Energy-Efficient Compressed Air Systems

Introduction

Investigation shows that industry can substantially reduce electricity costs by increasing the efficiency of compressed air systems. Improved maintenance procedures and more-efficient components are the key to accomplishing this objective.

This guide deals with both maintenance and component selection. The purpose is to help all users of compressed air get more value out of their electric power expenditures.

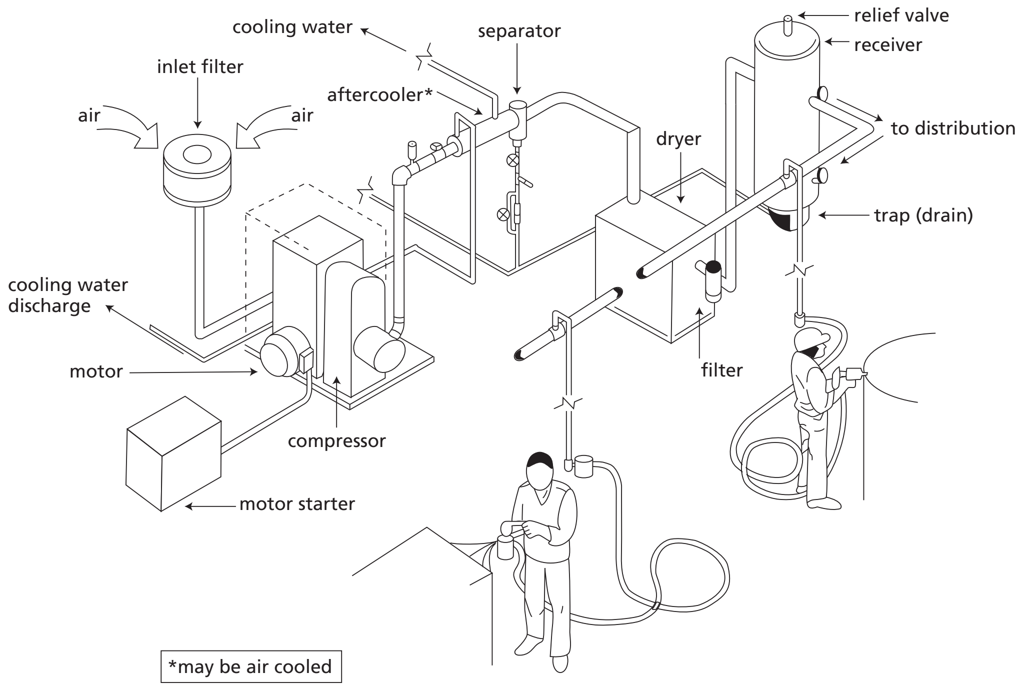

Figure 1: An industrial compressed air system

Basic components

Figure 1 shows the basic parts of most compressed air systems. Each will be discussed on the following pages.

BC hydro POWER SMART

The cost of wasted energy

Recent inspections of industrial plants in B.C. show that typical air plants use far more electricity than they actually need to use. The waste is sometimes caused by inefficient equipment and operating procedures. Often it is simply the result of neglected maintenance. Whatever the cause, the cost can be substantial, as discussed in the two examples that follow.

A single tiny leak, equal to a hole 3.2 mm (1/8") in diameter, wastes air at a rate of about 12 litres per second, or 25 scfm, in a standard 689 kPa (100 Psig) system. Even at the low rate of 4 cents per kWh, this leak alone can waste more than $1,000 a year — and most systems have several such leaks.

Some plants run large production compressors to leave their compressed air systems pressurized over weekends, holidays and overnight, even though the plant is shut down.

