HUMIDITY CONTROL IN MINNESOTA SCHOOLS

Facility Managers & Operators

Humidity Control in Schools for Facility Managers & Operators

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Introduction

Good humidity control can provide an immediate energy savings benefit because occupants will be comfortable over a wider range of temperature settings - warmer in summer and cooler in winter. The issue of finding the perfect balance between providing adequate ventilation while keeping humidity in check can be a challenge for building managers. Maintaining a comfortable healthy environment while ensuring the durability of the building and equipment and doing so cost effectively, can be a tall order.

This handbook is intended as a textbook and reference guide to help building managers and operators understand the process of moisture management in their buildings. It explains the means and methods of operation and maintenance to care for various types of humidity control systems and discusses how to:

- understand why controlling humidity is important, and what settings to choose,
- minimize both occupant complaints and energy bills,
- improve operations and maintenance of existing equipment, and
- make selections for equipment replacement.

The handbook deals with many complex issues and discusses specific types of equipment. The chapters should be read separately as the need for the information arises. To use this handbook effectively we suggest that you:

- First review the section on Humidity Control.
- Identify sections of this handbook that relate to the type of equipment and controls in your building (see Contents) and read those sections.
- Review the handbook maintenance schedule for your equipment and controls. Update your maintenance schedule if necessary.
- Review the Effects of Humidity on Buildings and Occupants section to improve understanding of the humidity variable in the building.
- As you have questions review the Psychrometrics section to improve your ability to understand how humidity control works in your building.
- Keep this handbook in a handy place for future reference.

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Humidity Control

The importance of control & how the equipment works

To operate school buildings with good humidity control, building operators must first understand humidity control and the equipment used for that control such as cooling coils and sensors. Because they often must communicate with contractors and other maintenance personnel, they also should be familiar with the common terms that are used to describe that control. It is important to have a basic understanding of the following terms:

- **Dry-bulb** temperature is the air temperature determined by an ordinary thermometer.
- **Wet-bulb** is the temperature of air that is being affected by the cooling of evaporating water.
- **Relative Humidity (RH)** is a measure of how much moisture is present compared to how much moisture the air could hold at that temperature.
- **Dew point** is the temperature below which moisture will condense out of air.
- **Saturation point** is the amount of moisture in the air when the air temperature is at dew point conditions.
- **Sensible Heat** is the heat energy stored in a substance as a result of an increase in its temperature.
- **Latent heat** describes the amount of energy in the form of heat that is required for a material to undergo a change of phase without changing temperature. Water has two latent heat values — the latent heat of melting, and the latent heat of evaporation.
- **Enthalpy** is a measure of the heat content of the air and is expressed in BTUs per pound of dry air; is the key concept of air conditioning.

These terms and how they relate to each other are explained in more depth in the section describing the psychrometric chart. A building operator will benefit greatly by having a basic understanding of the principals of this tool. Take the time to learn more about how this tool works.

RELATIVE HUMIDITY CONTROL

Relative humidity (RH) sensors are low-cost, widely used devices for humidity control. Traditionally, RH sensors have had a role in controlling humidifiers and economizers but they can also be used in cooling coil control. See the Humidity Sensors section for a detailed description of RH, dew point sensors and how to take care of them.

Precise relative humidity control is not necessary for most educational spaces. The comfort control range for dew point temperatures is quite broad, as shown in Table 1.

Table 1: Typical ranges of relative humidity and temperature settings

Space type	Winter	Summer	Comments
Classrooms, laboratories, auditoriums, administrative offices	20% to 30% minimum RH 68.5°F to 75.5°F	60% maximum RH 74.0°F to 80.0°F	Maximum 65°F Dew Point
Libraries	30% RH minimum	60% maximum RH	Active humidity control is recommended.
Natatorium	50% to 60% RH	50% to 60% RH	The recommended Air temp. is 2°F to 5°F above the pool water temperature.
Ice Rink	35°F Dew Point to 45°F Dew Point	35°F Dew Point to 45°F Dew Point	Air temp is recommended between 50°F and 65°F.

Dew points can range from 35°F to 65°F which is a good range for both for the health of the occupants and the durability of the building. Relative humidity in most spaces can be allowed to float from 30% RH to 60% RH for most of the year and as low as 20% RH in the coldest part of the winter. Below 20% RH the controls should be set to conserve moisture generated from the space as much as possible.

Economizing is a term used in the HVAC business to describe air handler controls that recognize cool air outside can be used instead of mechanical cooling. These controls along with dampers and duct work take advantage of the cool outside air to cool the inside space. “Free cooling” economizers can actually do more harm than good in some circumstances. Even enthalpy controlled economizers may load up a space with moisture. Any time the outside air dew point is above 65°F it is better to use return air. A dew point control should lock out the economizer when the ambient dew point is above 65°F regardless of the dry bulb temperature. A much better solution is to set any economizer control so it never uses outdoor air with a dew point that is higher than the level desired in the space.

This point can be illustrated on the psychrometric chart. If you are unfamiliar with the psychrometric chart this would be a good time to review the section on how to use the psychrometric chart. Plot the outside air condition on the chart and determine the dew point of the air. If the outside air dew point is above 65°F then the outside air flow should be at minimum. If the dew point is below 65°F then the system should be allowed to operate in economizer mode.

