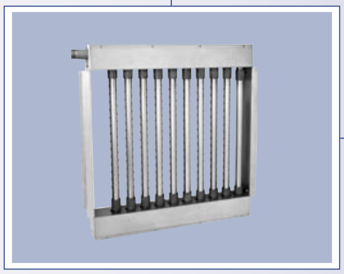
HUMIDIFICATION SYSTEM DESIGN GUIDE

DRISTEEM®



from the Humidification Experts

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DRI-STEEM Humidification System Design Guide

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Introduction to the Design Guide

Your guide to humidification system design

Welcome to DRI-STEEM's Design Guide. In tandem with our product catalogs, this guide gives you all the information you need to design a humidification system using DRI-STEEM® products. The Design Guide covers generic humidification issues such as calculating load, determining absorption distance, and laying out piping. Use this guide to help you understand general humidification system design issues.

Use this guide with our catalogs

Our catalogs describe information specific to our products, such as humidifier dimensions, capacities, and controller capabilities. Use the catalogs for selecting equipment and completing a product schedule.

Use this guide with DRI-CALC

DRI-CALC® is DRI-STEEM's humidification system sizing and selection software. The software sizes loads, selects equipment, writes specifications, and creates as-configured installation instructions and equipment schedules for DRI-STEEM products. DRI-CALC is the easiest way to design a humidification system. However, if you are interested in the basic theory behind system design, or if you want or need to design a system without a computer, the Design Guide walks you through the humidification system design process.

Note: DRI-CALC Europe Version 3, with the capabilities described above, will be released in Europe in 2003.

Use this guide with other DRI-STEEM resources

At DRI-STEEM we're known for educating our readers about humidification issues. If you've learned specifics about humidification, it's likely you learned them from us by reading one of our newsletters, case studies or articles. Or, perhaps you've read our ***Humidification Handbook,*** a comprehensive guide to humidification theory commonly used as a college textbook.

Let us know what you think!

We're constantly trying to improve the information we share with you. If you have comments or suggestions for improvements to this guide, please contact us at 800-328-4447 or e-mail us at sales@dristeem.com.

The tools you need

Review the table on the following page, which describes DRI-STEEM resources, to see how this guide fits in with our overall plan of educating you about humidification issues.

Table 2-1:
The tools you need — DRI-STEEM's educational resources

Tool	Purpose	Description	Location
Case studies	Humidification education	Application-specific stories about installed humidification systems. Recent topics include: • Mercy Medical Center; absorption case study • Waterloo Testing Facility; energy savings case study	• View, print, download pdf file, or order a preprinted copy at www.dristeem.com • Literature CD
Catalogs	Product-specific information needed to make a purchase decision and create a schedule	Available for the following products: CRUV® DRANE-KOOLER™ GTS® LTS® Steam Injection STS® ULTRA-SORB® VAPORMIST® VAPORSTREAM® HUMIDI-TECH® (available only in Europe)	• View, print, download pdf file or order a preprinted copy at www.dristeem.com • Literature CD
Design Guide	Explains the humidification system design process	With this document and a product catalog, HVAC engineers can design a humidification system.	• Order at www.dristeem.com
DRI-CALC software	Automates the humidification system design process	DRI-CALC automatically sizes loads, selects equipment, writes specifications, and creates as-configured installation instructions and equipment schedules for DRI-STEEM products.	• Order at www.dristeem.com • **Note:** DRI-CALC Europe Version 3 will be available in 2003
ENERGY-CALC™	Calculates energy savings by switching from electric to gas humidifiers	Easy-to-use and comprehensive, and includes weather data from numerous cities. Savings from switching from electricity to gas will usually cover the cost and installation of a new GTS humidifier.	• Use ENERGY-CALC online at www.dristeem.com • Not available with European weather and utility data
Engineering Humidification newsletters	Humidification education	Recent topics include: • Humidification and water types • Boiler chemicals and humidification • Six steps of humidification design • Steam absorption	• View, print, download pdf file, or order a preprinted copy at www.dristeem.com • Literature CD
Humidification Handbook	In-depth humidification theory	Use this handbook when you need more information than what is available in the Design Guide.	• Order at www.dristeem.com
Installation Guides	Humidification system installation instructions	Print job-specific as-configured Installation Guides using DRI-CALC, or print complete Installation Guides from the DRI-CALC library for any DRI-STEEM product.	• View, print, or copy Installation Guide pdf files from DRI-CALC • Order DRI-CALC at www.dristeem.com • **Note:** DRI-CALC Europe Version 3 will be available in 2003

More tools on the next page ▸

Table 2-1 (continued):
The tools you need — DRI-STEEM's educational resources

Tool	Purpose	Description	Location
Installation, Operation and Maintenance manuals (IOM)	Product-specific operation and maintenance information	Available for the following products: CRUV DRANE-KOOLER™ GTS LTS Steam Injection STS ULTRA-SORB VAPORMIST VAPORSTREAM VAPOR-LOGIC®3 HUMIDI-TECH (available only in Europe)	• View, print, or download pdf file, or order a preprinted copy at www.dristeem.com • Literature CD
Literature CD	All DRI-STEEM product literature in one place	Includes catalogs; Installation, Operation and Maintenance manuals; Engineering Humidification newsletters; case studies; and product photos and other documents for viewing, printing, or downloading to your computer. Also includes an absorption video clip.	• Order the Literature CD at www.dristeem.com
Psychrometric chart	For calculating humidification load	Laminated chart with steam absorption charts on the back	• Order a preprinted copy at www.dristeem.com • Not available in Europe
Specifications in CSI (Construction Specifications Institute) format	Descriptions of humidification systems for specification	Print job-specific as-configured product specifications using DRI-CALC. Print, view or download specifications for all DRI-STEEM products from the DRI-CALC library.	• View, print, or copy files from DRI-CALC (order at www.dristeem.com) • Not available with European data
Videos	General product information in video format	Available titles include: • Humidification Essentials • Absorption	• Videos can be ordered at www.dristeem.com • An absorption video clip is also on the Literature CD
Web site	Comprehensive information about DRI-STEEM products and humidification issues	Information available includes: • Detailed product information • Downloadable catalogs and manuals • Humidification education • New product announcements • Representative locator • News about trade shows	• www.dristeem.com

Calculating humidification load using inch-pound units of measure

Important notes about calculating load

- When outside air is 10% or less, it is wise to calculate the load twice. The first calculation should be made on the basis of air changes due to mechanical ventilation; the second should be based on the natural ventilation method. Use the larger of the two results for determining the load.
- Vapor naturally migrates from areas with high vapor pressure to areas with low vapor pressure, regardless of air movement. Vapor retarders reduce vapor migration, but should only be installed in accordance with local codes.

DRI-CALC software will calculate load for you

The easiest way to calculate humidification load is to use DRI-CALC, DRI-STEEM's humidification system sizing and selection software. The software not only sizes loads, but also selects equipment, writes as-configured specifications, creates equipment schedules, and provides as-configured installation instructions for DRI-STEEM products.

Three methods for calculating humidification load

DRI-CALC uses the following methods for calculating load. Read through the examples in this section to learn how to manually calculate load using these same methods:

1. Natural ventilation method
2. Mechanical ventilation method
3. Economizer cycle method

Natural ventilation method

As a general rule, humidification load is based only on the amount of air entering a building or space. In buildings without mechanical ventilation systems, humidification load is usually calculated using the air change method. Buildings can be classified by number of air changes per hour, with typical air changes being 1, 1½, or 2 air changes per hour. For more information about calculating air infiltration see the chapter on natural ventilation and infiltration in the ***ASHRAE Fundamentals Handbook*** (available at www.ashrae.org). For noncritical applications, we typically use 1½ air changes per hour for calculating load.

Sample Problem 1

Calculate the humidification load for a printing plant where:

- The desired conditions in the space are 70 °F and 50% RH.
- The outside entering conditions are 10 °F and 45% RH.
- The dimensions of the building are 120' × 80' × 12' (length × width × height).
- Air changes per hour = 1

Solution to Sample Problem 1 using the natural ventilation method

1. Find the moisture content of your desired conditions by referring to Table 6-1 on Page 6: Read across the 70 °F line to the 50% RH column to find 3.44 lbs/hr/100 cfm.

2. Find the moisture content of the entering air by reading across the 10 °F line to the 45% RH column to find 0.30 lbs/hr/100 cfm.

3. Determine the moisture in lbs/hr to be added per 100 cfm by subtracting the moisture content of the entering conditions from the moisture content of the desired conditions:

   3.44 lbs/hr/100 cfm – 0.30 lbs/hr/100 cfm

   = 3.14 lbs/hr/100 cfm

4. Determine the air quantity to be humidified by finding the total cubic feet of the space, multiplying that by the air changes per hour, and dividing by 60 minutes/hr to find air quantity to be humidified in cfm:

   $$\frac{120' \times 80' \times 12' \times 1 \text{ air change per hour}}{60 \text{ minutes/hr}}$$

   = 1,920 cfm

5. Determine the humidification load by multiplying the quantity of air to be humidified by moisture to be added:

   $$\frac{1{,}920 \text{ cfm} \times 3.14 \text{ lbs/hr}}{100 \text{ cfm}}$$

   = 60.29 lbs/hr

Table 6-1:
Pounds of moisture per hour per 100 cfm at sea level

Air temp.	Percentage of saturation															
°F	5%	10%	15%	20%	25%	30%	35%	40%	45%	50%	55%	60%	65%	70%	80%	90%	100%
-20	0.00	0.014	0.022	0.03	0.035	0.043	0.05	0.057	0.064	0.071	0.078	0.085	0.093	0.099	0.114	0.13	0.14
-10	0.012	0.025	0.037	0.05	0.06	0.074	0.085	0.097	0.11	0.121	0.134	0.147	0.159	0.171	0.20	0.22	0.24
0	0.02	0.04	0.06	0.081	0.102	0.121	0.142	0.162	0.184	0.204	0.223	0.245	0.265	0.285	0.33	0.36	0.40
10	0.033	0.066	0.10	0.133	0.166	0.20	0.232	0.266	0.30	0.332	0.364	0.40	0.434	0.465	0.54	0.59	0.66
20	0.053	0.107	0.16	0.215	0.262	0.32	0.374	0.430	0.494	0.535	0.583	0.635	0.695	0.758	0.86	0.96	1.05
30	0.085	0.17	0.25	0.33	0.42	0.50	0.585	0.67	0.75	0.84	0.92	1.00	1.09	1.17	1.34	1.49	1.65
40	0.12	0.24	0.37	0.48	0.60	0.74	0.84	0.96	1.08	1.20	1.31	1.45	1.53	1.68	1.98	2.20	2.43
50	0.17	0.35	0.52	0.70	0.88	1.05	1.24	1.40	1.58	1.76	1.93	2.12	2.30	2.46	2.83	3.16	3.49
55	0.21	0.42	0.63	0.84	1.05	1.26	1.47	1.68	1.90	2.10	2.30	2.53	2.74	2.94	3.37	3.76	4.16
60	0.22	0.44	0.75	0.89	1.25	1.49	1.74	1.98	2.24	2.50	2.72	2.99	3.24	3.48	4.00	4.46	4.93
65	0.29	0.58	0.86	1.16	1.36	1.75	2.04	2.32	2.63	2.92	3.20	3.50	3.80	4.06	4.73	5.27	5.82
68	0.32	0.65	0.98	1.30	1.63	1.96	2.28	2.60	2.84	3.26	3.56	3.91	4.24	4.55	5.23	5.84	6.05
69	0.33	0.67	1.00	1.33	1.68	2.00	2.35	2.66	3.01	3.35	3.66	4.03	4.36	4.68	5.40	6.04	6.38
70	0.34	0.68	1.02	1.37	1.72	2.05	2.40	2.74	3.10	3.44	3.75	4.12	4.46	4.80	5.56	6.20	6.45
71	0.36	0.72	1.07	1.43	1.78	2.15	2.50	2.85	3.21	3.55	3.90	4.29	4.65	5.00	5.74	6.40	7.07
72	0.37	0.74	1.10	1.47	1.84	2.20	2.58	2.94	3.32	3.68	4.03	4.44	4.80	5.15	5.91	6.60	7.29
73	0.38	0.76	1.14	1.51	1.90	2.28	2.66	3.03	3.43	3.80	4.16	4.57	4.95	5.31	6.12	6.83	7.54
74	0.39	0.78	1.19	1.56	1.97	2.37	2.75	3.13	3.54	3.93	4.31	4.74	5.14	5.51	6.32	7.05	7.78
75	0.40	0.81	1.21	1.62	2.03	2.42	2.84	3.23	3.65	4.06	4.45	4.86	5.28	5.65	6.55	7.27	8.03
77	0.42	0.85	1.29	1.73	2.16	2.58	3.02	3.42	3.82	4.33	4.73	5.13	5.63	6.04	6.94	7.75	8.55
80	0.47	0.94	1.42	1.90	2.37	2.84	3.30	3.75	4.20	4.75	5.19	5.63	6.18	6.62	7.62	8.50	9.38
85	0.54	1.09	1.66	2.19	2.78	3.32	3.88	4.39	4.91	5.56	6.07	6.59	7.23	7.75	8.92	9.95	10.98
90	0.62	1.25	1.87	2.47	3.12	3.74	4.37	4.95	5.53	6.25	6.84	7.43	8.15	8.73	10.03	11.20	12.37

Mechanical ventilation method

The following example shows how to calculate load using the mechanical ventilation method. This method works best when the percentage of outside air volume is at least 10%.

Sample Problem 2

Calculate the humidification load for a printing plant where:

- The desired conditions in the space are 70 °F and 50% RH.
- The outside entering conditions are 10 °F and 45% RH.
- A mechanical ventilation system circulates air at 9,000 cfm, of which 25% is outside air.

Solution to Sample Problem 2 using the mechanical ventilation method

1. Find the moisture content of your desired conditions by referring to Table 6-1 on Page 6. Read across the 70 °F line to the 50% RH column to find 3.44 lbs/hr/100 cfm.

2. Find the moisture content of the entering air by reading across the 10 °F line to the 45% RH column to find 0.30 lbs/hr/100 cfm.

3. Determine the moisture in lbs/hr to be added per 100 cfm by subtracting the moisture content of the entering conditions from the moisture content of the desired conditions:

   3.44 lbs/hr/100 cfm – 0.30 lbs/hr/100 cfm

   = 3.14 lbs/hr/100 cfm

4. Determine the air quantity to be humidified by multiplying total air circulation by the percentage of outside air:

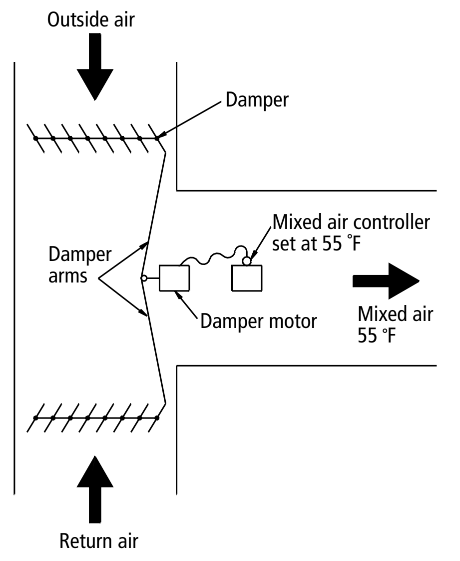
   9,000 cfm × 25% = 2,250 cfm

5. Determine the humidification load by multiplying the quantity of air to be humidified by moisture to be added:

   $$\frac{2{,}250 \text{ cfm} \times 3.14 \text{ lbs/hr}}{100 \text{ cfm}}$$

   = 70.65 lbs/hr

Figure 8-1:
Typical economizer control system



Economizer cycle method

Many year-round air conditioning systems use economizer cycle control. Economizer cycles use cool outside air instead of mechanical cooling to maintain building temperature when the outside temperature is moderate (typically spring and fall).

Figure 8-1 shows a typical application where a mixed-air controller positions a modulating damper motor, which adjusts the outside air intake and return dampers. Note that the dampers are opposing — as one moves toward open, the other moves toward closed, and vice versa — to maintain a mixed air temperature of 55 °F as the outside air temperature rises and falls.

When the outside air temperature rises to 55 °F (100% outside air), the outside air damper returns to a minimum setting (usually about 10%) and mechanical cooling takes over. Table 9-1 shows how outside air percentages change with varying outside and mixed air temperatures.

As the outside temperature rises, the ratio of outside air to return air increases. This works toward increasing the humidification load.

For example, to cool return air to 55 ˚F, you can admit 50% outdoor air at 40 ˚F, but only 17% outdoor air at -20 ˚F (see Table 9-1). The warmer the outdoor air temperature, the more air volume that can be admitted. More air volume means more air that needs to be humidified, thereby increasing the humidification load required to maintain RH set point.

To better understand how varying temperatures and air volumes affect humidification load calculations, review the following formulas, sample problems, and tables.

The formula for determining the quantity of outside air in an economizer cycle is:

$$V_2 = V_{AH} / [(A/B) + 1]$$

Where:

$V_{AH} = V_1 + V_2$

V_1 = Volume (cfm) of return air

V_2 = Volume (cfm) of outside air

A = Temperature difference between mixed air and outside air

B = Temperature difference between return air and mixed air

Sample Problem 3

Determine the outside air quantity in an economizer cycle system where:

- The outside air is 20 °F.
- The return (room) air is 70 °F.
- The mixed air is 55 °F.
- The total air is 12,000 cfm.

Solution to Sample Problem 3 using the economizer cycle method

1. A = 55 °F – 20 °F = 35 °F
2. B = 70 °F – 55 °F = 15 °F
3. V_{AH}= 12,000 cfm
4. V_2 = V_{AH} / [(A/B) + 1]
   = 12,000 cfm / [(35 °F/15 °F) + 1]
   = 3,600 cfm = outside air

To document outside air quantity at various points (typically 10 °F intervals) over a temperature range of outside air, create a table using the above formula. Table 9-1 shows percentages of outside air at a consistent 70 °F room temperature and three different mixed air temperatures.

Calculating maximum humidification load in an economizer system

Determining maximum humidification load involves the use of one of the three mixed air temperatures in Table 9-1 (or a similar table developed from different mixed and return air temperature conditions).

Also needed is the difference (lbs/hr/100 cfm) between the desired moisture content of the air in the space and that contained in the outside air. This difference is made up by the humidifier.

When calculating maximum humidification load in an economizer system for noncritical applications, calculate load using the daily minimum % RH for year by location. However, when calculating maximum humidification load in an economizer system for critical applications, to ensure that humidity set point can always be met, calculate maximum humidification load using the extreme minimum daily RH for year by location. Table 11-1 shows these values for select cities.

Table 9-1: Outside air percentages with 70 °F return air and various mixed air temperatures

Outside temp (°F)	Outside air percentage		
	of 50 °F mixed air	of 55 °F mixed air	of 60 °F mixed air
-20	22	17	11
-10	25	19	13
0	29	21	15
10	33	25	17
20	40	30	20
30	50	38	25
40	67	50	34
50	100	75	50
55	—	100	67
60	—	—	100

Notes about economizer cycle method

Economizer "free cooling," provided by using outside air, is not always cost effective. The operating cost advantage of ambient cooling may be lost when certain operating conditions prevail, such as:

- The indoor relative humidity requirements are in a fairly high range (40% RH or greater).
- Electricity is used to heat water into steam for humidification.

A crossover point occurs where the economizer cycle's increased humidification energy costs (due to increased air volume requiring humidification) are more than the savings derived by outside air cooling.

Sample Problem 4

Determine the maximum humidification load for an economizer system located in Minneapolis where:

- The desired conditions in the space are 70 °F and 35% RH.
- The mixed air is 55 °F.
- The total air is 12,000 cfm.

Solution to Sample Problem 4 using the economizer cycle method

1. Find the moisture content of your desired conditions by referring to Table 6-1 on Page 6. Read across the 70 °F line to the 35% column, and find 2.40 lbs/hr/100 cfm.

