Handbook HB-501

Armstrong

The Armstrong Humidification Handbook

Humidification Plays an Essential Role

Although humidity is invisible to our eyes, we can easily observe its effects. In human terms, we are more comfortable and more efficient with proper humidification. In business and industrial environments, the performance of equipment and materials is enhanced by effectively applying humidity control.

Maintaining indoor air quality through humidity management can lower energy costs, increase productivity, save labor and maintenance costs, and ensure product quality. In short, humidification can provide a better environment and improve the quality of life and work.

Armstrong has been sharing know-how in humidification application since 1938. Through the design, manufacturing, and application of humidification equipment Armstrong has led the way to countless savings in energy, time and money. Armstrong also provides computer software, video tapes, and other educational materials to aid in humidification equipment selection, sizing, installation, and maintenance.

Armstrong offers the newly updated Humidification Handbook as a problem-solving, educational aid for those involved with the design, installation, and maintenance of environmental control systems in all types of buildings. In addition, you may request a free copy of Armstrong's Software Program 2 (Humidifier Sizing and Selection) for step-by-step sizing of your own installation.

Your specific humidification questions can be answered by your Armstrong Representative. Additional support from Armstrong International humidification specialists is available to assist with difficult or unusual problems.

Controlled humidification helps protect humidity-sensitive materials, personnel, delicate machinery, and equipment. Beyond the important issues of comfort and process control, humidity control can help safeguard against explosive atmospheres. You can't afford NOT to humidify. And the best way to protect your investment is through proven humidification strategies and solutions pioneered by Armstrong.

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Why Humidification is Important

Glossary

Relative Humidity(RH):
The ratio of the vapor pressure (or mole fraction) of water vapor in the air to the vapor pressure (or mole fraction) of saturated air at the same dry-bulb temperature and pressure.

Sensible Heat:
Heat that when added to or taken away from a substance causes a change in temperature or, in other words, is "sensed" by a thermometer. Measured in Btu.

Latent Heat:
Heat that when added to or taken away from a substance causes or accompanies a phase change for that substance. This heat does not register on a thermometer, hence its name "latent" or hidden. Measured in Btu.

Dew Point:
The temperature at which condensation occurs (100%RH) when air is cooled at a constant pressure without adding or taking away water vapor.

Evaporative Cooling:
A process in which liquid water is evaporated into air. The liquid absorbs the heat necessary for the evaporation process from the air, thus, there is a reduction in air temperature and an increase in the actual water vapor content of the air.

Enthalpy:
Also called heat content, this is the sum of the internal energy and the product of the volume times the pressure. Measured in Btu/lb.

Hygroscopic Materials:
Materials capable of absorbing or giving up moisture.

Phase:
The states of existence for a substance, solid, liquid, or gas (vapor).

Humidification is simply the addition of water to air. However, humidity exerts a powerful influence on environmental and physiological factors. Improper humidity levels (either too high or too low) can cause discomfort for people, and can damage many kinds of equipment and materials. Conversely, the proper type of humidification equipment and controls can help you achieve effective, economical, and trouble-free control of humidity.

As we consider the importance of humidity among other environmental factors—temperature, cleanliness, air movement, and thermal radiation—it is important to remember that humidity is perhaps the least evident to human perception. Most of us will recognize and react more quickly to temperature changes, odors or heavy dust in the air, drafts, or radiant heat. Since relative humidity interrelates with these variables, it becomes a vital ingredient in total environmental control.

Humidity and Temperature

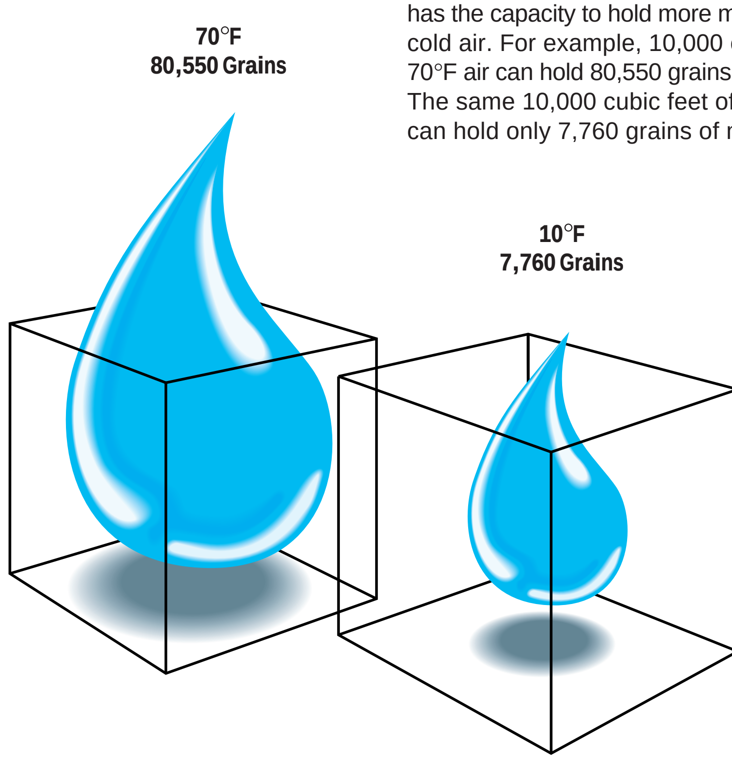
Humidity is water vapor or moisture content always present in the air. Humidity is definable as an absolute measure: the amount of water vapor in a unit of air. But this measure of humidity does not indicate how dry or damp the air is. This can only be done by computing the ratio of the actual partial vapor pressure to the saturated partial vapor pressure at the same temperature. This is relative humidity, expressed by the formula:

$$RH = \left.\frac{vp_a}{vp_s}\right|_t$$

vp_a = actual vapor pressure
vp_s = vapor pressure at saturation
t = dry-bulb temperature

For practical purposes, at temperatures and pressures normally encountered in building systems, relative humidity is considered as the amount of water vapor in the air compared to the amount the air can hold at a given temperature.

"At a given temperature" is the key to understanding relative humidity. Warm air has the capacity to hold more moisture than cold air. For example, 10,000 cubic feet of 70°F air can hold 80,550 grains of moisture. The same 10,000 cubic feet of air at 10°F can hold only 7,760 grains of moisture.



If the 10,000 cubic feet of 10°F air held 5,820 grains of moisture, its relative humidity would be 75%. If your heating system raises the temperature of this air to 70°F with no moisture added, it will still contain 5,820 grains of moisture. However, at 70°F, 10,000 cubic feet of air can hold 80,550 grains of moisture. So the 5,820 grains it actually holds give it a relative humidity of slightly more than 7%. That's very dry...drier than the Sahara Desert.

Air Movement and Humidity

Another variable, air movement in the form of infiltration and exfiltration from the building, influences the relationship between temperature and relative humidity. Typically, one to three times every hour (and many more times with forced air make-up or exhaust) cold outdoor air replaces your indoor air. Your heating system heats this cold, moist outdoor air, producing warm, dry indoor air.

Evaporative Cooling

We've discussed the effects of changing temperature on relative humidity. Altering RH can also cause temperature to change. For every pound of moisture evaporated by the air, the heat of vaporization reduces the sensible heat in the air by about 1,000 Btu. This can be moisture absorbed from people or from wood, paper, textiles, and other hygroscopic materials in the building. Conversely, if hygroscopic materials absorb moisture from humid air, the heat of vaporization can be released to the air, raising the sensible heat.

Dew Point

Condensation will form on windows whenever the temperature of the glass surface is below the dew point of the air. Table 5-2, from data presented in the ASHRAE Handbook & Product Directory, indicates combinations of indoor relative humidity and outside temperature at which condensation will form. Induction units, commonly used below windows in modern buildings to blow heated air across the glass, permit carrying higher relative humidities without visible condensation.

Table 5-1. Grains of Water per Cubic Foot of Saturated Air and per Pound of Dry Air at Various Temperatures. (Abstracted from ASHRAE Handbook)

°F	Per cu ft	Per lb Dry Air	°F	Per cu ft	Per lb Dry Air	°F	Per cu ft	Per lb Dry Air	°F	Per cu ft	Per lb Dry Air
-10	0.28466	3.2186	50	4.106	53.38	78	10.38	145.3	106	23.60	364.0
- 5	0.36917	4.2210	51	4.255	55.45	79	10.71	150.3	107	24.26	375.8
0	0.47500	5.5000	52	4.407	57.58	80	11.04	155.5	108	24.93	387.9
5	0.609	7.12	53	4.561	59.74	81	11.39	160.9	109	25.62	400.3
10	0.776	9.18	54	4.722	61.99	82	11.75	166.4	110	26.34	413.3
15	0.984	11.77	55	4.889	64.34	83	12.11	172.1	111	27.07	426.4
20	1.242	15.01	56	5.060	66.75	84	12.49	178.0	112	27.81	440.4
25	1.558	19.05	57	5.234	69.23	85	12.87	184.0	113	28.57	454.5
30	1.946	24.07	58	5.415	71.82	86	13.27	190.3	114	29.34	469.0
31	2.033	25.21	59	5.602	74.48	87	13.67	196.7	115	30.13	483.9
32	2.124	26.40	60	5.795	77.21	88	14.08	203.3	120	34.38	566.5
33	2.203	27.52	61	5.993	80.08	89	14.51	210.1	125	39.13	662.6
34	2.288	28.66	62	6.196	83.02	90	14.94	217.1	130	44.41	774.9
35	2.376	29.83	63	6.407	86.03	91	15.39	224.4	135	50.30	907.9
36	2.469	31.07	64	6.622	89.18	92	15.84	231.8	140	56.81	1064.7
37	2.563	32.33	65	6.845	92.40	93	16.31	239.5	145	64.04	1250.9
38	2.660	33.62	66	7.074	95.76	94	16.79	247.5	150	71.99	1473.5
39	2.760	34.97	67	7.308	99.19	95	17.28	255.6	155	80.77	1743.0
40	2.863	36.36	68	7.571	102.8	96	17.80	264.0	160	90.43	2072.7
41	2.970	37.80	69	7.798	106.4	97	18.31	272.7	165	101.0	2480.8
42	3.081	39.31	70	8.055	110.2	98	18.85	281.7	170	112.6	2996.0
43	3.196	40.88	71	8.319	114.2	99	19.39	290.9	175	125.4	3664.5
44	3.315	42.48	72	8.588	118.2	100	19.95	300.5	180	139.2	4550.7
45	3.436	44.14	73	8.867	122.4	101	20.52	310.3	185	154.3	5780.6
46	3.562	45.87	74	9.153	126.6	102	21.11	320.4	190	170.7	7581.0
47	3.692	47.66	75	9.448	131.1	103	21.71	330.8	195	188.6	10493.0
48	3.826	49.50	76	9.749	135.7	104	22.32	341.5	200	207.9	15827.0
49	3.964	51.42	77	10.06	140.4	105	22.95	352.6			

Table 5-2. Relative Humidities at Which Condensation Will Appear on Windows at 70°F When Glass Surface is Unheated

Outdoor Temperature	Single Glass	Double Glass (Storm Windows or Thermal Glass)
-10	11%	38%
0	16%	42%
+10	21%	49%
+20	28%	56%
+30	37%	63%
+40	48%	71%

Energy Conservation With Controlled RH

Indoor relative humidity as we have computed it is called Theoretical Indoor Relative Humidity (TIRH). It virtually never exists. RH observed on a measuring device known as a hygrometer will almost always exceed the TIRH. Why? Dry air is thirsty air. It seeks to draw moisture from any source it can. Thus it will soak up moisture from any hygroscopic materials (such as wood, paper, foodstuffs, leather, etc.) and dry out the nasal passages and skin of human beings in the building.

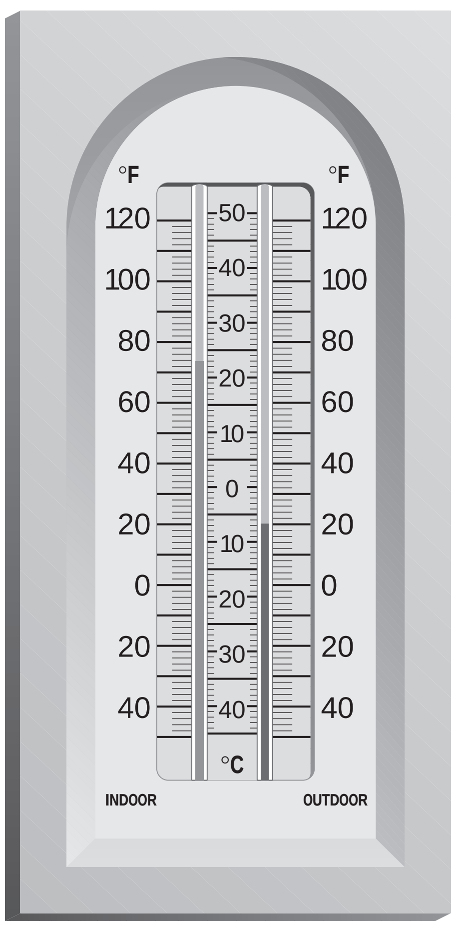
But is this free “humidification”? No, it is the most expensive kind there is when translated into terms of human comfort, material deterioration, and production difficulties. Moreover, it requires the same amount of energy whether the moisture is absorbed from people and materials or added to the air by an efficient humidification system.

The true energy required for a humidification system is calculated from what the actual humidity level will be in the building, NOT from the theoretical level. In virtually all cases, the cost of controlling RH at the desired level will be nominal in terms of additional energy load, and in some cases may result in reduced energy consumption.

A major convention center in the Central United States reported that it experienced a decrease in overall steam consumption when it added steam humidification. From one heating season with no humidification to the next with humidifiers operating, the steam consumption for humidification was 1,803,000 lbs, while the steam for heating decreased by 2,486,000 lbs in the same period. The decreased (metered) consumption occurred despite 7.2% colder weather from the previous year. The records from this installation indicate that it is possible to reduce the total amount of steam required for environmental control by maintaining a higher, controlled relative humidity.

Let’s examine a theoretical system using enthalpy (heat content) as our base.

- Assume a winter day with outside temperature of 0°F at 75% RH.
- The enthalpy of the air is .6 Btu/lb dry air (DA).
- If the air is heated to 72°F without adding moisture, the enthalpy becomes 18 Btu/lb DA.
- Theoretical relative humidity becomes 3.75%, but actual RH will be about 25%.
- At 72°F and 25% RH the enthalpy is 22 Btu/lb DA.
- The additional moisture is derived from hygroscopic materials and people in the area.



But what about the additional energy—the difference between the 18 Btu/lb DA and 22 Btu/lb DA? This 22% increase must come from the heating system to compensate for the evaporative cooling effect. If a humidification system is used and moisture added to achieve a comfortable 35% RH, the enthalpy is 23.6 Btu/lb DA.

This is only a 7% increase over the “inevitable” energy load of 22 Btu/lb DA—substantially less than the theoretical increase of 31% from 3.75% RH (18 Btu/lb DA) to 35% RH (23.6 Btu/lb DA) at 72°F. If the temperature was only 68°F at 35% RH (because people can be comfortable at a lower temperature with higher humidity levels), the enthalpy is 21.8 Btu/lb DA, or a slight decrease in energy.

Problems With Dry Air

Dry air can cause a variety of costly, troublesome, and sometimes dangerous problems. If you are not familiar with the effects of dry air, the cause of these problems may not be obvious. You should be concerned if you are processing or handling hygroscopic materials such as wood, paper, textile fibers, leather, or chemicals. Dry air and/or fluctuating humidity can cause serious production problems and/or material deterioration.

Static electricity can accumulate in dry atmospheric conditions and interfere with efficient operation of production machinery or electronic office machines. Where static-prone materials such as paper, films, computer disks, and other plastics are handled, dry air intensely aggravates the static problem. In potentially explosive atmospheres, dry air and its resultant static electricity accumulations can be extremely dangerous.

Humidity and Human Comfort

Studies indicate people are generally most comfortable when relative humidity is maintained between 35% and 55%. When air is dry, moisture evaporates more readily from the skin, producing a feeling of chilliness even with temperatures of 75°F or more. Because human perception of RH is often sensed as temperature differential, it's possible to achieve comfortable conditions with proper humidity control at lower temperatures. The savings in heating costs is typically very significant over the course of just a single heating season.

The Need for Humidity Control in Today's Electronic Workplace

Electronics are revolutionizing the way your office and plant floor operates, communicates, collects data, and maintains equipment. In the office, xerographic copies, phone systems, word processors, and typewriters, even wall thermostats are electronically controlled. Personal computers and CRT access points are sprouting everywhere. What's more, office decor has far more work stations incorporating wall panels and furniture with natural and synthetic fabric than ever before.

In manufacturing areas, more machines are electronically controlled. In fact, you see more control rooms (just to house electronic control systems) than in previous years.

All this means that the nature of today's business makes proper humidification a virtual necessity.

Why Improper Humidification Threatens Sensitive Electronic Equipment

Central to all electronic circuits today is the IC (integrated circuit) or "chip." The heart of the IC is a wafer-thin miniature circuit engraved in semiconductor material. Electronic components—and chips in particular—can be overstressed by electrical transients (voltage spikes). This may cause cratering and melting of minute areas of the semiconductor, leading to operational upsets, loss of memory, or permanent failure. The damage may be immediate or the component may fail sooner than an identical part not exposed to an electrical transient.

A major cause of voltage spikes is electrostatic discharge (ESD). Although of extremely short duration, transients can be lethal to the wafer-thin surfaces of semiconductors. ESD may deliver voltage as high as lightning, and it strikes faster.

ESD is a particularly dangerous phenomenon because you are the source of these transients. It is the static electricity which builds up on your body. The jolt you get from touching a doorknob or shaking someone's hand is ESD. Table 7-1 below shows voltages which can be generated by everyday activities.

Voltage accumulates on surfaces (in this case, the human body), and when the surface approaches another at a lower voltage a discharge of electrical voltage occurs. Note the humidity levels at which these voltages may be generated. As the level of humidity rises, voltages are reduced because a film of moisture forms on surfaces, conducting the charges to the ground. Although the 65%-90% RH cited in Table 7-1 is impractical for office areas, any increase in humidity will yield a significant reduction in ESD events.

ESD Damage is Not Only Possible but Probable

A study of personnel ESD events in a poorly controlled room with a wool carpet was conducted for 16 months. The strength of the ESD event was measured in current (amps). Results indicate, for example, that a current discharge of 0.3 amps is 100 times more likely to occur at 10%-20% RH than at 45%-50% RH. In other words, the higher the relative humidity, the lower the occurrence and severity of ESD.

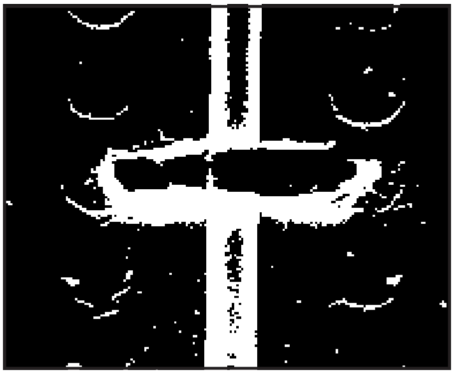
In addition to the risk of damage to electronic devices from static electricity charges, there are grave risks associated with sparks from static charges in many process applications. Static electricity is extremely dangerous in the presence of gases, volatile liquids, or explosive dusts such as is found in munitions plants, paint spray booths, printing plants, pharmaceutical plants, and other places.

While many static control products (special mats, carpeting, sprays, straps, etc.) are available, bear in mind that humidification is a passive static-control means. It is working to control static all the time—not just when someone remembers.

Table 7-1. Effect of Humidity on Electrostatic Voltages

Means of Static Generatioo	Electrostatic Voltages	
	10%-20% Relative Humidity	65%-90% Relative Humidity
Walking across carpet	35,000	1,500
Walking over vinyl floor	12,000	250
Worker at bench	6,000	100
Vinyl envelopes for work instructions	7,000	600
Common poly bag picked up from bench	20,000	1,200
Work chair padded with polyurethane foam	18,000	1,500

Figure 7-1.
Effect of humidity on electrostatic voltages



Integrated circuit damaged by ESD.
(Photo courtesy of Motorola Semiconductor, Inc.)

