CALIFORNIA ENERGY COMMISSION

CALIFORNIA'S FOOD INDUSTRY

COMPRESSED AIR CHALLENGE

CONSULTANT DRAFT FINAL

August 2013
CEC

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Contract Number: 400-10-013

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Acknowledgements

CIFAR, Draw Professional Services and KWW Energy Services would like to thank facility managers and staff from the collaborating facilities for their assistance with the compressed air assessments.

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Abstract

This report documents the results from Compressed Air Energy System Assessments (ESAs) conducted by Department of Energy (DOE) Qualified Specialists at eight California food and beverage processing facilities. The Qualified Specialists utilize the national Compressed Air Challenge[1] (CAC) standards to collect data, evaluate the performance of compressed air systems and identify industrial Best Practices (BPs)[2]. The CAC created and established a national standard to instructional curriculums, technical support methodologies and evaluation software tools.

The average payback period for Energy Efficiency Measures identified by ESAs is one year, with an economic potential to save $60,000 to $90,000 per year. Indirect benefits from the adoption of industrial BPs are not quantified, but they are tangible to plant engineers and operators who adopt recommended PBs. Some of these facilities are in need of basic improvements, some can benefit from the adoption of automated control systems, and all need to establish leak management BPs.

[1]The Compressed Air Challenge™ a voluntary collaboration between industrial users; manufacturers, distributors and their associations; consultants; state research and development agencies; energy efficiency organizations; and utilities. The mission of the CAC is to be the leading source of product-neutral compressed air system information and education, enabling end users to take a systems approach leading to improved efficiency and production and increased net profits. http://www.compressedairchallenge.org/

[2] US Department of Energy (DOE). http://www1.eere.energy.gov/manufacturing/tech_assistance/compressed_air.html

California's Food Industry Compressed Air Challenge

Since 2006, eight California food and beverage industrial facilities have participated in the national Compressed Air Challenge[3] (CAC). The goal was to evaluate the performance of compressed air systems and implement industrial Best Practices (BPs)[4] in their facilities. The CAC has created a national standard for instructional curriculums, technical support methodologies and evaluation software tools.

The instructional curriculum is delivered by Department of Energy (DOE) Certified Instructors who are the only qualified individuals to offer one-day intermediate, two-day advanced and three-day certification workshops leading to Qualified Specialist certification for attendees. Qualified Specialists are ASME Certified Practitioners in industrial process system evaluations[5]. These individuals conduct compressed air Energy System Assessments (ESAs) to evaluate system performance and identify Energy Efficiency Measures (EEMs).

By adopting the national standard, California's food industry gains the opportunity to adopt industrial Best Practices (BPs) that deliver improved use of compressed air resources and raises awareness about industrial energy assets. Most of the food industry facilities that received DOE compressed air ESAs have either adopted or will be adopting the EEM recommendations. Table 1, provides details of results obtained from conducting compressed air ESAs at eight California food industry facilities.

Table 1. Results from Compressed Air System Assessments Conducted at Food Industry Facilities

Compresed Air ESAs 2006-13	kWh/yr	$/yr Saved	$ Estimated Cost	Payback Years	Utility Partner
Fruit Canning	1,042,018	57,311	100,000	1.74	MID
Tomato Processing	131,476	8,000	5,000	0.63	MID
Raisin Processing	482,501	48,250	100,000	2.07	PG&E
Tomato Products Canning	176,555	25,442	20,000	0.79	PG&E
Potato Chips Manufacturing	1,500,000	150,000	50,000	0.33	MID
Tomato Paste	474,417	71,163	30,000	0.42	PG&E
Cereal Manufacturer	888,816	97,770	50,000	0.51	LodiElec.
Cheese Manufacturing	827,741	49,664	65,000	1.30	Tulare ID
Totals:	**5,523,524**	**507,600**	**420,000**		
Average:	**690,441**	**63,450**	**52,500**	**1**	

Purpose and Organization of this Report

The compressed air ESAs provide the potential to save $60,000 to $90,000 per year. This report is written to document results from ESAs that have already been performed and to identify general "lessons learned" that may be of use to food industry managers. The report presents examples of commonly recurring conditions identified at ESA facilities. Case Studies are included to describe ESA results and evaluate the adoption of recommendations.