2. Determine the moisture to be added at each 10 °F increment by using:
   - Table 11-1 to find entering RH
   - Table 6-1 to find moisture content of entering conditions
   - Table 9-1 to find the percentage of outside air

   Create a new table with your results by using the following formula (where H = lbs/hr/cfm):

   [H (space) – H (outside air)] × % outside air × [cfm (total air)/100 cfm] = lbs/hr (load)

   Table 12-1 shows data created from the above formula for this sample problem.

3. Find the maximum humidification load from your created table. The maximum load for this system is 70.68 lbs/hr and occurs when the outdoor temperature is 40 °F as shown in Table 12-1.

Table 11-1:
Average daily minimum % RH for year and extreme daily minimum % RH for year, by location (U.S. and Canada)*

Location	Average daily minimum % RH for year	Extreme daily minimum % RH for year	Location	Average daily minimum % RH for year	Extreme daily minimum % RH for year
Akron, Ohio	54	20	Green Bay, Wisconsin	57	21
Albany, New York	51	15	Indianapolis, Indiana	51	20
Albuquerque, New Mexico	22	4	Jacksonville, Florida	54	16
Amarillo, Texas	30	5	Kansas City, Missouri	46	14
Anchorage, Alaska	59	15	Lake Charles, Louisiana	55	16
Apalachicola, Florida	53	16	Las Vegas, Nevada	16	1
Atlanta, Georgia	49	12	Little Rock, Arkansas	50	16
Atlantic City, New Jersey	53	20	Los Angeles, California	52	6
Baltimore, Maryland	48	18	Madison, Wisconsin	53	20
Birmingham, Alabama	46	13	Medford, Oregon	43	11
Bismarck, North Dakota	46	11	Miami, Florida	56	13
Boise, Idaho	35	6	Milwaukee, Wisconsin	58	21
Boston, Massachusetts	47	5	Minneapolis, Minnesota	51	20
Brownsville, Texas	54	13	Montreal, Quebec	54	21
Cape Hatteras, North Carolina	62	17	Nashville, Tennessee	50	20
Caribou, Maine	52	11	New York, New York	45	11
Charleston, South Carolina	51	14	Norfolk, Virginia	52	21
Cheyenne, Wyoming	32	5	North Omaha, Nebraska	47	7
Chicago, Illinois	48	13	Oklahoma City, Oklahoma	45	11
Cleveland, Ohio	52	19	Olympia, Washington	60	19
Colorado Springs, Colorado	31	2	Philadelphia, Pennsylvania	49	12
Columbia, Missouri	47	9	Phoenix, Arizona	20	5
Columbus, Ohio	51	19	Pittsburgh, Pennsylvania	48	12
Dayton, Ohio	47	13	Portland, Maine	51	14
Denver, Colorado	27	1	Portland, Oregon	52	14
Des Moines, Iowa	50	17	Raleigh/Durham, North Carolina	46	12
Detroit, Michigan	51	20	Salt Lake City, Utah	32	5
Dodge City, Kansas	40	7	San Antonio, Texas	43	14
Duluth, Minnesota	55	21	Santa Maria, California	49	7
Edmonton, Alberta	53	10	Seattle, Washington	58	18
El Paso, Texas	22	3	St. Louis, Missouri	50	18
Ely, Nevada	29	2	Sterling, Washington	48	11
Fairbanks, Alaska	51	10	Tallahassee, Florida	48	12
Fort Worth, Texas	45	12	Tampa, Florida	51	15
Fresno, California	37	7	Toronto, Ontario	57	16
Grand Rapids, Minnesota	54	21	Vancouver, British Columbia	65	17
Great Falls, Montana	37	6	Winnipeg, Manitoba	54	14

Note:
* When providing humidity for critical applications, use the values in the "Extreme daily minimum % RH for year" column to ensure that humidity set point will always be met.

Table 12-1:
Calculation table from economizer cycle method Sample Problem 3 (inch-pound units)

Outside temp.	H (space)	–	H (outside air)	=	Subtotal	x	% of outside air	x	Total air	÷	100	=	Load
°F	lbs/hr/100 cfm		lbs/hr/100 cfm		lbs/hr/100 cfm		%		cfm		cfm		lbs/hr
-20	2.4	–	0.072	=	2.328	x	17	x	12,000	÷	100	=	47.49
-10	2.4	–	0.124	=	2.276	x	19	x	12,000	÷	100	=	51.89
0	2.4	–	0.208	=	2.192	x	21	x	12,000	÷	100	=	55.24
10	2.4	–	0.338	=	2.062	x	25	x	12,000	÷	100	=	61.86
20	2.4	–	0.545	=	1.855	x	30	x	12,000	÷	100	=	66.78
30	2.4	–	0.856	=	1.544	x	38	x	12,000	÷	100	=	70.41
40	2.4	–	1.222	=	1.178	x	50	x	12,000	÷	100	=	70.68
50	2.4	–	1.794	=	0.606	x	75	x	12,000	÷	100	=	54.54
55	2.4	–	2.140	=	0.260	x	100	x	12,000	÷	100	=	31.20

Calculating humidification load using SI (Système International) units of measure

DRI-CALC software will calculate load for you

The easiest way to calculate humidification load is to use DRI-CALC, DRI-STEEM's humidification system sizing and selection software. The software not only sizes loads, but also selects equipment, writes specifications, creates equipment schedules, and provides as-configured installation instructions for DRI-STEEM products.

Note: DRI-CALC Europe Version 3, with the capabilities described above, will be released in Europe in 2003.

Methods for calculating humidification load

DRI-CALC uses the following methods for calculating load. Read through the examples in this section to learn how to manually calculate load using these same methods:

- Natural ventilation method
- Mechanical ventilation method

DRI-CALC also calculates load using the economizer cycle method, which is not described in this section

Natural ventilation method

As a general rule, humidification load is based only on the amount of air entering a building or space. In buildings without mechanical ventilation systems, humidification load is usually calculated using the air change method. Buildings can be classified by number of air changes per hour, with typical air changes being 1, 1½, or 2 air changes per hour. See the chapter on natural ventilation and infiltration in the ***ASHRAE Fundamentals Handbook*** (available at www.ashrae.org) for more information about calculating air infiltration. For noncritical applications, we typically use 1½ air changes per hour for calculating load.

Important notes about calculating load

- When outside air is 10% or less, it is wise to calculate the load twice. The first calculation should be made on the basis of air changes due to mechanical ventilation; the second should be based on the natural ventilation method. Use the larger of the two results for determining the load.
- Vapor naturally migrates from areas with high vapor pressure to areas with low vapor pressure, regardless of air movement. Vapor retarders reduce vapor migration, but should only be installed in accordance with local codes.

Sample Problem 1

Calculate the humidification load for a printing plant where:

- The desired conditions in the space are 21 °C and 50% RH.
- The outside entering conditions are -10 °C and 45% RH.
- The dimensions of the building are:
  40 m × 25 m × 4 m (length × width × height).
- Air changes per hour = 1

Solution to Sample Problem 1 using the natural ventilation method

1. Find the moisture content of your desired conditions by referring to Table 15-1 on Page 15: Read across the 21 °C line to the 50% RH column to find 9.31 $g/m^3/h$.

2. Find the moisture content of the entering air by reading across the -10 °C line to the 45% RH column to find 0.97 $g/m^3/h$.

3. Determine the moisture in g/h to be added per m^3/h by subtracting the moisture content of the entering conditions from the moisture content of the desired conditions:

   $9.31\ g/m^3/h - 0.97\ g/m^3/h$

   $= 8.34\ g/m^3/h$

4. Determine the air quantity to be humidified by finding the total cubic meters of the space and multiplying that by the air changes per hour to find air quantity to be humidified in m^3/h:

   40 m × 25 m x 4 m × 1 air change per hour

   $= 4{,}000\ m^3/h$

5. Determine the humidification load by multiplying the quantity of air to be humidified by moisture to be added:

   $4{,}000\ m^3/h \times 8.34\ g/m^3/h$

   = 33,360 g/h = 33.36 kg/h

Table 15-1: Grams of moisture per m³/h at sea level

Air temp.	Percentage of saturation															
˚C	5%	10%	15%	20%	25%	30%	35%	40%	45%	50%	55%	60%	65%	70%	80%	90%	100%
-30	0.02	0.03	0.05	0.07	0.09	0.10	0.12	0.14	0.15	0.17	0.19	0.20	0.22	0.24	0.27	0.31	0.34
-25	0.03	0.06	0.08	0.11	0.14	0.17	0.19	0.22	0.25	0.28	0.31	0.33	0.36	0.39	0.44	0.50	0.56
-20	0.04	0.09	0.13	0.18	0.22	0.27	0.31	0.36	0.40	0.44	0.49	0.53	0.55	0.62	0.71	0.80	0.89
-15	0.07	0.14	0.21	0.28	0.35	0.42	0.49	0.56	0.63	0.70	0.77	0.84	0.91	0.98	1.12	1.25	1.39
-10	0.11	0.22	0.32	0.43	0.54	0.64	0.75	0.86	0.97	1.08	1.18	1.29	1.40	1.55	1.72	1.94	2.15
-5	0.16	0.33	0.49	0.65	0.82	0.98	1.14	1.31	1.47	1.63	1.80	1.96	2.12	2.28	2.61	2.93	3.26
0	0.24	0.49	0.73	0.98	1.22	1.47	1.71	1.95	2.20	2.44	2.68	2.93	3.17	3.41	3.90	4.38	4.86
5	0.34	0.69	1.03	1.37	1.72	2.06	2.40	2.74	3.09	3.42	3.77	4.11	4.45	4.79	5.46	6.15	6.82
10	0.48	0.95	1.43	1.91	2.38	2.86	3.33	3.80	4.27	4.75	5.21	5.69	6.16	6.62	7.57	8.50	9.43
13	0.58	1.15	1.73	2.31	2.88	3.45	4.02	4.59	5.17	5.73	6.30	6.87	7.44	8.01	9.13	10.30	11.40
14	0.61	1.23	1.84	2.45	3.06	3.67	4.28	4.89	5.49	6.10	6.71	7.32	7.92	8.52	9.72	10.90	12.10
16	0.70	1.39	2.08	2.78	3.47	4.16	4.84	5.53	6.22	6.90	7.58	8.27	8.95	9.63	11.00	12.30	13.70
18	0.79	1.57	2.35	3.14	3.92	4.69	5.47	6.24	7.02	7.79	8.57	9.33	10.10	10.90	12.40	13.90	15.40
19	0.84	1.67	2.50	3.33	4.16	4.99	5.81	6.63	7.45	8.27	9.09	9.90	10.70	11.50	13.10	14.80	16.40
20	0.88	1.77	2.66	3.53	4.41	5.29	6.16	7.04	7.92	8.78	9.65	10.50	11.40	12.20	14.00	15.70	17.40
21	0.94	1.88	2.82	3.75	4.68	5.61	6.55	7.47	8.40	9.31	10.20	11.10	12.10	13.00	14.80	16.60	18.40
22	1.00	2.00	2.99	3.98	4.97	5.96	6.94	7.92	8.90	9.87	10.80	11.80	12.80	13.80	15.70	17.60	19.50
23	1.06	2.12	3.17	4.22	5.27	6.32	7.36	8.40	9.43	10.50	11.50	12.50	13.50	14.60	16.60	18.60	20.70
24	1.12	2.24	3.36	4.48	5.60	6.70	7.80	8.90	10.00	11.10	12.20	13.30	14.30	15.40	17.60	19.70	21.80
25	1.19	2.38	3.56	4.75	5.92	7.09	8.27	9.42	10.60	11.80	12.90	14.10	15.20	16.30	18.60	20.90	23.10
27	1.34	2.67	4.00	5.32	6.64	8.00	9.27	10.60	11.90	13.20	14.40	15.70	17.00	18.30	20.80	23.30	25.80
30	1.59	3.17	4.74	6.30	7.87	9.42	11.00	12.50	14.00	15.60	17.10	18.60	20.10	21.60	24.60	27.50	30.50
35	2.10	4.19	6.26	8.33	10.40	12.40	14.40	16.40	18.50	20.40	22.40	24.40	26.30	28.30	32.20	36.00	39.70

Mechanical ventilation method

The following example shows how to calculate load using the mechanical ventilation method. This method works best when the percentage of outside air volume is at least 10%.

Sample Problem 2

Calculate the humidification load for a printing plant where:

- The desired conditions in the space are 21 °C and 50% RH.
- The outside entering conditions are -10 °C and 45% RH.
- A mechanical ventilation system circulates air at 15,000 m^3/h, of which 25% is outside air.

Solution to Sample Problem 2 using the mechanical ventilation method

1. Find the moisture content of your desired conditions by referring to Table 15-1 on Page 15. Read across the 21 °C line to the 50% RH column to find 9.31 $g/m^3/h$.
2. Find the moisture content of the entering air by reading across the -10 °C line to the 45% RH column to find 0.97 $g/m^3/h$.
3. Determine the moisture in g/h to be added per m^3/h by subtracting the moisture content of the entering conditions from the moisture content of the desired conditions:

   $9.31\ g/m^3/h - 0.97\ g/m^3/h$

   $= 8.34\ g/m^3/h$
4. Determine the air quantity to be humidified by multiplying total air circulation by the percentage of outside air:

   $15{,}000\ m^3/h \times 25\% = 3{,}750\ m^3/h$
5. Determine the humidification load by multiplying the quantity of air to be humidified by moisture to be added:

   $3{,}750\ m^3/h \times 8.34\ g/m^3/h = 31{,}275\ g/h$

   $= 31.275\ kg/h$

Reference tables for calculating load: Steam loss

Steam loss in lbs/hr/ft²

Table 17-1:
Steam loss in lbs/hr/ft² of duct area or ULTRA-SORB face area at 55 °F duct temperature for all ULTRA-SORB panels and for RAPID-SORB, Multiple-Tube, and Single-Tube evaporative dispersion units

Duct air velocity	Tube centers or duct height with Single-Tube								
	3"	6"	9"	12"	18"	24"	36"	48"	60"
fpm	lbs/hr/ft²	lbs/hr/ft²	lbs/hr/ft²	lbs/hr/ft²	lbs/hr/ft²	lbs/hr/ft²	lbs/hr/ft²	lbs/hr/ft²	lbs/hr/ft²
500	1.90	1.10	0.76	0.63	0.52	0.47	0.35	0.26	0.20
750	2.40	1.40	1.00	0.90	0.70	0.6	0.45	0.34	0.25
1000	2.80	1.77	1.20	1.00	0.85	0.75	0.56	0.42	0.32
1250	3.10	1.90	1.50	1.10	0.96	0.85	0.66	0.50	0.38
1500	3.40	2.10	1.60	1.25	1.05	0.95	0.72	0.55	0.42
1750	3.60	2.20	1.70	1.35	1.15	1.05	0.82	0.64	0.49
2000	3.70	2.30	1.75	1.40	1.25	1.10	0.86	0.68	0.53
2250	3.75	2.35	1.77	1.43	1.30	1.13	0.88	0.70	0.55
2500	3.78	2.37	1.78	1.44	1.32	1.15	0.89	0.71	0.56
2750	3.79	2.38	1.79	1.45	1.33	1.16	0.90	0.72	0.57
3000	3.80	2.39	1.80	1.46	1.34	1.17	0.91	0.73	0.58

Steam loss in kg/h/m²

Table 18-1:
Steam loss in kg/h/m² of duct area or ULTRA-SORB face area at 13 °C duct temperature for all ULTRA-SORB panels and for RAPID-SORB, Multiple-Tube, and Single-Tube evaporative dispersion units

Duct air velocity	Tube centers or duct height with Single-Tube								
	76 mm	152 mm	229 mm	305 mm	457 mm	610 mm	914 mm	1219 mm	1524 mm
m/s	kg/h/m²	kg/h/m²	kg/h/m²	kg/h/m²	kg/h/m²	kg/h/m²	kg/h/m²	kg/h/m²	kg/h/m²
2.54	9.28	5.37	3.71	3.08	2.54	2.30	1.71	1.27	0.98
3.81	11.72	6.84	4.88	4.39	3.42	2.93	2.20	1.66	1.22
5.08	13.67	8.64	5.86	4.88	4.15	3.69	2.73	2.05	1.56
6.35	15.14	9.28	7.32	5.37	4.69	4.15	3.22	2.44	1.86
7.62	16.60	10.25	7.81	6.10	5.13	4.64	3.52	2.69	2.05
8.89	17.58	10.74	8.30	6.59	5.62	5.13	4.00	3.13	2.39
10.16	18.07	11.23	8.55	6.84	6.10	5.37	4.20	3.32	2.59
11.43	18.31	11.48	8.64	6.98	6.35	5.52	4.30	3.42	2.69
12.70	18.46	11.57	8.69	7.03	6.45	5.62	4.35	3.47	2.73
13.97	18.51	11.62	8.74	7.08	6.49	5.66	4.39	3.52	2.78
15.24	18.56	11.67	8.79	7.13	6.54	5.71	4.44	3.56	2.83

Steam loss in lbs/hr/ft²

Table 19-1:
Steam loss in lbs/hr/ft² of duct area at 55 °F duct temperature for MAXI-BANK™, Multiple-Tube, and Single-Tube jacketed steam injection humidifiers

Duct air velocity	Tube centers or duct height with Single-Tube															
	6"		9"		12"		18"		24"		36"		48"		60"	
fpm	Insulated	Non-insulated	Insulated	Non-insulated	Insulated	Non-insulated	Insulated	Non-insulated	Insulated	Non-insulated	Insulated	Non-insulated	Insulated	Non-insulated	Insulated	Non-insulated
500	0.86	1.50	0.63	1.04	0.52	0.86	0.40	0.75	0.40	0.63	0.28	0.48	0.20	0.35	0.14	0.24
750	1.04	1.92	0.80	1.38	0.67	1.16	0.55	0.98	0.54	0.85	0.38	0.59	0.27	0.45	0.19	0.33
1000	1.15	2.30	0.92	1.73	0.81	1.38	0.69	1.15	0.57	1.04	0.48	0.73	0.32	0.55	0.24	0.42
1250	1.29	2.63	1.01	1.87	0.83	1.58	0.78	1.35	0.63	1.21	0.50	0.86	0.36	0.66	0.29	0.49
1500	1.38	2.93	1.04	2.07	0.86	1.73	0.85	1.50	0.68	1.42	0.53	1.02	0.40	0.78	0.30	0.57
1750	1.46	3.06	1.04	2.18	0.89	1.87	0.87	1.69	0.73	1.52	0.56	1.18	0.43	0.91	0.32	0.66
2000	1.53	3.21	1.07	2.26	0.93	1.95	0.89	1.83	0.77	1.61	0.58	1.22	0.46	0.97	0.32	0.66
2250	1.56	3.28	1.08	2.27	0.94	1.98	0.91	1.91	0.79	1.66	0.60	1.26	0.47	0.98	0.32	0.68
2500	1.57	3.29	1.10	2.30	0.95	2.00	0.93	1.95	0.80	1.67	0.60	1.27	0.48	1.01	0.33	0.68
2750	1.57	3.31	1.11	2.33	0.96	2.02	0.93	1.96	0.81	1.70	0.60	1.27	0.49	1.02	0.34	0.71
3000	1.58	3.32	1.11	2.33	0.96	2.03	0.95	1.99	0.81	1.71	0.61	1.28	0.49	1.02	0.35	0.73

Steam loss in kg/h/m²

Table 20-1:
Steam loss in kg/h/m² of duct area at 13 °C duct temperature for MAXI-BANK, Multiple-Tube, and Single-Tube jacketed steam injection humidifiers