TEMPERATURE CONTROL

Attempting to dehumidify a space by space temperature control of cooling coils is a poor choice. The fact that this practice wastes energy is only one reason to avoid it. Cooling coils that are controlled only by space temperature may deliver air with high dew points potentially loading up the space with moisture. Chilled water flow control in cooling coils may be reduced to the point where dehumidification stops completely.

Direct expansion coils will cycle off for long periods of time during periods of low sensible loads, during which there time will be no dehumidification. See the Humidity Control Equipment section for a more complete description of direct expansion equipment.

CARPET CLEANING

Carpet cleaning has a major impact on the ability to control humidity in schools. Below are several recommendations for managing the impact on humidity whenever steam or hot water extraction is used:

- When using hot water only, add an approved disinfectant to the water to kill spores. Test any chemical on scrap carpet for colorfastness.
- Keep the water injection as low as possible.

- When ventilating the room be certain the air is exchanged with dry air from outside the room. Do not simply move the air around in the room.
- Use high velocity air across the surface of the carpet. The movement of air across the carpet should be felt with a bare hand anywhere in the room.
- Maintain the ventilation for a minimum of 48 hours if the relative humidity is 50% RH or less. If the RH in the room is higher increase the velocity and time of ventilation.
- Using air conditioning for a long period (several days) can overcool the space and ultimately hinder drying. A better strategy is to use a combination of portable dehumidifiers, floor fans and HVAC for no more than one day.
- Portable dehumidifiers should be standard equipment for every maintenance department. For best value always choose an ENERGY STAR qualified dehumidifier. A rule of thumb is to use 1 dehumidifier for every 15,000 square feet. Floor fans are also useful to dry wet carpet when there is a source of warm, dry air to exchange in the room but if this isn't possible a dehumidifier is the only way to dry the room and the carpet.

HVAC System Cost Comparisons

The trade off between energy and maintenance costs

Since electric rates and hourly rates for maintenance will vary considerably, the examples shown here will give only the electrical consumption and number of hours for maintenance. Use your local rates to convert this information to dollar amounts. The application in this example is for cooling and dehumidifying only.

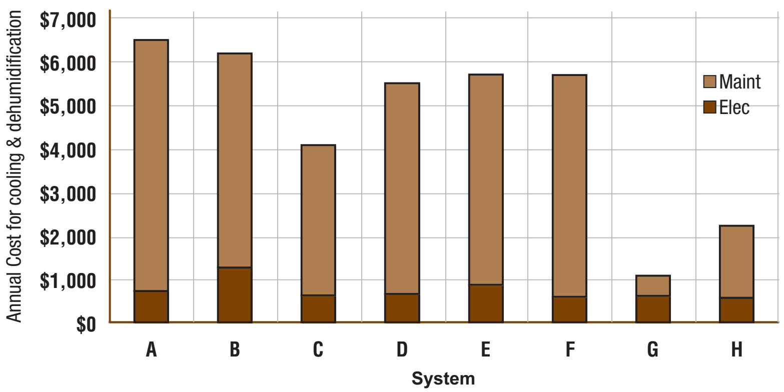
Table 2 identifies eight typical systems and shows the electrical demand and annual hours of maintenance needed for to condition a single hypothetical example classroom. The systems and their respective electrical demand estimates were selected from manufacturer catalogs. As you can see, there is considerable difference in the annual maintenance required for various HVAC systems. A detailed list of these maintenance tasks is in the Maintenance of Humidity Control Equipment section.

Table 2: Energy demand and maintenance hours for the cooling and humidity control elements of various HVAC systems

Identifier	Abbreviation	System description	Demand	Annual Maintenance Hours
System A	PTHP/EVAP	Heat Pump with Evaporative condensing	4.45 kW	385
System B	PTHP/DRY	Heat Pump with Dry Cooler	7.83 kW	328
System C	UV/DX	Unit Ventilator with DX	3.87 kW	230
System D	UV/CHW-EVAP	Unit Ventilator with Chiller and Wet Cooling Tower	4.09 kW	322
System E	UV/CHW-ACCH	Unit Ventilators with Central Air Cooled Chiller	5.39 kW	322
System F	UV/DX-HR	Unit Ventilators with DX and Heat Recovery	3.62 kW	340
System G	AHU/DX	Package Air Handling Unit with DX	3.78 kW	31
System H	AHU/CHW-EVAP	Package Air Handling with Chiller and Wet Cooling Tower	3.54 kW	110

By far the largest expense for the cooling and humidity control elements of HVAC systems is maintenance. The total cost of maintenance is the sum of the cost of parts, including consumables such as filters and grease, as well as the labor to perform the maintenance. All of the maintenance costs are proportional to the number and type of tasks that are needed for the system. For the estimate of energy costs, a typical operating time of 2,000 equivalent full load hours per year is used.

Figure A: Comparison of electrical and maintenance costs between various HVAC systems from Table 2. Note: Figure A assumes a demand charge of $7/kW per month for 5 months when dehumidification is required, $0.05/kWh and $15/hour maintenance cost.



