COMPRESSED AIR

SYSTEMS GUIDE

Customized Compressed Air Systems...
compressor, dryer, filters, etc.
prepiped and prewired on a single skid.

Compressed Air Dryers

Compressed Air Filters

Oil-Free Air Systems

Closed- and Open-Loop Water Cooling Systems

Breathing Air Systems...
by Pioneer Engineering, Inc.

PIONEER

INNOVATIVE QUALITY PRODUCTS

1-800-264-1AIR

Welcome to the World of PIONEER

Innovative Nature

PIONEER Air Systems was started in Spring of 1980. It was a time of deep recession for American industry. Out of necessity, we sought jobs that most of our competitors did not want to or could not handle. Soon, working with special products, thinking differently, and helping customers to solve their problems became second nature to us. This attitude gave birth to our slogan: "Nonstandard equipment is our specialty." Among the industry firsts introduced by ***PIONEER*** are:

1. **ADR** (After Cooler, Dryer and Reheater) Systems
2. Patented Triple Tube Heat Exchangers
3. **MR. GOOD AIRE** Systems
4. **PERFECT-AIRE** Systems
5. Multi-Stage Deliquescent and Refrigerant Dryers (deliver up to -40°F PDP)
6. **FUTURE-AIRE** Hybrid, Regenerative and Refrigerant Dryers
7. Oil-Free Air Systems

In a few years, ***PIONEER*** has become not only a major manufacturer but a leader in the field of compressed air. Today there are over 15,000 ***PIONEER*** products and systems in the field helping users solve their problems.

Awards and Patents

PIONEER has won numerous awards and patents including:

U.S. Patent No. 4,638,852 for Triple Tube Design heat exchanger.
U.S. Patent No. 4,761,968 for High Efficiency air drying system.
U.S. Patent No. 4,499,033 for a High Efficiency coalescing medium.
"Top Honor" Vaaler Award for **FUTURE AIRE** System.

Engineering Assistance

PIONEER designers, engineers, application engineers, inside sales staff, regional sales representatives and factory-trained distributor sales engineers are all available to work with you in selecting and sizing the most appropriate products for your compressed air system.

Our service personnel with in-depth factory training and field experience, are available for factory start-ups and service after the sale. They will help you achieve reliable performance and maximum benefits from ***PIONEER*** products.

Availability of Products

The full line of ***PIONEER*** products are available through a network of authorized distributors in major cities and marketing areas. Call the ***PIONEER*** factory to locate the authorized distributor nearest you.

Disclaimer

The information in this booklet has been carefully prepared, however, ***PIONEER***, its employees and its officers make no warranties respecting it and disclaim any responsibility or liability of any kind for any loss or damage as a consequence of anyone's use or reliance upon such information. We encourage verification and further investigation of the information contained herein.

Acknowledgements

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Joie Rose and Mitch Brooks of Visual Impact have been very diligent and cooperative in layout and design of this manual.

I sincerely thank them for their efforts.

I dedicate this publication to my parents.

Sam Basseen, *M.S.(EE)*
President & C.E.O.
PIONEER AIR SYSTEMS, INC.
Wartburg, TN
January 3, 1990

Introduction

This manual is written as a guide for professionals working in the field of compressed air. It offers helpful information on the selection, sizing and installation of proper equipment for your compressed air system.

In a plant, the potential for damage and loss due to compressed air contaminants is overwhelming. Contaminants damage air tools, instruments and controls resulting in excessive maintenance, down time or even plant shut downs. Moreover, contaminants may cause product or process spoilage.

A few minutes of your time in reading this manual will help you select the proper equipment and may save you tens of thousands of dollars.

Contents

Useful Definitions

ABSORB - To take in and hold, not just on the surface, but deep into the material, usually forming a mixture out of two or more substances.

ACTIVATED ALUMINA - A regenerative desiccant.

ADIABETIC DRYING - Drying without gain or loss of heat.

ADSORB - To take in and hold liquid and gas on the surface of a solid but porous material without causing a change in the basic structure of the material.

AFTER FILTER - A filter that usually follows a dryer for protection of down stream equipment.

AMBIENT TEMPERATURE - Temperature of air surrounding the equipment.

AUTOMATIC DRAIN - A device that automatically discharges condensate.

BAR - A metric unit of pressure equal to $10^5 N/m^2$ (newtons per square meter). One bar approximately equals 14.5 PSIG.

BTU - British Thermal Unit, a measure of heat or energy. One BTU is the amount of heat needed to raise temperature of one pound of water by one degree fahrenheit.

CAPILLARY - A device that controls flow of refrigerant.

COALESCE - To fuse, unite or grow into a mass large enough to fall due to gravity.

COMPRESSED AIR DRYER - A device designed to lower the dew point of compressed air.

COMPRESSOR, HERMETIC - A type of compressor in which the motor and the compressor are contained in a single pressure vessel. Because the systems are sealed (welded construction) from the outside, the systems are not serviceable in the field.

COMPRESSOR, SEMI-HERMETIC - Similar to a hermetic compressor except these can be serviced in the field because they have bolted instead of welded construction.

COMPRESSOR, OPEN TYPE - Motor and compressor are two separate units. Motor drives the compressor by direct couple, through belt(s) or through gear(s).

CONDENSATION - The process of changing vapor or gas into liquid.

CONTACT TIME - The amount of time the compressed air comes in contact with desiccant in a compressed air dryer.

DESICCANT - A substance suitable for absorbing or adsorbing moisture.

DEW POINT - The temperature at which moisture begins to condense.
a. Atmospheric Dew Point - Dew point at atmospheric pressure.
b. Pressure Dew Point - Dew point at pressure.

NOTE: In selecting an air drying system only pressure dew point is important because the compressed air is normally used at pressure.

DEW POINT SUPPRESSION - The reduction in dew point.

DRY BULB TEMPERATURE - The temperature of the air as indicated by an ordinary thermometer.

DRYERS, DELIQUESCENT - Dryers that use a desiccant tower to dry the air. Typically the desiccant is not regenerated and it is consumed in the drying process.

DRYERS, REFRIGERATED - Dryers that use a refrigeration system to cool and condense moisture.

DRYERS, REGENERATIVE - Dryers that use two desiccant towers. One tower dries the incoming air while the other regenerates the desiccant.

DYNAMIC ADSORPTION - The process of adsorption in moving or flowing air. The dynamic capacity of the desiccant to adsorb moisture is a function of the temperature and pressure to which it is subjected.

EVAPORATOR - A heat exchanger where refrigerant absorbs heat and changes from liquid to gas (evaporation).

EXPANSION VALVE - A valve that controls the flow of refrigerant.

FILTER - A device designed to remove solid and liquid particles.

FREE AIR - Air at ambient temperature, pressure and relative humidity (or atmospheric air at natural conditions).

HEAT EXCHANGER - A device capable of transferring heat from one place or medium to another.

HOT GAS BY-PASS VALVE - A valve that by-passes hot refrigerant gas from high pressure to the low pressure side of a refrigeration system. The valve is generally used to reduce refrigeration capacity to maintain a desired refrigerant temperature.

HUMIDITY, ABSOLUTE - Mass of water vapor in per unit volume of air, usually measured as grains/cu. ft. or lbs/cu. ft. or grams/cu. ft.

HUMIDITY, MOLAL - Mass of water vapor in Mols per Mole of air. The Molal composition of a mixture is proportional to its partial pressures.

HUMIDITY, RELATIVE - Ratio of the quantity of moisture present to the quantity that will saturate the air at a given temperature.

MICRON - One millionth of one meter or 1 meter = 1,000,000 microns.

MOISTURE SEPARATOR - A device that separates condensate from an air stream.

MOLE - Amount of substance in elementary entities as atoms.

MOLECULAR SIEVE - A regenerative desiccant.

PARTIAL PRESSURE - The pressure that a gas will have if it occupies the total volume of the gas mixture. The total pressure (P) of the mixture is the sum of the partial pressures i.e. $P = P_1 + P_2 + P_3 + \ldots$

PRECOOLER/REHEATER - A heat exchanger that lowers the temperature of the inlet air with the help of the outgoing cold air. In the process the outgoing air is reheated by the incoming air.

PSIA (ABSOLUTE PRESSURE) - Sum of the atmospheric pressure and the gauge pressure.

PSIG - Pounds per square inch of pressure as measured by a gauge.

PURGE - Usually refers to the removal of unwanted air or gas.

REFRIGERANT - A fluid used for heat transfer in a refrigeration unit. Freon 12, 22, and 502 are commonly used refrigerants.

REFRIGERANT ACCUMULATOR - A tank-like device used in a refrigeration system that holds liquid refrigerant and allows flow of gas refrigerant.

REFRIGERANT CONDENSER - A heat exchanger that converts gas refrigerant into liquid refrigerant in a refrigeration system.

REFRIGERANT RECEIVER - A storage tank for liquid refrigerant in a refrigeration system.

REGENERATION - Reactivation of desiccant.

SATURATED AIR - Air at 100% relative humidity. It takes 7.8 cu. ft. of free air to saturate compressed air at 100 PSIG. Therefore, as long as the atmospheric relative humidity is over 12.9% (7.8 x 12.9 = 100%), which it almost always is, the compressed air from an air compressor is saturated. (This also explains why an air dryer is a must for a compressed air system).

SCFM - "Standard" Cubic Feet per Minute. "Standard" air is defined at 68°F (20°C), 14.7 PSIA (1.01 Bar) and 36% relative humidity (density, 0.0750 lbs./cu. ft.).

SILICA GEL - A regenerative desiccant.

