Irrigation Design Tip: Locating the Controller and Sizing Valve and Power Lines

Now that all the pipe and components for the project have been sized and a complete hydraulic analysis has proven that the system will work, it's time to turn our attention to the electrical portion of the design starting with the location of the controller.

Locating the controller

On large projects, where several controllers are located in various areas across the site, the controller locations are selected using a few key factors. First, to minimize the lengths of field wires to the automatic valves, the controller serving those valves should be centrally located near or within the valve group. Secondly, the controllers, where convenient, should be located in pairs or groups to minimize the length of power supply lines on the project.*

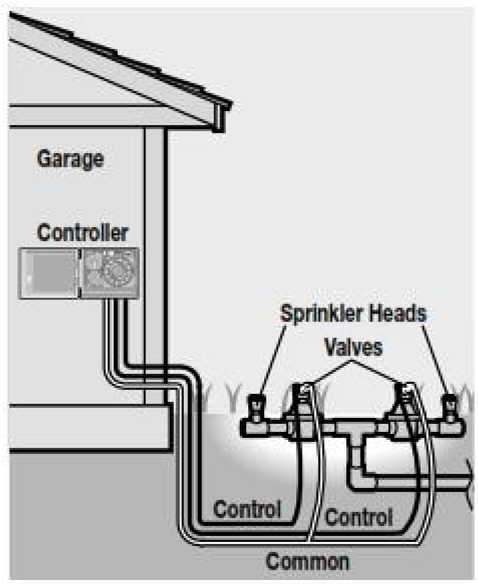
You should also keep in mind the convenience of the system for the installing contractor, the maintenance crew and the system owner. Where possible, place the controller where the sprinklers operated by the unit are visible from that location. This facilitates system operational tests during installation, and later, during normal maintenance.

Controllers designed for outdoor mounting do have weather-resistant cabinets. However, when the cabinet door is open this protection is greatly reduced. So, place your controllers on the site where the sprinklers they control will not douse the cabinet. This not only protects the electronics in the controller, it also keeps the user dry during manually initiated controller operations.

Sizing valve wires

On our sample residential plan, the electrical power, a standard 117 volts AC (or 230 volts AC), is available in the garage where the designer has indicated the controller should be installed. The actual position for the controller within the garage is left up to the installing contractor, who will decide where to mount the unit for the best connection to the power and most convenient hookup for the field wires to the valves.

Between the controller and the electric solenoid valves that feed the sprinklers there is a network of valve control wires. Each valve is hooked up to the controller with two wires, its own individual power or control wire and the "common" or "ground" wire. The common wire is connected to, and shared by, all the valves and completes the circuit back to the controller.



Valve control wire network

These wires carry a low voltage current, usually 24 volts AC, to energize the solenoid on the valve. A solenoid is simply a coil of copper wire that, when energized, lifts a plunger to open a control port in the valve. When the control port opens, it allows water pressure above the diaphragm in the valve's upper portion, or bonnet, to bleed off down stream. This pressure, which was holding back the main line water and pressure, when reduced allows the valve to open and operate the sprinklers.

*Controllers must not share either the valve common or the MV/PS circuit. To do so is a violation of the uniform electric code and will cause controller operation problems.

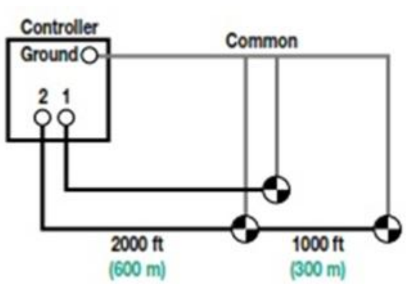
Excerpted from the Landscape Irrigation Design Manual

The higher the pressure at the valve, the more power it takes to raise the plunger against that pressure. Therefore, when sizing the valve control wires, the static pressure at the valve is an important factor. We will see in a moment how the various pressures require their own wire sizing charts.

The wire sizing procedure for Rain Bird 24-volt solenoid valves is simple and fast, especially if you are specifying one valve per station on the controller. One word of caution here is that this procedure was designed for Rain Bird solenoid valves. Rain Bird manufactures its own 24-volt solenoids and they are a highly efficient, low power consuming variety. The wire sizing procedure about to be presented is for this type of valve. For less efficient, 24-volt valves that require higher amperage, this procedure may not size the wires large enough.

