



Effective Evaporation

NWC's first evaporation system was developed specifically to evaporate the moisture out of the muds used by drilling rigs. By using a misting basket, injection system and a rotary head we avoid the problem associated with fixed nozzle systems. This design effectively deals with the issue of clogging, but it also gives the user unparalleled control over two key components that allows for Min-Maxing the evaporation potential.

The Min/Max Rule

Min-maxing is the practice of creating the "best" solution by means of minimizing undesired or unimportant traits and maximizing desired ones.

In order to follow this doctrine with regards to an evaporation system we want to minimize the risk of drift and maximize the amount of evaporation that occurs. This can be done several ways in the Typhoon system. Min-Maxing the Typhoon system is possible by the following:

Speeding up or slowing down the RPM's of the head to adjust droplet size and prevent drift
Adjusting the flow of liquid to the head so that the air is not oversaturated
and/or selecting the right basket diameter to further control droplet size and drift

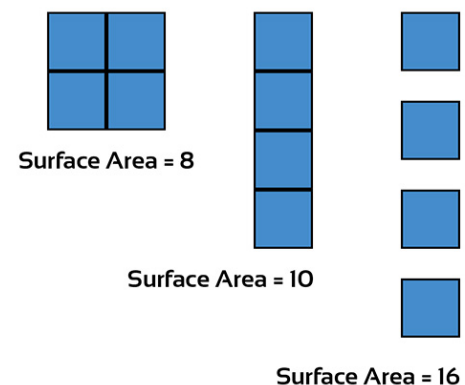
Why is Particle/Droplet Size Important?

Droplet Size and Correlation to Aggregate Surface Area:

As we talked about in the 'Understanding Evaporation' section we learned the saturation vapor pressure over a curved surface, such as a droplet, is greater than that over a flat surface.

If we break a set volume of liquid into droplets of ever decreasing size we find that the total surface area of the liquid exposed to the air increases exponentially as the droplet size decreases, largely because the number of droplets is increasing exponentially (see chart). With a greater number of small droplets and a greater total surface area, a higher volume of evaporation is possible. The increased surface area means more and faster evaporation is possible.

Volume = 4 Units



This principle works the same for water droplets. The chart below gives a perfect example of how the surface area of 1 gallon of water can change by breaking it up into droplets of every decreasing size and since evaporation occurs only on the surface of water it means we can increase the evaporation potential of that gallon of water.

Surface Area of 1 Gallon in Various Droplet Sizes		
Droplet Diameter (microns)	Number of Droplets	Surface area in Square Feet
1000	54,000,000	1800 ft.
250	3,400,000,000	7,300 ft.
100	34,700,000,000	7,000,000 ft.
20	6,700,000,000,000	34,000,000,000 ft.
Source: Michigan State University Research Study		

What does Droplet Size have to do with Drift

Droplet sizes are measured in microns. A micron is 1/1000 millimeter, or about 1/25,000 of an inch. In comparison, a human hair is about 100 microns in diameter. As a basic rule droplet smaller then 150 microns tend to be the most prone to drift. These small droplets fall more slowly than large droplets because they don't have the mass necessary to easily overcome resistance of the air. As a result wind currents often disperse these particles. This is what we refer to as Drift (see chart below).

Influence of droplet size on potential distance of drift			
Droplet Diameter (microns)	Type of Droplets	Time required to fall 10ft	Lateral distance droplets travel in falling 10 ft in a 3 mph wind
1000	Moderate Rain	0.85 sec	4.7 ft.
500	Light Rain	0.9 sec	7 ft.
400	Light Rain	1.9 sec	8.5 ft.
240	Very Fine Rain	6 sec	28 ft.
100	Misty Rain	11 sec	44 ft.
50	Light Misty Rain	40 sec	175 ft.
40	Wet Fog	64 sec	280 ft.
20	Fine Wet Fog	252 sec	1,100 ft.
10	Very Fine Fog	1,020 sec	4,500 ft.
5	Hazy Fog	43,560 sec	3 Miles
Source: American Society of Agricultural Engineers			



