The following five appendices have been included in the sourcebook:

**Appendix A**
This appendix is a glossary defining terms used in the compressed air industry.

**Appendix B**
This appendix contains information on packaged compressor efficiency ratings.

**Appendix C**
This appendix contains Data Sheets outlining a common format for reporting compressor and dryer performance.

**Appendix D**
This section presents an overview of the compressed air systems marketplace, including market size and dynamics, and a description of the stakeholders.

**Appendix E**
This section offers guidance for selecting a firm that offers integrated services to improve compressed air system performance. It also explains the different levels of system analysis service.
Appendix A: Glossary of Basic Compressed Air System Terminology

Absolute Pressure—Total pressure measured from zero.

Absolute Temperature—See Temperature, Absolute.

Absorption—The chemical process by which a hygroscopic desiccant, having a high affinity with water, melts and becomes a liquid by absorbing the condensed moisture.

Actual Capacity—Quantity of gas actually compressed and delivered to the discharge system at rated speed and under rated conditions. Also called Free Air Delivered (FAD).

Adiabatic Compression—See Compression, Adiabatic.

Adsorption—The process by which a desiccant with a highly porous surface attracts and removes the moisture from compressed air. The desiccant is capable of being regenerated.

Air Receiver—See Receiver.

Air Bearings—See Gas Bearings.

Aftercooler—A heat exchanger used for cooling air discharged from a compressor. Resulting condensate may be removed by a moisture separator following the aftercooler.

Atmospheric Pressure—The measured ambient pressure for a specific location and altitude.

Automatic Sequencer—A device that operates compressors in sequence according to a programmed schedule.

Brake Horsepower (bhp)—See Horsepower, Brake.

Capacity—The amount of air flow delivered under specific conditions, usually expressed in cubic feet per minute (cfm).

Capacity, Actual—See Actual Capacity.

Capacity Gauge—A gauge that measures air flow as a percentage of capacity, used in rotary screw compressors.

Check Valve—A valve which permits flow in only one direction.

Clearance—The maximum cylinder volume on the working side of the piston minus the displacement volume per stroke. Normally it is expressed as a percentage of the displacement volume.

Clearance Pocket—An auxiliary volume that may be opened to the clearance space, to increase the clearance, usually temporarily, to reduce the volumetric efficiency of a reciprocating compressor.

Compressibility—A factor expressing the deviation of a gas from the laws of thermodynamics.

Compression, Adiabatic—Compression in which no heat is transferred to or from the gas during the compression process.

Compression, Isothermal—Compression is which the temperature of the gas remains constant.

Compression, Polytropic—Compression in which the relationship between the pressure and the volume is expressed by the equation PVn is a constant.

Compression Ratio—The ratio of the absolute discharge pressure to the absolute inlet pressure.

Constant Speed Control—A system in which the compressor is run continuously and matches air supply to air demand by varying compressor load.

Critical Pressure—The limiting value of saturation pressure as the saturation temperature approaches the critical temperature.
Critical Temperature—The highest temperature at which well-defined liquid and vapor states exist. Sometimes it is defined as the highest temperature at which it is possible to liquefy a gas by pressure alone.

Cubic Feet Per Minute (cfm)—Volumetric air flow rate.

cfm, free air—cfm of air delivered to a certain point at a certain condition, converted back to ambient conditions.

Actual cfm (acfm)—Flow rate of air at a certain point at a certain condition at that point.

Inlet cfm (icfm)—cfm flowing through the compressor inlet filter or inlet valve under rated conditions.

Standard cfm—Flow of free air measured and converted to a standard set of reference conditions (14.5 psia, 68°F, and 0 percent relative humidity).

Cut-In/Cut-Out Pressure—Respectively, the minimum and maximum discharge pressures at which the compressor will switch from unload to load operation (cut-in) or from load to unload (cut-out).

Cycle—The series of steps that a compressor with unloading performs 1) fully loaded; 2) modulating (for compressors with modulating control); 3) unloaded; and 4) idle.

Cycle Time—Amount of time for a compressor to complete one cycle.

Degree of Intercooling—The difference in air or gas temperature between the outlet of the intercooler and the inlet of the compressor.

Deliquescent—Melting and becoming a liquid by absorbing moisture.

Desiccant—A material having a large proportion of surface pores, capable of attracting and removing water vapor from the air.

Dew Point—The temperature at which moisture in the air will begin to condense if the air is cooled at constant pressure. At this point the relative humidity is 100 percent.

Demand—Flow of air at specific conditions required at a point or by the overall facility.

Diaphragm—A stationary element between the stages of a multi-stage centrifugal compressor. It may include guide vanes for directing the flowing medium to the impeller of the succeeding stage. In conjunction with an adjacent diaphragm, it forms the diffuser surrounding the impeller.

Diaphragm Cooling—A method of removing heat from the flowing medium by circulation of a coolant in passages built into the diaphragm.

Diffuser—A stationary passage surrounding an impeller, in which velocity pressure imparted to the flowing medium by the impeller is converted into static pressure.

Digital Controls—See Logic Controls.

Discharge Pressure—Air pressure produced at a particular point in the system under specific conditions.

Discharge Temperature—The temperature at the discharge flange of the compressor.

Displacement—The volume swept out by the piston or rotor(s) per unit of time, normally expressed in cfm.

Droop—The drop in pressure at the outlet of a pressure regulator, when a demand for air occurs.

Dynamic Type Compressors—Compressors in which air or gas is compressed by the mechanical action of rotating impellers imparting velocity and pressure to a continuously flowing medium (can be centrifugal or axial design).

Efficiency—Any reference to efficiency must be accompanied by a qualifying statement which identifies the efficiency under consideration, as in the following definitions of efficiency:
Appendix A: Glossary of Basic Compressed Air System Terminology

Efficiency, Compression—Ratio of theoretical power to power actually imparted to the air or gas delivered by the compressor.

Efficiency, Isothermal—Ratio of the theoretical work (as calculated on a isothermal basis) to the actual work transferred to a gas during compression.

Efficiency, Mechanical—Ratio of power imparted to the air or gas to brake horsepower (bhp).

Efficiency, Polytropic—Ratio of the polytropic compression energy transferred to the gas, to the actual energy transferred to the gas.

Efficiency, Volumetric—Ratio of actual capacity to piston displacement.

Exhauster—A term sometimes applied to a compressor in which the inlet pressure is less than atmospheric pressure.

Expanders—Turbines or engines in which a gas expands, doing work, and undergoing a drop in temperature. Use of the term usually implies that the drop in temperature is the principle objective. The orifice in a refrigeration system also performs this function, but the expander performs it more nearly isentropically, and thus is more effective in cryogenic systems.

Filters—Devices for separating and removing particulate matter, moisture or entrained lubricant from air.

Flange Connection—The means of connecting a compressor inlet or discharge connection to piping by means of bolted rims (flanges).

Fluidics—The general subject of instruments and controls dependent upon low rate of flow of air or gas at low pressure as the operating medium. These usually have no moving parts.

Free Air—Air at atmospheric conditions at any specified location, unaffected by the compressor.

Full-Load—Air compressor operation at full speed with a fully open inlet and discharge delivering maximum air flow.

Gas—One of the three basic phases of matter. While air is a gas, in pneumatics the term gas normally is applied to gases other than air.

Gas Bearings—Load carrying machine elements permitting some degree of motion in which the lubricant is air or some other gas.

Gauge Pressure—The pressure determined by most instruments and gauges, usually expressed in psig. Barometric pressure must be considered to obtain true or absolute pressure.

Guide Vane—A stationary element that may be adjustable and which directs the flowing medium approaching the inlet of an impeller.

Head, Adiabatic—The energy, in foot pounds, required to compress adiabatically to deliver one pound of a given gas from one pressure level to another.

Head, Polytropic—The energy, in foot pounds, required to compress polytropically to deliver one pound of a given gas from one pressure level to another.