[3] The Compressed Air Challenge™. http://www.compressedairchallenge.org/
[4] US Department of Energy (DOE). http://www1.eere.energy.gov/manufacturing/tech_assistance/compressed_air.html
[5] American Society Mechanical Engineers, http://www1.eere.energy.gov/energymanagement/assistance.html

Industrial Best Practices (BP) Training

Food industry managers are encouraged to attend the Fundamentals of Compressed Air Systems BP training workshop. This class shows students how to compute the cost of operating compressed air systems at industrial facilities. Students learn how to collect data, measure and create a baseline of the system's performance. The instructor provides comparisons to determine the impact of different compressor control systems and how to achieve cost savings. The following Case Study illustrates the experience of a facility manager attending a workshop.

CIFAR Food Industry Energy Nexus

Compressed Air Challenge

Optimizing Compressed Air System Enhances Continues Improvements

Stanislaus Food Products

- Savings: 131,477 kWh ; @ $0.09/kWh
- $8,000 to cash flow.
- Training staff, adopting low-cost BPs.

Managers and plant operators at the Stanislaus Food Products, Modesto California tomato processing facility are encouraged to adopt resource efficiency improvements. In early 2007, the plant manager attended a US Department of Energy (DOE) Industrial Best Practices (BP) Compressed Air Workshop and was encouraged to adopt lessons learned. During the Summer of 2008, the facility invited a DOE Qualified Specialist to conduct a Compressed Air Energy System Assessment (ESA). Promptly the facility adopted the following ESA recommendations:

1. Reduced Pressure by 10 psig -- In order to lower pressure to the production floor, the facility replaced air manifolds with properly sized piping to insure adequate volumes of compressed air at all times. Lowering pressure by 10 psig, results in annual savings of 355 MMBtu or 34,699 kWh equivalent.

2. Reduced Air Leaks by 40 acfm -- Lowered the gross leak by 40 acfm from a baseline of about 90 acfm leakage or 60% of the storage volume, resulting in annual savings of 991 MMBtu or 96,778 kWh equivalent.

Stanislaus Food Products benefits from lower-than-average electricity costs from electricity provider Modesto Irrigation District (MID). The ESA used a weighted average electrical cost of $0.09/kWh. The baseline data showed compressed air operating cost at $37,160 annually. The energy efficiency measures identified by the ESA and already adopted reduced air system costs by 22% per year, generating almost $8,000 of annual savings.

Energy System Assessments (ESAs)

Establishment of a baseline of the compressed air system is required to gain a basic understanding of the dynamics occurring in the processing facility. A typical one-day walk through ESA includes the following activities:

- Identification of components of the supply side, including compressors, primary storage, filters, treatment equipment, drains, and system controls
- Determination of major uses of compressed air
- Identification of inappropriate uses of compressed air, measurement of gross air leakage and recommendations for repairs or alternatives
- Identification of any air quality problems
- Determination of highest point of use pressure requirements and likelihood of whether requirements are valid and pressure can be reduced
- Determination of highest volume point of use and ability of existing system to respond
- Determination of effectiveness of control strategies in meeting demand

The ESA reports provide specific supply-side and demand-side energy efficiency measures to improve compressed air system performance.

Compressed Air Systems: An Essential Industrial Utility

The compressed air system is an essential utility required for all aspects of industrial food processing and beverage manufacturing operations. Most facilities have an array of compressor assets that are integrated with wet and dry storage receivers, Nitrogen feeders, back pressure control valves, filters and dryers. These components are connected through pipes to deliver pressurized air to end-use locations. Figure 1 illustrates a typical industrial air system.

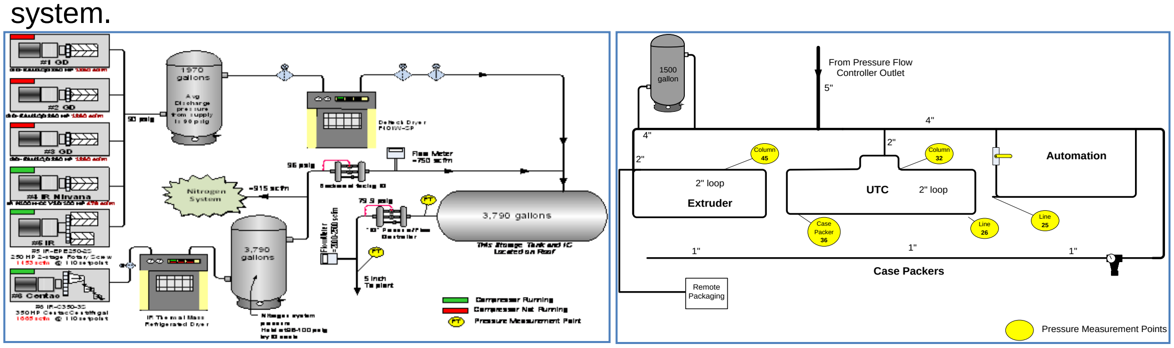


Figure 1. Standard Design Air Supply and Demand System

There are number of compressed air system inefficiencies that recur at food industry facilities. The following sections of this report draw from results obtained by the ESAs conducted at food industry facilities between 2006 and 2013.[6]

