Compressed Air

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Compressed Air Basics

Compressed air is used widely throughout industry and is often considered the 'fourth utility' at many facilities. Almost every industrial plant, from a small machine shop to an integrated iron and steel plant, has some type of compressed air system, and in many of those compressors use more electricity than any other type of equipment. In many cases, the compressed air system is so vital that the facility cannot operate without it.

Compressed air systems consist of a supply side, which includes compressors and air treatment, and a demand side, which includes distribution and storage systems and end-use equipment. These systems power a variety of equipment, including machine tools, material handling and separation equipment, and spray painting equipment.

While there are applications that require the use of compressed air, many uses of compressed air can be eliminated to save money. Calculating the cost of compressed air in your facility can help you justify system improvements that increase energy efficiency. This page offers tips for increasing your compressed air system's efficiency and decreasing costs.

Plant air compressor systems can vary in size from a small unit of 5 horsepower (hp) to huge systems with more than 50,000 hp. Inefficiencies in compressed air systems can therefore be significant Energy losses existing in these systems can range from 20 to 50 percent or more of electricity consumption. For many facilities this is equivalent to lakhs of Rupees (Rs) of wastage, and potential annual savings, depending on use. A properly managed compressed air system can save energy, reduce maintenance, decrease downtime, increase production throughput, and improve product quality.

A properly managed supply side will result in clean, dry, stable air being delivered at the appropriate pressure in a dependable, cost-effective manner. A properly managed demand side minimizes wasted air and uses compressed air for appropriate applications. Improving and maintaining peak compressed air system performance requires addressing both the supply and demand sides of the system and how the two interact.

What Is Compressed Air?

Compressed air is a form of stored energy that is used to operate machinery, equipment, or processes. Compressed air is used in most manufacturing and some service industries, often where it is impractical, expensive or hazardous to use electrical energy directly to supply power to tools and equipment.

Powered by electricity, a typical air compressor takes approximately 7 volumes of air at atmospheric conditions, and squeezes it into 1 volume at elevated pressure (about 100 psig/7 bar). The resulting high pressure air is distributed to equipment or tools where it releases useful energy to the operating tool or equipment as it is expanded back to atmospheric pressure.

In the compression process, and the subsequent cooling of the air to ambient temperatures, heat and moisture are released as by-products, as illustrated in the figure below.

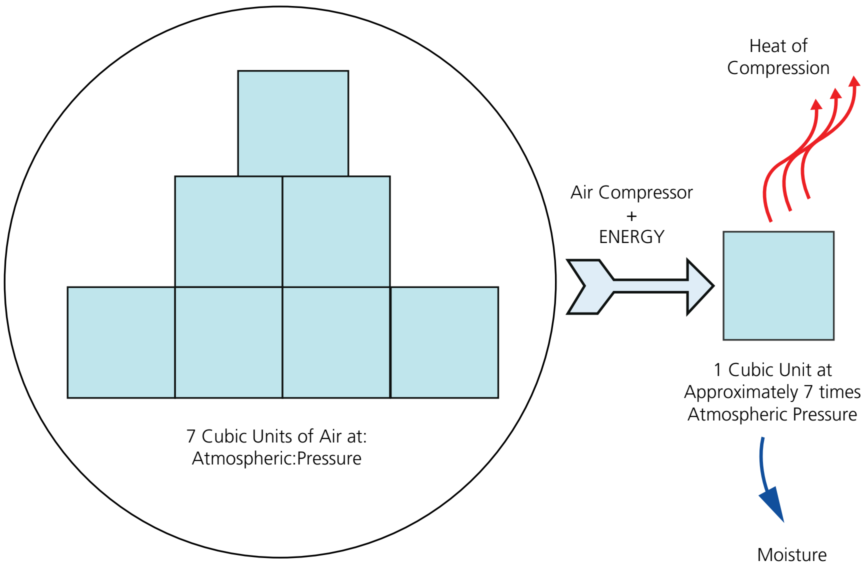


Figure 1: Conversion of Atmospheric Air into Compressed Air

Depending on the application, excessive moisture in compressed air needs to be managed as it can cause problems with piping and end use equipment.

Introduction to Compressed Air Systems

Compressed air systems consist of a number of major subsystems and components. Compressed air systems can be subdivided into the **Supply** side and the **Demand** side.

The **Supply** side includes compressors, air treatment and primary storage. A properly managed supply side will result in clean, dry, stable air being delivered at the appropriate pressure in a dependable, cost effective manner. Major compressed air supply subsystems typically include the air intake, air compressor (fixed speed and/or variable speed), aftercooler, motor, controls, treatment equipment and accessories.

The **Demand** side includes distribution piping, secondary storage and end use equipment. A properly managed demand side minimizes pressure differentials, reduces wasted air from leakage and drainage and utilizes compressed air for appropriate applications. Distribution piping systems transport compressed air from the air compressor to the end use point where it is required. Compressed air storage receivers on the demand side can also be used to improve system pressure stability.

As a **rule of thumb, for every horsepower (HP) in the nameplate capacity, the air compressor will produce approximat**ely 4 standard cubic feet per minute (scfm).

A simplified diagram illustrating how some of the major components are connected is shown in Figure below.

Compressed air is used for a diverse range of commercial and industrial applications. As it is widely employed throughout industry, it is sometimes considered to be the "fourth utility" at many facilities.

It has been common practice in the past to make decisions about compressed air equipment and the end uses based on a first cost notion. However, ongoing energy, productivity and maintenance costs need to also be considered for calculating system costs. In other words, best practice calls for decisions to be based on the life cycle cost of the compressed air system and components.

Improving and maintaining peak compressed air system optimization requires addressing both the supply and demand sides of the system and understanding how the two interact.

Optimal performance can be ensured by properly specifying and sizing equipment, operating the system at the lowest possible pressure, shutting down unnecessary equipment, and managing compressor controls and air storage. In addition, the repair of chronic air leaks will further reduce costs.

For a typical compressed air end use, like an air motor or diaphragm pump, it takes about 10 units of electrical energy input to the compressor to produce about one unit of actual mechanical output to the work.

For this reason other methods of power output, such as direct drive electrical motors, should be considered first before using compressed air powered equipment. If compressed air is used for an application, the amount of air used should be the minimum quantity and pressure necessary, and should only be used for the shortest possible duration. Compressed air use should also be constantly monitored and re-evaluated.

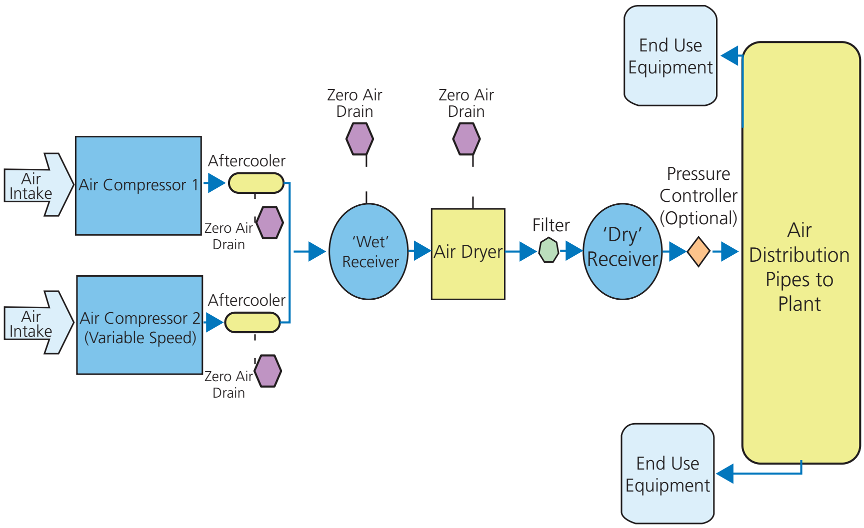


Figure 2: Common Air Compressor System Components

A. Compressors & Their Types

There are two basic compressor types: **Positive-Displacement** and **Dynamic**.

In **Positive-Displacement** compressors, a given quantity of air or gas is trapped in a compression chamber and the volume it occupies is mechanically reduced, causing a corresponding rise in pressure prior to discharge. At constant speed, the air flow remains essentially constant with variations in discharge pressure.

Dynamic compressors impart velocity energy to continuously flowing air or gas by means of impellers rotating at very high speeds. The velocity energy is changed into pressure energy both by the impellers and the discharge volutes or diffusers. In the centrifugal-type dynamic compressors, the shape of the impeller blades determines the relationship between air flow and the pressure (or head) generated.

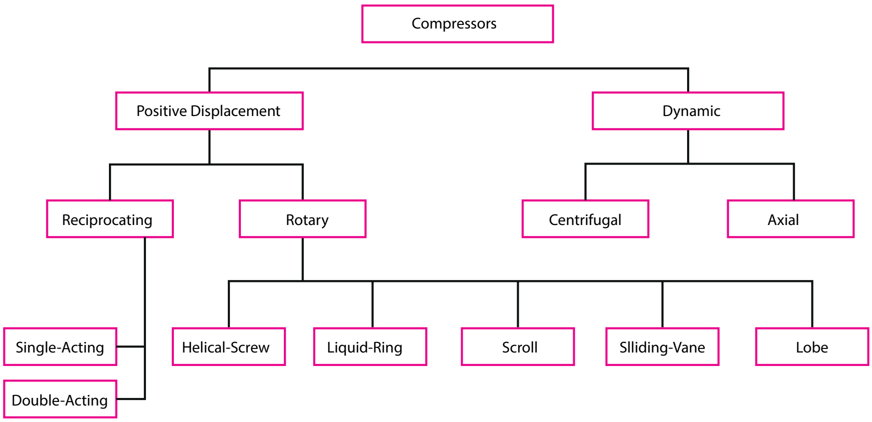


Figure 3: Types of Compressors

Positive Displacement Compressors

These compressors are available in two types: reciprocating and rotary.

I. Reciprocating compressor

In industry, reciprocating compressors are the most widely used type for both air and refrigerant compression (see Figure 5). They work on the principles of a bicycle pump and are characterized by a flow output that remains nearly constant over a range of discharge pressures. Also, the compressor capacity is directly proportional to the speed. The output, however, is a pulsating one.