Electrically efficient valves mean smaller, less costly, wires that can run greater distances on an irrigation project. The four-step procedure for sizing valve control wires has some similarities with the procedure for sizing pipe. We use the "worst case" valve circuit for sizing our first pair of wires. Electrically, the "worst case" valve circuit is the one requiring the heaviest current load. Later in the procedure, we will show you how to determine which is the "worst case" circuit. The "worst case" valve circuit will require the largest pair of wires. Because one of those wires is the "common," when we size the wire pair for the "worst case" circuit, we have sized the common wire for all the other valves.

We will use this diagram as a sample system for sizing field valve wires.



For simplicity, the controller has only two stations. Station #1 has one valve with a 2,000 ft (600 m) run of wire to connect it to the controller. Station #2 has two valves with a 2,000 ft (600 m) wire run to the first valve and another 1,000 ft (300 m) of wire to the second valve. The water pressure is 150 psi (10,3 bar).

Sizing field valve wires

1. Determine the actual wire run distance in feet (meters) from the controller to the first valve on a circuit and between each of the other valves on a multiple valve circuit. Complete this for each valve circuit (station) on the controller. In our diagram, step number one is complete.

All the wire lengths have been measured. This is easy to accomplish using a map measure and an accurate, scaled, drawing of the site.

2. Calculate the "equivalent circuit length" for each valve circuit. The equivalent circuit length is calculated by multiplying the actual wire run distance to the valve by the number of valves at that location on the circuit.

Station #1 in our example has only one valve on the circuit and a wire run of 2,000 ft (600 m). Its equivalent circuit length is calculated like this:

2,000 ft x 1 valve = 2,000 ft
(600 m x 1 valve = 600 m)

Station #2, however, is calculated with a slight variation because of its multiple valve situation. Working backward as we did for sizing pipe in a valve circuit, we start with the1,000 ft (300 m) of wire to the last valve. The equivalent circuit length for this section is:

1,000 ft x 1 valve = 1,000 ft
(300 m x 1 valve = 300 m)

The wire run of 2,000 ft (600 m) from the controller to the first valve of Station #2 provides the electricity for both valves. This section of the circuit is calculated like this:

2,000 ft x 2 valves = 4,000 ft
(600 m x 2 valves = 1200 m)

Adding these two figures together we have:

1,000 ft	(300 m)
+ 4,000 ft	(+1200 m)
5,000 ft	(1500 m)

Station #2 has a 5,000 ft (1500 m) equivalent circuit length.

3. From the Rain Bird wire sizing chart (on next page), select the common and control wire sizes for the circuit with the highest equivalent circuit length (the "worst case" circuit). Use the sizing chart that most nearly approximates the static pressure in your system.

On this "worst case" circuit, the wires should be the same size or no more than one size apart. In our sample system, the pressure was 150 psi (10,3 bar). So we can use that wire chart. Though we would ideally like to use the same size wires in the pair that supports this "worst case" circuit, the may give us two different sizes for this pair. As the rule states, these wires must be within one size of each other. When the wires are not the same size, the larger one is to be used as the common for the system. In wire gauge sizes, the higher the gauge number, the smaller the wire. #20 gauge wire is much smaller than #12 gauge wire.

Circuit #2 in our sample system has the highest equivalent circuit length which is 5,000 ft (1500 m). Looking at the 150 psi (10,3 bar) chart, we want to find a circuit length that is at least 5,000 ft (1500 m) and is closest to the upper left corner of the chart. This should give us the smallest acceptable wire pair.

For our 5,000 ft (1500 m) circuit length, 6,200 (1889,76) is the first number greater than or equal to 5,000 (1500).

Reading across to the left-hand column we see this corresponds to a #14 (2,5 mm^2) ground or common wire.

Reading up to the top of the chart, we find that a #14 (2,5 mm^2) control wire is sufficient also. The wires for the "worst case" circuit have been sized.

We could not use the 5,600 ft (1706,08 m) circuit-length number on the chart because that would have given us a #12 (4,0 mm^2) common and a #16 (1,5 mm^2) control wire pair which is more than one size apart. This "equal or only one size apart" restriction applies only for the "worst case" wire pair.

