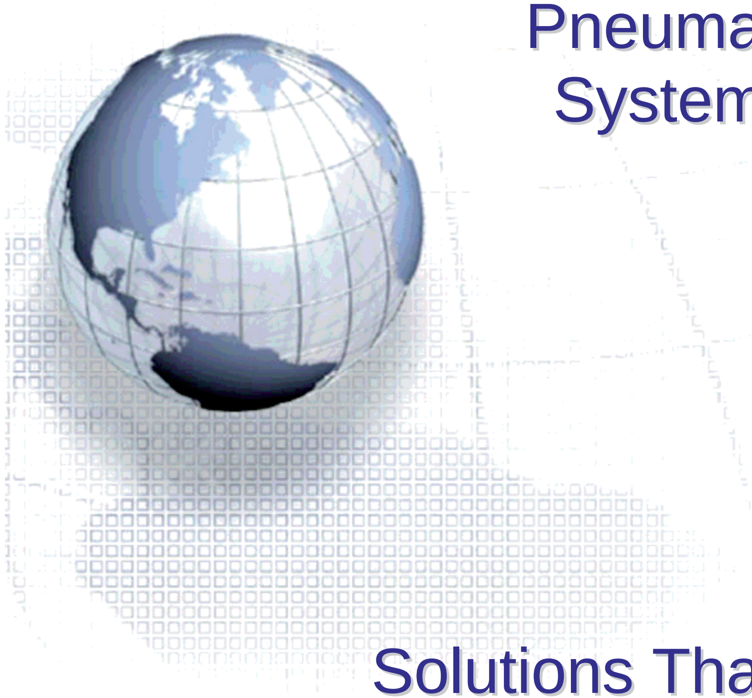
SMC

SMC CORPORATION OF AMERICA

Energy Conservation

Ecologically
Conscious
Pneumatic
Systems



Solutions That Save

Table of Contents

Objective

The purpose of this course is to review the fundamentals of energy conservation.
At the end of this course, the student should be able to:

1. Define energy conservation
2. Explain it's advantages
3. Be aware of the areas energy conservation can be applied and improved
4. Recognize customer's energy saving opportunities

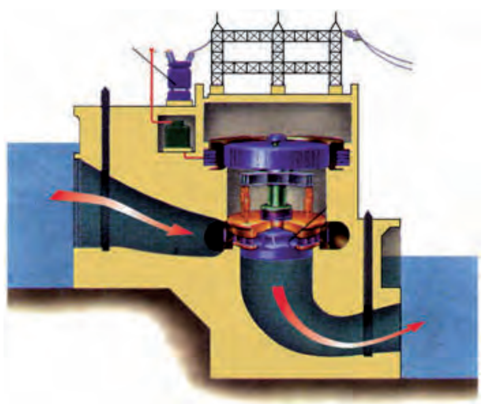
Topics

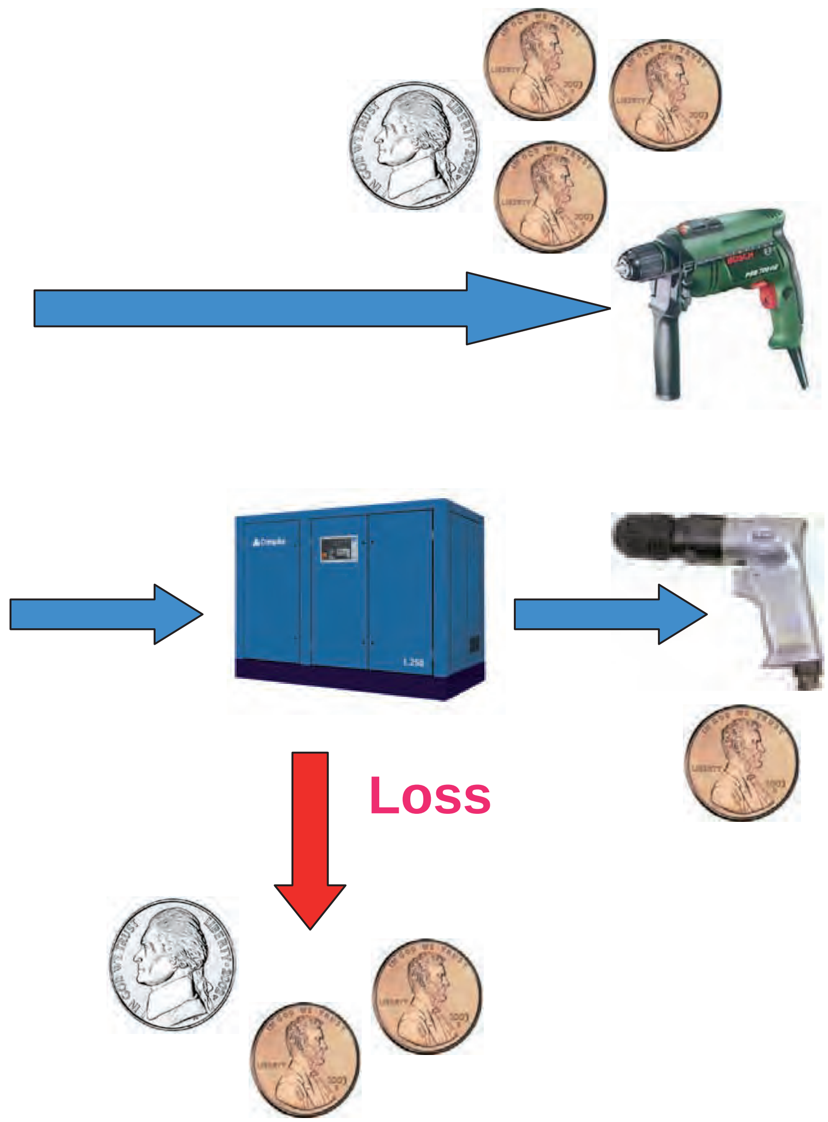
- Introduction
- What is energy conservation?
- Why conserve energy?
- What can we do to save energy?
- Typical areas for improvement
- Real-world examples

Compressed air energy audits conducted by the U.S. Department of Energy suggest that over 95 percent of compressed air systems in all industrial facilities have low-cost energy conservation opportunities.

Why do we use compressed air?

- It's expensive, right?





1 Kwh ~ $0.08

Source: Energy Information Administration

The Cost of Electricity

The cost of electricity per kilowatt-hour varies depending upon geographical location and usage (residential/commercial/industrial, etc.)

Census Division	Residential		Commercial1		Industrial1		Transportation[1]		All Sectors	
and State	Jul-09	Jul-08	Jul-09	Jul-08	Jul-09	Jul-08	Jul-09	Jul-08	Jul-09	Jul-08
New England	17.27	17.76	16.08	16.16	11.24	14.19	7.57	14.64	15.36	16.48
Middle Atlantic	16.52	16.66	14.58	16.15	8.39	9.5	13.56	13.58	14.18	15.18
East North Central	11.22	10.98	9.15	9.22	6.93	6.87	8.94	8.55	9.24	9.14
West North Central	10.09	9.83	8.27	8.1	6.48	6.07	8.06	7.26	8.52	8.2
South Atlantic	11.61	11.28	9.68	9.81	6.85	6.98	10.8	12.35	10.19	10.01
East South Central	9.59	9.76	9.21	9.31	6	6.42	9.55	10.91	8.36	8.5
West South Central	11.37	12.84	9.12	10.99	6.12	9.35	9.91	8.65	9.46	11.33
Mountain	10.87	10.59	9.08	8.96	6.95	6.83	9.2	9.22	9.21	9
Pacific Contiguous	13.58	12.98	14.01	12.69	8.74	8.72	8.93	8.03	12.76	11.93
Pacific Noncontiguous	21.15	28.94	18.14	24.61	16.38	25.18	--	--	18.47	26.1
U.S. Total	11.96	12.14	10.72	11.11	7.12	7.78	11.72	12.28	10.42	10.73

Cents per Kilowatt-hour

Source: Energy Information Administration
http://www.eia.doe.gov/cneaf/electricity/epm/table5_6_a.html

Cost of Compressed Air

Calculations will typically use these values:

- 8,760 hours of operation (24 hours/day, 365 days/year)
- 90% motor efficiency
- 4 CFM per BHP
- $0.10 per Kw hour.

The power-cost formula is:

$$\text{Annual cost} = \frac{\text{BHP} \times 0.746 \times \text{hours of operation} \times \text{cost per Kw hour}}{\text{Motor efficiency}}$$

For example:

The annual cost of running a 200 HP compressor

$$= \frac{200 \times 0.746 \times 8760 \times \$0.10}{0.90} = \$145{,}221.33$$

Let's look at this another way. . .

What is the annual cost of an air leak?

We have a leak in our system and we're losing 5 CFM.

- Convert CFM to BHP 5 CFM / 4 CFM per BHP = 1.25 BHP
- Apply the formula 1.25 x 0.746 x 8,760 x 0.10 / 0.90 = **$908/year**

For another example. . .

What is our air blow application costing us?

- We use 9 CFM in the application. 9 CFM / 4 CFM per BHP = 2.25 BHP
- The annual cost 2.25 x 0.746 x 8,760 x 0.10 / 0.90 = **$1,634/year**

When managed properly, compressed air is still the best power transmission system!

Electric

Pneumatic

Energy cost	low	High
Installation	Complex	Simple
Initial cost	High	Low
Replacement Cost	High	Low
Service Life	Short	Long

Even though people may argue that using electricity directly is more efficient, when you consider the flexibility of compressed air, and the low up-front cost, low replacement costs, long service life, and durability, compressed air still wins!

Why do we use compressed air?

Compressed air is frequently used in industry because of it's favorable features, however it can be <u>expensive when not properly managed!</u>

Hole Size	Leakage	Annual cost
1/16"	6 CFM	$89
1/8"	26 CFM	$3577
1/4"	104 CFM	$14,308

Note: $0.08/kwh, 8760 hours/year @ 100PSIG

Why save energy?

The decision to implement an energy savings program in a compressed air and pneumatic system is usually based on two main factors:

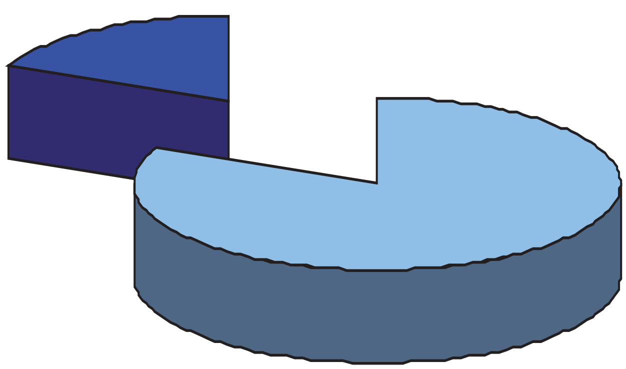
Operational cost savings

Environmental consciousness

Reducing energy consumption

Fifteen to twenty percent of the electricity used in a factory is to compress air. If we can find ways to make that use more efficient, we can realize operational cost savings and reduce our impact on the environment by reducing energy consumption.

15-20% is used to compress air



Electricity used in a factory

Why save energy?

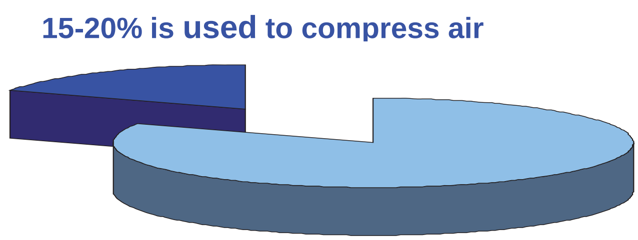
The following benefits often occur after energy savings measures are implemented:

- Reduction in maintenance
- Decreased downtime
- Increased production
- Decreased scrap rate
- Decreased number of compressors in operation

Implementing energy saving measures will often result in reduced maintenance, which will provide additional benefits

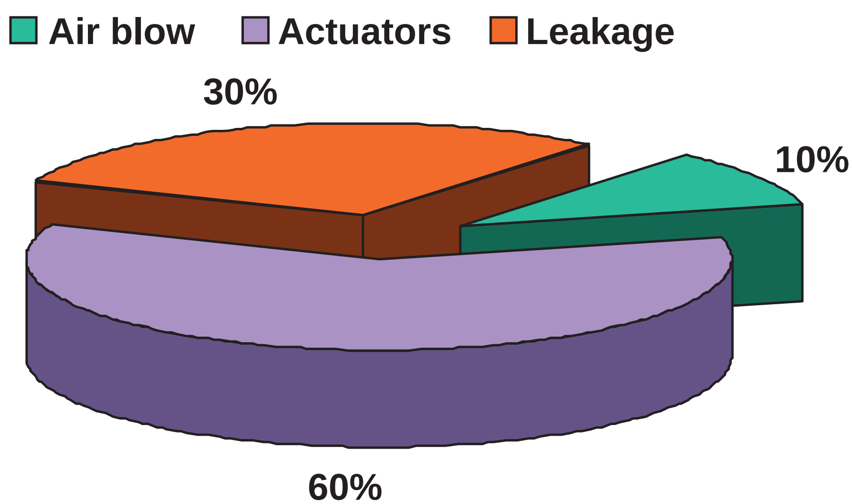
Pressures and flows at their optimum levels will reduce forces and stress on components in the system, thereby reducing failures and required maintenance. By reducing failures, downtime and scrap rate are naturally reduced, production is increased.
Excessive flows and pressures may require additional compressors to keep up with demand. Reducing consumption will often reduce the number of required compressors.

Where is the energy used?



Electricity used in a factory

Compressed air consumption by application



As we mentioned before, fifteen to twenty percent of electricity is used for air compression.
Actuators typically use sixty percent of that compressed air and air blow applications 10 percent.
Thirty percent of the compressed air is consumed by leakage.

All three of these areas provide opportunities for energy savings.

How can we save energy?

<u>Improvement of actuator systems</u>

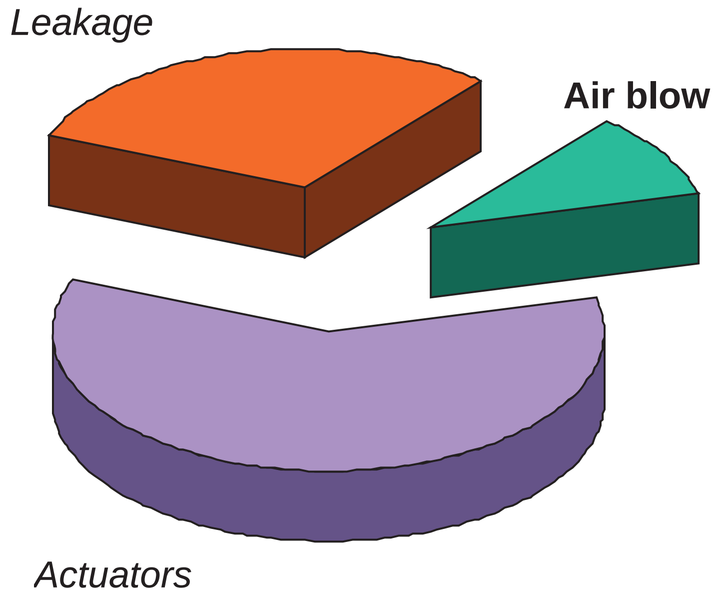
Limiting the pressure supplied to match the force required and using the proper actuator for the application can improve many systems.

<u>Optimization of Air-Blow Applications</u>

Air blow applications can often be improved by reducing the flow or pressure applied to the object to what is needed to get the job done.

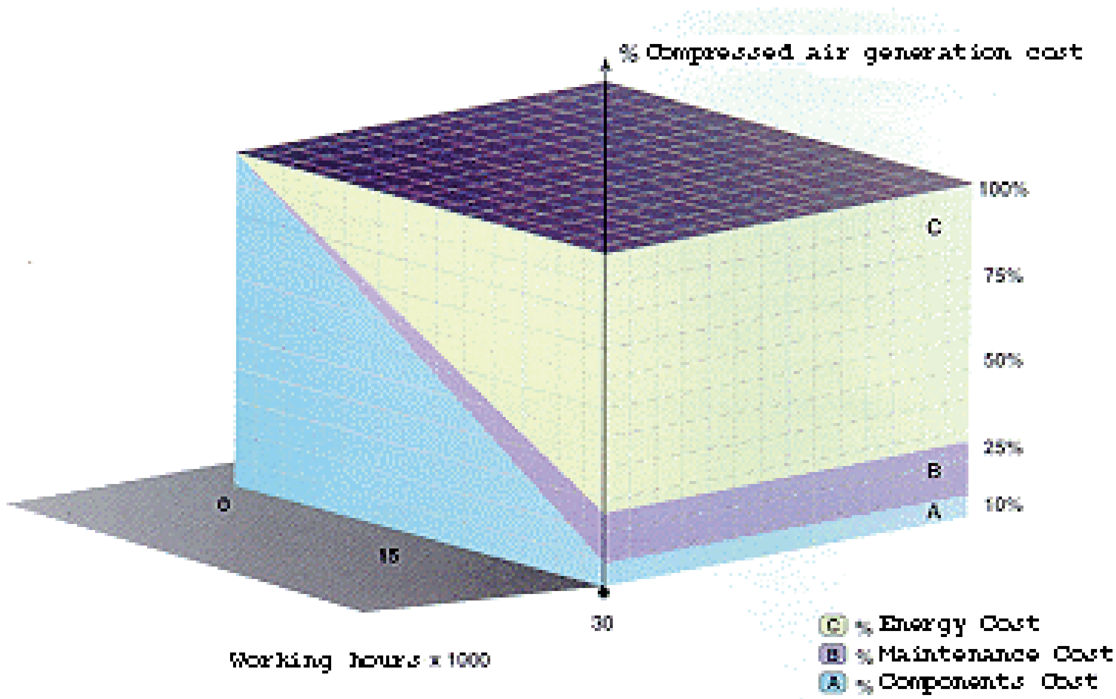
<u>System monitoring and leakage control</u>

While there is still some benefit to even inefficient actuator and air blow systems, there is absolutely no benefit in leaks!
Monitoring the system and repairing leaks is essential in maintaining efficient compressed air systems.



How can we save money?

- Electricity makes up more than the 80% of the total cost of a pneumatic system. A small increase in the amount spent on maintenance will considerably reduce the electricity cost.



Improving maintenance and reducing leaks will be money well spent!

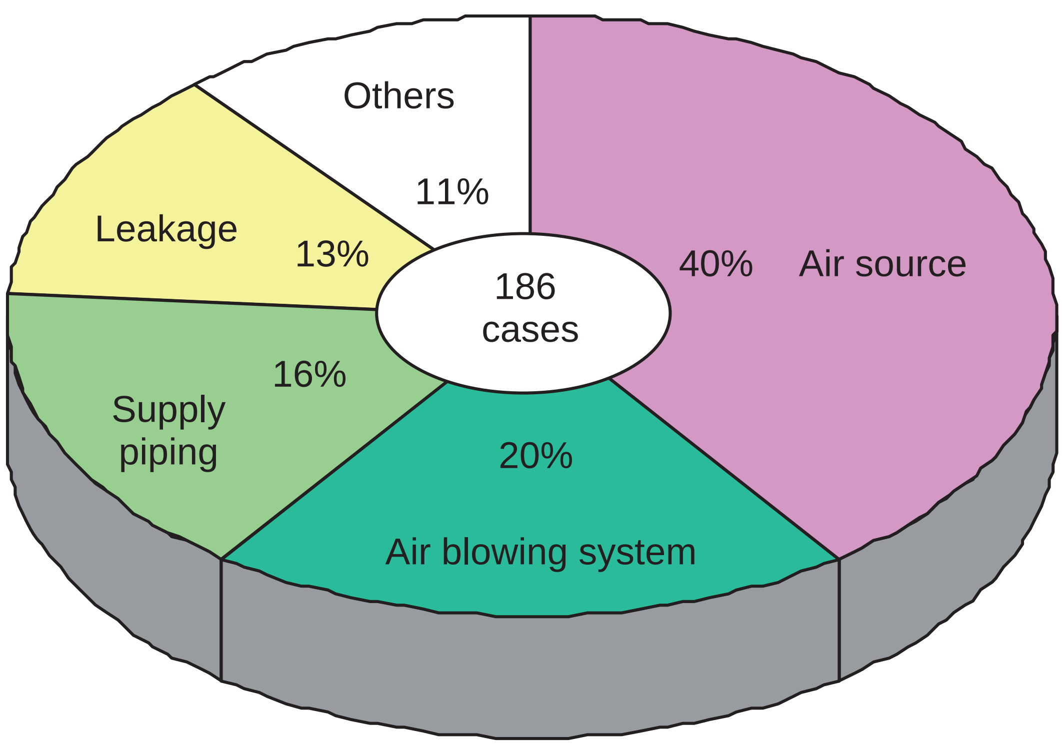
Where can we save energy?

This figure shows various energy saving targets from 186 pneumatic systems studied.

The air source accounts for 40% of the total, and it's true that sometimes changes to the compressors and controls become necessary. Because these are often expensive changes, they could perhaps be looked at last!

Note that Air Blow, Piping, and Leakage add up to more than 40% of the total -

> Great efficiencies can often be realized by making simple (read "less expensive") changes to air blowing systems, supply piping, and by implementing leakage control measures.

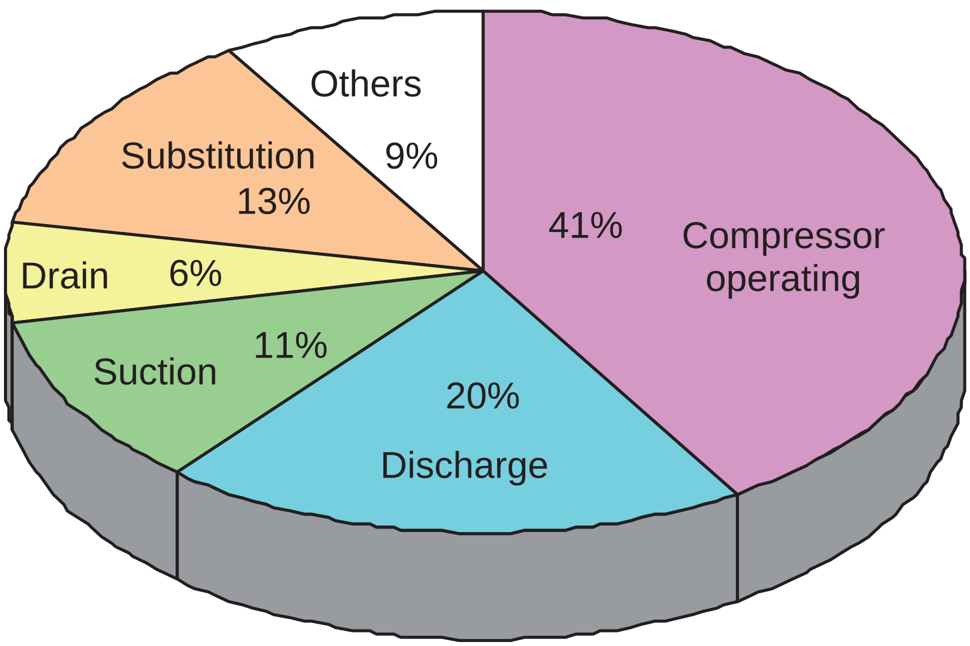


Savings Related to Air Source

This figure shows the energy saving measures related to air source.

"Compressor operating" is the main measure, and 41% in share.

This is mainly the load change by multiple-unit control of the compressor group and the reduction of the number of operating compressors.

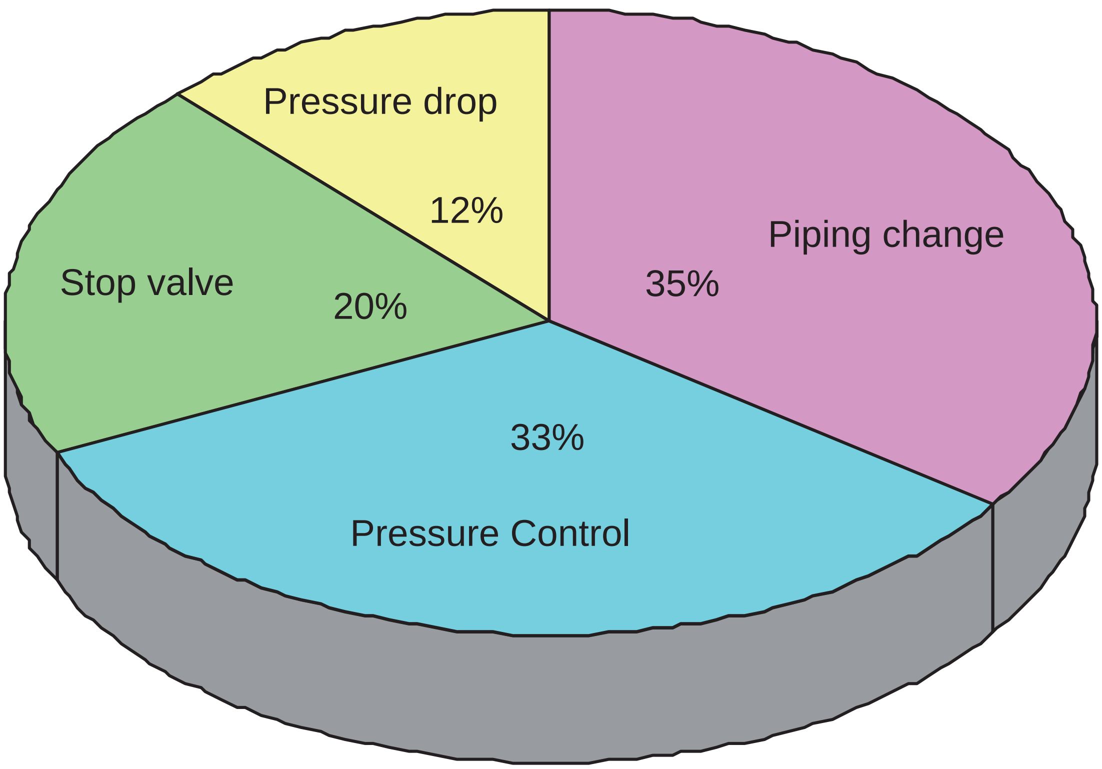


Savings Related to Supply Piping

This figure shows the energy saving measures related to supply piping.

"Piping Change" is the main measure and makes up 35% of the solutions. This is mainly the reduction pressure loss and the pressure equalization by the piping change.

