ENGINEERING STANDARD

FOR

HUMIDIFICATION AND DEHUMIDIFICATION SYSTEM

ORIGINAL EDITION

JAN. 1996

This standard specification is reviewed and updated by the relevant technical committee on Dec. 2002(1), June 2005(2) and Sep. 2015(3). The approved modifications are included in the present issue of IPS.

FOREWORD

The Iranian Petroleum Standards (IPS) reflect the views of the Iranian Ministry of Petroleum and are intended for use in the oil and gas production facilities, oil refineries, chemical and petrochemical plants, gas handling and processing installations and other such facilities.

IPS are based on internationally acceptable standards and include selections from the items stipulated in the referenced standards. They are also supplemented by additional requirements and/or modifications based on the experience acquired by the Iranian Petroleum Industry and the local market availability. The options which are not specified in the text of the standards are itemized in data sheet/s, so that, the user can select his appropriate preferences therein.

The IPS standards are therefore expected to be sufficiently flexible so that the users can adapt these standards to their requirements. However, they may not cover every requirement of each project. For such cases, an addendum to IPS Standard shall be prepared by the user which elaborates the particular requirements of the user. This addendum together with the relevant IPS shall form the job specification for the specific project or work.

The IPS is reviewed and up-dated approximately every five years. Each standards are subject to amendment or withdrawal, if required, thus the latest edition of IPS shall be applicable

The users of IPS are therefore requested to send their views and comments, including any addendum prepared for particular cases to the following address. These comments and recommendations will be reviewed by the relevant technical committee and in case of approval will be incorporated in the next revision of the standard.

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GENERAL DEFINITIONS

Throughout this Standard the following definitions shall apply.

COMPAN:

Refers to one of the related and/or affiliated companies of the Iranian Ministry of Petroleum such as National Iranian Oil Company, National Iranian Gas Company, National Petrochemical Company and National Iranian Oil Refinery And Distribution Company.

PURCHASER:

Means the “Company” where this standard is a part of direct purchaser order by the “Company”, and the “Contractor” where this Standard is a part of contract document.

VENDOR AND SUPPLIER:

Refers to firm or person who will supply and/or fabricate the equipment or material.

CONTRACTOR:

Refers to the persons, firm or company whose tender has been accepted by the company.

EXECUTOR:

Executor is the party which carries out all or part of construction and/or commissioning for the project.

INSPECTOR:

The Inspector referred to in this Standard is a person/persons or a body appointed in writing by the company for the inspection of fabrication and installation work.

SHALL:

Is used where a provision is mandatory.

SHOULD:

Is used where a provision is advisory only.

WILL:

Is normally used in connection with the action by the “Company” rather than by a contractor, supplier or vendor.

MAY:

Is used where a provision is completely discretionary.

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0. INTRODUCTION

In view of the importance of indoor air quality and the health factor demanded by the occupants and the environmental regulation for storing of hygroscopic and non-hygroscopic materials, this Standard is established on the basis of accumulated knowledge and experience for design engineers on humidification and dehumidification system.

Since the design of humidification and dehumidification varies with different system and since these cannot be verified under one heading, therefore this Standard is divided into the following parts:

Part 1 : General Engineering

Part 2 : Humidification system

Part 3 : Dehumidification system

Part 4 : Control system for humidification and dehumidification

1. SCOPE

This Standard sets forth standard engineering techniques covering minimum requirements for determining moist and dry air, applying design and description on types of industrial, commercial, institutional and residential humidification and dehumidification. It covers the various methods, recommended uses and limitations of individual system for the humidification and dehumidification.

Note 1:

This standard specification is reviewed and updated by the relevant technical committee on Dec. 2002. The approved modifications by T.C. were sent to IPS users as amendment No. 1 by circular No. 189 on Dec. 2002. These modifications are included in the present issue of IPS.

Note 2:

This standard specification is reviewed and updated by the relevant technical committee on June 2005. The approved modifications by T.C. were sent to IPS users as amendment No. 2 by circular No. 268 on June 2005. These modifications are included in the present issue of IPS.

Note 3:

This standard specification is reviewed and updated by the relevant technical committee on Sep. 2015. The approved modifications by T.C. were sent to IPS users as amendment No. 3 by circular No. 461 on Sep. 2015. These modifications are included in the present issue of IPS.

2. REFERENCES

Throughout this Standard the following dated and undated standards/codes are referred to. These referenced documents shall, to the extent specified herein, form a part of this standard. For dated references, the edition cited applies. The applicability of changes in dated references that occur after the cited date shall be mutually agreed upon by the Company and the Vendor. For undated references, the latest edition of the referenced documents (including any supplements and amendments) applies.

ASHRAE (AMERICAN SOCIETY OF HEATING REFRIGERATING AND AIR CONDITIONING ENGINEERS)

ASHRAE Std 35-2010 "Method of Testing Desiccants for Refrigerant Drying"

ASHRAE Std 62.1-2013 "Ventilation for Acceptable Indoor Air Quality"

ASHRAE Std 55-2014 "Thermal Environmental Conditions for Human Occupancy"

ASHRAE Guidebook

2008 ASHRAE handbook HVAC systems and Equipment (SI) chapter 21, 22

UL (UNDERWRITER'S LABORATORIES)

UL-474-2014 "Dehumidifiers"

IPS (IRANIAN PETROLEUM STANDARD)

IPS-E-GN-100 "Engineering Standard for Units"

3. DEFINITIONS & TERMINOLOGY

a) Absolute Humidity: Is the weight of moisture content in a given sample of air, expressed in grain per pound of dry air or pounds per pound of dry air.

b) Absorbent: A sorbent material which due to its affinity changes physically, and chemically or both, during the sorption process.

c) Adsorbent: A sorbent material which does not change physically or chemically during the sorption process.

d) Air, Dry: In psychrometry, air unmixed with, or containing no water vapor and contaminants.

e) Air, Saturated: A mixture of dry air and saturated water vapor, all at the same dry-bulb temperature.

f) Dehumidify: To reduce, by any process,the quantity of water vapor within a given space.

g) Dew Point Temperature: The temperature at which a given sample of air will be saturated. It is the temperature at which the condensation of moisture begins when the air is cooled.

h) Dry bulb Temperature: Dry bulb Temperature (DBT) is The Temperature of are easured by a thermometer freely exposed to air but shielded from radiation and moisture.

i) Grains of Moisture: Convenient unit of measurement of water vapor. One grain equals 1/7000 pound avoirdupois (Historically, the average weight of a grain of wheat).

j) Humidify: To increase, by any process, the density of water vapor within a given space.

k) Fog: Suspended liquid droplets generated, by condensation from the gaseous to the liquid state, or by breaking up a liquid into a dispersed state, such as splashing, forming and atomizing.

l) Hygrometer: Instrument responsive to humidity conditions (usually relative humidity) of the atmosphere.

m) Liquid sorbent: A liquid absorbent has the property of absorbing moisture from, or adding moisture to the air, depending on the vapor pressure difference between the air and the solution. The equilibrium vapor pressure of the solution depends on the temperature and concentration of the solution.

n) Metabolism: Chemical changes in living cells by which the solid energy is provided for vital processes. It is the process by which the body produces heat.

o) Mildew: Is a thin, often whitish, growth produced on many kinds of surfaces by molds.

p) Mist: Constitutes liquid water composed of water droplets in suspension.

q) Perm: The unit of permanence, a perm is equal to one grain per square feet/hr. inch of mercury vapor pressure difference.

r) Permeability: Water vapor permeability is a property of a substance which permits passage of water vapor and is equal to the permanence of 1" thick of the substance**.**

s) Relative Humidity: Is the percent of moisture in the air at a given temperature compared to the maximum it can hold at that temperature.

t) Solid sorbent: A solid adsorbent, having the property of absorbing moisture from, or adding moisture to, a gas, such as an air water vapor mixture, depending on the vapor pressure difference between the water in the gas and the water in the adsorbent.

u) Sorbent: A material which extracts one or more substances present in an atmosphere or mixture of gases or liquids with which it is in contact, due to an affinity for such substances. It refers to those materials having a large capacity for moisture, relative to their volume and weight. Such materials are divided into either absorbent or adsorbent.

v) Wet bulb Temperature: the wet bulb Temperature is Temperature a parcel of air would have if it were cooled to Saturation (100% Relative humidity) by the evaporation of into it with the laten heat being.
Humidity ratio is the ratio between actual mass of water vapor present in moist air to the mass of dry air.

4. UNITS

International System of Units (SI) shall be used, according to IPS-E-GN-100.

PART 1

GENERAL ENGINEERING

5. AIR CONDITIONING AND HUMIDITY CONCEPTS

5.1 Air Conditioning Concepts

5.1.1 Air conditioning processes such as heating, cooling; humidifying and dehumidifying together with properties of moisture are shown graphically in Attachment 1 (Figure 1 and 2).

5.2 Humidity Concepts

5.2.1 General

There are three basic parts to environmental control:

- indoor air quality-its cleanliness and purity,
- temperature,
- relative humidity.

Of the three, the most ignored is the level of relative humidity (RH) probably because the effects of temperature and air quality are more easily seen and felt than the effects of relative humidity. The relative humidity (RH) can affect human health and comfort, operation of production materials, quality and workability of production material, energy use and operating efficiency of a system.

5.2.2 Humidity level

5.2.2.1 High relative humidity levels inside a building cause destructive effects on building components. Mold and mildew can attack wall, floor and ceiling coverings and condensation can degrade health factors and many building materials.

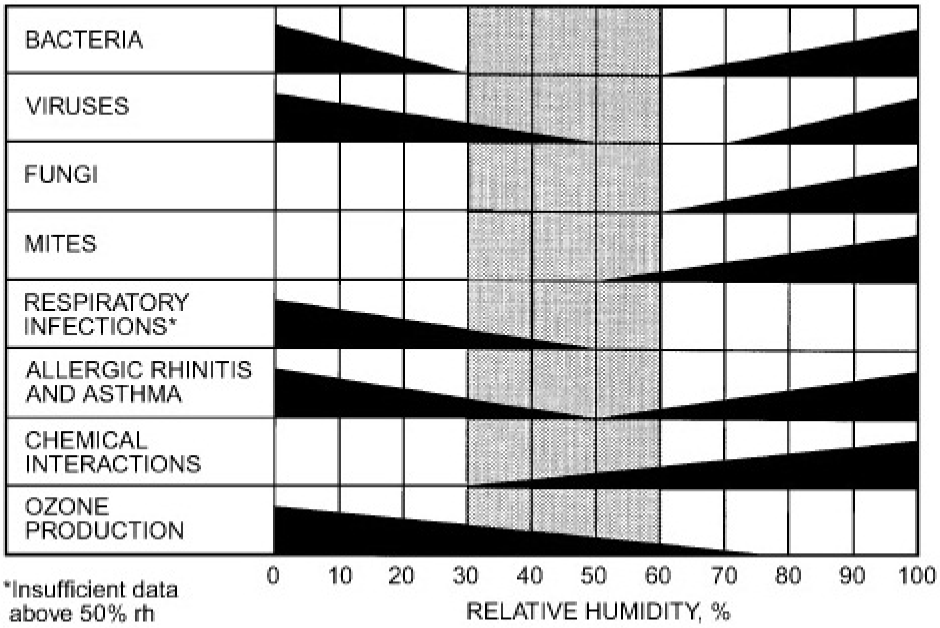
Relative humidity as mentioned in ASHRAE Std 62.1-2013 is directly related to the Indoor Air Quality (IAQ) and affects:

a) The health and comfort of building occupants.

b) Energy costs associated with cooling a structure.

c) Maintenance costs associated with the repair and replacement of building components.

5.2.2.2 Optimum zone for relative humidity are considered between 30% and 60% where health factors and human comfort coincide. Deviations from the mid-range of relative humidity can result in increased levels of bacteria, viruses, fungi, absenteeism and other factors that reduce air quality and lead to respiratory problems as illustrated in Fig. 1 below:



OPTIMUM RELATIVE HUMIDITY RANGES FOR HEALTH (DECREASE IN BAR WIDTH INDICATES DECREASE IN EFFECT)

Fig. 1

5.3 Dehumidification Concepts

Dehumidification is becoming increasingly important in the commercial and industrial field, particularly towards the refrigeration and desiccant application. Solving dehumidification problems shall be a service handled by HVAC&R organizations. However not all dehumidification problems can be solved by refrigeration alone. Use of absorbents alone or combination of refrigeration and desiccant are often the economically advantageous solution.

6. TECHNOLOGY OF HUMIDITY CONTROL

6.1 Air Conditioning and Humidity Control

6.1.1 Air conditioning process primarily involves the use of equipment for cooling or heating the air, and for adding or removing moisture from it. The process of adding moisture to the air is known as humidification, and the process of removing moisture is known as dehumidification.

6.1.2 In air conditioning the treatment of the atmosphere within a room or building involves the control of temperature, moisture content, air purity and circulation in a manner that is conductive to providing comfort and health for the occupants or for the purpose of creating conditions suitable for the manufacture or preservation of the product being stored.

6.2 Air and Relative Humidity

6.2.1 The weight or density of mixture of gases, primarily nitrogen, oxygen and water vapor, with small percentage of rare gases, referred to atmospheric pressure amounts to 101.35 kPa (14.7 lbs/square inch) at sea level. In accordance with Dalton's law of Partial Pressure, each one of these gases, including the water vapor, exerts its own partial pressure in the mixture, just as though the other gases were not present at all. The sum of each of these partial pressures equals the total pressure of the mixture. (Thus areas to be humidified must be isolated from nonhumidified areas).