4. Having the common wire size established, use the wire sizing chart to determine the control wire size for each of the remaining valve circuits on the controller. For Station #1 with its equivalent circuit length of 2,000 ft (600 m), we read across from the #14 (2,5 mm^2) gauge ground wire on the 150 psi (10,3 bar) chart to the first number equal to or greater than 2,000 ft (600 m). The 3,500 (1066,80) in the first column satisfies this requirement, and when we read up to the top of the chart we see that a #18 (0,75 mm^2) control wire will work for this circuit. If there were more stations being used on the controller, we would complete this step by sizing all the other valve circuit control wires.

The wire designed for use on automatic irrigation systems is known as U.F. or "underground feeder" wire. These are single, copper conductor, thickly insulated, low-voltage wires that are direct-buried without the need for electrical conduit. Always check the local electrical or building codes for the type of wire to use on your project.

On larger commercial projects, U.F. wire sizes smaller than #14 (2,5 mm^2) are seldom used. Even though the smaller wires can handle the load electrically (according to the sizing chart), they lack physical strength. As the wires get smaller, the combination of smaller conductors and thick insulation can hide wire breaks. When the installer is spooling off wires from several reels on the back of a truck, a smaller size conductor can break while its thick insulation remains intact. The result is a wire fault that will have to be discovered and fixed.

The other electrical wires that need to be sized for the project are the controller power wires. The variable factors that dictate what size wire to use for supplying power to the controller are:

RAIN BIRD 24 V AC SOLENOID VALVES WIRE SIZING CHART

Equivalent circuit length (in feet)

Rain Bird 5.5 VA solenoid electric valves with 26.5 V transformers

Common wire size	80 psi water pressure at valve, control wire size 18	16	14	12	10	8	6	4
18	3000	3700	4300	4800	5200	5500	5200	5800
16	3700	4800	5900	6900	7700	8300	8800	9100
14	4300	5900	7700	9400	11000	12300	13300	14000
12	4800	6900	9400	12200	15000	17500	19600	21100
10	5200	7700	11000	15000	19400	23900	27800	31100
8	5500	8300	12300	17500	23900	30900	38000	44300
6	5700	8800	13300	19600	27800	38000	49200	60400
4	5800	9100	14000	21100	31100	44300	60400	78200

Common wire size	100 psi water pressure at valve, control wire size 18	16	14	12	10	8	6	4
18	2800	3500	4100	4500	4900	5200	5400	5500
16	3500	4500	5500	6500	7300	7800	8300	8500
14	4100	5500	7200	8900	10300	11600	12500	13200
12	4500	6500	8900	11500	14100	16500	18400	19900
10	4900	7300	10300	14100	18300	22500	26200	29300
8	5200	7800	11600	16500	22500	29100	35700	41700
6	5400	8300	12500	18400	26200	35700	46300	56900
4	5500	8500	13200	19900	29300	41700	56900	73600

Common wire size	125 psi water pressure at valve, control wire size 18	16	14	12	10	8	6	4
18	2600	3200	3800	4200	4600	4800	5000	5100
16	3200	4200	5200	6000	6700	7300	7700	7900
14	3800	5200	6700	8200	9600	10800	11600	12200
12	4200	6000	8200	10700	13100	15300	17100	18500
10	4600	6700	9600	13100	17000	20900	24400	27300
8	4800	7300	10800	15300	20900	27100	33200	38800
6	5000	7700	11600	17100	24400	33200	43100	52900
4	5100	7900	12200	18500	27300	38800	52900	68500

Common wire size	150 psi water pressure at valve, control wire size 18	16	14	12	10	8	6	4
18	2400	3000	3500	3900	4300	4500	4600	4700
16	3000	3900	4800	5600	6300	6800	7200	7400
14	3500	4800	6200	7700	9000	10000	10800	11400
12	3900	5600	7700	10000	12200	14300	16000	17300
10	4300	6300	9000	12200	15900	19500	22800	25400
8	4500	6800	10000	14300	19500	25300	31000	36200
6	4600	7200	10800	16000	22800	31000	40200	49400
4	4700	7400	11400	17300	25400	36200	49400	63900

Figure 75a: Wire sizing for 24 VAC solenoid valves (U.S. Standard Units)

RAIN BIRD 24 V AC SOLENOID VALVES WIRE SIZING CHART

Equivalent circuit length (in meters)