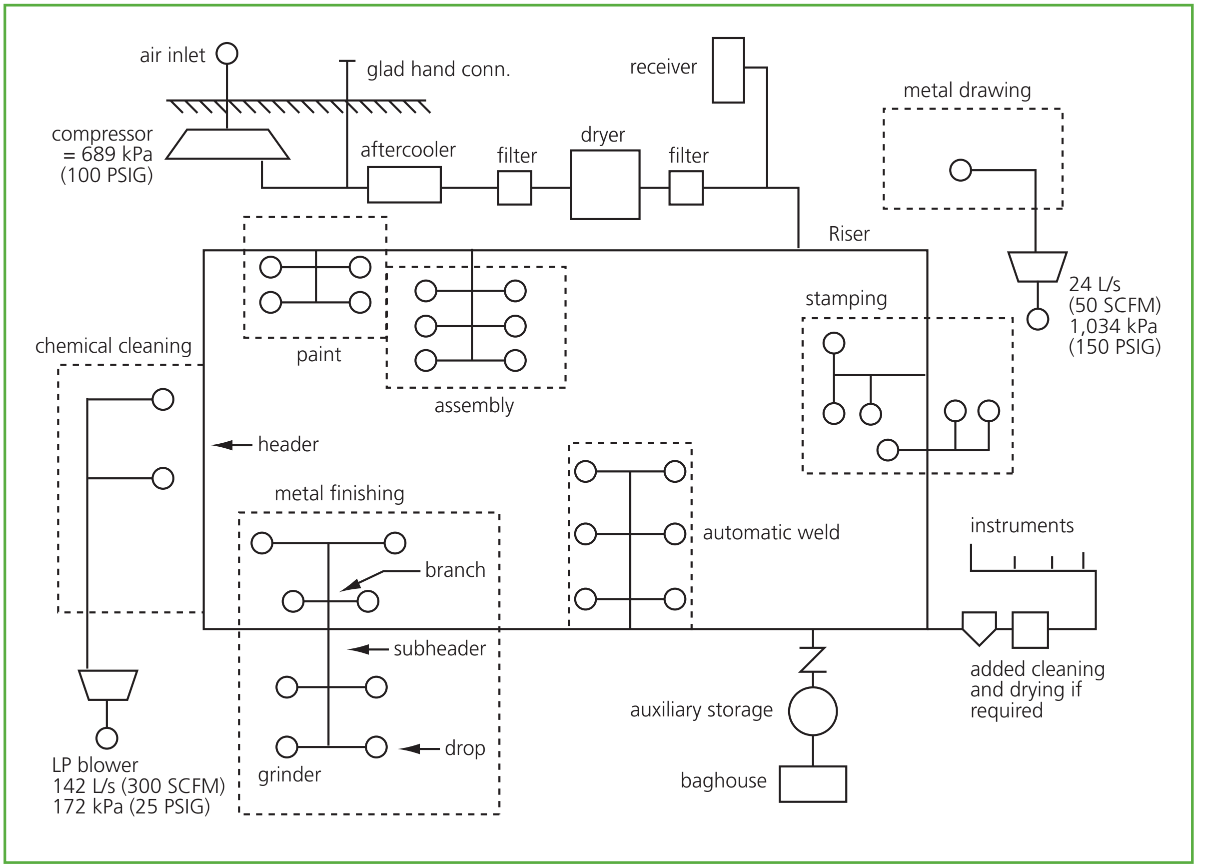

Figure 2: A typical compressed air system

On a system of 283 L/s (600 scfm) capacity, assuming a conservative 10% leakage and the most efficient compressor controls, more than $3,000 a year can be wasted. This could be eliminated by simply shutting down the system. Localized minor demands for air, if required, could be supplied by a separate small compressor at much less cost. (e.g. air for dry fire sprinkler system).

Design to maximize energy savings

Each of the components shown in Figure 2 can affect energy consumption. Current guidelines for designing such systems consist of the following steps:

- identify process air demand
- write system specification
- prepare system layout
- size the distribution system
- determine compressor size and type
- select compressor driver
- select controls for compressor and driver
- select compressed air conditioning equipment
- integrate energy-saving features

These steps should be followed not only when a new system is being designed, but also when additions or modifications are being made to an existing system.

System layout

System layout is important to achieve maximum plant efficiency and economy. Four factors need to be considered:

- number of systems required
- location of compressor(s)
- location of work stations
- piping arrangement

System distribution pressure should not be dictated by the arbitrary 689 kPa (100 psi) "convention," but rather by the true pressure requirements of the majority of applications in the system. The "true" pressure requirement includes the pressure drop of the point-of-use air treatment equipment such as filters or lubricators. The pressure drop of the point-of-use filters should be considered in the "dirt loaded" condition, which is the state where the filter's elements are at the end of their useful life and ready to be replaced. Standard criteria for selection, sizing, installation and maintenance of the point-of-use treatment equipment should be established. It is reasonable to limit the total point-of-use pressure drop to 50 kPa (7 psi). When there are applications that require significantly higher pressure than the majority of users (pressure-critical applications that are typically low volumetric users), a separate high-pressure system or local pressure boost is almost always warranted for small or intermittent usage.

The compressor room should be located to minimize the piping needed to access the farthest work station and be close to large air users. Even more important, however, is the proximity of the compressor to a source of efficient cooling to remove the heat of compression. Many compressed air system problems can be traced to poor cooling. Piping runs and equipment should be set up to minimize the number of valves and fittings.

Four examples of layouts are shown in Figure 3, in order of desirability. The unit loop and unit grid systems are sometimes used when a plant expansion takes place, and the existing air headers are too small or there is insufficient space for additional compressors at the original location. These layouts are an indication of poor original planning and are generally more challenging to operate efficiently.

System specification

System specification is the definition of the volumetric flow, pressure, temperature and quality requirements of the air throughout the system. Figure 2 on page 2 shows a typical system with the various components identified.

Starting from each work station or process, the individual users are identified along with the operating and performance requirements for each consuming device. In some processes, such as paint spraying, it may be necessary to provide additional, dedicated filtering and drying beyond that provided by the plant air system.

A drop line is provided for each air user. The branch line and subheader line capacities are determined for a worst-case condition (at the highest temperature and the lowest pressure) by adding up all requirements downstream that may run concurrently. A pressure drop limitation of 7 kPa (1 psi) in each of these lines and no more than 50 kPa (7 psi) for the point-of-use filter, lubricator, etc. is recommended.

The header and riser capacity is also determined from the sum of flow requirements for all equipment in the system. In this case, however, it is factored down by the duty cycle and work factor of each piece of equipment, and factored up by the anticipated growth during the next two to five years. Duty cycle is the percentage of time each device is used, and the work factor is the percentage of full-load flow actually used. In the header, a pressure drop limitation of 7 kPa (1 psi) is recommended and, in the riser, the pressure drop would usually be negligible. A common (and costly) error here is "padding" the total requirements because of insufficient data or "future demand." It is more efficient to design the system for easy expandability rather than overdesigning for the current conditions.

When sizing the air conditioning equipment and compressor, you must account for system leakage. Leakage can run as high as 40% of system capacity in poorly serviced systems, but a reasonable maximum figure for the specifications would be 10%, with a maintenance program instituted to maintain 5% or less.

