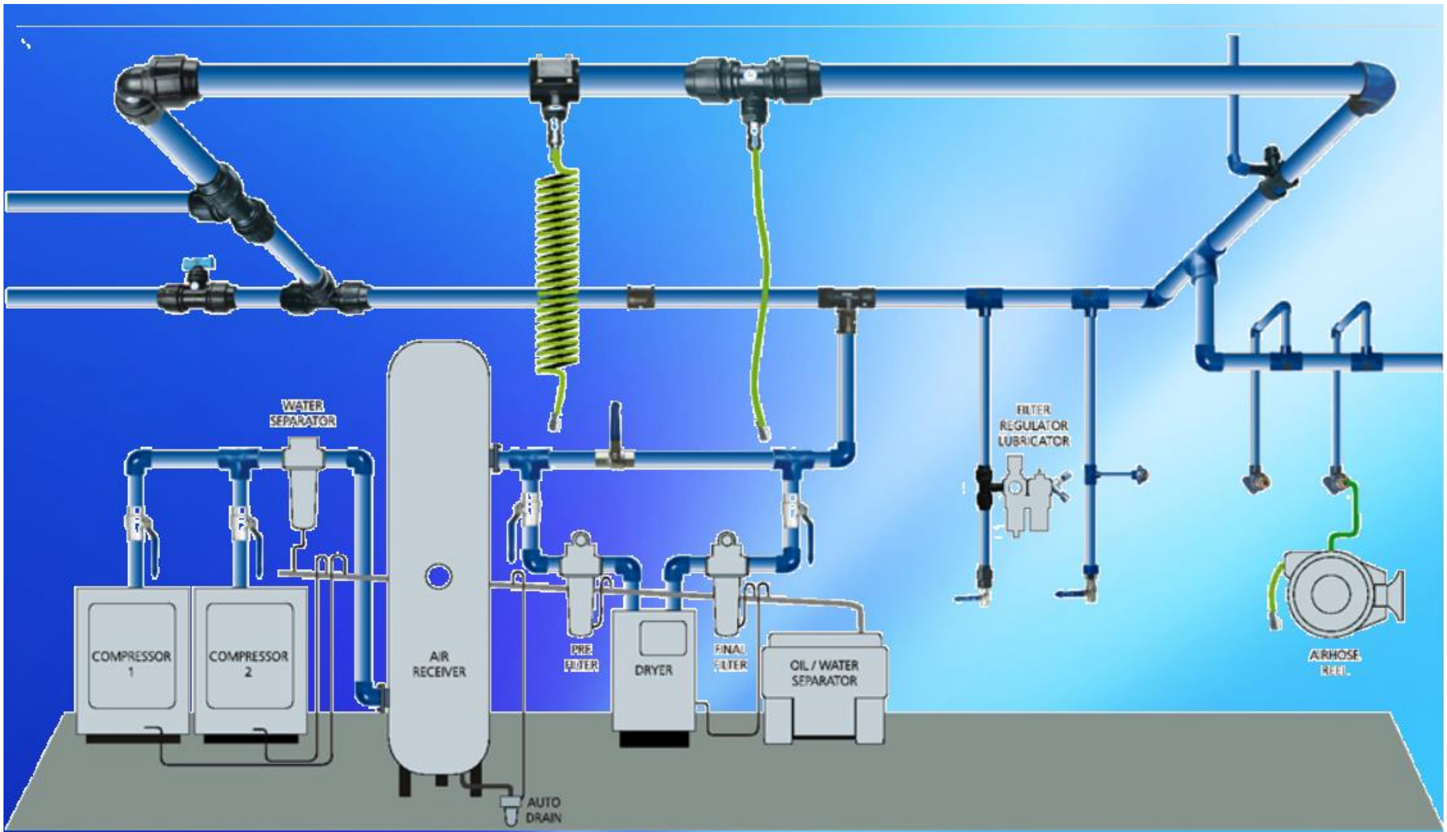

COMPRESSED AIR SYSTEMS

Managing Costs and Maintaining Efficiencies

CONTROL SPECIALTIES, INC.

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Compressed Air

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Chapter 1-Cost of Producing Compressed Air (Expensive)

Chapter 1 Highlights - Lots of mathematics in this chapter if you wish to get into calculations for your facility.

- Compressed air is so widely used that it is often regarded as the fourth utility, after electricity, natural gas, and water.
- The hourly energy cost for providing one cfm of delivered air is about $0.009
- The cost of 1000 cubic feet of compressed air at 100 psig is about $0.30.
- The average cost to operate a 100 HP compressor is about $10.00 an hour

Chapter 2 - Clean Dry Air

Chapter 2 Highlights- Compressed air prior to clean up contains large amounts of water and containments which will cause problems in your facility.

- Filters, separators, dryers, and adequate storage tanks are the key to providing clean dry air to your facility.
- Air receivers provide buffer storage and also allow for moisture to drop out of the compressed air.
- As a general rule of thumb, allow 4 gallons of tank storage per compressor horsepower.
- Ensure that your dryer(s) are operating properly to avoid water damage in your compressed air equipment.
- Dryers use energy to dry the air so study operating and maintenance costs carefully since they can significantly increase your cost of compressed air.
- Do regular maintenance on this equipment since improperly operating equipment can quickly do damage to your compressed air equipment.

Chapter 3 – Water in Compressed Air

Chapter 3 Highlights – The effectiveness of equipment designed to clean, dry, and condition air depends on the air drain trap selected and how well it operates.

- A 100 horsepower compressor operating at 100 psig will produce 3.74 gallons of water per hour. In one 24 hour cycle that amounts to 89.9 gallons of water.
- Air drain traps come in many styles and types so let's review your options along with pros and cons for each type offered.
- A manual drain valve requires an operator to open the drain valve at the right time and for the correct duration to blow the water from the system.
- Consider use of mechanical traps for only clean applications to avoid much frustration.
- Virtually all timer valves are set to over blow and not allow water in the system resulting in large air losses.
- We try to avoid product mention but the Float Operated Drain Trap made by Drain All is worth mentioning due to a long track record of reliable operation with zero air loss.

Chapter 4 – Filtration of Compressed Air

Chapter 4 Highlights - The compressed air contaminations can be in the form of solids, liquids, or vapors and will require filtration to remove them.

- One cubic foot of air contains four million particles of water vapor, oil aerosols, oils vapor, dust, and anything drawn into your compressor.
- Filtering out contaminants should be treated as a progressive process.
- Apply a golf ball filter to beach and basketball sized particles and you will quickly clog the filter.
- Mechanical separators should be considered the first option if the air to be filtered is really loaded with water and other containments.
- Particulate Filtration is the removal of solid particles from a gas or liquid.
- Coalescing Filtration is the separation of two 'phases'; for example the removal of water aerosols and droplets from a gas.
- Coalescing filter elements will also remove particulates at the same efficiency as particulate type elements of the same grade, but the opposite cannot be done so do not use a particulate element for the use of a coalescing element.

Chapter 5 – Compressed Air Leaks

Chapter 5 Highlights –

- Leaks are a significant source of wasted energy in a compressed air system, often wasting as much as 20-30% of the compressor's output.
- From chapter one, we calculated a cost of $0.30 per 1000 cubic feet of air.
- Recognize that $0.30 per 1000 cubic feet does not include the cost to operate dryers and any other energy consuming equipment used to filter and dry your air.
- A leak equal to ¼ " hole at 100 psig costs on average $1.80 per hour or for each 1000 hours of operation $1800.
- An 11 point simple and low cost plan to reduce leaks.
- How to calculate system leakage using your air receiver and a watch.

Chapter 6 – Compressed Air Tips to Cut Consumption

Chapter 6 Highlights – An assortment of hints, tips, and information gathered over the past 50 years. Note the paradox that increasing or decreasing air pressure can save you money in specific situations.

- Flow Meters for Compressed Air
- Increasing Compressed Air Pressure Can Save You Money
- Reduce Costs for Blow Off Air.
- One PSIG in Excess Air Pressure Increases Power Use by ½ %.
- An assortment of tips and hints for application in compressed air and vacuum systems.

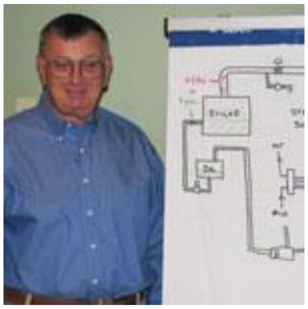
Chapter 7 – Sizing Compressed Air Lines

Chapter 7 Highlights – Compressed line sizes vary on the rate of flow, supply pressure and length of line run.

- Chart one (Compressed Air Pipe Lines) give you a quick overview in a single chart to see what typical air line capacities would be at 100 psig. This chart is handy for line runs up to 100.
- Chart two (Compressed Air Line Pressure Drop) allows you to make a precise section considering pressure, flow, and the impact of pressure drop as a function of line length.

BIOGRAPHY OF EDWARD MOSCHETTI

Edward brings over 50 years of knowledge and experience to the manufacturing, medical, university, and commercial arenas. His education background includes a degree in physics from Muhlenberg College. The last 30 years have been devoted to providing solutions to industrial facilities geared around plant utilities and processes. He has spearheaded energy teams in major corporations resulting in the savings of energy dollars as well as building/designing small to medium size boiler facilities.



Preface

Increasing productivity and gaining the benefits of lower operating costs through reduced energy costs is a winning proposition with the added benefit of reducing carbon emissions. Generating compressed air uses substantial electric power so lowering your consumption by increasing efficiency is the goal of the EBook.

