SPECNEWS
September/October 2018
Irrigation News and Product Updates
for Irrigation and Landscape Designers

Irrigation Design Tip: Understanding Basic Hydraulics

Hydraulics is defined as the study of fluid behavior, at rest and in motion. Properly designed irrigation piping based on sound hydraulics is the basis for a system that lasts longer and performs better.

1. Controlling the water flow velocity within proper limits reduces wear on the system components and lengthens service life.
2. Good hydraulic design results in the best system performance mitigating the potential for broken pipes or stressed landscape material that does not receive adequate water.
3. Understanding hydraulics and designing based on these requirements allows you to reduce over designing the system to accommodate "unknown" factors.
4. Proper hydraulic analysis is important to eliminate water waste and is the basis for an efficient system.

To accomplish all of these objectives we need to understand the nature of water.

- Water takes the shape of the container and is relatively incompressible.
- Water is also quite heavy — **one gallon (one liter) of water weighs 8.3 lbs (1 kg).**
- **Water has a specific weight per cubic foot of 62.4 lbs (one ton per cubic meter).**
- Water seeks its own lowest level.
- Water exerts pressure — defined as the force of water exerted over a given area.

In this irrigation design tip we will cover how to calculate feet of head (meters of head) and static pressure and dynamic pressure.

The formula for water pressure looks like this:

$$P = \frac{\text{force}}{\text{area}} = \frac{F}{A}$$

P = pressure in pounds per square inch (kilograms per square centimeter)

F = force in pounds (kilograms)

A = area in square inches (square centimeters)

The force is created by the weight of the water above the point where it is being measured. When the area is constant, such as 1 in^2 (1 cm^2), then the force in pounds (kilograms) is dependent on the height of the water. The more height to a column of water, the more weight, force, and pressure. Pressure is expressed as pounds per square inch (kilograms per square centimeter) and abbreviated as psi (kg/cm^2 or bar).

A container 1 in^2 (1 cm^2) and filled with water to a height of 1 ft (50 cm) — the pressure (psi/bar) would equal:

$$P = \frac{W}{A} = \frac{.036\ \text{lb in}^3 \times 12\ \text{in}^3}{1\ \text{in} \times 1\ \text{in}} = \frac{0.433\ \text{lb}}{1\ \text{in}^2}$$

$$\left(P = \frac{W}{A} = \frac{1\ \text{gm/cm}^3 \times 50\ \text{cm}^3}{1\ \text{cm} \times 1\ \text{cm}} = \frac{50\ \text{gm}}{\text{cm}^2} = 0{,}05\ \text{kg/cm}^2 \right)$$

P = 0.433 psi (0,05 bar)

$$P = \frac{W}{A} = \frac{.036\ \text{lb in}^3 \times 24\ \text{in}^3}{1\ \text{in} \times 1\ \text{in}} = \frac{0.866\ \text{lb}}{1\ \text{in}^2}$$

$$\left(P = \frac{W}{A} = \frac{1\ \text{gm/cm}^3 \times 100\ \text{cm}^3}{1\ \text{cm} \times 1\ \text{cm}} = \frac{100\ \text{gm}}{\text{cm}^2} = 0{,}10\ \text{kg/cm}^2 \right)$$

P = 0.866 psi (0,1 bar)

Consider a 1 in^2 (1 cm^2) container filled with water to a depth of 1 ft (50 cm). One foot (50 cm) of water creates a pressure of .433 psi (0,05 bar) at the base of the container. It makes no difference if the 1 ft (50 cm) of water is held in this narrow container or at the bottom of a 1 ft (50 cm) deep lake. The area we are concerned with is only 1 in^2 (1 cm^2) at the bottom of either container.

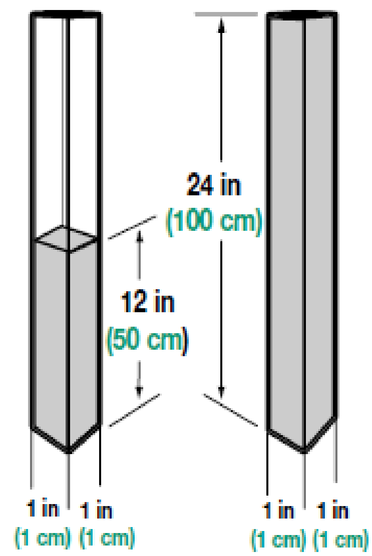

Figure 1: Water towers filled at 12 in and 24 in (50 cm and 100 cm)

If you double the height of the water, the pressure is doubled.