6.2.2 Since at atmospheric pressure and 38°C (100°F), air can contain approximately 300 grains of moisture per pound of dry air and exert a vapor pressure of 65.5m bar (1.933 inches of mercury), concentration beyond this point will exceed saturation, and condensation of water vapor will occur.

6.2.3 Humidity in terms of partial pressures shall be considered as the movement of moisture from one area to another, with the possibility of having air flow in one direction and the moisture flow in the opposite direction, as the total pressure head may be opposite to the vapor pressure head.

6.2.4 The relative humidity of an air mixture is the ratio between the total amount of moisture which an air mixture can contain and the actual amount of moisture in the air at a given condition. It is normally measured by taking dry bulb and wet bulb thermometer readings. The intersection of this reading plotted in a psychrometric chart corresponds to a relative humidity and specific or absolute moisture content of the air mixture, expressed in grains of moisture per pound of dry air.

6.3 Moisture Flow Between Air and Materials

6.3.1 Moisture exists not only in the air, but also in all solids and liquid materials to some extent. Hygroscopic materials such as wood or paper have this moisture all the way through them, while materials such as steel and glass hold the moisture in pores on the surface.

6.3.2 Where materials are placed in a dry atmosphere, moisture will flow into the air gradually and the materials will be progressively dried. As the air cannot hold as much moisture per unit of volume as most hygroscopic materials, the air will soon be saturated with the moisture given off, and unless new dry air is introduced, the drying process will soon stop. Thus the vapor pressure of air must always be maintained at a lower level than that of the materials to be dried for the process to continue.

6.3.3 Cold air is difficult to humidify as it does not give up heat as readily, hence special equipment must sometimes be used. Also since cold fresh air make-up can cause condensation problems in ducts, pre-heating arrangements are recommended.

6.4 Sensible and Latent Heating and Cooling

6.4.1 Four types of energy changes take place when heat or moisture is added or removed.

a) Sensible heating occurs when heat is added without the addition or reduction of moisture.

b) Sensible cooling is the reverse of the above.

c) Latent heat also known as humidification is the addition of moisture without changing the dry bulb temperature.

d) Latent cooling or dehumidification is the removal of moisture.

PART 2

HUMIDIFICATION SYSTEM

7. HUMIDIFICATION SYSTEM

7.1 General

7.1.1 Water vapor is always present in the air, and moisture is either absorbed, or adsorbed or both, or resulting from physical changes of state, and is present in most building space and material. (Beside changes of state, other factors such as surface tension, viscosity and isotopes complicate moisture behavior).

7.1.2 Water vapor condenses when the temperature of the air/vapor mixture drops below the dew point, a consequence of either;

a) Vapor flow to a region of lower temperature.

b) A reduction in surface temperature.

7.1.3 The prime defense against harmful condensation are through control of humid air movement within a building space and structure by means of airtight construction simultaneously preventing the creation of Sick Building Syndrome (SBS). (The SBS occurs when moisture and mold give rise to respiratory illness among a building's occupant. It is common in houses built directly on concrete slabs).

7.2 The Need for Humidification

The problems caused by dry air will vary from one building to another and from one area to another. With proper humidification system the following problems are prevented:

a) Static Electricity

b) Poor Moisture Stability

c) Poor Health and Comfort

7.3 Vapor Barrier and Insulation

Water vapor moves from higher to lower vapor pressure at a rate determined by the permeability of the structure. This process is similar to heat except that heat flow is reduced by adding insulation and vapor is reduced by addition of vapor barriers on insulation materials. The vapor barrier shall be placed on that side of structures where high vapor pressure exists.

8. METHOD OF HUMIDIFICATION

The two most common methods by which moisture is introduced into an air stream are:

a) Water spray injection.

b) Steam injection.

8.1 Water Spray Injection

8.1.1 Water spray methods, whether injected directly or as a mist are adiabatic processes, that is no heat is transfered to or from the working media. In the adiabatic process the following phenomena is achieved.

- Total heat remains constant.
- Reduction of sensible temperature.
- Addition of moisture.

8.1.2 Unless some method of pre-heating the air in the water spray system is employed, the moisture absorbing capacity of the air is limited by the amount of dry bulb temperature depression.

8.2 Steam Injection

8.2.1 The use of steam as a means to add moisture to an airstream is very nearly isothermal process. Since steam is already a vapor no additional heat is required to accomplish absorption by the airstream.

8.2.2 Steam being pure, odor free, containing no mineral dust, can be easily controlled to maintain the specified humidity. Steam eliminates the need for water in the heating ducts. Stagnant water can provide a fertile breeding ground for algae and bacteria which are linked to odor and respiratory irritation.

9. TYPE OF HUMIDIFIERS

The type of humidifiers mentioned below are used on central (air handlers or furnaces) ducted or non-ducted systems suitable for residential, commercial and industrial application.

9.1 Single plenum humidifier with water distribution through installed on vertical warm air furnaces. A motor and fan move the air for evaporation as heated air passes through the evaporator pad.

9.2 Under-cut and sidewinder humidifiers with nozzles without moving parts, operates in conjunction with a blower motor in warm air ducts for a central forced air heating system.

9.3 Atomizing, Pan type or Wetted element humidifiers for central air system depend upon airflow for evaporation and distribution and its description of types are as follows:

a) Pan type humidifiers can be either:

i) Basic pan type

ii) Electrically heated pan type

iii) Pans with wicking type plates

b) Wetted element type where air flow through such units are accomplished in one of three ways:

i) Fan type or rotating drum type

ii) By pass type which are fan-less mounted on the supply plenum of the furnace with an air connection to the return plenum

iii) Duct mounted type installed within the furnace plenum or ductwork with drum type element

c) Atomizing type

Small particles of water are introduce directly into air stream by:

i) A spinning disc or cone which break the water into a fine mist

ii) Sprays which rely on water pressure to create fine droplets

iii) Spray nozzle use compressed air to create fine mist compressed air nozzle humidifiers can operate in two ways:

1- Compressed air and water are combined inside the nozzle and discharged onto a resonator to create fine fog at the nozzle tip.

2- Compressed air is passed through an annular orifice at the nozzle tip, and water is passed through a center orifice. The air create a slight vortex at the tip, where the water breaks up into a fine fog on contact with the high-velocity compressed air.

iv) A rotating disc which slings water droplets into the airstream from a water reservoir.

v) Ultrasonic vibrations are used as the atomizing force.

9.4 Electrode Steam Humidifiers

These units are mounted outside of the airstream using the electrode boiler principle electrically with hot-element to produce pure steam from potable water. The steam is injected into the duct through a dispersal manifold and the minerals from the water are left behind on the electrodes and the steam cylinder.

9.5 Steam Grid Humidifiers

It is duct-mounted and applicable for low pressure direct steam which may contain an enclosure to catch condensate. It should be mounted downstream from the coil.

9.6 Jacketed Dry-Steam Humidifiers

Uses a jacket separator to keep condensate from entering the duct, a situation that often leads to microbial and fungus growth.

9.7 Air or Fan-powered Electric Humidifiers

For discharge of live dry-steam directly into space to be humidified, generally fan-less models are used in conjunction with heat exchangers so that boiler steam can create steam from potable water, suitable for ducted or ductless applications.

Note:

For additional information on type of humidifiers refer to chapter 21 of 2008 ASHRAE handbook – HVAC systems and equipment (SI).

10. HUMIDIFIER SELECTION

A humidifier can be selected when the following parameters are known:

a) Moisture content of the air to be humidified.

b) Desired moisture content.

c) Amount of air to be humidified per unit time.

d) Available duct size or air handler space (or lack of ducts).

e) Sources of energy and application.

Note:

For design data sheet for humidifiers, reference is made to Attachment 2.

11. LOAD CALCULATION FOR HUMIDIFICATION

11.1 Computation Method

The airflow rate can usually be determined from the system blower capacity, or if no blower exists, from calculation of air infiltration rates specified by ASHRAE. The following formulas are recommended for use in calculating the amount of moisture to be added to meet the desired conditions.

a) For ventilation systems having natural infiltration,

$$H = \rho VR(W_i - W_o) - S + L$$

b) For mechanical ventilation systems having a fixed quantity of outside air,

$$H = 60\rho Q_o (W_i - W_o) - S + L$$

c) For mechanical systems having a variable quantity of outside air,

$$H = 60\rho Q_t (W_i - W_o)\left(\frac{t_i - t_m}{t_i - t_o}\right) - S + L$$

Where

H = humidification load, lb of water/h
V = volume of space to be humidified, ft^3
R = infiltration rate, air changes per hour
Q_o = volumetric flow rate of outside air, cfm
Q_t = total volumetric flow rate of air (outside air plus return air), cfm
t_i = design indoor air temperature, ºF
t_m = design mixed air temperature, ºF
t_o = design outside air temperature, ºF
W_i = humidity ratio at indoor design conditions, lb of water/lb of dry air
W_o = humidity ratio at outdoor design conditions, lb of water/lb of dry air
S = contribution of internal moisture source, lb of water/h
L = other moisture losses, lb of water/h
ρ = density of air at sea level, 0.074 lb/ft^3

Note:

The Psychometric chart and the local weather data shall be referred to for parameters of moisture content and desired moisture content.

11.2 Load Calculation Summary

11.2.1 Factors to consider

In order to determine the humidification load four basic values need to be known:

a) The design conditions of the humidified space, i.e. the temperature and humidity required.

b) The conditions of the incoming air, i.e., the temperature and humidity available.

c) Incoming air volume and secondary conditions that can affect the humidification load.

d) Factors obtained from loads derived through sources of moisture.

11.2.1.1 Temperature and humidity required

The design temperature and humidity of a space depends mostly upon the job being performed once the design temperature and humidity have been established taking into consideration the worst case of temperature and humidity.

11.2.1.2 Temperature and humidity available

The outdoor conditions provides the moisture available in the incoming air and the worst condition shall be taken into consideration.

11.2.1.3 Incoming air volume

The following outlines the steps necessary to determine the amount of outside air being brought into the humidified space and the corresponding amount of moisture required. Outside air is introduced into a humidified space by the following means:

a) Through natural ventilation, i.e., opening and closing of doors and windows, and by infiltration through cracks and openings in the building construction.

b) Through mechanical ventilation, i.e., the introduction of make-up air, or the exhausting of stale air by the building HVAC system.

c) Through the economizer section of the HVAC system, if this feature is included in the system.

Note:

For maximum accuracy all three items shall be estimated but the largest load considered.

12. HUMIDIFIER USAGE LIMITATIONS

12.1 The predominant method of humidifying the air in buildings with direct steam humidification is with chemically (anti corrosion) treated live steam. Gross overfeed or misuse of live steam may contain amines and frequent exposure to this chemical may be within OSHA limits, irritating to skin and eyes.

12.2 To remain below permissible *OSHA exposure limits,pure demineralized, deionized or distilled water shall be used for generating steam.

12.3 Demineralizers may be used to remove dissolve solids, but a check should first be made with the humidifier manufacturer because treated water can be corrosive when in contact with some materials.

12.4 High mineral content potable water should not be used, as scaling (clogged nozzles, tubes) and precipitated solids (white dust carry-over into conditioned spaces) can create problems. Ion exchange water softening units, where magnesium or calcium salts are exchanged for sodium salts, may increase inefficiency. When using commercial water softeners, scaling due to undissolved solid should be eliminated by periodic purging.

12.5 Any volatile amines that enter the workplace through the steam humidifier and recognized as hazardous, must be measured and controlled as steam contaminants that cause environmental impacts within the workplace.

Notes:

1) To prevent irritation, exposures and health hazards in workplace, amines shall be duly treated for steam humidification. This steam shall not be overfeed, misused and/or improperly applied.

2) Each ppm of applied chemical (as rust inhibitors, etc.) is estimated to lead to approximately 270 mg/year of employee absorption. Inhalation of these water soluble chemicals creates total absorption through the wetted tissues upon which respiratory processes depend. Eyes of workers, whose workplaces are dosed with volatile amines are easily irritated because of the contact absorption of the chemicals into their tear films.

*** OSHA= Occupational Safety and Health Association**

PART 3

DEHUMIDIFICATION SYSTEM

13. DEHUMIDIFICATION SYSTEM

13.1 General

13.1.1 Dehumidification of air involves the removal of moisture from the gas mixture and Indoor Air Quality (IAQ) and productivity. Outdoor air may account for approximately 90% of the moisture load entering the space.

13.1.2 To eliminate the moisture problem at an effective and reasonable cost, the engineer should know how much moisture is present, how did it get in the facility and how to select the proper dehumidification system.

13.1.3 A typical dehumidifier shall have the capability to effectively control the following:

- Humidity
- Dampness
- Rusting
- Moisture
- Mildew, mold and corrosion
- Warping and decay
- Building and structural damage
- Electrical failures
- Problems normally associated with excessive and uncomfortable humidity laden environments

Note:

For design data sheet for dehumidifiers, reference is made to Attachment 3.