Much has been written about compressor types and their operation. In this book we will focus our attention on ways to improve efficiency by reducing consumption instead of adding compressor capacity. Following simple steps, setting a goal of a 25% reduction in usage is not an unrealistic goal.

At great source with lots of solid tips is the US Department of Energy which provides lots of excellent information as well as case studies. http://energy.gov/eere/amo/compressed-air-systems

A few opening comments from the US DOE website will hopefully set the stage as you read through our information based on over 50 years of helping plants improve their compressed air system.

Getting Started: The following is a seven step action plan from CAC Fundamentals of Compressed Air Systems to analyze and improve your compressed air systems:

- Develop a basic block diagram of your compressed air system

- Measure your baseline (kW, pressure profile, demand profile, and leak load), and calculate energy use and costs. Work with your compressed air system specialist to implement an appropriate compressor control strategy.
- Once controls are adjusted, re-measure to get more accurate readings of kW and pressures, and to determine leak load. Recalculate energy use and cots.
- Walk through to check for obvious preventive maintenance items and other opportunities to reduce costs and improve performance.
- Identify and fix leaks and correct inappropriate uses- know costs, re-measure, and adjust controls as above.
- Begin implementation of continuous improvement programs.

Analyzing Your Compressed Air System

The first step in analyzing a compressed air system is to determine your compressed air needs. Compressed air needs are defined by the air quality and quantity required by the end uses in your plant. Assessing these needs carefully and understanding the difference between air quality and air quantity will ensure that a compressed air system is configured properly. Determining your pressure and demand load requirements are also important steps in analyzing your compressed air system.

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. Over treating air beyond the required dryness and allowable contaminant level wastes money and energy.

Air Quantity

The required compressed air system volume can be determined by summing the requirements of your compressed air applications and process operations (taking into account load factors) and the duration of such volumes by those applications. The total air requirement is not the sum of the maximum requirements for each tool and process, but the sum of the average air consumption of each.

Pressure Requirements

The minimum required discharge pressure level must take into account the different pressure ratings of each 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. Pressure drop is a term used to characterize the reduction in air pressure from the compressor discharge to the actual point of end use. Pressure drop occurs as compressed air travels through the treatment and distribution system. Excessive pressure drop will result in poor system performance and excessive energy consumption. A pressure profile is a series of measurements of compressed air pressure at different points in the system, and allows identification of system components that are causing excessive pressure drop.

Demand Load Requirements

Another key to properly designing and operating a compressed air system is analyzing a plant's compressed air requirements over time, or load profile. The variation of demand for air over time is a major consideration in system design. Plants with wide variation in air demand need a system that operates efficiently under part-load. In such a case, multiple compressors with sequencing controls may provide more economical operation. Plants with a flatter load profile can use simpler control strategies.

To be of help in using the information contained in this book I am providing a brief summary of the contents of each chapter so you can decided if you wish to read all of the information in that chapter.

Chapter 1- Cost of Producing Compressed Air (Expensive)

Chapter 1 Highlights Lots of mathematics in this chapter if you wish to get into calculations for your facility.

- **Compressed air is so widely used that it is often regarded as the fourth utility, after electricity, gas, and water.**
- **The hourly energy cost of providing one cfm of delivered air is about 0.9 cents.**
- **The cost for 1000 cubic feet of compressed air at 100 psig is about $.30.**
- **The average cost to operate a 100 HP compressor is about $10.00 per hour.**

The origins of compressed air go back to about 2000 BC when hand or foot powered bellows were used to increase flame temperatures to smelt ore into metals. Over time water power was used to first power low pressure bellows and later to turn rotary or reciprocating equipment. With the entrance of steam turbines and later electric motors, the uses for compressed air grew at an ever increasing rate. In industry, compressed air is so widely used that it is often regarded as the fourth utility after electricity, natural gas, and water. However, compressed air is more expensive than the other three utilities when evaluated on a per unit energy delivered basis.

Compressed air is used for many purposes including naming just a few:

- Pneumatics
- Air tools
- HVAC control systems
- Medical Gas
- Spray painting
- Vehicle propulsion
- Energy storage
- Air brakes
- Scuba diving
- Refrigeration using a vortex tube
- Air-start systems in engines

In most plants, air compressors use a high percentage of the total electrical power consumption of the facility. Given bug improvements in motor design and construction, motor efficiencies can now routinely exceed 90%. Since the majority of compressed air generated lets first focus how much it costs to generate a unit of compressed air. The most typical units used are the cost per 1000 cubic feet of compressed air or the cost per cubic foot (CFM).

From the US Department of Energy-

“A rough estimate of the cost of compressed air is one cent per operating hour per cubic foot of compressed air (see example calculation below). Details of the equipment involved, conditions under which it will be operating, and the cost of energy from the local utility can influence this amount.

Note that large manufacturing plants generally employ centrifugal compressors to meet their compressed air needs. These compressors commonly provide from 1000-5000 cfm of airflow with discharge pressures up to 125 pounds per 100 cfm of plant air provided. “Plant Air’’ that is used to drive various pneumatic tools is typically provided in the range of 100 to 125 psig.

If an average centrifugal compressor requires 18Kw/100cfm, 0.18kW of electrical damage is required to provide one cubic foot per minute of compressed air. At an industrial electrical rate of $0.10/kWh, the hourly energy cost for providing **one cfm of delivered air about 0.9 cents.**

0.18kW x 1 hour x $0.10/kWh=$0.018 or 1.8 cents per hour

To calculate the cost of 1000 cubic feet of air using our example of $0.018 per hour, the cost per minute for one CFM would be $0.003 per minute ($0.018/60 minutes). **Cost for 1000 cubic feet would be $.30 ($.003 x 1000).**

The compressed air operating cost is dependent on compressor type and local energy rates. For instance, a double-acting reciprocating compressor typically requires 15 to 16 kW/100 cfm, while a single-stage lubricant-injected rotary screw compressor requires 18 to 19kW/100cfm. A lubricant free rotary screw compressor typically requires 20 to 22 kW/100 cfm. Electricity prices can vary tremendously. Additionally, the cost of compressed air is impacted by air pressure, altitude, and the temperature of incoming air.”

To arrive at annual costs-

[Horsepower x 0.746 x Hours x Electricity Cost] / Motor Efficiency

- Horsepower (hp) = motor full load horsepower
- 1 hp = 0.746 kilowatts (kW)
- Hours = number of hours that the compressor operates
- Electricity cost = $/kWh (Add in demand charges and calculate average $/kWh).
- Motor Efficiency = motor nameplate full-load efficiency can vary from 75% to 95%

As an example, what is the annual electricity cost to operate a fully loaded 100 hp compressor that runs 40% of the time (3,500 hrs/yr)? Motor efficiency is assumed to be 85% so the compressor is drawing approximately 175 kW. Electricity cost is $0.08kWh. If the monthly demand charge is $10/kW, then the customer will be charged $1,750 each month in addition to the kWh usage cost (51,040kWh with the above assumptions). For this situation, the average cost of electricity including the kWh use and demand charge is approximately $0.114kWh.

Annual Electricity Cost = [hp x 0.746 x Hrs. x Electricity Cost] / Motor Efficiency

Annual Electricity Cost = 100 hp x 0.746 kW/hp x 3,500 hrs x $.114/kWh] / 0.85

Annual Electricity cost = $35,018 per 100 HP

Increasing the motor efficiency would decrease operating costs. As an example increasing motor efficiency from 85% to 92% would reduce the annual power bill to $32,353 or a savings of $2,665 per year.

Compressed air systems on the other hand are at best 50% efficient in many facilities. A new 100hp compressor represents an expenditure of $40,000-$50,000 depending on type and manufacture. At $.10 per kWh, a 100 hp compressor operating at full load for ~ 300 hours in one month will consume ~$36,000 of electricity in one year. When a compressor is unloaded, it still consumes about 30% of the total power rating of the motor. Our same 100 hp compressor operating 65% of the time fully loaded and 35% of the time unloaded will still consume $27,400 of electricity in one year.

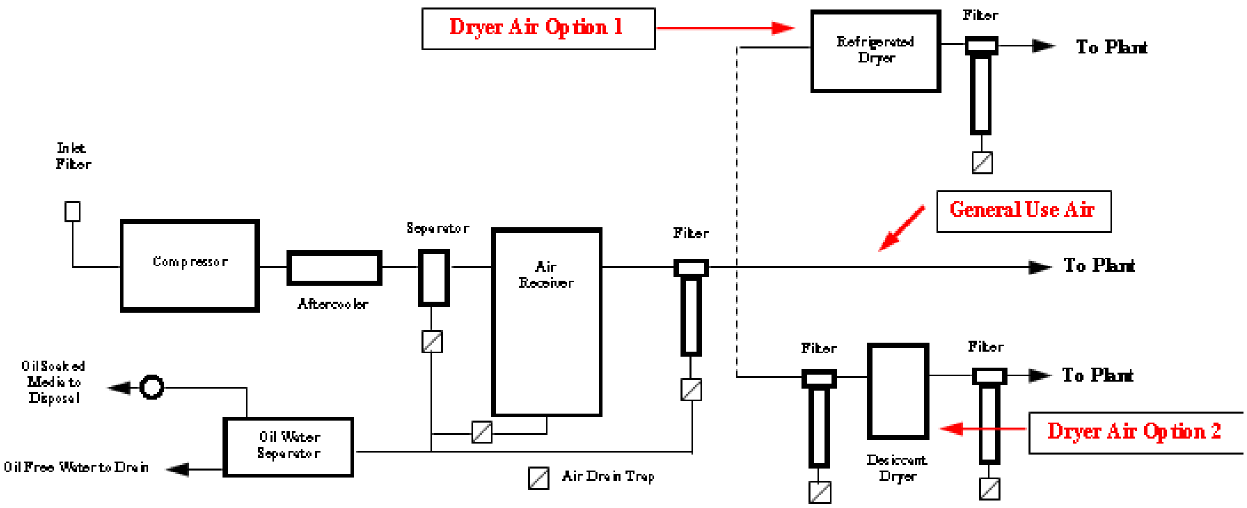
Chapter 2- Clean Dry Air

Chapter 2 Highlights- Compressed air prior to clean up contains large amounts of water and contaminants which will cause problems in your facility.

