KAESER COMPRESSORS®

Compressed Air System Installation Guide

Layout Considerations for a Reliable, Energy Efficient, and Safe Compressed Air System

By Kaeser's Compressed Air and Engineering Experts

About the Authors

This e-book was written for you by Kaeser's team of engineers and compressed air experts.

At Kaeser, we believe that the more you know about operating air systems, the more you'll get out of them. That's why we are committed to offering you the most current information you need to wisely install, operate, and maintain your compressed air system.

Our goal is to help you install the most successful compressed air system possible. The tips, guidelines, and warnings included in this e-book are meant to do just that.

While the information included in this e-book is comprehensive, we recognize that each system and application is unique. Applying the principles you read here is an excellent place to start. For the best in system optimization that is tailored to your needs, contact us for additional support.

Throughout the e-book, there are boxes with efficiency tips and additional resources. The links included in those will take you directly to more information that our engineers and compressed air experts have specifically selected to further assist with your compressed air system.

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Compressors Product Manager

Tip:

Look for these boxes throughout the e-book for additional tips.

More Resources:

Additional resources are in these boxes. Want to hear the latest Kaeser news? Visit us.kaeser.com/connect

Table of Contents

Introduction

Too often, compressed air systems are not given the same level of consideration as other plant equipment when planning a new installation. If you are planning a new facility, you have the opportunity to design an optimal compressed air system installation. Those who are upgrading an existing compressed air system often face many physical restrictions requiring creative solutions. In either case, whether you are modifying a compressed air system or planning a new system, the information contained in this e-book will assist you in identifying the best configuration possible and getting the best possible performance from your compressed air system. Take advantage of the opportunity! You will be rewarded with a more energy efficient system that is easier to maintain and delivers the quality and quantity of air you need.

For the purposes of this e-book, it is assumed that you have identified the three critical parameters for any compressed air system: (1) pressure, (2) capacity, and (3) air quality. These must be determined in order to properly size and select compressors, dryers, filters, piping, etc. If not, this e-book contains some basic example applications and guidelines as to what level of air treatment is needed for each. We strongly recommend that you consult a compressed air specialist to accurately measure these parameters.

> "...the three critical parameters for any compressed air system: (1) pressure, (2) capacity, and (3) air quality...

Most of this e-book is devoted to planning the layout and installation of your compressed air system. Emphasis is placed on providing you with an efficient, low maintenance system. It will also assist you in establishing compliance with safety and environmental regulations.

This e-book should be used as a supplement to the service manuals provided with your Kaeser compressed air equipment. These contain installation information pertaining to the specific model purchased.

Diagrams in this e-book are presented only as examples. They are not necessarily the best way of installing your particular system. If you need assistance, consult your Kaeser representative for expertise in installing compressed air systems.

More Resources:

Contact your local authorized Kaeser Representative for more information.

Location

{ *Placement Affects Performance*

Location: General Tips

Receiving your shipment is one of the first considerations in preparing for your new installation. Freight damage happens. It is important that you protect yourself. Be sure to thoroughly inspect your commercial freight before you sign for it. Our freight tips video has everything you need to know to successfully receive any kind of commercial shipment.

In summary:

- Don't sign until you have inspected
- Check the Tip n' Tell indicators
- Open the packaging
- Look for signs of replaced packaging

Our rotary screw compressors also ship with instructions attached to the packaging. Carefully read those for additional information.

Location: General Tips

Extreme temperatures (hot or cold), moisture, and airborne contaminants affect compressed air equipment's durability and air quality. For these reasons, we recommend installing compressed air equipment indoors. Because compressor noise is often cited as a reason to place compressors outdoors, Kaeser compressors come standard with full enclosures designed to significantly reduce noise levels.

Sometimes, however, the ambient conditions inside a facility may be worse than outside. Excessive heat, dirt/dust, corrosive chemicals and other conditions may warrant outdoor installation. If outdoor installation is necessary, the compressed air equipment should at least be under a roof.

> Excessive heat, dirt/dust, corrosive chemicals and other conditions may warrant outdoor installation...

Location: Floor

No special foundation or anchoring is necessary for rotary screw compressors. The compressor should be placed on a level surface able to withstand the combined load of the compressor and the equipment used to move it into place.

Location: Access

The entrance to the compressor room must be large enough to accommodate both the compressed air equipment and the equipment used to move it into place (such as a forklift, crane, or pallet truck). The space designated for the compressed air equipment must provide enough clearance around it to:

- Open maintenance doors and access panels
- Remove and replace components
- Install piping and air treatment equipment
- Provide adequate ventilation

Kaeser has designed its compressors so that internal components are easily accessible. Do not defeat this feature by blocking maintenance doors. Your service manual contains dimensional drawings for your specific model.

More Resources:

Need a service manual? Contact your local Kaeser representative.

Introduction
Location
Ventilation
Water-cooling
Electrical Supply
Correct Air Storage
Efficiency Enhancing Equipment
Air Purity & Treatment
Condensate Management
Piping
Preventive Maintenance
Leaks
Safety Advisories
Additional Resources
Appendices

Location: Environmental Considerations

Temperature: Be mindful of how the system temperature impacts equipment operation and make sure temperatures remain within the manufacturer's stated temperature ranges. For air treatment components, the dryer correction factors must be applied.

Low temperatures may impede the proper flow of some types of lubricant and promote undesirable moisture condensation in control lines and other components. For lower ambient temperature applications, Kaeser offers options to protect the compressor including cabinet heaters and electric heat trace tape.

High ambient temperatures, on the other hand, often result in reduced lubricant life. They may also result in excessively high approach temperatures, which would hinder the cooling and condensation efficiency in the aftercooler and subsequent air treatment equipment. (See Ventilation Section for more information.)

Location: Environmental Considerations

Ambient Particulate: The Kaeser cabinet and pre-filter protect the compressor interior from most dirt and dust. In high dust areas it will be necessary to clean and replace the filters more often. In high dust applications, such as flour, cement, or talc production, an additional high dust filtration option may be needed.

Moisture: If possible, avoid exposing the compressor to excessive moisture (from humidity, rain, steam vents, dryer vents, etc.) in the ambient air. Excessive moisture can lead to electrical problems in the motor or with any electronics such as the main compressor controller, promotes rust development on the cabinet and interior components, and hinders lubrication. Kaeser offers a number of options to allow compressor operation in wet/moist conditions, including motor winding heaters, and rain hoods.

Corrosives: Isolate the compressor from corrosive agents such as salt spray, ammonia, chlorine, and other chemicals. These may degrade the protective finishes on the cabinet, attack and erode internal components, and contaminate lubricants and filters.

Introduction
Location
Ventilation
Water-cooling
Electrical Supply
Correct Air Storage
Efficiency Enhancing Equipment
Air Purity & Treatment
Condensate Management
Piping
Preventive Maintenance
Leaks
Safety Advisories
Additional Resources
Appendices

Location: Optional Equipment

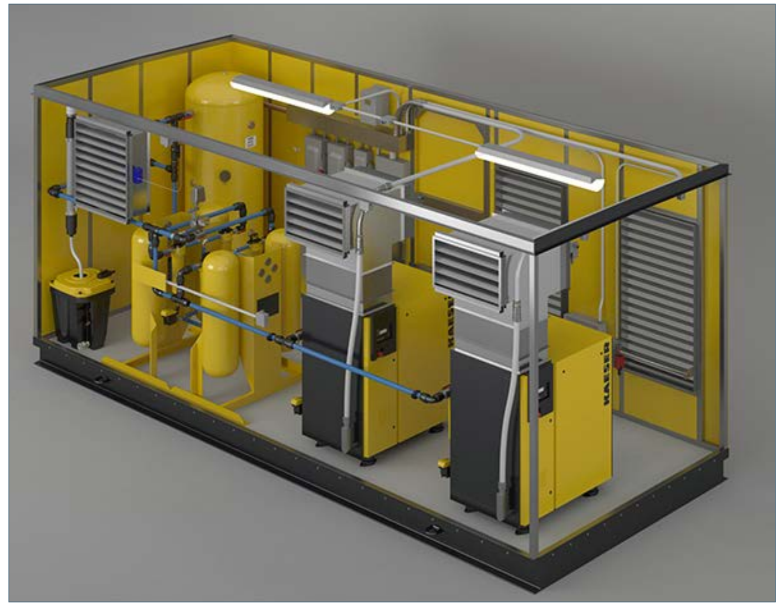
Rain hoods: As stated, a compressor should normally be installed indoors. If it must be installed outside, it should have overhead protection from rain and snow. If no shelter is provided or if wind driven rain or snow can reach the compressor, rain hoods must be added to both air inlet and exhaust ends of the compressor cabinet exterior. These are available from Kaeser factory installed. Rain hoods may be insufficient in the case of high wind and rain, therefore a shed may be better suited than a covered overhang.

Motor winding heaters: In very wet or humid environments, a motor winding heater will prevent moisture from collecting and condensing within the compressor's motor windings when the motor is off. Motor winding heaters shut off during operation. They are available from Kaeser factory installed.

Compressor here shown with optional rain hoods and cover for compressor controller that protect from the elements and water ingress.

Location: Optional Equipment

Cabinet heaters: If the ambient temperature of inlet air ever drops below 40° F (but is still above 25° F), a cabinet heater must be installed. Cabinet heaters are designed to maintain the cabinet temperature at 40° F. This ensures proper oil flow during start-up and inhibits moisture collecting inside the cabinet. It is thermostatically controlled to shut off once the minimum operating temperature within the cabinet is reached. They are available from Kaeser factory installed or as a retrofit kit.



Exhaust air re-circulation systems: If your compressor is located such that it will be exposed to temperatures between 5° and 25 °F, Kaeser suggests installing an exhaust re-circulation system. These are designed to duct compressor exhaust air back to the air inlet in order to maintain the minimum operating temperature and prevent moisture freezing in the compressor components. Since compressors produce approximately 2550 Btu/hour per horsepower, the compressor is an excellent source of heating air.

Keep in mind that, at cold temperatures, aftercoolers and control lines may freeze even when the compressor is running and the airend reaches the proper operating temperature. A combination of cabinet heater, electric heat-trace tape, and duct re-circulation may be necessary.

High ambient temperature option: Compressor components can be special ordered to operate in temperatures up to 126 °F. These are not available as a retrofit.

Tip:

Although Kaeser can assist in sizing and designing duct-work, we recommend that you contact your local heating and air conditioning contractor for installation.

Introduction
Location
Ventilation
Water-cooling
Electrical Supply
Correct Air Storage
Efficiency Enhancing Equipment
Air Purity & Treatment
Condensate Management
Piping
Preventive Maintenance
Leaks
Safety Advisories
Additional Resources
Appendices

Location: Other Options

As an alternative, it's also possible to install the compressed air system in a custom built enclosure. This can save time and money on installation since no special building permits are needed.

More Resources:

Click here to see a flipbook with more examples of custom built enclosures.

Introduction
Location
Ventilation
Water-cooling
Electrical Supply
Correct Air Storage
Efficiency Enhancing Equipment
Air Purity & Treatment
Condensate Management
Piping
Preventive Maintenance
Leaks
Safety Advisories
Additional Resources
Appendices

Ventilation

Options to Ensure Proper Cooling and Equipment Longevity

Ventilation

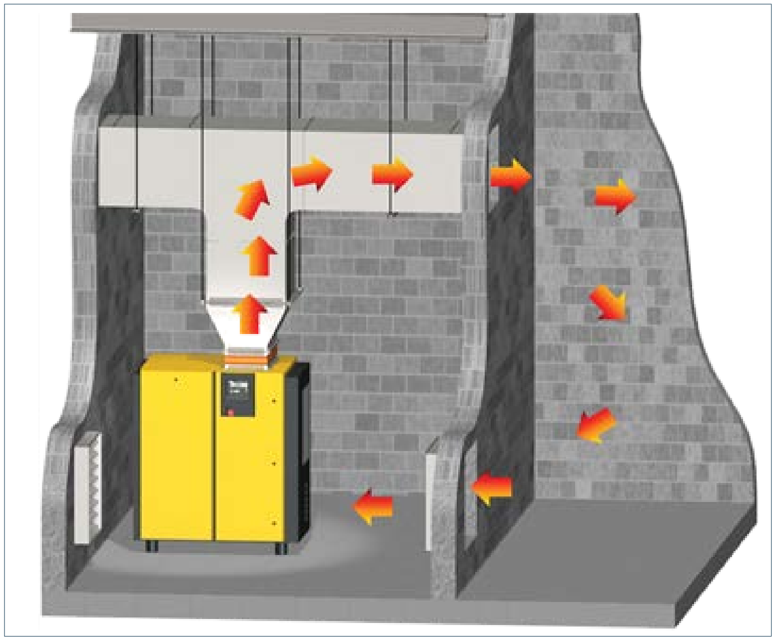
Air compressors, refrigerated dryers, and heated desiccant dryers produce large volumes of heat. Compressors produce approximately 2550 Btu per hp. If not removed from the compressor room, the ambient temperature will increase, reducing system efficiency and operator comfort. There are various ways to provide ventilation. Your choice should consider the following factors:

- Conditions in the compressor room
- Conditions outside
- Whether you intend to recover heat from the compressor

This figure shows how ducting can be installed to recover the heat from the compressor to warm the room during the winter and vent the warm air outside during the summer months, for added energy savings.

The fresh air inlet needs to be sized appropriately for the equipment to avoid creating negative pressure in the room. Thermostatically controlled louvers should be installed at the source of inlet air and where exhaust is discharged to protect units from extreme cold when not running or running under low load.

> Compressors produce approximately 2550 Btu per hp...



The diagrams on the following pages provide some basic hints for proper ventilation.

