Water Treatment Plant and Pumping Station Dehumidifier Sizing

INTRODUCTION

This application note will examine the causes and cure for humidity problems in water treatment plants and pumping stations. Moisture load calculations are provided for areas with closed piping only and facilities with open tanks. The closed piping section will also pertain to pumping stations and pipe galleries.

CAUSES OF HUMIDITY

Many municipalities are installing enclosures over their treatment plants to obtain better control of their process. In addition, these utilities require the installation of pumping stations (both subterranean and above ground) to facilitate the movement of water throughout the distribution system.

An ever increasing problem for the utilities is the deterioration of the treatment plant's physical structures. Many of these problems stem from condensation on pipes, tanks, supports and electrical equipment. The moisture enters these facilities from a variety of sources;

- Infiltration and permeation
- Ventilation and make-up air
- Door and window openings
- Evaporation from open tanks

Moisture follows a physical law of nature which causes it to migrate to locations of lower concentration. This means that on hot humid summer days, moisture will find a path to the inside of a structure. This could be from poor or non-existent vapor barriers or cracks in the wall. In some instances, the outdoor air is purposely brought inside to eliminate a dangerous build-up of methane or chlorine gases. Finally, open tanks will provide a continuous source of moisture within the structure.

The moisture inside the plant will condense on any surface which has a lower dew point temperature such as the outside wall of a pipe or tank. This water will cause rust and corrosion on any of the metal surfaces. In addition, electrical controls and contacts can be affected causing extensive damage and possible process problems.

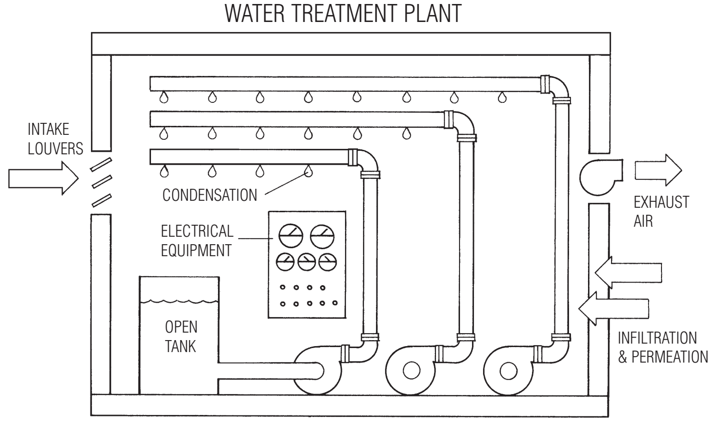

Figure 1- Condensation - Humid Environment

ELIMINATION OF MOISTURE

Regardless of the source of moisture, the solution to the corrosion problem is simply to remove enough moisture in the space to drop the air's dew point below that of the pipe or tank surface temperature. The following sections provide a step-by-step analysis to determine the amount of moisture removal which is required.

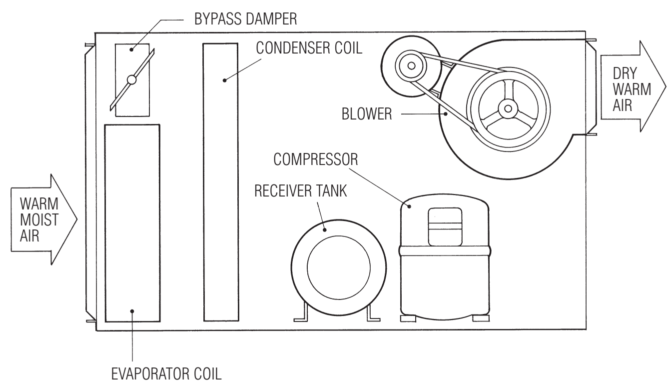

Figure 2 - Refrigeration Dehumidifier Schematic

Refrigeration dehumidifiers reduce moisture in the air by passing the air over a cold surface, removing the moisture by condensation. A detailed discussion on this technique is explained in Desert Aire's *Technical Bulletin 1*. This method is effective for desired conditions down to 45% RH for standard applications. Specially designed systems can achieve dew points as low as 39° F. This method has moderate capital costs and can recover much of the latent energy which offsets operating costs. (See Figure 2.)

