usually be approximately half the resistance of a single valve circuit. If three valves are combined, the total circuit resistance will be approximately one-third of the resistance of a single valve.

✍ Notes

Notes

CAUTION: As more valves are turned on simultaneously, the velocity of water will increase and the pressure will drop in the piping system, resulting in poor to inadequate sprinkler coverage. With electricity, a similar situation will occur; the amperes will increase and the voltage will decrease, resulting in a blown fuse and/or not enough power (voltage and amperage) to turn on the valve.

Series Circuits

As previously discussed in the "System Wiring" section of this module, a series circuit is an incorrect circuit for valve operation. The reason is simple: as the resistance increases the amperage decreases. There isn't enough amperage to create a sufficient electromagnetic field that will pull up the plunger in the solenoid.

dc Circuits

There is a small percentage of irrigation systems that utilize dc electricity. They are usually found where ac voltage is either not available or won't be available for some time. The circuit is similar to ac in that there is a hot and common wire. While troubleshooting dc circuits, there are a few things to remember:

- Polarity is essential. If proper polarity is not observed there will be unexpected results. For example, a signal is sent that should turn on the valve but instead it turns off the valve and vice versa, the signal is sent to turn off the valve but instead the valve comes on and water starts flowing to the sprinklers.
- The wire color, as shown in figures 23 and 24, is usually red for hot and black for common, or negative. Red and black wires may be found on controllers with four stations or less.

Figure 23. dc latching solenoid

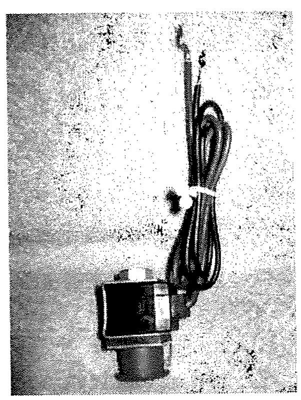
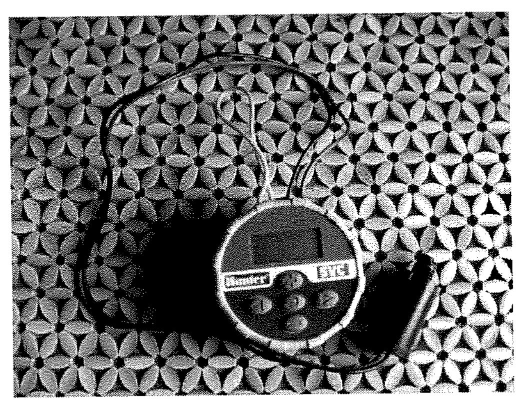
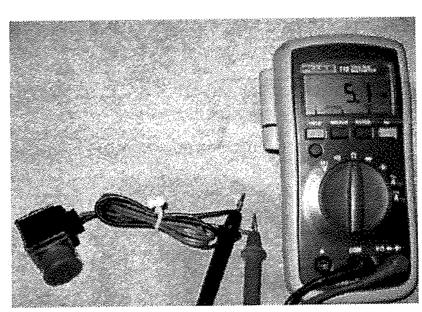


Figure 24. Battery powered controller



- The terminal strip on larger controllers is usually marked with a plus symbol (+) for the hot wire and a minus symbol (–) for negative, or common, wire.
- Resistance of dc solenoids is usually low: approximately 5 ohms (see fig. 25). Remember, while troubleshooting the circuit it is a process of elimination. If a measurement of 5 ohms is observed, how does one determine if the reading is the result of field wires shorted together or the dc solenoid?

Figure 25. Ohms reading of dc latching solenoid



- Because there is a finite power source (i.e., a battery), opening and closing a valve is done with a very short electrical pulse. Many manufacturers incorporate a magnet into their solenoid. The magnet has a dual purpose. It helps pull up or push down the solenoid plunger, and it acts as a latching mechanism to keep the solenoid plunger up inside the shaft allowing water to flow through the valve.
    - To turn the valve on, the controller will send out a positive electrical pulse. The pulse is the opposite polarity of the magnet just under the coil. (Remember that opposites attract.) This creates just enough of a magnetic field to overcome gravity and pressure, which pulls up the plunger. Once the plunger is up the magnet is used to hold it in place.
    - To turn off the valve, the controller sends out a negative pulse. Similar to how polarities repel, this will create a repelling force that will cause the plunger to be pushed from its latched position, covering up the exhaust port in the solenoid chamber, allowing the upper portion of the valve to pressurize and shutting the valve off.