Mass of the Droplet and Evaporation:

Even small changes in droplet diameter make a big difference in droplet weight, the distance it travels, and how quickly it falls to the ground, where it reverts to a low vapor pressure, flat surface liquid. For example an increase in droplet diameter from 150 microns to about 190 microns doubles the droplet mass and if you increase in droplet diameter even further from 150 microns to about 240 microns it increases the mass by 4 times. If you take it a step further by doubling the diameter to 300 microns it results in an increase of mass by 8x.

The chemical constituency of the liquid being evaporated also impacts Mass of a droplet. Thus, suspended solids and dissolved solids can increase or decrease the molecular weight of a droplet. For example, salt has a very high molecular weight of approximately 58. So depending upon the salinity of the solution, the weight of a briny solution, which has 5000 mg/liter of salt, could have a combined molecular weight of 19.3 (seawater is about 3500 mg/liter with a molecular weight of 18.35). Anhydrous Ammonia on the other hand is lighter than Oxygen, having a molecular weight of 17.03, so if the liquids have high ammonia levels, the droplet mass will likely be lighter.

Thus, evaporation, which is effectively an energy transfer, will have less time to occur with heavier droplets than with lighter droplets.

Droplet Size Spectrum:

'Spray quality' or 'droplet size spectrum (DSS)', refers to the droplet sizes that a particular nozzle or atomizer produces; described in terms ranging from "very broad" to "very narrow" band of droplet sizes. The Typhoon offers a very narrow band of droplet sizes, which can be adjusted by some of the controls designed into our system. This offers unprecedented control over a key issue with misting. Drift

Adjusting Droplet Size

The Typhoon Head uses centrifugal force combined with a two-stage atomization system to create droplets. The motor spins the hub (stage 1) and the misting basket (stage 2) at a very high rate. The speed at which the droplet is struck by either the hub or the basket in the second stage of atomization is the controlling factor for determining droplet size. The greater the distance the droplet point of impact is from the center of rotation, the faster that point of impact is traveling around the center of rotation. The faster the screen or holes striking the fluid, the smaller the droplet size. Thus a 6-inch basket travels slower than a 12-inch basket. The 3 inches first stage-atomizing hub is traveling slower the attached stainless steel basket and screen. The final adjust can be made by changing the mesh of the second stage atomizing screen. This means there are four ways to control droplet size.

- Changing the RPM's of the motor spinning the basket
- Changing the size of the basket
- Changing the mesh of the screen of the second stage of atomization
- Changing the flow rate of the liquid going to through the system

1000
Microns

400
Microns

240
Microns

100
Microns

20
Microns

5
Microns



Droplet Size Comparison

Changing the RPM's of the Motor

When the liquid flows into the hub and exits the first stage of atomization, it is initially broken into larger droplets of 400 – 500 microns. Centrifugal force throws the liquid away from the center and is then struck by the mesh screen on the second stage atomization basket where it breaks into tiny droplets. As we have noted the faster the screen in the second stage hits the larger droplets created by the first stage of atomization, the smaller the droplet size. Thus, one way to decrease or increase the speed is to increase or decrease the rotation of the shaft of the motor in either of the two following ways.

- **Two Speed Motors** - Using a two-speed motor is an option, which allows the motor to run at either 3450 rpm's or 1750 rpms. Two speed motors allow for programing which can automatically switch the motor to running at slower or faster rpms depending upon the environmental conditions. Its limitations are that it cannot exceed the 3450 rpms and it is not changing the electrical pattern, which drives the motor. Typically, this is not the option we would recommend.
- **Infinite Variation Motors** - Using Variable Frequency Drives: The use of the VFD (variable frequency drive) will allow for an infinite variation of the rpm's of the motor, including running the motor at rpms higher than 3450 rpms. Again speed Programing can be done on site and verified visually to assure that no droplets are escaping the pond protected area. Thus, motors could be run at very low speeds that will allow evaporation at higher than pond pan evaporation rates during high humidity or high wind periods, but at rates, which do not allow for the drift of particles.