Duct air velocity	Tube centers or duct height with Single-Tube															
	76 mm		152 mm		229 mm		305 mm		457 mm		610 mm		914 mm		1219 mm	
m/s	Insulated	Non-insulated	Insulated	Non-insulated	Insulated	Non-insulated	Insulated	Non-insulated	Insulated	Non-insulated	Insulated	Non-insulated	Insulated	Non-insulated	Insulated	Non-insulated
2.5	4.21	7.30	3.09	5.06	2.53	4.21	1.97	3.65	1.97	3.09	1.35	2.33	0.99	1.72	0.67	1.16
3.8	5.06	9.40	3.92	6.74	3.29	5.65	2.70	4.80	2.65	4.13	1.85	2.87	1.31	2.19	0.93	1.60
5.1	5.62	11.24	4.49	8.43	3.93	6.74	3.37	5.62	2.78	5.06	2.36	3.57	1.56	2.70	1.18	2.05
6.4	6.32	12.85	4.92	9.13	4.07	7.73	3.79	6.60	3.08	5.90	2.46	4.21	1.76	3.23	1.40	2.39
7.6	6.74	14.33	5.06	10.11	4.21	8.43	4.13	7.33	3.32	6.91	2.59	4.97	1.95	3.79	1.46	2.78
8.9	7.11	14.94	5.08	10.66	4.36	9.15	4.25	8.27	3.54	7.44	2.74	5.76	2.11	4.42	1.55	3.24
10.2	7.45	15.65	5.25	11.02	4.53	9.52	4.35	8.95	3.74	7.85	2.83	5.94	2.26	4.74	1.57	3.28
11.4	7.63	16.03	5.28	11.09	4.60	9.66	4.44	9.33	3.85	8.09	2.92	6.14	2.29	4.80	1.58	3.32
12.7	7.65	16.05	5.35	11.24	4.64	9.75	4.54	9.53	3.89	8.17	2.95	6.22	2.35	4.94	1.59	3.34
14.0	7.69	16.15	5.41	11.36	4.70	9.87	4.56	9.57	3.96	8.32	2.95	6.20	2.38	5.00	1.66	3.48
15.2	7.71	16.20	5.41	11.36	4.78	9.91	4.62	9.70	3.97	8.33	2.98	6.26	2.38	5.00	1.71	3.58

Steam loss in lbs/hr/ft^2 and kg/h/m^2

Table 21-1:
Steam loss in lbs/hr/ft^2 and kg/h/m^2 of duct area at 55 °F or 13 °C duct temperature for MINI-BANK® jacketed steam injection humidifiers

Duct air velocity		3" or 76 mm tube centers			
		Insulated		Noninsulated	
fpm	m/s	lbs/hr/ft^2	kg/h/m^2	lbs/hr/ft^2	kg/h/m^2
500	2.5	1.0	5.1	2.0	9.8
750	3.8	1.4	6.7	2.8	13.5
1000	5.1	1.6	7.9	3.0	14.4
1250	6.4	1.6	7.6	3.1	15.0
1500	7.6	1.7	8.1	3.3	16.0
1750	8.9	1.7	8.5	3.5	16.9
2000	10.2	1.8	8.9	3.6	17.8
2250	11.4	1.9	9.2	3.7	18.2
2500	12.7	1.9	9.2	3.7	18.2
2750	14.0	1.9	9.2	3.7	18.2
3000	15.2	1.9	9.2	3.7	18.2

Steam loss in lbs/hr/ft² and kg/h/m²

Table 22-1:
Steam loss of interconnecting vapor hose, tubing, and pipe

Description	Nominal hose, tubing, or pipe size		Steam loss				Insulation thickness	
			Noninsulated		Insulated			
	inches	DN	lbs/hr/ft	kg/h/m	lbs/hr/ft	kg/h/m	inches	mm
Hose	1½	40	0.15	0.22	N/A	N/A	N/A	N/A
	2	50	0.20	0.30	N/A	N/A	N/A	N/A
Tubing	1½	40	0.11	0.16	0.020	0.030	2.0	50
	2	50	0.14	0.21	0.025	0.037	2.0	50
	3	80	0.20	0.30	0.030	0.045	2.5	64
	4	100	0.26	0.39	0.030	0.045	3.0	76
	5	125	0.31	0.46	0.035	0.052	3.0	76
	6	150	0.36	0.54	0.039	0.058	3.0	76
Pipe	1½	40	0.22	0.33	0.020	0.030	2.0	50
	2	50	0.25	0.38	0.025	0.037	2.0	50
	3	80	0.39	0.58	0.030	0.045	2.5	64
	4	100	0.49	0.73	0.030	0.045	3.0	76
	5	125	0.59	0.88	0.035	0.052	3.0	76
	6	150	0.70	1.04	0.039	0.058	3.0	76

Note: Data based on ambient air temperature of 80 °F (26.7 °C), fiberglass insulation, copper tubing, and Schedule 40 pipe.

Reference tables for calculating load: Heat gain

Heat gain in °F

Table 23-1:
Heat gain in °F at 55 °F duct temperature for all ULTRA-SORB panels and for RAPID-SORB, Multiple-Tube, and Single-Tube evaporative dispersion units

Duct air velocity	Tube centers or duct height with Single-Tube								
	3"	6"	9"	12"	18"	24"	36"	48"	60"
fpm	°F	°F	°F	°F	°F	°F	°F	°F	°F
500	3.41	1.98	1.37	1.13	0.93	0.84	0.63	0.47	0.36
750	2.87	1.68	1.20	1.08	0.84	0.72	0.54	0.41	0.30
1000	2.52	1.59	1.12	0.90	0.76	0.68	0.50	0.38	0.29
1250	2.23	1.37	1.08	0.79	0.69	0.61	0.47	0.36	0.27
1500	2.04	1.26	0.96	0.75	0.63	0.57	0.43	0.33	0.25
1750	1.85	1.13	0.87	0.69	0.59	0.54	0.42	0.33	0.25
2000	1.66	1.03	0.79	0.63	0.56	0.49	0.39	0.31	0.24
2250	1.50	0.94	0.71	0.57	0.52	0.45	0.35	0.28	0.22
2500	1.36	0.85	0.64	0.52	0.47	0.41	0.32	0.26	0.20
2750	1.24	0.78	0.58	0.47	0.43	0.38	0.29	0.24	0.19
3000	1.14	0.72	0.54	0.44	0.40	0.35	0.27	0.22	0.17

Heat gain in °C

Table 24-1:
Heat gain in °C at 13 °C duct temperature for all ULTRA-SORB panels and for RAPID-SORB, Multiple-Tube, and Single-Tube evaporative dispersion units

Duct air velocity	Tube centers or duct height with Single-Tube								
	76 mm	152 mm	229 mm	305 mm	457 mm	610 mm	914 mm	1219 mm	1524 mm
m/s	°C	°C	°C	°C	°C	°C	°C	°C	°C
2.54	1.90	1.10	0.76	0.63	0.52	0.47	0.35	0.26	0.20
3.81	1.60	0.93	0.67	0.60	0.47	0.40	0.30	0.23	0.17
5.08	1.40	0.88	0.62	0.50	0.42	0.38	0.28	0.21	0.16
6.35	1.24	0.76	0.60	0.44	0.38	0.34	0.26	0.20	0.15
7.62	1.13	0.70	0.53	0.42	0.35	0.32	0.24	0.18	0.14
8.89	1.03	0.63	0.49	0.39	0.33	0.30	0.23	0.18	0.14
10.16	0.92	0.57	0.44	0.35	0.31	0.27	0.21	0.17	0.13
11.43	0.83	0.52	0.39	0.32	0.29	0.25	0.20	0.16	0.12
12.70	0.76	0.47	0.36	0.29	0.26	0.23	0.18	0.14	0.11
13.97	0.69	0.43	0.33	0.26	0.24	0.21	0.16	0.13	0.10
15.24	0.63	0.40	0.30	0.24	0.22	0.19	0.15	0.12	0.10

Heat gain in °F

Table 25-1:
Heat gain in °F at 55 °F duct temperature for MAXI-BANK, Multiple-Tube, and Single-Tube jacketed steam injection humidifiers

Duct air velocity	Tube centers or duct height with Single-Tube															
	6"		9"		12"		18"		24"		36"		48"		60"	
fpm	Insulated	Non-insulated	Insulated	Non-insulated	Insulated	Non-insulated	Insulated	Non-insulated	Insulated	Non-insulated	Insulated	Non-insulated	Insulated	Non-insulated	Insulated	Non-insulated
500	1.6	2.7	1.1	1.9	0.9	1.6	0.7	1.3	0.7	1.1	0.5	0.9	0.4	0.6	0.2	0.4
750	1.2	2.3	1.0	1.7	0.8	1.4	0.7	1.2	0.7	1.0	0.5	0.7	0.3	0.5	0.2	0.4
1000	1.0	2.1	0.8	1.6	0.7	1.2	0.6	1.0	0.6	0.9	0.4	0.7	0.3	0.5	0.2	0.4
1250	0.9	1.9	0.5	1.3	0.6	1.1	0.6	1.0	0.5	0.9	0.4	0.6	0.3	0.5	0.2	0.4
1500	0.8	1.8	0.6	1.2	0.5	1.0	0.5	0.9	0.5	0.9	0.4	0.6	0.3	0.5	0.2	0.3
1750	0.7	1.6	0.5	1.1	0.5	1.0	0.4	0.9	0.4	0.8	0.3	0.6	0.2	0.5	0.2	0.3
2000	0.7	1.4	0.5	1.0	0.4	0.9	0.4	0.8	0.3	0.7	0.3	0.5	0.2	0.4	0.1	0.3
2250	0.6	1.3	0.4	0.9	0.4	0.8	0.4	0.8	0.3	0.7	0.2	0.5	0.2	0.4	0.1	0.3
2500	0.6	1.2	0.4	0.8	0.3	0.7	0.3	0.7	0.3	0.6	0.2	0.5	0.2	0.4	0.1	0.2
2750	0.5	1.1	0.4	0.8	0.3	0.7	0.3	0.6	0.3	0.6	0.2	0.4	0.2	0.3	0.1	0.2
3000	0.5	1.0	0.3	0.7	0.3	0.6	0.3	0.6	0.2	0.5	0.2	0.4	0.1	0.3	0.1	0.2

Heat gain in °C

Table 26-1:
Heat gain in °C at 13 °C duct temperature for MAXI-BANK, Multiple-Tube, and Single-Tube jacketed steam injection humidifiers

Duct air velocity	Tube centers or duct height with Single-Tube															
	76 mm		152 mm		229 mm		305 mm		457 mm		610 mm		914 mm		1219 mm	
m/s	Insulated	Non-insulated	Insulated	Non-insulated	Insulated	Non-insulated	Insulated	Non-insulated	Insulated	Non-insulated	Insulated	Non-insulated	Insulated	Non-insulated	Insulated	Non-insulated
2.5	0.86	1.50	0.63	1.04	0.52	0.86	0.40	0.75	0.40	0.63	0.28	0.48	0.20	0.35	0.14	0.24
3.8	0.69	1.28	0.54	0.92	0.45	0.77	0.37	0.66	0.36	0.56	0.25	0.39	0.18	0.30	0.13	0.22
5.1	0.58	1.15	0.46	0.86	0.40	0.69	0.35	0.58	0.35	0.52	0.24	0.37	0.16	0.28	0.12	0.21
6.4	0.52	1.05	0.40	0.75	0.33	0.63	0.31	0.54	0.30	0.48	0.20	0.35	0.16	0.26	0.12	0.20
7.6	0.46	0.98	0.35	0.69	0.29	0.58	0.28	0.50	0.27	0.47	0.20	0.34	0.15	0.26	0.11	0.19
8.9	0.42	0.87	0.30	0.62	0.25	0.54	0.23	0.48	0.21	0.44	0.16	0.34	0.12	0.2	0.09	0.19
10.2	0.38	0.80	0.27	0.56	0.23	0.49	0.22	0.46	0.19	0.40	0.14	0.30	0.12	0.24	0.08	0.17
11.4	0.35	0.73	0.24	0.51	0.21	0.44	0.20	0.42	0.18	0.37	0.13	0.28	0.10	0.22	0.07	0.15
12.7	0.31	0.66	0.22	0.46	0.19	0.40	0.19	0.39	0.16	0.34	0.12	0.26	0.10	0.20	0.07	0.14
14.0	0.29	0.60	0.20	0.42	0.18	0.37	0.17	0.36	0.15	0.31	0.11	0.23	0.09	0.19	0.06	0.13
15.2	0.26	0.55	0.18	0.39	0.16	0.34	0.16	0.33	0.14	0.28	0.10	0.21	0.08	0.17	0.06	0.12

Heat gain in °F and °C

Table 27-1:
Heat gain in °F and °C of duct area at 55 °F and 13 °C duct temperature for MINI-BANK jacketed steam injection humidifiers

Duct air velocity		3" or 76 mm tube centers			
		Insulated		Noninsulated	
fpm	m/s	°F	°C	°F	°C
500	2.5	1.87	1.04	3.63	2.01
750	3.8	1.66	0.92	3.32	1.84
1000	5.1	1.45	0.81	2.90	1.61
1250	6.4	1.12	0.62	2.22	1.23
1500	7.6	1.00	0.55	1.97	1.09
1750	8.9	0.90	0.50	1.78	0.99
2000	10.2	0.82	0.46	1.64	0.91
2250	11.4	0.75	0.42	1.49	0.83
2500	12.7	0.68	0.38	1.34	0.74
2750	14.0	0.62	0.34	1.22	0.68
3000	15.2	0.57	0.31	1.12	0.62

Air duct pressure loss in wc and Pa

Table 28-1:
Air duct pressure losses for all ULTRA-SORB panels and for RAPID-SORB, Multiple-Tube, and Single-Tube evaporative dispersion units

Duct air velocity		Tube centers or duct height with Single-Tube (without airflow stabilizer panel)						Add to pressure values if ULTRA-SORB has an airflow stabilizer panel	
		3"	76 mm	6"	152 mm	9″ and greater	229 mm and greater		
fpm	m/s	wc	Pa	wc	Pa	wc	Pa	wc	Pa
250	1.3	0.010	2.5	0.005	1.2	There is no measurable air pressure loss for these tube spacings.		0	0
500	2.5	0.020	5.0	0.010	2.5			0.010	2.5
750	3.8	0.045	11.2	0.015	3.7			0.040	10.0
1000	5.1	0.080	20.0	0.025	6.2			0.090	22.0
1250	6.4	0.120	29.9	0.035	8.7			0.150	37.0
1500	7.6	0.170	42.0	0.050	12.4			0.210	52.0
1750	8.9	0.230	57.0	0.070	17.4			0.270	67.0
2000	10.2	0.300	75.0	0.090	22.0			0.330	82.0
2250	11.4	0.380	95.0	0.110	27.0			0.420	105.0
2500	12.7	0.470	117.0	0.140	35.0			0.500	124.0
2750	14.0	0.570	142.0	0.170	42.0			0.620	154.0
3000	15.2	0.680	169.0	0.200	50.0			0.740	184.0

Air duct pressure loss in wc and Pa

Table 29-1:
Air duct pressure losses for MAXI-BANK, Multiple-Tube, and Single-Tube jacketed steam injection humidifiers

Duct air velocity		With insulated jackets: Tube centers or duct height with Single-Tube									
		6"	152 mm	9"	229 mm	12"	305 mm	18"	457 mm	24"	610 mm
fpm	m/s	wc	Pa	wc	Pa	wc	Pa	wc	Pa	wc	Pa
500	2.5	0.02	5.0	0.02	5.0	0.01	2.5	0.01	2.5	0.01	2.5
1000	5.1	0.08	20.0	0.06	15.0	0.04	10.0	0.03	7.5	0.03	7.5
1500	7.6	0.18	45.0	0.14	35.0	0.10	25.0	0.07	17.0	0.07	17.0

Duct air velocity		With noninsulated jackets: Tube centers or duct height with Single-Tube									
		6"	152 mm	9"	229 mm	12"	305 mm	18"	457 mm	24"	610 mm
fpm	m/s	wc	Pa	wc	Pa	wc	Pa	wc	Pa	wc	Pa
500	2.5	0.02	5.0	0.01	2.5	0.01	2.5	0.01	2.5	0.01	2.5
1000	5.1	0.06	15.0	0.05	12.0	0.04	10.0	0.03	7.5	0.03	7.5
1500	7.6	0.14	35.0	0.11	27.0	0.08	20.0	0.07	17.0	0.07	17.0

Select energy source

Choices when using on-site steam

Using on-site steam for humidification can be a good economic choice. Pressurized steam can be injected directly into the airstream, or passed through a heat exchanger to heat potable, softened, or DI/RO water for humidification steam.

Chemically-treated boiler steam may affect indoor air quality. Many humidifier users are finding that chemically treated, boiler-generated steam is unsuitable for direct injection humidification. This is because boiler water is treated with anticorrosion chemicals that are then emitted with the steam into the occupied space. These chemicals can irritate eyes and skin and aggravate respiratory disorders such as asthma. In addition, they can accelerate the aging process of certain materials like paper and wood, an issue especially relevant to museums.

When designing your humidification system using boiler steam, consider a closed loop system such as DRI-STEEM'S STS Steam-to-Steam humidifier to prevent the discharge of chemically treated steam into your building.

Choose energy source wisely

A pound of water requires approximately 1,000 BTUs to vaporize. Given that proper humidification typically requires vaporizing two to three pounds of water for every 100 cfm of outside air introduced into the system, humidification energy use ranges from 2,000 to 3,000 BTUs per 100 cfm of outside air.

A kilogram of water requires approximately 2.4 kJ to vaporize. Given that proper humidification typically requires vaporizing 1.5 to 2.5 kilograms of water for every 100 m^3/h of outside air introduced into the system, humidification energy use ranges from 3.5 kJ to 5.8 kJ per 100 m^3/h of outside air.

Two major types of humidifiers

- Isothermal systems use heat from an external source to create humidity. Electricity, natural gas, hot water, and boiler steam are isothermal heat sources used to boil water into steam for humidification.

  The table on Page 32 shows DRI-STEEM's isothermal humidifiers described by energy type.
- Adiabatic systems use heat from the surrounding air to change water into vapor for humidification (evaporation). Foggers, ultrasonic, and pezio disk humidifiers are typical adiabatic systems.

Why choose isothermal humidification?

- Choose isothermal humidification if you require predictable, controllable, and short absorption distances. Adiabatic systems require long absorption distances and often do not provide complete absorption in typical HVAC applications.
- Choose isothermal humidification if you have low air temperatures in your ducts. Adiabatic humidification requires very warm or preheated air for absorption to occur.
- Choose isothermal humidification if there is an on-site boiler or hot water source. Direct steam injection or a heat-exchanger type isothermal system may be most appropriate. Consider DRI-STEEM's:
  - Steam injection humidifiers: ULTRA-SORB, MAXI-BANK, Multiple-Tube, MINI-BANK, Single-Tube, or AREA-TYPE
  - STS Steam-to-Steam (with heat exchanger) evaporative steam humidifier
  - LTS Liquid-to-Steam (with heat exchanger) evaporative steam humidifier

  See also the text at left for more detail about choices when using on-site steam.

- Choose isothermal electric humidification for application flexibility. Electric element humidification systems easily integrate into existing systems. They are available in a wide range of sizes, capacities and options, allowing them to meet the humidification demands of virtually any environment. Consider DRI-STEEM's:
  - VAPORSTREAM humidifier
  - VAPORMIST humidifier
  - CRUV humidifier
  - HUMIDI-TECH humidifier (available only in Europe)
- Choose isothermal humidification to gain the economic benefits of natural gas. Gas-fired humidification systems offer substantial energy savings over electric systems. Consider DRI-STEEM's:
  - GTS Gas-to-Steam humidifier

When is adiabatic appropriate?

