Psychrometric Engineering Applications

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Credit: 1 PDH

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“Psychrometric Engineering Applications”

Many HVAC contractors/designers in the industry have a tendency to oversize HVAC systems for clients. While they believe they are both helping their customer and also protecting themselves against liability issues, the opposite is actually true.

When you oversize an HVAC system, it wastes energy rather than saves energy and the ratio of sensible cooling to latent cooling shifts dramatically to sensible only (or cooling without dehumidification). Oversizing can result in the system switching the temperature of the air too rapidly causing customers and employees to be uncomfortable. In extreme conditions, the system will drop the temperature of the air quicker than it can wring out the moisture and you end up with a very cool, clammy environment.

We will discuss how the peak load design conditions were met in a facility which is similar to a country club that we evaluated recently. The facility usually hosts a banquet on the weekends with over 300 people but during the week is fairly quiet with about 20-30 people in the dining room and congregation afterwards in various other rooms. This facility is subject, most of the time, to partial-load conditions that only require 10% to 20% of the actual installed tonnage.

Oversizing the HVAC system in this facility resulted in a very uncomfortable environment. While eating areas were designed for large celebrations with the capacity for 300 people, like a wedding, there would be less than 6 people in the same space during the week. As this massive oversized HVAC system would turn on, the temperature would drop 15˚F to 20˚F degrees within minutes leaving the diners shivering and cold. This was an extremely uncomfortable situation, and one of the reasons was oversizing the HVAC system which was not beneficial to anyone.

Some of the things that we will address are the psychrometric definitions which are the parameters that change, as we evaluate and temper the air by taking it through different conditions.

- **Atmospheric Air**: Air which contains many gaseous components as well as water vapor and miscellaneous contaminants (e.g., smoke, pollen and gaseous pollutants not normally present in free air far from pollution sources).

- **Dry Air**: Atmospheric air with all vapor and contaminants removed. Its composition is relatively constant, but small variations in the amounts of individual components occur with time, geographic location and altitude.

- **Moist Air**: A binary (two component) mixture of dry air and water vapor. The amount of water vapor varies from zero (dry air) to a maximum that depends on temperature and pressure (saturated air).

- **Saturation**: a state of neutral equilibrium between moist air and the condensed water phase (liquid or solid); unless otherwise stated it assumes a flat interface surface between moist air and the condensed phase.

- **Humidity Ratio, (W)**: (Alternatively, the moisture content or mixing ratio). The ratio of the mass of water to the mass of dry air in a sample.

- **Specific Humidity, (γ)**: The ratio of the mass of water vapor to the total mass of the moist air in a sample.

- **Absolute Humidity, (d_v):** (Alternatively, water vapor density). The ratio of the mass of water vapor to the total volume of a sample.

- **Relative Humidity, (%rh):** The ratio of the mole fraction of water vapor x_w (or partial pressure of water vapor) in a given moist air sample to the mole fraction x_{ws} (or pressure of water vapor) in an air sample saturated at the same temperature and pressure.