- Filters, separators, dryers, and adequate storage tanks are the key to providing clean dry air to your facility.
- Air receivers provide buffer storage and also allow for moisture to drop out of the compressed air. As a general rule of thumb, allow 4 gallons of tank storage per compressor horsepower.
- Ensure that your dryer(s) are operating properly to avoid water damage in your compressed air equipment.
- Dryers use energy to dry the air so study operating and maintenance costs carefully since they can significantly increase your cost of compressed air.
- Do regular maintenance on this equipment since improperly operating equipment can quickly do damage to your compressed air equipment.

Eight volumes of air at atmospheric pressure are required to produce one volume of air at 100 psig. Consider then whatever quality is being drawn through the air intake filter, eight times that quantity of contaminants will be present in your compressed air. Car exhausts, air dust, pollen, water vapor, and other items are all concentrated by this 8:1 factor. This should clue you why your compressed air is so dirty. Typically water in compressed systems will create major problems with air consuming equipment. High humidity air also increases the amount of water present as the air is compressed.

In our operating costs discussions (Chapter 1) we covered only the operating costs of a compressor. Additional costs have to be incurred to clean up the air and dry it before it can be used in most applications. The schematic shown below is a layout of this cleanup process using either a refrigerated dry to desiccant dryers. Both cost money to operate.



A complete compressor installation should include-

- Filters on the compressor inlet line and rain shields as required
- An after cooler to reduce compressor air temperatures which can be either water cooled or use a refrigeration unit.
- An air receiver to provide buffer storage and also allow for moisture to drop out of the compressed air. As a general rule of thumb allow 4 gallons of tank storage per compressor horsepower.
- A refrigerated or desiccant dryers with added filters for dryer air as required for your specific needs in your facility.
- For medical and breathing air additional steps will be required.

Sizing compressed air receiver charts-

Airflow Capacity		Recommended Receiver Volume		
(cfm)	(m3/h)	(cu ft)	(gal)	(m3)
100	170	13	100	0.4
200	340	27	200	0.8
300	510	40	300	1.1
400	680	54	400	1.5
500	850	67	500	1.9
750	1275	101	750	2.9
1000	1700	134	1000	3.8
1500	2550	201	1500	5.7
2000	3400	268	2000	7.6
3000	5100	402	3000	11.4
4000	6800	536	4000	15.2
5000	8500	670	5000	19.0
7500	12750	1005	7500	28.5
10000	17000	1340	10000	38.0

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Compressor Power		Recommended Receiver Volume		
(hp)	(kW)	(cu ft)	(gal)	(m3)
5	3.7	3	20	0.1
7.5	5.6	4	30	0.1
10	7.5	5	40	0.2
15	11.2	8	60	0.2
20	14.9	11	80	0.3
25	18.7	13	100	0.4
30	22.4	16	120	0.5
40	29.8	21	160	0.6
50	37.3	27	200	0.8
60	44.8	32	240	0.9
75	56.0	40	300	1.1
100	74.6	54	400	1.5
125	93.3	67	500	1.9
200	149.2	107	800	3.0
350	261.1	188	1400	5.3
450	335.7	241	1800	6.8
500	373.0	268	2000	7.6

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Air Receiver Capacities (cubic feet)					
Tank Size	Tank Size	Gauge Pressure on Tank *(psig)*			
(inches)	*(gallons)*	0	100	150	200
12 x 24	10	1.3	11	15	19
14 x 36	20	2.7	21	30	39
16 x 36	30	4.0	31	45	59
20 x 48	60	8.0	62	90	117
20 x 63	80	11	83	120	156
24 x 68	120	16	125	180	234
30 x 84	240	32	250	360	467

The air receiver size is important since it is both a buffer to even our loads swings on the air compressor and also where the first substantial remove of water occurs in most compressed air systems. An undersized air receiver can create major problems so use these guidelines as minimum suggestions. If you operate in high humidity locations, and/or your compressed air flow demand varies widely larger receivers or added receivers can help relieve loads on desiccant or refrigerated dryers. Air receivers are passive devices so no energy is required for the benefits they provide. Desiccant dryers use compressed air to purge moisture and refrigerant dryers consume electrical power.

Water damages a compressed air system several ways:

- Erosion-Water mist erodes piping, valves and other system components
- Corrosion- Mist condenses and combines with salts and acids within the system forming highly corrosive solutions.
- Microbial Contamination- Moisture supplies a growth medium for bacteria and mold, which produce acidic waste and can be a health threat.
- Freezing- Water can freeze in compressed air lines, shutting down the system.

The result is a lower productivity, increased maintenance, and higher operating costs. You can minimize the damage wet compressed air can inflict on your system by drying it.

Refrigerated Air Dryers utilize a mechanical refrigeration system to cool the compressed air and condense water and hydrocarbon vapor. Most refrigerated air dryers cool the compressed air to a temperature of approximately 35°F to 50°F (1.6°C to 10°C) which results in a pressure dew point of 33°F-39°F (.5°C to 3.8°C). This range permits the pressure dew point to fall within limits that are achievable with common refrigeration system controls. This pressure dew point range is also the lowest achievable with a refrigerated design since the condensate will begin to freeze at 32°F (0°C). Refrigerated air dryers are available in two basic configurations, non-cycling and cycling.

Regenerative dryers use a desiccant, which adsorbs the water vapor in the air stream. A distinction needs to be made between adsorb and absorb. Adsorb means that the moisture adheres to the desiccant, collecting in the thousands of small pores within each desiccant bead. The composition of the desiccant is not changed, and the moisture can be driven off in a regeneration process by applying dry purge air, or by the application of heat, or a combination of both. Absorb means the material that attracts the moisture is dissolved in and used up by the moisture. Absorption takes place in a deliquescent desiccant type dryer.

Regenerative desiccant dryers normally are of twin tower construction. One tower dries the air from the compressor while the desiccant in the other tower is being regenerated after the pressure in the tower has been reduced to atmospheric pressure. Regeneration can be accomplished using a time cycle or on demand by measuring the temperature or humidity in the desiccant towers or by measuring the dew point of the air leaving the on-line tower.

In the heatless regenerative desiccant type, no internal or external heaters are used. Purge air requirement can range up to 18% of the total air-flow. The typical regenerative desiccant dryer at 100 psig has a pressure dew point rating of -40°F but dew points down to -100°F can be obtained.

Heat reactivated regenerative desiccant dryers may have internal or external heat applied by heaters. In the internal type, steam or electricity may be used in heaters embedded in the desiccant bed. This reduces the amount of purge air required for regeneration to less than 10%. The purge air plus normal radiation is used to cool the desiccant bed after regeneration to prevent elevated air temperatures going downstream.

In externally heated regenerative desiccant dryers, the purge air is heated to an elevated temperature and then passes through the desiccant bed. The amount of purge air is approximately 5-10% of the air flow through the dryer. The purge air from the compressed air system can be eliminated if a blower is used for the circulation of heated atmospheric air through the desiccant bed. To protect the desiccant bed from oil contamination from the air compressor, a coalescing filter is required upstream of the dryer. To protect downstream equipment from desiccant dust or ''fines'', a particulate filter downstream of the dryer is also recommended.

Compressed air is dried to protect the system's piping and process equipment. Dry air also protects against lost product. Many pneumatic equipment have a recommended operating pressure, dryness level, and a maximum operating temperature. Set your compressed air's systems dryness level to exceed the requirements of the equipment it powers.

Recommended Dew Points

Application	Pressure Dew Point (°F)	Pressure Dew Point (°C)
Air Motors (high efficiency)	-40 to 38	-40 to 3.3
Air Motors (low efficiency)	-20	-28.8
Breathing Air (subsequently humidified)	-40 to 38	-40 to 3.3
Chemical Processing	-40	-40
Control Air (industrial services)	-40	-40
Cryogenic Systems	-100	-73.3
Drying Processes	-40 to 4	-40 to -15.5
General Services (indoors)	-40 to 50	-40 to 10
General Services (outdoors)	-100 to 38	-73.3 to 3.3
Instrumentation (industrial services)	-40	-40
Instrumentation (laboratory services)	-60	-51.1
Microelectronic Services	-100 to -40	-73.3 to -40
Paint Spray Systems	-40 to 38	-40 to 3.3
Pharmaceutical Services	-100 to -40	-73.3 to -40

Chapter 3- Water in Compressed Air

Chapter 3 Highlights- The effectiveness of equipment design to clean, dry, and condition air depends on the air drain trap selected and how well it operates.