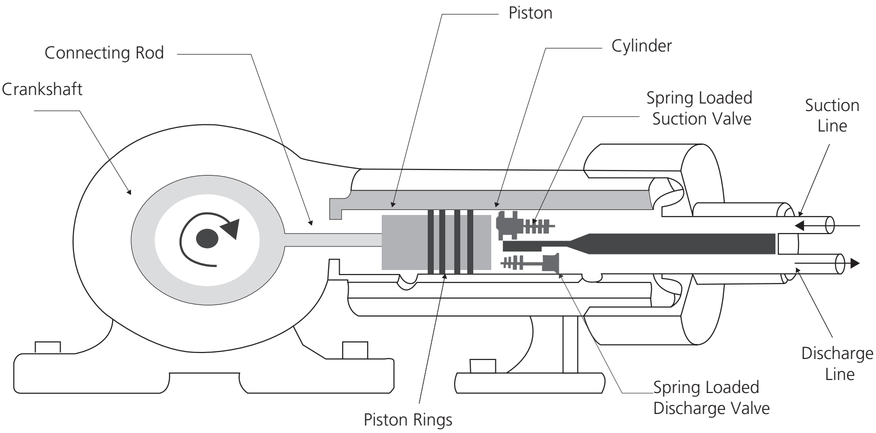


Figure 4: A cross-sectional view of a reciprocating compressor

Reciprocating compressors are available in many configurations, the four most widely used are horizontal, vertical, and horizontal balance-opposed and tandem. Vertical type reciprocating compressors are used in the capacity range of 50 – 150 cfm. Horizontal balance opposed compressors are used in the capacity range of 200 – 5000 cfm in multi-stage design and up to 10,000 cfm in single stage designs.

The reciprocating air compressor is considered single acting when the compressing is accomplished using only one side of the piston. A compressor using both sides of the piston is considered double acting.

A compressor is considered to be single stage when the entire compression is accomplished with a single cylinder or a group of cylinders in parallel. Many applications involve conditions beyond the practical capability of a single compression stage. Too great a compression ratio (absolute discharge pressure/ absolute intake pressure) may cause excessive discharge temperature or other design problems. Two stage machines are used for high pressures and are characterized by lower discharge temperature (140 to 160°C) compared to single-stage machines (205 to 240°C).

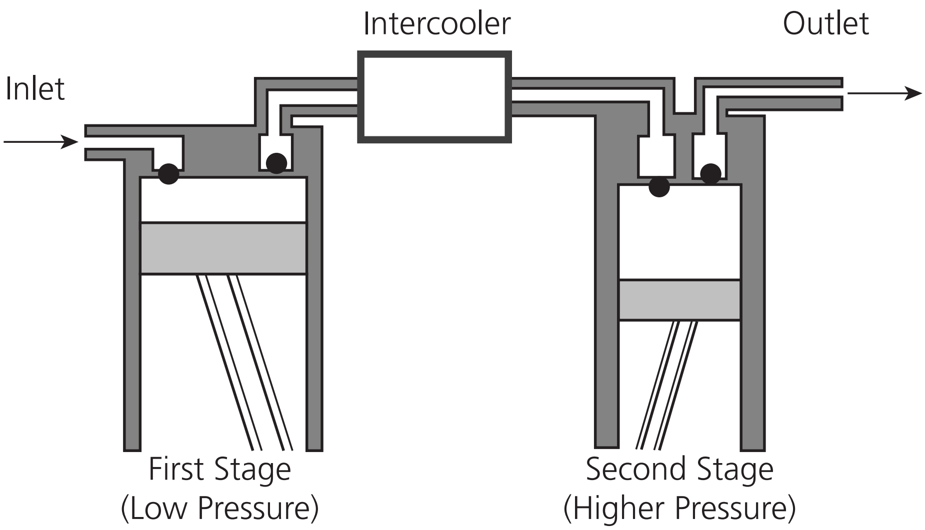


Figure 5: View of a multistage compressor

For practical purposes most plant air reciprocating air compressors over 100 horsepower are built as multi-stage units in which two or more steps of compression are grouped in series. The air is normally cooled between the stages to reduce the temperature and volume entering the following stage. Reciprocating air compressors are available either as air-cooled or water-cooled in lubricated and non- lubricated configurations, may be packaged, and provide a wide range of pressure and capacity selections.

II. Rotary compressor

Rotary compressors have rotors in place of pistons and give a continuous pulsation free discharge. They operate at high speed and generally provide higher throughput than reciprocating compressors. Their capital costs are low, they are compact in size, have low weight, and are easy to maintain. For this reason they have gained popularity with industry. They are most commonly used in sizes from about 30 to 335 hp or 22 to 250 kW.

Types of rotary compressors include:

1. Lobe compressor (roots blower)
2. Screw compressor (rotary screw of helical-lobe, where male and female screw rotors moving in opposite directions and trap air, which is compressed as it moves forward, see Figure Below)
3. Rotary vane / sliding- vane, liquid-ring, and scroll-type

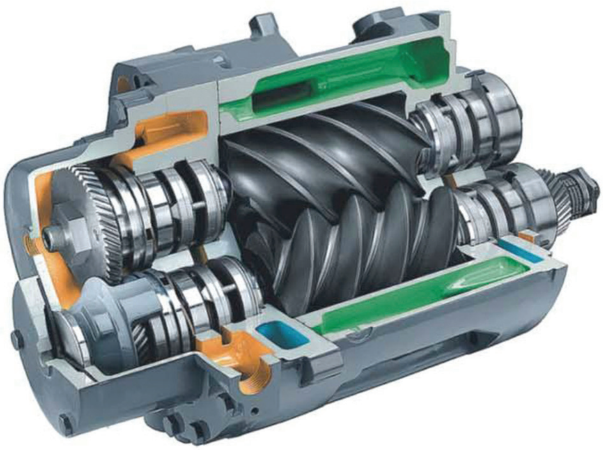


Figure 6: View of screw compressor

Rotary screw compressors may be air or water-cooled. Since the cooling takes place right inside the compressor, the working parts never experience extreme operating temperatures. The rotary compressor, therefore, is a continuous duty, air cooled or water cooled compressor package.
Because of the simple design and few wearing parts, rotary screw air compressors are easy to maintain, operate and provide great installation flexibility. Rotary air compressors can be installed on any surface that will support the static weight.

Dynamic Compressors

The centrifugal air compressor (see Figure 7) is a dynamic compressor, which depends on transfer of energy from a rotating impeller to the air. The rotor accomplishes this by changing the momentum and pressure of the air. This momentum is converted to useful pressure by slowing the air down in a stationary diffuser. The centrifugal air compressor is an oil free compressor by design. The oil lubricated running gear is separated from the air by shaft seals and atmospheric vents.

The centrifugal is a continuous duty compressor, with few moving parts, that is particularly suited to high volume applications-especially where oil free air is required.

Centrifugal air compressors are water-cooled and may be packaged; typically the package includes the after-cooler and all controls.

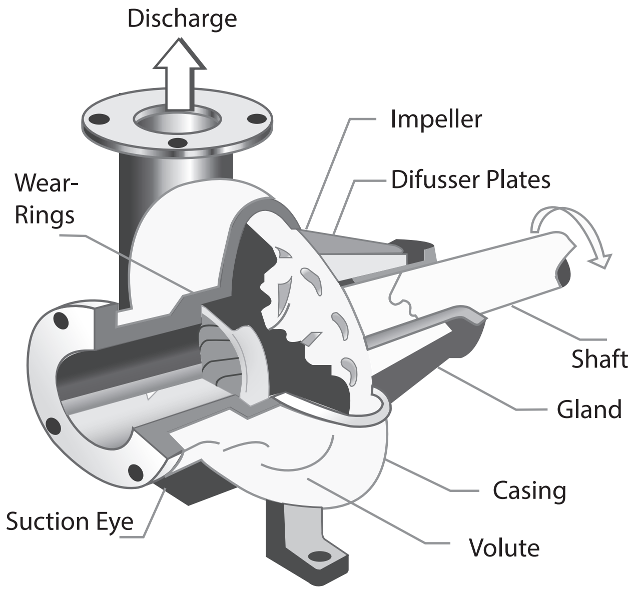


Figure 7: View of centrifugal compressor

B. Dryers – Types & Operation

Moisture content in compressed air is harmful to most end-use applications and must be removed from the system at the earliest. Dryers help to eliminate any remaining moisture in the compressed air by using either a refrigerated condenser or a desiccant.

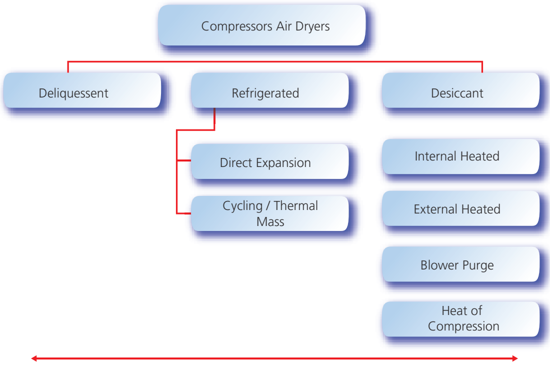


Figure 8: Types of Dryers

The two most commonly types of dryers prevalent in industries are Refrigerant and Dessicant dryers

I. Refrigerant Dryers

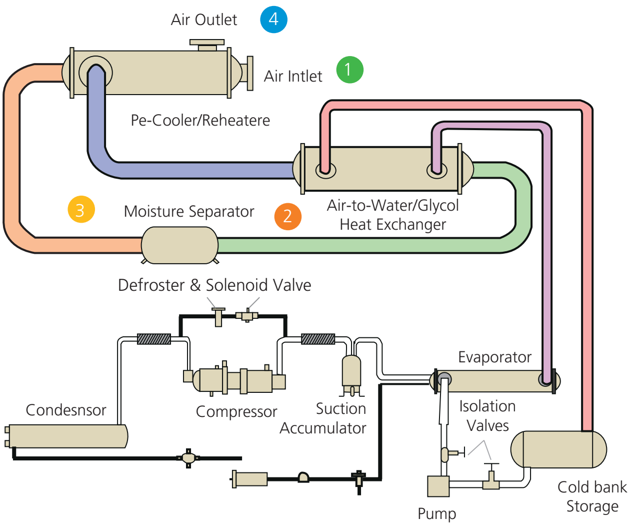


Figure 9: View of a Refrigerant Dryer

Refrigerated air dryers deliver dry air by cooling the compressed air down, thereby aiding condensation after which the condensed moisure is removed via a separator. These dryers typically use two heat exchangers – one air-to-refrigerant and one air-to-air – to bring down the temperature of the incoming air.