Rain Bird 5.5 VA solenoid electric valves with 26.5 V transformers

Common wire size	5,5 bar water pressure at valve, control wire size 0,75	1,5	2,5	4,0	6,0	10,0	16,0	25,0
0,75	914,40	1127,76	1310,64	1463,04	1584,96	1676,40	1584,96	1767,84
1,5	1127,76	1463,04	1798,32	2103,12	2346,96	2529,84	2682,24	2773,68
2,5	1310,64	1798,32	2346,96	2865,12	3352,80	3749,04	4053,84	4267,20
4,0	1463,04	2103,12	2865,12	3718,56	4572,00	5334,00	5974,08	6431,28
6,0	1584,96	2346,96	3352,80	4572,00	5913,12	7284,72	8473,44	9479,28
10,0	1676,40	2529,84	3749,04	5334,00	7284,72	9418,32	11582,40	13502,64
16,0	1737,36	2682,24	4053,84	5974,08	8473,44	11582,40	14996,16	18409,92
25,0	1767,84	2773,68	4267,20	6431,28	9479,28	13502,64	18409,92	23835,36

Common wire size	6,9 bar water pressure at valve, control wire size 0,75	1,5	2,5	4,0	6,0	10,0	16,0	25,0
0,75	853,44	1066,80	1249,68	1371,60	1493,52	1584,96	1645,92	1676,40
1,5	1066,80	1371,60	1676,40	1981,20	2225,04	2377,44	2529,84	2590,80
2,5	1249,68	1676,40	2194,56	2712,72	3139,44	3535,68	3810,00	4023,36
4,0	1371,60	1981,20	2712,72	3505,20	4297,68	5029,20	5608,32	6065,52
6,0	1493,52	2225,04	3139,44	4297,68	5577,84	6858,00	7985,76	8930,64
10,0	1584,96	2377,44	3535,68	5029,20	6858,00	8869,68	10881,36	12710,16
16,0	1645,92	2529,84	3810,00	5608,32	7985,76	10881,36	14112,24	17343,12
25,0	1676,40	2590,80	4023,36	6065,52	8930,64	12710,16	17343,12	22433,28

Common wire size	8,6 bar water pressure at valve, control wire size 0,75	1,5	2,5	4,0	6,0	10,0	16,0	25,0
0,75	792,48	975,36	1158,24	1280,16	1402,08	1463,04	1524,00	1554,48
1,5	975,36	1280,16	1584,96	1828,80	2042,16	2225,04	2346,96	2407,92
2,5	1158,24	1584,96	2042,16	2499,36	2926,08	3291,84	3535,68	3718,56
4,0	1280,16	1828,80	2499,36	3261,36	3992,88	4663,44	5212,08	5638,80
6,0	1402,08	2042,16	2926,08	3992,88	5212,08	6370,32	7437,12	8321,04
10,0	1463,04	2225,04	3291,84	4663,44	6370,32	8260,08	10119,36	11826,24
16,0	1524,00	2346,96	3535,68	5212,08	7437,12	10119,36	13136,88	16123,92
25,0	1554,48	2407,92	3718,56	5638,90	8321,04	11826,24	16123,92	20878,80

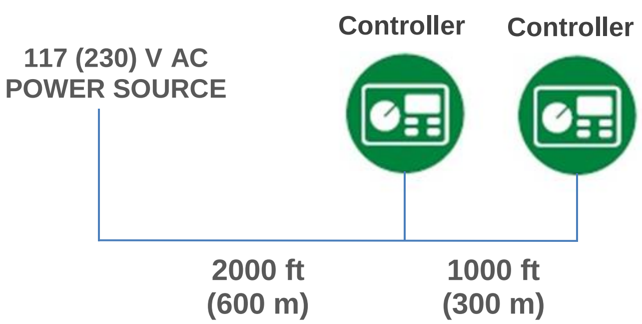
Common wire size	10,3 bar water pressure at valve, control wire size 0,75	1,5	2,5	4,0	6,0	10,0	16,0	25,0
0,75	731,52	914,40	1066,80	1188,72	1310,64	1371,60	1402,08	1432,56
1,5	914,40	1188,72	1463,04	1706,88	1920,24	2072,64	2194,56	2255,52
2,5	1066,80	1463,04	1889,76	2346,96	2743,20	3048,00	3291,84	3474,72
4,0	1188,72	1706,88	2346,96	3048,00	3718,56	4358,64	4876,80	5273,04
6,0	1310,64	1920,24	2743,20	3718,56	4846,32	5943,60	6949,44	7741,92
10,0	1371,60	2072,64	3048,00	4358,64	5943,60	7711,44	9448,80	11033,76
16,0	1402,08	2194,56	3291,84	4876,80	6949,44	9448,80	12252,96	15057,12
25,0	1432,56	2255,52	3474,72	5273,04	7741,92	11033,76	15057,12	19476,72