Changing the Size of the Baskets

The Typhoon Evaporation Head is a two-stage process. The first stage liquid is injected through a 3-inch diameter hub filled with holes. Centrifugal force again breaks up this liquid into droplets with enough mass to quickly fall in any wind condition and can be run with just the first stage if environmental conditions make it necessary.

As we have noted before, we can change the second stage atomizing basket that is spinning with the hub to either a 6 or 12 inch diameter basket with the result being, the larger the diameter of the basket, the smaller the droplet size.



12 inch Diameter Baskets

The 12-inch basket creates the smallest droplet size, generally from 20 micron to 50 microns in size with the basket electric motor running at 3400-3500 rpms. This creates a wet fog type of mist. Operating the Evaporation head at this level with this diameter basket has to be done with care. This is the ideal basket for indoor systems. In outdoor systems you would want flow controls to go with operating at this droplet size to minimize oversaturation that would allow drift of un-evaporated particles. We also recommend that you do not operate a Typhoon with a 12" basket in windy conditions.

6 inch Diameter Basket

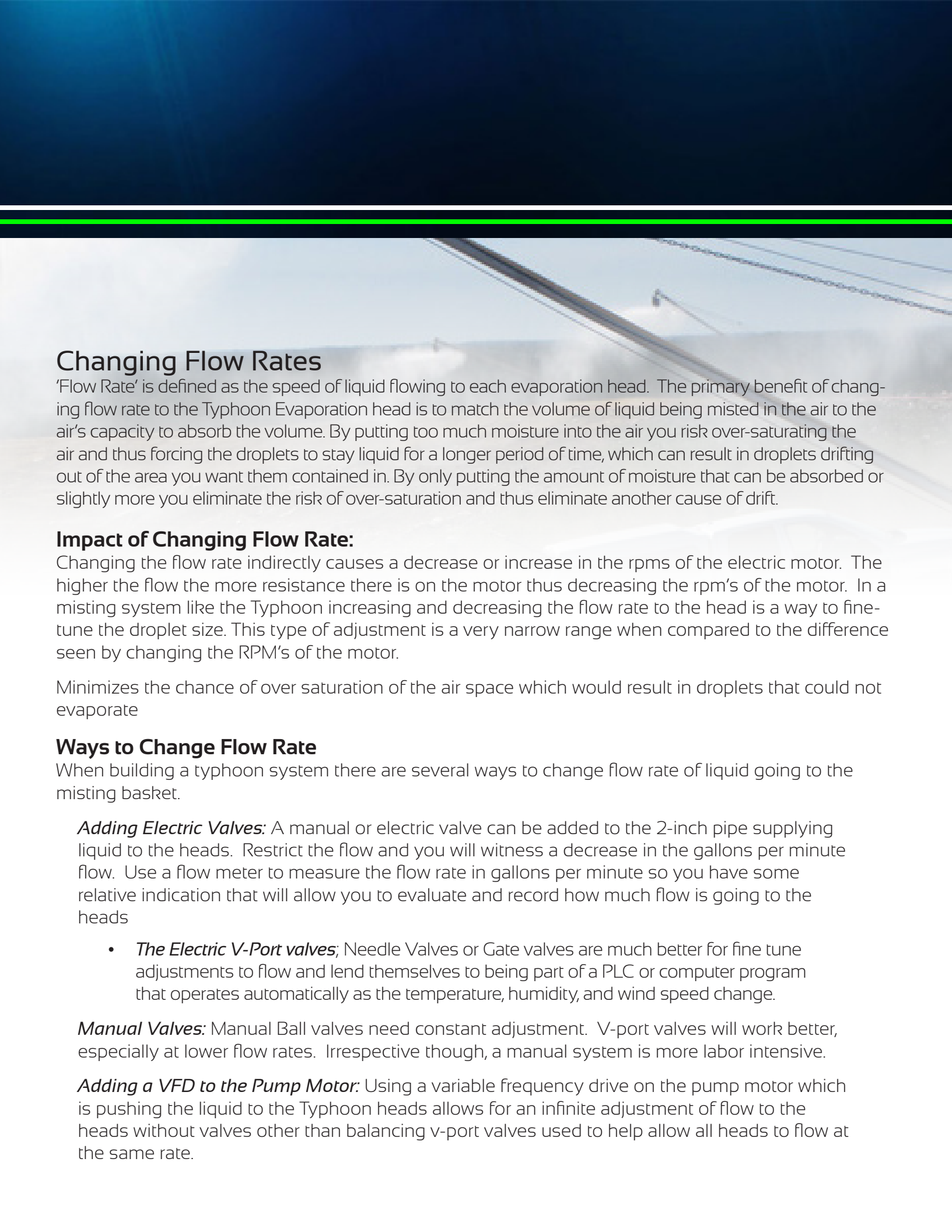
The 6-inch basket provides for a much slower speed at the point of impact of the droplet and the screen. The 6-inch basket generally creates droplets from 100 micron to 150 microns in size again with the basket electric motor running at 3400-3500 rpms. This creates a heavy mist/drizzle type precipitation. Indoor systems that have high velocity and high volume airflow can use 6" baskets to reduce drift or the floating of particles out the exhaust system. Running at a slower RPM allows for the creation of a rain curtain, which can be used to knock smaller particles down before they exit a building. As with any outdoor evaporation system using a basket of this size should be done with some care. Times it should not be operated: winds above 15 mph, and humidity levels of greater than 85%.