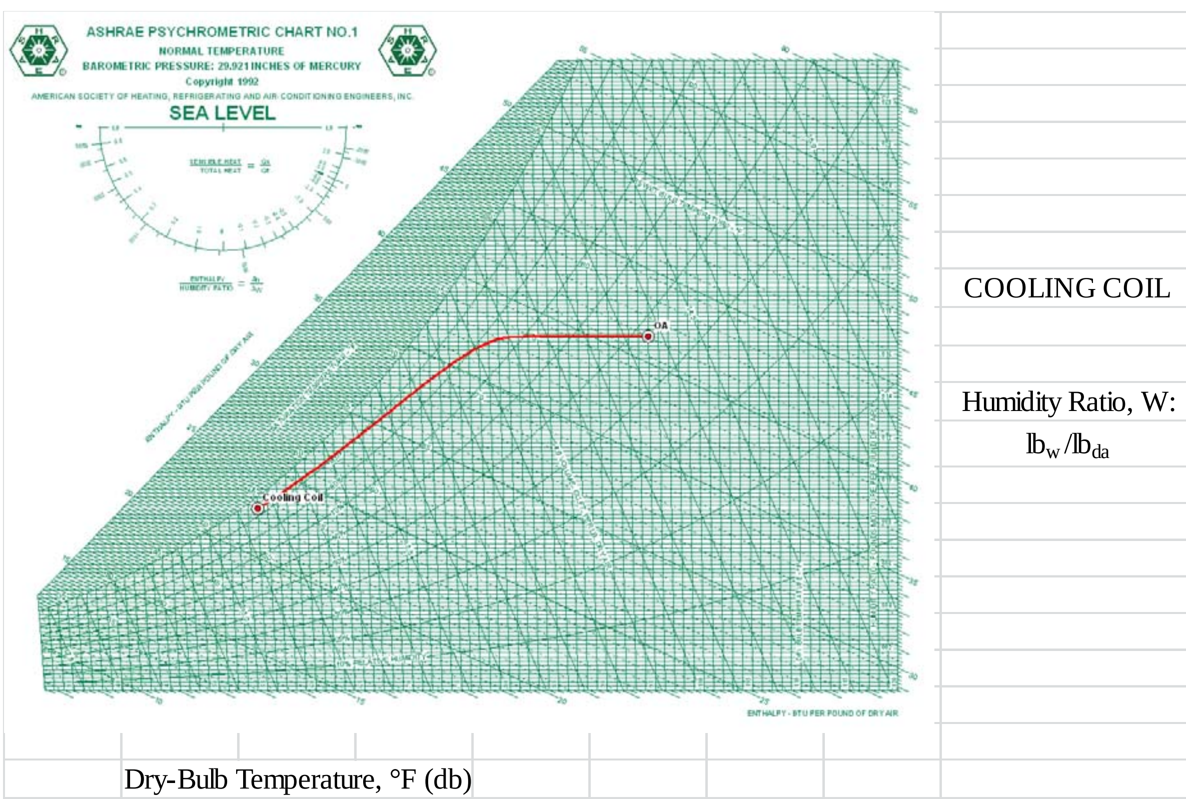
- **Dew-point Temperature:** Temperature of moist air saturated at pressure p, with the same humidity ratio as that of the given sample of moist air.