STATIC ADSORPTION - The process of adsorption in static or still air.

SUPERHEAT - The difference between the actual refrigerant temperature at the evaporator outlet and the theoretical evaporation temperature for the refrigerant pressure at the oulet.

TONS OF REFRIGERATION CAPACITY - One ton of refrigeration capacity equals 12,000 BTU/HR.

VERI-DRI 40 PLUS - ***PIONEER*** deliquescent desiccant.

WET-BULB TEMPERATURE - If a thermometer is covered with a wet cloth and exposed to the atmosphere, the temperature read by it is lower because the evaporation of water cools the thermometer. This is called the "Wet-Bulb Temperature" (also the temperature read by a psychrometer). It is an indicator of the humidity (or lack of it) in the air and lies between Dry-Bulb Temperature and dew point. Only at saturation is the Wet-Bulb Temperature, the Dry-Bulb Temperature and the dewpoint equal, otherwise they are different.

Why Treat Compressed Air?

Because it is economical. All pneumatically operated equipment is designed to operate more efficiently and reliably with clean, dry compressed air.

A compressor takes in atmospheric air that is loaded with moisture, dirt, dust fibers and bacteria. Due to constant use and often abuse, most compressors deliver large amounts of oil fumes along with compressed air. The hot air delivered by a compressor carries contaminants which cause corrosion, excessive wear, malfunction and ultimately failure of your compressed air components, tools and system. To assure a reliable and efficient operation of a plant, they must be removed.

Field tests prove that a typical *PIONEER* system pays for itself in less than a year.

Contaminant Removal Equipment

The chart below shows the most common contaminants present in compressed air and the equipment suitable for their removal:

CONTAMINANTS	REMOVAL EQUIPMENT
1. Condensed Moisture	■ Separator Particulate Filter Coalescer Filter Dryer
2. Moisture in Aerosol or Mist form	■ Coalescer ■ Dryer
3. Moisture in Vapor Form (invisible). *NOTE: A separator or a filter does not remove moisture vapor*	■ Dryer
4. Condensed Oil	■ Particulate Filter Separator Coalescer Filter Dryer Carbon Adsorber
5. Oil in Aerosol or Mist Form	■ Coalescer Dryer
6. Oil in Vapor Form (invisible)	■ Carbon Adsorber Dryer
7. Particles (dirt, scale, etc.)	■ Particulate Filter Coalescer Filter
■ Better choice(s).	

TABLE 1

A Reliable Compressed Air System

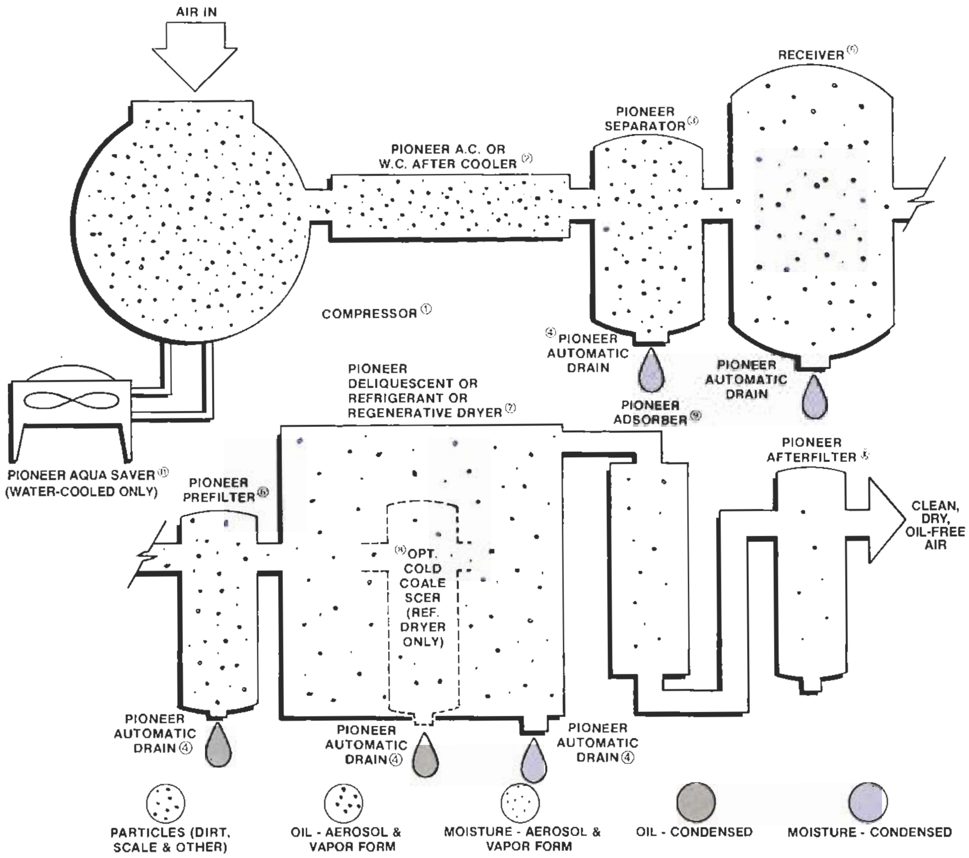


FIGURE 1

Component Functions

1. **Compressor** - Compresses atmospheric air into a useful and versatile utility. During the process, lubricants are commonly added. If not removed, dirt, oil and moisture will flow downstream causing maintenance problems, product rejects and costly production shutdowns.
2. **After Cooler** - Condenses up to 70% of the moisture.
3. **Separator** - Separates condensed liquids.
4. **Automatic Drain** - Automatically drains condensate.
5. **Receiver** - Provides storage for compressed air.
6. **Prefilter** - Improves performance, reliabilty and service life of the dryer
7. **Dryer** - Condenses and removes moisture.
8. **Cold Coalescer** - Condenses and removes oil vapors at the most effective location.
9. **Adsorber** - Removes leftover traces of oil and water vapors.
10. **After Filter** - Removes leftover particles.
11. **AQUA SAVER** - Closed-loop water cooling system. Also available with trim cooler and process chiller.

Separators

Baffle Type

A separator with one or more baffles to cause change in direction of the air stream. Baffle type separators are 80-90% efficient.

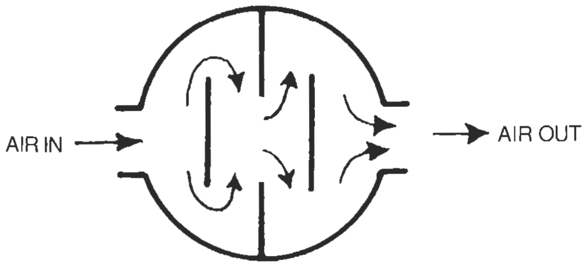


FIGURE 2

Cyclone Type

A separator that spins the air to throw off the free water. Cyclone type separators are 90-95% efficient.

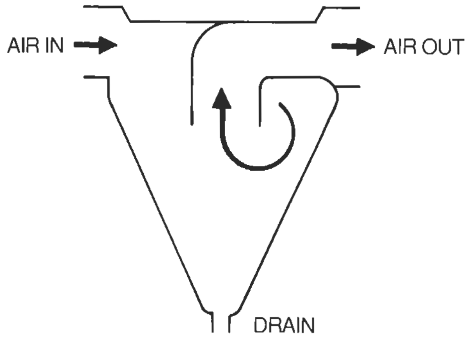


FIGURE 3

Centrifugal Type

Their 95% plus efficiency rating makes them the most efficient type. They incorporate baffle, cyclone, impingement and centrifuge action. ***PIONEER*** **CENTRI-FLO** Separators (2" and larger) have a separate condensate chamber which further improves their efficiency to over 99%.

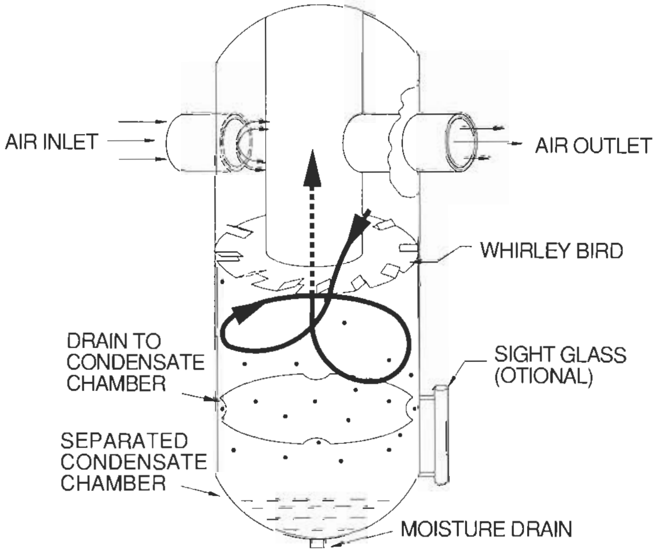


FIGURE 4

Filtration

Proper filtration is an essential part of a reliable compressed air system because:

1. Air logic, instruments and other precision type air devices malfunction when dirt and oil plug orifices.
2. Oil aerosols in compressed air cause uneven painting and increased product rejection rate.
3. Oil aerosols in compressed air coat sensing devices in instruments and equipment; causing malfunction and work stoppage.
4. Acidic contaminants in compressed air damage seals in cylinders, valves and tools causing reduced production or shutdowns.
5. Contaminated air coming in contact with food, pharmaceutical or similar products will cause rejection of the complete production run.
6. **Contaminated air will hinder performance of, and may damage your air drying equipment.**

Sources of Contaminants

Atmospheric Air

It contains millions of solid particles of dust and pollutants. It takes 7.8 cu. ft. of atmospheric air to produce 1.0 cu. ft. of compressed air @ 100 PSIG. In other words, the concentration of contaminants is 7.8 times greater in compressed air as compared to atmospheric air.