13.2 Application

Typical applications where desiccant dehumidifiers, requiring both the environmental conditions of occupancy or process and the characteristics of the building enclosure can serve the humidity control requirement are in the following areas:

- Critical storage areas such as for paper, film or tape
- Food processing and wrapping operations for candy manufacturing
- Computer and dry clean rooms
- Machine tools and die making
- Meat packaging and cheese producing
- Underground facilities/tunnel
- Storage and warehouse facilities for dry goods, metals, etc.
- Condensation control for water treatment plants and pipe galleries
- Pharmaceutical and research labs

- Museum artifacts
- Electrical components
- Health and fitness areas
- Storage of hygroscopic and non-hygroscopic materials
- Drying of seeds, plastic granules, etc.
- Production of dry nitrogen

14. SOURCES OF MOISTURE (FOR DEHUMIDIFICATION LOAD CALCULATION)

Common sources of moisture in a facility to be dehumidified can be classified into the following types.

a) Infiltration and permeation

b) Ventilation and fresh (make-up) air

c) Door and window opening

d) Product, process and people

14.1 Infiltration and Permeation

14.1.1 Infiltration and permeation are often considered similar where infiltration is the movement of water vapor through cracks, joints and seals and permeation as the migration of water vapor through materials such as brick and wood.

14.1.2 Moisture load in a space due to infiltration and permeation depend on factors such as the actual moisture deviation, materials of construction, vapor barrier and room size all have an effect on the vapor migration.

14.2 Ventilation and Make-Up Air

Where the facility uses fresh outside make-up air for ventilation as required by some building codes, then this air can contribute to the moisture load. This is especially important in months when high humidity is common.

14.3 Door Openings

14.3.1 The opening of doors and windows to the conditioned space or other openings such as conveyer passages are sources of moisture. In these cases, the amount of moisture is directly proportional to the frequency of the opening, the difference in indoor and outdoor moisture content and the wind velocity at the opening.

14.3.2 The wind velocity shall vary depending on the location of the opening with respect to the wind source. Local weather stations can provide details on the normal prevailing wind direction and speed. However, a guideline is 20 m^3/hr. (12 cfm) of outside air per square feet of opening.

14.4 Process and People

Process and people must also be included in the moisture evaluation. For indoor design conditions for processes and places, reference is made to Attachment 6.

Note:

For information on various formulas, reference is made to relevant ASHRAE Guidebook.

15. METHOD OF DEHUMIDIFICATION (DRYING AIR)

There are several methods of drying air, the common types of which are:

a) Refrigerant dehumidification

b) Desiccant dehumidification

c) Make-up air method

d) Heat pump dehumidification

e) Compression method

Note:

All dehumidifiers shall conform to UL 474-1993.

15.1 Refrigerant Dehumidification

15.1.1 General

15.1.1.1 A refrigerant dehumidification system is a combination of sensible/latent cooling and sensible heating. First the system cools the air to reduce the dry bulb temperature to the dew point. Then latent cooling reduces the absolute humidity and finally the air is reheated increasing its dry bulb temperature.

15.1.1.2 Refrigerant dehumidifiers reduce the moisture in air by passing the air over a cold surface, removing the moisture by condensation. This method is effective for desired conditions down to 45% RH, able to achieve dew point as low as 2.8°C. This method requires moderate capital costs and can recover much of the latent energy thus offsetting operating costs.

15.1.2 Modes of operation

15.1.2.1 In the dehumidification process heat is transferred from the room air to the refrigerant as it passes through the evaporator coil. Having been cooled below its dew point, moisture will condense on the coil. The resulting heat (latent) generated by this condensation process is absorbed by the mechanical refrigeration system along with the power consumption of the compressor, and given up as sensible heat to be distributed as required.

15.1.2.2 The closed-loop design mandates that a heat sink be available to convert the refrigerant from gas to liquid in the condensing coil. Three types of potential heat sinks are:

- Air reheat
- Water reheat
- Cooling using a remote condenser

15.2 Desiccant Dehumidification

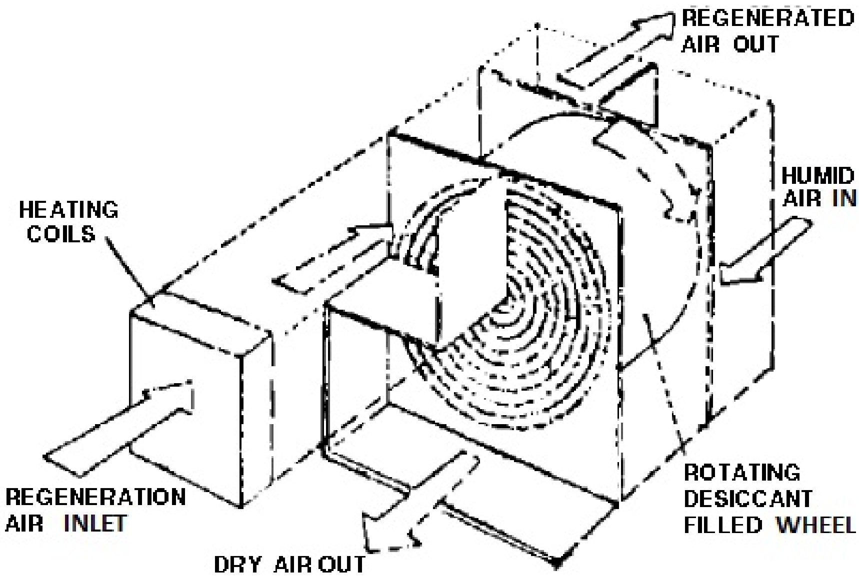
15.2.1 Various type of desiccant (drying agents) which are used in rotary wheel technology are:

- Silica gel
- Lithium chloride

- Activated alumina or charcoal
- Molecular sieve (synthetic zeolite)

15.2.2 Desiccants are drying agents (substance) that have a high affinity for water-so high, that they can draw moisture directly from the surrounding air. Most desiccants are solid in their normal state but some may be liquids. Desiccants shall be non-toxic, non-corrosive, shall be able to remove bacteria and able to be continuously regenerated.

15.2.3 Desiccant dehumidifier use special materials that absorb or hold moisture through a process of continuous physical absorption. The material does not change its size or shape when acquiring the moisture and can be regenerated by applying heat. This technique is used effectively to dry air in the range of 0 to 50% RH.



DESICCANT DEHUMIDIFIER

Fig. 2

15.2.4 Methods of applying desiccant dehumidifier can either be alone or in conjunction with cooling equipment. The selection of equipment for any particular system will depend on the application, the results which are desired, and the sources from which the air to be dehumidified is drawn.

15.2.5 Desiccant dehumidifier units suitable for indoor or outdoor may be divided into four basic types:

a) Liquid absorbent

b) Rotary absorbent wheel

c) Packed tower adsorbent

d) Rotary bed adsorbent

15.2.6 Absorbents undergo chemical and physical changes when picking up moisture. Some like silica gel do not undergo these changes but instead hold large amount of water on their particle surfaces. The illustration of a desiccant dehumidifier using an absorbent to collect moisture in the air is shown in Fig. 2.

15.2.7 The regeneration section uses heat to drive off the moisture, as the wheel turns, thus continuously returning the drying agent to an active status. The heat used for regeneration (recharged) process may be by steam, direct or indirect gas heat, electricity or in some cases by hot refrigerant gas on its way to the condenser.

15.2.8 The desiccant in the liquid absorbent wheel is impregnated into thousands of honeycomb-shaped cells mounted within a cylindrical rotating wheel between dehumidifying and regeneration sectors that are separated by flexible seals.

The two air streams flow in opposite, or counterflow directions to increase efficiency. Water is directly removed from the humid air as it flows through and contacts the desiccant material (see Fig. 2).

15.2.9 Dry food products may be stored at near freezing or below freezing temperatures, and the humidity must be kept low at the same time to avoid the formation of mold, the deterioration of the product, and the deterioration of the packaging that contain the product. Since the energy requirements for low temperature refrigeration are much greater than for comfort air conditioning, desiccant type dehumidification in conjunction with the cooling equipment can be incorporated. (In this manner the air does not have to cool to a low level and reheated again to obtain humidity control).

Notes:

1) The desiccant wheel is a bed with enormous contact surface for continuous regeneration providing dry air at constant dew point down to -40°C without fluctuation or peaks.

2) Method of testing desiccants for refrigerant drying shall conform to relevant sections of ASHRAE Std 35-2010 standards.

15.3 Make-Up Air Method

It uses the principle of dilution, removing a portion of the moisture laden air from a space and replacing it with dryer air; net result being lower average moisture content. The outside make up air method is difficult to apply in summer months and not recommended for cities with high humidity.

15.4 Heat Pump Dehumidification

15.4.1 The heat pump can be used for dehumidification at warmer temperatures upto 26.7°C (80°F) and humid environments most often encountered in product or space drying applications.

15.4.2 It works by cooling the air to condense and drain away its moisture, then reheating it using the latent heat energy recovered from the process of condensation. Under appropriate operating conditions it can provide an extremely energy efficient and effective dry air solution.

15.5 Compression Method

15.5.1 Compression of dry air is effective when small air quantities are needed. When air is compressed, the dew point is raised, that is, the temperature at which vapor will condense is raised.

15.5.2 This method has high installation and operational cost and most common when less than 160 m^3/hr of dry air is required, mainly for industrial, petrochemical, hospital and laboratory application.

PART 4

CONTROL SYSTEM FOR HUMIDIFICATION AND DEHUMIDIFICATION

16. CONTROL SYSTEM

16.1 Instruments and Transmitters

16.1.1 Control of any piece of dehumidification or humidification equipment can be handled by a humidistat. A humidistat can either reduce humidity by bringing in outside or hot air, or add humidity by activating the humidifier. (Measuring humidity with instruments such as hair hygrometer (sensing element) invented 200 years ago shall not be used).

16.1.2 Thin-film humidity sensors (introduced in the early 1970s) are packaged into transmitters that relay humidity data. These transmitters must be able to measure low moisture levels accurately and rapidly.(Application for these transmitters have spread from weather balloon to industrial processes and into hospital operating rooms, where they are used to protect patients and surgical staff from hazardous bacteria and other microorganisms).

16.1.3 Mechanical sensors depend on a change in the length or size of the sensor as a function of relative humidity. The most commonly used sensors are synthetic polymers or human hair. They can be attached to a mechanical linkage to control the mechanical, electrical, or pneumatic switching element of a valve or motor. This design is suitable for most human comfort applications, but it may lack the necessary accuracy for industrial applications.

16.1.4 A humidity controller is normally designed to control at a set point selected by the user. Some controllers have a setback feature that lowers the relative humidity set point as outdoor temperature drops to reduce condensation within the structure.

16.1.5 Measuring humidity with these instruments should be with an accuracy of ±1% and dew point temperatures to ±0.1°C (±0.2°F), capable to detect moisture as low as 10 to 20 ppb (parts per billion).

16.1.6 In traditional HVAC applications, humidity transmitters may not be required to be highly accurate or stable, and the instrument can drift a few percent each year without creating headaches for its caretakers. Hospitals must be provided with stable and accurate transmitter to prevent the growth of bacteria and other contaminants.

16.1.7 Electronic type of humidistat shall be used for close control. These have as a sensing element a wire coated with a salt material, and the amount of moisture absorbed by the salt changes the resistance of the electrical circuit of the wire element, and this in turn operates a relay within the humidistat. The electronic devices shall be capable to control to 1% RH at the point on the scale at which they are selected, as each sensing element may be limited to a narrow range of about 5% RH.

16.1.8 Electronic control is common in laboratory or process applications requiring precise humidity control. It is also used to vary fan speed on portable humidifiers to regulate humidity in the space more closely and to reduce noise and draft to a minimum.

16.1.9 Electronic controls are now widely used for residential applications because of low-cost, accurate, and stable sensors that can be used with inexpensive microprocessors. They may incorporate methods of determining outside temperature so that relative humidity can be automatically reset to some predetermined algorithm intended to maximize human comfort and minimize any condensation problems.

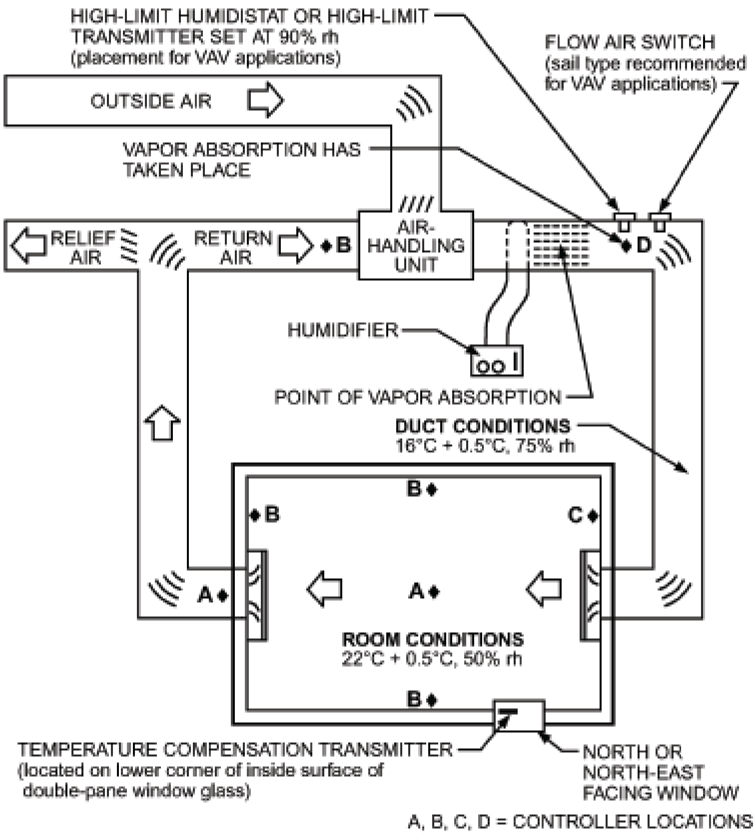
16.1.10 Pneumatic humidity control devices operate where the movement of the element causes a change in control air pressure and this in turn will operate a pneumatic-electric switch to energize the dehumidifier.