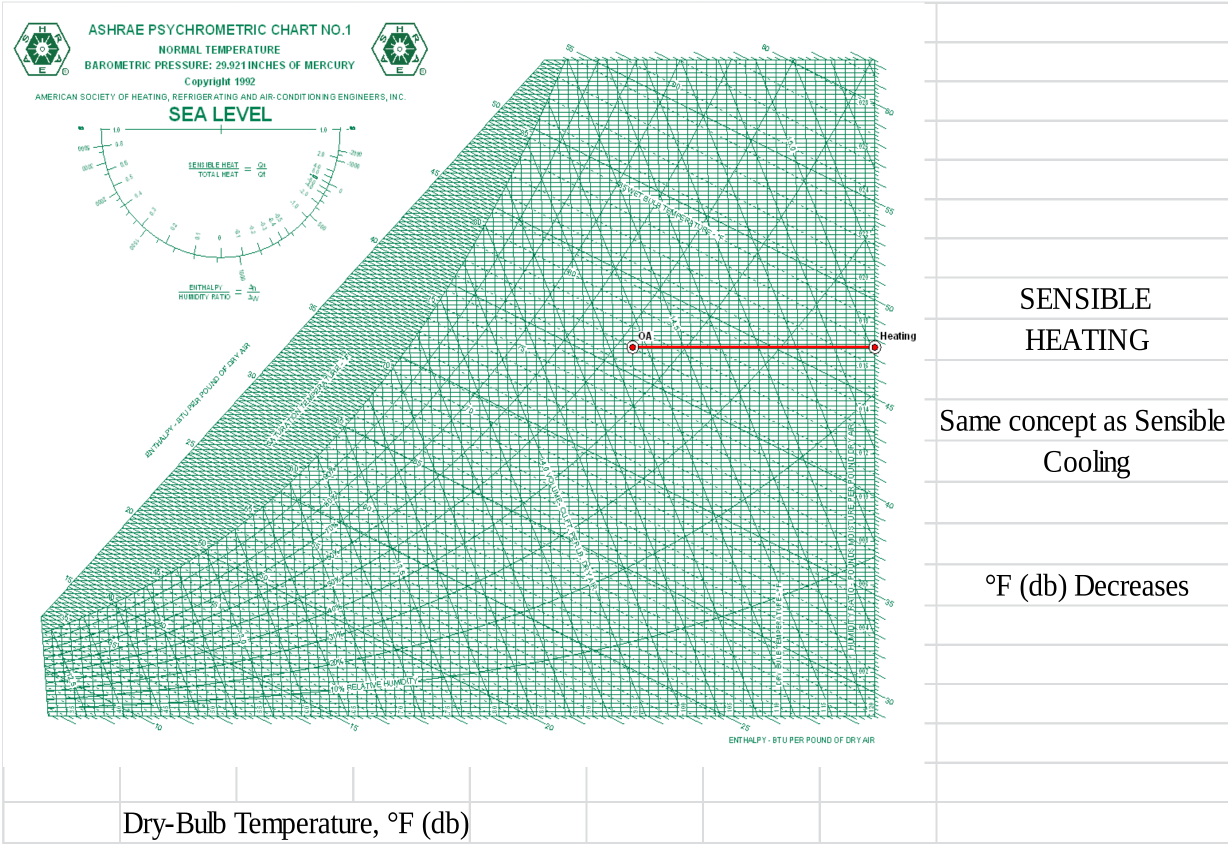
In the above noted case where the system was ten times as large as it needed to be for most of the run time, we did not try to make the existing equipment work under those conditions. We implemented a more economical method which was to add smaller phased systems that were the proper size and would run for 90% of the run times. Then, where a 20 ton system was servicing a small dining area, we proposed a 3-ton system which matched the load perfectly and made everyone much more comfortable. In addition, there were tremendous energy savings. With the short cycling of large equipment, the electrical contactors were wearing out in a matter of months. Now, with the more appropriately sized HVAC system, the life span is closer to 20 years. So, common sense and moderation are good approaches and generally win out.

The following definitions of the psychrometric processes are described in every day vernacular that will be referenced further on. It is intended to give introductory terminology to what we will discuss and explore through this course.

- Sensible Cooling
- Sensible Heating
- Cooling Coil: sensible cooling and dehumidification
- Evaporative Cooling: humidification and sensible cooling
- Air Mixing: several possible outcomes
- Humidification and Heating
- Dehumidification: Desiccant or Cooling Coil-Reheat

We will describe the psychrometric process where the cooling coil is doing quite a bit of dehumidification and reducing the moisture content of the air, known as latent cooling. If you increase the air-flow over the coil you will reduce the amount of moisture, (latent cooling); you are also wringing out and tempering more air; but you will only change the temperature and hold the humidity in. One thing about cooling is that it is not always desirable. If you do not have people or components in the space to bring the temperature back up to something closer to 70˚F, people will be uncomfortable. The way to solve this problem is to do some form of re-heat, if the space does not provide it; or temper the amount of air-conditioning you are doing so you hit a target temperature; typically done with a thermostat.