How Humidity Affects Materials

Paper and Paper Products

Every production superintendent in the paper industry is, by experience, familiar with the excessive scrap losses and customer complaints that can result from the following wintertime headaches:

1. Curling of stock.
2. Cracking or breaking at creases of folding boxes, cartons, corrugated and solid fiber containers.
3. Loss of package and container strength.
4. Production delays when sheets fail to go through machines smoothly due to static electricity.
5. Gluing failures.

All of the above wintertime problems have a common cause—dry or curling paper caused by low indoor relative humidities.

Whenever you heat air, without adding moisture, its RH drops. Table 8-1 shows that 0°F outside air at 75% RH will have a relative humidity of only 4.4% when heated to 70°F indoors. Even though the theoretical RH should be 4.4% in your plant, the actual observed humidity will be much higher because of the moisture given off by the paper. This type of humidification is very expensive in terms of stock and production.

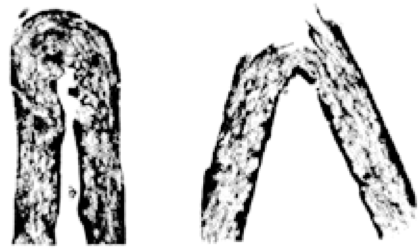


Figure 9-1. Effects of moisture content in folding paper. Sheet on left has proper moisture. Sheet on right lacks enough moisture—is dry and brittle—breaks on fold.

The RH of surrounding air governs the moisture content of paper, as shown in Table 9-1. The fibrils in paper take on moisture when the paper is drier than the surrounding air and give up moisture when the conditions are reversed.

A paper moisture content range of 5%-7% is essential to maintain satisfactory strength and workability of paper. This requires an indoor RH of about 40%-50%, depending upon the composition of the paper.

Moisture contents of different types of papers will vary slightly from those shown in the table but will follow an identical pattern.

Changes in moisture content thus cause paper to become thicker or thinner, flatter or curlier, harder or softer, larger or smaller, limp or brittle.

Table 8-1. How Indoor Heating Reduces Indoor RH and Dries Out Paper

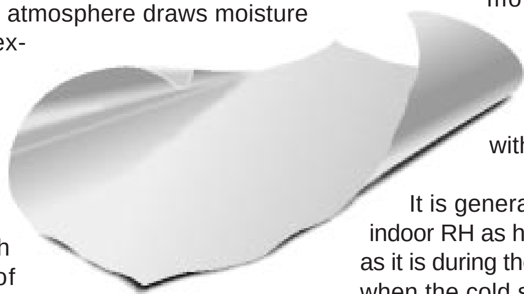
	Indoor Temperature 70°F	
Outdoor Temperature Degrees	Indoor Relative Humidity %	Approx. Moisture Content of Paper
-20	1.5	0.5
-10	2.5	0.8
0	4.4	1.2
10	7.2	2.2
20	11.6	3.3
30	18.1	4.3
40	26.8	5.3
50	38.3	6.4
60	54.0	8.0
70	75.0	11.6

Effect of Indoor Heating Upon RH and Moisture Content of Kraft Wrapping Paper. NOTE: This table assumes an outdoor relative humidity of 75%. When outdoor RH is less, as is common, indoor RH will also be less. Indoor temperatures higher than 70°F will also cause lower relative humidities.

Printing

The dry air problems found in paper manufacturing are equally common to the printing industry.

Paper curling, generally caused by the expansion and contraction of an unprotected sheet of paper, takes place when too dry an atmosphere draws moisture from the exposed surface which shrinks and curls. The curl will be with the grain of the sheet. This trouble is most pronounced with very lightweight stocks or with cover stocks, and coated-one-side papers.



Wood Products, Woodworking, and Furniture Manufacture

Like all hygroscopic materials, wood takes on or gives off moisture as the RH of the surrounding air varies. When, at any given temperature and relative humidity, the wood finally stops absorbing or liberating moisture, it is said to have reached its equilibrium moisture content (EMC). The moisture in the wood is then "in balance" with the moisture in the air.

It is generally not practical to hold indoor RH as high during the cold months as it is during the warm months. However, when the cold season sets in, humidifiers permit a gradual reduction of RH and EMC to a practical minimum working level. Under this controlled condition, warping and cracking will not occur.

Leather Processing

RH maintained uniformly in the 40%-60% range (higher in muller rooms) reduces cracking, minimizes loss of pliability, helps maintain quality and appearance, and reduces the dust problem in the plant.

Offices

RH maintained at 30%-40% stops splitting, checking, shrinkage, and glue joint failure in paneling and furnishings, adds life to carpeting and draperies. Electronic office equipment such as computers, xerographic copiers, and phone systems require a constant RH of 40%-50% to guard against harmful electrical transients (see page 7).

Libraries and Museums

Relative humidity maintained uniformly at 40%-55% in storage rooms, vaults, and galleries prolongs the life of valuable collections by stabilizing the pliability of glue, starch and casein. The embrittlement of fibers in paper, canvas, papyrus, leather bindings, etc., is minimized.

Table 9-1. Moisture Content of Paper at Various Relative Humidities

Material	Description	Relative Humidity %								
		10	20	30	40	50	60	70	80	90
M.F. Newsprint	Wood Pulp 24% Ash	2.1	3.2	4.0	4.7	5.3	6.1	7.2	8.7	10.6
HMF Writing	Wood Pulp 3% Ash	3.0	4.2	5.2	6.2	7.2	8.3	9.9	11.9	14.2
White Bond	Rag 1% Ash	2.4	3.7	4.7	5.5	6.5	7.5	8.8	10.8	13.2
Com. Ledger	75% Rag 1% Ash	3.2	4.2	5.0	5.6	6.2	6.9	8.1	10.3	13.9
Kraft Wrapping	Coniferous	3.2	4.6	5.7	6.6	7.6	8.9	10.5	12.6	14.9

Determining Humidity Requirements of Materials

No single level of relative humidity provides adequate moisture content in all hygroscopic materials. Moisture content requirements vary greatly from one material to the next. We will discuss typical hygroscopic materials which require specific RH levels to avoid moisture loss and materials deterioration and/or production problems that result.

Table 10-1. Recommended Relative Humidities

PROCESS OR PRODUCT	Temp.°F	%RH
Residences	70-72	30
Libraries & Museums		
Archival	55-65	35
Art storage	60-72	50
Stuffed fur animals	40-50	50
Communication Centers		
Telephone terminals	72-78	40-50
Radio & TV studios	74-78	30-40
General Commercial & Public Buildings	70-74	20-30
(including cafeterias, restaurants, airport terminals, office buildings, & bowling centers)		
Hospitals & Health Facilities		
General clinical areas	72	30-60
Surgical area		
Operating rooms	68-76	50-60
Recovery rooms	75	50-60
Obstetrical		
Full-term nursery	75	30-60
Special care nursery	75-80	30-60
Industrial Hygroscopic Materials		
Abrasive		
Manufacture	79	50
Ceramics		
Refractory	110-150	50-90
Molding room	80	60-70
Clay storage	60-80	35-65
Decalcomania production	75-80	48
Decorating room	75-80	48
Cereal		
Packaging	75-80	45-50
Distilling		
Storage		
Grain	6	35-40
Liquid yeast	32-33	
General manufacturing	60-75	45-60
Aging	65-72	50-60
Electrical Products		
Electronics & X-ray:		
Coil & transformer winding	72	15
Semi conductor assembly	68	40-50
Electrical instruments:		
Manufacture & laboratory	70	50-55
Thermostat assembly & calibration	75	50-55
Humidistat assembly & calibration	75	50-55
Small mechanisms:		
Close tolerance assembly	72	40-45
Meter assembly & test	75	60-63

PROCESS OR PRODUCT	Temp.°F	%RH
Switchgear:		
Fuse & cutout assembly	73	50
Capacitor winding	73	50
Paper storage	73	50
Conductor wrapping with yarn	75	65-70
Lightning arrester assembly	68	20-40
Thermal circuit breakers assembly & test	75	30-60
High-voltage transformer repair	79	55
Water wheel generators:		
Thrust runner lapping	70	30-50
Rectifiers:		
Processing selenium & copper oxide plates	73	30-40
Fur		
Storage	40-50	55-65
Gum		
Manufacturing	77	33
Rolling	68	63
Stripping	72	53
Breaking	73	47
Wrapping	73	58
Leather		
Drying	68-125	75
Storage, winter room temp.	50-60	40-60
Lenses (Optical)		
Fusing	75	45
Grinding	80	80
Matches		
Manufacture	72-73	50
Drying	70-75	60
Storage	60-63	50
Mushrooms		
Spawn added	60-72	nearly sat.
Growing period	50-60	80
Storage	32-35	80-85
Paint Application		
Oils, paints: Paint spraying	60-90	80
Plastics		
Manufacturing areas:		
Thermosetting molding compounds	80	25-30
Cellophane wrapping	75-80	45-65
Plywood		
Hot pressing (resin)	90	60
Cold pressing	90	15-25
Rubber-Dipped Goods		
Cementing	80	25-30*
Dipping surgical articles	75-80	25-30*
Storage prior to manufacture	60-75	40-50*
Laboratory (ASTM Standard)	73.4	50*

* Dew point of air must be below evaporation temperature of solvent

PROCESS OR PRODUCT	Temp.°F	%RH
Tea		
Packaging	65	65
Tobacco		
Cigar & cigarette making	70-75	55-65
Softening	90	85-88
Stemming & stripping	75-85	70-75
Packing & shipping	73-75	65
Filler tobacco casing & conditioning	75	75
Filter tobacco storage & preparation	77	70
Wrapper tobacco storage & conditioning	75	75
Pharmaceuticals		
Powder storage (prior to mfg)*		*
Manufactured powder storage & packing areas	75	35
Milling room	75	35
Tablet compressing	75	35
Tablet coating room	75	35
Effervescent tablets & powders	75	20
Hypodermic tablets	75	30
Colloids	75	30-50
Cough drops	75	40
Glandular products	75	5-10
Ampoule manufacturing	75	35-50
Gelatin capsules	75	35
Capsule storage	75	35
Microanalysis	75	50
Biological manufacturing	75	35
Liver extracts	75	35
Serums	75	50
Animal rooms	75-80	50
Small animal rooms	75-78	50
* Store in sealed plastic containers in sealed drums.		
Photographic Processing		
Photo Studio		
Dressing room	72-74	40-50
Studio (camera room)	72-74	40-50
Film darkroom	70-72	45-55
Print darkroom	70-72	45-55
Drying room	90-100	35-45
Finishing room	72-75	40-55
Storage room		
b/w film & paper	72-75	40-60
color film & paper	40-50	40-50
Motion picture studio	72	40-55
Static Electricity Control		
Textiles, paper, explosive control		> 55
Clean Rooms & Spaces		45
Data Processing	72	45-50
Paper Processing		
Finishing area	70-75	40-45
Test laboratory	73	50

Abstracted from the ASHRAE Handbook Systems and Applications

How Psychrometrics Help in Humidification

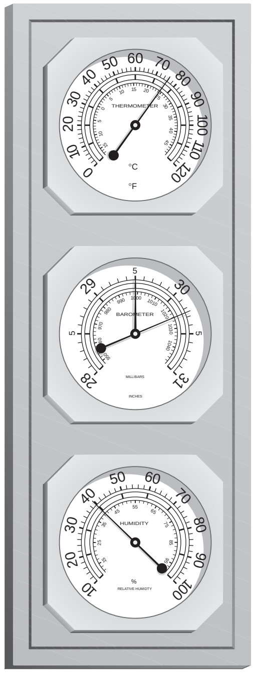
Psychrometrics is the measurement of thermodynamic properties in moist air. As a problem-solving tool psychrometrics excel in clearly showing how changes in heating, cooling, humidification, and dehumidification can affect the properties of moist air. Psychrometric data is needed to solve various problems and processes relating to air distribution.

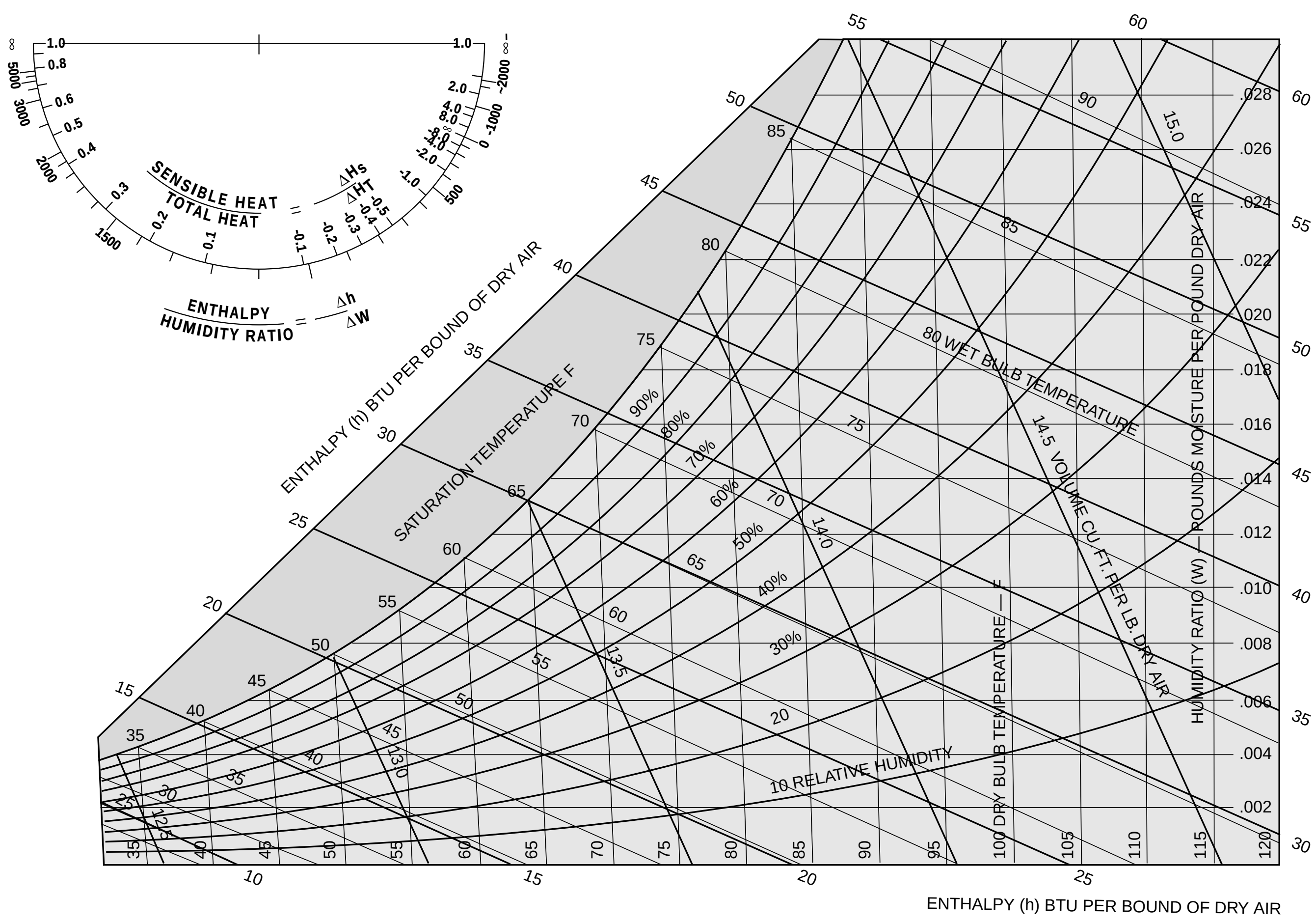
Most complex problems relating to heating, cooling and humidification are combinations of relatively simple problems. The psychrometric chart illustrates these processes in graphic form, clearly showing how changes affect the properties of moist air.

One of the reasons psychrometric data is particularly important today is traceable to the way most new buildings (and many older ones) are heated. The lower duct temperatures (55°F and below) used in new buildings make accurate humidity control more difficult to achieve. (This is because low duct temperatures have a limited ability to absorb moisture. Adding moisture via the central air handling system must compensate for reheating of air before it leaves the duct.)

For such applications, booster humidification must sometimes be accomplished in the duct of the zone after it has reached its final temperature (reheated).

To maintain typical conditions of 70°F and 50% RH, duct humidities will be very high (75% RH and above). To keep the duct from becoming saturated, a duct high limit humidistat is used, and becomes in these cases *the main controller of the humidifier.* Since this humidistat is in close proximity to the humidifier, and air is constantly moving, and must be controlled close to saturation, the humidifier output control must be fast, accurate and repeatable.

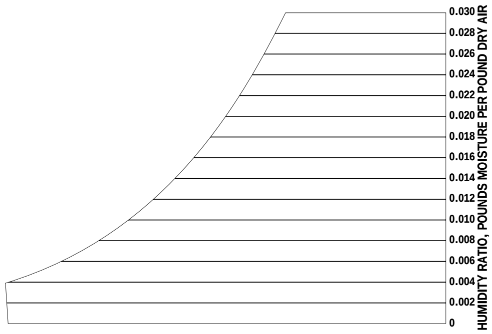




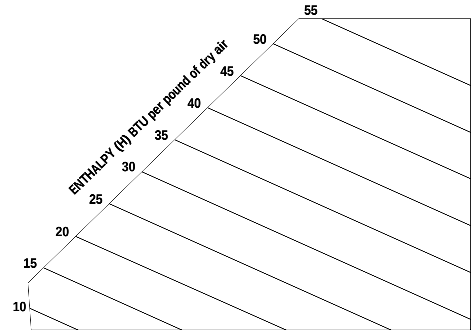
Using the Psychrometric Chart

The psychrometric chart is a graphical representation of the thermodynamic properties which impact moist air.

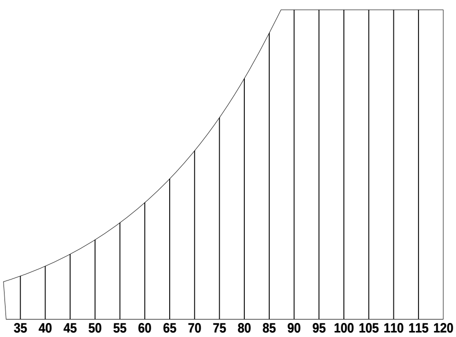
It consists of eight major components:



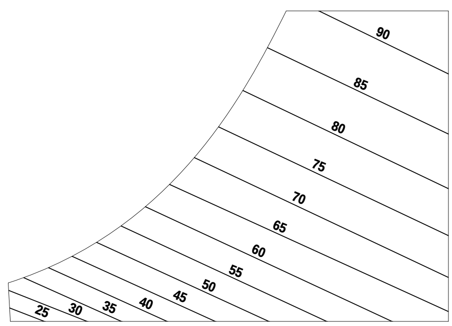
1. Humidity ratio values are plotted vertically along the right-hand margin, beginning with 0 at the bottom and extending to .03 at the top.



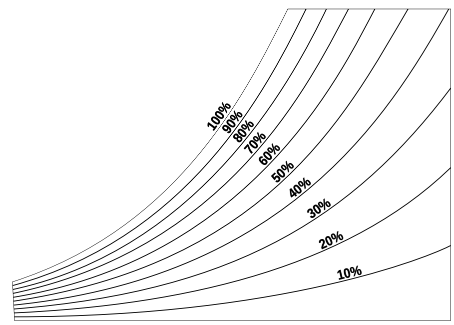
2. Enthalpy, or total heat, is plotted with oblique lines, at intervals of 5 Btu/lb of dry air, extending from upper left to lower right.



