Compressed Air and Gas Drying

CONTENTS

I Why Do Compressed Air And Gas Need Drying?

Moisture Is Always Present.

All atmospheric air contains some water vapor which will begin to condense into liquid water in the compressed air or gas system when the air or gas cools past the saturation point, i.e., the point where it can hold no more water vapor.*

The temperature at which this happens is known as the **dew point**.** This dew point becomes all-important in determining how much drying is needed.

Condensation in the compressed air system would occur at the inlet air saturation temperature if temperature remained constant as air was compressed. However, since there is a rise in temperature during actual compression, condensation generally is avoided **within** the compressor. Later, as compressed air is discharged and cooled in an aftercooler, condensation begins to occur. The condensed moisture must be removed by a separator and trap. The air leaving the aftercooler normally is saturated at the aftercooler discharge temperature.

For many years, problems from moisture in air lines were tolerated. To prevent freezing, alcohols were injected into the lines and electric heaters were used during cold periods. Filters were used to separate moisture and other contaminants but did not completely solve the problem.

The increased use of compressed air and the development of many new and more sophisticated devices and controls have accelerated the need for clean dry air. Hence, drying technology advanced, and dryers came into general use.

Moisture Is Damaging.

Moisture in compressed air used in a manufacturing plant causes problems in the operation of pneumatic air systems, solenoid valves and air motors. This moisture causes rust and increased wear of moving parts as it washes away lubrication.

Moisture adversely affects the color, adherence, and finish of paint applied by compressed air.

Moisture jeopardizes process industries where many operations are dependent upon the proper functioning of pneumatic controls. The malfunctioning of these controls due to rust, scale, and clogged orifices can result in damage to product or in costly shutdowns. Additionally, the freezing of moisture in control lines in cold weather commonly causes faulty operation of controls.

Corrosion of air or gas operated instruments from moisture can give false readings, interrupting or shutting down plant processes.

II Applications Requiring Clean, Dry Air

Plant Air

In almost every operation, clean, dry compressed air will result in lower operating costs. Dirt, water and oil entrained in the air will be deposited on the inner surfaces of pipes and fittings, causing an increase in pressure drop in the line. A loss of pressure is a loss of the energy used to compress the air and a reduced pressure at the point of use results in a loss of performance efficiency.

Liquid water accelerates corrosion and shortens the useful life of equipment and carry over of corrosion particles can plug valves, fittings and instrument control lines. When water freezes in these components, similar plugging will occur.

Valves and Cylinders

Deposits of sludge formed by dirty, wet and oily air act as a drag on pneumatic cylinders so that the seals and bearings need frequent maintenance. Operation is slowed down and eventually stopped. Moisture dilutes the oil required for the head and rod of an air cylinder, corrodes the walls and slows response. This results in loss of efficiency and production.

Moisture flowing to rubber diaphragms in valves can cause these parts to stiffen and rupture. Moisture also can cause spools and pistons to pit.

In high-speed production, a sluggish or stuck cylinder could create costly downtime. A clean, dry air supply can prevent many of these potential problems.

Air Powered Tools

Pneumatic tools are designed to operate with clean, dry air at the required pressure. Dirty and wet air will result in sluggish operation, more frequent repair and replacement of parts due to sticking, jamming and rusting of wearing parts. Water also will wash out the required oils, resulting in excessive wear.

A decrease in pressure at the tool caused by restricted or plugged lines or parts will cause a reduction in the efficiency of the tool.

Clean, dry air at the required pressure will enable the production worker to start operating immediately at an efficient level, with no time lost to purge lines or drain filters and will help to maintain productivity and prolong tool life.

Instrument Air

Control air supplied to transmitters, relays, integrators, converters, recorders, indicators or gauges is required to be clean and dry. A small amount of moisture passing through an orifice can cause

** The maximum water vapor the air can hold depends upon the temperature and pressure. The amount of vapor the air actually does contain - relative to the most it can contain is relative humidity (the ratio of the quantity of water vapor present to the quantity present at saturation at the same temperature).*

*** Dew Point. The temperature at which water vapor in the air starts to condense or change from vapor to a liquid or a solid state. (Dew points may be expressed at an operating pressure or at atmospheric pressure. Operating pressure should be specified when using pressure dew point. The relationship between pressure and atmosphere dew point is shown on Chart No. 3 in the appendix.*

malfunction of the instrument and the process it controls. Moisture and resultant corrosion particles also can cause damage to instruments and plug their supply air lines.

Pneumatic thermostats, which control the heating and air conditioning cycles in large and small buildings, also require clean, dry air.

Instruments and pneumatic controllers in power plants, sewage treatment plants, chemical and petrochemical plants, textile mills and general manufacturing plants, all need clean, dry air for efficient operation.

The Instrument Society of America (ISA) has published ISA-S7.3 Quality Standard for Instrument Air.

Preservation of Products

When used to mix, stir, move or clean a product, air must be clean and dry. Oil and water in compressed air used to operate knitting machinery will cause the tiny latches on the knitting needles to stick. When used to blow lint and thread off finished fabrics, contaminants in the air may cause product spoilage.

If air is used to blow a container clean before packaging, entrained moisture and oil may contaminate the product. Moisture in control line air can cause the wrong mixture of ingredients in a bakery, the incorrect blend in liquor, water-logged paint, or ruined food products.

In some printing operations, air is used to lift or position paper, which will be affected by dirty, wet air and any water on the paper will prevent proper adhesion of the inks.