Tip:

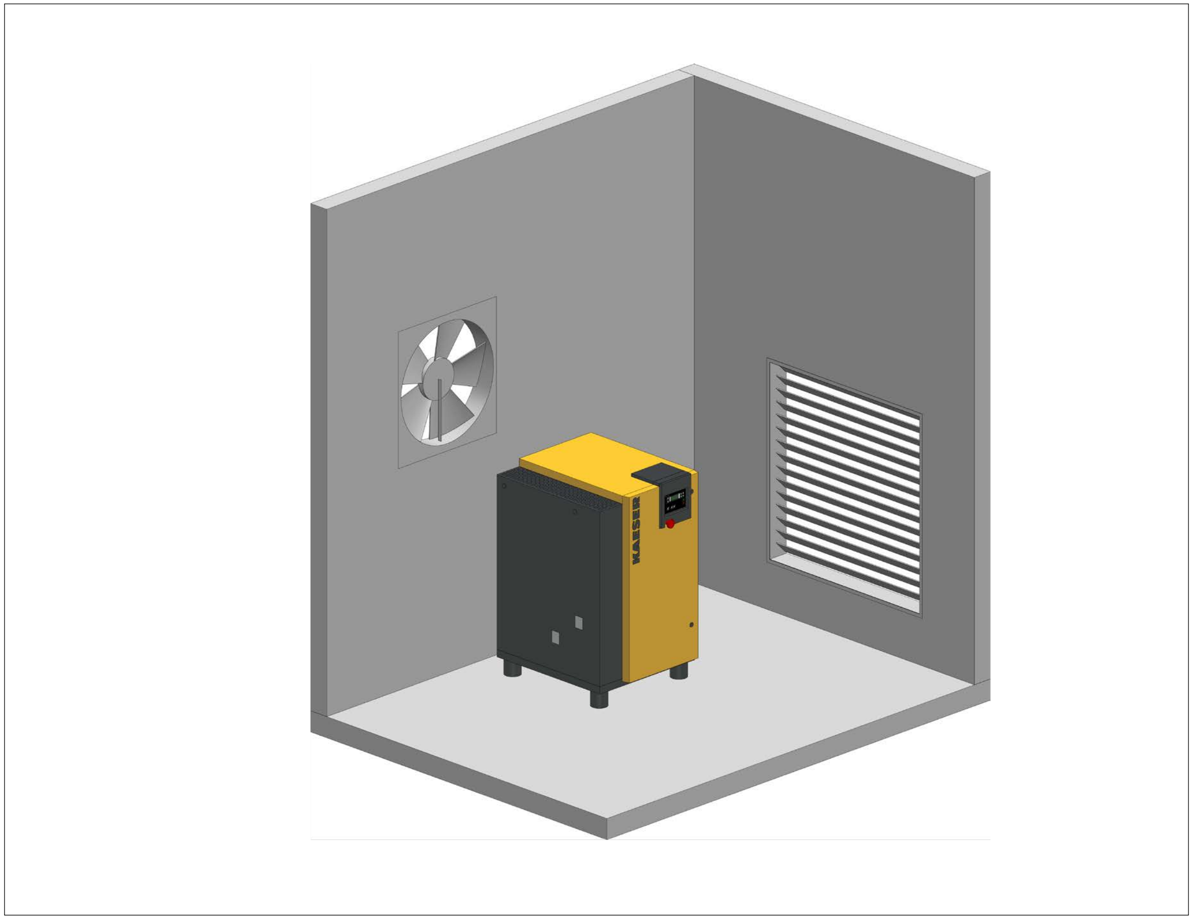
Detailed information about the proper ventilation for your compressor is in the Technical Specifications and Installation sections of the Service Manual.

More Resources:

Click here for more information on how to integrate heat recovery into your compressed air installation.

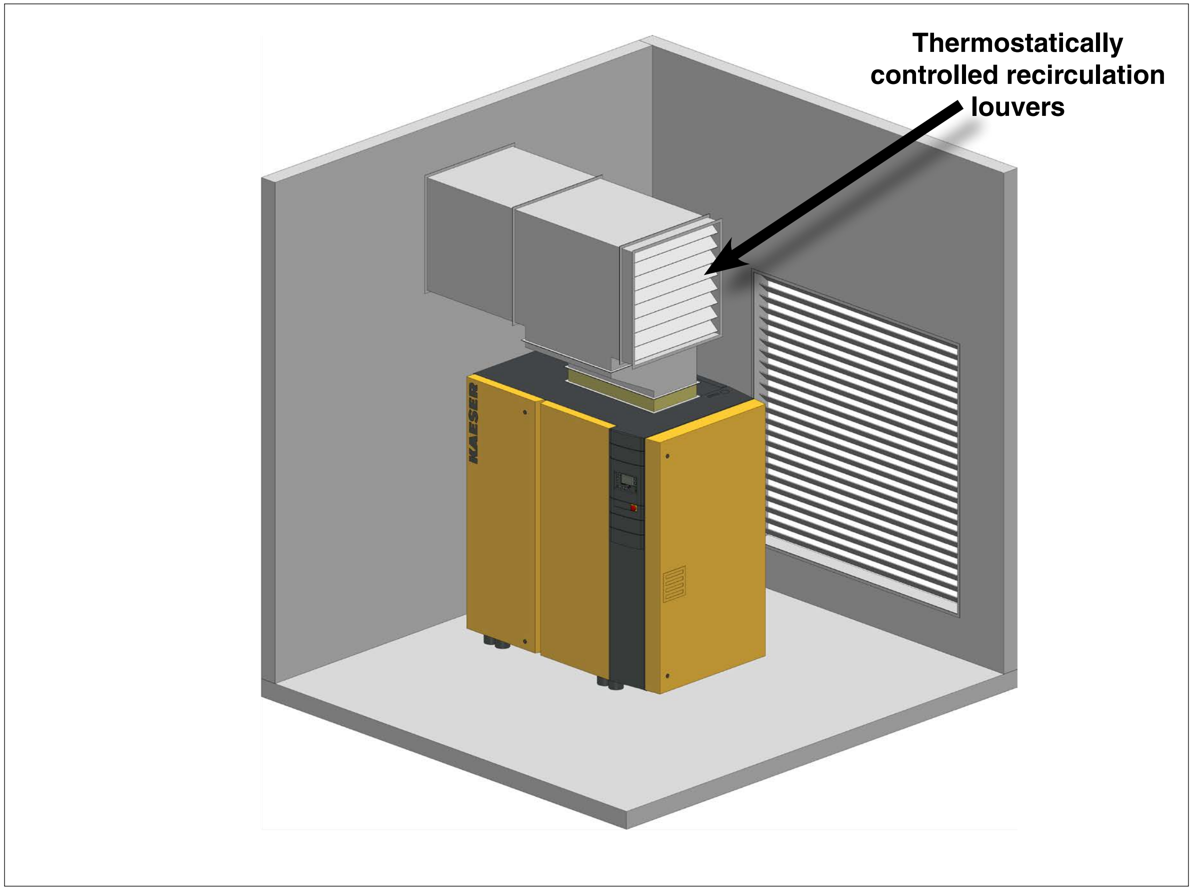
Ventilation

For small compressors up to 15 hp, louvered inlets and outlets are often sufficient, as shown here. An exhaust fan is also recommended. Depending on the location, thermostatically controlled inlet louvers are recommended.



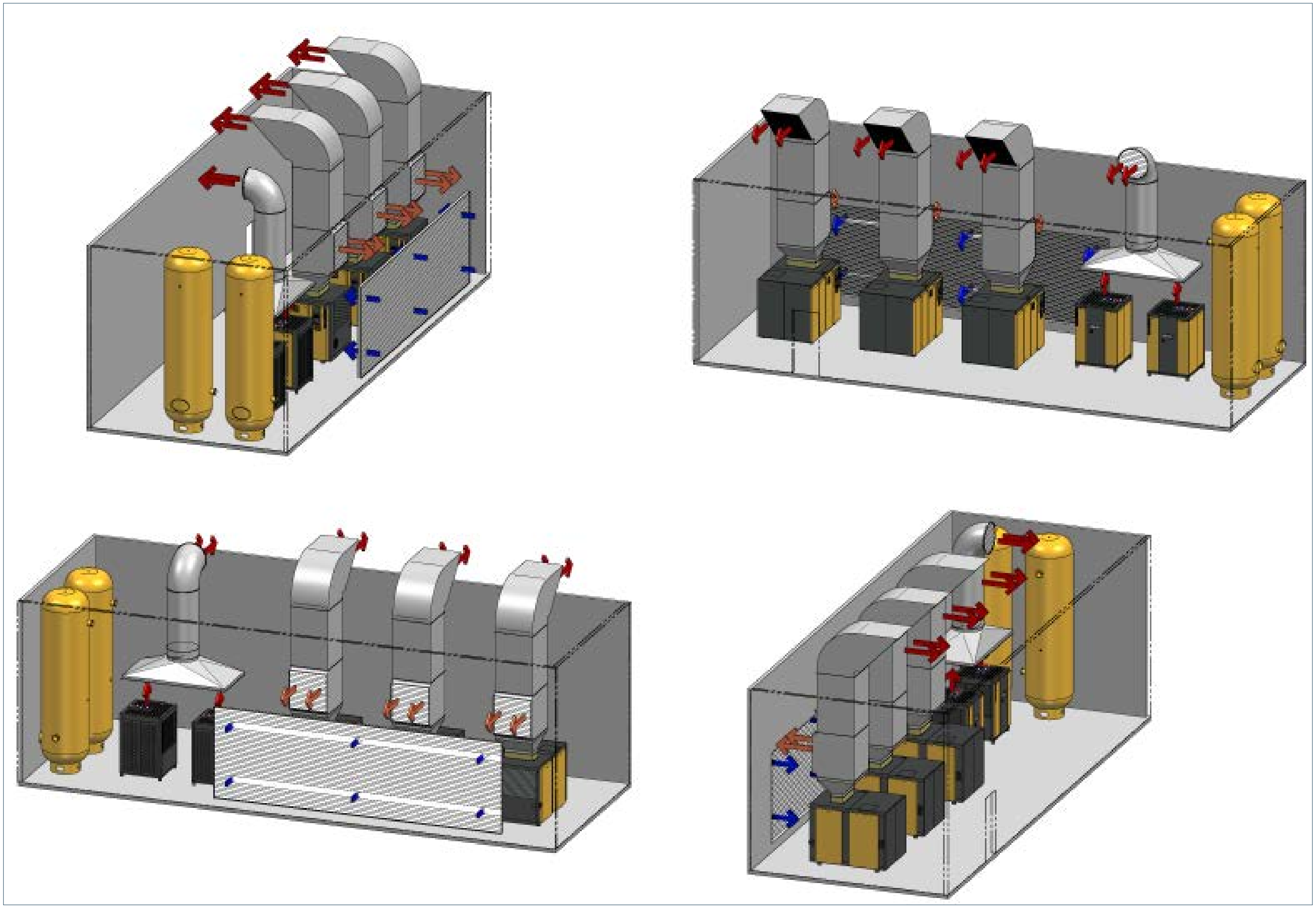
Ventilation

Forced ventilation is recommended for larger compressors above 20 hp as shown here. Depending on the location, thermostatically controlled inlet louvers are also recommended.



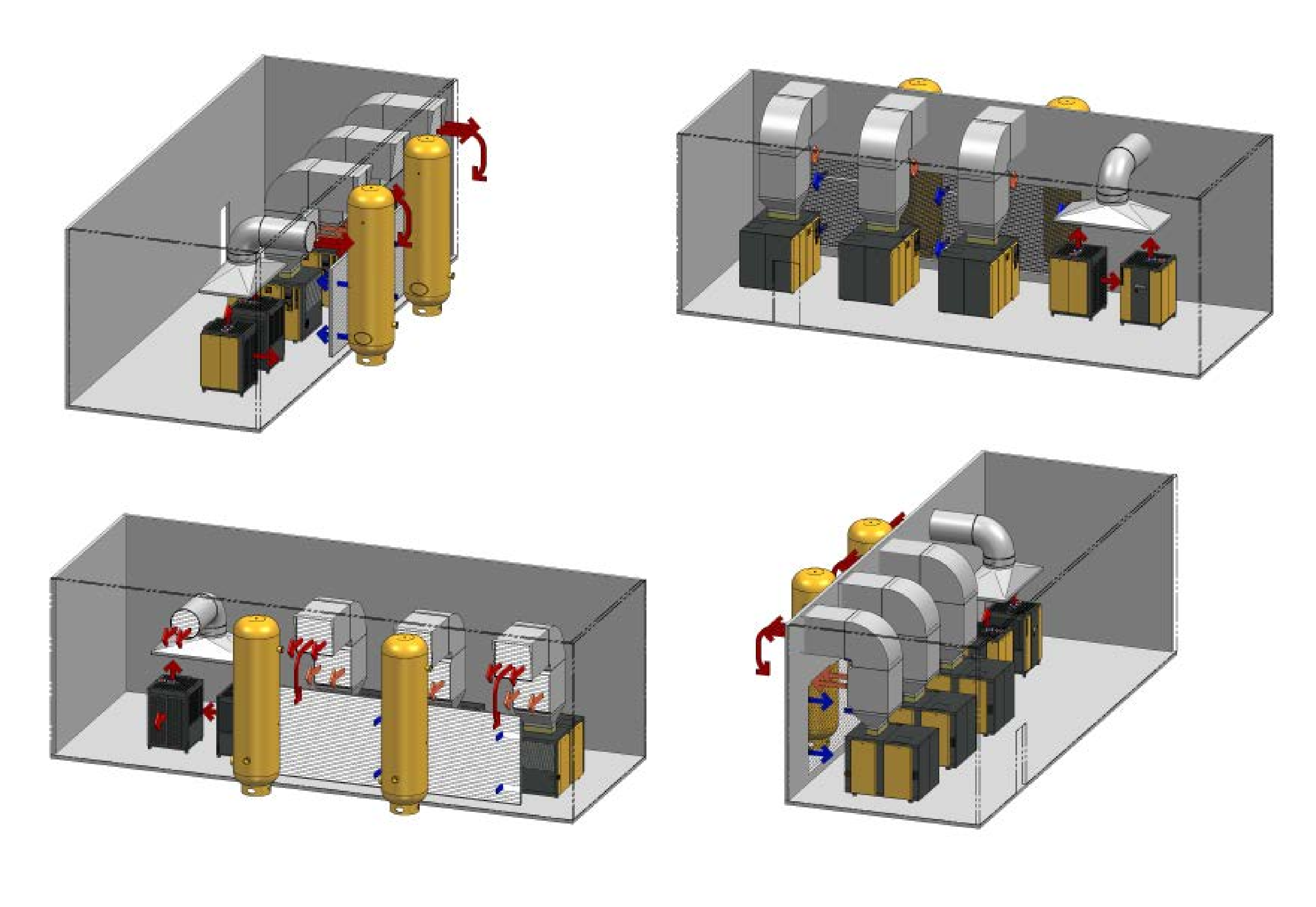
Ventilation

The figure below shows a proper arrangement of multiple compressors, dryers, air receiver tanks, and ventilation:



Ventilation

Do not place equipment so that exhaust from a compressor blows onto an air receiver, dryer, or into the air inlet of another compressor as shown here:



Water-cooling

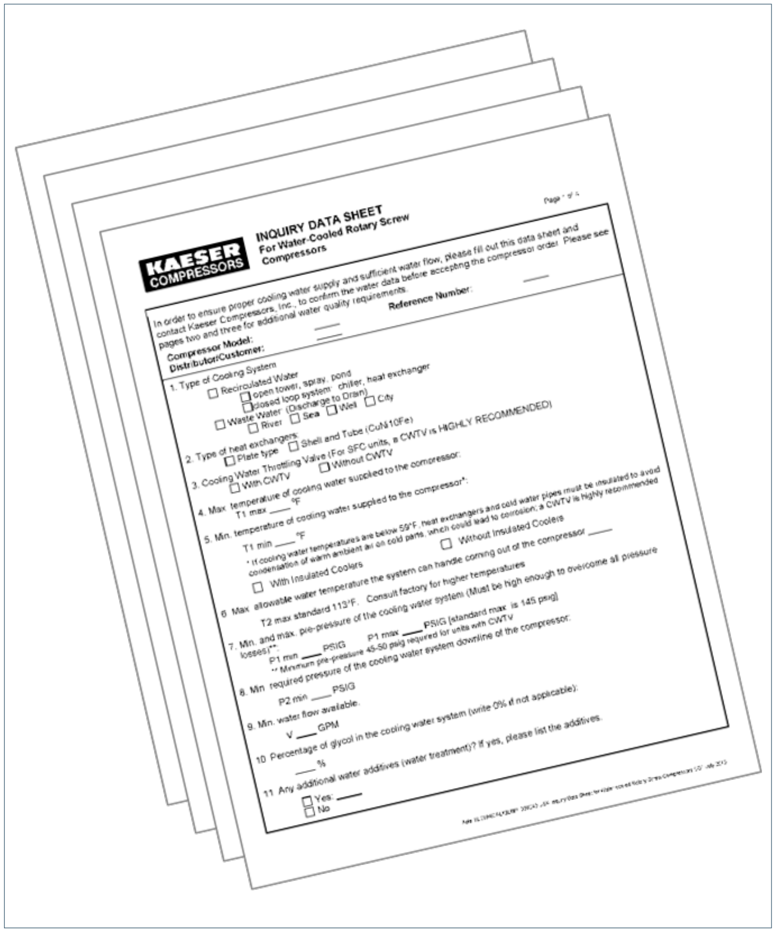
Important Additional Considerations

Water-cooling

Through air-cooled compressors are the norm, water-cooling is an option (40 hp and above for Kaeser). Customers who plan to install water-cooled compressors will receive water data forms to complete, and in addition to an adequate supply of suitable water and drainage, special pumps and plumbing, as well as filtration, water treatment, and chilling equipment may be required depending on the cooling water source. The data collected on this form provides Kaeser's application engineers with detailed information about the source and characteristics of the water to be used, and enables them to select the proper cooling water piping and heat exchangers for each application.