- **A 100 horsepower compressor operating at 100 psig will produce 3.74 gallons of water per hour. In one 24 hour cycle that amounts to 89.9 gallons of water.**

- **Air drain traps come in many styles and types so let's review your options along with pros and cons for each type offered.**
- **A manual drain valve requires an operator to open the drain valve at the right time and for the correct duration to blow the water from the system.**
- **Consider use of mechanical traps for only clean applications to avoid much frustration.**
- **Virtually all time valves are set to over blow and not allow water in the system resulting in large air losses.**
- **We try to avoid product mention but the Float Operated Drain Trap made by Drain All is worth mentioning due to a long track record of reliable operation with zero air loss.**

We've made condensate water drain traps chapter 3 since they tend to be small pieces of equipment with low cost and yet can account for the largest air loss in compressed air systems due to lack of maintenance, improper application while being your first line of defense to keep water out of your compressed air equipment and the resulting damage which will occur.

Does your plant air system resemble a high pressure water system? During warm weather, air contains water vapor in the form of humidity. As an example, at 90°F and 85% relative humidity, one cubic foot of air contains 12.70 grains of moisture (7,000 grains= 1 pound). A 100 horsepower compressor will condense this air and at 100 psig produce 3.74 gallons of water per hour. In one 24 hour cycle that amounts to 89.9 gallons of water!

Water is present in the air which is drawn into the compressor. The water is gaseous-invisible and completely mixed with air. The exact amount of water is called the "humidity" of the air, a) Relative Humidity- The amount of water vapor that can be held in air is dictated by the temperature of the air. Hot air can hold more water (as vapor) than cold air. Typically, atmospheric air contains approximately 50% of its water vapor holding capacity for a given temperature. This proportion of the maximum vapor holding capacity is referred to as relative humidity.

To properly dry this air requires the proper combination of dryers, filters, separators, and receivers. Each of these pieces of equipment become water separation points which then require an automatic drain trap to discharge the water from the compressed air system. You have a number of options to drain this collected moisture from your system. Air drain traps tend to be neglected pieces of equipment and yet the most effective dryer system or filtration system will not do its job properly without effective air drain traps.

Inspect the condensate traps and determine if they are operating properly. Review your condensate removal method and if possible, the load on compressors during the non-production hours. If it releases too much air, consider upgrading to zero-loss drain traps.

Air drain traps come in many styles and types so let's review your options along with pros and cons for each type offered. We'll go from simple by

typically less effective to more expensive but much more effective.

Manual Drain Valves

A manual drain valve requires an operator to open the drain valve at the right time and for the correct duration to blow the water from the system. This system requires great diligence and an excellent memory! In most cases this system will also result in substantial air losses and water in your system. The valve used could be a ball, gate, or globe valve. Pros and cons-

- Operators manually open valves to discharge condensate
- Depends on people opening valves at the appropriate time for the necessary amount of time.
- Often leads to excess loss because air escapes when the valves are left open to drain the condensate.
- Typically operators will leave valves partially open resulting in costly air losses.

Level-Operated Mechanical Float, Bucket, or Disc Traps

A wide variety of adaptations of steam traps are offered by an assortment of manufacturers to drain water from air systems. If your water is clean and free of oils or aerosols, these types of air drain traps can do an acceptable job. Consider use of mechanical traps for only clean applications to avoid much frustration. Pros and cons-

- Use a float connected by linkage to a drain valve that opens when an upper setting is reached and closes when the drain is emptied.
- Disc traps operate on an internal bleed so air loss can become excessive on light condensate applications
- Require considerable maintenance
- Are prone to blockage from sediment in condensate
- Are prone to getting stuck in open position (leak excess air) and in the closed position (does not allow condensate to be drained).
- Inverted bucket traps may require less maintenance, but will waste air if the condensate rate is inadequate to maintain the liquid level in the trap.
- Most suited for a fully-attended powerhouse operation with scheduled maintenance.

Timer Drains Utilizing Solenoid or Other Electrically Operated Valves

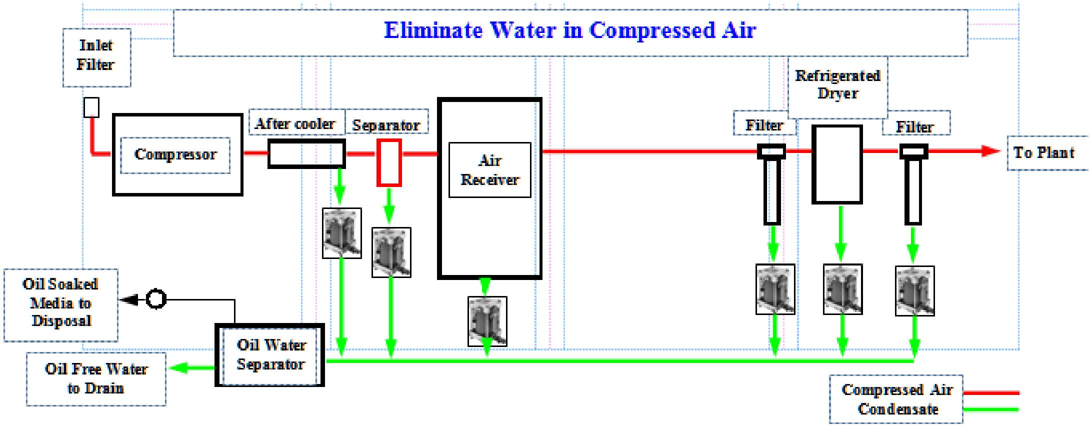
Timer operated blow down valves have been sold as an inexpensive method to blow water from systems. All you are required to do is set the duration of water blow and number of times per hour. Sounds simple. Assume the day you set the times, the humidity and air temperatures were moderate. After some effort on your part, you get the duration and frequency just right with no wasted air but complete elimination of the water. Then the weather changes! If temperatures and humidity drop, you blow compressed air. Pros and cons-

- Have timing devices that can be set to open for specified amounts of time at pre-set adjustable intervals.
- The period during which the valve is open may not be long enough for adequate drainage of accumulated condensate.
- The valve will operate even if little or no condensate is present, resulting in air loss.
- Virtually all timer valves are set to over blow and not allow water in the system resulting in large air losses.
- Require strainers to reduce contaminants, which can block the inlet and discharge ports of these devices.

Zero Loss Float Traps

We try to avoid product mention but the Float Operated Drain Trap made by Drain All is worth mentioning due to a long track record of reliable operation with zero air loss. Drain All is a float operated self-powered drain unit which uses compressed air to drive an actuator which opens a full port ½" ball valve to eliminate the water from the separation device. The unit uses air power to eject the water, is self-cleaning on every cycle, and operates automatically without maintenance of any kind. It is offered in a variety of configurations for most any compressed air application. Pros and cons-

- Has a float to maintain the condensate level in the reservoir below the high level point, and activates a pneumatic signal to an air cylinder to open a ball valve through a linkage to expel the condensate in the reservoir to the low level point.
- Wastes no air.
- Considered very reliable.
- Precautions need to be taken to prevent freezing if subjected to cold weather.
- Added initial cost offset by zero air loss.



Chapter 4- Filtration of Compressed Air

Chapter 4 Highlights- The compressed air contaminants can be in the form of solids, liquids, or vapors and will require filtration to remove them.

- **One cubic foot of air contains four million particles of water vapor, oil, vapor, dust, and anything drawn into your compressor.**
- **Filtering out contaminants should be treated as a progressive process.**
- **Apply a golf ball filter to beach and basketball sized particles and you will quickly clog the filter leading to a major maintenance headache-frequent filter changes.**
- **Mechanical separators should be considered the first option if the air to be filtered is really loaded with water and other contaminants.**
- **Particulate Filtration is the removal of solid particles from a gas or liquid.**
- **Coalescing Filtration is the separation of two 'phases', for example the removal of water aerosols and droplets from a gas.**
- **Coalescing filter elements will also remove particulates at the same time efficiency as particulate type elements of the same grade, but the opposite cannot be done so do not use a particulate element for the use of a coalescing element.**

From the US Department of Energy Website-

"Knowing the proper air quality level required for successful production is an important factor in containing compressed air energy and other operating costs, because higher quality air is more expensive to produce. Higher quality air requires additional air treatment equipment, which increases capital costs as well as energy consumption and maintenance needs. The quality of air produced should be guided by the degree of dryness and filtration needed and by the minimum acceptable contaminant level to the end uses.

Level of Air Quality	Applications
Plant Air	Air tools, general plant air
Instrument Air	Laboratories, paint spraying, powder coating, climate control
Process Air	Food and pharmaceutical process air, electronics
Breathing Air	Hospital air systems, diving tank refill stations, respirators for cleaning and/or grit blasting

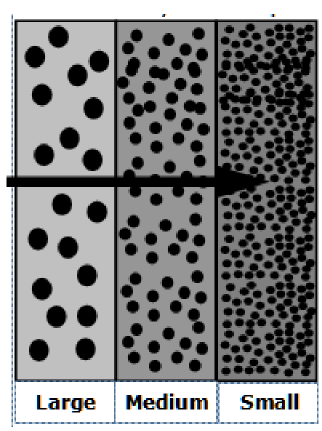
Compressed air contaminants can be in the form of solids, liquids or vapors. Contaminants can enter a compressed air system at the compressor intake, or can be introduced into the air stream by the system itself. Air quality class is determined by the maximum particle size, pressure dew point, and maximum oil content allowed.