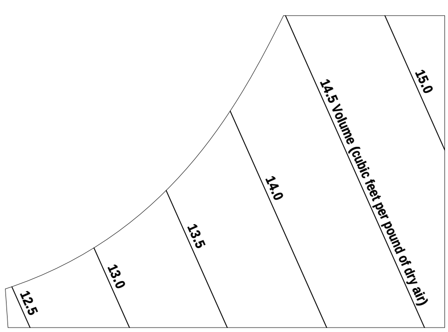
3. Dry-bulb temperature lines are plotted vertically at 1°F intervals.



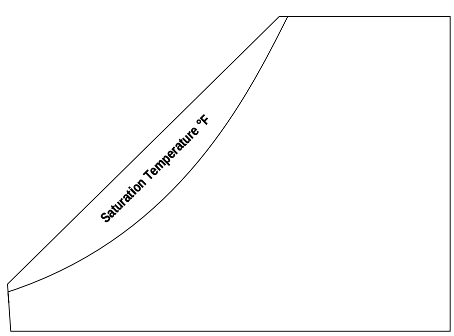
4. Wet-bulb temperature lines are indicated obliquely and fall almost parallel to enthalpy lines. They are shown at 1°F intervals.



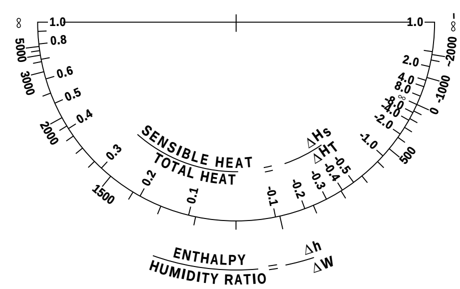
5. Relative humidity lines curve across the chart from left to right at intervals of 10%. They begin at the bottom at 10% and end at the top with the saturation curve (100%).



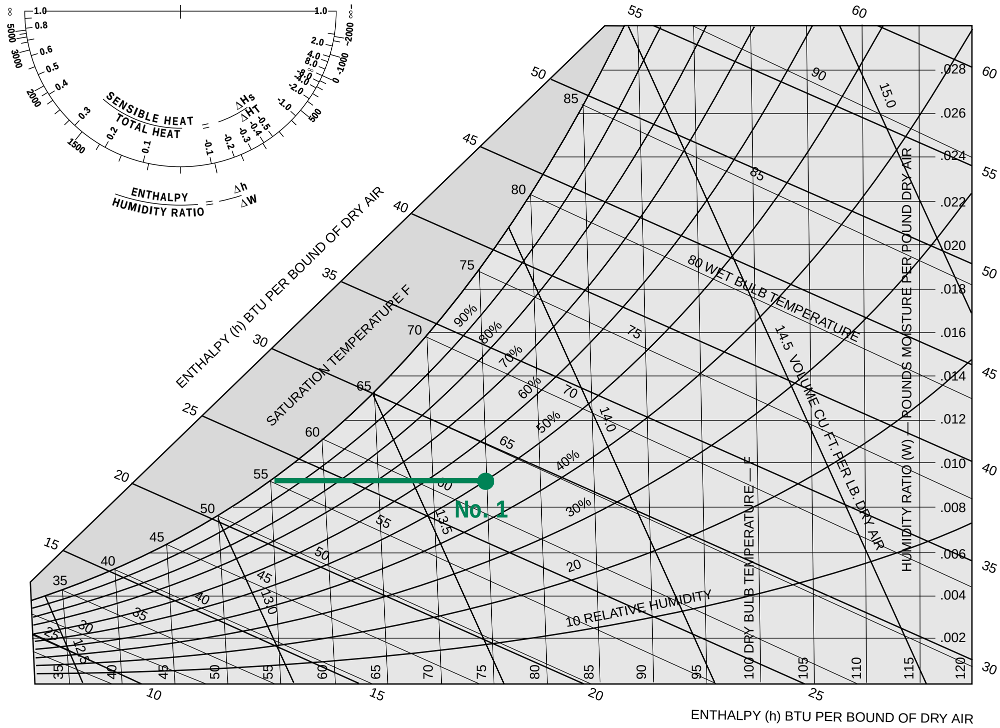
6. Volume lines indicating cubic feet per pound of dry air are plotted at intervals of .5 cubic foot.



7. Two-phase region includes a narrow, cross-hatched area to the left of the saturation region indicating a mixture of condensed water in equilibrium.



8. The protractor at the upper left of the chart contains two scales. One is for the ratio of enthalpy difference. The other is for a ratio of sensible heat to the total heat. The protractor establishes the angle of a line on the chart along which a process will follow.



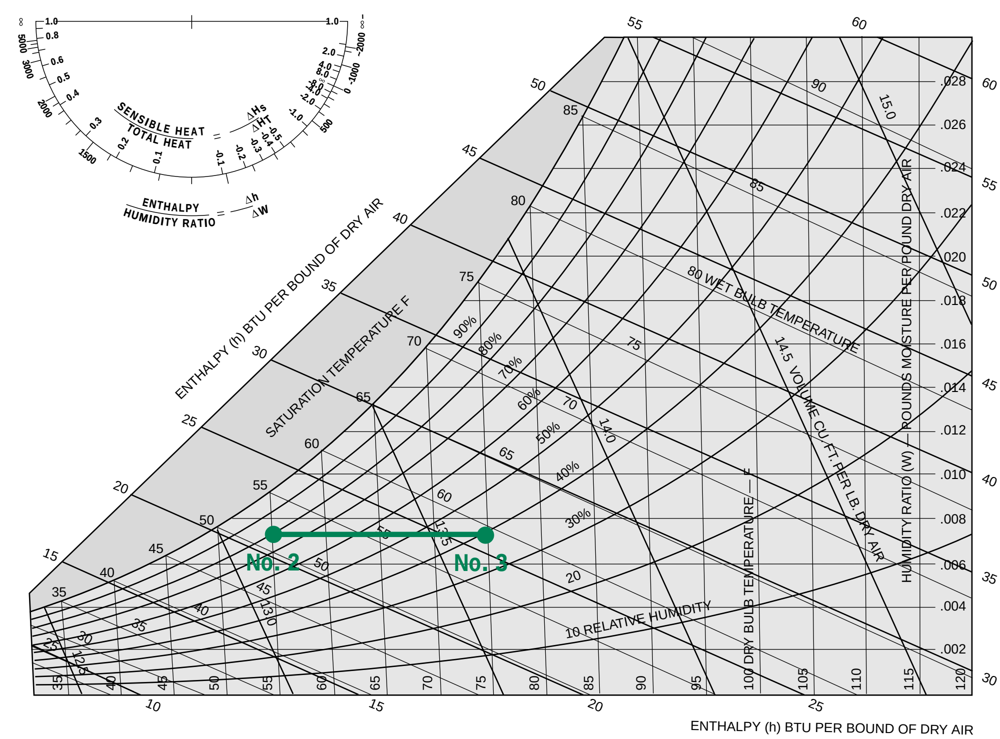
Example 1

Given the conditions of 75°F dry bulb and 50% RH, determine the dew point, volume and humidity content in grains per cubic foot of dry air.

Solution:

1. Locate the state point, where the 75°F dry-bulb line intersects the 50% RH line. Call this state point number 1.
2. Project horizontally to the left to the saturation curve and read 55°F (dew point).
3. Project horizontally to the right and read .0092 pounds of moisture per pound of dry air.
4. Draw a line through the state point parallel to 13.5 volume line and estimate a volume of 13.68 cubic feet per pound of dry air.
5. Solve for grains per cubic foot by converting:

0.0092 x 7,000 ÷ 13.68 = 4.71 grains/cu ft
See also Table 27-5 for quick values.



Example 2

Determine resultant RH when 55°F air at 80% RH is heated to a temperature of 75°F.

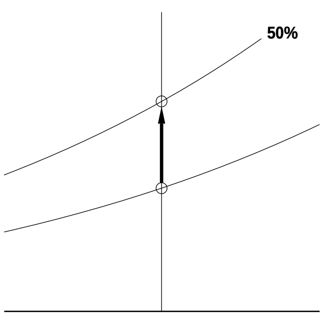
Solution:

1. Locate the state point where 55°F dry-bulb line intersects 80% RH line. Call this state point number 2.
2. Project horizontally to the right to intersect the 75°F dry-bulb line at 40% RH. Call this state point 3.
3. Observe that if air is delivered to a system at state point 2, that a reheat operation can deliver it to an area at state point 3.
4. If state point 1 (example 1) is desired in the area, then booster humidification is needed.

How Humidifiers Work

Steam Humidification

Unlike other humidification methods, steam humidifiers have a minimal effect on dry-bulb (DB) temperatures. The steam humidifier discharges ready-made water vapor. This water vapor does not require any additional heat as it mixes with the air and increases relative humidity. Steam is pure water vapor existing at 212°F (100°C). This high temperature creates a perception that steam, when discharged into the air, will actually increase air temperature. This is a common misconception. In truth, as the humidifier discharges steam into the air, a steam/air mixture is established. In this mixture steam temperature will rapidly decrease to essentially the air temperature.



The psychrometric chart helps illustrate that steam humidification is a constant DB process. Starting from a point on any DB temperature line, steam humidification will cause movement straight up along the constant DB line. The example illustrates that 70°F DB is constant as we increase RH from 30%-50%. This is true because steam contains the necessary heat (enthalpy) to add moisture without increasing or decreasing DB temperature. Actual results utilizing high pressure steam or large RH increases (more than 50%) increase DB by 1° to 2°F. As a result, no additional heating or air conditioning load occurs.

Direct Steam Injection Humidifiers

The most common form of steam humidifier is the direct steam injection type. From a maintenance point of view, direct steam humidification systems require very little upkeep. The steam supply itself acts as a cleaning agent to keep system components free of mineral deposits that can clog water spray and evaporative pan systems.

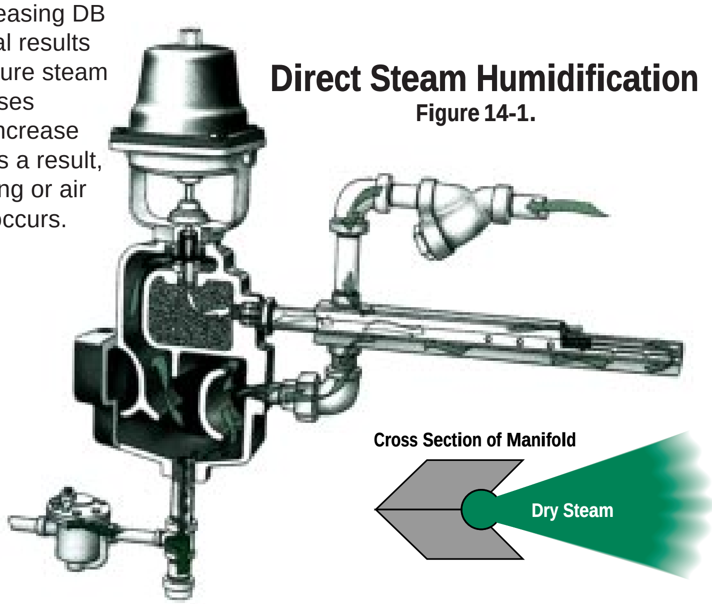
Response to control and pinpoint control of output are two other advantages of the direct steam humidification method. Since steam is ready-made water vapor, it needs only to be mixed with air to satisfy the demands of the system. In addition, direct steam humidifiers can meter output by means of a modulating control valve. As the system responds to control, it can position the valve anywhere from closed to fully open. As a result, direct steam humidifiers can respond more quickly and precisely to fluctuating demand.

The high temperatures inherent in steam humidification make it virtually a sterile medium. Assuming boiler makeup water is of satisfactory quality and there is no condensation, dripping or spitting in the ducts, no bacteria or odors will be disseminated with steam humidification.

Corrosion is rarely a concern with a properly installed steam system. Scale and sediment—whether formed in the unit or entrained in the supply steam—are drained from the humidifier through the steam trap.

Direct Steam Humidification

Figure 14-1.



Steam-to-Steam Humidifiers

Steam-to-steam humidifiers use a heat exchanger and the heat of treated steam to create a secondary steam for humidification from untreated water. The secondary steam is typically at atmospheric pressure, placing increased importance on equipment location.

Maintenance of steam-to-steam humidifiers is dependent on water quality. Impurities such as calcium, magnesium and iron can deposit as scale, requiring frequent cleaning. Response to control is slower than with direct steam because of the time required to boil the water.

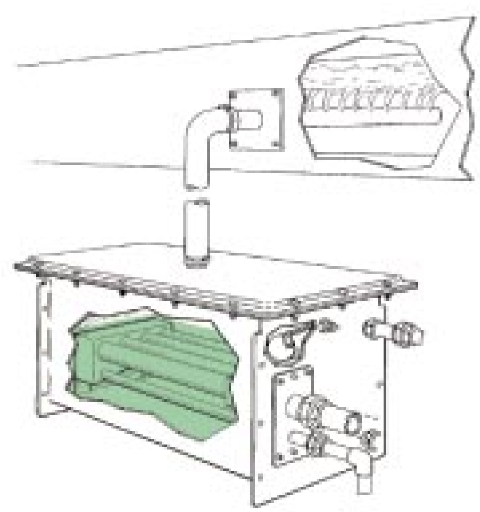
Electronic Steam Humidifiers (Electrode)

Electronic steam humidifiers are used when a source of steam is not available. Electricity and water create steam at atmospheric pressure. Electrode-type units pass electrical current through water to provide proportional output. Use with pure demineralized, deionized or distilled water *alone* will generally not provide sufficient conductivity for electrode units.

Water quality affects the operation and maintenance of electrode-type humidifiers. Use with hard water requires more frequent cleaning, and pure softened water can shorten electrode life. Microprocessor-based diagnostics assist with troubleshooting.

Steam-to-Steam Humidification

Figure 14-2.



Electrode units are easily adaptable to different control signals and offer full modulated output. However, the need to boil the water means control will not compare with direct-injection units.

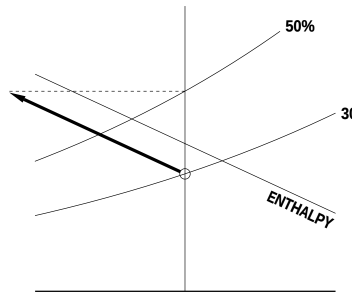
Electronic Steam Humidifiers (Ionic Bed)

Ionic bed electronic humidifiers typically use immersed resistance heating elements to boil water. Since current does not pass through water, conductivity is not a concern. Therefore, ionic bed technology makes the humidifier versatile enough to accommodate various water qualities. These units work by using ionic bed cartridges containing a fibrous media to attract solids from water as its temperature rises, minimizing the buildup of solids inside the humidifier. Water quality does not affect operation, and maintenance typically consists of simply replacing the cartridges.

Ionic bed humidifiers are adaptable to different control signals and offer full modulated output. Control is affected by the need to boil the water, however.

Water Spray

The water spray process can create potential temperature control problems. In order to become water vapor or humidity, water requires approximately 1,000 Btu per pound to vaporize. This heat must be drawn from the air, where it will hopefully vaporize. If not enough heat is available quickly enough, the water remains a liquid. This unvaporized water can result in overhumidification, and the water can “plate out” on surfaces, creating a sanitation hazard.

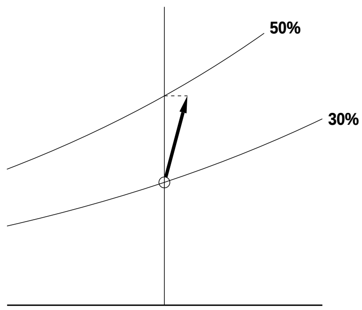


Water spray contains virtually none of the heat of vaporization required to increase the RH of the air to desired conditions. For this reason, water spray humidification is a virtually constant enthalpy process. However, as the psychrometric example illustrates, DB temperature changes as we increase RH from 30%-50%. The result of this loss of DB temperature is an increased heating load to maintain 70°F.

Response of water spray humidifiers to control is slow due to the need for evaporation to take place before humidified air can be circulated. On/off control of output means imprecise response to system demand and continual danger of saturation. Water spray systems can distribute large amounts of bacteria, and unevaporated water discharge can collect in ducts, around drains and drip pans, and on eliminator plates, encouraging the growth of algae and bacteria. Corrosion is another ongoing problem with water spray humidification. Scale and sediment can collect on nozzles, ductwork, eliminator plates, etc., leading to corrosion and high maintenance costs.

Evaporative Pan

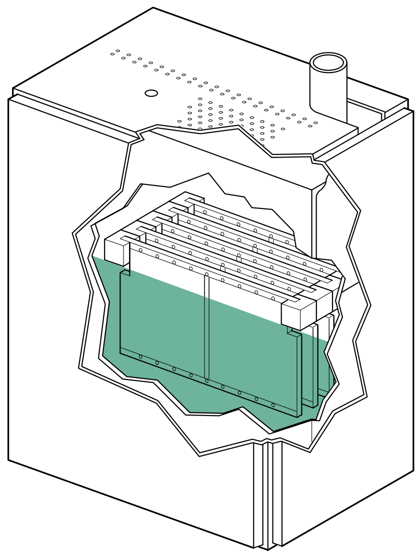
The evaporative pan method uses steam, hot water or electricity to provide energy for heating coils which in turn heat water and create water vapor. This method is most effective when installed in smaller capacity environments either in the air handling system or individually within the area(s) to be humidified.



Evaporative pan humidification can increase dry-bulb temperature as measured on the psychrometric chart. This unwanted temperature change may occur as air is forced across the warmed water in the pan. The increase in DB can cause damaging results in process applications and increase the need for humidity control. The psychrometric chart helps illustrate that evaporative pan humidification is not a constant DB process. This example shows DB temperature increasing as we move from 30%-50% RH. To maintain a constant DB of 70°F some cooling load (air conditioning) is required.

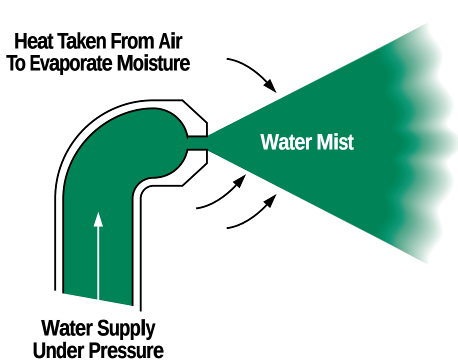
Electronic Steam Humidification

Figure 15-1.



Water Spray

Figure 15-2.



Maintenance of evaporative pan humidification systems demands regular cleaning of the heating coils and pan, which are subject to "liming up."

The use of chemical additives added either automatically or manually to the water in the pan can reduce this problem by as much as half.

Response to control with the evaporative pan method is slow due to the time required for evaporation to take place before humidified air can be circulated. Output is determined by water temperature and surface area.

Evaporative pan humidifiers can sustain bacteria colonies in the reservoir and distribute them throughout the humidified space. High water temperatures, water treatment, and regular cleaning and flushing of the humidifier help to minimize the problem, however.

Cost Comparisons

To fairly evaluate the costs of selecting a humidification system, you should include installation, operating, and maintenance costs as well as initial costs. Total humidification costs are typically far less than heating or cooling system costs.

Initial costs, of course, vary with the size of the units. Priced on a capacity basis, larger capacity units are the most economical, regardless of the type of humidifier, i.e.: one humidifier capable of delivering 1,000 pounds of humidification per hour costs less than two 500 lbs/hr units of the same type.

Direct steam humidifiers will provide the highest capacity per first cost dollar; water spray and evaporative pan are the least economical, assuming capacity needs of 75 lbs/hr or more.

Installation costs for the various types cannot be accurately formulated because the proximity of water, steam and electricity to humidifiers varies greatly among installations. Operating costs are low for direct steam and slightly higher for steam-to-steam. Water spray and evaporative pan operating costs are also low. Energy costs are higher for electronic humidifiers.

Direct steam humidifiers have the lowest maintenance costs. Ionic bed electronic humidifiers are designed specifically to minimize maintenance while adapting to various water qualities. Maintenance costs for other types can vary widely, depending on water quality and applications.

These are the principal considerations in selecting a humidification system. Table 16-1 summarizes the capabilities of each humidifier type.

Evaporative Pan

Figure 16-1.

