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# Getting the Most for Your Money

## *How to Select and Protect Your Air Compressor Investment*


Evaluating a Compressed Air System

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*Provided as a service by Kaeser Compressors, Inc.*

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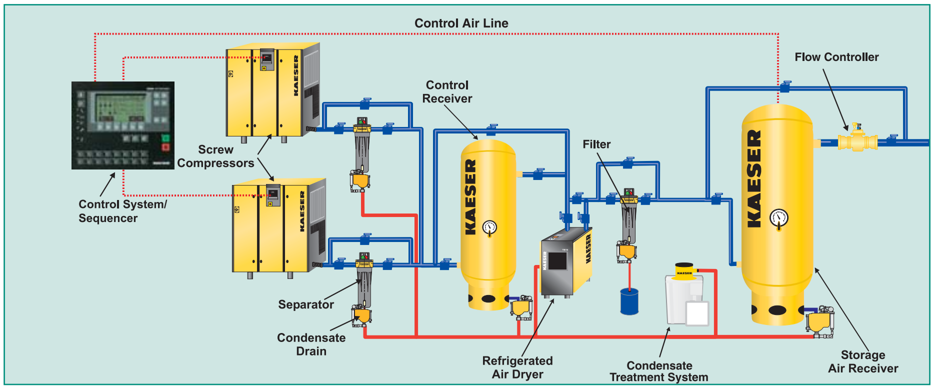
# Evaluating a Compressed Air System




***Optimized Compressed Air System***

*This diagram depicts multiple compressors controlled by a system controller, followed by clean air treatment and a storage air receiver with a flow controller. This setup ensures optimal use of energy.*

To evaluate a compressed air system, you must begin at the end: What are your air requirements at the point of use? Once you determine exactly what type and how much air you need, you can begin to factor-in design considerations, costs, and efficiencies.

## Design Considerations

Careful planning is essential for smooth operation. System configuration should take into consideration both your requirements and the physical characteristics of your installation.

***Air-cooled vs. Water-cooled.*** Air-cooled compressors have either integrally-mounted or separate oil and air coolers. These coolers require adequate ventilation to perform reliably. For water-cooled compressors, an adequate supply pressure and quality water must be available.

***Full or Part Load.*** Air compressors operate most efficiently at full load or off. Depending on your usage profile, it may be more cost-effective to purchase multiple compressors to accommodate load variations. In some cases, variable frequency/speed drive controlled units offer the best solution for part-load control/operation.

***Sequencers.*** Sequencers improve the efficiency and reliability of multiple compressor systems. With microprocessor controls, they can stabilize system pressure and even track each unit's service, load, and maintenance hours.

***Heat Recovery.*** Recovering and using the heat generated by an air compressor conserves energy. Waste heat has many applications including process use, space heating, and preheating boiler feedwater.

***Aftercoolers.*** These heat exchangers cool the compressed air and condense much of the moisture for easy removal. This prepares the air for further treatment.

***Receiver Tank.*** If you have widely varying compressed air loads, consider a receiver tank to boost capacity during peak periods. With a larger receiver tank, you can meet occasional peak demand with a small compressor and avoid high electrical demand charges.

***Dryers.*** Removing moisture from compressed air is essential for virtually all applications. Air quality requirements and ambient conditions will help determine the type of dryer required.

***Piping.*** Pipes must be carefully sized and arranged to minimize pressure drop and should be sloped to drain towards a drop leg or moisture trap.

***Filters, Regulators, & Lubricators.*** These should be installed at the point-of-use.

***Condensate Control.*** Because condensate must be expelled from the system for reliable operation, drain traps should be included in the system plan. Additionally, most localities require that

### Engineering expertise

*With decades of combined experience in compressed air systems and design, our entire team of qualified engineers is always at your service. For specialized systems or unique requirements, Kaeser's highly trained engineers provide expert applications assistance. From complex installations and challenging environments to facilities with limited space, Kaeser can design and lay out a system to meet the specified requirements for performance and reliability.*

*Using specialized tools such as our Power Cost Analysis and Air Demand Analysis, we can provide an accurate assessment of the existing installation as well as a contrasting view of the proposed system's performance.*

*Kaeser uses state-of-the-art CAD systems to lay out the proposed system and produce traditional two-dimensional and three-dimensional drawings for project execution. Variables such as distance, diameters, equipment order, location, accessories and connections can be reviewed and modified, if necessary, prior to installation.*

any oil be separated from condensate before the water can be disposed of in the municipal system.

