Humidification Load Calculation Manual

Engineering Manual

Includes What is Humidity, Affects of Relative Humidity, Calculating Relative Humidity, Requirements to Calculate Humidifier Load, and Load Calculations

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What is Humidity

If a closed container is partially filled with water, then some of the water molecules in the liquid will leave the surface of the water and become vapor. Once some water molecules are present as vapor they will also re-enter the liquid. After some time at constant temperature equilibrium will be reached where the same number of molecules are leaving and entering the liquid. At this equilibrium point the relative humidity of the water vapor is 100%.

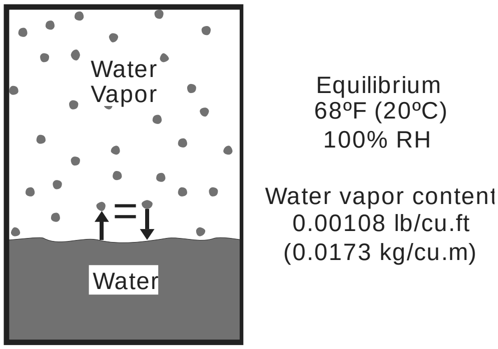

Figure 1: Water Vapour Equilibrium

> *Relative humidity (RH)* is the percentage of water vapour present in the air relative to the amount that would be present in the equilibrium state.

The equilibrium point is temperature dependent. At higher temperatures the equilibrium occurs with more water vapor. If the container above was heated to 86ºF (30ºC) the water and water vapor would no longer be in equilibrium. The relative humidity of the vapor right after increasing the temperature would be 57%. This means that immediately after heating there are 57% as many water vapor molecules as would be present in the equilibrium state.

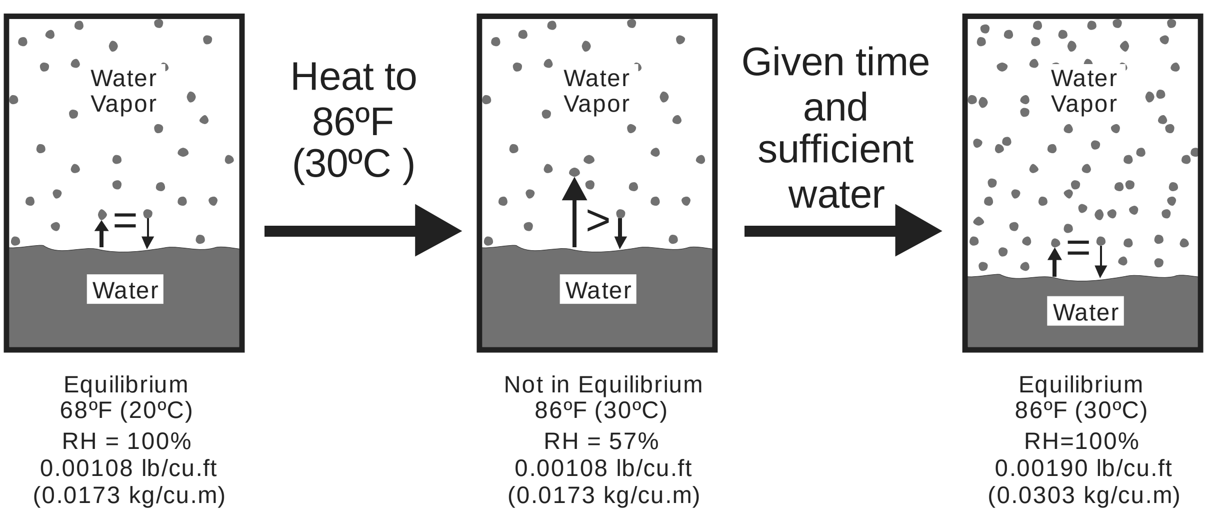

Figure 2: Relative Humidity after Heating

It is the above process that causes dry air in buildings. As cold incoming air is heated, its relative humidity value drops. Therefore moisture must be added to attain an acceptable level of humidity within the building.

> *Load Calculations* - on page 22 outlines how to calculate the amount of moisture that must be added to maintain a constant relative humidity.

Effects of Relative Humidity

The reasons for humidifying dry air vary from one building to another and from one geographic area to another, however there are three fundamental reasons. These are:

- Static Electricity
- Poor Moisture Stability
- Health and Comfort

Static Electricity

Static electricity is a condition caused by stationary charges of electricity and is a major problem in most unhumidified areas. Since static electricity is caused by friction, particularly when the elements in friction are dry, the problem increases proportionately with the speed of production machinery. Without sufficient humidification, high-speed machinery might well defeat its own purpose. Reduced efficiency is frequently the result of static electricity.

In the printing industry presses must self-feed paper evenly, one sheet at a time at very high speeds. When the static electricity causes sheets of paper to stick together, the paper bunches, the feeding becomes uneven, and eventually the paper jams the presses.

In the textile industry static electricity causes the yarns to adhere to each other, the shuttles miss threads and improper weaving patterns result.

In offices, static electricity can disrupt operations and increase operating costs. In many photocopiers, sheets of paper stick together and jam the machine, wasting time and paper. Severely jammed equipment may even require service calls.

In computer rooms and data processing areas, the lack of humidity results in static electricity that causes problems such as circuit board failure, dust buildup on heads, and storage tape breakage.

Static electricity can also be dangerous. Sparks caused by static are extremely hazardous in locations such as hospital operating rooms where flammable gases are present. Many flash fires – even explosions - are caused by static electricity.

> *Controlling Static Electricity* - Maintaining relative humidity above 35% is one important measure that can be taken to reduce static electricity.

Controling Static Electricty
One of the easiest and most common methods of minimizing static electricity is to increase the relative humidity level. Electrostatic charges do not dissipate through moist air, but through a moisture film that is absorbed on the charged surfaces. This moisture film decreases the surface resistance and causes static charges to be drained.

This effect is most pronounced at RH above 30-35% and it also corresponds with a decrease in ozone production (a by-product of electrostatic discharge). Static electricity is a problem that should be of primary concern to any manufacturing plant interested in running efficiently and accurately.

Moisture Stability

When air is heated the relative humidity will decrease. When this occurs the rate at which water molecules leave objects containing water or the rate at which water evaporates is increased. All hygroscopic or fibrous materials either lose of gain moisture in direct relation to the relative humidity of the surrounding air

Moisture stability is the ability of a material to maintain a level of moisture content despite fluctuations in the humidity of the environment. Many materials give off, or take on moisture rapidly which can result in serious damage to the material or the process in which it may be involved. The drying out of a material can result in product deterioration, while conversely, a dry material can also suffer damaging side effects of moisture regain. In many cases, product deterioration is directly related to the lack of moisture stability

Table 1 gives the hygroscopic regain of some common hygroscopic materials. Hygroscopic regain is defined as the amount of water a completely dry material will absorb from the air. It is expressed as a percent of the dry weight. (For example the weight of completely dry timber will increase by 9.3% if it is stored at an RH of 50%)

Table 1: Hygroscopic Regain of Some Common Materials

Industry and/or Material	Relative Humidity - %								
	10	20	30	40	50	60	70	80	90
Baking									
Crackers	2.1	2.8	3.3	3.9	5	6.5	8.3	10.9	14.9
Flour	2.6	4.1	5.3	6.5	8	9.9	12.4	15.4	19.1
White Bread	0.5	1.7	3.1	4.5	6.2	8.5	11.1	14.5	19
Leather - Sole Oak, Tanned	5	8.5	11.2	13.6	16	18.3	20.6	24	29.2
Printing									
Paper – Comm. Ledger – 75% Rag1% Ash	3.2	4.2	5	5.6	6.2	6.9	8.1	10.3	13.9
Paper M.F. Newsprint – 24% Ash	2.1	3.2	4	4.7	6.1	7.2	8.7	10.6	
Paper White Bond Rag – 1% Ash	2.4	3.7	4.7	5.5	6.5	7.5	8.8	10.8	13.2
Paper Writing – 3% Ash	3	4.2	5.2	6.2	7.2	8.3	9.9	11.9	14.2
Textile									
Cotton – Absorbent	4.8	9	12.5	15.7	18.5	20.8	22.8	24.3	25.8
Cotton – American-cloth	2.6	3.7	4.4	5.2	5.9	6.8	8.1	10	14.3
Cotton – Sea Isle-roving	2.5	3.7	4.6	5.6	6.6	7.9	9.5	11.5	14.1
Hemp – Manila and Sisal	2.7	4.7	6	7.2	8.5	9.9	11.6	13.6	15.7
Jute – Average Grade	3.1	5.2	6.9	8.5	10.2	12.2	14.4	17.1	20.2
Linen – Dried Spun – Yarn	3.6	5.4	6.5	7.3	8.1	8.9	9.8	11.2	13.8
Rayon – Celulose – Acetate – Fibre	0.8	1.1	1.4	1.9	2.4	3	3.6	4.3	5.3
Rayon – Cupramonium – Average Skein	4	5.7	6.8	7.9	9.2	10.8	12.4	14.2	10
Rayon – Viscose Nitrocel	4	5.7	6.8	7.9	9.2	10.8	12.4	14.2	16
Silk – Raw Chevennes-Skein	3.2	5.5	6.9	8	8.9	10.2	11.9	14.3	18.8
Wool – Australian-Marino-Skein	4.7	7	8.9	10.8	12.8	14.9	17.2	19.9	23.4
Tobacco - Cigarette	5.4	8.6	11	13.3	16	19.5	25	33.5	50
Wood									
Timber – Average	3	4.4	5.9	7.6	9.3	11.3	14	17.5	22
Glue – Hide	3.4	4.8	5.8	6.6	7.6	9	10.7	11.8	12.5
Miscellaneous									
Charcoal-Steam Activated	7.1	14.3	22.8	26.2	28.3	29.2	30	31.1	32.7
Gelatin	0.7	1.6	2.8	3.8	4.9	6.1	7.6	9.3	11.4
Silica Gel	5.7	9.8	12.7	15.2	17.2	18.6	20.2	21.5	22.6
Soap	1.9	3.8	5.7	7.6	10	12.9	16.1	19.8	23.8
Starch	2.2	3.8	5.2	6.4	7.4	8.3	9.2	10.6	12.7

NOTE: Moisture content expressed in per cent of dry weight of the substance at various relative humidities – Temperature 75°F (22ºC)

Hygroscopic Regain – is defined as the amount of water a completely dry material will absorb from the air. . Any hygroscopic product that is purchased and sold by weight must have a carefully controlled environment.

Products such as vegetable, cut flowers, fruit and many grocery items cannot be brought back to original quality once they have lost their moisture. By installing an efficient humidification system this costly loss of products can be avoided. Many food processors humidify their plant and storage areas and are able to store fruits and vegetables for months without any loss of product quality or weigh.

For any product that requires a certain percentage of moisture to maintain its quality, loss of that moisture reduces its valve. Some products can be brought back to their original condition by returning the moisture to them. However, among those that cannot reabsorb moisture to regain their lost quality are fruit and vegetable products, paintings and art objects.

Deterioration caused by loss of moisture is also a problem for treasures such as antiques, rare books, and works of art, all of which are susceptible to damage caused by moisture loss. It causes antiques, paintings, paper and book bindings to crack, warp and deteriorate. Fortunately, most libraries and museums are well aware of the need for controlled humidity to protect their collections. They know that proper humidity control is a very inexpensive preventive measure that will avoid costly and often impossible restorations.

A specific moisture content in materials is essential to the quality of products produced by a wide range of manufacturers of hygroscopic or fibrous materials. Wood, paper and textiles are examples of materials particularly affected by changes in content. If these materials have a correct moisture content when they arrive at a plant, and if they are used immediately, they will respond properly to the manufacturing process. But problems can be anticipated if the materials are stored in a dry atmosphere.

Paper provides a good example of the effects of dry air and the lack of moisture stability. When it is stored under dry atmospheric conditions, moisture from the outer layers and edges of the stacks escapes into the air. The moisture loss is much more rapid from the outer edges than from the center of the stacks. The result is not only curled stock, but also uneven moisture content, which creates printing and processing problems.

If moisture stability in the surrounding atmosphere is the answer to a manufacturing operation, then complete humidification of the plant and storage areas is an absolute necessity. Humidification is the best and least expensive way of maintaining moisture stability. If the air surrounding the material is maintained at a proper and constant relative humidity level, so that no moisture is emitted or absorbed by the materials, then the products will remain stable in both moisture content and dimension.

Ideally, humidification equipment should be installed in raw material storage areas, manufacturing facilities, and finished goods' storage rooms, for full control of the product moisture content.

Health and Comfort

During the heating season, inside air dries to the point where the humidity is substantially lower or comparable to that of the Sahara Desert. The effect on people is to dry out nasal and throat membranes. For employees this means more susceptibility to colds and virus infections. The subsequent increased absenteeism proves costly for any employers. Another aspect of comfort is the fact that humidity in the air makes a room feel warmer, so there will be fewer requests to have the thermostat turned up.

Most employers provide air conditioning for employee comfort and productivity during the hot days of summer. Adding humidification for full winter comfort and productivity is just as important as air conditioning in the summer months. In fact, it is one of the most important functions of the complete air conditioning or “total comfort” system.