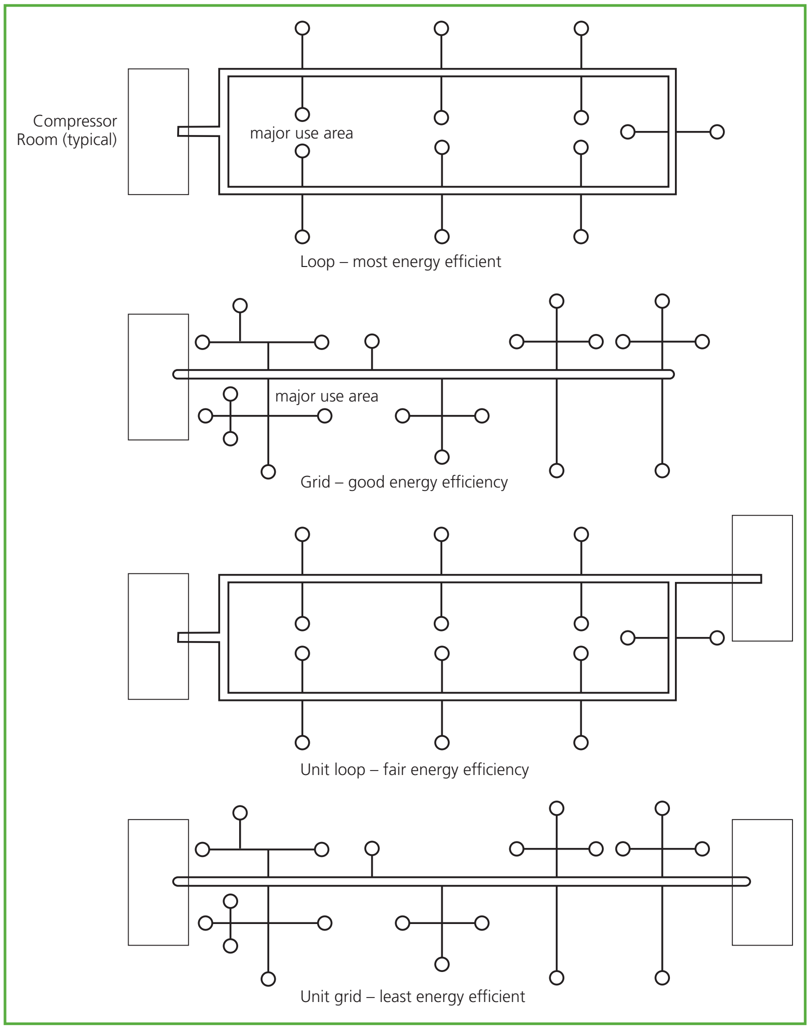

Figure 3: Distribution systems piping diagram

It is a very good practice to eliminate any free liquid, such as water and oil, from the general plant system. Since the absolute amount of moisture suspended in the air diminishes exponentially with temperature, a completely dry system can be achieved by depressing the dew point close to freezing (approximately 3°C or 38°F). This can be done very efficiently and economically using a properly applied and correctly configured refrigerating drying system. The air clean-up system should be selected and sized in consideration of the maximum pressure loss. A reasonable limitation is 70 kPa (10 psi) overall pressure loss with the filters "dirt loaded." Any applications with specific air quality requirements should be treated separately. When there are a significant number of applications requiring a higher level of air treatment than the rest of the system (such as the pneumatic instruments), a separate distribution system is warranted.

One of the most important considerations while designing a compressed air system is providing appropriate capacity to store air. The very concept of using compressed air as distributed energy is the ability of the air to be stored in the compressed state and than be expanded through the air-using applications. This means that no system can function without storage capacity. At the minimum, the air is stored in the distribution piping. Air storage in the piping is typically inadequate for efficient operation, and therefore additional storage receivers are required.

The amount of useful storage in a given volume is directly proportional to the volume of the containment and differential pressure due to removing the stored air from that containment. The greater the pressure differential at a given size of the receiver, the greater the useful storage capacity. Inversely, if the pressure is controlled within a narrow band, a larger receiver is required to store a comparable useful amount of air.

The distribution pressure should be maintained within a narrow margin. It is advantageous to operate the supply side at some higher pressure than that required by demand, and then control the demand pressure using a suitable control arrangement. Operating the supply storage through a greater differential pressure band will generate more useful storage with reasonably sized receivers. The supply storage capacity should be designed to effectively "average" the demand variations.

The supply storage receiver should always be located on the "dry" side of the clean-up system. Since its only function is storing air, it may be connected to the system using a single line. This offers more flexibility in locating the receiver.

There may be additional requirements for "wet" storage. Reciprocating compressors require pulsation dampeners. These are typically small-volume vessels designed and supplied by the compressor manufacturers. In the absence of proper pulsation dampeners, a receiver may be installed as close as possible to the discharge of the reciprocating compressor(s).

Additional storage capacity may be required in association with the distribution system (general storage) and to support operation of specific applications (dedicated storage).

The compressor requirements can now be specified by collecting the following information:

- **Flow** specifies the minimum and the maximum sustained system demand. The minimum demand typically occurs during lunch breaks, night shifts and weekends.
- **Pressure** includes the pressure losses of the distribution piping and the point-of-use equipment, plus the control dead-band of the supply.
- **Water and oil** specification should include the water content of the air, the particulate size in the air stream, and oil carry-over in micrograms per unit volume. It is important to remember that too much conditioning of the air costs money. Do not specify more stringent requirements than are necessary.

- **Inlet air** details are needed to specify the compressors completely:
  - inlet volume flow iL/s (icfm), allowing for inlet air temperature and local barometric pressure
  - availability of cooling water
  - compressor and air inlet locations
  - static pressure at the compressor inlet
  - range of relative humidity at the air inlet
  - presence of impurities
  - availability of ventilation air in the compressor room
  - availability of power

Final compressor selection should provide efficient turn-down for the established demand range.

Final compressor room location, configuration and support should provide for potential future growth and expansion.

Distribution system

Proper sizing and layout of the distribution system is an often neglected aspect of system design, yet it is one of the most important. Proper design can pay high dividends in reduced energy costs over the life of the system. It is often decided that a plant needs additional compressor capacity when the air plant can no longer maintain adequate pressure for each work station. Experience has shown that replacing high pressure loss portions of the system with larger pipe, as well as reducing leaks, often not only eliminates the need for an additional compressor, but also results in partial shutdown of existing capacity.

