ENGINEERING STANDARD

FOR

HUMIDIFICATION AND DEHUMIDIFICATION SYSTEM

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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.

2. REFERENCES

Throughout this Standard the following standards and codes are referred to. The editions of these standards and codes that are in effect at the time of publication of this Standard shall, to the extent specified herein, form a part of this Standard. The applicability of changes in Standards and Codes that occur after the date of this Standard shall be mutually agreed upon by the Company and the Consultant.

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

ASHRAE 35-1983	"Method of Testing Desiccants for Refrigerant Drying"
ANSI/ASHRAE 15-1989	"Ventilation for Acceptable Indoor Air Quality"
ASHRAE 55-1981	"Dew Point Limits of 1.7°C and 17.2°C (35°F and 62°F)"

UL (UNDERWRITER'S LABORATORIES)

ANSI/UL-474-1987	"Dehumidifiers"

ARI (AIR CONDITIONING AND REFRIGERATING INSTITUTE)

ARI-630-82	"Selection, Installation and Servicing of Humidifiers"

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) 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).

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

j) 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.

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

l) 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.

m) 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.

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

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

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

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

r) 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.

s) 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.

t) 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.

4. UNITS

International System of Units (SI) shall be used, unless otherwise mentioned.

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 (Exhibits A and B).

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.

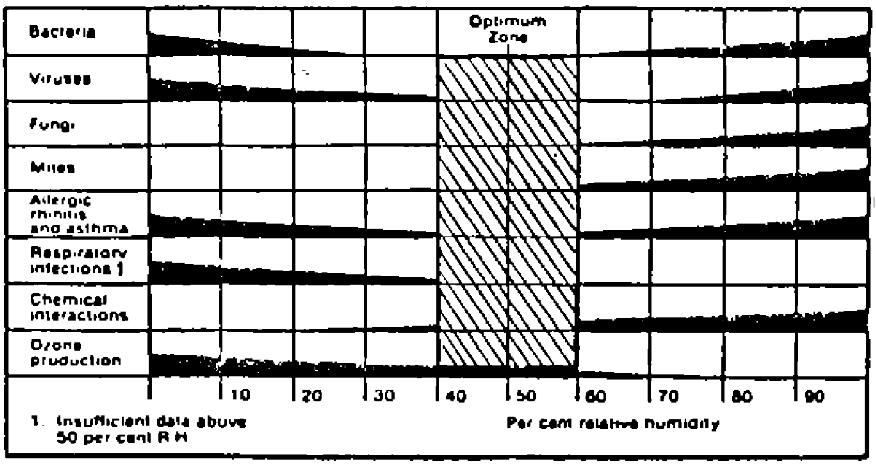
Of the three, the most ignored is the level of relative humidity (RH) probably because the effects of temperature and air quality are more easily seen and felt than the effects of relative humidity. The relative humidity (RH) can affect human health and comfort, operation of production materials, quality 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 ANSI/ASHRAE Standard 15-1989 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 40% 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 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 g/kg (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 takes place when heat of 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 mould 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 furnace) ducted or non-ducted systems suitable for residential, commercial and industrial application.

9.1 Single plenum humidifier with water distribution trough 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 air flow 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 introduced directly into airstream by:

i) A spinning disc or cone which breaks the water into a fine mist
ii) Sprays which rely on water pressure to create fine droplets
iii) A rotating disc which slings water droplets into the airstream from a water reservoir

9.4 Electrode Steam Humidifiers

These unit 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.

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 air flow rate can usually be determined from the system blower capacity, or if no blower exists, from calculation of air filtration 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) Natural infiltration

$$F = V \times (M_2 - M_1) \times P$$

Where:

F = pounds of moisture per hour required to maintain design conditions
V = volume to be humidified in 1000 cu.ft.
M_1 = moisture content (lb.) of 1000 cu.ft. of standard air to be humidified
M_2 = moisture content (lb.) of 1000 cu.ft. of standard air at design conditions
P = number of air changes per hour

b) Forced air circulation

$$F = \frac{cfm \times (M_2 - M_1) \times R}{1.67}$$

Where:

cfm = volume rate of air to be humidified
R = maximum percentage of outdoor air to be handled

Note:

The Psychrometric 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.

