Bahnson Humidification Calculations

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Controlled humidification is the addition of moisture to the air in an enclosure in order to maintain a constant relative humidity. Proper humidification of the air is important and necessary for many commercial and industrial areas. Dry air will absorb moisture from hygroscopic substances, thus damaging the materials and hampering manufacturing processes.

In most commercial and industrial spaces humidification is a cold weather problem. During the colder seasons the outside air, which can hold little moisture, enters the enclosure by forced or natural ventilation and is heated to room temperature. The temperature rise reduces the relative humidity inside to a fraction of what it was outside.

Humidification may be required in warmer seasons (1) if the outside relative humidity is low and the rate of air change is such that the relative humidity falls, (2) if there is a great amount of heat generated in the enclosure which increases the room temperature or (3) if the relative humidity to be maintained is very high. Humidification may also be required in tightly closed rooms where the natural temperature rise on warm days lowers relative humidity.

Maximum humidification requirements usually occur during the winter in the Northern section of the country unless the relative humidity desired is very high, heat generated within the enclosure is extensive, and/or air change rate is high with a low outdoor relative humidity.

In order to select the equipment required, it is first necessary to determine the maximum amount of moisture which must be added in gallons per hour.

A. Table 1 shows the amount of moisture, in grains, contained in a cubic foot of air at various temperatures and relative humidities. The table is divided into normally encountered outside and inside conditions.

B. To determine the required capacity for winter humidification, it is necessary to know or estimate the following:

1. Inside relative humidity required. This may be determined from application information or by asking.
2. Maximum average inside temperature during heating season. Determined by control settings on automatic heating equipment or by asking.
3. Minimum outside temperature and relative humidity. Minimum temperature usually taken as local winter design temperature for heating systems. Outside relative humidity taken at prevailing winter local minimum at design temperature, usually not less than 50 per cent.
4. Rate of air change. For forced ventilation, taken at capacity of ventilation system. For natural ventilation, taken at estimated number of air changes per hour. Natural air change seldom exceeds one per hour in rooms over 60 feet minimum dimensions, but may be increased to 11/2 per hour for loose construction, sawtooth roof, etc. Air changes may be taken at 11/2 to 2 per hour for smaller rooms with 2 or 3 exposed walls depending upon tightness of construction, number of open doors to other parts of building, etc. Natural ventilation seldom exceeds 2 per hour except in small rooms with walls exposed and loose construction.
5. One gallon equals 8.33 pounds of water or 58,300 grains of water.
6. Room volume in cubic feet.

C. When the information called for above has been obtained, find the amount of moisture, in grains, which must be added to each cubic foot of outside air to bring it to the desired relative humidity when heated to room temperature. This will be found on Table 1 as the difference in grains between the inside and outside design conditions, and is termed "grains added."

D. Capacity required m,ay also be determined by use of a psychrometric chart. On the chart, find the inside and outside conditions and obtain the difference in moisture content in grains per pound. Divide this figure by number of cubic feet of air per pound at the room condition and use the formulae on following page.

1. For natural ventilation, use the following formulae:

$$\text{Capacity required in gallons per hour} = \frac{\text{Room Volume (cubic ft.)}}{\text{1 air change}} \times \frac{\text{Number air changes}}{\text{1 hour}} \times \frac{\text{Grains added}}{\text{1 cu. ft.}} \times \frac{\text{1 gallon}}{\text{58,300 grains}}$$

$$\text{GPH} = \frac{\text{Volume x no. air changes x grains added}}{58{,}300}$$

2. For forced ventilation, use the following formulae:

$$\text{Capacity required in gallons per hour} = \frac{\text{Ventilation rate in cfm*}}{1} \times \frac{\text{60 minutes}}{\text{1 hour}} \times \frac{\text{grains added}}{\text{1 cu. ft.}} \times \frac{\text{1 gallon}}{\text{58,300 grains}}$$

$$\text{GPH} = \frac{\text{Ventilation lab* x grains added}}{970}$$

***use only percent cfm of outside air supplied to the space.**

E. In those instances where summer humidification requirements are likely to be considerable due to high internal heat gain, low outdoor relative humidity, high air change, etc., calculation should be made to be certain that summer maximum requirements do not exceed winter. This calculation may be performed as above with the following changes in data. Refer to paragraph B.

1. Becomes maximum average inside temperature in summer as determined by records of the customer.
2. Becomes local summer design conditions. Use lowest prevailing relative humidity at design temperature.
3. Becomes rate of air change in summer—almost always exceeds winter and may be difficult to estimate. This seldom exceeds 4 per hour in large rooms, but may be much more in small rooms with exposed walls. It can be pointed out to the customer that if the relative humidity drops below the desired level, windows and doors can be closed to reduce the air change.