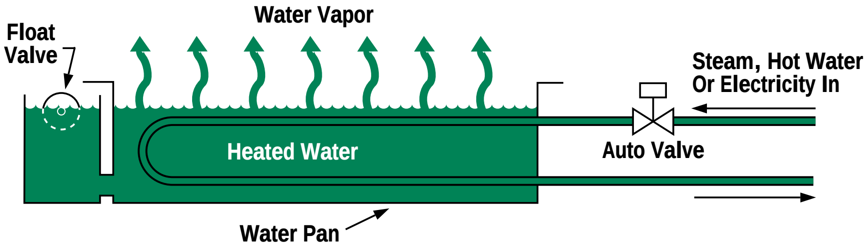


Table 16-1. Comparison of Humidification Methods

	Direct Steam	Steam-to-Steam	Electronic Steam	Ionic Bed Electronic Steam	Evaporative Pan	Water Spray
Effect on temperature	Virtually no change				Small temperature rise	Substantial temperature drop
Unit capacity per unit size	Small to very large	Small	Small to medium	Small to medium	Small	Small
Vapor quality	Excellent	Good	Good	Good	Good	Poor
Response to control	Immediate	Slow	Fair	Fair	Slow	Slow
Control of output	Good to excellent	Below average	Average	Average	Average	Average
Sanitation/corrosion	Sterile medium; corrosion free	Bacteria can be present	Programmed to not promote bacteria	Programmed to not promote bacteria	Pan subject to corrosion; bacteria can be present	Subject to severe corrosion and bacteria problems
Maintenance frequency	Annual	Monthly	Monthly to quarterly	Quarterly to semi-annually	Weekly to monthly	Weekly to bimonthly
Maintenance difficulty	Low	High	Medium	Low	High	High
Costs: Price (per unit of capacity)	Low	High	Medium	Medium	High	Medium to high
Installation	Varies with availability of steam, water, electricity, etc.					
Operating	Low	Low	Medium	Medium	Low	Low
Maintenance	Low	High	High	Low to medium	High	Very high

Recommended Applications

Steam: Recommended for virtually all commercial, institutional and industrial applications. Where steam is not available, small capacity needs up to 50-75 lbs/hr can be met best using ionic bed type self-contained steam generating units. Above this capacity range, central system steam humidifiers are most effective and economical. Steam should be specified with caution where humidification is used in small, confined areas to add large amounts of moisture to hygroscopic materials. We recommend that you consult your Armstrong Representative regarding applications where these conditions exist.

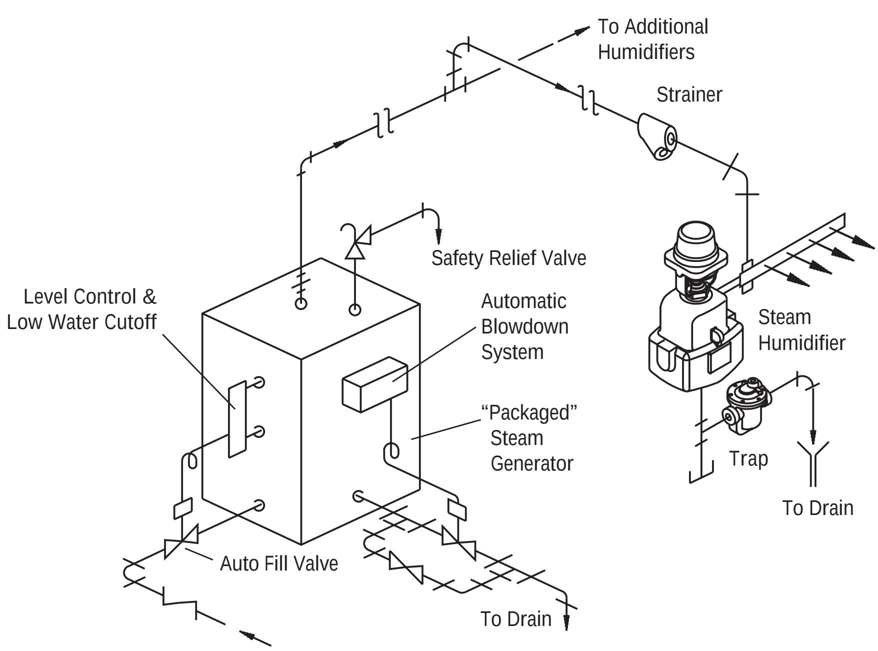
Evaporative Pan: Recommended only as an alternative to self-contained steam generating unit humidifiers for small load commercial or institutional applications. Generally not recommended where load requirements exceed 50-75 lbs/hr.

Water Spray: Recommended for industrial applications where evaporative cooling is required; typical application is summertime humidification of textile mills in the southern U.S.

The evidence supports the conclusion that steam is the best natural medium for humidification. It provides ready-made vapor produced in the most efficient evaporator possible, the boiler. There is no mineral dust deposited, and because there is no liquid moisture present, steam creates no sanitation problems, will not support the growth of algae or bacteria, has no odor and creates no corrosion or residual mineral scale. Unless there are particular requirements to an application that can only be met with evaporative pan or water spray methods, steam humidification will meet system needs most effectively and economically.

With these advantages in mind, engineers specify steam boilers and generators solely for humidification when the building to be humidified does not have a steam supply. The minimum humidification load where this becomes economically feasible falls in the range of 50-75 lbs/hr. Steam generator capacity is generally specified 50% greater than maximum humidification load, depending on the amount of piping and number of humidifiers and distribution manifolds that must be heated. Typical piping for boiler-humidifier installations is shown in Fig. 17-1.

Figure 17-1. Typical Piping for Boiler-Humidifier Installation



Design Guidelines—Boiler-Humidifier Combinations

1. Boiler gross output capacity should be at least 1.5 times the total humidification load.
2. Water softeners should be used on boiler feedwater.
3. Condensate return system is not necessary (unless required by circumstances).
4. Boiler pressure should be at 15 psig or less.
5. An automatic blowdown system is desirable.
6. All steam supply piping should be insulated.
7. No limit to size or number of humidifiers from one boiler.

Considerations in Selecting Steam Humidifiers

Electronic Steam Humidifiers

When steam is not available, self-contained electronic humidifiers can meet low-capacity requirements. The primary consideration in selecting this type of humidifier is its ability to work with wide ranges in water quality. Ionic bed electronic humidifiers are frequently selected for this capability.

Direct Injection Steam Humidifiers

An evaluation of three performance characteristics is essential to understand the advantages steam holds over other humidification media:

- Conditioning
- Control
- Distribution

The humidifier must condition the steam so that it's completely dry and free of significant particulate matter. Response to control signals must be immediate, and modulation of output must be precise. Distribution of steam into the air must be as uniform as possible. Inadequate performance in any of these areas means the humidifier will not meet the basic humidification requirements.

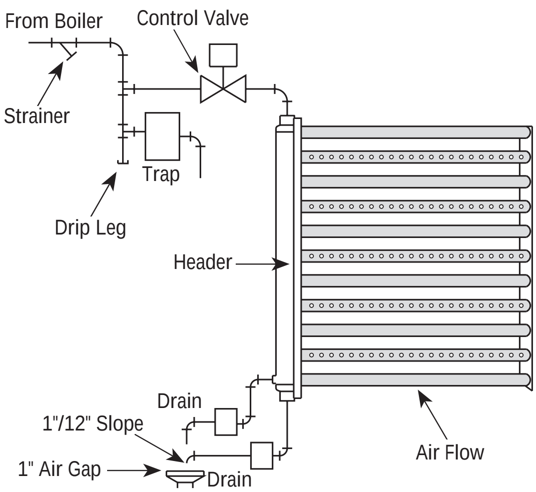
Direct injection steam humidifiers are available in three basic types: specially designed steam grids, steam cups and the steam separator.

Specially designed steam grid systems incorporate advanced engineering in addressing unique applications where vapor trail is of prime concern.

Steam cup humidifiers receive steam from the side of the cup which theoretically permits the condensate to fall by gravity to the steam trap. However, in practice a great deal of the liquid moisture in the steam goes into the air flow, and the steam itself is poorly distributed.

The steam separator is a more sophisticated device which, when properly designed, meets essential performance criteria.

Figure 18-1. Steam Grid Humidifier



NOTE: Condensate cannot be lifted or discharged into pressurized return.

Figure 18-2. Cup Type Steam Humidifier

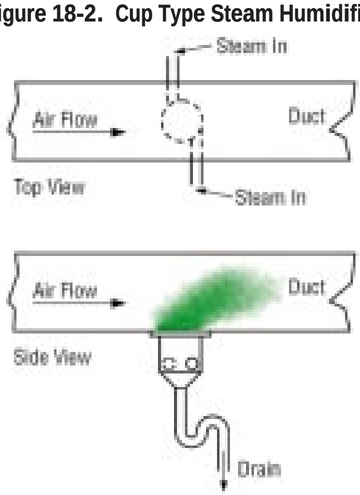
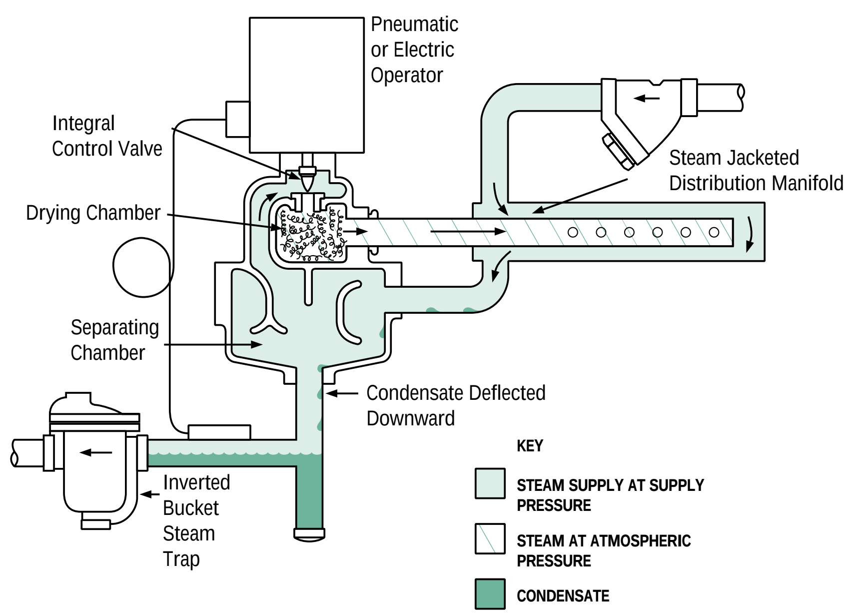


Figure 18-3. Steam Separator Type Humidifier



Steam Conditioning

As steam moves through supply lines, scale and sediment may be entrained in the flow—a Y-type strainer is required to remove larger solid particles. Similarly, the condensation that occurs in the supply lines permits water droplets or even slugs of condensate to be carried into the humidifier.

Several steps within the humidifier are required to positively prevent the discharge of liquid moisture and finer particulate matter along with the humidifying steam.

The separating chamber in the humidifier body should provide the volume required for optimum velocity reduction and maximum separation of steam from condensate. Properly separated, the condensate carries a substantial portion of the significant micronic particulates with it to be discharged through the drain trap.

Steam from the separating chamber can still carry liquid mist which must be removed. Humidifiers equipped with an inner drying chamber that is jacketed by the steam in the separating chamber can effectively re-evaporate any remaining water droplets before steam is discharged. Similarly, the control valve should be integral with the humidifier. Both the humidifier and the distribution pipe should be jacketed by steam at supply pressure and temperature to prevent condensation as steam is discharged.

Only proper design of the humidifier for conditioning of steam can assure the essential levels of sanitation and a clean atmosphere. These guidelines contribute to better comfort conditions and ensure that the humidifier meets the vital physical requirements of the system.

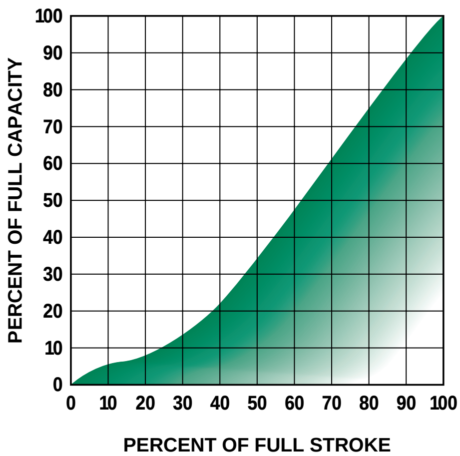
Table 19-1.
Steam Humidifier Valve Rangeabilities

Valve Size	Rangeability	
Equivalent Diameter	Ratio of Flow Max: Mii	Minimum Flow as % of Maximuu
1 1/2"	63:1	1.6
1 1/4"	69:1	1.4
1 1/8"	61:1	1.6
1"	53:1	1.9
7/8"	44:1	2.3
3/4"	33:1	3.0
5/8"	123:1	0.8
9/16"	105:1	0.9
1/2"	97:1	1.0
15/32"	85:1	1.2
7/16"	75:1	1.3
13/32"	64:1	1.6
3/8"	70:1	1.4
11/32"	59:1	1.7
5/16"	49:1	2.0
9/32"	40:1	2.5
1/4"	31:1	3.2
7/32"	24:1	4.2
3/16"	18:1	5.6
5/32"	59:1	1.7
1/8"	37:1	2.7
7/64"	28:1	3.5
3/32"	21:1	4.8
5/64"	15:1	6.9
1/16"	10:1	10.0

Control of Output

As discussed, the duct high-limit humidistat can become the controlling humidistat due to psychrometric conditions in the duct. In typical duct air flow rates, the high limit humidistat senses humidifier output in one second or less. In most applications, humidifiers consistently operate at a fraction of maximum output.

Chart 19-1. Desirable modified linear characteristic curve for valves used under modulating control. The modification of true linear characteristics provides more precise control when capacity requirements are very low and the valve is just cracked off the seat.



Humidifier control must provide immediate response and precise modulation in order to accurately maintain the required relative humidity. Faulty control can make it difficult to provide the desired humidity level, and can lead to overloading the ducts with moisture and the creation of wet spots.

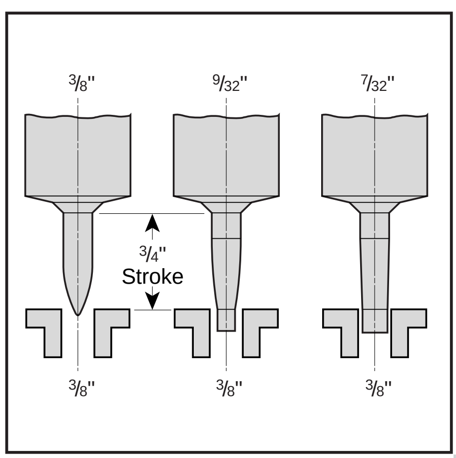
Two design factors affect the accuracy of humidifier control that can be achieved—the metering valve and the actuator that positions the valve.

Precise flow control can be achieved with a valve designed expressly for the purpose of adding steam to air. Parabolic plug type valves have been established as best for this service. They permit a longer stroke than comparable industrial valves, and the plug normally extends into the orifice even with the valve in "full open" position. This facilitates full and accurate modulation of flow over the complete stroke of the valve.

The Control Valve

The parabolic plug design also provides exceptionally high rangeability. Rangeability is the ratio between the maximum controllable flow and the minimum controllable flow of steam through the valve. The higher the rangeability of a valve, the more accurately it can control steam flow. Rangeabilities of the parabolic plug valves used in Armstrong Series 9000 Humidifiers shown in Table 19-1 are typical of the ratios that can be achieved with this type of valve.

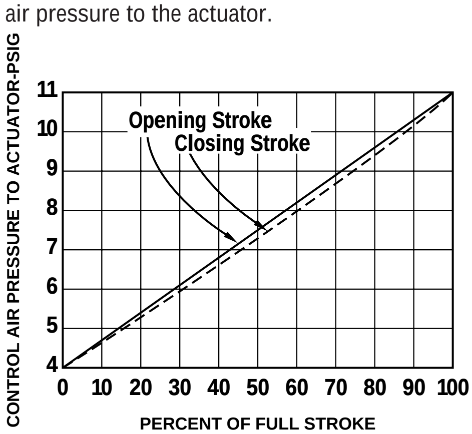
Figure 19-1. Parabolic Plug Metering Valve



The actuator is another important component in humidity control. Several types are available to provide compatibility with various system types. The actuator must be able to position the valve in very nearly identical relationship to the seat on both opening and closing strokes. This is essential to provide consistent, accurate metering of steam discharged by the humidifier.

By their design, electric motor modulating actuators provide true linear positioning characteristics on both opening and closing cycles. Pneumatic actuators may or may not be able to provide the precise positioning and holding characteristics essential to accurate control. Rolling diaphragm type pneumatic actuators are recommended, providing they meet the following criteria:

Chart 20-1. Desirable Operating Characteristic for Pneumatic Actuators
Position of valve is very nearly identical on both opening and closing strokes at any given air pressure to the actuator.



1. Large diaphragm area—22 sq in or more—to provide ample lifting force. This permits the use of a spring heavy enough to stabilize both the hysteresis effect and the flow velocity effect on the positioning of the valve stem versus air pressure to the actuator.
2. Diaphragm material highly resistant to wear or weakening from continuous cycling.
3. Actuator stroke long enough (in conjunction with valve plug and seat design) to provide high rangeability ratios.

All modulating actuators, whether electric or pneumatic, should incorporate a spring return. This is necessary to ensure closing the valve if there is an interruption of power or control air to the unit.

For industrial in-plant operation and for very limited duct applications, a solenoid actuator may be used to provide simple on-off operation. This type of actuator should not be specified for duct applications without a detailed analysis of the system.

Distribution of Steam

The third essential factor in proper humidifier design is distribution. Steam must be discharged as uniformly as possible into the air to permit the fastest possible absorption without creating damp spots or saturated zones.

In normal ducts, a single distribution manifold installed across the long dimension will provide good distribution of steam. In large ducts or plenum chambers, it may be necessary to broaden the pattern of vapor discharge to achieve the required distribution, thus requiring multiple manifolds from single or multiple humidifiers.

Humidification for industrial areas without central air handling systems is customarily achieved with unit humidifiers discharging steam directly into the atmosphere. Proper mixing of steam and air can be accomplished in two ways. A dispersing fan may be mounted on the humidifier or a unit heater can be positioned to absorb and distribute the water vapor.

Figure 20-1.

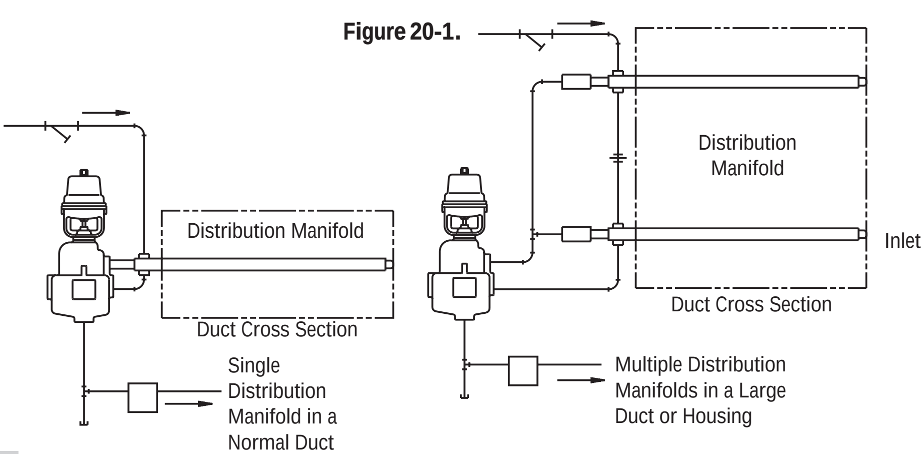
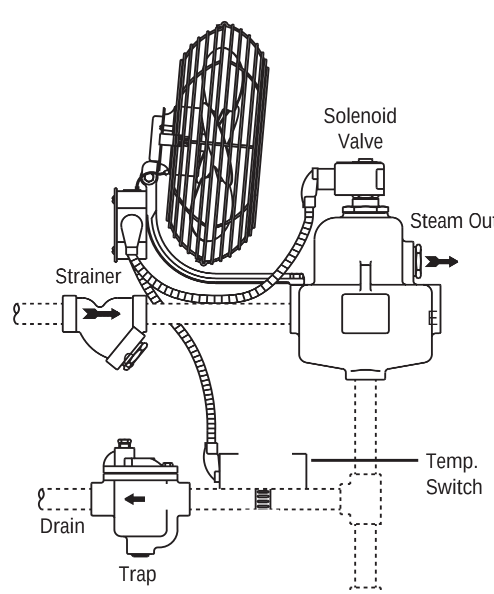


Figure 20-2.
Unit Humidifier for Direct Discharge into Area Humidified



Operating Noise

In addition to these crucial performance characteristics, operating noise is a consideration in selecting steam humidifiers for areas where quiet operation is essential or desirable, i.e., hospitals, office buildings, schools, etc.