16.1.11 In order to measure a true average within the controlled space, the humidistat shall be so located where it will not receive a direct blast from the air outlet of the dehumidifier or humidifier.

16.1.12 In a complete system where air is constantly being removed from and returned to the controlled space, humidistat sensing element can be located on return air ducts, as long as air is always circulating through the duct. If air flows only when the unit is in operation, then the humidistat must be located within the space itself, preferably close to the return air duct.

16.1.13 Figure 3 shows general recommended locations for the humidistat for a centrally air-conditioned room.

The manufacturer's instructions regarding the use of the controller on counterflow furnaces should be followed because reverse airflow when the fan is off can substantially shift the humidity control point in a home. The sensor should be located where it will not be affected by (1) air that exits the bypass duct of a bypass humidifier or (2) drafts or local heat or moisture sources.



RECOMMENDED HUMIDITY CONTROLLER LOCATION

Fig. 3

16.1.14 Along with a main humidity controller, the system may require other sensing devices:

• **High-limit sensors** may be required to ensure that duct humidity levels remain below the saturation or dew-point level. Sometimes cooler air is required to offset sensible heat gains. In these cases, the air temperature may drop below the dew point. Operating the humidifier under these conditions causes condensation in the duct or fogging in the room. High-limit sensors may be combined with a temperature sensor in certain designs.

• **Airflow sensors** should be used in place of a fan interlock. They sense airflow and disable the humidifier when insufficient airflow is present in the duct.

• **Steam sensors** are used to keep the control valve on direct-injection humidifiers closed when steam is not present at the humidifier. A pneumatic or electric temperature-sensing switch is fitted between the separator and the steam trap to sense the temperature of the condensate and steam. When the switch senses steam temperature, it allows the control valve to function normally.

16.1.15 For the steam humidification system, the steam valves shall be pneumatic, electronic or electric. The control systems shall be on/off (2-position, solenoid valves), modulating, proportional and multi-staging type. The steam metering valve shall be modulating normally closed type having linear flow characteristics and shall close against the flow of steam.

16.1.16 Controllers shall preferably feature sturdy construction, stainless steel metal parts, high setting accuracy, large setting ranges together with durable micro switches.

16.1.17 Various types of humidistat, such as, snap action high limit, proportional controlling, on-off high limit etc., as required per job requirements may be used. For typical example of control application and pneumatic piping for airoperated humidifiers reference is made to Attachments 4 and 5.

16.1.18 Control in VAV (Variable air Volume) systems is much more demanding than in constant volume systems. VAV systems, common in large, central station applications, control space temperature by varying the volume rather than the temperature of the supply air. Continual airflow variations to follow load changes within the building can create wide and rapid swings in space humidity. Because of the fast-changing nature and cooler supply air temperatures (13°C or lower) of most VAV systems, special modulating humidity controls should be applied.

16.1.19 In VAV systems, best results are obtained by using both space and duct modulating-type humidity sensors in conjunction with an integrating device, which in turn modulates the output of the humidifier. This allows the duct sensor to respond quickly to a rapid rise in duct humidity caused by reduced airflow to the space as temperature conditions are satisfied. The duct sensor at times overrides the space humidistat by reducing the humidifier output to correspond to decreasing air volumes. This type of system, commonly referred to as anticipating control, allows the humidifier to track the dynamics of the system and provide uniform control. Due to the operating duct static pressures of a VAV system, use of an airflow proving device is recommended to detect air movement.

Notes:

1) Further information on the evaluation of humidity sensors can be found in ASHRAE (1992a).

2) Further Information on Humidity Control system refer to Attachment 7.

16.2 Micro-Processor Controlled

16.2.1 This system shall be capable to display operating status, performance data and defined parameters, through data using text and numbers displayed on Liquid Crystal Display (LCD) screens.

16.2.2 Networking systems shall be available as optional accessory; designating one unit as the director linked to control between five to seven humidifier units. These shall respond to independent humidistat or share an external control signal. The integrated standard shall allow linkage to a personal computer or a Building Management control System (BMS). All operating data of interest shall be transmitted and monitored by the computer.

16.2.3 Some humidifier manufacturers provide the circuitry necessary to accept a modulating signal from most modulating humidity controllers with a set point (furnished by manufacturers of controls) allowing for easy interface with a Building Automation System (BAS). In such cases fully integrated modulation adapter shall be supplied.

PART 5

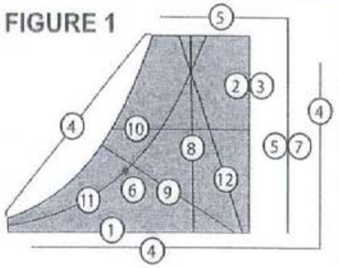
ATTACHMENTS

(The attachments are not part of this Standard but are included for information purpose only)

ATTACHMENT 1

HOW TO USE THE PSYCHROMETRIC CHART

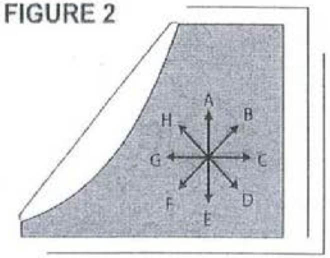
FIGURE 1



LINES AND SCALES

1. Dry Bulb Temperature Scale
2. Humidity Ratio Scale
3. Dew Point Scale
4. Enthalpy Scale
5. Sensible Heat Ratio Index
6. Sensible Heat Ratio Index Origin
7. Vapor Pressure Scale
8. Dry Bulb Temperature Line
9. Wet Bulb Temperature Line
10. Humidity Ratio Line
11. Relative Humidity Line
12. Specific Volume Line

FIGURE 2



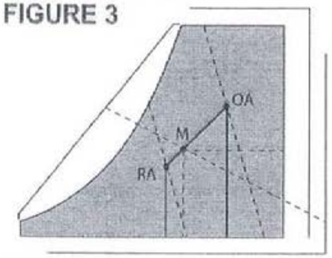
PROCESSES

A - Humidify Only
B - Heat & Humidify
C - Sensible Heat Only
D - Chemical Dehumidify
E - Dehumidify Only
F - Cool & Dehumidify
G - Sensible Cool Only
H - Evaporative Cool

PROBLEM 1

Return Air (RA) of 7500 cfm at 80°F dry bulb and 67°F wet bulb is mixed with Outside Air (OA) of 2500 cfm at 95°F dry bulb and 78°F wet bulb.
Using the psychrometric chart, determine the Mixed Air (M) condition.

FIGURE 3



Solution

Locate the Outside Air and Return Air points on the chart. Connect the points using a straight line. Record the specific volumes for each point.

OA = 14.4 cu.ft./lba
RA = 13.8 cu.ft./lba

Convert the airflow from cfm to lbs/min for each point by dividing the airflow cfm by the specific volume:

OA: 2500 / 14.4 = 173.6 lba/min.
RA: 7500 / 13.8 = 543.5 lba/min.
TOTAL = 717.1 lba/min.

Mixed Air (M) dry bulb temperature =

95 x 173.6 / 717.1 = 23.0
80 x 543.5 / 717.1 = 60.6
Mixed Air (M) dry bulb = 83.6 °F

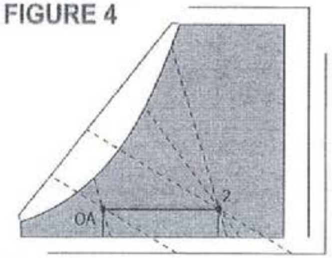
Read other properties at the intersection of this dry bulb line and the line between the RA & OA points:

Wet bulb = 69.9°F, Enthalpy = 33.9 Btu/lba
Humidity Ratio = 88 gr/lba

PROBLEM 2

Outside Air (OA) of 5000 cfm is at 35°F and 60% relative humidity and is to be heated to 95°F (2).
Using the psychrometric chart, determine the final relative humidity, wet bulb and amount of sensible heat energy needed.

FIGURE 4



Solution

Locate the Outside Air point on the chart. Draw a horizontal line to the 95°F dry bulb line. The final point is the intersection of the horizontal line and the 95°F dry bulb line. Record the relative humidity, wet bulb and enthalpy for point 2.

Point 2:
Wet Bulb Temperature = 59.1°F
Relative Humidity = 7.3%
Enthalpy = 25.6 Btu/lba

Record the enthalpy and specific volume for the Outside Air (OA) point.

OA:
Enthalpy = 11.2 Btu/lba
Specific Volume = 12.5 cu.ft./lba

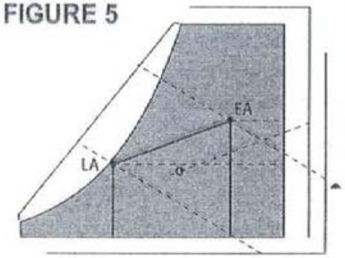
The required sensible heat energy is given by the following equation:
Q = (h2 - h1) x (cfm x 60) / specific vol.

Q = (25.6 - 11.2) x (5000 x 60) / 12.5
Q = 345,600 Btu/hr

PROBLEM 3

Entering Air (EA) of 6000 cfm at 82°F and 50% RH goes through a cooling coil with Leaving Air (LA) at 55°F and 98% RH. Determine the total heat removed, moisture removed (dehumidification) and the sensible heat ratio (SHR).

FIGURE 5



Solution

Locate the Entering Air (EA) and Leaving Air (LA) on the chart. Record the enthalpy and large unit humidity ratio (lb/lb) for both points. Also record the specific volume for the Entering Air (EA).

EA Enthalpy = 32.5 Btu/lba
EA Humidity Ratio = .0117 lbw/lba
EA Specific Volume = 13.9 cu.ft./lba
LA Enthalpy = 23 Btu/lba
LA Humidity Ratio = .009 lbw/lba

The total heat removed is given by:
Q = (h2 - h1) x (cfm x 60) / specific vol.

Q = (23 - 32.5) x (6000 x 60) / 13.9
Q = -246,043 Btu/hr

The moisture removed is given by:
dW = (W2 - W1) x (cfm x 60) / specific vol.

dW = (.009 - .0117) x (6000 x 60) / 13.9
dW = -69.9 lbw/hr

The SHR is determined by drawing a parallel line from the SHR index to the SHR scale and reading the value.

SHR = .691

Commonly Used Sea Level Rules of Thumb:

Qtotal = CFM x (hi-hf) x 4.5 Btuh
Qsensible = CFM x (ti-tf) x 1.085 Btuh
Qlatent = CFM x (Gri - Grf) x .68 Btuh
Humidification = CFM x (Grf - Gri) / 1,555 lbs/hr

ATTACHMENT 2

DESIGN DATA FOR
SPACE AND/OR PROCESS HUMIDIFICATION

PROJECT ....
ADDRESS ....
NAME OF AREA TO HUMIDIFY ....
DESCRIBE PROCESSING TO BE DONE IN THIS AREA ....
CONDITIONS: DESIRED LEVEL OF RH____ % ACCURACY ± ....%
MAXIMUM TEMPERATURE IN AREA: DURING HEATING SEASON ....
DURING COOLING SEASON ....
WHAT IS MINIMUM OUTSIDE DESIGN TEMPERATURE IN YOUR AREA ....
IS EXPLOSION PROOF SYSTEM REQUIRED ....
....
AIR VOLUME: SIZE OF AREA TO BE HUMIDIFIED: L__ W__ H ....
HOW IS AREA ISOLATED FROM NON-HUMIDIFIED AREAS IN THE BUILDING ....
....
TOTAL CFM AIR EXHAUSTED FROM AREA: WINTER ___ SUMMER..
IS EXHAUST CONTINUOUS OR INTERMITTENT __________IF INTERMITTENT,
LONGEST PERIOD OF OPERATION IN ANY ONE HOUR OF TIME …..
TOTAL CFM OF MAKE-UP AIR UNITS SUPPLYING THE AREA: WINTER ....
SUMMER..................................
IS MAKE-UP CONTINUOUS OR INTERMITTENT____________IF INTERMITTENT,
LONGEST PERIOD OF OPERATION IN ANY ONE HOUR OF TIME ....
ARE THESE SYSTEMS SHUT DOWN WHEN THE PLANT IS NOT IN OPERATION ?
EXHAUST:________________________ MAKE-UP AIR..
ANY OPEN DOORWAYS?_____ STAIRWAYS? .____ ELEVATOR SHAFTS? ……...................
TOTAL AREAS OF EACH:________________ ______________..
....
CONSTRUCTION DETAILS: LOOSE OR TIGHT? ____ INSULATION? WALLS ....
ROOF ____ MATERIALS?____-BRICK ____ BLOCK ____ FRAME ____ STEEL ....
VAPOR BARRIERS?: ROOF____ WALLS ______ FLOOR …...
TOTAL WINDOW AREA____ Sq. Ft. SINGLE OR DBL. GLAZED?
……………………………………………………………………………..............…………...............
HEATING SYSTEM: TYPE: WARM AIR ___ HYDRONIC___ STEAM ___ ELEC ....
FUEL: OIL___ GAS ___ COAL____ ELEC. ______
UNIT HEATERS ?.______ DUCTED DISTRIBUTION ?__________
IF DUCTED: TOTAL FAN CAPACITY ________________________CFM
OUTSIDE AIR ADDED __________________________ CFM
WARM AIR SUPPLY TEMPERATURE______________
DOES AIR MIX WITH AIR FROM OTHER NON-HUMIDIFIED AREAS ? ….......................
IF SO, TOTAL CFM AIR DELIVERED TO AREA TO BE HUMIDIFIED ....