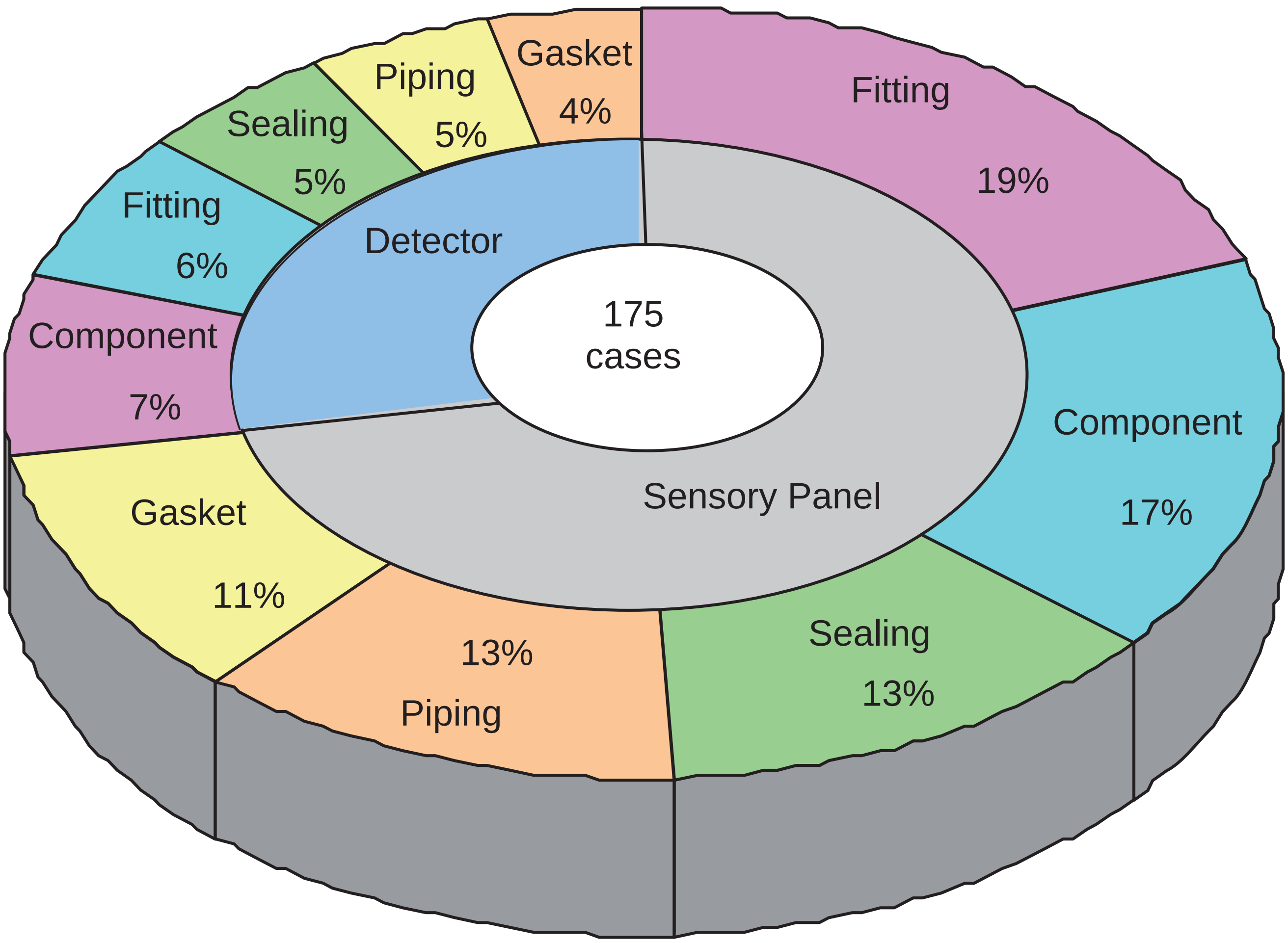
"Pressure Control" is the pressure optimization and the pressure reservation using the tank.



Savings Related to Air Leakage

The leakage accounts 10-20% of air consumption in factory according to leakage investigations.

This figure shows the example of leakage repair, based on 175 cases studied.

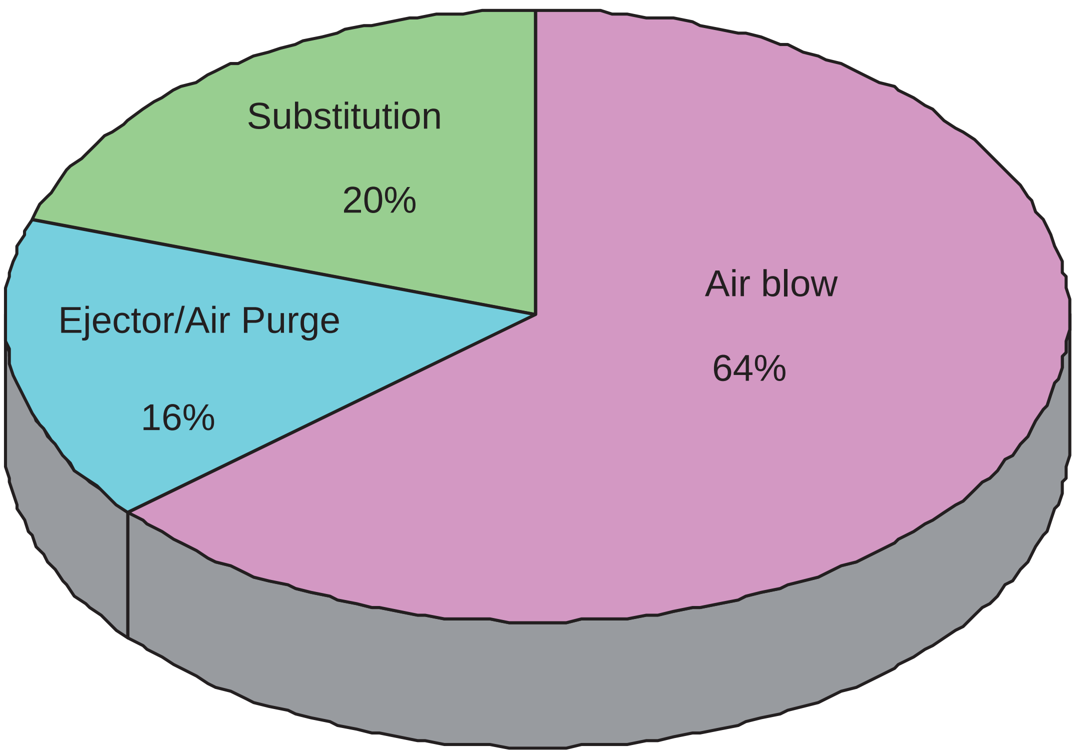


There are some cases where leakage sensory panels and leakage detectors are produced and used as solution.

Savings Related to Air Blowing

Improvement of “air-blow” is the primary energy saving opportunity in more than half of the cases.
The energy saving in a facility is mostly applied to air blowing applications because they comprise about half of the total air consumption.

This means the improvement of efficiency in the existing facility is large.

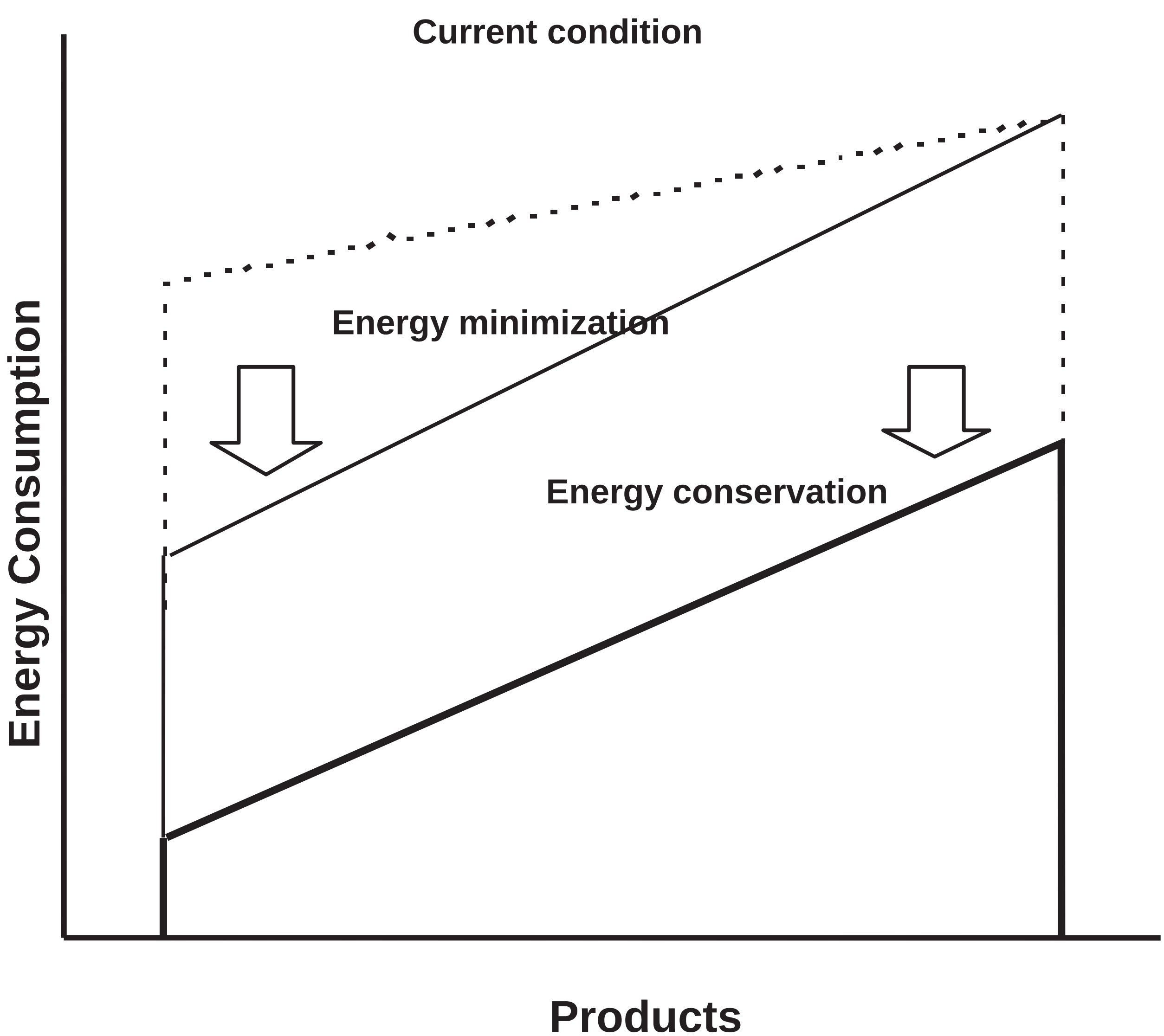


Two Steps to Energy Saving

We can effectively review energy consumption by classifying it into these two categories.

<u>Energy Minimization</u>
Energy Minimization is constructing a production system in such a way that the necessary energy is used only when required.

<u>Energy Conservation</u>
Next, Energy Conservation is targeting improvement of energy efficiency in each production process.



Keys of Energy Saving

The following table shows energy saving points of major pneumatic system components.
Among those items, Energy Minimization items should be the first to give measures. Priorities are operation according to load with air source and elimination of leakage, and intermittent operation suitable for work in blowing systems. Compressed air pressure and air consumption are common keys of Energy Conservation measures with each component.

Component		Energy Minimization (Proportional to Production)	Energy Conservation (Consumption Efficiency)
Air Source		Volume control Multiple unit control	Power rate Discharge pressure
Supply Piping			Pressure loss/ Piping cost Diameter, pressure, flow rate, loop piping
Leakage		Search & Elimination Shut-off valve Work Standard	
Blowing System	Air- Blow	Intermittent operation	Piping, nozzle size pressure Quantity, target
	Air-Micrometer	Intermittent operation	
	Vacuum Ejector	Intermittent operation Vacuum holding	Ejector, pad size Pressure
Cylinder Actuation		(Essentially of energy minimization)	Device size, Air consumption Cylinder, Solenoid valve Speed controller, tubing, pressure
Right Pressure In Right Place			Pressure reducing valve Booster regulator, Tank Dual pressure actuation circuit

Where to Start?

Lean Thinking

We suggest using a holistic approach and using Six Sigma principles to develop a Energy Conservation program at your plant.

- Define: How much energy is consumed to produce compressed air? How much compressed air is used?
- Measure: How much compressed air is wasted? What are the potential savings?
- Analyze: Identify causes of waste.
- Improve: Remedy causes of waste.
- Control: Continue to measure, analyze and improve.

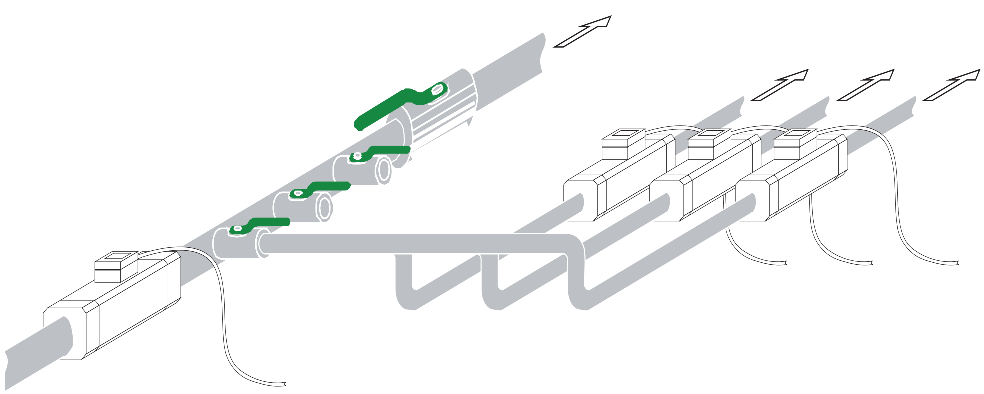
Define and Measure

"If you can't measure it, you can't manage it,"

- A baseline needs to be established.
- Temperature and dew point are useful air system measurements…however the key metrics are:
    - o Pressure
    - o Rate of air flow
    - o Electrical consumption
- This trio helps to determine the cost, monitor system operation and establishes a baseline for evaluating future modifications.

Monitor Air Flow

Install flow sensors to determine flow rates through main branches and secondary branches of pneumatic system.



Monitor Pressure

Develop a pressure profile.

Take readings at the following points:

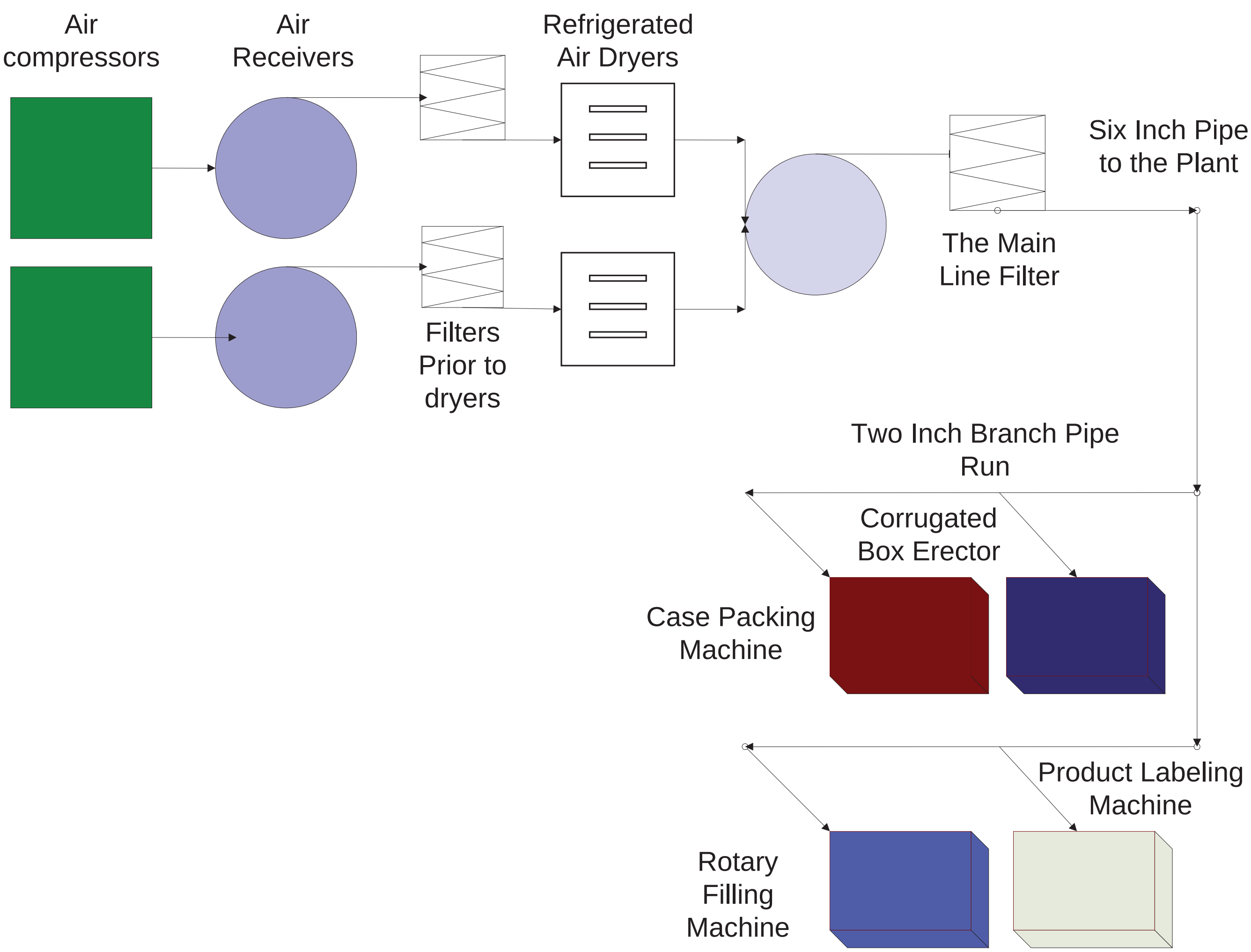
1. Main supply components
2. Beginning and end of the main piping system
3. Points of use

Identifying Energy Saving Opportunities

- The following steps have been created to locate energy savings improvement opportunities in any manufacturing environment.
- Observing the following steps will provide simple and effective measures to corrective action in any compressed air and pneumatics system.

Step One

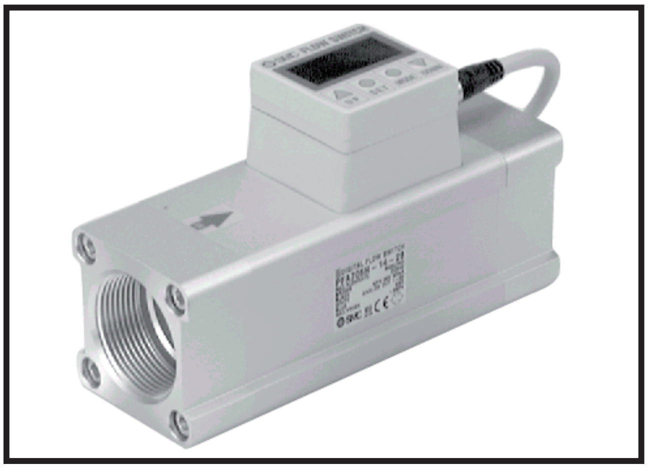
Develop a basic diagram of your system.



Step Two

Confirm that equipment CFM and PSI settings match OEM engineering specifications.

PF2A Digital Flow



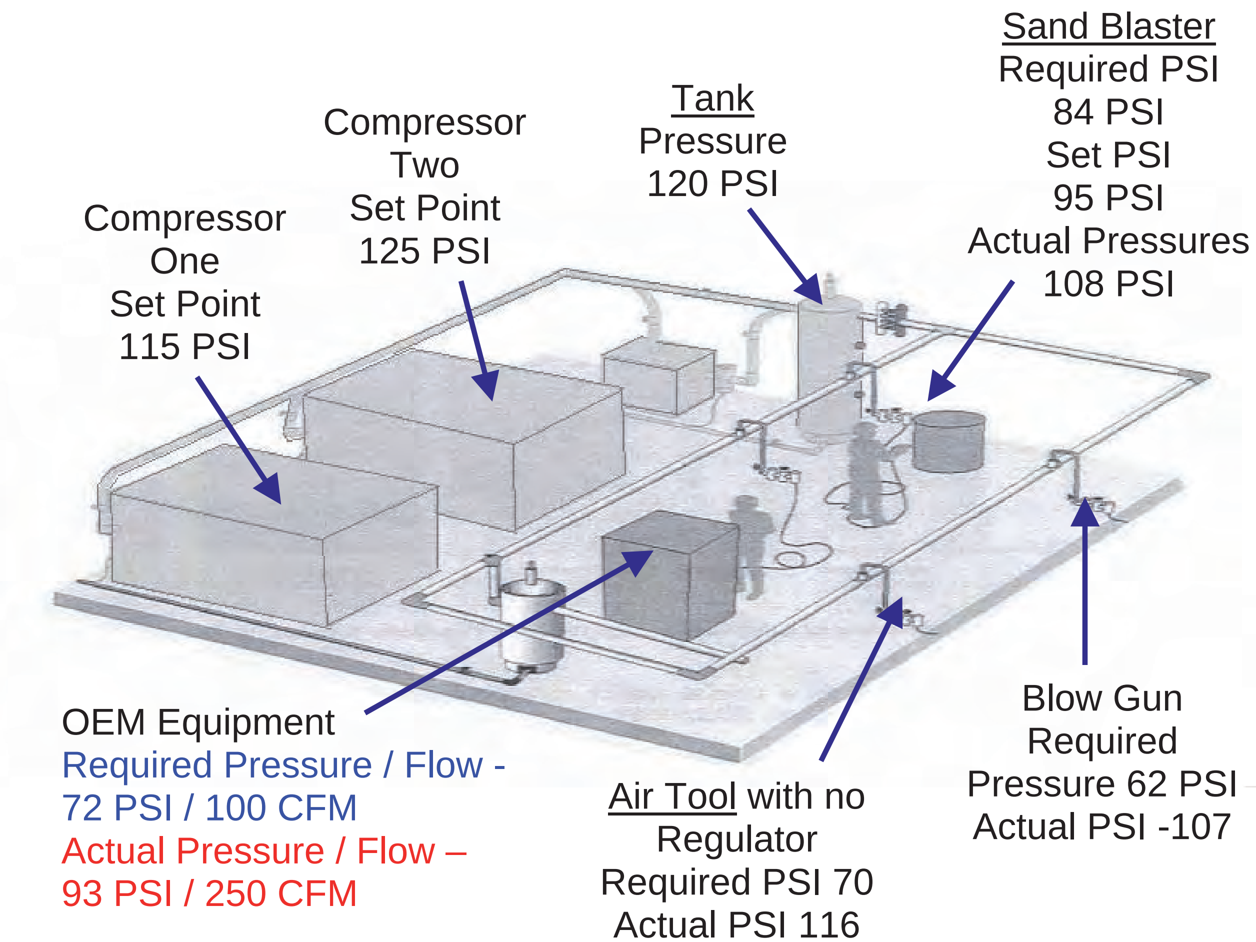
ISE3 Digital Pressure

The PF2A digital flow switch allows you to baseline flow requirements to mission critical equipment running 24/7 and monitor for deviation from the baseline.

The ISE digital pressure switch can be installed to monitor overall system pressure, branch runs or individual drops. High, low and current pressures are available to assess pressure needs.

Step Two Example

Verify your pressure & flow profiles:



Step Three

Select an ISO compressed air quality standard to deliver the compressed air quality you require on a consistent basis.

ISO 2001: 8537 Air Quality Standards

Quality Class	Pressure Dewpoint (100 PSI)	Oil Mist & Particulate (mg/m^3)
1	-94 ºF	0.01
2	-40 ºF	0.1
3	-4 ºF	1.0
4	37.4 ºF	5
5	44.6 ºF	--
6	50 ºF	--

Consider appropriate levels of filtration at the main-line, branch, and for specific equipment. Monitor filtration.

Air Quality Classes for Typical Applications

Application	Suggested Air Quality			Additional Requirements
	Solids	Water	Oil	
Air bearings, Tubing, Gauging	2	3	2	-
Instrumentation	2	3	2	-
Abrasive Blasting	3	3	-	-
Pharmaceuticals, Food & Beverage	3	1	2	Odor Removal

“A” series filter grades provide air suitable for virtually all applications.

Filter Model	AMG	AFF	AM	AMD	AMH	AME	AMF
Filter Type	Water Separator	Mainline Filter	Mist Separator	Micro-mist Separator	Micro-mist Separator with Pre-filter	Super Mist Separator	Odor Removal Filter
Element Type	Resin Mesh	Cotton Paper	Glass Fiber	Glass Fiber	Glass Fiber	Glass Fiber	Adsorbent Activated Carbon
Particle Size	6	3	3	1	1	1	1
Oil Content Class	6	4	3	2	2	2	2

SMC “A” series filters perform to ISO 8573-1

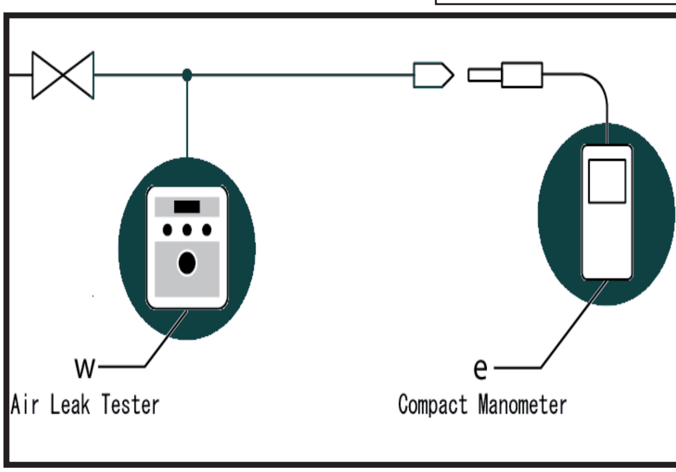
Step Four

Identify demand side issues including pressure loss, excessive pressure, inappropriate use and intermittent demand.

Find, measure & verify air leakage on each line.

IN-241 Air Leakage Tester

PPA Manometer



Step Five

Take corrective action.
Re-evaluate compressor and dryer controls and see the effect improvements have made on the energy bill.

SMC’s IDFB Refrigerated Air Dryers

Target Areas for Savings

What to tackle first?

Where do we get the most benefit for the least expenditure of energy?

What will provide the best return on investment?

In the next section, we'll discuss the top areas for energy savings.

Pneumatic System Savings

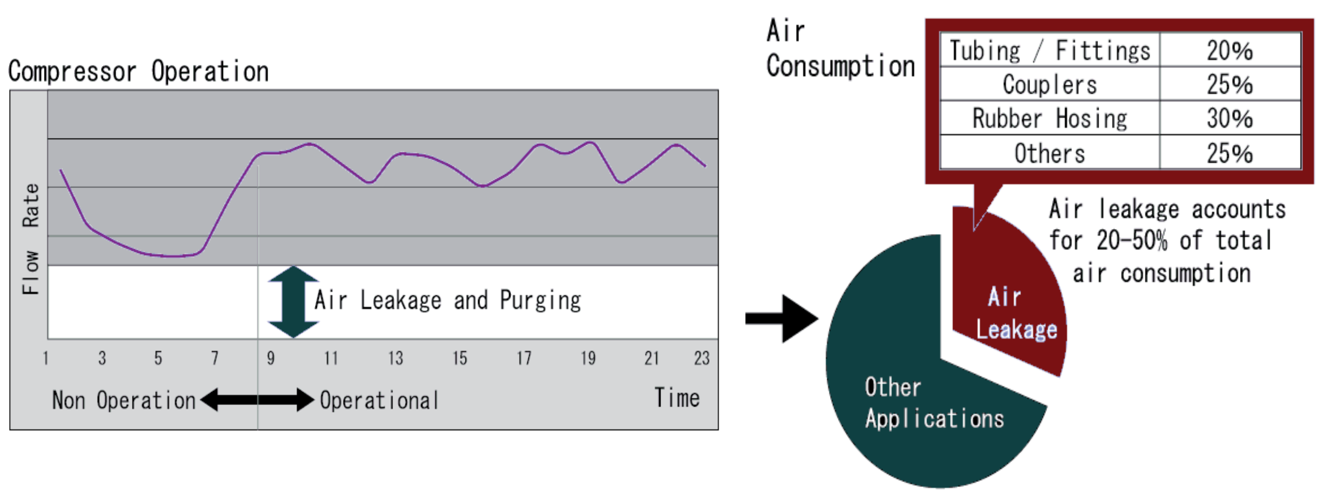
Top target areas of energy savings in pneumatic systems that need to be “Analyzed and Improved” are:

1. *Leaks*
2. *Air Blow*
3. *Excessive Pressure*
4. *Intermittent Demand*
5. *Inappropriate Usage of Compressed Air*
6. *Cylinder Consumption – Sizing & Design Mistakes*

We’ll take a look at them one at a time.