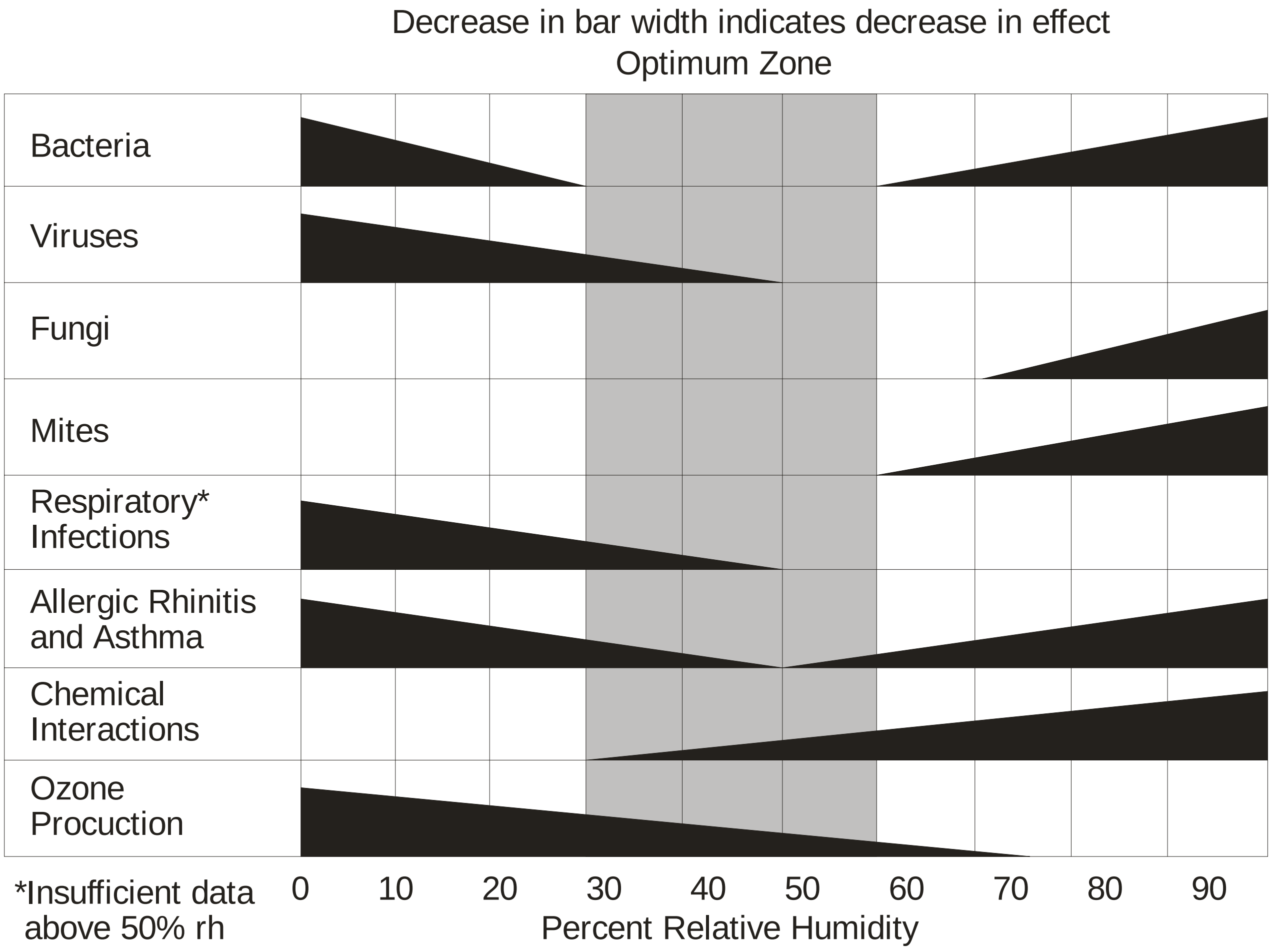

Figure 3: Optimum Humidity Range for Human Comfort and Health

The advantage of conditioning the interior space of a building to increase productivity and reduce the downtime of machinery has been documented many times. Unfortunately it is usually equipment, such as computers and communications systems, that is placed in separate climate controlled rooms, while the majority of employees have temperature control only.

Temperature control must be combined with humidity control to maintain proper comfort parameters in an office environment. More than 75% of all I.A.Q. problems start with a comfort complaint. If this is not rectified, the employees will continue to complain and become less productive.

Temperature control alone does not take into account the physiological aspects of the employees. As demonstrated in Figure 3, indoor RH variations above and below the 40-60% range have a dramatic effect on the comfort and well being of employees. Humidity conditions above this range are usually controlled easily by the normal dehumidification process of the air-conditioning system. However, as the cold, dry weather of winter approaches or in arid climates, the indoor RH can easily drop well below the recommended 40% parameter. It is not uncommon to find relative humidities in the 10-15% range in most offices during this period. This low RH creates comfort, productivity, and absenteeism problems costing immeasurable dollars to employers worldwide. Studies conducted by Dr. George Green of the University of Saskatchewan indicates that increasing the indoor RH from 20 to 30% will reduce absenteeism by 15%. This, along with the productivity increase that can be gained from additional comfort result in a real economic benefit from general office humidification.

Calculating Relative Humidity

If initial temperature and relative humidity are known then Table 2 and Table 3 can be used to calculate the relative humidity after heating, cooling, or adding steam. The following two examples use Table 3 and SI units to show the method used for calculating the RH after heating or after adding steam.

Example 1: RH After Heating - What is the RH if air at 5ºC and 80% RH is heated to 30ºC?

1 Obtain moisture content of air at 5ºC and 100% RH from Table 3.

A = 0.00680 kg/cu.m

2 Multiply by starting RH to get the actual moisture content of the air.

B = 0.00680 x 80%/100% = 0.00544 kg/cu.m

3 Obtain moisture air at 30ºC and 100% RH from Table 3.

C = 0.0303 kg/cu.m

4 Divide actual moisture content by moisture content at 100% RH

D = B / C = 0.00544 / 0.0303 x 100%= 18% *RH After Heating*

Example 2: RH after Adding Steam - What is RH if 10 kg of steam is added to 1,000 cu.m of the heated air in example 1?

1 Multiply B (the actual moisture content) by the volume to get mass of water in the air.

E = B x 1000 cu.m = 0.00544 kg/cu.m x 1000 cu.m = 5.44 kg

2 Add the amount of steam being added to the total mass of water.

F = E + 10 kg = 5.44 kg + 10 kg = 15.44 kg

3 Divide by the volume of air to kg/cu.m

G = F / 1000 cu.m = 15.44 kg /1,000 cu.m = 0.0154 kg/cu.m

4 Divide by moisture content at 100 % RH

H = G / C = 0.0154 / 0.0303 x 100% = 51% *RH After Adding steam*

Grains/cu.ft – A common unit used for measuring water vapor in air is grains / cubic foot. This document uses pounds/cubic foot and kilograms/cubic meter to simplify calculating humidifier output which is generally expressed in pounds per hour or kilograms per hour.

1 pound water = 7,000 grains.

Table 2: Water Content of Air at 100% RH (IP units)

°F	lb/cu.ft	°F	lb/cu.ft	°F	lb/cu.ft	°F	lb/cu.ft	°F	lb/cu.ft
-20	0.0000343	41	0.000424	61	0.000857	81	0.00163	101	0.00293
-10	0.0000414	42	0.000440	62	0.000886	82	0.00168	102	0.00302
-5	0.0000500	43	0.000457	63	0.000916	83	0.00173	103	0.00310
0	0.0000686	44	0.000474	64	0.000946	84	0.00178	104	0.00319
5	0.0000871	45	0.000491	65	0.000979	85	0.00184	105	0.00328
10	0.000111	46	0.000509	66	0.00101	86	0.00190	106	0.00337
15	0.000141	47	0.000527	67	0.00104	87	0.00195	107	0.00347
20	0.000177	48	0.000547	68	0.00108	88	0.00201	108	0.00356
25	0.000223	49	0.000567	69	0.00111	89	0.00207	109	0.00366
30	0.000279	50	0.000587	70	0.00116	90	0.00213	110	0.00376
31	0.000291	51	0.000609	71	0.00119	91	0.00220	111	0.00387
32	0.000304	52	0.000630	72	0.00123	92	0.00226	112	0.00397
33	0.000316	53	0.000651	73	0.00127	93	0.00233	113	0.00408
34	0.000327	54	0.000674	74	0.00131	94	0.00240	114	0.00419
35	0.000340	55	0.000699	75	0.00135	95	0.00247	115	0.00430
36	0.000353	56	0.000723	76	0.00139	96	0.00254	120	0.00491
37	0.000366	57	0.000747	77	0.00144	97	0.00262	125	0.00559
38	0.000380	58	0.000773	78	0.00149	98	0.00269	130	0.00634
39	0.000394	59	0.000800	79	0.00154	99	0.00277	135	0.00719
40	0.000409	60	0.000829	80	0.00158	100	0.00285	140	0.00812

Table 3: Water Content of Air at 100% RH (SI units)

°C	kg/cu.m	°C	kg/cu.m	°C	kg/cu.m	°C	kg/cu.m	°C	kg/cu.m
-30	0.000578	-10	0.00218	10	0.00943	30	0.0303	50	0.0828
-29	0.000553	-9	0.00238	11	0.0100	31	0.0320	51	0.0867
-28	0.000540	-8	0.00259	12	0.0107	32	0.0337	52	0.0908
-27	0.000540	-7	0.00281	13	0.0114	33	0.0356	53	0.0951
-26	0.000551	-6	0.00305	14	0.0121	34	0.0375	54	0.0995
-25	0.000573	-5	0.00330	15	0.0129	35	0.0395	55	0.104
-24	0.000606	-4	0.00357	16	0.0137	36	0.0416	56	0.109
-23	0.000650	-3	0.00385	17	0.0145	37	0.0438	57	0.114
-22	0.000704	-2	0.00415	18	0.0154	38	0.0461	58	0.119
-21	0.000769	-1	0.00447	19	0.0163	39	0.0485	59	0.124
-20	0.000845	0	0.00481	20	0.0173	40	0.0510	60	0.130
-19	0.000931	1	0.00516	21	0.0183	41	0.0536	61	0.136
-18	0.00103	2	0.00554	22	0.0194	42	0.0563	62	0.142
-17	0.00113	3	0.00594	23	0.0206	43	0.0592	63	0.148
-16	0.00125	4	0.00636	24	0.0218	44	0.0621	64	0.154
-15	0.00138	5	0.00680	25	0.0230	45	0.0652	65	0.161
-14	0.00152	6	0.00727	26	0.0243	46	0.0685	66	0.168
-13	0.00167	7	0.00777	27	0.0257	47	0.0718	67	0.175
-12	0.00183	8	0.00829	28	0.0272	48	0.0753	68	0.182
-11	0.00200	9	0.00884	29	0.0287	49	0.0790	69	0.190

Requirements to Calculate Humidification Load

The humidification load calculation assumes that the humidity and temperature in the space being humidified are at the design conditions. Therefore the moisture that must be added is the amount required to bring incoming air to the design condition. Figure 4 shows a schematic of a typical air conditioning system generated by Nortec's HELP software. The figure also shows the 3 factors that must be known to calculate humidification load.

Design Conditions – Temperature and RH that must be maintained in the humidified space.

Outdoor Air Conditions (Incoming Air) – Temperature and RH of the outdoor air.

Incoming Air Volume - The volume of outdoor air that flows into the space being humidified.

H.E.L.P. Software

The easiest way to calculate the humidification load for any application is to use Nortec's Humidifier Engineering and Load-sizing Program (H.E.L.P.). The software can be downloaded from www.humidity.com. The software guides you through the different factors and design considerations affecting humidifier selection and provides an easy means for examining the effect of changing conditions.