Horsepower, Brake—Horsepower delivered to the output shaft of a motor or engine, or the horsepower required at the compressor shaft to perform work.

Horsepower, Indicated—The horsepower calculated from compressor indicator diagrams. The term applies only to displacement type compressors.

Horsepower, Theoretical or Ideal—The horsepower required to isothermally compress the air or gas delivered by the compressor at specified conditions.

Humidity, Relative—The relative humidity of a gas (or air) vapor mixture is the ratio of the partial pressure of the vapor to the vapor saturation pressure at the dry bulb temperature of the mixture.

Humidity, Specific—The weight of water vapor in an air vapor mixture per pound of dry air.

Hysteresis—The time lag in responding to a demand for air from a pressure regulator.
Appendix A: Glossary of Basic Compressed Air System Terminology

Impeller—The part of the rotating element of a dynamic compressor which imparts energy to the flowing medium by means of centrifugal force. It consists of a number of blades which rotate with the shaft.

Indicated Power—Power as calculated from compressor-indicator diagrams.

Indicator Card—A pressure-volume diagram for a compressor or engine cylinder, produced by direct measurement by a device called an indicator.

Inducer—A curved inlet section of an impeller.

Inlet Pressure—The actual pressure at the inlet flange of the compressor.

Intercooling—The removal of heat from air or gas between compressor stages.

Intercooling, Degree of—The difference in air or gas temperatures between the inlet of the compressor and the outlet of the intercooler.

Intercooling, Perfect—When the temperature of the air or gas leaving the intercooler is equal to the temperature of the air or gas entering the inlet of the compressor.

Isentropic Compression—See Compression, Isentropic.

Isothermal Compression—See Compression, Isothermal.

Leak—An unintended loss of compressed air to ambient conditions.

Liquid Piston Compressor—A compressor in which a vaned rotor revolves in an elliptical stator, with the spaces between the rotor and stator sealed by a ring of liquid rotating with the impeller.

Load Factor—Ratio of average compressor load to the maximum rated compressor load over a given period of time.

Load Time—Time period from when a compressor loads until it unloads.

Load/Unload Control—Control method that allows the compressor to run at full-load or at no-load while the driver remains at a constant speed.

Modulating Control—System which adapts to varying demand by throttling the compressor inlet proportionally to the demand.

Multi-Casing Compressor—Two or more compressors, each with a separate casing, driven by a single driver, forming a single unit.

Multi-Stage Axial Compressor—A dynamic compressor having two or more rows of rotating elements operating in series on a single rotor and in a single casing.

Multi-Stage Centrifugal Compressor—A dynamic compressor having two or more impellers operating in series in a single casing.

Multi-Stage Compressors—Compressors having two or more stages operating in series.

Perfect Intercooling—The condition when the temperature of air leaving the intercooler equals the temperature of air at the compressor intake.

Performance Curve—Usually a plot of discharge pressure versus inlet capacity and shaft horsepower versus inlet capacity.

Piston Displacement—The volume swept by the piston; for multistage compressors, the piston displacement of the first stage is the overall piston displacement of the entire unit.

Pneumatic Tools—Tools that operate by air pressure.

Polytropic Compression—See Compression, Polytropic.

Polytropic Head—See Head, Polytropic.

Positive Displacement Compressors—Compressors in which successive volumes of air or gas are confined within a closed space and the space mechanically reduced, resulting in compression. These may be reciprocating or rotating.
Appendix A: Glossary of Basic Compressed Air System Terminology

**Power, Theoretical (Polytropic)**—The mechanical power required to compress polytropically and to deliver, through the specified range of pressures, the gas delivered by the compressor.

**Pressure**—Force per unit area, measured in pounds per square inch (psi).

**Pressure, Absolute**—The total pressure measured from absolute zero (i.e. from an absolute vacuum).

**Pressure, Critical**—See Critical Pressure.

**Pressure Dew Point**—For a given pressure, the temperature at which water will begin to condense out of air.

**Pressure, Discharge**—The pressure at the discharge connection of a compressor. (In the case of compressor packages, this should be at the discharge connection of the package.)

**Pressure Drop**—Loss of pressure in a compressed air system or component due to friction or restriction.

**Pressure, Intake**—The absolute total pressure at the inlet connection of a compressor.

**Pressure Range**—Difference between minimum and maximum pressures for an air compressor. Also called cut-in/cut-out or load/no-load pressure range.

**Pressure Ratio**—See Compression Ratio.

**Pressure Rise**—The difference between discharge pressure and intake pressure.

**Pressure, Static**—The pressure measured in a flowing stream in such a manner that the velocity of the stream has no effect on the measurement.

**Pressure, Total**—The pressure that would be produced by stopping a moving stream of liquid or gas. It is the pressure measured by an impact tube.

**Pressure, Velocity**—The total pressure minus the static pressure in an air or gas stream.

**Rated Capacity**—Volume rate of air flow at rated pressure at a specific point.

**Rated Pressure**—The operating pressure at which compressor performance is measured.

**Required Capacity**—Cubic feet per minute (cfm) of air required at the inlet to the distribution system.

**Receiver**—A vessel or tank used for storage of gas under pressure. In a large compressed air system there may be primary and secondary receivers.

**Reciprocating Compressor**—Compressor in which the compressing element is a piston having a reciprocating motion in a cylinder.

**Relative Humidity**—see Humidity, Relative.

**Reynolds Number**—A dimensionless flow parameter \((\eta<\Delta/:_t)\), in which \(\eta\) is a significant dimension, often a diameter, \(t\) is the fluid velocity, \(\Delta\) is the mass density, and \(\:\) is the dynamic viscosity, all in consistent units.

**Rotor**—The rotating element of a compressor. In a dynamic compressor, it is composed of the impeller(s) and shaft, and may include shaft sleeves and a thrust balancing device.

**Seals**—Devices used to separate and minimize leakage between areas of unequal pressure.

**Sequence**—The order in which compressors are brought online.

**Shaft**—The part by which energy is transmitted from the prime mover through the elements mounted on it, to the air or gas being compressed.

**Sole Plate**—A pad, usually metallic and embedded in concrete, on which the compressor and driver are mounted.

**Specific Gravity**—The ratio of the specific weight of air or gas to that of dry air at the same pressure and temperature.

**Specific Humidity**—The weight of water vapor in an air-vapor mixture per pound of dry air.
Specific Power—A measure of air compressor efficiency, usually in the form of bhp/100 acfm.

Specific Weight—Weight of air or gas per unit volume.

Speed—The speed of a compressor refers to the number of revolutions per minute (rpm) of the compressor drive shaft or rotor shaft.

Stages—A series of steps in the compression of air or a gas.

Standard Air—The Compressed Air & Gas Institute and PNEUROP have adopted the definition used in ISO standards. This is air at 14.5 psia (1 bar); 68°F (20°C) and dry (0 percent relative humidity).

Start/Stop Control—A system in which air supply is matched to demand by the starting and stopping of the unit.

Surge—A phenomenon in centrifugal compressors where a reduced flow rate results in a flow reversal and unstable operation.

Surge Limit—The capacity in a dynamic compressor below which operation becomes unstable.

Temperature, Absolute—The temperature of air or gas measured from absolute zero. It is the Fahrenheit temperature plus 459.6 and is known as the Rankin temperature. In the metric system, the absolute temperature is the Centigrade temperature plus 273 and is known as the Kelvin temperature.

Temperature, Critical—See Critical Temperature.

Temperature, Discharge—The total temperature at the discharge connection of the compressor.

Temperature, Inlet—The total temperature at the inlet connection of the compressor.

Temperature Rise Ratio—The ratio of the computed isentropic temperature rise to the measured total temperature rise during compression. For a perfect gas, this is equal to the ratio of the isentropic enthalpy rise to the actual enthalpy rise.