Suggested Specification:

Steam humidifiers for pneumatic or electric modulating control: humidifier shall be the steam separator type providing full separation ahead of an integral steam jacketed control valve. Steam shall be discharged through an internal steam jacketed drying chamber, a silencing chamber and a steam jacketed distribution manifold.

A. Humidifier shall receive steam at supply pressure and discharge at atmospheric pressure. It shall be furnished with inlet strainer and external inverted bucket steam trap.

B. Separating chamber shall be of a volume and design that will disengage and remove all water droplets and all particulate matter larger than 3 microns when humidifier is operating at maximum capacity.

C. The stainless steel metering valve shall be integral within the body of the humidifier, and shall be jacketed by steam at supply pressure and temperature to prevent condensation.

D. The stainless steel metering valve shall be a parabolic plug, with a full 3⁄4" stroke. This valve shall provide the high rangeabilities required to achieve full and accurate modulation of steam flow over the entire stroke of the valve.

E. The internal drying chamber shall receive total steam flow at essentially atmospheric pressure and be jacketed by steam at supply pressure.

F. The silencing chamber shall be steam jacketed and utilize a stainless steel silencing medium.

G. The distribution manifold shall provide uniform distribution over its entire length and be jacketed by steam at supply pressure to assure that vapor discharged is free of water droplets. A full length stainless steel internal silencing screen shall be provided.

H. Humidifier shall be equipped with an interlocked temperature switch to prevent the humidifier from operating before start-up condensate is drained.

Figure 21-1.
The noise of escaping steam is generated at the control valve. Muffling materials around the valve are necessary to minimize this noise.

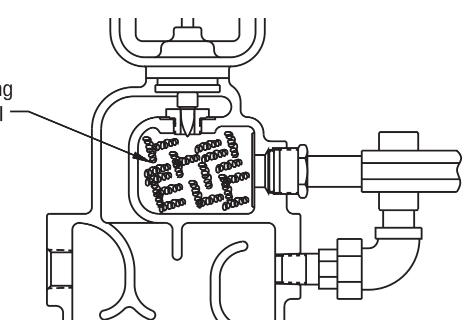
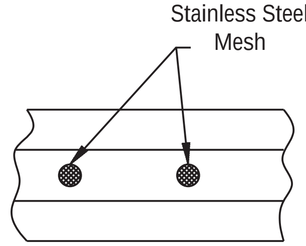


Figure 21-2.
Steam moving at high velocity through the distribution manifold can create loud, high-pitched whistling as it passes the discharge holes. An internal silencing screen or similar material is required to interrupt the air flow and prevent whistling.



Basic Application Principles

Several basic principles must be considered in the application of steam humidification equipment to avoid potential operating problems.

Vapor dissipation in air ducts is one of these considerations. In the steam humidification process, pure water vapor at 212°F is mixed with air at a lower temperature. The mixing of hot steam with cooler air results in heat transfer. Any time heat is transferred from steam, condensation takes place. This condensation is referred to as visible vapor. When steam is discharged from a manifold in an air duct, it quickly changes from an invisible gas into visible water particles, and then dissipates to become invisible again.

Visible vapor indicates an area of supersaturation, where the invisible steam gas is condensing into water particles. When condensation occurs, the steam gas releases its latent heat of vaporization (about 1,000 Btu/lb of vapor) to duct air. Then, as the vapor completely mixes with the duct air, the latent heat previously given off is reabsorbed, converting the visible vapor back into invisible gas with essentially no change in DB temperature. (See Fig. 22-1).

Clearly, the vapor dissipation in air ducts is very important to proper location of temperature or humidity controllers. Any controller located in or near the visible vapor pattern will produce inaccurate results because of pockets of saturated air. Under typical duct conditions, all controllers should be located at least 10 to 12 feet downstream of a manifold. However, the following system characteristics will affect the visible vapor pattern, and therefore should be considered in controller location:

1. **Aspect Ratio of Duct.** The ratio of duct height to width is a factor that influences the visible vapor pattern. Fig. 22-2 shows two ducts with equal cross section areas, but with different aspect ratios. Air velocities, temperatures, RH and vapor output from the manifolds are all identical. However, in the taller duct the manifold is shorter and its vapor output comes in contact with a much smaller percentage of duct air, causing a longer visible vapor pattern.

Figure 22-1.

Typical dry-bulb (sensible) temperature variations within a duct near the humidifier manifold. As the latent heat of vaporization is released, the temperature increases (in or near the visible vapor the temperature may rise as much as 20° to 30°F). However, as the visible vapor mixes and re-evaporates in the air flow, the heat of vaporization is reabsorbed and the duct air temperature returns to its former level.

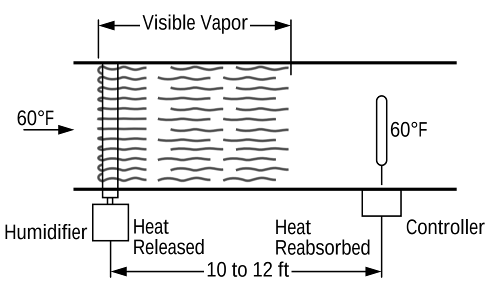
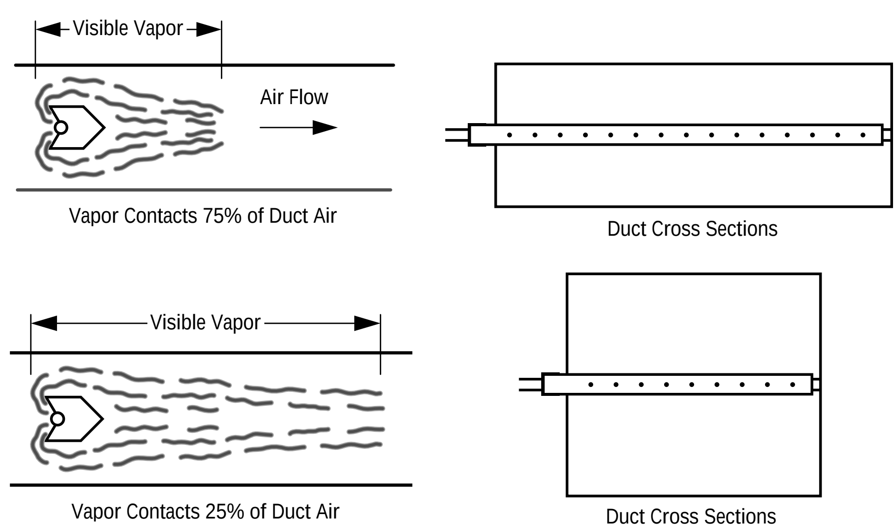


Figure 22-2.



2. **Duct Air Temperature.** The temperature of the air flow in the duct also affects the length of the visible vapor pattern. Warmer air produces shorter vapor pattern, as shown in Fig. 23-1. All other conditions are the same. In 75°F duct air, the average vapor output from a manifold produces a visible vapor pattern shorter than 12 inches in length.

3. **Duct Air Velocity.** As the duct air velocity increases, the length of the visible vapor pattern increases. Fig. 23-2 shows two sections of air ducts with air velocities of 500 fpm and 2,000 fpm respectively. Other conditions are the same: temperature, duct air humidity, duct dimensions and the amount of steam released from the identical manifolds. The length of the visible vapor pattern is approximately proportional to the velocity of the air in the duct.

4. **Number of Manifolds in Duct.** In a large duct section requiring the discharge capacity of two humidifiers, better vapor distribution is achieved by using two manifolds full across the duct and vertically spaced to divide the duct section into thirds. The same effect is achieved by using multiple distribution manifolds from a single humidifier that has adequate capacity to meet the requirements. When a quantity of vapor is distributed among multiple manifolds, the amount released through each manifold is smaller, and more of the duct air comes into contact with the vapor. This effect is shown in Fig. 23-3.

5. **Duct Air RH.** Relative humidity in the duct also affects the visible vapor. The higher the relative humidity downstream of the humidifier discharge, the longer the visible vapor trail. The closer duct conditions are to saturation, the longer the vapor trails are likely to be. Fortunately, duct air RH may be controlled with a duct high-limit humidistat, as shown in Fig. 25-2.

Figure 23-1.

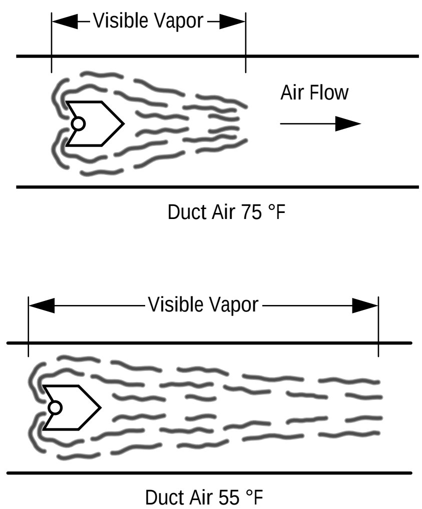


Figure. 23-2.

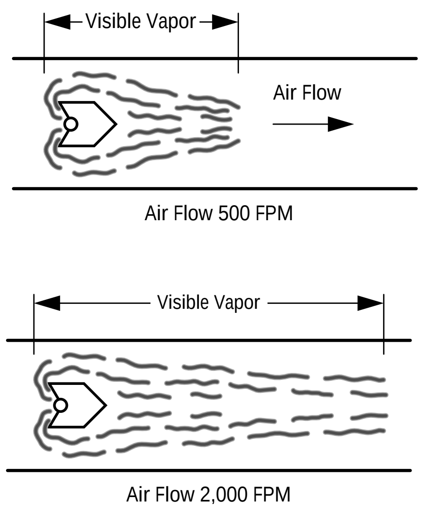
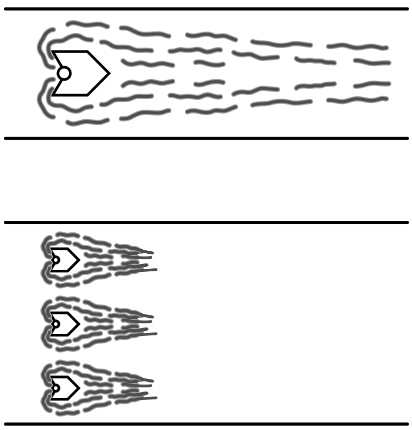


Figure 23-3.



Since the use of multiple manifolds reduces the length of visible vapor, their use should be considered whenever any of the following conditions exist at the humidifier location:

A. Duct air temperature is below 65°F or relative humidity is above 80%.

B. Duct air velocity exceeds 800 fpm.

C. "Final" or "high efficiency" filters are located within 10 feet downstream from humidifier.

D. Height of duct section exceeds 36".

E. Visible vapor impinges upon coils, fans, dampers, filters (not final), turning vanes, etc. located downstream from humidifier.

Table 24-1 and Fig. 24-1 show a typical number of manifolds and typical spacing between them when duct height exceeds 36".

Table 24-1. Typical Number of Manifolds for Various Duct Heights

Duct height at humidifier location	No. of manifolds to be installed from one or more humidifiers
37" to 58"	2
59" to 80"	3
81" to 100"	4
101" & Over	5

Consult your Armstrong Representative for specific recommendations.

Consult your Armstrong Representative for specific recommendations regarding your needs.

The piping arrangement for humidifiers with multiple manifolds varies with the location of the manifolds.

When all manifolds are located above the humidifier inlet, manifold piping should be as shown in Fig. 24-2.

When one or more manifolds are located below the humidifier inlet, the manifolds should be trapped separately, as shown in Fig. 24-3.

Smaller manifolds, when possible to use, reduce the cost of multiple manifold installations. Care must be taken that the humidifier capacity does not exceed the combined capacity of the multiple manifolds. Piping arrangement is shown in Fig. 25-3.

6. **Humidifier Manifold too Close to High Efficiency Filter.** Many air handling systems require the use of high efficiency filters (also called "absolute" or "final" filters). These filters remove up to 99.97% of all particles 0.3 micron in diameter, and up to 100% of larger particles. The significance of these filtering qualities is shown in the following table, where particle sizes of common substances are compared.

Table 24-2. Typical Particle Sizes of Common Substances

Material	Particle Size in Microns
Particles visible to human eye	10 or more
Human hair	100
Dust	1 to 100
Pollen	20 to 50
Fog (visible steam vapor)	2 to 40
Mist (water spray)	40 to 500
Industrial fumes	0.1 to 1
Bacteria	0.3 to 10
Gas molecules (steam gas)	0.0006

Figure 24-1.

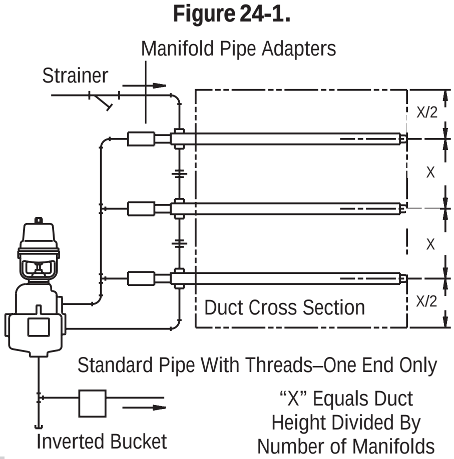


Figure 24-2.

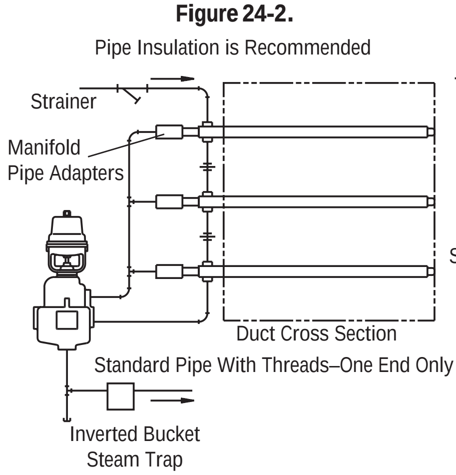
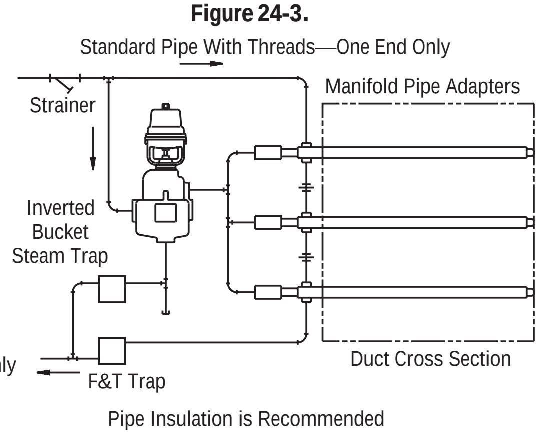
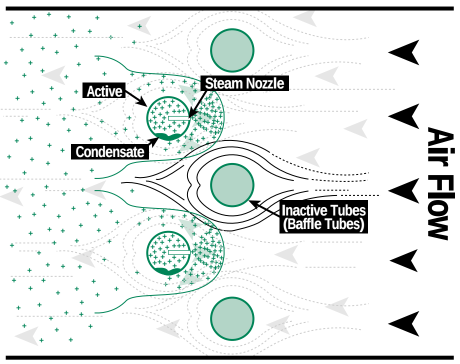


Figure 24-3.



Since water particles present in visible vapor range from 2 to 40 microns, these particles are trapped by high efficiency filters. Some types of filters absorb moisture and expand, reducing air flow through the filter material. As a result, the static pressure in the duct rises from normal (about 1" water gauge) to as high as 40" wg. When the filter absorbs moisture, it also releases the latent heat of condensed steam into the duct air.

Figure 25-1.



When a humidifier manifold is located too close to an absolute filter, the filter collects water vapor, preventing the moisture from reaching the space to be humidified. Placing the humidifier manifold farther upstream allows the water vapor to change into steam gas, which will pass unhindered through an absolute filter.

Under most circumstances, the water vapor will dissipate properly if the humidifier manifold is located at least 10 feet ahead of the final filter. However, if the duct air temperature is low, air velocity is high or the duct is tall, multiple manifolds may be installed to speed the mixing of steam with the duct air. For additional protection, install a duct high-limit controller just ahead of the final filter to limit the maximum humidity to approximately 90%. (See Fig. 25-2.)

Specially Designed Steam Grid Systems
For applications with particularly limited downstream absorption distances, custom engineered systems may be considered. The system includes a separator/header and multiple dispersion tube assembly packaged with a control valve, strainer, steam supply drip trap and one or two header drain traps. Each system is customized to provide uniform distribution and shortened wettable vapor trail (See Fig. 25-4.)

How Steam Grid Systems Shorten Impingement Distances

Dry steam enters each of the dispersion tubes and flows through stainless steel steam nozzles which extend from the center of each tube, before discharging through orifices into the airstream.

Air flow first encounters baffle tubes (See Fig. 25-1) which influence its flow pattern and increase its velocity. Air traveling around each set of baffle tubes encounters opposing flow of high velocity steam exiting the orifices. The result is more uniform distribution and faster absorption of moisture into the air, resulting in shorter impingement distances than experienced with traditional manifolds or dispersion tubes.

Figure 25-2.

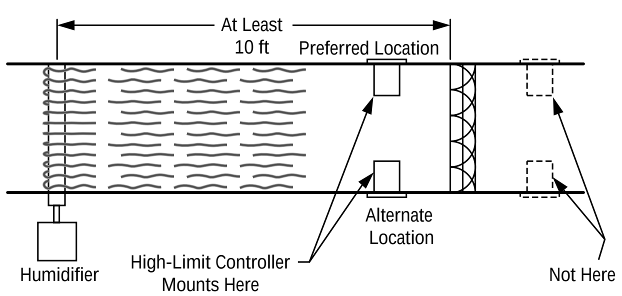


Figure 25-3.

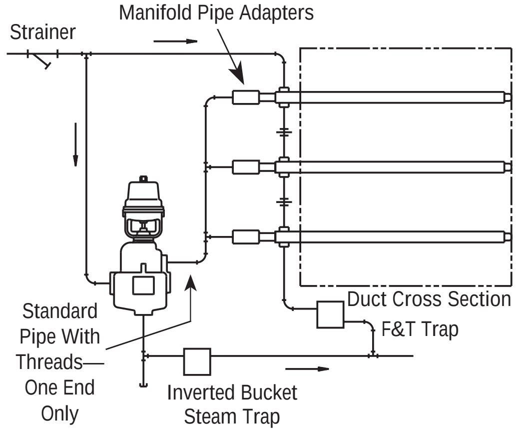
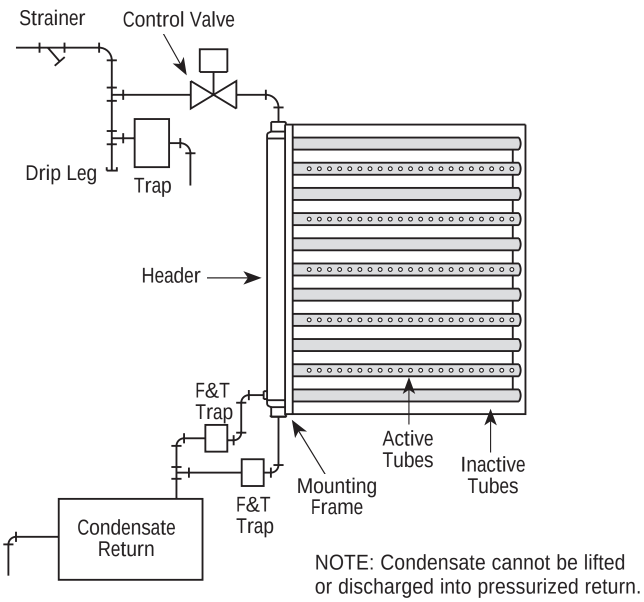


Figure 25-4. Steam Grid System



NOTE: Condensate cannot be lifted or discharged into pressurized return.