***Booster Compressors.*** These compressors efficiently increase plant air pressure for equipment or processes that require up to 650 psig.

## Air Requirements

***Air Quality.*** There are many key levels of compressed air quality ranging from shop air to breathing air. The required air quality will determine the type of filtration and drying system.

***Air Capacity.*** Begin with capacity requirements and load factors for each tool and machine that will use compressed air. These compressed air requirements are generally available from the equipment manufacturers. For an existing system, a professional air system audit will provide valuable information.

***Air Pressure.*** Determine the pressure required at the point of use. Pneumatic tool manufacturers rate tool capacities at specific pressure ratings. The minimum required pressure can be determined by the equation:

Pr = Pp + PL where:

Pr = Minimum required pressure, psig.

Pp = Pressure at point of use, psig.

PL = Total pressure loss, psid.

Total pressure loss includes any losses at the dryers, centrifugal separator, particulate filter, oil removal filter, and oil vapor adsorber, as well as piping and valves.

Once capacity and pressure requirements are known, the air compressor size and input power requirements can be obtained from manufacturers.

## Cost of Compressed Air

You must go beyond initial cost when evaluating compressed air systems. During the first year, operating costs for compressed air can be 1½ to 2½ times the initial purchase price of the equipment. Efficiency of the compressor and the overall system efficiency are critical.

***Electrical Expense.*** As much as 70% of compressed air cost is electrical.

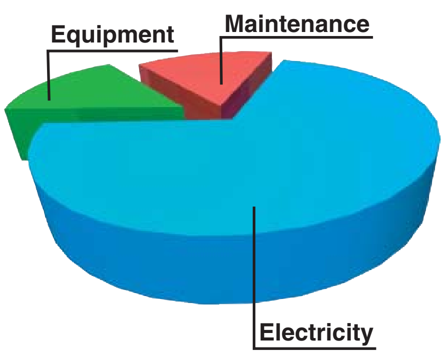
***Cooling Cost.*** If you are considering air-cooled compressors, factor in the electricity used to run cooling fan motors. If evaluating a water-cooled system, consider the quantity and required quality of the water, as well as treatment, electrical, and disposal costs.

***Maintenance Costs.*** The easier the system is to maintain, the more you save in the long run.

***Leaks and Unnecessary Demand.*** Any leaks in your system will add to your operating costs. Unnecessary use of compressed air is wasteful and expensive.

***Reliability.*** An unreliable compressed air system can be disastrous to the bottom line. A lost production day is never made up.

## 70% of Your Long Term Compressor Cost is Electricity




Analyze the total cost of a compressed air system and you'll realize that power cost is significant. In just one year it could exceed the cost of the compressor itself. Over a period of ten years, this could consume 70% of your overall costs.

That's why it is important to investigate energy efficiency when considering a new compressor.

### Global Standards

*ISO 8573.1 was developed in 1991 by ISO (International Organization for Standardization) to help facility engineers specify compressed air quality globally with "Quality Classes" for solid particulates, humidity and oil. Quality classes provide an internationally accepted unit of measure. A typical pharmaceutical plant, for example, would have a compressed air specification of ISO Quality Class 1.2.1. This is equivalent to 0.01 micron particulate filtration, -40° F (-40°C) dew point, and 0.008 ppm (0.01 mg/m³) oil filtration.*

| Quality Classes | SOLIDS Maximum Particle Size (microns) |
|---|---|
| 0 | as specified |
| 1 | 0.1 |
| 2 | 1 |
| 3 | 5 |
| 4 | 15 |
| 5 | 40 |
| 6 | — |