In pneumatic conveying of a product such as paper cups or cement, dry air is essential.

Test Chambers

Supersonic wind tunnels are designed to simulate atmospheric conditions at high altitudes where moisture content is low. These chambers use large volumes of air, which must be dried to a very low dew point to prevent condensation in the tunnel air stream.

Breathing Air

The air coming from an air compressor, whether lubricated or oil free type, is not suitable for breathing. Treatment of the air is required before the air can be considered suitable for breathing and certain health and safety standards must be met.

In industrial plants, air may be supplied to respirators, hoods and helmets and for applications such as sand blasting. Occupational Safety and Health Administration (OSHA) standard OSHA:1910:13d applies and requires drying, filtration and treatment to meet specific levels, including carbon monoxide, with an alarm system.

The Compressed Gas Association (CGA) Standard Commodity Specification G-7.1, Grade D, commonly is specified for plant breathing air systems.

Medical air for hospitals must meet National Fire Protection Association (NFPA) Standard NFPA-99.

Air Quality Classes encompassing pollutants have been established in an International Standard ISO 8573-1. For moisture content, these are as follows:

Class	Maximum Pressure °C	Dew point °F
1	-70	-100
2	-40	-40
3	-20	-4
4	+3	+38
5	+7	+45
6	+10	+50
7	not specified	

III How To Measure Moisture Content

Obviously there are times when it is desirable to know with varying degrees of accuracy the moisture content of the compressed air. Methods are available which will give you readings, which vary from approximations to precise measurements.

Moisture Indicating Desiccants. A typical example is silica gel, which when treated with a solution of cobaltous chloride*, is dark blue in color when dry. As moisture is adsorbed, the color changes to pink at approximately a 0ºF dew point.

Dew Point Cup. This apparatus consists of a small polished stainless steel cup placed in a container into which you pass the sample air or gas. The temperature of the polished surface is lowered by immersing dry ice (solid carbon dioxide) in an acetone solution contained in the cup. The temperature at which fog appears on the cup is the dew point of the sample.

Refrigerant Evaporation Dew Point Instrument. This device permits direct gauge reading of the dew point temperature of the sample, as determined by the appearance of a fog on the surface of a highly polished vessel in which a refrigerant is being evaporated. Dew point temperatures can be determined at either system or atmospheric pressure.

Fog Chamber Instrument. This device relies on the relationship between pressure and temperature during adiabatic expansion. A sample of gas enters a small chamber where it is compressed, then rapidly vented to atmospheric pressure. The point at which fog appears establishes a relationship with the amount of compression, and from this the dew point may be calculated.

Capacitance Instrument. This analyzer consists of two strips of metal, which form the electrodes of a capacitor. Water vapor passing across the electrodes causes a change in electric impedance and this is used as a measurement of dew point temperature.

Hygroscopic* Cells. These analyzers use a sensing element which contains a moisture adsorbing material. A change in the moisture content of the element is detected by an electronic network and is used as a measurement of dew point temperature.

Infrared Analyzer. This instrument uses two beams of infrared radiation. One beam travels through a comparison cell and the other through the sample cell. The difference in absorption in the radiation is used as a means of measurement of the dew point of the sample.

Frequency Oscillator Analyzer. This moisture analyzer uses the change in frequency of a hygroscopically coated quartz crystal as means of dew point measurement.

IV Selecting The Right Dryer

Before looking at the several types of dryers available, we need to look at what to consider in deciding which dryer is best for the specific requirements.

Know the Specific Uses of the Compressed Air

The selection of an air dryer is done best by the professional who knows or learns the particular end uses, the amount of moisture which each use can tolerate and the amount of moisture which needs to be removed to achieve this level.

Air which may be considered dry for one application, may not be dry enough for another. Dryness is relative. Even the desert has moisture. There is always some moisture present in a compressed air system regardless of the degree of drying. Different types of dryers, therefore, are available with varying degrees of pressure dew point ability.

To specify a dew point lower than required for an application is not good engineering practice. (Naming a pressure dew point is how to state the degree of dryness wanted.) It may result in more costly equipment and greater operating expense.

Know the Temperatures

To determine whether or not the compressed air will remain sufficiently dry, we must know the end use of the air and the temperature at which it must work.

In an industrial plant where the ambient temperature is in the range of 70°F or higher, a dryer capable of delivering a pressure dew point 20°F lower than ambient, or 50°F, may be quite satisfactory. Summer temperatures do not require a very low dew point whereas winter temperatures may dictate a much lower dew point. In winter, the temperature of the cooling medium, air or water, usually is lower than in summer, resulting in a variation of the air temperature to the dryer. This will affect the size of the dryer needed, since the same dryer must work in both summer and winter temperatures and relative humidities.

Many chemical processing plants, refineries, and power plants distribute instrument and plant air throughout the facility with lines and equipment located outside the buildings. In such plants two different temperature conditions exist at the same time in the same system. Also, a dryer, which may be satisfactory for high daytime temperatures may not be satisfactory for lower nighttime temperatures. In areas where freezing temperatures are encountered, a lower pressure dew point may be required. In general, the dew point should be specified 20°F lower than the lowest ambient temperature encountered in order to avoid potential condensation and freezing. To specify a winter dew point when only summer temperatures will be encountered, can result in over-sizing the equipment and increased initial and operating costs.