Compressor

The compressor lubricants become entrained in the compressed air. Additionally, higher compression temperatures (up to 425°F) vaporize and burn some lubricants. The result is a hot, acidic, corrosive and abrasive mixture that must be removed.

Typical Industrial Atmosphere Contaminants

Particulates

Particulates	Quantity
.01 µm to 0.2µm	6×10^8 particles/ft^3
.2 µm to 1.0 µm	3×10^7 particles/ft^3
.0 µm to 2.0 µm	1×10^5 particles/ft^3
2.0 µm to 10.0 µm	10
0.0 µm and larger	Settle down

TABLE 2

Hydrocarbons

Up to 10 PPM hydrocarbons are commonly present in industrial atmospheres. This explains why even non-lubricated compressors require filtration.

Moisture

Temperature	Moisture Held by Air (at Dew Point) PPM(Weight)	Ounce/1000 ft.^{3}
150°F	200,000	287 oz.
120°F	80,000	115 oz.
100°F	42,000	60 oz.
80°F	22,000	32 oz.
60°F	12,000	17 oz.
40°F	5,100	7 oz.
32°F	3,200	4.6 oz.
-25°F	200	.3 oz.

TABLE 3

Contaminant Removal by PIONEER Filters

Filters remove solid and/or liquid contaminants from air or gas by one or more of the following methods:

Impact

Particles 1.0 μm and larger collide and adhere to the filter media.

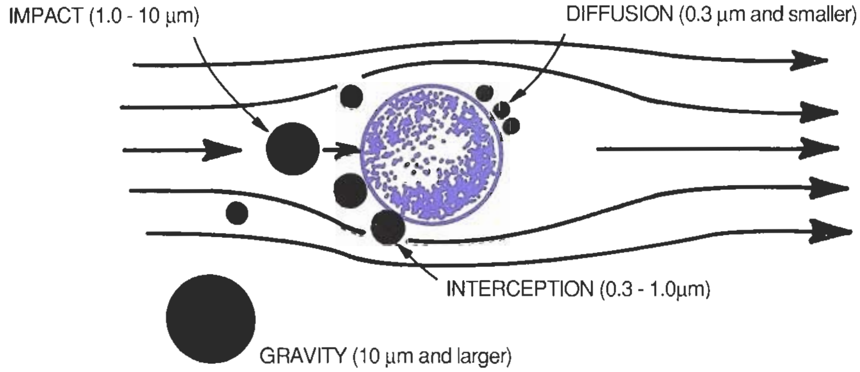


FIGURE 5

Interception

Particles larger than the filter media pores (0.1 - 0.3 μm) are removed by interception.

Diffusion

Particles 0.3 μm and smaller are removed by diffusion. These smaller particles diffuse from the air/gas stream to the surface of the filter media.

Gravity

Coalescing makes smaller particles into larger particles which fall to the bottom of the filter due to gravity (10 μm and larger).

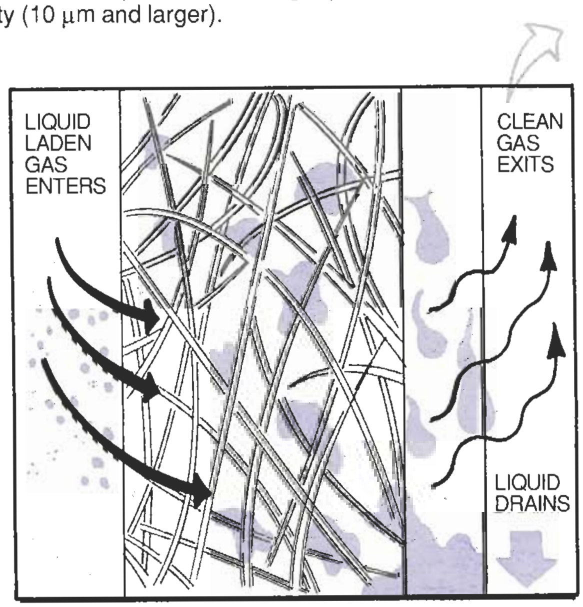


FIGURE 6

Separator Plus Feature

Larger ***PIONEER*** filters are available with built-in centrifuge separators, designed for increased efficiency and longer element life.

PIONEER Particulate Filters

Resin-bonded fiber element and pleated design give these filters 10 to 20 times the filter area of coalescing filters. Therefore, these filters have very low initial pressure drop (0.5 to 1.5 PSI) and an extremely large holding capacity. Particulate filters will increase the useful life of the coalescing filters by up to 6 times while reducing the overall system differential pressure during that period.

Particulate filters are recommended for:

Pre-filters for coalescing filters
After-filters for regenerative dryers
After-filters for deliquescent dryers and adsorbers
General purpose filter for basic protection of air operated equipment, tools and instruments.

PIONEER Coalescing Filters

Coalescing means to come together. It is a continuous process in which small aerosols come in contact with other small aerosols on the surface of the filter media. The collection of aerosols form droplets that are large enough to be separated and drained by gravitational force.

Coalescer Filter Media is resin impregnated for strength which prevents rupture due to differential pressures as high as 40 PSIG. It has an enormous 90% plus void volume which assures constant high efficiency and low initial pressure drops, 1.0 to 2.0 PSI at maximum flow. ***PIONEER*** coalescing filters have 99.9% plus lubricant removal efficiency down to 0.3 µm (based on D.O.P. test) and are effective in removing particles down to .01 µm.

PIONEER Micro-coalescers

For finer coalescing ***PIONEER*** offers Micro-Coalescers. Their D.O.P. efficiency for 0.01-0.06 µm particles is 99.999%. A coalescer is recommended as a pre-filter for a Micro-Coalescer.

Adsorbers

These filters are carbon coated to remove traces of oil.

A very thin layer of carbon, usually 1/8" to 1/4" adsorbs the oil; therefore, these filters have a very limited practical value. Moreover, replacement of elements is easy to overlook, because the pressure drop across an adsorber filter goes down not up, as in other filters.

The ***PIONEER*** vessel type adsorbers charged with carbon usually have carbon depth in feet. These are extremely effective in removing oil vapors, providing oil-free air.

Deliquescent Dryers

Designed for 30°F to 70°F PDP Suppression

To deliquesce means to melt away. A typical deliquescent dryer consists of a pressure vessel holding deliquescent desiccant. The desiccant absorbs moisture and dissolves itself into a liquid state. In a typical deliquescent dryer the dew point of air is suppressed or reduced by only 15-20°F.

PIONEER manufactures a super deliquescent dryer which is capable of up to 70°F dew point suppression. It involves four step drying: In step one the air passes through the separator section and drops easily separated and free liquids. The steps two and three involve drying by liquid absorber sections. The air comes in contact with increasing concentrations of desiccant and water solution. Step four involves drying by solid desiccant.

As the solid desiccant in the upper portion of the dryer becomes a concentrated solution it drips to the trays below to form the liquid absorber section. The upper tray overflows into the tray below. A dilute desiccant solution falls to the bottom, from where it is drained periodically.

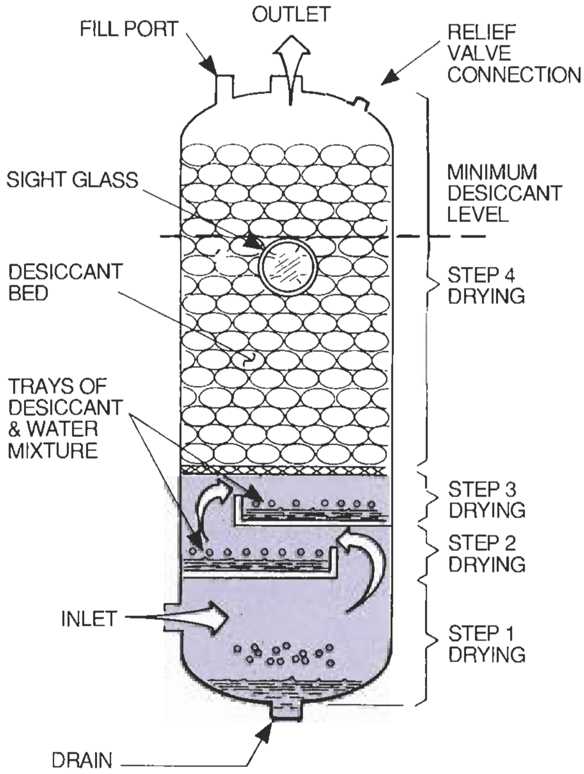


FIGURE 7

PIONEER 'Super' design has several advantages over other deliquescent dryers

1. Minimum Desiccant Consumption

About half of the moisture is removed in steps 1, 2 and 3. Since they do not use any new or additional desiccant, its usage per Lb. of water removal is about half that used in competitive systems.

2. Trouble Free

Because the drain solution is almost free of solids, the drain clogging commonly associated with other deliquescent dryers is virtually eliminated.

3. Lowest Overall Cost

Minimum desiccant usage, no energy usage and virtually no maintenance costs result in the lowest overall cost.

The warm, moist air enters the air to air heat exchanger, where it is precooled with outgoing cool air. The cooling of air causes moisture condensation and minimizes heat load on the refrigeration system. This condensate is removed (larger sizes), and air flows to the air-refrigerant heat exchanger.