(to be continued)

ATTACHMENT 2 (continued)

COOLING SYSTEM: (ANSWER ONLY IF LEVEL OF R.H. DESIRED EXCEEDS 50%)

TOTAL CAPACITY: ______(TONS) TOTAL CFM AIR OVER COILS ....

AIR TEMPERATURE DROP ACROSS COILS ____IS SYSTEM DUCTED?.......................................…

OUTSIDE AIR ADDED_____CFM. DOES AIR MIX WITH AIR FROM OTHER NON-

HUMIDIFIED AREAS? ________ IF SO, TOTAL CFM AIR DELIVERED TO AREA TO

BE HUMIDIFIED ………………………………………………………………………………...................

(FOR REFRIGERATION ONLY, WHAT IS DEFROST CYCLE)? ....

ECONOMIZER CYCLE: IS THE AIR HANDING SYSTEM EQUIPPED WITH MODULATING OUTSIDE AIR SUPPLY?______ IF SO, WHAT IS MIXED AIR TEMPERATURE MAINTAINED? ____________F.

....

PROCESS REDUCTION: IS ANY WATER VAPOR BEING DISCHARGED DIRECTLY INTO THE AIR IN THE AREA TO BE HUMIDIFIED? .... IF SO, HOW MANY POUNDS OF WATER VAPEOR PER HOUR? ....

IS THE DISCHARGE CONSTANT OR INTERMITTENT? ______ IF INTERMITTENT, WHAT IS THE SHORTEST TIME PER HOUR IT OPERATES? ....

IF APPLICABLE, DOES THE EXHAUST AND MAKE-UP AIR SYSTEM OPERATE ONLY WHEN THIS WATER VAPOR IS BEING DISCHARGED?..

PRODUCT LOAD: DO YOU RECEIVE A HYGROSCOPIC MATERIAL AT ONE MOISTURE CONTENT AND SHIP AT ANOTHER? _______ . IF SO, WHAT IS THE MOISTURE CONTENT UPON

RECEIPT?_________ %, AT SHIPMENT? __________ %.

WHAT IS THE MAXIMUM NUMBER OF POUNDS (DRY WEIGHT) OF PRODUCT PASSING THROUGH THE AREA PER HOUR? ....

………

PEOPLE REDUCTION: HOW MANY PEOPLE WORK IN THE AREA? …...

DO YOU CONSIDER THEM PHYSICALLY ACTIVE?...

HOW MANY HOURS DO THEY OCCUPY THE AREA PER DAY?...

....

SERVICES AVAILABLE: ELECTRICAL: VOLTS/PHASES/CYCLES ....

MAXIMUM AMPERAGE OF PLANT SERVICE ....

MAXIMUM AMPERAGE IN USE ....

WATER SUPPLY: MUNICIPAL OR WELL ....

PRESSURE AT FLOOR LEVEL ____ HARDNESS IN GRAINS/GAL. ....

OR PPM ____ IS IT RAW____ SOFTENED _____ DEMINERALIZED ....

COMPRESSED AIR: IS COMPRESSED AIR AVAILABLE?.____ kPa(Psi) ....

TOTAL HP_____ CAPACITY IN CFM FREE AIR DELIVERY ....

HOW MUCH OF RATED CAPACITY IS NOW IN USE ....

STEAM SUPPLY: BOILER HP _____ HP IN USE..

AVAILABLE SUPPLY PRESSURE _____ FUEL USED ....

Note:

A suitable sketch shall be provided to show details of the area to be humidified.

ATTACHMENT 3

DESIGN DATA FOR

SPACE AND / OR PROCESS DEHUMIDIFICATION

PROJECT: ……………………………………………..

ADDRESS:..

CITY: ....

REQUIRED CONDITIONS:	TEMPERA TURE: ....
	RELATIVE HUMIDITY: ....
DESIGN CONDITIONS:	
INSIDE THE SPACE:	TEMPERATURE:..................(SUMMER).........(WINTER)
	RELATIVE HUMIDITY:...........(SUMMER).........(WINTER)
OUTSIDE SPACE:	SUMMER-TEMPERATURE: ....
	RELATIVE HUMIDITY: ....
	WINTER-TEMPERATURE: ....
	RELATIVE HUMIDITY: ....

1) SIZE OF ROOM: (USE SEPARATE SHEET FOR SKETCH IF NECESSARY)

LENGTH........................WIDTH…………..........HEIGHT ....

2) DESCRIBE DOORS:

NUMBER..SIZE ....

TYPE..SEALING..

3) NUMBER OF DOOR OPENINGS PER HOUR:

TOTAL FOR ALL DOORS ....

4) CONSTRUCTION OF ROOM AND HOW IT IS SEALED (WATER BASE, OIL BASE, ALUMINUM PAINT, PLASTIC, STEEL, ETC.)

A. WALLS (PLASTER, ETC.) …..................………………………………………………..

PAINT..THICKNESS ....

B. Ceiling (plaster, etc.) ....

PAINT..THICKNESS...

C. FLOOR (WOOD, CONCRETE, ETC.)………………………………. ....

PAINT..THICKNESS ....

D. THE SPACE TIGHT AGAINST INFILTRATION OF AIR?

....

(to be continued)

ATTACHMENT 3 (continued)

5. DESCRIBE WINDOWS:

NUMBER ....SIZE ....

TYPE ....SEALING ....

6. MATERIAL TO BE STORED IN ROOM..

…………………………………………………………………………...

7. IS ANY MOISTURE GIVEN OFF OR TAKEN UP BY THE PROCESS OF MATERIALS IN THE ROOM? ....

A. IF SO, MATERIALS MOVED IN AND OUT OF THE ROOM ARE:

1. ....lbs. IN AND OUT IN .... HOURS / DAY (WEEK) OR SCRIBE:……

…...

2. MOISTURE CONTENT OF MATERIALS ENTERING ....

3. MOISTURE CONTENT OF MATERIALS LEAVING ....

4. IF MOISTURE IS TO BE REMOVED, WHAT LENGTH OF TIME DOES IT HAVE TO BE REMOVED IN? …………...

B. DESCRIBE PRODUCT MOVEMENT:...

TUNNELS IN WALLS: NUMBER..

LENGTH .... WIDTH .... HEIGHT ....

C. ANY OTHER MOISTURE LOADS? ....

8. NUMBER OF PEOPLE IN ROOM CONTINUOUSLY ....

HOURS PER DAY ....

HOW MANY PEOPLE ENTER THE ROOM OCCASIONALLY..

9. IS ANY OUTSIDE AIR BEING BROUGHT IN? ....

BY WHAT MEANS .... HOW MUCH ....

WHAT TEMPERATURE .... RELATIVE HUMIDITY ....

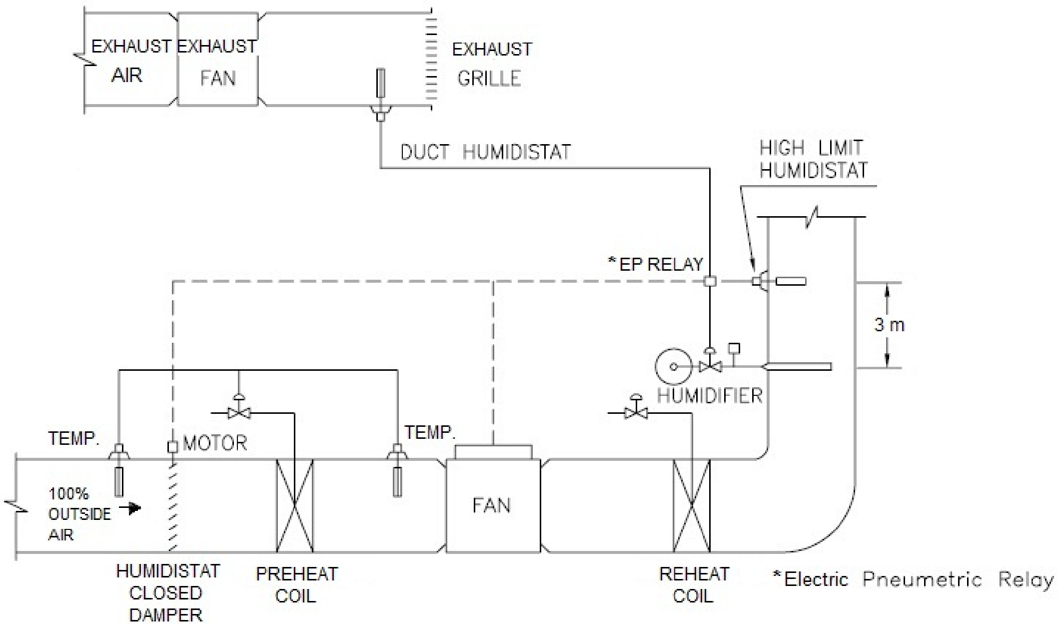
10. STATE AVAILABLE STEAM .... GAS..

11. ELECTRICAL SUPPLY VOLES / PHASES / CYCLIE: ....

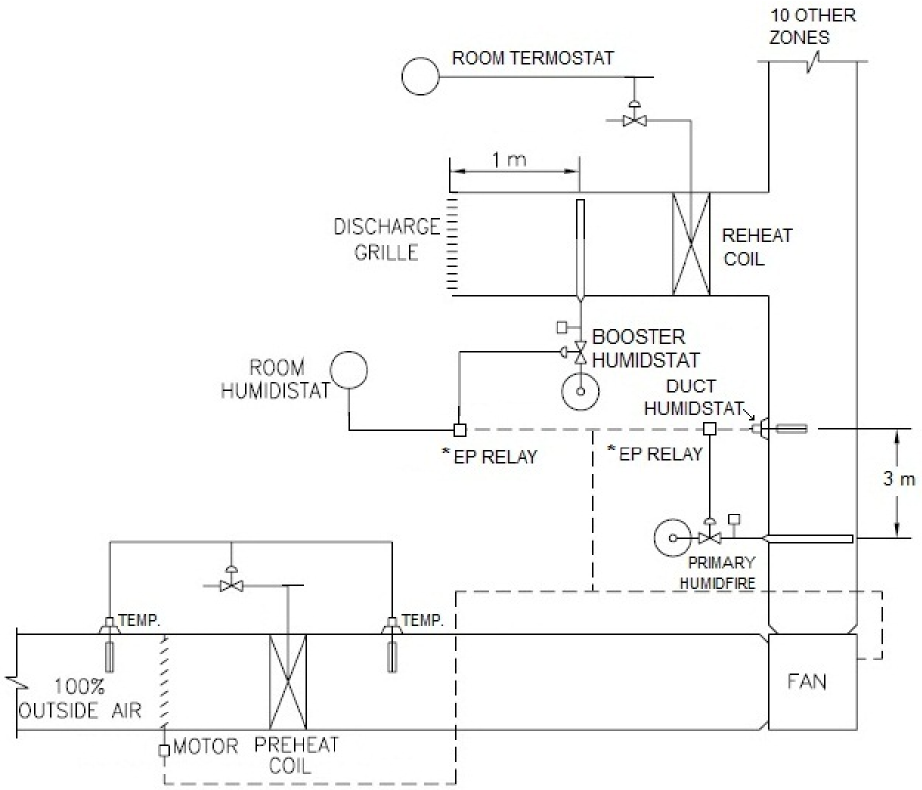
Note:

A suitable sketch shall be provided to show details of the area to be dehumidified.