However, water-cooling introduces several additional considerations, which can have significant impact on system design, installation, and operating costs. For example, the costs of treating and chilling the cooling water.

> Customers who plan to install water-cooled compressors will receive water data forms...


KAESER COMPRESSORS
INQUIRY DATA SHEET
For Water-Cooled Rotary Screw Compressors

Tip:

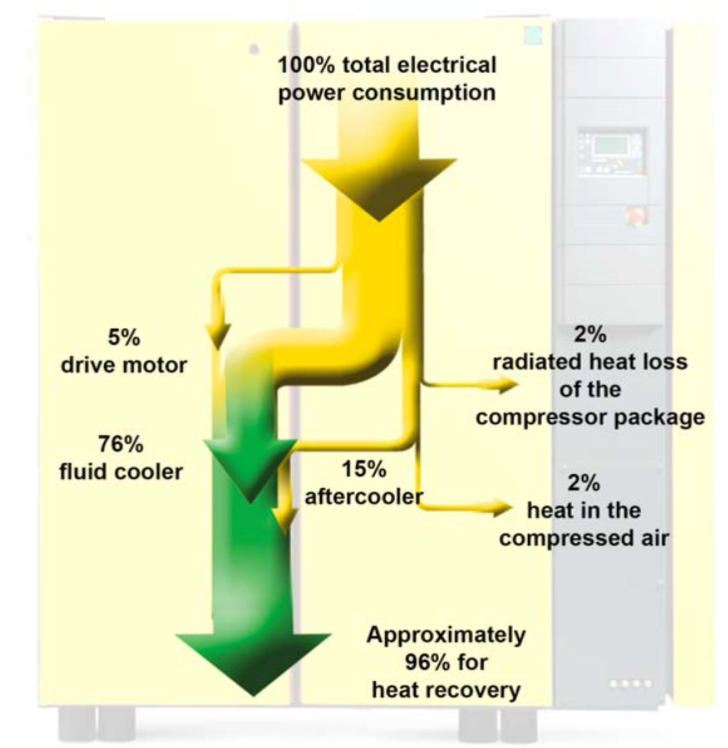
Contact your local Kaeser representative for assistance with water-cooled systems.

Introduction
Location
Ventilation
Water-cooling
Electrical Supply
Correct Air Storage
Efficiency Enhancing Equipment
Air Purity & Treatment
Condensate Management
Piping
Preventive Maintenance
Leaks
Safety Advisories
Additional Resources
Appendices

Water-cooling: Heat Recovery

Water-cooled applications also give extra opportunities to incorporate heat recovery for additional energy savings. 100% of the electrical energy used by an industrial air compressor is converted into heat. 96% of this heat can be recovered (the balance remains in the compressed air or radiated from the compressor into the immediate surroundings).

For water-cooled compressors, discharged cooling water is connected directly to a continuous process heating application for year-round energy savings—such as a heating boiler's return circuit. Other applications include heating process fluids, food and beverage products, or even heating the water for showers and bathrooms.



> 100% of the electrical energy used by anindustrial air compressor is converted into heat. 96% of this heat can be recovered...

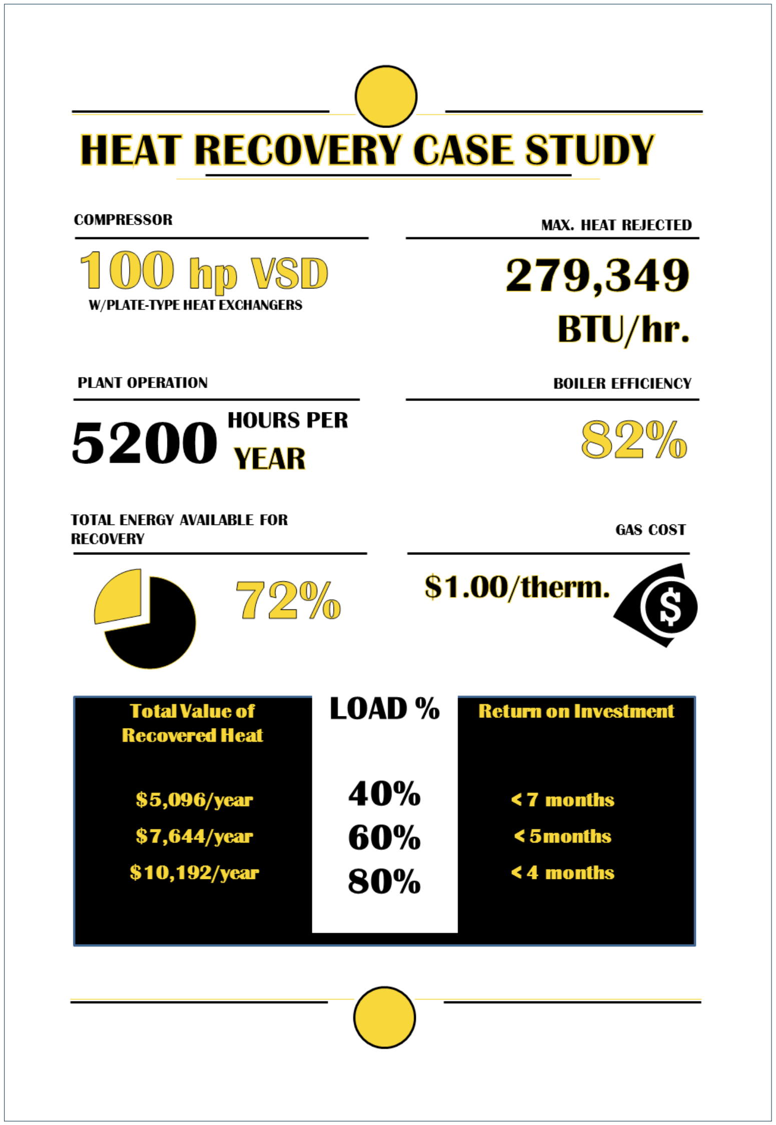
More Resources:

Click here to download a complimentary whitepaper for more information on the energy savings potential of heat recovery

Water-cooling: Heat Recovery Example

The following shows a real life example of the energy saving potential of integrating heat recovery into your plant operations.

Keep in mind that your energy savings will depend on the type of energy source you have (electricity, heating oil, propane, natural gas, coal), as well as the actual heat that is available for recovery from the compressors.



Total Value of Recovered Heat	LOAD %	Return on Investment
$5,096/year	40%	< 7 months
$7,644/year	60%	< 5months
$10,192/year	80%	< 4 months

Introduction
Location
Ventilation
Water-cooling
Electrical Supply
Correct Air Storage
Efficiency Enhancing Equipment
Air Purity & Treatment
Condensate Management
Piping
Preventive Maintenance
Leaks
Safety Advisories
Additional Resources
Appendices

Electrical Supply

Important Warnings to Follow

Electrical Supply

Before installing the compressor, check to ensure that your electrical service voltage matches the voltage on the compressor nameplate (located inside the electrical cabinet). Whether your compressor is a dual or tri-voltage model, ensure it is internally wired for the proper voltage.

Actual operating voltage must be within +/- 10% of compressor nameplate voltage. Damage or failures due directly or indirectly to insufficient or excessive voltage may not be covered under warranty. Consequently, Kaeser does not recommend operating a 230-volt system on a 208-volt circuit, for example.

Kaeser recommends that each compressor have its own dedicated electrical circuit and disconnect panel. This makes it possible to lock out and tag out an individual piece of equipment without having to shut down other equipment that may be on the same panel. Electrically operated air treatment equipment should be powered through a separate circuit.

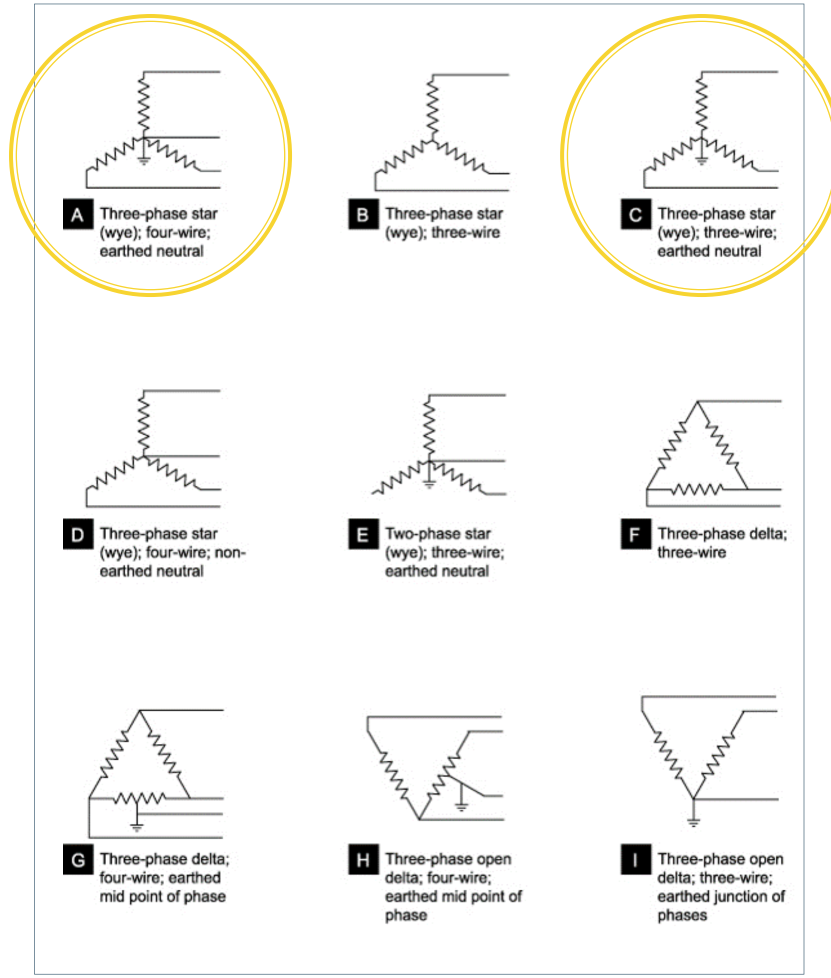
Electrical planning should include wiring for a master controller (multiple unit control device) if it is to be installed.

The compressor should be properly grounded. Install an appropriately sized fuse or circuit breaker between the compressor and main electric service.

Electrical Supply

For variable speed drive units, make sure that the power supply transformer has a symmetrical, three-phase supply. In a symmetrical three-phase supply, the phase angles and voltage are all the same.

Kaeser's Sigma Frequency Control (SFC) units require a symmetrical power supply transform with a wye configuration output. The circled configurations indicate the two acceptable options for SFC units.



Safe Electrical Supply

Never use air piping or electrical conduit as a means of grounding.

All wiring and electrical connections must be performed by a qualified electrician in accordance with NEC and local electrical codes. Supply conductors must be properly sized in accordance with all applicable national and local codes.

The electrical service disconnect should be within sight of the compressor and have an easily recognizable lock-out tag. Lock-out Tag-out procedures must be followed. Check the tightness of all connections internal to the package.

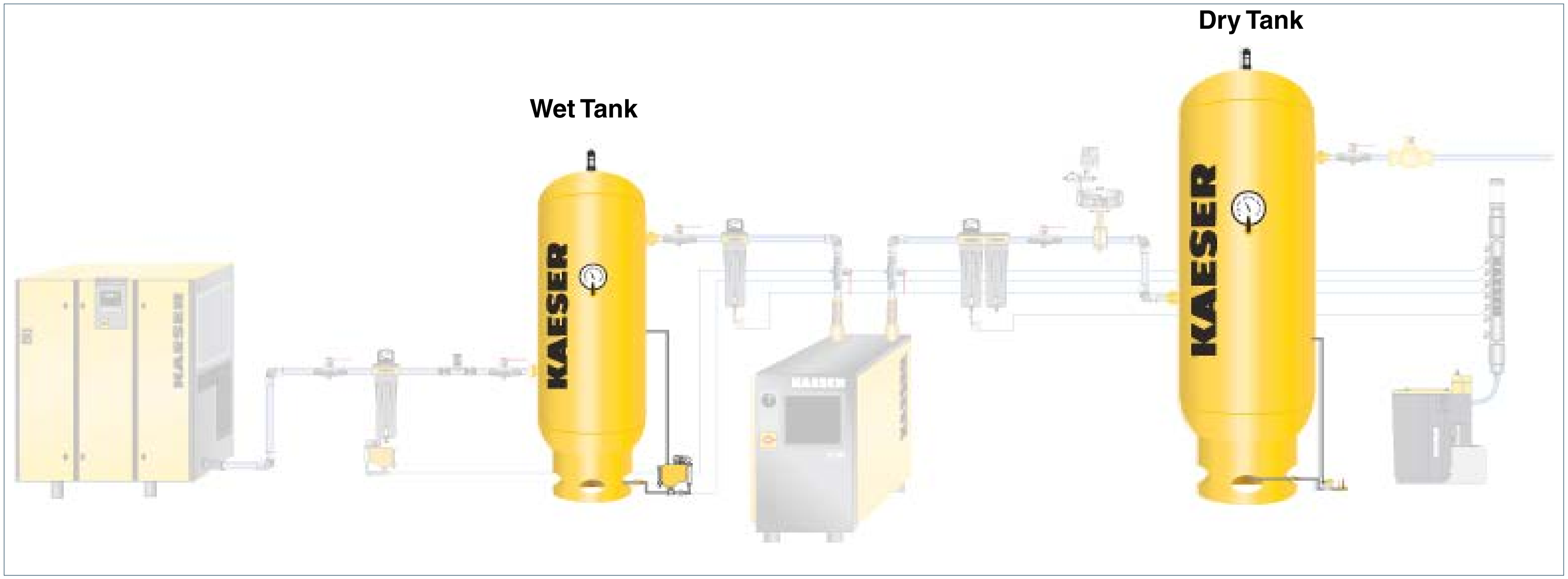
Correct Air Storage

Utilizing Wet and Dry Tanks

Correct Air Storage

To optimize performance, Kaeser suggests installing two receivers. A "wet tank" provides a steady source of controlled air, additional air-cooling, and moisture separation. A "dry tank" stores clean dry air needed for demand surges.