The following guidelines should be applied:

- The discharge pipe from the compressor should be 1.5 times as large as the compressor discharge connection and should be run directly to the aftercooler.
- The riser, header and selected branch piping should be oversized to handle predicted growth over the next two to five years.
- The riser should be one size larger than the header and compressor discharge line. It must be fitted with a drip leg and drain to prevent contaminants from flowing back to the compressor. The horizontal leg should enter the header at the side or bottom and slope away from it.
- The header should be sloped 10 mm per metre (one-eighth inch per foot) down from the riser connection to facilitate condensate runoff and removal.
- The system should be sized for a pressure drop of less than 10% of the compressor discharge pressure.
- A loop system is recommended because it provides two-way air flow to the points of greatest demand.
- Low resistance-to-flow fittings and valves should be used.
- Locations of subheaders, branch lines and drops should be as close as possible to the points of air use.
- Outlets from headers and branch lines should be taken from the top to minimize water carry-over.
- Drop lines require a drain in the vertical leg and a horizontal valved take-off to the equipment.
- Pressure loss to the equipment is significantly increased by using quick-connect fittings, hoses that are too long or too small in diameter, and improperly sized filters and lubricators.
- Features to minimize system leakage should be incorporated. An example is electrically operated valves to isolate portions of the plant used seasonally and machines used intermittently. These air valves are automatically shut down when the power to the machines is switched off.
- Welded joints are less likely to leak than threaded joints and provide less resistance to flow.

Compressed air conditioning equipment

Compressed air conditioning equipment in an overall system must provide for both contaminant removal and preparation of the air for equipment use. The following components and points must be considered:

Inlet air filter

Since there is considerable dirt in even the cleanest atmospheric air, the primary function of these filters is to remove particulate as small as 3 microns from entering the compressor with minimum pressure loss.

Aftercooler

An aftercooler is usually recommended, being an economical way to reduce the moisture content of the air. It can be either water- or air-cooled, depending on the price of water and whether a heat recovery system is used. Because it has a high pressure drop, it is good economy to oversize the aftercooler.

Separator

This is usually supplied with the aftercooler and should always be connected to a drain or trap for removing condensate.

Filters

Filters remove oil, water and solid particles for protection of downstream components. Sizing must be based on specific flow capacities and pressures, not on incoming pipe size. There are three primary types of filters: standard mechanical, coalescing and absorbing. The mechanical filter – when used in conjunction with aftercoolers, separators and receivers – can remove enough solids and aerosols for most manufacturing plant air systems. Coalescing filters are used to provide air with low oil content in lieu of installing non-lubricated compressors. Point-of-use filters should be considered where there are only a few isolated applications of oil-free air, rather than filtering the whole system. Absorbing filters are used in manufacturing plants to prevent oil contamination only when regenerative dryers are used.

Dryers

Three general types of dryers are available: regenerative, deliquescent and refrigerated. To prevent moisture from condensing in the distribution system, the absolute moisture content of the air should be reduced to an insignificant level. The most economical approach is through cooling air close to the freezing point and removing condensed liquid. The air should then be reheated to ambient temperature. A well designed refrigerating dryer will accomplish this task automatically and efficiently. Applications requiring specific low water vapour pressure may require use of a desiccant regenerative-type dryer. The deliquescent-type dryer is not suitable for general plant air systems and should be avoided. The cost, attainable pressure dew points, pressure drop and maintenance requirements of dryers vary considerably. Therefore, it is important to consider the alternatives carefully and choose a dryer that just meets the system needs – neither over-sized nor over-designed.

Receivers

Receivers should be sized to “average” the system demand requirements. In small systems, receivers may also be useful for suppressing pressure pulsations from the discharge of reciprocating compressors and reducing motor starting energy by “softening” the start/stop duty cycle.

Regulators and lubricators

These, combined with point-of-use filters, provide local conditioning of air for tools and other lubricated devices. They should be used only when required by the operating equipment. Any application operating at less than the distribution pressure should be regulated to its true requirements. Regulators should be selected with understanding of the minimum differential pressure requirements.

Sizing of the point-of-use equipment must be done for the maximum flow during the working cycle. If an air cylinder uses 20 standard L/sec in 2 seconds twice per minute, the nominal demand would be 40 sL/sec. The maximum demand, however, would be 600 sL/sec and the supply piping and equipment must be selected and sized for this flow.

Traps and drains

These components collect and expel contaminants and are critical to proper system performance. The contaminants can be expelled by manual valves, automatic condensate traps or motorized valves. Manual operation is the simplest and surest method but is often not practical when condensate flows are high. Too often these valves are left "cracked open" and become a major source of air leakage.

Automatic traps are a good choice where the removal of condensate is continuous. As long as they remain clean, they provide proper drainage of oil and water, while minimizing air loss. Direct-acting traps containing small orifices, however, are notoriously unreliable. As the mechanical components become fouled, the trap can seize open, creating major leakage, or seize closed, allowing condensate to build up in the system.

Motorized drain valves with automatic controls for sequencing have become a popular technique for draining condensate. They provide positive draining and shut-off, but invariably waste air. Their high momentary demand depresses local pressure and, when installed close to control systems, causes false compressor starts and/or prevents compressors from unloading.

The best traps currently available combine automatic on-demand operation with large unrestricted ports.

Silencers

These are typically designed as an integral unit with the inlet filter and are supplied with the compressor.

Instrumentation

Strategic location of pressure gauges and thermometers can provide a quick identification of system problems and can signal the need for system maintenance.