SOURCES OF MOISTURE (CLOSED PIPING)

There are many sources of moisture in a facility. A list of the common ones follows:

- Infiltration
- Permeation
- Ventilation and make-up air
- Door and window openings
- People
- Process
- Product

Moisture load in a space due to infiltration and permeation is not easily measured. Factors such as the actual moisture deviation, materials of construction, vapor barrier and room size all have an effect on the vapor migration. Desert Aire uses some basic models to make assumptions to estimate moisture infiltration and permeation.

The combined infiltration and permeation load can be approximated from the following equation:

$$\text{LB/HR Moisture} = \frac{V \times AC \times \Delta GR \times MF \times CF}{7000 \times 13.5}$$

Where:

V = Volume of room to be conditioned (cu. ft.)
AC = Air change factor from Table 1
ΔGR = The deviation from the outdoor to the desired conditions (grains/LB)
MF = Migration factor is $\Delta GR \div 30$ (min. value = 1.0)
CF = Construction factor from Table 4
13.5 = Conversion factor for CU. FT. /LB
7000 = Conversion factor for GR/LB

According to ASHRAE, the median number of air changes per hour is 0.5. The actual number of air changes is influenced by several factors, the most dominant being the size of the room. The larger the room, the longer it takes to convert one volume. The following table compensates for the reduction in infiltration/permeation on larger or smaller volumes. The rate of infiltration is a function of the magnitude of imbalance between the outdoor absolute humidity and that of the inside of the conditioned space. The greater the difference, the greater the driving force to make the vapor pressures equal. The migration factor compensates for this influence.

VOLUME, (CU. FT.)	AC	VOLUME	AC
Less than 10,000	0.65/HR.	40,001-60,000	0.45
10,001-20,000	0.60	60,001-100,000	0.40
20,001-30,000	0.55	100,001-200,000	0.35
30,001-40,000	0.50	OVER 200,000	0.30

Table 1 - Air Changes for Specific Volumes

It is necessary to determine the grain differential between the outdoor condition and the "Design Condition" which is normally 5° below fluid dewpoint temperature to compensate for thermometer error, unexpected fluid temperature changes, and pipe surface temperature fluctuations. By locating the outdoor conditions (refer to Table 2) and the design condition on the psychrometric chart an absolute humidity in grains/LB can be obtained. The formula uses the difference in grains/LB between these two conditions.

Please refer to Desert Aire's *Technical Bulletin 3* if assistance is required to read the psychrometric chart.

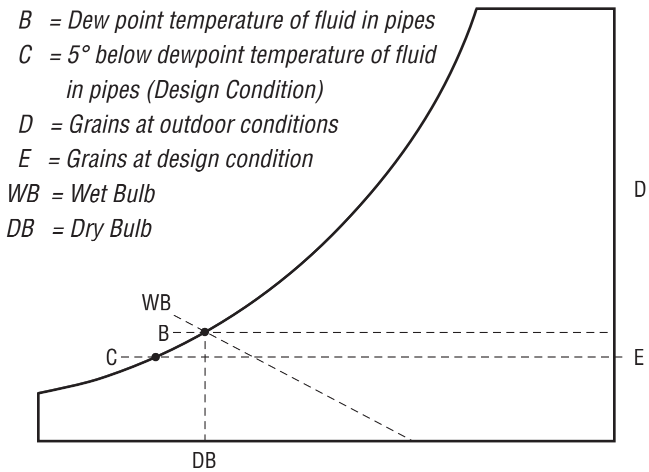

Figure 3 - Determining Moisture

Another primary factor is the amount of moisture that is allowed to permeate through the walls, floor and roof. The construction factor takes into account the effect good vapor barriers and construction materials will have on the moisture migration. Table 4 gives factors for common construction materials. This factor will vary between 0.3 and 1.0. A composite wall must be modeled and a factor estimated.

DESCRIPTION	CF FACTOR
Frame construction, no vapor barrier	1.0
Masonry, no vapor barrier	1.0
Masonic, vapor proof paint	0.75
Plastic modules	0.75
Frame construction, vapor proof paint	0.75
Frame construction, mylar vapor wrap	0.5
Sheet metal, good seals	0.3
Glass	0.3

Table 4 - Construction Factor

VENTILATION AND MAKE-UP AIR

If the facility is using outdoor make-up air for ventilation as required by some building codes, this source of air can contribute to the moisture load. This is especially important in the summer months when high humidity is common. As with the calculation for infiltration, the difference in absolute humidity must be used, along with the volume of make-up air being brought in by the air handling system.