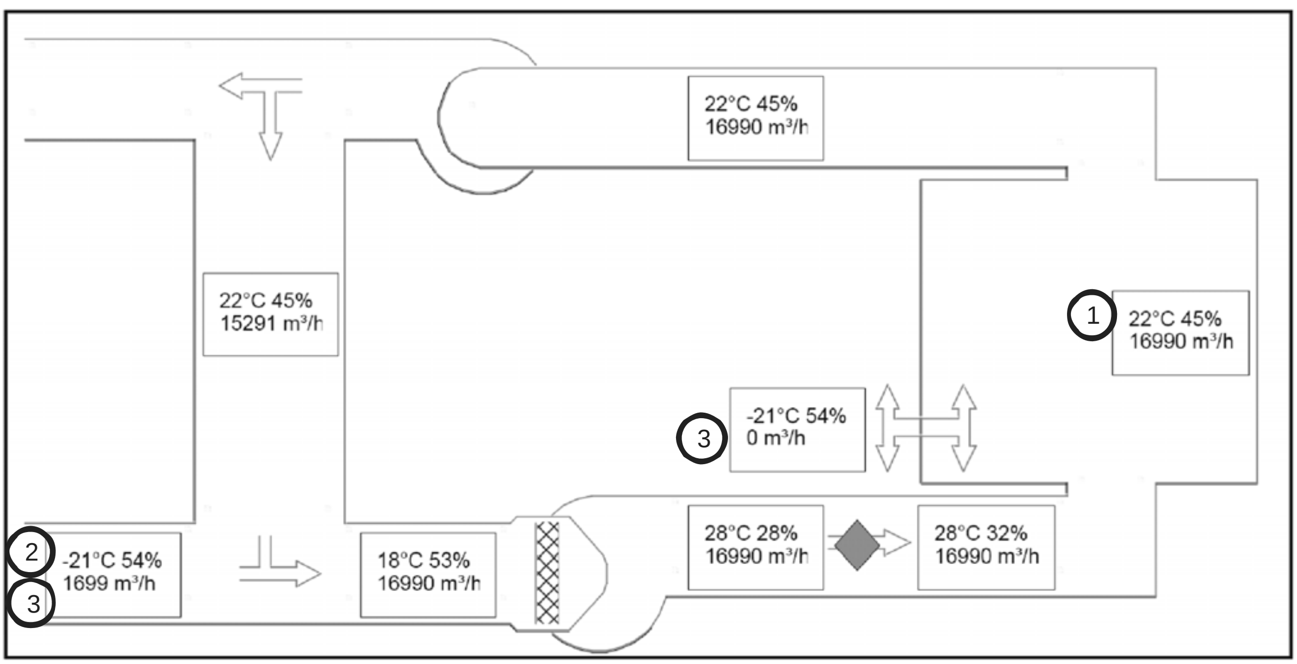

Figure 4: Help Software System Schematic

Design Conditions – Selecting an RH Setpoint

The optimum humidity setpoint depends on the reasons that a space is being humidified. Some of the most common reasons are outlined in Effects of Relative Humidity starting on page 6. The "ASHRAE Handbook – HVAC Applications" recommends specific design relative humidity levels for specific applications. Table 4 provides recommendations for temperature and humidity ranges for various purposes as taken from the ASHRAE Handbook and can be used for the purpose of load calculations.

For More Information on Design Conditions see:

- Nortec Form #00-124A – When You Need Humidity
- The ASHRAE HVAC Applications Handbook.
- Humidifiers section in the ASHRAE HVAC Systems and Equipment Handbook

Table 4: Design Indoor Conditions for Various Places, Products, and Processes

Product and/or Process	Temperature		RH %
	°F	°C	
Abrasives Manufacturing	78	25	50
Bowling Alleys	73 – 75	23 – 24	50 – 55
Billiard Rooms	73 – 75	23 – 24	40 – 50
Bread			
Flour and Powdered Product Storage	70 – 80	21 – 27	60
Fermentation (Bread Dough)	80	27	75
Retarding of Doughs	32 – 40	0 – 4	85
Final Proof	95 – 120	35 – 49	85 – 90
Counterflow Cooling	75	24	80 – 85
Brewing			
Brewing Hop Storage Yeast Culture Room	29 – 32	2 – 0	50 – 60
Yeast Culture Room	--	--	80
Candy			
Chocolate Pan Supply Air	55 – 62	13 – 17	45 – 55
Enrober Room	80 – 85	27 – 29	25 – 30
Chocolate Cooling Tunnel Supply Air	40 – 45	4 – 7	70 – 85
Hand Dippers	62	17	45
Molded Goods Cooling	40 – 45	4 – 7	70 – 85
Chocolate Packing Room and Finished Stock Storage	65	18	50
Centers Tempering Room	75 – 80	24 – 27	30 – 35
Marshmallow Setting Room	75 – 78	24 – 26	40 – 45
Grained Marshmallow (deposited in starch) Drying	110	43	40
Gum (deposited in starch) Drying	125 – 150	52 – 66	15 – 25
Sanded Gum Drying	100	38	25 – 40
Gum Finished Stock Storage	50 – 65	10 – 18	65
Sugar Pan Supply Air (engrossing)	85 – 105	29 – 41	20 – 30
Polishing Pan Supply Air	70 – 80	21 – 27	40 – 50
Pan Rooms	75 – 80	24 – 27	30 – 35
Nonpareil Pan Supply Air	100 – 120	38 – 49	20
Hard Candy Cooling Tunnel Supply Air	60 – 70	16 – 21	40 – 55
Hard Candy Packing	70 – 75	21 – 24	35 – 40
Hand Candy Storage	50 – 70	10 – 21	40
Caramel Rooms	70 – 80	21 – 27	40
Ceramics			
Refractory	110 – 150	43 – 66	50 – 90
Molding Room	80	27	60 – 70
Clay Storage	60 – 80	16 – 27	35 – 65
Decalcomania Production and Decorating room	75 – 80	24 – 27	48
Cereal Packaging	75 – 80	24 – 27	45 – 50
Cheese Curing			
Cheddar	45 – 55	7 – 13	85 – 90
Swiss	60	16	80 – 85
Blue	48 – 50	9 – 10	95
Brick	60 – 65	16 – 18	90
Limburger	60 – 65	16 – 18	95
Camembert	53 – 59	12 – 15	90

Table 4: Design Indoor Conditions for Various Places, Products, and Processes (Continued)

Product and/or Process	Temperature		RH %
	°F	°C	
Clean Rooms – Computer Rooms			
Computer Room	70 – 80	21 – 27	40 – 60
Clean Room – General	70 – 74	21 – 23	40 – 60
Clean Room – Critical	71.5 – 72.5	22 – 22.5	43 – 47
Comfort Air Conditioners	75 – 80	24 – 27	50 – 60
Distilling			
Grain Storage	60	16	35 – 40
General Manufacturing	0 – 75	16 – 24	45 – 60
Aging	65 – 72	18 – 22	50 – 60
Electrical Products			
Coil and Transformer Winding	72	22	15
X-ray Tube Assembly	68	20	40
Instruments Manufacture and Laboratory	70	21	50 – 55
Thermostat and Humidistat Assembly and Calibration	76	24	50 – 55
Close Tolerance Assembly	72	22	40 – 45
Meter Assembly and Test	76	24	60 – 63
Fuse and Cutout Assembly, Capacitor Winding and Paper Storage	73	23	50
Conductor Wrapping with Yarn	75	24	65 – 70
Lightning Arrestor Assembly	68	20	20 – 40
Thermal Circuit Breaker Assembly	76	24	30 – 60
Runner Hopping	70	21	30 – 50
Processing Selenium and Copper Oxide Plates	74	23	30 – 40
Fruit Storage			
Apples	30 – 40	-1– 4	90
Apricots	31 – 32	-1 – 0	90 – 95
Grapefruits (California)	58 – 60	14 – 16	85 – 90
Grapefruits (Florida)	50	10	85 – 90
Grapes (Eastern)	31 – 32	-1 – 0	85
Grapes (Western)	30 – 31	-1	90 – 95
Lemons	58 – 60	14 – 16	86 – 88
Oranges (California)	40 – 44	4 – 7	85 – 90
Oranges (Florida)	32 – 34	0 – 1	85 – 90
Peaches and Nectarines	31	-1	90
Plums	30 – 32	-1 – 0	90 – 95
Specialty Citrus Fruit	38 – 40	3 – 4	90 – 95
Fur Storage	40 – 50	4 – 10	55 – 65
Gum			
Manufacture	77	25	33
Rolling	68	20	63
Stripping	72	22	53
Breaking	74	23	47
Wrapping	74	23	58
Hospitals			
Operating, Cystoscopic and Fracture Rooms	68 – 76	20 – 24	50
Patient Rooms	75	24	40 – 50
Intensive Care Unit	75	24	40
Administrative and Service Areas	70 – 80	21 – 27	30 – 50
Leather			
Drying	70 – 120	21 – 49	75
Storage, Winter Room Temperature	50 – 60	10 – 16	40 – 60
Lenses (Optical)			
Fusing	75	27	45
Grinding	80	27	80
Libraries and Museums			
Normal Reading and Viewing Rooms	70 – 74	21 – 23	40 – 50
Rare Manuscript Storage Vaults	70 – 72	21 – 22	45
Art Storage Areas	65 – 72	17 – 22	50

Table 4: Design Indoor Conditions for Various Places, Products, and Processes (Continued)

Product and/or Process	Temperature		RH %
	°F	°C	
Matches			
Manufacture	72 – 74	22 – 23	50
Drying	70 – 75	21 – 24	60
Storage	60 – 62	16 – 17	50
Meat and Fish			
Beef (Fresh)	32 –34	0 – 1	88 – 92
Beef, Fish, Lamb and Pork (Frozen)	-10 – 0	-23 – -18	90 – 95
Fish (Fresh)	33 – 35	1 – 3	90 – 95
Lamb and Pork (Fresh)	32 – 34	0 – 1	85 – 90
Mushrooms			
Sweating-out Period	120 – 140	49 – 60	–
Spawn Added	60 – 75	16 – 24	Nearly Sat.
Growing Period	48 – 60	9 – 16	80
Storage	32 – 35	0 – 2	80 – 85
Oil Paints: Paint Spraying	60 – 90	16 – 32	80
Pharmaceuticals			
Manufactured Powder Storage and Packaging Area	75	24	35
Milling Room, Table Compressing and Coating	75	24	35
Effervescent Tablets and Powders	75	24	20
Hypodermic Tablets	75	24	30
Colloids	70	21	30 – 50
Cough Drops	80	27	40
Glandular Products	76	24	5 – 10
Ampoule Manufacturing	75	24	35 – 50
Gelatin Capsules and Storage	76	24	35
Microanalysis	76	24	50
Biological Manufacturing and Liver Extracts	76	24	35
Serums	76	24	50
Animal Rooms	75 – 80	24 – 27	50
Plastics			
Manufacturing Areas Thermosetting	80	27	35 – 30
Molding Compounds	75 – 80	24 – 27	45 – 65
Plywood			
Hot Pressing (Resin)	90	32	60
Cold Pressing	90	32	15 – 25
Printing			
Platemaking	75 – 80	24 – 27	45 Max
Lithographic Press Room	76 – 80	24 – 27	43 – 47
Letterpress and Web Offset Press Rooms and Paper Storage	76 – 80	24 – 27	50
Paper Storage (Multicolor Sheet Feed Lithography)	76 – 80	24 – 27	5 – 8 (higher than press Room)
Raw Material Storage			
Nuts (insect)	45	7	65 – 75
Nuts (rancidity)	34 – 38	1 – 3	65 – 75
Eggs	30	-1	85 – 90
Chocolate (flats)	65	18	50
Butter	20	-7	
Dates, Figs, etc.	40 – 45	4 – 7	65 – 75
Corn Syrup	90 – 100	32 – 38	–
Liquid Sugar	75 – 80	24 – 27	30 – 40
Rubber Dipped Goods			
Cementing	80	27	25 – 30
Dipping Surgical Articles	75 – 90	24 – 32	25 – 30
Storage Prior to Manufacture	60 – 75	16 – 24	40 – 50
Laboratory (ASTM Standard)	73.4	23	50
Tea Packaging	65	18	65

Table 4: Design Indoor Conditions for Various Places, Products, and Processes (Continued)

Product and/or Process	Temperature °F	Temperature °C	RH %
Textiles			
Opening and Picking Cotton	75 – 80	24 – 27	55 – 70
Opening and Picking Man-Made	70 – 75	21 – 24	50 – 55
Carding Cotton	75 – 80	24 – 27	50 – 55
Carding Wool	75 – 80	24 – 27	60 – 70
Carding Man-Made	70 – 75	21 – 24	50 – 60
Silver and Ribbon Lapping Cotton	75 – 80	24 – 27	55 – 60
Silver and Ribbon Lapping Man-Made	70 – 75	21 – 24	55 – 65
Combing Cotton	75 – 80	24 – 27	55 – 65
Combing Wool	75 – 80	24 – 27	65 – 75
Combing Man-Made	70 – 75	21 – 24	55 – 65
Drawing Cotton and Wool	75 – 80	24 – 27	50 – 60
Drawing Man-Made	70 – 75	21 – 24	50 – 60
Roving Cotton	75 – 80	24 – 27	50 – 60
Roving Man-Made	70 – 75	21 – 24	50 – 60
Spinning Cotton	75 – 80	24 – 27	35 – 60
Spinning Wool	75 – 80	24 – 27	50 – 55
Spinning Man-Made	70 – 75	21 – 24	50 – 65
Winding and Spooling Cotton	75 – 80	24 – 27	55 – 65
Winding and Spooling Wool	75 – 80	24 – 27	55 – 60
Winding and Spooling Man-Made	70 – 75	21 – 24	60 – 65
Twisting Cotton	75 – 80	24 – 27	50 – 65
Twisting Man-Made	70 – 75	21 – 24	50 – 65
Warping Cotton	75 – 80	24 – 27	55 – 70
Warping Wool	75 – 80	24 – 27	50 – 65
Warping Man-Made	70 – 75	21 – 24	50 – 65
Knitting Cotton	76	24	60 – 65
Knitting Man-Made	76	24	50 – 60
Weaving Cotton	75 – 80	24 – 27	70 – 85
Weaving Wool	75 – 80	24 – 27	50 – 60
Weaving Man-Made	70 – 75	21 – 24	60 – 70
Tobacco			
Cigar and Cigarette Making	70 – 75	21 – 24	55 – 65
Softening	90	32	85 – 88
Stemming and Stripping	75 – 85	24 – 29	70 – 75
Filler Tobacco Casing and Conditioning	75	24	75
Filler Tobacco Storage and Preparation	78	26	70
Wrapper Tobacco Storage and Conditioning	75	24	75

Outdoor Air Conditions

The outdoor air conditions vary with geographic location and the time of year. For the purpose of calculating the humidification load the worst case condition is generally used. Table 6: Weather Data – Canada and Table 5: Weather Data - United States provide temperature and RH values for many US and Canadian cities taken from monthly weather data compiled by ASHRAE. The temperature value used is the 99% heating dry bulb temperature for the coldest month of the year. The relative humidity value is the average relative humidity of the driest month of the year.

