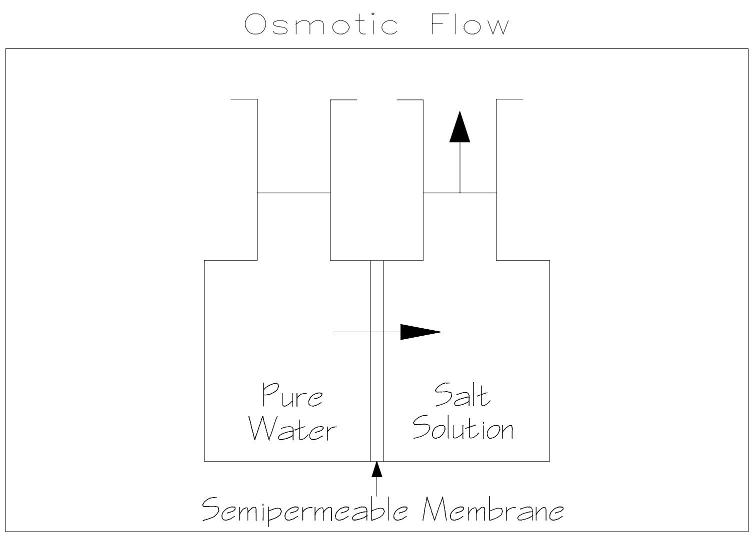
Reverse Osmosis - The Process

Simply put, reverse osmosis (RO) can be thought of as a filtration process at the molecular level. This “filtering action” is capable of removing 99% of the dissolved minerals, 95-97% of most dissolved organics, and more than 98% of biological and colloidal matter from water. These high degrees of separation are made possible by the use of a semi-permeable membrane. This membrane will allow only certain substances (i.e., water) to pass through easily while passage of other items (i.e., dissolved salts) is impeded.

If the solution of pure water is separated from a salt solution by a semi-permeable membrane (as shown in Figure 1, below), the pure water will pass through the membrane into the salt solution.

Figure 1: OSMOTIC FLOW

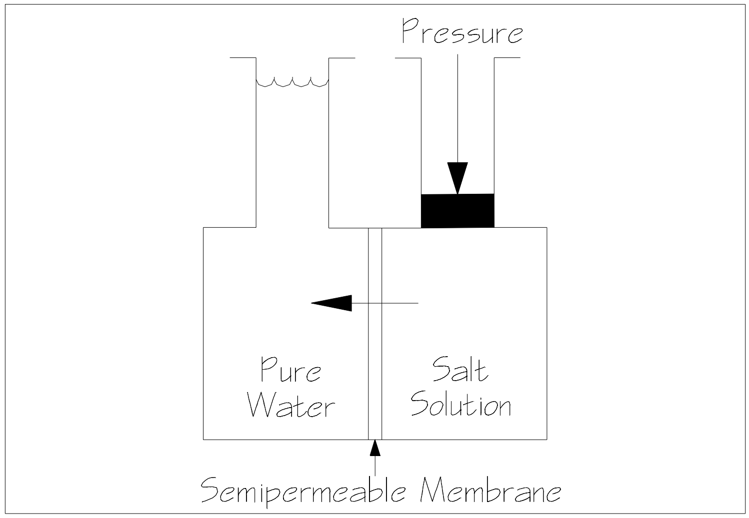


This process is natural osmosis. It is found in nature all around us. By this process, plant and animal cells ingest water.

Every solution has a specific osmotic pressure which is determined by the type and concentration of dissolved materials in the water. This pressure is the driving force that causes flow through the semi-permeable membrane.

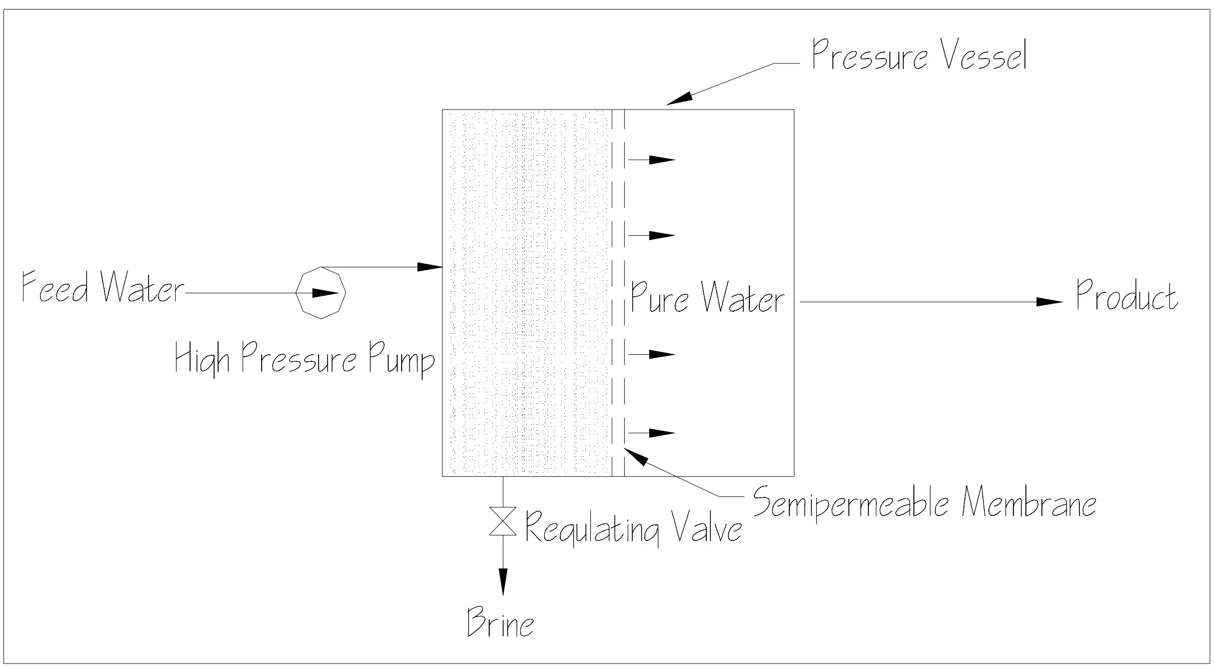
Reverse osmosis is a process in which the natural osmotic flow is reversed. As shown below (Figure 2), this reversal is affected by the application of pressure to the concentrated solution sufficient to overcome the natural osmotic pressure of the less concentrated (pure water) solution.