.433 x 2 ft of height = .866 psi

0,05 bar x 2 = 0,1 bar

Feet of Head (or Meters of Head)

This relationship between pressure and elevation is known as "feet of head" (meters of head). By using this conversion factor, we can easily determine the static (no flow) water pressure within any pipe.

The factors for converting pressure to feet of head (meters of head) and feet of head (meters of head) back to pressure **are both multipliers.**

Convert feet of head or meters of head to pressure

To convert feet of head to pressure in psi, multiply the feet by .433. (One foot of water = .433 psi.)

To convert meters of head to pressure in kg/cm^2, divide the meters by 10. (One meter of water = 0,1 kg/cm^2)

Example: 200 ft of water height x .433 produces 86.6 psi at its base or 100 meters of water x 0,1 kg/cm2 = 10kg/.cm^2 or 10 bar of pressure at its base.

Further, using this factor we can determine that a water tower with a water surface 200 ft (100 m) above the point where we need it would create a pressure of 86.6 psi (10 bar).

Convert pressure to feet of head or meters of head

To convert pressure in psi to feet of head, multiply the pressure by 2.31. One psi = 2.31 ft of water.

For example, 100 psi x 2.31 = 231 feet of head.

To convert pressure in bar or kg/cm2 to meters of head, multiply the pressure by 10. 1 kg/cm2 = 10 meters of water = 1 bar.

For example, 10kg/cm2 = 100 meters of head.

Example

Calculating with this factor, we would know that we can't pump water up into a lake that is 300 ft (200 m) above our water source if we had a pumping water pressure of 100 psi (10 bar).

Pressure of 100 psi (10 bar) would only lift the water 231 ft (100 m).

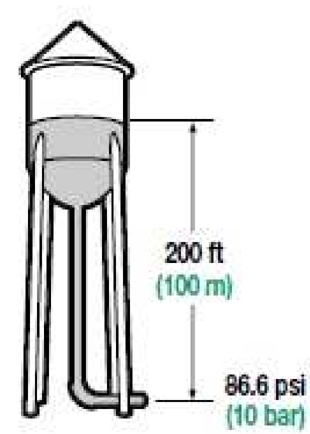

Figure 2: Water lower – 200ft

Calculating Static and Dynamic Pressure

The word hydrostatic refers to the properties of water at rest. We will be discussing static water pressure as a starting point for hydraulic design of an irrigation system. Hydrodynamic refers to the properties of water in motion.

Moving water, at the correct flow and pressure, to where it's needed is the hydraulic basis of irrigation design. Static water pressure refers to the pressure of a closed system with no water moving. A water-filled main line, with all valves closed, would experience full static pressure with only pressure variation due to elevation. Static water pressure is an indication of the potential pressure available to operate a system.

Static water pressure

There are two ways to create static water pressure. As we have seen in our discussion regarding the relationship between psi (bar) and elevation, water height can create pressure. By elevating water in tanks, towers and reservoirs, above where the water is needed, static pressure is created. Water systems may also be pressurized by a pump or a pump can be used to increase, or boost, pressure. Whether from elevation differences or by mechanical means, understanding the static pressure at the water source for an irrigation system is where hydraulic calculations begin.

EXAMPLE

Here is an example of a simple system for supplying water to a house from a city main line. The supply system to this home looks like this (see Figure 3): at point "A," under the street at a depth of 4 ft (1,2 m), is the city water main with a fairly high static pressure of 111 psi (7,7 bar). From the main line there is a supply pipe made of 1-1/2 in (40 mm) copper that rises 3 ft (1 m) to connect to the meter and is 12 ft (4 m) in length. At the curb side is an existing 3/4 in (20 mm) size water meter. Connected to the meter is a 3/4 in (20 mm) copper service line that runs 35 ft (11 m) to where it enters the house through the garage. There is a small rise in elevation of 2 ft (0,5 m) from the meter location to the house. Finally, 1 ft (0,3 m) above the point where the service line enters the house is a hose valve connection.