To obtain the outdoor conditions find the city (or nearest city) where the humidification is required and read the RH and Temp values from the columns with the heading “Load Calculation”. Example; The outdoor air conditions that would be used for a humidification load calculation in the city of Calgary Alberta are 42% RH and -20ºF (-29ºC).

Table 5: Weather Data - United States

State	City	Load Calculation		Econimizer Calculation - Temperature F (C) and Relative Humidity in %											
		RH	Temp F (C)	J	F	M	A	M	J	J	A	S	O	N	D
AL	Birmingham	51%	15 (-10)	15 (-10)	21 (-6)	24 (-4)	40 (4)	48 (9)	56 (13)	62 (17)	62 (17)	52 (11)	41 (5)	25 (-4)	20 (-7)
				61%	55%	52%	51%	55%	56%	60%	59%	59%	54%	57%	60%
	Mobile	52%	24 (-5)	24 (-5)	29 (-2)	38 (3)	47 (8)	56 (13)	62 (17)	69 (20)	68 (20)	57 (14)	46 (8)	38 (3)	28 (-2)
				61%	56%	55%	52%	54%	55%	60%	61%	59%	53%	57%	61%
AK	Anchorage	49%	-11 (-24)	-11 (-24)	-5 (-21)	-1 (-18)	14 (-10)	30 (-1)	42 (6)	47 (8)	42 (6)	32 (0)	14 (-10)	-1 (-18)	-8 (-22)
				72%	67%	57%	53%	49%	56%	62%	64%	63%	66%	73%	76%
	Fairbanks	38%	-38 (-39)	-38 (-39)	-34 (-37)	-23 (-31)	0 (-18)	21 (-6)	42 (6)	46 (8)	39 (4)	22 (-6)	-2 (-19)	-24 (-31)	-36 (-38)
				69%	63%	53%	46%	38%	43%	50%	54%	55%	67%	73%	71%
AR	Little Rock	53%	15 (-10)	15 (-10)	16 (-9)	29 (-2)	41 (5)	52 (11)	59 (15)	65 (18)	63 (17)	52 (11)	42 (6)	31 (0)	18 (-8)
				61%	59%	56%	56%	58%	55%	56%	56%	58%	53%	58%	62%
CA	Bakersfield	22%	31 (-1)	31 (0)	36 (2)	40 (5)	44 (7)	49 (10)	57 (14)	63 (17)	62 (17)	56 (13)	44 (7)	38 (4)	31 (-1)
				63%	50%	43%	33%	26%	23%	22%	24%	28%	33%	49%	61%
	Fresno	22%	30 (-1)	30 (-1)	34 (1)	37 (3)	42 (5)	47 (8)	54 (12)	60 (15)	58 (15)	50 (10)	41 (5)	36 (2)	30 (-1)
				67%	55%	47%	34%	26%	23%	22%	25%	28%	35%	53%	68%
	Los Angeles	59%	37 (3)	37 (3)	43 (6)	44 (7)	48 (9)	52 (11)	56 (13)	58 (14)	60 (15)	57 (14)	52 (11)	45 (7)	42 (6)
				59%	63%	65%	64%	66%	67%	68%	69%	67%	65%	61%	59%
	Sacramento	28%	30 (-1)	32 (0)	34 (1)	37 (3)	41 (5)	45 (7)	50 (10)	55 (13)	56 (13)	51 (11)	45 (7)	37 (3)	30 (-1)
				70%	60%	54%	43%	35%	31%	28%	29%	31%	38%	57%	70%
	San Diego	56%	41 (5)	41 (5)	45 (7)	48 (9)	50 (10)	56 (13)	58 (15)	62 (17)	64 (18)	60 (16)	54 (12)	48 (9)	43 (6)
				56%	59%	60%	59%	64%	67%	66%	67%	65%	64%	61%	58%
	San Francisco	58%	33 (1)	35 (2)	37 (3)	40 (4)	41 (5)	45 (7)	49 (9)	50 (10)	51 (10)	49 (9)	45 (7)	38 (3)	33 (1)
				66%	65%	63%	59%	59%	58%	59%	61%	59%	59%	63%	67%
CO	Denver	34%	-3 (-19)	-2 (-19)	-3 (-19)	9 (-13)	18 (-8)	35 (2)	43 (6)	53 (12)	51 (11)	34 (1)	22 (-6)	11 (-12)	-2 (-19)
				49%	44%	40%	35%	38%	35%	34%	35%	34%	35%	49%	52%
	Grand Junction	19%	-2 (-19)	-2 (-19)	5 (-15)	20 (-7)	27 (-3)	39 (4)	48 (9)	56 (13)	55 (13)	43 (6)	32 (0)	16 (-9)	3 (-16)
				64%	48%	36%	28%	25%	19%	22%	24%	26%	33%	47%	60%
	Pueblo	28%	-5 (-21)	-5 (-21)	-4 (-20)	5 (-15)	21 (-6)	37 (3)	48 (9)	55 (13)	52 (11)	41 (5)	23 (-5)	6 (-15)	-3 (-19)
				51%	38%	34%	30%	32%	28%	32%	35%	32%	33%	47%	52%
CT	Bridgeport	54%	9 (-13)	9 (-13)	11 (-12)	19 (-7)	31 (-1)	43 (6)	52 (11)	59 (15)	57 (14)	49 (9)	39 (4)	29 (-2)	14 (-10)
				60%	58%	56%	54%	60%	61%	61%	62%	62%	59%	61%	61%
DE	Wilmington	50%	6 (-14)	6 (-14)	11 (-11)	20 (-7)	32 (0)	43 (6)	53 (12)	60 (15)	56 (14)	49 (10)	37 (3)	28 (-3)	12 (-11)
				60%	57%	52%	50%	53%	53%	54%	57%	56%	54%	56%	60%
DC	Washington	49%	13 (-11)	13 (-11)	19 (-7)	26 (-3)	37 (3)	47 (9)	59 (15)	65 (18)	62 (16)	53 (12)	42 (5)	31 (-1)	18 (-8)
				55%	52%	50%	49%	52%	52%	53%	55%	56%	53%	54%	57%
FL	Jacksonville	48%	26 (-3)	26 (-3)	33 (1)	38 (3)	46 (8)	56 (13)	60 (16)	68 (20)	69 (21)	61 (16)	50 (10)	38 (3)	29 (-2)
				58%	53%	50%	48%	50%	57%	58%	60%	62%	59%	56%	58%
	Miami	54%	47 (8)	47 (8)	48 (9)	50 (10)	59 (15)	65 (18)	70 (21)	75 (24)	74 (24)	74 (23)	64 (18)	55 (13)	48 (9)
				59%	57%	56%	54%	59%	65%	63%	64%	66%	63%	62%	59%
GA	Atlanta	49%	14 (-10)	14 (-10)	22 (-6)	28 (-2)	40 (5)	50 (10)	58 (15)	63 (17)	64 (18)	52 (11)	42 (6)	25 (-4)	20 (-7)
				59%	54%	51%	49%	53%	56%	60%	60%	59%	53%	55%	58%
	Augusta	45%	18 (-8)	18 (-8)	24 (-5)	29 (-2)	39 (4)	48 (9)	58 (15)	64 (18)	64 (18)	52 (11)	38 (3)	30 (-1)	22 (-6)
				54%	49%	48%	45%	49%	51%	54%	57%	55%	49%	50%	53%
	Savannah	46%	23 (-5)	23 (-5)	30 (-1)	36 (2)	45 (7)	53 (12)	62 (17)	69 (20)	67 (19)	57 (14)	44 (7)	34 (1)	27 (-3)
				55%	50%	48%	46%	51%	55%	57%	60%	60%	53%	52%	54%
HI	Honolulu	51%	61 (16)	61 (16)	61 (16)	63 (17)	65 (18)	67 (20)	71 (21)	72 (22)	73 (23)	72 (22)	69 (20)	66 (19)	63 (17)
				61%	59%	57%	55%	53%	52%	51%	52%	52%	55%	58%	60%
ID	Boise	22%	1 (-17)	4 (-15)	8 (-13)	21 (-6)	30 (-1)	35 (2)	44 (6)	48 (9)	47 (9)	38 (3)	27 (-3)	16 (-9)	1 (-17)
				70%	60%	45%	36%	34%	30%	22%	23%	29%	39%	60%	71%
	Lewiston	25%	5 (-15)	5 (-15)	10 (-12)	20 (-6)	32 (0)	37 (3)	46 (8)	52 (11)	52 (11)	41 (5)	31 (-1)	18 (-8)	5 (-15)
				70%	61%	49%	42%	39%	36%	25%	25%	31%	48%	68%	73%
IL	Chicago	54%	-5 (-21)	-5 (-21)	2 (-17)	12 (-11)	25 (-4)	38 (3)	49 (9)	53 (12)	53 (12)	43 (6)	32 (0)	18 (-8)	-1 (-18)
				67%	65%	61%	55%	54%	55%	57%	57%	57%	56%	64%	70%
	Peoria	56%	-4 (-20)	-4 (-20)	2 (-17)	12 (-11)	29 (-1)	40 (4)	52 (11)	58 (15)	54 (12)	43 (6)	33 (1)	17 (-8)	0 (-18)
				69%	67%	63%	56%	56%	56%	59%	60%	59%	57%	67%	72%
	Springfield	54%	-1 (-18)	-1 (-18)	1 (-17)	12 (-11)	33 (0)	42 (6)	53 (12)	59 (15)	55 (13)	46 (8)	33 (0)	18 (-8)	2 (-16)
				68%	68%	64%	56%	54%	54%	58%	60%	56%	54%	65%	72%
IN	Fort Wayne	54%	-1 (-19)	-1 (-19)	2 (-17)	11 (-11)	25 (-4)	40 (4)	51 (10)	56 (13)	51 (11)	44 (6)	33 (0)	18 (-8)	4 (-16)
				71%	69%	64%	57%	54%	54%	56%	58%	58%	58%	68%	74%
	Indianapolis	56%	0 (-18)	0 (-18)	2 (-17)	14 (-10)	31 (-1)	42 (5)	51 (11)	57 (14)	54 (12)	44 (7)	32 (0)	18 (-8)	2 (-17)
				70%	67%	62%	56%	56%	56%	60%	61%	58%	57%	67%	72%
	South bend	54%	-1 (-18)	-1 (-18)	3 (-16)	10 (-12)	27 (-3)	38 (4)	49 (9)	56 (13)	53 (11)	43 (6)	33 (1)	15 (-9)	5 (-15)
				72%	69%	62%	57%	54%	55%	57%	59%	60%	60%	69%	76%
IA	Des Moines	55%	-5 (-20)	-5 (-20)	0 (-18)	5 (-15)	27 (-3)	43 (6)	52 (11)	59 (15)	54 (12)	42 (6)	30 (-1)	15 (-9)	-1 (-18)
				67%	65%	61%	55%	55%	56%	58%	58%	59%	55%	64%	69%
	Sioux city	52%	-7 (-22)	-7 (-22)	-4 (-20)	4 (-16)	20 (-7)	40 (4)	51 (10)	55 (13)	52 (11)	40 (4)	28 (-2)	11 (-12)	-4 (-20)
				68%	67%	63%	52%	54%	57%	59%	61%	58%	54%	64%	71%

Table 5: Weather Data - United States (Continued)