Single Stage - 3 inch Evaporation Hub

Moving to a 3-inch evaporation hub, single stage atomization, and means removing the six-inch 2nd stage atomizer from the spindle. Doing this will allow the creation of the largest droplet size which is between 300 and 400 micron in size. Although using this single stage atomization process creates a rain type of look, there is still a significant increase in the total surface area being exposed to the air. You will note above that a 250-micron droplet, for every 4.8 gallons misted, increases the surface area exposed to evaporation by 7300 square feet. If you have 6 Typhoon evaporation heads each misting

4.8 gallons per minute, you will have approximately 44,000 additional square feet of surface area that can be evaporated. This type of set up is ideal for heavy winds or used as a rain curtain.



Changing Flow Rates

'Flow Rate' is defined as the speed of liquid flowing to each evaporation head. The primary benefit of changing flow rate to the Typhoon Evaporation head is to match the volume of liquid being misted in the air to the air's capacity to absorb the volume. By putting too much moisture into the air you risk over-saturating the air and thus forcing the droplets to stay liquid for a longer period of time, which can result in droplets drifting out of the area you want them contained in. By only putting the amount of moisture that can be absorbed or slightly more you eliminate the risk of over-saturation and thus eliminate another cause of drift.

Impact of Changing Flow Rate:

Changing the flow rate indirectly causes a decrease or increase in the rpms of the electric motor. The higher the flow the more resistance there is on the motor thus decreasing the rpm's of the motor. In a misting system like the Typhoon increasing and decreasing the flow rate to the head is a way to fine-tune the droplet size. This type of adjustment is a very narrow range when compared to the difference seen by changing the RPM's of the motor.

Minimizes the chance of over saturation of the air space which would result in droplets that could not evaporate

Ways to Change Flow Rate

When building a typhoon system there are several ways to change flow rate of liquid going to the misting basket.

Adding Electric Valves: A manual or electric valve can be added to the 2-inch pipe supplying liquid to the heads. Restrict the flow and you will witness a decrease in the gallons per minute flow. Use a flow meter to measure the flow rate in gallons per minute so you have some relative indication that will allow you to evaluate and record how much flow is going to the heads

- **The Electric V-Port valves;** Needle Valves or Gate valves are much better for fine tune adjustments to flow and lend themselves to being part of a PLC or computer program that operates automatically as the temperature, humidity, and wind speed change.