11.2.2 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.

11.2.3 Temperature and humidity available

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

11.2.4 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 work place 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
- Musuem 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 Product, Process and People

The three "P's", product, process and people must also be included in the moisture evaluation. If the product has an affinity for water, then it may also release the water in the conditioned room. (For example, wet wood brought into a conditioned warehouse will release the water at a specific rate). For indoor design conditions for product, 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 ANSI/UL 474-1982.

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

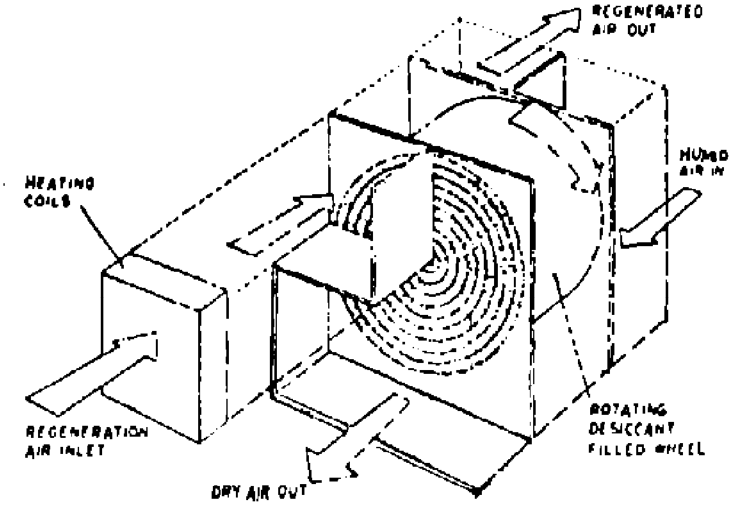
15.2 Desiccant Dehumidification

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 35-1983 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 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).

16.1.4 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.

16.1.5 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.

16.1.6 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.

16.1.7 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.

16.1.8 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.

16.1.9 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.

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

16.1.11 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 air-operated humidifiers reference is made to Attachments 4 and 5.

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.

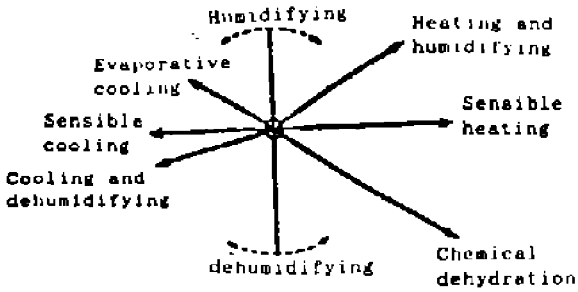
16.2.3 Some humidifier manufacturers provide the circuitry necessary to accept a modulating signal from most modulating humidity controllers with a set point (furnished by manufacturers of controls) allowing for easy interface with a Building Automation System (BAS). In such cases fully integrated modulation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