For plant air and instrument air, primary considerations in specifying a dryer are condensation and freezing. In a system where a lot of internal pipe corrosion could occur, high humidity in the air stream should be avoided.

Know the ACTUAL Performance

While many dryers have a standard rating of 100°F saturated inlet air temperature and 100 PSIG operating pressure, it is important to check on the **actual** performance of the units obtained in **actual** plant operating conditions.

Know Each Use

In addition to plant and instrument air applications, there are many other uses requiring moisture removal to a low dew point. For example, railroad tank cars which carry liquid chlorine are padded (charged) with compressed air to enable pneumatic unloading. Chlorine will combine with water vapor to form hydrochloric acid; therefore, the compressed air must have a minimum moisture content to prevent severe corrosion.

Droplets of moisture in wind tunnel air at high-testing velocities may have the effect of machine gun bullets, tearing up the test models.

Air used for low temperature processing (for example, liquefaction of nitrogen or oxygen) can form ice on cooling coils, thus requiring defrosting. The lower the moisture content of the air, the longer the periods between defrosting shutdowns.

* *The EEC has re-classified cobalt chloride, as of July 1, 2000, as a potential carcinogen by inhalation. Manufacturers and users should check with OSHA before using or specifying this product.*

** ***Hygroscopic:*** *Any material which picks up moisture.*

For these and similar temperature applications, compressed air must not only be free of liquid phase water but must also have a minimum content of vapor phase water. Usually specified for these requirements are dew points in the range of -40°F to -100°F at pressure.

With these characteristics in mind, what types of dryers are available?

V Types Of Compressed Air Dryers

Different methods can be used to remove the moisture content of compressed air. Current dryer types include the following:

- **Refrigerant type**
  - -cycling
  - -non-cycling
- **Regenerative desiccant type**
  - -Heatless (no internal or external heaters)
  - -Heated (internal or external heaters)
  - -Heat of Compression
  - -Non-regenerative single tower
- **Deliquescent**
- **Membrane**

Each of these dryer types will be discussed in some detail.

Refrigerant Type Dryers

Although it does not offer as low a dew point as can be obtained with other types, the refrigerant type dryer has been the most popular, as the dew point obtained is acceptable in general industrial plant air applications. The principle of operation is similar to a domestic refrigerator or home air conditioning system. The compressed air is cooled in an air to refrigerant heat exchanger to about 35°F, at which point the condensed moisture is drained off. The air is then reheated in an air to air heat exchanger by means of the incoming air which also is pre-cooled before entering the air to refrigerant heat exchanger. This means that the compressed air leaving the dryer has a pressure dew point of 35 to 40°F. A lower dew point is not feasible in this type of dryer as the condensate would freeze at 32°F or lower.

In a non-cycling refrigerant dryer, the refrigerant circulates continuously through the system. Since the flow of compressed air will vary and ambient temperatures also vary, a hot gas bypass valve or unloader often is used to regulate the flow of the refrigerant and maintain stable operating conditions within the refrigerant system. In most designs, the refrigerant evaporates within the air to refrigerant heat exchanger (evaporator) and is condensed after compression by an air or water to refrigerant heat exchanger (condenser). A typical schematic diagram is shown in Figure 1.

This design provides rapid response to changes in operating loads. While older refrigerant type air dryers have used CFC refrigerants such as R12 and R22, newer designs are in compliance with the Montreal Protocol and use chlorine free refrigerants such as R134A and R407C. The properties of these newer refrigerants require careful attention to the refrigeration system design, due to differences in operating pressures and temperatures.

Cycling type refrigerant dryers chill a mass surrounding the air passage in the evaporator. This mass may be a liquid such as glycol or a metal such as aluminum block, beads or related substance, which acts as a heat sink. The compressed air is cooled by the heat sink which has its temperature controlled by a thermostat and shuts off the refrigerant compressor during reduced loads, providing savings in operating costs but at higher initial capital cost.

Advantages of Refrigerant Type Air Dryers include:
- Low initial capital cost.
- Relatively low operating cost.
- Low maintenance costs.
- Not damaged by oil in the air stream (Filtration normally is recommended).

Disadvantages of Refrigerant Type Air Dryers include:
- Limited dew point capability.

Advantages of Direct Expansion Control include:
- Low and precise dew point.
- Refrigerant compressor operates continuously.

Disadvantages of Direct Expansion Control include:
- No energy savings at partial and zero air flow.

Advantages of Cycling Control include:
- Energy savings at partial and zero air flow.

Disadvantages of Cycling Control include:
- Dew point swings.
- Reduced life of refrigerant compressor from starting and stopping.
- Increased size and weight to accommodate the heat sink mass.
- Increased capital cost.

Regenerative Desiccant Type Dryers

These dryers use a desiccant, which adsorbs the water vapor in the air stream. A distinction needs to be made between adsorb and absorb. Adsorb means that the moisture adheres to the desiccant, collecting in the thousands of small pores within each desiccant bead. The composition of the desiccant is not changed and the moisture can be driven off in a regeneration process by applying dry purge air, by the application of heat, or a combination of both. Absorb means that the material which attracts the moisture is dissolved in and used up by the moisture as in the deliquescent desiccant type dryer.