| Quality Classes | MOISTURE Dew Point | |
|---|---|---|
| | °C | °F |
| 0 | as specified | |
| 1 | -70 | -94 |
| 2 | -40 | -40 |
| 3 | -20 | -4 |
| 4 | 3 | 38 |
| 5 | 7 | 45 |
| 6 | 10 | 50 |

| Quality Classes | OIL Liquid and Gas | |
|---|---|---|
| | $mg/m^3$ | $ppm_{w/w}$ |
| 0 | as specified | |
| 1 | 0.01 | 0.008 |
| 2 | 0.1 | 0.08 |
| 3 | 1 | 0.8 |
| 4 | 5 | 4 |
| 5 | 25 | 21 |
| 6 | — | — |

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### Sigma Profile Airend

*Airend performance is critical to the compressor's overall efficiency and thus the compressor's energy consumption and operating costs. The Sigma Profile airend, developed by Kaeser Compressors, can save up to 20% in energy consumption. The Sigma Profile is standard on Kaeser rotary screw compressors. Units are available from 9 to 3140 cfm with discharge pressures up to 217 psig. Rotary screw compressors produce virtually pulsation-free air.*

# Types of Air Compressors

Compressed air is the fourth utility. Along with gas, electricity and water, it is essential to most modern industrial and commercial operations. It runs tools and machinery, provides power for material handling systems, and ensures clean, breathable air in contaminated environments. It is used by virtually every industrial segment from aircraft and automobiles to dairies, fish farming, and textiles.

A plant's expense for its compressed air is often viewed only in terms of the cost of the equipment. Energy costs, however, represent as much as 70% of the total expense in producing compressed air. As electricity rates escalate across the nation and the cost of maintenance and repair increases, selecting the most efficient and reliable compressor becomes critical.

## Rotary Screw Compressor: The Plant Workhorse

Rotary screw compressors operate on the principle of positive displacement. Filtered air enters the inlet of the airend where male and female rotors unmesh. The air is trapped between the rotors and the airend housing. This space is reduced as the rotors remesh on the opposite side of the airend. Thus, the air is compressed and moved to the discharge port. Cooling fluid injected into the housing mixes with the air to seal, lubricate, and remove the heat generated by compression. This fluid forms a thin film between the rotors that virtually eliminates metal-to-metal contact and wear. The fluid is separated from the compressed air, cooled, filtered, and returned to the injection point. The compressed air passes through an aftercooler to reduce its temperature and is ready for the air treatment equipment.

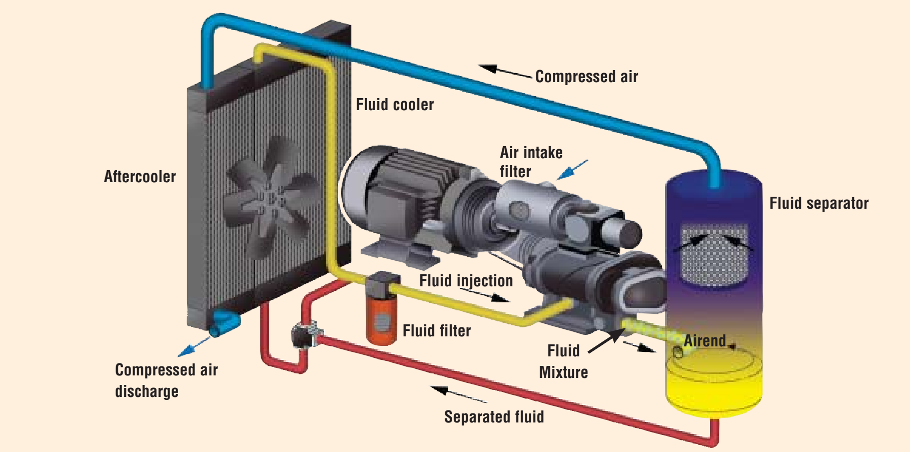
### Types of Air Compressors

**Air Compressors**

| Dynamic | Positive Placement | |
|---|---|---|
| **Centrifugal/Axial** | **Rotary** | **Reciprocating** |
| Use a rotating impeller to impart velocity to the air, which is converted to pressure. | Compress air through the action of rotating elements. Most common types are rotary screw, which uses rotating male and female rotors to compress air, and sliding vane, which uses radially moving vanes. | Compress air through the use of a reciprocating piston. |