Thermometers are recommended on both the aftercooler and dryer discharge. They can also be useful in monitoring the cooling water inlet and discharge temperatures.

Pressure gauges in the piping from the header to the drops can be used to verify that pressure drops in the various sections are not too high. Differential pressure gauges should be installed across all air conditioning equipment, and remote alarms – to be activated when a preset pressure drop is exceeded – could also be considered.

Compressor size and type

Developing a system specification as outlined above determines the minimum compressor capacity to meet system needs. In addition, consideration must be given to the cost of system down-time if unscheduled repairs to the compressor are necessary. This usually dictates that standby compressor capacity is necessary.

Stand-by capacity must equal the output of the largest single unit in the compressor mix. It is therefore easier to manage supply consisting of several smaller units than one large compressor. Several smaller units will also provide for more efficient turn-down. The multiple compressor arrangement is desirable for widely variable load profiles when multiple compressor sequencing control systems can be used. These controls automatically reduce energy consumption by operating the minimum number of compressors at any time. One compressor is operated in a trim mode for small variations in demand, with the other compressors operated at full load and turned on or off as needed to meet the large system changes.

Comparative features of commonly used compressors

Single-stage rotary	• Minimal maintenance • Ease of installation • Compact size • Relatively inexpensive purchase price
Multi-stage reciprocating	• High-efficiency two-stage models are 10% to 15% more efficient than rotary models • More-efficient part loading • High maintenance cost • High initial and installation cost • No longer manufactured
Centrifugal	• Good for high-volume applications – 330 to 44,000 L/s (700 to 30,000 cfm) • Smaller, smoother and more compact because of high-speed operation • High availability factor • Comparatively low maintenance • Smooth non-pulsating flow within the stable operating range • Limited turn-down • Inefficient part loading

Some plant operations have special characteristics that require more than one compressor for maximum energy efficiency. Here are two examples:

- Plant X has mostly low-load usage interspersed with occasional brief high-demand periods. One compressor serves the normal, low-capacity requirements, and a second is installed to serve the infrequent high-demand situations.
- Plant Y has a large network of work sites whose pressure requirements vary widely. Separate compressor systems are set up so as not to waste power on sites that cannot use it.

There are two major classes of compressors with various types in each class:

- **positive displacement:** reciprocating single acting, double acting, or rotary-helical screw, sliding vane, rotary lobe
- **dynamic:** centrifugal or axial (rarely used)

Each of the positive displacement types is available in an oil-free or lubricated design. Centrifugal compressors are inherently oil-free. The table on the left compares features of the commonly used types.

The specific efficiency of an air compressor operating under full-load conditions is measured in units of bhp/47 L/s (100 cfm), when compressing to 689 kPa (100 psig). Typical values of specific efficiency versus horsepower capability from 10 to 10,000 bhp are shown in Figure 4 on the next page.

Note that it can be misleading to compare compressors solely on the basis of specific efficiency, since compressors will be called on to operate at no-load or partial-load conditions to match varying demands. Under these conditions the performance will be determined largely by the control methodology covered below.

Note also that it is not appropriate to select a compressor based on its best efficiency alone. The overriding concern should be the overall system efficiency. It is important to obtain a complete and accurate picture of all present and future costs, including initial purchase price, engineering and installation, operating, maintenance, energy consumption and cooling water for the system operating at all production modes. Doing a present-value analysis would then give a cost figure for each combination of compressors, which could then be used to make a realistic decision on what compressors to buy.

Compressor driver

AC electric motors are by far the most common drivers for compressed air systems, and the induction motor is used in 90% of industrial applications. Since compressed air drivers frequently experience high usage, a high-efficiency motor, although more costly, can almost always be cost effective.

Control selection

With compressor capacity sized to meet the system's maximum demand, a control system must be employed to reduce compressor output to match lower demand requirements. The system pressure is monitored so that the control equipment can decrease compressor volume as pressure increases to a predetermined level because of reduced demand. Conversely, the compressor volume flow is increased as an increase in demand causes pressure to drop to another predetermined level. The differential pressure between these two pressure levels is called the control range. Each individual compressor is typically supplied with its own dedicated, on-board control system. Following are some of the popular control mechanisms.