PART 5
ATTACHMENTS

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

ATTACHMENTS 1

EXHIBIT 1

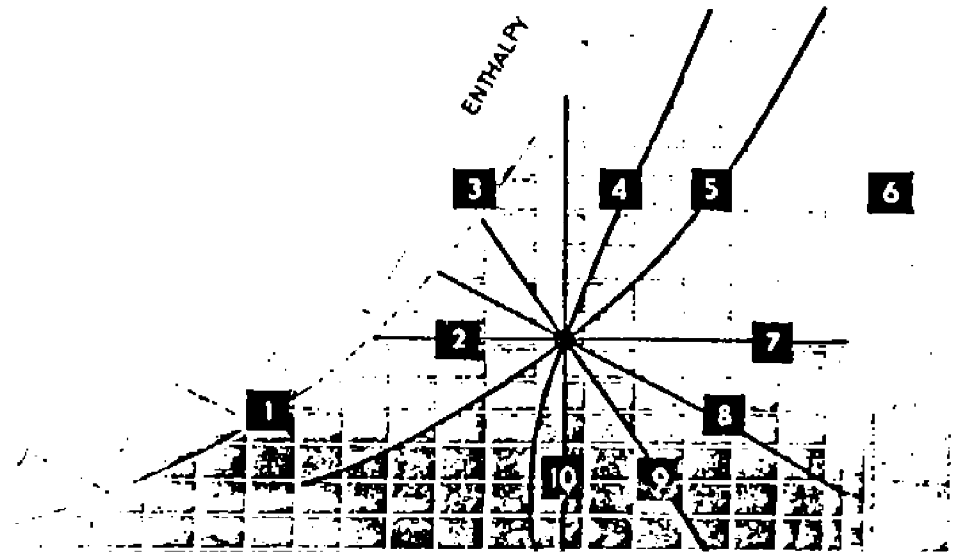


AIR CONDITIONING PROCESSES

EXHIBIT 2

LEGEND

1 SATURATION TEMPERATURE
2 DEWPOINT TEMPERATURE
3 ENTHALPY AT SATURATION
4 ENTHALPY DEVIATION
5 RELATIVE HUMIDITY (%)
6 SENSIBLE HEAT FACTOR
7 GRAINS OF MOISTURE
8 WET-BULB TEMPERATURE
9 VOLUME OF MIXTURE
10 DRY-BULB TEMPERATURE



PROPERTIES OF MOIST AIR

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 VAPER 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)
RELATIVEHUMIDITY:........................(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 DESCRIBE:
....

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 ....

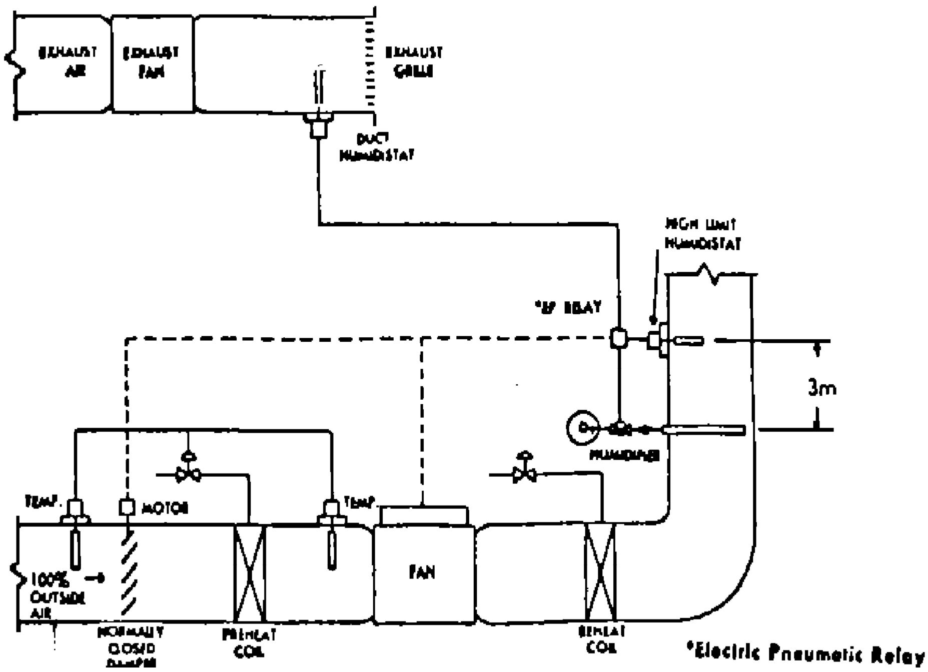
10. STATE AVAILABLE STEAM .... GAS...