Leakage

Leaks are the thieves in any compressed air system, causing the compressor to operate even during machine stoppage.

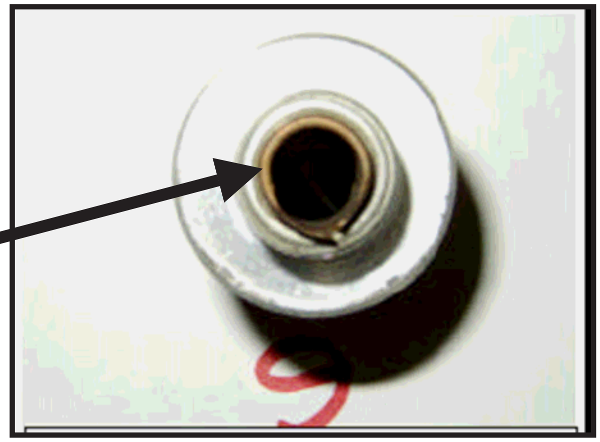


Air leakage can account for 20 ~ 50 % of total air consumption in a pneumatic system. That’s what makes this the first and one of the best places to make improvements and realize energy savings!

We’ll start by looking our first suspect. . .

Actuators

Low quality cylinders begin to leak around rod-seal after 1 million cycles or less and fail after 7 million cycles. This leaking cylinder costs **$73** more per year compared to SMC cylinder NCM.

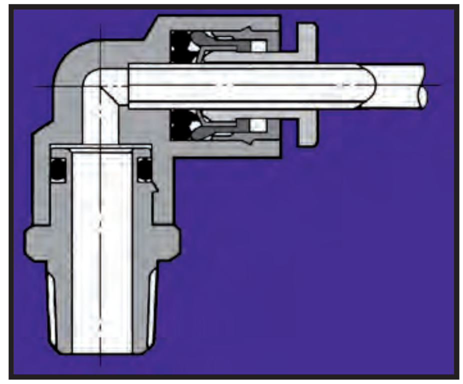


Comparable SMC NCM Cylinder last 5x longer!

SMC #2 Bushing

Fittings

Improperly cut tubing causes 70% of tubing and fitting leaks!
Use of tubing cutters ensures a 90-degree cut 100% of the time.



Tubing Cutters

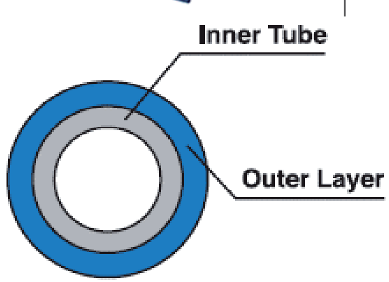
TK-1
Applicable tubing O.D.: 13mm or less.

TK-2
Applicable tubing O.D.: 18mm or less.

TK-3 (Simple type)
Applicable tubing O.D.: 12mm or less.

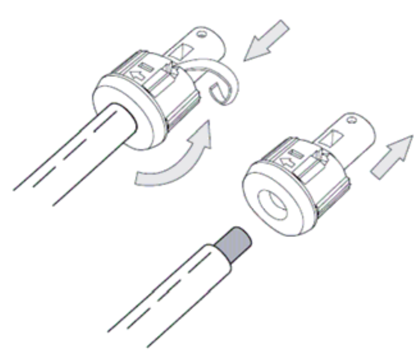
Tubing

Using double layer tubing can solve leaks caused by tubing wear.



FR Double Layer Tubing
Sectional View

To simplify cutting and stripping of the tubing, SMC offers the TKS line of stripping tools.



Air leakage is useless energy, but it accounts for 10 to 20% of the total air consumption in factory at present.

As mentioned above, leakage often exists in each component, as well as the fittings of equipment and piping, and they are dispersed throughout the factory.

So, we need to achieve reduction of allowable equipment leak rate as well as research and development of simple leak detector and flow meter in the field.

Flow switch is connected with in-line to the facility and measures wide range of flow rate.

Leak tester is connected in parallel to the facility and measures leak rate simply.

Cost of Air Leaks

Discharge Through An Orifice						
Diameter of Orifice in Inches						
	1/16	1/8	1/4	1/2	3/4	1
Pressure	**Discharge in Cubic Feet of Air Per Minute (CFM)**					
70 PSI	4.79	19.2	76.7	307	690	1227
Annual Cost to Operate	$590	$2,269	$9,062	$36,281	$81,545	$145,009
100 PSI	6.49	26	104	415	934	1661
Annual Cost to Operate	$765	$3,072	$12,290	$49,045	$110,382	$196,300
125 PSI	7.90	31.6	126	506	1138	2023
Annual Cost to Operate	$931	$3,734	$14,890	$59,800	$134,491	$239,082

Case Study- Leaks

A recent leak detection exercise during an energy audit at a large plant found 276 leaks!

642.5 CFM Annual cost = $ 40,410

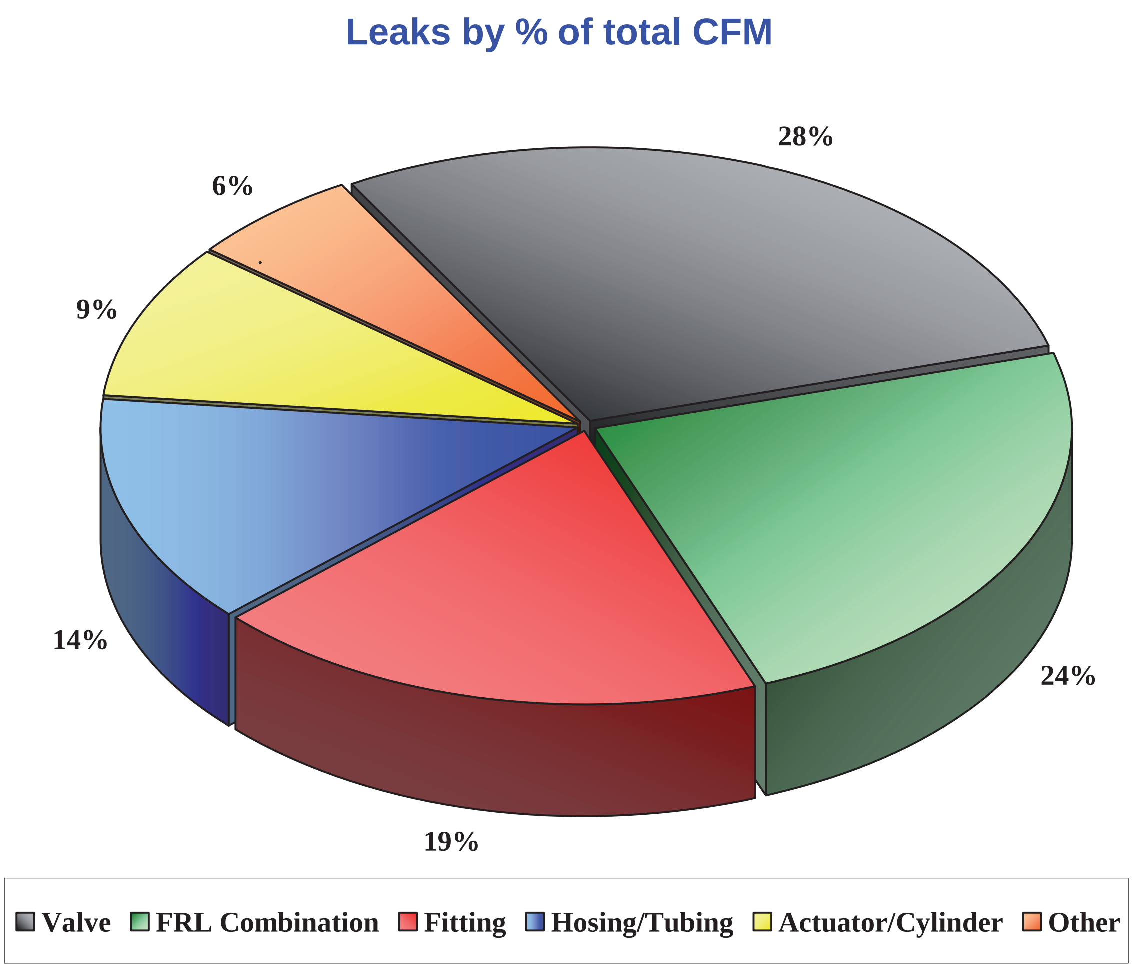
All of these leaks were documented and tagged, so the entire cost can be eliminated by replacing these components.

See a sample of actual leaks found in a recent compressed air audit. This particular study found an annual leakage cost of $40,410.00
Leaks are the thieves in every compressed air system and typically account for 10 – 20% of compressed air usage. The ECG utilizes an ultrasonic leak detector to identify leaks. This detector focuses on the frequency level that compressed gases create. During the audit **276** compressed air leaks were discovered, totaling **642.5 CFM**. In some departments it was not possible to open up the machines and look at the components within. It is possible, and likely, that more leaks exist that were not found during the audit. In addition, the case packers were found to have excessive amount of leaks during a machine analysis performed several months ago. The average case packer was found to have 20 CFM in leaks without opening the doors and guards.

Tag #	Location in Plant	Component	Port Size	Leak Description	CFM	COST
410	Coater #1, start of line.	Fitting	3/8"	Copper fitting leak.	3	$188.72
411	Coater #1, FF belt #2.	Valve	1/2"	Manual valve leak.	2	$125.81
412	Coater #1, reject chute.	Valve	3/8"	Pneumatic valve leak.	3	$188.72
413	CTR #2, finished, #1 conveyor.	Valve	3/8"	Pneumatic valve leak.	2	$125.81
414	#2 CTR cooler, FEG machine inlet.	Filter-Regulator	1/2"	Filter/regulator leak.	1	$62.91
415	Behind and above #3 CTR weigh off chute, at inlet.	Regulator	1/4"	Regulator leak, pic	1	$62.91
416	#3 CTR, Dryer #3.	Filter	1/2"	Filter leak. SN: F602048BJ/MS.	0.5	$31.45
417	Under stage C conveyor, discharge screw.	Filter	3/4"	Filter leak.	1	$62.91
418	Under stage C conveyor, discharge screw.	Valve	1"	Ball valve leak.	10	$629.06

The pie chart above illustrates the leaks as a percent of components leaking by rate of flow (CFM). The most common leaking components were valves, FRLs and fittings making up the top three most commonly leaking components. Valves and filter-regulator-lubricator combinations combine to make up half of the leak load in CFM.

As long as the system is pressurized, contaminants will cause the size of the leak to grow, contributing to an increase in air consumption. When demand can no longer be met, production will ask maintenance to increase pressure, which effectively allows contaminants to bore through holes at an increased velocity. This allows leaks to grow even faster than before.

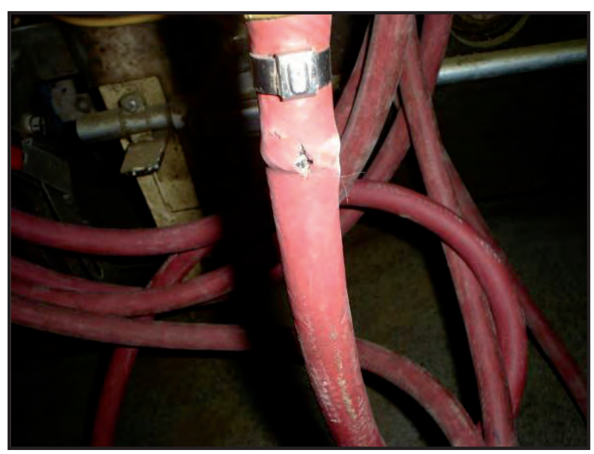


Case Study – Examples of Leaks

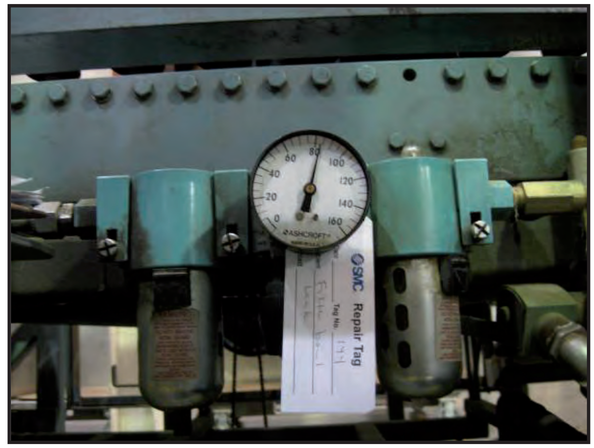
Causes of Valve Leaks:
Internal exposure to water
Polyolester and Diester oils or rust.
Age and general wear.
Most leaking components should failures indicative of general wear.
Operator/Mechanical damage.

Causes of Fitting Leaks:
Faulty installation.
Poor quality – Tubing or fitting failure not caused by the environment.
Misapplication – Fittings or tubing exposed to wash down or other environments it was not manufactured to handle.

Causes of Hose Leaks:
Faulty installation.
Poor quality – Hose failure not caused by the environment.
Misapplication – Hoses exposed to bending, wash down, or other environments it was not manufactured to handle.



FRL Leaks:
Age and general wear. Most leaking components showed failures indicative of general wear.
Internal exposure to water
Internal exposure to Polyolester and Diester oils
Internal exposure to rust.
Note: Leaks due to internal contamination tend to be the largest.
External damage by operator or mechanical force.



Ball-Valve Leaks:
Internal exposure to water, polyolester and diester oils, pipe scale or rust.
Age and general wear.
Note: Most leaking components should failures indicative of general wear.
Operator/Mechanical damage.

Cylinder Leak:
Internal exposure to water, Polyolester and Diester oils or rust.
Age and general wear. Most leaking components should failures indicative of general wear.
Operator/Mechanical damage.

Case Study- Remediation

•Fixing the leaks discovered at this plant will save **$** 40,410 per year.
•**To realize long-term savings, launch a Leak Remediation Campaign**
–Tag audible leaks as they develop
–Notify maintenance.
–Perform ultrasonic leak detection quarterly
–Assemble a leak repair crash cart to ensure that replacement components are in stock

Leak Remediation Campaign Techniques

To keep leaks from consuming unnecessary compressed air, it is important to have a leak remediation campaign in place. Machine operators should combat leaks as they develop by immediately tagging them and notifying maintenance. This method of leak remediation is perfect for leaks that can be easily felt and heard. A proactive approach to such a campaign should involve the education in the cost of leaks to all individuals within the plant.

Unfortunately, many leaks cannot be detected by the human ear, nor are they easily palpable. An ultrasonic leak detector is the perfect tool for detecting these types of leaks. SMC's Energy Conservation Group used an ultrasonic leak detector during the audit of Kellogg's Omaha and found many leaks that were either out of range of being felt or too miniscule to feel or hear.

It is recommended that ultrasonic leak detection be performed at least quarterly to catch the energy robbing leaks that sneak past the every-day leak reduction campaign.

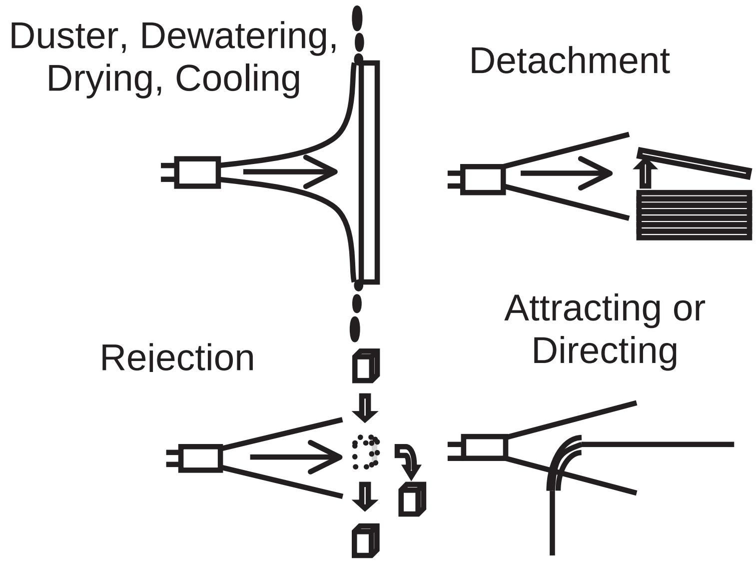
Air Blow

The next consideration is the air-blowing system.

Applications

As shown in the following figure, there are many air-blow applications.

- Cleaning, removing moisture, drying and cooling
- Detachment or separation of film or thin sheets
- Part rejection
- Directing movements



In some applications of compressed air, the air is kept running continuously. This fact is often overlooked, despite the fact that air consumption in these applications exceeds air consumption of actuators.

Many factories do not regulate air pressure to air blow applications or blow guns. OSHA Directive 100-1 states that air should be regulated below 30 PSI (0.2 MPa) for cleaning applications.

There is a tremendous potential for savings in air-blow systems. Making some minor changes, such as turning off the air when not needed, properly sizing nozzles and piping, and controlling pressure levels to what is absolutely needed will dramatically improve efficiency.

Questions On Air Blow Applications

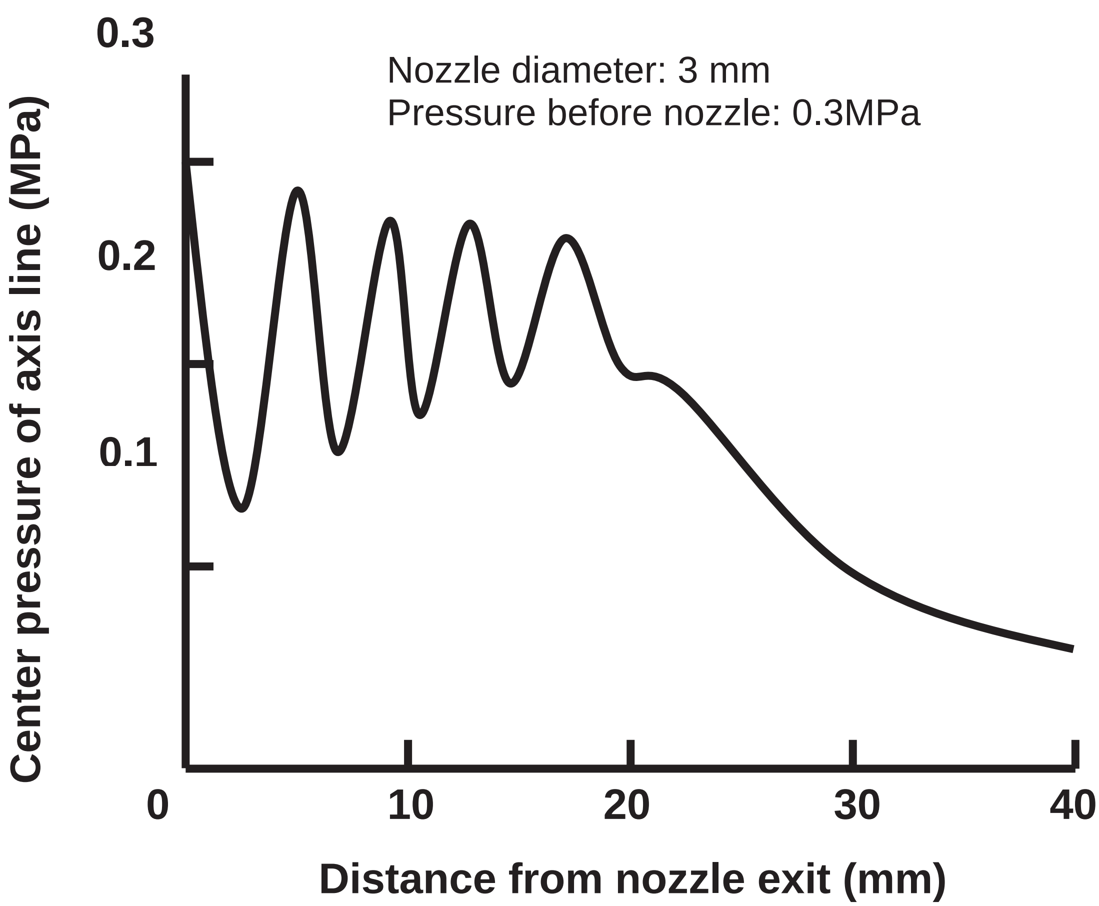
Questions to determine if a compressed air blow-off circuit is efficient:

1. Is air blow-off truly needed for this application?
   - If not, why was it added?
   - If so, what purpose does the air blow-off accomplish?
2. Does the process need "*impact pressure*" or *"air volume"* to accomplish the task?
   - Drying bottles may require a large volume of air but low pressure while conveying a heavy part may require more pressure than volume.
3. If the process needs pressure, what impact pressure is "required" and what pressure does the task cease to be accomplished?
   - If lower pressures continue to do the job, significant savings can be realized.
4. If the process needs air volume, what flow is "required" and at what flow does the circuit fail?
   - If lower flows continue to do the job, significant savings can be realized.
5. Is compressed air truly needed for this process?
   - The opportunity to use a centrifugal blower should be explored.
6. If the process requires compressed air, must it run constantly?
   - Shutting the air blow off when not needed will quickly add up the savings.

Document all "Current State" parameters so that any variations made during testing can be restored.

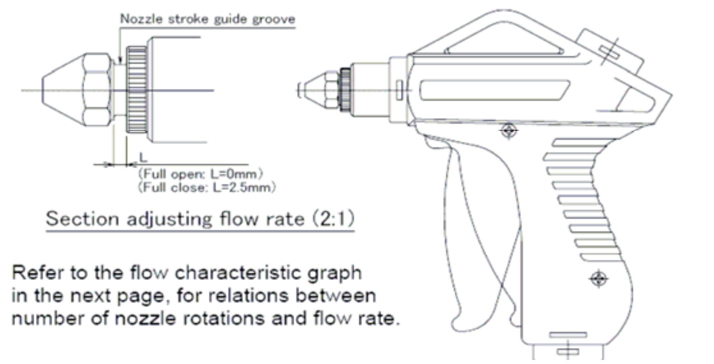
Pressure and Distance

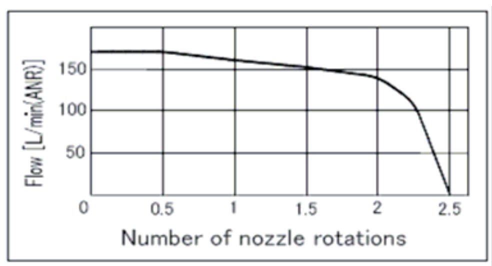
The task of air-blow is supplying an air jet directly to the work-piece using a nozzle.
The following figure shows the pressure along the jet axis, where air-blow is used in the fully developed flow region.

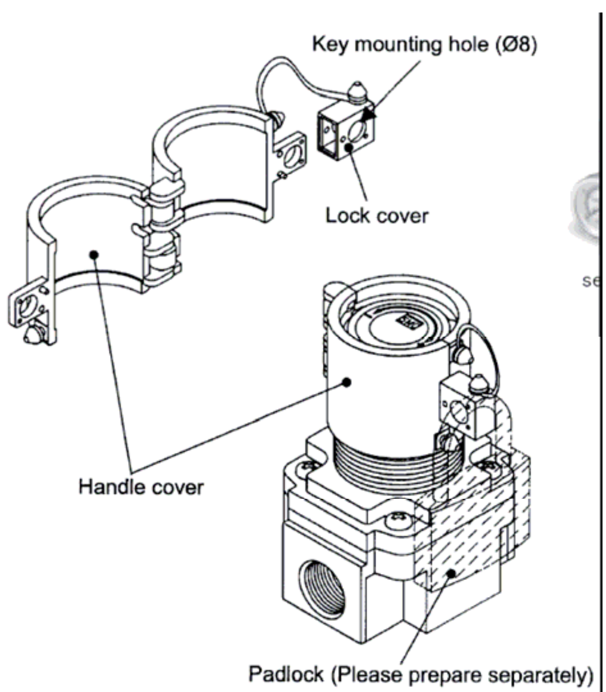


Improvements

With measures such as high efficiency nozzles, adjustable blowguns, etc., we can reduce air consumption by 50 – 75%, while in some cases increasing impact pressure!



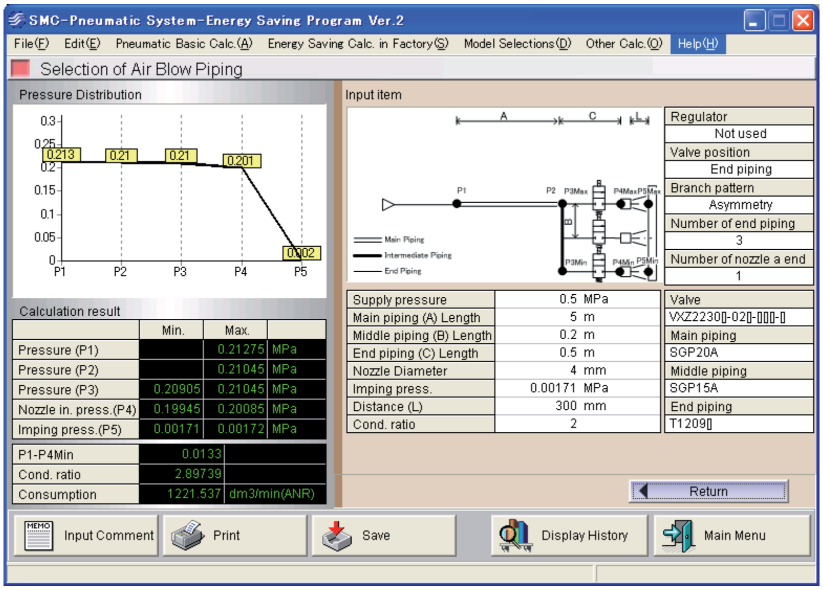




Locking regulators ensure proper pressure settings.