**Select air compressors based on your plant needs. Positive displacement compressors take in quantities of air and mechanically reduce the space occupied by the air to increase pressure. Dynamic compressors use the mechanical action of rotating impellers to transfer pressure to the air.**

### Basic Operation of a Rotary Screw Compressor



# Selecting an Air Compressor

The heart of the compressed air system is the air compressor itself. When selecting an air compressor, the most important factors to consider are quality and reliability. Reflected in quality and reliability are overall costs, efficiency, and ease of maintenance. The most cost-effective unit may not be the lowest priced. Components to evaluate in a compressor include:


***Airend.*** Look at the package efficiency. Most reputable manufacturers report performance and efficiency using the Compressed Air and Gas Institute's (CAGI) data sheet. This reporting standard helps end-users make a one to one comparison between similar units.

***Cooling Systems.*** Coolers and fans must be sized to provide low discharge temperatures in high ambient temperatures. In air-cooled units, low-noise radial fans generally provide better cooling while using less electricity than axial fans. Also consider the ability to easily duct air in and out of the compressor package. Topside exhaust often simplifies ducting for heat recovery and reduces footprint.

***Drive.*** Efficiency and simplicity are important. Direct-coupled, 1-to-1 drives offer the best efficiency with no loss in transmission efficiency and require no maintenance. Belt drives require only simple maintenance and offer advantages such as flexibility in pressure selection. Automatic belt-tensioning devices are a must to ensure transmission efficiency and protect bearings from excess stress.

***Operating Interface:*** The control panel must be reliable, user-friendly, and run the compressor efficiently. It should indicate operational status as well as offer maintenance interval reminders, diagnostic information and external communications capability for remote monitoring and control.

***Interconnecting Piping.*** Look for rigid piping with flexible connections to eliminate leaks.

***Vibration Isolation.*** Vibrations can |loosen fluid and air fittings as well as electrical connections. Some compressors mount the motor and airend on vibration isolators to eliminate this source of stress. Additional isolators under the compressor package offers another layer of vibration protection, and for most rotary screw compressors, these isolators eliminate the need for special foundations.

***Motor.*** Motor efficiency affects electrical consumption. Ensure your compressor motor meets or exceeds EPAct standards. TEFC motors offer much better protection from airborne dirt and dust than ODP motors.

***Sound Enclosures.*** A noise-insulated enclosure can reduce the compressor noise emissions well below safety limits, eliminating the need for a separate compressor room. This can save you thousands of dollars in site preparation costs.


### Integration

*Compressor manufacturers are adding more value through integrating system components. Some offer variable speed/ frequency drive for improved pressure stability and energy efficiency. Dryers, filters, and drain traps are now commonly integrated to reduce system installation costs and save space.*

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## Simple Service

*Kaeser compressors are designed for easy maintenance and serviceability. The air filter, oil filter, and oil separator are all easy to reach, check, and replace. Special inlet filter mats are readily accessible. To facilitate oil changes, each rotary screw compressor is fitted with an oil change pressurization valve and drain hose. The doors and lid on the compressor cabinet allow immediate access to all maintenance points.*

# Maintenance

To most people who select an air compressor, the most important factors are overall cost, efficiency, ease of maintenance, and troubleshooting.

## Who Can Fix It?

If an air compressor system can be serviced by in-house personnel, overall operating costs will be less and downtime will be reduced. The more complex the compressor and compressor controls, the more difficult repairs will be. Selecting the simplest system will save you money.