State	City	Load Calculation		Econimizer Calculation - Temperature F (C) and Relative Humidity in %											
		RH	Temp F (C)	J	F	M	A	M	J	J	A	S	O	N	D
KS	Dodge City	44%	2 (-17)	5 (-15)	6 (-15)	10 (-12)	30 (-1)	41 (5)	53 (12)	59 (15)	58 (15)	45 (7)	31 (0)	18 (-8)	2 (-17)
				58%	56%	50%	46%	51%	48%	44%	47%	48%	46%	53%	58%
	Topeka	54%	0 (-18)	0 (-18)	1 (-17)	15 (-10)	28 (-2)	42 (5)	55 (13)	57 (14)	55 (13)	44 (7)	33 (1)	19 (-7)	0 (-18)
				64%	62%	57%	55%	58%	60%	59%	58%	57%	54%	61%	65%
KY	Louisville	52%	4 (-16)	4 (-16)	6 (-15)	20 (-7)	36 (2)	45 (7)	54 (12)	61 (16)	58 (14)	48 (9)	36 (2)	20 (-7)	9 (-13)
				64%	61%	57%	52%	55%	56%	58%	58%	59%	55%	61%	65%
LA	New Orleans	59%	30 (-1)	30 (-1)	34 (1)	40 (5)	47 (8)	55 (13)	62 (17)	69 (20)	68 (20)	58 (14)	49 (9)	40 (4)	30 (-1)
				66%	63%	60%	59%	60%	63%	66%	66%	65%	59%	61%	66%
	Shreveport	54%	21 (-6)	21 (-6)	27 (-3)	35 (2)	45 (7)	54 (12)	63 (17)	67 (20)	64 (18)	56 (13)	43 (6)	33 (0)	23 (-5)
				63%	59%	56%	57%	59%	58%	57%	55%	57%	54%	58%	62%
ME	Portland	55%	-11 (-24)	-5 (-21)	-11 (-24)	4 (-16)	23 (-5)	35 (2)	45 (7)	51 (11)	47 (8)	38 (3)	29 (-2)	19 (-7)	0 (-18)
				60%	58%	57%	55%	58%	60%	59%	59%	60%	59%	62%	61%
MD	Baltimore	49%	10 (-12)	10 (-12)	13 (-10)	22 (-6)	33 (1)	44 (7)	53 (12)	60 (16)	57 (14)	49 (9)	37 (3)	27 (-3)	16 (-9)
				57%	54%	51%	49%	52%	52%	53%	55%	55%	54%	55%	58%
MA	Boston	55%	7 (-14)	7 (-14)	12 (-11)	21 (-6)	30 (-1)	44 (7)	54 (12)	60 (15)	58 (14)	49 (10)	39 (4)	29 (-2)	12 (-11)
				57%	56%	57%	55%	59%	58%	57%	59%	60%	58%	59%	59%
MI	Detroit	53%	-1 (-18)	-1 (-18)	3 (-16)	14 (-10)	25 (-4)	38 (3)	48 (9)	53 (12)	51 (10)	43 (6)	31 (-1)	23 (-5)	8 (-14)
				69%	65%	61%	55%	53%	54%	54%	56%	57%	57%	65%	71%
	Grand Rapids	53%	-1 (-18)	-1 (-18)	0 (-18)	11 (-12)	21 (-6)	36 (2)	46 (8)	53 (12)	51 (10)	40 (5)	31 (-1)	20 (-7)	3 (-16)
				72%	68%	64%	57%	53%	55%	56%	58%	61%	62%	70%	75%
MN	Duluth	53%	-19 (-28)	-19 (-28)	-13 (-25)	-5 (-20)	14 (-10)	30 (-1)	40 (4)	47 (8)	45 (7)	35 (2)	24 (-5)	1 (-17)	-13 (-25)
				70%	65%	63%	56%	53%	60%	59%	63%	64%	62%	70%	74%
	Minneapolis-St.P	52%	-14 (-25)	-14 (-25)	-7 (-22)	-3 (-19)	21 (-6)	35 (2)	48 (9)	55 (13)	52 (11)	40 (5)	29 (-2)	6 (-14)	-7 (-22)
				67%	65%	61%	52%	52%	54%	54%	57%	59%	58%	66%	70%
MS	Jackson	53%	19 (-7)	19 (-7)	25 (-4)	32 (0)	41 (5)	51 (11)	59 (15)	63 (17)	64 (18)	51 (11)	40 (5)	32 (0)	22 (-6)
				65%	60%	56%	54%	56%	56%	59%	58%	58%	53%	57%	63%
MO	Kansas City	55%	1 (-17)	2 (-17)	3 (-16)	13 (-10)	30 (-1)	44 (7)	55 (13)	62 (17)	56 (14)	47 (8)	33 (1)	19 (-7)	1 (-17)
				64%	64%	59%	56%	59%	59%	58%	59%	59%	55%	62%	65%
	St. Louis	54%	3 (-16)	3 (-16)	10 (-12)	17 (-8)	36 (2)	46 (8)	56 (14)	63 (17)	59 (15)	50 (10)	38 (3)	21 (-6)	7 (-14)
				66%	63%	59%	54%	55%	55%	56%	56%	58%	55%	63%	68%
MT	Billings	30%	-7 (-22)	-6 (-21)	-7 (-22)	5 (-15)	17 (-9)	31 (-1)	44 (7)	52 (11)	48 (9)	36 (2)	17 (-8)	4 (-16)	-6 (-21)
				56%	51%	46%	41%	42%	39%	31%	30%	37%	41%	53%	56%
	Great Falls	31%	-12 (-25)	-11 (-24)	-7 (-22)	-1 (-18)	15 (-9)	30 (-1)	42 (5)	49 (9)	43 (6)	34 (1)	14 (-10)	2 (-17)	-12 (-25)
				60%	54%	49%	41%	41%	40%	31%	31%	38%	43%	55%	60%
NE	North Platte	46%	-9 (-23)	-5 (-21)	-2 (-19)	3 (-16)	22 (-5)	34 (1)	44 (6)	52 (11)	48 (9)	34 (1)	24 (-5)	6 (-14)	-9 (-23)
				63%	59%	53%	47%	51%	52%	50%	51%	48%	46%	55%	61%
	Omaha	52%	-4 (-20)	-4 (-20)	0 (-18)	8 (-13)	24 (-4)	41 (5)	51 (11)	57 (14)	55 (13)	41 (5)	29 (-2)	12 (-11)	-2 (-19)
				65%	63%	57%	52%	54%	55%	58%	59%	59%	55%	62%	67%
NV	Las Vegas	11%	23 (-5)	23 (-5)	29 (-1)	35 (2)	43 (6)	52 (11)	61 (16)	70 (21)	67 (20)	58 (15)	42 (6)	34 (1)	24 (-4)
				31%	27%	22%	16%	14%	11%	15%	17%	17%	19%	26%	32%
	Reno	18%	4 (-16)	4 (-15)	6 (-14)	16 (-9)	25 (-4)	31 (-1)	38 (3)	44 (7)	39 (4)	33 (0)	22 (-5)	16 (-9)	4 (-16)
				51%	40%	33%	27%	25%	22%	18%	19%	21%	27%	41%	51%
NH	Concord	47%	-11 (-24)	-11 (-24)	-11 (-24)	5 (-15)	22 (-6)	33 (1)	43 (6)	48 (9)	44 (7)	36 (2)	24 (-4)	13 (-11)	-2 (-19)
				58%	55%	52%	47%	47%	52%	51%	53%	55%	53%	59%	61%
NJ	Atlantic City	52%	8 (-14)	8 (-14)	8 (-13)	20 (-7)	28 (-2)	39 (4)	50 (10)	55 (13)	54 (12)	46 (8)	34 (1)	25 (-4)	12 (-11)
				58%	56%	54%	52%	56%	56%	57%	58%	58%	56%	58%	58%
	Newark	48%	10 (-12)	10 (-12)	11 (-12)	22 (-6)	31 (0)	45 (7)	55 (13)	62 (17)	58 (15)	49 (10)	40 (5)	29 (-2)	16 (-9)
				58%	54%	51%	48%	51%	51%	51%	53%	55%	53%	56%	59%
NM	Albuquerque	18%	4 (-15)	4 (-15)	13 (-11)	22 (-6)	31 (0)	40 (5)	51 (11)	60 (16)	58 (15)	48 (9)	34 (1)	14 (-10)	10 (-12)
				41%	33%	25%	19%	19%	18%	27%	31%	30%	29%	36%	44%
NY	Albany	49%	-7 (-21)	-7 (-21)	-2 (-19)	4 (-16)	25 (-4)	38 (3)	47 (9)	52 (11)	48 (9)	39 (4)	29 (-2)	20 (-7)	0 (-18)
				63%	58%	53%	49%	52%	56%	55%	58%	59%	57%	62%	65%
	Buffalo	55%	1 (-17)	3 (-16)	1 (-17)	11 (-11)	26 (-3)	39 (4)	48 (9)	54 (12)	51 (11)	45 (7)	33 (1)	23 (-5)	8 (-13)
				72%	70%	65%	58%	55%	56%	55%	58%	60%	60%	69%	73%
	New York	55%	13 (-10)	13 (-10)	14 (-10)	23 (-5)	33 (1)	45 (7)	55 (13)	64 (18)	59 (15)	52 (11)	39 (4)	32 (0)	18 (-8)
				59%	57%	56%	55%	59%	60%	59%	60%	60%	56%	59%	60%
	Rochester	54%	1 (-17)	2 (-17)	1 (-17)	12 (-11)	26 (-3)	38 (3)	47 (8)	53 (12)	49 (9)	42 (5)	33 (0)	21 (-6)	5 (-15)
				69%	67%	62%	56%	54%	55%	54%	58%	61%	61%	68%	72%
	Syracuse	53%	-4 (-20)	-4 (-20)	-3 (-20)	7 (-14)	24 (-4)	38 (3)	46 (8)	54 (12)	51 (10)	42 (5)	32 (0)	21 (-6)	2 (-17)
				68%	65%	60%	53%	55%	56%	56%	59%	62%	61%	67%	71%
NC	Asheville	50%	6 (-14)	6 (-14)	15 (-10)	21 (-6)	34 (1)	41 (5)	49 (9)	55 (13)	54 (12)	45 (7)	34 (1)	24 (-5)	13 (-11)
				59%	55%	53%	50%	57%	59%	62%	63%	63%	56%	57%	59%
	Raleigh	45%	12 (-11)	12 (-11)	20 (-7)	27 (-3)	37 (3)	45 (7)	53 (12)	60 (16)	59 (15)	51 (11)	36 (2)	27 (-3)	20 (-7)
				55%	52%	49%	45%	54%	56%	58%	60%	58%	53%	52%	55%
ND	Bismarck	46%	-21 (-29)	-21 (-29)	-15 (-26)	-5 (-20)	12 (-11)	31 (-1)	43 (6)	48 (9)	45 (7)	29 (-2)	13 (-10)	-4 (-20)	-18 (-28)
				68%	68%	62%	51%	48%	52%	47%	46%	50%	51%	65%	71%

Table 5: Weather Data - United States (Continued)