Is the supply air warm and dry? If so, your humidification needs may be met by an adiabatic system such as a fogger, which uses sensible heat in the air for its energy source. In the right environment, these systems can be very economical due to the cooling effect they provide. Exercise caution, however, when applying adiabatic humidification to standard commercial applications with short absorption distances and low discharge air temperatures. We have found there are very few applications where adiabatic humidification provides complete absorption, often resulting in wet ducts.

Table 32-1:
DRI-STEEM products by energy source

Energy source	DRI-STEEM product		Key features	Maximum capacity lbs/hr	Maximum capacity kg/h	RH control capability*
PRESSURIZED STEAM	ULTRA-SORB	Pressurized steam injection dispersion	• Shortest absorption available • No unnecessary heat gain • Double-header design • Pre-assembled	4,000	1,814	±1%
	MINI-BANK		• Short to moderate absorption distance • Suitable for medium capacity systems • Sized for small ducts • Pre-assembled	84	38	±1%
	MAXI-BANK/ Multiple-Tube		• Short to moderate absorption distance • Suitable for large capacity systems • Fits small ducts to large air handlers • MAXI-BANK pre-assembled • Multiple-Tube field-assembled	3,328 (Unlimited with multiple valves)	1,509 (Unlimited with multiple valves)	±1%
	Single-Tube		• Long absorption distance • Suitable for small capacity systems • Pre-assembled	2,312	1,048	±1%
	AREA-TYPE™		• Suitable for medium capacity systems • Used in ductless spaces • Absorption varies by application	286	130	±3%
	STS	Evaporative steam dispersion	• Chemical-free steam • Economical: Uses on-site boiler steam • Extra large capacity	1,600 (6,400 when four units are connected)	726 (2,903 when four units are connected)	±3%
GAS	GTS		• Economical benefits of gas • Large capacity • Indoor and outdoor enclosures	600 (3,600 when six units are connected)	272 (1,633 when six units are connected)	±3%
ELECTRICITY	VAPORSTREAM		• Precise RH control (±1%) • Industrial grade • Suitable for any application	285 (1,140 when four units are connected)	129 (517 when four units are connected)	±1%
	VAPORMIST		• For use in finished spaces • Attractive cabinet	102	46	±3%
	HUMIDI-TECH		• For use in finished spaces • Attractive cabinet • Available only in Europe	102	46	±3%
	CRUV		• For packaged AC units or small ducted appliances • Designed for easy service access	102	46	±3%
HOT WATER	LTS		• Economical when there is on-site hot water (minimum 240 °F [115 °C]) • Large capacity	540 (2,160 when four units are connected)	245 (980 when four units are connected)	±3%

Note:
* Many variables affect RH control capability. See Pages 52-56 for more information about the factors that affect humidifier controllability.

Humidifiers and water type

Water type affects humidifier performance, maintenance, vapor quality, and efficiency

Water is often called the universal solvent because almost everything is soluble to some degree in water. This property causes water to become contaminated by virtually any material it contacts, with the mix of contaminants varying greatly from one location to another.

Humidification is the process of transforming water into vapor, and so it is not surprising that water type has a great impact on humidifier performance, maintenance requirements, humidification vapor quality, and efficiency of operation.

There are four types of water used in humidifiers:

- Potable water (drinking, tap, or well water)
- Softened water (hardness reduced through an ion exchange process)
- High-purity water (deionized and/or reverse osmosis treated water)
- Boiler water (typically treated with anticorrosion chemicals)

Potable water: Usually safe for drinking but can be hard on humidifiers

Potable water, commonly referred to as drinking, tap, or well water, can contain any number of living microorganisms, dissolved organic material, dissolved minerals, and suspended materials. While all of these substances can affect humidification vapor quality, humidifier maintenance, performance, and efficiency are significantly affected by dissolved minerals and suspended materials.

- Living microorganisms (bacteria) are killed when water is heated to 180 °F (83 °C), and so bacteria are not a concern when using isothermal humidifiers where water is boiled to make steam (vapor). However, care should be taken to ensure that all harmful microorganisms are removed from water sources feeding nonboiling (adiabatic) humidifiers such as air washers, foggers, atomizers, or pezio disk systems. In addition, even though a water supply may be free of harmful bacteria, contaminants from the air can still cause microbial growth in wetted-media or wick systems. Water treatment for bacteria includes filtration, reverse osmosis, chemical oxidation, and disinfection. The most common treatment for bacteria is chemical oxidation by either ozonation or by adding chlorine.

Figure 34-1:
How a water softener works

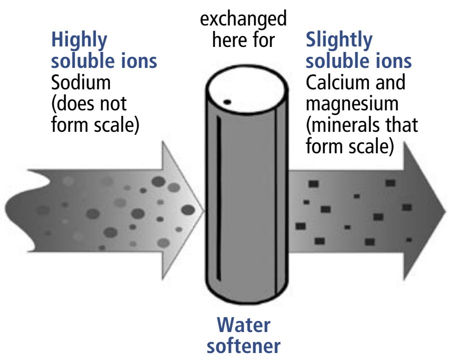
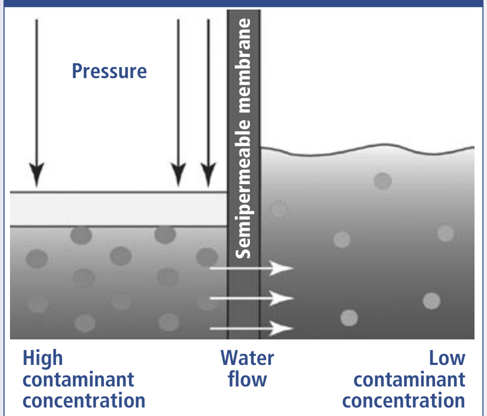


Figure 34-2:
How reverse osmosis filtration works



- Dissolved organic material comes from three major sources:
  - The breakdown of naturally occurring organic materials (plant and animal matter)
  - Domestic and commercial chemical wastes (agricultural and urban runoff, or leaching from contaminated soils)
  - Chemical reactions that occur during water treatment processes (from disinfection by-products or pipe joint adhesives)

  Activated carbon and microfiltration, and reverse osmosis and deionization processes remove dissolved organic material.
- Dissolved minerals found in potable water are magnesium, calcium, iron, and silicon, with calcium and magnesium the primary elements causing "hard" water. Water hardness is commonly measured in grains per gallon (gpg). As water hardness increases, so does the need for humidifier cleaning to remove scale buildup. Downtime for cleaning, as well as time required to heat fresh water that replaces frequently skimmed or drained water (to remove minerals), can significantly affect humidifier performance and efficiency. Water softening is the most common method for reducing water hardness.
- Suspended materials, typically clay or silt, give water a cloudy appearance. These particles should be removed from humidifier makeup water as they will settle out and collect in humidifier water reservoirs. These particles typically are removed by filtration.

Softened water significantly reduces cleaning requirements

Water softening is an ion exchange process where slightly soluble magnesium and calcium ions are replaced by very soluble sodium ions. The exchanged sodium ions stay in solution when in water and do not attach to humidifier tank walls and elements as scale in the way magnesium and calcium will.

Softening water can dramatically improve humidifier performance, maintenance requirements, and efficiency. It is not unusual for systems using softened water to go several seasons without cleaning. However, water softeners need their brine tanks regularly replenished with sodium (so that there are sodium ions available to exchange with the magnesium and calcium ions). For this reason, owners should regularly inspect their humidifiers using softened water to verify softener operation. To lessen maintenance requirements, we recommend softening water for humidifier use where water hardness is greater than 12 gpg.

High purity water yields high purity humidification for critical process environments

Semiconductor, pharmaceutical, and electronics manufacturers, as well as laboratories, industrial clean rooms, and healthcare facilities often require high purity humidification. To avoid water contaminants that can be carried into the air with water vapor, these types of environments use highly processed – and very pure – water in their humidification systems. For these environments, water is cycled through several prefilters, through a reverse osmosis permeable membrane and, frequently, through a chemical deionization process. This type of high purity water is often called "DI/RO" water (deionized, reverse osmosis water) and, depending on the quality of process, can be free of minerals and other contaminants. The purity of this water degrades upon contact with the atmosphere and certain materials, and should remain in a closed system contacting only chemically stable materials.

Properly maintained DI/RO water is not corrosive

A well-maintained DI/RO system produces water that consists solely of hydrogen and hydroxides and is free of most or all total dissolved solids (TDS) including chlorides and other molecules that cause metal corrosion.

Many users of high purity water have the false impression that it is highly corrosive to metals. This may be due, in part, to the water quality found in systems that have not been properly maintained or operated. If, for example, DI beds are not properly maintained, or the flow rate through them exceeds their capacity, the first of the two DI beds (the cation bed) typically becomes saturated or ineffective, and then the weak acid solutions generated by the second bed (the anion bed) cannot be neutralized and flow into the water system. If this happens, chlorides and other electrolytes are introduced into the system in large quantities, with the ability to cause substantial corrosion. This is important to note, for any damage to DRI-STEEM equipment caused by chlorides will void your DRI-STEEM warranty.

Another misconception about DI/RO water is that its ion-hungry nature causes metal corrosion, but while properly maintained high-purity water will take some ions from the metal it contacts, this exchange process causes, at worst, only minimal corrosion.

Figure 35-1: Single tank (mixed bed) DI system

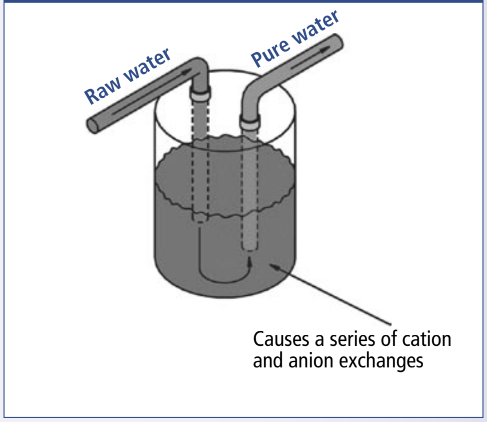
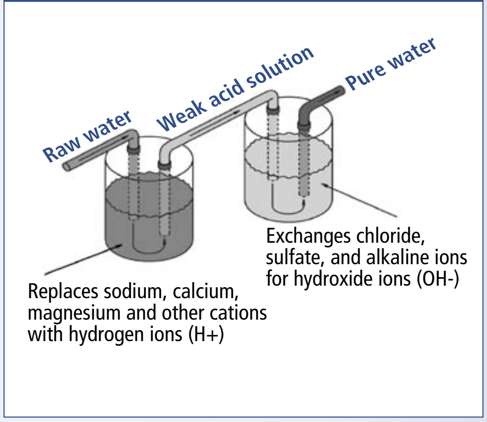


Figure 35-2: Two-tank DI system



How water type affects humidifier performance

Isothermal systems — systems that boil water to make steam (vapor) — typically maintain relative humidity (RH) levels within 1%-5% of an established set point, with the ability to maintain a specific level of control directly dependent on the system's ability to respond to changing environmental conditions. Responsiveness is affected by two things: delivery of the energy source and the amount of water discarded (through skim, drain, and flush cycles) to remove minerals.

In combination with a programmable controller, using high quality valves or substituting electronic heater controllers such as SSRs for mechanical contactors allow responsive steam production.

Water hardness, however, plays a critical part in an isothermal humidifier's ability to maintain RH set point. As water hardness increases, so does the need for skimming, draining, and flushing. Skimming removes precipitated minerals before they attach to humidifier tank walls and elements as scale. As water is skimmed off, cold water is introduced into the tank. In some cases, this introduction of cold water causes a delay in steam output until the cold water is heated to boiling. Drain and flush cycles, automated on most systems, completely drain the humidifier and then typically flush the tank with cold water. In this situation, not only is the humidifier off-line for a period of time, but the tank needs to be filled and heated to boiling before it can produce steam. In the meantime, the RH level can drop 5% or more until the humidifier is producing steam again. In certain applications, such as office buildings or other environments humidified to improve comfort, RH fluctuation is not a major issue. In process-critical environments, however, a 5% RH fluctuation can affect processes. Humidifiers in these environments typically use softened or DI/RO water, depending on the level of control required. The fewer the minerals in the water, the better the control capability.

Low mineral content means low maintenance

From a maintenance point of view, the lower the mineral content in the water, the less maintenance required. Mineral buildup in improperly-maintained isothermal systems can cause humidifiers to malfunction: heater coils can fail prematurely, heat exchanger output is reduced by scale buildup, conductivity probe systems that measure water levels quit working, and drain valves become plugged. DI/RO water has the lowest mineral content, but its use is cost-prohibitive unless needed for high purity humidification or to meet very strict performance requirements (such as in semiconductor manufacturing). Hard water can be used in isothermal humidifiers with the understanding that these systems require regular inspection and cleaning and that RH performance will fluctuate. But the easiest and most cost-effective way to reduce maintenance requirements is to soften the fill water.

Direct injection of boiler steam affects indoor air quality

Boiler steam is often directly injected into the air through steam dispersion units to provide humidification. Owners of existing boiler systems have found this a cost-effective, energy efficient, and easily controllable way to add humidity without adding additional equipment to make steam. However, boiler water is typically treated with anticorrosion chemicals that, when directly injected into the air as steam, negatively impact indoor air quality. Concerned owners wishing to make use of an existing boiler for humidification should consider a closed loop system such as our STS Steam-to-Steam system that provides chemical-free steam for humidification by running boiler steam through a heat exchanger.

Humidification as pure as the fill water

In general, the quality of humidification vapor is only as good as the humidifier tank's fill water. High purity water (DI/RO) provides the purest humidification. Humidification produced through an isothermal process (boiling) is a bit more pure than humidification produced through an adiabatic process (unheated water turned into vapor by evaporation, pressure and/or compressed air). Some adiabatic systems using potable or softened water leave a fine dust on area surfaces, and wetted-media or wick systems may contaminate humidification vapor. Process-critical environments, such as surgical suites, clean rooms, semiconductor manufacturing, or museums requiring artifact preservation, use high purity water to ensure very clean humidification vapor. Potable hard and softened water in isothermal systems typically provide humidification vapor that is adequately clean for comfort applications such as office or residential buildings.

Hard water reduces energy efficiency

How water type affects energy efficiency is closely related to how water type affects performance. Simply stated, the harder the water, the more water wasted down the drain to remove minerals and, therefore, the more water that will need to be replaced and reheated, resulting in increased energy costs.

Table 38-1:
How fill water type affects performance, maintenance, steam quality, and efficiency in isothermal humidification systems

Fill water type/ conductivity	Skimming required? (Y/N)	Drain/flush frequency	Hardness	RH performance (control range)	Maintenance requirements	Humidification steam quality	Water and energy efficiency
Potable (minimum conductivity 100 µS/cm)	Y	System with a manual drain: Humidifier typically drains one time per season, but may need to increase drain and flush frequency based on quarterly inspections, especially with water over 12 gpg (205 mg/L).	2-35 gpg (35-600 mg/L)	±3% of set point with service interrupted by draining and flushing	If water is harder than 12 gpg (205 mg/L), scale buildup occurs quickly. Increasing skim and drain/flush cycles helps reduce scale, as does regular cleaning. The key is to skim or flush minerals while they are still in solution and before they attach to humidifier components as scale.	As pure as the fill water. Dissolved solids may transfer to the airstream with humidity vapor.	As water hardness increases so does the need for skimming and draining, thus increasing water and energy usage, for makeup water replacing water lost to skim and fill cycles must be heated. In addition, performance degradation can occur in heat exchanger-based systems if the heat exchanger becomes coated with mineral scale.
Potable (minimum conductivity 100 µS/cm)	Y	System with auto drain and flush: Several times per season.	2-35 gpg (35-600 mg/L)	±3% of set point with service interrupted by draining and flushing			
Softened (minimum conductivity 100 µS/cm)	Y	System with a manual drain: Humidifier typically drains one time per season, but may need to increase drain and flush frequency based on quarterly inspections.	2-12 gpg (35-205 mg/L)	±3% of set point with no service interruption	Can go up to two years without cleaning, but quarterly inspections are encouraged to verify softener operation. Drain, flush and skim frequency/duration affect maintenance requirements.	As pure as the fill water. Dissolved solids may transfer to the airstream with humidity vapor.	As water hardness increases so does the need for skimming and draining, thus increasing water and energy usage, for makeup water replacing water lost to skim and fill cycles must be heated.
Softened (minimum conductivity 100 µS/cm)	Y	System with auto drain and flush: Several times per season.	2-12 gpg (35-205 mg/L)	±3% of set point with no service interruption			
High purity (DI/RO)	N	Typically need to drain one time per season.	0-2 gpg (0-35 mg/L)	±1% of set point	Cleaning typically not required, but quarterly inspections are encouraged to verify filtration operation.	Pure humidification steam. Steam generated by an isothermal process is more pure than humidification produced by an adiabatic process.	Efficient, because there is no water used for skimming or drain/flush cycles. However, a very small amount of water regularly overflows to keep the P-trap filled.
Boiler steam (direct injection)	N/A	N/A	N/A	±1% of set point	Yearly inspection. Typically, no other regular maintenance is required.		Efficient, because an existing boiler can be used.

Evaporative system components and operation

Components are part of a humidification system

Creating humidity with a DRI-STEEM evaporative humidification system is a three-step process:

1. **Create steam.**

   A DRI-STEEM humidifier with an evaporating chamber (such as VAPORSTREAM or GTS) boils water to create steam.

2. **Control.**

   DRI-STEEM controllers (such as VAPOR-LOGIC3), humidity sensors, humidistats, water level sensors, and/or a building management system control water levels and humidifier steam output.

3. **Disperse.**

   Dispersion units disperse steam created in the evaporating chamber into the airstream through either a tube assembly such as an ULTRA-SORB installed in a duct or AHU, or by using DRI-STEEM's AREA-TYPE fan to disperse steam directly into a space.

The components of this three-step process work together as an engineered system, configured for each particular application.

This section of the Design Guide focuses on evaporating chamber components and operation.