Troubleshooting Ground Faults

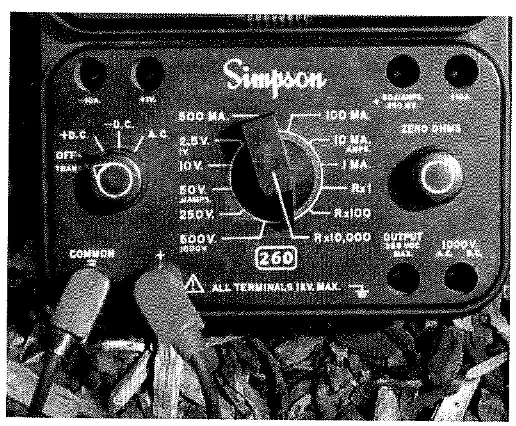
This portion of the module addresses ground faults: how to determine which wire has the fault and the process to correct the problem. A quick review of what a ground fault is may help to understand why, if detected, this type of fault should be corrected as soon as possible.

A ground fault is any part of the conductor that comes in contact with the soil. The affects of a ground fault may not cause an immediate problem. A wire with a small nick in the insulation is technically a ground fault. It may not be detected during a routine ohm check of the circuit. It may not even cause a problem initially; however, as time passes the copper may become corroded and break resulting in an open circuit.

There are two ways to perform a ground fault test.

- Test the wire with a device that sends a DC voltage down the conductor and measures the resistance between the conductor and the soil. The higher the resistance measured, the better the insulation around the wire. The common term for the test is "megger," which is a combination of the units measured {mega-ohms} and the device {meter}. As the device uses high voltage, it is imperative to follow manufacturer's instructions to avoid personal injury or equipment damage.
- A good quality analog multimeter (see fig. 26) with an ohm scale of R × 10,000 or greater may also be used to perform this test. The meter must be sensitive enough to read the amount of resistance from the conductor through the soil and back to the ground probe. Although this test doesn't use high voltage, do not allow the tips of the meter probes to come in contact with the body,

Figure 26. Ground fault test with analog meter



Notes

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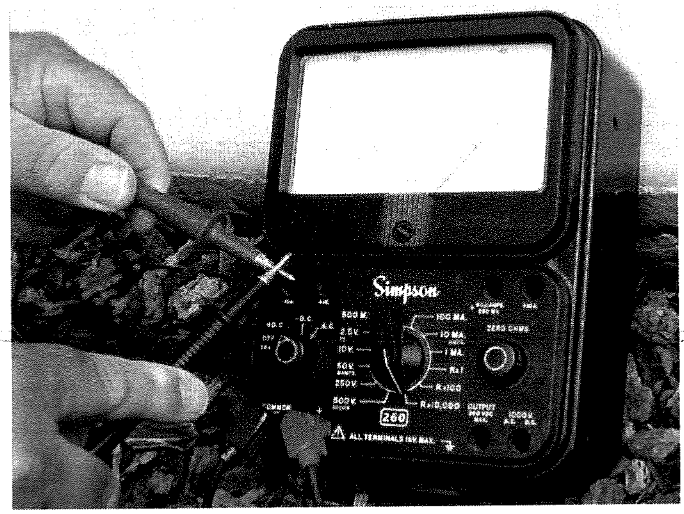
otherwise the measurements may be the resistance through your body. A digital multimeter should not be used to perform this test because it will measure the capacitance of the ground fault as well, which may cause confusion to the person performing the test.

Use the following steps to perform this test:

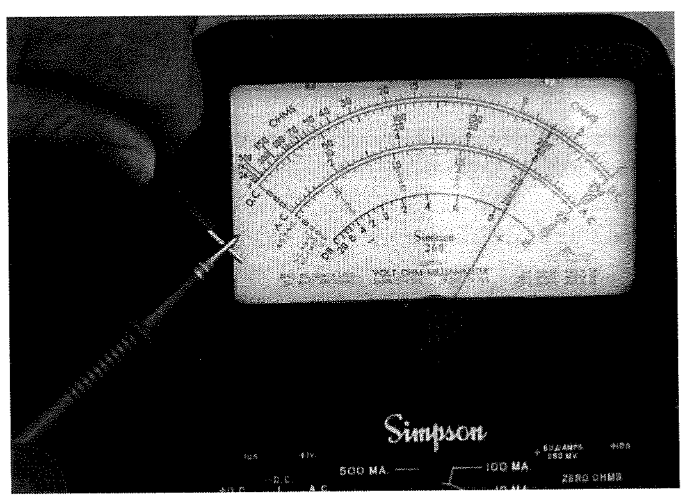
1. Set the function knob to R × 10,000.
2. Calibrate or zero out the meter by connecting the red probe with the black probe (see fig. 27).