Humidity Sensors

What they do, how they work, and how to care for them

Humidity sensors and transmitters are common components of building HVAC control systems. Their selection and performance can have a significant impact on the comfort, energy use, and indoor air quality of school spaces. These devices are used to select the economizer mode in air handling units by measuring both the outside air relative humidity and the return air relative humidity. The electronic controller in typical direct digital control (DDC) systems use RH values in concert with dry bulb temperature values to compute air enthalpy. This computation can also be accomplished manually by using the psychrometric chart. For a more thorough discussion of humidity sensors see item 1, References section.

Regular maintenance of humidity sensors and transmitters is very important. If either one or both of the relative humidity sensors or the transmitter is wrong, significant energy penalties can result. Considerable moisture loading of building materials can also occur, which will have a latent load impact on the system for a long time afterward as well as cause questionable indoor air quality. *Every maintenance department should have a rigorous humidity sensor testing and calibration program for sensors.* There are several different kinds of sensors, each with advantages and disadvantages. The following describes the common types used in schools. More detailed information about humidity sensors is available from the International Instrumentation and Control Engineering Web site (see: http://www.iceweb.com.au/Analyzer/humidity_sensors.html).

The most widely used humidity transmitters in HVAC control applications use capacitive or resistive sensors. These low-cost transmitters consist of an integrated sensor and transducer assembly. The sensor provides a measure of the relative humidity while the transducer generates an electronic output signal representative of the sensed humidity. Both capacitive and resistive humidity transmitters range in accuracy from +/- 5% to +/-1% for HVAC applications. The cost ranges are $50 to $1000 for the capacitive type and $100 to $1500 for the resistive type.

CAPACITIVE HUMIDITY SENSORS

In this type of sensor, a capacitor is formed by depositing a polymer or metal oxide film between a conductive material and a porous conductive material onto a glass, ceramic, or silicon substrate. The polymer layer adsorbs (meaning to collect on a surface) water molecules as they permeate through the porous upper electrode. The dielectric constant of the polymer layer changes as it adsorbs moisture, causing the capacitance of the two electrodes to increase. The change in capacitance is directly proportional to the relative humidity.

Capacitive humidity sensors are generally considered to be accurate at low humidity and high ambient temperature. A disadvantage of these sensors is that they include in their measurement an electrical characteristic of their connecting wire or cable. Because the cable can have a capacitance larger than the sensor, a significant amount of signal conditioning is required to correct this problem. The capacitive sensor also is sensitive to contaminants and chemicals and generally not accurate at high RH (above 85%) due to saturation of the sensing material. They therefore may require frequent recalibration and time to dry out once they have become saturated so their accuracy at high humidity levels is suspect (see item 2, References section).

RESISTIVE HUMIDITY SENSORS

Resistive humidity sensors are composed of interlocked metal electrodes that are deposited on a substrate. The substrate is then coated with a moisture-sensitive material, such as a conductive polymer or a salt. As the polymer coating adsorbs moisture, ions are released causing the electrical resistance to change. The resistance decreases as humidity increases. This change in electrical resistance of the polymer is measured by the sensor.

Resistive humidity sensors are economical to manufacture, have long-term stability, are operational over a broad humidity range, perform well at high humidity, and are resistant to surface contaminants. However, resistive sensors are less accurate at low humidity, have slow response times (on the order of tens of seconds to minutes) because the moisture must fully permeate the conductive polymer layer before the resistance reading is affected, and are sensitive to chemicals that are similar to the polymer material (see item 3, References section).

Polymer based sensors also have a strong temperature dependence, requiring units to be temperature compensated. The use of a water-soluble coating causes resistive sensors to be less accurate if condensation occurs. Some sensors have avoided this problem by using a ceramic substrate coated with a polymer/ceramic mixture.

HAIR HUMIDITY SENSOR

The hair humidity sensor measures humidity by sensing the change of length of certain organic and synthetic fibers when these fibers are exposed to a moist atmosphere. A mechanical linkage is used to amplify the element movement for readout. These sensors were widely used in the 1950s in pneumatic control systems by using the hair (usually horse hair or even human hair) to move a bleed valve on a pneumatic air line to modulate a humidifier. These devices were susceptible to drafts, but still needed good exposure to the sensed air in a room in order to give accurate control.

CELLULOSE HUMIDITY SENSORS

Cellulose in the form of strips or other shapes is also used to measure humidity. Like human hair or horse hair, cellulose changes its dimensions as the water vapor concentration varies. Cellulose humidity sensors use this elongation to display readings on either a dial or digital indicator. They are relatively inexpensive HVAC type transmitters and recorders. They do have the same problems as hair sensors.

DEW POINT SENSORS

Dew point control is expensive and difficult to accomplish. Nevertheless, it is the best method of controlling the humidity in a space. If at all possible, dew point sensors should be used to determine when economizers can be used for free cooling. There is no comparison between outside air humidity and return air humidity because dew point is an absolute parameter whose value for cooling never varies. For example, if the outside dew point is lower than 55°F, outside air should be used for cooling because that is the same dew point that would be created by a cooling coil.

These sensors are usually more expensive than relative humidity sensors and require some working knowledge of how they function and how to care for them. The surface conductivity sensor and chilled mirror sensor are types of dew point sensors discussed below. Both types determine the point when condensation first begins to occur on a surface. The difference is in the method used to detect the condensate.

