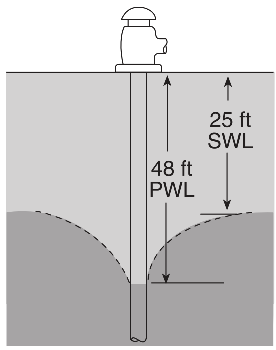
The following two examples illustrate how to calculate well drawdown.

Example 4

The water level in a well is 25 ft below the ground surface when the pump is not in operation. If the water level is 48 ft below the ground surface when the pump is in operation, what is the drawdown in feet?



Drawdown is the measure of water level *drop* once the pump has been turned on. In this problem, the drawdown is

$$\begin{aligned} \text{drawdown} &= \text{pumping water level} - \text{static water level} \\ &= 48 \text{ ft} - 25 \text{ ft} \\ &= 23 \text{ ft} \end{aligned}$$

Example 5

When the pump is not in operation, the water level in a well is 76 ft below ground surface. The water level drops to 88 ft when the pump is in operation. What is the drawdown in feet?

$$\begin{aligned} \text{drawdown} &= \text{pumping water level} - \text{static water level} \\ &= 88 \text{ ft} - 76 \text{ ft} \\ &= 12 \text{ ft} \end{aligned}$$

SPECIFIC CAPACITY

The specific capacity of a well is a measure of the well yield per unit of drawdown. It is usually expressed in terms of gallons-per-minute well yield per foot of drawdown. Therefore, the equation used to calculate specific capacity is

$$\text{specific capacity} = \frac{\text{well yield}}{\text{drawdown}}$$

The following examples illustrate the calculation of specific capacity.

Example 6

It takes a well pump 0.6 min to fill a 55-gal barrel. If the drawdown while the pump is in operation is 11 ft, what is the specific capacity of the well?

To calculate the specific capacity of the well, you must know the gallons-per-minute well yield and the feet of drawdown.

$$\text{well yield} = \frac{55 \text{ gal}}{0.6 \text{ min}}$$

$$= 91.67 \text{ gpm}$$

Using the gallons-per-minute well yield and drawdown information, calculate the specific capacity of the well:

$$\text{specific capacity} = \frac{\text{well yield in gpm}}{\text{drawdown in ft}}$$

$$= \frac{91.67 \text{ gpm}}{11 \text{ ft}}$$

$$= 8.33 \text{ gpm/ft}$$

Example 7

If the well yield is 14.3 L/s when the drawdown for the well is 6.1 m, what is the specific capacity of the well?

The equation used in calculating specific capacity is

$$\text{specific capacity} = \frac{\text{well yield in L/s}}{\text{drawdown in m}}$$

To solve the problem, fill in the information given in the equation and complete the calculation:

$$\text{specific capacity} = \frac{14.3 \text{ L/s}}{6.1 \text{ m}}$$

$$= 2.34 \text{ (L/s)/m}$$

Hydraulics

Density and Specific Gravity

When we say that one substance is heavier than another, we mean that any given volume of the substance is heavier than the same volume of the other substance. For example, any given volume of steel is heavier than the same volume of aluminum, so we say that steel is heavier than—or has greater density than—aluminum.

DENSITY

For scientific and technical purposes, the density of a body or material is precisely defined as *the weight per unit of volume*. In the water supply field, perhaps the most common measures of density are pounds per cubic foot (lb/ft^3) and pounds per gallon (lb/gal). The density of a dry material, such as sand, activated carbon, lime, and soda ash, is usually expressed in pounds per cubic foot. The density of a liquid, such as water, liquid alum, or liquid chlorine, can be expressed either as pounds per cubic foot or as pounds per gallon. The density of a gas, such as air, chlorine gas, methane, or carbon dioxide, is normally expressed in pounds per cubic foot.

The density of a substance changes slightly as the temperature of the substance changes. This happens because substances usually increase in size (volume) as they become warmer, as illustrated in Figure H1-1. Because of expansion with warming, the same weight is spread over a larger volume, so the density is lower when a substance is warm than when it is cold.

The effects of pressure and temperature on solids and liquids are very small and are usually ignored. However, temperature and pressure have a significant effect on the density of gases. Whenever the density of a gas is given, the temperature and pressure at that density are usually also given.

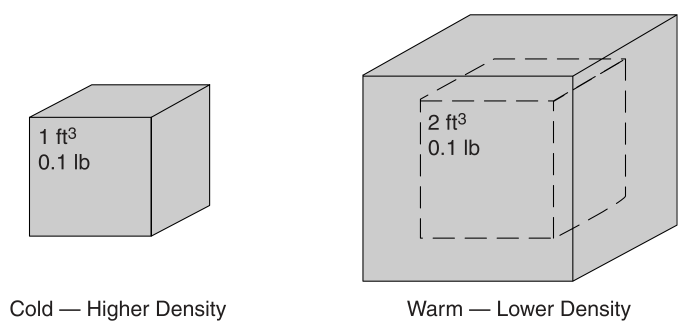


FIGURE H1-1 Changes in density based on temperature

Table H1-1 indicates how the density of water (usually specified as a constant 62.4 lb/ft^3) varies only slightly with temperature, especially within the water temperature ranges in effect at most water supply operations. Water is unusual in that it is most dense at 39.2°F (4.0°C) and becomes less dense when the temperature rises or falls.