Temperature, Static—The actual temperature of a moving gas stream. It is the temperature indicated by a thermometer moving in the stream and at the same velocity.

Temperature, Total—The temperature which would be measured at the stagnation point if a gas stream were stopped, with adiabatic compression from the flow condition to the stagnation pressure.

Theoretical Power—The power required to compress a gas isothermally through a specified range of pressures.

Torque—A torsional moment or couple. This term typically refers to the driving couple of a machine or motor.

Total Package Input Power—The total electrical power input to a compressor, including drive motor, belt losses, cooling fan motors, VSD or other controls, etc.

Unit Type Compressors—Compressors of 30 bhp or less, generally combined with all components required for operation.

Unload—(No-load) compressor operation in which no air is delivered because the intake is closed or modified not to allow inlet air to be trapped.

Vacuum Pumps—Compressors which operate with an intake pressure below atmospheric pressure and which discharge to atmospheric pressure or slightly higher.

Valves—Devices with passages for directing flow into alternate paths or to prevent flow.

Volute—A stationary, spiral shaped passage which converts velocity head to pressure in a flowing stream of air or gas.

Water-Cooled Compressor—Compressors cooled by water circulated through jackets surrounding cylinders or casings and/or heat exchangers between and after stages.
Appendix B: Packaged Compressor Efficiency Ratings

Evaluating and comparing industrial air compressor capacities and efficiencies can be a daunting task. Standards exist for testing the performance of a compressor, but they have not always been applied in a consistent manner, and performance test results and efficiency ratings are not always published in consistent, standard formats. The result is that purchasers of air compressors can find it difficult to compare the equipment performance.

The Compressed Air and Gas Institute (CAGI), the primary compressed air industry trade association in the United States, has developed performance testing standards. CAGI, in conjunction with its European counterpart PNEUROP, has developed simplified performance testing standards which have been incorporated as addenda in International Standards Organization (ISO) Standard ISO 1217, Displacement Compressors Acceptance Tests. These Simplified Test Codes were adopted by the membership of CAGI and will be reflected in performance data published in manufacturers’ literature. Some CAGI members also have ISO 9001 Certification which requires documentation of compliance with published performance and procedures. Compressed air system users should be aware that not all manufacturers marketing compressors in the United States are members of CAGI, and some may test their compressors using different standards.

The following standards have been developed for measuring air compressor performance.

- CAGI/PNEUROP—Acceptance Test Code for Bare Displacement Air Compressors (PN2CPTC1)
- CAGI/PNEUROP—Acceptance Test Code for Electrically-Driven Packaged Displacement Air Compressors (PN2CPTC2)
- CAGI/PNEUROP—Acceptance Test Code for I.C. Engine-Driven Packaged Displacement Air Compressors (PN2CPTC3)
- American Society of Mechanical Engineers (ASME)—Power Test Code 9, Displacement Compressors, Vacuum Pumps, and Blowers
- International Standards Organization (ISO)—ISO 1217, Displacement Compressors Acceptance Tests [distributed in the United States by the American National Standards Institute (ANSI)]

The revised ISO 1217 with Simplified Test Codes will likely be the most commonly used standard in the future. CAGI has also developed data sheets outlining a common format and style for reporting compressor performance, including efficiency. For more information on CAGI Data Sheets, see Appendix C.

The industry norm for comparison of compressor efficiency is given in terms of brake horsepower per actual cubic feet per minute (bhp/100 acfm) at a compressor discharge pressure of 100 pounds per square inch gauge (psig). A typical single-stage, lubricant-injected, rotary screw compressor will have a rating of approximately 22 bhp/100 acfm (referenced to standard inlet conditions). Users should remember that performance at site conditions will be different from test data because of differences in factors such as ambient temperature, pressure, and humidity.

Even when accurate, consistent efficiency information is available, it may only be specified for full-load operation (i.e., full capacity and specified full-load discharge pressure). Since most systems operate at part-load much of the time, it is also important to compare part-load efficiencies when evaluating the performance of different compressors. The variety of control methods can, however, make this difficult.

When gathering information on compressor performance and comparing different models, users should make sure the compressors have been tested using the same standard, at the same conditions, and that the data is being reported in a consistent manner. Some situations can lead to “apples-and-oranges” comparisons. For example:

- Manufacturers may test their compressors under different “standard” conditions. Standard conditions should be at 14.5 psia (1 bar); 68°F (20°C) and dry (0 percent relative humidity).
Appendix B: Packaged Compressor Efficiency Ratings

- The actual full-load power required by a typical air compressor package might exceed the nominal nameplate rating of the main-drive electric motor. Such motors have a continuous service factor, usually 15 percent, which allows continuous operation at 15 percent above the nominal rating. Most manufacturers use up to two-thirds of the available service factor, so that full-load power will be 10 percent above the nominal motor rating. It is therefore important to use the bhp rating, not the motor nameplate horsepower (hp) rating, when comparing efficiency ratings in hp/acfm. To include the motor efficiency and all package accessories and losses, use a rating in total kilowatt input per acfm to provide more precise data.

- Manufacturers may use a flange-to-flange rating that does not include inlet, discharge, and other package losses. This can affect overall efficiency by 5 percent or more.

- Energy consumption for accessory components, such as cooling fan motors, may not be treated consistently.

- Manufacturers may apply ranges or tolerances to performance data.

- Performance is usually based on perfect intercooling, which may not be realized under actual operating conditions. Perfect intercooling requires the air inlet temperature at each stage to be the same, requiring a cooling water temperature approximately 15°F below the ambient air temperature. Poor intercooling will adversely affect compressor performance.

As the revised ISO standard and CAGI Compressor Data Sheets become more commonly used, these equipment comparison problems should become less significant.
Appendix C: CAGI’s Compressor and Dryer Data Sheets

These data sheets have been developed by the Compressed Air & Gas Institute (CAGI) as an aid to the end user/customer in the selection of pneumatic equipment for the planned operating conditions. The data sheets can be used to compare like equipment under equal operating parameters. Data sheets for rotary screw compressors, refrigerant dryers, and regenerative desiccant type dryers are included in this appendix.

The members of the Compressed Air & Gas Institute (CAGI) have long been involved in standards for the equipment manufactured by the industry. CAGI has worked closely with the European Committee of Compressors, Vacuum Pumps and Pneumatic Tools (PNEUROP), the International Organization for Standardization (ISO), and other standards development bodies to develop appropriate standards for compressed air and gas equipment.

For displacement type compressors, including rotary screw compressors, American Society of Mechanical Engineers (ASME) Power Test Code 9 has been the recognized performance standard in the United States and ISO 1217 in Europe. These are too complex for performance testing in volume production. CAGI and PNEUROP developed Simplified Test Codes which have been incorporated as appendices to ISO 1217. CAGI members agreed that published performance of their products would be based upon the Simplified Test Codes, and Performance Data Sheets were developed to provide a standardized method of presenting the performance data. The attached data sheets allow a common basis for comparison of rotary screw compressors, a type of displacement compressor.