1. Create steam (STS humidifier)

2. Control (VAPOR-LOGIC3 keypad)

3. Disperse (ULTRA-SORB dispersion)

Typical evaporative system configurations

Figure 40-1:
Multiple evaporating chambers and an ULTRA-SORB dispersion panel installed in an AHU

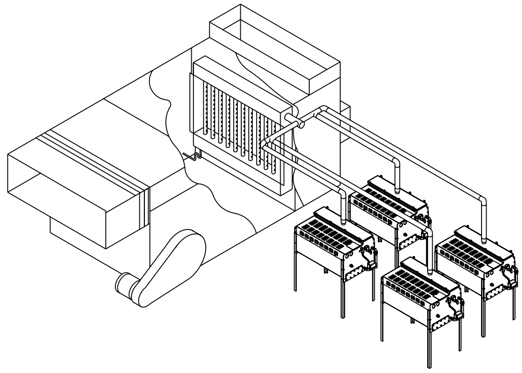


Figure 40-2:
Evaporating chamber and a RAPID-SORB dispersion unit installed in a duct

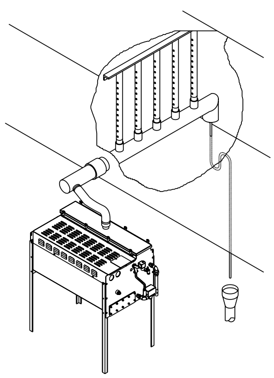
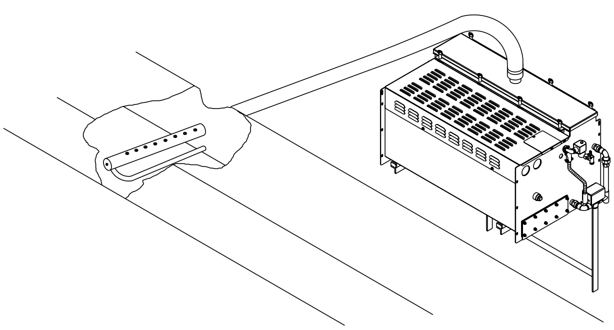


Figure 40-3:
Evaporating chamber and a single dispersion tube installed in a duct



Typical evaporative system configurations (continued)

Figure 41-1:
Evaporating chamber and a Space Distribution Unit installed in a finished space

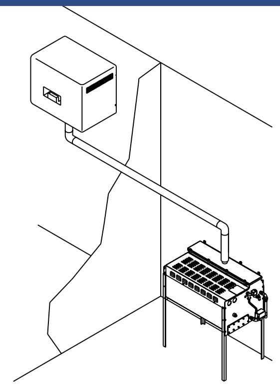


Figure 41-2:
Evaporating chamber with a Space Distribution Unit installed directly above

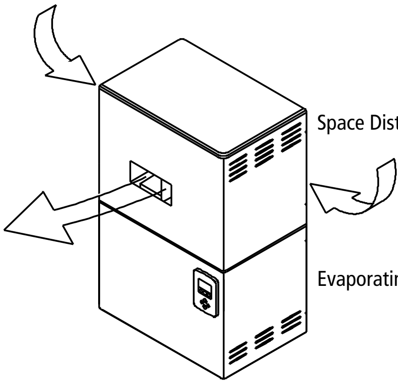


Figure 41-3:
Evaporating chamber and an AREA-TYPE fan

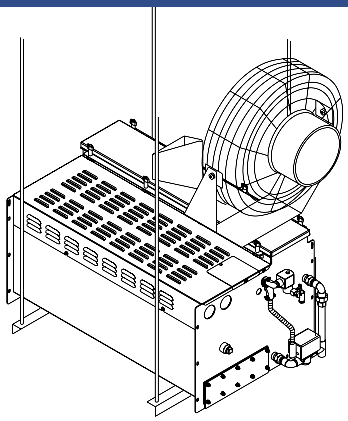


Figure 42-1:
VAPORSTREAM electric system

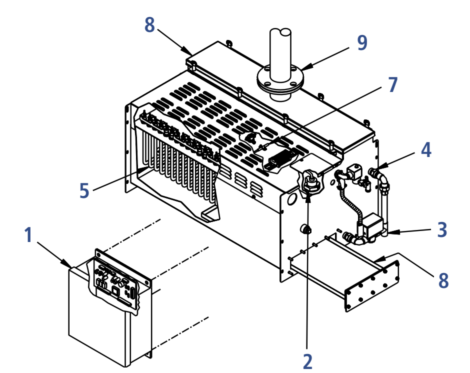


Figure 42-2:
VAPOR-LOGIC3 keypad

Evaporative system components

1. Control cabinet

If a humidifier has a separate control cabinet, it can be mounted either on the humidifier or remotely. Some humidifiers, like the VAPORMIST, have control components integrated into the humidifier cabinet. Systems using VAPOR-LOGIC control also have a keypad (see Figure 42-2).

2. Water level control

Potable or softened water systems control water level electronically using a three-rod probe. DI/RO water systems control water levels using a float valve. Electric systems also have a low-water cutoff float switch for heater protection (see detail drawings on Pages 44 and 45).

3. Drain

DRI-STEEM offers a variety of drain types. Standard water systems have electric drains that open for drain or drain/flush cycles. Some standard water systems automatically drain when there has been no call for humidity for 72 hours ("end-of-season draining"). DI/RO water systems do not cycle through regular drain or drain/flush cycles because DI/RO water does not cause scale buildup. For this reason, most DI/RO systems have a manual drain, although an electric drain can be ordered for automated draining at end of season or when the humidifier is idle for a defined period of time. Some systems allow the user to adjust drain duration and interval either through a keypad or by changing switches on the control board.

4. Water skimmer/overflow port

The water skimmer reduces minerals in the evaporating chamber of standard water systems. Skimming occurs each time the humidifier fills. The skim time duration is user adjustable on all DRI-STEEM humidifiers by either using the keypad or setting a switch on the control board. In DI/RO water models, the skimmer port serves as an overflow port.

5. Heating elements/heat exchanger

Electric systems: Low-watt-density INCOLOY-sheathed heating elements ensure operation for many seasons. Constant expansion and contraction of heating elements sheds mineral scale. In the unlikely event of heater failure, heating elements can be replaced easily.

Heat exchanger systems: The heat exchanger transfers energy from boiler steam (STS), hot water (LTS) or gas-fired burners (GTS) to water in the evaporating chamber, generating steam.

6. Valve (heat exchanger systems)

Upon a call for humidity, valves allow steam (STS), hot water (LTS), or an air/gas mixture (GTS) to enter the heat exchanger.

7. Temperature sensor

Systems with VAPOR-LOGIC3 have a temperature sensor mounted on the evaporating chamber enabling:

- Over-temperature protection (electric systems)
- Freeze protection
- Preheating, allowing rapid response to a call for humidity

8. Service access

Access cover and cleanout plates allow periodic inspection and servicing of the evaporating chamber.

9. Steam outlet

Steam generated in the evaporating chamber rises and exits through the steam outlet and travels to the dispersion unit through either vapor hose or piping. See Page 46 for steam outlets available on DRI-STEEM humidifiers.

**Figure 43-1:
STS Steam-to-Steam system**

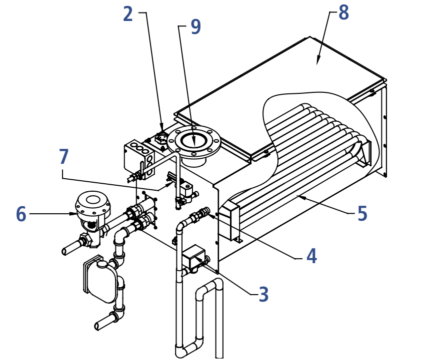


Figure 44-1:
Standard water systems

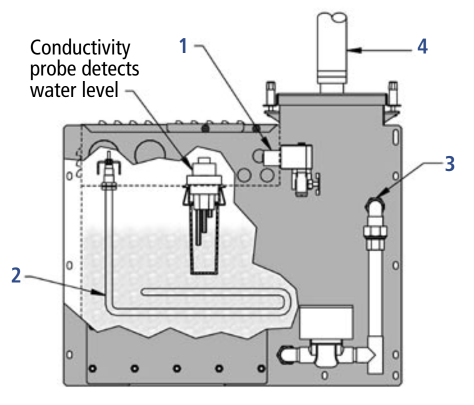
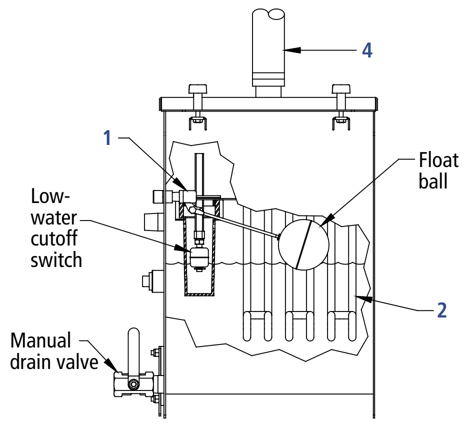


Figure 44-2:
DI/RO water systems



Evaporative system principle of operation

1. When the system is first activated, the fill valve opens and the evaporating chamber fills with water to the operating level.

2. On a call for humidity, the heating elements are energized, causing the water to boil. The fill valve opens and closes as needed to maintain the operating water level.

3. During refill, a portion of the surface water is skimmed off, carrying away precipitated minerals (standard water systems only; DI/RO systems don't require skimming).

4. Steam created in the evaporating chamber flows through vapor hose or piping to the dispersion assembly, where it is discharged into the airstream.

Evaporative system water level control

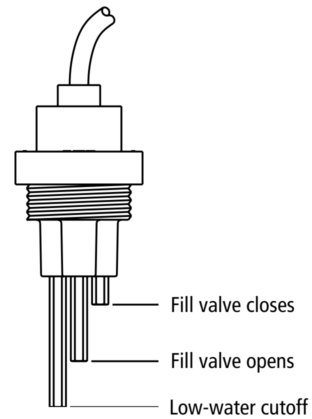
Standard water systems require conductive water

DRI-STEEM's standard water evaporating chambers (found in DRI-STEEM evaporative humidifiers with model numbers that do not end in "DI") require fill (makeup) water to have conductivity of at least 100 µS/cm (2 grains/gallon). These systems use a conductivity probe to measure water levels and, therefore, will not operate with DI/RO water (which is demineralized and not conductive).

Important note about chloride corrosion

Corrosion can occur in evaporating chambers when chloride levels are unusually high in the supply water. This is usually caused by improperly maintained DI treatment beds, but has occurred with potable water supplies. If you see stainless steel pitting, call DRI-STEEM technical support.

Figure 45-1:
Standard water systems



Systems using tap or softened water control water levels electronically using a three-rod probe. The controller responds with the above actions when the water level reaches each rod.

Figure 45-2:
DI/RO water systems

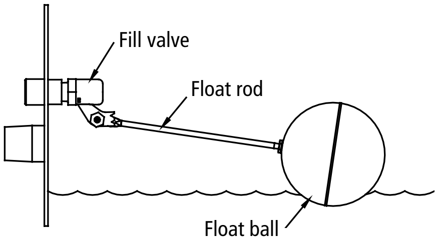


Figure 46-1:
Hose connection

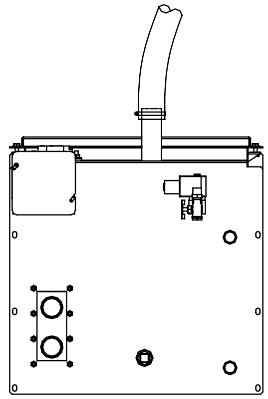


Figure 46-2:
Threaded pipe connection

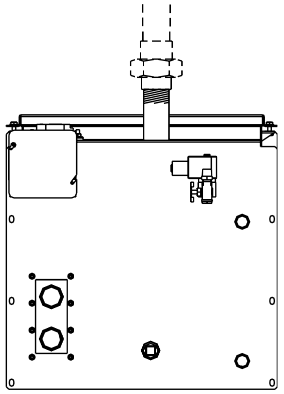
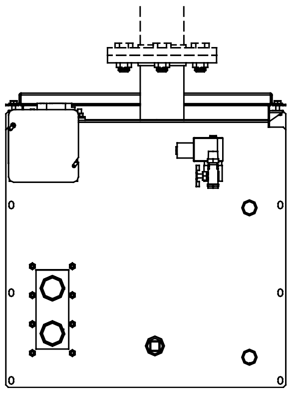


Figure 46-3:
Flange connection



Evaporative system steam outlet connections

Outlet sizes and connections vary by model. See product catalogs for availability. See also Table 65-1: Maximum steam carrying capacity and length of interconnecting vapor hose, tubing, and pipe on Page 65 of this document.

Steam injection system components and operation

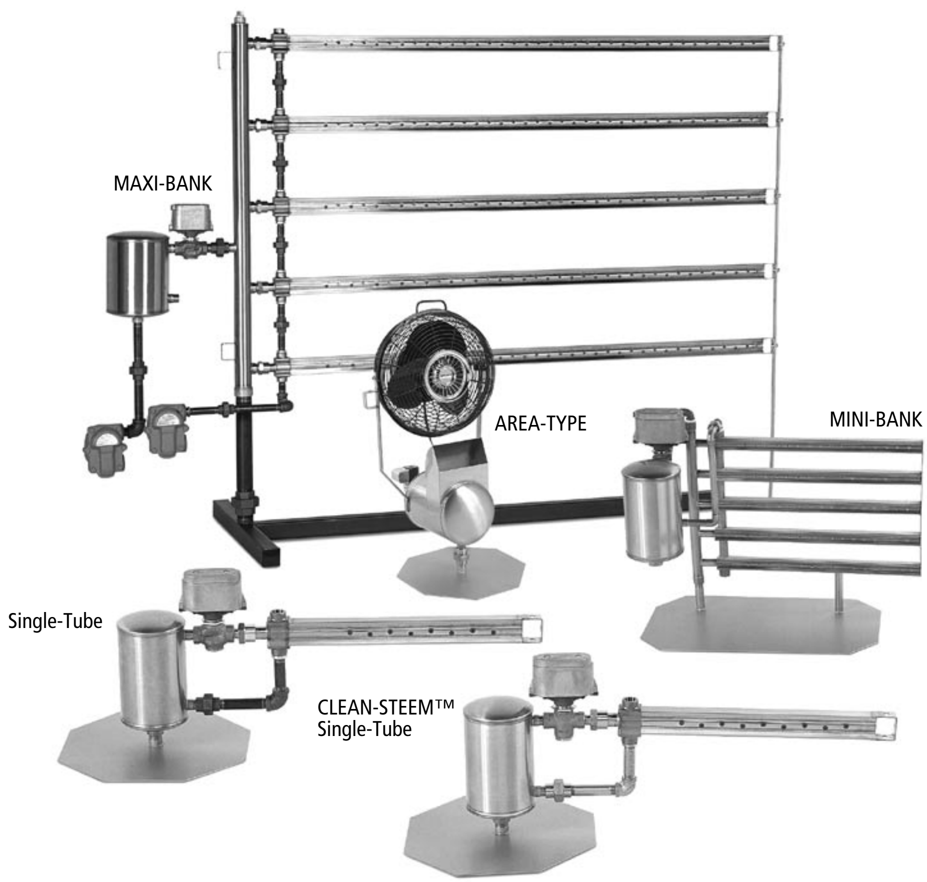
Direct injection of boiler steam

DRI-STEEM’s steam injection humidifiers use steam from an external source, such as an in-house boiler, an unfired steam generator, or a district steam system. Basic operation and components are described in this section. For more complete information, see the steam injection catalog.

Steam injection components

The drawings and text on the next two pages show a steam injection model in its most elemental form — the Single-Tube Humidifier. Each single- or multiple-tube model has the same basic components: a stainless steel separator, a steam valve, and one or more jacketed dispersion tubes. For ductless spaces, boiler steam can be dispersed by the fan of an AREA-TYPE model.

Figure 47-1:
Steam injection humidifiers



Steam injection components

1. Steam jacket

The steam jacket is a steam-filled chamber surrounding the inner dispersion tube to keep it warm and eliminate condensation and dripping.

2. Steam separator

The steam separator removes entrained water droplets and slugs of condensation.

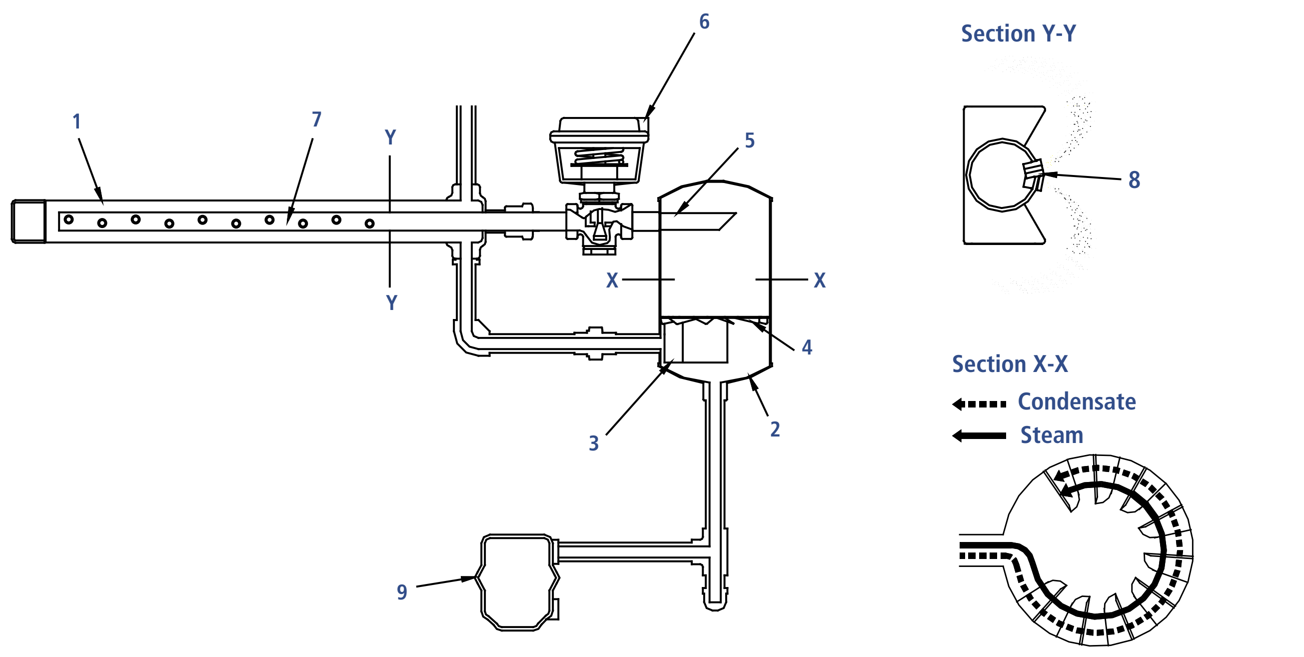
3. Deflector plate

The deflector plate directs water inside the separator toward the drain.

4. Multi-baffle plate

The multi-baffle plate allows only steam to rise into the upper region of the separator.

Figure 48-1:
Steam injection components



5. Internal drying tube

The internal drying tube excludes any remaining moisture particles, allowing only dry steam to leave the separator.

6. Steam valve

The steam valve controls the amount of steam allowed into the dispersion tube.

7. Dispersion tube

The dispersion tube provides uniform steam dispersion across the duct width.

8. Thermal-resin tubelet

Unique tubelets extend into the center of the dispersion tube so only the driest steam is discharged into the air. These tubelets also have an exceptional ability to trap noise generated by the valve, making DRI-STEEM's Steam Injection humidifiers the quietest in the industry.

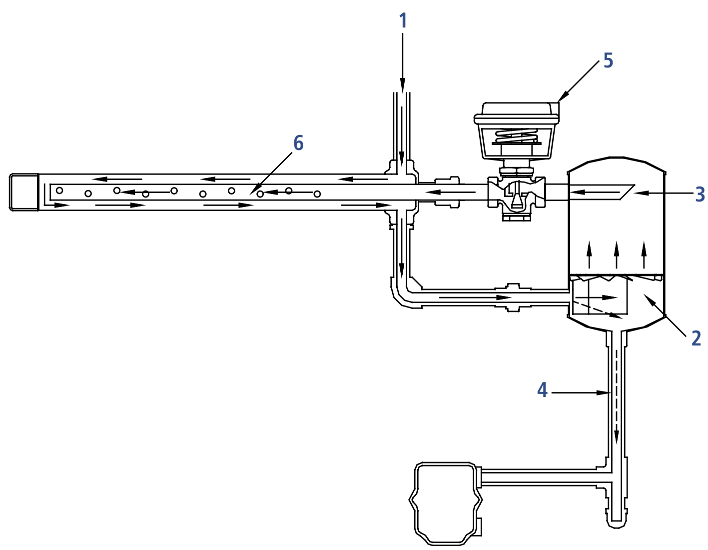
9. Steam trap

The steam trap allows only condensate to pass to the condensate return system.

Steam injection principle of operation

1. Boiler steam with entrained water enters the humidifier and flows through a chamber surrounding the inner dispersion tube, jacketing it with steam to eliminate condensation and dripping.
2. The steam with entrained water slows from entering the larger space of the separator and from hitting the perimeter deflector plate, and then begins to spin and separate.
3. The separated steam rises through the slots of the multi-baffle plate to the upper region of the separator and enters the internal drying tube that excludes any remaining moisture particles, allowing only dry steam to leave the separator.
4. Separated condensate drains from the separator to the steam trap.
5. The steam valve controls the amount of steam allowed into the preheated dispersion tube. The steam valve is typically controlled in one of three ways:
   - By a humidistat connected to the steam valve
   - By another signal, such as a building management system
   - By one of DRI-STEEM's controllers, such as VAPOR-LOGIC3.
6. Steam is discharged uniformly through the tubelets into the airstream. Any condensate formed while passing through the steam valve is re-evaporated in the inner tube because of heat supplied by the outer steam jacket.