The "wet" tank should be installed after the compressor and will remove much of the moisture from your compressed air. By providing a stable volume of air, this receiver will also prevent excessive compressor cycling. This receiver also provides some protection for your downstream components from any oil slugs discharged from a malfunctioning compressor. The wet tank should be sized accordingly: one to three gallons per compressor(s) cfm at full load.



Correct Air Storage

The “dry” tank should be installed downstream of all air treatment components. This receiver is the main storage reservoir for your compressed air system and should be sized appropriately. Kaeser suggests providing between three and five gallons per cfm at full load.

If a master controller is used, the pressure sensors should be attached to the “dry” receiver.

If your system includes a Kaeser Flow Controller (KFC), it should be installed immediately downstream of the “dry” tank. The KFC is a precision instrument that will stabilize pressure downstream at the desired level, reducing costly leaks and artificial demand.

“If a master controller is used, the pressure sensors should be attached to the “dry” receiver...

Tip:

Tank Sizing Guidelines:
Wet tanks: 1- 3 gal/cfm
Dry tanks: 3 - 5gal/cfm

More Resources:

Use our calculator for help estimating with sizing your air receiver.

Correct Air Storage

Use the following points as guidelines for installing "wet" or "dry" receiver tanks. Each receiver tank should be:

- Piped in low and piped out high
- ASME approved pressure vessels marked with the maximum working pressure rating. A receiver's maximum pressure rating must meet or exceed the maximum system pressure.
- Fitted with a good quality pressure gauge (Kaeser recommends large liquid filled gauges for accuracy).
- Fitted with a safety relief valve sized to handle the system's pressure and total flow with a relieving pressure lower than the rated pressure of the tank.
- Fitted with a dependable drain trap at the lowest point.
- Fitted with an isolation valve at both the inlet and outlet ports.
- Installed in a cool area. Do not place receivers in path of compressor or dryer exhaust flow. Doing so will re-heat the compressed air, reduce moisture separation, and possibly reduce the effectiveness of dryers and filters.

Some applications with heavy intermittent demands should have their own tanks as close to the point of use as possible.

More Resources:

See our blog post on Receiver Tanks for Small Compressed Air Systems for more tips.

Efficiency Enhancing Equipment

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Optimizing Your System

Efficiency Enhancing Equipment: Master Controllers

Master Controllers control multiple compressors more efficiently while maintaining a steady supply of compressed air. They can even rotate like-sized machines to equalize service hours.

A master controller's computing capacity enables it to rapidly recognize changes in system air pressure and react to prevent pressure drop. Unlike cascading pressure control methods used in many older sequencers, advanced master controllers are adaptive and learn the system over time to ensure a reliable supply of air flow at all times.

Tip:

Place the air pressure sensor for the master controller as far down stream as possible to accurately supply the demand pressure. The "dry" receiver is an excellent choice.

Introduction
Location
Ventilation
Water-cooling
Electrical Supply
Correct Air Storage
Efficiency Enhancing Equipment
Air Purity & Treatment
Condensate Management
Piping
Preventive Maintenance
Leaks
Safety Advisories
Additional Resources
Appendices

Efficiency Enhancing Equipment: Master Controllers

Benefits of Master Controllers:

Save Energy:

- Run compressors less
- Run compressors on lower pressure
- Reduce air lost to leaks
- Lower artificial demand

Reduced Maintenance Costs:

- Less cycling and switching = longer valve life
- Fewer motor starts = longer motor life
- Balanced hours and fewer PM visits

Improve Operations with More Stable Pressure:

- Improve production equipment performance
- Less downtime due to pressure alarms
- Less scrap and product quality problems
- Learn system operation and select most efficient compressors

More Resources:

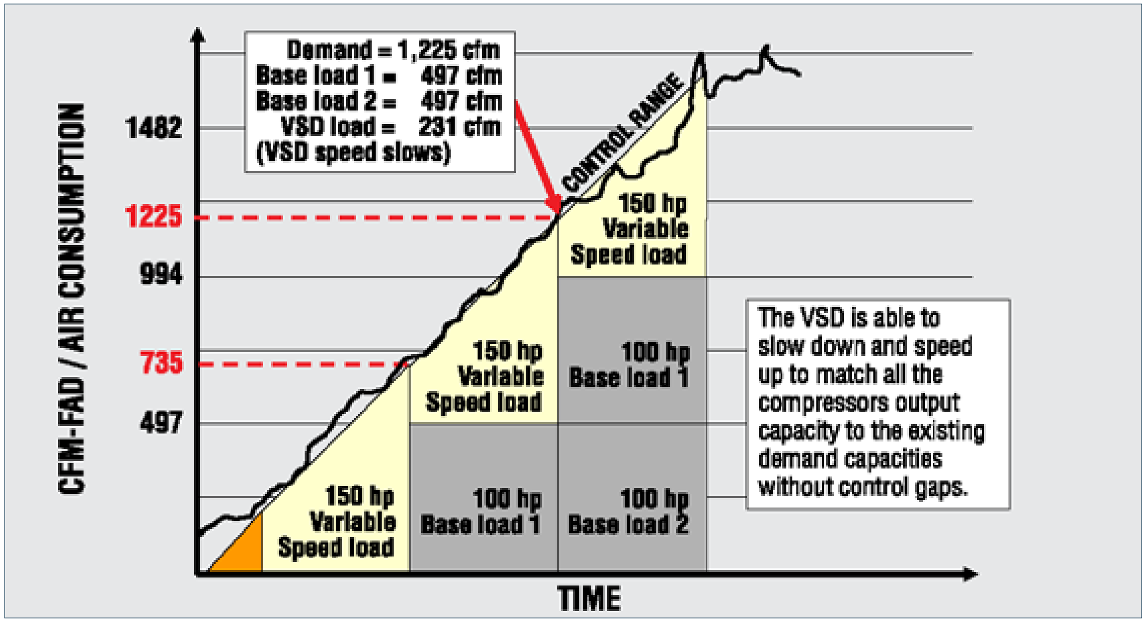
Download our whitepaper "Using Master Controls to Improve the Performance and Efficiency of Industrial AIr Compressors" here.

Efficiency Enhancing Equipment: Master Controllers

Master controllers can also be effective when used in conjunction with a variable speed drive compressor and multiple smaller fixed speed compressors. However, care must be taken in sizing the system to avoid control gap, which causes pressure fluctuations and energy inefficiencies.

Control gaps are flaws in the system design that occur when the control range of the variable speed compressor is not considered. The majority of the time, this happens because a variable speed drive compressor is selected that is the same size or smaller than the fixed speed machines in the system.

This graph shows a system designed to avoid control gap. It can provide a steady operating pressure throughout the flow range of the system since it is properly sized and controlled by a master controller, like Kaeser's Sigma Air Manager (SAM) 4.0.



> Control gaps are flaws in the system design that occur when the control range of the variable speed compressor is not considered...

More Resources:

Download our whitepaper "Applying Variable Speed Compressors in Multiple Compressor Applications" for more information on avoiding control gap.

Efficiency Enhancing Equipment: Master Controllers

Kaeser's Sigma Air Manager (SAM) 4.0 offers complete compressed air system management for industrial plants by tying compressors, blowers, or vacuum units together into a secure Sigma Network. SAM 4.0's powerful 3D*advanced* Control improves pressure stability and system reliability, while the built-in Kaeser Connect web server provides remote monitoring and ongoing energy audit information according to ISO 50001 energy management.

Contact us for help customizing a solution for your system.

More Resources:

See our video on our SAM 4.0 master controller for more information.

Energy Enhancing Equipment: Kaeser Flow Controller

The Kaeser Flow Controller (KFC) reduces or eliminates energy waste in some applications. Energy consumption is managed by the KFC by its capacity to prevent the air system's demand side pressure from rising above the minimum pressure for proper plant (demand side) function. By maintaining very tight control (±0.25 psi is not uncommon) of the demand side pressure, the loss of air through **leaks and unregulated uses can be greatly reduced**. Maintaining the demand side pressure at its optimum level also **eliminates artificial demand** on the supply side (compressors and air treatment) of the air system. They are effective in multi-unit installations that also include air storage and master controllers.

The KFC should be installed in the air distribution system at a point that maximizes the volume of the system upstream of the KFC. Ideally this location would be immediately upstream of the first tee in the air distribution piping. In all cases, the KFC must be installed downstream of the air treatment (filtration, drying, and storage receivers). The KCF must have dry side storage for proper operation.

KFCs work in conjunction with air storage and master controllers. When system pressure drops, air storage can be utilized to meet the demand and bring the pressure back up. A master controller is necessary to make sure the most efficient combination of units is selected at any given time to meet the demand. It can also monitor the number of motor starts and prevent units from turning on and off too frequently.

Multiple KFCs can be used to control air pressure in areas of a plant that have differing operating pressure requirements. This allows for "fine tuning" your energy conservation initiative and maximizing your operating cost savings.

> Maintaining the demand side pressure at its optimum level also eliminates artificial demands on the supply side...

Air Purity and Treatment

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Ensuring Proper Air Quality

Air Purity and Treatment

The proper combination and order of filters, receivers, and dryers will ensure efficient elimination of moisture, oil, and particulates. Filters and dryers are available in various sizes and should be selected based on air flow ratings. Keep in mind that the stated performance of air treatment equipment is based on specific constant conditions and may vary with temperature, pressure, and relative humidity. ISO 8573.1:2010 was developed by ISO (International Organizational for Standardization) as a reference to help facility engineers specify compressed air quality for solid particulates, humidity, and oil. A typical pharmaceutical plant, for example, might have a compressed air specification of ISO Quality Class 1.2.1 as shown outlined in the specifications below.

SOLID PARTICLES / DUST If particles greater than 5µm have been measured, class 0-5 cannot be applied			
Class	0.1 - 0.5 µm	0.5 - 1 µm	1 - 5 µm
0	As specified and more stringent than Class 1		
1	≤ 20,000	≤ 400	≤ 10
2	≤ 400,000	≤ 6000	≤ 100
3	---	≤ 90,000	≤ 1000
4	---	---	≤ 10,000
5	---	---	≤ 100,000
6	0 - ≤ 5 mg/m³		
7	5 - ≤ 10 mg/m³		
8			
9			
X	> 10 mg/m³		

HUMIDITY AND LIQUID WATER		
Class	Pressure Dew Point	
0	As specified and more stringent than Class 1	
1	≤ -70°C	≤ -94°F
2	≤ -40°C	≤ -40°F
3	≤ -20°C	≤ -4°F
4	≤ 3°C	≤ 38°F
5	≤ 7°C	≤ 45°F
6	≤ 10°C	≤ 50°F
	Concentration of liquid water	
7	≤ 0.5 g/m³	
8	0.5 - ≤ 5 g/m³	
9	5 - ≤ 10 g/m³	
X	> 10 g/m³	

TOTAL OIL Liquid, aerosol, and vapor		
Class	mg/m³	ppm w/w
0	As specified and more stringent than Class 1	
1	≤ 0.01	≤ 0.008
2	≤ 0.1	≤ 0.08
3	≤ 1.0	≤ 0.8
4	≤ 5.0	≤ 4
5		
6		
7		
8		
9		
X	> 5.0	> 4

At reference conditions: 68°F, 14.5 psia, 0% relative humidity

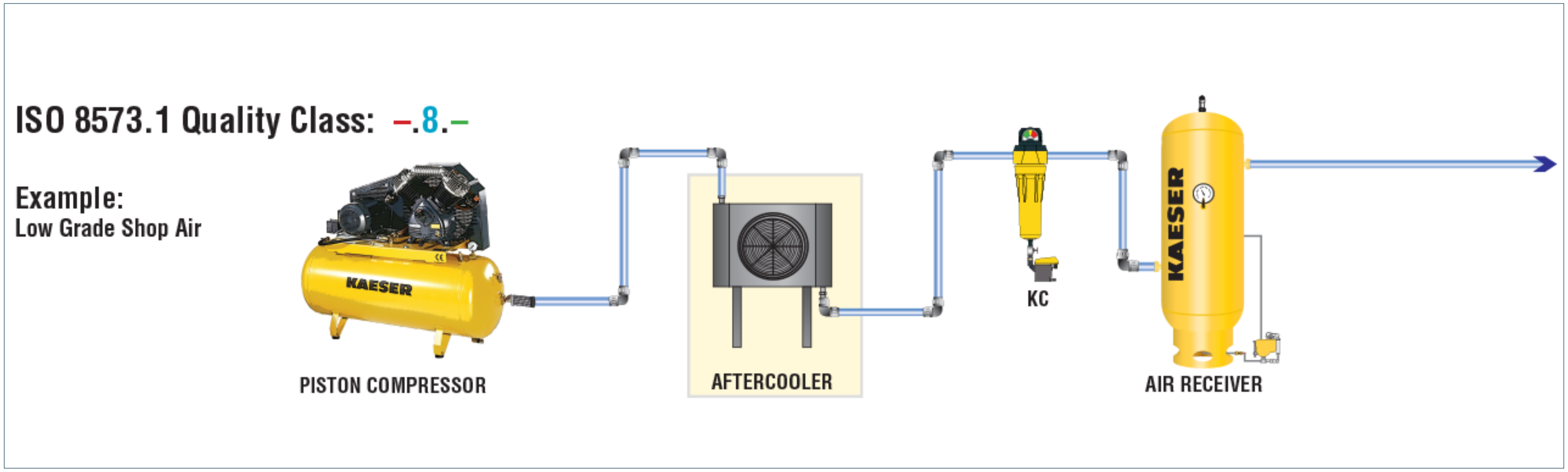
Air Purity and Treatment

The next few pages include examples of system layouts and various ISO Air Quality Classes.

The layout below would provide typical low grade air and could be used where the possible presence of some liquid water would be problematic. Note that an aftercooler is necessary with a piston compressor. Kaeser rotary screw compressors include built-in aftercoolers.

Aftercoolers provide an economical way to remove about 70% of the water vapor in compressed air and can be air-cooled or water-cooled. An aftercooler, however, is not a replacement for a compressed air dryer. The air exiting an aftercooler will typically always be saturated and additional condensation in the outlet air can occur.