ATTACHMENT 4
CONTROL APPLICATIONS



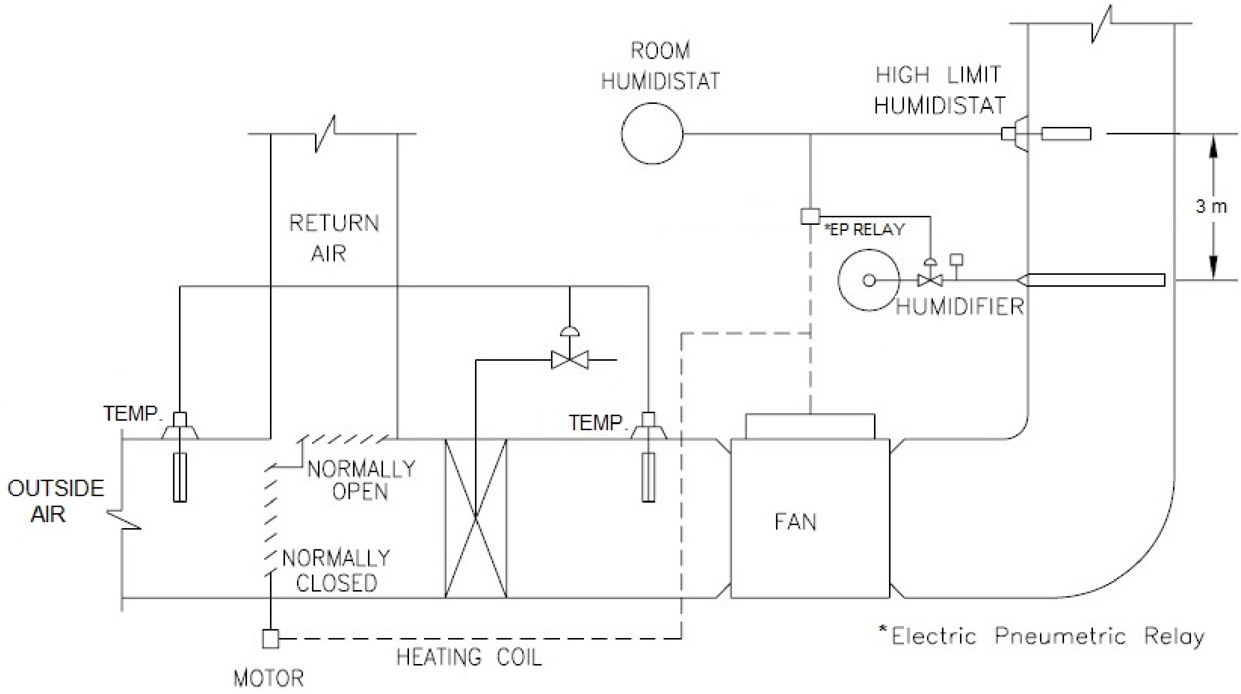
TYPICAL PRIMARY SYSTEM WITH 100% OUTSIDE AIR
Fig. 1



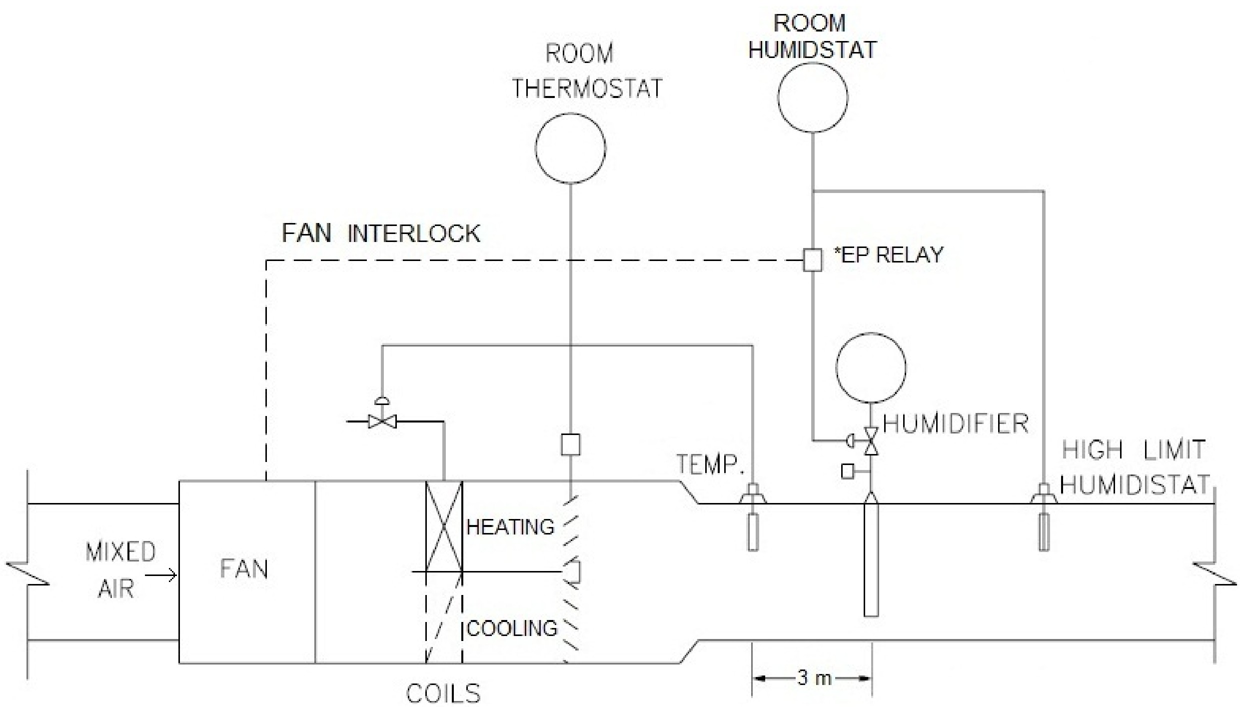
TYPICAL PRIMARY AND BOOSTER HUMIDIFICATION WITH 100% OSA
Fig. 2

*** Electric Pneumatic Relay.**

(Continued to Fig. 3 & 4)



TYPICAL PRIMARY SYSTEM HUMIDIFICATION WITH RETURN AIR
Fig. 3



TYPICAL SINGLE ZONE HEATING VENTILATING
Fig. 4

*** Electric Pneumatic Relay**

ATTACHMENT 5

TYPICAL PNEUMATIC PIPING FOR AIR-OPERATED HUMIDIFIERS

a) Connect 103.41 kPa (15 psig) air supply to the control valve. This air should be clean and free of any moisture. A ¼" copper tubing or equivalent is recommended for all air connections.

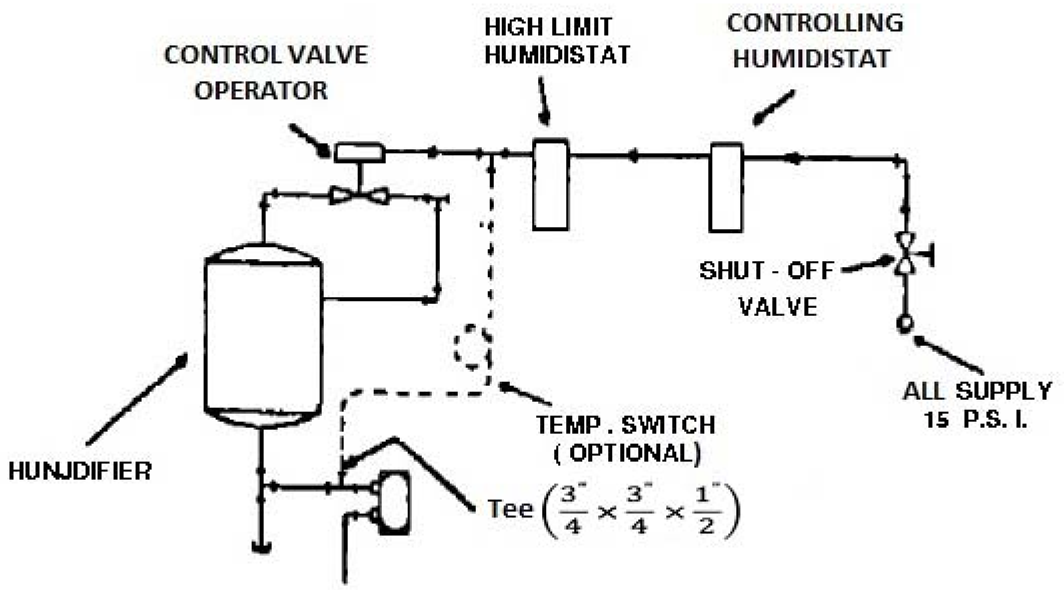
b) Install a humidistat as per manufacturer's instructions. The common practice is to install in the area controlled or in the return air or exhaust air duct.

c) Interlocks for shutdown should be provided between humidi-fier and fans in case of a power failure or some other trouble in the system (Fig. B).

d) A high limit duct humidistat, generally set at 90% relative humidity is recommended about 2 meter downstream of the humidifier. This is to prevent any over saturation of the duct due to a failure in air conditioning system or malfunctioning of controlling humidistat (Fig. A).

e) On humidifier systems that are shut down frequently a temperature switch as shown in Fig. B is available.

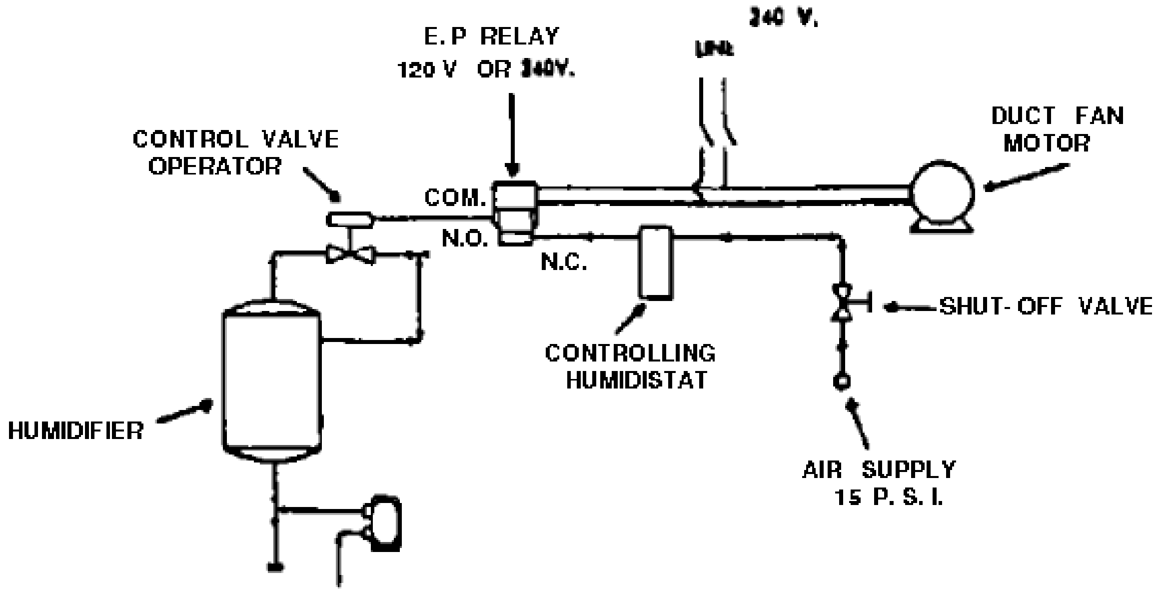
This keeps the control valve closed until the humidifier reaches the steam temperature, thereby eliminating any condensation which could occur when steam is admitted into cold humidifiers.



TYPICAL STANDARD PNEUMATIC CONTROL HOOK-UP

Fig. A

(Continued to Fig. B)



PNEUMATIC CONTROL HOOK-UP WITH SAFETY INTERLOCKS

Fig. B

ATTACHMENT 6

DESIGN CRITERIA

Building/Area	Design Outdoor Cooling/ Heating Dry-Bulb[a]	Indoor Temperature, °C Maximum	Indoor Temperature, °C Minimum	Relative Humidity, %	Room Ventilation Rate, ach*	Filtration Efficiency, %	Pressurization	Redundancy[b]
Steam Turbine Area								
Suboperating level	0.4%/99.6%	Design outdoor + 6	7	None	30	None	None	Multiplicity
Above operating floor	0.4%/99.6%	Design outdoor + 6	7	None	10	None	None	Multiplicity
Combustion Turbine Area	0.4%/99.6%	Design outdoor + 5	7	None	20	None	None	Multiplicity
Steam Generator Area								
Below burner elevation	0.4%/99.6%	Design outdoor + 6	7	None	30	None	None	Multiplicity
Above operating floor	0.4%/99.6%	Design outdoor + 6	7	None	15	None	None	Multiplicity
Other Non-Air-Conditioned Areas								
Shops	1%/99%	Design outdoor + 6	18	None	15	None	None	None
Air-Conditioned Areas[c]								
Control rooms and control equipment rooms containing instruments and electronics	Extreme	24 ± 1	22 ± 1	30 to 65	ASHRAE *Std.* 62.1	85 to 90	Positive	100%
Offices	1%/99%	26	21	30 to 65	ASHRAE *Std.* 62.1	ASHRAE *Std.* 62.1	Positive	None
Laboratories	1%/99%	26	21	30 to 65	ASHRAE *Std.* 62.1	High	Positive	None
Locker rooms and toilets	1%/99%	26	21	None	ASHRAE *Std.* 62.1	ASHRAE *Std.* 62.1	Negative	None
Shops (air-conditioned)	1%/99%	26	18	None	ASHRAE *Std.* 62.1	None	None	None
Mechanical Equipment								
Pumps, large power	0.4%/99.6%	Design outdoor + 6	7	None	30	None	None	Multiplicity
Valve stations, miscellaneous	0.4%/99.6%	Design outdoor + 6	7	None	15	None	None	None
Elevator machine rooms	0.4%/99.6%	32	7	None	None	Low	Positive	None
Fire pump area	0.4%/99.6%	NFPA *Std.* 20	NFPA *Std.* 20	None	NFPA *Std.* 20	None	None	None
Diesel generator area	0.4%/99.6%	Design outdoor + 6	7	None	30	None	None	None
Electrical Equipment[c]			7					
Enclosed transformer equipment areas	0.4%/99.6%	Design outdoor + 6	7	None	60	Low	Positive	100%
Critical equipment	Extreme	Design outdoor + 6	7	None	30	None	Positive	100%
Miscellaneous electrical equipment	0.4%/99.6%	Design outdoor + 6	7	None	20	None	None	Multiplicity
Water Treatment								
Chlorine equipment rooms								
When temporarily occupied	0.4%/99.6%	Design outdoor + 6	None	None	60	None	Negative	None
When unoccupied	0.4%/99.6%	Design outdoor + 6	16	None	15	None	Negative	None
Chemical treatment	0.4%/99.6%	Design outdoor + 6	16	None	10	None	None	None
Battery Rooms	0.4%/99.6%	—	—	None	As required for hydrogen dilution	None	Negative or neutral	50%

*Listed numbers are for estimating purposes only. When heat gain data are available, use Equation (1) [Chapter 21 of ASHREA Handbook(SI) -Application (2011)] to calculate required ventilation rate.

[a]See Chapter 14 of the 2009 *ASHRAE Handbook—Fundamentals* for design dry-bulb temperature data corresponding to given annual cumulative frequency of occurrence and specific geographic location of plant.