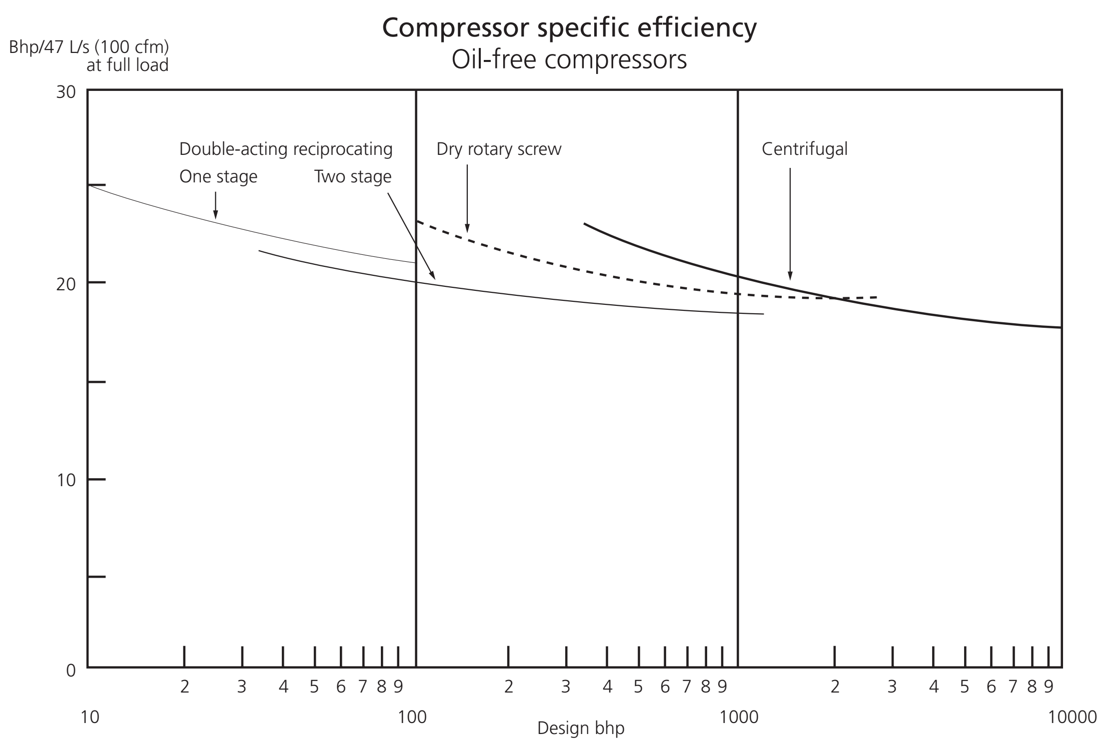

Figure 4: Relative full-load power required of typical oil-free compressors, 689 kPa (100 psig), at sea level

Start/stop and load/unload controls

Start/stop simply turns the motor on or off in response to system pressure changes. However, because repeated starts cause motor overheating, this procedure cannot be used in a system that has frequent cycling. Alternatively, the motor and compressor can be allowed to run continuously, but the compressor is unloaded, prohibiting the further delivery of compressed air to the system. In the case of rotary compressors, this often means closing a valve in the inlet line. With the compressor still rotating against full system pressure, this still requires 50 to 70% of full-load horsepower, even with no air flowing.
To overcome this inefficiency, some compressor manufacturers lower the compressor discharge pressure during the unloaded state by venting to atmosphere. In the case of lubricated rotary compressors, the oil sump on the discharge end of the unit is vented. Some control arrangements require a certain minimum residual pressure for the controls to function, which causes the unloaded horsepower to be within the range from 15 to 40% of full-load horsepower. It is always prudent to request the unloaded horsepower when soliciting offers for a compressor.

Multi-step part-load control

These systems, applied to reciprocating compressors, use multiple pressure switches at evenly spaced intervals over the pressure control range. These switches progressively either activate inlet valve depressors or open clearance pockets in the cylinder heads. In a double-acting reciprocating compressor, for example, this would result in five-step control capability at 0, 25, 50, 75 and 100% of delivery capacity. The respective unloaded horsepower at these capacities would be 10, 32, 55, 78 and 100% of full-load horsepower. This is very efficient part-loading, as there is no air being blown to atmosphere. The multi-step arrangement does not improve the part-load efficiency beyond the full-load/no-load, but generates smaller step changes in the system, which make the overall system control somewhat simpler. On the other hand, it broadens the control pressure range and the mechanical equipment involved is a source of high maintenance. If neglected, it frequently quickly loses its efficiency.

Adjustable speed driver

The compressor driver (steam turbine, diesel engine, or adjustable speed electric motor) controls the output of the compressor by varying the speed of the compressor. Drivers usually have a capacity range from 0 to 100%, although the compressor can typically utilize only a portion of the full range. In the case of the variable frequency drives applied to electric motors, the electrical inefficiency of the drive must also be considered.

Modified throttle controls

Rotary compressors typically use this type of control. Several mechanisms are available, the most common of which is similar to the load/unload mode of control in that an input throttling valve closes off the inlet. In this case, however, rather than being an on/off valve, it modulates the valve position in response to system pressure. As the valve progressively closes off the inlet, it causes a partial vacuum to develop, effectively increasing the compression ratio and thus increasing the horsepower requirement per unit of delivered air.

The valve continues to close in response to rising system pressure until the compressor is delivering 50 to 70% of its capacity with a corresponding power requirement of 70 to 85% of full-load horsepower. If the system pressure continues to rise and reaches a preset high pressure value, the valve closes to a minimum opening and the compressor delivers virtually no output. Similar to the load/unload mode of control, the unloaded power requirement will be 50 to 70% of full-load horsepower unless the discharge side is vented.

Variable displacement mechanisms are used on some rotary screw compressors to reduce the volume of air delivered by venting a variable portion of the helical screw length to the inlet side of the compressor. One manufacturer uses several separate air-controlled poppet valves along the screw, while another uses a rotating turn valve that uncovers successive ports along the screw. With these mechanisms, a continuous throttling range down to 40% capacity is theoretically achievable, with a power requirement of 60% of full-load horsepower. For throttling below 40% capacity, an inlet throttle valve is used to achieve zero air output with a power requirement of about 20% of full-load horsepower. In practice, these two independent control systems may be difficult to coordinate.

Centrifugal compressors, by design, tend to decrease their output as the system pressure increases with a dropping demand for air, thereby maintaining a constant specific efficiency. They can very efficiently modulate the output at a constant pressure using an inlet throttling arrangement, such as a butterfly valve or guide vanes. Unfortunately, this efficient modulation is only over a limited range (typically 70 to 80% of rated output and above). If the system demand drops below the minimum throttling range, a by-pass valve in the discharge generates artificial demand, resulting in a rapid drop in efficiency. These compressors can, however, be fully unloaded by closing the inlet valve to some minimum opening and venting the discharge close to atmospheric pressure. The unloaded power is generally 15 to 20% of the full rated horsepower.