Precooling allows use of a smaller refrigeration unit and lowers the cost of drying. The precooled air is further cooled to the 35°F range in the air to refrigerant heat exchanger. The cooling capacity is provided by the refrigeration system. The cooling of compressed air causes condensation of moisture which is separated by a highly efficient centrifugal separator. Condensed moisture is drained automatically by an automatic drain from the separator.

The cold dry air flows through the air-to-air heat exchanger where it is re-heated by the incoming warm air. Re-heating increases the volume of air, prevents the sweating of air lines and lowers the relative humidity of the air **thus enabling it to do more work.** The clean, dry air is then available for use. (Heat Exchangers and Refrigeration Systems in an **ADR** System are about twice the size of that of an **R** series dryer of equal capacity).

PIONEER Refrigerant Dryers

Designed for 35°F to 50°F PDP

Typical Flow Diagram for PIONEER R & ADR Systems

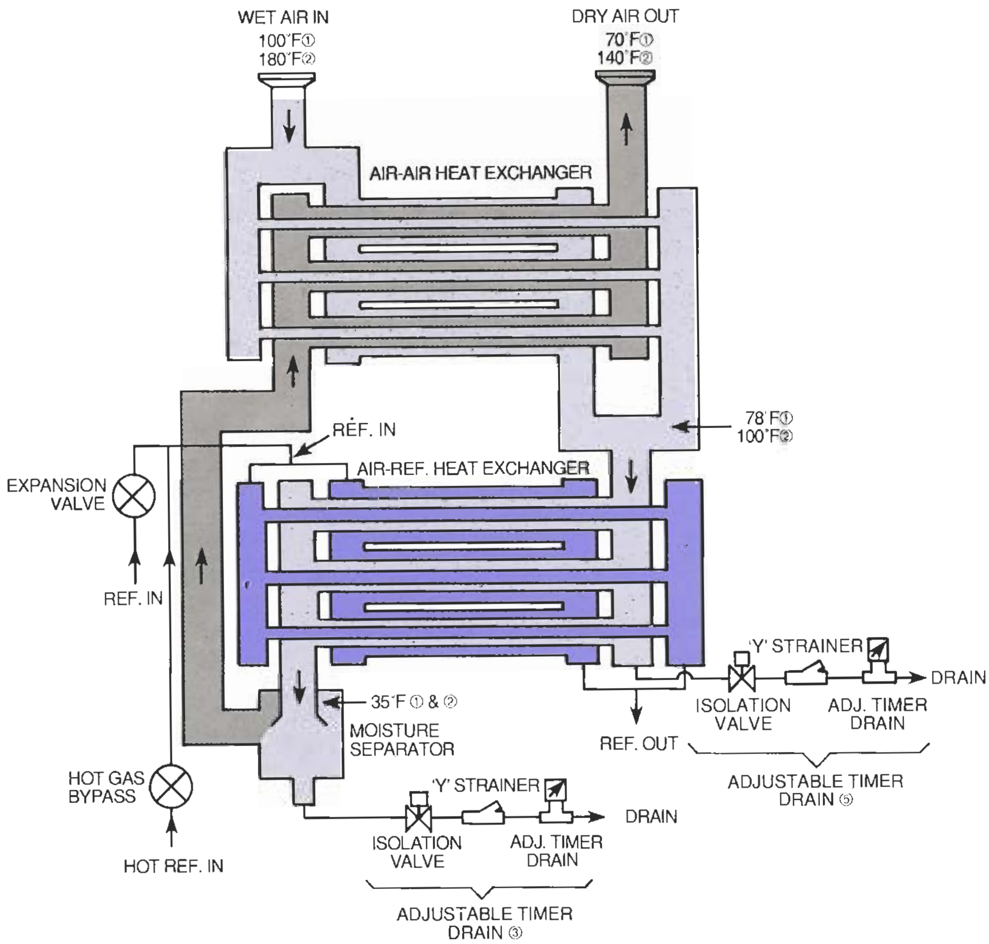


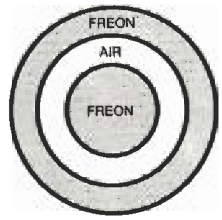
FIGURE 8

NOTES:
1. Typical temperatures in **R** series dryers.
2. Typical temperatures in **ADR** series dryers.
3. Standard drain system in **R100 (ADR50)** & up.
4. Wet Air Dry Air Freon
5. Standard in **R3000 (ADR1500)** & up; optional in smaller sizes.

PIONEER Triple Tube Design [R100 (ADR 50) & Up]

U.S. Patent No. 4,638,852

FIGURE 9



PIONEER TRIPLE TUBE DESIGN
U.S. PAT. NO. 4,638,852

FIGURE 10

***PIONEER'S* "TRIPLE TUBE**" design subjects a thin layer of compressed air between two cold surfaces.

Advantages:

1. Two out of three tubes provide heat transfer surface versus one out of two in a conventional heat exchanger.
2. Because the air is exposed to the cold surfaces from the top and the bottom, the required tube lengths and therefore the pressure drop is reduced.
3. It provides a more compact heat exchanger and system design.
4. Because of shorter required tube lengths, tube bends are eliminated. This further reduces pressure drop.
5. Heat transfer surfaces are of copper to prevent rust and corrosion.
6. Optimum performance and maximum efficiency are achieved with plain tubes and without the disadvantages of the extended surface tubes which increase pressure drop and foul the heat transfer surfaces.
7. Full six year warranty.

PIONEER Offers Several Types of Refrigerant Dryers

1. R-Series

Designed for use with an aftercooler, the **R**-Series design conditions (In accordance with the NFPA and CAGI Standards) are: 100°F Inlet, 100 PSIG Inlet, 100°F Ambient, maximum Pressure Drop of PSIG at rated flow and 35°F range Pressure Dew Point.

2. ADR Series (After Cooler-Dryer-Reheater Combination System)

ADR systems are designed for compressed air systems which do not have a previously installed aftercooler. They perform three functions – aftercooling, air drying and reheating of compressed air. These systems can take inlet air temperatures of up to 200°F.

3. MR. GOOD AIRE Systems

Available with **R** and **ADR** series, these systems include:

1. Prefilter with ΔP Gauge.
2. Cold Coalescer with ΔP Gauge.
3. Timer-operated drain valves complete with a cleanable 'Y' Strainer and an isolation valve.
4. Three valve by-pass for the complete system.
5. Full five year compressor warranty.
6. Full six year heat exchanger warranty.

Advantages:

1. No Hassle.
2. No Cost overruns.
3. Timely Installation.
4. Better Quality Air – Tests prove that the strategically located cold coalescer is 50 to 100% more effective.

FIGURE 11

MR. GOOD AIRE Plus (Oil Free Air)

A coalescer is designed to remove oil aerosols and not oil vapors. To remove oil vapors and to provide the finest industrial and instrument quality oil free air ***PIONEER*** offers a carbon adsorber and a particulate filter installed after the cold coalescer. The particulate filter prevents the carbon carry over.

Regenerative Desiccants

Types of Desiccants

Commonly used regenerative desiccants are silica gel, molecular sieve, activated alumina or a suitable combination of these desiccants.

Silica Gel

Probably the most effective desiccant when the relative humidity of the air stream ranges between 35 to 80%.

Typical characteristics:

Silica (SiO_2): 99.71% by Wt.
Pore Sizes: 4 - 22 angstrom (1 angstrom = 1×10^{-8}cm)
Surface Area: 750 - 800 Sq. meters/gram
Sp. Heat: 0.22 BTU/Lb/°F
Apparent Bulk Density: 45 Lbs/Cu. Ft.

In the presence of heavy moisture or liquid water, the desiccant is susceptible to fractures. The breakup causes desiccant fines and excessive pressure drop. **Therefore, the desiccant is typically used with a pre-drying bed of activated alumina.**

The bead type silica gel (e.g. Sorbead) are spherical in shape and are less susceptible to breakup. The bead type silica gel is preferred when used alone.

Although pressure swing regeneration is often used, the thermal reactivation is more common. Regeneration temperatures of 250°F to 500°F can produce dew points down to -80°F. Silica gel is often used for drying natural gas.

Molecular Sieve

Probably the most effective desiccant when the relative humidity of the air stream is below 35%. It is very effective in achieving low dew points down to -120°F. Molecular sieve is often used for drying unsaturated hydrocarbons and other gases.

Typical characteristics:

Molecular sieves are made of crystalline metal aluminosilicates (silica and alumina tetrahedra).
Average Pore Size: 3 angstroms (1 angstroms = 1×10^{-8} cm)
Sp. Heat: 0.23 BTU/Lb/°F
Apparent Bulk Density: 45 Lbs/Cu. Ft.

Disadvantages:

1. Higher regeneration temperatures 350°F to 700°F.
2. High cost.

Activated Alumina

Overall, it is probably the finest all purpose desiccant. It is ideal for drying air and most other gases at high relative humidity.

Advantages:

1. Although prolonged exposure to liquid water will damage activated alumina, it is more resilient to water than silica gel or molecular sieve.
2. Low pressure drop due to its spherical shape.
3. High crush strength.
4. Less expensive.
5. Low abrasion rate.
6. Long service life.

Typical characteristics:

Activated alumina is primarily aluminum oxide (AL_2O_3).
Pore sizes: 4-22 angstroms (1 angstroms = 10^{-8} cm)
Sp. Heat: 0.22 BTU/Lb/°F
Apparent Bulk Density: 48 Lbs/Cu. Ft.

Pressure swing as well as thermal regeneration at 250°F to 500°F are both commonly used. With low inlet stream temperatures it can produce dew points down to -100°F.