State	City	Load Calculation		Econimizer Calculation - Temperature F (C) and Relative Humidity in %											
		RH	Temp F (C)	J	F	M	A	M	J	J	A	S	O	N	D
OH	Cleveland	57%	1 (-17)	1 (-17)	4 (-15)	14 (-10)	26 (-4)	38 (3)	46 (8)	53 (12)	51 (11)	45 (7)	33 (1)	21 (-6)	7 (-14)
				69%	68%	63%	57%	57%	57%	57%	60%	60%	59%	65%	70%
	Columbus	53%	2 (-17)	2 (-17)	6 (-14)	15 (-10)	29 (-2)	40 (4)	49 (9)	55 (13)	52 (11)	45 (7)	33 (1)	22 (-6)	6 (-15)
				67%	64%	57%	53%	55%	55%	56%	58%	57%	55%	63%	69%
	Greater Cincinna	54%	-1 (-18)	-1 (-18)	8 (-13)	13 (-11)	32 (0)	41 (5)	52 (11)	58 (14)	55 (13)	46 (8)	32 (0)	20 (-7)	5 (-15)
				68%	64%	59%	54%	55%	56%	57%	58%	58%	55%	63%	69%
	Toledo	52%	-1 (-18)	-1 (-18)	4 (-16)	12 (-11)	24 (-4)	38 (3)	46 (8)	52 (11)	48 (9)	41 (5)	30 (-1)	19 (-7)	3 (-16)
				70%	66%	61%	55%	52%	54%	55%	58%	58%	57%	66%	73%
OK	Oklahoma City	50%	12 (-11)	13 (-11)	15 (-9)	23 (-5)	36 (2)	49 (10)	59 (15)	64 (18)	62 (17)	51 (11)	35 (2)	27 (-3)	12 (-11)
				60%	58%	53%	52%	58%	56%	50%	50%	55%	52%	56%	58%
OR	Portland	45%	18 (-8)	18 (-8)	19 (-7)	31 (-1)	37 (3)	40 (4)	48 (9)	52 (11)	52 (11)	45 (7)	37 (3)	28 (-2)	22 (-5)
				75%	67%	60%	55%	53%	49%	45%	46%	48%	62%	74%	78%
PA	Harrisburg	49%	8 (-13)	8 (-13)	11 (-12)	21 (-6)	32 (0)	43 (6)	52 (11)	59 (15)	57 (14)	45 (7)	36 (2)	27 (-3)	11 (-12)
				58%	55%	52%	49%	52%	53%	52%	55%	56%	54%	57%	58%
	Philadelphia	49%	10 (-12)	10 (-12)	12 (-11)	22 (-6)	33 (0)	42 (6)	55 (13)	61 (16)	57 (14)	49 (9)	38 (3)	28 (-2)	17 (-9)
				59%	55%	52%	49%	52%	53%	54%	55%	56%	54%	56%	59%
	Pittsburgh	50%	2 (-17)	2 (-17)	6 (-14)	16 (-9)	28 (-2)	39 (4)	47 (9)	54 (12)	52 (11)	44 (7)	31 (0)	19 (-7)	8 (-13)
				65%	62%	57%	50%	52%	52%	54%	56%	57%	54%	62%	67%
	Williamsport	49%	2 (-17)	2 (-17)	5 (-15)	16 (-9)	29 (-2)	40 (4)	48 (9)	54 (12)	51 (11)	43 (6)	33 (0)	23 (-5)	6 (-14)
				62%	58%	54%	49%	51%	54%	55%	58%	59%	57%	61%	63%
RI	Providence	49%	5 (-15)	5 (-15)	9 (-13)	17 (-8)	28 (-2)	40 (5)	51 (11)	58 (14)	53 (12)	45 (7)	34 (1)	22 (-5)	9 (-13)
				56%	54%	53%	49%	52%	56%	56%	56%	56%	54%	57%	58%
SC	Charleston	49%	24 (-5)	24 (-5)	28 (-2)	33 (1)	43 (6)	51 (11)	62 (16)	67 (20)	66 (19)	57 (14)	44 (6)	33 (1)	26 (-3)
				56%	52%	51%	49%	53%	58%	62%	63%	62%	55%	53%	55%
	Columbia	43%	18 (-8)	18 (-8)	22 (-6)	25 (-4)	40 (4)	48 (9)	57 (14)	64 (18)	63 (17)	54 (12)	39 (4)	29 (-2)	21 (-6)
				54%	49%	48%	43%	49%	51%	54%	57%	56%	51%	51%	53%
SD	Rapid City	37%	-7 (-21)	-6 (-21)	-2 (-19)	5 (-15)	19 (-7)	32 (0)	43 (6)	51 (10)	49 (9)	34 (1)	18 (-8)	4 (-16)	-7 (-21)
				63%	61%	54%	46%	47%	48%	41%	37%	38%	45%	59%	64%
	Sioux Falls	53%	-14 (-26)	-14 (-26)	-9 (-23)	2 (-17)	22 (-6)	33 (1)	47 (8)	52 (11)	49 (9)	37 (3)	25 (-4)	5 (-15)	-8 (-22)
				68%	68%	64%	54%	53%	55%	54%	55%	57%	55%	66%	71%
TN	Knoxville	51%	3 (-16)	3 (-16)	16 (-9)	21 (-6)	35 (2)	45 (7)	54 (12)	60 (15)	59 (15)	50 (10)	38 (3)	23 (-5)	14 (-10)
				63%	59%	55%	51%	57%	59%	61%	61%	60%	55%	59%	64%
	Memphis	51%	13 (-11)	15 (-9)	14 (-10)	30 (-1)	43 (6)	52 (11)	60 (16)	64 (18)	62 (16)	52 (11)	40 (5)	28 (-2)	13 (-11)
				63%	60%	56%	53%	55%	56%	57%	57%	56%	51%	56%	61%
	Nashville	51%	7 (-14)	7 (-14)	10 (-12)	23 (-5)	37 (3)	47 (9)	55 (13)	62 (17)	59 (15)	51 (10)	39 (4)	21 (-6)	12 (-11)
				63%	59%	53%	51%	56%	55%	57%	57%	58%	53%	59%	63%
TX	Amarillo	38%	7 (-14)	7 (-14)	8 (-13)	17 (-8)	30 (-1)	42 (5)	53 (12)	60 (16)	58 (15)	45 (7)	30 (-1)	18 (-8)	10 (-12)
				51%	50%	42%	38%	43%	45%	42%	47%	49%	43%	47%	49%
	Corpus Christi	57%	32 (0)	32 (0)	35 (2)	42 (5)	50 (10)	60 (16)	68 (20)	71 (22)	72 (22)	63 (17)	48 (9)	44 (7)	33 (0)
				69%	65%	61%	63%	66%	63%	57%	58%	61%	59%	61%	64%
	Dallas-Fort Worth	49%	20 (-7)	20 (-6)	24 (-4)	32 (0)	44 (7)	54 (12)	63 (17)	69 (20)	67 (19)	57 (14)	44 (7)	35 (1)	20 (-7)
				60%	58%	56%	56%	60%	55%	49%	49%	55%	54%	57%	59%
	El Paso	16%	13 (-11)	13 (-11)	23 (-5)	29 (-2)	38 (3)	46 (8)	57 (14)	65 (18)	63 (17)	53 (12)	39 (4)	22 (-6)	20 (-7)
				35%	27%	21%	16%	17%	18%	30%	33%	34%	30%	32%	38%
	Houston	56%	27 (-3)	28 (-2)	33 (1)	38 (3)	47 (8)	56 (13)	63 (17)	69 (21)	68 (20)	60 (16)	45 (7)	36 (2)	27 (-3)
				64%	61%	59%	58%	60%	60%	57%	57%	60%	56%	60%	62%
	San Antonio	51%	21 (-6)	21 (-6)	26 (-4)	36 (2)	47 (8)	56 (14)	65 (18)	71 (21)	70 (21)	57 (14)	45 (7)	37 (3)	25 (-4)
				59%	57%	53%	56%	59%	56%	52%	51%	54%	53%	55%	57%
UT	Salt Lake City	22%	-1 (-18)	1 (-17)	-1 (-18)	19 (-7)	28 (-2)	37 (3)	47 (8)	54 (12)	51 (11)	41 (5)	30 (-1)	10 (-12)	2 (-17)
				70%	60%	47%	39%	33%	26%	22%	23%	29%	41%	59%	71%
VT	Burlington	51%	-9 (-23)	-9 (-23)	-9 (-23)	3 (-16)	20 (-7)	37 (3)	46 (8)	51 (11)	48 (9)	39 (4)	29 (-2)	16 (-9)	-3 (-20)
				64%	62%	58%	53%	51%	55%	53%	57%	61%	61%	66%	68%
VA	Richmond	46%	9 (-13)	9 (-13)	11 (-12)	26 (-4)	36 (2)	45 (7)	53 (12)	61 (16)	58 (15)	49 (9)	36 (2)	26 (-3)	16 (-9)
				57%	53%	49%	46%	51%	53%	56%	57%	56%	53%	51%	55%
WA	Seattle	49%	20 (-7)	20 (-7)	21 (-6)	27 (-3)	37 (3)	39 (4)	47 (8)	51 (11)	52 (11)	45 (7)	39 (4)	25 (-4)	23 (-5)
				74%	67%	62%	58%	54%	53%	49%	50%	56%	67%	75%	78%
	Spokane	28%	0 (-18)	1 (-17)	6 (-14)	13 (-10)	28 (-2)	35 (2)	43 (6)	48 (9)	47 (8)	37 (3)	25 (-4)	6 (-15)	0 (-18)
				79%	69%	55%	44%	41%	36%	28%	28%	34%	48%	76%	83%
WV	Charleston	47%	6 (-14)	6 (-14)	12 (-11)	20 (-7)	33 (0)	41 (5)	48 (9)	57 (14)	54 (12)	47 (8)	33 (0)	23 (-5)	10 (-12)
				63%	59%	53%	47%	51%	54%	59%	58%	56%	54%	56%	62%
WI	Green Bay	54%	-11 (-24)	-11 (-24)	-6 (-21)	-2 (-19)	22 (-5)	34 (1)	45 (7)	51 (11)	49 (10)	38 (4)	29 (-2)	11 (-12)	-5 (-21)
				70%	68%	65%	58%	54%	57%	58%	61%	62%	62%	69%	73%
	Milwaukee	60%	-5 (-21)	-5 (-21)	0 (-18)	10 (-12)	26 (-3)	35 (2)	46 (8)	53 (12)	54 (12)	42 (6)	32 (0)	15 (-10)	1 (-17)
				68%	67%	65%	61%	60%	60%	61%	62%	63%	62%	67%	71%
WY	Cheyenne	38%	-6 (-21)	-5 (-21)	-6 (-21)	3 (-16)	13 (-11)	30 (-1)	39 (4)	48 (9)	46 (8)	28 (-2)	18 (-8)	6 (-15)	-4 (-20)
				50%	48%	47%	42%	44%	41%	38%	38%	38%	41%	51%	53%

Table 6: Weather Data – Canada

Prov	City	Load Calculation		Econimizer Calculation - Temperature F (C) and Relative Humidity in %											
		RH	Temp F (C)	J	F	M	A	M	J	J	A	S	O	N	D
AB	Calgary	42%	-20 (-29)	-20 (-29)	-18 (-28)	-7 (-22)	5 (-15)	22 (-6)	38 (3)	42 (6)	40 (4)	25 (-4)	10 (-12)	-6 (-21)	-17 (-27)
				59%	57%	55%	43%	42%	44%	44%	43%	45%	43%	56%	60%
AB	Edmonton	40%	-23 (-30)	-21 (-30)	-20 (-29)	-6 (-21)	10 (-12)	28 (-2)	42 (6)	45 (7)	44 (7)	29 (-2)	12 (-11)	-4 (-20)	-23 (-30)
				69%	66%	61%	44%	40%	46%	51%	52%	52%	49%	65%	70%
AB	Red Deer	43%	-25 (-32)	-25 (-32)	-20 (-29)	-14 (-26)	2 (-17)	22 (-5)	36 (2)	42 (6)	39 (4)	26 (-3)	8 (-13)	-11 (-24)	-22 (-30)
				68%	67%	63%	47%	43%	48%	51%	51%	51%	47%	64%	69%
BC	Kelowna	37%	-5 (-20)	-2 (-19)	6 (-15)	14 (-10)	26 (-3)	35 (2)	41 (5)	45 (7)	43 (6)	33 (1)	20 (-6)	6 (-15)	-5 (-20)
				78%	70%	51%	40%	40%	40%	37%	38%	46%	55%	72%	79%
BC	Prince George	42%	-24 (-31)	-24 (-31)	-16 (-27)	-5 (-21)	10 (-12)	29 (-2)	37 (3)	40 (4)	37 (3)	26 (-3)	10 (-12)	-10 (-23)	-18 (-28)
				75%	68%	55%	42%	43%	46%	47%	49%	55%	61%	76%	79%
BC	Prince Rupert	69%	10 (-12)	10 (-12)	17 (-8)	19 (-7)	29 (-2)	37 (3)	42 (5)	45 (7)	46 (8)	39 (4)	28 (-2)	16 (-9)	12 (-11)
				78%	73%	71%	69%	71%	76%	78%	80%	77%	78%	78%	80%
BC	Victoria	58%	20 (-7)	20 (-7)	22 (-6)	27 (-3)	34 (1)	39 (4)	44 (7)	47 (9)	48 (9)	41 (5)	35 (2)	24 (-4)	22 (-6)
				80%	73%	67%	62%	61%	60%	58%	59%	62%	71%	78%	82%
MB	The Pas	49%	-32 (-35)	-30 (-35)	-32 (-35)	-16 (-27)	2 (-17)	25 (-4)	39 (4)	46 (8)	44 (7)	32 (0)	19 (-7)	-8 (-22)	-26 (-32)
				69%	66%	61%	54%	49%	51%	54%	54%	59%	64%	73%	73%
MB	Winnipeg	45%	-25 (-32)	-25 (-32)	-25 (-32)	-11 (-24)	8 (-13)	28 (-2)	40 (5)	47 (8)	45 (7)	33 (1)	19 (-7)	-5 (-20)	-17 (-27)
				75%	75%	72%	54%	45%	50%	52%	50%	53%	56%	72%	77%
NB	Fredericton	51%	-13 (-25)	-12 (-24)	-13 (-25)	1 (-17)	20 (-7)	32 (0)	42 (6)	47 (8)	46 (8)	36 (2)	27 (-3)	14 (-10)	-7 (-22)
				64%	60%	57%	54%	51%	53%	55%	56%	58%	59%	67%	68%
NB	Moncton	57%	-7 (-22)	-7 (-22)	-7 (-21)	2 (-17)	18 (-8)	32 (0)	40 (4)	47 (8)	45 (7)	37 (3)	27 (-3)	16 (-9)	-2 (-19)
				70%	67%	65%	62%	57%	58%	59%	60%	61%	63%	71%	74%
NB	St John	61%	-11 (-24)	-7 (-22)	-11 (-24)	0 (-18)	18 (-8)	30 (-1)	40 (4)	45 (7)	44 (7)	35 (2)	27 (-3)	17 (-8)	-6 (-21)
				68%	65%	64%	61%	61%	64%	67%	66%	65%	66%	71%	72%
NL	Churchill Falls	57%	-31 (-35)	-30 (-34)	-31 (-35)	-18 (-28)	-3 (-19)	12 (-11)	33 (0)	42 (6)	40 (4)	30 (-1)	13 (-11)	-5 (-21)	-24 (-31)
				76%	73%	71%	68%	60%	57%	58%	60%	67%	75%	80%	78%
NL	Gander	61%	-5 (-20)	0 (-18)	-5 (-20)	1 (-17)	17 (-8)	27 (-3)	37 (3)	44 (7)	43 (6)	38 (4)	29 (-1)	20 (-7)	4 (-16)
				74%	70%	70%	69%	63%	61%	61%	63%	66%	70%	76%	78%
NL	St Johns	69%	5 (-15)	6 (-14)	5 (-15)	7 (-14)	19 (-7)	29 (-2)	36 (2)	42 (6)	44 (7)	40 (4)	32 (0)	23 (-5)	12 (-11)
				80%	78%	77%	76%	73%	70%	69%	71%	72%	76%	80%	81%
NT	Yellowknife	45%	-41 (-41)	-41 (-41)	-39 (-39)	-27 (-33)	-13 (-25)	13 (-10)	37 (3)	45 (7)	42 (6)	28 (-2)	4 (-15)	-23 (-31)	-35 (-37)
				67%	65%	59%	57%	48%	45%	48%	54%	62%	76%	78%	71%
NS	Halifax	62%	1 (-17)	2 (-17)	1 (-17)	8 (-13)	25 (-4)	34 (1)	43 (6)	51 (11)	50 (10)	41 (5)	32 (0)	22 (-6)	7 (-14)
				76%	73%	69%	65%	62%	63%	64%	64%	64%	67%	75%	77%
NS	Syndey	66%	1 (-17)	3 (-16)	1 (-17)	6 (-14)	20 (-7)	29 (-2)	37 (3)	47 (8)	48 (9)	40 (4)	33 (0)	23 (-5)	12 (-11)
				76%	73%	74%	73%	68%	67%	67%	66%	69%	71%	77%	78%
ON	Hamilton	57%	0 (-18)	0 (-18)	2 (-17)	10 (-12)	24 (-5)	37 (3)	47 (8)	53 (11)	48 (9)	41 (5)	31 (0)	22 (-5)	4 (-16)
				74%	72%	68%	58%	57%	57%	57%	60%	63%	67%	73%	77%
ON	London	55%	-4 (-20)	-4 (-20)	-2 (-19)	7 (-14)	24 (-5)	35 (2)	44 (7)	51 (11)	47 (9)	40 (4)	28 (-2)	17 (-8)	3 (-16)
				77%	74%	70%	59%	55%	57%	56%	59%	62%	65%	74%	79%
ON	Ottawa	49%	-12 (-24)	-12 (-24)	-11 (-24)	0 (-18)	19 (-7)	35 (2)	45 (7)	52 (11)	49 (9)	39 (4)	30 (-1)	12 (-11)	-10 (-23)
				66%	61%	58%	50%	49%	52%	52%	55%	59%	60%	69%	72%
ON	Sudbury	48%	-18 (-28)	-18 (-28)	-16 (-26)	-3 (-19)	13 (-11)	32 (0)	42 (5)	50 (10)	44 (7)	36 (2)	27 (-3)	7 (-14)	-11 (-24)
				71%	67%	62%	54%	48%	51%	51%	56%	60%	64%	74%	75%
ON	Thunder Bay	51%	-22 (-30)	-22 (-30)	-20 (-29)	-9 (-23)	11 (-12)	28 (-2)	38 (3)	44 (7)	42 (6)	31 (0)	22 (-6)	0 (-18)	-15 (-26)
				63%	61%	59%	51%	51%	57%	58%	60%	62%	62%	66%	67%
ON	Toronto	53%	-4 (-20)	-4 (-20)	-4 (-20)	3 (-16)	19 (-7)	34 (1)	44 (7)	50 (10)	47 (8)	39 (4)	30 (-1)	17 (-8)	-1 (-18)
				75%	72%	68%	57%	54%	55%	53%	56%	60%	63%	73%	77%
ON	Windsor	52%	2 (-17)	2 (-17)	6 (-14)	14 (-10)	28 (-2)	39 (4)	49 (10)	54 (12)	53 (12)	44 (7)	35 (2)	21 (-6)	8 (-13)
				71%	69%	64%	55%	52%	54%	55%	58%	59%	59%	68%	74%
PE	Charlottetown	63%	-4 (-20)	-4 (-20)	-2 (-19)	6 (-15)	21 (-6)	31 (0)	41 (5)	50 (10)	48 (9)	41 (5)	32 (0)	20 (-7)	1 (-17)
				76%	74%	74%	69%	63%	65%	66%	66%	66%	69%	76%	79%
QC	Mont Joli	60%	-11 (-24)	-11 (-24)	-8 (-22)	-1 (-18)	18 (-8)	26 (-3)	41 (5)	46 (8)	46 (8)	35 (2)	29 (-2)	14 (-10)	-4 (-20)
				73%	72%	70%	67%	60%	62%	64%	66%	68%	69%	74%	76%
QC	Montreal	52%	-13 (-25)	-13 (-25)	-9 (-23)	1 (-17)	21 (-6)	37 (3)	46 (8)	53 (12)	50 (10)	40 (5)	31 (-1)	15 (-10)	-5 (-21)
				69%	66%	61%	55%	52%	56%	55%	58%	60%	62%	70%	72%
QC	Quebec	50%	-13 (-25)	-13 (-25)	-13 (-25)	-1 (-19)	16 (-9)	31 (0)	43 (6)	48 (9)	46 (8)	36 (2)	27 (-3)	9 (-13)	-7 (-22)
				67%	64%	61%	55%	50%	55%	57%	59%	61%	62%	70%	72%
QC	Sept-Iles	64%	-23 (-31)	-23 (-31)	-17 (-27)	-5 (-21)	8 (-13)	25 (-4)	38 (3)	45 (7)	42 (6)	32 (0)	22 (-6)	2 (-17)	-13 (-25)
				67%	64%	66%	68%	65%	67%	70%	70%	70%	69%	71%	70%
QC	Sherbrooke	50%	-17 (-27)	-16 (-27)	-17 (-27)	-5 (-21)	13 (-10)	31 (0)	40 (4)	45 (7)	42 (5)	32 (0)	22 (-5)	7 (-14)	-12 (-25)
				68%	61%	58%	52%	50%	57%	58%	62%	62%	61%	71%	72%
SK	Regina	77%	-31 (-35)	-31 (-35)	-26 (-32)	-13 (-25)	6 (-15)	26 (-3)	37 (3)	43 (6)	39 (4)	24 (-5)	9 (-13)	-9 (-23)	-27 (-33)
				77%	80%	84%	81%	77%	78%	81%	80%	81%	81%	83%	80%
SK	Saskatoon	74%	-31 (-35)	-31 (-35)	-28 (-34)	-16 (-27)	7 (-14)	27 (-3)	39 (4)	44 (7)	41 (5)	28 (-2)	10 (-12)	-11 (-24)	-23 (-31)
				75%	77%	80%	78%	74%	76%	80%	80%	81%	79%	81%	77%
YT	Whitehorse	38%	-34 (-37)	-34 (-37)	-28 (-34)	-14 (-26)	3 (-16)	24 (-5)	36 (2)	40 (5)	36 (2)	19 (-7)	3 (-16)	-15 (-26)	-27 (-33)
				72%	65%	55%	46%	38%	40%	46%	48%	54%	63%	75%	75%