## Easy to Maintain?

Proper maintenance adds to the reliability and efficiency of the air compressor. A compressor that is difficult to maintain causes problems and costs money. Some air compressors and air compressor components are specially designed for easy maintenance.

## Noise and Other Site Requirements?

Air compressors with low-sound enclosures and vibration isolators can save thousands of dollars in site preparation costs. You may be able to eliminate the expense of a separate compressor room or special foundation.

## What's the Warranty?

A warranty is the manufacturer's pledge to the customer. Make sure you have a comprehensive warranty on your equipment that is backed by solid manufacturer and distributor support.

### Maintenance Checklist

- ✓ **Compressor prefilters:** Check and clean or replace; service frequency relates to conditions in operating environment.
- ✓ **Compressor fluid level:** Should be at "full" mark; change per manufacturer's recommendation; DO NOT OVERFILL
- ✓ **Inlet filter cartridges:** Remove and clean or replace.
- ✓ **Drain traps:** Periodically check for proper operation.
- ✓ **Check for leaks throughout:** Piping and flexible joint packings, control lines, control line fittings, clamps and connectors, valves, air pressure safety relief valves, and pressure gauge connections.
- ✓ **Compressor cleanliness:** Maintain in a clean condition; a compressor should never leak fluid.
- ✓ **Coolers:** Check water quality, flow, and temperature in water-cooled units; check inlet filters and cooler surfaces on air-cooled models.
- ✓ **Belt condition:** Check for wear or damage and re-tension as required.
- ✓ **Compressor temperature:** Should be within manufacturer's limits.
- ✓ **Record service and load hours:** Systems that record both service and load hours are easier to maintain and troubleshoot.

***Refer to the service manual for recommended maintenance schedule. Accurate maintenance and operating records are essential for smooth and trouble-free operation.***

# Troubleshooting

In a compressed air system, as in any plant system, problems occur during routine operation. Most of these problems are minor and can be corrected by simple adjustments, cleaning or replacing a part, or eliminating an adverse condition. Any major problem that may develop is generally related to improper cooling or lubrication, poor maintenance and operating practices, or misapplying the system.

The troubleshooting chart below is not comprehensive, but indicates some common problems that can develop in compressed air systems using positive displacement compressors.

## Troubleshooting Compressed Air Systems

| Problem | Probable Cause | Remedial Action |
|---|---|---|
| Low pressure at point of use | Leaks in distribution piping | Check lines, connections and valves for leaks |
| | Clogged filter elements | Clean or replace filter elements |
| | Fouled dryer heat exchanger | Clean heat exchanger |
| | Low pressure at compressor discharge | See below |
| Low pressure at compressor discharge | For systems with modulating load controls, improper adjustments of air capacity control | Follow manufacturer's recommendation for adjustment of control |
| | Worn or broken valves | Check valves and repair or replace as required |
| | Improper air pressure switch setting | Follow manufacturer's recommendations for setting air pressure switch |
| Water in lines | Faulty air/oil separation | Check air/oil separation system; change separator element |
| | Failed or undersized compressed air dryer | Follow manufacturer's recommendation for proper oil level |
| Dirt, rust, or scale in air lines | In the absence of liquid water, normal aging of the air lines | Install filters at the point of use |
| Excessive service to load/hour ratio | System idling too much | For multiple compressor systems, consider sequencing controls to minimize compressor idle time; adjust idle time according to manufacturer's recommendations |
| | Improper pressure switch setting | Readjust according to manufacturer's recommendations |
| Elevated compressor temperature | Restricted air flow | Clean cooler exterior and check inlet filter mats |
| | Restricted water flow | Check water flow, pressure, and quality; clean heat exchanger as needed |
| | Restricted fluid flow | Check compressor fluid level, add fluid as required |
| | Low fluid level | Remove restriction, replace parts as required |
| | Excessive ambient temperatures | Improper ventilation of compressor; check with manufacturer to determine maximum operating temperature |

### Remote Monitoring

*Sigma Air Manager combines the benefits of a modern industrial PC technology with Internet technology to provide unparalleled compressor control, monitoring and reports. Optional software provides enhanced reporting and enables end users to control air system operation from any location.*

## Mission Statement

We strive to earn our customers' trust by supplying high quality Kaeser air compressors, related compressed air equipment and premium blower systems. Our products are designed for reliable performance, easy maintenance, and energy efficiency. Prompt and dependable customer service, quality assurance, training, and engineering support contribute to the value our customers have come to expect from Kaeser. Our employees are committed to implementing and maintaining the highest standards of quality to merit customer satisfaction. We aim for excellence in everything we do.