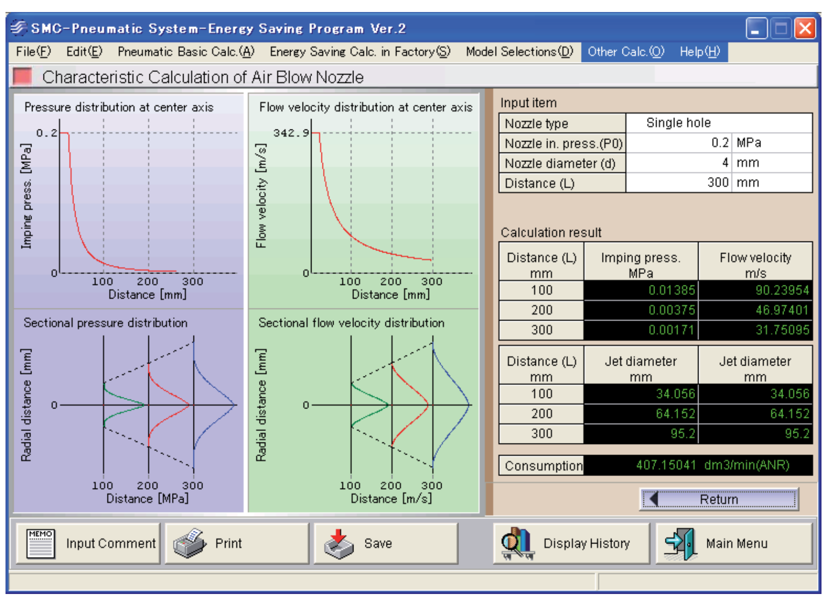
Design Tools

In some current system, the air is kept blowing regardless of existence of works. Also, some are not efficient, because nozzle size is larger than necessary.



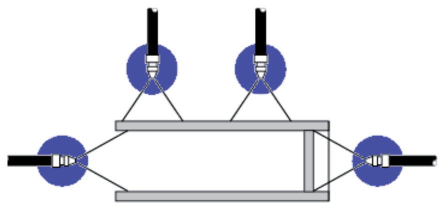
For these reasons, we developed the program to design optimum air-blow system. This program is included in SMC Energy Saving Program.

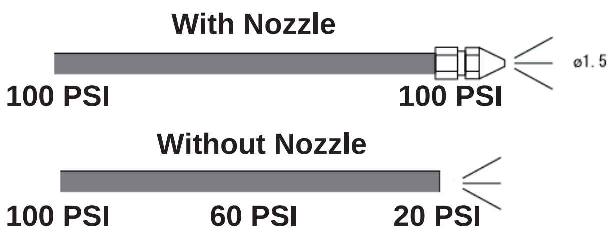
Above is the screen for selection of the upstream piping system. Below is the screen for selection of the proper air-blow nozzle.



Reduce pressure loss and air consumption while increasing work surface impact.

Series KNH
high-efficiency
nozzle





Pressure Loss is minimal

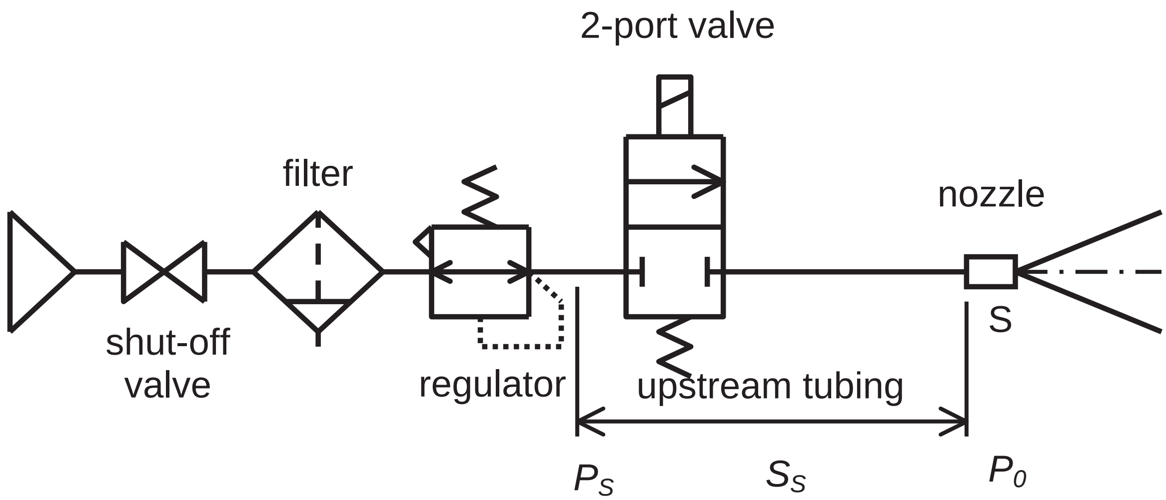
Pressure loss is great

It is understood that airflow decreases if nozzle pressure is set larger than critical pressure when blowing work is performed.
The following table shows an example.

	Nozzle Diameter mm	Pressure before nozzle MPa	Distance of work mm	Impact Pressure MPa	Air flow rate dm^3/min (ANR)
Current	4.0	0.02	100	0.0014	120
Improvement	1.8	0.09	100	0.0014	52
	1.0	0.29	100	0.0014	33

By making nozzle diameter smaller than the current 4 mm, and increasing pressure before nozzle, flow-rate can be reduced by 70%.

Recommended Circuits for Air-blow



This figure shows our recommended system for optimization. The pressure regulator is indispensable for setting the pressure before nozzle for optimum air-blow effect and air flow-rate. The 2-port valve is a key item, which will allow air-blow only when necessary. As a result, extra air consumption is prevented.

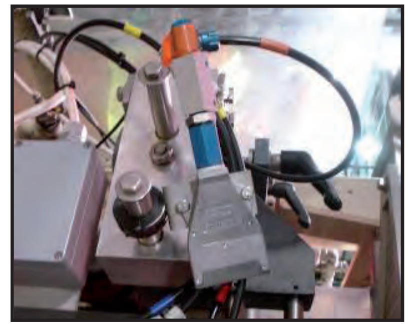
If the valve size is determined by doubling the conductance of upstream tubing, the pressure drop ratio shall be controlled within 5%.

Case Study - Examples

•Our example plant currently uses air blow to:

–Move, cool, or guide product

–Dry and clean conveyor belts.

While some of the uses were efficient and practical, there were also applications where air blow was used quite inefficiently.

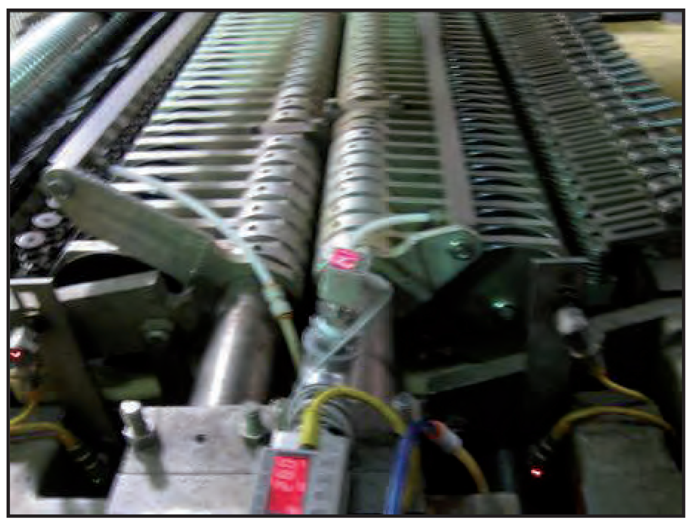
A ¼" open tube is used on this conveyor to keep the belt clean. There are a few issues with this particular application. First, there is no regulator present for the open tubing. The only form of control is a ball valve opened ¼ turn. Second, there is no nozzle at the end of the tubing, simply an open orifice. The tubing also seems to be too far away from the belt and its target. It is nearly pointing to nothing at all. This raises the question whether the air blow is actually necessary or not. The ECG was able to conduct a study on this application to measure exact air consumption.

Air Consumption = 7 CFM or $440 per year

The same application as our previous example is present here with one difference. On this application the tubing has a nozzle at the end. The ball valve on this line was actually fully open allowing air to blow at a higher flow rate. Due to the difference in ball valve opening, the application with the nozzle actually consumed more air than the tubing with no nozzle.

Air Consumption = 13 CFM or $818 per year

Pictured here are two Exair Super Air Knives used to keep the cutters from sticking when they get hot. The operator informed the ECG the air knives do not always run. However, they were on the higher end of consumers for air blow at the plant when in use. Use of these super air knives should be sparingly.



Air Consumption = 25 CFM or $1,572 per year

This area utilized four air knives. According to the operator, the air knives were used to keep the product closer to the middle of the belt to keep it from falling off the side when transferring to the next conveyor belt. During the audit, the ECG was able to test the air knives for air consumption and pressure. The knives were being run at approximately 45 psi and consuming a total average flow of 22.5 CFM.

Statistics			
	Min.	Avg.	Max.
Flow (CFM)	21.90	22.50	23.00
Pressure (psi)	43.30	44.61	45.20

The knives were also continually running even when product was not coming down the line. A solenoid valve and flow controls were present and should be used to stop the air flow when product is not coming across.

Air Consumption = 22.5 CFM or $1,415 per year

Air Blow Applications before Improvements	
Location	**CFM**
1. Packaging Baggers 1 & 2 - Windjet air knife (24 CFM	48 CFM
2. Packaging LL107 Baggers 1 & 2 - air knife (19 CFM each)	38 CFM
3. Packaging BIB 128 Baggers 1 & 2 - air knife (5 CFM	10 CFM
4. Packaging BIB 202 - 5 air knives	40 CFM
5. Packaging Line 9 Bottom Maker Infeed - 1/4" orifice	10 CFM
6. #3 CTR Supply Bin - 2 broken/missing air knives	30 CFM
7. Processing Cutter - Exair Super Air Knives (2)	29 CFM
8. Processing West - crimped copper tubing	13 CFM
9. Processing East - 1/4" open tube	7 CFM
10. Processing - 4 Windjet air knives	23 CFM
11. Packaging 4 & 3 - Air bars (2)	25 CFM
12. Packaging CV0404 - Windjet - no regulator	24 CFM

Total Air Blow Compressed Air Consumption 297.00 CFM

CURRENT ANNUAL CONSUMPTION AND COST	
Total Air Blow Compressed Air Consumption	**297.00**
Total bhp to Produce that Air	**58.67**
Total kWh to Produce that bhp	**43.77**
TOTAL ANNUAL COST TO RUN AIR BLOW	**$18,305**

Potential for Improved Efficiency and Cost Savings

Due to the potential for misapplication, over-pressurization, lack of shut off, etc., there are usually fantastic opportunities for improved efficiency in air blow. By taking the time to analyze the existing air blow applications, the ECG has compiled a list of recommended improvements and alternatives to the situation as it exists today. More importantly, these recommendations offer substantial opportunities with short payback periods.

Air Blow Applications after Improvements	
Location	**CFM**
1. Packaging Baggers 1 & 2 - KNH nozzles regulated to 50 psi	10 CFM
2. Packaging LL107 Baggers 1 & 2 - KNH nozzles reg. to 50 psi	10 CFM
4. Packaging BIB 128 Baggers 1 & 2 - KNH nozzles reg. to 30 psi	6 CFM
5. Packaging BIB 202 - 5 KNH nozzles regulated to 30 psi	15 CFM
11. Packaging Line 9 Bottom – KNH nozzle regulated to 30 psi	3 CFM
12. #3 CTR Supply Bin - 2 KNH nozzles regulated to 30 psi	6 CFM
19. Processing West - use KNH nozzle regulated at 30 psi	13 CFM
20. Processing East - add KNH nozzle/regulator at 30 psi	3 CFM
21. Processing - Remove air knives - use guide arm	0 CFM
22. Packaging 4 & 3 - Remove air bars - use guide rails	0 CFM
23. Packaging Mezzanine - use KNH/add regulator at 50 psi	5 CFM

POTENTIAL ANNUAL CONSUMPTION AND COST		
Initial air blow consumption		297.00 CFM
Total air blow after improvements		71.00 CFM
Total savings		226.00 CFM
Total savings in bhp		45.56 bhp
Total annual savings after improvements		$14,216

Blow Guns

Statistics			
	Min.	Avg.	Max.
Flow (CFM)	54.50	54.81	55.30
Pressure (psi)	1.51	2.81	3.47

There were many blow guns used for cleaning. The blow guns currently at the plant are very inefficient and large consumers of air. During the audit, the ECG tested one of these large “air cannons” and the massive amount of air used was clearly shown. Supply pressure to this particular gun was equal to the line pressure of the plant. The excessive flow of 55 CFM is causing a significant drop in pressure across the blowgun. These blowguns do not have a high efficiency nozzle and are huge consumers of air.

Air Consumption = 55 CFM or $3,460 per year

The ECG then tested a SMC VMG blow gun with a KNH high efficiency nozzle attached. There was a vast difference in both flow and pressure. The pressure averaged 77 psi during the test. The flow averaged 8 CFM.

If this is a possible replacement for cleaning, quite a bit of savings is available.

Statistics			
	Min.	**Avg.**	**Max.**
Flow (CFM)	**7.55**	**7.79**	**8.32**
Pressure (psi)	**75.4**	**76.6**	**78.2**

While delivering an effective impact pressure with minimal flow, the VMG with nozzle will conserve a significant of compressed air. Taking into consideration the total number of air guns used on a regular basis, using a more efficient application will decrease surges in demand.

Air Consumption = **8 CFM** or $503 per year
Savings ~ 85%

- **To improve the efficiency of the current state of air blow:**
- Remove air blow unnecessary to production
- Move air blow as close to the work surface as possible
- Regulate pressure to the lowest level of effectiveness
- Observe OSHA standards regarding orifice pressure
- Maintain supply pressure with a locking or fixed regulator
- Size supply tubing correctly
- Replace existing nozzles with high-efficiency models
- Shut off circuits when not needed in the production process
- Consider installing centrifugal blowers as an alternative to air blow

Air Blow Summary

• Typical areas of concern are unregulated air blow applications, continually running air blow, open orifices and large blow guns.
• Simple solutions such as installing regulators, nozzles, and valves are quick, cost-effective approaches to solving these problems and operating much more efficiently.

Excessive Pressure

To help achieve a decrease in overall plant pressure, it is vital that point-of-use applications are properly pressurized. Operating equipment at pressures beyond their designed levels causes a number of issues:

1. **Safety:** Machinery designed to operate at an intended pressure is built with components and hardware specified for the stresses produced at this pressure. When supply pressure is increased, however, the force created by every actuator in the machine is increased as well. So a three inch bore cylinder that was intended to exert 425 pounds of force upon extension at 60 psi is creating 850 pounds of force when running at 120 psi. The increase in kinetic energy reverberates throughout the machine and can cause the failure of mounting hardware or structural support. More importantly, operators are put at greater risk as the increased force can turn a potential “pinch point” into a dangerous situation.

2. **Lifespan:** Every component has a lifespan, and operating at excessive pressure levels only serves to shorten that life. Shorter component lifespan means more downtime and more maintenance costs.

3. **Variations in Process or Product:** An increase in supply pressure often changes the effectiveness of a given process. For example, the speed of a work piece through a critical cell may increase or an air blow nozzle may cool a work piece too quickly.

4. **Increased Waste Rates:** Running equipment at higher pressure levels than they were designed may cause excessive waste rates. For example cylinders designed to gently push a work piece to a conveyor are now making impact with damaging force.

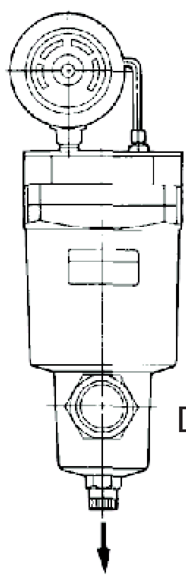
5. **Inefficient Operation:** The greater the pressures, the greater the amount of air consumed by actuators, air blow and leaks. This affects the compressors, as they have to work harder to meet the increases in demand.

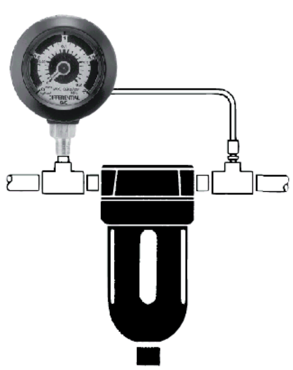
SMC has products that allow you to recognize flow maintenance needs.

Clogged Filters

Clogged filters are one of the main causes of pressure loss. As pressure builds before a clogged filter, flow is sacrificed downstream. The compressor must work harder to overcome this pressure differential, which costs you money. Monitoring filter elements is an important part of any preventive maintenance program, and can help prevent excessive pressure situations.
Use FRLs with:

- Metal bowls to prevent damage (cracked bowl, leaking, loss of pressure)
- Locking regulators to prevent tampering
- Embedded gauges to minimize damage to gauge
- Differential pop-up indicators or gauges to monitor filter element life.





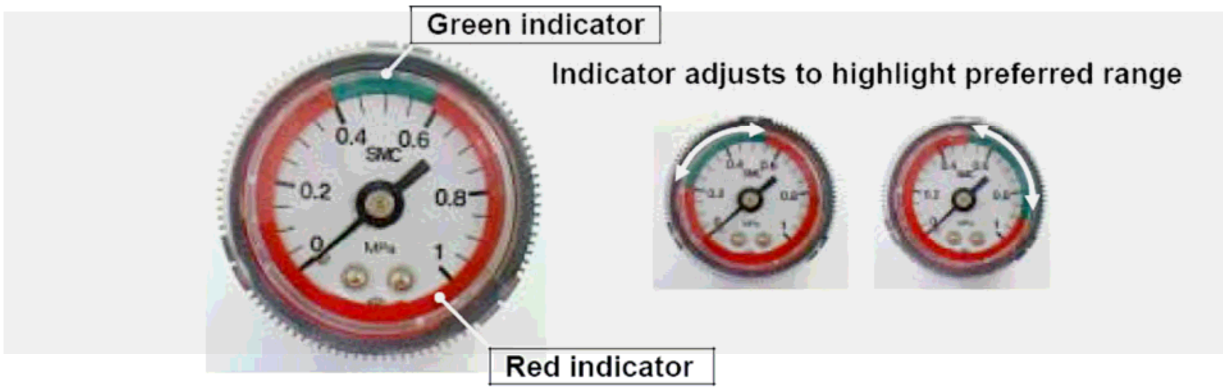
DIFERENTIAL PRESSURE GAUGE

ELEMENT SERVICE INDICATOR

PRESSURE SWITCH

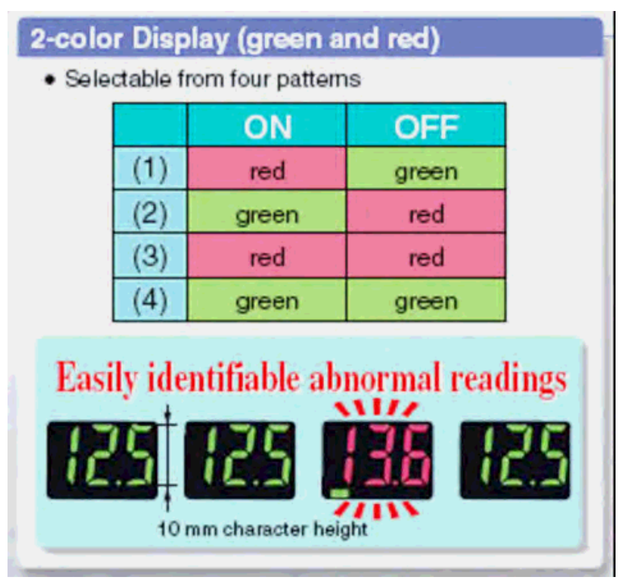
To prevent excessive filter clogging, the differential pressure gauge is put in line. Use Gauges with visual pressure range display.

Feature : Red and green zones offer improved visibility of pressure control range.



Abnormal Pressures

The ISE pressure switch stores high, low and current readings. Use pressure switches with 2-color display to easily identify abnormal pressures.



Air Tools

Regulating pressure to air tools allows tools to generate the appropriate amount of torque to do work without damaging the tool. A regulator with a locking cap may be desirable.

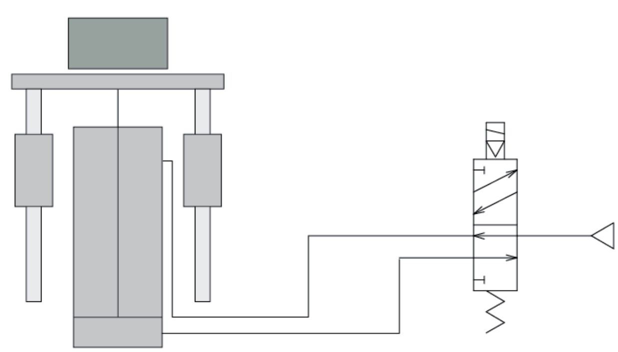
50-75% of air tool consumption can be saved.

Connections to air tools can often be a source of wasted energy as well. Replacing leaking or restrictive couplers is another possible solution.

Superior KK coupler & KKH shock resistant coupler designed not to leak or restrict flow.

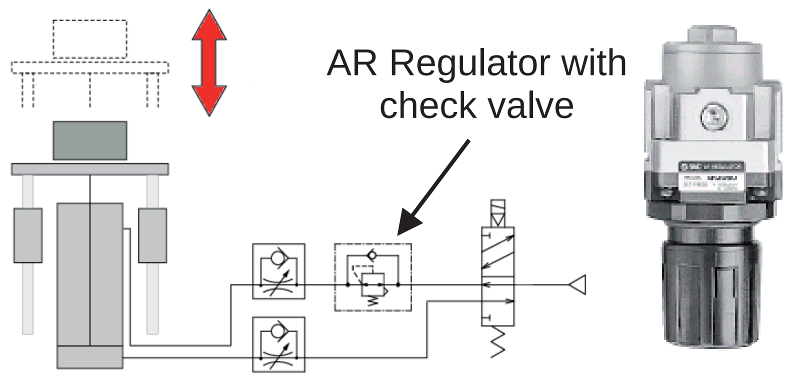
Actuators

Actuator selection is another way of reducing the amount of pressure required for an application. In many applications, the actuator is only performing work in the extension direction, but the same pressure is used in both extension and retraction.

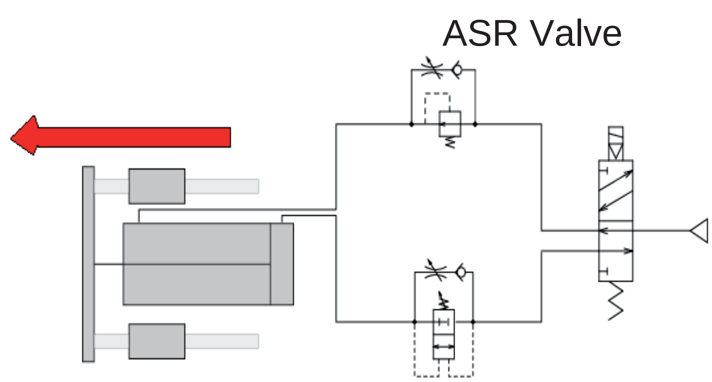


Pressure can be regulated since large forces are not generally required on the return stroke of many applications.

Mass of guide unit works on up and down stroke



Large force only for extension stroke



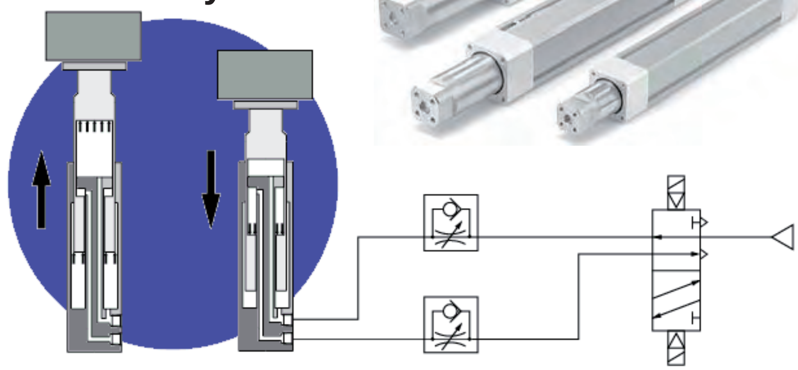
ASR Valve

ASQ Valve

As an alternative, SMC's MGZ double-force guided cylinder can decrease the dimensions and air consumption of a circuit.

This cylinder has twice the surface area in the extension direction, so a smaller actuator can be used.

MGZ non-rotating double power cylinder



Case Study – Excessive Pressure

•There were four main causes of excessive pressure in our example plant:

–Broken, unreadable or missing pressure gauges

–FRL components

–Inappropriate settings.

–Domino DDC3 (Dot Matrix LASER)

Case Study – Pressure Gauges

Broken and/or Unreadable Gauges

These pictures are examples of point of use regulators that have either been broken, missing parts (i.e. gauge covers), filthy components, or a combination of the list. If a regulator does not have a pressure gauge or can not see the reading there is no way for an operator to know what setting the machine is operating at.

Broken/poorly performing gauges will always lead to operators over-pressurizing equipment. The average cost associated with operating a piece of equipment above and beyond the required pressure can add up to be very significant.

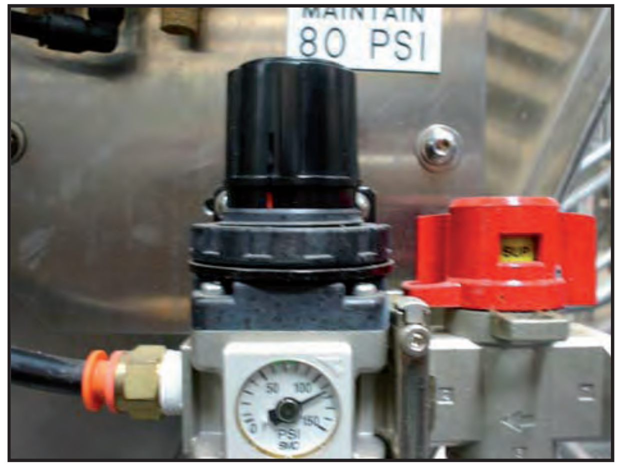
Case Study – FRL Components

Clogged filters create excessive pressure because more pressure is needed for air to flow through the filter. For example, filters that once had a 3 psi pressure drop now have a 12-15 psi pressure drop. It is important to keep filter elements clean to prevent excessive pressure drop across the filter.