Desiccant Service Life

With repeated regeneration, typically desiccants are subject to a SLOW decline in their useful dynamic capacity. The useful service life of desiccant is highly dependent on the composition of air/gas to be dried and the dew point requirement. In drying clean air, a service life of ten years is not uncommon. Factors that affect desiccant life are:

1. Therma Shock - Constant heating and cooling causes fracturing and reduction of pores and capillaries in desiccant. Higher regeneration temperatures produce greater thermal shock.
2. Fouling of pores and capillaries from dirt, dust and hydrocarbons.

EQUILIBRIUM ADSORPTION CAPACITIES OF DESICCANTS

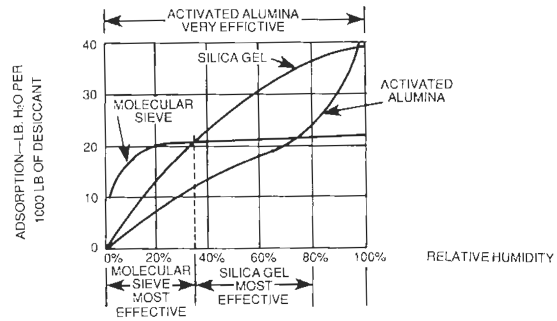


FIGURE 12

Why More Desiccant?

A typical ***PIONEER*** dryer is supplied with premium quality, high-crush strength (70 Lbs.), low-abrasion loss (less than 0.1% Wt.) type, U.S. made activated alumina. Most competitors use less costly, foreign made alumina. ***PIONEER*** supplies more desiccant in their products than the competition.

Example: To dry 1000 SCFM of 100°F, 100 PSIG, saturated air to -40°F PDP with an external heater type dryer (***PIONEER*** Model PHE 1000).

Pounds of water to be removed in a four hour (W_{H_2O}) Cycle =

$$\left(\frac{Fi}{387}\right)\left(\frac{P^{\circ}}{p}\right)(18.016)\quad(t)$$

Where,

- Fi - Saturated or wet air flow in SCFM
- 387 - SCFM per Lb. mole
- P° - Vapor pressure in PSIA @ inlet conditions
- p - Minimum drying pressure in PSIA
- t - Drying time in minutes
- 18.016 - Molecular weight of water (Lb/Lb mole)

$$W_{H_2O} = \left(\frac{1000}{387}\right)\left(\frac{0.94959}{114.7}\right)(18.016)\quad(240) = 92.5 \text{ Lbs.}$$

To remove 92.5 Lbs. of water, ***PIONEER*** provides 800 Lbs. of desiccant per tower—more than its competitors.

Comparison

	Lbs. of Desiccant/Tower	% Dynamic Adsorption Capacity
PIONEER (PHE 1000)	800 Lbs.	92.5/800 = 12%
Brand X	580 Lbs.	92.5/580 = 16%

TABLE 4

PIONEER provides more desiccant for several reasons:

1. Dynamic adsorption capacity of desiccant decreases with use.
2. The adsorption process gives off heat, reducing the relative humidity of the air, and decreasing the adsorption capacity of the desiccant.
3. Slight changes in operating conditions can have a severe effect on dryer performance.
4. More desiccant usually requires larger diameter vessels. Larger diameter vessels produce lower air velocities typically less than 40 F.P.M. The lower air velocities produce minimum desiccant attrition, more contact time (up to 10 secs) and more consistent and lower dew point.

Regenerative Dryers

A typical Regenerative Dryer consists of two towers charged with activated alumina desiccant. One tower dries air while the desiccant in the other tower is being regenerated with low pressure and low humidity air. Often heat is added to assist the regeneration process.

Heatless Regenerative Dryers (PIONEER PHL Series)

In this design, a small amount of the dried air (from the drying tower) is expanded to near atmospheric pressure in the regenerating tower. The dry air becomes super dry on expansion and readily absorbs the moisture from the saturated desiccant bed.

PHL Series offers maximum in reliability. A solid state timer and valves control the entire drying and regeneration process.

A typical -40°F PDP system uses a ten minute cycle; five minutes drying, 4.5 minutes regeneration and 30 seconds repressurization.

Due to their low initial cost and low maintenance cost, **PHL** dryers are generally used whenever sufficient compressed air capacity is available. They purge approximately 14%.

External Heater Type Regenerative Dryers (PIONEER PHE Series)

The ***PIONEER*** **PHE** series is equipped with an external electric or steam (optional) heater to raise the temperature of purge air. The higher the temperature, the greater the capacity of air to absorb moisture, thus heating of the purge air reduces the volume of dry air required for regeneration.

The heater element does not come in contact with the desiccant, thereby the heater tube prevents physical deterioration of the desiccant material.

PHE dryers mostly retain the simplicity of **PHL** dryers and yet **cut the purge air requirement to 3 to 6%,** depending upon the regeneration temperature. This feature makes them particularly suitable for installations where not enough excess compressor capacity is available for **PHL** dryers.

Blower Purge-Zero Purge (PIONEER PHEB Series)

External heater type dryers easily lend themselves to the use of an external blower to supply purge air. Because purge air is needed at near atmospheric pressure, use of a blower for purging is ideal, especially in larger drying systems. Their disadvantage is the fluctuating dewpoint.

Internal Heater Type (PIONEER PHI Series)

In these dryers the purge air heaters are installed inside the desiccant chambers within protective tubes to avoid contact with desiccant. Besides heating the purge air, heaters heat the desiccant because of their location. This helps evaporate moisture from the desiccant and reduce the purge air requirement to approximately 3%. Their disadvantages are higher regeneration temperatures and uneven heating of the desiccant.

Hybrid Drying System (PIONEER FUTURE-AIRE)

FUTURE-AIRE combines the advantages of a refrigerant dryer and a regenerative dryer. A ***PIONEER*** Refrigerant Dryer is used to lower the pressure dew point (PDP) of compressed air or gas to 35°F to 40°F and a ***PIONEER*** Heatless Regenerative Dryer is used to lower the pressure dew point (PDP) to -40°F to -100°F.

The moisture content of saturated air @ 100 PSIG is:

At 100°F PDP: 0.603 oz/100 SCFM
At 40°F PDP: 0.077 oz/100 SCFM

The moisture content of the air @ 40°F PDP is less than 13% of the moisture content of air @ 100°F PDP. The **FUTURE-AIRE** System takes advantage of this fact. Because the refrigerant dryer removes 87% of the moisture, the purge air requirement by the regenerative dryer is only a fraction. ***PIONEER*** design of this hybrid system further reduces the purge air requirement by heating the purge air to 150°F with the normally wasted condenser heat of the refrigerant dryer. The net purge air requirement is:

For -40°F: 2% approximately
For -100°F: 3% approximately

These are the most efficient and reliable regenerative dryers.

A Comparison of Regenerative Dryers

Cost Comparison

Dryer Type	Capacity in SCFM	Average Refrig. or Heater KW Usage	Yearly Operating Cost of Refrig. or Heater ①	Yearly Cost of Purge Air Loss ②	Yearly Equip. Cost ③	Total Yearly Cost Sum of ①,②,③	Overall Cost
FUTURE-AIRE (HDS)	100	0.4	$ 210	$ 263	$ 945	$ 1418	Lowest
	500	2.0	1051	1314	1973	4338	Lowest
	1000	4.0	2102	2628	3289	8019	Lowest
	2000	8.0	4205	5256	5068	14529	Lowest
Heatless (PHL)	100	-	-	$ 1840	$ 559	$ 2399	Highest
	520	-	-	9198	1022	10220	Highest
	1000	-	-	18396	1750	20146	Highest
	2000	-	-	36792	2660	39452	Highest
External Heater (PHE)	100	1.0	$ 526	$ 526	$ 811	$ 1863	Medium
	500	5.0	2630	2630	1393	6653	Medium
	1000	10.0	5260	5260	1750	12270	Medium
	2000	20.0	10520	10520	2660	23700	Medium
Internal Heater (PHI)	100	1.0	$ 526	$ 394	$ 1106	$ 2026	Medium
	500	5.0	2630	1970	1750	6350	Medium
	1000	10.0	5260	3940	2730	11930	Medium
	2000	20.0	10520	7880	4130	22530	Medium

TABLE 5

Assumptions:

1. Cost of compressed air – $0.25/1000 SCF
2. Average KW usage by a refrigeration system of a **FUTURE-AIRE** System – 0.40 KW/100 SCFM.
3. Average KW usage by a heater in a heat reactivated dryer – 1 KW/100 SCFM.
4. The dryer is operating 8760 Hrs/Year.
5. The equipment is depreciated over five years.
6. Energy cost is $0.06/KW.
7. All amounts are rounded to nearest dollar amount.

Sample Calculations:

1. Yearly operating cost of a refrigeration unit for a **HDS 500** Dryer.
   = Avg. KW Usage x Hours x Energy Cost
   $= \left(500 \times \frac{0.40}{100}\right) \times 8760 \times 0.06 = \$1051.20/\text{Year}$
2. Yearly operating cost of a heater for a **PHE 500** Dryer.
   = Avg. KW Usage x Hours x Energy Cost
   $= \left(500 \times \frac{1.0}{100}\right) \times 8760 \times 0.06 = \$2628.00/\text{Year}$
3. Yearly operating cost of purge air loss for a **HDS 500** Dryer.
   = Purge Loss in SCFM x 60 x Hours x Cost of Air per SCF
   $= \left(500 \times \frac{2.0}{100}\right) \times 60 \times 8760 \times \left(\frac{0.25}{1000}\right) = \$1314.00$
4. Equipment Cost.
   The average price of a **HDS 500** unit sold is $9863.00. With a five-year depreciation the cost per year is $1972.60.