Manual Valves: Manual Ball valves need constant adjustment. V-port valves will work better, especially at lower flow rates. Irrespective though, a manual system is more labor intensive.

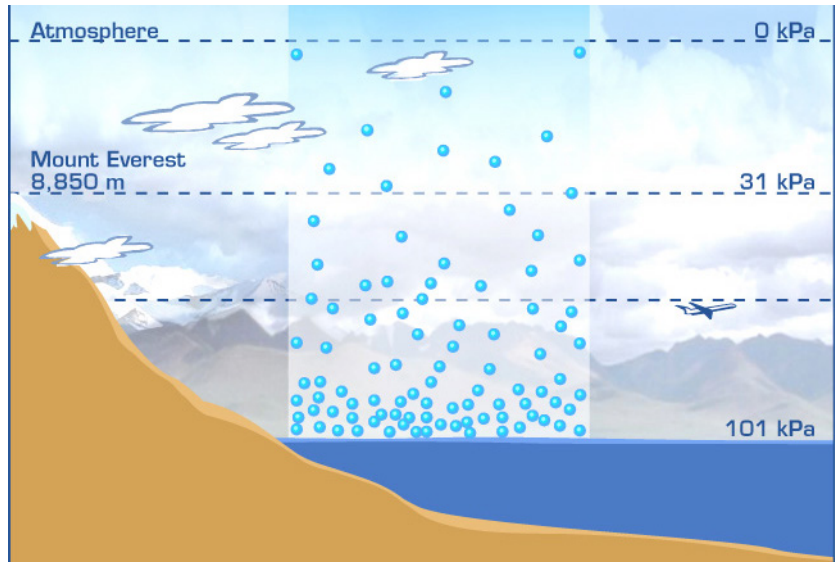
Adding a VFD to the Pump Motor: Using a variable frequency drive on the pump motor which is pushing the liquid to the Typhoon heads allows for an infinite adjustment of flow to the heads without valves other than balancing v-port valves used to help allow all heads to flow at the same rate.



Understanding Evaporation

Evaporation is a type of vaporization that encompasses the phase transition of a liquid to a gas at a temperature below boiling. This may seem like a lot of mumbo jumbo, but most people are familiar with evaporation and the essential role it plays in the “water cycle” of our planet. In lay terms the definition basically states that the Sun’s energy (heat) drives the evaporation of water from oceans, lakes, rivers, soil, etc.. into the atmosphere where it forms clouds which eventually cools and falls back to earth in the form of rain or snow.

There are three main factors that impact the evaporation process: Air Density, Temperature and Humidity.



Air Density

The density of air is the mass per unit volume of atmospheric gases. The density of air, or how light/heavy it is, is impacted by the temperature and barometric pressure of the air. This is why Temperature, Air Pressure and Humidity correlate directly with how much you can evaporate.

Temperature’s Impact on the Density of Dry Air

The molecules of nitrogen, oxygen and other gases that make up our air are moving around at incredible speeds, colliding with each other and all other objects including us. The higher the temperature, the faster the molecules are moving. As the air is heated, the molecules speed up, which means they impact harder against their surroundings.

If you were to fill a balloon full of air and observed it as heat is applied to the exterior surface, you will notice the balloon expanding as the molecules of heated air inside the balloon speed up. Effectively, as the balloon expands, it takes up more cubic volume, but the number of molecules inside the balloon remains the same. This means, as the balloon heats, the density of the air falls and becomes less. Cooling the air inside the balloon will have the opposite effect, causing the balloon to shrink as the molecules slow down, as well as increasing the density of the air. In the free atmosphere (what we call outdoors), as the air heats and becomes less dense it rises; which is why hot air rises and colder and denser air tends to sink.

Atmospheric Pressure has the opposite effect on air density.