Regenerative desiccant type dryers normally are of twin tower construction. One tower dries the air from the compressor while the desiccant in the other tower is being regenerated after the pressure in the tower has been reduced to atmospheric pressure. Regeneration can be accomplished using a time cycle or on demand by measuring the temperature or humidity in the desiccant towers or by measuring the dew point of the air leaving the on-line tower. In the heatless regenerative desiccant type, no internal or external heaters are used. Purge air requirement can range up to 18% of the total air flow. The typical regenerative desiccant dryer at 100 psig has a pressure dew point rating of -40°F but a dew point down to -100°F can be obtained. A typical schematic diagram is shown in Figure 1.

Heat reactivated regenerative desiccant dryers may have internal or external heat applied by heaters. In the internal type, steam or electricity may be used in heaters embedded in the desiccant bed. This reduces the amount of purge air required for regeneration to about 5%. The purge air plus normal radiation is used to cool the desiccant bed after regeneration to prevent elevated air temperatures going downstream.

In externally heated regenerative desiccant dryers, the purge air is heated to a suitable temperature and then passes through the desiccant bed. The amount of purge air is approximately 5-10% of the air flow through the dryer. The purge air can be eliminated if a blower is used for circulation of atmospheric air through the desiccant bed.

To protect the desiccant bed from contamination from oil carry-over from the air compressor, a coalescing filter is required upstream of the dryer. To protect downstream equipment from desiccant dust or "fines", a particulate filter downstream of the dryer also is recommended.

Advantages of Regenerative Desiccant Type Dryers include:

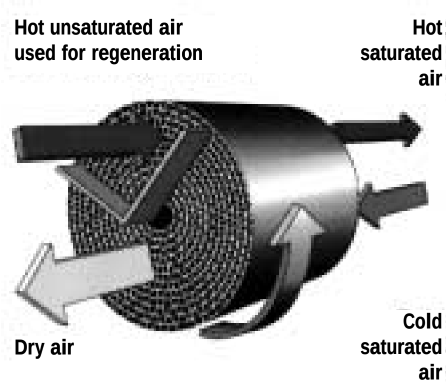
- Very low dew points can be achieved without potential freeze-up.
- Moderate cost of operation for the dew points achieved.
- Heatless type can be designed to operate pneumatically for remote, mobile or hazardous locations.

Disadvantages of Regenerative Desiccant Type Dryers include:

- Relatively high initial capital cost.
- Periodic replacement of the desiccant bed (typically 3-5 years).
- Oil aerosols can coat the desiccant material, rendering it useless if adequate pre-filtering is not maintained.
- Purge air usually is required.

Heat of Compression Type Dryers

Heat of Compression Type Dryers are Regenerative Desiccant Dryers which use the heat generated during compression to accomplish desiccant regeneration, so they can be considered as Heat Reactivated. There are two types, the Single Vessel Type and the Twin Tower Type.



The Single Vessel Heat of Compression Type Dryer provides continuous drying with no cycling or switching of towers. This is accomplished with a rotating desiccant drum in a single pressure vessel divided into two separate air streams. One air stream is a portion of the hot air taken directly from the air compressor at its discharge, prior to the aftercooler, and is the source of heated purge air for regeneration of the desiccant bed. The second air stream is the remainder of the air discharged from the air compressor after it passes through the air aftercooler. This air passes through the drying section of the dryer rotating desiccant bed where it is dried. The hot air, after being used for regeneration, passes through a regeneration cooler before being combined with the main air stream by means of an ejector nozzle before entering the dryer.

The Twin Tower Heat of Compression Type Dryer operation is similar to other Twin Tower Heat Activated Regenerative Desiccant Dryers. The difference is that the desiccant in the saturated tower is regenerated by means of the heat of compression from the hot air leaving the discharge of the air compressor. The total air flow then passes through the air aftercooler before entering the drying tower. Towers are cycled as for other Regenerative Desiccant Type Dryers.

Advantages of Heat of Compression Type Dryers include:

- Low electrical installation cost.
- Low power costs.
- Minimum floor space.
- No loss of purge air.

Disadvantages of Heat of Compression Type Dryers include:

- Applicable only to oil free compressors.
- Applicable only to compressors having a continuously high discharge temperature.
- Inconsistent dew point.
- Susceptible to changing ambient and inlet air temperatures.
- High pressure drop and inefficient ejector nozzle on single vessel type.
- Booster heater required for low load (heat) conditions.

Single Tower Deliquescent Type Dryers

The deliquescent desiccant type dryer uses a hygroscopic desiccant material having a high affinity for water. The desiccant absorbs the water vapor and is dissolved in the liquid formed. These hygroscopic materials are blended with ingredients to control the pH of the effluent and to prevent corrosion, caking and channeling. The desiccant is consumed only when moist air is passing through the dryer. On average, desiccant must be added two or three times per year to maintain a proper desiccant bed level.

Deliquescent dryers normally are designed to give a dew point depression from 20ºF to 50ºF at an inlet temperature or 100ºF. This means that with air entering at 100ºF and 100 PSIG, a leaving pressure dew point of 80ºF to 50ºF may be obtained (a reduction of 20ºF to 50ºF from the inlet temperature). Dew point suppression of 15 to 50°F is advertised. This type of dryer actually dries the air to a specific relative humidity rather than to a specific dew point.

Advantages of Single Tower Deliquescent Desiccant Type Dryers include:

- Low initial capital and installation cost.
- Low pressure drop.
- No moving parts
- Requires no electrical power.
- Can be installed outdoors.
- Can be used in hazardous, dirty or corrosive environments.