Our engineers continue to refine manufacturing techniques and take full advantage of the newest machining innovations. Extensive commitment to research and development keeps our products on the leading edge of technology to benefit our customers.

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# Compressed Air System Glossary

**Absolute pressure:** Total pressure measured from absolute zero.

**Aftercooler:** Heat exchanger for cooling air discharged from air compressor.

**Atmospheric pressure:** Pressure above absolute zero at a specific location and altitude

**Capacity:** The amount of air flow delivered or required under some specific conditions. May be stated as acfm, scfm, or cfm FAD.

- **Cubic feet of air per minute (cfm):** Volume delivery rate of air flow.
- **Cubic feet of air per minute, free air (cfm FAD):** cfm of air delivered to some specific point and converted back to ambient air (free air) conditions.
- **Actual cubic feet per minute (acfm):** Flow rate of air measured at some reference point and based on actual conditions at that reference point.
- **Inlet cubic feet per minute (icfm):** cfm flowing through the compressor inlet filter or inlet valve under rated conditions.
- **Standard cubic feet per minute (scfm):** Flow of free air measured at a reference point and converted to a standard set of reference conditions (e.g., 14.5 psia, 68°F, and 0% relative humidity).

**Demand:** Flow of air under specific conditions required at a particular point.

**Discharge pressure, rated:** Air pressure produced at a reference point.

**Discharge pressure, required:** Air pressure required at the system inlet.

**Displacement:** Amount of air (in cfm) displaced by the compressor piston under no load, discharging directly to the atmosphere.

**Dual control:** Load/unload control system that maximizes compressor efficiency. Compressor is normally operated at full load or idle, and is stopped and restarted automatically depending on demand.

**Free air:** Air at ambient conditions of temperature, humidity, and atmospheric pressure at any specific location.

**Inlet pressure:** The total pressure at the inlet flange of the compressor.

**Load factor:** Ratio of the average compressor load to the maximum rated compressor load during a given period of time.

**Modulating control:** Control system which will run the compressor at reduced output to accommodate demand variations. Running a compressor at less than full load results in a drop in compressor efficiency and thus an increase in operating costs.

**Pressure:** Force per unit area.

- **Pounds per square inch (psi):** Force per unit area exerted by compressed air.
- **Pounds per square inch absolute (psia):** Absolute pressure above zero pressure.
- **Pounds per square inch gauge (psig):** Pressure difference between absolute pressure (psia) and ambient pressure.
- **Pounds per square inch differential (psid):** Pressure difference between two defined points in the system.

**Pressure dew point:** Temperature at which water will begin to condense out of air at a given pressure.

**Pressure drop:** Loss of pressure in a compressed air system due to friction or flow restriction.

## Rules of Thumb

Air compressors normally deliver 4 to 5 cfm per horsepower at 100 psig discharge pressure.

Depending on the size of the system, compressed air costs about 25 to 30 cents per thousand cfm (including operating and maintenance costs).

Every 2 psi pressure drop costs 1% of compressor horsepower in efficiency.

Power cost for each 1 horsepower operating constantly for one year at 10 cents per kwh is about $750.

A 50 hp compressor rejects heat at approximately 126,000 Btu per hour.

Size air receivers for about 2-5 gallon capacity for each cfm of compressor capacity.

The water vapor content at 100°F of saturated compressed air equals about 6 gallons per day for each 100 cfm of compressor capacity.

## Effects of Ambient Conditions on Compressor Ratings