[b]Multiplicity indicates that the HVAC system should have multiple units.

[c]See ASHRAE research project RP-1104 (White 2003) for heat release values

Note: Further information on Hospital design criteria Refer to chapter 8 of ASHREA Handbook (SI) -Application (2011).

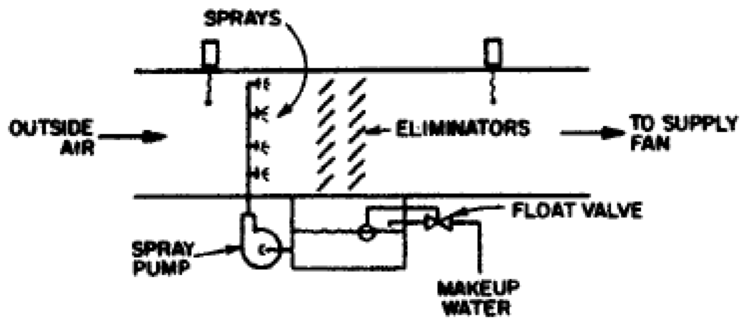
ATTACHMENT 7

HUMIDITY CONTROL SYSTEMS

1. HUMIDIFICATION

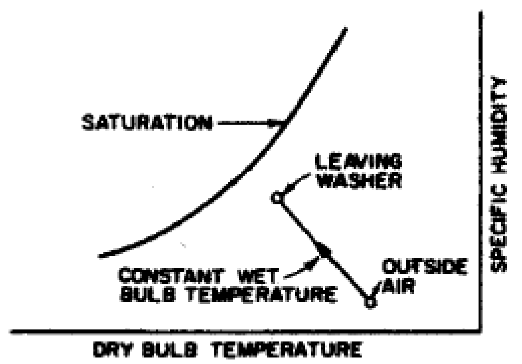
1.1 Air Washer

Air washer often used for its sensible cooling capability, it is also known as a direct evaporative cooler (Figure1.). Whether an inexpensive wetted-pad residential-type unit or a large industrial unit with an elaborate system of sprays and eliminators, any air washer operates on the adiabatic cooling principle. That is, the cooling is done by using the sensible heat of the air to evaporate water. Thus, the air passing through the washer changes conditions along a constant web bulb line, with the final state being dependent on the initial state and the saturation efficiency of the washer (generally 70% to 90%). There is no control of humidity but with turn off the water jet pumps and use a humidity controller, the amount of humidity can be controlled.



EVAPORATIVE COOLING (AIR WASHER)

Fig. 1

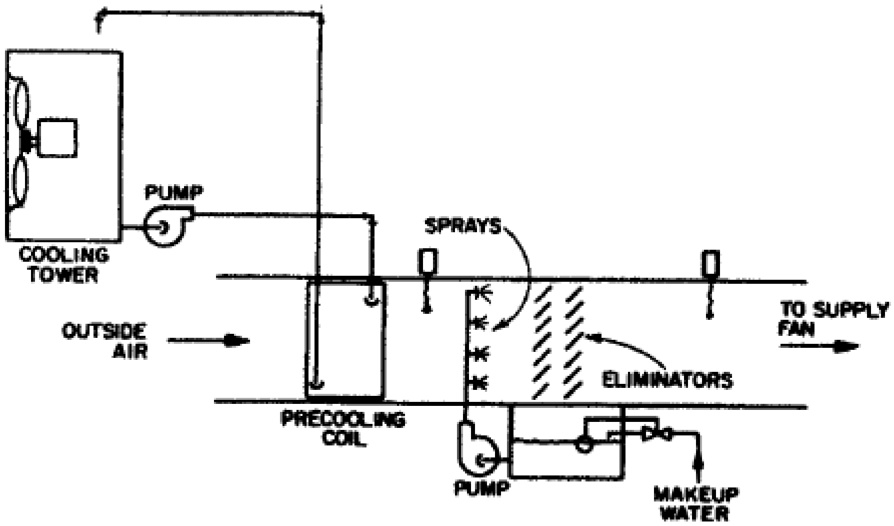


PSYCHROMETRIC CHART FOR EVAPORATIVE COOLING

Fig. 2

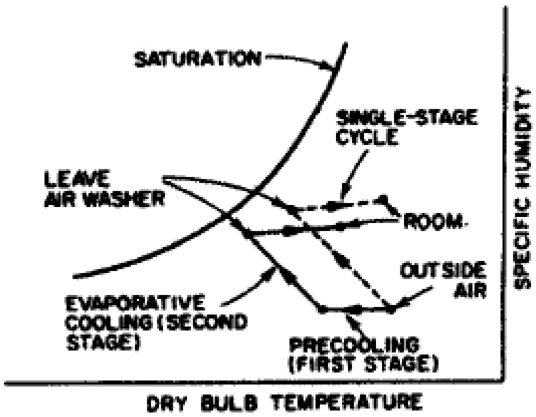
1.2 Two-Stage Evaporative Cooling

Two-stage evaporative cooling may be used as an alternative to mechanical refrigeration, when outdoor conditions allow it. This system provides lower dry bulb temperatures and relative humidities than can be obtained with ordinary evaporative cooling. Figure 3 shows the arrangement and control of a two-stage evaporative cooling system. Figure 4 is the psychrometric chart of the cycle. The dashed lines on the chart show a single-stage cycle as in Figure 2.



TWO – STAGE EVAPORATIVE COOLING

Fig.3



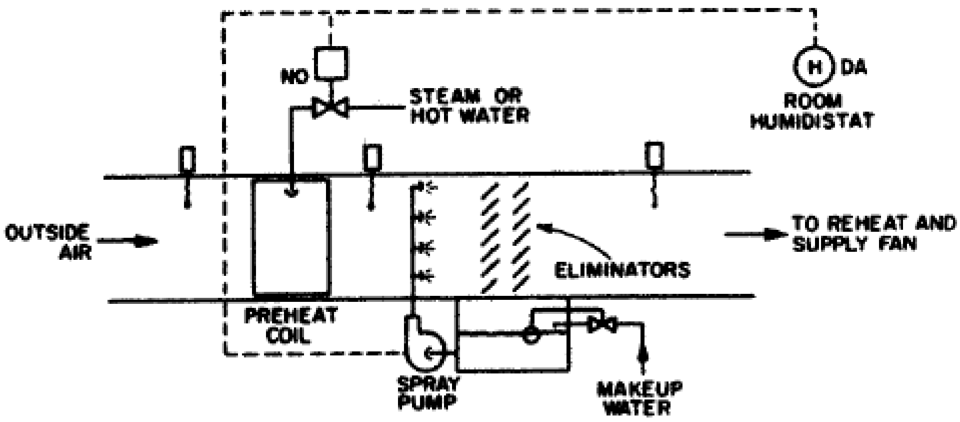
PSYCHROMETRIC CHART FOR FIGURE 3

Fig. 4

The cooling tower and the precooling coil are the first stage. This sensible cooling reduces both the wet and the dry bulb temperatures of the air, so that in the second stage a lower dry bulb temperature may be obtained. The room thermostat will be a two-position type, with two-stage control optional. The controllability of the system depends on the condition of the outside air.

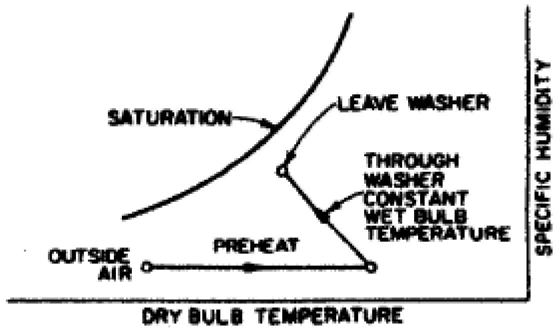
1.3 Air Washer with Preheat

About the only control that can be applied to the ordinary air washer is to turn the spray water (or pump) on or off. If a minimum humidity is required, it is sometimes necessary to preheat the air to the desired wet bulb temperature. Such a control system is shown in Figure 5. The room humidistat senses low humidity and turns on the spray pump and then opens the preheat coil supply valve. As room humidity increases, the preheat valve is closed first, then if the increase continues, the sprays are shut down. Under high outdoor humidity conditions the cooling capacity is limited. Final room temperature control is provided by reheat coils. The psychrometric chart in Figure 6 shows this cycle.



MINIMUM HUMIDITY; AIR WASHER WITH PREHEAT

Fig. 5



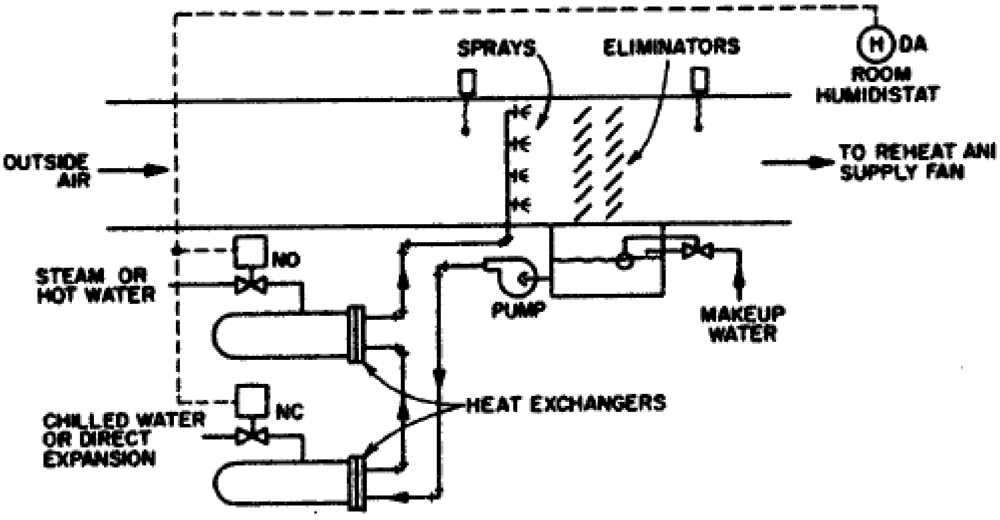
PSYCHROMETRIC CHART FOR FIGURE 5

Fig. 6

1.4 Air Washer with Preheat and Refrigeration

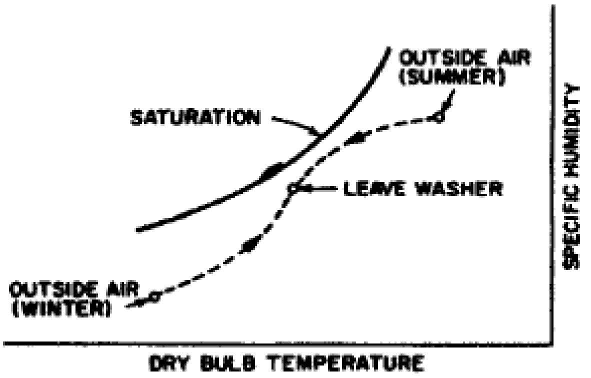
An air washer with preheat will not control the upper limits of humidity. To accomplish this two choices are available, both requiring refrigeration:

1. Heat and/or cool the spray water with a shell and tube heat exchangers (Figure 7). By allowing the humidistat to control the heat exchanger supply valves it is possible to obtain very accurate control of the humidity as well as the air temperature leaving the washer. Figure 8 is the psychrometric chart diagram of this process. Reheat is required because the temperature leaving the washer is constant and is not a function of the building load.



HUMIDITY CONTROL BY HEATING OR COOLING SPRAY WATER

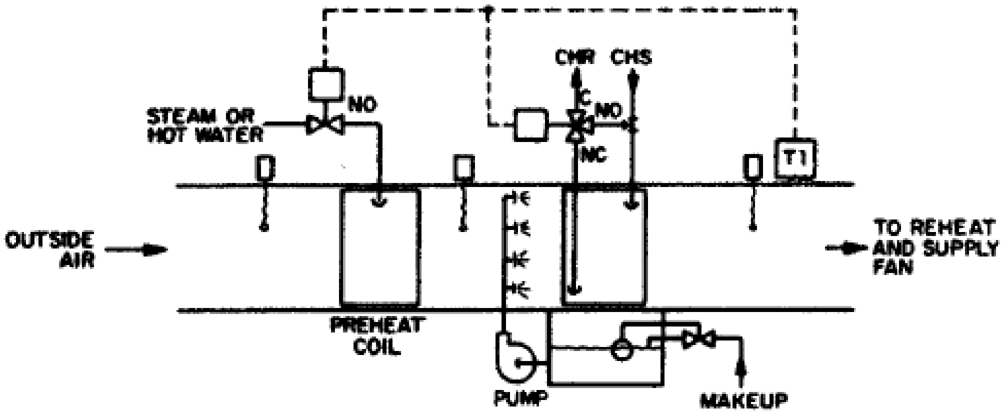
Fig. 7



PSYCHROMETRIC CHART FOR FIGURE 7

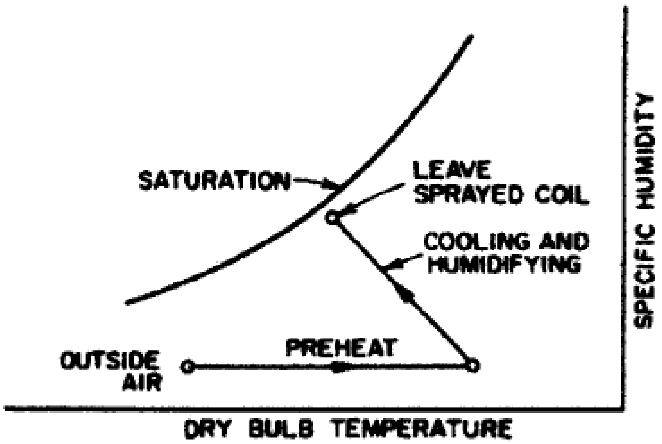
Fig. 8

2. Add a cooling coil in the air washer, creating a sprayed-coil dehumidifier (Figure 9). This designation is not incorrect, because at high humidity conditions dehumidification does take place, but the device also acts as a humidifier if necessary. Because the addition of the coil increases the saturation efficiency to between 95% and 98%, it is possible to do away with the humidistat and use a simpler, less expensive dry bulb thermostat (T1) in the air leaving the coil (the so-called dew point thermostat). This is set to maintain a fixed condition of dry bulb and relative humidity. When the mixed-air wet bulb temperature is above the required wet bulb temperature of the air leaving the coil, then refrigeration must be used. Reheat is necessary for final space temperature control. If all control settings are properly selected, it is possible to maintain very accurate control of the space temperature and humidity. Figure 10 shows the cycle on a psychrometric chart, assuming cool, low-humidity outside air. The dew point thermostat senses a decrease in the coil leaving-air temperature and shuts down the chilled water flow to the coil and then opens the preheat coil valve. Evaporative cooling is used. As the coil leaving-air temperature increases, the preheat coil valve is gradually closed. A further increase in the controlled temperature above the thermostat setting will cause the chilled water valve to open, using refrigeration for cooling. Figure 11 is a psychrometric chart showing what happens with high temperature outside air. As long as the entering-air wet bulb is above the dew point thermostat setting, chilled water will be required, and the coil leaving-air temperature will be maintained by varying the flow of chilled water through the coil. Direct expansion may be used instead of chilled water.