A liquid separator is included for its ability to capture and remove heavy liquid loads. The liquid separator should be placed as close as possible to the aftercooler outlet and always upstream of all other air treatment components, and must include a no-loss air drain rated for the amount of condensate from the compressor.



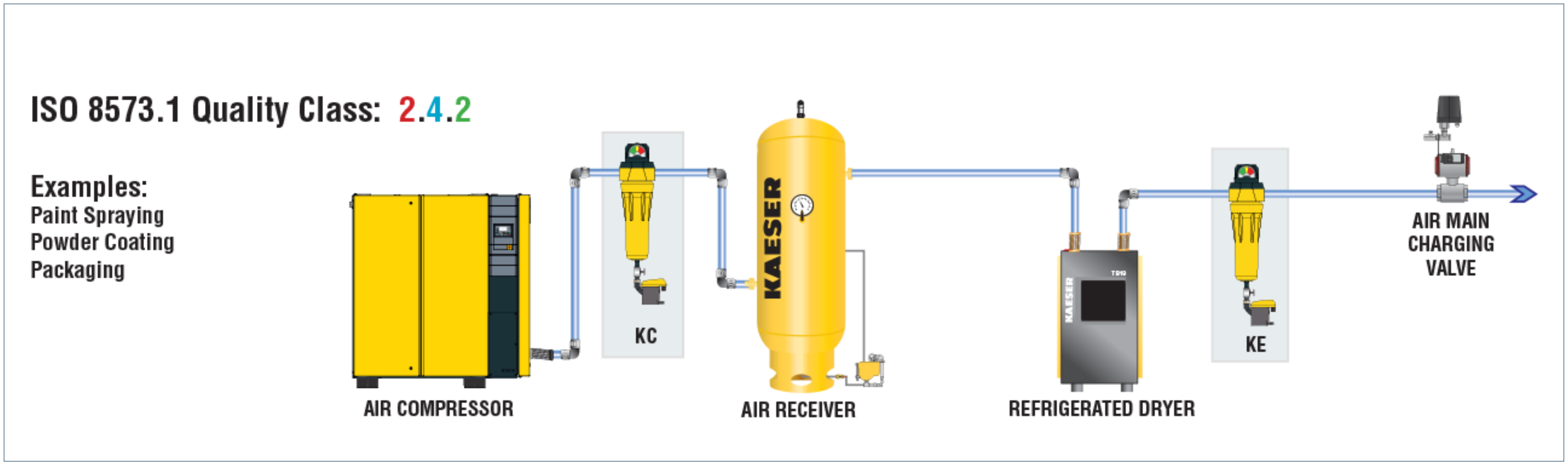
Air Purity and Treatment

The layout below would meet the compressed air quality needs typical for packaging, paint spraying, or most compressed air systems. As with the previous layout, the liquid separator is placed after the compressor (which has a built-in aftercooler) for liquid removal.

The oil coalescing filter after the refrigerated dryer removes oil aerosols and remaining liquids and well as fine particles.

The Air Main Charging Valve protects the air treatment components while the air network is pressurized and in the case of low pressure in the facility where air quality is paramount.

Note: Receivers installed before dryers should include an additional filter if the wet receiver is not galvanized or internally coated.

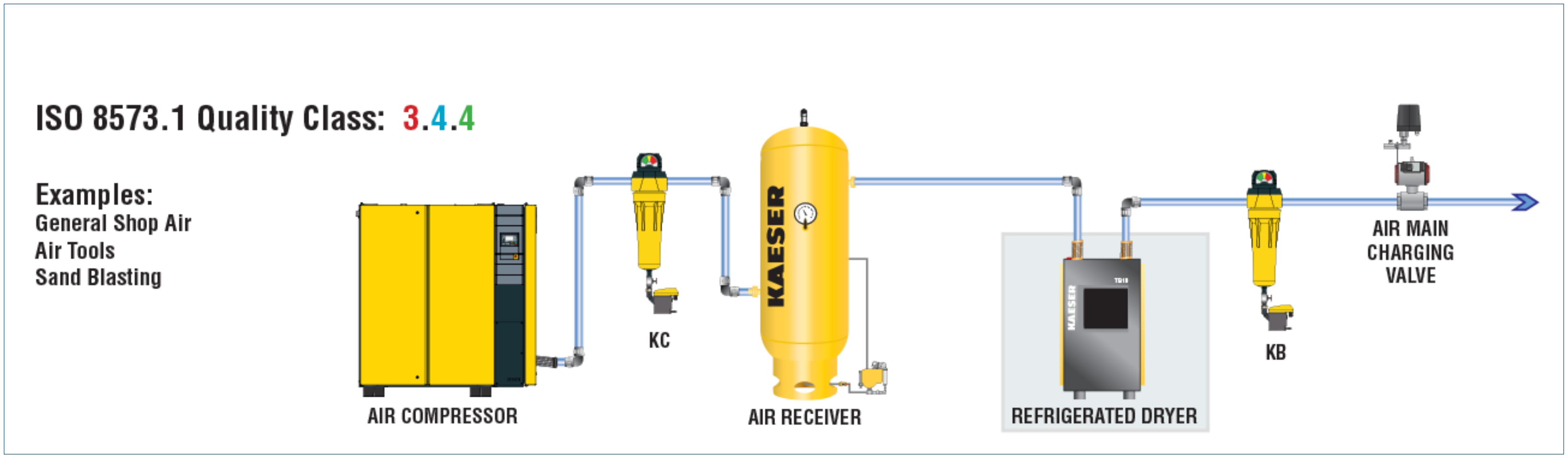


Air Purity and Treatment

For applications that are not overly sensitive to oil, but still require protection from particulates, a particulate filter can be installed downstream of the refrigerated dryer.

These general purpose filters are designed to remove particles and water and most oil aerosols.

Note: Receivers installed before dryers should include an additional filter if the wet receiver is not galvanized or internally coated.

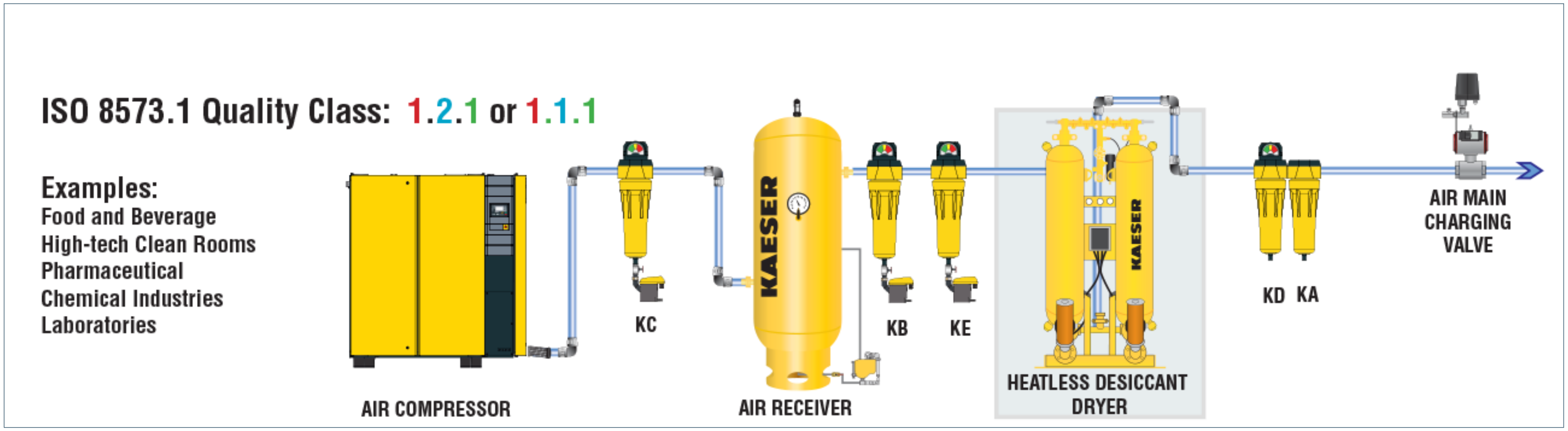


Air Purity and Treatment

Compressed air systems with a desiccant dryer require additional filtration to maintain air quality and protect the dryer and downstream components.

The particulate filter and oil coalescing filter upstream of the heatless desiccant dryer protect the desiccant bed from contamination. Desiccant will not adsorb moisture if contaminated with even trace amounts of oil/compressor fluids.

The particulate filter after the desiccant dryer removes any of the desiccant fines. The oil vapor removal filter adsorbs any oil vapor, eliminating odor and taste from the compressed air. These two filters produce high quality air as typically required for clean rooms and pharmaceutical applications.



Tip:

Kaeser has a complete line of filtration and filter options. Contact your local authorized Kaeser representative for more information.

More Resources:

Click here to download a copy of our Air Treatment Literature.

Air Purity and Treatment: Breathing Purifiers

The Kaeser Breathing System (KBS) is a complete air treatment system designed to produce OSHA Grade D breathing air. It includes particulate and high efficiency oil coalescing pre-filtration for its heatless desiccant dryer. The dryer provides protection for the catalyst material which removes carbon monoxide. Particulate and oil vapor adsorbing afterfilters complete the package.

Ideally, a KBS purifier should be installed at a location where the entering compressed air will have cooled to near normal ambient air temperature. The purifier should be selected for the required volume of breathing air and the air compressor sized for the purifier's inlet air requirement. Due to its high operating costs, it should be sized and used only for breathing air.

Only air treated by a designated breathing air system, or competitive product having carbon monoxide removing capability (filtration alone IS NOT adequate) should be considered safe for breathing.

Air Purity and Treatment: Dryers

Your selection of drying equipment should be based on the dew point necessary for the application and then sized based on the volume and ambient conditions where the dryer is installed. If your dryer or air lines will be exposed to freezing temperatures, for example, you will need a desiccant (or membrane) type dryer even if your pressure dew point requirements might normally be met by a refrigerated dryer. Be sure to apply the appropriate correction factors to correct the rated capacity for the actual operating conditions.

Ensure that dryers (and their drain traps) are rated for at least the maximum system working pressure and airflow. Dryers should be placed along the air line before any pressure reducing valves and after air has been cooled to 100°F or less (the combination of the aftercooler and "wet" tank normally achieves this). High air temperatures will reduce dryer efficiency and may increase power consumption. For this reason, do not place the dryer in the flow of the compressor exhaust. Use the following temperature guidelines for installing dryers:

	Min. Ambient °F	Max. Ambient °F	Max. Inlet °F
Refrigerated Dryer	40	110	120
Desiccant Dryer	35, -20*	120	120

If properly equipped

When sizing air treatment equipment, consider that different sections of your plant may require different levels of compressed air quality. It is more economical to treat smaller amounts of compressed air for a particular application rather than to treat the entire air supply for the highest level of air quality needed.

"Be sure to apply the appropriate correction factors to correct the rated capacity for the actual operating conditions...

Tip:

If your application requires any dryer to be installed in ambient conditions beyond these limits, consult Kaeser for information on how to prepare the equipment.

Condensate Management

{ *Safely Disposing of Contaminants*

Condensate Management

Condensate is formed as a result of compressing and then cooling air. The higher the ambient temperature and relative humidity, the greater the volume of condensate produced. Most of this is water, but it is contaminated with some oil and particles from the compressed air system components and airborne particles drawn into the compressor.

This condensate accumulates in receiver tanks, filters, dryers, and piping. If it is not removed, it will be carried downstream with compressed air and contaminate both production equipment and products at the points of use. This may greatly increase your maintenance costs and product reject percentage. In addition, the condensate will saturate filter elements and render them useless. These costs far outweigh the costs of installing a dependable condensate system.

A condensate system is made up of three elements: drain traps (attached to receivers, filters, and dryers), an oil/water separator, and the piping that connects these.

On a 75° F day with 75% relative humidity...

...a 25 hp compressor producing 100 cfm at 100 psig with its aftercooler delivering 90° F compressed air...

...produces approximately 4.5 gallons of condensate during a single eight hour shift.

> "Condensate... may greatly increase your maintenance costs and product reject percentage....

Condensate Management: Drain Traps

Drain traps are a critical, but often overlooked component in compressed air systems. Drain traps are the devices that remove condensate that accumulates in receivers, filters, and dryers. They prevent the production contamination problems identified earlier. Drain traps must be properly sized to handle the volume of condensate generated and they must be dependable. There are several types of drains, but they may be divided into two categories: manual and automatic.

Manual drains are simply hand-operated valves. They are simple and inexpensive, but are only as reliable as the person expected to check them.

Automatic drain traps open and close without human operation. They should be checked periodically to ensure they are operating properly, but do not need daily attention like manual drains. Automatic drain traps come in two basic types: timed and demand operated.

More Resources:

Click here to read a blog entry on the savings potential of automatic drains over manual drains.

Condensate Management: Drain Traps

Timed electric traps (TETs) are fairly inexpensive and simple. A timer operates a solenoid and opens the drain valve at preset intervals for a preset duration.

TET's are not recommended for three reasons:

1. If they open too often, they waste compressed air.
2. If don't open often enough, condensate can build up, render air treatment ineffective, and contaminate the equipment and products.
3. Even when operating correctly, they introduce excess pressurized air into the condensate line. This creates turbulence, which inhibits condensate separation at the separator.

> TET's do not adjust automatically to the level of condensate present...

Introduction
Location
Ventilation
Water-cooling
Electrical Supply
Correct Air Storage
Efficiency Enhancing Equipment
Air Purity & Treatment
Condensate Management
Piping
Preventive Maintenance
Leaks
Safety Advisories
Additional Resources
Appendices

Condensate Management: Drain Traps

Demand operated drain traps are simple mechanical devices that use mechanical floats or electronic sensors to activate the drain valve when the amount of condensate reaches a certain level inside the trap. They prevent condensate build-up even in case of heavy liquid loading and do not discharge air with the water. Kaeser offers three types: Eco-Drain, Automatic Drain Trap (ADT), and Automatic Magnetic Drain (AMD).

Drain traps should be installed on the following:

- Immediately after the compressor (when piping runs vertically)
- Liquid separators
- All receivers
- Particulate Filters
- Oil Removal Filters
- Oil Mist Eliminators (OME)
- Refrigerated dryers (Kaeser refrigerated dryers and most other brands have drain traps built-in.)

The following do not require drain traps:

- Desiccant dryers
- Filters downstream of desiccant dryers. However, manual drain valves are recommended as an inexpensive way to check for proper dryer function.
- Oil Vapor Adsorbers. Note that a manual drain valve is recommended in order to de-pressurize the filter for maintenance and also to check for contamination/saturation.

Tip:

Kaeser suggests using demand operated drain traps because they are reliable and minimize compressed air losses.

Condensate Management: Drain Traps

Drain traps should be mounted below filters and should be fed from the lowest point possible on receivers and dryers. To prevent clogging of the drain trap orifices and mechanisms on equipment other than filters, Kaeser suggests installing a Y-strainer before drain traps. Also, a ball valve should be placed before the Y-strainer to enable maintenance personnel to isolate the strainer from pressure during cleaning. The use of a Y-strainer may not be necessary in conjunction with the AMD 6550 trap. The large orifice and the design of the mechanism make the AMD 6550 less susceptible to clogging than other traps.