Case Study – Inappropriate Settings

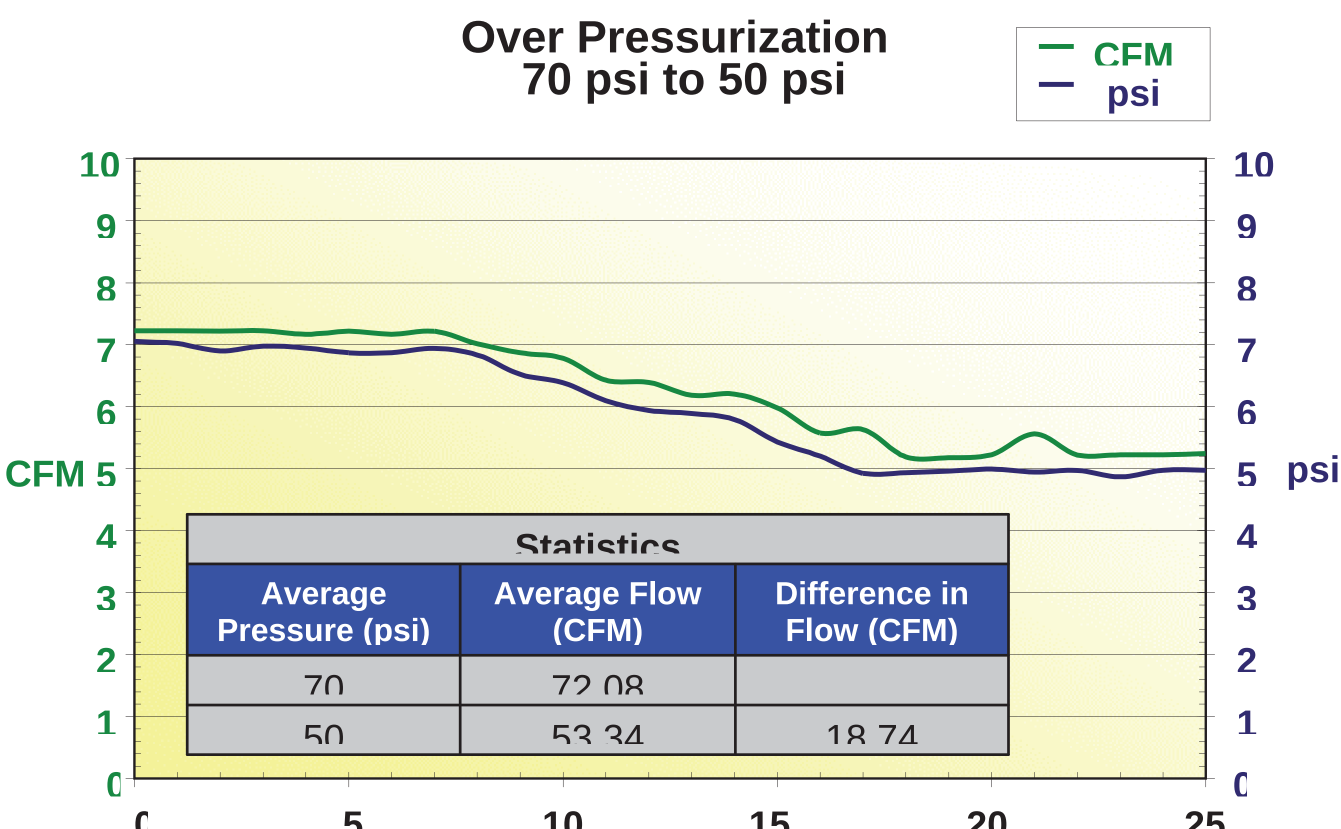
This picture illustrates pressure gauge that has been marked to depict the pressure settings that should be required. The gauge has a sticker labeled '80 PSI' but is actually set to 112 psi.

Some gauges have a pie slice on the gauge cover to mark the correct required pressure.



To better understand the full effects of over-pressurizing an entire plant we will examine the costs associated with one piece of equipment. In the charts below, the cost of operating a piece of equipment is illustrated at 70 psi versus 50 psi.

Turning pressure up beyond what the OEM recommends will never help a process; it will only cost the facility additional money.



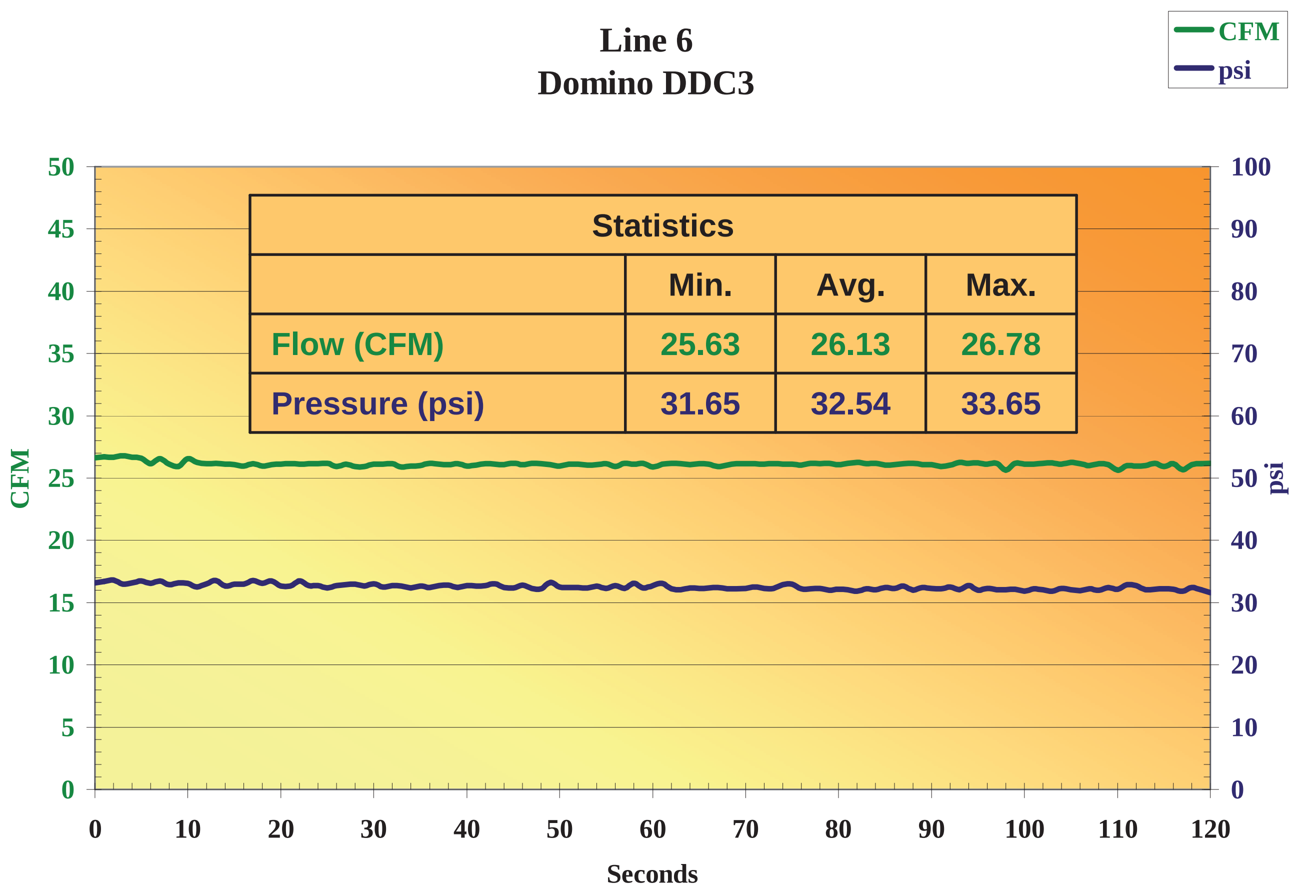
Statistics		
Average Pressure (psi)	Average Flow (CFM)	Difference in Flow (CFM)
70	72.08	
50	53.34	18.74

Case Study – Domino DDC3

Domino DDC3 (DOT Matrix Laser)
According to Domino, these units have a built in purge system that is designed to serve two purposes. First, the purge line flows to the inside of the encoder where the compressed air cools the 7 lasers found inside. The purge can also be used as a cleaning utility to keep dust and particulate free from the unit. This purge is required in two settings, one where heavy dirt and particulates are present, or in industry that is using the laser encoder on a high speed continual application. The DDC3 is not sold with any sort air prep equipment (i.e. filter, regulator, shut off valve, etc.), but are available as a special if the customer so chooses. Being that there is no regulatory device standard on the unit, Domino does not have a published equipment requirement for pressure setting.

According to Domino, supply pressure is not a requirement for the DDC3 – flow is. This unit requires 4 to 7 CFM to effectively cool / clean the encoder. This particular unit (pictured above) is flowing far more than that. On the following page is a flow and pressure study that will further investigate this unit.

As previously mentioned, the DDC3 is rated to flow 4 to 7 CFM, yet this data portrays another story. In this particular example the laser encoder was flowing approximately 19 CFM beyond what it is specified to. Compressed air was used on this application for two specific functions – cleaning and cooling; doing so through an open ¼" piece of tubing that fed into the back of the encoder. There were many of these encoders noticed during the Nestlé Waters audits in 2009 that were being used. It should be noted that these applications were running intermittently when identified, and should be depressurized when not necessary. Continually running applications similar to this are discussed in greater detail in the "Intermittent Demand" section of this report. **Annual Air Consumption Beyond Requirement = 19 CFM**



Statistics			
	Min.	Avg.	Max.
Flow (CFM)	25.63	26.13	26.78
Pressure (psi)	31.65	32.54	33.65

Intermittent Demand

Intermittent Demand and Idling
Intermittent demand is an issue in every facility we audit and is one of the top ten wasteful uses of compressed air. If OEM equipment is not in operation, then supplying compressed air is often not required. Even a very small hole blowing off a work piece can cost thousands of dollars per year in energy. Shutting off compressed air when equipment is not in operation will also isolate any potential air leaks.

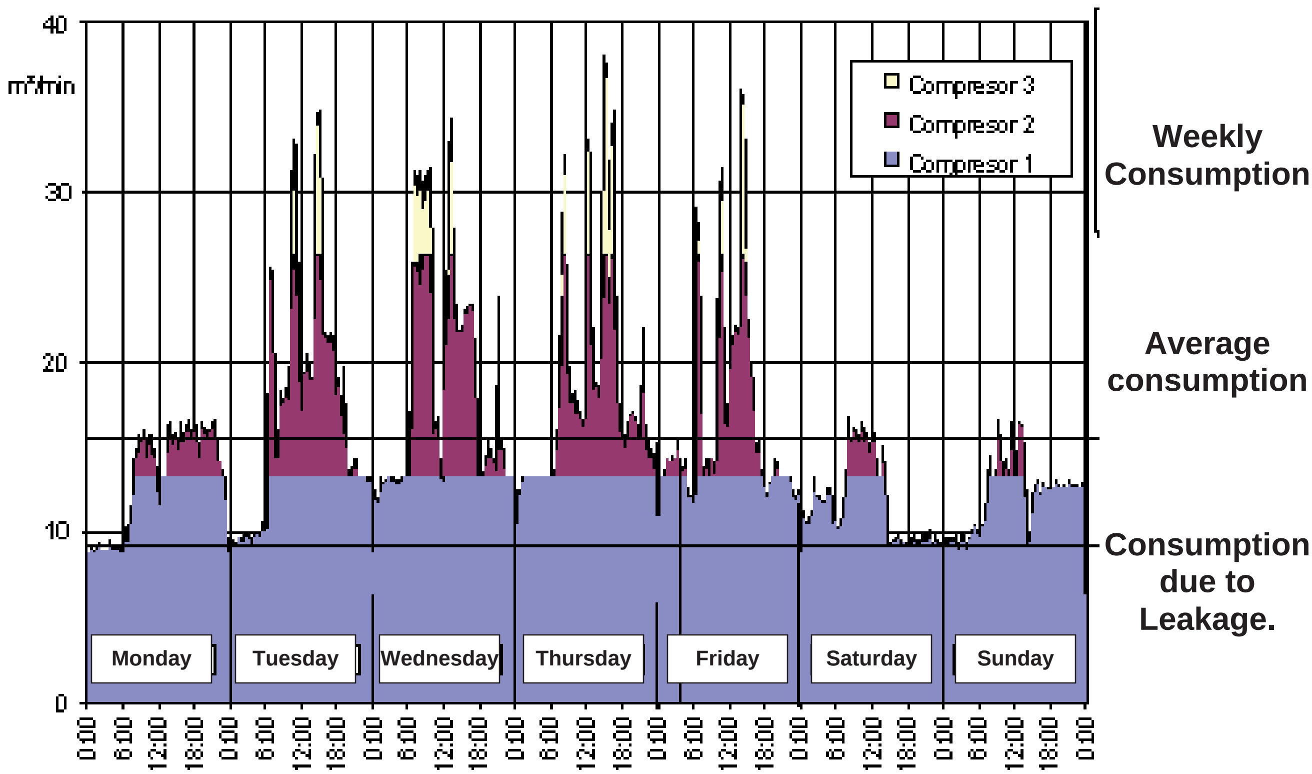
Intermittent Demand Macro Example – When reviewing a plant wide flow study, intermittent demand may be depicted as a compressor(s) operating to meet a zero production demand, leak load, air blow and inappropriate uses.
Intermittent Demand Micro Example – On a single piece of OEM equipment, intermittent demand is equipment leaking while an operator stops production equipment from running during a product change over, preventative maintenance or scheduled operator breaks. Additionally, air blow, purging and vacuum are examples of systems that may not be required to operate if production has paused or shut down for an extended period.

Whether it is a macro or micro problem, intermittent demand or idling can be a significant draw on a compressed air system. The Compressed Air and Gas Institute (CAGI) says the maintainable leak load goal of any facility should be approximately 8% of the total flow. Assuming the facility is operating at that extremely efficient level, the plant can still save 8% of the total flow by simply turning off supply air when equipment is not in use.

It is important to set up machinery so that non-required compressed air, nitrogen and CO_2 automatically stops being delivered to equipment to prevent one of the top ten ways to waste compressed air, equipment idling. If OEM equipment is not required to operate, then supplying compressed air, nitrogen or CO_2 is most likely not required.

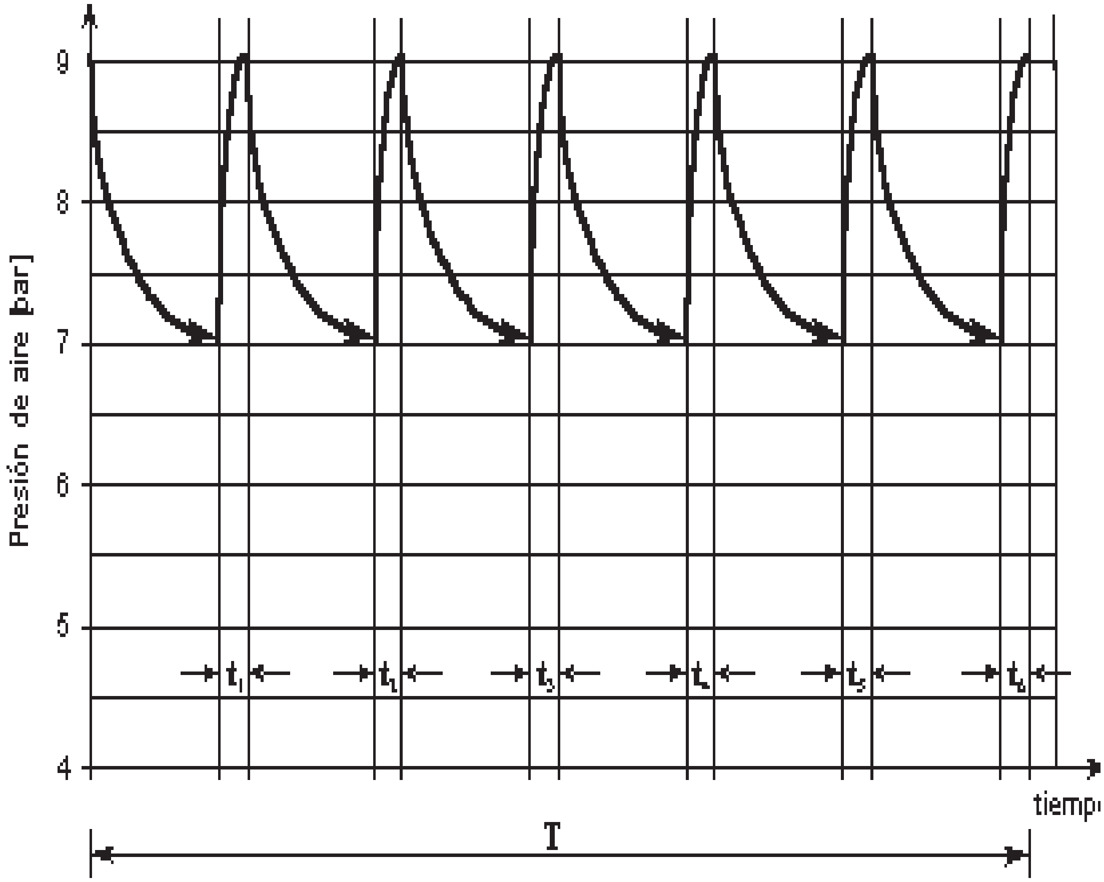
Intermittent Demand Testing

The compressor may be on continuous operation due to air leaks.



Calculating Leakage

Test and formula to calculate leakage on a pneumatic system.



$$V_L = \frac{V_c \times t}{T}$$

Where:

$V_L = Leakage$ $(m^3/\min)$

$V_c = Flow\ from\ compressor$ $(m^3/\min)$

t = $t_1 + t_2 + t_3 + \ldots$ *(Compressor working times)*

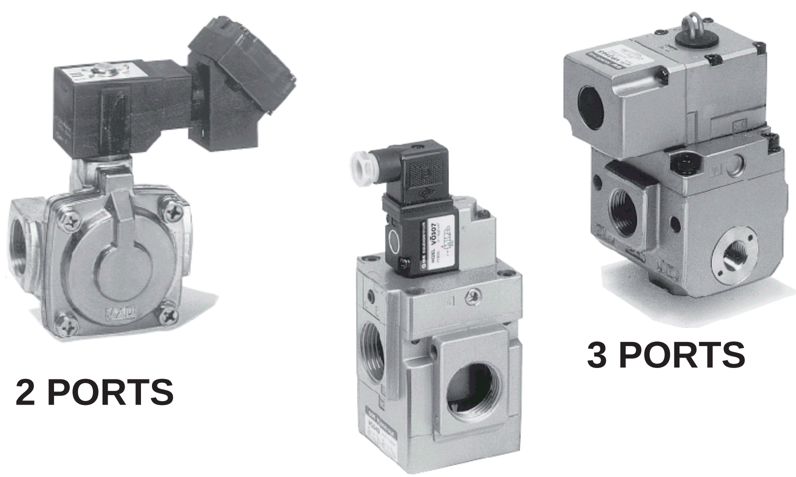
and *T = Total time*

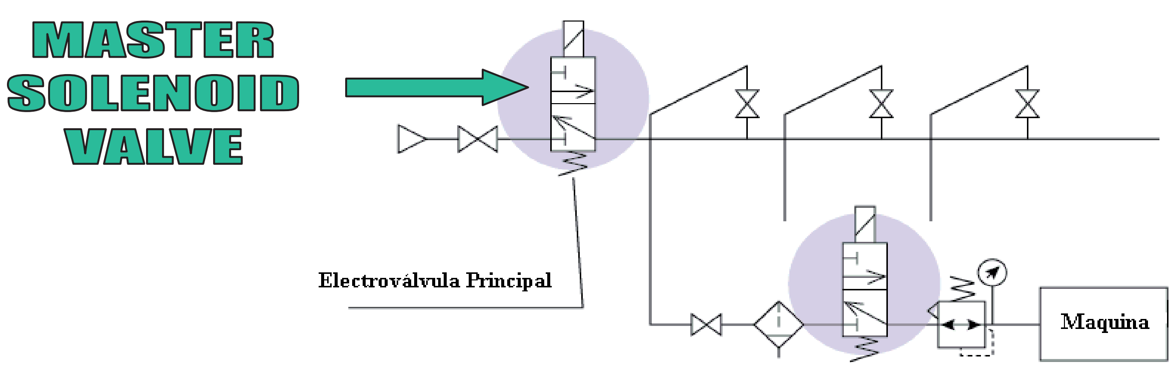
Solutions

- Intermittent demand is an issue in every facility.
- In most cases, if OEM equipment is not running then compressed air should not be supplied.
- There are simple, cost-effective ways to solve common intermittent demand issues:
- Use a two-way valve that shuts air off to equipment when no work piece is present.
- Use a mechanical valve that actuates when a work piece is present.

Using a master solenoid valve, the air supply to the equipment can be stopped when it is not in operation.

WE ARE ABLE TO REDUCE AIR CONSUMPTION DURING NON-OPERATION PERIODS (WEEKENDS,…) 100% BY INSTALLING SOLENOID VALVES ON EACH AIR LINE.

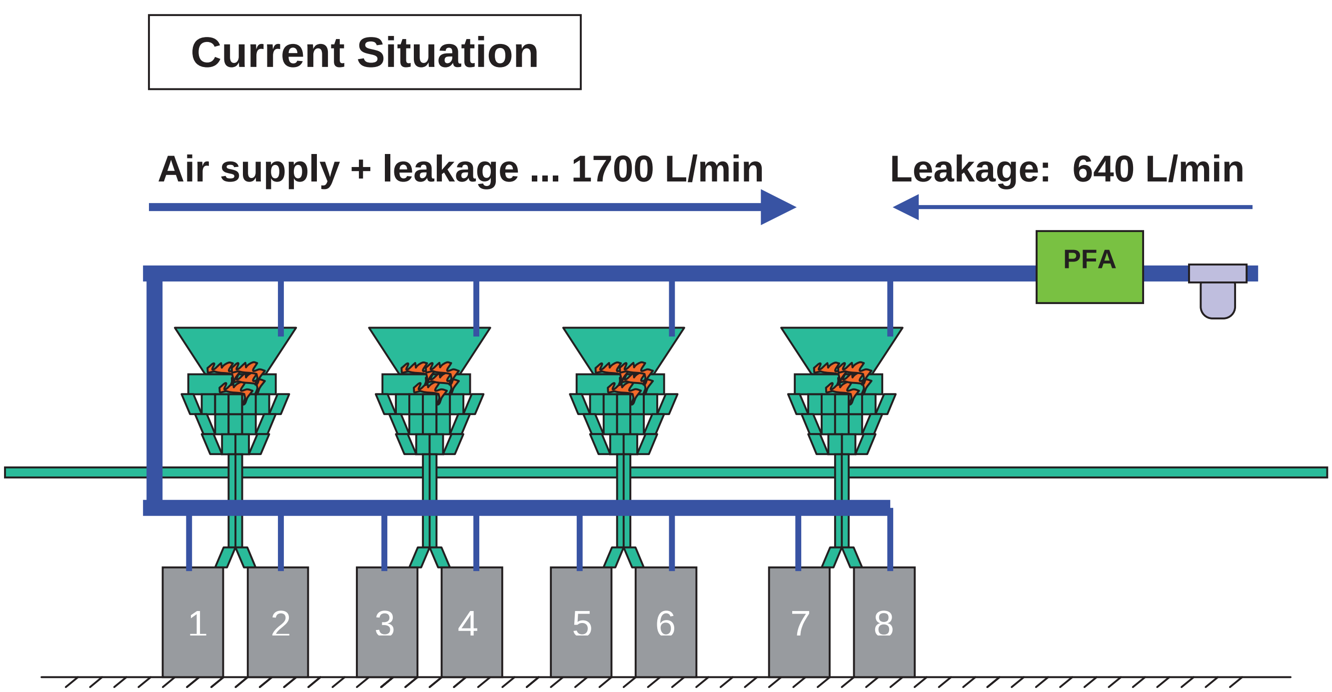




Case Study- Bottling Line
Cap Feeder

- Multiple air blow jets are used on cap feeders to assist in feeding the caps into a capper. When the capper stops the air blow continues to run, consuming 20 CFM.
- A high level sensor could send a signal to a valve that would shut air off when the capper stops.
- Suppose this happens 5 minutes of every 1-hour or 730 hours per year on 10 different cappers throughout a plant.
- This equates to $303 per year per capper, **$3,030** per year for all cappers in the plant!