CAGI has also developed similar Performance Data Sheets for Refrigerant Type, Regenerative Desiccant Type, and Membrane Type Compressed Air Dryers to allow a common basis for performance comparison. As a sponsor of the Compressed Air Challenge®, CAGI agreed to include these Performance Data Sheets in the sourcebook for use by those involved with the performance characteristics of compressors and dryers. Additional Performance Data Sheets will be added for centrifugal air compressors and other compressed air equipment as they become available. CAGI is also preparing a consumer fact sheet that will assist consumers in using the Performance Data Sheets.
# Compressor Data Sheet

## Rotary Screw Compressor

## Model Data

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<thead>
<tr>
<th></th>
<th>Manufacturer</th>
<th>Model Number</th>
<th># of stages</th>
<th>Air-cooled</th>
<th>Water-cooled</th>
<th>Oil-injected</th>
<th>Oil-free</th>
<th>VALUE</th>
<th>UNIT</th>
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<tbody>
<tr>
<td>3</td>
<td>Rated Capacity at Full-Load Operating Pressure&lt;sup&gt;a, e&lt;/sup&gt;</td>
<td>acfm&lt;sup&gt;a, e&lt;/sup&gt;</td>
<td>3</td>
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<td>4</td>
<td>Full-Load Operating Pressure&lt;sup&gt;b&lt;/sup&gt;</td>
<td>psig&lt;sup&gt;b&lt;/sup&gt;</td>
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</tr>
<tr>
<td>5</td>
<td>Maximum Full Flow Operating Pressure&lt;sup&gt;c&lt;/sup&gt;</td>
<td>psig&lt;sup&gt;c&lt;/sup&gt;</td>
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</tr>
<tr>
<td>6</td>
<td>Drive Motor Nameplate Rating</td>
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</tr>
<tr>
<td>7</td>
<td>Drive Motor Nameplate Nominal Efficiency</td>
<td>percent</td>
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<tr>
<td>8</td>
<td>Fan Motor Nameplate Rating (if applicable)</td>
<td>hp</td>
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<td>9</td>
<td>Fan Motor Nameplate Nominal Efficiency (if applicable)</td>
<td>percent</td>
<td>9</td>
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<td></td>
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<tr>
<td>10</td>
<td>Total Package Power Input at Rated Capacity and Full-Load Operating Pressure&lt;sup&gt;d&lt;/sup&gt;</td>
<td>kW&lt;sup&gt;d&lt;/sup&gt;</td>
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<td>11</td>
<td>Specific Package Input Power at Rated Capacity and Full-Load Operating Pressure&lt;sup&gt;f&lt;/sup&gt;</td>
<td>kW/100 cfm&lt;sup&gt;f&lt;/sup&gt;</td>
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<td></td>
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</table>

## NOTES:

a. Measured at the discharge terminal point of the compressor package in accordance with the CAGI/PNEUROP PN2CPTC2 Test Code (Annex C to ISO 1217).

b. ACFM is actual cubic feet per minute at inlet conditions.

c. Maximum pressure attainable at full flow, usually the unload pressure setting for load/no-load control or the maximum pressure attainable before capacity control begins. May require additional power.

d. Total package input power at other than reported operating points will vary with control strategy.

e, f. Tolerance is specified in the CAGI/PNEUROP PN2CPTC2 Test Code (Annex C to ISO 1217) as follows:

<table>
<thead>
<tr>
<th>Volume Flow Rate at specified conditions</th>
<th>Volume Flow Rate&lt;sup&gt;e&lt;/sup&gt;</th>
<th>Specific Energy Consumption&lt;sup&gt;f&lt;/sup&gt;</th>
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<tbody>
<tr>
<td>Below 0.5 m&lt;sup&gt;3&lt;/sup&gt;/min</td>
<td>+/- 7 %</td>
<td>+/- 8 %</td>
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<td>0.5 to 1.5 m&lt;sup&gt;3&lt;/sup&gt;/min</td>
<td>+/- 6 %</td>
<td>+/- 7 %</td>
</tr>
<tr>
<td>1.5 to 15 m&lt;sup&gt;3&lt;/sup&gt;/min</td>
<td>+/- 5 %</td>
<td>+/- 6 %</td>
</tr>
<tr>
<td>Above 15 m&lt;sup&gt;3&lt;/sup&gt;/min</td>
<td>+/- 4 %</td>
<td>+/- 5 %</td>
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</table>

## Appendix C: CAGI’s Data Sheets

This form was developed by the Compressed Air and Gas Institute for the use of its members. CAGI has not independently verified the reported data.
# Dryer Data Sheet

## Refrigerant Dryers

<table>
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<tr>
<th>Description</th>
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<th>60% Flow</th>
<th>Units</th>
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<tbody>
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<td>5 Tested Flow*</td>
<td>scfm**</td>
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<tr>
<td>6 Outlet Pressure Dewpoint</td>
<td>°F</td>
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<td></td>
</tr>
<tr>
<td>7 Pressure Drop</td>
<td>psi(d)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8 Total Dryer Input Power</td>
<td>kW</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9 Specific Package Power***</td>
<td>kW/100 scfm</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Dryer ratings at the following inlet conditions to the dryer (as per adopted CAGI Standard ADF 100):
  - Inlet Compressed Air Temperature: 100°F (37.78°C)
  - Inlet Compressed Air Pressure: 100 psig (6.9 Bar)
  - Max. Ambient Air Temperature: 100°F (37.78°C)
  - Inlet Compressed Air Relative Humidity: 100% (Saturated)

** SCFM defined as the volume of free air in cubic feet per minute measured at 14.5 psia (1.0 Bar), 68°F (20°C) temperature and 0% R.H. (0 WVP).

*** (Total Dryer Input Power/tested flow) x 100

This form was developed by the Compressed Air and Gas Institute for the use of its members. CAGI has not independently verified the reported data.
# Dryer Data Sheet
## Regenerative Desiccant-Type Dryers

### Model Data

<table>
<thead>
<tr>
<th></th>
<th>Manufacturer</th>
<th>Model Number</th>
<th>Unit Type</th>
<th>Desiccant Type</th>
<th>psig</th>
</tr>
</thead>
</table>

### Description

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>Full Flow</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Maximum Design Flow*</td>
<td>scfm**</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Outlet Pressure Dewpoint</td>
<td>°F</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Pressure Drop</td>
<td>psi(d)</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Purge Flow (average)</td>
<td>scfm</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Total Dryer Input Power***</td>
<td>kW</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Specific Package Power****</td>
<td>kW/100 scfm</td>
<td></td>
</tr>
</tbody>
</table>

* Dryer ratings at the following inlet conditions to the dryer (as per adopted CAGI Standard ADF 200):
  - Inlet Compressed Air Temperature: 100°F (37.78°C)
  - Inlet Compressed Air Pressure: 100 psig (6.9 Bar)
  - Inlet Compressed Air Relative Humidity: 100% (Saturated)

** SCFM defined as the volume of free air in cubic feet per minute measured at 14.5 psia (1.0 Bar), 68°F (20°C) temperature and 0% R.H. (0 WVP).

*** This total includes Calculated Power-Purge, Input Power for Blower and/or Heater (if any), and Control Power

****(Total Dryer Input Power/Max. Design Flow) x 100

Assumptions:
1. Average purge flow power calculation: (Purge Flow/4.2) x .746
2. Blower run time is average over one half a cycle.
3. Heater run time is average over one half a cycle.

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This form was developed by the Compressed Air and Gas Institute for the use of its members. CAGI has not independently verified the reported data.
## Dryer Data Sheet
### Membrane-Type Dryers

#### Model Data—For Compressed Air

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Manufacturer</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Model Number</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Air-cooled</td>
<td>Water-cooled</td>
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<tr>
<td></td>
<td>Oil-injected</td>
<td>Oil-free</td>
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<td></td>
<td>VALUE</td>
<td>UNIT</td>
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<td>3</td>
<td>Rated Capacity at Full-Load Operating Pressure</td>
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<tr>
<td>4</td>
<td>Full-Load Operating Pressure</td>
<td>psig</td>
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<tr>
<td>5</td>
<td>Maximum Full Flow Operating Pressure</td>
<td>psig</td>
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<tr>
<td>6</td>
<td>Drive Motor Nameplate Rating</td>
<td>hp</td>
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<td>7</td>
<td>Drive Motor Nameplate Efficiency</td>
<td>percent</td>
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<tr>
<td>8</td>
<td>Fan Motor Nameplate Rating (if applicable)</td>
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<td>9</td>
<td>Fan Motor Nameplate Efficiency (if applicable)</td>
<td>percent</td>
</tr>
<tr>
<td>10</td>
<td>Total Package Power Input at Rated Capacity and Full-Load Operating Pressure</td>
<td>kW</td>
</tr>
<tr>
<td>11</td>
<td>Specific Package Input Power at Rated Capacity and Full-Load Operating Pressure</td>
<td>kW/100 cfm</td>
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</table>