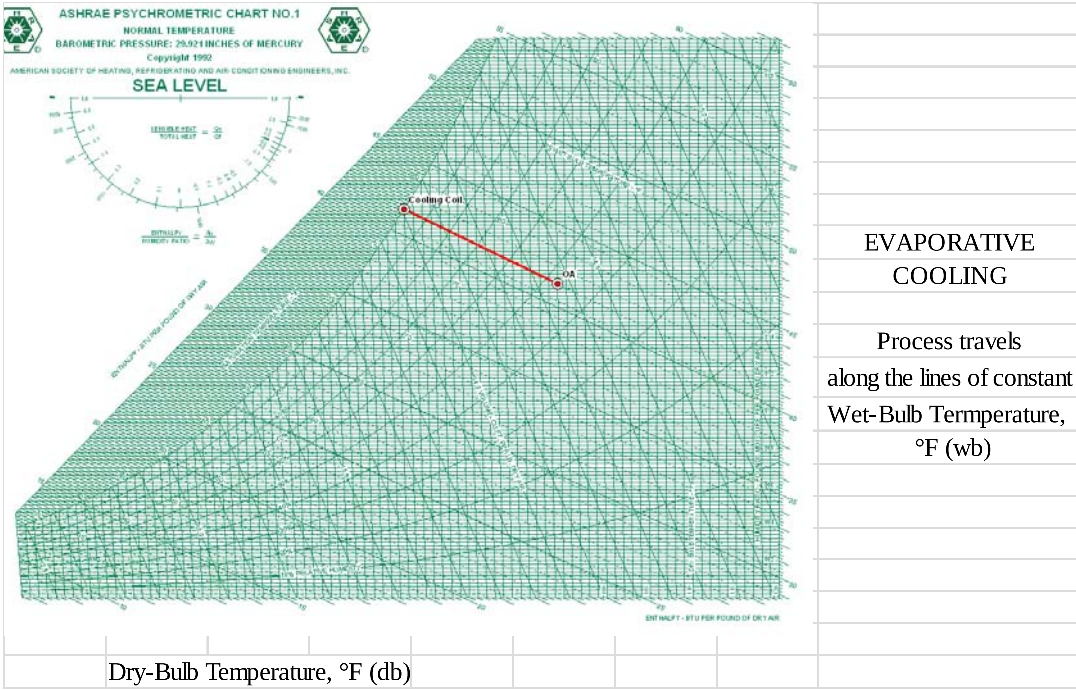




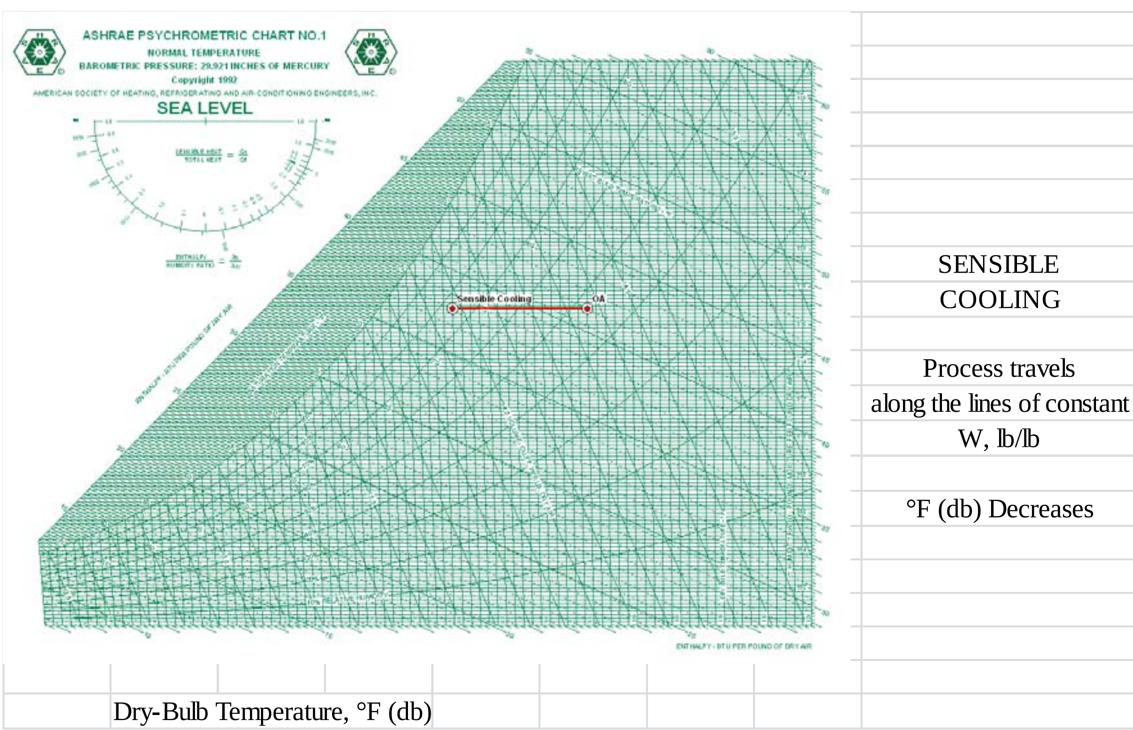
For environments where humidity is more of an issue, and the temperature is already close to room temperature, we have to use a cooling coil and perform another psychrometric process called "sensible heating," where the temperature is simply raised. This can be done with either an electric resistive coil or a heat exchanger that pre-cools the air coming in and re-heats the air being exhausted. The most efficient thing is to use a heat exchanger with energy recovery. The least efficient thing to perform is electric resistive heating.