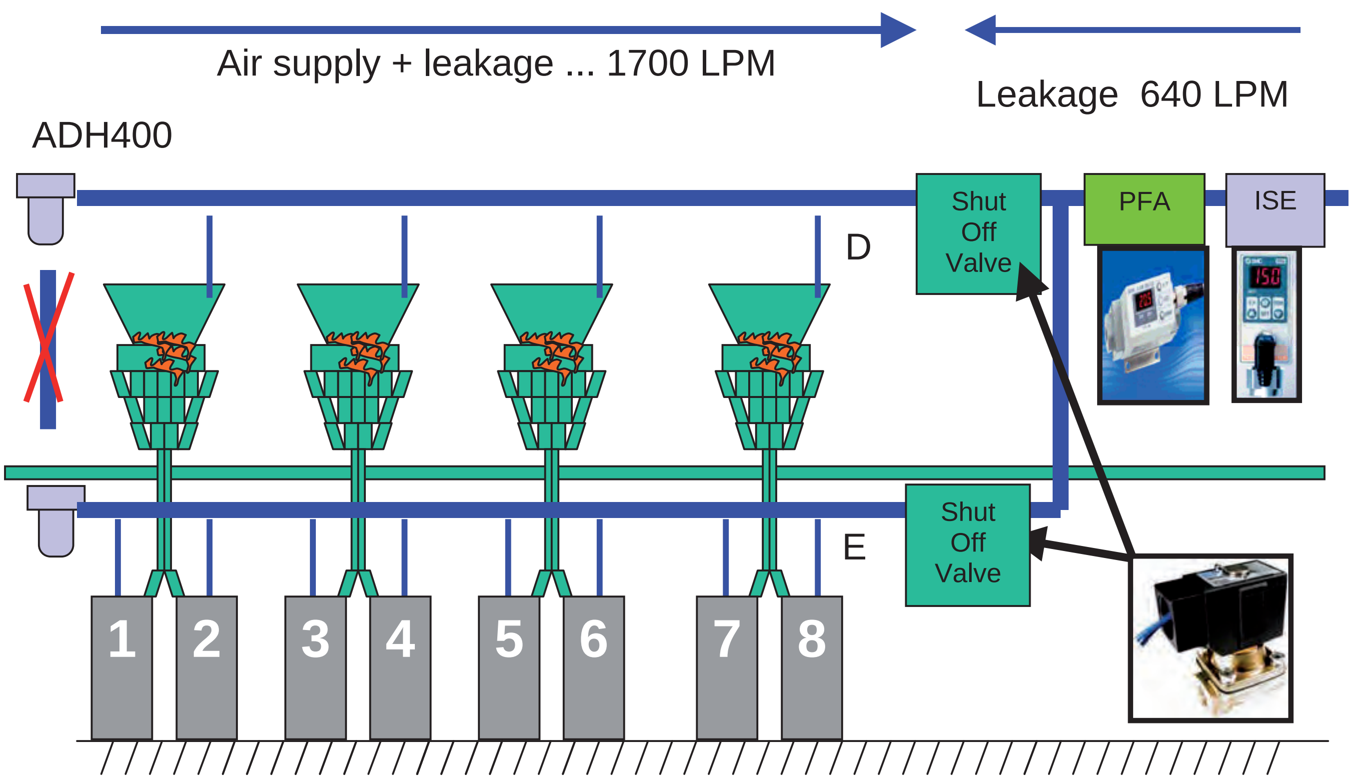
Case Study- Snack Line



Product flow Line Snack Chips

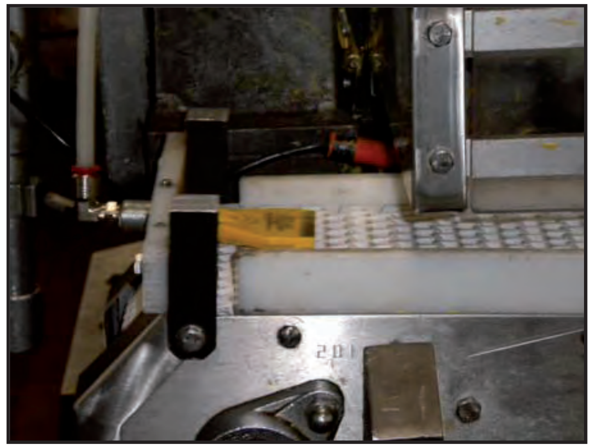
- 640 liter/min is 22.60 CFM.
- To make it HP we need to divide by 4.5, which equals: 5.02 HP.
- Using a cost per Kwh of .14 and hours of operation at 8760 (24/7/365) the cost is $5,103 for leaks per packaging line.
- 8 packaging lines in this plant equates to **$40,824** per year for all packaging lines in the plant!
- Without fixing any leaks and only shutting off the air during shut-down, will provide **$13,607 in savings!**

SMC Proposition

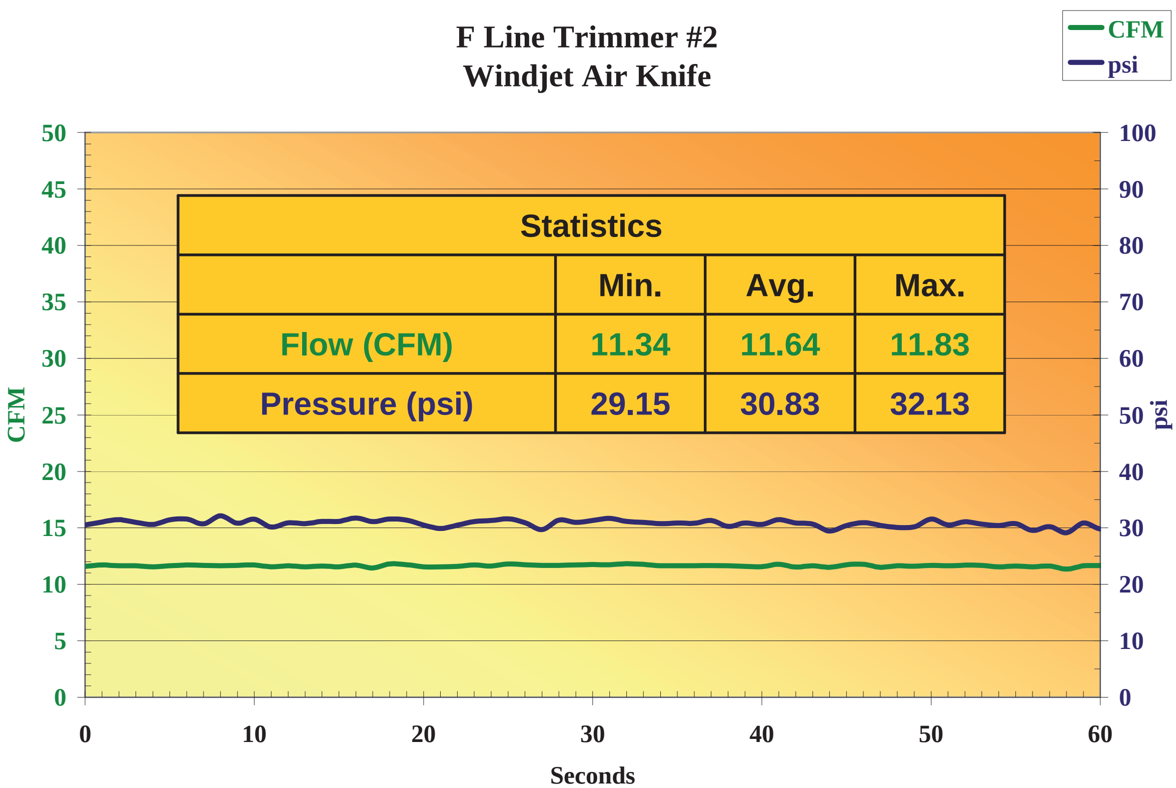


Product flow Line Snack Chips

Case Study – Air Knife



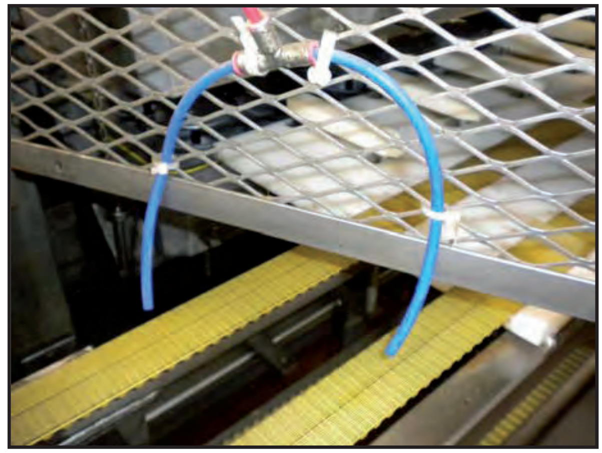
On the 4th Floor Line F Cutters there is a Lechler air knife and a Windjet air knife blowing to keep packages together as they move down the line. The knives are regulated down, but they are far away from product. If moved closer, they can possibly be regulated even lower, which in turn uses less energy. On the other hand, because the knives are so far away there is very little impact pressure, which questions the necessity of these knives. What is known is that these knives are blowing continuously even when the trimmer is not running and can be controlled by a solenoid valve when not required.



Statistics			
	Min.	Avg.	Max.
Flow (CFM)	11.34	11.64	11.83
Pressure (psi)	29.15	30.83	32.13

Case Study – Air Blow

4th Floor Line F1
There are two ¼" tubes running from a union tee fitting blowing air on the conveyor on line F1. This air is blowing continually, and was noticed blowing even when the line was down.
Air Consumption = 30.00 CFM



4th Floor – Line D Pack Cutter
As discussed in the air blow section, downstream of the pack cutter there are two air blow applications in use. Both applications are blowing constantly and are consuming an abundance of air.
Air Consumption = 34.37 CFM

4th Floor – Line D Box Filler
There are two Silvent air knives blowing to hold packages against the rail on line D. One is pointed correctly, and one is missing, however both are running constantly.
Air Consumption = 37.30 CFM

Case Study – Intermittent Demand Summary

The ECG noted 178.55 CFM worth of intermittent demand during the audit. Due to the sporadic nature of intermittent demand, examples are easy to miss when not in a plant on a full-time basis. However, 1,600 CFM in waste is illustrated in the flow and pressure analysis on the down days of the facility. The good news is that there is an easy way to control this intermittent waste. A low energy use solenoid valve that, when used in conjunction with a controller like a laser sensor, can easily control this waste. Below is a hypothetical example of the cost of intermittent demand.

	Intermittent Demand Applications	
1	4th Floor - Line F1 - 2 nozzles	5.84 CFM
2	4th Floor - Line F1 - 1/4" tube (2) blowing @ 40 psi	20.46 CFM
3	4th Floor - Line F Cutters - 1 Lechler/1 Windjet	11.64 CFM
3	4th Floor - Line G Package Cutter - Windjet 727-15 @ line pressure	14.57 CFM
5	7th Floor - Line E Pack Filler Belt - Air bar & 1/4" orifices (2) @ line pressure	34.37 CFM
6	4th Floor - Line D Pack Cutter - Lechler knife & 1/4" orifice	34.37 CFM
7	4th Floor - Line D Box Filler - 2 air knives	37.30 CFM
8	6th Floor - Line 3 - Air blow bar (27 holes)	20.00 CFM

Case Study – Hypothetical Cost

The Hypothetical Cost of Intermittent Demand
The current demand - The current annual cost of operation of the second example in the table above or line F1's ¼" tubing blowing at 40 psi is $1,541 (operating 24 hours a day 365 days a year). The true demand - Hypothetically, if this line only is required to run 16 hours per day (5,840 hours per year) because of downtime for breaks, maintenance, etc. the annual cost of operation without scheduled intermittent demand is $1,028. The savings - Since air blow is not required to operate when the line is down, the cost needs to be evaluated minus the 2,920 scheduled hours of down time on line F1 per year. The savings based on this intermittent demand is $513.

Intermittent Demand Return on Investment Example	
Line F1's air blow cost of annual operation	**$1,541**
Line F1's hypothetical cost of annual operation	**$1,028**
Cost of SMC VXE valve (PN- VXE2360B-04N-5DL1) Reduces air blow annual operation by 5616 hours	**$79.35**
Total Savings Year One	**$433.65**

Inappropriate Usage

Inappropriate uses are the applications that can be done more effectively or more efficiently by a method other than compressed air. Because it is a clean, readily available, and simple to use energy source, compressed air is often used before its true costs are taken into account. Many operations can be accomplished more economically using alternative energy sources. Air blow and air tools are included in this category but are addressed in other sections.

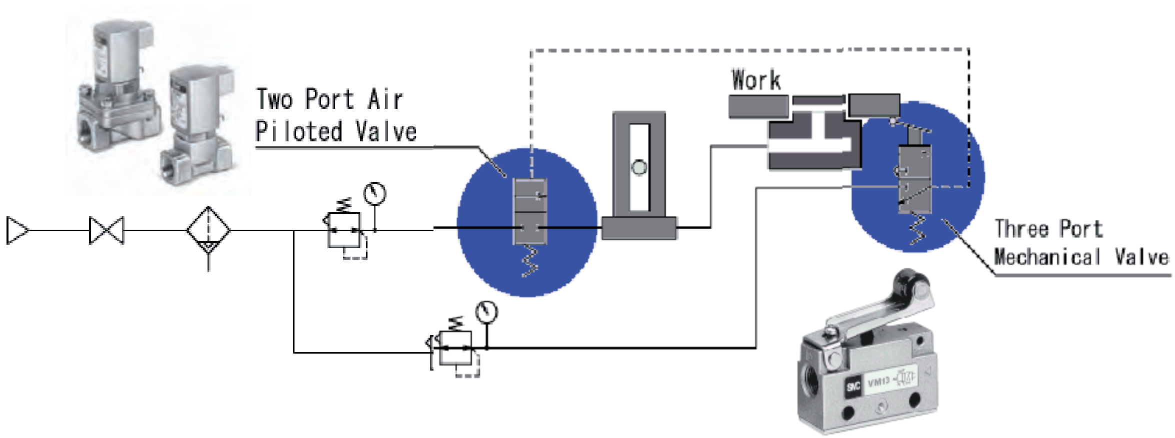
Examples:

- Air blowing
- Air tools
- Air purging
- Paint stirring
- Cabinet cooling
- Vacuum generators
- Liquid removal.

In previous sections, we've discussed air blowing without nozzles. We also looked at excessive pressure use in air blow and air tool applications. Now we'll review another wasteful use of compressed air.

Air Purging

Work precision is often measured using an air micro gauge that purges air whether work is present or not.

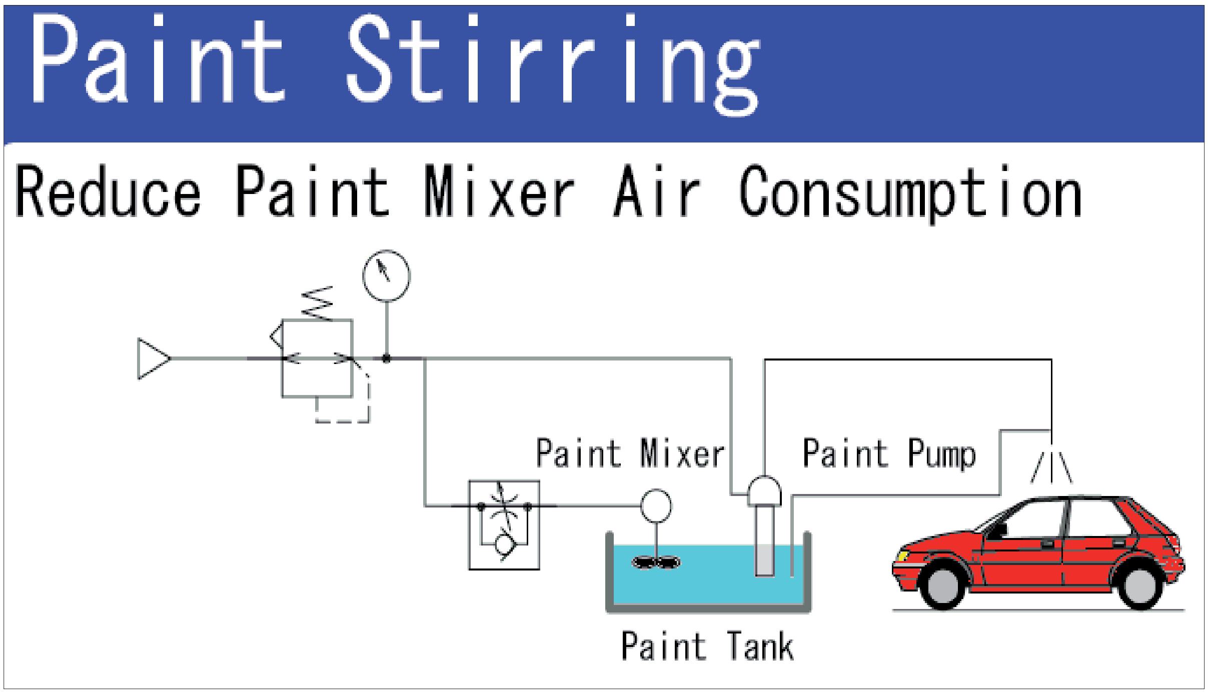


Up to 95% of purging air can be conserved using a VM three port mechanical valve circuit.

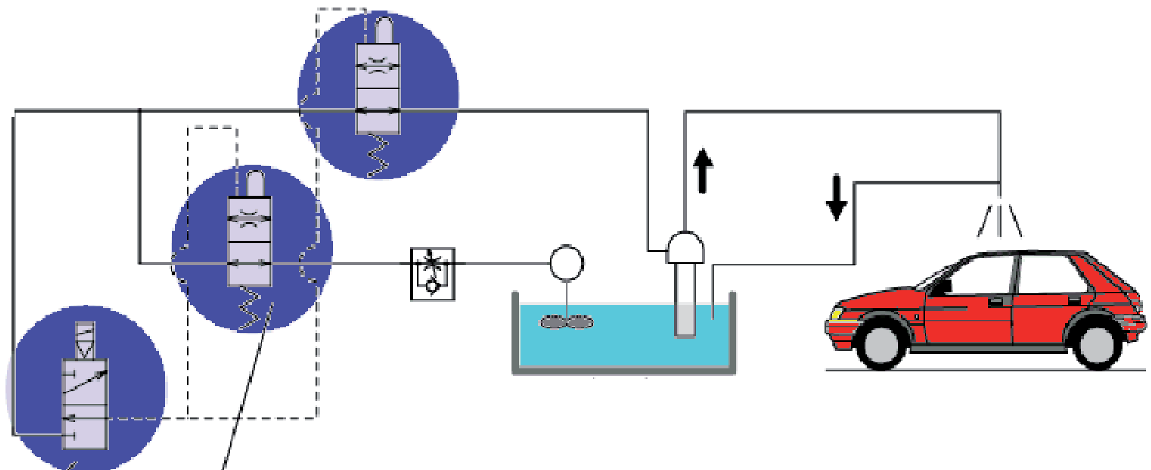
The workpiece contacts the roller-lever on the 3-port valve and activates the supply to the air gauge. Alternatively, the operator can use a mechanical pushbutton.

Paint Stirring

Paint in a painting booth must be continually stirred so that it does not harden. This means that air is consumed by the paint mixer even during line stoppage.



The Circuit shown below was designed for maximum air conservation in air motor paint stirring applications by changing the airflow rate according to line operation.



The flow switching VKFA, 2 port air operated metering valve (special order) makes conservation possible.

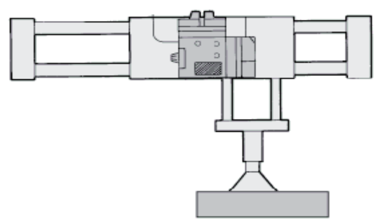
3-port, pilot-type solenoid valve

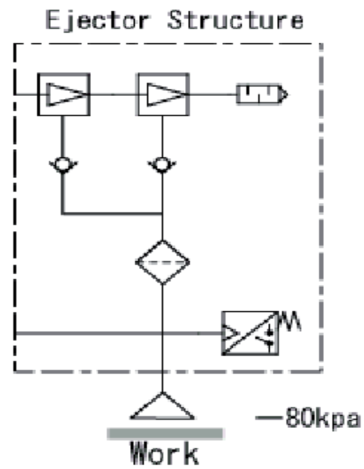
Vacuum Ejectors

A check valve ejector can hold work while the air source is cut.
50-75% of air can be conserved.

Vacuum

Reduce air consumption of ejectors with transfer vacuum





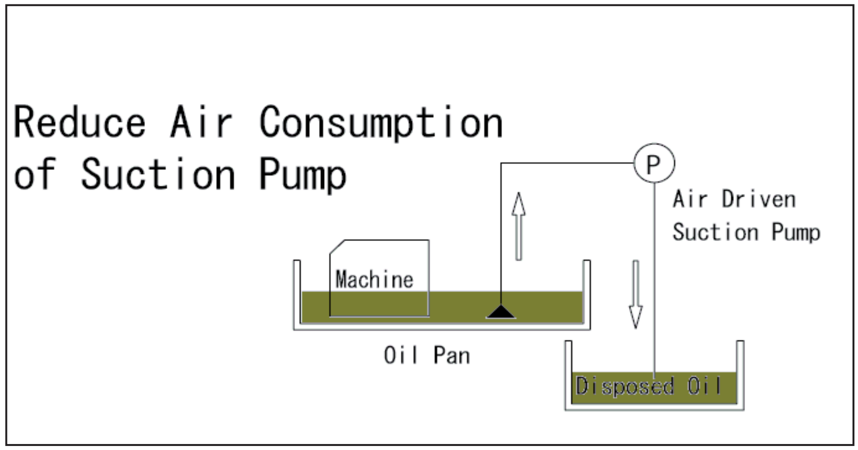
When leakage occurs, multi-staged ejectors can save up to 58% of single stage ejectors air consumption.

The ZL series vacuum ejector has an energy-saving three stage diffuser construction which increases flow rate 250% while decreasing air consumption by 20% (Versus ø1.3, one stage model)

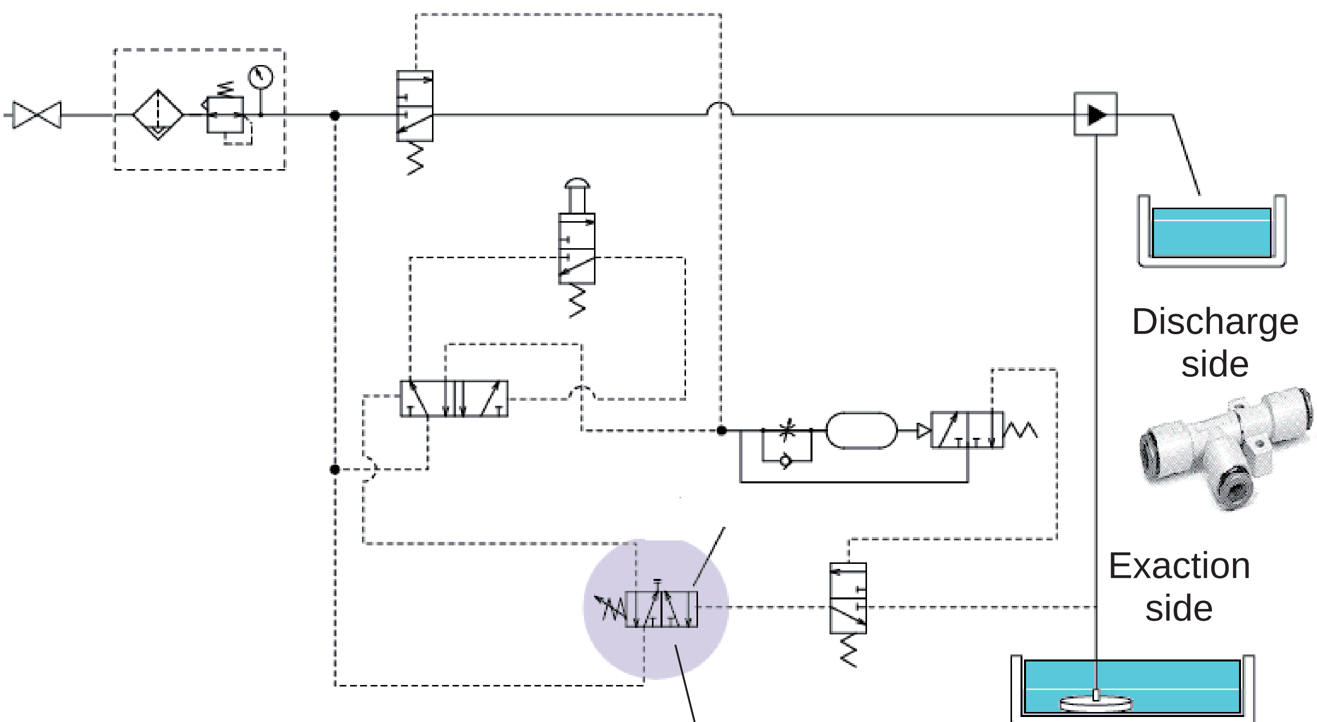
Available with integrated vacuum gauge or digital vacuum pressure gauge and integrated release valve.

Liquid Removal

Reduce air consumption for oil collecting/recycling applications. Use SMC’s ZU linear vacuum ejector for oil based coolant removal versus a coolant pump.



The circuit should be designed so that vacuum stops when no liquid is present. Clogging is prevented due to ejector non-check valve structure.



Negative pressure detection valve XT-92-65 (Special order item)

Case Study – Inappropriate Usage

For this particular customer, two examples of inappropriate usage were discovered.

- Point of use air dryers
- Domino LASER encoders

Point of Use Dryers

There are six Domnick Hunter Pneudri DM025P point of use dryers at Anheuser Busch St. Louis. These dryers are rated to dry to -40ºF dewpoints. Are these dryers necessary? These are rated as the same dewpoint rating of the mainline dryers installed in the compressor rooms.

In the, “Dryer and Dewpoint,” section of this report, the dewpoint was shown to be exceptional by the tests conducted during the audit. If the dryers in the compressor rooms are working as they should, running these dryers is unnecessary. According to Domnick Hunter, these dryers are rated for 52.97 CFM at 100 psi, 68ºF and 0% relative water vapor pressure, and consume 19% of their flow, or 10.07 CFM, when running.

There is already a backup mainline dryer system in place, and as previously stated, the existing dryer system is producing amazingly dry air already. These dryers should be removed and completely bypassed. By installing a properly reading mainline hygrometer coupled with an alarm to the already superbly operating dryer system, the plant will have no need for such a point of use dryer.

Pictured below is one of the Domino S300+ Sealed CO2 Laser Encoders found at Anheuser Busch St. Louis. These units have a built in purge system that is designed (according to Domino) to serve two purposes. First, the purge line flows as an open orifice to the inside of the encoder where the compressed air cools the 7 lasers found inside. The purge is/can also be used as a cleaning utility to keep the unit dust and particulate free.

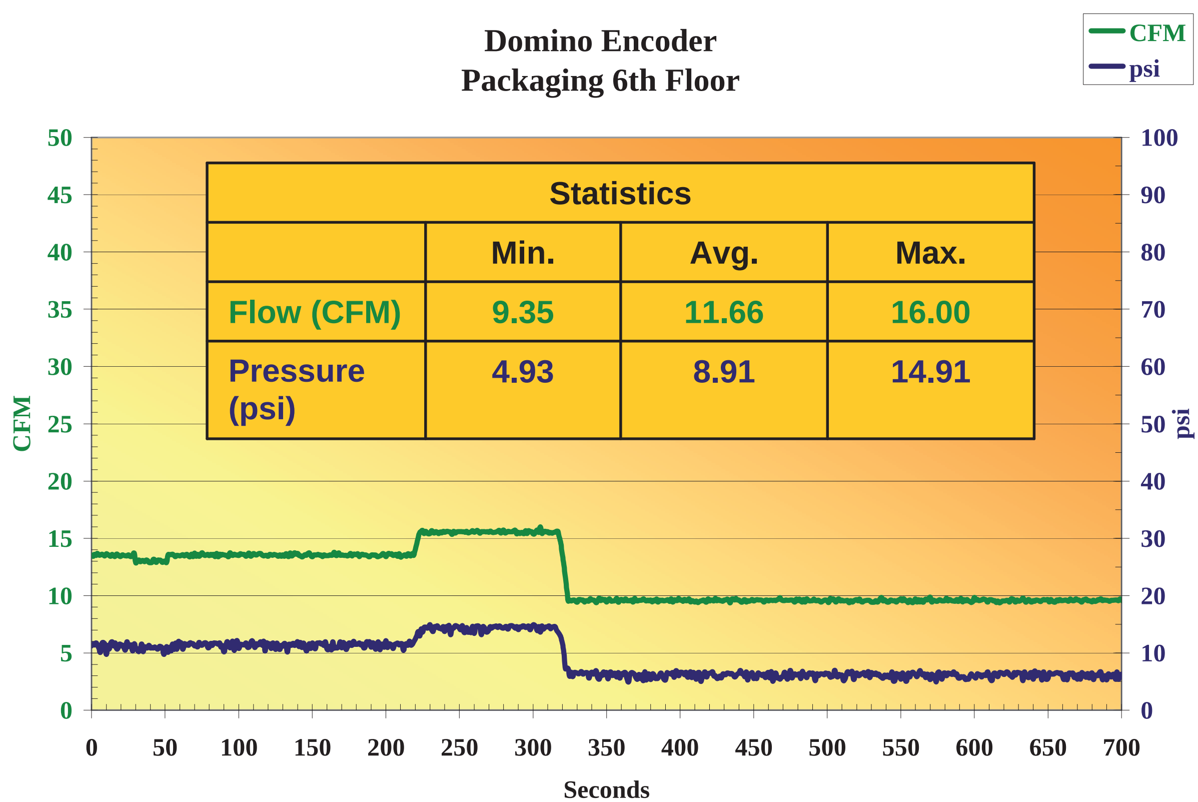
According to Domino, this purge is only required in two settings. First, where heavy dirt and particulate are present, and can harm the unit. Second, in an industry that is using the laser encoder on a high speed continual application, as used at AB St. Louis. The S300+ is not sold (stock) with any sort of air preparation equipment, i.e. filter, regulator, shut off valve, etc. These units are available if requested by the customer. Being that there is no regulatory device standard on the unit, Domino does not have a published equipment requirement for pressure setting.

According to Domino, supply pressure is not a requirement for the S300+, however flow is. This unit requires 7 CFM to effectively cool / clean the encoder. Any flow in excess of 7 CFM is waste, and this particular unit (pictured above) is flowing at a higher rate. On the following page is a flow and pressure study that will further investigate this unit.

As previously mentioned, the S300+ is rated to flow at 7 CFM, but the data recorded shows otherwise. At the line on the 6th floor of packaging, the laser encoder is flowing approximately 7 CFM above and beyond what it is specified to. Compressed air is used on this application for two specific functions – cleaning and cooling. This is accomplished through an open ¼" piece of tubing that feeds into the back of the encoder. It is important to note that the regulator is not reading the correct pressure. It is constantly reading about 6 psi higher than the actual pressure.