One of the main factors in determining air quality is whether lubricant-free air is required. Lubricant-free air can be produced either by using lubricant-free compressors, or with lubricant-injected compressors and additional air treatment equipment. The following factors can help one decide whether lubricant-free or lubricant-injected air is appropriate:

- If only one end use requires lubricant-free air, only the air supply to it should be treated to obtain the necessary air quality. Alternatively, it may be supplied by its own lubricant-free compressor. If the end uses in a plant require different levels of air quality, it may be advisable to divide the plant into different sections so that air treatment equipment that produces higher quality air is dedicated to the end uses that require the higher level of compressed air purification.
- Lubricant-free rotary screw and reciprocating compressors usually have high initial costs, lower efficiency, and higher maintenance costs than lubricant injected compressors. However, the additional separation, filtration, and drying equipment required by lubricant-injected compressors will generally cause some reduction in system efficiency, particularly if the system is not properly maintained."

One cubic foot of air contains four million particles of water vapor, oil aerosols, oil vapor, dust, and anything drawn into your compressor. To produce compressed air at 100 psig requires 8 times of concentration by volume or one cubic foot of air at 100 psig contains 32 million particles of contaminants in all sizes and shapes.

Filtering out contaminants should be treated as a progressive process. Think of throwing beach balls, basketballs, baseballs, and tennis balls into a wooded area. The large balls will drop out first and the small balls will penetrate further into the woods before hitting a tree and being knocked down. Filtration of compressed air should also be treated in the same manner. By count, the number of smaller particles will outnumber larger particles by a substantial amount. To clean air effectively and not go insane changing filter elements requires a step approach. Take out the beach and basket balls first, then hard and soft baseballs, and finally the golf ball and smaller sized particles. Apply a golf ball filter to beach and basketball sized particles and you will quickly clog the filter leading to a major maintenance headache-frequent filter changes.



Mechanical separators should be considered the first option if the air to be filtered is really loaded with water and other contaminants. Most separators will remove 95-98% of the contaminants in air-think beach ball to baseball sized particles which will eliminate a major overload on your finer filtration elements. With no filter elements to clean or clog, maintenance is essentially zero and it may clean up your compressed air sufficiently non critical applications.

Coalescing filters remove small sized particles by erecting a barrier of finely woven fibers to knock out small sized particles-think golf balls, peas, and sand sized particles. Coalescing filters come in three filtration sizes.

- Large-99.999% particle retention
- Medium-99.99998% particle retention
- Fine-99.99999% particle retention rate.

Using any of the filters in this range to handle a point of use problem would lead to clogged filters and major maintenance headaches.

Clean air in steps for most effective results and long filter life. Install a separator first to remove 95-98% of the contaminants. If you need to remove additional contaminants, then add a "Large-99.999%" coalescing filter as the next step and continue the filtration process until your problem is solved. For most applications, a separator followed up by a 99.999% coalescing filter will solve your problem. Install added filtration units in steps to achieve the 99.99999% level.

Particulate filtration is the removal of solid particles from a gas or liquid. The liquid or gas flows through the element from the outside to inside to maximize the service life. The size of the particle removed depends upon the grade of the filter element and we can offer a size range from very high efficiency 0.1 micron grades to 200 micron.

Coalescing Filtration is the separation of the two 'phases', for example the removal of water aerosols and droplets from a gas. Using a coalescing filter element installed in housing with three ports, the wet gas sample passes through the element inside to outside. The inner capture layer is a high efficiency coalescing layer and the outer is a coarser drainage layer. The fine fivers of the inner layer capture the fine liquid aerosols and droplets and they run together along the fibers to form large drops within the depth of the element. These larger drops are then forced to the outside of the filter element and then drain to the bowl of the housing by gravity.

Coalescing filter elements will also remove particulates at the same efficiency as particulate type elements of the same grad, but the opposite cannot be done so do not use a particulate element for the use of a coalescing element.

Chapter 5- Strategies for Low-Pressure End Uses

Chapter 5 Highlights-Because compressed air is also clean, readily available, and simple to use, it is often chose for applications in which other methods or sources of air are more economical. To reduce compressed air energy costs, alternative methods of supplying low-pressure end uses should be considered before using compressed air in such applications.

- **Rotary vane compressors can generate air at pressures up to 22.5 kg psig with compression ratios of 6.5 CFM per HP.**
- **Regenerative blowers are designed based on the regenerative principle and can produce up to 25 CFM per HP.**
- **Air Knives System can provide an attractive option to using compressed air for drying, debris clean-up, and other applications requiring high volume of low pressure air.**
- **Vacuum can be produced in a number of ways with two common approaches being a vacuum pump or venture. In large installations, a pump normally makes more sense-as long as the installation is correct.**

From the US Department of Energy website-

"Compressed air is expensive to produce. Because compressed air is also clean, readily available, and is simple to use, it is often chosen for applications in which other methods or sources of air are more economical. To reduce compressed air energy clots, alternative methods of supplying low-pressure end uses should be considered before using compressed air in such applications. Many alternative methods of supplying low-pressure end uses can allow a plant to achieve its production requirements effectively. Before deciding to replace a low-pressure end use with an alternative source, it is important to determine the minimum practical pressure level required for the application."

Alternative Applications to Low-Pressure End Uses

Existing Low-Pressure End Use	Potential Alternatives	Reasoning
Open blowing, mixing	Fans, blower, mixers, nozzles	Open-blowing applications waste compressed air. For existing open-blowing applications, high efficiency nozzles could be applied, or if high-pressure air isn't needed, consider a blower or a fan. Mechanical methods of mixing typically use less energy than compressed air.
Personnel cooling	Fans, air conditioning	Using compressed air for personnel cooling is not only expensive, but can also be hazardous. Additional fans or an HVAC upgrade should be considered instead.
Parts cleaning	Brushes, blowers, vacuum pumps	Low-pressure blowers, electric fans, brooms, and high-efficiency nozzles are more efficient for parts cleaning than using compressed air to accomplish such tasks.
Air motors and air pumps	Electric motors, mechanical pumps	The tasks performed by air motors can usually be done more efficiently by an electric motor except in hazardous environments. Similarly, mechanical pumps are more efficient than air-operated double diaphragm pumps. However, in an explosive atmosphere and/or the pumping of abrasive slurries, the application of a double diaphragm pump with appropriate pressure regulating and air shut-off controls may be appropriate.

Rotary vane compressors can generate air at pressures up to 22.5 psig. Compressors are offered in sizes to 25 HP. For applications requiring more air volume than one compressor can supply, PLC controlled expandable systems can be used at considerable savings. As an example, you can start with a duplex system and as your requirements grow, expand up to six compressors Since the system is PLC controlled, only the required compressors to meet your load are running, which can save you substantial electrical costs. Automatic lead lag is also provided to spread wear on the compressors.

Regenerative blowers are designed based on the regenerative principle. The impeller blades passing the inlet port of the blower draw air or other gases into the blower. Then impeller blades then, by centrifugal action, accelerate the air outward and forward. Here the "regenerative" principle takes effect as the air is turned back by the annular shaped housing to the base of the following blades where it is again hurled outward. Each "regeneration" imparts more pressure to the air. When the air reaches the stripper section at the outlet (the stripper is the part of the blower located between the inlet and the outlet in which the annulus is reduced in size to fit closely to the sides and tips of the impeller blades) the air is "stripped from the impeller and diverted out of the blower. The pressures or vacuums generated by the one or two spinning, non-contacting, oil-free impellers are equal to those obtained by many larger multi-stage or positive displacement blowers.

Air Knives Systems can provide an attractive option to using compressed air for drying, debris clean-up, and other applications requiring high volumes of low pressure air.

If you are currently using house air at pressures of 100 psig to clean, dry, aerate, agitate or other similar low pressure applications, you have an opportunity to reduce electrical consumption by ~ 65%. Most applications of this type require velocity and volume, which is a perfect application for a regenerative or high speed blower. Air knives, nozzles, and air wipes can be arranged in most any configuration to suit your application. The air is typically warmed about 50 F due to the heat of compression the blower. Since ambient air is used, oil contamination is eliminated.

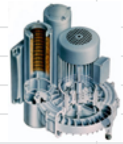
Vacuum can be produced in a number of ways with two common approaches being a vacuum pump or venture. A vacuum pump is a rotary or reciprocating mechanical vacuum generating device. A venture generates a vacuum by passing compressed air over a small opening creating a vacuum. Think of the device you attach to your garden hose to spray a fertilizer on your lawn using water pressure instead of air flow.

In larger installations, a pump normally makes more sense-as long as the installation is correct. In a large lifting application where larger vacuum flows are required to either accommodate product leakage (cardboard box handling) or to supply many vacuum cups, a pump is normally the better choice for efficiency reasons and certainly a simpler installation. The pick-up in efficiency when switching from compressed air driven vacuum to electric-driven vacuum ranges from two to fifty times. A good rule of thumb average is that the electric driven vacuum pumps are four times more energy than compressed air driven vacuum generators.

Compressed air-driven vacuum pumps each use quite a bit of compressed air for proper operation and facilities with large numbers of these devices may have issues maintaining adequate supply pressure. These facilities will typically have several “extra” compressors online to maintain site pressure requirements. Replacement of the vacuum generators with electric vacuum pumps will allow for large horsepower compressors to be taken off-line and be replaced with much smaller horsepower vacuum pumps.

Compressed Air Cost Evaluation Analysis

Compressed air is an expensive utility and improper use will substantially increase your monthly electric bill. This analysis sheet will permit to you compare the costs of generating compressed air using high pressure air compressors, rotary vane air compressors, high speed centrifugal blowers, and regenerative blowers.