Sensible Heating is where you are neither adding moisture nor taking it away. You are simply heating the air. As you do this the relative humidity will drop; i.e., as the ability of air to hold water increases, the relative humidity to the temperature decreases.

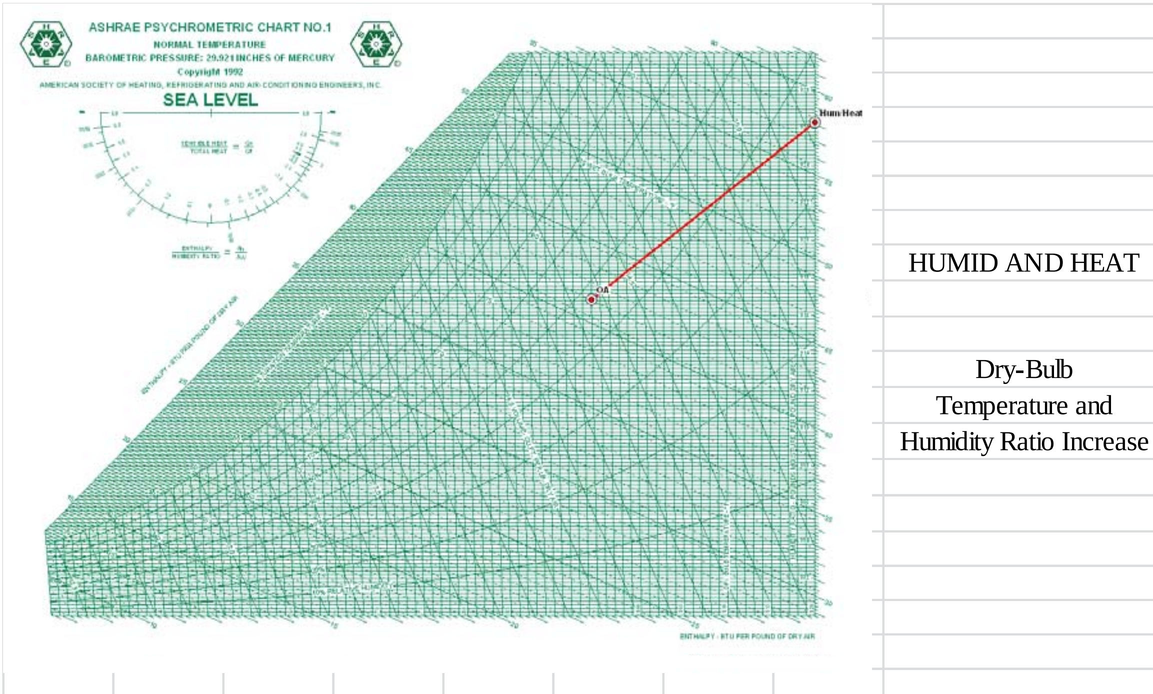
Evaporative Cooling is a process where you add moisture to the incoming air, and while the moisture evaporates you also cool the air. In dry areas such as Arizona or New Mexico, it is beneficial to raise the relative humidity of the air while cooling the air. In areas like New Jersey, this is not as desirable because New Jersey is relatively humid in the summer time. If the air is relatively dry and warm, which happens in New Mexico, Arizona and other places, this becomes a very beneficial process.