Multiple compressor system controls

While the individual controllers can be set anywhere from around 20 to 170 kPa (3 to 25 psi), the pressure range in multiple compressor systems broadens with the number of compressors. The challenge of multiple compressor systems is in coordinating the individual controllers for the overall system efficiency, which requires more-complex control systems. Ideally, all compressors but one are programmed to operate at full load to maximize efficiency, while the remaining compressor is part-loaded (or trimmed) for output control. The most sophisticated controllers do not respond to fixed pressure levels, but rather to a derivative of pressure change. This approach helps to achieve the highest system efficiency.

Figure 5 shows typical compressor efficiencies at part-load conditions as a function of compressor type and control mechanism. The solid lines indicate continuous throttling ranges, while the broken lines connect discrete operating points, indicated by dots. The most striking observation from this data relates to where inlet valving is used to control compressors. A power reduction of 50% or more can be achieved during unloaded periods of operation if the compressor discharge pressure is reduced to atmospheric pressure. This is an obvious requirement to save energy on compressed air systems.

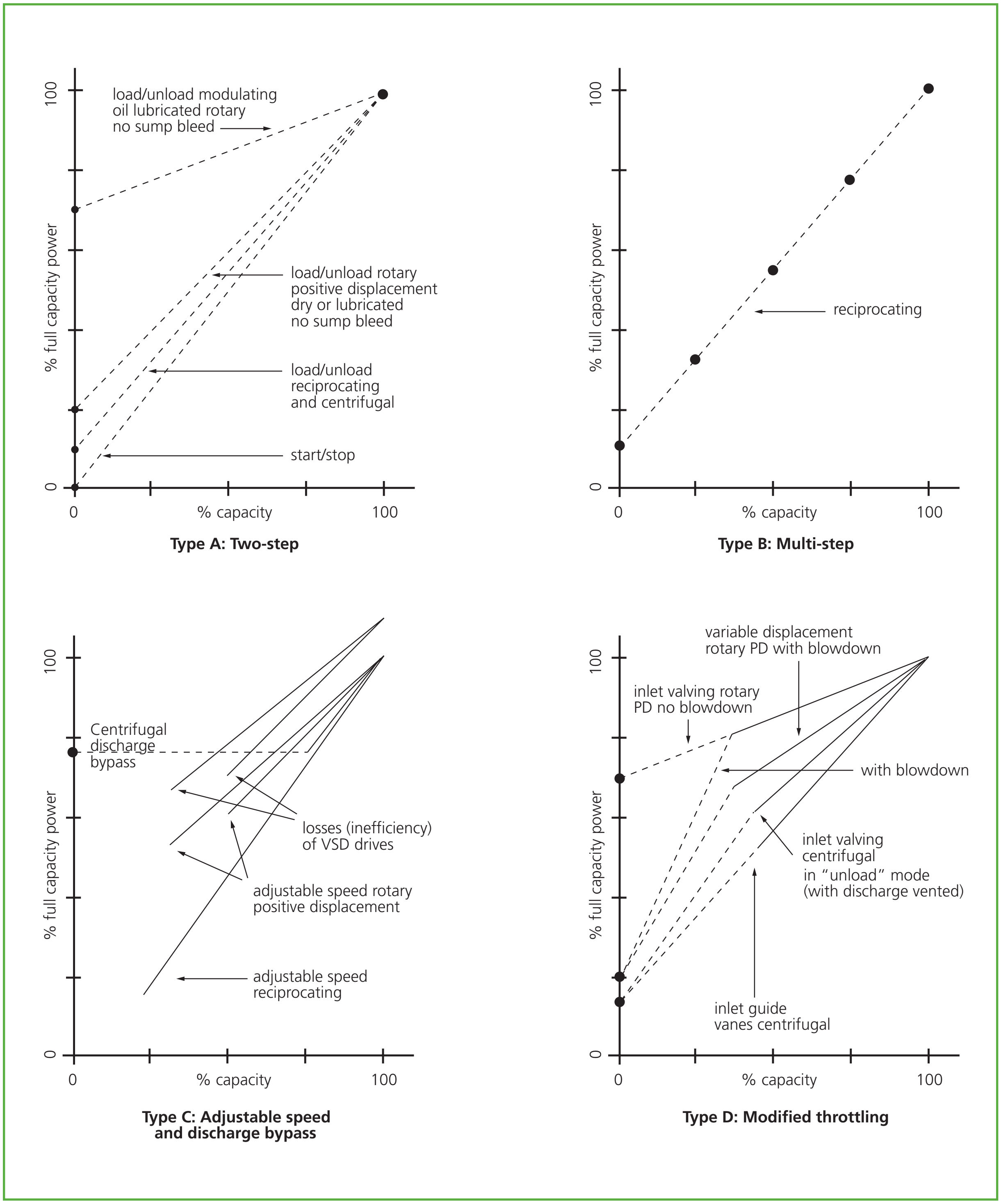

Figure 5: Per cent full load power required for reduced output

Maintenance and energy saving checklist

Item	Maintenance frequency
Compressor drives	
❑ Check bearing temperatures	3 months
❑ Check for obstructed motor passages	3 months
❑ Check for V-belt tension	3 months
❑ Check for worn or frayed belts	3 months
❑ Check voltage, current and power factor	3 months
Compressors	
❑ Check piston rings, valves and cylinder walls for wear	6 months
❑ Check outlet air temperature	weekly
❑ Check for fouling of compressor and intercooler surfaces	6 months
❑ Check pressure drop of inlet air filter	weekly
❑ Check oil for contamination	weekly
❑ Check cooling water inlet and outlet temperatures	weekly
Compressed air conditioning equipment	
❑ Check pressure drop across air filters	monthly
❑ Check pressure drop across aftercooler	monthly
❑ Check pressure drop across dryers	monthly
❑ Check pressure drop across separators	monthly
❑ Check aftercooler air outlet temperature	daily
❑ Check aftercooler cooling water inlet and outlet temperatures	daily
Traps and drains	
❑ Check trap operation (Automatic direct-acting traps should have open, visible discharge. Motorized and automatic zero-air-loss traps have test switches)	daily
❑ Check for drain valves left partially open	monthly
❑ Check motorized valve drain cycle for condensate accumulation	monthly
Filters/lubrication	
❑ Check differential pressure across filter under rated load	monthly
❑ Check for proper lubrication	monthly
System leakage	
❑ Check total system leakage with air tester or flow indicator	monthly
❑ Check for leaks with acoustic detector or soap solution at the following locations: • Threaded pipe joints • Valve stems • Traps and drains • Filters • Hoses • Connectors • Operating valves on pneumatic devices • Check valves (back flow leakage) • Relief valves	3 months
Excessive pressure drop	
❑ If low at work station, check pressure back up the distribution system to isolate internal blockage or heavy leakage areas	3 months
❑ Check static pressure at all work stations	3 months

Energy-saving features

Some equipment items are directed specifically at saving energy:

- Consider a reheater to increase the temperature of discharge air after aftercooling, drying or both. These units recover heat from the cooling oil of rotary screw compressors, further reducing relative humidity and providing a larger volume of air. This saves money, but care must be taken as hot air (up to 74°C) can accelerate deterioration of hoses and valve packing. In addition, insulation of drop lines and equipment may be required for workers' protection. A bypass for the reheater is recommended in hot summer weather.
- Sixty-five to 80% of the electrical energy consumed by an air compressor is converted to heat which, if it can be recovered, will be available for use in the plant. Heat recovery, if it is not too expensive to implement, can be valuable in supplying a large quantity of thermal energy for the plant. Besides being used to heat work spaces, there may be applications elsewhere in the plant, for example, pre-heating for a boiler or participating in some heat-dependent plant process.
- Lower power consumption features, such as inlet throttling, sump blowdown and multi-step unloading, are being targeted by compressor manufacturers, as are total energy management systems and micro processor controls for multi-compressor systems.