II. Dessicant Dryers

These type of driers push compressed air through a system of highly absorbent dessicant gels which remove any moisture and let out dry air. Once these gels are saturated with extracted moisture, compressed air is used to purge the moisture

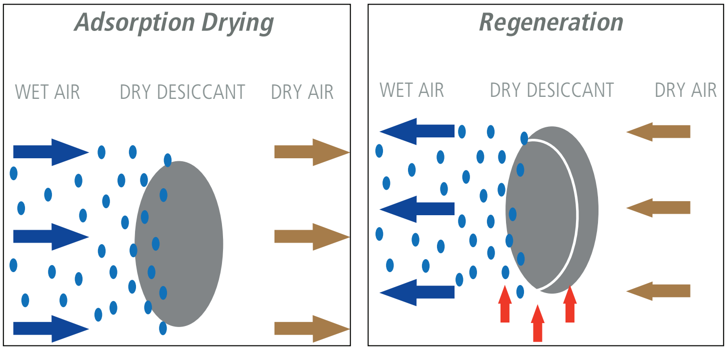


Figure 10: Working of a Dessicant dryer

C. Controls

Controls serve to adjust the amount of compressed air being produced to maintain constant system pressure and manage the interaction between system components. Air filters and air dryers remove moisture, oil and contaminants from the compressed air. Compressed air storage (wet and dry receivers) can also be used to improve system efficiency and stability. Accumulated water is manually or automatically discharged through drains. Optional pressure controllers are used to maintain a constant pressure at an end use device.

D. Accessories

- Moisture Separator: removes liquids from the compressed air
- Airline Filter: removes solids and liquids from the compressed air stream. Can be placed throughout the system.
- Condensate Trap: collects and discharges liquid that condenses out of the air stream. It is an integral part of after-coolers, dryers and separators

Energy Efficiency & Energy Saving

With 73% of the cost of a compressor due to energy use, significant cost savings will be made by improving energy efficiency, as well as the added benefits of improving the performance of your system and reducing your organisation's 'carbon footprint'.

Energy efficiency will also increase the proportion of compressed air that is used for production and minimise unnecessary wastage, again resulting in significant cost savings. An example of just how much demand on the compressed air system can be wasted is shown in figure below.

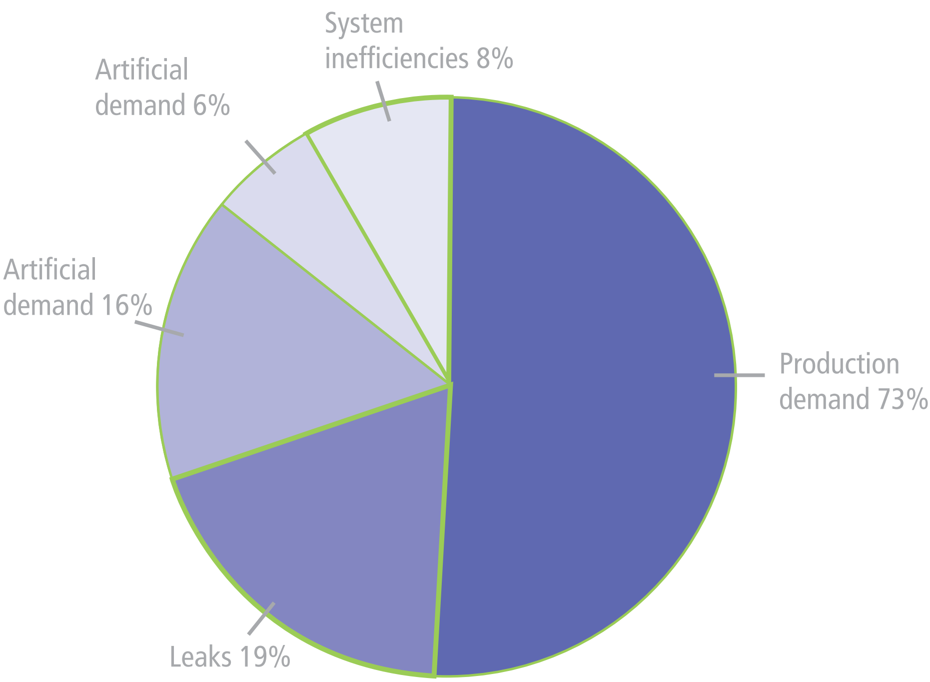


Figure 11: Compressed Air Usage Patterns

This Is What An Ordinary Compressed Air Network Looks Like

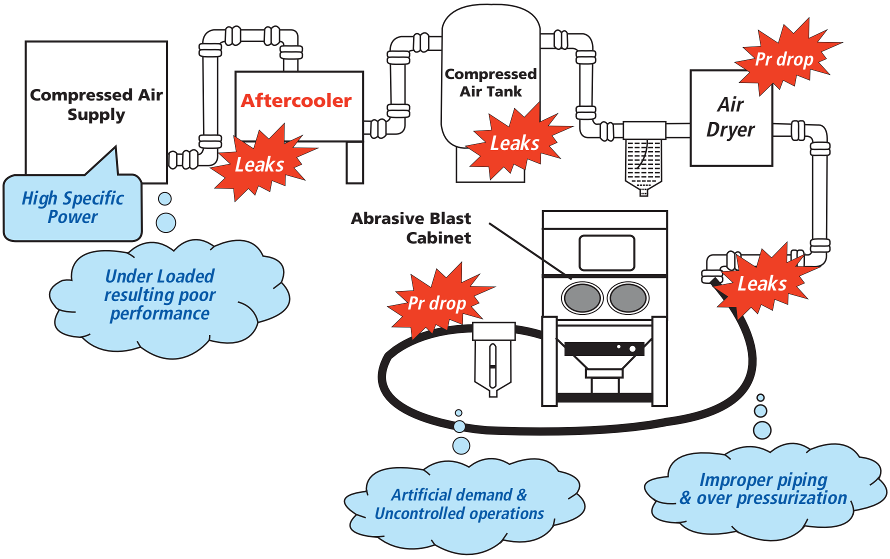


Figure 12: Typical issues of a Compressed Air System

Compressed Air Costs

The given tendency in industry today is to look at compressed air costs solely in terms of the equipment purchase costs. However, the real cost to measure is the **'Lifetime Compressed Air Cost'**. Calculating the cost of compressed air can help you justify improvements for energy efficiency.

A.Lifetime Compressed Air Cost

of a compressor accurately measures the real cost of installing, operating and maintaining a compressors over a ten year period, and includes the capital (equipment purchase) cost, installation costs, maintenance costs, and the energy costs. This section will help you to understand how much it costs to produce and use compressed air. Over the first ten years of life of a typical air cooled compressor (see figure below), with a two shift operation, the operating cost - energy and maintenance - will equal about 80% of the total lifetime cost. The cost of the original equipment and installation will only account for the remaining 20%.

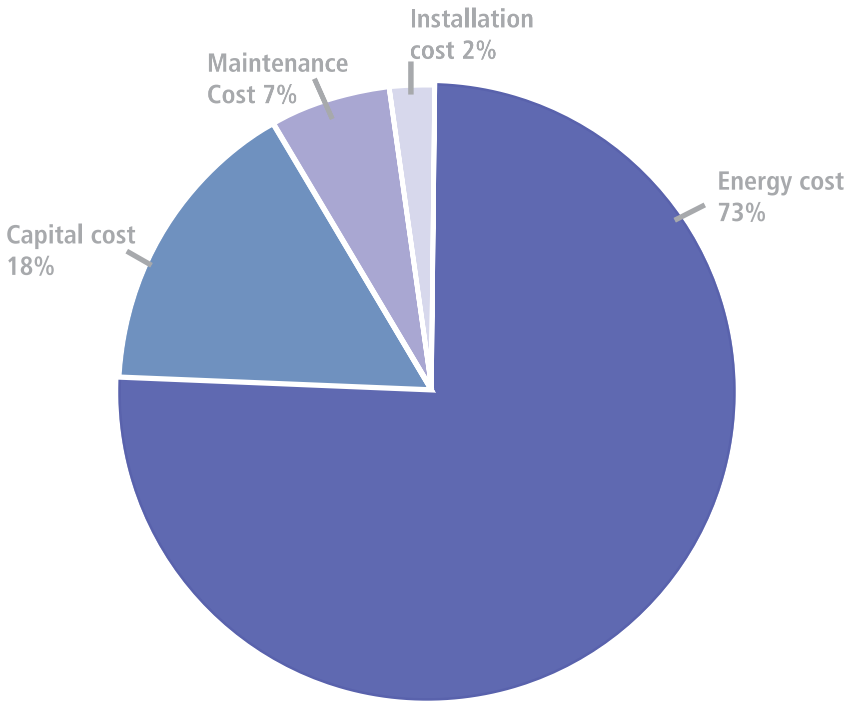


Figure 13: Typical Lifetime Ownership Cost of Compressed Air Systems

We can thereby arrive at the actual expense of using compressed air in any compressed air system, and therefore the need to identify and correct any possible losses in energy efficiency of compressed air systems.

The figure below (Fig. 3) illustrates the typical losses associated with producing and distributing compressed air. Assuming 100 HP energy input, approximately 91 HP ends up as losses, and only 9 HP as useful work. In other words, about 90% of the energy to produce and distribute compressed air is typically lost.

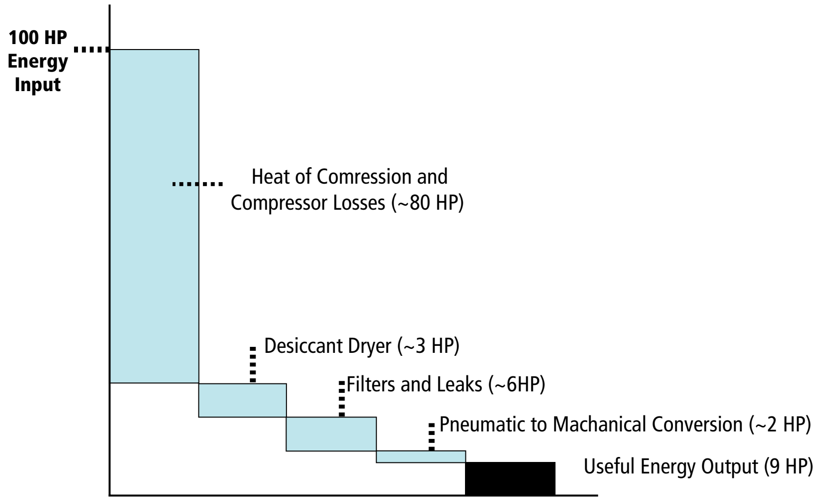


Figure 14: Compressed Air Energy Input and Useful Energy Output

B. Cost Per Year

To find the annual cost of electricity used to power a compressed air system, calculate the cost for running the system under loaded and unloaded conditions. For each, multiply:

» Horsepower (hp)
» Conversion factor 0.746 kW/hp
» Total operating hours per year (hr/yr)
» Cost per kilowatt-hour (Rs./kWh)
» % time fully-loaded or unloaded
» % full-load hp, loaded or unloaded

Divide the product by the motor's efficiency.

$$\frac{(hp) * (0.746\ kw/hp) * (hr/yr) * (Rs/kWh) * (\%\ time) * (\%\ full\text{-}load\ bhp)}{motor\ efficiency}$$

C. Cost for Specific End Uses

Calculate the cost of compressed air for specific end uses. This allows you to determine if compressed air should be used in specific applications (ie. as fans or blowers), or if other electric-motor operated equipment would be more efficient. First calculate the volume of air produced annually for a specific operation by multiplying:

- horsepower (hp)
- cubic feet per minute per horsepower (cfm/hp)
- total operating hours per year (hr/yr)
- 60 minutes per hour (60 min/hr)
- % time fully loaded
- % full-load horsepower

Volume of air produced annually

(hp) * (cfm/hp) * (hr/yr) * (60 min/hr) * (% time) *(% full-load hp)

Then calculate the cost per 1,000 cubic feet (cf) by dividing the total energy cost to operate the air compressor by the volume of air produced annually, then multiply by 1,000.
Cost per year / Volume of air products * 1000 cf

Factors Affecting Energy Efficiency

Efficiency of Compressed Air systems can be affected by a wide ranging set of factors. In order to maintain efficiency of your compressed air network you must take care of the following

A. Location of Compressor - The location of air compressors and the quality of air drawn by the compressors will have a significant influence on the amount of energy consumed. Compressor performance as a breathing machine improves with cool, clean, dry air at intake.