SURFACE CONDUCTIVITY DEW POINT SENSOR

Every object in a moist atmosphere has water molecules on its surface; the concentration of these molecules is related to the temperature of the object and the dew point of the atmosphere. If the temperature of the surface is above the dew point, the thin layer of molecules is invisible; however, as the surface is cooled to the dew point, the density of water molecules at the surface becomes so great that water condenses on the surface and dew can be seen. At surface temperature above the dew point, the moisture density at the surface can be detected electrically although the water vapor is not visible to the eye. This water vapor will permit a current to flow on the surface of even an excellent insulator. This current flow is a function of the surface material and moisture density at the surface. The measuring element consists of a highly polished inert surface inlaid with an intermeshed gold grid and a thermocouple imbedded in the surface. A fixed potential is maintained across the gold grids, and the current flow is compared to the reference current flow at dew point. This signal amplified and used to modulate a cooler so that the surface is maintained at the dew point of the sample. The cooler is often a bismuth-telluride crystal that pumps heat away from the sensor when it is supplied with electric power.

CHILLED MIRROR DEW POINT SENSOR

The optical chilled-mirror dew point technique is a fundamental measurement, because the saturation temperature determines the saturation partial pressure of the water vapor. These relationships have been experimentally and theoretically determined and tabulated. In a chilled mirror sensor, the object is to bring the condensation and the evaporation of moisture to and from the mirror surface to equilibrium by controlling the temperature of the mirror surface. Equilibrium is determined visually either by the trained eye or, more recently, electronically with optical phototransistors. These sensors can be self-calibrating which makes them easier to maintain.

A variation of the chilled mirror sensor is the cycled chilled-mirror probe. This device is simpler by making the periods of dew formation short (about 5% of the time); the probability of contaminant condensation on the mirror surface is reduced.

MAINTENANCE AND CALIBRATION

Maintenance requirements depend on the type of technology used in the sensor, environmental conditions and exposure to contaminants. Both capacitive and resistive humidity transmitters require calibration checks and occasional cleaning. *In general, manufacturers recommend that transmitters be checked and calibrated once a year.* Transmitters that are subjected to high temperature and/or humidity conditions or harsh environments should be checked and recalibrated at a frequency of every six months or as recommended by the manufacturer. Dew point sensors may require periodic cleaning as well. Be familiar with the manufacturer's instructions for maintenance and calibration.

Humidity Control Equipment

The pros and cons of various types

COOLING COILS

Cooling coils make good dehumidifiers. However, they can only perform when their temperature is continuously cold (< 55°F) and air is flowing over them continuously. Therefore, either chilled water or direct expansion (DX) coils will work well for dehumidification as long as they do not cycle off. If the DX compressor stops, then there is no dehumidifying happening. In fact, if the compressor stops and the fan continues to run, whatever water that hasn't fallen off of the evaporator coil fins will re-evaporate into the supply air and that moisture will be delivered into the space to be dehumidified.

DIRECT EXPANSION

Part load conditions are a problem for DX systems. As unitary equipment becomes more energy efficient, as indicated by their higher EER and SEER ratings, their cooling coils have a lower capacity to remove moisture at part load conditions. An important variable appears to be the greater fin surface area of newer, higher efficiency cooling coils compared to those from 20 years ago. These larger fins can store more moisture before it runs off into the drain pan. Research has shown that coils from the 1980s typically store 200 runtime seconds of moisture on their fins whereas coils from the 1990s can store 720 runtime seconds of moisture. This is why DX coils have trouble with moisture removal unless they have run times of fifteen minutes or more. Continuous fan operation without continuous coil operation may re-evaporate this stored moisture. Intermittent fan operation will reduce this re-evaporation if the off cycle is relatively short.

If a DX coil must cycle off, then the cycle times must be sufficiently long to make the warm coil time as short as possible relative to the total cycle time. The Air Conditioning and Refrigeration Institute (ARI) publication "Guideline A" recommends a minimum off cycle for refrigeration compressors of five minutes. A fifteen minute or longer "on" cycle and a five-minute "off" cycle is reasonable. Another variation of the cycling DX coil is the two stage coil. It is important to be aware of the method of splitting the coils to avoid a warm coil temperature. Coils that are "row-split" may have an average coil temperature warm enough to allow a high space relative humidity. A "face-split" coil will keep the active coil cold enough for good dehumidification. This arrangement is especially good when the air volume varies and the "dead" coil is isolated by dampers. An ideal DX system will modulate both the air volume and the compressor output to match the load continuously.

CHILLED WATER SYSTEMS

A chilled water coil) works well for dehumidification if it is served by a steady supply of continuously low temperature water (less than

45°F). The chilled water coil must also be continuously cold. If the coil temperature rises from over design airflow or low water volume, the coil will become dry. Control systems that reset chilled water temperature upward should monitor the dew point temperature to lock out this reset until the ambient dew point falls below 55°F.

A cooling coil's ability to dehumidify also depends upon the contact time of the air on the fin. Coils that are deep (8-10 rows) have more capacity to dehumidify than shallow coils. These deep coils also tend to have a higher air pressure drop, so the designer must trade off these variables.