Figure 75b: Wire sizing for 24 VAC solenoid valves (International System Units)

- available voltage at the power source
- distance from the power source to the controllers
- minimum voltage required to operate the controller
- power required by the type of valve used
- the number of valves used on any one station of the controller
- the number of controllers operating at one time

As irrigation projects get bigger, with more controllers, sizing the 120 (230) volt supply wires to their minimum can become quite complicated. To simplify the process, you can use the five-step procedure outlined here with the charts that include information on the power requirements for Rain Bird automatic controllers and valve.

Let's do one example so that you will become familiar with this procedure. The diagram illustrates the situation: a 3,000 ft (900 m) wire run with two controllers at different locations, and two solenoid valves per station on at least one station of each controller.



Sizing power wires

The following is the 120 (230) V AC primary wire sizing procedure.

1. Determine the power requirements for the controller you have selected, as well as the requirements for the number of solenoid valves that will be operating at one time. (You may have only one valve per station. However, if you are using a master valve to shut down the project's main line between irrigation cycles, this would raise the requirement to two valves.)

Example controller primary current requirements:

One controller alone	= .03 amps
Two solenoid valves .12 x 2	= .24 amps +
Primary requirements for a controller and 2 valves	= .27 amps

2. Determine the maximum allowable voltage drop along the wires from the power source to the controllers. To do this you find the voltage available at the power source and subtract from it the voltage required at the controller. The result is how much can be lost. It's like sizing pipe to determine pressure loss.

Example: Maximum allowable voltage drop

Power available at the source	= 120 V AC (230 V AC)
ISC power requirement stated in catalog	= 117 V AC (220 V AC) –
Maximum allowable voltage drop	= 3 V AC (10 V AC)

Example controller electrical characteristics:

- Input required: 117 (220) V AC ± 10%, 60 (50) Hz
- Output: 24 to 26.5 V AC, 1.5 A
- Circuit breaker: 1.5 A
- UL listed and tested
- Sequential operation: When more than one station is programmed to start at the same time, those stations will water in sequence starting from the station with the lowest number

3. Calculate the equivalent circuit length for the power wire and controller or controllers. You will see how similar this is to the way we calculated equivalent circuit lengths for valve wires.

Example: Calculate the equivalent circuit length working backwards (farthest out) from the controller

1 controller x 1000 ft (300 m)	= 1000 ft (300 m) +
2 controllers x 2000 ft (600 m)	= 4000 ft (1200 m) +
Total equivalent circuit length	= 5000 ft (1500 m) +

4. Using the formula, calculate the F factor for the circuit.

Example: To calculate the circuit's F factor, the formula is:

$$F = \frac{\text{allowable voltage drop}}{\text{Amps/control unit x equivalent}}$$

Length in thousands of feet (meters)

$$F = \frac{3\ V}{.17\ A \times 5} = 3.529 \text{ or } 3.53$$

$$F = \frac{3\ V}{.17\ A \times 1524} = ,012$$

5. Select a power wire size from the Wires size and F factor table that has an F factor equal to or less than the calculated F factor. Think of the F factor as friction loss in a pipe. We want to select a wire with an F factor for loss that is equal to or less than the loss or "F" factor for the circuit.

Wire size		"F" factor	
#18	(,75 mm^2)	13.02	(,043)
#16	(1,5 mm^2)	8.18	(,027)
#14	(2.5 mm^2)	5.16	(,017)
#12	(4,0 mm^2)	3.24	(,011)
#10	(6,0 mm^2)	2.04	(,007)
#8	(10,0 mm^2)	1.28	(,004)
#6	(16,0 mm^2)	0.81	(,003)
#4	(25,0 mm^2)	0.51	(,002)

Wires size and F factor table

Example: Select a power wire from the table above that has an F factor equal to or less than the 3.53 (0,012) we have calculated.

Number 12 (4,0 mm^2) wire has an F factor of 3.24 (0,011) which is the factor immediately less than our calculated 3.53 (0,012). Our supply wires for the controllers would be size #12 (4,0 mm^2).

With all the hydraulic and electrical calculations complete, you are ready to prepare the final irrigation plan.