Figure 50-1: Steam injection principle of operation



Water hardness determines maintenance requirements

When choosing a humidification system, keep in mind that the more minerals in your supply water, the more maintenance your system will require.

Maintenance requirements for systems using DI/RO water

Humidification systems using DI/RO water require minimal maintenance. Properly processed DI/RO water has no minerals or other contaminants in the water that cause scale buildup. Therefore, maintenance requirements for this type of system are:

- No regular cleaning (although regular inspections are recommended)
- No skimming or drain and flush cycles (although end-of-season draining is recommended)
- Regular inspections to verify that water processing equipment is operating correctly. The presence of chlorides in improperly processed DI water eventually causes pitting and failure of the tank and its components.

Maintenance requirements for systems using potable water

The best way to determine how often your particular system needs maintenance is to remove the tank cover and inspect it for mineral deposits after three months of duty. Potable water carries a variety of minerals and other materials in a mix that varies from location to location. This variation in water quality, combined with the hours of operation and duty cycle, will determine your own unique maintenance schedule. Use the following maintenance schedules as guidelines.

- Hard water (more than 12 gpg [more than 205 mg/L] hardness):
  - Cleaning frequency determined by use and water quality; the harder the water, the more cleaning required; inspect at least every three months
  - Regular skimming
  - Regular drain and flush cycles; end-of season draining
- Naturally soft (2-12 gpg [35-205 mg/L] hardness) or softened water:
  - Annual cleaning
  - Regular skimming
  - Drain and flush cycles only as needed; end-of season draining

Softened water reduces maintenance

The easiest way to avoid maintenance in a standard water system is to use water with low levels of hardness. Keep in mind that standard water systems require water to have conductivity of at least 100 µS/cm (2 gpg hardness) for the conductivity probe to measure water levels accurately.

Also, most DRI-STEEM humidifiers have adjustable skim durations. Increasing skim time will often substitute for periodic drain and flush sequences.

Controlling DRI-STEEM humidifiers

Application determines acceptable RH control range

Controlling relative humidity (RH) in commercial and industrial environments can be easy or challenging, depending on the level of control required. RH fluctuations of 5% to 7% are common in commercial or office building environments where the purpose of providing humidification is primarily to improve occupant comfort and health. Humans are quite forgiving when it comes to RH fluctuations, and most would not notice a 5% change in RH. Materials used in industrial processes, however, are much more particular about humidity fluctuations. Since most materials are hygroscopic in nature — they absorb and release moisture — many processes, such as printing or food processing, require humidity to be within a set range and to not fluctuate more than ±3%. ASHRAE publishes tables listing the ideal RH for materials used in industrial applications ranging from 80% RH for grinding optical lenses to 50% RH for manufacturing abrasives.[1] The closer to set point that RH levels track, the more processing productivity improves.

Control the variables to control the humidity

Some process environments require extremely tight RH control, and are the most challenging environments to humidify properly. Semiconductor and pharmaceutical manufacturing facilities, cleanrooms, laboratories, and testing facilities typically require RH control within 1% of set point. To achieve such tight control many variables must be managed.

The most important variable to control is dry bulb temperature, for as dry bulb fluctuates so does RH. (A 1 °F drop in temperature causes a 2-3% increase in RH, and a 1 °C drop in temperature causes a 3-4% increase in RH.) Key to controlling temperature is careful attention to air handling system design. Moisture containment, accomplished with vapor barriers and proper pressurization, is also important, as are the number of air changes per hour. As the number of air changes increases, humidifier output fluctuations become more apparent in the humidified space. Other variables affecting RH control are controller capabilities, sensor type and placement, dispersion assembly placement, location of duct components, and varying duct temperatures. This section of the Design Guide explains how water type, water replenishment, and energy source control affect RH control.

Notes

1 *1995 ASHRAE Handbook, HVAC Applications,* I-P Edition, pages 11-2, 11-3.

Isothermal humidifier basics

Isothermal humidifiers use an energy source to boil water into steam for dispersion either directly into an occupied space or through an HVAC system. All isothermal humidifiers have a makeup water fill valve, a drain valve for periodic and/or end-of-season draining, and a water level control mechanism. Our systems also have a water surface skimmer for reducing particulates at the high-water level. Isothermal humidifiers use a variety of water types, from purified water such as deionized (DI) or water filtered by reverse osmosis (RO), to softened or tap water. DRI-STEEM humidifiers can use any type of water.

Float-fill valve allows best water control

As a humidifier boils off water to supply humidification steam, that water must be replaced. When makeup water is introduced into the tank, it stops the boil, and steam output ceases until the makeup water reaches boiling temperature. However, if water replenishment modulates to match the rate that steam boils off, there is no interruption in steam production, and no fluctuation in steam output. Float-fill valves are currently the only humidifier water level control mechanisms that provide fully modulated water replenishment (see Figure 53-1).

Float-fill valves are not effective in tap or softened water systems because precipitated minerals collect on the float-fill assembly and interrupt float movement. Float-fill valves, therefore, are used only with DI or RO filtered water systems.

Replenishing water levels using conductivity probes

Conductivity probe systems (used in our standard-water models) replace boiled-off water periodically and therefore cause interruption in steam output (see Figures 53-2 and 53-3).

In these systems, a probe with three rods of three lengths detects water levels. When water reaches the top rod, the fill valve stops filling; when water reaches the middle rod, the fill valve starts filling. Once water no longer touches the bottom rod, heaters are de-energized for low-water protection. The vertical distance between the ends of the top and middle rods defines how much water is replaced when the fill valve is on, which corresponds to the time period of reduced or no steam output. Conductivity probe systems require a minimum level of minerals in the water to operate and therefore do not work with DI or RO water.

An advantage of this type of water level control is that it provides accurate water level readings, allowing a predictable skim cycle for removing precipitated minerals by water surface skimming with each fill cycle. Skimming flushes floating precipitates to drain

Figure 53-1:
Humidifier with float-fill valve

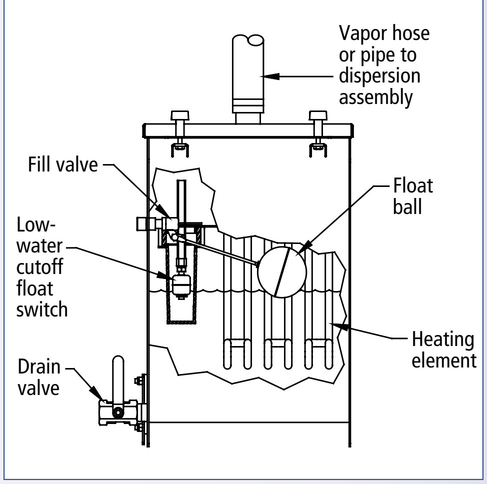


Figure 53-2:
Humidifier with conductivity probe

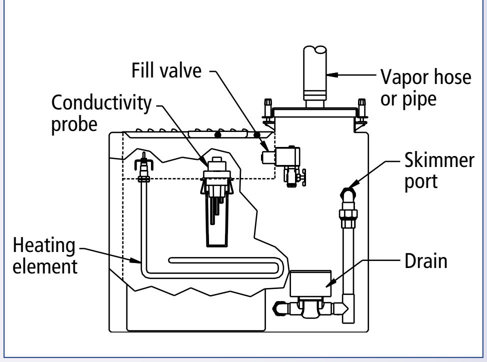
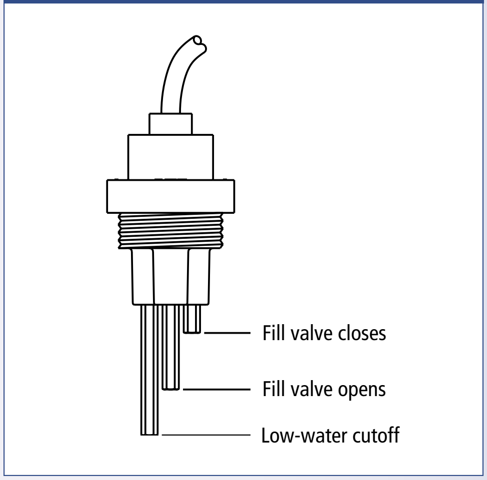


Figure 53-3:
Detail of conductivity probe



Output control basics

On-off control

On-off control is the simplest control scheme and does exactly what its name implies: the output device turns fully on, then fully off. Residential furnaces and air conditioners often use this type of control.

In a humidification system, an on-off humidistat has a differential between the on and off switch points. The differential is established at a range sufficient to prevent output short cycling. In other words, the humidity level has to fall a little below set point before the humidistat closes and energizes the humidifier. Once the humidifier is energized, the humidistat stays closed until the humidity is a little above set point. This creates an operating range that prevents the humidifier from running for very short periods of time.

Modulating demand signal control

With modulating demand signal control, a modulating humidistat or a building management system sends a signal to the humidifier, which then produces a directly proportional output. For example, if a humidistat operating between 4 mA and 20 mA sends a 4 mA signal, the humidifier produces no output. A 12 mA signal causes the humidifier to operate at 50% of capacity, and a 20 mA signal causes the humidifier to run at 100% capacity. Humidity set point is adjusted at the humidistat from within a building management system, or by using the humidifier controller keypad.

and dilutes the mineral concentration in the tank water while causing a minimal reduction in steam output. Surface skimming systems produce a negligible interruption to steam output because heaters remain on during skimming, and because tanks that are regularly skimmed require minimal or no tank draining and flushing. Draining and flushing a tank causes steam output to stop for the entire drain duration, which in some systems can be as long as 60 minutes. All DRI-STEEM skim durations are user-adjustable, allowing operators to change the length of time the tank skims, as well as the frequency, often eliminating drain and flush requirements.

Energy modulation also key to maintaining consistent RH

The other key mechanical aspect of maintaining RH output within a specified range is to provide consistent energy to the heating components. There are two ways to modulate energy delivery to an isothermal humidifier: full, analog modulation, such as with a steam or gas valve, or on-off modulation such as with a time-proportioning electric element system.

Valve systems falter at low end

Steam valves, such as those used in a steam-to-steam humidification system, modulate steam flow to heat exchangers in direct proportion to demand signals. Theoretically, if the system demand is 25%, the valve opens 25%. However, steam delivery is part of a mechanical system that includes a boiler, valve, actuator, and steam trap. So while in theory it would seem that a valve system would provide the most directly responsive energy metering, it does not due to mechanical limitations of the system's components.

To provide peak performance, steam valves require supply steam to be at a consistent pressure. Supply steam can be controlled with a pressure reducing valve, which converts an inconsistent supply pressure to a steady, lower pressure, eliminating one source for steam fluctuation. Steam pressures may drop when a bucket steam trap empties, reducing steam output. But the main issue with valves is low-end controllability. If very tight RH control is essential with a steam valve system, specify a valve with a high turndown ratio (50:1).

Systems using gas valves cannot burn efficiently when demand is low. This is why many gas valve systems switch to on-off modulating control below a certain demand point. For example, a gas system may be fully modulating until demand reaches 25%, where it begins time-proportioning modulation control – that is, the burner system turns on for a period of time and then turns off for a period of time. With a high quality valve and responsive control at low demand, a gas humidifier should be able to provide steam output rangeability at a ratio of 40 to 1 and, especially in a large capacity system, can yield RH control to ±1%.

SSRs deliver energy most consistently

Electric resistive heating elements are controlled using on-off time proportioning modulation control. Heaters cycle on and off for durations ranging from one second, using electronic controllers such as solid state relays (SSRs) or silicon controlled rectifiers (SCRs), to 100 seconds using mechanical contactors. Every time the heaters are off, there is an interruption to steam production. However, when cycle times are at or near one second, steam interruption is unnoticeable. So, while at first it may seem counterintuitive that an on-off modulating system provides tighter control than a modulating valve system, an electronic system can cycle heaters at such a rapid rate that the steam interruption does not impact controllability. In addition, electronic controllers operate as accurately at low demand as at high demand.

Float-fill valve with SSRs provides tightest RH control

In conclusion, there are many variables that affect isothermal humidity control, and the tighter the control required, the more variables that must be carefully managed. There are two main humidifier mechanical issues that affect RH control: replenishing water and modulating energy. The humidification system type you choose will be defined by the requirements of your particular application. But if your goal is to achieve the tightest RH control possible, then for most applications, the preferred humidification system will replenish water levels using a float-fill valve and will have electronically controlled electric resistive heating elements.

Output control basics

Time-proportioning modulation control of electric heaters

Humidifiers with electric heaters responding to a modulating demand signal use time-proportioning (TP) modulation control. With TP modulation, outputs cycle on and off at a rate corresponding to the demand signal. Cycle times range from 1 second to 100 seconds. Mechanical contactors are typically used when cycle times are above 60 seconds; electronic controllers such as solid-state relays (SSRs) or silicon-controlled rectifiers (SCRs) are used for rapid cycling, tight control and quiet operation. The faster the heaters cycle on and off, the closer the humidifier output tracks humidity set point.

When a humidifier has more than one heater, heater duty time is shared. For example, if a humidifier has four output stages controlled by four contactors, to achieve a 55% system demand using a 60-second cycle time, two contactors are on (each providing 25% of the output) and a third contactor is on for 5/25 of 60 seconds, or 12 seconds on and 48 seconds off. On-off cycling duty is typically rotated to reduce contactor wear. To increase the cycling rate (up to 1 second), a single SSR or SCR can be added and do all the cycling (this is called SSR modulation with contactors). Or, all heat stages can be controlled by SSRs or SCRs (called 100% SSR or SCR modulation), allowing the tightest possible control because all heat stages can cycle rapidly.

Achieving RH control with DRI-STEEM equipment

Table 56-1: RH control comparison

RH control capability*	Application	Energy source	DRI-STEEM product	Energy modulation	Water type
±1%	Critical processes; preservation	Pressurized steam	Steam Injection: ULTRA-SORB MINI-BANK MAXI-BANK Multiple-Tube Single-Tube	Industrial-grade control valve	Pressurized steam
		Electricity	VAPORSTREAM	SSR modulation with PID control	DI/RO
±3%	General manufacturing; static electricity control	Hot water	LTS	Industrial-grade control valve	DI/RO
		Gas	GTS	Valve with high turndown ratio	DI/RO
		Pressurized steam	STS	Industrial-grade control valve	DI/RO
		Electricity	VAPORMIST	TP or SSR modulation	DI/RO
			HUMIDI-TECH	TP or SSR modulation	DI/RO
			CRUV	TP or SSR modulation	DI/RO
		Pressurized steam	Steam Injection: AREA-TYPE	Commercial-grade valve	Pressurized steam
±5%	Comfort; health	Any	All DRI-STEEM products	Any	Any

Note:
* Many variables affect RH control capability. See Pages 52-55 for more information about the factors that affect humidifier controllability.

How to design for proper humidification steam absorption

Drip-free dispersion is possible

HVAC engineers often express concerns about steam condensation on internal duct elements when specifying humidification systems. And these concerns are valid, for if severe enough, water accumulation from condensation can leak through ducts to cause damage below. This is an immediate — and easily noticeable — problem. A less visible and potentially more harmful situation is condensation causing standing water on duct floors. A warm air handling system containing moist dust is an ideal breeding ground for microorganisms.

But these harmful situations do not need to occur. Understanding the factors that affect absorption, and selecting and maintaining the proper equipment, will eliminate moisture problems caused by humidification.

Factors that affect absorption

Absorption is affected primarily by three things:

1. Duct or AHU temperature. Cool air absorbs less than warm air and requires a longer absorption distance.

   When equal amounts of steam are introduced into equivalent ducts but with different air temperatures, the lower temperature systems of 50 °F to 55 °F (10 °C to 13 °C) are more challenging to ensure absorption than systems with higher temperatures.

2. Δ RH (the difference between entering and leaving RH). The more vapor that needs to be dispersed into the airstream, the longer the absorption distance.

   Generally speaking, the higher the relative humidity that must be produced in the airstream the more challenging the task. The desired room or space RH enters into this discussion as well.

3. Mixing of air and steam. Uneven airflow, non-uniform mixing of steam with air, and the number of steam discharge points on a dispersion assembly affect absorption distance. Also important is the percentage of the airstream covered by the dispersion assembly (see Figure 58-1).

Placement in airstream critical

Absorption or nonwetting distance is the dimension downstream from the leaving side of the steam dispersion assembly to the point where wetting will not occur, although wisps of steam may

Multiple tubes increase air and steam mixing

A bank of closely spaced multiple dispersion tubes is far superior to a single duct tube. In the example shown on the next page, the absorption distance of 48"(1.2 m) can be reduced to less than 6" (15 cm) by adding dispersion tubes and a condensate header. With multiple tubes, steam is more evenly distributed into the airstream. This causes a rapid homogenization of the steam/air mixture, which results in a faster re-evaporation or second change of state. Adding a condensate header allows increased capacity. DRI-STEEM has a variety of steam dispersion devices that accommodate absorption requirements ranging from the simplest application to the most difficult.

Determine the absorption distance

Use the graphs in our catalogs or use DRI-CALC to calculate absorption distances by product for your particular application. These published absorption distances are guaranteed so that you can be confident of complete absorption.

be present. Solid objects at duct air temperature, such as coils, dampers, fans, etc., downstream of this dimension will remain dry.

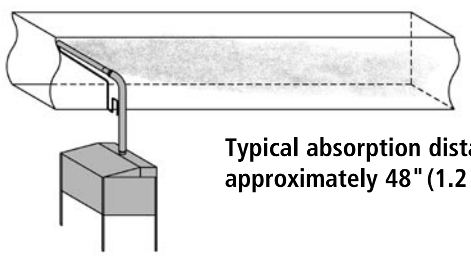
When installing upstream of high-efficiency filters, visible condensed steam wisps entering the filter bank can result in a wetted filter. If you need to install upstream of high-efficiency filters, consult your representative or DRI-STEEM directly for special recommendations.

Figure 58-1:
Evaporative steam absorption comparison

The drawings below show how increasing the number of steam discharge points and/or number of dispersion tubes shortens absorption distance.

Single-tube dispersion

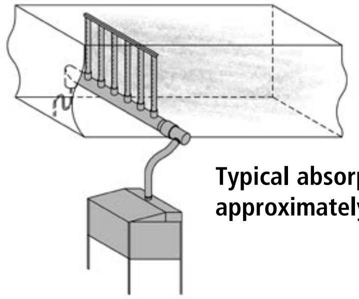
Of the three examples shown here, the single-tube covers the smallest percentage of the airstream and has the longest absorption distance.



Typical absorption distance approximately 48" (1.2 m)

RAPID-SORB dispersion

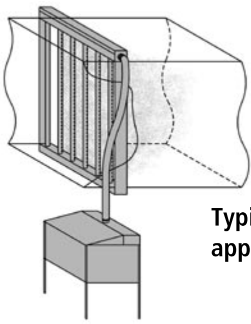
With the same conditions, absorption occurs in a shorter distance with a multiple-tube dispersion assembly because it has more steam discharge points and it covers almost all of the airstream.



Typical absorption distance approximately 18"– 48" (0.46 m – 1.2 m)

ULTRA-SORB dispersion

With the same conditions, this dispersion assembly provides the shortest absorption distance. It has multiple tubes, two rows of discharge points on each tube, and an additional header for managing condensate, allowing increased capacity.



Typical absorption distance approximately 6"– 24" (0.15 m – 0.60 m)

Humidification system components placement

Determine humidifier placement

A humidification system generally consists of a vapor or steam generator and a dispersion assembly. The proper placement of these two components is crucial for successful system operation. Usually, there is no single correct placement for a humidifier. Much depends on system design and application. However, the following paragraphs and dispersion assembly placement examples are presented as guidelines for common situations.