Intuitively, we know that increasing the pressure increases the density. Think of what happens when you press down the handle of a bicycle pump. The air is compressed. The density increases as pressure increases. There are more molecules in a set volume of space. The simplest way to define Atmospheric pressure is the weight of the gases on top of you pressing down. Altitude has the biggest impact on atmospheric pressure.

Altitude & Weather

Altitude and weather systems can change the air's pressure. As you go higher, the air's pressure decreases from around 1,000 millibars at sea level to 500 millibars at around 18,000 feet. This is due to the fact that there is less air pressing down on you. At 100,000 feet above sea level the air's pressure is only about 10 millibars and molecules are spaced so far apart it would feel like a vacuum to us. Weather systems that bring higher or lower air pressure can also affect the air's density, but not nearly as much as altitude.

Real World Examples

Thus, based upon the above science, the air's density is lowest at a high elevation on a hot stormy day when the atmospheric pressure is low. Denver when a storm is moving in on a hot day would be a perfect example.

The opposite would hold true as well. The air's density is highest at low elevations when the atmospheric pressure is high and the temperature is low. A sunny and extremely cold winters day in Alaska next to the ocean would be an example of extremely dense air.

Hold on a sec...

We all know water's heavier than air, so wouldn't the air density be higher on a hot sunny day in Denver rather than when a rainstorm is moving in? True, liquid water is heavier, or denser than air. But, the water that makes the air humid isn't liquid. It's water vapor, which is a gas that is lighter than nitrogen or oxygen.

Humidity and its Impact on Air Density

It is counter intuitive to consider that humid air is lighter, or less dense, than dry air. How can the air become lighter if we add water vapor to it? Sir Isaac Newton discovered this in 1717, stating that humid air is less dense than dry air.

The Science - why humid air is less dense than dry air:

The Italian physicist, Amadeo Avogadro, discovered in the early 1800s, that a fixed volume of gas, say one cubic meter, at the same temperature and pressure, would always have the same number of molecules no matter what gas is in container.

Thus, a cubic foot of perfectly dry air contains 78% nitrogen molecules, 21% oxygen molecules, and the final one percent being a mixture of other gases.

Molecules are free to move in and out of our cubic foot of air. What Avogadro discovered was that if we added water vapor molecules to our cubic foot of air, some of the nitrogen and oxygen molecules would leave. Remember, the total number of molecules in our cubic foot of air must stay the same.