To calculate the static water pressure available to the site, we start at point "A" where the water purveyor advises that we can expect a static pressure in their main line of 111 psi (7,7 bar). Point "B " in this diagram is at the same elevation as the main line and has the

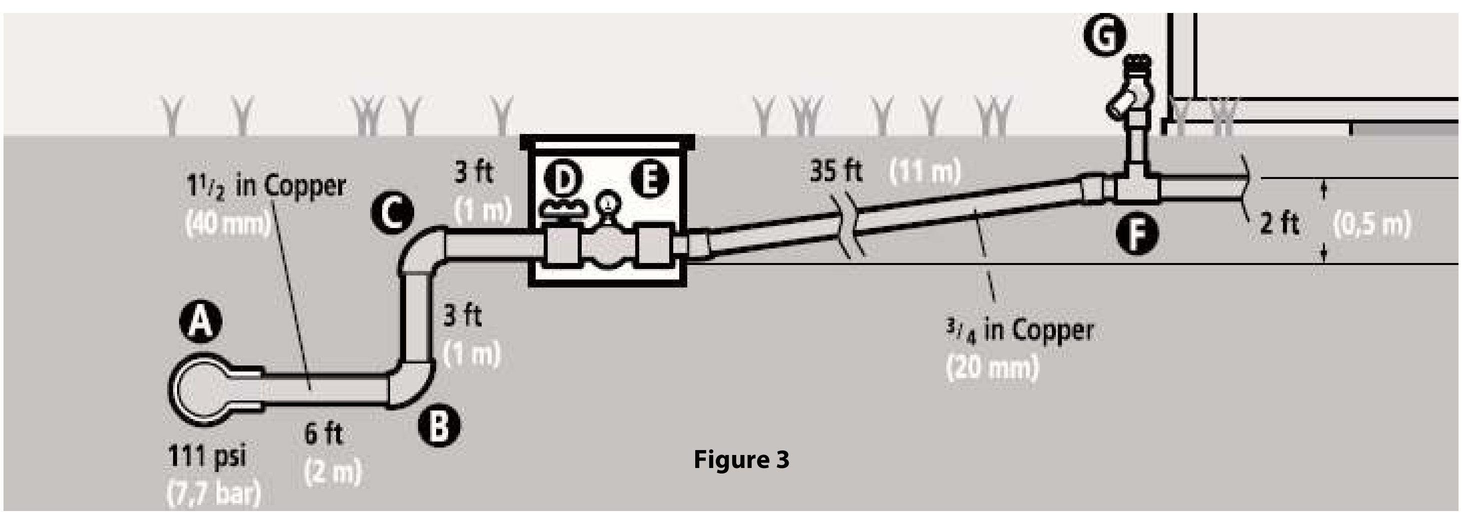

Figure 3

same 111 psi (7,7 bar) pressure. Point “C” is 3 ft (1 m) above the main and we would calculate the pressure at point “C” as follows: 3 ft x .433 psi =1.299 psi (1 m ÷ 10 = 0,1 bar), or for simplification, 1.3 psi (0,1 bar). Since the supply source is from below, the 1.3 psi (0,1 bar) is a weight against the source pressure, so it is a loss.

Therefore, the static pressure at point “C” is 111 psi – 1.3 psi (7,7 bar – 0,1 bar) for a remainder of 109.7 psi (7,6 bar).

Points “D” and “E,” which are on each side of the meter, are on the same elevation as point “C,” so they have the same 109.7 psi (7,6 bar) static pressure. Between points “E” and “F” there is a 2 ft (0,5 m) rise in elevation that we calculate as follows to get a static pressure for point “F:”

2 x .433 psi = .866 psi (0,5 ÷ 10 = 0,05 bar)
109.7 psi – .866 psi = 108.8 psi (7,6 bar – 0,05 bar = 7,55 bar). This is the static pressure remaining at point “F”.

Point “G,” the hose bib in the garage, is 1 ft (0,3 m) above point “F,” for which we would calculate the static pressure by subtracting .433 psi (0,03 bar) from the 108.8 psi (7,55 bar) at point “F” to determine there is approximately 108.36 psi (7,52 bar) at point “G.”