- Distribution system cut-off devices are being developed based upon the principle of sensing usage and having the line at full pressure only at times when there is a need for working quantities of air.
- Accessibility to the system is very important. Difficult or vexing maintenance tasks tend to be postponed and potential sources of leaks are more likely to be checked if they can be seen or reached.
- Systems should be well instrumented with an air-flow indicator, pressure gauges, pressure differential gauges and thermometers to facilitate system and equipment diagnosis. A set of readings taken when the new system first goes online can become a comparative base to determine how much system deterioration is occurring.
- Regenerative air dryers should be fitted with dewpoint controllers to minimize the quantity of purge air being wasted to atmosphere.

Maintenance

Compressed air systems respond to proper maintenance with quick and substantial energy savings. They are more sensitive to variations in maintenance than most other industrial systems.

All too often the observation is made that "pressure is too low" so it is time to "buy another compressor." However, it may be that:

- a filter at the point of use is blocked
- a hose of excessive length and/or insufficient diameter is used
- a large air user or leak increased flow through the connecting equipment. At fast-acting applications, the relatively slow air transmission speed may be an issue and a dedicated storage receiver may be required.

Merely adding more compressor capacity to try to force more air through such a system is not the most cost-effective solution, and rarely succeeds.

It is important to establish a base set of pressures, temperatures and leakage rates when the compressor system is new so that deterioration can be recognized.

All of the equipment in a compressed air system should be maintained in accordance with the manufacturer's instructions and detailed recommendations. These will not be repeated here. However, some maintenance requirements are closely linked to energy use. The checklist in this guide can be used as a reminder to follow up on these items.

Leakage

Compressed air leaks are an obvious source of aggravation and a potential energy loss. This energy loss can be significant. If the level of leakage in the plant forces operation of the next compressor, there is a substantial step change in the system energy requirement and cost. On the other hand, if the system is supplied by a centrifugal compressor operating at minimum control flow and with the bypass valve open, reducing leakage means that less air is being bypassed and there is no corresponding saving. Because of the general poor part-load efficiency of compressed air systems, the relationship between leakage and energy is a complex issue. As a rule of thumb, the system efficiency at all demand levels must be addressed before the leakage control becomes meaningful.

The most cost-effective approach to leak management is the application of benchmarking. A benchmark can be established by measuring the process demand at low-demand conditions using a reliable method, such as a mass flow meter or monitoring the loading cycle of positive displacement compressors.

When the demand increases beyond this benchmark with no corresponding production activity, the leak repair action should be initiated. Using an ultrasonic detector, enough large leaks should be identified and repaired to bring the demand under the benchmark. When this becomes too easy, the benchmark should be lowered. Because leak control is an exercise of diminishing return, a reasonable level should be found in time to make it cost effective.

Summary

Many opportunities exist for most compressed air systems to realize substantial energy savings. The measures necessary to take advantage of these opportunities include integrating system equipment for efficient operation, simple maintenance procedures (finding and fixing leaks), low-cost modifications (adding receivers or a heat recovery system), and major upgrading programs (replacing the compressor or redesigning the layout of the system).

Most compressed air users can significantly reduce the amount of electricity consumed by their compressed air systems by following the practical guidelines presented here.

References

Plant Engineering, "Compressor System Upgrade," August 13, 1987 p.26.

Compressed Air Systems: A Guidebook on Energy and Cost Savings, E.M. Talbot. The Fairmont Press, 1986.

Installation

This is designed as a general guide. Please ensure that installations meet your requirements, manufacturers' instructions and all applicable codes, standards and regulations. BC Hydro is not responsible for installations.

Ask us for more information

The guide provides advice for BC Hydro customers and the trades. For additional information, call your Key Account Manager.

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