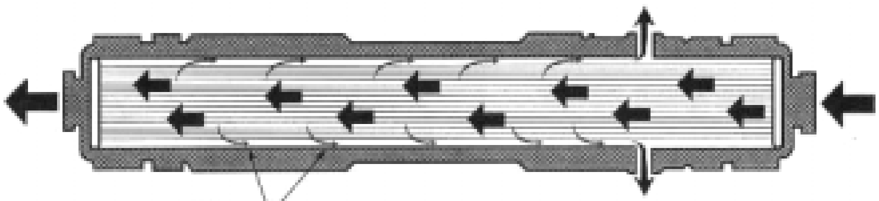
Disadvantages of Single Tower Deliquescent Type Dryers include:

- Limited suppression of dew point.
- Desiccant bed must be refilled periodically.
- Regular periodic maintenance.
- Desiccant material can carry over into downstream piping if there is no after-filter and if the dryer is not drained regularly. Certain desiccant materials may have a damaging effect on downstream piping and equipment.
- Some desiccant materials may melt or fuse together at temperatures above 80°F.

Membrane Type Dryers

Membrane technology has advanced considerably in recent years. Membranes commonly are used for gas separation such as in nitrogen production for food storage and other applications. The structure of the membrane is such that molecules of certain gases (such as oxygen) are able to pass through (permeate) a semi-permeable membrane faster than others (such as nitrogen) leaving a concentration of the desired gas (nitrogen) at the outlet of the generator.

When used as a dryer in a compressed air system, specially designed membranes allow water vapor (a gas) to pass through the membrane pores faster than the other gases (air) reducing the amount of water vapor in the air stream at the outlet of the membrane dryer, suppressing the dew point. The dew point achieved normally is 40°F but lower dew points to -40°F can be achieved at the expense of additional purge air loss.



* *CAGI ADF 100 can be ordered through the CAGI office at (216) 241-7333.*

Advantages of Membrane Type Dryers include:
- Low installation cost.
- Low operating cost.
- Can be installed outdoors.
- Can be used in hazardous atmospheres.
- No moving parts.

Disadvantages of the Membrane Type Dryers include:
- Limited to low capacity systems.
- High purge air loss (15 to 20%) to achieve required pressure dew points.
- Membrane may be fouled by oil or other contaminants.
- High initial capital cost.

Dryer Ratings

The standard conditions for the capacity rating in scfm of compressed air dryers, are contained in CAGI ADF 100, *Refrigerated Compressed Air Dryers – Methods for Testing and Rating**. These commonly are called the three 100s. That is, a dryer inlet pressure of 100 psig, an inlet temperature of 100°F and an ambient temperature of 100°F. If the plant compressed air system has different operating conditions, this will affect the dryer rating and must be discussed with the supplier to ensure compatibility.

VI Specifying A Compressed Air Dryer

The air dryer with certain auxiliary equipment becomes a system, which is an important component of the whole plant compressed air system. Various components comprising the dryer subsystem should be selected on the basis of the overall requirements and the relationship of the components to each other.

There are just three main factors to analyze in selecting the appropriate dryer (including size) to provide your required performance – dew point, operating pressure and inlet temperature.

Dew Point

Refrigerant dryers provide a pressure dew point of 35°F or 50°F at operating pressure based on saturated inlet air temperature of 100°F.

Regenerative desiccant dryers generally provide a pressure dew point of minus 40°F or lower, at operating pressure and 100°F saturated inlet air temperature.

Deliquescent dryers are more sensitive to the saturated inlet temperature and, based upon a saturated inlet air temperature of 100°F, provide a dew point from 64°F to 80°F at operating pressure.

Membrane dryers deliver pressure dew points ranging from -40°F to 50°F or higher, if required. The dry air flow from a membrane dryer is dependent on the inlet dew point and pressure of the supply air and outlet pressure dew point required by the application. Supply air temperature has no appreciable impact on capacity.

Operating Pressure

At higher pressures, saturated air contains less moisture per standard cubic foot than lower pressure saturated air. Drying air at the highest pressure consistent with the plant design will result in the most economical dryer operation. Chart 1 shows the relationship between operating pressure and water content. Taking air at 100 PSIG as the normal pressure, a subsequent decrease in pressure results in a substantial increase in the water to be removed. At higher pressures the water content curve tends to increase at a slower rate.

Inlet Temperature

The temperature of air entering the dryer usually is close to the temperature at which it leaves the aftercooler. Saturated air at 100°F saturated contains almost twice the amount of moisture of saturated air at 80°F. For every 20°F increase in the temperature of saturated air, there is an approximate doubling of the moisture content. Thus it is desirable to operate the dryer at the **lowest feasible inlet temperature.** The moisture content of saturated air at a given temperature, in grains per cubic foot, is given in Chart No. 2 in the appendix.

With that in mind, a dryer specification is needed.