The formula for calculating moisture load is:

$$\text{LB/HR Moisture} = \frac{\text{CFM} \times \Delta\text{GR} \times 60}{7000 \times 13.5}$$

CFM = Volume of outdoor air introduced

ΔGR = The deviation from the outdoor to the desired conditions (grains/LB)

60 = Conversion factor for min/hr

13.5 = Conversion factor for CU.FT./LB

7000 = Conversion factor for GR/LB

DOOR OPENINGS

Another source of moisture is the opening of doors and windows or other openings such as conveyor passages to the conditioned space. The amount of moisture is directly proportional to the frequency of the opening, the difference between the "Design Condition" and outdoor moisture content and the wind velocity at the opening. Wind velocity is more difficult to determine as it varies depending on the location of the opening with respect to the wind source. Local weather stations can provide details on prevailing direction and speed. A guideline is 12 CFM of outdoor air per square foot of opening. The amount of air can be estimated by the following formula. When this equation is used for a fixed opening like a window, the minutes open/hr. equals 60.

$$\text{LB/HR} = \frac{\text{AREA} \times \text{OPEN} \times \Delta\text{GR} \times 12}{7000 \times 13.5}$$

Where: AREA = Surface area of opening (sq.ft.)

OPEN = Minutes area is open per hour

ΔGR = The deviation from the outside to the desired conditions (grains/LB)

12 = Estimated ingress of moisture (CFM/Sq.Ft.)

13.5 = Conversion factor for CU.FT./LB

7000 = Conversion factor for GR/LB

OUTDOOR AIR MOISTURE CONTENT TO BE REMOVED											
State	City	GR lbs	State	City	GR lbs	State	City	GR lbs	State	City	GR lbs
AK	Anchorage	59	IL	Rockford	119	NY	Albany	109	TX	San Antonio	128
AK	Annette	65	IN	Fort Wayne	121	NY	Buffalo	108	UT	Salt Lake City	76
AK	Kodiak Island	60	IN	Indianapolis	130	NY	New York	121	VA	Norfolk	124
AK	Yakutat	65	KS	Wichita	120	NY	Rochester	116	VA	Richmond	130
AL	Birmingham	126	KY	Louisville	125	NY	Syracuse	110	VA	Roanoke	113
AL	Mobile	137	LA	Baton Rouge	136	OH	Cincinnati	120	VT	Burlington	105
AR	Little Rock	102	LA	New Orleans	143	OH	Cleveland	116	WA	Seattle	71
AZ	Phoenix	102	LA	Shreveport	134	OH	Columbus	119	WA	Spokane	61
CA	Long Beach	91	MA	Boston	112	OK	Oklahoma City	125	WA	Yakima	63
CA	Los Angeles	96	MD	Baltimore	120	OR	Eugene	73	WI	Green Bay	117
CA	Sacramento	72	ME	Portland	106	OR	Portland	72	WI	Madison	115
CA	San Diego	103	MI	Detroit	114	PA	Erie	114	WI	Milwaukee	115
CA	San Francisco	67	MI	Flint	117	PA	Philadelphia	124	WV	Charleston	120
CA	Santa Barbara	85	MI	Grand Rapids	116	PA	Pittsburgh	116			
CO	Stockton	75	MN	St. Paul	114	PA	Scranton	114		**CANADA**	
CO	Denver	78	MO	Kansas City	126	RI	Providence	114			
CT	Hartford	111	MO	St. Louis	132	SC	Charleston	136	AL	Calgary	69
DC	Washington	129	MS	Jackson	136	SC	Columbia	122	BC	Vancouver	76
DE	Wilmington	121	MT	Billings	70	SD	Sioux Falls	119	MN	Winnipeg	97
FL	Daytona Beach	137	NC	Cape Hatteras	142	TN	Bristol	118	NB	Saint John	87
FL	Jacksonville	134	NC	Charlotte	122	TN	Chattanooga	126	NF	St. John's	89
FL	Miami	137	NC	Raleigh	126	TN	Knoxville	124	NS	Halifax	100
FL	Tallahassee	136	ND	Fargo	109	TN	Memphis	132	ON	Ottawa	101
FL	Tampa	136	NE	Omaha	125	TN	Nashville	126	ON	Sudbury	93
GA	Atlanta	123	NH	Concord	109	TX	Brownsville	136	ON	Thunder Bay	91
GA	Augusta	128	NJ	Atlantic City	123	TX	Corpus Christi	141	ON	Toronto	108
HI	Honolulu	117	NJ	Newark	121	TX	Dallas / Ft. Worth	121	ON	Windsor	115
IA	Des Moines	122	NM	Albuquerque	80	TX	El Paso	99	QC	Montreal	106
ID	Boise	59	NV	Las Vegas	82	TX	Houston	135	QC	Quebec	100
IL	Chicago	118	NV	Reno	59	TX	Lubbock	111	SK	Regina	80