A more direct way to calculate the static pressure for point “G” would be to multiply the 6 ft rise in elevation by .433 psi (divide the 2 m rise by 10) and subtract the 2.6 psi (0,2 bar) answer from 111 psi (7,7 bar) for a remainder of 108.4 psi (7,5 bar) in rounded numbers.

In this example, you would need to consider and control the high water pressure condition on this site. Had the pressure in the city main been low, say 40 psi (2,8 bar), the you would adjust the design and equipment selection to provide a system that operates correctly even with the low service line pressure. If the water main was in a street higher than the site, all the elevation change coming down to the project would have produced pressure gains instead of losses.

For example, had the main line been located 10 ft (3 m) above the site, the static pressure at the hose bib would have been: 10 ft x .433 psi = 4.33 psi + 111 psi static pressure in the main line = 115.33 psi static pressure at the valve (3 m ÷ 10 = 0,3 bar + 7,7 bar static pressure in the main line = 8,0 bar static pressure at the valve).

In the previous example, we could have measured the water pressure with a pressure gauge rather than using the water purveyor’s estimate. However, it is important to design the irrigation system for the “worst case” pressure conditions. In most locales, the “worst case” situation will be on hot weekend days in the summer when a lot of people water their lawns. The water purveyor probably uses a computer model to predict the lower summer pressures in their system, so they can provide data regardless of the season.

The water purveyor may also be able to predict if pressures may change in the future. For example, they may be planning to install a new pump to increase pressure or conversely, the additional houses to be built in the future may cause the pressure to be lower. Good advice can generally be obtained from the professionals working for the water purveyor, and it is good to call them even if a pressure reading is made at the site.

The pressures calculated in the previous example were all static water pressures with no water movement in the system. When a valve is opened, and water in the system begins flowing, we have a new pressure situation to take into account.

Friction loss is a pressure loss caused by water flowing through pipes, fittings, and components in the system. Pipes, fittings, valves, water meters and backflow prevention devices all offer resistance to water flowing, and the resistance creates a pressure loss. The roughness and turbulence on the inside surfaces of pipes and components creates a drag or friction on the passing water, which causes the pressure of the flowing water to decrease.

Dynamic water pressure

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

Pipe flow loss charts are available for quickly determining the pressure loss at particular flows, in gallons per minute (gpm), meters cubed per hour (m3/h) or liters per second (L/s), through various types and sizes of pipe. This flow loss is usually given as psi (bar) loss per 100 ft (100 m) of pipe. The loss varies with differing types of pipe; different pipes have varying dimensions and degrees of internal smoothness. This fact makes each type of pipe hydraulically unique.

In addition to the pound per square inch loss per 100 ft (bar loss per 100 m), friction loss charts will often show the velocity of the water passing through the pipe at that flow rate.

Velocity, the rate at which water moves within the components of the system, is an important factor to understand. The faster the water moves through a pipe, the higher the friction loss. Fast moving water can cause other problems in a system as well.

The industry has established 5 ft/s (1,5 m/s) as an acceptable maximum velocity. Velocities less than 5 ft/s (1,5 m/s) are less likely to cause damaging surge pressures. Also, pressure losses due to friction increase rapidly as velocities increase beyond 5 ft/s (1,5 m/s).

In addition to checking a pipe chart to find velocity for a certain type and size of pipe at a given flow, you can use an equation to determine flow mathematically. The formula is:

$$V = \frac{\text{gpm}}{2.45 \times \text{dia}^2} \qquad V = \frac{1273{,}24 \times \text{L/s}}{\text{dia}^2}$$

V = velocity in feet per second (meters per second)
dia = inside diameter of pipe in inches (millimeters)

The amount of water flowing through the components of the system also affects the friction loss. The more water being forced through the system, the higher the flow velocity, and the higher the pressure loss. Because of this, the physical size of the water path through a component also determines how much pressure is lost.

You can find pressure loss charts in the Rain Bird Landscape Irrigation Products Catalog.

A sound irrigation design cannot begin with subjective terms like "good pressure," or "high pressure." To begin an irrigation system design you must have the critical data or make critical assumptions about the water source.

Hopefully, these examples have provided an understanding of how to calculate the static and dynamic pressures. Rain Bird's Landscape Irrigation Design manual has additional excercises you can do to reinforce your understanding. You can find the manual under Design Guides on www.rainbird.com.