The AMD 1550 is designed for use with aftercoolers, coalescing filters, and on liquid separators. The AMD 6550 is for use with aftercoolers, liquid separators, receiver tanks, coalescing filters, drip legs, and other low points in your piping.

Condensate Management: Disposal

As mentioned previously, condensate is not just water, but usually also contains oil and solid particles. The combination of oil and particulates often makes the condensate an environmentally hazardous material that must be properly disposed of. You may choose to collect all condensate in large vessels for disposal, but this is an expensive option. Typically, water makes up 95% of the condensate. It will be more economical to separate the water and pay only for disposing of oils and other contaminants. These may be effectively separated at the end of the condensate system in a Condensate Management System (Kaeser's KCF) or an equal performing oil/water separator. The KCF should be sized to handle the total volume of water collected in the system. Consider the flow demand when sizing the KCF.

Do not pipe untreated condensate into a storm sewer.

Condensate treated by a KCF may then be piped to a sanitary sewer drain using appropriately sized pipe. The treated condensate should be monitored periodically to confirm purity is in compliance with local, state, and federal environmental regulations. The separated oil is captured by the KCF adsorption filter. This filter may be disposed of in the normal manner. Oil that has only been separated, rather than adsorbed, is considered hazardous waste and appropriate disposal methods must be adhered to.

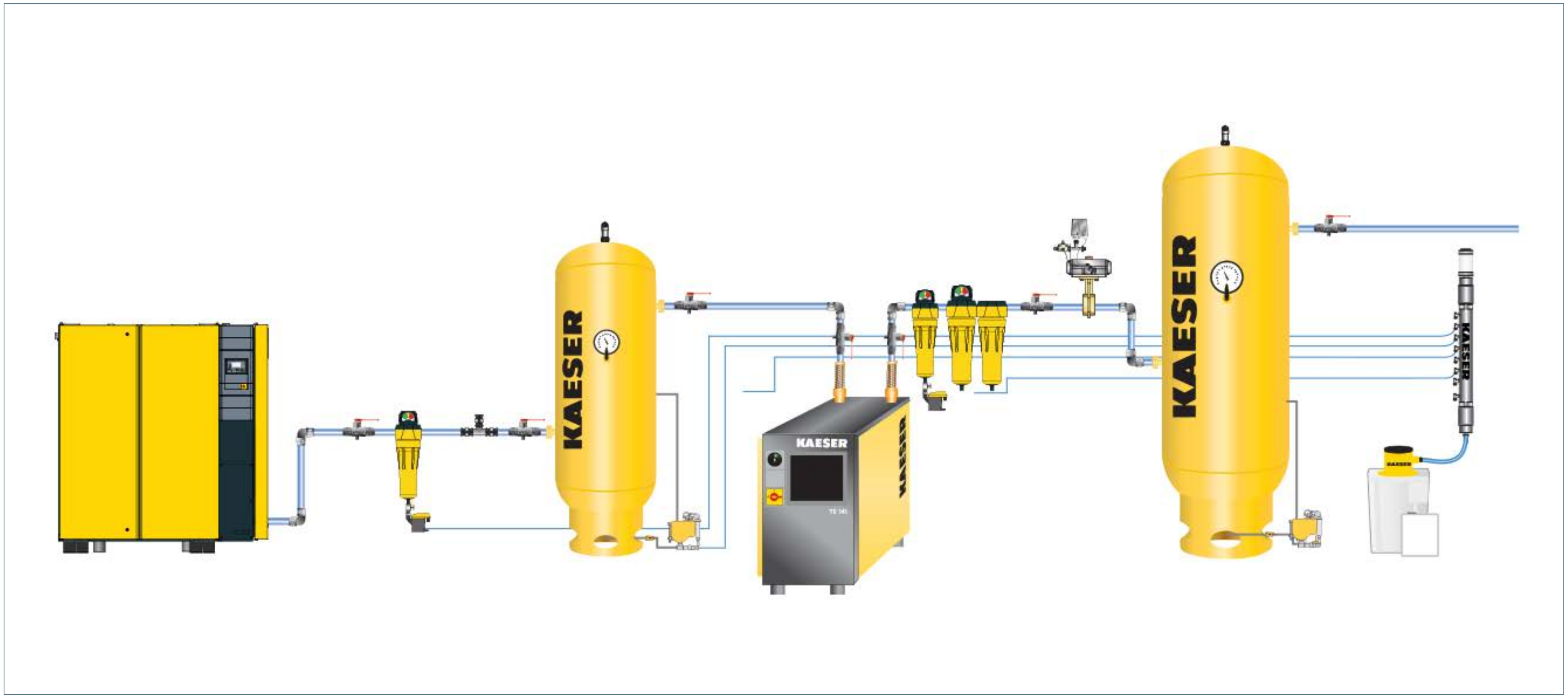
Introduction
Location
Ventilation
Water-cooling
Electrical Supply
Correct Air Storage
Efficiency Enhancing Equipment
Air Purity & Treatment
Condensate Management
Piping
Preventive Maintenance
Leaks
Safety Advisories
Additional Resources
Appendices

Condensate Management: Manifold

For maximum condensation collection, install a condensate manifold. These small vessels collect condensate from multiple sources, such as receiver tanks, filters, and dryers, and safely diffuse residual air pressure to maximize separation effectiveness when used in conjunction with a oil/water separator.

Introduction
Location
Ventilation
Water-cooling
Electrical Supply
Correct Air Storage
Efficiency Enhancing Equipment
Air Purity & Treatment
Condensate Management
Piping
Preventive Maintenance
Leaks
Safety Advisories
Additional Resources
Appendices

Disposal of Condensate: Condensate Management



Sample Air Treatment Diagram with Condensate Management

Piping

Materials and Installation Considerations

Piping

The correct sizing of pipework is important to provide ample flow and steady pressure to all points of use.

Pipe diameter dramatically impacts pressure drop. The Compressed Air and Gas Institue publishes tables for estimating pressure drop due to friction loss at specific pressures. Appendix A contains the chart for 100-psig system pressure. Note that the information in the chart is based on straight pipe that is smooth and clean inside. Pipe bends are an additional source of friction losses in compressed air piping. You will notice that pressure drop due to friction increases with flow.

Leaks will be discussed later on in this e-book.

"...pressure drop due to friction increases with flow...

Tip:

Every 2 psig of pressure drop requires a 1% increase of input energy to maintain desired pressure.

Piping

The following example from the Compressed Air Challenge demonstrates how to calculate pressure drop in your system.

What is the pressure drop in a 2-inch pipe, 350 feet in length, with an initial pressure of 85 psig and a flow rate of 500 cfm-FAD?

According to the chart in Appendix A, a pressure drop for 500 cfm in 1,000 feet of 2-inch pipe is 19.2 psi.

This means:

$$\frac{19.2 \text{ x } 350 \text{ ft. x } (85 \text{ psig} + 14.5)}{1{,}000 \text{ ft. x } (100 \text{ psig} + 14.5)} = 5.84 \text{ psi}$$

This pressure drop is considered excessive. Using 3-inch pipe would be recommended:

$$\frac{2.34 \text{ x } 350 \text{ ft. x } (85 \text{ psig} + 14.5)}{1{,}000 \text{ ft. x } (100 \text{ psig} + 14.5)} = 0.71 \text{ psi}$$

214 Compressed Air Distribution (Systems) Chap. 4

Table 4.7 Loss of Air Pressure Due to Friction

Cu ft Free Air Per Min	Equivalent Cu ft Compressed Air Per Min	Nominal Diameter, In.											
		1/2	3/4	1	1 1/4	1 1/2	2	3	4	6	8	10	12
10	1.28	6.50	.99	0.28									
20	2.56	25.9	3.90	1.11	0.25	0.11							
30	3.84	58.5	9.01	2.51	0.57	0.26							
40	5.12	....	16.0	4.45	1.03	0.46							
50	6.41	....	25.1	9.96	1.61	0.71	0.19						
60	7.68	....	36.2	10.0	2.32	1.02	0.28						
70	8.96	....	49.3	13.7	3.16	1.40	0.37						
80	10.24	....	64.5.	17.8	4.14	1.83	0.49						
90	11.52	....	82.8	22.6	5.23	2.32	0.62						
100	12.81	....	....	27.9	6.47	2.86	0.77						
125	15.82	....	....	48.6	10.2	4.49	1.19						
150	19.23	....	....	62.8	14.6	6.43	1.72	0.21					
175	22.40	....	....	....	19.8	8.72	2.36	0.28					
200	25.62	....	....	....	25.9	11.4	3.06	0.37					
250	31.64	....	....	....	40.4	17.9	4.78	0.58					
300	38.44	....	....	....	58.2	25.8	6.85	0.84	0.20				
350	44.80	....	....	....	....	35.1	9.36	1.14	0.27				
400	51.24	....	....	....	....	45.8	12.1	1.50	0.35				
450	57.65	....	....	....	....	58.0	15.4	1.80	0.46				
500	63.28	....	....	....	....	71.6	19.2	2.34	0.55				
600	76.88	....	....	....	....	....	27.6	3.36	0.79				
700	89.60	....	....	....	....	....	37.7	4.55	1.09				

Chart courtesy of CAGI

More Resources:

The Compressed Air Challenge is committed to helping educate compressed air users and has a number of excellent resources. Visit their website for more information.

Piping: Materials

Piping selection directly affects three key elements of every compressed air system: flow, pressure, and air quality. Poor choices in pipe materials, diameter, and layout cause flow restrictions, often resulting in significant pressure drop.

The chart on the next page outlines the key advantages and disadvantages of common piping materials.

Regardless of the type of piping material used, it must be rated for at least your maximum working pressure and meet all applicable codes.

> Poor choices in pipe materials, diameter, and layout cause flow restrictions, often resulting in significant pressure drop...

Piping: Materials

Material	Advantages	Disadvantages
Black Iron	• Moderate material costs • Readily available in multiple sizes	• Labor intensive installation • May rust and leak • Rough inside promotes contaminant build-up and creates pressure drop
Galvanized Iron	• Moderate material costs • Readily available in multiple sizes • Some rust protection	• Often exterior is coated • Labor intensive installation • Rough inside promotes contaminant build-up and creates pressure drop • May rust at joints and leak
Copper	• No rust, good air quality • Smooth interior—low pressure drop	• Requires quality brazing to prevent leaks • Susceptible to thermal cycling • Installation requires open flame
Stainless Steel	• No rust, good air quality • Smooth interior—low pressure drop	• Labor intensive installation • Expensive materials
PVC	• Lightweight • Inexpensive	• Lower safety • In certain areas, not compliant with certain codes • Carries static charge • Subject to bursting • Adhesives not compatible with compressor oils
Aluminum	• Corrosion resistant • Lightweight • Easy to install • Lower cost of ownership	• Lower pressure rating

Piping: Materials

Kaeser ***does not*** recommend using PVC or ABS (plastics) because some synthetic lubricants degrade plastics, which may lead to pipe rupture. Also, air traveling through a plastic pipe may accumulate a significant static electric charge that could discharge at the point of use when an employee touches the air-driven tool.

More Resources:

For more information on the dangers of using PVC piping for compressed air, read our blog entry.

Piping: Installation Tips

Use couplings (connections, elbows, etc.) of the same material and pressure rating. Seal threaded joints with a high quality pipe sealant in order to minimize leaks.

- Minimize “T”s and right angles in order to reduce friction losses. Use rounded elbows whenever possible.
- Where “T”s are used, pipe the main flow through the head of the “T” and use the stem to feed the bypass, air drop, etc.
- Full-bore ball valves are recommended wherever valves are required. Ball valves should be placed to facilitate future expansion of compressed air system (e.g., multiple compressors, more points of use).
- Pipe in low and out high of air receiver tanks.

Piping: Installation Tips

- Use braces to secure piping to walls, floor, or ceiling to prevent movement of piping and stressing of pipe joints (which causes leakage).
- Discharge piping should be at least the same diameter as the compressor discharge outlet.
- A flexible pipe/hose connection between rigid air piping and compressor discharge outlet is highly recommended in order to protect the aluminum discharge flange.
- A full-bore ball valve should be installed immediately after the flexible hose connection to isolate and maintain stored pressure downstream when the compressor is serviced. On large compressors (400 hp and higher) a high performance butterfly valve may be a less expensive and more convenient option. Also, an appropriate means of blow-down is required between the compressor and the isolation valve.
- Install an additional fitting (e.g. “Chicago” or “Dixon”) to allow temporary connection of mobile or backup compressor for uninterrupted air flow during maintenance/repair service.

Piping: Air Treatment Piping

Piping should enter receiver tanks low and exit high to promote maximum moisture separation and prevent accumulated condensate from migrating downstream.

Kaeser filters are designed to allow quick access to the filter cartridges without disconnecting any piping. Do not run piping at heights that will put them out of reach or too close to the floor. Doing so will make filter replacement and proper installation of drain traps difficult. To ensure ease of filter cartridge replacement, allow enough space under the filter to remove the filter bowl. This will eliminate the need to disconnect the entire filter from the inlet and outlet piping just to change filter elements.

Mount liquid separators, particulate, and oil coalescing filters so that inlet and outlet connections are horizontal and the filter bowls are vertical. Since separated and coalesced liquids drain by gravity downward inside the filters to the filter sump (and into the drain trap), the vessel must be mounted nearly plumb vertically, so that drainage will not be impeded.

Ensure that the filter heads are installed so that air flows through the filter in the proper direction (as shown on the filter head).

> "To ensure ease of filter cartridge replacement, allow enough space under the filter to remove the filter bowl...

Piping: Installation Tips (cont'd)

Use full-bore ball valves to isolate all air treatment items to facilitate routine maintenance without loss of compressed air. In applications where air quality is critical and the user cannot afford to shut down the compressed air system, each filter should have bypass piping with a redundant filter. The bypass must have ball valves to isolate it. With this configuration, the user may bypass filters during filter cartridge changes or other filter maintenance without compromising air quality.

Piping: Distribution Piping

Airdrops to points of use should be fed from a loop system (rather than a dead end system). This effectively reduces air travel distances and helps ensure stable pressure to all points of use. Also, individual airdrops should exit the main pipe from the top so that condensed moisture will not enter the line.

Avoid exposing air lines to freezing temperatures. If the air lines will be exposed to freezing temperatures, use a desiccant or membrane dryer to treat the air before the piping reaches areas where it is exposed to freezing temperatures.

Any time piping goes through various temperature gradients in a facility, consider using additional flexible hoses and remember to size your air treatment appropriately.

> "Friction loss is related both to the type of pipe used and the length of pipe...

More Resources:

See the "Loss of Air Pressure Due to Friction" Chart in Appendix A for help with estimating pressure drop.