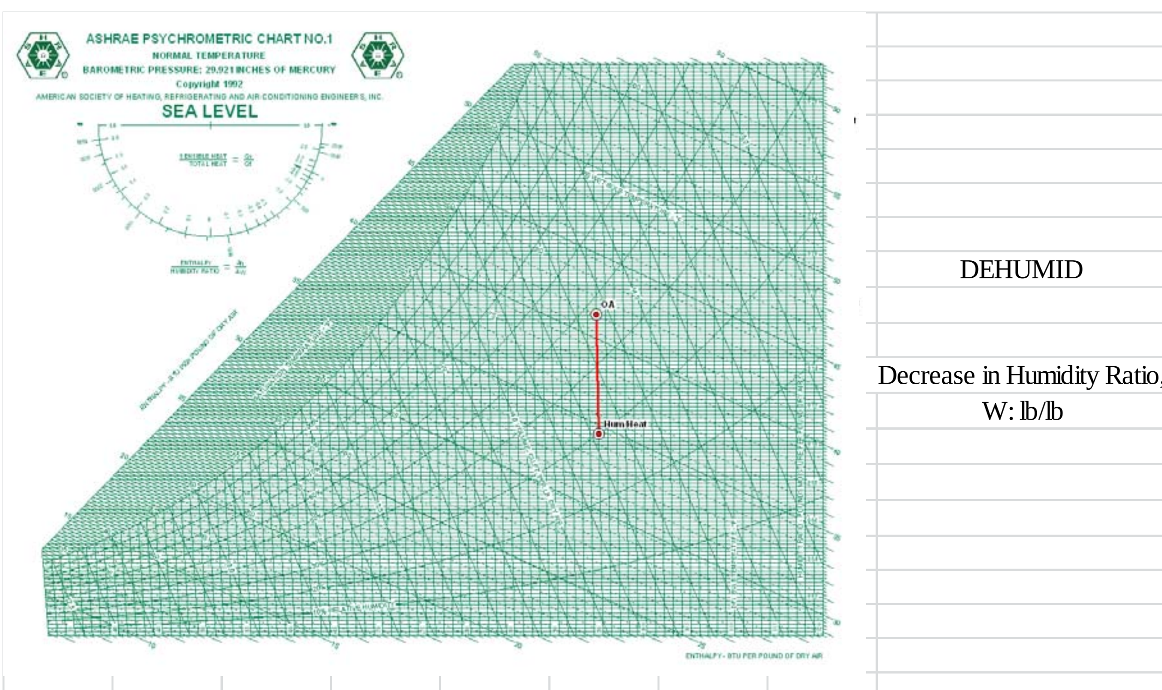
The next thing to address is when you do not want to add moisture. Then you would only want to do Sensible Cooling, which involves dropping the temperature but neither raising nor lowering the moisture content of the air. If you do not take out or add any moisture and you drop the temperature, the relative humidity will increase. Relative Humidity is the ability of the air to hold moisture in relation to the temperature of the air.