Incoming Air Volume

For the humidification load calculation it is assumed that the humidity that must be added is the amount required to bring outdoor air to indoor design conditions. Therefore for any type of air conditioning system the volume of incoming air by mechanical means and infiltration must be determined to obtain an accurate humidification load. The incoming volume depends on the construction of the space being humidified and the type of air conditioning system used. The main types of air conditioning systems are;

Natural Ventilation – In this type of system there is no direct mechanical means for providing fresh outdoor air into the space. The amount of makeup air is calculated based on the volume of the humidified space and an estimate of air changes per hour. Table 7 can be used to estimate the air changes for the four types of construction listed.

Table 7: Air Changes for Natural Ventilation.

Type of Construction	Air Changes / hour
Tight	0.3
Average	0.6
Poor	1
Loose with lots of in/out traffic	2.5

To calculate incoming air volume for natural ventilation calculate the volume of the space being humidified and multiply by air changes/hour from Table 7.

Mixed air system – In this type of system a fixed percentage of the return air is exhausted and replaced with fresh incoming air. The volume of incoming air is what needs to be humidified. The building is generally pressurized however when calculating the load the space should be examined to determine if there is any infiltration possible due to a loose building envelope, large doors in the building envelope, high level of in/out traffic or any other reason. If infiltration is present it should be estimated and added to the incoming air volume provided by the air conditioning system.

Makeup air system –This type of system consists of an air conditioner providing fresh incoming with no return air. The entire volume of the air conditioning system must be humidified to bring it to the design condition. The building is generally pressurized however as with a Mixed air system the building should be examined to determine if infiltration is present. Any infiltration should be added to the incoming air volume.

Exhaust air system - In this type of system a fixed volume of air is exhausted from the building. The incoming air volume must be at least equal to the volume of exhausted air and is what needs to be humidified. As with the mixed air system and makeup air system the building should be examined to determine if any additional infiltration is present and the volume of infiltration added to the incoming air volume.

Note:

For all mechanical air conditioning systems the space being humidified should be examined to determine if there is any infiltration possible due to loose building envelope, large doors in the building envelope, high level of in/out traffic or any other reason. If infiltration is present it should be added to the incoming air volume calculated by mechanical means.

Load Calculations

Natural Ventilation

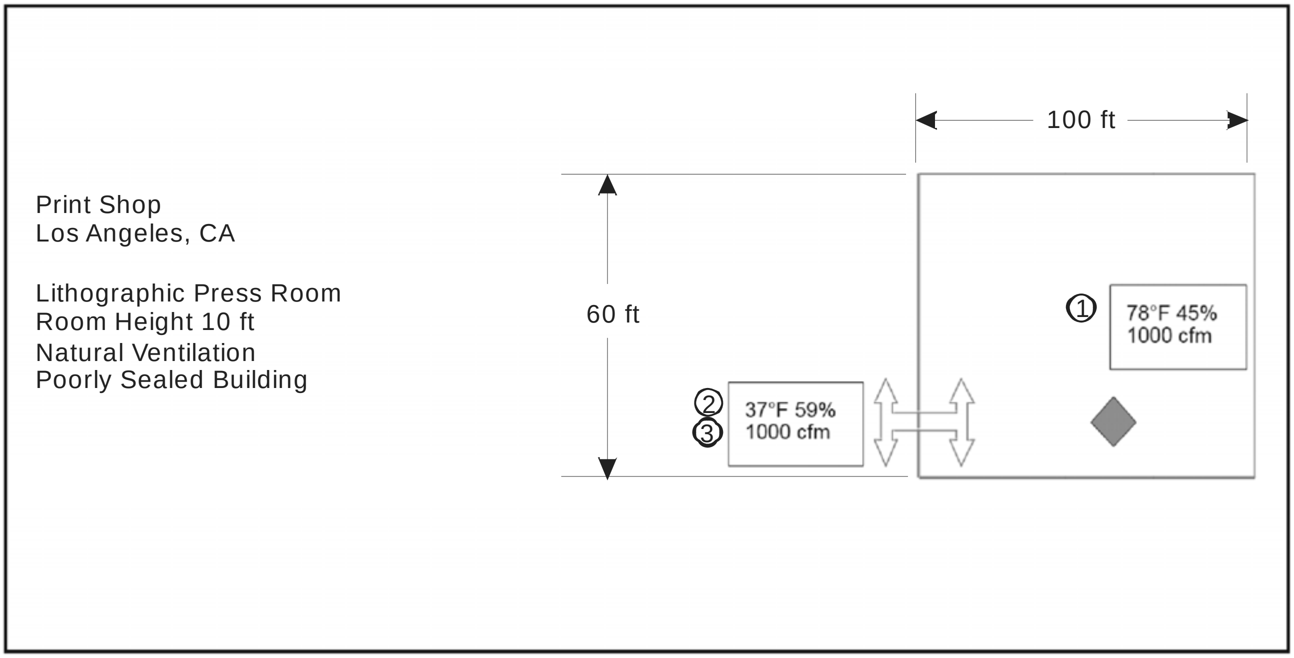

Figure 5: Print Shop, Los Angeles California, Natural Ventilation

Example 3: Load Calculation Natural Ventilation - Figure 5 shows a schematic from HELP depicting a print shop in Los Angeles that is poorly sealed with a volume of 60 ft x 100 ft x 10 ft.

1 Get design condition for Printing – Lithographic Press from Table 4 (assume design condition is the middle of the range). Calculate the moisture content using method given in Calculating Relative Humidity on page 10.

Design Condition = 78ºF and 45% RH

A = 0.00149 lb/cu.ft — *From Table 2*

B =A x 45%/100% = 0.00149 x 0.45 = 0.000671lb/cu.ft — *At 45% RH*

2 Get incoming air conditions for Los Angeles from Table 5: Weather Data - United States. Calculate the moisture content at the incoming air conition.