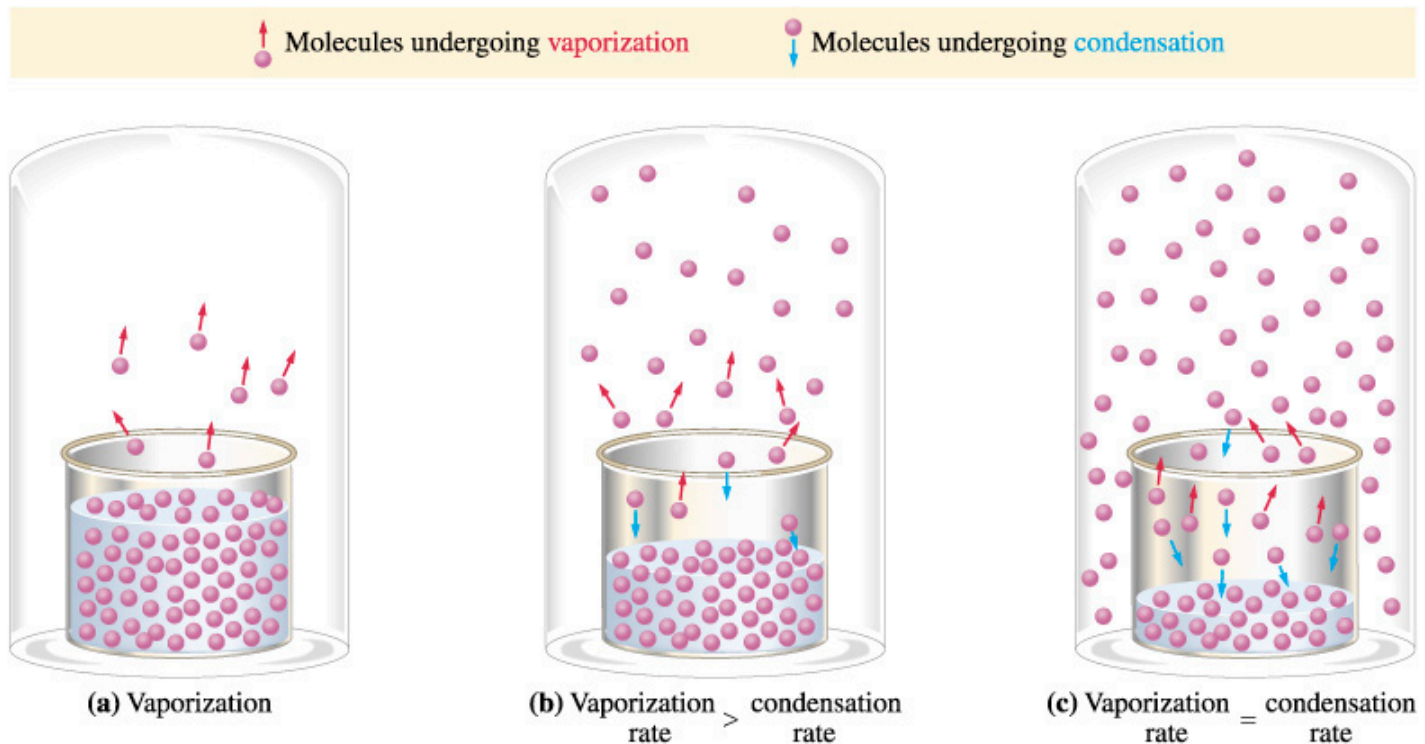
The Atomic Weight of the Components is Important:

The water molecules (H_2O), which must replace nitrogen and/or oxygen molecules, have a molecular weight of 18. *(One oxygen atom with an atomic weight of 16, and two hydrogen atoms each with an atomic weight of 1).* This is lighter than the atomic weight of both nitrogen (each N_2 molecule has a molecular weight of 28 *(2 atoms each with an atomic weight of 14)*) and oxygen (with each O_2 molecule having a molecular weight of 32 *(2 atoms each with an atomic weight of 16)*). In other words, replacing nitrogen and oxygen with water vapor decreases the weight of the air in the cubic foot; that is, it's density decreases. This is how humidity levels can change the air's density.

How is Evaporation & Humidity Related?

Meteorologists have defined several different measures of humidity. These can be divided into two categories: those that describe the actual amount, or concentration, of water vapor in the air and those that relate the actual amount to the potential amount that the air could hold if it were saturated with respect to water vapor.

Air is saturated when it holds the maximum possible amount of water vapor (see image). At that point, the rate at which water molecules enter the air by evaporation exactly balances the rate at which they leave by condensation. This phenomenon is called the equilibrium vapor pressure of water or the saturation pressure point.



In a mixture of gases like our atmosphere, each gas has what is called a partial pressure. The partial pressure of a gas is the hypothetical pressure of that gas if it alone occupied the volume (in this case our atmosphere) of the mixture at the same temperature. Oxygen, Nitrogen, Ammonia each have their own partial pressures. Water vapor also has a partial pressure. 100% relative humidity occurs when the actual vapor pressure of water is equal to the equilibrium vapor pressure/saturation pressure. This is the theoretical maximum amount of water vapor that can be put in a specific volume of air via evaporation.

The saturation vapor pressure of water increases rapidly with temperature; the value at 90°F (32°C) is about double the value at 70°F (21°C). The saturation vapor pressure over a curved surface, such as a droplet, is greater than that over a plane. And the saturation vapor pressure over pure water is greater than that over water with dissolved solids.