Preventive Maintenance

Keeping Your System Up and Running

Preventive Maintenance

All mechanical and electrical equipment requires varying degrees of attention to ensure that it operates efficiently. Since most customers rely heavily upon an uninterrupted supply of compressed air, it is sensible for them to invest in preventive maintenance rather than suffer costly downtime and repairs.

It is highly recommended to establish a regular maintenance routine to ensure proper operation of all parts of your compressed air system and maintain a service log for each component. Regular preventive maintenance will ensure optimal performance and longer equipment life.

Each system component (e.g., compressor, filter, dryer, and drain trap) has a service manual or guide with specific instructions on maintenance procedures and intervals. Follow all recommended maintenance procedures. Taking the few minutes to perform these checks will maintain the quality of your compressed air and your air driven tools, reducing the costs associated with repairs and lost production.

Many modern compressed air components (e.g. compressors, blower packages) come equipped with computerized controllers which monitor equipment health and operation in real time, as well as provide typical maintenance intervals reminders. Some offer the capability to send these messages to plant control systems or provide messaging to responsible plant personnel for the equipment.

> Regular preventive maintenance will ensure optimal performance and longer equipment life...

More Resources:

Click here to contact your local authorized Kaeser representative for maintenance recommendations.

Preventive Maintenance

In addition to the regular checks by your plant personnel, an effective preventive maintenance program should include regular professional servicing. Standard services are usually performed at manufacturer recommended intervals, but may be recommended more often depending on the usage and operating environment.

Kaeser has a factory-trained, national distribution network that is always ready to assist you with your maintenance needs. Contact your local authorized Kaeser representative to schedule a service appointment.

Lack of proper maintenance may invalidate any warranty claims if failures are directly related to a failure to perform routine preventive maintenance. A preventive maintenance contract with your local Kaeser distributor is a means of having this work carried out properly.

Caution: Compressed air can be dangerous. Extreme care should be exercised at all times. Prior to performing any maintenance or service, system pressure must be vented at all points to ensure human safety. High pressure air should never be directed at anyone. Valves should be opened and closed slowly to prevent damage to separators, filters, and controls caused by sudden surges of pressurized air.

Caution: Before performing any work, be sure to follow OSHA recommendations for electrical lock-out/tag-out and compressed air blow-down precautions.

Leaks

Cost and Detection

Leaks

Most systems have air leaks. Some are present from the time of installation and some develop over time. Regardless of the source, they can greatly reduce your operating effectiveness and cost a lot in energy.

Kaeser recommends a post installation leak check as well as periodic leak detection checks.

Upon commissioning, the air system can be checked for leaks by simply charging the system with air and not using air. If the compressor cycles on to recharge the system or if the pressure drops in the storage tank, there are leaks. Ultrasonic leak detection equipment can easily locate the leaks.

We also recommend annual leak audits to identify and fix leaks that develop over time.

And if you are considering a system energy audit, we strongly recommend a leak audit first to determine how much of your system demand is due to leaks rather than actual production needs.

The graphic on the right shows how much even a single leak can cost you each year. An annual leak detection plan can help you stay ahead of the game.

Leak Size	90 psig	110 psig
1/16”	$933	$1,112
1/4”	$14,948	$17,818
3/8”	$33,586	$40,051
1/2”	$59,761	$71,271

Based on 8,760 operating hours and $0.10/kWh.

See Appendix C: Discharge of Air Through an Orifice for more information.

A single, small hole, 1/4” in diameter, costs you approximately $1155 every month.

Tip:

Consult your local authorized Kaeser representative for as-sistanceobtaining leak savings information for other pressures.

Tip:

Make leak detection and air audits a part of your regular maintenance plan.

Safety Advisories

Health and Safety Considerations

Safety Advisories

Installation should be conducted in a safe manner in accordance with OSHA and appropriate local regulations. Compressed air can be dangerous and should never be directed towards people. Improper and unsafe contact with compressed air can cause eye damage, sub-cutaneous embolisms, and other serious injuries, including death.

When working in a lift, technicians should use a proper harness and rigging.

Qualified technicians must perform electrical work in a safe manner using UL approved materials and properly insulated tools, equipment, and appropriate personal protective equipment (PPE) for the work. All applicable local, state, and national regulations must be followed.

All pressure vessels must meet ASME and other appropriate local standards.

The compressed air system must be installed so that normal operation poses no threat to worker health or safety. The system must be sufficiently ventilated so that it poses no heat threat to persons nearby.

Hearing protection must be worn in accordance with OSHA standards. Where applicable, prominently display signs warning of noise hazards. Compressor operating noise levels are listed in Kaeser service manuals.

Condensate must be disposed of in accordance with local, state, and federal environmental regulations.

Follow OSHA recommendations for electrical lock-out/tag-out and compressed air blow-down precautions.

Follow all safety recommendations in the manufacturer's service manual.

Additional Resources

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More Tips and Resources

Additional Resources

Looking for more information on compressed air topics? Check out the following resources below:

- kaesertalksshop.com: Our company blog features posts on a wide range of compressed air topics written by our subject matter experts and is updated regularly. You can also sign up to follow the blog to receive updates whenever there is a new blog post.
- us.kaeser.com/cagi: Kaeser is a member of the Compressed Air and Gas Institute (CAGI), a non-profit organization of competitive companies that manufacture air and gas compressors and related equipment. As a member, Kaeser participates in the performance verification program. You can view the performance data sheets for our units on this website.
- us.kaeser.com/resources: This webpage has a collection of technical articles, material safety data sheets (MSDS), tools, presentations, and much more.
- us.kaeser.com/whitepapers: Our collections of whitepapers provide in-depth technical information on challenges those in the compressed air industry are currently facing.
- Our online Kaeser Toolbox has a number of handy tools for making common compressed air calculations.
- us.kaeser.com/ada: Our Air Demand Analysis (ADA) compressed air assessments can help you improve your existing system.

Appendices

Charts and References

Appendix A: Loss of Pressure Drop Due to Friction

Table 4.7 Loss of Air Pressure Due to Friction

Cu ft Free Air Per Min	Equivalent Cu ft Compressed Air Per Min	Nominal Diameter, In.											
		1/2	3/4	1	1 1/4	1 1/2	2	3	4	6	8	10	12
10	1.28	6.50	.99	0.28									
20	2.56	25.9	3.90	1.11	0.25	0.11							
30	3.84	58.5	9.01	2.51	0.57	0.26							
40	5.12	....	16.0	4.45	1.03	0.46							
50	6.41	....	25.1	9.96	1.61	0.71	0.19						
60	7.68	....	36.2	10.0	2.32	1.02	0.28						
70	8.96	....	49.3	13.7	3.16	1.40	0.37						
80	10.24	....	64.5.	17.8	4.14	1.83	0.49						
90	11.52	....	82.8	22.6	5.23	2.32	0.62						
100	12.81	....	....	27.9	6.47	2.86	0.77						
125	15.82	....	....	48.6	10.2	4.49	1.19						
150	19.23	....	....	62.8	14.6	6.43	1.72	0.21					
175	22.40	....	....	....	19.8	8.72	2.36	0.28					
200	25.62	....	....	....	25.9	11.4	3.06	0.37					
250	31.64	....	....	....	40.4	17.9	4.78	0.58					
300	38.44	....	....	....	58.2	25.8	6.85	0.84	0.20				
350	44.80	....	....	....	....	35.1	9.36	1.14	0.27				
400	51.24	....	....	....	....	45.8	12.1	1.50	0.35				
450	57.65	....	....	....	....	58.0	15.4	1.89	0.46				
500	63.28	....	....	....	....	71.6	19.2	2.34	0.55				
600	76.88	....	....	....	....	....	27.6	3.36	0.79				
700	89.60	....	....	....	....	....	37.7	4.55	1.09				
800	102.5	....	....	....	....	....	49.0	5.89	1.42				
900	115.3	....	....	....	....	....	62.3	7.6	1.80				
1,000	128.1	....	....	....	....	....	76.9	9.3	2.21				
1,500	192.3	....	....	....	....	....	....	21.0	4.9	0.57			
2,000	256.2	....	....	....	....	....	....	37.4	8.8	0.99	0.24		
2,500	316.4	....	....	....	....	....	....	58.4	13.8	1.57	0.37		
3,000	384.6	....	....	....	....	....	....	84.1	20.0	2.26	0.53		
3,500	447.8	....	....	....	....	....	....	....	27.2	3.04	0.70	0.22	
4,000	512.4	....	....	....	....	....	....	....	35.5	4.01	0.94	0.28	
4,500	576.5	....	....	....	....	....	....	....	45.0	5.10	1.19	0.36	
5,000	632.8	....	....	....	....	....	....	....	55.6	6.3	1.47	0.44	0.17
6,000	768.8	....	....	....	....	....	....	....	80.0	9.1	2.11	0.64	0.24
7,000	896.0	....	....	....	....	....	....	....	....	12.2	2.88	0.87	0.33
8,000	1,025	....	....	....	....	....	....	....	....	16.1	3.77	1.12	0.46
9,000	1,153	....	....	....	....	....	....	....	....	20.4	4.77	1.43	0.57
10,000	1,280	....	....	....	....	....	....	....	....	25.1	5.88	1.77	0.69
11,000	1,410	....	....	....	....	....	....	....	....	30.4	7.10	2.14	0.83
12,000	1,540	....	....	....	....	....	....	....	....	36.2	8.5	2.54	0.98
13,000	1,668	....	....	....	....	....	....	....	....	42.6	9.8	2.98	1.15
14,000	1,795	....	....	....	....	....	....	....	....	49.2	11.5	3.46	1.35
15,000	1,923	....	....	....	....	....	....	....	....	56.6	13.2	3.97	1.53
16,000	2,050	....	....	....	....	....	....	....	....	64.5	15.0	4.52	1.75
18,000	2,310	....	....	....	....	....	....	....	....	81.5	19.0	5.72	2.22
20,000	2,560	....	....	....	....	....	....	....	....	....	23.6	7.0	2.74
22,000	2,820	....	....	....	....	....	....	....	....	....	28.5	8.5	3.33
24,000	3,080	....	....	....	....	....	....	....	....	....	33.8	10.0	3.85
26,000	3,338	....	....	....	....	....	....	....	....	....	39.7	11.9	4.65
28,000	3,590	....	....	....	....	....	....	....	....	....	46.2	13.8	5.40
30,000	3,850	....	....	....	....	....	....	....	....	....	53.0	15.9	6.17

In psi in 1000 ft of pipe, 100 lb gage initial pressure. For longer or shorter lengths of pipe the friction loss is proportional to the length, i.e., for 500 ft, one-half of the above; for 4,000 ft, four times the above, etc.

Chart taken from Compressed Air and Gas Handbook. For additional pressures, visit www.cagi.org.

Introduction
Location
Ventilation
Water-cooling
Electrical Supply
Correct Air Storage
Efficiency Enhancing Equipment
Air Purity & Treatment
Condensate Management
Piping
Preventive Maintenance
Leaks
Safety Advisories
Additional Resources
Appendices

Appendix B: Dryer Correction Factors for Kaeser's Refrigerated Dryers

Secotec: Capacity Correction Factors for Operating Conditions

Pressure (psig)	Temperature (°F)											
	75	80	85	90	95	100	105	110	115	120	125	130
60	0.96				0.86	0.77	0.67	0.60	0.53	0.47	0.41	0.37
80	1.11				0.99	0.89	0.78	0.69	0.61	0.54	0.48	0.42
100	1.25				1.12	1.00	0.88	0.78	0.69	0.61	0.53	0.48
115	1.32				1.18	1.05	0.93	0.62	0.73	0.64	0.57	0.50
120	1.33				1.19	1.06	0.94	0.83	0.73	0.65	0.57	0.51
125	1.35				1.21	1.08	0.95	0.84	0.75	0.66	0.58	0.52
140	1.39				1.25	1.11	0.98	0.87	0.77	0.68	0.60	0.53
160	1.46				1.31	1.16	1.02	0.91	0.80	0.71	0.63	0.56
180	1.51				1.35	1.21	1.06	0.94	0.83	0.73	0.65	0.58
200	1.55				1.39	1.24	1.09	0.97	0.85	0.75	0.67	0.59
230	1.59				1.43	1.27	1.12	0.99	0.88	0.77	0.68	0.61

Capacity Correction Factors for Ambient Temperature

	Ambient Air Temperature (°F)							
	75	80	85	90	95	100	105	110
Factor	1.09				1.05	1.00	0.96	0.92

Selecting the Proper Dryer

To correct rated capacity for actual operating conditions, refer to "Capacity Correction Factors for Operating Conditions" and "Capacity Correction Factors for Ambient Temperature". Find the capacity correction factors corresponding to the inlet and ambient conditions. Multiply these factors to find the "overall" capacity correction factor, then multiply any dryer's rated capacity by the overall correction factor to determine its capacity at your operating conditions. Capacity correction factors for conditions not shown may be interpolated.

Note that these correction factors are specific to Kaeser model dryers. For additional assistance in sizing dryers for your installation, contact your local authorized Kaeser representative.

Introduction
Location
Ventilation
Water-cooling
Electrical Supply
Correct Air Storage
Efficiency Enhancing Equipment
Air Purity & Treatment
Condensate Management
Piping
Preventive Maintenance
Leaks
Safety Advisories
Additional Resources
Appendices

Appendix B: Dryer Correction Factors for Kaeser's Refrigerated Dryers

Kryosec:
Capacity Correction Factors for Operating Conditions

Pressure (psig)	Temperature (°F) 75	80	85	90	95	100	105	110	115	120	125	130
60	0.95				0.85	0.76	0.67	0.59	0.52	0.46	0.41	0.36
80	1.10				0.98	0.88	0.77	0.68	0.60	0.53	0.48	0.42
100	1.25				1.12	1.00	0.88	0.78	0.69	0.61	0.54	0.48
115	1.32				1.18	1.05	0.93	0.62	0.73	0.64	0.57	0.50
120	1.32				1.18	1.06	0.93	0.82	0.73	0.64	0.57	0.50
125	1.35				1.21	1.08	0.95	0.94	0.75	0.66	0.58	0.52
140	1.38				1.24	1.11	0.97	0.86	0.76	0.67	0.60	0.53
160	1.45				1.29	1.16	1.02	0.90	0.80	0.70	0.62	0.55
180	1.50				1.34	1.20	1.05	0.93	0.82	0.73	0.65	0.57
200	1.54				1.38	1.23	1.08	0.96	0.85	0.75	0.67	0.59
230	1.58				1.42	1.26	1.11	0.99	0.87	0.77	0.69	0.60

Capacity Correction Factors for Ambient Temperature

Ambient Air Temp (°F)	Factor
75	1.09
80	
85	
90	
95	1.05
100	1.00
105	0.96
110	0.92

TX Series
Capacity Correction Factors for Operating Conditions

Inlet Pressure (psig)	Inlet Temperature (°F) 90	100	110	120
80	1.17	0.95	0.79	0.66
100	1.23	1.00	0.82	0.70
115	1.28	1.04	0.88	0.73
125	1.31	1.07	0.91	0.74
150	1.37	1.13	0.95	0.80
175	1.42	1.18	0.99	0.84
200	1.47	1.22	1.03	0.89
230	1.49	1.24	1.05	0.91

Capacity Correction Factors for Ambient Temperature

	Ambient Air Temperature (°F) 80	90	100	110
Factor	1.12	1.06	1.00	0.94

Selecting the Proper Dryer

To correct rated capacity for actual operating conditions, refer to "Capacity Correction Factors for Operating Conditions" and "Capacity Correction Factors for Ambient Temperature". Find the capacity correction factors corresponding to the inlet and ambient conditions. Multiply these factors to find the "overall" capacity correction factor, then multiply any dryer's rated capacity by the overall correction factor to determine its capacity at your operating conditions. Capacity correction factors for conditions not shown may be interpolated.