Figure 27. Meter calibration



3. Connect the black probe to earth ground. This can be done by connecting it to a ground rod or by placing the tip of the black probe into the soil.
4. Connect the red probe, as shown in figure 28, to the conductor of the field wire being careful not to touch any of the metal with your fingers.

Figure 28. Ground fault test on control wire



The needle may or may not move to the right and then back to the left. This is normal. The needle should come to rest on the far left of the meter face.

Note: When using an analog meter set to R x 10,000, a measurement less than 800,000 ohms is an indication of a broken wire resulting in a valve not operating.

PRACTICE PROBLEMS #5

Ground Fault

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

Name______________________________

Date______________________________

1. A ground fault is

   A. earth contact with any part of the conductor.
   B. a splice.
   C. any part of an insulated wire in contact with the soil.

2. What instrument may be used when measuring a wire for a ground fault?

   A. a digital multimeter
   B. a quality analog multimeter
   C. a megger
   D. A or B
   E. B or C
   F. A or C

3. With a ground fault less than 800,000 ohms, the valve will

   A. operate all the time.
   B. operate some of the time.
   C. not operate.

4. With the meter set to R × 10,000, the needle pointing to 5 is

   A. 5 ohms.
   B. 50 ohms.
   C. 50,000 ohms.
   D. 500,000 ohms.
   E. 5,000,000 ohms.

The Relationship Among Voltage, Amperage, and Resistance

✍ Notes

There is also a relationship between voltage, ampere, and resistance. Voltage is the driving force in the circuit, amperage is the rate at which current flows, and resistance is what limits current. The equation, $I = V \div R$, describes the relationship among current [I], voltage [V], and resistance [R].

The following are a few questions to think about:

- What will happen to the voltage when one valve is turned on?
- If two valves are turned on simultaneously, will the voltage stay the same, go up, or go down?
- What will happen to the voltage if three valves are turned on at the same time?
- What will happen to the ampere if two or more valves are turned on concurrently?

The following are some facts to remember:

- *When resistance goes down, amperage will increase.* If a normal valve circuit measures 30 ohms and pulls approximately 0.25 amps when turned on, what will happen if the valve is taken out of the circuit and the hot and common wires are tied, or shorted, together? The ohm reading, which was 30 with the solenoid, is now close to 0–5 ohms, depending on the length of wire in the field. Without the solenoid, we are only reading the resistance of the wire! With little to no resistance, the amperage will increase and create more energy in the form of heat. The energy will increase to a level of the weakest component in the system, which hopefully is a fuse. A fuse is a wire sized to handle a specific design current. If current exceeds the design current, the wire fuses (melts) and breaks the circuit. Therefore, less resistance means more amperage can flow, which creates more energy in the form of heat, and if the heat exceeds the fuse limit, it will melt.

- *When amperage increases voltage will decrease.* The beginning of this module included analogies between electricity and water. Voltage is analogous to pressure and amperage is analogous to velocity. What happens to pressure when one valve is turned on? It goes down. What happens to the pressure when two valves are turned on? It goes down even more. The same is true with electricity. As more valves are turned on, the amperage will increase because of an increase in demand, and the voltage will decrease.

- *When resistance goes down, voltage will also go down.* As stated earlier, as resistance decreases amperage increases. As the amperage increases, the voltage decreases. Therefore, as resistance decreases, the voltage will also decrease. This is explained by the equation $V = I \times R$. When resistance decreases, voltage will also decrease.

Answers to Practice Problems

Practice Problems #1

1. B
2. C
3. B
4. A

Practice Problems #2

1. C
2. B
3. C
4. C

Practice Problems #3

1. B
2. C
3. B

Practice Problems #4

1. C
2. A
3. A
4. B

Practice Problems #5

1. A
2. E
3. C
4. C

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Irrigation ASSOCIATION®

8280 Willow Oaks Corporate Drive
Suite 400
Fairfax, VA 22031-4511
Tel: 703.536.7080
Fax: 703.536.7019
info@irrigation.org
www.irrigation.org

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