Sizing Considerations

Psychrometric Considerations in Ducted Systems

In practice you may find that areas need humidification but cannot be satisfactorily humidified through the central air handling system. These are often areas having high sensible heat loads that must be balanced with low duct air temperatures to maintain design temperature conditions in the area. Typical examples are data processing rooms or hospital operating rooms where duct air temperatures may be held as low as 50°F to maintain a design condition of 75°F in the room. These low duct air temperatures prevent adding enough moisture to the air to meet design RH requirements in the room—say, 55% RH.

Using these conditions as an example, duct air at 50°F and 90% RH holds slightly less than 3.7 grains of moisture per cubic foot. At 75°F the same 3.7 grains of moisture yield a relative humidity of 39%. To achieve design conditions of 55% RH at 75°F, the air must contain 5.2 grains of moisture per cubic foot—1.5 grains more than it psychrometrically can hold at duct air temperature.

For such applications, booster humidification must be accomplished in the air of the area after it has reached its final temperature. Evaporative pan humidifiers may be used for this purpose, although we would recommend using combined steam humidifier-fan units which can be installed either within the humidified space or remote ducted to the space. For hospital applications, steam humidifier-fan units should include an integral high efficiency (95%) filter to satisfy code requirements.

Determining Humidification Loads for Air Handling Systems

Most engineers prefer to determine humidification requirements psychrometrically on the basis of design conditions and humidification requirements. However, short-cut methods for making these calculations or for checking psychrometric calculations are described below.

Sizing for Primary Humidification

In sizing duct humidifiers for air handling systems, you should know:
CFM of air.
Design outdoor air temperature and relative humidity.
Required indoor temperature and relative humidity.
Humidifier steam supply pressure.

The formula for load calculation is:

$$\text{Humidification Load in lbs/hr} = \frac{\text{CFM (R2 - R1) 60}}{7{,}000}$$

Where:

CFM	=	air flow of unhumidified air at moisture condition R1
R2	=	moisture content of required indoor condition air in gr/ft^3
R1	=	moisture content of air to be humidified (from outdoor condition) in gr/ft^3
7,000	=	gr/lb conversion
60	=	min/hr conversion

EXAMPLE, assume:
6,800 CFM of outdoor air.
Design outdoor air temperature 0°F.
Steam pressure 10 psig.
Required 40% RH at 70°F.
Air controls used.

From Table 27-1, for 70°F final temperature, read 2.456 under 40% and opposite 0°F. This is pounds of vapor per hour for 100 CFM. Then 68 x 2.456 = 167.01 or, call it 167 lbs per hour required for design conditions.

A single humidifier can provide this capacity although sequence control for two humidifiers might be needed to avoid duct condensation on very light loads. Length of distribution manifold is governed by width of duct where the humidifier is to be located.

Sizing for Booster Humidifier

Assume that a primary humidifier provides air that will have 40% RH at 70°F, but you want to maintain 60% RH in a laboratory supplied with 900 CFM of the air at 40% at 70°F. Refer to Table 27-3 and read 1.38 under 60% and opposite 70°F—40%. 9 x 1.38 = 12.42 lbs. The humidifier must be able to provide this capacity at steam supply pressure.

Special Conditions

When relative humidities must be figured for temperature conditions other than those given in Tables 27-1 through 27-3, Table 27-5 will prove helpful.

New Condition—55% RH at 77°F.
Makeup Air—35% RH at 70°F.
From Table E-23:
Grains per cu ft
New Condition ________________ 5.54
Less Grains per cu ft,
Makeup Air ________________ 2.82
Grains to be added ________________ 2.72
Assume 800 CFM

$$\frac{800 \times 2.72 \times 60}{7{,}000} = 18.65 \text{ lbs/hr}$$

NOTE: .857 lb of steam per hour will add 1 grain to 100 CFM. Use of this factor simplifies the above equation to: 8 x 2.72 x .857 = 18.65.

Where Table 27-5 is used for outdoor air makeup, assume 75% RH for the outdoor air at 0° to -20°F.

Room to Duct Comparisons

When high humidity is needed in a room (70°F-60% RH) and the duct temperature is lower than the room temperature (50°F), the duct high-limit humidistat often acts as the controlling stat. Duct high-limit humidistats should be set between 70% and 90% RH. We do not recommend setting the high-limit stat any higher than 90% RH. Table 27-4 shows the maximum room humidity that can be achieved for the given duct conditions.

Computer Software Can Simplify Humidifier Selection

Armstrong offers a free software program which can eliminate the need for time-consuming pencil-and-paper calculations. The Armstrong Software Program 2 runs on IBM PC or compatible MS-DOS computers. Once the user-friendly software is loaded into your computer, the program displays on your monitor a series of easy-to-understand questions about your humidification application.

You respond to the questions—often with a single keystroke—and the Software Program 2 can:

- Calculate humidification load.
- Determine correct humidifier model number.
- Determine correct orifice size.
- Indicate psychrometric properties of air.
- Calculate equivalent room humidity from known duct conditions.
- Print the complete humidification application specification.

For a free copy of Armstrong Software Program 2, contact Armstrong or your Armstrong Representative.

Table 27-1. 70°F Primary Humidification Pounds of vapor required per hour per 100 CFM to secure desired RH at 70°F (outside air 75% saturated)

Outdoor emp.	Relative Humidity Desired 35%	40%	45%	50%	55%	60%	65%	70%
*30	1.165	1.510	1.855	2.200	2.545	2.891	3.236	3.581
20	1.618	1.963	2.308	2.653	2.998	3.344	3.689	4.034
10	1.918	2.263	2.608	2.953	3.298	3.644	3.989	4.334
0	2.111	2.456	2.801	3.146	3.591	3.837	4.182	4.527
-10	2.233	2.578	2.923	3.268	3.613	3.959	4.304	4.649
-20	2.309	2.654	2.999	3.344	3.689	4.035	4.380	4.725

Table 27-2. 75°F Primary Humidification Pounds of vapor required per hour per 100 CFM to secure desired RH at 75°F (outside air 75% saturated)

Outdoor emp.	Relative Humidity Desired 35%	40%	45%	50%	55%	60%	65%	70%
*30	1.584	1.989	2.394	2.799	3.204	3.609	4.014	4.419
20	2.034	2.439	2.844	3.249	3.654	4.059	4.464	4.869
10	2.334	2.739	3.144	3.549	3.954	4.359	4.764	5.169
0	2.529	2.934	3.339	3.744	4.149	4.554	4.959	5.364
-10	2.652	3.057	3.462	3.867	4.272	4.677	5.082	5.487
-20	2.727	3.132	3.537	3.942	4.347	4.752	5.157	5.562

* When outdoor design temperatures exceed 30°F, use Table 27-5 entering the table with both outdoor design temperature and outdoor design RH.

Table 27-3. Booster Humidification Pounds of vapor per hour per 100 CFM to secure desired relative humidity with no change in air temperature

Initial Condition Temp.	RH	Relative Humidity Desired 40%	45%	50%	55%	60%	65%	70%
70	35%	.345	.690	1.03	1.38	1.72	2.07	2.42
70	40%	—	.345	.69	1.03	1.38	1.72	2.07
72	35%	.368	.728	1.10	1.46	1.83	2.20	2.57
72	40%	—	.368	.73	1.10	1.46	1.83	2.20
75	35%	.405	.810	1.22	1.62	2.03	2.43	2.84
75	40%	—	.405	.81	1.22	1.62	2.03	2.43

Table 27-4. Maximum Room RH for Given Duct Conditions

Duct Temperature °F	Duct Relative Humidity (RH)	Room RH @ Temperature °F 68°	70°	72°	75°
50	90%	47%	44%	41%	37%
	85%	44%	41%	39%	35%
	80%	42%	39%	36%	33%
55	90%	57%	53%	49%	44%
	85%	53%	50%	46%	42%
	80%	50%	47%	44%	39%
60	90%	68%	63%	59%	53%
	85%	64%	60%	56%	50%
	80%	60%	56%	52%	47%

Table 27-5. Grains of Water Vapor per cu ft of Air at Various Temperatures and Relative Humidities

Air Temp.	Grains cu ft Saturated	Grains per cu ft at Relative Humidity Specified 35%	40%	45%	50%	55%	60%	65%	75%
80	11.04	3.86	4.42	4.97	5.52	6.07	6.62	7.18	8.28
79	10.71	3.75	4.28	4.82	5.36	5.89	6.43	6.96	8.03
78	**10.38**	**3.63**	**4.15**	**4.67**	**5.19**	**5.71**	**6.23**	**6.75**	**7.79**
77	10.06	3.52	4.03	4.53	5.03	5.54	6.04	6.55	7.55
76	9.749	3.41	3.90	4.39	4.87	5.36	5.85	6.34	7.31
75	**9.448**	**3.31**	**3.78**	**4.25**	**4.72**	**5.20**	**5.67**	**6.14**	**7.09**
74	9.153	3.20	3.66	4.12	4.58	5.03	5.49	5.95	6.86
73	8.867	3.10	3.55	3.99	4.43	4.88	5.32	5.76	6.65
72	**8.568**	**3.01**	**3.44**	**3.86**	**4.29**	**4.72**	**5.15**	**5.58**	**6.44**
71	8.319	2.91	3.33	3.74	4.16	4.58	4.99	5.41	6.24
70	8.055	2.82	3.22	3.62	4.03	4.43	4.83	5.24	6.04
65	**6.845**	**2.40**	**2.74**	**3.08**	**3.42**	**3.76**	**4.11**	**4.45**	**5.13**
60	5.795	2.03	2.32	2.61	2.90	3.19	3.48	3.77	4.35
55	4.889	1.71	1.96	2.20	2.44	2.69	2.93	3.18	3.67
50	**4.106**	**1.44**	**1.64**	**1.85**	**2.05**	**2.26**	**2.46**	**2.67**	**3.08**
40	2.863	1.00	1.15	1.29	1.43	1.57	1.72	1.86	2.15
30	1.946	.58	.68	.78	.97	1.07	1.17	1.26	1.46
20	**1.242**	**.43**	**.50**	**.56**	**.62**	**.68**	**.75**	**.81**	**.93**
10	.776	.27	.31	.35	.39	.43	.47	.50	.58
0	.475	.17	.19	.21	.24	.26	.29	.31	.36
-10	**.285**	**.10**	**.1**	**.13**	**.14**	**.16**	**.17**	**.19**	**.21**
-20	.166	.06	.07	.07	.08	.09	.10	.11	.12

Steam required to add 1 gr per cu ft to 100 CFM:
100 x 60 = 6,000 cu ft per hour or 6,000 grains per hour.

$$\frac{6{,}000}{7{,}000} = .857 \text{ lb/hr}$$

Economizer Cycles

Fan coil air systems which mix return air and outside air in varying amounts to obtain a given final mixed air temperature require special consideration in determining maximum humidification loads.

Systems of this type usually use a fixed minimum amount of outside air (approximately 10%-30%) when outside air temperature is at a maximum design (-10°F). As the outside air temperature increases, more outside air is mixed with return air to achieve a final mixed air temperature (55°F). Since humidification load is a function of the amount of outside air introduced (plus its moisture content) the maximum humidification requirement will occur at some outside air temperature other than maximum design.

Conditions

Tables 28-1 and 28-3 below give the percent of outside air required to maintain desired mixed air temperature when out-side air temperature is as shown. Table 28-1 is used when return air (room air) temperature is at 70°F. Table 28-3 is for 75°F return air systems.

Tables 28-2 and 28-4 can be used to determine maximum humidification load at the given conditions of mixed air temperature and required RH, assuming 50% RH OSA and 10% minimum OSA.

NOTE: Consideration must be given to over-saturating conditions in lower temperature systems.

EXAMPLE

Given conditions that 70°F return air temperature is mixed with outside air to produce 55°F constant mixed air temperature in duct. The design of the space being conditioned is 70°F at 40% RH. Total volume of air through the fan system is 4,000 CFM. Determine maximum humidification load.

From Table 28-2 with 55°F mixed air temperature and 40% RH space design, the maximum humidification load is 8.4 pounds per 1,000 CFM of total air volume. This maximum load occurs when the outside air temperature is at 46°F. Multiplying 8.4 x 4 results in total pounds per hour required in the 4,000 CFM system. Therefore maximum humidification load becomes 33.6 pounds of vapor per hour.

Table 28-1. With 70°F Return Air

Desired Mixed Air Temp. °F	% Outside Air Required at Temperature Shown														
	-10°	0°	5°	10°	15°	20°	25°	30°	35°	40°	45°	50°	55°	60°	65°
50	25	29	31	33	36	40	45	50	57	67	80	100	—	—	—
55	19	21	23	25	27	30	33	36	43	50	60	75	100	—	—
60	12	14	15	17	18	20	22	25	29	33	40	50	67	100	—
65	6	7	7	8	9	10	11	13	14	16	20	25	33	50	100

Table 28-2. With 70°F Return Air

Max. Humidification Load (given in lbs of vapor/hr/1,000 CFM of total air) Occurs at Outside Air Temp. Shown for Given Inside RH												
Inside RH	30%		35%		40%		45%		50%		55%	
Mixed Air Temp. °F	Outside Air °F	Max. Load	Outside Air °F	Max. Load	Outside Air °F	Max. Load	Outside Air °F	Max. Load	Outside Air °F	Max. Load	Outside Air °F	Max. Load
50	30	6.7	39	8.6	46	11.2	50	14.5	50	18.0*	50	21.5*
55	30	5.0	39	6.5	46	8.4	54	11.1	55	14.6	55	18.1*
60	30	3.3	39	4.3	46	5.6	54	7.4	60	10.5	60	14.0
65	0	1.9	0	2.2	46	2.8	54	3.7	65	5.7	65	9.2

Table 28-3. With 75°F Return Air

Desired Mixed Air Temp. °F	% Outside Air Required at Temperature Shown														
	-10°	0°	5°	10°	15°	20°	25°	30°	35°	40°	45°	50°	55°	60°	65°
50	30	33	36	38	42	45	50	56	62	71	83	100	—	—	—
55	23	26	28	31	33	36	40	44	50	57	67	80	100	—	—
60	18	20	21	23	25	27	30	33	37	43	50	60	75	100	—
65	12	13	14	15	16	18	20	22	25	29	33	40	50	67	100

Table 28-4. With 75°F Return Air

Max. Humidification Load (given in lbs of vapor/hr/1,000 CFM of total air) Occurs at Outside Air Temp. Shown for Given Inside RH												
Inside RH	30%		35%		40%		45%		50%		55%	
Mixed Air Temp. °F	Outside Air °F	Max. Load	Outside Air °F	Max. Load	Outside Air °F	Max. Load	Outside Air °F	Max. Load	Outside Air °F	Max. Load	Outside Air °F	Max. Load
50	35	9.7	43	12.6	50	16.4*	50	20.5*	50	24.7*	50	28.8*
55	35	7.8	43	10.1	50	13.1	55	17.0*	55	21.2*	55	25.4*
60	35	5.8	43	7.6	50	9.8	59	13.0	60	17.1	60	21.3*
65	35	3.9	43	5.1	50	6.5	59	8.6	65	12.3	65	16.5*

* Humidification loads will exceed 90% RH in duct at temperature indicated. Booster humidification is recommended.

Steam Humidifiers in Central Systems

Proper location, installation and control of humidifiers is essential to achieve totally satisfactory, trouble-free performance. The primary objective is to provide the required relative humidity without dripping, spitting or condensation. Liquid moisture, even in the form of damp spots, cannot be tolerated in the system. Aside from the hazards to the structure caused by water in the ducts, there is an even more critical health hazard if breeding grounds are provided for bacteria.

In addition to the need for proper humidifier design and performance, several other factors deserve close attention. The humidifier must be the proper capacity for the system; properly located in relation to other components of the system; properly installed and piped in a manner that will not nullify all the other precautions taken. In sizing humidifiers you should be sure that they deliver the amount of steam per hour called for in the design calculations.

Steam pressure to the humidifiers must be kept relatively constant to assure sufficient capacity. Double-check to be sure you're not trying to put more moisture into the air stream than it can hold at its existing temperature. Use of psychrometics can be a helpful aid in determining moisture potential in your application.

Proper location of humidifiers in the system is most important, although sometimes the design of the system makes this difficult to achieve. The following examples of typical systems demonstrate proper humidifier location.

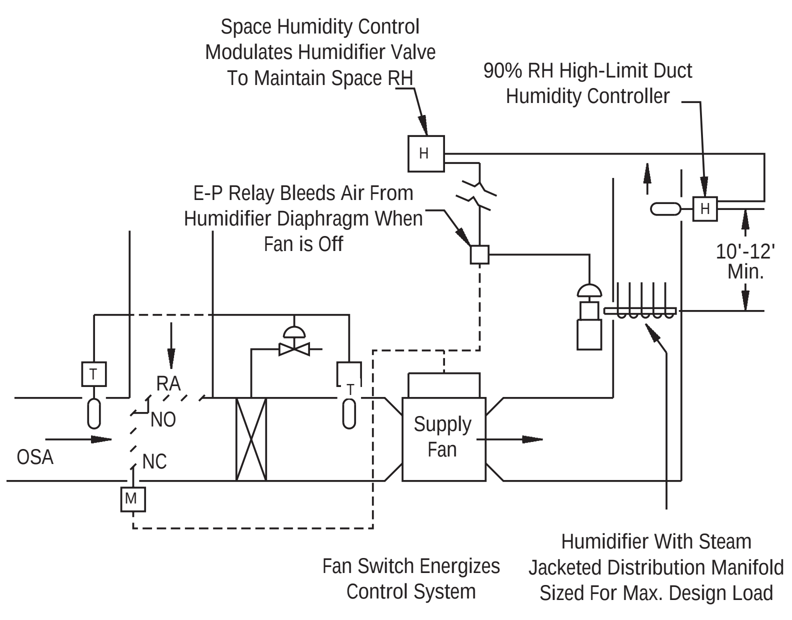
System 1

This is a simple ventilating system. We assume final duct air temperature to be slightly above desired room temperature. The desirable location of the steam jacketed distribution manifold of the primary humidifier is downstream from the supply fan. This humidifier would be sized for maximum design load. If the humidifier were located between the coil and the fan, it might interfere with the temperature sensing bulb. The indicated use of a high-limit duct humidity controller shown is optional. It is advisable if the capacity of the humidifier at design loads could possibly overload air when outside air moisture content is higher than the design. The high-limit controller should be 10 to 12 feet downstream from the humidifier. Place the high-limit controller where it will see the same temperature as the humidifier. A cooler temperature at the humidifier would allow saturation if the high-limit controller were in warmer air.

This is shown as a pneumatic control system. The fan switch activates the control system and the electric pneumatic relay bleeds air from the humidifier actuator diaphragm when the fan is off. The following examples also show pneumatic control—if the systems were electric, control locations would remain the same.

System 1

Figure 29-1.
Ventilation system with primary humidification.



Features of this system and the following systems include:

A. Accurate control is possible because of immediate response of steam humidifier.
B. Control can be modulating electric or pneumatic (shown).
C. No need for drain pans or eliminator plates; makes location of humidifier more flexible.
D. Addition of moisture is accomplished with no appreciable change in duct dry-bulb temperature.
E. The humidifier's integral steam jacketed control valve with parabolic plug is accurately sized to meet capacity requirements.