	Air Compressor	**Rotary Vane Compressor**	**Regenerative Blower**	**High Speed Blower**
				
Cost of Electricity (KWH)	$0.10	$0.10	$0.10	$0.10
CFM per Horsepower	4.3	6.5	25	20
Air Pressure (psig)	100	22	4.2	3.5
Cost per 1,000 cubic Ft of Air	**$0.388**	**$0.256**	**$0.067**	**$0.083**

Operational Cost Comparison

Air Volume Required (CFM)	430	430	430	430
Horsepower Required	100.0	66.2	17.2	21.5
Cost of Electricity	$0.10	$0.10	$0.10	$0.10
Cost per Hour	$7.46	$4.93	$1.28	$1.60
Hours per Month of Operation	720	720	720	720
Cost per Month	$5,369.04	$3,551.83	$923.47	$1,154.34

Chapter 6-Compressed Air leaks

Chapter 6 Highlights-

- **Leaks are a significant source of wasted energy in a compressed air system, often wasting as much as 20-30% of the compressor's output.**
- **From chapter one, we calculated a cost of $.30 per 1000 cubic feet of air.**
- **Recognize that $.30 per 1000 cubic feet does not include the cost to operate dryers and any other energy consuming equipment used to filter and dry your air.**
- **A leak equal to a ¼" hole at 100 psig costs on average $1.80 per hour or for each 1000 hours of operation $1,800.**
- **How to calculate system leakage using your air receiver and a watch.**

From the US Department of Energy website-

"Leaks are a significant source of wasted energy in a compressed air system, often wasting as much as 20-30% of the compressor's output. Compressed air leaks can also contribute to problems with system operations, including:

- Fluctuating system pressure, this can cause air tools and other air-operated equipment to function less efficiently, possibly affecting production.
- Excess compressor capacity, resulting in higher than necessary costs.
- Decreased service life and increased maintenance of supply equipment (including the compressor package) due to unnecessary cycling and increased run time.

Although leaks can occur in any part of the system, the most common problem areas are couplings, hoses, tubes, fittings, pipe joints, quick disconnects, FRL's (filter, regulator, lubricator), condensate traps, valves, flanges, packing's, thread sealants, and point-of-use devices. Leakage rates are a function of the supply pressure in an uncontrolled system and increase with higher system pressures. Leakage rates identified in cubic feet per minute (cfm) are also proportional to the square of the orifice diameter. See table below"

Leakage rates[a] (cfm) for different supply pressures and approximately equivalent orifice sizes[b]						
Pressure (psig)	Orifice Diameter (inches)					
	1/64	1/32	1/16	1/8	1/4	3/8
70	0.29	1.16	4.66	18.62	74.4	167.8
80	0.32	1.26	5.24	20.76	83.1	187.2
90	0.36	1.46	5.72	23.1	92	206.6
100	0.40	1.55	6.31	25.22	100.9	227
125	0.48	1.94	7.66	30.65	122.2	275.5

We will look at a number of strategies you can use to reduce leaks and save large amounts of money. From chapter one, we calculated a cost of $.30 per 1000 cubic feet of air. You should refer back to chapter one and do a calculation for your plant based on your power costs and the efficiency of your compressor system. Also recognize that $.30 per 1000 cubic feet does not include the cost to operate dryers and any other energy consuming equipment used to filter and dry your air.

From chapter one, we calculated a cost of ~$10 per hour to operate a typical 100HP compressor. You should do a calculation for your plant using the information in chapter one for your plant to arrive at a cost per hour to operate your compressors. Let's look at a quick example using chapter 1 data to look at the cost of leaks based on DOE average data.

- Assume you operate two 100 HP compressors 5 days a week, 10 hours per day and 52 weeks per year. Total hours of operation works out to 2600 hours per year.
- Using our calculated cost per hour of $10 per total operating costs per year would be $26,000 per year.
- We'll split the difference with the DOE average figure and call the system loss to due leaks at 25% or $6500.
- If you run all the numbers you will come up with a leak rate of ~ 138 CFM or a leak equal to about a 5/16" single hole in your system. It would be great if in fact one 5/16" plugged would solve your air leak problems but of course leaks are spread all around the system so we can offer some practical methods to reduce your leak problem. We'll arrange our list from simple and low cost to complex and costly.

Starting from simple and low cost-

1. Pick a non-operating or quiet time in your facility with the compressor air system up to pressure and take a walk listening for leaks. If your plant air pressure is about 75 psig, larger leaks can usually be heard to take notes and have them repaired.
2. During a quiet time inspected every drain trap in the facility for proper operation starting in the compressor room. Check drain traps on your air receiver, dryers, filters, and other equipment. If you have time, verify that they are discharging water and not air. Perform the same test on any other drain traps. Perform the same test walking through your facility.
3. Note the air pressure in the compressor rom on your air receiver. Turn off all compressors and note how much the receiver pressure drops in 15 minutes. If it is more than 5-10% leaks are an issue.
4. Consider purchasing a low cost ultrasonic leak detector and check suspect areas in your plant around hoses, valves, pipe joints, and other connective type leaks.

5. With the plant in operation, look for compressed air being used for blow off and cleaning, which operates at line pressure. Install an air pressure reducing valve to reduce pressure to appoint that does not impact blow off or debris removal.
6. Consider installing amplifying blow off guns which mix atmospheric air with compressed air to cut air consumption.
7. If you are using venture devices to generate vacuum, consider using a vacuum pump.
8. If you are using desiccant dryers which regenerate using reverse plant air to regenerate consider using a refrigerate dryer.
9. Study your air usage habits and how you operate your compressors to increase operating efficiency. Consider using a load management system to stage multiple compressors to best math your load requirements.
10. Consider flow meters for total flow to the facility and smaller meters in high usage areas to understand your demand rates.
11. Consider adding more receiver storage to deal with load spikes and level out your average load.

Expensive solutions will work best where very large dollar amounts are being spent to generate compressed air. Our $6500 savings example would point at simple low cost solution with expenditure not to exceed one year in savings. If your large amounts of compressed air and savings forecast into the $100,000 or more range, you have many more options you can pursue.

You can hire survey companies to study and make recommendations to reduce costs. You should be aware that “free surveys” by actual or potential new vendors might not be free in the final result and cost you money in equipment or controls that might not be suited for your facility. Be an informed buyer and carefully check references.

Calculating System Leakage

You can use your compressed air receiver to do a leak and consumption test on your compressed air system. The formula for doing these tests is as follows:

$$\text{Leak Rate} = (V^* (P1-P2))/(T) * 14.7 \text{ psig})$$

Where

V=Volume of air receiver in cubic feet
P1=Receiver pressure at start of test in psig
P2= Receiver pressure at conclusion of test in psig
T= Time in minutes for test

To calculate the receiver volume, use V=3.14 x R x R x H where R is the receiver tank radius and H is the receiver height in feet. As an example, a 4’ x 10’ receiver would have a volume of 3.14 x 2 x 2 x 10 or 125.6 cubic feet.

To calculate air consumption, time the loss in pressure in the tank. As an example, let’s assume you lost 5 bar (73.5 psig) in 2 minutes. Your plant air consumption would be 314 cubic feet per minute. Most compressors generate about 4.3 cfm of air per HP, so your air use is about 73 HP for that measurement.

To calculate the leakage rate in your plant air system, you will need to have all consuming equipment shut down. Perform the same leak down test. As an example, assume that you lost 2 bar (29.4 psig) in 15 minutes using the same receiver. Your leak rate in the system would be 16.7 cfm or 3.9 HP.

Chapter 7- Compressed Air Tips to Cut Consumption

Chapter 7 Highlights- An assortment of hints, tips, and information gathered over the past 50 years. Note the paradox that increasing or decreasing air pressure can save you money in specific situations.

- **Flow Meters for Compressed Air.**
- **Increasing Compressed Air Pressure Can Save You Money.**
- **Reduce Costs for Blow Off Air.**
- **One PSIG in Excess Air Pressure Increases Power Use By ½%.**
- **An Assortment of Tips and Hints for Application in Compressed Air and Vacuum Systems.**

Flow Meters for Compressed air

An old truism, "if you can't measure it, you can't manage it." If your power bill to generate compressed air in your facility is in excess of $100,000 per year, it might be the time to consider adding a flow meter or meters to your air system to identify opportunities for reduce your annual operating bill. Some primary causes of higher than normal compressor operating costs include:

- Operating at higher than required air pressures
- Leaks in piping and point of use equipment
- Faulty drain traps
- Desiccant dryer purge air consumption
- Using compressed air to generate vacuum or to cool equipment
- Lots of other issues which you can find on other articles on our website.

If you are considering a flow meter, what types should you consider? Four common air flow meters include orifice pates, vortex meters, turbine meters, and thermal flow meters.

- Orifice plates use a calibrated plate with a precise hole in the plate to generate a pressure drop at a specific flow rate. The pressure drop is measured with a differential pressure measuring transmitter and a reading is based on the change in pressure drop across the plate. Although simple in operation, both pressure and temperature needs to be also measured to get a precise fix on the air density which adds considerable cost to the system. Turn down, which is a measure of the accuracy range, is poor and typically 4:1. This means a meter calibrated for a full scale flow 10,000 SCFM will read only 2500 SCFM.
- Vortex meters use a shedder bar (wing like plate) on the air flow which generates vortices in the downstream air flow and generate vibrations on the shedder bar. A transducer reads the vibrations and generates a signal. Pressure and temperature still need to be read to correct for density but turn down is improved to 10/15:1. Cost is about the same as an orifice plate.
- Turbine meters use air flow velocity to turn a fan blade which in turn generates an electrical signal which is proportional to the air or gas flow rate. Turbine meters are offered in both inline as well as insertion models. Pressure and temperature both need to be measured to correct for density and turn down is in the 10/15:1 range.
- Thermal mass flow meters use a heated element which is then cooled by the air or gas flow with a reading taken to measure the amount of power used in the cooling process. The heating element is very small and the power changes in the mill watt range are used to provide a flow measurement signal. Sensor placement is not critical and should be about the center of the pipe. Since the cooling effect measured is based on the mass of compressed air or gas flow, no pressure or temperature compensation is required. Turn down ratios are in excess of 100:1.