How To Specify

To provide a good basis for the purchase of each type of compressed air dryer the following sample specifications are given:

Refrigerant Type

1. Inlet Conditions
   - Flow scfm ____________
   - Operating Pressure ____________
   - Inlet Temperature ____________
2. Performance
   - Outlet Dew Point ____________
   - Pressure Drop- ____________
   - Maximum Allowable ____________
3. Design
   - Pressure ____________
   - Temperature ____________
   - Ambient Temperature-
     - Minimum ____________
     - Maximum ____________
   - Air cooled or water cooled ____________
4. Utilities
   - Electric
     - ______ Volts ______ Phase ______ Hz.
   - Cooling Water Temperature
     - (if applicable) ____________
   - Electric Enclosure
     - NEMA-1 General Purpose ____________
     - NEMA-4 Weatherproof ____________
     - NEMA-7 Explosion Proof ____________
     - NEMA-12 Dust Tight ____________

Regenerative Desiccant Type

1. Inlet Conditions
   - Flow scfm ____________
   - Operating Pressure ____________
   - Inlet Air Temperature ____________
2. Performance
   - Outlet Dew Point ____________
   - Pressure Drop ____________
3. Design
   - Pressure ____________
   - Temperature ____________
   - Inlet and Outlet Connections ____________
4. Utilities
   - Electric
     - ______ Volts ______ Phase ______ Hz.
   - Steam
     - ______ PSIG ______ Temperature
   - Water
     - ______ F ______ PSIG
   - Electric Enclosure
     - NEMA-1 General Purpose ____________
     - NEMA-4 Weatherproof ____________
     - NEMA-7 Explosion Proof ____________
     - NEMA-12 Dust Tight ____________

Single Tower Deliquescent Type

1. Inlet Conditions
   - Flow scfm ____________
   - Operating Pressure ____________
   - Inlet Air Temperature ____________
   - Ambient Temperature ____________
2. Performance
   - Outlet Dew Point ____________
   - Pressure Drop- ____________
   - Maximum Allowable ____________
3. Design
   - Pressure ____________
   - Temperature ____________
   - Ambient Temperature-
     - Minimum ____________
     - Maximum ____________

Membrane Type

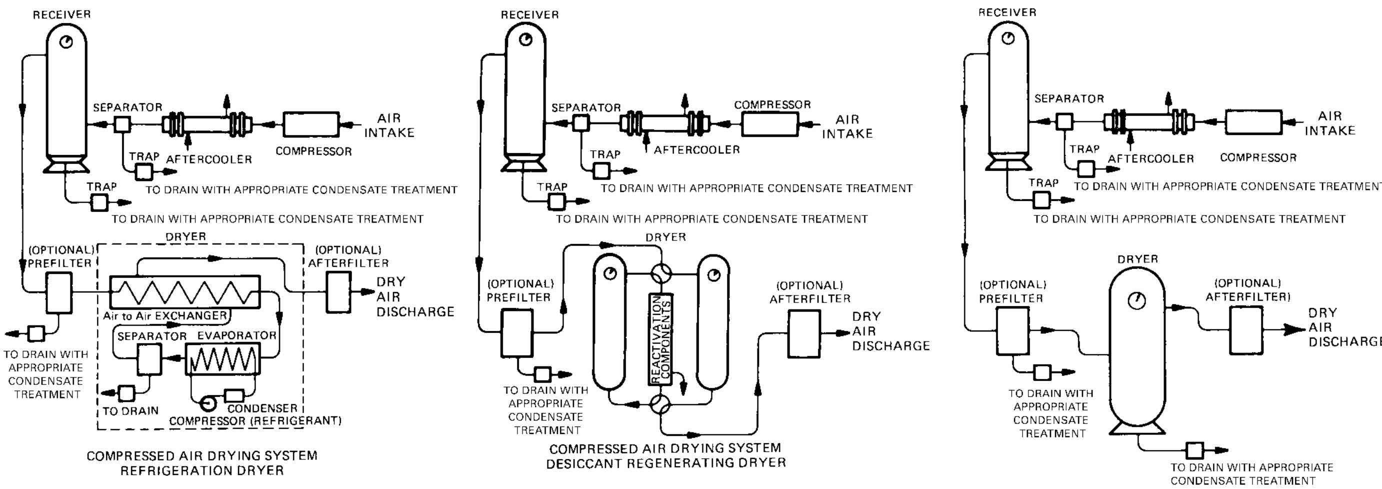
1. Inlet Conditions
   - Flow scfm ____________
   - Operating Pressure ____________
   - Inlet Air Temperature ____________
   - Ambient Temperature ____________
2. Performance
   - Outlet Dew Point ____________
   - Pressure Drop- ____________
   - Maximum Allowable ____________
3. Design
   - Pressure ____________
   - Temperature ____________
   - Ambient Temperature-
     - Minimum ____________
     - Maximum ____________

These specifications are of a general nature for most plant and instrument and air applications. Add special requirements along with any additional data regarding the application.

Certainly good suppliers are available who can assess your system and specify the drying equipment, but even the finest supplier does a better job when the operator or owner or buyer of the apparatus is himself knowledgeable.

VII What Is A Compressed Air Drying System?

While the dryer is the heart of the matter, good drying performance usually requires it to be supported by auxiliary components in a drying **system.**



COMPRESSED AIR DRYING SYSTEM
REFRIGERATION DRYER

ISO Class 1.4.1
Refrigerant

COMPRESSED AIR DRYING SYSTEM
DESICCANT REGENERATING DRYER

ISO Class 1.2.1
Desiccant

COMPRESSED AIR DRYING SYSTEM
DELIQUESCENT DRYER

Single Tower
Deliquescent

Figure 1

Above: left to right:
Typical flow diagrams of drying systems.
Left: Refrigerant.
Center: Desiccant.
Right: Single Tower Deliquescent.

Filters are shown in the flow diagrams as single components. Local operating conditions and selection of equipment will dictate which filters may be required and whether a bypass is to be installed for servicing. Also dual filters and block valves may be considered.