Overall Comparison

	Lower ←		Medium		→ Higher
1. Initial Cost	Heatless(PHL)		Ext. Heater(PHE)		Int. Heater (PHI) Blower Purge (PHEB) Future-Aire (HDS)
2. Operating Cost	Future-Aire	Blower Purge		Int. Heater Ext. Heater	Heatless
3. Overall Cost	Future-Aire	Blower Purge		Int. Heater Ext. Heater	Heatless
4. Purge Requirement	Blower Purge	Future-Aire	Int. Heater	Ext. Heater	Heatless
5. Maintenance	Future-Aire		Heatless	Ext. Heater	Int. Heater Blower Purge
6. Equipment Life	Int. Heater Blower Purge		Ext. Heater-		Future-Aire Heatless
7. Reliability	Int. Heater Blower Purge		Ext. Heater		Future-Aire Heatless
8. Dew Point Performance	Blower Purge		Heatless Int. Heater Ext. Heater		Future-Aire

TABLE 6

Demand Cycle Control

This optional feature available in heatless as well as heat reactivated dryers ensures that the dryer will use the minimum of air/gas for regeneration, minimum of air/gas for repressurization and minimum heater usage (in heat reactivated dryers) for regeneration.

In systems with Demand Cycle Control, a humidity sensor monitors the dew point of the filtered outgoing air/gas. When the dew point of outgoing air reaches the preset point, the drying and regenerating towers shift their roles. In other words, with Demand Cycle Control the frequency of tower switching, and therefore the amount of energy needed for regeneration, is in proportion to the air usage.

This makes Demand Cycle Control a useful tool for saving energy in applications with fluctuating air demand.

Comparison

Demand Cycle vs. FUTURE-AIRE

1. **FUTURE-AIRE** saves on energy costs all the time.
2. Demand Cycle Control makes regenerating costs proportional to the air usage instead of being fixed to the maximum flow through the dryer. **The Demand Cycle Control saves when the air usage is less than the maximum, however, it does not save when the air usage is at or near maximum.** Therefore, the demand cycle does not reduce the needed compressor capacity.
3. In practice, the **FUTURE-AIRE** over regenerates the desiccant whereas the Demand Cycle Control regenerates the desiccant to **just necessary** level. Therefore, the **FUTURE-AIRE** delivers lower and more consistent dew point (-60°F is common). Because the desiccant is over regenerated in a **FUTURE-AIRE** System, the problems of residual moisture and desiccant decay is minimized, and the desiccant life is increased.
4. **FUTURE-AIRE** is more rugged and reliable than available humidity sensors.

Overall, FUTURE-AIRE is more reliable, better performing and more economical.

Air Dryer Selection Table

Desired Pressure Dew Point	Application	Regenerative	Refrigerated	Deliquescent	Refrigerant & Deliquescent Combination	FUTURE-AIRE
50°F	General Plant air for tools, cylinders, valves, etc., ambient over 65°F	YES	■YES	■YES	YES	YES
35°F	General plant air for tools, cylinders, valves, instruments, controls, air gauges, etc., when ambient is over 50°F	YES	■YES	■YES	YES	YES
0°F	General plant air for tools, cylinders, valves, instruments, controls, gauges, chemical processing, when ambient is over +20°F	■YES			■YES	■YES
-40°F	Applications requiring exceptionally dry and/or sub zero ambient conditions	■YES				■YES
-80°F	Applications requiring exceptionally dry air and/or ambients down to -40°F	YES				■YES

■ Better Choice(s)

TABLE 7

Water Cooling Systems

City Water Cooling

Disadvantages:

1. High cost of water.
2. Sewage cost.
3. Uncontrolled water temperature.
4. Scaling problems.
5. Possible government restrictions.

The use of city water for a trim cooler in conjunction with a closed-loop cooling system is economical because the city water is generally needed only during the day in summer months. The rest of the time, the atmosphere is usually cool enough to cool the water. The average city water usage is only about 2%.

Evaporative Cooling

1. Typically, 15% of the cooling water is lost resulting in high water and sewage costs.
2. Algae and scaling problems.
3. Water treatment costs.
4. Required sump water heating in winter.
5. High maintenance and cleaning costs.

Closed-Loop Cooling (AQUA SAVERS)

Free atmospheric air is used as the cooling media. **These systems are virtually maintenance free with the lowest overall cost.** The only limitation is that by itself it can only cool water to within 10 - 15°F over the ambient temperatures.

PIONEER offers two options that overcome this limitation and make closed-loop cooling systems the ideal choice for cooling air compressors and other industrial equipment.

1. Trim Cooler

These heat exchangers provide supplemental cooling using city water as a cooling medium and are ideal for providing 85 - 95°F water.

Advantages:

1. Allows you to select a smaller **AQUA SAVER.**
2. Provides desired temperature.
3. Minimizes water costs because the city water is used only on hot days for a few hours when the ambient temperature is too high. The average city water usage is only about 2%, and for most of the year, there is no water cost.
4. Minimizes sewer cost.
5. Minimizes maintenance because it does not have the problems commonly associated with evaporation-type cooling systems (caused by evaporation of water).

2. Refrigerant Cooling

In conjunction with a closed loop cooling system this is an economical and reliable way to provide cooling water at temperatures below 85°F. The cost of cooling is low because the refrigeration cooling is generally needed only during the day and in summer months.

PIONEER offers pre-piped and pre-wired combination cooling systems with both options.

The additional benefit of **AQUA SAVERS** is that they lend themselves to heat recovery.

Heat Recovery

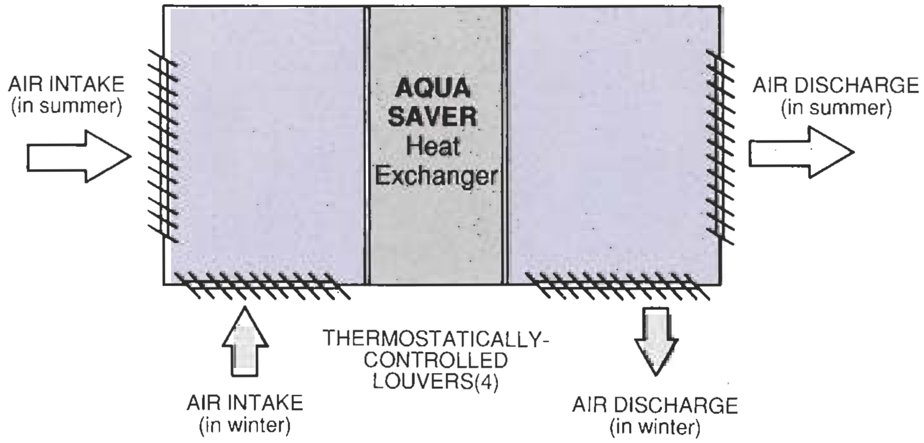


FIGURE 13

Instrument Quality Air

Requirements: In accordance with the Instrument Society of America standards (ANSI/ISA - 57.3 - 1975) (R1981) are:

1. Maximum Particle Size – 3 micron
2. Oil content – 1 PPM w/w or v/v or less under normal operating conditions.
3. Pressure Dew Point – At least 10°C or 18°F below the lowest ambient temperature.
4. Air shall be free of all corrosive contaminants and hazardous substances.

How To Estimate Compressed Air Capacity

Generally, the compressed air capacity of an air compressor is related to its horsepower (HP). A good rule of thumb is:

DISCHARGE PRESSURE (PSIG)	SCFM CAPACITY/HP
75	6.0
100	5.0
125	4.5
150	4.0

TABLE 8

Example:

The typical capacity of a 100.0 HP compressor at 100 PSIG is 5 x 100 = 500 SCFM.

Air Discharge in SCFM Through An Orifice to Atmosphere

Air Pressure Before Orifice (PSIG)	Orifice Diameter (in inches)										
	1/64	1/32	1/16	1/8	1/4	3/8	1/2	5/8	3/4	7/8	1
1	.028	0.112	0.450	1.80	7.18	16.2	28.7	45.0	64.7	88.1	115
2	.040	0.158	0.633	2.53	10.1	22.8	40.5	63.3	91.2	124	162
3	.048	0.194	0.775	3.10	12.4	27.8	49.5	77.5	111	152	198
4	.056	0.223	0.892	3.56	14.3	32.1	57.0	89.2	128	175	228
5	.062	0.248	0.993	3.97	15.9	35.7	63.5	99.3	143	195	254
6	.068	0.272	1.09	4.34	17.4	39.1	69.5	109	156	213	278
7	.073	0.293	1.17	4.68	18.7	42.2	75.0	117	168	230	300
9	.083	0.331	1.32	5.30	21.1	47.7	84.7	132	191	260	339
12	.095	0.379	1.52	6.07	24.3	54.6	97.0	152	218	297	388
15	.105	0.420	1.68	6.72	26.9	60.5	108	168	242	329	430
20	.123	0.491	1.96	7.86	31.4	70.7	126	196	283	385	503
25	.140	0.562	2.25	8.98	35.9	80.9	144	225	323	440	575
30	.158	0.633	2.53	10.1	40.5	91.1	162	253	365	496	648
35	.176	0.703	2.81	11.3	45.0	101	180	281	405	551	720
40	.194	0.774	3.10	12.4	49.6	112	198	310	446	607	793
45	.211	0.845	3.38	13.5	54.1	122	216	338	487	662	865
50	.229	0.916	3.66	14.7	58.6	132	235	366	528	718	938
60	.264	1.06	4.23	16.9	67.6	152	271	423	609	828	1,082
70	.300	1.20	4.79	19.2	76.7	173	307	479	690	939	1,227
80	.335	1.34	5.36	21.4	85.7	193	343	536	771	1,050	1,371
90	.370	1.48	5.92	23.7	94.8	213	379	592	853	1,161	1,516
100	.406	1.62	6.49	26.0	104	234	415	649	934	1,272	1,661
110	.441	1.76	7.05	28.2	113	254	452	705	1,016	1,383	1,806
120	.476	1.91	7.62	30.5	122	274	488	762	1,097	1,494	1,951
125	.494	1.98	7.90	31.6	126	284	506	790	1,138	1,549	2,023

TABLE 9

NOTE:
Above figures are based on 100% coefficient of flow. For a non-smooth orifice, air discharge may be only 50% of above figures.