F. In some cases, product load must be considered in addition to ventilation load. This is true where the product absorbs moisture and is expected to pick up moisture while in the humidified space. In such cases, find the weight of moisture to be picked up by the product in a certain time period, convert to gallons per hour, and add to capacity required.

Recommended Relative Humidities For Handling, Processing and Storing Hygroscopic Materials

Process or Product	Temp F	Percent R.H.
Abrasives		
Manufacture	79	50
Cereal		
Packaging	75-80	45-50
Fur		
Storage	40-50	55-60
Leather		
Drying	68-125	75
Storage	50-60	40-60
Libraries & Museums		
General Stacks	70-74	40-50
Museum Galleries	70-72	50-55
Matches		
Manufacture	72-73	50
Drying	70-75	60
Storage	60-63	50
Mushrooms		
Storage	32-35	80-85
Office Buildings		
General (winter)	70-74	30-40
Paint Application		
Oil Paints — Spraying	60-90	80
Pharmaceuticals	75	35
Plastics		45-65
Cellophane Wrapping	75-80	
Printing		
Sheet Fed Printing	75-80	45-50
Newspaper & Other Web Printing	70-75	50-52
Other Paper Storage	70-80	50-52
Textiles		
Wool Storage	75-80	50-55
Cotton, Weaving	*	70-85
Manufacturing		
Synthetic Fibers	70-75	50-70
Tobacco		
Cigar & cig. making	70-75	55-65
Packing & Shipping	74-76	65
Wrapper Tobacco Storage & Conditioning	75	75
Wood Products	*	45-55*

*Depends on the process or conditions

(Extracted by permission from ASHRAE, from 1982 ASHRAE Applications Handbook.)

Table 1

Grains of moisture per cubic foot at OUTSIDE CONDITIONS

Relative Humidity

	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
-20°	.017	.033	.050	.066	.083	.100	.116	.133	.149	.166
-15°	.022	.044	.065	.087	.109	.131	.153	.174	.196	.218
-10°	.028	.057	.086	.114	.142	.171	.200	.228	.256	.285
- 5°	.037	.074	.111	.148	.185	.222	.259	.296	.333	.370
0°	.048	.096	.144	.192	.240	.289	.337	.385	.433	.481
5°	.061	.122	.183	.244	.305	.366	.427	.488	.549	.610
10°	.078	.155	.233	.310	.388	.466	.543	.621	.698	.776
15°	.099	.197	.296	.394	.493	.592	.690	.789	.887	.986
20°	.124	.247	.370	.494	.618	.741	.864	.988	1.112	1.235
25°	.155	.310	.465	.620	.766	.931	1.086	1.241	1.396	1.551
30°	.194	.387	.580	.774	.968	1.161	1.354	1.548	1.742	1.935

*Grains of moisture per cubic foot at INSIDE CONDITIONS

Relative Humidity

	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
35°	.237	.473	.710	.946	1.183	1.420	1.656	1.893	2.129	2.366
40°	.285	.570	.855	.140	1.424	1.709	1.994	2.279	2.564	2.849
45°	.341	.683	1.024	.366	1.707	2.048	2.390	2.731	3.073	3.414
50°	.408	.815	1.223	1.630	2.038	2.446	2.853	3.261	3.668	4.076
55°	.485	.970	1.455	1.940	2.424	2.909	3.394	3.879	4.364	4.849
60°	.574	1.149	1.724	2.298	2.872	3.447	4.022	4.596	5.170	5.745
65°	.678	1.356	2.035	2.713	3.391	4.069	4.747	5.426	6.104	6.782
70°	.798	1.596	2.394	3.192	3.990	4.788	5.586	6.384	7.182	7.980
75°	.936	1.871	2.807	3.742	4.678	5.614	6.549	7.485	8.420	9.356
80°	.093	2.187	3.280	4.374	5.467	6.560	7.654	8.747	9.841	10.934
85°	1.274	2.547	3.821	5.094	6.368	7.642	8.915	10.189	11.462	12.736
90°	1.479	2.958	4.437	5.916	7.395	8.874	10.353	11.832	13.311	14.790
95°	1.712	3.425	5.137	6.850	8.562	10.274	11.987	13.699	15.412	17.124
100°	1.977	3.953	5.930	7.906	9.883	11.860	13.836	15.813	17.789	19.766
105°	2.275	4.550	6.825	9.100	11.375	13.650	15.925	18.200	20.475	22.750
110°	2.611	5.222	7.834	10.445	13.056	15.667	18.278	20.890	23.501	26.112

(Interpolation Possible)

$$* = \frac{\text{specific humidity in grains of moisture per pound of dry air}}{\text{specific volume in cubic feet per pound of dry air}}$$