Glossary of Symbols

EA ______ Exhaust air
E-P relay ______ Electric-Pneumatic relay
H ______ Humidity controller
M ______ Damper motor
MA ______ Mixed air
NC ______ Normally closed
NO ______ Normally open
OSA ______ Outside air
RA ______ Return air
T ______ Temperature controller

System 2

This is a typical 100% outside air system with preheat and reheat coils. The preheat coil heats outside air to a duct temperature controlled at 50° to 60°F. The reheat coil adds more sensible heat depending on the space heat requirement. Here the desirable location for the primary humidifier is downstream from the reheat coil to introduce moisture into the highest level of dry-bulb air temperature.

Note the humidity controller location in the exhaust air duct. When a good pilot location for a humidity controller is not available in the space humidified, one placed in the exhaust air duct as close to the outlet grille as possible serves the purpose very well.

Again, the high-limit controller is optional but generally recommended.

System 3

This system is similar to the previous one. It also shows 100% outside air and preheat and reheat coils. But here two humidifiers are used and are controlled in sequence from a single space or exhaust air duct humidity controller. The two humidifiers are indicated as V-1 and V-2.

V-1 will deliver one-third of the total capacity with a 4 to 7 psig spring range. V-2 is sized for two-thirds of the capacity, with a spring range of 8 to 13 psig. This sequencing control arrangement allows closer moisture input control, particularly when operating conditions vary considerably from design, thus preventing the possibility of overrun and duct saturation. With milder outdoor air conditions, V-1 can satisfy space conditions by introducing only a portion of the total design capacity.

As the outdoor air becomes colder and drier, humidifier V-1 will not satisfy demand so the V-2 unit starts to open in response to the additional demand. This gives much closer control in all kinds of outside air conditions, as well as preventing a super-saturated condition in the duct at minimum design. Again the high-limit controller is optional but desirable.

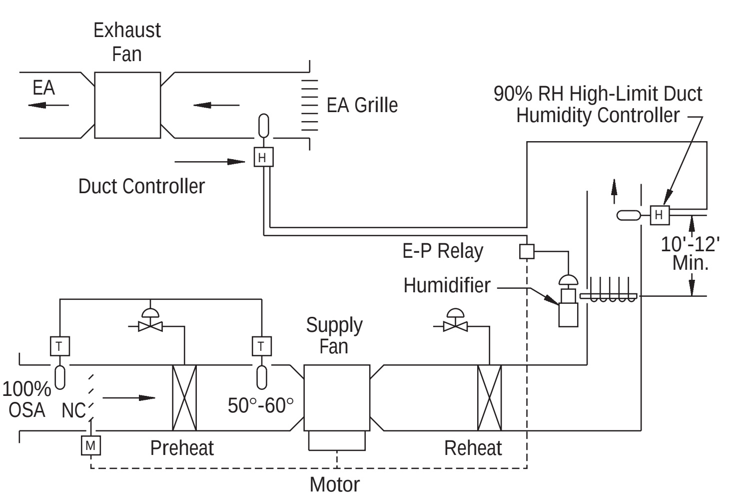
Glossary of Symbols

EA	Exhaust air	NC	Normally closed
E-P relay	Electric-Pneumatic relay	NO	Normally open
H	Humidity controller	OSA	Outside air
M	Damper motor	RA	Return air
MA	Mixed air	T	Temperature controller

System 2

Figure 30-1.

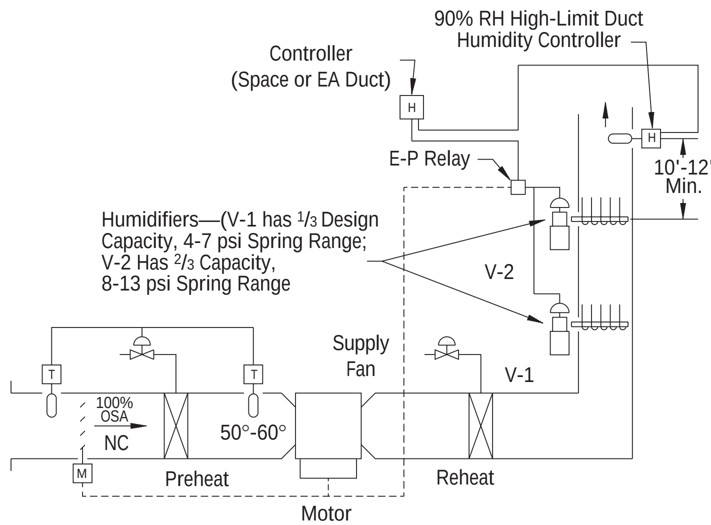
100% OSA heat-vent system with primary humidification.



System 3

Figure 30-2.

100% OSA heat-vent system with sequence control on primary humidification.



System 4

Here is another 100% outside air system. In this case, the air leaving the preheat coil is held at a constant dry-bulb temperature in the 55° to 60°F range. This system indicates the use of two humidifiers—one as a primary humidifier and the second as a booster or secondary humidifier.

This system allows a primary humidifier to be controlled directly from a duct humidity controller at a level high enough to maintain a space condition of about 35% RH at a space temperature of 75°F. The booster unit, located downstream from a reheat coil and fan, can then be sized and controlled to produce the necessary moisture to raise the space RH from 35% to some higher condition, say 55%, where and when desired. This allows individual humidity control for each zone at a higher level than otherwise possible.

This is an important combination because the use of the primary unit allows the capacity of the booster unit to be small enough so that super saturation and visible moisture will not occur, even when the units are located as close as three feet from the discharge grille. Tests indicate that with capacities in the 8 to 10 lbs/hr range, three feet minimum distance will not produce visible vapor.

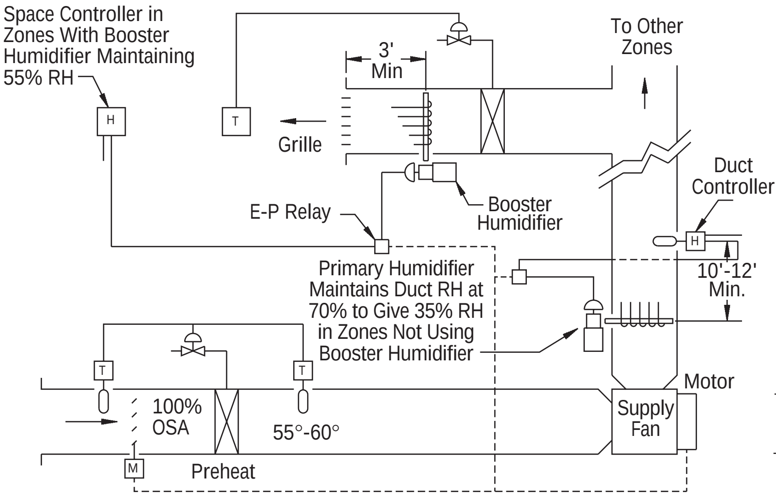
In this typical air handling system, it would not be psychrometrically possible to introduce enough humidity into the air temperature downstream from the preheat coil to give the maximum required condition in excess of 35% RH in the space. See Example 2, page 13. The use of both primary and booster humidifiers is the only method for controlling the relative humidity in space at any level above approximately 35%.

System 5

Here is a single zone packaged heating and ventilating unit with internal face and by-pass dampers. The humidifier should be positioned downstream from the mixing dampers so that moisture is introduced into the final leaving air temperatures of the heating ventilating unit. This location permits a high level of space relative humidity to be maintained without duct saturation. It is a preferable location to just ahead of the coils because of higher air temperature and better mixing conditions. Again a high-limit controller is recommended to prevent possible duct saturation, installed 10 to 12 feet downstream from the humidifier.

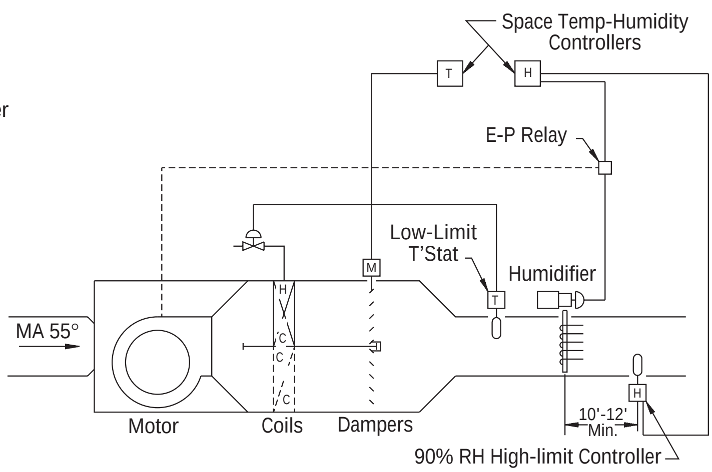
System 4

Figure 31-1.
100% OSA heat-vent system with primary and booster humidification.



System 5

Figure 31-2.
Single zone heat-vent unit with internal face and by-pass dampers—primary humidification.



System 6

This is a multi-zone heating/ventilating unit with face and by-pass dampers on each zone. The example shows a method and location for primary humidification, but it should be restricted to design conditions of “comfort humidification” of, say, 35%. These systems are normally package units and it is standard practice to incorporate the humidifier ahead of the coils as shown. This location of the humidifier will provide equal moisture distribution in hot or cold decks before heat zone takeoff, but it does limit the amount of moisture that can be added to the 55° air. Design conditions above 35% RH risk impingement of visible vapor on the coils. See Example 2, page 13.

With these units, it is sometimes possible to use two humidifiers at this location with baffles between zone takeoff and sized for different conditions of relative humidity in their respective sections. Booster humidifiers can be used in individual zones for a higher relative humidity where required.

System 7

Here is a high-velocity dual duct system with primary and booster humidification shown. Like System 6, above, the primary humidifier is capable of providing “comfort humidification” only—30% to 35% RH. Because of space limitations, the primary humidifier, sized to maintain a duct condition of, say, 90% RH in the mixed air temperature, can be located as shown ahead of the fan. The humidifier should be located as far as possible upstream—no closer than three feet from the face of the supply fan—to ensure good air mixing and to allow the duct controller ample time to sense the condition short of saturation. The use of multiple manifolds will help provide good air mixing.

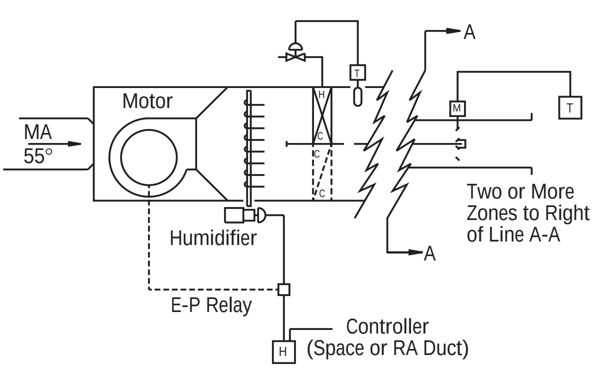
Note that the primary humidifier in this case should not be controlled from a space controller or an exhaust air duct controller, but rather from the supply duct controller as indicated. Since each zone has its own temperature-controlled mixing box, a location of the primary humidifier controller in the space or exhaust duct could not provide accurate control. Further, the distance between the humidifier and the controller could cause delayed response or override.

Glossary of Symbols

EA	Exhaust air	NC	Normally closed
E-P relay	Electric-Pneumatic relay	NO	Normally open
H	Humidity controller	OSA	Outside air
M	Damper motor	RA	Return air
MA	Mixed air	T	Temperature controller

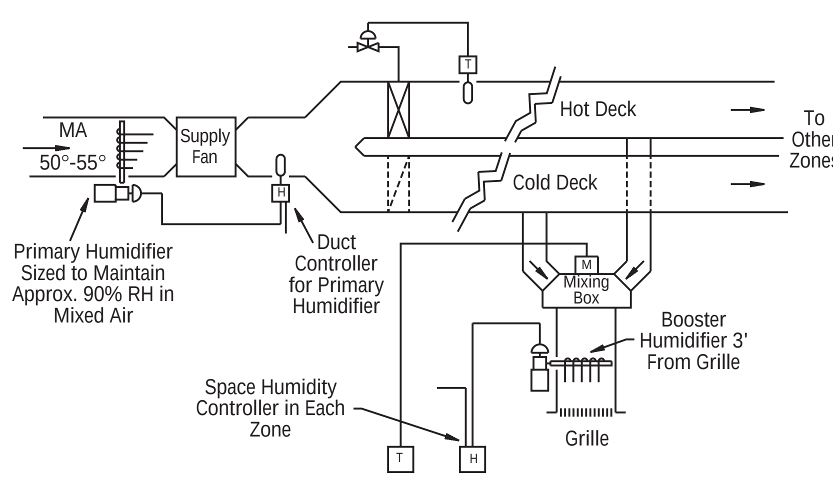
System 6

Figure 32-1.
Multi-zone heat-vent unit with internal face and by-pass dampers for each zone—primary humidification.



System 7

Figure 32-2.
High-velocity dual duct system with primary and booster humidification.



Packaged Air Conditioner Installations

Humidifiers frequently must be installed in packaged central station air conditioners. This can present some unusual location requirements due to the close quarters within the packaged units.

In the horizontal discharge draw-thru type packaged unit shown in Fig. 33-1, the recommended location of the humidifier is at the fan discharge. In some instances this may not be possible. Note that with the alternate location, the humidifier manifold is installed to discharge upward into the area of greatest air turbulence. This permits the air to achieve optimum mixing before reaching the fan blades. A high-limit controller, set at 80%, should be located as shown when the humidifier is installed at the alternate location.

Recommended humidifier locations for a vertical discharge draw-thru type air conditioner (Fig. 33-2) are identical to the horizontal unit. If the alternate location must be used, a high-limit controller set at 80% is desirable. The humidifier manifold should discharge upward, as with the horizontal discharge unit.

Figure 33-1. Horizontal Discharge

With humidifier installed at recommended location, high-limit duct controller should be set at 90% RH maximum—alternate location at 80% RH maximum.

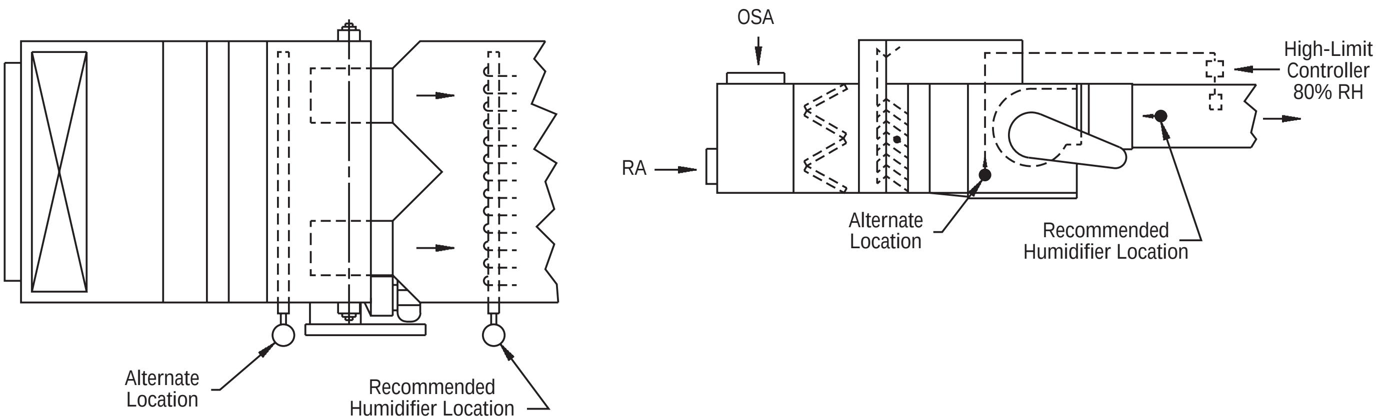
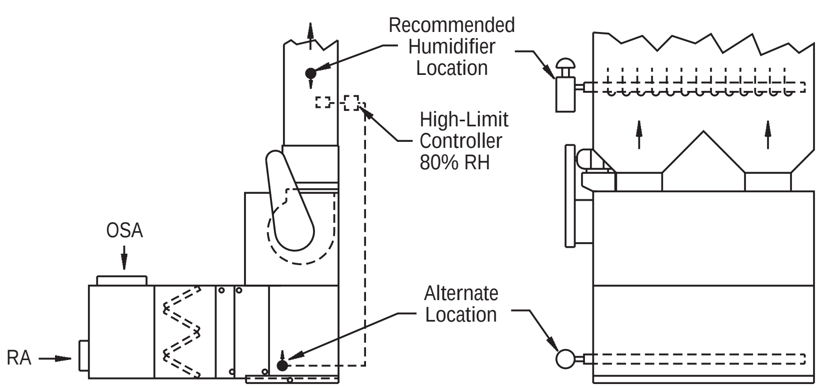


Figure 33-2. Vertical Discharge



Steam Humidifiers in Central Systems, Continued…

In a low pressure blow-thru type, multi-zone, packaged air conditioner (Fig. 34-1), the recommendations are much the same. However, to avoid overloading the cold deck and to avoid impingement of discharge, the manifold is installed to discharge upward instead of directly into the fan discharge.

As with the draw-thru units, a high-limit controller set at 90% should be installed. In a high pressure blow-thru type packaged unit (Fig. 34-2), again the recommended location is as close to the fan as possible, with the manifold discharging directly into the fan discharge. A high-limit controller set at 90% is desirable.

In either high or low pressure systems, where the humidifier is installed at the alternate location, set the high-limit humidity controller at 80% RH.