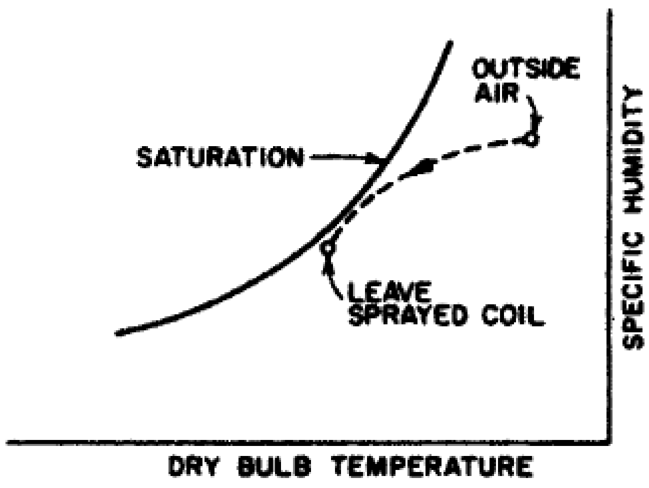
HUMIDITY CONTROL, SPRAYED COIL AND PREHEAT

Fig. 9



PSYCHROMETRIC CHART FOR FIGURE 9 (WINTER)

Fig. 10



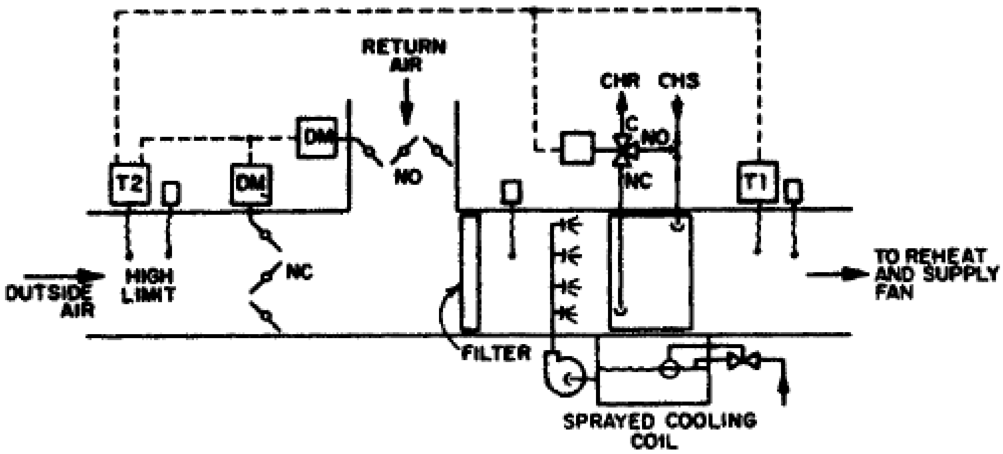
PSYCHROMETRIC CHART FOR FIGURE 9 (SUMMER)

Fig. 11

1.5 Air Washer with Mixed Air and Refrigeration

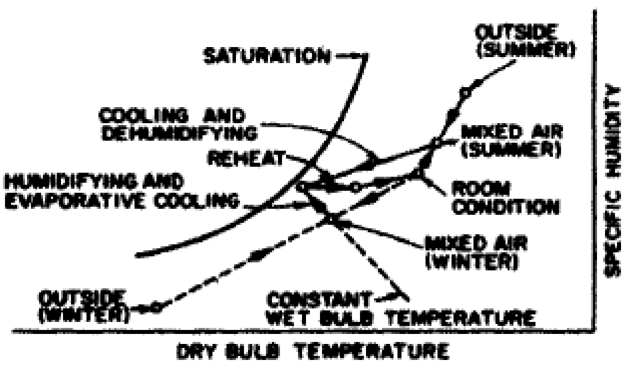
Mixed air can be used rather than 100% outside air if the control system is altered as shown in Figures 12 and 13. As long as the outside air wet bulb temperature is below the coil leaving-air set point of T1, the desired condition can be maintained by adjusting the mixing dampers to obtain a mixture that falls on the coil leaving-air wet bulb line, and using the evaporative cooling effect of the sprayed coil. When the outside air damper is fully open and the coil leaving-air temperature increases above the set point of T1, then refrigeration must be used, either chilled water as shown or direct expansion. Again, reheat is required for space temperature control.

All of these systems using open sprays require chemical treatment of the spray water to minimize solids deposition. The systems with finned coils pose a severe maintenance problem due to deposition. The only satisfactory solution is to use demineralized water in the spray system. Sprayed coils may not be allowed under some codes because of the potential for bacterial contamination.



HUMIDITY CONTROL; SPRAYED COOLING COIL WITH MIXED AIR

Fig. 12

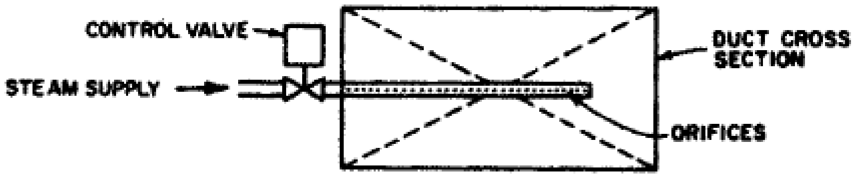


PSYCHROMETRIC CHART FOR FIGURE 12

Fig. 13

1.6 Steam Humidifiers

Steam humidifiers are often used because of their simplicity. A piping manifold with small orifices is provided in the air duct or plenum (Figure 14). The steam supply valve is controlled by a space or duct humidistat. Avoid the use of steam that has been treated with toxic chemicals. Almost any humidity ratio, up to saturation, can be obtained in the supply air stream. If a space humidistat is used a duct high-limit humidistat should be provided to avoid condensation in the duct.



STEAM GRID HUMIDIFIER

Fig. 14

1.7 Pan Humidifiers

Evaporative pan humidifiers vary in capability and controllability. The old-fashioned evaporator pan found in many residential warm-air heating systems is not very efficient, and lacks any kind of control. The addition of a heater, of immersion or radiant type, improves efficiency and allows a limited amount of control. Even with heaters, however, this type of humidifier will not usually provide space relative humidity of over 40%.

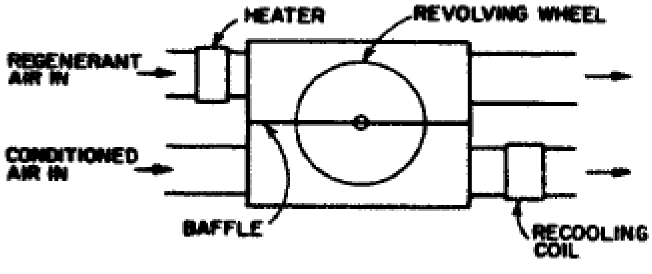
1.8 Atomizer Humidifiers

Slinger or atomizer humidifiers may be controlled on-off by a humidistat or manually. Again, space relative humidity will seldom exceed 40%. During "off' periods the lime deposits left from the water evaporation may be entrained in the air stream as dust. When evaporative or atomizer humidifiers are used, the water supply should be distilled or deionized. Mineral deposits from evaporation are a serious maintenance problem. "Rental" deionizers are very satisfactory for small installations.

2. DEHUMIDIFICATION

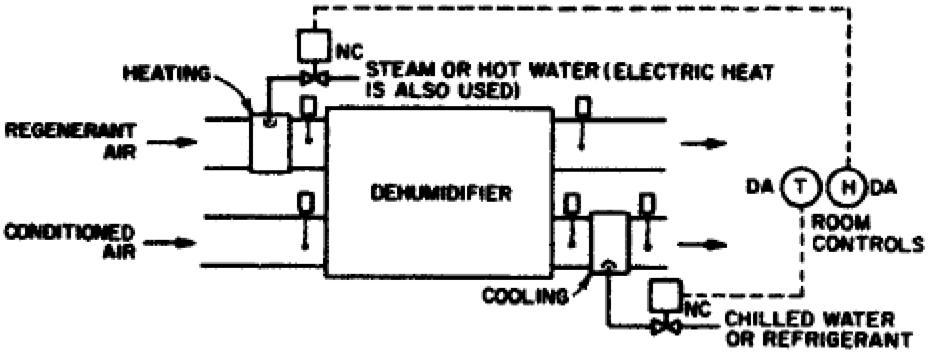
2.1 Chemical Dehumidifiers

Chemical dehumidifiers use a chemical adsorbent, usually with provision for continuous regeneration (drying) to avoid system shutdown. One form of dehumidifier (Figure 15) uses a wheel containing silica gel that revolves first through the conditioned air stream, absorbing moisture, and then through a regenerative air stream of heated outside air that dries the gel. In the process, heat is transferred to the conditioned air and recooling is necessary. The dehumidification efficiency is largely a function of the regenerative air stream temperature. Figure 16 shows the control system. The space humidistat controls the heating coil in the regenerative air stream. Final control of space temperature is accomplished by the room thermostat and the recooling coil. Very low humidities may be obtained in this way.



CHEMICAL DEHUMIDIFIER

Fig. 15



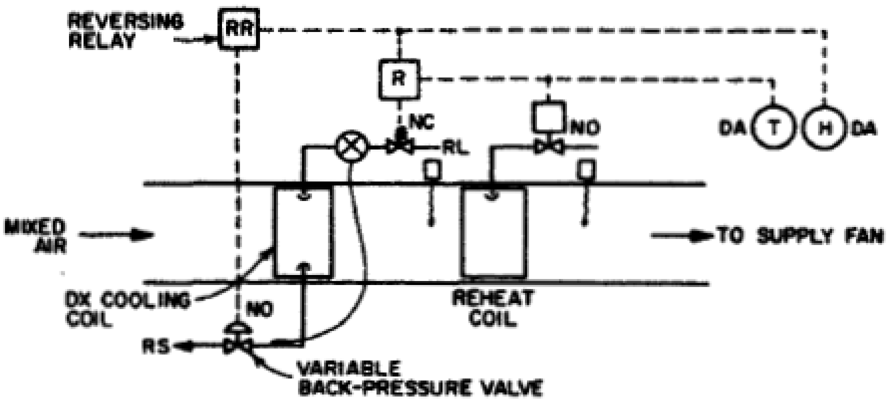
CONTROL OF CHEMICAL DEHUMIDIFIER

Fig. 16

Another type of system uses a water-absorbing liquid chemical solution that is sprayed over a cooling coil in the conditioned air stream, thus absorbing moisture from the air. A portion of the solution is continuously pumped to a regenerator where it is sprayed over heating coils and gives up moisture to a scavenger air stream that carries the moisture outside. Control of the specific humidity of the leaving conditioned air is accomplished by controlling the temperature of the solution. Because this is a patented, proprietary system, the control system recommended by the manufacturer should be used.

2.2 Dehumidifying by Refrigeration

Low temperature cooling coils may also be used to reduce humidity to low values. Because coil surface temperatures may be below freezing, with ice formation resulting, special DX coils with wide fin spacing must be used, and provision must be made for defrosting by hot gas, electric heat or warm air. This approach tends to be inefficient at very low humidities and requires intermittent shutdown for defrosting, or parallel coils so that one may operate while the other is being defrosted. Reheat is necessary for control of space temperature. Because space humidity is largely a function of the coil temperature, fairly good control may be achieved through humidistat control of a variable back-pressure valve (Figure 17). The selective relay (R) allows the room thermostat to operate the cooling coil at minimum capacity when the humidistat is satisfied.



DEHUMIDIFYING WITH LOW TEMPERATURE COOLING UNIT

Fig. 17

Reference:

Control Systems For Heating, Ventilating, And Air Conditioning, Sixth Edition, By Roger W. Haines & Douglas C. Hittle, Solar Energy Applications Laboratory Colorado State University.