Table H1-2 shows some densities of typical solid, liquid, and gaseous substances. You'll notice that some of the solids given in the table have density reported as *bulk density.* Bulk density is defined as the weight of a cubic foot of material as it would be shipped from the supplier to the treatment plant. Bulk density is much less than laboratory density because its calculation includes the volume of the air mixed in with the material; the amount of air (and therefore the bulk density) varies according to whether the material comes in rock, crystal, pellet, granular, or powder form. For example, for laboratory purposes the density of pure sodium chloride (table salt) is about 135 lb/ft^3. However, the bulk density of sodium chloride as it is shipped in rock form (rock salt) is only 50–60 lb/ft^3. This means that over half the volume of a bulk container of rock salt is occupied by air between the individual pieces.

TABLE H1-1 Density of water

Temperature		
°*F*	°*C*	Density, *lb/ft*^{3}
32.0	0	62.416
35.0	1.7	62.421
39.2	4.0	62.424
40.0	4.4	62.423
50.0	10.0	62.408
60.0	15.6	62.366
70.0	21.1	62.300
80.0	26.7	62.217
90.0	32.2	62.118
100.0	37.8	61.998
120.0	48.9	61.719
140.0	60.0	61.386

TABLE H1-1 Density of water (Continued)

Temperature		
°F	*°C*	Density, *lb/ft*^{3}
160.0	71.1	61.006
180.0	82.2	60.586
200.0	93.3	60.135
212.0	100.0	59.843

TABLE H1-2 Densities of various substances

	Density	
Substance	*lb/ft*^{3}	*lb/gal*
Solids		
Activated carbon*†	8–28 (Avg. 12)	
Lime*†	20–50	
Dry alum*†	60–75	
Aluminum (at 20°C)	168.5	
Steel (at 20°C)	486.7	
Copper (at 20°C)	555.4	
Liquids		
Propane (–44.5°C)	36.5	4.88
Gasoline†	43.7	5.84
Water (4°C)	62.4	8.34
Fluorosilicic acid (30%, –8.1°C)	77.8–79.2	10.4–10.6
Liquid alum (36°Bé, 15.6°C)	83.0	11.09
Liquid chlorine (–33.6°C)	97.3	13.01

TABLE H1-2 Densities of various substances (Continued)

Substance	Density *lb/ft³*	Density *lb/gal*
Sulfuric acid (18°C)	114.2	15.3
Gases		
Methane (0°C, 14.7 psia)	0.0344	
Air (20°C, 14.7 psia)	0.075	
Oxygen (0°C, 14.7 psia)	0.089	
Hydrogen sulfide†	0.089	
Carbon dioxide†	0.115	
Chlorine gas (0°C, 14.7 psia)	0.187	

* Bulk density of substance.
† Temperature and/or pressure not given.

SPECIFIC GRAVITY

Since density can be expressed as pounds per cubic foot, pounds per gallon, pounds per cubic inch, or even grams per cubic centimeter, it is sometimes difficult to compare the density of one substance with that of another. Specific gravity is one way around this problem. Although there may be many numbers that express the density of the same substance (depending on the units used), there is only one specific gravity associated with each substance (for one particular temperature and pressure). The specific gravity of a substance is the density of that substance relative to a "standard" density.

Specific Gravity of Solids and Liquids

The standard density used for solids and liquids is that of water, 62.4 lb/ft^3, or 8.34 lb/gal. Therefore, the specific gravity of a solid or liquid is the density of that solid or liquid *relative to the density of water*. It is the ratio* of the density of that substance to the density of water. In a calculation of specific gravity, it is *essential* that the densities be expressed in the *same units*. Otherwise the calculation will be wrong.

*Mathematics 5, Ratios and Proportions.

For example, the density of granite rock is about 162 lb/ft^3, and the density of water is 62.4 lb/ft^3. The specific gravity of granite is found by this ratio:

$$\text{specific gravity} = \frac{\text{density of granite}}{\text{density of water}} = \frac{162\ \text{lb}/\ \text{ft}^3}{62.4\ \text{lb}/\ \text{ft}^3}$$

$$= 2.60$$

In this case, the specific gravity (the ratio of the density of granite to the density of water) indicates that a cubic foot of granite weighs about $2^1/_2$ times as much as a cubic foot of water.

Let's look at another example. The density of SAE 30 motor oil is about 56 lb/ft^3. Its specific gravity is therefore

$$\text{specific gravity} = \frac{56\ \text{lb}/\ \text{ft}^3}{62.4\ \text{lb}/\ \text{ft}^3}$$

$$= 0.90$$

In other words, specific gravity in this example tells you that oil is only $^9/_{10}$ as dense as water. Because a cubic foot of oil weighs less than a cubic foot of water, oil floats on the surface of water.

Table H1-3 lists specific gravities for various liquids and solids.

Example 1

Aluminum weighs approximately 168 lb/ft^3. What is the specific gravity of aluminum?

To calculate specific gravity, compare the weight of a cubic foot of aluminum with the weight of a cubic foot of water:

$$\text{specific gravity} = \frac{\text{density of aluminum}}{\text{density of water}}$$

$$= \frac{168\ \text{lb}/\ \text{ft}^3}{62.4\ \text{lb}/\ \text{ft}^3}$$

$$= 2.69$$