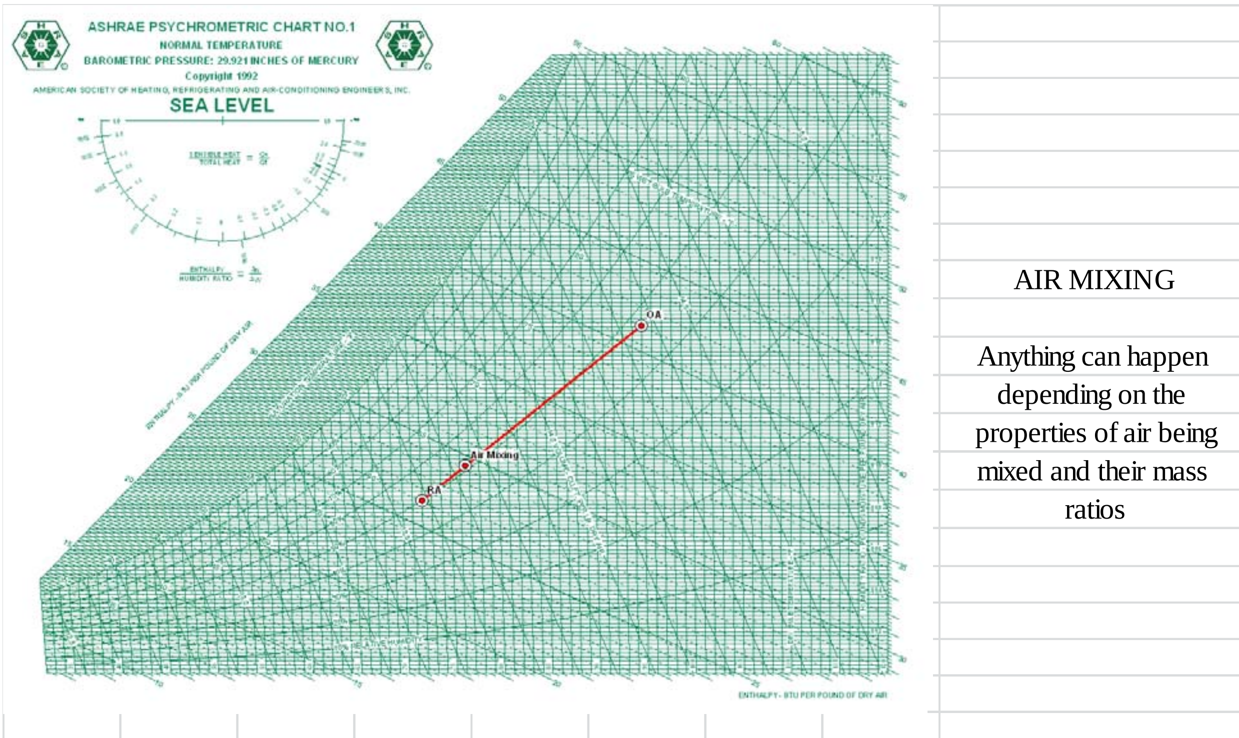
Heat and Humidity - At this point you are adding moisture in the form of humidity while you are heating. As the temperature and the humidity increase, you are still lowering the relative humidity. This is typically done in the wintertime with a humidifier as you try to keep the humidity at a reasonable level while heating the air.



If you are purely dehumidifying, but not changing the temperature, you do this with a run-around loop and a heat exchanger, where you pre-cool the air in order to re-heat it. Basically, it is a latent only type of device which is much preferred for industrial processes where humidity needs to be tightly controlled.



Air Mixing is where we have return air that is mixing to form a relatively cooler tempered air. We are not changing the relative humidity; we are simply dropping the temperature of the air. Any of the processes talked about previously can be combined so that in several steps you can basically create any temperature and humidity combination that you want. If you are clever with the way you engineer this, you can do it for a lot less energy than with other systems.



If you not as clever with air mixing and the psychrometric process, you could theoretically end up with a very uncomfortable situation that would waste a lot of energy and would not function effectively for human comfort. Up until recently this would effectively meet code. The more recent revisions of ASHRAE Standards 62.1-2004 now mandates that you address the issues with these part loads in order to make the HVAC equipment function properly to meet the standards for human comfort. ASHRAE Standard for Human Comfort is ASHRAE 55. Generally, this standard dictates that you keep relative humidity and temperature within a span that most people will find comfortable. Typically this range would be somewhere between 68˚F to 78˚F with 30% to 55% relative humidity. This could differ depending upon the use and occupancy of the individual space.