B. Air Intake Quality – Intake air that is contaminated by dust or other contaminants can increase wear and tear of compressors, causing loss of efficiency. Similarly, higher intake temperature of air means lower volumetric efficiency of compressors. ‘As a rule for every 4oC rise in air temperature results in 1%

higher power consumption from the compressors'.

C. Pressure Drops in Air Filter – Mismatched or choked filters cause pressure drop across the filters. The table below shows affect of pressure drop on power consumption

Pressure Drop Across air filter (mm WC)	Increase in Power Consumption (%)
0	0
200	1.6
400	3.2
600	4.7
800	7.0

D. Elevation/Altitude – Compressors located at higher altitude consumer more power than those at sea level as the compression ratios are higher.

Altitude Meters	Barometric Pressure milli bar*	Percentage Relative Volumetric Efficiency Compared with Sea Level	
		At 4 bar	At 7 bar
Sea level	1013	100.0	100.0
500	945	98.7	97.7
1000	894	97.0	95.2
1500	840	95.5	92.7
2000	789	93.9	90.0
2500	737	92.1	87.0
*1 milli bar - 1.01972 x 10-3 kg/cm2			

E. Inter and After-Coolers – Inadequate cooling negatively affects the efficiency of the compressors. Ideally, the temperature of the inlet air at each stage of a multi-stage machine should be the same as it was at the first stage. With increased temperature, the volume handled is higher, therefore causing higher energy consumption. With excess cooling however, there is a danger of further condensation and inadequate moisture removal.

Details	Imperfect Cooling	Perfect Cooling (Base Value)	Chilled Water Cooling
First Stage intel temperature 0C	21.1	21.1	21.1
Second Stage intel temperature 0C	26.6	21.1	15.5
Capacity (nm3/min)	15.5	15.6	15.7
Shaft Power (kW)	76.3	75.3	74.2
Specific energy consumption kW (nm3/min)	4.9	4.8	4.7
Percent Change	+ 2.1	Reference	- 2.1

F. Optimising Delivery Pressure –

i. Reducing Delivery Pressure – Operators tend to deliver a higher set pressure to the demand side than what is absolutely necessary. This can be optimised by a careful study of the requirement for each equipment, and pressure drop between generation and demand side.

ii. Compressor Modulation by Optimum Pressure Setting – In case of multiple compressors running to satisfy varying demand, proper selection of a right combination of compressors and optimal modulation of different compressors can conserve energy. The pressure set points (loading & unloading) should be such that the smallest compressor modulates first to cater to the varying demand.

iii. Segregating Low & High Pressure Requirements – Reducing from a common pressure to feed low-pressure requirements is a waste of energy. It is advisable to segragate the two different lines.

iv. Pressure Drop in Delivery Lines – The layout of the distribution lines has a significant impact, as an inefficient design can cause pressure drops.

Such imbalances between demand requirement and supply cause excess energy to be consumed, without any productive use.

"For every 1 Bar of excess pressure generated, the energy consumption of a compressed air system goes up by an average 7%"

Pipe Nominal Bore(mm)	Perfect drop(bar) per 100 meter	Equivalent power losses (kW)
40	1.80	9.5
50	0.65	3.4
65	0.22	1.2
80	0.04	0.2
100	0.02	0.1

G. Leakage – Compressed air leaks are the single largest source of losses in most compressed air networks. A study by the Buereau of Energy Efficiency (Govt. of India) states that up to 30% of excess energy consumed in compressed air systems is directly due to leaks. While most leaks are hard to find, they are relatively easy to identify with the right equipment.

H. Condensate Removal – Presence of moisture reduces the efficiency of compression by reducing the available air to be compressed. Similarly, it has the potential to harm the end-use equipment, if it is not safe to used as such.

I.Maintenance Practices – Regular check-ups and servicing of compressors is vital to maintain good health and therefore higher efficiency. Periodic servicing and replacement of parts like filters, traps, lubrication oil etc has to be undertaken. One must inspect the air-end fo the compressors as well.

Achieving Energy Efficiency

Reducing energy consumption of one's compressed air system requires a series of measures to be taken from the compressed air generation to the consumption sides. Major consumers of compressed such as cement, textiles and automobiles often face problems compressed air related issues solely from the utility or the user sides. In such setups, due to the scale of the issue it is imperative that the two sides work together in order to achieve lower losses and better efficiency.

A. Understand Your System –

Before implementing energy reduction strategies, be familiar with all aspects of your compressed air system.

System Supply Analyze the supply side of your compressed air system for the types of compressors used and the type, suitability and settings of capacity controls and other operating conditions. Understand the basic capabilities of the system and its various modes of operation. Verify that air compressors are not too big for end uses. For example, an air compressor is oversized if the end use only requires air pressure that is 50 % of the pressure that the compressor is capable of producing. Once the big picture is in view, supply side operating conditions can be modified, within the constraints of the compressed air unit, to better match the demand side uses of compressed air.

System Demand - Identify all the uses of compressed air in the plant. Quantify the volume of air used in each application and generate a demand profile, quantity of air used as a function of time, for the compressor. Equipment specifications for operations that use air are good resources for obtaining data on air volume use rates. The profile highlights peak and low demand. A general assessment of compressed air use will help identify inappropriate uses of air.

Air Quality - Air quality is determined by the air dryness and contaminant level required by end uses. Learn the actual dryness level needed and the maximum contaminant level allowed for reliable production. Overtreating air beyond the required dryness and allowable contaminant level wastes money and energy.

Pressure Requirements - The minimum required discharge pressure level must take into account the different pressure ratings of compressed air applications and processes as well as the pressure drops from components in the system. Too often, low or fluctuating pressure at end uses is misdiagnosed as not enough discharge pressure

System Diagram - Develop a sketch of your compressed air system—including compressors, air supply lines with dimensions, and compressed air end uses—to provide an overall view of the entire compressed air process.

Distribution system - Investigate the distribution system for any problems related to line size, pressure loss, air storage capacity, air leaks and condensation drains. Verify that all condensation drains are operating properly because inadequate drainage can increase pressure drop across the distribution system.

Maintenance - Evaluate maintenance procedures, records and training. Ensure that procedures are in place for operating and maintaining the compressed air system, and that employees are trained in these procedures

B. Conservation Strategies

Identify easy to implement energy conservation opportunities in your compressed air system by conducting a walk-through assessment. Simple conservation opportunities can result in savings up to 25% of the current cost to run the compressed air system.

Leaks - Routinely check your system for leaks. A distribution system under 100 pounds-per-square-inch gauged (psig) of pressure, running 40 hours per week, with the equivalent of a quarter-inch diameter leak will lose compressed air at a rate of over 100 cfm costing over Rs. 173348 per year. In noisy environments an ultrasonic detector may be needed to locate leaks.

Compressor pressure - The compressor must produce air at a pressure high enough to overcome pressure losses in the supply system and still meet the minimum operating pressure of the end use equipment. Pressure loss in a properly designed system will be less than 0.2 PSI of the compressor's discharge pressure—found on a gauge on the outlet of the compressor. If pressure loss is greater than 0.2 PSI, evaluate your distribution system and identify areas causing excessive pressure drops. Every two pounds-per-square-inch decrease in compressor pressure will reduce your operating costs 1.5%.

Identify artificial demands - Artificial demand is created when an end use is supplied air pressure higher than required for the application. If an application requires 50 psi but is supplied 90 psi, excess compressed air is used. Use pressure regulators/demand controllers at the end use to minimize artificial demand.

Inappropriate use of compressed air - Look for inappropriate uses of compressed air at your facility. Instead of using compressed air, use air conditioning or fans to cool electrical cabinets; use blowers to agitate, aspirate, cool, mix, and inflate packaging; and use low-pressure air for blow guns and air lances. Disconnect the compressed air source from unused equipment.

Heat Recovery - As much as 80 to 90% of the electrical energy used by an air compressor is converted to heat. A properly designed heat recovery unit can recover 50 to 90% of this heat for heating air or water. Approximately 50,000

British thermal units (Btus) per hour is available per 100 cfm of compressor capacity when running at full load. For example, consider a 100 hp compressor that generates 350 cfm at full load for 75% of the year. If 50% of heat loss is recovered to heat process water, the savings, at 31.04 per therm, would be about Rs. 2,54,528 per year in natural gas.

Inlet Air Filters - Maintain inlet air filters to prevent dirt from causing pressure drops by restricting the flow of air to the compressor. Retrofit the compressor with large-area air intake filters to help reduce pressure drop.

Compressor Capacity - If your compressor is oversized add a smaller compressor and sequence-controls to make its operation more efficient when partially loaded. Sequence-controls can regulate a number of compressors to match compressed air needs, as they vary throughout the day.

Cooler Intake Air - When in taking cooler air, which is more dense, compressors use less energy to produce the required pressure. For example, if 90 degree F intake air is tempered with cooler air from another source to 70 degree F, the 20 degree F temperature drop will lower operating costs by almost 3.8%.

V-belts - Routinely check the compressor's v-belts for proper tightness. Loose belts slip more frequently which reduces compressor efficiency.