<table>
<thead>
<tr>
<th>Volume Flow Rate at specified conditions</th>
<th>Volume Flow Rate</th>
<th>Specific Energy Consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>m³/min</td>
<td>ft³/min</td>
<td>%</td>
</tr>
<tr>
<td>Below 0.5</td>
<td>Below 15</td>
<td>+/- 7</td>
</tr>
<tr>
<td>0.5 to 1.5</td>
<td>15 to 50</td>
<td>+/- 6</td>
</tr>
<tr>
<td>1.5 to 15</td>
<td>50 to 500</td>
<td>+/- 5</td>
</tr>
<tr>
<td>Above 15</td>
<td>Above 500</td>
<td>+/- 4</td>
</tr>
</tbody>
</table>

---

a. Measured at the discharge terminal point of the compressor package in accordance with the CAGI/PNEUROP PN2CPTC2 Test Code (Annex C to ISO 1217). ACFM is actual cubic feet per minute at inlet conditions.

b. The operating pressure at which the Capacity (Item 3) and Electrical Consumption (Item 10) were measured for this data sheet.

c. Maximum pressure attainable at full flow, usually the unload pressure setting for load/no-load control or the maximum pressure attainable before capacity control begins. May require additional power.

d. Total package input power at other than reported operating points will vary with control strategy.

e. f. Tolerance is specified in the CAGI/PNEUROP PN2CPTC2 Test Code (Annex C to ISO 1217) as follows:

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This form was developed by the Compressed Air and Gas Institute for the use of its members. CAGI has not independently verified the reported data.
Appendix C: CAGI’s Data Sheets
Appendix D: The Compressed Air System Marketplace

Compressed air is used in a wide variety of commercial and industrial applications. It is used to lift, hold, and position pneumatic and hydraulic devices; to operate air cylinder devices such as rivet guns and chipping hammers; to pressurize and atomize paint in spray guns; to operate air motors on grinders and drills; and to agitate liquids. In these applications, compressed air offers the advantages of being flexible, versatile, safe, and lightweight.

Market Size and Energy Consumption

More than 1 million air compressors are sold in the United States each year, the majority of which are powered by small motors of 5 horsepower (hp) or less. These small compressors are sold primarily to the commercial and residential markets to operate portable tools, air pumps, and pneumatic heating, ventilation, and air conditioning (HVAC) controls. Although these small compressors account for approximately 98 percent of all air compressors sold, they account for only 12 percent of annual electricity consumption. Larger air compressors (25 hp or above) on the other hand, are sold primarily to the industrial and institutional sector. Although they account for less than 1 percent of annual sales, they represent an estimated 80 percent of the annual electricity consumption.

Industrial sector air compressors are typically plant air compressors in the range of 10 to 350 hp. Compressors larger than 350 hp are typically used to supply air for large process applications or plant air for very large manufacturing facilities. According to a recent analysis by Easton Consultants, Inc., energy consumption by these two populations of air compressors is approximately 27 to 32 terawatt hours per year, equivalent to about 6 percent of all motor-driven electricity consumption in the industrial sector.

There are three basic types of (plant) air compressors: reciprocating, rotary screw, and centrifugal. Within the compressor types, options such as lubricated and lubricant-free designs are available. For example, lubricant-free rotary screw compressors are used in applications that require clean air, such as food processing, pharmaceuticals, and electronics. Lubricant-injected, rotary screw air compressors are the dominant type used in applications above 25 hp, accounting for 75 percent of unit sales. The popularity of the rotary screw air compressor is because of its low initial and maintenance costs and lower noise and vibration.

Although tools driven by compressed air can consume 10 times as much energy as comparable electric tools, they are used because of their ability to provide high torque in a small, light, and safe package, and because they usually have significantly lower maintenance costs than electric tools in manufacturing environments. The primary benefits of using compressed air in applications instead of alternative approaches include flexibility, versatility, and safety.

Compressed Air System Marketplace

The air compressor marketplace (see Figure D-1.1) is somewhat complex, with at least five key players or stakeholders.

- Air compressor manufacturers
- Air compressor auxiliary equipment manufacturers
- Air compressor and auxiliary equipment distributors
- Contractors and architect-engineering (A&E) firms
- Compressed air system users.

In addition to influencing each other, these stakeholders are affected by trade associations, auditors, governmental entities, and electric utilities.

Each of the stakeholder groups is discussed below.

Air Compressor Manufacturers

Rotary compressor or “air-end” manufacturers play a primary role in the air compressor industry. Since they are involved in component design and manufacturing, packaging, and assembly, they determine the effort applied to compressor engineering and the overall level of efficiency of compressor packages. A standard air compressor package consists of an electric motor, motor starter, compressor, controls,
filter, lubricant and air coolers, and lubricant/air separator. An air-end accounts for a significant portion of a packaged air compressor’s initial cost.

The market structure for plant air compressors is a mature market that has, in recent years, made the transformation from reciprocating to rotary screw compressors. A number of factors led to this transformation, including the lower first cost, lower maintenance requirements, and ease of installation of rotary screw units compared with reciprocating compressors. The market is fairly well concentrated and competitive, and the number of companies that manufacture industrial compressors continues to decline. Single-stage, lubricant-injected, rotary screw type compressors account for about 70 percent of the market. The industrial compressor market is dominated by a handful of manufacturers. Most domestic manufacturers are members of the Compressed Air and Gas Institute (CAGI). In addition, a few non-domestic companies also market compressors in the United States. Since compressor equipment is perceived as a commodity, competition is high. Taking inflation into account, industrial compressor prices have fallen over the past 5 years.

**Auxiliary Equipment Manufacturers**

Auxiliary equipment manufacturers produce components such as filters, dryers, aftercoolers, receiver tanks, pneumatic tools, lubricant separators, and distribution system components. There are thousands of different equipment manufacturers, ranging in size from small, family-owned businesses to large, multi-national corporations.

**Air Compressor Distributors**

A group of 500 to 600 distributors dominate the plant air compressor market, representing 85 to 90 percent of sales. The remainder are sold directly from the manufacturer to the compressed air system user, specifying engineer, or design-build contractor. Sales to other original equipment manufacturers are rare.

Distributors provide many useful services to compressed air system users and specifying engineers by offering information on new products, responding to requests for bids, supplying sample specifications, providing compressed air system design recommendations, and offering parts and service.

Although many distributors furnish detailed technical proposals with sound engineering design,
they are often not able to convince the user to purchase a higher-cost compressed air system design based on energy efficiency, even though total life-cycle costs are lower on the energy efficient system. This is in part because of the way requests-for-proposals are issued by compressed air system users. Often decisions are made purely on the lowest initial cost. Depending on customer specifications, distributors may offer a high-cost, energy-efficient compressed air system, along with a low-cost, less efficient system.

There are three types of distributors who provide different levels of service to the market: compressed air specialists, general industrial distributors, and warehouse distributors.

**Compressed Air Specialists.** Compressed air specialists work with complete compressed air systems, including the compressor and all ancillary components. These firms typically offer assistance with layout, specification, and sizing of components, storage, and controls. They offer a wide variety of maintenance programs, complete parts and service facilities, and locally stocked parts inventories. Compressed air specialists may also test, audit, and redesign systems, or install the complete system including the distribution network.

**General Industrial Distributors.** General industrial distributors offer limited assistance in system design; most of their business is responding to bids or specifications. These distributors also depend on parts and service business, but they do not generally service or install complete compressed air systems or offer consulting services on existing systems like distributors that specialize in compressed air systems or professional compressed air system auditors.

**Warehouse Distributors.** Warehouse distributors offer little or no technical support services, and do not provide repair, maintenance, or other services. Their sales tend to lean toward smaller equipment.