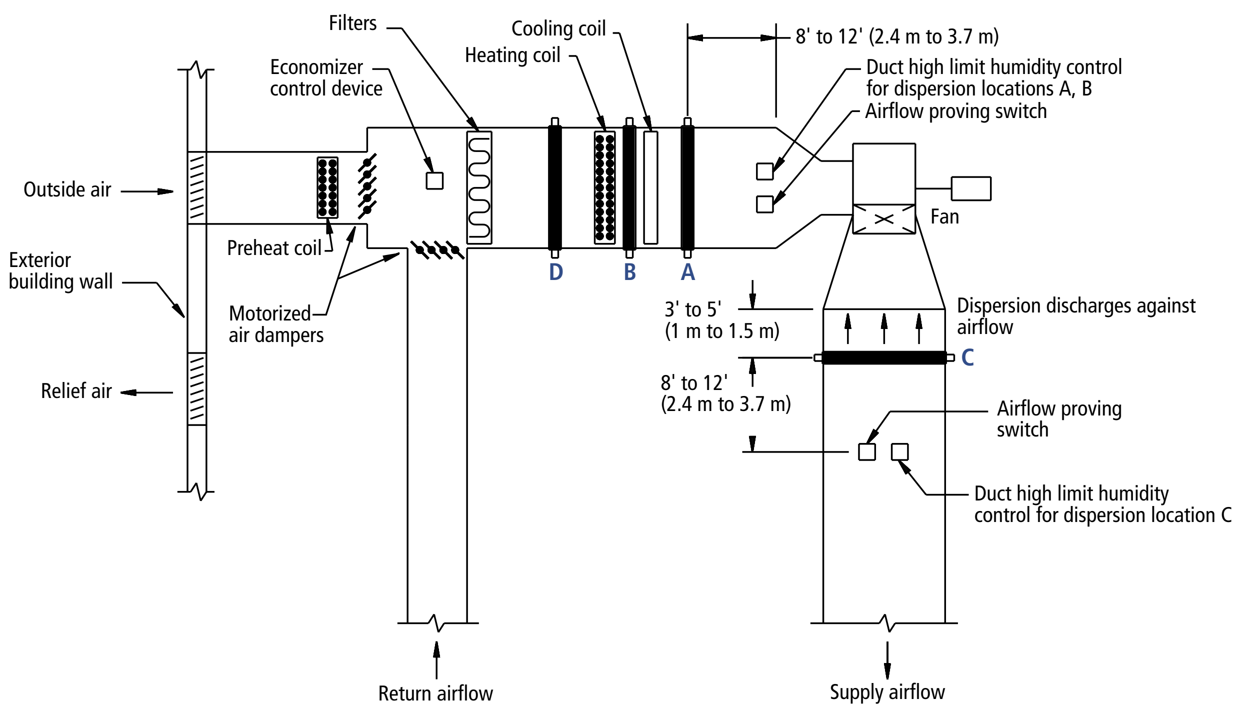
First, check available absorption distance

Available absorption distance affects system choice. Dispersed steam must be absorbed into the airflow before it comes in contact with any duct elbows, fans, vanes, filters, or any object that can cause condensation and dripping. Not all humidification systems guarantee absorption within a short distance, so it is important to be aware of the available absorption distance early in your design process.

Placing a dispersion assembly in an AHU (see Figure 59-1)

- Location A is the best choice. Installing downstream of heating and cooling coils provides laminar flow through the dispersion unit; plus, the heated air provides an environment for best absorption. Use a multiple tube dispersion unit to ensure complete absorption of steam vapor before fan entry.
- Location B is the second-best choice. However, in change-over periods, the cooling coil will eliminate some moisture for humidification.
- Location C is the third-best choice. Air leaving a fan is usually very turbulent and may cause vapor to not absorb at the expected absorption distance. Allow for more absorption distance if installing downstream of a fan.
- Location D is the poorest choice. The cooler air at this location requires an increased absorption distance.

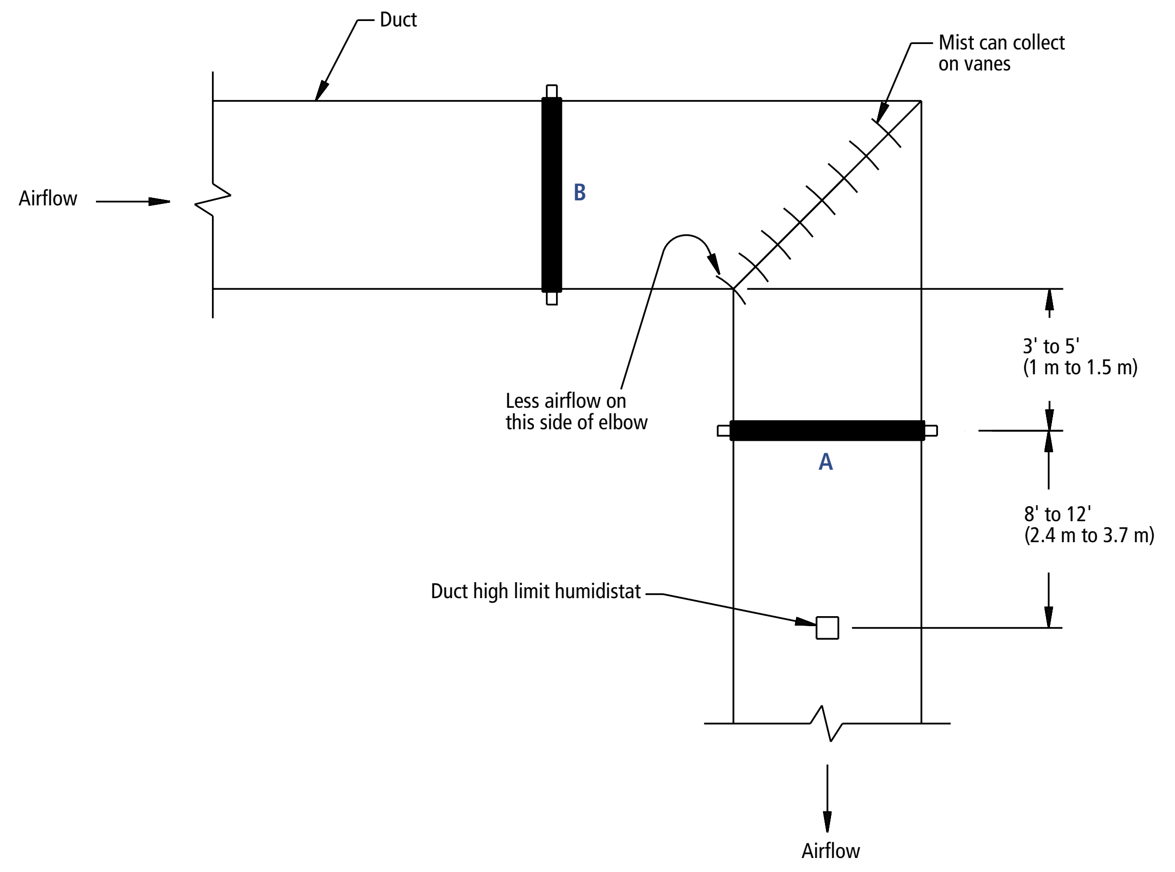
Figure 59-1:
Placing a dispersion assembly in an AHU



Placing a dispersion assembly near an elbow (see Figure 60-1)

- Location A is the best choice. Better absorption occurs on the downstream side of an elbow than on the upstream side.
- Location B is the second-best choice. Installing upstream of an elbow can cause wetting at the turning vanes. In cases where it is structurally impossible to avoid Location B, use a multiple tube dispersion unit to ensure complete absorption. Also, since more air flows along the outside of a turn, better absorption occurs if the humidifier discharges proportionately more steam in that part of the airstream.
- At both locations, discharging steam against or perpendicular to the airstream gives slightly better mixing and absorption than discharging with the airstream.

Figure 60-1:
Placing a dispersion assembly near an elbow



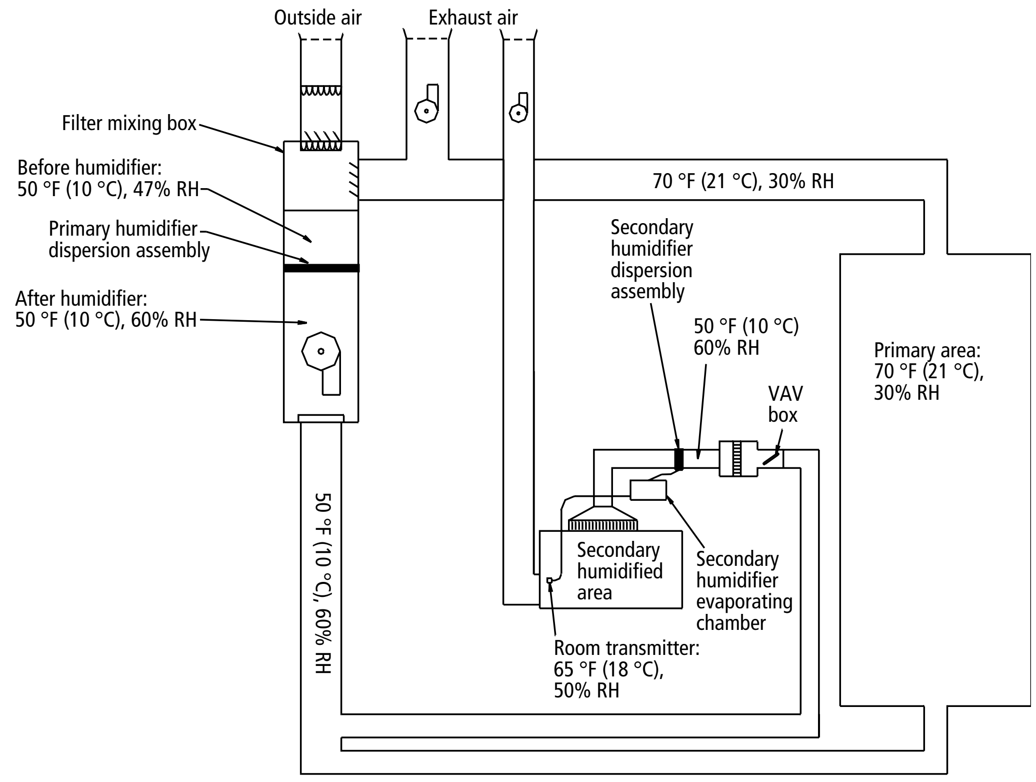
Placing a dispersion assembly in a primary/secondary system (see Figure 61-1)

This type of system is commonly applied to facilities where most of the building requires one level of humidity (typically to meet comfort requirements) and part of the building requires additional humidity. In Figure 61-1, the primary humidification system is within the main air handling unit. The secondary humidification system is located close to the point of steam discharge into the secondary area.

Sensor and transmitter locations are critical (see Figure 62-1 on next page)

Sensor or transmitter location has a significant impact on humidifier performance. In most cases, we recommend that you do not interchange duct and room humidity devices. Room humidity devices are calibrated with zero or little airflow; whereas duct humidity devices require air passing across them. Recommended sensor locations (next page):

Figure 61-1:
Placing a dispersion assembly in a primary/secondary system



A This is the ideal sensing location because this placement ensures the best uniform mix of dry and moist air with stable temperature control.

B This location is acceptable, but the room environment may affect controllability such as when the sensor is too close to air grilles, registers, or heat radiation from room lighting.

C This location is acceptable because it provides a good uniform mixture of dry and moist air, but if an extended time lag exists between moisture generation and sensing, make sure the control contractor extends the sampling time.

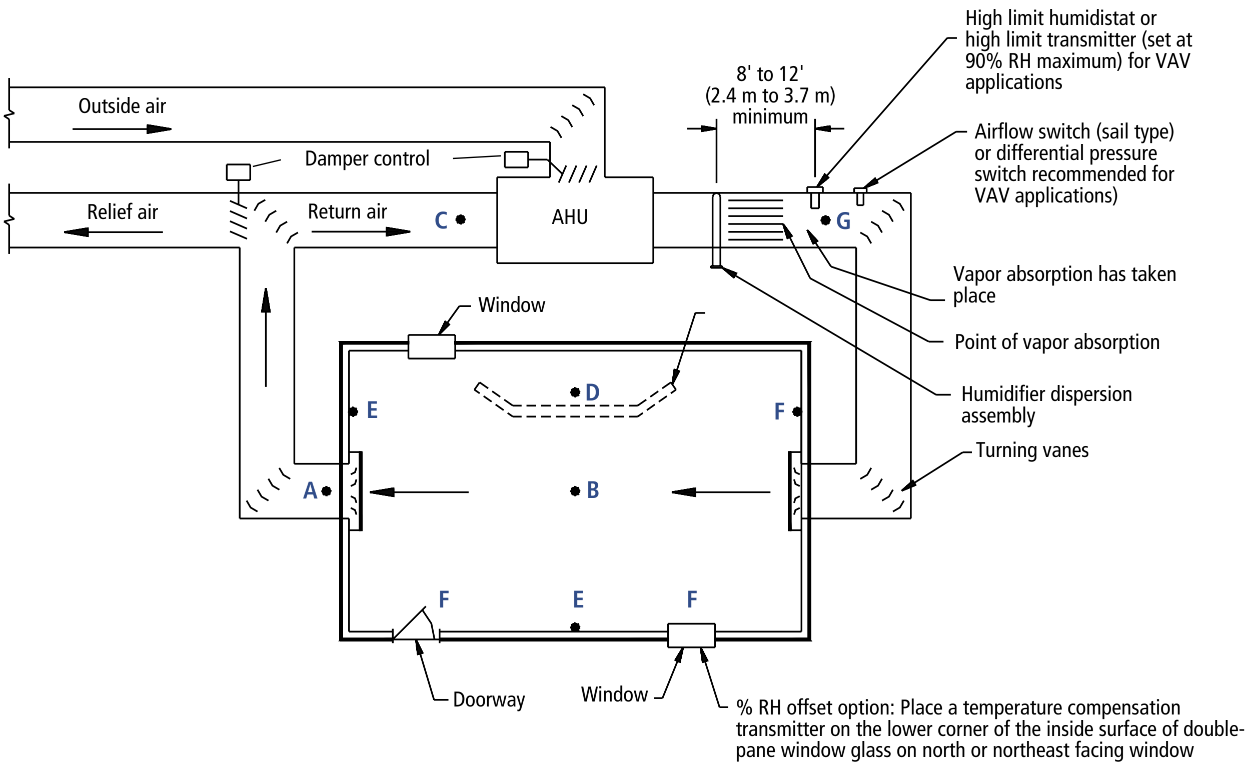
D This location behind a wall or partition is acceptable for sampling the entire room if the sensor is near an air exhaust return outlet. This location is also typical of sensor placement for sampling a critical area.

E These locations are not acceptable because they may not represent actual overall conditions in the space.

F These locations are not acceptable. Do not place sensors near windows, door passageways, or areas of stagnant airflow.

G This is the best location for a duct high limit humidistat or humidity sensor.

Figure 62-1:
Recommended sensor locations



Piping an evaporative humidification system

The drawing below shows a typical piping configuration for an evaporative system. For detailed information about how to pipe a specific DRI-STEEM evaporative humidifier, see the Installation Guides available by product in DRI-CALC.

Figure 63-1:
Fill, drain and condensate return piping for a typical evaporative humidifier

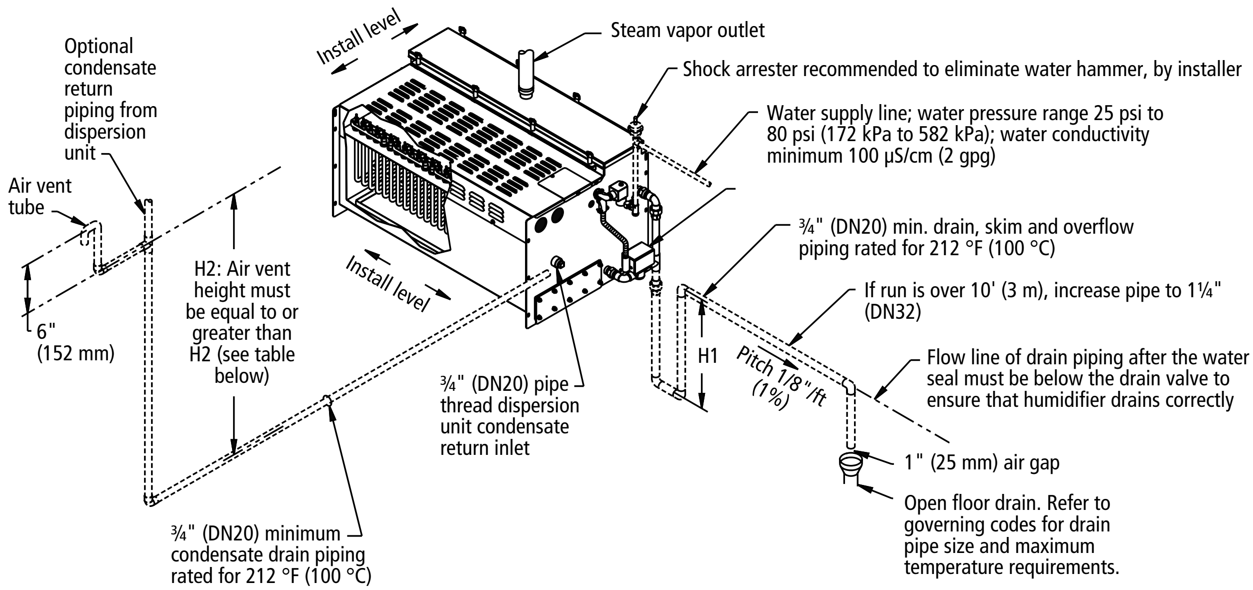


Table 63-1:
Heights required to overcome humidifier internal pressure (H1 and H2)

Unit output			Water seal height (H1)		Air vent height (H2)	
kW	lbs/hr	kg/h	inches	mm	inches	mm
≤ 48	≤ 138	≤ 62	12	305	22.5	572
49-64	139-183	63-83	15	381	27.5	699
> 64	> 183	> 84	18	457	30.5	775

Table 64-1:
Pitch of dispersion tube(s) and interconnecting piping for Single- or Multiple-Tube evaporative dispersion units

Condensate drain	Type of interconnecting piping	Diameter of dispersion tube and interconnecting piping	Pitch of interconnecting piping	Pitch of dispersion tube(s)	Pitch of condensate drain
Without drain	Vapor hose	1½" (DN40)	2"/ft (15%) toward humidifier	2"/ft (15%) toward humidifier	No drain
		2" (DN50)			
	Tubing or pipe	1½" (DN40)	1/8"/ft (1%) toward humidifier		
		2" (DN50)			
With drain	Vapor hose	1½" (DN40)	2"/ft (15%) toward humidifier	1/8"/ft (1%) toward condensate drain	¼"/ft (2%) toward floor drain or toward humidifier if humidifier is below dispersion unit
		2" (DN50)			
	Tubing or pipe	1½" (DN40)	½"/ft (5%) toward humidifier		
		2" (DN50)	¼"/ft (2%) toward humidifier		

Table 64-2:
Pitch of interconnecting piping, dispersion tubes, and headers for RAPID-SORB evaporative dispersion units

Airflow	Type of interconnecting piping	Diameter of interconnecting piping	Pitch of interconnecting piping	Pitch of dispersion tubes	Pitch of header
Horizontal	Vapor hose	1½" (DN40), 2" (DN50)	2"/ft (15%) toward RAPID-SORB	Vertically plumb	1/8"/ft (1%) toward condensate drain
	Tubing or pipe	1½" (DN40), 2" (DN50), 3" (DN80), 4" (DN100), 5" (DN125), 6" (DN150)	1/8"/ft (1%) toward RAPID-SORB		
Vertical	Vapor hose	1½" (DN40), 2" (DN50)	2"/ft (15%) toward RAPID-SORB	2"/ft toward header	1/8"/ft (1%) toward condensate drain
	Tubing or pipe	1½" (DN40), 2" (DN50), 3" (DN80), 4" (DN100), 5" (DN125), 6" (DN150)	1/8"/ft (1%) toward RAPID-SORB		