Figure 34-1. Low Pressure System

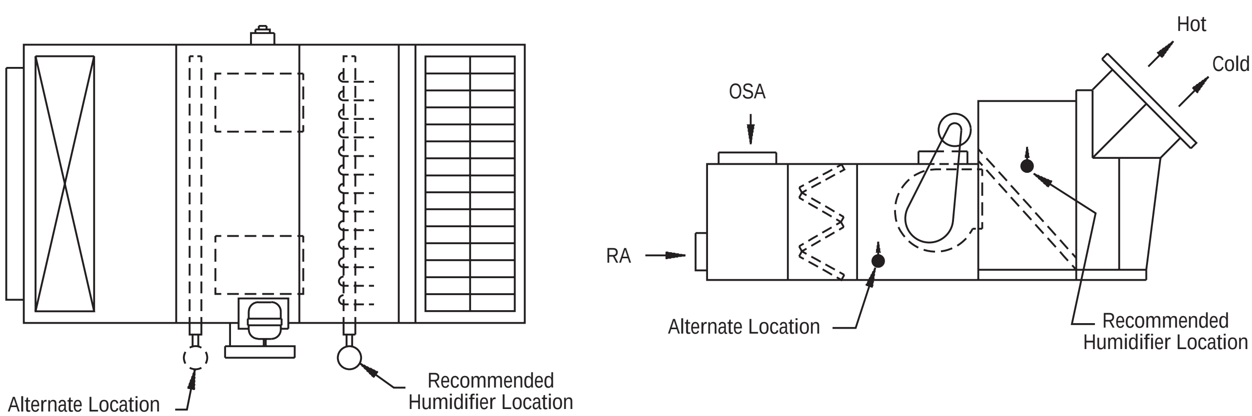
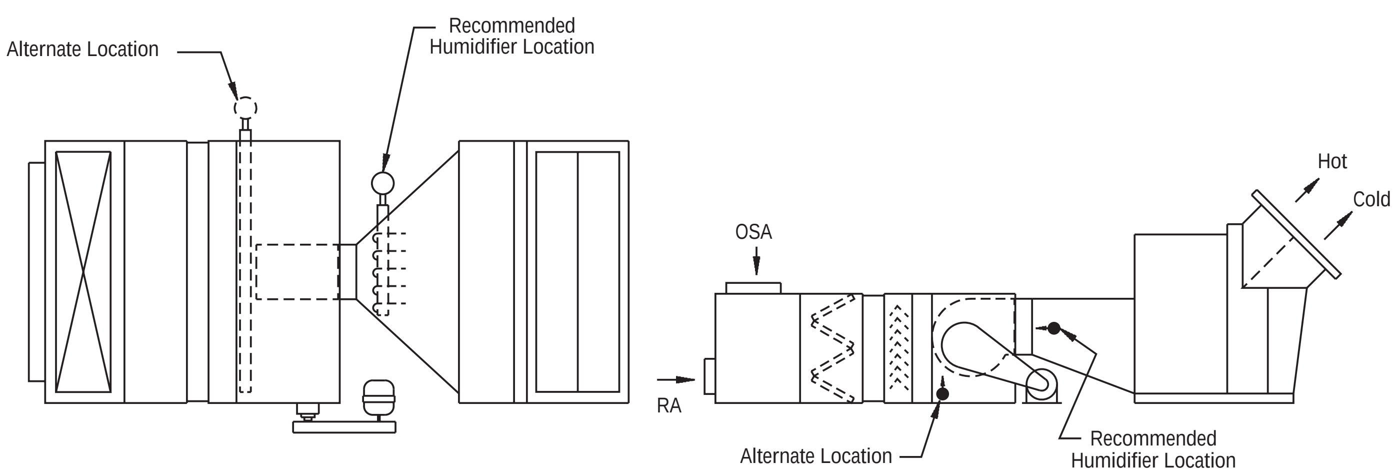
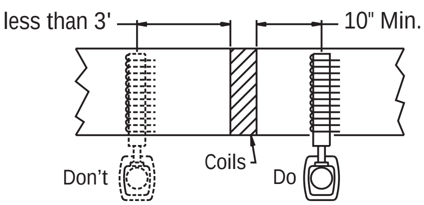


Figure 34-2. High Pressure System

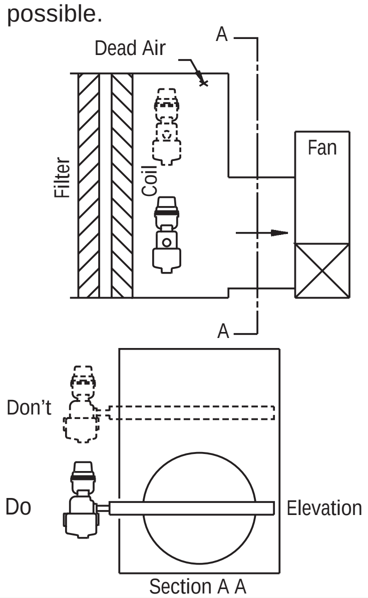


Installation Do's and Don'ts

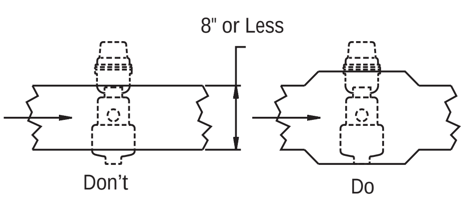
In discussing the systems, we mentioned a few location "do's and don'ts." Let's review these precautions that may help to keep you out of trouble. For example, whenever possible, install the distribution manifold downstream from coils. If you have more than three feet of distance available between the manifold and the coil on the upstream side, the manifold can be installed at this location (greater than three feet for higher velocity systems).



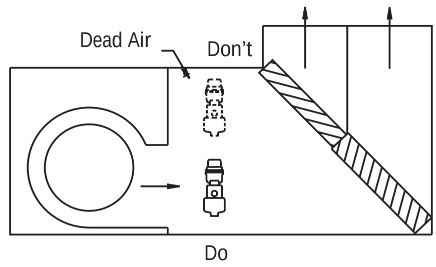
When it is necessary to place the humidifier in the coil section ahead of the fan, locate the manifold in the most active air flow and as far upstream from the fan inlet as possible.



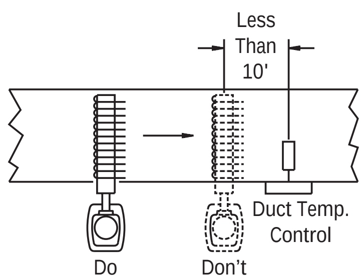
Don't risk restriction of the air flow in ducts 8" or less in depth. Use an expanded section as shown.



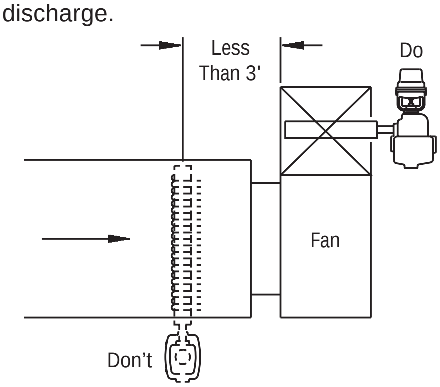
When it is necessary to place the humidifier discharge into a packaged multi-zone air handling system, install the distribution manifold into the center of the active air flow and as close to the fan discharge as possible.



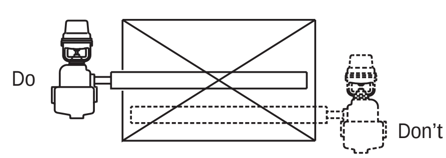
Do not install a distribution manifold closer than 10 feet upstream from a temperature controller or you may get false signals.



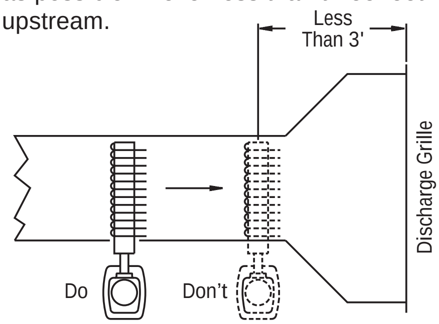
The distribution manifold should never be placed within three feet of an air fan intake. The best location is at the fan discharge.



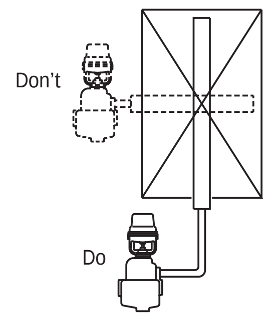
Whenever possible, install the distribution manifold into the center of the duct.



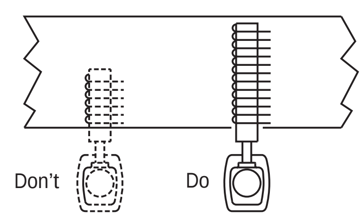
Always install distribution manifolds as far upstream from discharge air grilles as possible—never less than three feet upstream.



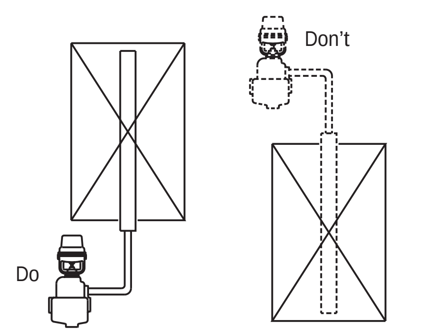
Always size and install the distribution manifold to span the widest dimension of the duct section.



Always select the stream distribution manifold length that will span the maximum width of the duct.



The manifold should never be installed vertically downward from the humidifier. This presents a condensate drainage problem in the jacket of the manifold. Vertical upward installation is permissible.



NOTE: All dimensions shown in the above figures are based on duct temperature of 65°F or higher and duct velocities of 800 ft/min, or lower. If duct air is cooler or velocities are higher, these dimensions should be greater or multiple manifolds considered.

Application of Unit Humidifiers for Direct Discharge

A survey of your requirements should be taken to determine the amount of steam needed for humidification, the number, size and type of units required, and the location of both humidifier and humidity controllers.

Sizing and Location with Natural Ventilation

These are the average industrial humidification applications with:

Room temperatures—65° to 80°F.
Relative humidities—35% to 80%.
Natural ventilation—i.e., infiltration around windows and doors.

Selection Data Required

Minimum Outdoor Temperature: For most jobs, figure 10°F above the lowest recorded temperature for your locality. The lowest temperatures are seldom encountered for more than a few hours.

- Indoor Temperature
- RH Desired
- Pressure of Steam Available for Humidification
- Number of Cubic Feet in Room
- Air Changes Per Hour: air changes taking place under average conditions exclusive of air provided for ventilation or regain of hygroscopic materials.

Rooms, 1 side exposed ______ 1
Rooms, 2 sides exposed ______ 1 1/2
Rooms, 3 or 4 sides exposed ______ 2
Rooms with no windows or outside doors ______ 1/2 - 3/4

Typical Problem:
Design outdoor temperature ______ 0°F
Indoor temperature ______ 70°F
RH required 40%
Air changes per hour ______ 2
Steam pressure available ______ 5 psi

Room size 400' x 160' with 10' ceiling
Natural ventilation
Heated by: Unit heaters-fan on-off control

Step I: Steam required for humidification. Our room contains (400' x 160' x 10') or 640,000 cu ft.

From the 70°F Table 36-1, read across from 0°F outside temperature to the 40% RH column where you find the figure .409 lbs of steam/hour per 1,000 cu ft of space for each air change. Then, 640 times .409 times 2 equals 524 lbs of steam/hour installed humidification capacity required.

Step II: Electric or air-controlled units. The large floor area calls for multiple humidifiers. No explosion hazard has been specified so use of air-controlled units is not required. Electric units are recommended.

Step III: Number of humidifiers for job. Divide steam required by capacity of humidifiers at steam pressure available.

Step IV: What size humidifier to use. For this example, a large number of smaller capacity units is recommended. Larger capacity units could cause condensation on the low ceiling. Also, because of the large floor area, the humidistats for fewer units would be widely spaced which could result in less accurate control than desirable.

Step V: What type humidifier to use. In this example, integral fan units are preferable to steam jet units installed in conjunction with unit heaters. Since the unit heater fans are on or off to control temperature, it follows that the humidist at may call for steam when the nearest unit heater is not running. With the low ceiling, the discharge from a steam jet humidifier might rise to the ceiling and produce condensation. Therefore, the integral fan type should be used.

Step VI: Location of humidifiers. Several patterns are possible, and actual location can usually conform with the existing steam supply and return lines to make an economical installation with a minimum of new piping.

Pounds of steam per hour, per air change for each 1,000 cu ft of space to secure desired indoor relative humidity at 70°F with various outdoor temperatures (outside air 75% saturated).

Table 36-1. 70°F Humidification

Outdoor Temp.	70°F—Relative Humidity Desired Indoors—70°F										
	25%	30%	35%	40%	45%	50%	55%	60%	65%	70%	75%
*30	.079	.136	.194	.251	.309	.367	.424	.482	.539	.597	.654
20	.154	.212	.269	.327	.385	.441	.499	.557	.615	.672	.730
10	.204	.262	.319	.377	.434	.492	.549	.607	.665	.722	.780
0	.237	.294	.352	.409	.467	.524	.582	.639	.697	.754	.812
-10	.257	.314	.372	.430	.487	.545	.602	.660	.717	.775	.832
-20	.270	.327	.385	.442	.500	.557	.615	.672	.730	.787	.844

In our problem of a 400' x 160' x 10' room, there would likely be steam lines along both sides of the room, and humidifiers can be located as shown in black in Fig. 37-1. If the supply lines run down the center of the room the colored line pattern would be practical. Runouts to integral fan units in a 160' wide room would be about 20' long. If the room were only 60 or 80 feet wide, runouts need be no longer than required for actual hookup.

Step VII: Location of humidistat. This should be from 20 to 30 feet away from the humidifier and slightly to one side of the air stream from the unit. The humidistat should "see" its humidifier and be in "active" air. Do not hide it behind a post or in the channel of an H-beam. It must get a good sample of the air to control the humidity.

Sizing and Location with Forced Ventilation

Typical Jobs: Mill and sanding rooms in furniture factories. Here, the problem of selecting and installing humidifiers is much the same as previously described except for:

1.Determining the number of air changes.

2.Location of humidifiers and humidistats.

Air Changes: These can be determined from the exhaust fans' capacities. The cubic feet per hour capacity of the fans, divided by the cubic feet of space to be humidified, will give the number of air changes.

Where the capacity of fan or fans is not known, air changes can be measured with velometer readings at all open doors, elevator shafts, etc. leading to the room and with fans operating at full capacity. Your Armstrong Representative can determine air changes for you.

Humidifier Location: Bear in mind that humidifiers will have to control the humidity 24 hours a day, seven days a week during the heating season. Exhaust fans may operate only 40 hours or 80 hours per week. Thus the humidifiers and humidistats must be located for good distribution of humidity during fan-off periods as well as when the fans are operating.

Figure 37-1. Where practical, locate humid-ifiers to minimize piping. Locations shown in black where steam supply lines are along outer walls; in color where supply is in center of room.

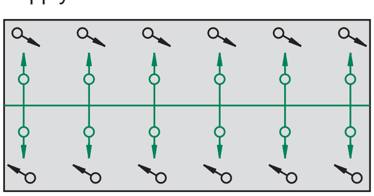
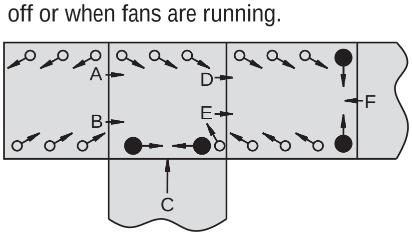


Figure 37-2. Outlines a typical requirement. Schematic layout of humidifiers in woodworking plant where exhaust fans are used. Arrows indicate air flow induced by fans. Humidifiers are sized for load conditions imposed by fan. Humidifiers are located to give uniform distribution of humidity when fans are off or when fans are running.



Pounds of steam required per hour per air change for each 1,000 cu ft of space to secure desired indoor relative humidity at 75°F with various outdoor temperatures (outside air 75% saturated).

Table 37-1. 75°F Humidification

Outdoor Temp.	75°F—Relative Humidity Desired Indoors—75°F										
	25%	30%	35%	40%	45%	50%	55%	60%	65%	70%	75%
*30	.129	.196	.264	.331	.399	.466	.533	.601	.668	.736	.803
20	.204	.271	.339	.406	.474	.541	.609	.676	.744	.811	.879
10	.254	.321	.389	.456	.524	.591	.659	.726	.794	.861	.929
0	.286	.354	.421	.489	.556	.624	.691	.759	.826	.894	.961
-10	.307	.374	.442	.509	.577	.644	.711	.779	.846	.914	.981
-20	.319	.387	.454	.522	.589	.657	.724	.792	.859	.927	.994

NOTE: When outdoor design temperatures exceed 30°F, use Table 5-1.

Sizing for High or Low Temperature Humidification

Where air temperatures are well above 75°F or below 70°F, it is impractical to use Tables 36-1 or 37-1. Humidification requirements must be figured from Table 5-1, page 5, showing grains of water per cu ft of saturated air at various temperatures. Typical problem: How much steam per hour is required to humidify 60,000 cu ft of space with four air changes per hour to 40% RH when the air temperature is 90°F? Assume that any makeup air will come from outdoors at 0°F, 75% saturated.

90°F saturated air = 14.9 gr/cu ft saturated = 5.976 gr/cu ft at 40% RH

Outdoor air 0°F saturated = .475 gr/cu ft

75% saturated = .356 gr/cu ft

5.976 minus .356 = 5.620 grains to be added per cu ft

$$\frac{5.620 \text{ X } 1{,}000}{7{,}000} = .803 \text{ lb per M cu ft per air change}$$

NOTE: 7,000 gr = 1 lb

With four air changes in a 60,000 cu ft room, then .803 x 60 x 4, or 193 lbs steam would be required per hour. Humidifier capacity required for temperatures below 70°F is determined in exactly the same manner.

NOTE: For high temperature air in particular, air volume changes dramatically with RH. Armstrong Software Program 2 will provide greater accuracy in humidifier sizing for these applications.

Explosion Hazard Humidification

Sizing air-operated humidifiers for areas when explosion hazard exists is done exactly as for other requirements except that they should be sized for the most severe conditions of makeup air, RH required and minimum steam pressure.

Humidifiers should be located to get the best possible dispersal and distribution of vapor in the area.

Special Purpose Industrial Applications

In some industrial operations, a stratum of high relative humidity is required in close proximity to a fast moving sheet or film of paper, thin gauge plastic, fabric, cellophane, etc. The objective may be to prevent accumulation of static electricity charges, or to prevent loss of moisture from the material. If the sheet or film is hot, as it very well might be, it tends to give up its moisture very quickly. By using steam shower humidifiers expressly adapted for this application to create a laminar zone of high humidity adjacent to the sheet, moisture loss is prevented and moisture content of the material is properly maintained.

For this application, the humidifier must be interlocked with the drive of the machine, and it is essential that the steam be discharged in a dry state, with no water droplets or liquid spray.

Conclusion

Your humidification needs can be met if you follow Armstrong's five basic guidelines:

1. Evaluate the requirements of the system.
2. Select the most suitable medium.
3. Size the humidifiers properly.
4. Locate and install the humidifiers correctly.
5. Employ suitable humidity controllers also properly located.

The Armstrong organization includes specialists–from researchers to application engineers–in every aspect of humidification. Armstrong International has been successfully solving humidification problems for over 60 years. When you contact your local Armstrong Representative, he will make available to you the vast knowledge and experience of the entire organization. We urge you to involve your Armstrong Representative in the initial planning of your system for a greater payoff in efficiency and economy.

Armstrong Humidification Literature, Software and Videos

Product Literature:

Catalog 504
Series 9000 and 1000 Conditioned-Steam Humidifiers for air handling systems and direct area humidification

Bulletins 570 & 571
Series CS-10
Steam-to-Steam Humidifiers

Bulletin 514
Series EHU-700
Electronic Steam Humidifiers

Bulletin 516
Series EHU-600 Solutions for Sensitive Environments

Bulletin 581
Series HC-4000 HumidiClean™
with patented ionic bed technology

Bulletin 565
HumidiPack®
Steam Humidifier System

Computer Software:

Software Program 2
Humidifier Sizing and Selection

Installation Bulletins:

Bulletin 544
Series 9000 and 1000 Humidifiers for Air Handling Systems

Bulletin 549
Series 9000 Humidifiers for Direct Area Humidification

Bulletin IB-87
Series CS/CSE
Steam-to-Steam Humidifiers

Bulletin 527
Series EHU-700
Electronic Steam Humidifiers

Bulletin 526
Series EHU-600 Solutions for Sensitive Environments

Bulletin 537
Series HC-4000
HumidiClean™ with patented ionic bed technology

Bulletin 560
HumidiPack®
Steam Humidifier System

Video Tapes:

It's the Humidity
This video tape covers the essentials of humidity and outlines the primary reasons for humidity control.

Improving Humidification with the Series 9000
This tape discusses the design of the Armstrong Series 9000 Conditioned-Steam humidifiers and explains why it's the key to efficient and reliable steam humidification.

Series EHU-700
This tape demonstrates the installation, start-up and maintenance of the Armstrong Series EHU-700 Electronic Steam Humidifier.

Ionic Bed Technology
Ionic bed technology is the problem-solving key that makes Armstrong's HumidiClean™ line of humidifiers unique. This tape explains how these patented ionic beds work.

References

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ASHRAE Handbook of Fundamentals, 1989.

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IBM Installation Planning Manual, April, 1973.

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Static Electricity, National Fire Protection Association. 1941. U.S. National Bureau of Standards.

Application Engineering Service

Representative/Factory Assistance
Armstrong Representatives have years of practical experience in solving humidification problems. What's more, they're experts at assessing your humidification needs. Backing the Representatives, of course, are Armstrong humidification specialists who are available to assist with difficult or unusual problems.

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Armstrong provides detailed instruction materials to assist customers in the proper installation and operation of Armstrong steam equipment.

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Thorough but concise application data sheets are provided by Armstrong for many of its steam products.

Computerized Sizing
Given the basic parameters of an installation, Armstrong humidification specialists can use computers to quickly size equipment for efficient humidification, especially when complex economizer systems are involved. In addition, you may request a free copy of Armstrong's Software Program 2 (Humidifier Sizing and Selection) for step-by-step sizing of your own installation.

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