These encoders are present throughout packaging at AB St. Louis, and according to the facility there are approximately 10 of these running at any given time. Below is an example of just how costly this can be:

Air Consumption Beyond Requirement = 7 CFM = $448 x 10 **= $4,480** annually



Statistics			
	Min.	Avg.	Max.
Flow (CFM)	9.35	11.66	16.00
Pressure (psi)	4.93	8.91	14.91

Design Mistakes

As we know, actuators typically consume 60% of the compressed air in a manufacturing facility, so designing a system correctly and efficiently are of utmost importance.

Examples of design mistakes include, but are not limited to:

- Using double-acting instead of single-acting cylinders
- Excessive tubing length.
- Applying higher pressure than needed

Cylinder Consumption

- Cylinders are used in manufacturing plants for many different applications. Often times operating costs are not considered when cylinder selection occurs.
- Selecting the correct bore size/pressure combination for the application can save energy.

For example:

- A rotary filler has 163, 32mm bore cylinders (12 mm rod, 100 mm stroke) operating at 60 PSI. One cylinder produces 74.71 ft-Lb of force, consuming 0.805 CFM and costing $146.20 per year in compressed air costs at 30 cycles per minute.
- An air study is performed and it is discovered that a 25 mm bore cylinder (100 mm stroke, 10 mm rod) operating at 100 PSI will produce the same required force. This cylinder consumes 0.359 CFM less than the 32 mm bore cylinder.
- Annual savings realized is **$10,623 per filler!**

In this particular example, a smaller bore cylinder, using higher pressure, will cost less than the actuators and pressure originally selected. This may not always be the case. It is important to do the math and compare several possibilities, in order to find the most efficient combination. Review the following table for example.

Cylinder Consumption Analysis

Choosing The Correct Cylinder

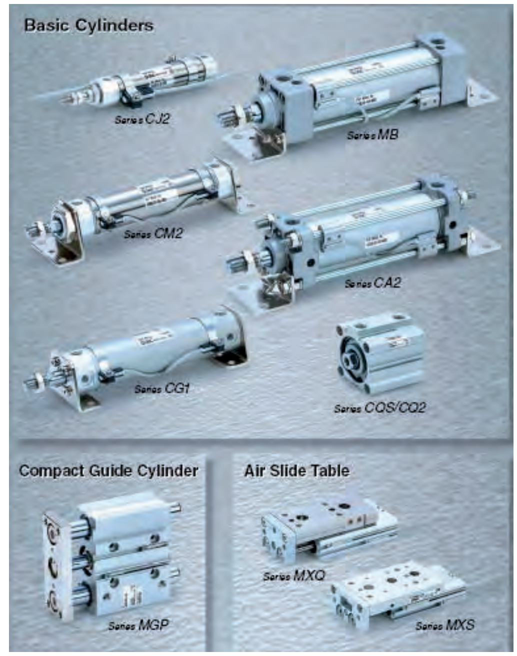
Bore & Rod Diameter	Pressure (PSI)	Force (Ft-Lb)	Flow (CFM)	Annual Cost of Operation ($)
20 mm Bore, 8 mm Rod	100	48.65	0.48	$86.64
vs.				
25 mm Bore, 10 mm Rod	60	45.63	0.29	**$52.70**
****Increasing the cylinder size and lowering the pressure saves energy costs!**				
32 mm Bore, 12 mm Rod	100	124.69	1.237	**$224.39**
vs.				
40 mm Bore, 16 mm Rod	60	116.75	1.243	$225.71
****Decreasing the cylinder size and increasing pressure saves energy costs!**				

*Calculations based upon 100 mm stroke, 30 cycles/min, 8,760 hours of operation, 4 CFM/BHP and 90% motor efficiency

SMC has standard cylinders with a range of 20 bore sizes!

Series	Bore size
CJ2 	6
	10
	16
CM2 	20
	25
	32
	40
CG1 	20
	25
	32
	40
	50
	63
	80
	100
MB(ø32-ø125) 	32
	40
	50
CA2(ø40-ø100) 	63
	80
	100
	125
CQS(ø12-ø25) 	12
	16
	20
	25
	32
	40
	50
CQ2(ø12-ø200) 	63
	80
	100
	125
	140
	160
	180
	200

Series	Bore size
C85 	8
	10
	12
	16
	20
	25
C76 	32
	40
C95 	32
	40
	50
	63
	80
	100
	125
	160
	200
	250
CP95 	32
	40
	50
	63
	80
	100

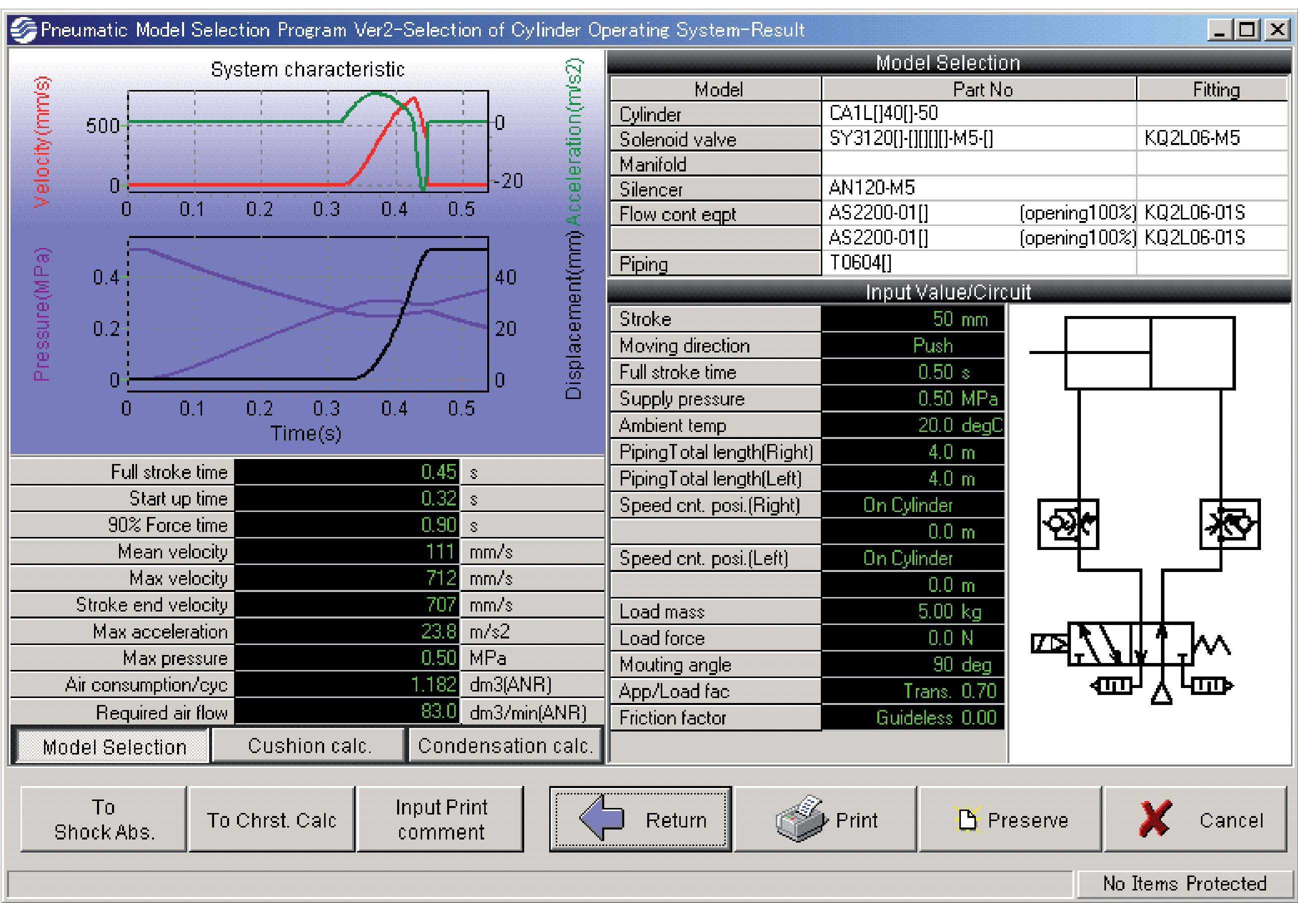


Series	Bore size mm
MXS 	6 x 2
	8 x 2
	12 x 2
	16 x 2
	20 x 2
	25 x 2
MXQ 	6 x 2
	8 x 2
	12 x 2
	16 x 2
	20 x 2
	25 x 2

Series	Bore size mm
MGP 	12
	16
	20
	25
	32
	40
	50
	63
	80
	100

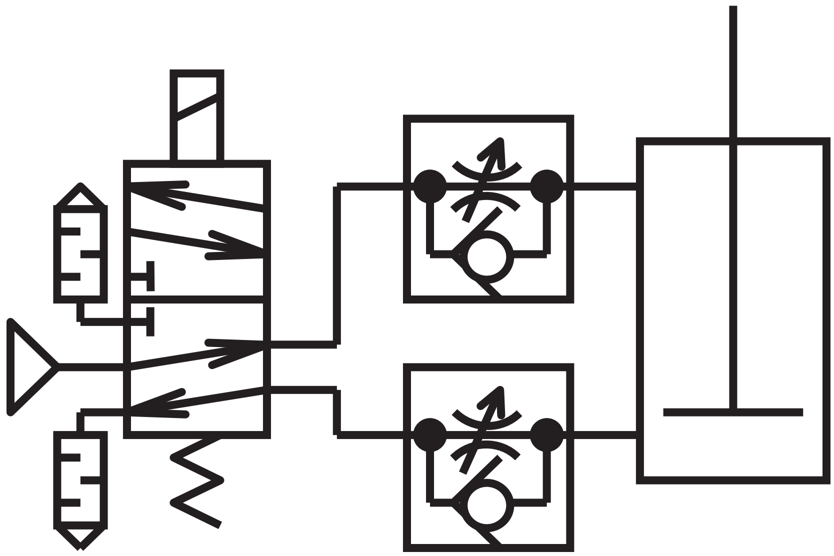
Model Selection Program-Output Screen

We developed highly accurate model selection method based on dynamic characteristics simulation.
In this method, first, operating circuit is configured on input screen and then the requirements such as load type, required time and stroke are entered.
The output screen in this figure shows a combination of suitable models of cylinder, solenoid valve, speed control valve, etc.
The selection result is always a combination of minimum units which correspond to total energy minimum.
Also, response curves and main characteristic values of this operating system are indicated.



Pneumatic Cylinder Driving System

The next is cylinder-driving system.
Cylinder movement is intermittent and therefore it is essential to realize “Energy Minimization”.



When it comes to energy conservation, we have to consider the entire system, not just the actuator being utilized. Next, we’ll take a look at the valve conductance and air consumption.

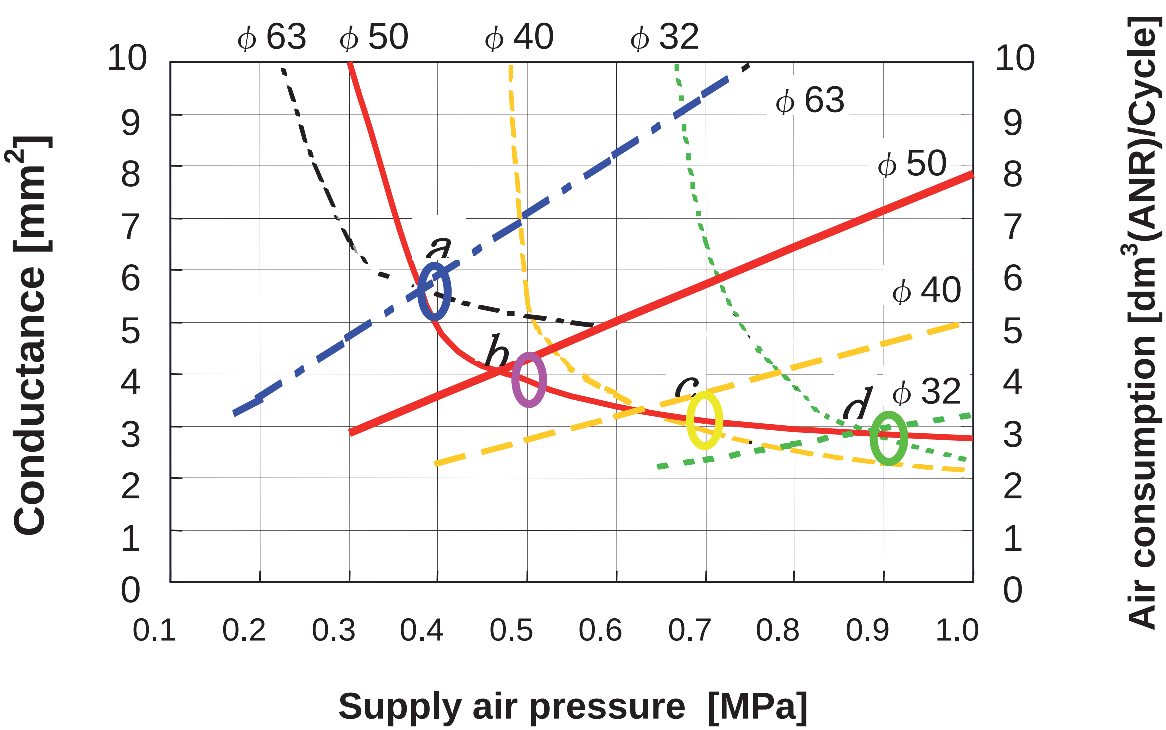
Cost Minimization

The following figure shows an example of horizontal movement in with certain specifications.

- Horizontal drive
- a mass of 300kg
- a stroke of 200mm
- full stroke time 1second.

The **Initial cost** of driving circuit is determined by conductance (size) of the solenoid valves and **running cost** is determined by air consumption.

If the cylinder bore size is 50 mm, using lower pressure, air consumption is less but large conductance is needed.
In higher pressure conditions, air consumption is more but a smaller conductance is needed.
We can say that around intersection "*b*" of curves is the optimum driving conditions.

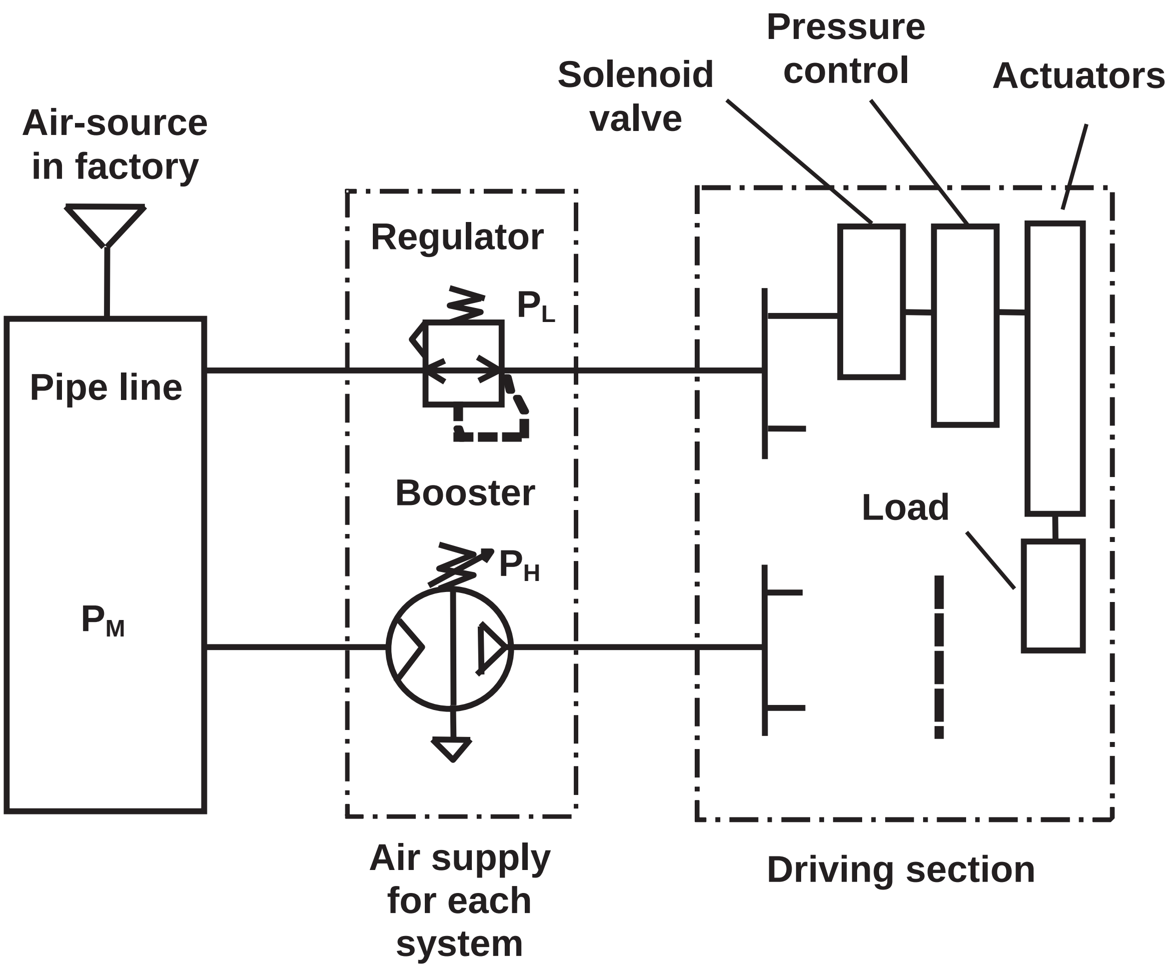


Similar characteristic values of optimum intersection are collected in this Table*.
As points move in order of *a*, *b*, *c*, *d*, circuit shall be with smaller cylinder bore sizes, smaller conductance // and load ratio becomes larger and air consumption becomes less.
If this is totally evaluated, including cushioning mechanism, we can get optimum index of total energy minimum.

Point	a	b	c	d
Supply air pressure (MPa)	0.4	0.5	0.7	0.9
Cylinder bore size (mm)	63	50	40	32
Conductance of valve (mm^2)	5.5	3.9	2.9	2.8
Air Consumption (dm^2 (ANR)/cycle)	5.9	4.3	3.7	3.0
Load ratio (%)	24	30	33	41

The right pressure in the right place.

As shown in this figure, the pneumatic system has constant-pressure source and it is easy to set the optimum power level for each unit by using pressure regulators and booster regulators.



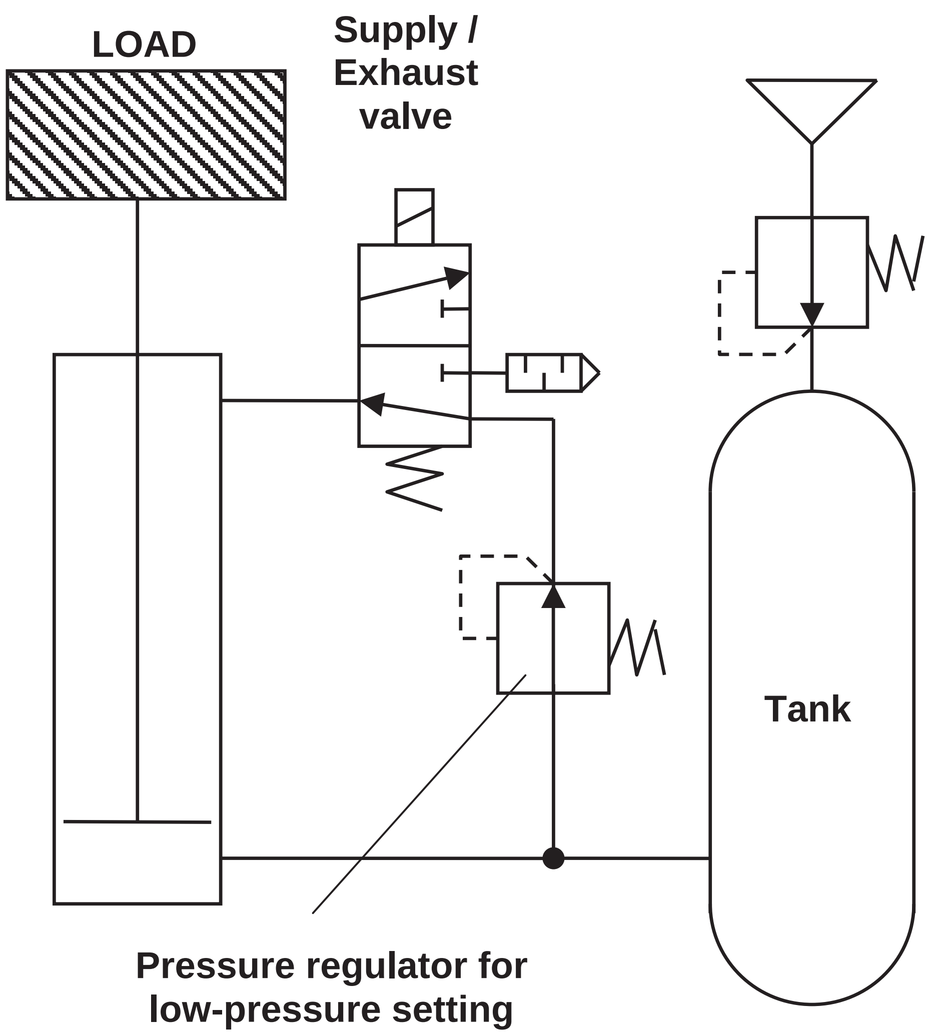
Energy Saving Lifter

This Fig.* shows energy saving lifter which lifts and takes down heavy load.

Compressed air in under chamber of cylinder // shall be balanced with heavy load and shall not be exhausted, it only goes and returns from tank.

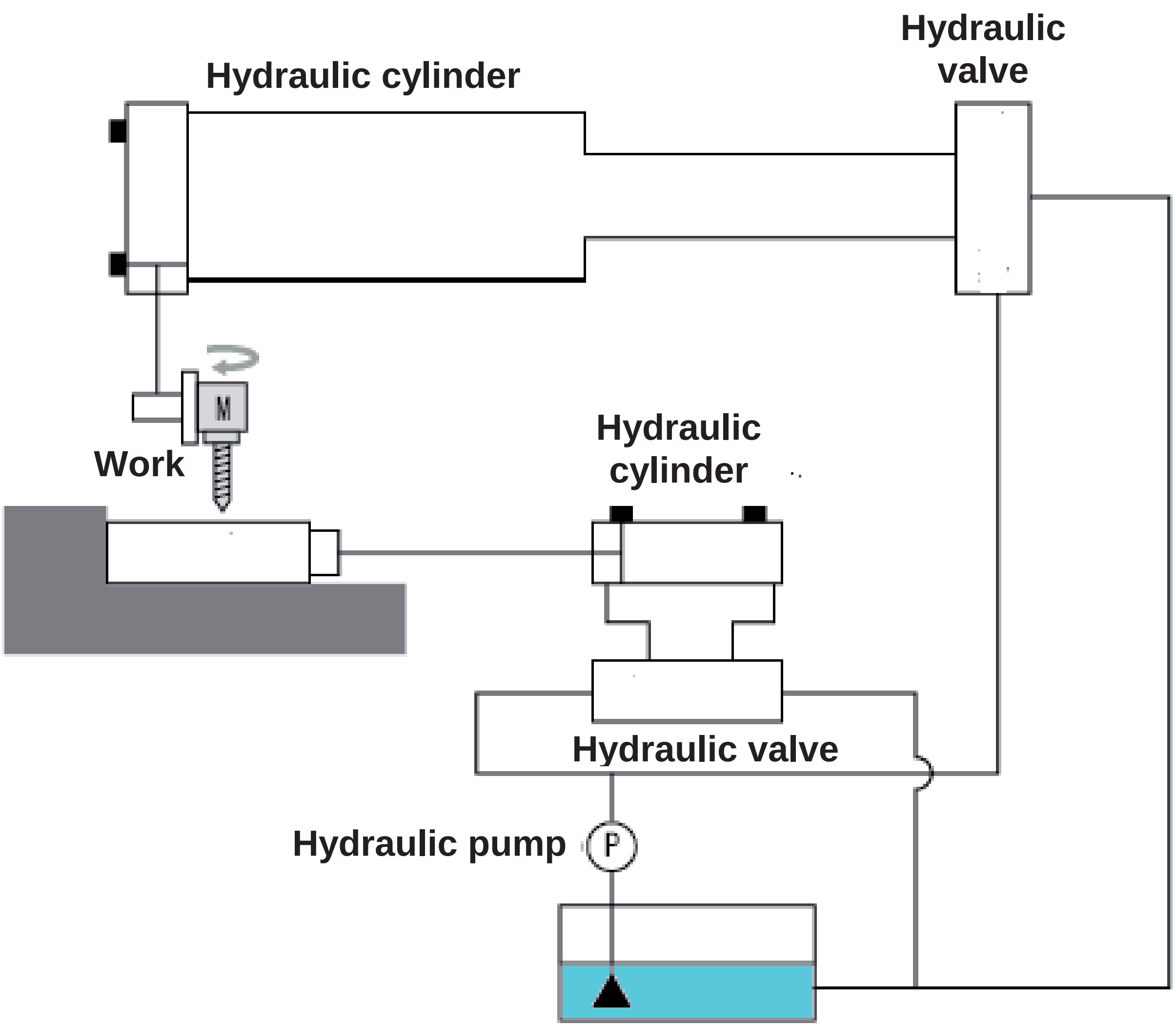
Air consumption can be reduced by 75%, because exhaust of low pressure air shall be done // just only one time in single cycle.

Systems of the right pressure in the right place like these // are suggested in various ways.

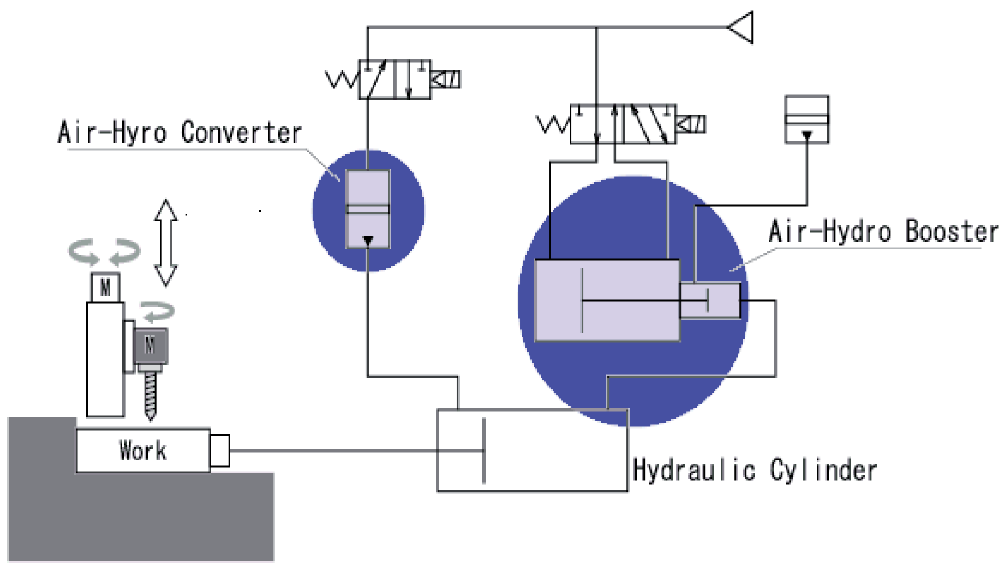


Hydraulic Clamp

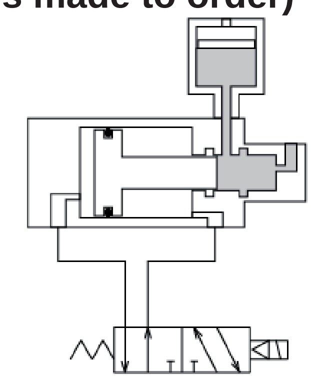
Reduce energy consumption from the hydraulic pump.