11. ELECTRICAL SUPPLY: ....

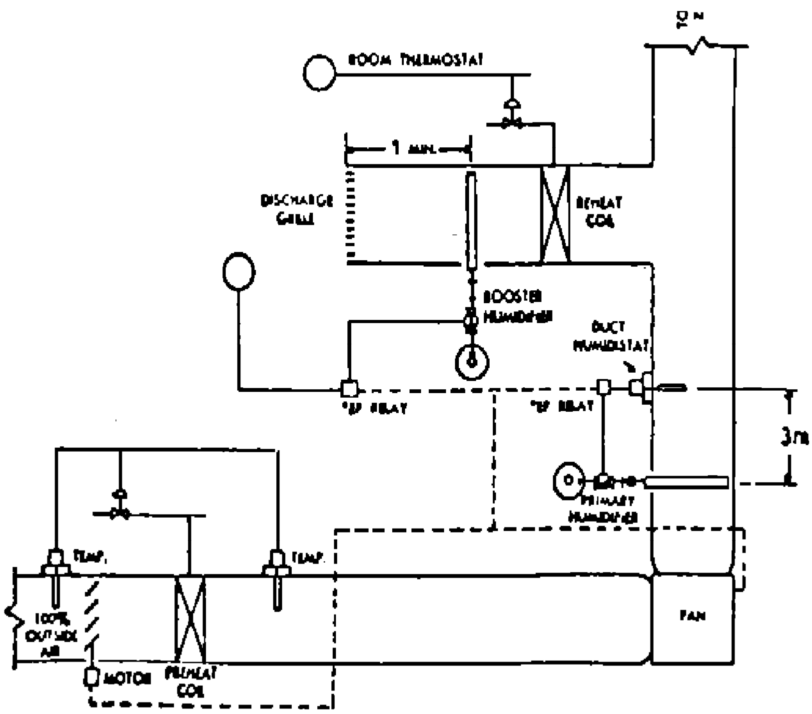
Note:

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

ATTACHMENT 4
CONTROL APPLICATIONS



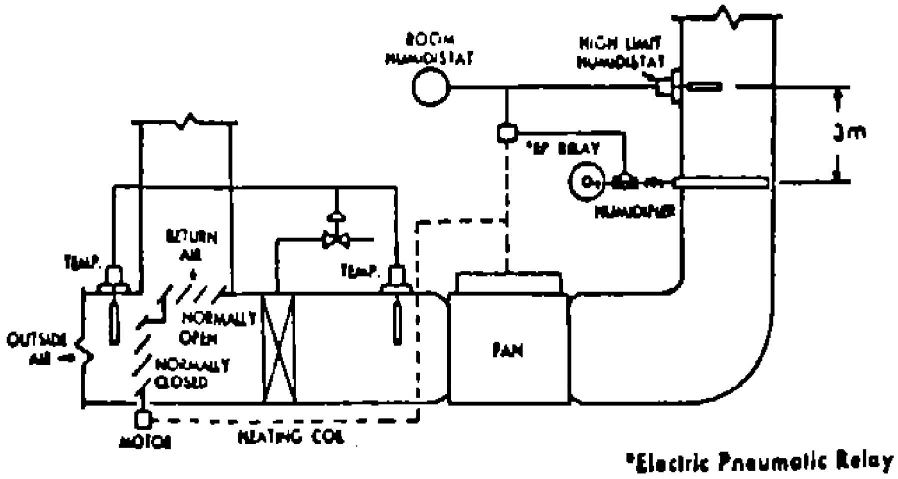
TYPICAL PRIMARY SYSTEM WITH 100% OUTSIDE AIR
Fig. 1