**Contractors and Architect-Engineering Firms**

Contractors and architect-engineering (A&E) firms are typically concerned with designing and specifying systems for reliability, ease of maintenance, and low noise, but not for efficiency. Other than a small number of national firms, regional and local consulting engineering firms generally lack an air compressor system department or specialist. Contractors and A&E firms often do, however, play an important role in writing equipment bid specifications. Since it is often difficult to compare the performance of equipment offered by different manufacturers, consulting engineers may oversize equipment by using high-safety factors.

**Compressed Air System Users**

Industrial users of compressed air systems possess a wide range of expertise. While a small number of large, sophisticated firms have compressed air specialists in-house and proactively manage and control their plant’s compressed air systems, many manufacturers do not, although the situation is improving. Compressed air system users often misdiagnose problems in air systems and do not recognize the amount of energy wasted due to poor compressed air system design, equipment selection, and operation and maintenance (O&M) practices. In addition, users are not represented by an industry or professional organization that emphasizes compressed air system issues.

Compressed air system users often do not consider energy costs when buying new air compressors. Because of a focus on lowest first cost, which is driven by separate budgeting and accounting for operating and capital costs, energy-efficient options (such as premium efficiency motors, the best microprocessor and part-load controls, and the most efficient equipment type or model for the applications) are usually not purchased.

**Rebuilders**

Compressor rebuilders are a rather minor force in the air compressor market with less than 5 percent of unit sales. Rebuilders were a larger influence 2 decades ago when reciprocating compressors dominated the plant air market and rebuilt equipment accounted for 25 percent of sales. Today, users are more likely to replace their defunct reciprocating compressor with a low-cost rotary compressor instead of rebuilding it. Remanufacturing is performed by some manufacturers and distributors and by a few independent rebuilders.

**Compressed Air System Audit Firms**

Compressed air system audit firms audit, analyze and troubleshoot a plant’s compressed air systems and then recommend improvements to equipment, systems, and O&M practices. Audits can frequently decrease energy consumption by 20 to 50 percent or more with actions such as revised operation and maintenance plans, leak programs, equipment downsizing, and
other efficiency upgrades. Auditors may be independent consultants or affiliated with manufacturers of controls, compressors, or auxiliary equipment.

**Other Stakeholders**

The other stakeholders that play a major role in the compressed air system marketplace by influencing it include trade associations, crosscutting organizations, government entities, and electric utilities. Each is discussed below.

**Trade Associations.**

*CAGI*—The most important trade association in the compressed air industry is the Compressed Air and Gas Institute (CAGI). CAGI is a nonprofit organization of 45 companies that manufacture air and gas compressors, pneumatic machinery and air and gas drying equipment; products which have a myriad of applications worldwide in construction, manufacturing, mining, and the process and natural gas industries.

The principal objectives of the CAGI are:

- To promote cooperation among its members for the improved production, proper use and increased distribution of air and gas compressors and related equipment
- To develop and publish standards and engineering data for air and gas compressors and related equipment
- To increase the amount, and improve the quality of service of air and gas compressors and related equipment to the general public
- To collect and distribute information of value to CAGI members and to the general public
- To engage in cooperative educational and research activities
- To cooperate with governmental departments and agencies and other bodies in matters affecting the industry.

Many of CAGI’s activities are carried out in its separate sections, which are categorized by product scope. Individual member companies may affiliate with one or more of these sections, depending upon their product lines.

In addition, important work of the Institute is carried out by committees, whose membership is composed of one representative from each section. These ongoing committees include the Energy Awareness, Educational and Promotional, Standards, Statistical Coordinating, and Technical.

More information on CAGI can be found in the sections of this sourcebook on BestPractices and the Compressed Air Challenge® (CAC), and in the fact sheet titled *Packaged Compressor Efficiency Ratings*. CAGI contact information can be found in the section titled *Directory of Contacts*.

**Compressor Distributor Associations**—Another important group of trade associations serves compressed air equipment distributors. Compressor distributor associations usually focus around one compressor manufacturer. Several associations coordinate their activities for the CAC through an umbrella group named the Compressor Distributors Association (CDA). Distributor association contact information can be found in the section titled *Directory of Contacts*.

**Crosscutting Organizations.** The CAC is a national effort involving all compressed air system stakeholders aimed at improving compressed air system performance. This collaborative will: deliver best-practice compressed air system information to the plant floor; create a consistent national market message that supports the application of these best practices; provide a technically sound and professionally delivered training program for plant operating personnel; and through a certification program, recognize plant personnel’s skills in operating compressed air systems. Participants include large industrial users of compressed air; manufacturers and distributors of compressed air equipment and their associations; facility engineers and their associations; compressed air system consultants; state research and development agencies; energy efficiency organizations; and utility companies. The CAC is described in detail in the *Where To Find Help* section of this sourcebook.

**Government Entities.** The major governmental influence on the compressed air systems marketplace is the U.S. Department of Energy’s (DOE) BestPractices program, which is an industry/government partnership designed to help industry improve the performance of their systems (including compressed air systems). BestPractices activities are described in the *Where To Find Help* section of this sourcebook.

**Electric Utilities.** During the past 10 to 15 years, electric utilities have influenced the compressed air system marketplace primarily through their demand-side management programs, largely under the influence
Appendix D: The Compressed Air System Marketplace

of state utility regulatory boards. Many electric utilities offered programs, such as compressor rebates that paid the incremental cost difference between a high-performance compressor and one of an average efficiency, or offered free or reduced-priced audits of compressed air systems. Most of these programs have now been discontinued, however.

As the electric utilities industry continues to deregulate and evolve, many utilities are interested in providing value-added energy services to their industrial customers. Compressed air systems offer a good opportunity for such services. Under the unregulated environment, utilities may offer anything from assistance with audits to complete outsourcing of a customer's compressed air operations.

The Market for Compressed Air System Efficiency Services

The Assessment of the Market for Compressed Air Efficiency Services1 is a report commissioned by DOE with technical support provided by CAC. The objective of this report is to provide a comprehensive and balanced view of the market for engineering and consulting services to improve the energy efficiency of plant compressed air systems. These services include plant assessments or audits to identify opportunities to improve compressed air system operations, preventive maintenance services, such as leak detection and repair that are aimed at reducing energy use, and redesign of controls and other system components to reduce energy use. The report is intended for use by the CAC and other industrial energy efficiency program operators in developing strategies to encourage the growth of the compressed air system efficiency industry and enhance the quality of the services it offers. Compressed air system vendors and designers may also find it useful in charting their own approach to providing energy efficiency services.

The project was designed to answer a number of key questions concerning the demand and supply sides of the market for compressed air efficiency services. Among the key research questions to be addressed on the demand side of the market were:

- To what extent are customers in key end-use sectors aware of compressed air usage, costs, and savings opportunities?
- What practices do these customers follow to monitor, maintain, and enhance the efficiency of compressed air systems?
- What, if any, services do these customers purchase to maintain or enhance the efficiency of compressed air systems?
- What barriers do customers experience in purchasing such services?

The key research questions on the supply-side of the market were:

- What efficiency services do compressed air distributors, installers, and consultants currently offer?
- What is the current volume of sales for these services (number of customers, number of projects, dollar volumes)? How has volume changed over the past few years? What are vendors’ expectations regarding growth?
- What role do these services play in the overall business strategy of manufacturers, distributors, and consultants?
- What barriers do these businesses face in developing and selling compressed air system efficiency services?

Key Findings

Demand-Side Findings

- Customer awareness of and concern for compressed air efficiency is low. Only 9 percent of customers interviewed for the program identified controlling energy costs as the primary objective in compressed air system maintenance and management. Only 17 percent mentioned efficiency at all as a system management objective. This low level of interest and knowledge was echoed in findings from the regional studies and interviews with compressed air system efficiency consultants.