Deep cooling coils also have the problem of hiding accumulated dirt. Cleaning these coils is therefore more difficult than shallow coils. Cooling coils deeper than ten rows should not be selected for this reason.

ROOFTOP UNITS, DX

The package rooftop unit is one of the least expensive methods to air condition the modern classroom. This economy is not just in the lower cost of the unit itself; this type of air handler uses less space within the building to house equipment and they are also quite easy to install and therefore require less labor. For these reasons these units tend to be popular.

There are some problems associated with this equipment, however. The first and most obvious is the poor conditions for the maintenance person to service the unit. It is important that all roofs be accessible so service will happen routinely. Another problem is the nature of the units themselves. By design, the outside air and exhaust air ports are close together. This can lead to entrainment of moist exhaust air into the fresh air stream causing additional latent and sensible load on the cooling coil as well as defeating the purpose of using outside air for ventilation. They also tend to have trouble with dehumidifying. DX coils, as has been described above, will cycle off and allow condensed moisture to be re-evaporated into the supply air stream. They may not have an economizer system which will take advantage of cooler and drier air from the outside to dehumidify without the use of electricity.

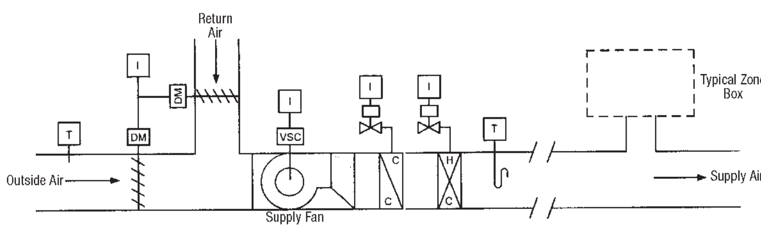
Although these are common problems with DX rooftop units in general, there are now units coming onto the market with solutions to all of these problems. One innovative and highly useful feature in modern rooftop units is the hot gas reheat coil. This coil will use the conditioned supply air to condense part of the refrigerant fluid and at the same time provide some reheat to bring the supply air away from the saturation point. This improves the efficiency of the condenser process and provides supply air with lower relative humidity.

Another good feature is the variable capacity compressor. This arrangement will lower compressor capacity rather than cycle the compressor on and off. This gives the ability to provide constant dehumidification.

AIR HANDLING UNITS: CHILLED WATER

A traditional air handling unit, such as the one shown in Figure B has proven to be the overall most economical application of HVAC equipment when long term or life cycle cost is considered. Both the electrical demand and the maintenance cost are low for these units. Chilled water plants do take an experienced mechanic to remain trouble-free but are well worth the time for the value they provide.

Figure B: Air Handling Unit



The unit shown in the figure is a generic version that includes features not found on all units installed today. The reheat coils are not shown here since they are located close to the load so they can respond to the changing and uneven demands of the local thermometer. The terminal reheat system design has the highest control for dehumidifying a space since the dew point of the supply air can be fixed by the cooling coil sensible temperature control without overcooling the space.

Maintenance of air handling units is simple and the frequency is reasonable. See Table 4 for the tasks and for the system applications. The key element to any maintenance program for wet cooling coils is to keep the coil and the drain pan clean to prevent drain lines from becoming clogged and to reduce the chance of biological growth. This type of system offers savings because there are many fewer central air handlers than classroom terminal units such as unit ventilators.

UNIT VENTILATORS

Unit ventilators are common in schools. The traditional horizontal unit has several different configurations. One type has the heating or cooling coils near the top discharge. Another has the fan near the top of the unit.

A common design feature that provides effective humidity control is a face and bypass arrangement. This allows the cooling/dehumidifying coil to remain on to provide cooling while some of the air bypasses the coil to provide temperature control of the discharge air.

If you are looking to purchase new unit ventilators for your building, consult with vendors and manufacturer's representatives about the features that will provide the best humidity control.

MAINTENANCE OF HUMIDITY CONTROL EQUIPMENT

The maintenance tasks identified in Tables 3 and 4 are for a hypothetical set of 10 classrooms. The unitary equipment energy and maintenance hours assumes 10 units. The central equipment such as chillers and towers assumes one device for all 10 classrooms. Table 3 sequentially assigns task IDs that are used in Table 4.

The maintenance tasks listed are one possible solution to the care of these various systems. This list of tasks comes from the Operations and Maintenance Estimates handbook published by RSMeans.

Table 3: Maintenance tasks for humidity control equipment

Maintenance Task ID (assigned for reference in table 4)	Task Description	Frequency	Hours per Task per Unit	Total Annual Hours
M-1	Clean condenser coils.	Semi-Annually	1	2
M-2	Clean drain pan, fan motor and drain piping.	Annually	1	1
M-3	Check filter; Fill out maintenance checklist and report deficiencies.	Quarterly	2	8
M-4	Check belt, controls, and refrigerant pressure.	Quarterly	2	8
M-5	Check lubrication.	Semi-Annually	.5	1
M-6	Check for noise and vibration.	Monthly	.25	6
M-7	Check for leaks, oil level, and temperature.	Weekly	.1	5.2
M-8	Run system self-diagnostics.	Monthly	1	12
M-9	Check chemical water treatment system.	Weekly	.5	27
M-10	Clean out strainers, check water levels in both upper and lower basins.	Weekly during season	2	32
M-11	Clean evaporator coils.	Annually	8	8

Table 4: A hypothetical compilation of tasks listed in Table 3 intended to show the relative differences in maintenance effort between systems.