Table 2 - Geographic Outdoor Design Criteria (ASHRAE Fundamentals 1%)

OPEN WATER TANKS

In the case of open water tanks, the evaporation rate can be calculated with the following equation:

$$LB/HR = 0.1 \times AREA \times (VP_{H2O} - VP_{AIR})$$

Where:

0.1 = Factor to compensate for air movement over surface

Area = Surface area of water (square feet)

VP_{H2O} = Vapor pressure of water at water temperature

VP_{AIR} = Vapor pressure of air at its corresponding dew point.

**See Table #3 for Vapor Pressure.*

The above equation assumes 10 to 30 FPM air velocity in room. Vapor pressures can be obtained from technical publications. Consult Desert Aire if you need assistance.

If vapor pressure of air at its corresponding dew point exceeds vapor pressure of water at water temperature, then the open water tank equation can be eliminated.

CONCLUSION

Properly selecting and sizing a dehumidification system to condition a facility requires careful planning. The engineer or facility operator must specify the operating conditions to be maintained and must evaluate all of the potential sources of water and the outdoor ambient conditions. This information can then be used to size the system. The enclosed worksheet is provided to organize the minimum information required for selection and sizing and the formulas will provide an approximation of the moisture load. An engineer should be consulted to confirm that the assumptions are appropriate for the application.

To select the appropriate dehumidifier, the inside ambient temperature is required. Plot the inside ambient temperature on a psychrometric chart along the horizontal design dew point line. (Line C-E in Fig. 3.) This intersection will establish a dry bulb temperature and RH which can then be used to properly select a unit that provides the appropriate moisture removal capacity. If the inside ambient temperature is not known, an estimate can be made. Add 15° F to the design dew point temperature along line C-E (Fig. 3) and proceed as described above.

Table 3 - Vapor Pressure Table

FLUID TEMP. F°	VAPOR PRESSURE in HG	FLUID TEMP. F°	VAPOR PRESSURE in HG	FLUID TEMP. F°	VAPOR PRESSURE in HG	FLUID TEMP. F°	VAPOR PRESSURE in HG	FLUID TEMP. F°	VAPOR PRESSURE in HG
35	.20356	49	.34937	63	.58041	77	.93589	91	1.46824
36	.21181	50	.36264	64	.60113	78	.96733	92	1.51471
37	.22035	51	.37636	65	.62252	79	.99970	93	1.56248
38	.22920	52	.39054	66	.64454	80	1.03302	94	1.61154
39	.23835	53	.40518	67	.66725	81	1.06728	95	1.66196
40	.24784	54	.42031	68	.69065	82	1.10252	96	1.71372
41	.25765	55	.43592	69	.71479	83	1.13882	97	1.76685
42	.26781	56	.45205	70	.73966	84	1.17608	98	1.82141
43	.27831	57	.46870	71	.76528	85	1.21445	99	1.87745
44	.28918	58	.48589	72	.79167	86	1.25388	100	1.93492
45	.30042	59	.50363	73	.81882	87	1.29443	101	1.99397
46	.31206	60	.52193	74	.84684	88	1.33613	102	2.05447
47	.32408	61	.54082	75	.87567	89	1.37893	103	2.11661
48	.33651	62	.56032	76	.90533	90	1.42298	104	2.18037

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