C. System Control Strategies

Improving and maintaining compressed air system performance requires not only addressing individual components, but also analysing both the supply and demand sides of the system and how they interact, especially during periods of peak demand. This practice is often referred to as taking a systems approach because the focus is shifted away from components to total system performance.

Matching Supply with Demand - With compressed air systems, system dynamics (changes in demand over time) are especially important. Using controls, storage, and demand management to effectively design a system that meets peak requirements but also operates efficiently at part-load is key to a high performance compressed air system. In many systems, compressor controls are not coordinated to meet the demand requirements, which can result in compressors operating in conflict with each other, short-cycling, or blowing off—all signs of inefficient system operation.

Individual Compressor Controls - Controls such as start/stop and load/unload respond to reductions in air demand by turning the compressor off or unloading it so that it does not deliver air for periods of time. Modulating inlet and multi-step controls allow the compressor to operate at part-load and deliver a reduced amount of air during periods of reduced demand. Variable speed controls reduce the speed of the compressor in low demand periods. Compressors running at part-load are generally less efficient than when they are run at full-load.

Multiple Compressor Controls - Systems with multiple compressors should use more sophisticated controls to orchestrate compressor operation and air delivery to the system. Network controls use the on-board compressor controls' microprocessors linked together to form a chain of communication that makes decisions to stop/start, load/unload, modulate, and vary displacement and speed. Usually, one compressor assumes the lead role with the others being subordinate to the commands from this compressor. System master controls coordinate all of the functions necessary to optimize compressed air as a utility. System master controls have many functional capabilities, including the ability to monitor and control all components in the system, as well as trending data, to enhance maintenance functions and minimize costs of operation. Most multiple compressor controls operate the appropriate number of compressors at full-load and have one compressor trimming (running at part-load) to match supply with demand.

Pressure/Flow Controllers - Pressure/Flow Controllers (P/FC) are system pressure controls that can be used in conjunction with the individual and multiple compressor controls described above. A P/FC does not directly control a compressor and is generally not part of a compressor package. A P/FC is a device that serves to separate the supply side of a compressor system from the demand side, and requires the use of storage. Controlled storage can be used to address intermittent loads, which can affect system pressure and reliability. The goal is to deliver compressed air at the lowest stable pressure to the main plant distribution system and to support transient events as much as possible with stored compressed air. In general, a highly variable demand load will require a more sophisticated control strategy to maintain stable system pressure than a consistent, steady demand load.

D.Compressed Air Storage Strategies –

Compressed air storage can allow a compressed air system to meet its peak demand needs and help control system pressure without starting additional compressors. The appropriate type and quantity of air storage depends on air demand patterns, air quantity and quality required, and the compressor and type of controls being used. An optimal air storage strategy will enable a compressed air system to provide enough air to satisfy temporary air demand events while minimizing compressor use and pressure.

The use of air receivers is especially effective for systems with shifting air demand patterns. When air demand patterns are variable, a large air receiver can provide enough stored air so that a system can be served by a small compressor and can allow the capacity control system to operate more effectively. For systems having a compressor operating in modulation to support intermittent demand events, storage may allow such a compressor to be turned off. By preventing pressure decay due to demand events, storage can protect critical end-use applications and prevent additional units from coming online.

Air entering a storage receiver needs to be at a higher pressure level than the system pressure. A good air storage strategy will allow the differential between these two pressure levels to be sustained. To accomplish such a pressure differential, two types of devices can be employed: Pressure/Flow Controllers (P/FC) and metering valves.

A P/FC is a device that serves to separate the supply side of a compressed air system from the demand side. In a system that employs P/FCs, the compressors generally operate at or near design discharge pressure to ensure that the P/FC receives air at a higher pressure level than it will discharge into the system. This allows the pressure in the demand side to be reduced to a stable level that minimizes actual compressed air consumption. P/FCs are added after the primary receiver to maintain a reduced and relatively constant system pressure at points of use, while allowing the compressor controls to function in the most efficient control mode and discharge pressure range. Properly applied, a P/FC can yield significant energy savings in a system with a variable demand load. See figure below

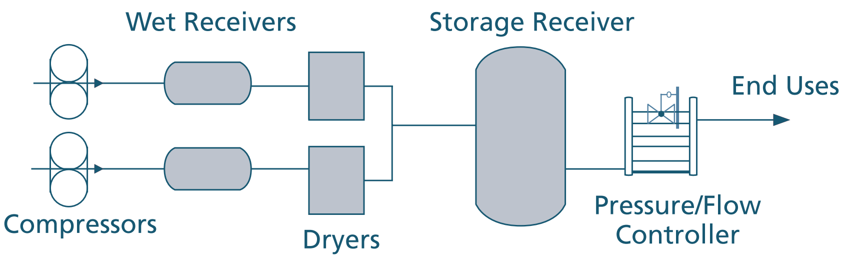


Figure 15 – Compressed Air System with a Pressure/Flow Controller

For situations in which just one or a few applications have intermittent air demand, a correctly-sized storage receiver close to the point of the intermittent demand with a check valve and a metering valve can be an effective and lower cost alternative. For this type of storage strategy, a check valve and a tapered plug or needle valve are installed upstream of the receiver. The check valve will maintain receiver pressure at the maximum system pressure; the plug or needle valve will meter the flow of compressed air to "slow fi ll" the receiver during the interval between demand events. This will have the effect of reducing the large intermittent requirement into a much smaller average demand. See Figure Below.

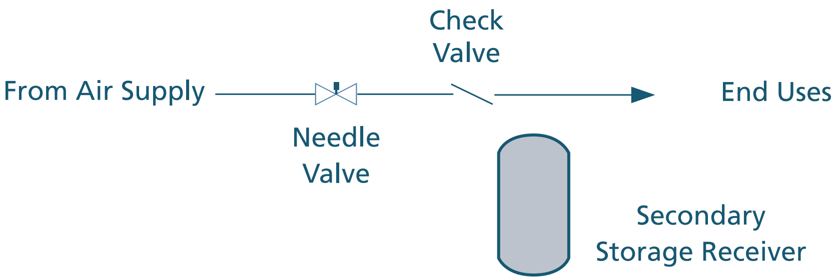


Figure 16 – Compressed Air System with Check and Needle Valves

E. Engineering End Uses

Compressed Air directly serves processes and applications such as pneumatic tools, pneumatic controls, and compressed air operated cylinders for machine actuation, product cleansing and blow-off applications. Ensuring an appropriate, stable pressure level at the end-use applications is critical to the performance of any industrial compressed air system. End uses that are engineered for maximum efficiency can help provide the consistent supply of compressed air that ensures reliable production.

To ensure the efficiency of compressed air end-use applications, a number of steps should be taken:

Steps	Action	Description
1	Review pressure requirements of end-use applications	Those pressure level requirements should determine the system pressure level. There is often a substantial difference in air consumption and pressure levels required by similar tools available from different manufacturers, request exact figures from each manufacturer for the specific application.
2	Monitor Air Pressure at the inlet to the tool	Improperly-sized hoses, fittings and quick disconnects often result in large pressure drops. These drops require higher system pressures to compensate, thus wasting energy.
3	Avoid the operation of any air tool at "free speed" with no load	Operating a tool this way will consume more air than a tool that has the load applied.
4	Check the useful life of each end-use application	A worn tool will often require higher pressure, consume excess compressed air, and can affect other operations in the immediate area.
5	Deliver moisture free air	Presence of moisture in air to end-use applications can lead to damage of parts and deficiency in process.
6	Grouping of applications with similar pressure requirements	This is a good engineering practice for optimising compressed air network, which will help reduce generation load.

7	Investigate and reduce the highest point-of-use pressure requirements	This will helps to reduce the pressure demands in system. Also minuses the pressure drops.
8	Investigate and replace inefficient end uses such as open blowing with efficient ones such as vortex nozzles	This permits conserving use of compressed air. By such implementations air wastage can avoided by a considerable amount.

F. Conducting Self-Assessments

Taking steps to reduce energy efficiency of compressed air systems, requires thorough insights into the existing working parameters of the system and the potential opportunities.
The utilities manager must keep a regular check on the cost of compressed air and the utilisation of compressed air in the right manner. Keep a check on at least the following:

1. Lifetime cost of compressed air
2. Cost per year
3. End-Use costs
4. Pressure Delivery and Pressure Demand
5. Leakages
6. Malpractices and Inefficient Uses of compressed air

With the right tools and techniques it is fairly easy to do a basic self-assessment of one's compressed air system. It is important to be honest with one's assessment of the existing compressed air system and keeping an open mind about deficiencies in the practices being currently maintained.

Self-Assessment Forms, such as the one enclosed in this book, should be used to conduct a preliminary audit of one's own compressed air system. These will at the first-go help in identifying the most basic opportunities for saving energy.

G. Engage External Compressed Air Experts

Having conducted a self-assessment of one's compressed air system, it is advised to incorporate external viewpoints for further improvements. External experts in compressed air systems, such as Forbes Marshall's Air Efficiency Solutions, bring with them experience gained from managing and improving compressed air systems across many different setups and industries. The insights gained from such experience can help identify higher level opportunities for energy efficiency and help implement solutions and 'Best Practices'.

H. Implement Solutions

Reducing energy intake in compressed air systems can only be achieved by taking the vital step of implementing the solutions identified by the self-assessment and audits by external experts. Moreover, beyond just initially achieving reduction in energy consumption, system managers and users have to continuously work to ensure that these efficiency levels are sustained over a long term.

Air Efficiency Solutions

Forbes Marshall has over 60 years of experience in providing solutions for energy savings in various industries and utilities. We boast of expertise in providing energy efficiency services for utilities such as Compressed Air, Steam, Water & Electrical system.

Forbes Marshall's Air Efficiency Solutions are comprehensive bundle of services that help optimization of compressed air networks. Our services help identify and define system problems, whether they are in demand, distribution or supply, and provide solutions, allowing you to meet your return on investment goals.

We have a varied range of products for Monitoring, Controlling, Optimizing compressed Air and Energy Conservation which offers a complete control of your whole compressed air network and thus help to increase efficiency & reduce your energy costs.

Our range of solutions includes compressed air audits, demand control systems, compressor control systems, network monitoring solutions and flow meters etc. Through our various services and solutions we have been able to support our customers in achieving energy efficiency in diverse industrial sectors such as Automobiles, Textiles, Cement, Power, Glass and many others.

Compressed Air Audits

Compressed Air Audits focus on identifying the potential for increasing the energy savings on compressed air network. Compressed air being one of the most inefficient and costly utilities, compressed air audits bring out the various areas that cause inefficiencies and losses in your compressed air network and lead to wastage of energy.