- Maintenance of consistent, reliable compressed air supply is the principal objective of system management. Seventy-one percent of customers reported that ensuring adequate air supply is their primary objective in system management. According to

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1 XENERGY, Inc. (June 2001) Assessment of the Market for Compressed Air Efficiency Services, U.S. DOE in cooperation with Lawrence Berkeley National Laboratory and Oak Ridge National Laboratory.
Appendix D: The Compressed Air System Marketplace

consultants interviewed for this project, concern about operating consistency provides an effective route to selling efficiency-oriented services.

- A large portion of customers report serious problems in compressed air system operation and maintenance. Thirty-five percent of those interviewed reported that they had experienced unscheduled shutdowns of their compressed air systems during the previous 12 months. For 60 percent of these establishments, or 21 percent of all establishments, the shutdown had lasted 2 days or more. Two-thirds of the customers reported experiencing potentially serious operating problems in their compressed air systems. Excess moisture and inadequate air pressure were the most frequently reported problems.

- A significant portion of customers report having service contracts for their compressed air systems, but few of these contracts address system efficiency. Thirty percent of customers reported that they had service contracts for their compressed air systems. However, only one-third of these (or 10 percent of all participants) reported that efficiency-oriented services such as leak detection, energy-use monitoring, or assessment of control strategies were included in the service contract. There was no difference in the incidence of unscheduled system shutdowns or operating problems between customers with service contracts and those without such contracts.

- Thirty-five percent of customers interviewed reported that they conducted leak prevention programs.

- Reported implementation of compressed air efficiency measures is very low. The United States Industrial Electrical Motor Market Opportunities Assessment found that 57 percent of manufacturing plants had taken no action to improve compressed air system efficiency—including repairing leaks—in the 2 years prior to the survey. A 1999 survey of 270 large industrial users served by Pacific Gas & Electric obtained a similar finding.

- Seventy-five percent of operators of the systems installed had had no formal training in compressed air system efficiency.

- Seventeen percent of customers reported that they had undertaken a compressed air system audit over the past 7 years. Most of the audits had been conducted in the past 6 years; and six audits were underway at the time of the interview. While most of the audits included estimates of energy use and identified potential energy-saving measures, fewer than half included estimated savings and costs for recommended measures. Two-thirds of the customers who conducted system audits reported that they had implemented at least one of the recommended measures.

- One-third of the customers reported that vendors selling “services specifically designed to reduce energy costs in compressed air systems” had approached them. The nature of these services varied widely. The most frequently mentioned were preventive maintenance for compressors, assessment of control strategies, and identification of energy-saving measures. No one service was mentioned by more than 46 percent of those interviewed. This result reflects the formative state of the market for compressed air system efficiency services. Vendors have not defined the nature of such services consistently. Only 3 percent of customers reported that they had purchased compressed air efficiency services in response to these sales approaches. The most frequent objections to these services were high cost and the customers’ view that they could undertake such activities with in-house staff.

Supply-Side Findings

- A large portion of distributors report that they offer compressed air efficiency services. Over three-quarters offer system-efficiency measures, while over one-half offer end-use analyses and leak services.

- Over one-half of vendors feel that the demand for efficiency services has increased in the last year.

- Most distributors that offer efficiency-related services have entered the market within the past 10 years; one-third have entered in the past 4 years.

- Most distributors interviewed consider efficiency services essential to their competitive positions. Sixty-seven percent of distributors rate efficiency services as being important to their competitive position. Their major motivation to enter the market is customer retention. With the number of firms that offer efficiency services increasing, vendors believed that they needed to reply in kind to maintain satisfaction among their equipment purchasers. Access to additional revenue streams from consulting was not mentioned at all as a motivating factor.

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Most distributors identified customers’ lack of understanding of the benefits of compressed air efficiency measures as the major barrier to their increased sale. These findings mirror the experience of compressed air efficiency consultants. Forty-five percent of the vendors identified customer perceptions that compressed air efficiency services were already being provided by in-house staff as an objection to sales efforts. This finding, combined with the reported low incidence of specific measure implementation, further reinforces the consultants’ observation that customers are largely in the dark about the nature of compressed air system efficiency measures and maintenance practices.
Appendix E: Guidelines for Selecting a Compressed Air System Provider

Compressed air is one of the most important utility requirements of the typical industrial manufacturer. Compressed air is used throughout many processes, such as pneumatic tools, pneumatic controls, compressed air operated cylinders for machine actuation, product cleansing, and blow-offs. Without a consistent supply of quality compressed air, a manufacturing process can stop functioning.

The Compressed Air Challenge® (CAC) is a national collaboration that was created to assist industrial facilities in achieving greater reliability, improved quality control, and lower operating costs for their compressed air systems. The CAC encourages facilities to take a systems approach to optimizing compressed air operation. Taking a systems approach means looking beyond individual components to assess how well your compressed air system meets actual production needs. This is known as “matching supply with demand.” It also means identifying the root causes of system problems, rather than treating the symptoms.

For most industrial facilities, this approach will require specialized knowledge and equipment, both to assess system needs and to continue to service those needs over time. Outside assistance frequently is required. System assessment services and ongoing system maintenance may require the use of separate firms, although there is a growing market trend toward more fully integrated services. The process of selecting the right mix of services can be confusing. The CAC is working with the compressed air industry to help industrial compressed air users become informed consumers. Guidelines for Selecting a Compressed Air System Service Provider offers guidance to assist you in selecting a firm that offers integrated services. Independent compressed air system specialists typically provide comprehensive system assessment services as their principal business; many are not involved in sales of equipment, other products, or maintenance.

The CAC also is developing guidelines to define three levels of system analysis services, independent of the type of firm offering these services. These three levels of service include: a walk-through evaluation, a system assessment, and a fully instrumented system audit. More information on analysis services guidelines can be found under the CAC Levels of Analysis of Compressed Air Systems in this Guidelines document, or you can visit the CAC Web site at www.compressedairchallenge.org. In selecting a service provider, a compressed air user should consider the guidelines that follow.
Appendix E: Guidelines for Selecting a Compressed Air System Provider

WHAT TO LOOK FOR WHEN SELECTING A SERVICE PROVIDER

In selecting a service provider, a compressed air user should consider the following guidelines.

I. Familiarity with the Systems Approach

The Compressed Air Challenge® (CAC) provides Fundamentals of Compressed Air Systems and Advanced Management of Compressed Air Systems training to end users and service providers. One way to gauge a service provider’s commitment to the systems approach is whether they have staff who have received CAC training. If they do, ask whether these individuals will be providing or supervising services for your facility. Providers who are familiar with using a systems approach are much more likely to address situations, both inside and outside the compressor room, that are having an effect on the reliability of your compressed air supply.

II. Availability of Compressed Air System Assessment Services

Does the provider offer compressed air system analysis services? If yes, how well do these services fit your needs? If no, can the provider outsource these services to an experienced system specialist? How experienced are the individuals who will be providing these services? Once a walk-through, assessment, or audit is performed, what kind of follow-up services are available to ensure that the recommendations are properly implemented and produce the desired results? Ask for a sample of similar work that the provider has done for others, résumés of the personnel who will be performing the work, and client references. Please note that while leak detection is a useful element of a system assessment, a true system assessment should include much more. See www.compressedairchallenge.org for additional guidance.

Important Note: recommendations resulting from system analysis activities should provide product-neutral solutions to system problems and include, only if needed, performance-based rather than brand-based equipment recommendations.

III. Compressor Knowledge and Expertise

Does the service provider have the expertise to work on your equipment? Can the service provider work on all types of compressors in your facility? How much experience do the service technicians have? How are the service technicians trained? Is formal schooling involved? Knowledgeable service technicians are worth the premium price they may demand because of their ability to troubleshoot and get equipment back on line efficiently and effectively.