System Description	Electric Demand	Maintenance Task	Multiplier
Package Terminal Heat Pump with water source from Central Evaporative Cooling Tower	4.45 kW	**PTHP:** M-2, M-3, M-4, M-5, M-6, M-11	For each PTHP
		Evap. Tower: M-6, M-9, M-10	1 for each building
Package Terminal Heat Pump with water source from Central Dry Cooler	7.83 kW	**PTHP:** M-2, M-3, M-4, M-5, M-6, M-11	For each PTHP
		Dry Cooler: M-1, M-6	1 for each building
Unit Ventilator (DX) with Air Cooled Condenser	3.87 kW	M-1, M-2, M-3, M-4, M-5, M-6, M-11	For each UV
Unit Ventilator with Chilled Water from Central Centrifugal Chiller and Evaporative Tower	4.09 kW	**UV:** M-2, M-3, M-5, M-6, M-11	For each UV
		Chiller & Tower: M-6, M-7, M-8, M-9, M-10	1 for each building
Unit Ventilator with Chilled Water from Central Air Cooled Chiller	5.39 kW	**UV:** M-2, M-3, M-5, M-6, M-11	For each UV
		Chiller: M-1, M-6, M-7, M-8	1 for each building
Unit Ventilator with DX and Energy Recovery	3.62 kW	M-1, M-2, M-3, M-4, M-5, M-6, M-11	For each UV
Central AHU with DX	3.78 kW	M-1, M-2, M-3, M-4, M-5, M-6, M-7	1 for many or perhaps all rooms.
Central AHU with Chilled Water from Central Centrifugal Chiller and Evaporative Tower	3.54 kW	M-1, M-2, M-3, M-4, M-5, M-6, M-7, M-8, M-9, M-10, M-11	1 for many or perhaps all rooms.

Effects of Humidity on Buildings and Occupants

What we know from the research

HEALTH EFFECTS

Asthma: A study done by doctors at the University Hospital in Uppsala, Sweden found a statistically significant correlation between the occurrence of asthma among school staff and the total concentration of mold organisms in the school air. It is not unusual to find accounts of school buildings in which mold was discovered and were subsequently closed temporarily or evacuated. The direct connection between mold and the health of building occupants has not yet been definitively established by science. This is in spite of the many attempts to do so in the court system. Nevertheless, enough circumstantial evidence shows that it is best to avoid mold growth in public buildings, especially schools.

Mold: Mold needs four elements to grow: 1) one (and only one) viable spore, 2) an acceptable temperature range, 3) a usable food source, and 4) adequate moisture in the food source. Moisture control is the easiest method to prevent mold growth. Moisture in the air is only indirectly responsible for mold growth because the mold absorbs the moisture not from the air but from the moist food source. Mold that has fully developed and released spores will act as a vapor retarder, protecting the moisture in its food source. It will continue to grow until it runs out of food, the temperature changes or it is killed by ultraviolet light or bleach. Mature mold will generate moisture from metabolizing its food so that lack of moisture from the air will not limit growth. Air moisture is only relevant as it might influence the amount of water absorbed into the material used by the fungus as a food source. Therefore, mold may grow even at a room humidity of 50% RH. What really maters is the RH at the surface of the food. Periodic “pumping” of moisture into the food causes a rise in retained moisture over time to the point when the mold seems to “explode” even if the air is relatively dry at the time.

Dust Mites: Dust mites are sensitive to low humidity. They do not breathe in the fashion of mammals or even other insects. Dust mites gain oxygen and lose water through their entire exterior shell. This is why they tend to inhabit crevices in humid fabrics, where air flow is slow and the dew point is high. The mites will thrive in moist and warm environments and will fail in low dew point environments. Research has shown that young and middle aged people are more likely to suffer asthmatic reactions to dust mite fecal pellets than are senior citizens (see item 4, References section). Dust mites can develop in school carpets when the building has infrequent and incomplete cleaning and when indoor humidity stays above 50% RH. The humidity must be below 40% RH near the surface of the mite's food source, i.e. at the floor, in order to kill existing mites.

COMFORT EFFECTS

Comfort in schools can be best defined as a condition where the occupant is not distracted by the environment. This definition leaves a somewhat broader range of acceptable conditions available to the designer than that defined by most guidelines because of the variation of metabolism and clothing worn by students and faculty. Another benefit of a broad definition is realized when the HVAC designer purposefully controls both temperature and humidity separately. The understanding of how various combinations of temperature and humidity affects occupants is well researched (see items 5 and 6, References section).

In elementary schools during the warm weather months, students with slight builds may be quite comfortable at a temperature that makes their teachers hot and uncomfortable. In winter, teachers who are comfortable at cooler temperatures leave their lightweight students to feel cold. This becomes a distraction to the learning process. The body mass difference can be partly offset through independent humidity control. A good working range of humidity control is 35°F to 65°F dew point. The 65°F upper limit has been suggested by the ASHRAE Standard 62.1 committee.