To ensure the expected performance and reliability of the compressed air system, good attention must be exercised in the selection of all components. A typical system may include several of the following items:

Compressor – to increase the pressure of the air to that desired in the system. Numerous types and pressure ratings are available. Compressor discharge pressure must allow for pressure drops through downstream treatment equipment, piping and valves.

Aftercooler – to remove the heat of compression and cool the air to within 10°F to 15°F of the cooling medium. The major portion of the water vapor entering the compressor is condensed in the aftercooler.

Separator – to remove liquids condensed by the aftercooler. An automatic trap discharges the liquids to a drain.

Receiver – to smooth compressor pulsations, and function as a reservoir of compressed air. It also permits liquid water, oil, and solid particulate matter not removed by the aftercooler-separator to settle out of the air stream. Adequate drain provision, with appropriate treatment, is essential.

A receiver before a dryer is filled with saturated air. A sudden demand for air exceeding the dryer rating, may result in overloading the dryer and a higher downstream dew point. A receiver placed after the dryer will be filled with air already dried and can satisfy a sudden demand without impacting the dryer performance and presure dew point.

Mechanical Prefilter– to remove solid and liquid entrainments which remain in the air or which have condensed in the piping. All dryers are designed for an inlet condition of only saturated air or gas. Liquids should not be allowed to enter the dryer.

Coalescing Filter – to remove contaminants, such as the aerosols of water and oil, from an air stream by causing the particles to unite, or coalesce, so that the droplets formed may be removed.

Oil Vapor Filter – to adsorb oil vapors generated by oil lubricated compressors. Oil in the compressed air system is a contaminant and can be hazardous. It can also contaminate desiccants, thereby reducing their ability to adsorb water.

Air Dryers – to remove water vapor. See Section V for a description of the compressed air dryer types.

Afterfilters – to remove dust, pipe scale, and desiccant particles from the dry compressed air stream.

Drains – All condensate discharges to sewer or water systems should comply with all Federal, State and local codes.

VIII Additional Literature

National Fluid Power Association
- Glossary of Terms for Fluid Power

American National Standards Institute
- ANSI Standard B93.2 – 1971

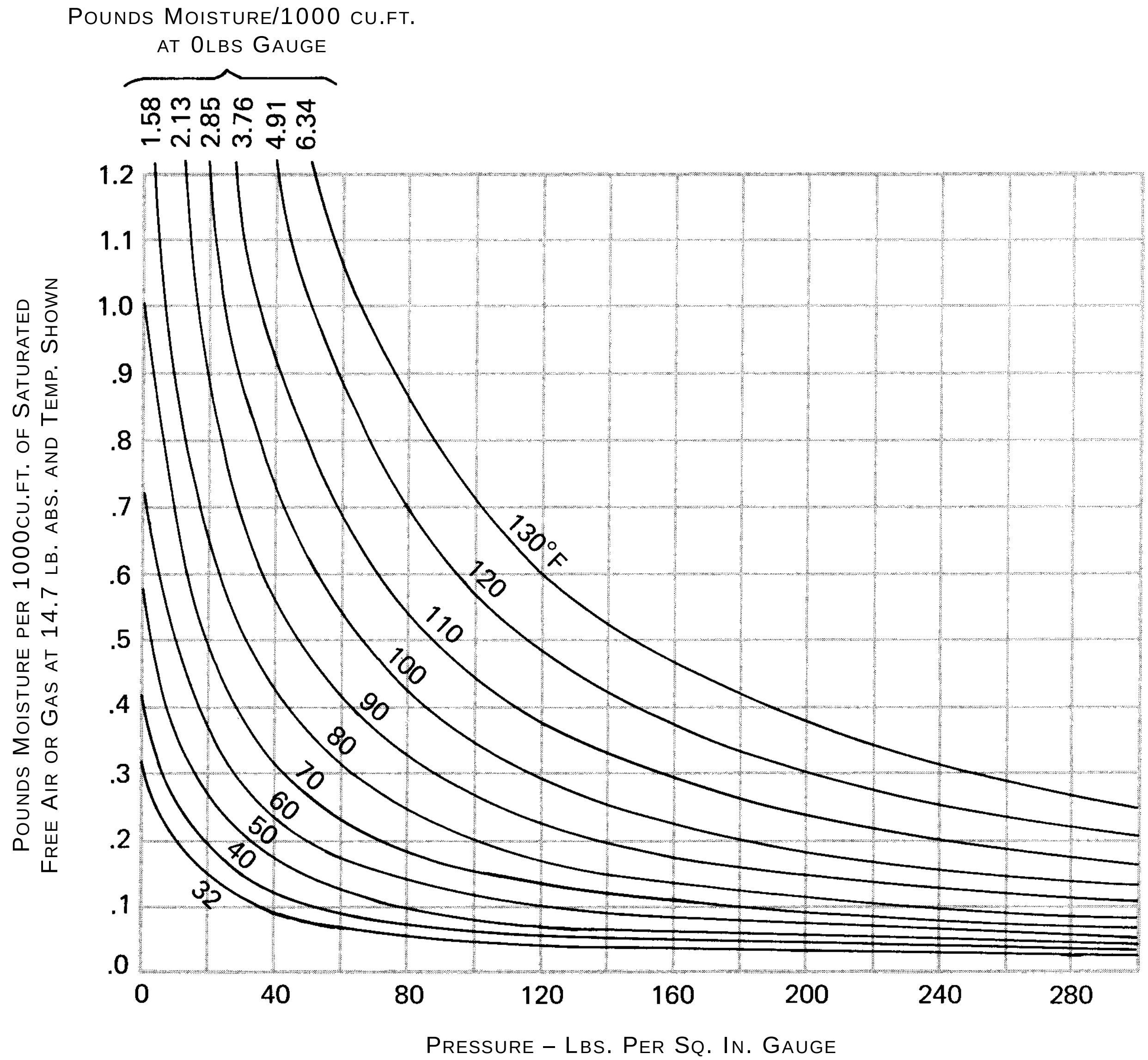
Compressed Air & Gas Institute
- Compressed Air & Gas Handbook
- ADF 100 – Refrigerated Compressed Air Dryers – Methods for Testing and Rating
- ADF 200 – Dual Tower Regenerative Desiccant Compressed Air Dryers – Methods for Testing and Rating
- ADF 300 – Single Tower (Non-Regenerative) Desiccant Compressed Air Dryers – Methods for Testing and Rating
- ADF 700 – Membrane Compressed Air Dryers – Methods for Testing and Rating