From accuracy, turn down, and cost point of view, we suggest using a thermal mess flow meter for measuring compressed air, natural gas, and other gas flows. Typical savings for equipment is about 50% when compared to the other meter choices discussed in this article.

Increasing Compressed Air Pressure Can Save You Money

Adding compressed air capacity either in the form of additional compressors or added tank storage is costly. If your demand is a steady increase, then adding additional compressor capacity should be considered. An option to consider is to increase your air pressure especially if added demand occurs during peaks situations in your facility.

Boyle's Law is an experimental gas law which describes how the pressure of a gas tends to decrease as the volume of a gas increases. Boyle's Law at constant temperature can be stated as:

$$P1V1 = P2V2$$

If your current compressed air pressure P1 as an example is 100 PSIG (114.7 PSIA) and we were to increase the pressure to 200 PSIG (214.7) the system stored volume would increase by 190% (214.7/114.7). As another example if your current compressed air storage tank is 5,000 gallons, increasing the air pressure from 100 to 200 psig would effectively provide you with an air volume of about the equivalent of a 9,500 gallon tank. The best example is to think of a "scuba tank" principal using your air receiver.

As with most issues, please consider the pros and cons to this approach. The first issue is to verify every component in your compressed air system is rated to operate at the proposed higher pressure. You should carefully check the pressure of every component in your compressed air systems.

Compressor output is a function of the system pressure and typically most compressors generate about 4.3 cubic feet of air per compressor HP at 100 psig. Higher pressures will mean somewhat longer compressor run times. If your new air requirement is 24/7, then adding compressor capacity is a worthwhile issue to evaluate so evaluates the added power cost vs. the added capital costs for new equipment. As mentioned sporadic load spikes can sometimes be more cost effective by boosting pressures if your system components are capable of higher pressure.

Since you're compressing more air molecules, you will increase the volume of contaminants present in air such as aerosols and moisture. Make sure you have effective filtration of the air in the system and air drain traps on the air receiver that will work properly and higher pressures.

Increasing air pressure is not a perfect solution for all compressed air systems but certainly worthy of consideration if your demand spikes are sporadic.

Reduce Costs for Blow off Air

Using compressed air to blow off debris and moisture is commonly used in many industries. With most plant air systems operating at around 100 psig as the source for the blow off air, costs can be high and sound levels generated can be substantial. With electric power costs on the rise, consider options to generate blow off air can reduce operating costs and generate a better result. We'll examine some options that can achieve this result in your facility going from simple and low cost to higher in cost.

- Reduce pressure-in many cases lowering pressures will accomplish the required task but use less compressed air. As an example, air at 100 psig is compressed at the rate of about 7.6:1. If you lower your blow off pressure to say 30 psig and still meet your requirements you will reduce air consumption by over 50% and also reduce noise levels substantially.

- Piab Manufacturing-Piab manufactures On/Off switches to control preset vacuum pump level, proportional pressure regulators, PiSave Release to release, restrict and sense an object. Piab is a reliable partner to many of the world's largest manufacturers by providing complete line of vacuum pumps, vacuum accessories, vacuum conveyors, and suction cups for a variety of automated material handling and factory automation processes. Go here for more information.

- Compressed Air Nozzle Upgrade- All air nozzles and jets are not the same. ITW Vortec's Nozzles and Jets amplify airflow volume up to 25 times more than the compressed air supplied. The result is less compressed air usage to deliver the same or grater thrust performance. Perfect for all types of blow off, cooling and drying applications, these Nozzles and Jets are available in a variety of low and high thrust models. Use them to meet OSHA compliance as they meet OSHA specifications for noise and dead-end pressure. Additionally, Vortec Nozzles and Jets deliver a very precise airflow making them idea for parts movements and ejections.

- Use a Blower to generate Blow Off Air- Blowers are offered in a number of styles and include regenerative, centrifugal, and high speed belt driven blowers.

In many cases air volume and not air pressure is the primary driving force in effective debris removal or drying applications. With low pressure, but high volume air usage, air knives and specialized nozzles can become an effective combination to reduce compressed air usage.

One PSIG in Excess Air Pressure Increases Power Use by ½ %

Compressed air is one of the most expensive uses of energy in a manufacturing plant. About eight horsepower of electricity is used to generate one horsepower of compressed air. The following example represents a typical small industrial air compressor installation. A facility operates a 100 HP air compressor 4,160 hours annually. It runs fully loaded at 94.5 percent efficiency, 85 percent of the time. It runs unloaded at 25 percent of full load at 90 percent efficiency, 15 percent of the time. The electric rate is $.10 per kWh, including energy and demand costs. The cost per year to power the air compressor will be as follows:

- Fully loaded $27,913
- Unloaded $1,293
- Total $29,206

Total compressed air generated for one year is 76,377,600 cubic feet. Cost per 1000 cubic feet is $.38. A common energy conservation measure is 1 PSIG of excess operating pressure increases power consumption by ½ %.

As an example if your required minimum compressed air operating pressure for your facility is 90 psig, then operating your compressors at 10 psig about that minimum required pressure would be a good starting point for your compressor room. The compressors 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 property designed system will be less than 10% of the compressor's discharge pressure- found on a gauge on the outlet of the compressor.

If you find that you have to operate your plant air pressure at 110 psig to offset issues in your compressed air system, your power bill would be 5% higher than required or in our example an added $1,460 per year.

Carrying excess pressures can be corrected by examining the following:

- Leaks which can rob large amounts of air. Consider doing a leak test on your system.
- Air Drain Traps which do not operate properly or in the case of timer drains waste large amounts of compressed air.
- Dryers and filters which are clogged and not maintained at proper intervals.
- 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.

- If your compressed air system does not have an air receiver tank, add one to buffer short term demand changes and reduce on/off cycling of the compressor needs approximately a 50-gallon air receiver tank.
- 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 at the end use to minimize artificial demand.

Here is an assortment of tips and hints for application in compressed air and vacuum systems.

Compressed Air System Tips

- At $.10 per KWH, a 100 HP compressor operating at full load for one month will consume $35,000 of electricity in one year. When a compressor is unloaded, it still consumes about 30% of the total power rating of the motor. The same 100 HP compressor operating 65% of the time fully loaded and 35% of the time unloaded will still consume $25,000 of electricity in one year.
- Review the piping and valves in your compressor room to make sure that no dryers or filters are bypassed.
- Make sure a piping change connecting wet air and dry air has not been done along with any open valves separating the two systems.
- Make sure there are coalescing filters in front of all dryers.
- Verify that all dryers are cycling, purging, and re-pressurizing properly.
- Dyer desiccant should be changed every 3-4 years for lubricated compressors and every 5-6 years for oil free compressors.
- Air cooled after coolers will never operate as well as water cooled after coolers in high summer temperatures. A fine water spray on an air cooled unit will gain 10-15 degrees F in hot weather.
- Verify that all drainers are working properly. Each piece of drying and filtration equipment must have its own drain trap. Every air receiver should also have its down drain trap to remove water which will accumulate in the tank. Remember that timer style drains can never be set to properly drain all water without wasting enormous amounts of air.
- Eliminate Time Drains-Timer drains do not operate! It is impossible to set a frequency and duration time to meet all the varying humidly conditions which exist.
- Reduce Air-Pressure- lowering air pressure by 2 psig will cut operating costs 1%
- Air Leaks- a single 1/8" hole at 100 psig will waste $2,400 of air in one year.
- Improper uses of compressed air-most air compressors will produce about 4 cfm of air per horsepower consumed. Most blowers will produce about 16 cfm of air per horsepower consumed. Using a blower in place of plant compressed air will cut operating costs by as much as 75%.