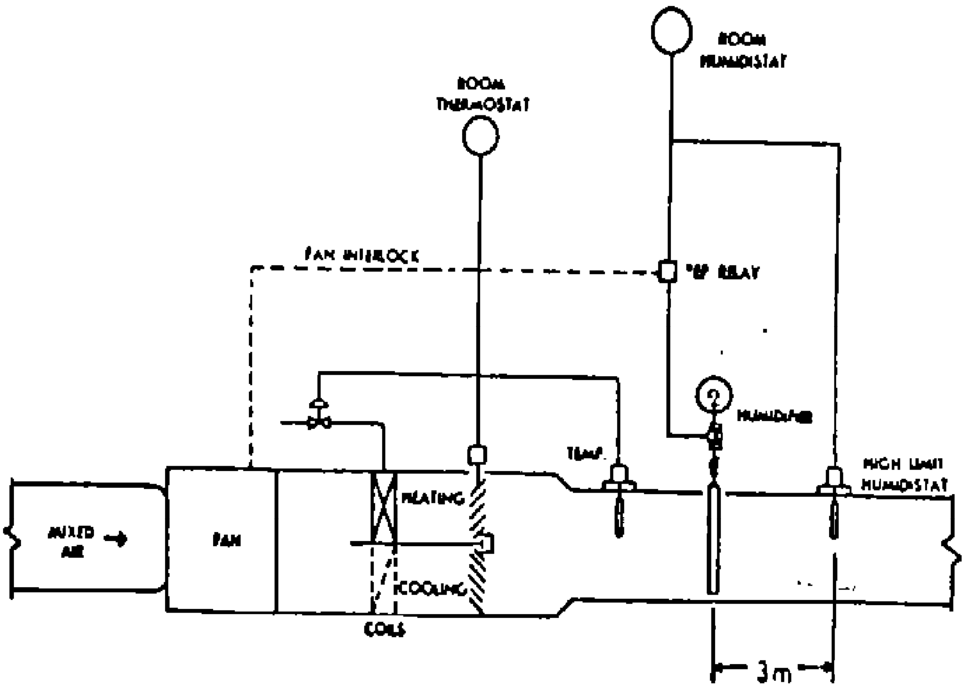
TYPICAL PRIMARY AND BOOSTER HUMIDIFICATION WITH 100% OSA
Fig. 2

* 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

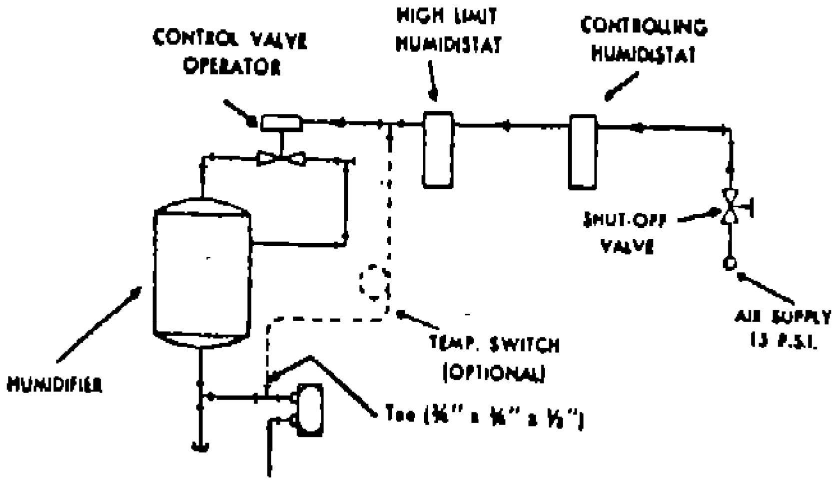
a) Connect 103.41 kPa (15 psig) air supply to the control valve. This air should be clean and free of any moisture. A ¼" copper tubing or equivalent is recommended for all air connections.

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).

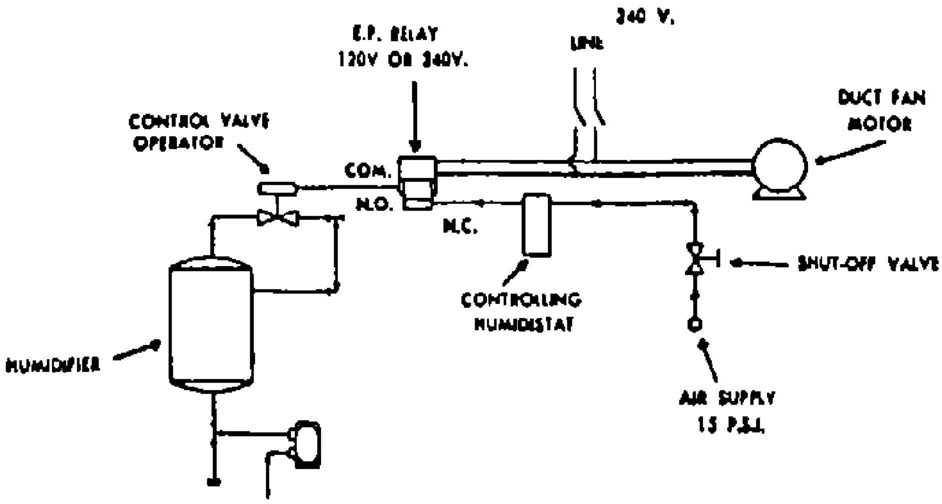
d) A high limit duct humidistat, generally set at 90% relative humidity is recommended about 2 meter downstream of the humidifier. This is to prevent any over saturation of the duct due to a failure in air conditioning system or malfunctioning of controlling humidistat (Fig. A).