Incoming Air Conditions = 37ºF, 59% RH. — *From* Table 5

C = 0.000366lb/cu.ft — *From Table 2*

D = C x 59%/100% = 0.000366 x 0.59 = 0.000216 lb/cu.ft — *At 59% RH*

3 Subtract the moisture content of incoming air from moisture content at design condition to get moisture which must be added per cu.ft

E = B – D = 0.000671 – 0.000216 = 0.000455 lb/cu.ft

4 Calculate the volume of incoming air for a poorly sealed building.

V = 100 ft x 60 ft x 10 ft = 60,000 cu.ft — *Volume of the space*

Air changes / hr = 1 — *From* Table 7

$V_{Incoming}$ *= V x Air Changes = 60,000 x 1 = 60,000 cu.ft/hr*

5 Calculate humidification load by multiplying moisture to be added by incoming air volume.

L = E x $V_{incoming}$ *= 0.000455 lb/cu.ft x 60,000 cu.ft/hr=* ***27 lb/hr*** — ***Humidification Load***

Mixed Air System

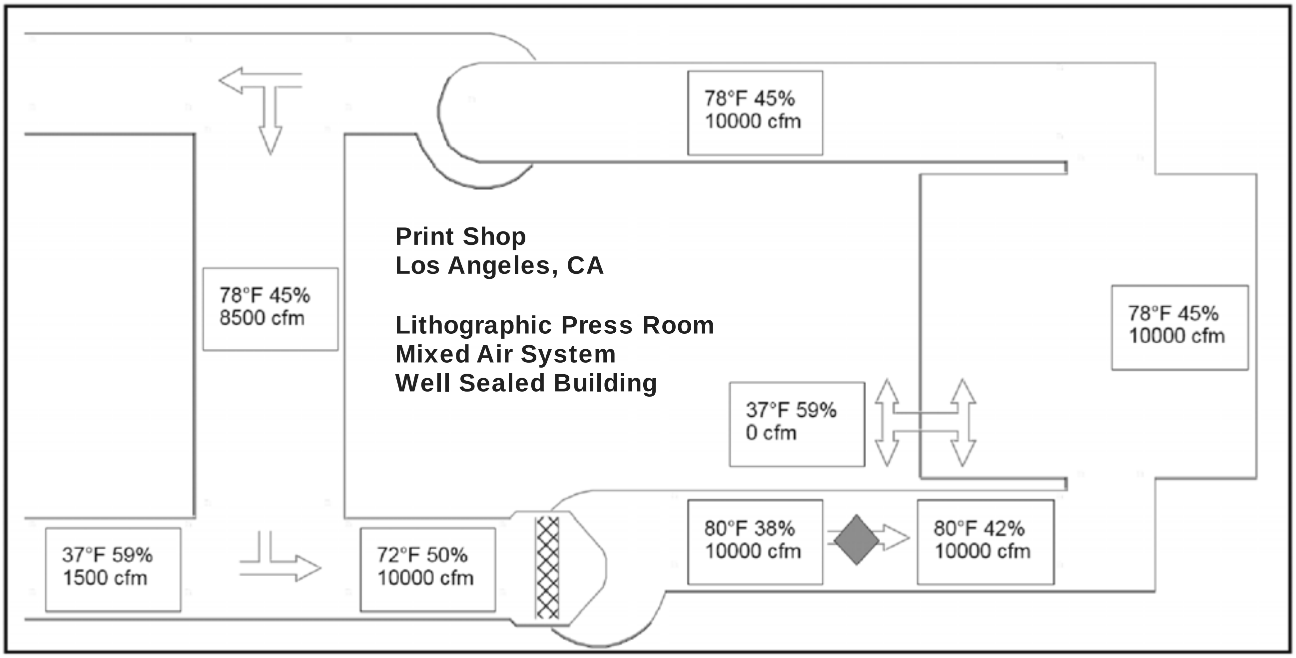

Figure 6: Print Shop, Los Angeles California, Mixed Air System

Example 4: Load Calculation Mixed Air System - Figure 6 shows a schematic from HELP depicting a print shop in Los Angeles with a Mixed Air System. The mixed air system provides 15% makeup air and this building is well sealed.

1 Since design conditions and incoming air conditions are the same as in the previous example the moisture which must be added is the same (Steps 1, 2, and 3).

E = 0.000455 lb/cu.ft *Moisture which must be added*

2 Calculate the volume of incoming air per hour with 15% makeup air shown in the illustration.. Since this building is well sealed we will assume infiltration will be 0 cfm.

$V_{Incoming} = V_{Return\ Air} \times 15\% / 100\% = 10{,}000\ cfm \times 15\% / 100\% = 1{,}500\ cfm$

$V_{Incoming} = 1{,}500\ cu.ft/min \times 60\ min / hr = 90{,}000\ cu.ft/hr$

3 Calculate humidification load by multiplying moisture which must be added by incoming air volume.

$L = E \times V_{incoming} = 0.000455\ lb/cu.ft \times 90{,}000\ cu.ft/hr = 41\ lb/hr$ *Humidification Load*

Makeup or Exhaust Air System

The load calculation for a Makeup Air System, or an Exhaust Air System, are the same as for a mixed air system except that all the air moving through the system must be humidified. For the example above with no return air the load would be calculated as follows.

1 The moisture which must be added is the same.

E = 0.000455 lb/cu.ft

2 The entire volume of 10,000 cfm must be humidified so volume per hour is;

$V_{Incoming} = 10{,}000\ cu.ft/min \times 60\ min / hr = 600{,}000\ cu.ft/hr$

3 Calculate humidification load by multiplying moisture to be added by incoming air volume.

$L = E \times V_{incoming} = 0.000455\ lb/cu.ft \times 600{,}000\ cu.ft/hr = 273\ lb/hr$ *Humidification Load*

Economizer Cycles

Care should be taken in sizing humidification load when an economizer cycle is incorporated into a building HVAC system. Under normal heating conditions the makeup air volume is usually relatively small to avoid heating large amounts of outside air. However when the economizer cycle is in operation the makeup air volume may be as high as 100% of the supply air volume.

To calculate the humidification load for a system with an economizer cycle the load must be calculated for each month in which the economizer mode may operate. The calculations are performed using a low temperature for each month and the average humidity. The monthly values for the calculation are given in Table 6: Weather Data – Canada and Table 5: Weather Data - United States in the columns under “Economizer Calculation”.

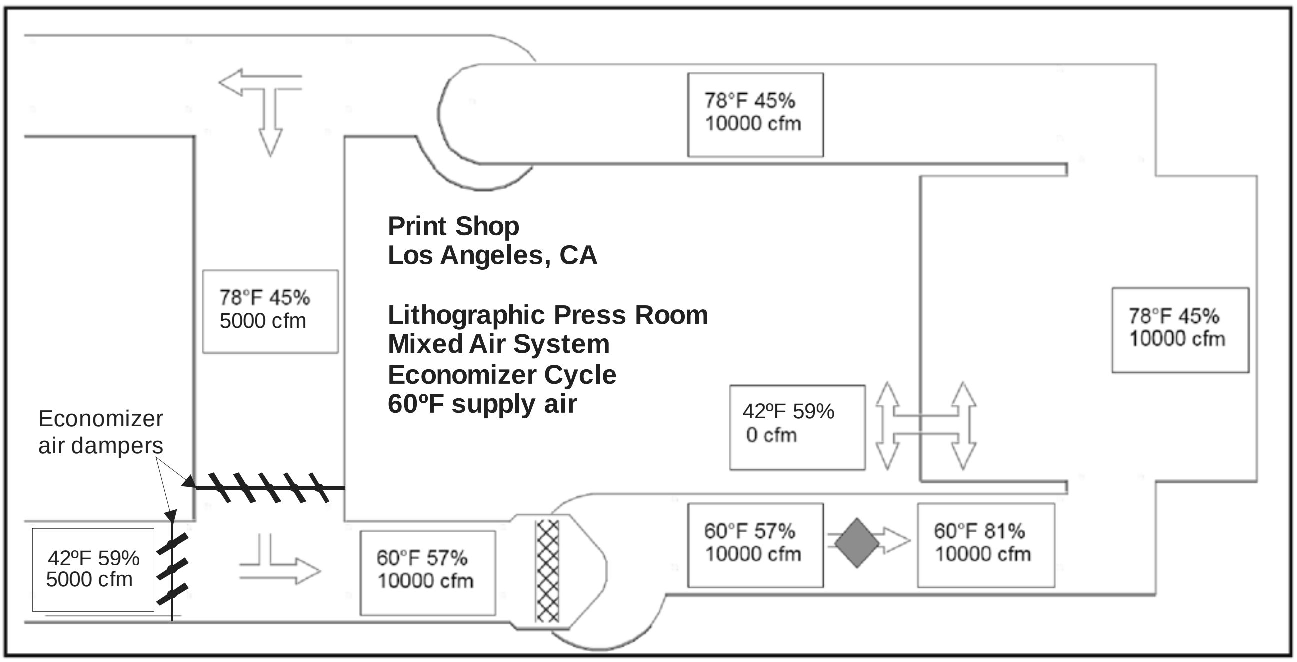

Figure 7: Economizer Cycle with 100% Makeup Air

Example 5: Load Calculation Economizer Cycle - Figure 7 shows the print shop in Los Angeles California for the condition which HELP software has determined will be the maximum economizer cycle humidification load . The supply air temperature for the economizer cycle is 60ºF. The following example shows how to manually calculate the maximum humidification load for a system with an economizer cycle.

1 Create a table listing the months (column A) that the economizer may be active with headings as shown in Table 8. In this case all 12 months are listed.

2 Get the relative humidity (column B) and temperature (column C) for each month from the columns under “Economizer Calculation” in Table 5.

3 Calculate the moisture content of the Outdoor Air (column D and E) for each month using the method outlined in Calculating Relative Humidity on page 10.

4 Calculate the moisture content at the 78ºF 45% RH design conditions (Column F) using the method outlined in Calculating Relative Humidity on page 10.

5 Calculate the moisture that must be added to the outdoor air (Column G) by subtracting moisture content of outdoor air from moisture content at design conditions.

6 Calculate the percentage outdoor air that economizer cycle will use (column H) to obtain the supply air temperature of 60ºF using the formula;

$$\% \text{ Outdoor Air} = \frac{(Ts - Td)}{(Tod - Td)} \times 100\%$$

Where: *Ts = Supply air temperature*

Td = Design temperature

Tod = Outdoor air temperature

7 Calculate the Incoming Air Volume that must be humidified each hour (column I) by multiplying the air handler volume in cu.ft/hr x % Outdoor Air.

V = Air Handler Volume cu.ft/min x % Outdoor Air x 60 min/hr

8 Calculate the humidification load (column J) for each month by multiplying the hourly air volume by the moisture that must be added.

Table 8: Economizer Load Calculation, Los Angeles

A	B	C	D	E	F	G	H	I	J
Month	**Outdoor RH**	**Outdoor Temp**	**Outdoor Air Moisture content at Outdoor temp and 100% RH**	**Outdoor Air Moisture content at Outdoor RH**	**Design Moisture Content**	**Moisture that must be added**	**Required % Incoming Air Volume**	**Required Incoming Air Volume**	**Humid-ification Load**
	(from Table 10)	**(from Table 10)**	**(from table 6)**	**(B x D)**	**(from table 6 x Design RH)**	**(F - E)**	**(Ts-Td) / (Tod-Td)**	**(H x Volume)**	**(G x I)**
	%	**°F**	**Lb/cu.ft**	**lb/cu.ft**	**lb/cu.ft**	**lb/cu.ft**	**%**	**cu.ft/hr**	**lb/hr**
Jan	59	37	0.000366	0.000216		0.000455	44%	263415	119.9
Feb	63	43	0.000457	0.000288		0.000383	51%	308571	118.2
Mar	65	44	0.000474	0.000308		0.000363	53%	317647	115.3
April	64	48	0.000547	0.000350		0.000321	60%	360000	115.5
May	66	52	0.000630	0.000416		0.000255	69%	415385	106.0
June	67	56	0.000723	0.000484	0.000671	0.000187	82%	490909	91.6
July	68	58	0.000773	0.000526		0.000145	90%	540000	78.5
Aug	69	60	0.000829	0.000572		0.000099	100%	600000	59.4
Sept	67	57	0.000747	0.000500		0.000171	86%	514286	87.7
Oct	65	52	0.000630	0.000410		0.000262	69%	415385	108.6
Nov	61	45	0.000491	0.000300		0.000371	55%	327273	121.3
Dec	59	42	0.000440	0.000260		0.000411	50%	300000	123.4

Obtain the maximum humidification load with an economizer cycle from column J. In this case it will be 123.4 lb/hr and will occur in December if the economizer draws 50% outdoor air.

Note:

- The energy saving function of the economizer cycle may be defeated if the humidification cost exceeds the energy saved by the cycles free cooling.
- Maximum humidification load does not occur at the 100% makeup air condition in August because of the high moisture content of the outdoor air in that month.

Warranty

Walter Meier Inc. and/or Walter Meier Ltd. (hereinafter collectively referred to as THE COMPANY), warrant for a period of two years after installation or 30 months from manufacturer's ship date, whichever date is earlier, that THE COMPANY's manufactured and assembled products, not otherwise expressly warranted (with the exception of the cylinder), are free from defects in material and workmanship. No warranty is made against corrosion, deterioration, or suitability of substituted materials used as a result of compliance with government regulations.

THE COMPANY's obligations and liabilities under this warranty are limited to furnishing replacement parts to the customer, F.O.B. THE COMPANY's factory, providing the defective part(s) is returned freight prepaid by the customer. Parts used for repairs are warranted for the balance of the term of the warranty on the original humidifier or 90 days, whichever is longer.

The warranties set forth herein are in lieu of all other warranties expressed or implied by law. No liability whatsoever shall be attached to THE COMPANY until said products have been paid for in full and then said liability shall be limited to the original purchase price for the product. Any further warranty must be in writing, signed by an officer of THE COMPANY.

THE COMPANY's limited warranty on accessories, not of the companies manufacture, such as controls, humidistats, pumps, etc. is limited to the warranty of the original equipment manufacturer from date of original shipment of humidifier.

THE COMPANY makes no warranty and assumes no liability unless the equipment is installed in strict accordance with a copy of the catalog and installation manual in effect at the date of purchase and by a contractor approved by THE COMPANY to install such equipment.

THE COMPANY makes no warranty and assumes no liability whatsoever for consequential damage or damage resulting directly from misapplication, incorrect sizing or lack of proper maintenance of the equipment.

THE COMPANY makes no warranty and assumes no liability whatsoever for damage resulting from freezing of the humidifier, supply lines, drain lines, or steam distribution systems.

THE COMPANY makes no warranty and assumes no liability whatsoever for equipment that has failed due to ambient conditions when installed in locations having climates below 14°F (-10°C) during January or above 104°F (40°C) during July.

THE COMPANY retains the right to change the design, specification and performance criteria of its products without notice or obligation.

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