IV. System Components and Controls Knowledge and Expertise

Treatment, accessory, and ancillary equipment—Does the service provider have the expertise to perform refrigeration and other work on dryers and related equipment? Is the service provider capable of servicing the types of filters, drains, distribution and point of use equipment found in your facility?

System controls—Does the service provider have the diagnostic and technical controls capability to determine how to optimize your existing control configuration and make recommendations for improvements? Can they help network compressors together or remotely monitor, if necessary? Advanced controls can save energy and improve reliability through automatic start and stop, as well as turning compressors off that can then serve as back-ups. Advance warning through remote monitoring may help identify a problem before it turns into a major shutdown.

V. Company Capabilities

Ask about the standards of performance that the prospective service provider has established for:

- Emergency service response
- Parts shipments
- Other factors which may influence your decision, such as:
  - Installation capabilities internally or through a mechanical contractor
  - Emergency rental fleet availability—electric or portable diesel-driven
- Your company may request information on the service provider’s
  - Financial stability
  - Insurance coverage
  - Compliance with specific government regulations or those of your company.

VI. Service Facilities

Visit the facilities of two or three service providers under consideration to see first hand the type of repair shop and parts warehouse with which you will be dealing.
Appendix E: Guidelines for Selecting a Compressed Air System Provider

COMPRESSED AIR CHALLENGE®
LEVELS OF ANALYSIS OF COMPRESSED AIR SYSTEMS

OVERVIEW

The Levels of Analysis of Compressed Air Systems listed below have been developed in an effort to provide commonality of terminology, methods, and procedures to be used by service providers and the results to be expected by end users. This overview is essentially brief. More detailed versions of these Levels of Analysis are under development, at this time, and will be available through the CAC Web site at www.compressedairchallenge.org.

Energy utilities are actively involved in these efforts and some provide incentives to use these analyses to improve the energy efficiency of compressed air systems.

Conducting a walk-through evaluation is the first step in analyzing a compressed air system. Depending on individual needs, this can be conducted either by plant personnel or by an experienced compressed air system services provider. A walk-through evaluation is not intended to provide the level of detail found in a system assessment or a system audit but lower maintenance costs frequently have resulted from a walk-through evaluation alone. Once initial opportunities have been identified, a decision should be made concerning whether additional analysis services are required to further define system dynamics and corresponding system improvement opportunities. This decision will depend, in part, on the size and complexity of the system being examined (both supply and demand) and whether critical issues surfaced during the Evaluation that require further investigation to understand the root cause and suggest potential remedies.

LEVELS OF ANALYSIS

Walk-through Evaluation (1/2 to 2 days)
A walk-through evaluation is an overview of a plant compressed air system by identifying the types, needs, and appropriateness of end uses, pressures and air quality requirements.

• The distribution system is analyzed for any apparent problems of size, pressure drops, storage, leaks, and drains.
• The supply side is analyzed for types of compressors, and the types, suitability and settings of capacity controls.
• A simple block diagram of the system is drawn.
• Maintenance procedures and training are also analyzed.
• Written report of findings and proposed solutions is submitted.
• Solution and product neutrality should be maintained with any recommendations.

System Assessment (2 to 5 days)
A system assessment is more detailed than a walk-through evaluation of a plant compressed air system.

• In addition to identifying the items and problems of the walk-through evaluation, readings are taken at appropriate locations to identify the dynamics of the system.
• A simple block diagram of the system is drawn, also a pressure profile and a demand profile, to help identify potential problems and how they could be resolved.
• Again, maintenance procedures and training are reviewed.
• A written report of findings and recommendations is submitted.
• Solution and product neutrality should be maintained with any recommendations.

System Audit (3 to 10 days)
A system audit is similar to a system assessment but in more depth and detail.

• Data logging of readings throughout the system is conducted for more in-depth analysis of the dynamics of the system and resulting problems.
• Again, maintenance procedures and training are reviewed.
• The objective is a proper alignment of the supply side and the demand side for optimum efficiency, energy savings, and reliability. A baseline is established, against which the results of any proposed changes are measured.
• A comprehensive written report of all findings, recommendations, and results is submitted.
• Solution and product neutrality should be maintained with any recommendations.
About Compressed Air Challenge®

A national collaborative, the Compressed Air Challenge®, was formed in October of 1997 to assemble state-of-the-art information on compressed air system design, performance, and assessment procedures. This collaborative is delivering best-practice compressed air system information to the plant floor, creating a consistent national market message that supports the application of these best practices, providing a technically sound and professionally delivered training program for plant operating personnel, and will, through a certification program, recognize plant personnel’s skills in operating compressed air systems. Participants include large industrial users of compressed air, manufacturers and distributors of compressed air equipment and their associations, facility engineers and their associations, compressed air system consultants, state research and development agencies, energy efficiency organizations, and utilities. The goals of the Compressed Air Challenge® are to:

- Increase the reliability and quality of industrial production processes
- Reduce plant operating costs
- Expand the market for high quality compressed air services
- Save energy, a 10 percent improvement over current usage, resulting in annual savings of approximately 3 billion kilowatt hours of electricity nationwide.

The purpose of the Compressed Air Challenge® is to initiate a national collaborative that develops materials, a training curriculum, a certification program, and other information that can be used by the project sponsors in cooperation with others to:

- Raise awareness of the importance of efficient, effective plant air systems
- Train industrial plant operating personnel on best practices for plant air systems
- Expand the market for expert plant air assessment services
- Help build the local market infrastructure to deliver these services.

The Compressed Air Challenge® includes:

- A Board of Directors comprised of the project sponsors
- A Project Development Committee, which includes a representative from each key stakeholder group and is responsible for overall project coordination
- Working Groups, which provide essential technical input to the project.

The Compressed Air Challenge® is seeking additional participants interested in sponsorship or contributing to materials development. For general information, call the Compressed Air Challenge® at (800) 862-2086. If you would like to join the Challenge, see www.compressedairchallenge.org.

About the Office of Energy Efficiency and Renewable Energy

A Strong Energy Portfolio for a Strong America

Energy efficiency and clean, renewable energy will mean a stronger economy, a cleaner environment, and greater energy independence for America. By investing in technology breakthroughs today, our nation can look forward to a more resilient economy and secure future.

Far-reaching technology changes will be essential to America’s energy future. Working with a wide array of state, community, industry, and university partners, the U.S. Department of Energy’s Office of Energy Efficiency and Renewable Energy invests in a diverse portfolio of energy technologies that will:

- Conserve energy in the residential, commercial, industrial, government, and transportation sectors
- Increase and diversify energy supply, with a focus on renewable domestic sources
- Upgrade our national energy infrastructure
- Facilitate the emergence of hydrogen technologies as a vital new “energy carrier.”

The opportunities

Biomass Program
Using domestic, plant-derived resources to meet our fuel, power, and chemical needs

Building Technologies Program
Homes, schools, and businesses that use less energy, cost less to operate, and ultimately, generate as much power as they use

Distributed Energy & Electric Reliability Program
A more reliable energy infrastructure and reduced need for new power plants

Federal Energy Management Program
Leading by example, saving energy and taxpayer dollars in federal facilities

FreedomCAR & Vehicle Technologies Program
Less dependence on foreign oil, and eventual transition to an emissions-free, petroleum-free vehicle

Geothermal Technologies Program
Tapping the earth’s energy to meet our heat and power needs

Hydrogen, Fuel Cells & Infrastructure Technologies Program
Paving the way toward a hydrogen economy and net-zero carbon energy future

Industrial Technologies Program
Boosting the productivity and competitiveness of U.S. industry through improvements in energy and environmental performance

Solar Energy Technology Program
Utilizing the sun’s natural energy to generate electricity and provide water and space heating

Weatherization & Intergovernmental Program
Accelerating the use of today’s best energy-efficient and renewable technologies in homes, communities, and businesses

Wind & Hydropower Technologies Program
Harnessing America’s abundant natural resources for clean power generation

To learn more, visit www.eere.energy.gov.