Features -

- » A specialized service, focused on energy conservation
- » A comprehensive study of your compressed air network – from generation to consumption
- » Designed to identify and address a wide range of issues
- » Qualified, BEE certified auditing company

Benefits of Air Audit –

- It gives the complete real time scenario of complete compressed air network
- Air audits leads to energy savings which can ranges from 15% to 25%
- It highlights the drawbacks & artificial demands in air network, which upon addressing gives huge cost savings

Objective:

The major goals of the audit are:

- Estimating the existing power consumption, efficiency of compressors, specific power consumption for individual compressors and the system as a whole.
- Study of the existing demand at various areas & operating patterns & thereby optimizing of compressed air consumption at various points of uses.
- Study of existing compressor layout, system capacitance and distribution network,and recommend improvements, if any.
- Recommend steps for potential energy conservation in all above areas and suggest ways for optimum utilization of the compressed air system.
- Study of the present supply & demand relations for process, cleaning & instrument air system.

Methodology of Audit

In order to provide a comprehensive analysis, we analyze the quantity, quality, reliability, repeatability, and cost of the existing compressed air system. Production capacity at the time of audit. Over many numbers of data points we collect and the analysis is based upon this data and plant personnel interviews and feedback.

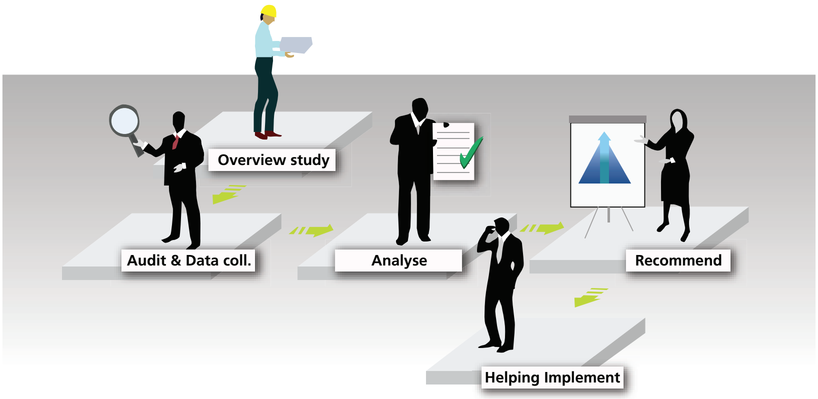


Figure 17: Approach of a Compressed Air Audit

Master Air Control (MAC)

In every industry the air demand of the plant keeps fluctuating constantly due to intermittent use of pneumatic equipment. When the demand for compressed air increases, the compressor responds to a low-pressure signal and starts loading. However, there always exists a lag between the compressor getting the signal to load and when it builds up the required pressure, and by that time the demand is likely to have vanished. As a result, the compressor pumps air into the system till it reaches its unload set point. This extra air that the compressor injects into the system is purely artificial demand.

The lag in response time between demand & supply forces the compressor operators to maintain higher level of pressure in the air system to sustain a sudden demand. This goes towards feeding just the artificial demand. Simply lowering supply side air pressure is also not an option, since it causes a negative impact on production. Doing so may result in decreased production efficiencies and quality related problems. In effect, industries end up with losses due to inefficiencies and higher energy bills. In this situation you need a proper balancing of supply and demand of compressed air.

Master air Control is a demand side load controller that helps control the artificial demand in your compressed air network. Continuously fluctuating demand in the plant causes the compressors to run in continuous load-unload cycles, and in a higher pressure band. The MAC helps deliver a steady pressure to the demand side and ensures that the compressors run at a steadier rate and therefore conserve energy.

MAC is an energy saving control system, which actively helps you control the balance across the demand and supply sides. It introduces a differential pressure between the receiver and itself and thus creates a useful high-pressure storage. This helps in isolating the compressors from the demand surges. Peaks in demand are handled by **MAC**, rather than being directed towards the compressors. This allows compressors to run for longer on no-load. As a result, mass of air is reduced and a high and compressor load cycles are reduced. This decrease in compressor load cycles is directly proportional to the decrease in energy consumed by the compressors.

Thus, due to the **MAC** compressors are protected from artificial demand and the have to cater only to base demand, and resulting in savings on compressed air energy consumption.

Furthermore, a constant pressure is now delivered to all plants and pneumatic equipment, increasing quality and productivity in production processes.

Figure 18: Master Air Control (MAC)

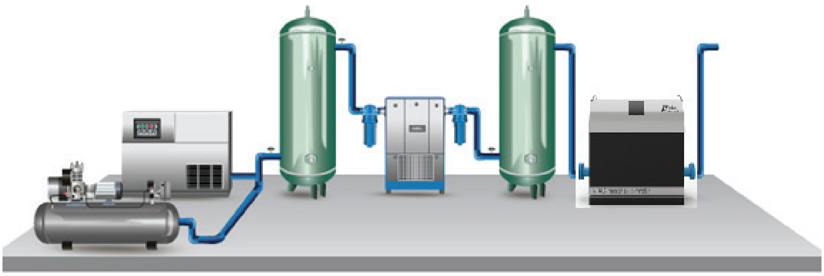


Figure 19: Forbes Marshall- MAC installation Scheme

Benefits of Master Air Control

- » Saves energy consumed by air compressors by cutting artificial demand for air
- » Reduction in compressor loading & induces higher unloading period
- » Separates compressors from demand side peaks & lows, thus prevents compressor cycling to minimal
- » Consistent air pressure delivery to demand side
- » Enhanced useful air storage capacity
- » Accommodates to any make of compressor
- » Demand reduction tends to reduce leakages in plant

Features of Master Air Control

- HMI for better GUI
- History & trending feature
- Fail safe operation
- Accurate pressure control
- Provision of pressure control via addition of air demand meter
- Highly responsive to fine changes in demand

CountAir – The Complete Air System Monitor

Compressed air networks tend to be spread out over wide areas, and the expanse of the systems makes it difficult to monitor closely. However, compressed air being an energy intensive utility, it is imperative that the utility is monitored closely and completely.

Count Air is a central monitoring solution for your entire compressed air network. It helps you monitor even the most remote corner of your network through instruments such as flow meters, pressure transmitters, etc. Through its various features it helps you identify and address issues before they turn into problems, thus saving on downtime.

It offers features like trends, history, graphs, alarms etc. This work equally well in wired or wireless mode.

Benefits of CountAIR

- Real-time specific compressor & machine data
- Deviations of any machine or area from its trend line and rated consumption
- An overall plant demand overview
- Presence of leakages in your distribution lines
- Historical trends of each area/unit with graphs
- Identification of unaccounted losses in the system

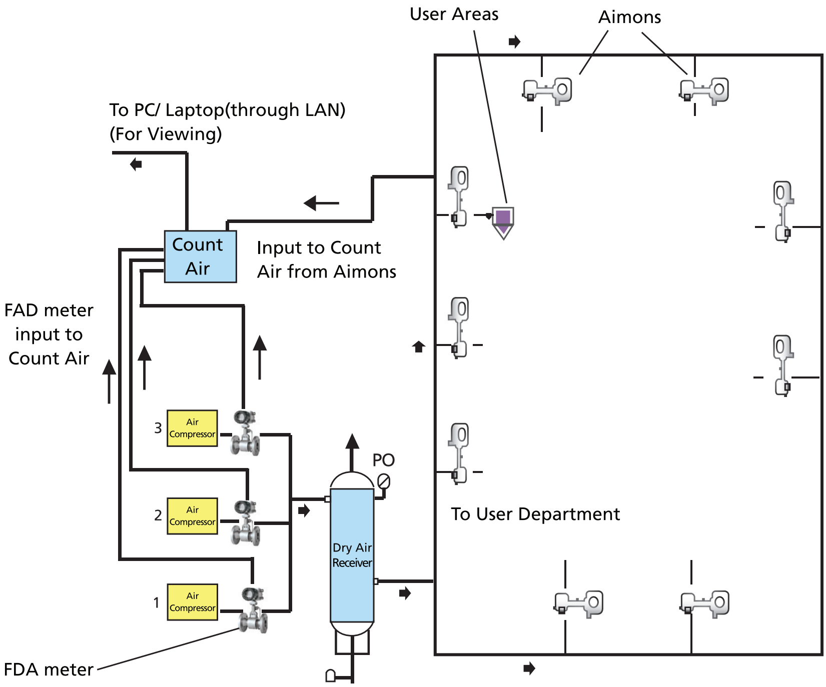


Figure 20: Sample schematic for monitoring of compressed air network

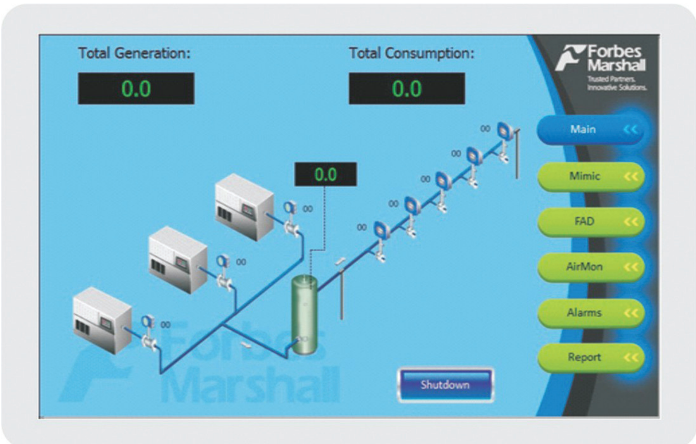


Figure 21: CountAIR User Interface

Figure 22: CountAIR – Flowmeter Individual Display

Features of CountAIR

» Forbes Marshall's CountAIR is the ideal solution for complete monitoring of your compressed air network – from compressors to utility points

» It continuously keeps track of the generation of each compressor, and each consumption point , and keeps you informed on the overall system efficiency

» It enables you to monitor because an unmonitored consumption side leaves you with an incomplete picture

Free Air Delivery Meter – FAD Meter

FAD Meter is one of the most accurate solutions available for compressed air efficiency monitoring. Due to its in-built online pressure and temperature compensation it gives a highly accurate reading of your compressors' actual output and can monitor its health and efficiency continuously.

It is prfectly suitable for measurement of compressed Air, It replaces older technologies like the orifice plate or DPT system by combining pressure/temparature sensors in a single instrument. The figure below shows how the FAD meter replaces conventional orifice/DPT systems.