Note that these correction factors are specific to Kaeser model dryers. For additional assistance in sizing dryers for your installation, contact your local authorized Kaeser representative.

Introduction
Location
Ventilation
Water-cooling
Electrical Supply
Correct Air Storage
Efficiency Enhancing Equipment
Air Purity & Treatment
Condensate Management
Piping
Preventive Maintenance
Leaks
Safety Advisories
Additional Resources
Appendices

Appendix B: Dryer Correction Factors for Kaeser's Refrigerated Dryers

Demand Manager Series

Capacity Correction Factors for Ambient Temperature

Pressure (psig)	Temperature (°F)								
	80	85	90	95	100	105	110	115	120
80	1.50	1.34	1.17	1.06	0.95	0.87	0.79	0.73	0.66
100	1.55	1.39	1.23	1.12	1.00	0.91	0.82	0.76	0.70
110	1.58	1.42	1.26	1.15	1.03	0.94	0.86	0.79	0.72
115	1.60	1.44	1.28	1.16	1.04	0.96	0.88	0.80	0.73
125	1.63	1.47	1.31	1.19	1.07	0.99	0.91	0.83	0.74
145	1.69	1.52	1.36	1.24	1.12	1.03	0.94	0.87	0.79
175	1.75	1.59	1.42	1.30	1.18	1.09	0.99	0.92	0.84
200	1.80	1.64	1.47	1.35	1.22	1.13	1.03	0.96	0.89
230	1.82	1.66	1.49	1.37	1.24	1.15	1.05	0.98	0.91

Capacity Correction Factors for Ambient Temperature

	Ambient Air Temperature (°F)							
	75	80	85	90	95	100	105	110
Air-Cooled	1.15	1.12	1.09	1.06	1.03	1.00	0.97	0.94

Selecting the Proper Dryer

To correct rated capacity for actual operating conditions, refer to "Capacity Correction Factors for Operating Conditions" and "Capacity Correction Factors for Ambient Temperature". Find the capacity correction factors corresponding to the inlet and ambient conditions. Multiply these factors to find the "overall" capacity correction factor, then multiply any dryer's rated capacity by the overall correction factor to determine its capacity at your operating conditions. Capacity correction factors for conditions not shown may be interpolated.

Note that these correction factors are specific to Kaeser model dryers. For additional assistance in sizing dryers for your installation, contact your local authorized Kaeser representative.

Appendix B: Dryer Correction Factors for Kaeser's Desiccant Dryers

Kaeser Heatless Desiccant Dryers (KAD)

Inlet Flow Capacity

All Models (E and PS)	Inlet Flow @ 100 psig (scfm)
KAD 40	40
KAD 60	60
KAD 90	90
KAD 115	115
KAD 165	165
KAD 260	260
KAD 370	370
KAD 450	450
KAD 590	590
KAD 750	750
KAD 930	930
KAD 1130	1130
KAD 1350	1350
KAD 1550	1550
KAD 2100	2100
KAD 3000	3000
KAD 4100	4100
KAD 5400	5400

Inlet Pressure Correction Factor

Inlet Pressure (psig)	Multiplier	Inlet Pressure (psig)	Multiplier
60*	0.65	125	1.10
70	0.74	130	1.12
80	0.83	140	1.16
90	0.91	150	1.20
100	1.00	175	1.29
110	1.04	200	1.37
115	1.06	225	1.45
120	1.08	250	1.52

**For operation at pressures lower than 60 psig, please contact factory.*

Selecting the Proper Dryer

To determine a dryer's inlet flow capacity at inlet pressures other than 100 psig, multiply the dryer's rated inlet flow by the multiplier from that corresponds to the system pressure at the dryer inlet.

Note that these correction factors are specific to Kaeser model dryers. For additional assistance in sizing dryers for your installation, contact your local authorized Kaeser representative.

Kaeser Purge Dryers KED (Heated) and KBD (Blower)

Inlet Flow Capacity

KED Model Number	Inlet flow @ 100 psig 100°F (scfm)
300	300
400	400
500	500
600	600
750	750
900	900
1050	1050
1300	1300
1500	1500
1800	1800
2200	2200
2600	2600
3200	3200

KBD Model Number	Inlet flow @ 100 psig 100°F (scfm)
500	500
600	600
750	750
900	900
1050	1050
1300	1300
1500	1500
1800	1800
2200	2200
2600	2600
3200	3200
3600	3600
4300	4300

KED/KBD Inlet Conditions Correction Factors

Inlet Pressure (psig)	Inlet Temperature °F (°C)						
	60	70	80	90	100	110	120
60	1.03	1.01	0.99	0.80	0.58	0.43	0.32
70	1.10	1.08	1.07	0.94	0.68	0.50	0.37
80	1.17	1.15	1.14	1.08	0.79	0.58	0.43
90	1.24	1.22	1.20	1.18	0.89	0.66	0.49
100	1.30	1.28	1.26	1.24	1.00	0.74	0.55
110	1.36	1.34	1.32	1.30	1.11	0.82	0.61
115	1.39	1.37	1.35	1.33	1.16	0.86	0.64
120	1.42	1.40	1.38	1.36	1.22	0.90	0.67
125	1.45	1.43	1.41	1.39	1.27	0.94	0.70
130	1.48	1.46	1.44	1.42	1.33	0.99	0.74
140	1.53	1.51	1.49	1.47	1.44	1.07	0.80
150	1.58	1.56	1.54	1.52	1.50	1.16	0.87

Appendix C: Discharge of Air Through an Orifice

TABLE 8.25 Discharge of Air Through an Orifice

Gage Pressure before Orifice, psi	Nominal Diameter, In.										
	1/64	1/32	1/16	1/8	1/4	3/8	1/2	5/8	3/4	7/8	1
	Discharge, Cu. ft. Free Air Per Min.										
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

Based on 100% coefficient of flow. For well-rounded entrance multiply values by 0.97. For sharp-edged orifices a multiplier of 0.65 may be used.
This table will give approximate results only. For accurate measurements see ASME Power Test Code, Velocity Volume Flow Measurement.
Values for pressures from 1 to 15 psig calculated by standard adiabatic formula.
Values for pressures above 15 psig calculated by approximate formula proposed by S. A. Moss: $w = 0.5303\ aCp_1\quad T_1$ where w = discharge in lb per sec, a = area of orifice in sq. in., C = coefficient of flow, p_1 = upstream total pressure in psia, and T_1 = upstream temperature in deg F abs.
Values used in calculating above table were C = 1.0, p_1 = gage pressure + 14.7 psi, T_1 = 530 F abs.
Weights (w) were converted to volumes using density factor of 0.07494 lb. per cu. ft. This is correct for dry air at 14.7 psia and 70°F.
Formula cannot be used where p_1 is less than two times the barometric pressure.

Chart taken from Compressed Air and Gas Handbook. For additional pressures, visit www.cagi.org.

Appendix D: ISO Air Quality Classes

Compressed Air Purity Classes
ISO 8573-1:2010

SOLID PARTICLES / DUST If particles greater than 5µm have been measured, class 0-5 cannot be applied			
Class	0.1 - 0.5 µm	0.5 - 1 µm	1 - 5 µm
0	As specified and more stringent than Class 1		
1	≤ 20,000	≤ 400	≤ 10
2	≤ 400,000	≤ 6000	≤ 100
3	---	≤ 90,000	≤ 1000
4	---	---	≤ 10,000
5	---	---	≤ 100,000
6	0 - ≤ 5 mg/m^3		
7	5 - ≤ 10 mg/m^3		
8			
9			
X	> 10 mg/m^3		

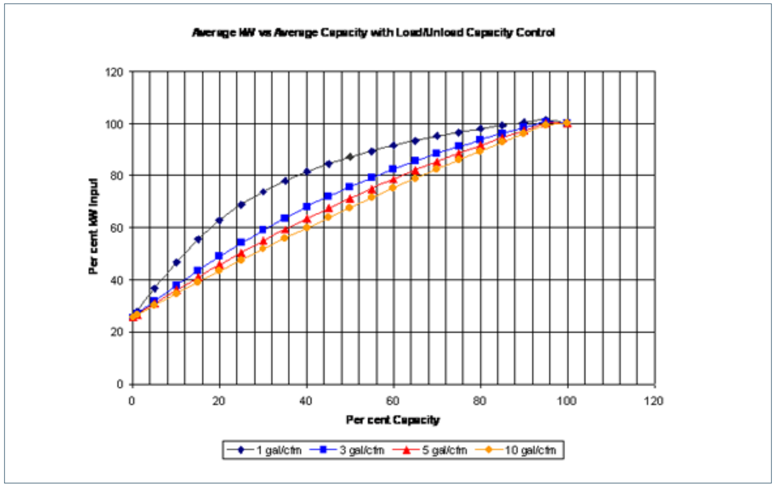
HUMIDITY AND LIQUID WATER		
Class	Pressure Dew Point	
0	As specified and more stringent than Class 1	
1	≤ -70°C	≤ -94°F
2	≤ -40°C	≤ -40°F
3	≤ -20°C	≤ -4°F
4	≤ 3°C	≤ 38°F
5	≤ 7°C	≤ 45°F
6	≤ 10°C	≤ 50°F
	Concentration of liquid water	
7	≤ 0.5 g/m^3	
8	0.5 - ≤ 5 g/m^3	
9	5 - ≤ 10 g/m^3	
X	> 10 g/m^3	

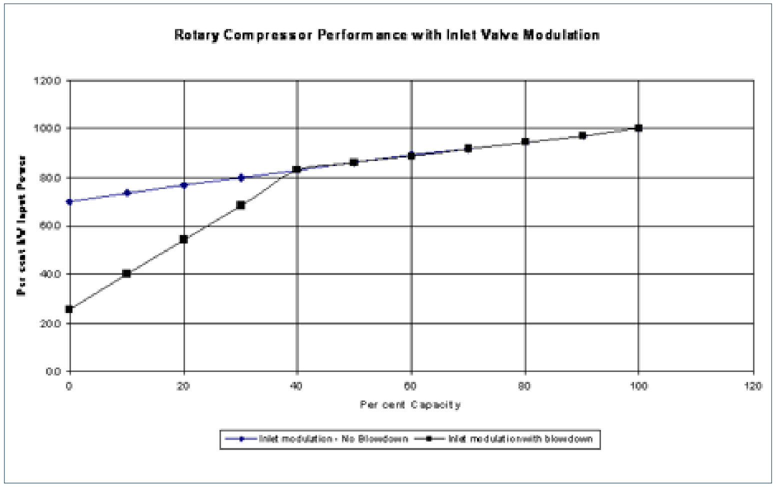
TOTAL OIL Liquid, aerosol, and vapor		
Class	mg/m^3	ppm w/w
0	As specified and more stringent than Class 1	
1	≤ 0.01	≤ 0.008
2	≤ 0.1	≤ 0.08
3	≤ 1.0	≤ 0.8
4	≤ 5.0	≤ 4
5		
6		
7		
8		
9		
X	> 5.0	> 4

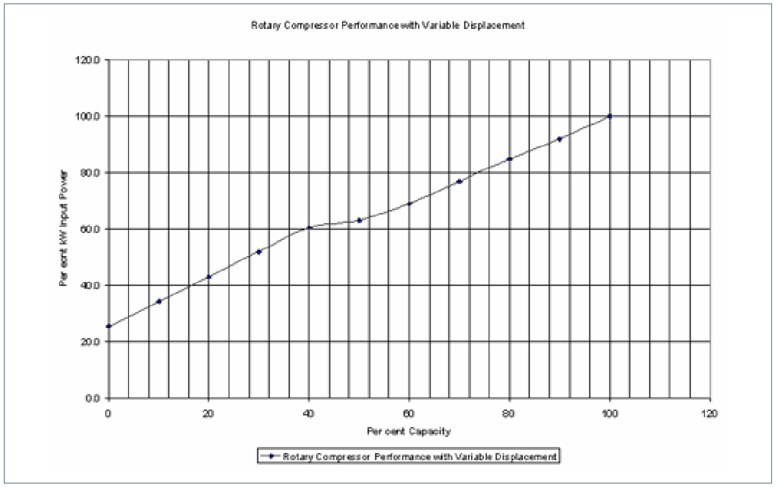
At reference conditions: 68°F, 14.5 psia, 0% relative humidity

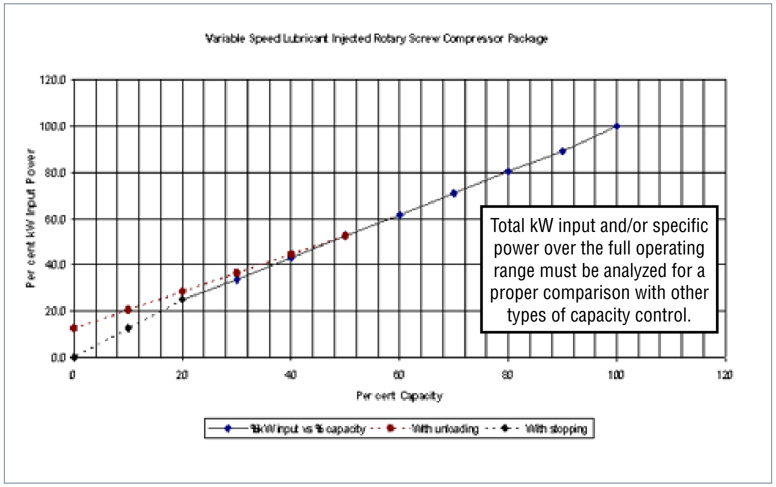
Introduction
Location
Ventilation
Water-cooling
Electrical Supply
Correct Air Storage
Efficiency Enhancing Equipment
Air Purity & Treatment
Condensate Management
Piping
Preventive Maintenance
Leaks
Safety Advisories
Additional Resources
Appendices

Appendix E: Power vs. Flow Characteristics Curves









Source: Compressed Air Challenge. For more information, visit: [www.compressedairchallenge.org.](www.compressedairchallenge.org)

Introduction
Location
Ventilation
Water-cooling
Electrical Supply
Correct Air Storage
Efficiency Enhancing Equipment
Air Purity & Treatment
Condensate Management
Piping
Preventive Maintenance
Leaks
Safety Advisories
Additional Resources
Appendices

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