Convert to an air-hydro circuit by using air-hydro booster and converter.



CCT Air-hydro converter (Booster is made to order)



Internal structure: Air hydro converter

Case Study – Design Mistakes

A rotary filler has 163 32mm bore cylinders (12 mm rod, 100 mm stroke) operating at 60 PSI. One cylinder produces 74.71 Lbs. of force, consuming 0.805 CFM and costing $146.20 per year in compressed air costs at 30 cycles per minute.

An air study is performed and it is discovered that a 25 mm bore cylinder (100 mm stroke, 10 mm rod) operating at 100 PSI will produce the same required force. This cylinder consumes 0.359 CFM less than the 32 mm bore cylinder.

Annual savings realized = **$10,623 per filler!**

Case Study- System Piping

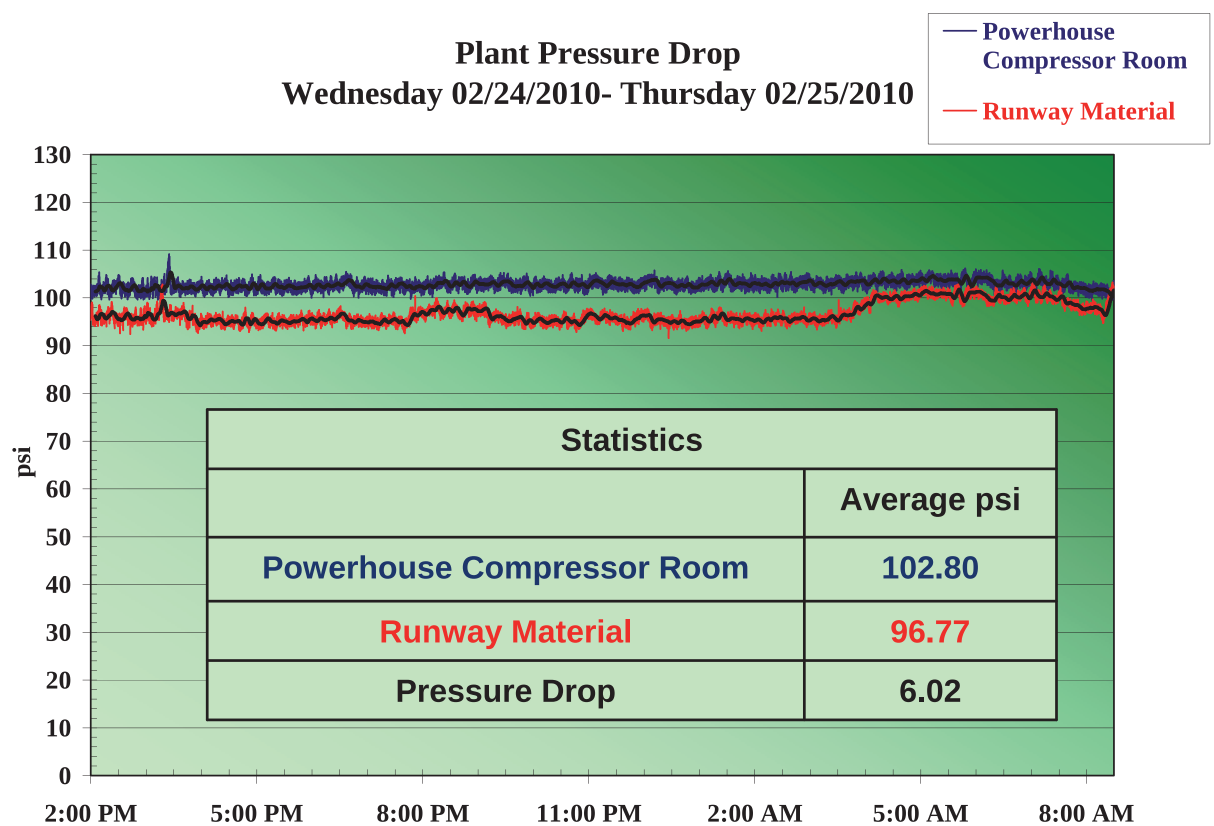
Piping SummaryThere is a significant pressure drop at the Covidien Commerce facility.

During the audit, the average pressure drop recorded was 6.02 psi when comparing the pressure of the Powerhouse Compressor Room to the Runway Material Room. This number could be substantially higher if Compressor Room #2 and #3 are looped with the Powerhouse Compressor Room piping (which may or may not be the case, but could not be determined at the time of the audit). According to the flow and pressure study, the second compressor room had an average pressure near 111 psi while the third room averaged almost 114 psi.

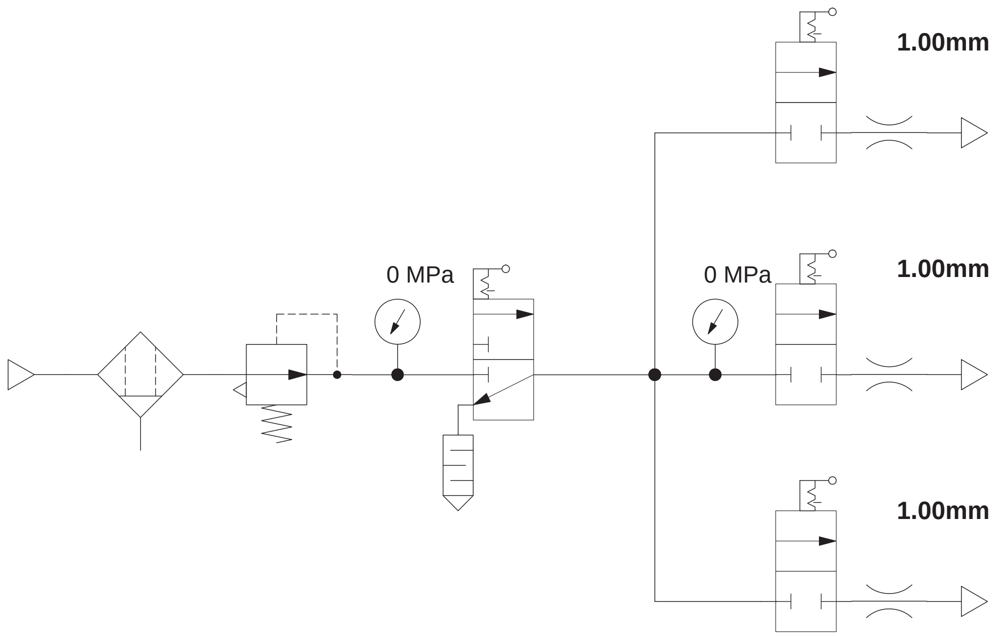
The rather complex, pieced together piping system is a major concern for a plant of this size. Due to the layout of the piping system, the plant is running up to eight compressors (plus one more that was not running during the audit) to meet demand. This seems to stem from the uncertainty of what mainline is feeding each area of the plant. Essentially, it was nearly impossible for the ECG to determine what each compressor was supplying to the plant; and two compressors (the Atlas Copco’s) were overlooked in the pre-audit ball valve installations.

The redesign of a piping layout is an undertaking in itself and it is fully understood that such a recommendation could be costly to Covidien. However, it should be considered. The current compressors operating have a capacity of 6,301 CFM compared to the recorded plant average flow of 1,880 CFM. Granted, this average does not include the flow from the two Atlas Copco compressors, but the size and number of compressors running is clearly supplying far too much capacity for current demand. The “Cost of Compressor” section near the end of the report will shed some more light on potential savings that can be garnered by simply shutting off certain compressors, which may not be possible due to the current piping layout.

Storage is an important factor to examine here too. One of the main 3” piping leaving the Powerhouse compressor room goes directly to the plant. It is recommended to have storage between supply side and the main equipment, especially with a load/no-load compressor configuration. Adding storage just downstream of the Powerhouse compressor room would help alleviate a surge in plant demand and reduce the pressure drop. Another option to consider would be to pipe the Powerhouse compressors together with the third compressor room, which has adequate storage.



Air Blow Energy Saving-   Energy Saving Lab #1



1. Construct the circuit as shown using a 2m length of 4mm OD tubing.

2. Confirm that the 3 finger valves are closed (knobs 90 degrees to the air flow path).

3. Adjust the regulator so that the pressure gauge on the manifold reads 0.2 MPa.

4. Open all 3 of the finger valves, and record the pressure from the gauges on the regulator and manifold in the chart below.

5. Close 1 of the finger valves and leave the other 2 open. Record the pressure from the gauges on the regulator and manifold in the chart below.

6. Close another finger valve and leave 1 open. Record the pressure from the gauges on the regulator and manifold in the chart below.

7. Close all of the finger valves, shift the 3/2 valve to “Exhaust”, and construct the circuit as shown using two 2 meter lengths of 4mm OD tubing.

8. Repeat steps 2 – 6, recording pressures as before.

9. Close all of the finger valves, shift the 3/2 valve to “Exhaust”, and construct the circuit as shown using a 250mm length of 4mm OD tubing.

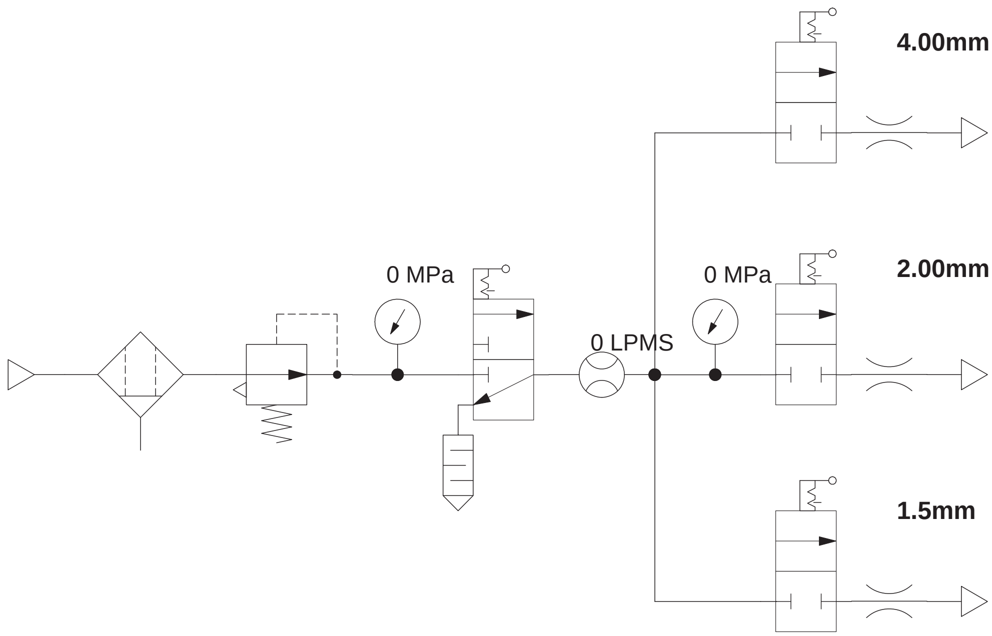
10. Repeat steps 2 – 6, recording pressures as before.

Review: Look up the effective areas of the tubes used, and verify your findings.

Bonus: Calculate the maximum length of 6mm OD tubing which could be used in this application, and verify experimentally.

Piping Length / # of Pieces	Where to Measure	Number of Open Nozzles			
		Closed	3 open	2 open	1 open
4mm OD, 2 Meters, 1 pc.	Regulator	.20 mPa			
	Manifold	.20 mPa			
4mm OD, 2 Meters, 2 pcs.	Regulator	.20 mPa			
	Manifold	.20 mPa			
4mm OD, 0.25 Meters, 1 pc.	Regulator	.20 mPa			
	Manifold	.20 mPa			
6mm OD, __ Meter(s), 1 pc.	Regulator	.20 mPa			
	Manifold	.20 mPa			

Air Blow Energy Saving-   Energy Saving Lab # 2



1. Construct the circuit as shown, connecting the flow meter with 6 mm OD tubing.

2. Replace the 1mm nozzles with a 6 mm OD nipple, 2mm nozzle, and 1.5mm nozzle

3. Confirm that the 3 finger valves are closed (knobs 90 degrees to the air flow path).

4. Open the finger valve at the 6 mm nipple, and adjust the pressure at the regulator so that the flow meter reads 100 liters/minute.

5. Record the values in the chart below.

Note: this impact pressure is now your baseline

6. Open the finger valve at the 2 mm nozzle, and adjust the pressure at the regulator so that the impact pressure is the same as that recorded in step #5.

7. Record the values in the chart below.

8. Open the finger valve at the 1.5 mm nozzle, and adjust the pressure at the regulator so that the impact pressure is the same as that recorded in step #4 & #5.

9. Record the values in the chart below.

Review: Which nozzle performs best?

Bonus: Will the 1 mm nozzle use any less flow? Verify experimentally.

Nozzle	Impact Pressure	Regulator Pressure	Manifold Pressure	Flow Rate (l/min)
4 mm				
2 mm				
1.5 mm				
1 mm				

ENERGY SAVINGS LAB# 3

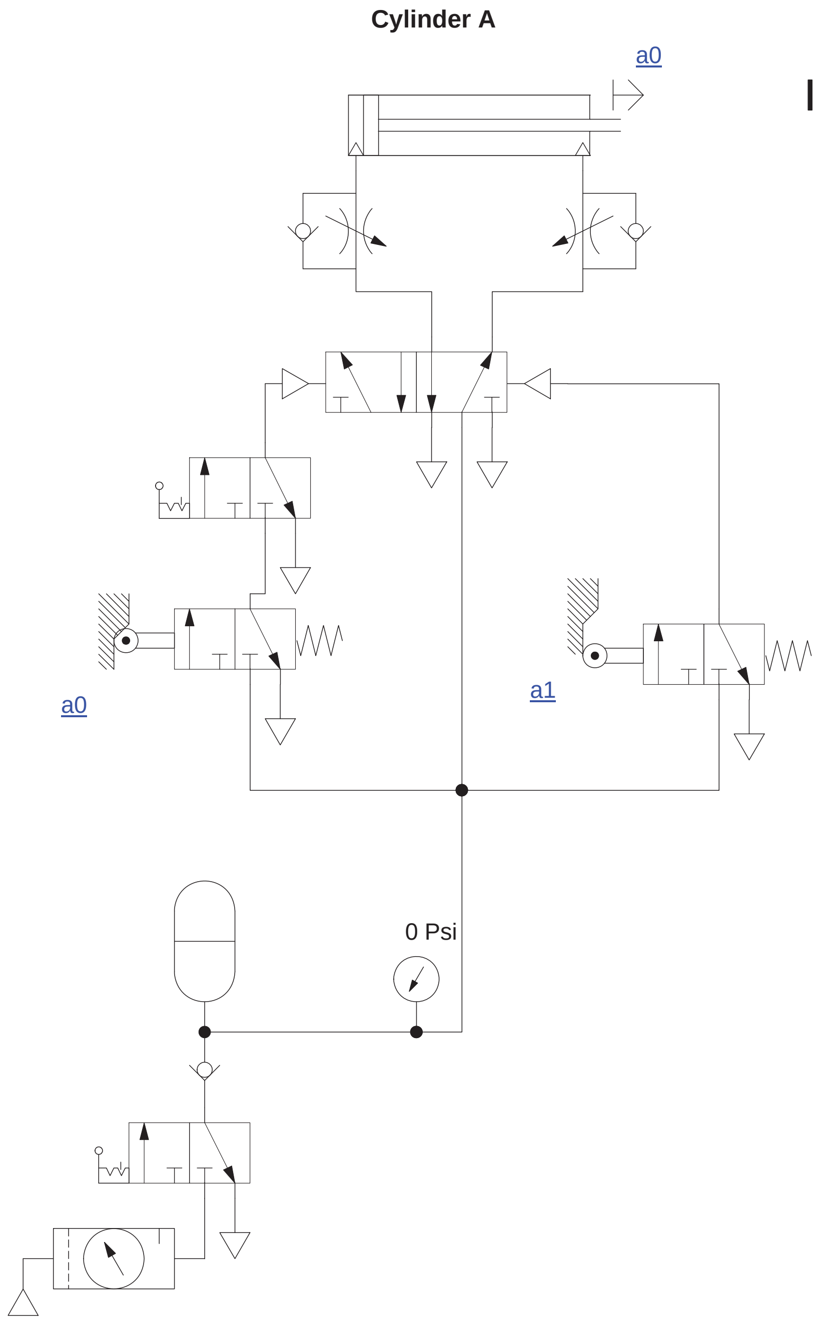
Set-Up:

Fill tank to 100 PSIG, using 3-Port valve attached to the regulator. Close 3-Port Valve, then open the other 3-Port that is between the 5/2 valve & 3/2 valve a0. Operate Circuit, counting the number of cycles.

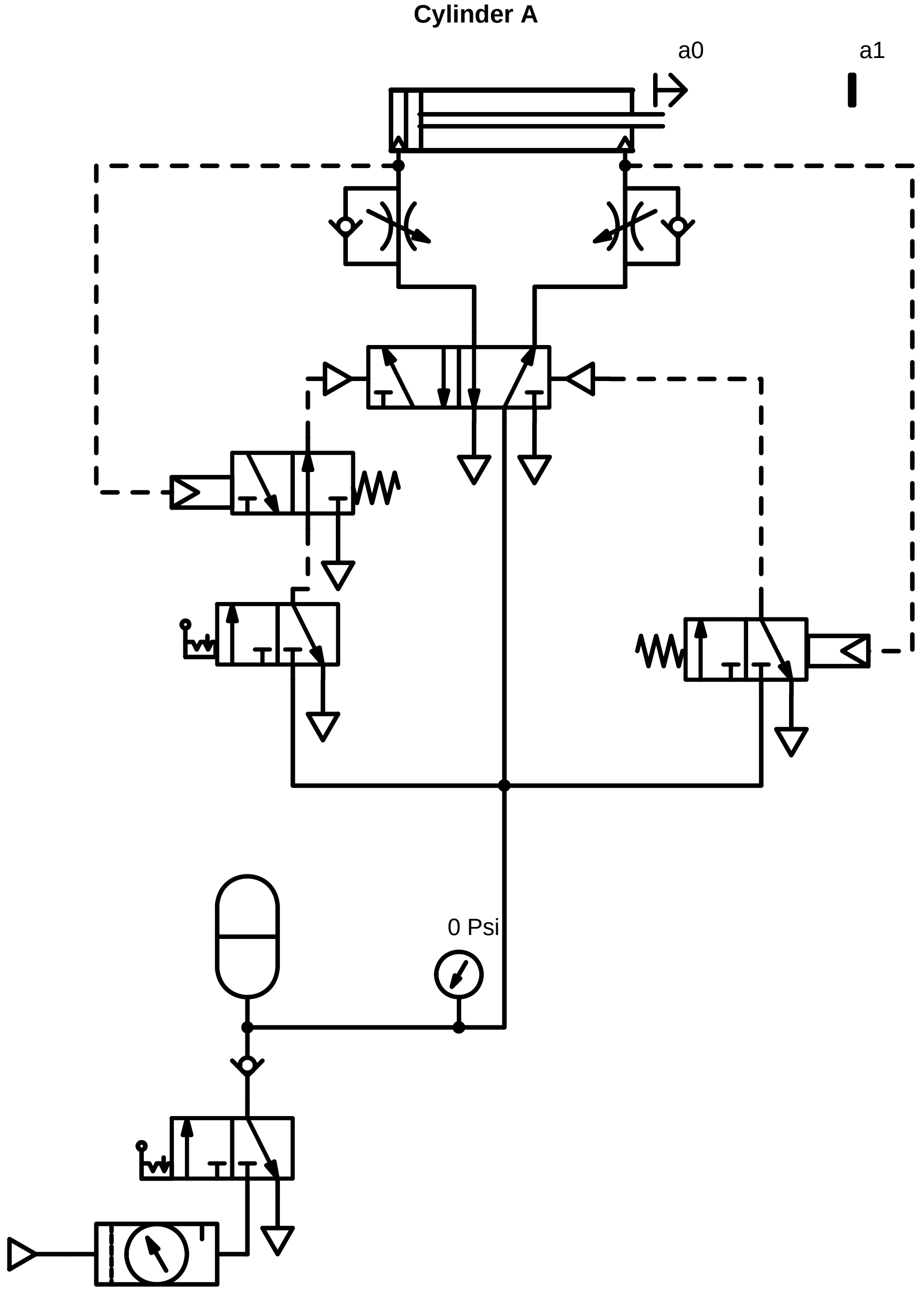
Challenge:

What can you do to increase the number of cycles possible using the given volume of air?

Try several things, singly, and in combination, and record your results.



ENERGY SAVINGS LAB# 3A



Set-Up:

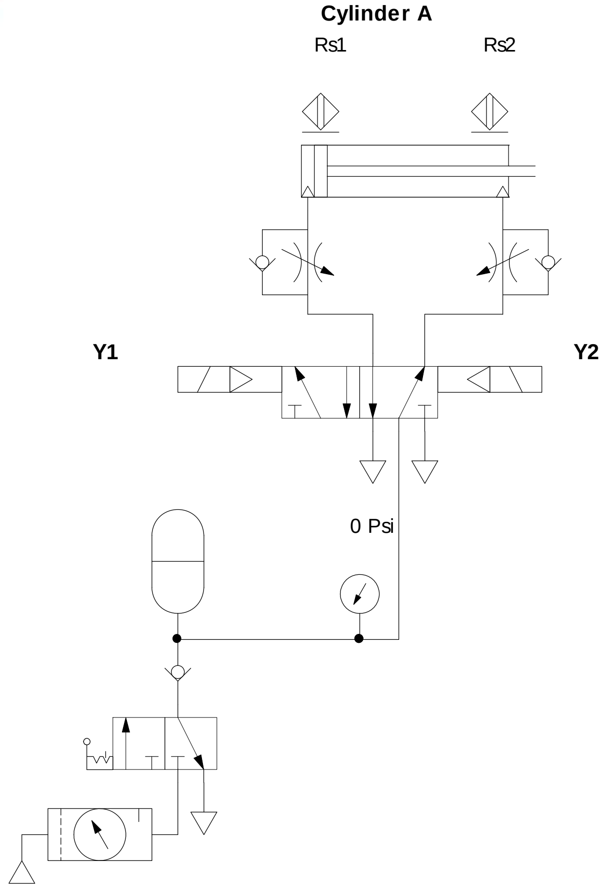
Fill tank to 100 PSIG, using 3-Port valve.
Close 3-Port Valve, then open the other 3 port that is between the 5/2 valve & a0 3/2.
Operate Circuit, counting the number of cycles.

Challenge:

What can you do to increase the number of cycles possible using the given volume of air?

Try several things, singly, and in combination, and record your results.

ENERGY SAVINGS LAB# 3B



Set-Up:

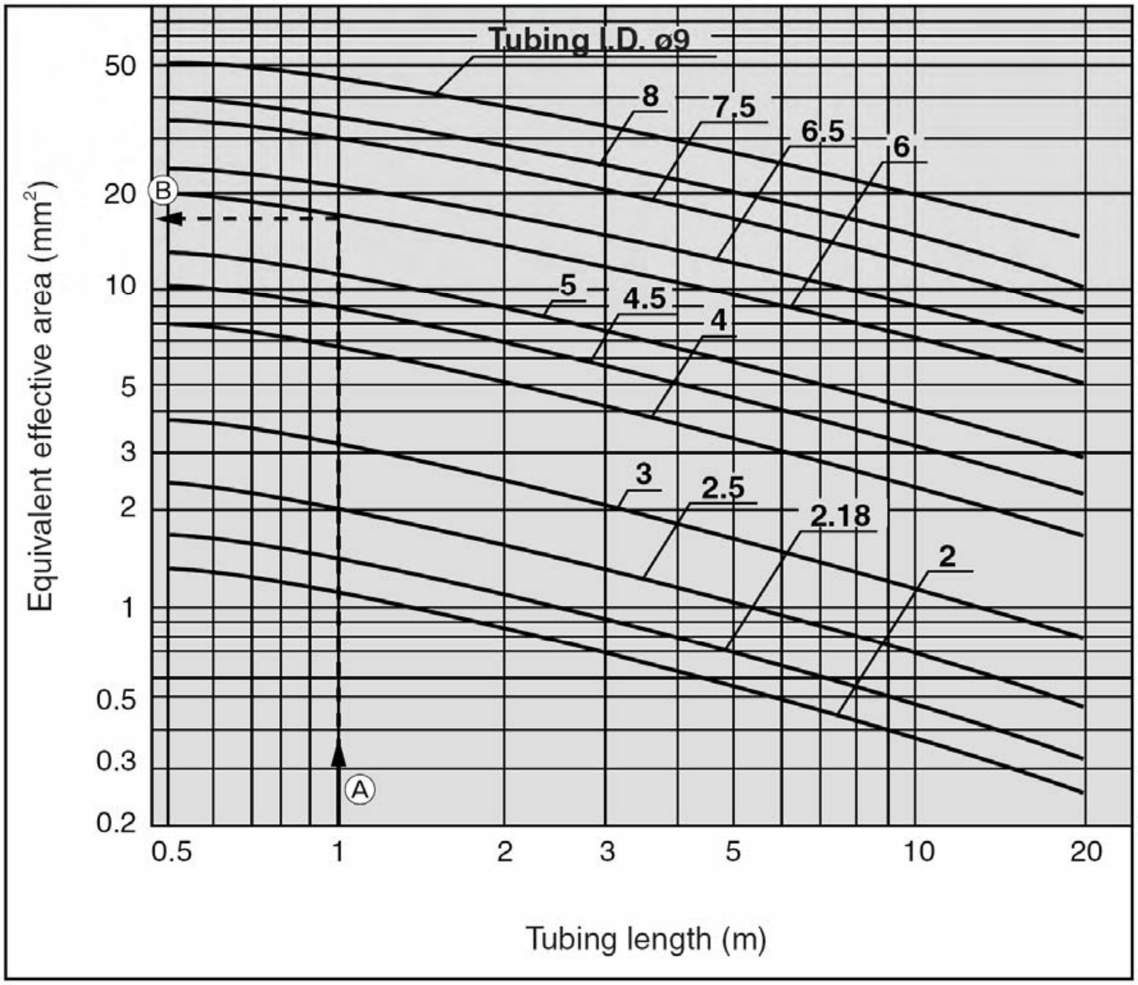
Fill tank to 100 PSIG, using 3-Port valve attached to air-prep.
Close 3-Port Valve, then operate the circuit by depressing the yellow pushbutton, counting the number of cycles.

Challenge:

What can you do to increase the number of cycles possible using the given volume of air?

Try several things, singly, and in combination, and record your results.

Selection Graph (5) Effective area of tubing I.D.



Best Pneumatics 4, Page 840