BUILDING MATERIAL EFFECTS

Corrosion in metals exposed to air is strongly influenced by the relative humidity and contaminants in the air. Clean iron in pure air does not corrode until the air is nearly saturated. However, if the air contains even a trace of sulfur dioxide, the critical relative humidity drops to 70%. Any salt in the air drops the critical relative humidity to 55%, and with any higher RH the corrosion rate becomes rapid. Similar effects occur for copper. Nickel has a critical RH of 70%.

Materials change their moisture content and undergo physical changes based on the relative humidity of the air around them, not based on the absolute amount of moisture in that air. Paper can absorb moisture if the relative humidity is high. Organic materials such as skin and bone can experience salt migration and crystallization in high RH. Physical damage to materials can occur without movement if the RH swings frequently due to expansion and contraction. Without some type of control, RH can swing from 10% to 80% over the course of a year in Minnesota school buildings.

Libraries contain a large amount of fungal food in the form of books and papers. A good target humidity for libraries is 55% RH or less down to a minimum dew point of 30°F. Gymnasiums with maple floors pose a particular humidity control problem. The Maple Flooring Manufacturers Association (MFMA) specifies that the humidity at the floor level "shall be maintained between 35% and 50% RH at all times." The MFMA guidelines allow humidity excursions for the relatively short periods of public events. For example, an 8 hour humidity excursion will not damage the floor. However, if humidity is allowed to rise above 50% over the whole summer or fall below 35% during the winter, the floor will be damaged by expansion and contraction. The flooring does not have to buckle to reveal damage as the wood planks may compress their fibers during the humid summer and shrink to reveal cracks in the winter. These compressed fibers will never fully re-expand.

Psychrometrics

What it means and how to read that funny chart

Air psychrometrics is the study of moist and humid air and the change in air conditions. Air consists mainly of nitrogen and oxygen gasses and a certain amount of water vapor. The amount of water vapor in the air will vary greatly depending upon the conditions. When air is hot it can contain a large amount of water vapor. When it is cold, its capacity to hold the water as a vapor is reduced considerably.

Before delving further into the mysteries of psychrometrics, let's review the following terms that were presented in the Introduction:

- **Dry-bulb** temperature is the air temperature determined by an ordinary thermometer.

- **Wet-bulb** is the temperature of air that is being affected by the cooling of evaporating water.
- **Relative Humidity (RH)** is a measure of how much moisture is present compared to how much moisture the air could hold at that temperature. The amount of water vapor in moist air varies from zero to a maximum that depends on temperature and pressure. The maximum condition refers to saturation, a state of neutral equilibrium between moist air and the condensed water phase. Relative humidity is the ratio of the amount of water in a given volume of air at a specific temperature and pressure to the amount of water in the same air volume at the same temperature and pressure at saturation.

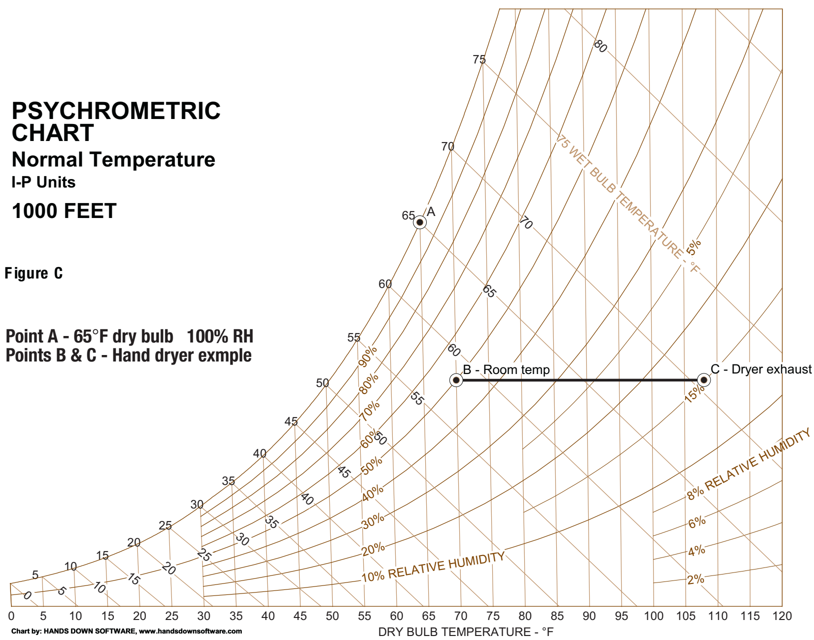
These values can be measured by a device known as the "psychrometer." This device consists of two thermometers, one is dry and the other is covered in a cotton sock that is wetted. In order to read the psychrometer, the two thermometers must have air traveling over them in a constant velocity. A common version of this device is known as the sling psychrometer because it is operated like a sling where the thermometers are whirled around to produce the proper air movement across the thermometer bulbs. The thermometer with the wet sock on it gives you the "wet bulb" temperature and the other the "dry bulb" temperature. If the wet bulb temperature is very close to the dry bulb temperature then the RH is nearly 100 percent. Most psychrometers also have a printed scale to read RH directly.