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 INDOOR CONDITIONS FOR VARIOUS PRODUCTS PROCESSES AND PLACES

Product and/or Process	Temperature °F	Temperature °C	Relative Humidity % R/H
Abrasives Manufacturing	78	25	50
Bowling Alleys	73 - 75	23 - 24	50 - 55
Billiard Rooms	73 - 75	23 - 24	40 - 50
Bread			
Flour and Powdered Product Storage	70 - 80	21 - 27	60
Fermentation (Bread Dough)	80	27	75
Retarding of Doughs	32 - 40	0 - 4	85
Final Proof	95 - 120	35 - 49	85 - 90
Counterflow Cooling	75	24	80 - 85
Brewing			
Hop Storage	29 - 32	-2 - 0	50 - 60
Yeast Culture Room	-	-	80
Candy			
Chocolate Pan Supply Air	55 - 62	13 - 17	55 - 45
Enrober Room	80 - 85	27 - 29	30 - 25
Chocolate Cooling Tunnel Supply Air	40 - 45	4 - 7	85 - 70
Hand Dippers	62	17	45
Moulded Goods Cooling	40 - 45	4 - 7	85 - 70
Chocolate Packing Room and Finished Stock Storage	65	18	50
Centers Tempering Room	75 - 80	24 - 27	35 - 30
Marshmallow Setting Room	75 - 78	24 - 26	45 - 40
Grained Marshmallow (deposited in starch) Drying	110	43	40
Gum (deposited in starch) Drying	125 - 150	52 - 66	25 - 15
Sanded Gum Drying	100	38	25 - 40
Gum Finished Stock Storage	50 - 65	10 - 18	65
Sugar Pan Supply Air (engrossing)	85 - 105	29 - 41	30 - 20
Polishing Pan Supply Air	70 - 80	21 - 27	50 - 40
Pan Rooms	75 - 80	24 - 27	35 - 30
Nonpareil Pan Supply Air	100 - 120	38 - 49	20
Hard Candy Cooling Tunnel Supply Air	60 - 70	16 - 21	55 - 40
Hard Candy Packing	70 - 75	21 - 24	40 - 35
Hard Candy Storage	50 - 70	10 - 21	40
Caramel Rooms	70 - 80	21 - 27	40
Raw Material Storage			
Nuts (insect)	45	7	65 - 75
Nuts (rancidity)	34 - 38	1 - 3	65 - 75
Eggs	30	-1	85 - 90
Chocolate (flats)	65	18	50
Butter	20	-7	-
Dates, Figs, etc.	40 - 45	4 - 7	75 - 85
Corn Syrup	90 - 100	32 - 38	-
Liquid Sugar	75 - 80	24 - 27	40 - 30
Comfort Air Conditions	75 - 80	24 - 27	60 - 50
Ceramics			
Refactory	110 - 150	43 - 66	50 - 90
Molding Room	80	27	60 - 70
Clay Storage	60 - 80	16 - 27	35 - 65
Decalcomania Production and Decorating Room	75 - 80	24 - 27	48
Cereal Packaging	75 - 80	24 - 27	45 - 50
Cheese Curing			
Cheddar	45 - 56	7 - 13	85 - 90
Swiss	60	16	80 - 85
Blue	48 - 50	9 - 10	95
Brick	60 - 65	16 - 18	90
Limburger	60 - 65	16 - 18	95
Camembert	53 - 58	12 - 14	90
Clean Rooms - Computer Rooms			
Computer Room	70 - 80	21 - 27	40 - 60
Clean Room - General	70 - 74	21 - 23	40 - 50
Clean Room - Critical	71.5 - 72.5	22 - 22.5	43 - 47
Distilling			
Grain Storage	60	16	35 - 40
General Manufacturing	60 - 75	16 - 24	45 - 60
Aging	65 - 72	18 - 22	50 - 60
Electrical Products			
Coil and Transformer Winding	72	22	15
X-ray Tube Assembly	68	20	40
Instruments Manufacture and Laboratory	70	21	50 - 55
Thermostat and Humidistat Assembly and Calibration	76	24	50 - 55
Close Tolerance Assembly	72	22	40 - 45
Meter Assembly and Test	76	24	60 - 63
Fuse and Cutout Assembly, Capacitor Winding and Paper Storage	73	23	50
Conductor Wrapping with Yarn	75	24	65 - 70
Lightning Arrestor Assembly	68	20	20 - 40
Thermal Circuit Breaker Assembly and Test	76	24	30 - 60
Water Wheel Generators Thrust Runner Housing	70	21	30 - 50
Processing Selenium and Copper Oxide Plates	74	23	30 - 40
Fruit Storage			
Apples	30 - 40	-1 - 4	90
Apricots	31 - 32	-1 - 0	90 - 95
Grapefruits (California)	58 - 60	14 - 16	85 - 90
Grapefruits (Florida)	50	10	85 - 90
Grapes (Eastern)	31 - 32	-1 - 0	85
Grapes (Western)	30 - 31	-1	90 - 95
Lemons	58 - 60	14 - 16	85 - 88
Oranges (California)	40 - 44	4 - 7	85 - 90
Oranges (Florida)	32 - 34	0 - 1	85 - 90
Peaches and Nectarines	31	-1	90
Plums	30 - 32	-1 - 0	90 - 95
Specialty Citrus Fruit	38 - 40	3 - 4	90 - 95
Fur Storage	40 - 50	4 - 10	55 - 65
Gum			
Manufacture	77	25	33
Rolling	68	20	63
Stripping	72	22	53
Breaking	74	23	47
Wrapping	74	23	58