McGraw Hill Book Company
- Adsorption – C. L. Mantell

Appendix 1

Water Content Of Air At Various Temperatures And Pressures

Chart No. 1



Appendix 2

Moisture Content Of Saturated Air At Various Temperatures

Chart No. 2

°F	Grains per cu. ft.	°F	Grains per cu. ft.	°F	Grains per cu. ft.	°F	Grains per cu. ft.
−60	.01470	−15	.218	+30	1.935	+75	9.356
−59	.01573	−14	.234	+31	2.023	+76	9.749
−58	.01677	−13	.243	+32	2.113	+77	9.962
−57	.01795	−12	.257	+33	2.194	+78	10.38
−56	.01914	−11	.270	+34	2.279	+79	10.601
−55	.02047	−10	.285	+35	2.366	+80	11.04
−54	.02184	−9	.300	+36	2.457	+81	11.27
−53	.02320	−8	.316	+37	2.550	+82	11.75
−52	.02485	−7	.332	+38	2.646	+83	11.98
−51	.02650	−6	.350	+39	2.746	+84	12.49
−50	.02826	−5	.370	+40	2.849	+85	12.73
−49	.03004	−4	.389	+41	2.955	+86	13.27
−48	.03207	−3	.411	+42	3.064	+87	13.53
−47	.03412	−2	.434	+43	3.177	+88	14.08
−46	.03622	−1	.457	+44	3.294	+89	14.36
−45	.03865	0	.481	+45	3.414	+90	14.94
−44	.04111	+1	.505	+46	3.539	+91	15.23
−43	.04375	+2	.529	+47	3.667	+92	15.84
−42	.04650	+3	.554	+48	3.800	+93	16.15
−41	.04947	+4	.582	+49	3.936	+94	16.79
−40	.05249	+5	.640	+50	4.076	+95	17.12
−39	.05583	+6	.639	+51	4.222	+96	17.80
−38	.05922	+7	.671	+52	4.372	+97	18.44
−37	.06292	+8	.704	+53	4.526	+98	18.85
−36	.06677	+9	.739	+54	4.685	+99	19.24
−35	.07085	+10	.776	+55	4.849	+100	19.95
−34	.07517	+11	.816	+56	5.016	+101	20.33
−33	.07962	+12	.856	+57	5.191	+102	21.11
−32	.08447	+13	.898	+58	5.370	+103	21.54
−31	.08942	+14	.941	+59	5.555	+104	22.32
−30	.09449	+15	.986	+60	5.745	+105	22.75
−29	.09982	+16	1.032	+61	5.941	+106	23.60
−28	.10616	+17	1.080	+62	6.142	+107	24.26
−27	.11258	+18	1.128	+63	6.349	+108	24.93
−26	.11914	+19	1.181	+64	6.563	+109	25.41
−25	.12611	+20	1.235	+65	6.782	+110	26.34
−24	.13334	+21	1.294	+66	7.069	+111	27.07
−23	.14113	+22	1.355	+67	7.241	+112	27.81
−22	.14901	+23	1.418	+68	7.480	+113	28.57
−21	.15739	+24	1.483	+69	7.726	+114	29.34
−20	.166	+25	1.551	+70	7.980	+115	30.14
−19	.174	+26	1.623	+71	8.240	+116	30.95
−18	.184	+27	1.697	+72	8.508	+117	31.79
−17	.196	+28	1.773	+73	8.782	+118	32.63
−16	.207	+29	1.853	+74	9.153	+119	33.51

7,000 grains = 1 pound
1 pound = 0.833 gallons at 60°F
-80°F = .00035 gr/ft^3
-100°F = .00007 gr/ft^3

Appendix 3

Dew Point Conversion Chart No. 3

To obtain the dew point temperature expected if the gas were expanded to a lower pressure proceed as follows:

1. Using "dew point at pressure," locate this temperature on scale at right hand side of chart.
2. Read horizontally to intersection of curve corresponding to the operating pressure at which the gas was dried.
3. From that point read vertically downward to curve corresponding to the expanded lower pressure.
4. From that point read horizontally to scale on right hand side of chart to obtain dew point temperature at the expanded lower pressure.
5. If dew point temperatures of atmospheric pressure are desired, after step 2, above read vertically downward to scale at bottom of chart which gives "Dew Point at Atmospheric Pressure."