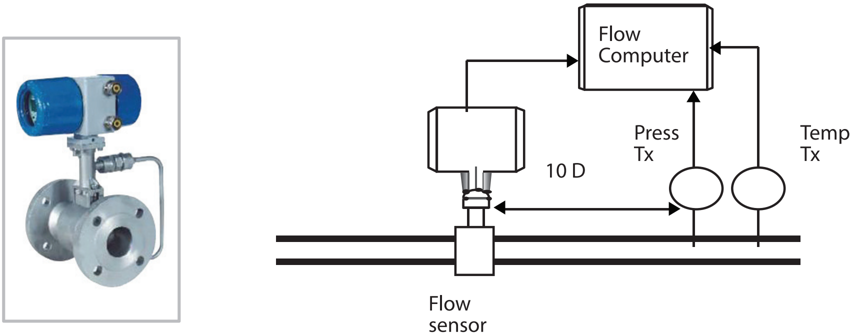
Benefits of FAD Meter

- » Accuracy of +/- 1% of measured value
- » Optimum process reliability thanks to Flodoc Intelligent Signal Processing stable readings, free of external disturbances
- » Reconcile generation with consumption and losses
- » Reduce downtime through preventive maintenance
- » Avoid periodical overhauls, When not necessary
- » Better process control resulting in enhanced product quality

Features of FAD Meter

- » Forbes Marshall FAD meter is a Vortex type with online temperature and
- » Pressure compensation
- » It is the most accurate and the most effective way to measure and monitor compressor efficiency
- » Enables you to monitor health of your compressor

Figure 23: Free Air Delivery Meter



- Simple system
- Accuracy 1% of M.V.
- Simpler Installation
- Lower Cost
- Single Source

- Complicated System
- Higher Inaccuracies as the inaccuracies of all components get added in the system
- Cumbersome Installation
- Much Higher Cost
- Several Manufacturers

Figure 24: FAD Vs Convential Flowmeters

AirMon

AirMon is custom-designed flow meter for distribution line metering. It is easy to install and convenient to use. Once fixed on any distribution line, it gives very accurate inputs on the consumption of air through that line. Moreover, it is a budget-friendly flow meter.

It is an innovative cost-effective solution for monitoring of compressed air on plant lines. Its microprocessor-based electronics features software designed jointly by a team of flow metering and compressed air experts. This gives you the most accurate solution for compressed air utility metering.

Benefits of AirMon

» Specialized solution for utility metering of compressed air
» Accuracy +/- 3% of measured value
» Airmon facilitates remote monitoring of the key data which is conveniently viewed by the operators
» Maintenance free sensor design
» User friendly- No need of Expert operator
» Cost effective solution.

Features of AirMon

- » It is an innovative cost-effective solution for monitoring of compressed air on plant lines
- » It makes users data available with minimum hardware/electronics without compromising on the accuracy, reliability and durability
- » Its online pressure and temperature compensation makes it the most practical solution that helps to tally the compressed air usage at the distribution line

Figure 25: AirMon

Beyond these standardised solutions, Forbes Marshall offers a wide variety of customised solutions which will help the compresses air system managers monitor and control their networks in a more comprehensive manner, and help keep energy efficiency levels high.

You can get further details of our solutions on our website www.forbesmarshall.com/airaudits, or email us at airaudits@forbesmarshall.com.

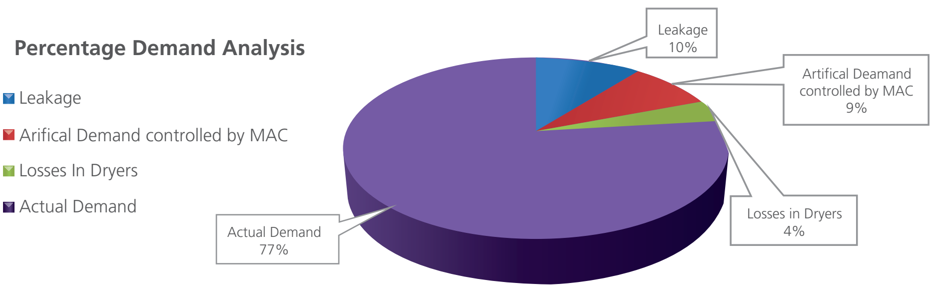
Achieving Energy Efficiency – Case Studies

Compressed Air Audit at a 500 MW Thermal Power Plant

Forbes Marshall's Air Efficiency Solutions team conducted an Energy Audit of Compressed Air System at one 250 MW unit of 02X 250 MW Thermal Power Plant in Maharashtra in December 2013.

Compressed air is one of the most critical utility in the plant. Compressed air is widely used across the plant for applications such as Instrument Air, Service Air & Ash Conveying System. **The total existing annual power cost for compressed air system was Rs. 2.25 Crores/annum.** The chief purpose of audit was study and analysis of the existing system, estimate the saving potential and provide appropriate energy conservation solutions to achieve the savings.

As part of the audit, the Air Efficiency Solutions team carried out Power Profiling of compressors, Compressor Efficiency Measurement, Pressure Profiling & Mapping of the entire compressed air network, Flow Profiling of the Demand side, Air Leak Detection, Air Pipeline Network Study. Analysis of the data collected during the audit revealed huge potential for reduction in energy consumption by the compressed air system. **The true productive demand was identified to be only around 77%, with losses contributing to excess 23% energy consumption.**



On the generation side, the main potential for energy conservation was reduction in pressure drop by replacing existing desiccant dryers with refrigerant dryers. This change in technology presented not only short-term savings, but also long-term benefits in system efficiency. Additionally, we recommended replacement of two of the existing reciprocating compressors with a single Centrifugal Compressor of higher capacity. Centrifugal compressors are ideal for processes with high air flow demand since their average specific power consumption (0.16 KW per CFM) is lower than that of reciprocating compressors (0.2 KW per CFM).

On the Demand Side, we recommended installation of the Master Air Control (demand controller) in order to reduce excess pressurization and artificial demand in existing system without affecting the plant operations. **This offered a savings of approximately 9.5% of the annual compressed air electricity cost.** In addition to this, general guidelines, tips and techniques for maintaining overall system were also recommended in order to run compressed air system efficiently for longer period. Including other solutions like arresting Compressed Air leaks and installation of No-Loss Drain Traps, the **total achievable energy saving potential was up to 22.5% of the annual energy costs. Savings in terms of cost was Rs.51 Lacs/annum with a payback period of 6 months only.**

Controlling Demand in an Automobile Plant in North India

Forbes Marshall Air Efficiency Solutions team implemented the Master Air Control at a Two Wheeler Manufacturing Automobile Plant in North India in May 2014 and delivered greater savings than those committed.

Compressed Air was mainly used in this plant as Instrument Air for operating pneumatic machine tools. The plant management had identified the demand side of the compressed air system as an area where they wanted solutions to reduce energy consumption. According to plant management, the plant demand was very fluctuating and power consumption was higher than design and benchmark standards. Hence, after discussions with the plant management we conducted an audit f the compressed air system to get a precise idea about existing scenario.

After analyzing the collected data, we found significant energy saving potential due to excess pressure generation, pressure fluctuations and artificial demand. The existing average pressure at generation was around 6 Bar, whereas the actual minimum required pressure was found to be only 5.4 Bar. This presented an opportunity to conserve energy by ensuring reduction in pressure delivery while catering to the fluctuating demand.

To achieve this saving, Forbes Marshall's Master Air Control (Demand Controller) was recommended with a minimum saving potential of 7.3% in power and compressed air consumption. After installation of Master Air Control on the main header line after the air receiver, this controller ensured reduction of the excess air consumption at higher pressure and delivered a constant set pressure to the plant.

One month after the installation of the Master Air Control, we conducted a secondary study to ascertain the impact of the controller on the energy consumption. **The saving achieved through this implementation was determined to be 9.3%,** significantly greater than the committed energy saving. The user was also able to get a better payback period, which now stood at 10 months, as against the earlier expected 12 months.

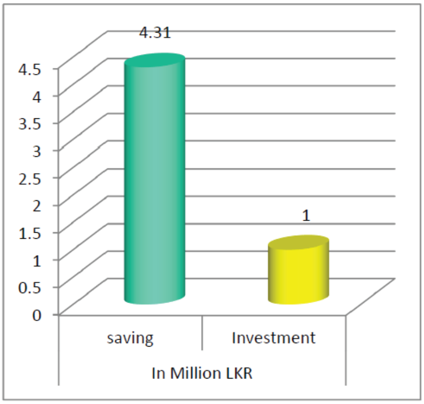
Compressed Air Audit at an FMCG Plant in Sri Lanka

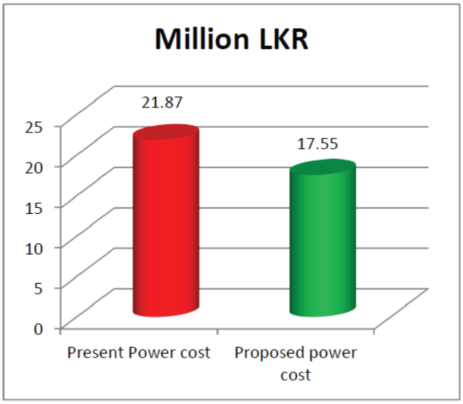
Forbes Marshall Air Efficiency Solutions team conducted an Energy Audit of Compressed Air System at a Consumer Goods manufacturing plant in Sri Lanka in August 2014.

Compressed air is one of the most critical utilities in a manufacturing plant and is mainly used for Instrument Air, Packing & Cleaning. This organization is a progressive company that is very conscious about energy conservation and takes several internal initiatives to reduce energy consumption. They engaged us to do an audit to identify further potential for increasing energy efficiency. Since they were largely satisfied with performance of the generation side, the primary mandate given to us was to map the air flow requirement in the various plant lines, while identifying further potential in the demand side.

Major activities involved in air audit were: Power profiling at compressors, Compressor Efficiency measurement, Pressure Profiling and Mapping, Flow Profiling, Air Leak Detection and Air Pipeline Network study. **After conducting the audit of the complete system, surprisingly we found that, in addition to the saving potential in the demand side, there was a huge energy saving potential on the Generation side as well, which the plant management wasn't aware of.** On the basis of findings, we recommended following solutions:

- Replacement of Desiccant Air Dryers with new Refrigerant Dryers.
- Air Leak arresting and regular proactive maintenance.
- Replacing existing Drain Traps by No-Loss Drain Traps.
- Ring Main network was recommended over existing dead end Branched network. **By implementing simple modifications in existing Air Pipeline Network, the problem of user side pressure drop was resolved with very less effort.**
- Compressor Pressure Set-points Reduction: Pressure set point reduction was achieved by modifying piping network, air dryers and installing a demand controller. Installation of a Master Air Control (Demand controller) was recommended to reduce excess pressurization and excess compressed air demand in existing system without affecting the plant operations.