Source: ASHRAE

(to be continued)

ATTACHMENT 6 (continued)

Product and/or Process	Temperature (°F)	°C	Relative Humidity % R/H
Hospitals			
Operating, Cystoscopic and Fracture Rooms	(68 - 76)	20 - 24	50
Patient Rooms	75	24	40 - 50
Intensive Care Unit	75	24	40
Administrative and Service Areas	70 - 80	21 - 27	30 - 50
Leather			
Drying	70 - 120	21 - 49	75
Storage, Winter Room Temperature	50 - 60	10 - 16	40 - 60
Lenses (Optical)			
Fusing	75	27	45
Grinding	80	27	80
Libraries and Museums			
Normal Reading and Viewing Rooms	70 - 74	21 - 23	40 - 50
Rare Manuscript Storage Vaults	70 - 72	21 - 22	45
Art Storage Areas	60 - 72	17 - 22	50
Matches			
Manufacture	72 - 74	22 - 23	50
Drying	70 - 75	21 - 24	60
Storage	60 - 62	16 - 17	50
Meat and Fish			
Beef (Fresh)	32 - 34	0 - 1	88 - 92
Beef, Fish, Lamb and Pork (Frozen)	0 - -10	-23 - -18	80 - 95
Fish (Fresh)	33 - 35	1 - 2	90 - 95
Lamb and Pork (Fresh)	32 - 34	0 - 1	85 - 90
Mushrooms			
Sweating-out Period	120 - 140	49 - 60	-
Spawn Added	60 - 75	16 - 24	Nearly Sat
Growing Period	48 - 60	9 - 16	80
Storage	32 - 35	0 - 2	80 - 85
Oil Paints: Paint Spraying	60 - 90	16 - 32	80
Pharmaceuticals			
Manufactured Powder Storage and Packaging Area	75	24	35
Milling Room, Table Compressing and Coating	75	24	35
Tablets and Powders	75	24	20
Hypodermic Tablets	75	24	30
Colloids	70	21	30 - 50
Cough Drops	80	27	40
Glandular Products	76	24	5 - 10
Ampoule Manufacturing	75	24	35 - 50
Gelatin Capsules and Storage	78	24	35
Microanalysis	78	24	50
Biological Manufacturing and Liver Extracts	76	24	35
Serums	76	24	50
Animals Rooms	75 - 80	24 - 27	50
Plastics			
Manufacturing Areas Thermosetting			
Molding Compounds	80	27	25 - 30
Cellophane Wrapping	75 - 80	24 - 27	45 - 65
Plywood			
Hot Pressing (Resin)	90	32	60
Cold Pressing	90	32	15 - 25