Cost Of Air Leaks To Atmosphere At 100 PSIG

Assumptions:

1. Cost of compressed air $0.25/1000 SCFM
2. 24 hour/day operation 50 wks/year

EQUIVALENT ORIFICE SIZE	COST/YEAR
1/32	$ 204.12
1/16	817.74
1/8	3,276.00
1/4	13,104.00
3/8	29,484.00

TABLE 10

NOTE:
Above figures show that a good compressed air treatment system pays for itself in a short time.

Freon Pressure - Temperature Relationship

Pressure PSIG	Temperature, F "Freon" Refrigerant Type 12	22	502	Pressure PSIG	Temperature, F "Freon" Refrigerant Type 12	22	502
0	-22	-41	-50	60	62	34	26
1	-19	-39	-47	62	64	35	28
2	-16	-36	-45	64	65	37	29
3	-14	-34	-42	66	67	38	30
4	-11	-32	-40	68	68	40	32
5	-9	-30	-38	70	70	41	33
6	-7	-28	-36	75	74	44	36
7	-4	-26	-34	80	77	47	40
8	-2	-24	-32	85	81	51	43
9	0	-22	-30	90	84	53	46
10	2	-20	-29	95	87	56	49
11	4	-19	-27	100	90	59	51
12	5	-17	-25	105	93	62	54
13	7	-15	-24	110	96	64	57
14	9	-14	-22	115	99	67	59
15	11	-12	-20	120	102	69	62
16	12	-11	-19	125	104	72	64
17	14	-9	-17	130	107	74	67
18	15	-8	-16	135	109	76	69
19	17	-6	-15	140	112	78	71
20	18	-5	-13	145	114	81	73
21	20	-4	-12	150	117	83	75
22	21	-2	-11	155	119	85	77
23	23	-1	-9	160	121	87	80
24	24	0	-8	165	123	89	82
25	26	1	-7	170	125	91	83
26	27	2	-6	175	128	92	85
27	28	4	-5	180	130	94	87
28	29	5	-3	185	132	96	89
29	31	6	-2	190	134	98	91
30	32	7	-1	195	136	100	93
32	34	9	1	200	138	101	95
34	37	11	3	210	141	105	98
36	39	13	5	220	145	108	101
38	41	15	7	230	148	111	104
40	43	17	9	240	152	114	108
42	45	19	11	250	155	117	111
44	47	21	13	260	158	120	114
46	49	23	15	270	162	123	116
48	51	24	16	280	-	126	119
50	53	26	18	290	-	128	122
52	55	28	20	300	-	131	125
54	57	29	21				
56	59	31	23				
58	60	32	24				

TABLE 11

Moisture Content of Air in Grains/Cu.Ft. at Various Temperatures and Relative Humidity

	%Saturation									
	10	20	30	40	50	60	70	80	90	100
Temperature (°F)	Weight of Water Vapor (grains)									
-10	0.028	0.057	0.086	0.114	0.142	0.171	0.200	0.228	0.256	0.285
0	0.048	0.096	0.144	0.192	0.240	0.289	0.337	0.385	0.433	0.481
10	0.078	0.155	0.233	0.210	0.388	0.466	0.543	0.621	0.698	0.776
20	0.124	0.247	0.370	0.494	0.618	0.741	0.864	0.988	1.112	1.235
30	0.194	0.387	0.580	0.774	0.968	1.161	1.354	1.548	1.742	1.935
32	0.211	0.422	0.634	0.845	1.056	1.268	1.479	1.690	1.902	2.113
35	0.237	0.473	0.710	0.947	1.183	1.420	1.656	1.893	2.129	2.366
40	0.285	0.570	0.855	1.140	1.424	1.709	1.994	2.279	2.564	2.749
45	0.341	0.683	1.024	1.366	1.707	2.048	2.390	2.731	3.073	3.414
50	0.408	0.815	1.223	1.630	2.038	2.446	2.853	3.261	3.668	4.076
55	0.485	0.970	1.455	1.940	2.424	2.909	3.394	3.879	4.364	4.849
60	0.574	1.149	1.724	2.298	2.872	3.447	4.022	4.596	5.170	5.745
62	0.614	1.228	1.843	2.457	3.071	3.685	4.299	4.914	5.528	6.142
64	0.656	1.313	1.969	2.625	3.282	3.938	4.594	5.250	5.907	6.563
66	0.701	1.402	2.103	2.804	3.504	4.205	4.906	5.607	6.208	7.009
68	0.748	1.496	2.244	2.992	3.740	4.488	5.236	5.974	7.732	7.480
70	0.798	1.596	2.394	3.192	3.990	5.788	5.586	6.384	7.182	7.980
72	0.851	1.702	2.552	3.403	4.254	5.105	5.956	6.806	7.657	8.508
74	0.907	1.813	2.720	3.626	4.553	5.440	6.346	7.523	8.159	9.066
76	0.966	1.931	2.896	3.862	4.828	5.793	6.758	7.724	8.690	9.655
78	1.028	2.055	3.083	4.111	5.138	6.166	7.194	8.222	9.249	10.277
80	1.093	2.187	3.280	4.374	5.467	6.560	7.654	8.747	9.841	10.934
82	1.163	2.325	3.488	4.650	5.813	6.976	8.138	9.301	10.463	11.626
84	1.236	2.471	3.707	4.942	6.178	7.414	8.649	9.885	11.120	12.356
86	1.313	2.625	3.938	5.215	6.564	7.877	9.189	10.502	11.814	13.127
88	1.394	2.787	4.181	5.575	6.968	8.362	9.576	11.150	12.543	13.937
90	1.479	2.958	4.437	5.916	7.395	8.874	10.353	11.832	13.311	14.790
92	1.569	3.138	4.707	7.276	7.844	9.413	10.982	12.551	13.120	15.689
94	1.663	3.327	4.990	6.654	8.317	9.980	11.644	13.307	14.971	16.634
96	1.763	3.525	5.288	7.050	8.813	10.576	12.338	14.101	15.863	17.626
98	1.867	3.734	5.601	7.468	9.336	11.203	13.070	14.937	16.804	18.671
100	1.977	3.953	5.930	7.906	9.883	11.860	13.836	15.813	17.789	19.766

TABLE 12

Free Flow (or Volume) vs. Flow (or Volume) at Pressure Conversion

Pressure Conversion Table

Pressure PSIG	Flow @ Pressure Per SCFM of Free Flow	Pressure PSIG	Flow @ Pressure Per SCFM of Free Flow
0	1.0	100	0.13
10	0.6	125	0.11
20	0.42	150	0.09
30	0.33	175	0.08
40	0.27	200	0.07
50	0.23	250	0.06
60	0.20	300	0.05
70	0.17	400	0.04
80	0.16	500	0.03
90	0.14		

TABLE 13

Formula:

Flow or volume @ 'p' PSIG= $\left(\frac{14.7}{p + 14.7}\right)$ x free flow

Moisture Content at Various Conditions

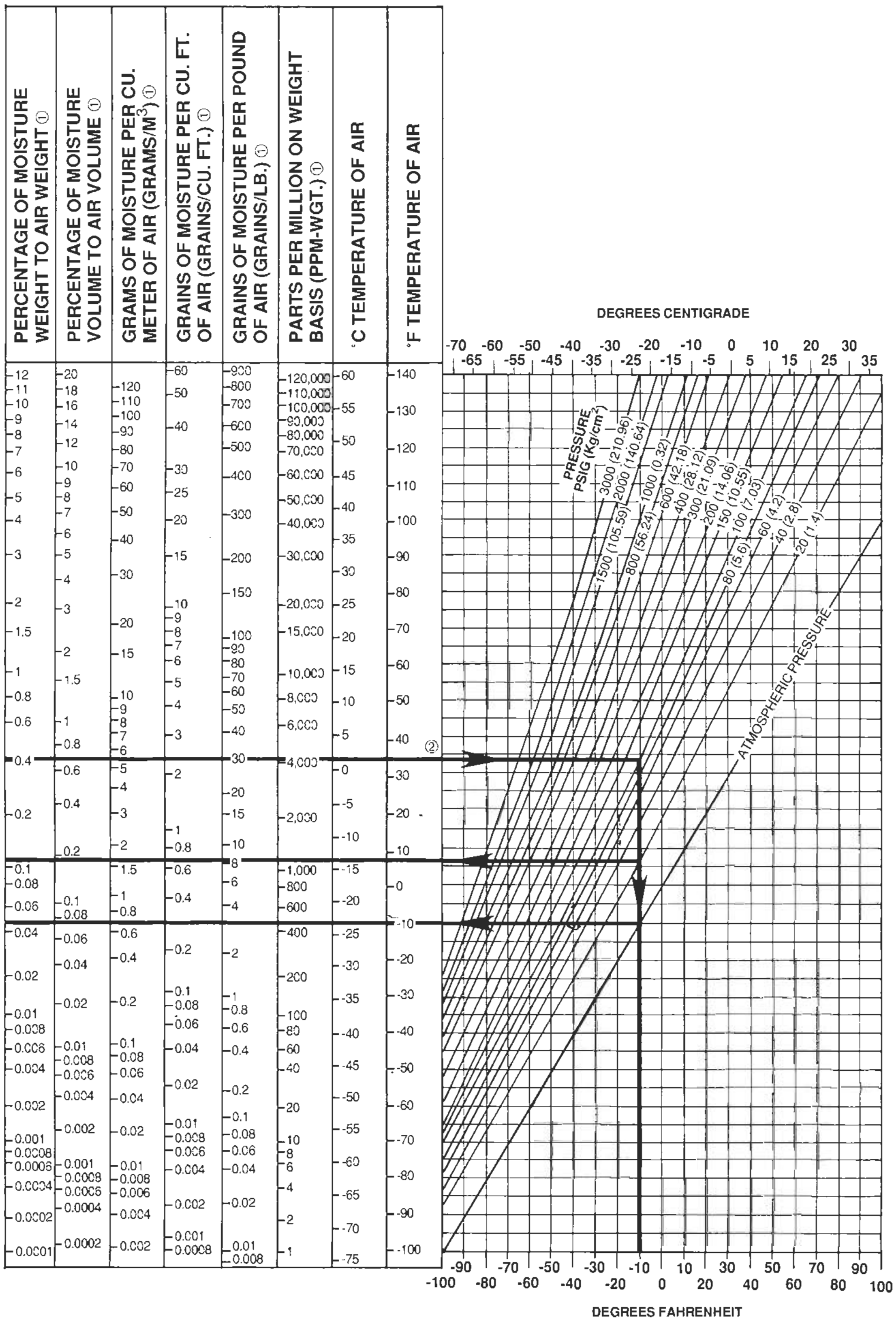


FIGURE 14

NOTES:
[1] At saturated conditions
[2] 35°F dew point @ 100 PSIG is equivalent to -10°F dew point @ ATM. pressure or +7°F dew point @ 20 PSIG; However, only the pressure dew point at the line pressure is important.

Useful Technical Data

Heat Load (Q)

Fluid	Formula
Water	Q = 500 x GPM x ΔT x SP. HEAT[1]
Oil	Q = 210 x GPM x ΔT x SP. HEAT
50% E.G.	Q = 450 x GPM x ΔT x SP. HEAT
Air	Q = 1.08 x SCFM x ΔT x SP. HEAT[2]

[1] For Water 1.0.
[2] For Air 0.24 BTU/Lb./°F

TABLE 14

Overall Heat Transfer Coefficient (U)

TUBE SIDE FLUID	WATER	OIL	50% E.G.	AIR
Water	400	100	350	20
Oil	30	-	-	-
50% E.G.	-	90	300	-
Air	14	-	-	-

TABLE 15

Conversion Data

1 PSI = 2.036 In. OF MERCURY = 2.13 Ft. OF WATER
= 0.069 BAR = .070 KG/cm^2 = 6895 PASCAL

1 Cu. Ft. = 7.48 U.S. GALLONS = 0.0283 Cu. METER = 28.32 LITER
= 29.92 QUARTS = 59.84 PINTS = 6.233 Imp. Gals.

1 Ft. = 0.3048 METERS

1 Lb. = 0.4536 KG = 7000 GRAINS

1 U.S. Gallon of Water = 8.34 Lbs.

1 Cu. Ft. of Water = 62.4 Lbs.

1 Cu. Ft. of Air = .076 Lbs. (Std. Pres. and Temp.)

1 Cu. Ft. of Natural Gas = 1000 BTU (Approx.)

1 Cu. Ft. = 7.48 Gals.

1 Liter = 1000 Grams

1 Cu. Meter = 1000 Liters

1 HP = 746 WATTS = 2547 BTU/HR = 33,000 Ft. Lbs./Min.
= 10.68 K.CALORIES/Min.

ABS. TEMP. °K = °C + 273

ABS. TEMP. °R = °F + 460

°F = 32 + 1.8 x °C

1 BTU raises 1 Lb. of water 1°F

1 BTU raises 54 Cu. Ft. of air 1°F.

1 Lb. of steam raises 1 Gal. water approx. 100°F.

Maximum Recommended Air Flow in SCFM Through Standard Pipes @ 85 - 115 PSIG

0.5"	0.75"	1"	1.25"	1.5"	2.0"	2.5"	3.0"	4.0"	5.0"	6"	8"	10"	12"	16"
40	100	150	200	250	600	900	1500	2500	3500	5000	9000	15,000	20,000	35,000

TABLE 16

Maximum Recommended Water Flow in GPM Through Standard Pipes @ 25 - 50 PSIG

0.5"	0.75"	1"	1.25"	1.5"	2.0"	2.5"	3.0"	4.0"	5.0"	6.0"	8.0"
8	14	23	36	50	78	120	180	300	450	600	1200

TABLE 17

Approx. Equiv. Length of Sch. 40 Pipe in Feet with Same Pressure Drop as a Typical Fitting or Valve

NOM. PIPE SIZE INS.	GLOBE VALVE	GATE VALVE	SWING[1] CHECK VALVE	90° STD. ELBOW	TEE	TEE	90° WELDING ELBOW SHORT	90° WELDING ELBOW LONG
1/2	18	1	7	1.5	1.0	3.1	-	-
3/4	23	1	9	2.0	1.5	4.2	-	-
1	30	1.2	12	2.6	1.8	5.2	-	-
1/-1/2	46	1.8	18	4.0	2.7	8	2.0	1.6
2	59	2.3	23	5.0	3.5	10.5	3.0	2.0
2-1/2	70	2.7	28	6.2	4.1	12.4	3.3	2.6
3	2	3.3	35	7.8	5.2	15.4	4.1	3.2
4	2	4.5	45	10.0	6.8	20.0	5.5	4.1
5	2	5.6	56	12.5	8.5	25.0	6.7	5.0
6	2	6.8	[2]	15.0	10.0	30.0	8.0	6.1
8	2	9.0	[2]	20.0	13.0	40.0	11.0	8.0

NOTES: [1] A typical swing check valve requires 1/2 PSIG to open.
[2] Too much pressure drop for most applications.

TABLE 18

Useful Electrical Information

NEMA Enclosures

Type		Type	
1	General Purpose (Indoor)	**7**	Class I, Group A, B, C or D Hazardous Locations, Air-Break (Indoor)
2	Dripproof (Indoor)	**8**	Class I, Group A, B, C or D Hazardous Locations, Oil-Immersed (Indoor)
3	Dusttight, Raintight, Sleet tight (Outdoor)	**9**	Class II, Group E, F or G Hazardous Locations, Air-Break (Indoor)
3R	Rainproof, Sleet Resistant (Outdoor)	**10**	Mines
3S	Dusttight, Raintight, Sleetproof (Outdoor)	**11**	Corrosion-Resistant and Dripproof, Oil-Immersed (Indoor)
4	Watertight, Dusttight, Corrosion Resistant (Indoor or Outdoor)	**12**	Industrial use, Dusttight and Driptight (Indoor)
4X	Watertight, Dusttight, Corrosion Resistant (Indoor or Outdoor)	**13**	Oiltight and Dusttight (Indoor)
5	Dusttight - Indoor		
6	Submersible, Watertight, Dusttight, Sleet Resistant (Indoor or Outdoor)		

TABLE 19

Formulas

1. Volts = Amps x Ohms
2. HP = $\frac{\text{Watts} \times \text{Efficiency}}{746}$
3. 1-phase Kw = $\frac{\text{Volts} \times \text{Amps} \times \text{Power Factor}}{1000}$
4. 3-phase Kw = $\frac{1.732 \times \text{Volts} \times \text{Amps} \times \text{Power Factor}}{1000}$
5. Torque (Lb./Ft.) = $\frac{\text{HP} \times 5250}{\text{RPM}}$
6. Pump HP = $\frac{\text{GPM} \times \text{Ft. Head} \times \text{Sp. Gr.}}{3960 \times \text{Pump Efficiency}}$
7. Fan/Blower HP = $\frac{\text{CFM} \times \text{Pressure in PSIG}}{33000 \times \text{Efficiency}}$

TABLE 20

Motor Full Load Amps (Approx.)

SINGLE PHASE MOTORS HP	115V	230V
1/6	4.2	2.1
1/4	5.6	2.8
1/3	7.2	3.6
1/2	9.8	4.9
3/4	13.6	6.8
1	15	7.5
1-1/2	20	10
2	24	12
3	34	17
5	56	28

TABLE 21

THREE PHASE MOTORS HP	200V	230V	460V	575V
1/2	2.2	2	1	.8
3/4	3.2	2.8	1.4	1.1
1	4.1	3.6	1.8	1.4
1-1/2	6	5.2	2.6	2.1
2	7.8	6.8	3.4	2.7
3	11	9.6	4.8	3.8
5	17	15	7.5	6
7-1/2	25	22	11	9
10	32	28	14	11
15	48	42	21	17
20	62	54	27	22
25	78	68	34	27
30	92	80	40	32
40	120	104	52	41
50	150	130	65	52
60	177	154	77	62
75	221	192	96	77
100	285	248	124	100
AMPS/HP LARGER SIZES	2.8	2.4	1.2	1.0

TABLE 22

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