Figure 2: REVERSE OSMOSIS



In practical application, the force required to reverse natural osmotic flow is supplied by high pressure pumps. Figure 3 is a simplified flow diagram of a typical RO system.

Figure 3: RO FLOW DIAGRAM



Water is pumped to the shells containing the semi-permeable membranes by the high pressure pump. Product water is withdrawn from the system at atmospheric pressure. The dissolved solids rejected by the membrane are continuously flushed from the system through the regulating valve. This is the concentrate stream.

Several operating factors influence the performance of RO membranes. Table 5 shows the effect of these factors when all other conditions remain the same.

Table 1: Operating factors influence the performance of RO membranes

PARAMETER	ACTION	PRODUCT PRODUCTIVITY	PRODUCT QUALITY
Applied Pressure	Raise	Increase	Increase
Applied Pressure	Lower	Decrease	Decrease
Feed Temperature	Raise	Increase	Increase
Feed Temperature	Lower	Decrease	Decrease
Feed Concentration (TDS)	Raise	Decrease	Decrease
Feed Concentration (TDS)	Lower	Increase	Increase
Percent Conversion	Raise	Decrease	Decrease
Percent Conversion	Lower	Increase	Increase
Product Pressure	Raise	Decrease	Decrease
Product Pressure	Lower	Increase	Increase

NOTE: **The effect on product quality is generally a very small change compared to the change observed in productivity. For example, capacity decreases approximately 13% for every 9º F (5º C) temperature decrease. Under the same conditions, product quality will only improve by a few PPM.**

Two terms commonly used in discussion of reverse osmosis are “salt rejection” and “conversion”. The amount of total dissolved solids rejected by the membrane is called “salt rejection” and is expressed as a percentage. A 99% rejection rate means that 99% of the dissolved solids in the water will be rejected by the membrane. To calculate % rejection, use the following equation:

$$\% \text{ Rejection} = \frac{\text{Feed TDS - Product TDS}}{\text{Feed TDS}} \times 100$$

Where “Feed TDS” is the total dissolved solids content of the water going into the module, and “Product TDS” is the total dissolved solids content of the fresh water. For example, if Feed TDS is 35,000 PPM and Product TDS is 350 PPM.

$$\% \text{ Rejection} = \frac{35{,}000 - 350}{35{,}000} \times 100 = 99\%$$

The amount of water recovered for use as a percentage of the water fed into the reverse osmosis unit treatment is called % recovery or conversion. To calculate % recovery, use the following equation:

$$\% \text{ Recovery} = \frac{\text{Product Water Flow Rate}}{\text{Feed Water Flow Rate}} \times 100$$

Note that the feed water flow rate is equal to the product water flow rate plus the waste (concentrate) flow rate, both of which are easily measured. For example, if the product flow is 0.4 gallons per minute and the waste flow is 3.6 GPM, the calculation should be:

$$\% \text{ Recovery} = \frac{0.4}{4.0} \times 100 = 10\%$$

The amount of salt rejected by the semi-permeable membrane is proportional to the TDS concentration of the feed water, but is independent of the applied pressure. The rate of purified water production, however, is proportional to the pressure applied to the membrane. An increase in operating pressure will raise the rate of water production without affecting salt rejection. Therefore, greater applied pressure means better quality water and greater productivity. It is desirable to operate at high conversion to decrease the operational cost of the system. The HYDROPRO system is designed to satisfy these criteria.

In the reverse osmosis (RO) units pressurized feedwater enters the membrane shell and flows through the channels between the spiral windings of the first spiral wound element. Some of the feedwater permeates through a 2000 angstrom thick membrane and travels a spiral path to the product water collection tube at the center of the element. The feedwater then encounters the next cartridge in the shell and the process is repeated. The product from each element exits from the common product tube in the membrane shell. The feedwater becomes more concentrated as it passes through each membrane element and exits from the membrane shell as waste.