Vacuum System Types

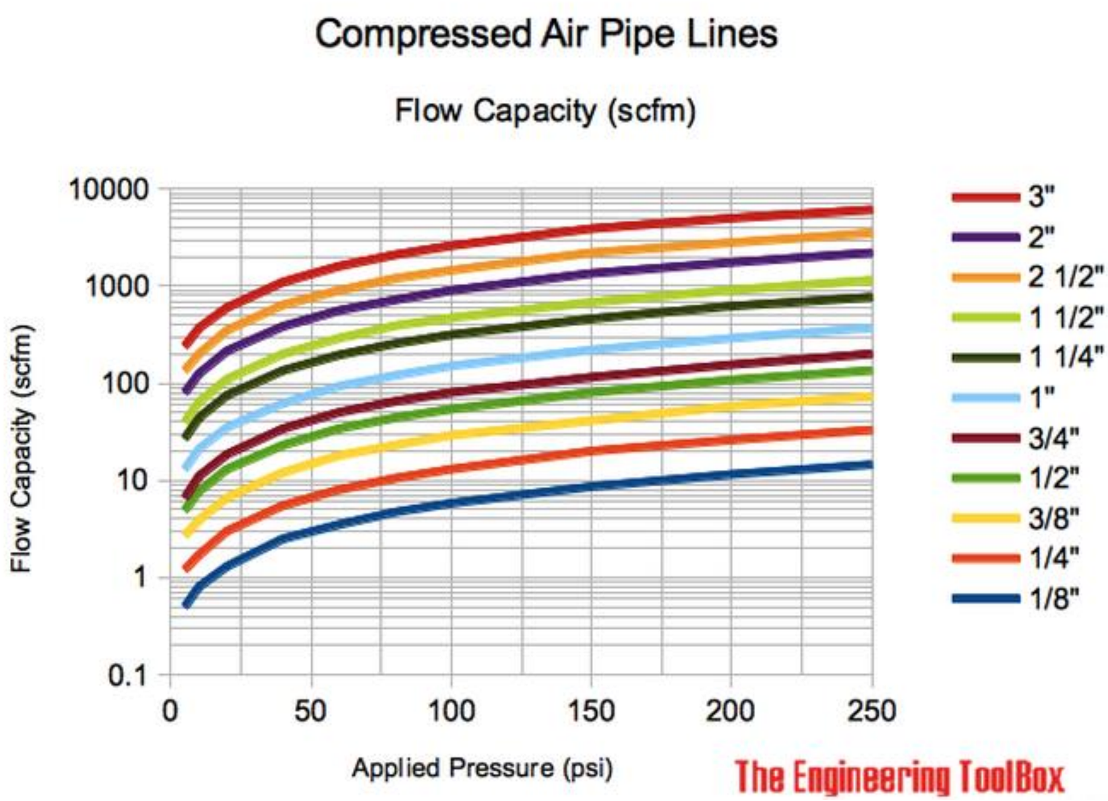
- The term "pressure" usually refers to absolute pressure. Full vacuum is equal to zero.
- The term "vacuum" usually refers to relative gauge pressure where atmospheric pressure is equal to zero.
- Maximum pressure drop through a pipe in a system should not exceed 10% of the absolute pressure (add 14.7 to gauge pressure) from the point of source to point of use. Higher pressure drops cost you energy and system efficiency.
- To find a leak in a vacuum piping, try placing Saran or other sticky plastic wrap around the open points. Watch to see if the wrap draws in tighter due to the leak being sealed.
- For every 18°F over 210°F, oil life is reduced by one half.
- It costs about $6,480.00 per year to operate a one horsepower running 100% of the time at a cost of electricity of $.10 per kWh.
- An oil leak of about one drop every two minutes is equal to one quart every 39.5 days or 2.3 gallons per year.
- To reduce the absolute operating pressure half requires twice the pump capacity.
- To pump the same load in half the time requires twice the pump capacity.

Chapter 8- Sizing Compressed Air Lines

Chapter 8 Highlights-Compressed line sizes vary on the rate of flow, supply, pressure, and length of line run.

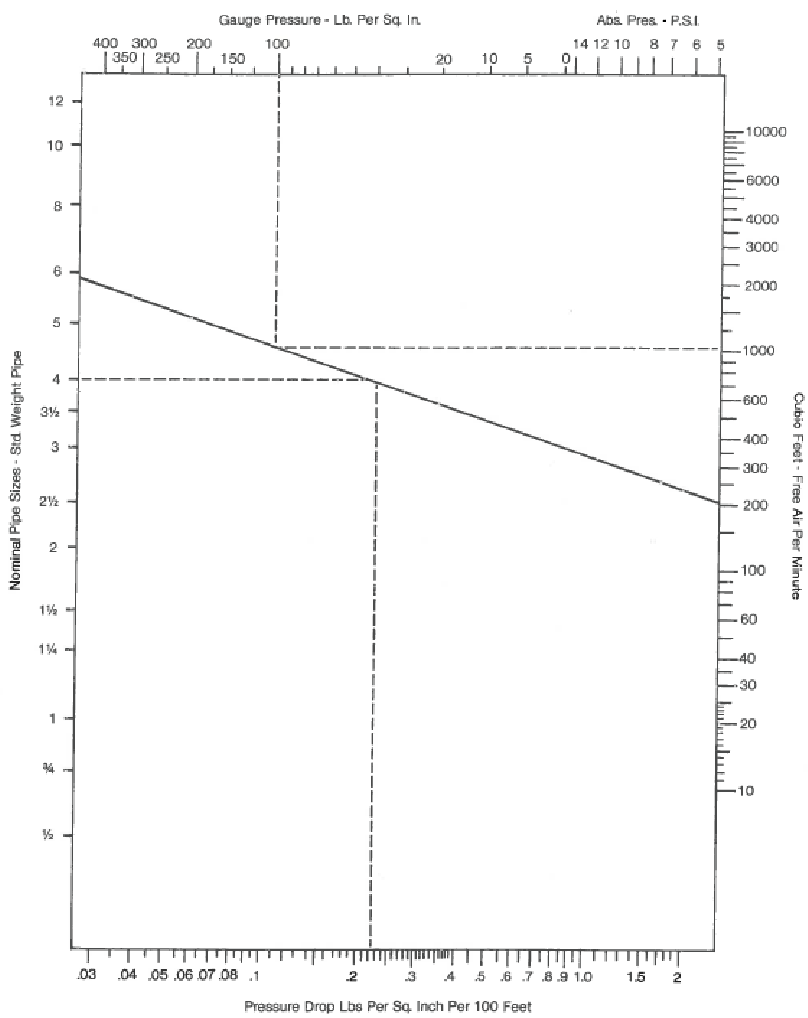
- **Chart one (Compressed Air Pipe Lines) gives you a quick overview in a single chart to see what typical air line capacities would be at 100 psig. This chart is handy for line runs up to 100'**
- **Chart two (Compressed Air Line Pressure Drop) allows you to make a precise section considering pressure, flow, and impact of pressure drop as a function of line length.**

The web is a great source for sizing compressed airlines with lots of sites and information to review. From the EngineeringToolBox.com site, this chart allows you to have a quick look at airline capacities as a function of pressure, flow, and line size.



A more detailed chart is from an older Spirax Sarco technical manual and allows you a more detailed look at pressures, flows, line sizes over a broad range and pressure drops per 100' of line under consideration.

COMPRESSED AIR LINE PRESSURE DROP



To use this chart, use the following instructions-

1. On the top axis enter at the system pressure and the right axis at the system flow chart in CFM with a dashed vertical and horizontal dashed like using the vertical and horizontal reference lines. The example shows a system pressure of 100 psig and a flow of 1000 CFM.
2. Using the angular lines which pitch down from the left axis to the right axis draw a line parallel to the angular lines the lower right and 90 degree point of the dashed lines draw in step one. In the example the angular reference line drawn in the step is slightly below the 6" line size on the left axis and right at 200 CFM on the right axis.
3. Using the left right angular line you can then trial fit different line sizes to arrive at the pressure drop her 100' of selected line size under evaluation. The example shows a 4" line will have a pressure drop of .225 psig per 100' of schedule 40 pipe.
4. Note that the pressure drop increases at an exponential rate as you move to the right on the bottom axis reflecting that pressure in smaller size lines increases at a logarithmic rate.

Final Thoughts

Setting a goal to reduce compressed air use in your facility is the easy part. Finding the most effective path to accomplish that goal can be a real challenge. Some thoughts for you to consider-

- Set a budget target for potential cost improvements that is within the guidelines of your company. A quick approach is to do your best to determine how much you spend in electric power year to produce compressed. A simple of approach of totaling your compressor HP, assign an estimate or hours of operation and load factor and you can come up with ball park power expenditure. Take that number and multiply it by an average savings goal for an annual savings target. Multiply that by your company payback period and you have a budget estimate for the entire project. As an example of annual savings are $30,000 based on $120,000 annual power estimate and acceptable payback period is two years, you have a budget up to about $60,000 if needed and still pass muster.

- Decide if you wish to do the project or go outside and hire a consultant. Either way write a scope of work and carefully evaluate those areas you can accomplish in house. The more you can do in house and assign responsibility and recognition to will ensure long term positive results. From my experience projects like this heavily delegate to outside resources tend to not get good long term results due to no internal ownership.
- Consider carefully what outside sources you draw on for help. Free surveys and equipment reviews by vendors typically result in recommendations for buy more equipment. As an example in consulting with a company that sells compressors could well result I a proposal to buy new or more compressor capacity. Their study may be totally valid and maybe much newer equipment much run in a more efficient manner but was that in your original scope of work.
- If you use paid consultants who do not offer product sales but rather earn the living by doing consulting engineering work might be a better result. Check references on prior studies. A somewhat expensive study by an engineering firm might yield a much better cost benefit. Do you have an engineer or someone with good hands on capabilities that can do the study on your staff? Mechanical knowledge and decent math skills are two important requirements. Remember in house is going to tend to get you a better long term result.
- Spend some modest money on basics such as good quality accurate pressure gauges. Consider spending some modest investment on an air flow meter and possibly smaller meters to high uses areas.
- Talk to your electric power provider. They in many cases can provide assistance to reduce your power consumption and make suggestions on programs to improve your power rates.
- Document and measure what you accomplish so that your management stays informed on progress and results.
- Go after the low fruit first which include air leaks and defective air drain traps. Look for any open drain valves on air receivers. Take that walk through your facility at some quiet time and just listen and look for losses.

Good luck with your project! If you need technical help with ideas or equipment let us know if we can be of help.

We hope our E-book has given you some ideas to improve your productivity while reducing your cots and emission footprint. Thank you! - Ed Moschetti