The total existing annual power cost for compressed air system was 21.8million LKR/annum **(164,000 USD/annum). The total energy saving potential was up to 19.7%.** Savings in terms of cost was 4.3million LKR/annum **(32,500 USD/annum)** with a **payback period of 4 months** only.

Compressed AIR Leak Audit in Refinery

Forbes Marshall Air Efficiency Solutions team conducted Compressed Air and Nitrogen Leak survey of Compressed Air System at Oil and Gas Refinery in Andhra Pradesh, India in January 2015.

Oil refineries are typically large, sprawling industrial complexes with extensive piping running throughout, carrying streams of fluids between large chemical processing units. Compressed Air is a very important utility in the refinery with the network spread over in the whole refinery, and contributes to a large portion of their energy expenses. It is, therefore, vital for refineries to maintain their compressed air networks at a high level by conducting audits regularly. As part of these efforts, this refinery regularly engages experts for conducting leak audits regularly with extensive efforts. This is a specialized requirement due to the highly explosive and highly reactive environment in the refinery.

Here, Forbes Marshall conducted a Three-Week extensive Leak Audit with special purpose Explosion-Proof equipment and will conduct further audits periodically within a period of 2.5 years. The scope of the audit involved Compressed Air and Nitrogen Leak Detection, Leak Quantification, Leak Classification and Leak Tagging. After conducting the Leak audit, the total air loss through leaks was found to be around 2000 Nm3/Hour which was 9.5% of total generation capacity. Total loss in terms of cost was Rs. 1.56 Crore/Annum. These leaks will be corrected with utmost urgency by the refinery maintenance team.

Using the Compressed Air Self-Assessment Form

The Compressed Air Self-Assessment Form has three main sections:

Section A - for recording system and operating data including calculating the annual running cost.
Section B - for calculating the sources of wastage and the system efficiency score.
Section C - for verifying that key efficiency items have been checked and appropriate actions taken.

The following is a guide on how to use each section.

Section A - Compressed Air System Measurements
This section of the form is used to capture system operating data important to either completing the efficiency scoring in Section B or to making other recommendations to the business owner. Note: In cases where the plant has two or more distinct compressed air systems (separate from each other), separate self-assessment forms should be completed for each system.

Items	Data Measured	Explanation
A to D	Compressor cycling time measurements	Measurement of compressor loading data during a typical production period is required to identify the appropriateness of the compressor to its use, and to calculate the percentage of air leakage if required.
	For Fixed speed compressors	For a fixed speed compressor, the measurements should be taken to cover at least two full cycles of loading and unloading. Record the total length of time that the compressor runs loaded, the total length of time it runs unloaded (idles), and the total length of time that it is in shutdown mode. Add and record the total duration of the three cycle phases.
	For Variable speed compressors	For a variable flow compressor either:a) for a period of approximately 15 minutes, record the average kW loading of the compressor; or b) refer to the running records of the compressor and record its historic average loading Make a judgment as to the most representative average loading.

E	Leakage percentage	Estimate the leakage rate to the best of your abilities (formulae given below) Ideally such measurements are made by observing the compressors for 5 compressor cycles.
F	Pressure drop across the system	Measure the system pressure between the generation and the final point of use. Compare the pressure reading taken at the end use tool, with the unload pressure setting of the compressor. The difference is the pressure drop across the system (or system pressure drop).
G	Pressure setting	Record the reload pressure setting on the compressor
H	Compressor capacity	The compressor power in kW should be available from the compressor or motor data plate
I	Annual operating hours	This detail is normally available from the compressor control panel. Alternatively, calculate from the business's operating hours (e.g. 8 hr day x 5 day week x 50 week year = 2000 hrs).
J	Minimum pressure requirement	This is determined by the air pressure required by the air tools used by the business, but should be confirmed by the manager running the plant.
K	Electricity Cost	As provided by the manager of the business. If not available use a default of Rs. 6.5/kWh – the average for a small business.
L	Off-Load running power (as a% of capacity)	For screw compressors, the off-load running power is typically about 30% of the full load power. Unless specificinformation is available use 30% as a default
M	Off-load shutdown time setting	Normally the off-load shutdown time setting is adjustable either through the digital control menu or the off-load run timer within the starter cabinet (for non-digital control units). On some smaller compressors there is a no shutdown timer and the compressor goes from on-load running to shutdown. In this case the 'off-load running to shutdown time' is zero. At the commencement of 'off-load' running the shutdown timer commences a count down. If at the end of a set time (the off-load shutdown time setting) the compressor has not re-loaded, it will shut down. If the compressor has a long 'off-load' running time (before shutdown) there might be excessive energy use. Comparing the off-load shutdown time setting to the unload running time may result in a shortening of the time setting to reduce wasted electricity.

Calculating Air Leakage Percentage

1. Timing Method
Start the compressor when there is no operational demand for compressed air, and allow the system to rise to normal operating pressure and unload. If there is leakage the compressor will go into a reload/unload cycle. The load and unload cycle times (when the only demand for air is leakage) provide the data needed to measure the leakage rate.

$$\text{Air leakage rate (m3/min)} = \frac{\text{Air flow rating (m3/min)} \times T}{(t+T)}$$

Where, for a full load/unload cycle:
Air flow rating = flow rating of the compressor at the operating pressure being used
T = time compressor is fully loaded
t = time compressor is fully unloaded (idling and shutdown time)
Measuring the times over about five cycles (and checking that cycle times are consistent during over those cycles) will provide confidence that the only demand for compressed air is leakage.

2. Pressure Decay Method
This method measures the time taken for the system pressure to decay during a period when there is no operational demand for compressed air.

It requires the following:

- Estimating the volume of the air network (including the receiver) in cubic metres. The receiver volume should be shown on the cylinder and the rest of the volume will need to be estimated;
- Allowing the compressor to run until the system reaches its operating pressure and unloads;
- Note the reading on the receiver's pressure gauge and immediately turn the compressor off; and
- Measure the time in seconds (T) for the pressure on the gauge on drop by 1 bar;

The air leakage rate can then be calculated as:

$$\text{Air leakage rate (m3/min)} = \frac{\text{Air network Volume} \times 60}{T}$$

Compressed Air Self-Assessment Form

COMPANY DETAILS	
Company Name	
Address	

SECTION A: COMPRESSED AIR SYSTEM MEASUREMENTS				
mandatory input fields	defaults for use if necessary			
Operating measurements				
Cycle phase time measurements	On-load	A		sec
	Off-load	B		sec
	Shutdown	C		sec
Total time elapsed (A_f+B+C)		**D**		**sec**
Leakage estimate		E		%
Pressure drop across system		F		bar
Pressure setting		G		bar(g)
Static information				
Compressor capacity		H		kW
Annual operating hours		I		hours
Minimum pressure requirement		J		bar(g)
Electricity cost		K		
Off-load running power (as a % of capacity)		L	30	%
Off-load shutdown time setting		M		sec
Calculations:				
Percentage of time on-load	=(A_f/D)*100	X		%
Percentage of time off-load	=(B/D)*100	Y		%
Average load	=H*(X+L*Y)	Z		kW
Existing annual usage cost	=Z*I*K	T		**per annum**

SECTION B: WASTAGE AND EFFICIENCY SCORING			
Idling wastage	=Y*L*H*I*K/10,000		per annum
Leakage wastage	=E*X*H*I*K/10,000		per annum
System pressure drop	=F*0.07*X*H*I*K/100		per annum
Excess operating pressure	=(G-J-F)*0.07*X*H*I*K/100		per annum
Sum of energy wastage (sum of above calculated values)			**per annum (W)**
Wastage as percentage of total usage	=100*W/T		**% (W%)**

Note: Excess operating pressure cost formula does not double count the effect of being able to reduce operating pressure if system pressure drop is fixed
Assumption: Every 1bar excess operating pressure is equivalent to 7% power wastage

Efficiency Score	=100-W%	
Efficiency score to AERS Rating	Efficiency Score Range	Rating
	0 to 29	1
	30 to 59	2
	60 to 79	3
	80 to 89	4
	90 and over	5
AERS rating - range from 1 (poor) to 5 (excellent)		

SECTION C: CHECKLIST OF ITEMS FROM WHERE IMPROVEMENTS IN COMPRESSED AIR PERFORMANCE MIGHT BE AVAILABLE

Item	**Comments and actions recommended** (Please refer to Annexure 2 for instructions)
Air leakage	
Off-load running wastage	
System pressure drop	
Other excess operating pressure	
Compressor intake clear and filter clean	
Ventilation ducts on compressor motor	
V-belts tension	
Condensate drains	
Artificial demand identified	
Air storage capacity	

CER Rating sign off

Self-Assessment conducted by (Utility Manager):		Date:
Self-Assessment accepted by (Technical Head/Plant Head):		Date:

Air Audits Customer Information Sheet

(If you require a visit by our trained engineers to help evaluate the energy saving potential in your plant, please fill in this information sheet and email it to us, along with the self-assessment form.)

S. No.	CUSTOMER INFORMATION		
1	NAME:		
2	COMPANY:		
3	ADDRESS:		
4	CITY:		
5	STATE:		
6	PIN CODE:		
7	TELEPHONE:		
8	EMAIL:		
	GENERAL DATA		
9	Are there any issues with your compressed air network that you are aware of		
10	Please explain the 3 most important uses for compressed air in your plant	Desciption	Pressure Required
	Use # 1		
	Use # 2		
	Use # 3		
11	Any areas in your plant that experiences pressure problems? Please explain.		
12	What is the pressure going into the Main Header		
13	What is the pressure for typical operation in the plant?		
14	Have compressor set points been raised to try and compensate for low pressure at end use applications?		
15	Have compressor set points been raised to try and compensate for low pressure at end use applications?		

16	**COMPRESSOR INFORMATION**						
S. No	Make	Type	KW	CFM Capacity	Loading Pressure	Unloading Pressure	Operating Status
1							
2							
3							
4							
5							
6							
7							
8							
If you have more compressors, please mention the details for the rest of the compressors in a separate page							

17	How many compressors do you operate during work production?		
18	How many off shift?		
19	Total CFM Demand		
19	Nos. of Units to be Audited		
20	If we perform a compressor air delivery test or a plant air leak test, this work **may** have be done off shift. The system **MAY *require to*** be isolated and off line (winterrupted or closed off) for a brief period of time. I**s this possible to do?**		
	PLANT INFORMATION		
21	Number of operating hours per year		
22	What is your KWH rate?		
23	Plant Pipe Size		
	Main		inches
	Auxiliary		inches
	To Equipment		inches

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