Table 65-1:
Maximum steam carrying capacity and length of interconnecting vapor hose, tubing, and pipe*

Vapor hose†††						Copper or stainless steel tubing and Schedule 40 steel pipe					
Hose I.D.		Maximum capacity		Maximum length**		Tube or pipe size***		Maximum capacity		Maximum developed length†	
inches	DN	lbs/hr	kg/h	ft	m	inches	DN	lbs/hr	kg/h	ft	m
1½	40	150	68	10	3	1½	40	150	68	20	6
2	50	250	113	10	3	2	50	220	100	30	9
						3††	80††	450	204	80	24
						4††	100††	750	340	100	30
						5††	125††	1400	635	100	30
						6††	150††	2300	1043	100	30

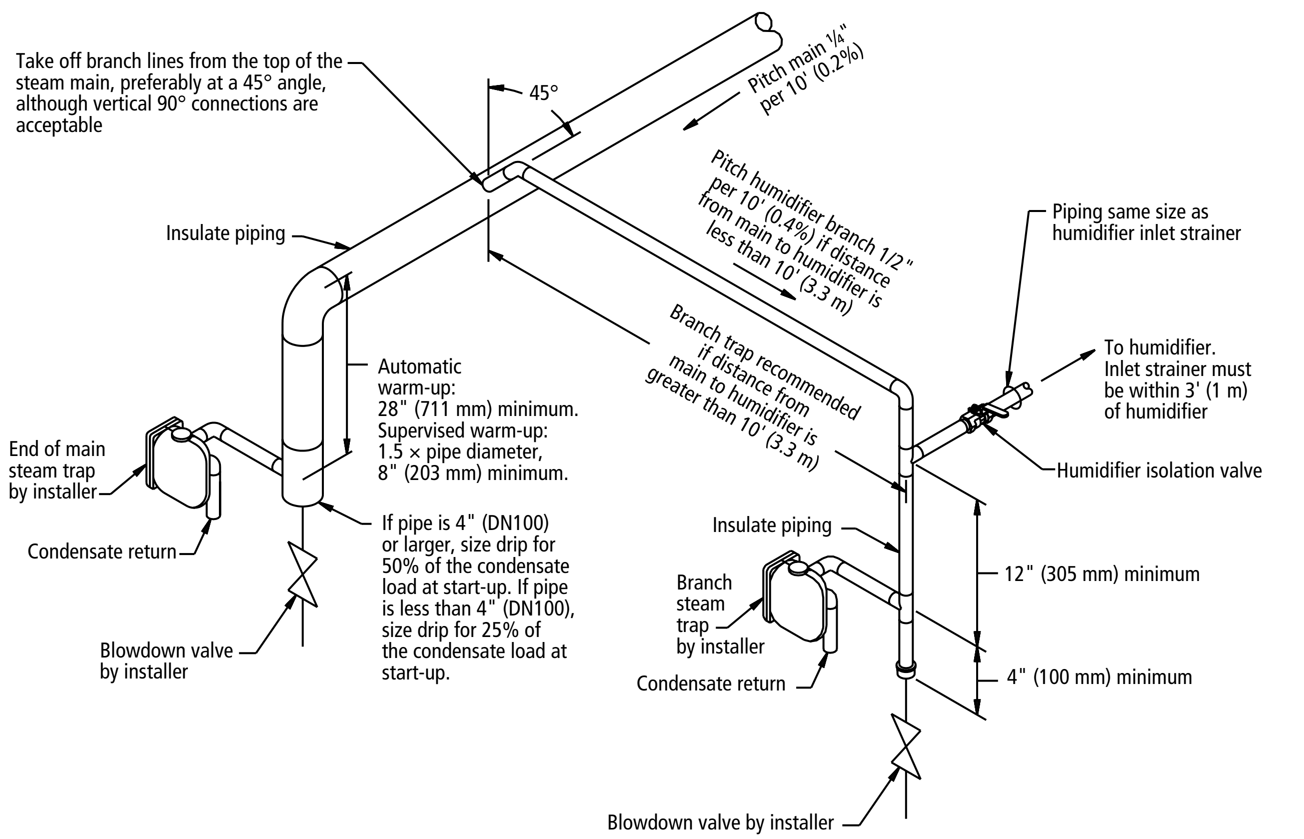
* Based on total maximum pressure drop in hose, tubing, or piping of 5" wc (1244 Pa)
** Maximum recommended length for vapor hose is 10' (3 m). Longer distances can cause kinking or low spots.
*** To minimize loss of capacity and efficiency, insulate tubing and piping.
† Developed length equals measured length plus 50% of measured length to account for pipe fittings.
†† Requires flange connection
††† When using vapor hose, use DRI-STEEM vapor hose for best results. Field-supplied hose may have shorter life and may cause foaming in the evaporating chamber resulting in condensate discharge at the dispersion assembly. Do not use vapor hose for outdoor applications.

Piping a steam injection system

Pressurized steam piping guidelines

- Size piping in accordance with ASHRAE recommendations.
- The humidifier's steam supply should be taken off the top of the steam main (not the side or bottom) to ensure the driest steam. The main should be dripped and trapped (in accordance with ASHRAE recommendations).
- The humidifier steam trap(s) must drain by gravity to the return main having little or no back pressure. If condensate cannot drain by gravity, then it must be elevated to the return main (see the next page for instructions).
- If steam pressure is < 15 psi (103.4 kPa), use float and thermostatic (F&T) traps for the humidifier.
- If steam pressure is >15 psi (103.4 kPa), use inverted bucket traps for the humidifier.
- If lifting condensate, use an inverted bucket trap. See drawings and instructions on the next page.
- Condensate from unavoidable heat loss in the distribution system must be removed promptly to eliminate water hammer,

Figure 66-1:
Piping from boiler to humidifier



degradation of steam quality, and heat transfer capability. Install drip legs at all low points and natural drainage points in the system, such as at the ends of mains and at the bottoms of risers, and ahead of pressure regulators, control valves, isolation valves, pipe bends, and expansion joints. On straight horizontal runs with no natural drainage points, space drip legs at intervals not exceeding 300' (91.4 m) when the pipe is pitched down in the direction of the steam flow and at a maximum of 150' (45.7 m) when the pipe is pitched up, so that condensate flow is opposite of steam flow. These distances apply to systems where valves are opened manually to remove air and excess condensate that forms during warm-up conditions. Reduce these distances by about half in systems that are warmed up automatically.

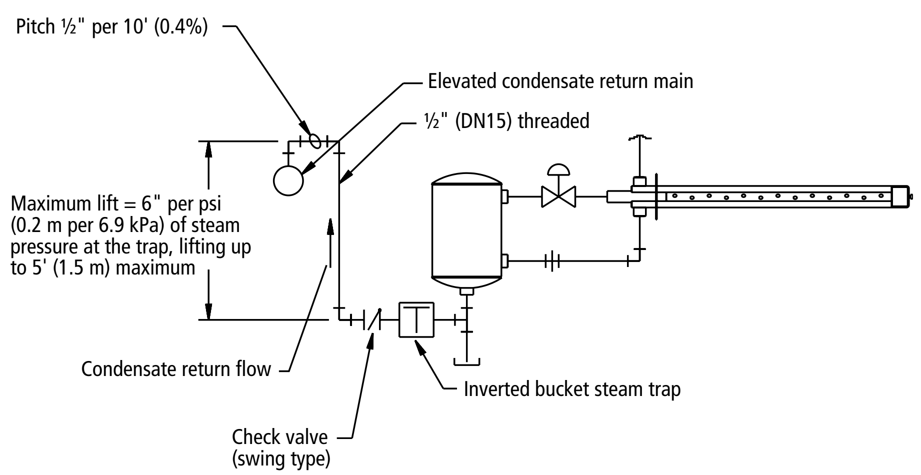
- Insulate piping well to avoid unnecessary heat loss.
- Pitch return lines downward in the direction of the condensate flow at ½" per 10' (0.4%).

Elevating condensate from a pressurized steam humidifier

In certain installations, it is not possible to drain the humidifier steam trap by gravity. The condensate must be lifted. Generally, lifting condensate is not recommended, but it can be done successfully by observing the following rules:

- Steam pressure. Theoretically, 1 psi (6.9 kPa) of steam pressure lifts condensate about 2' (0.6 m). But in practice, because of pipe friction, pressure drop through a steam trap, and back pressure in a return line, we recommend that you consider the maximum lift to be 6" per psi (0.2 m per 6.9 kPa) of steam pressure at the trap. For example, a steam pressure of 5 psi (34.5 kPa) provides a

Figure 67-1:
Elevating condensate



maximum lift of 2.5' (0.76 m). Do not attempt lifts in excess of 5' (1.5 m).

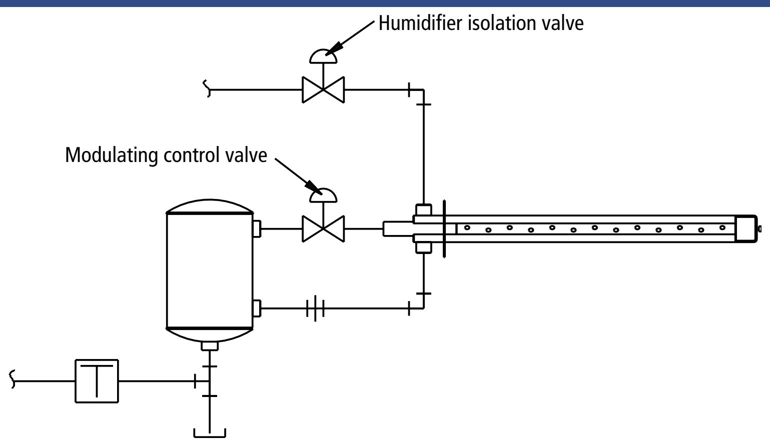
- Steam trap. When lifting condensate, use an inverted bucket type steam trap. Float and thermostatic (F&T) traps are more prone to water hammer damage with a flooded trap, which may occur when lifting condensate.
- Pipe size. The size of the vertical portion of the piping should be ½" (DN15) pipe thread.
- Check valve (swing type). Install a low-pressure differential swing check-valve adjacent to the trap. This will prevent backflow of condensate into the humidifier during periods of little or no steam pressure. Failure to do so could result in the accumulated backflow discharging from the humidifier when steam pressure is resumed. Spring type check-valves are not recommended as they can reduce pressure available for condensate lifts.

Eliminating excess heat from pressurized steam-jacketed humidifiers

In some applications with steam-jacketed humidifiers, the heat given off by the steam-heated tube (not the sensible heat of the steam) may be undesirable. While relatively insignificant in a single-tube unit (usually a rise of less than 2 °F [1 °C]), it can be much greater in a closely-spaced, multiple-tube installation. This can be dealt with in several ways:

1. Manually turn off the steam supply valve during nonhumidifying periods.
2. Insulate the tube exterior. (Note that this enlarges the tube profile, causing additional resistance to airflow.)
3. Provide an automatic shut-off valve for the jacketing steam circuit in addition to the modulating control valve. This

Figure 68-1:
Single humidifying steam path

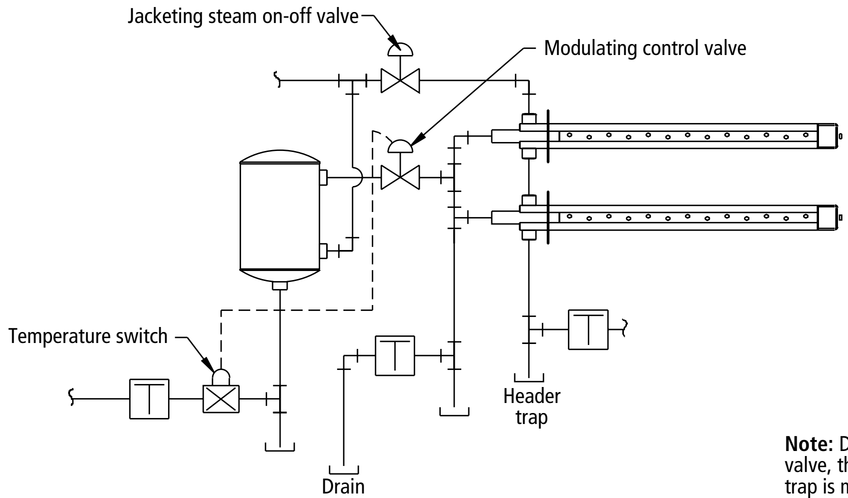


eliminates heat gain during the “off” humidification periods only (see Figures 68-1 and 69-1). The jacketing steam valve should be a two-position type, with a minimum Cv of 5, and set to the full-open position prior to opening the modulating valve.

In Figure 68-1, all of the steam (for jacketing and humidification) must pass through the jacket steam valve, and it must do so with very little or no pressure drop across the valve, or maximum capacity will be reduced. More importantly, with just one supply source for jacket and humidification steam, the temperature of the jacket steam may drop below the temperature required to eliminate dripping. Therefore, the valve must be adequately sized. This is not significant in a small capacity humidifier. However, in a large capacity humidifier, the valve of the size required may be quite expensive. Another option is to install two valves: one sized for jacket steam and one sized for humidification steam.

Figure 69-1 shows a steam flow that has been divided into two paths: a humidifying steam path (which passes through the separator valve assembly) and a jacket steam path. When dividing the steam path, install a temperature switch as shown in the drawing to ensure that condensate is not present when the control valve opens. Install a header trap, as shown, to collect condensation when the jacket steam is off.

Figure 69-1:
Divided humidifying steam path



Note: Due to the pressure drop across the valve, the steam pressure at the header trap is minimal; therefore, you cannot lift condensate or return condensate to a pressurized return from this trap.

Summary

Designing a humidification system is a straightforward process of:

- Calculating load
- Selecting the energy source
- Choosing a water type
- Understanding humidifier maintenance requirements
- Defining control requirements
- Selecting humidification equipment
- Placing dispersion assemblies to ensure complete absorption
- Piping the humidification system

In tandem with a product catalog, this Design Guide has hopefully given you the information you need to design a DRI-STEEM humidification system. If you need more information, your DRI-STEEM representative is always available to help you (you can find your local representative by going to www.dristeem.com). Also, keep in mind that DRI-STEEM provides many educational tools to help you understand humidification issues. Those tools are listed on Pages 2 and 3 of this document, and many can be found on our web site, www.dristeem.com.

Glossary of humidification terms

Numbers and symbols

3PDT — three-pole, double throw

μS/cm — microSiemens per centimeter, a measure of conductivity

A

A — ampere, amps, amp

ac — alternating current

adiabatic humidifier — uses heat from air to convert water into vapor

AGA — American Gas Association

AHU — air-handling unit

ANSI — American National Standards Institute

aquastat — thermostat designed for use in water

ASCII — American Standard Code for Information Interchange

ASHRAE — American Society of Heating, Refrigerating, and Air-Conditioning Engineers

ASTM — American Society for Testing and Materials

atomizer — device that creates a fine spray from a liquid

B

ball valve — valve consisting of a ball resting on a spherical seat

BOM — bill of material

BSP — British standard pipe

BSPT — British standard pipe tapered

Btu — British thermal unit

C

°C — degrees Celsius

CE — Conformité Européen — required marking for selling our products in Europe

C-ETL — Electrical Testing Laboratory, Canada

cfh — cubic feet per hour

cfm — cubic feet per minute

cfs — cubic feet per second

check valve — a valve allowing fluid flow in one direction only

cold-snap offset RH transmitter — during periods of very cold weather, this window-mounted temperature transmitter lowers the RH control point to permit maximum room RH without condensation on windows

condensate — in humidification, water condensed from steam

condensation — change of state of a vapor into a liquid by extracting heat from vapor

conductivity — ability to carry electrical current

contactor — electromagnetic switching device

controller — device that regulates the humidification system

CPVC — chlorinated polyvinyl chloride

CSA — Canadian Standards Association

CSI — Construction Specifications Institute

C-UL — Certified by UL in both Canada and the U.S.

Cv — valve flow coefficient

D

dB — decibel

dBA — decibel, weighted

dc — direct current

DEAE — diethylamino ethanol

dia. — diameter

DIN standard — Deutsches Institut für Normung (German Institute for Standardization)

DI/RO — deionized/reverse osmosis (water)

DK — DRANE-KOOLER

DN — diameter nominal — used to describe pipe sizes in metric literature

DPDT — double pole, double throw

E

EEPROM — electrically erasable programmable read-only memory

EMI — electromagnetic interference

entrained condensate — water droplets transported by steam flow

EOS — end of season

EPDM — ethylene propylene dienemonomer

ETL — Electrical Testing Laboratory

F

°F — degrees Fahrenheit

F&T trap — float and thermostatic trap

flue piping —

Type B: Double-wall construction with aluminum inner wall and galvanized steel outer wall

Type B-W: Same as Type B except fabricated in an oval shape

Type L: Same as Type B except inner wall is stainless steel

ft — foot, feet

ft^2 — square foot, feet

fpm — feet per minute

fps — feet per second

G

gpg — grains per gallon

gph — gallons per hour

gpm — gallons per minute

GTS humidifier — Gas-to-Steam humidifier

H

heat exchanger — a device specifically designed to transfer heat between physically separated fluids or gasses

HEPA — high-efficiency particle arrestor

hp — horsepower

hr — hour, hours

humidistat — a regulatory device, actuated by changes in humidity; used for automatic control of relative humidity

humidity transmitter — a monitoring device that senses humidity level and provides an output signal based on humidity level

HVAC — heating, ventilation, air conditioning

hygrometer — an instrument responsive to humidity conditions of the atmosphere

Hz — hertz

I

IAQ — indoor air quality

ID — inside diameter

in — inch, inches

in^2 — square inch(es)

in^3 — cubic inch(es)

IOM — Installation, Operation and Maintenance manual

I-P units — inch-pound units

J

J — joule

JIC — Joint Industrial Council

K

kW — kilowatt

kWh — kilowatt-hour

K_{vs} — valve flow coefficient, Europe

L

L — litre

lb — pound

lbs/hr — pounds per hour

lbs/hr/ft — pounds per hour per foot (as in vapor hose capacity)

$lbs/hr/ft^2$ — pounds per hour per square foot

LON — local operating network

LP — liquefied petroleum

LTS humidifier — Liquid-to-Steam humidifier

M

mA — milliampere

max — maximum

MB — megabyte

mb — millibar

MBh — one thousand Btu per hour

micromho — one-millionth of a mho. The micromho is the practical unit of measurement for conductivity, and is used to approximate the total dissolved solids content of water. The preferred term for conductivity is µS/cm

microSiemens/cm — microSiemens per centimeter (abbreviated µS/cm); a measure of conductance; see also ***micromho***

N

NEMA — National Electrical Manufacturing Association

NIST — National Institute of Standards and Technology

No. — number

NOx — nitrogen oxide

NPT — National Pipe Thread

O

oc — on center

OD — outside diameter

P

PID — proportional, integral, derivative

ppm — parts per million

psi — pounds per square inch

PVC — polyvinyl chloride

R

RFI — radio frequency interference

RH — relative humidity

S

SCR — silicon-controlled rectifier

SDU — space distribution unit

SI — Système International D'unités (International system of units based on the meter, kilogram, second, ampere, Kelvin, candela, and mole)

SSR — solid state relay

SST — stainless steel

STS humidifier — Steam-to-Steam humidifier

T

T — temperature

TDS — total dissolved solids

TP — time-proportioning

U

UL — Underwriters' Laboratories

V

VA — volt-ampere

Vac — volts alternating current

Vdc — volts direct current

VL3 — VAPOR-LOGIC3 controller

VLC — VAPORSTREAM's standard-water model

VLDI — VAPORSTREAM's DI/RO-water model

VM — VAPORMIST

W

W — watt

wc — water column

wt — weight