Product and/or Process	Temperature °F	°C	Relative Humidity % R/H
Printing			
Platemaking	75 - 80	24 - 27	45 Max
Lithographic Press Room	76 - 80	24 - 27	43 - 47
Letterpress and Web Offset Press Rooms and Paper Storage	76 - 80	24 - 27	50
Paper Storage (Multicolor Sheet Feed Lithography)	76 - 80	24 - 27	5 - 8 Higher than Press Room
Rubber Dipped Goods			
Cementing	80	27	25 - 30
Dipping Surgical Articles	75 - 90	24 - 32	25 - 30
Storage Prior to Manufacture	60 - 75	16 - 24	40 - 50
Laboratory (ASTM Standard)	73.4	23	50
Tea Packaging	65	18	65
Textiles			
Opening and Picking			
Cotton	75 - 80	24 - 27	55 - 70
Man-Made	70 - 75	21 - 24	50 - 55
Carding			
Cotton	75 - 80	24 - 27	50 - 55
Wool	75 - 80	24 - 27	60 - 70
Man Made	70 - 75	21 - 24	50 - 60
Silver and Ribbon Lapping			
Cotton	75 - 80	24 - 27	55 - 50
Man Made	70 - 75	21 - 24	55 - 65
Combing			
Cotton	75 - 80	24 - 27	55 - 65
Wool	75 - 80	24 - 27	60 - 70
Man-Made	70 - 75	21 - 24	55 - 65
Drawing			
Cotton and Wool	75 - 80	24 - 27	50 - 60
Man-Made	70 - 75	21 - 24	50 - 60
Roving			
Cotton	75 - 80	24 - 27	50 - 60
Man-Made	70 - 75	21 - 24	50 - 60
Spinning			
Cotton	75 - 80	24 - 27	35 - 60
Wool	75 - 80	24 - 27	50 - 55
Man-Made	70 - 75	21 - 24	50 - 65
Winding and Spooling			
Cotton	75 - 80	24 - 27	55 - 65
Wool	75 - 80	24 - 27	55 - 60
Man-Made	70 - 75	21 - 24	60 - 65
Twisting			
Cotton	75 - 80	24 - 27	50 - 65
Man-Made	70 - 75	21 - 24	50 - 65
Warping			
Cotton	75 - 80	24 - 27	55 - 70
Wool	75 - 80	24 - 27	50 - 55
Man-Made	70 - 75	21 - 24	50 - 65
Knitting			
Cotton	76	24	60 - 65
Man Made	76	24	50 - 60
Weaving			
Cotton	75 - 80	24 - 27	70 - 85
Wool	75 - 80	24 - 27	50 - 60
Man-Made	70 - 75	21 - 24	60 - 70
Tobacco			
Cigar and Cigarette Making	70 - 75	21 - 24	55 - 65
Softening	90	32	85 - 88
Stemming and Stripping	75 - 85	24 - 29	70 - 75
Filler Tobacco Casing Conditioning	75	24	75
Filler Tobacco Storage and Preparation	78	26	70
Wrapper Tobacco Storage and Conditioning	75	24	75