When the temperature of warm air begins to fall, the vapor also cools and, if cooling continues, will eventually condense into tiny moisture droplets. The common example is condensation running down the outside of a glass of iced water. In the atmosphere this results in the formation of clouds and eventually rain. When condensation is beginning to occur, the air is said to be at the **saturation point** and cannot hold any more moisture, the point of 100% relative humidity. The temperature at this point is the **dew point** which is the temperature below which moisture will condense out of air.

Enthalpy is a measure of the heat content of the air and is expressed in BTUs per pound of dry air. If air is heated to a given temperature, humidity, and pressure and then it is cooled down to the same condition, it will have the same enthalpy. This is the key concept of air conditioning. After first filtering, heat is either added or removed from the air, thereby changing its enthalpy value.

THE PSYCHROMETRIC CHART

The dehumidifying process is often perceived as “magic” and therefore is met with considerable skepticism. To aid in visualizing this complex process engineers have developed the “psychrometric chart” to provide a graphic representation of the state or condition of a quantity of air at any particular time (see Figure C). At first glance, it looks quite complex, something only an engineer could love. However, a basic understanding of this tool will enable the building operator to more effectively manage their HVAC system for optimum performance.



The chart represents air temperature (dry bulb) along the horizontal X-axis and a measure of moisture content of the air along the vertical Y-axis. If conditions change, then the point will move around on the graph. The direction the point moves depends upon which properties of the air are changing.

The curved line boarding the chart on the left is called the saturation line. When the humidity in the air is 100% for any given temperature it can be represented as a point along the saturation line (Point A on Figure C) and the temperature at that point is at the dew point. Air simply cannot exist at a state above and to the left of this saturation line. If the air is cooled beyond its dew point, excess vapor appears as condensation.

The wet bulb temperatures are shown on the psychometric chart as parallel diagonal lines. As just illustrated (by Point A on Figure C) whenever the relative humidity is 100%, the wet bulb is equal to the dew point temperature.

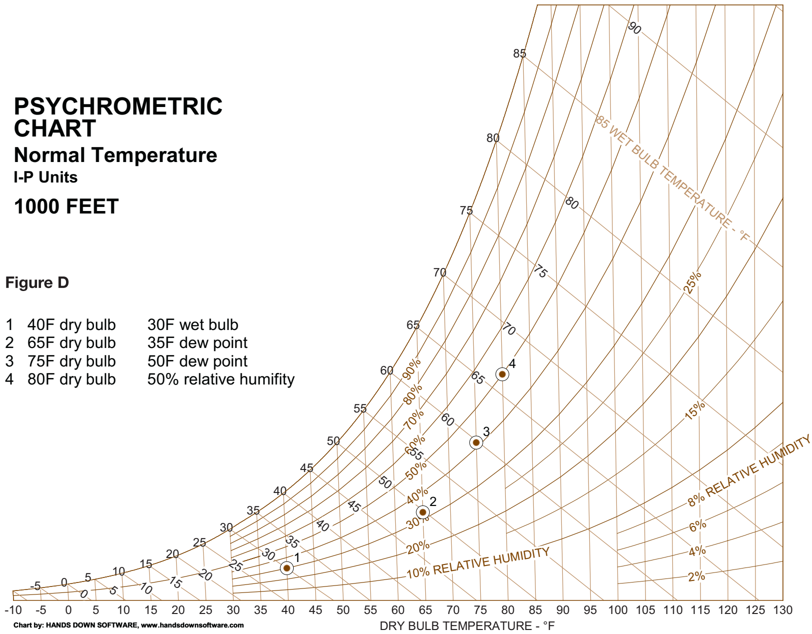
FINDING VALUES ON THE PSYCHROMETRIC CHART

For every combination of dry bulb temperature and dew point temperatures there is a unique relative humidity value. Similarly, when you find the intersection of a particular dry bulb temperature and wet bulb temperature, you can put a mark at the intersection of these two lines and look horizontally to the left at the saturation curve—the dew point.

Here's a straight forward example that will help illustrate how the chart works. Imagine a bathroom with a typical blow dryer. Point B on Figure C shows that the room temperature is 70°F, the RH is 50%, the wet bulb is 57°F and the dew point is 50°F. When the dryer is turned on, the air is heated to about 107°F (point C), the RH will fall to 15%, the wet bulb temperature is now slightly over 70°F. Note that moisture has been neither added nor taken from the air, and that the dew point is the same.

Now that you have a basic understanding of what the lines on the chart mean, look at the points plotted on Figure D. Carefully look at each point plotted on the chart. Verify the following:

- Point #1 – dry bulb is 40°F; wet bulb is 30°F.
- Point #2 – dry bulb is 65°F; dew point is 35°F.
- Point #3 – dry bulb is 75°F; dew point is 50°F.
- Point #4 – dry bulb is 80°F; relative humidity is 50°F.



There are many applications for the use of this chart that are beyond the scope of this introduction. The chart can be used to visualize a simple process such as the mixing of outside and return air or a more complex one like the passage of air through an entire HVAC system. If you understand these few examples, you should be prepared to discuss the performance of your particular equipment with various vendors and engineers. Additional training with the chart can prepare the building operator to take full advantage of this tool to understand, operate and maintain the dehumidification equipment.

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