Building Case Study:

- All equipment was working as designed.
- System was made up of various DX Rooftop and Split Systems.
- HVAC systems were properly designed for full load conditions.

Building Issues:

- Building had low occupancy during different times of the day.
- The rooftop DX systems had a ratio of one ton of cooling per 80 to 150 sqft of floor space.
- Electrical equipment had accelerated maintenance issues. Contactors frequently needed to be replaced.
- Maintenance people complained of jammed doors.
- Carpets seemed wet or damp.
- Wall paint was pealing only a few months after being maintained or painted.

Occupant Issues:

- People were not comfortable at any temperature; chronic comfort complaints.
- People complained about cold like symptoms.
- People wore sweaters.

Initial Site Visit:

- Air felt cold and clammy on a mild spring day.
- Psychrometric solid state tester showed elevated humidity levels in building on 42% RH, 81 F Outdoor Day.
- All systems were working and operating.

Next Step - Site Visit to Test Conditions in Building:

- We used Solid State Equipment to analyze air and structural framing of building.
- For Psychrometrics, we used handheld temperature, humidity and gas sensors for Carbon Dioxide.
- For moisture in building materials, we used a penetrating two prong probe.

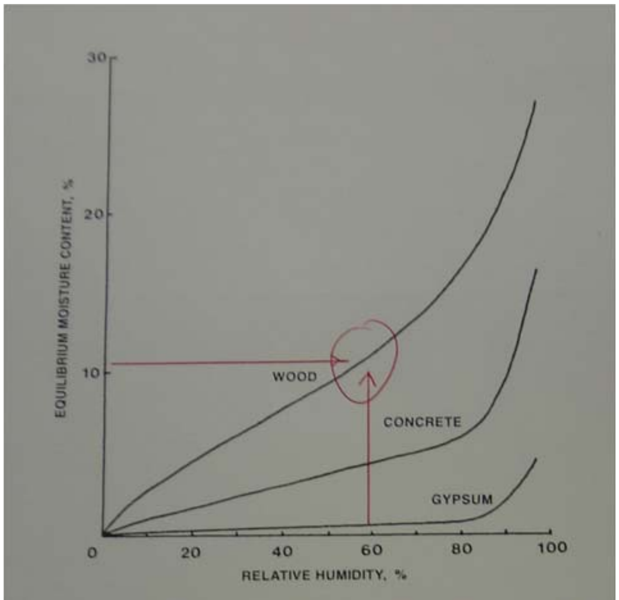
"ASHRAE Table of Relative Humidity versus Material Sorption" - We have found that the relative humidity we recorded matched this table very closely and effectively predicted the amount of moisture that the different building materials would absorb. The ASHRAE Fundamental 2001, Chapter 23 was very accurate in predicting what happened with the actual materials. It is interesting that you can go back to textbook material that predicts what you will find in a field test.

Location	% RH	Temperature
Outdoors	41	81.6 F
Front Entrance	61	71.4
Lobby	76	70.4
Meeting Area	64	69.8

Moisture Content of Materials

Location	Moisture %	Material Desc.
Lobby	9.8 %	Wood Trim
Kitchen	12.1%	Drywall
Meeting Area	11.2%	Wood Trim
Office	10.5%	Wood Door

ASHRAE TABLE OF % RH V. MATERIAL SORPTION



Typical Sorption Isotherms for Wood, Concrete, and Gypsum (Hysteresis Is Ignored)

- ASHRAE FUNDAMENTAL 2001, Chapter 23.13 - Thermal and Moisture Control in Insulated Assemblies.
- Note Correlation between previous data and chart.

Gas Sensor for Carbon Dioxide and Carbon Monoxide levels are described in a case study where the indoor air quality levels are very good. There is no carbon monoxide detectable and the CO_2 levels are way below 800 ppm, or 1100 ppm depending upon whether you are using an OSHA Standard or an ASHRAE Standard. This level of carbon dioxide is more typical of outdoor or fresh air than an indoor working environment. Overall the ventilation rates were very good or in excess of what we normally find.