Pressure Drops

Delivering air at consistent pressure is among the most important industrial compressed air BPs. Pressure drop in a compressed air system is a critical factor. Pressure drop is caused by friction of the compressed air flowing against the inside of the pipe and through valves,

[6] The ESA reports are available at the CIFAR, Resource Efficiency Portal, http://www.cifar.ucdavis.edu/

tees, elbows and other components that make up a complete compressed air piping system. Pressure drop can be affected by pipe size, type of pipes used, the number and type of valves, couplings, and bends in the system. Each header or main should be furnished with outlets as close as possible to the point of application. This avoids significant pressure drops through the hose and allows shorter hose lengths to be used. To avoid carryover of condensed moisture to tools, outlets should be taken from the top of the pipeline. Larger pipe sizes, shorter pipe and hose lengths, smooth wall pipe, long radius swept tees, and long radius elbows all help reduce pressure drop within a compressed air piping system.

The layout of the system can also affect the compressed air system. A very efficient compressed air piping system design is a loop design. The loop design allows airflow in two directions to a point of use. This can cut the overall pipe length to an end use in half, which reduces pressure drop. It also means that a large volume user of compressed air in a system will not starve users downstream since they can draw air from another direction. Industrial BPs help increase throughput and prevent product interruptions from pressure drops and system instabilities. The following Case Study illustrates the need for proper piping design to address unwelcomed drops in air pressure.

CIFAR Food Industry Energy Nexus

Compressed Air Challenge

- $50K Investment
- $150,000 savings
- 0.3 yr. simple payback

FritoLay Good fun!

Snack Manufacturing Facility Estimates $150,000 Electric Savings from the Adoption of Industrial Best Practices

Recommendations from a **Compressed Air Challenge Energy System Assessment** conducted at the **Frito Lay** Modesto facility include: 1) connecting and looping the piping to the Extruder, the UTC and the Automation to counter the pressure gradients that currently exist. 2) addressing low pressure to Case Packers due to piping design limitations. 3) addressing pressure drop in the piping network to dust collectors, as they should work at 80 psig but are operating inefficiently at 45 psig. Although the compressors are properly controlled at the facility, significant energy is wasted on overpressure and piping inefficiencies.

Frito Lay engineers have adopted the following implementation plan:

1) Piping system has been modified as suggested (a few weeks after assessment) to increase pressure to a constant through the packaging department. This modification has stabilized the pressure, eliminating low pressure faults and reducing line downtime caused by air pressure issues. 2) All items that could be converted to blowers instead of compressed air have been converted. 3) Our site ultrasound program has been improved with air leak studies being performed every 4 weeks throughout the plant on the compressed air and nitrogen lines. 4) Training is performed for the site explaining the cost of compressed air. We utilize production team members to audit their departments for air leaks as well. 5) We have added a new 2" line off the main header to feed the waste water diaphragm pumps and dust collector line. This has stabilized the pressure to both systems. More data will be needed for replacing the diaphragm pumps. We understand the cost associated and have since eliminated one pump. The benefits of currently having a self-priming pump which cost little to rebuild and has great reliability is a great benefit to the waste water operation. This should be easily accomplished. 6) We would request funds from HQ to install new receiver tanks at each dust collector but will need help with the savings calculation and sizing of the tanks.

Pressure Profile

The chart below shows an example of the facility's measured pressure profile. Pressure at the outlet of the flow control valve is set at 95 pounds per square inch gage (psig). Aseptic filling is the brown line and is only 1 psig below that set-point. This indicates that the flow to this area is well-matched to the pipe sizes that feed it. The evaporator vegetable preparation area and the Hot Break area show the greatest pressure drop from the set-point of the pressure flow controller. The dips in pressure actually correspond to the use of air operated diaphragm pumps. See the impact on the pressure profile that additional flows of up to 200 standard cubic feet per minute (scfm) can have.

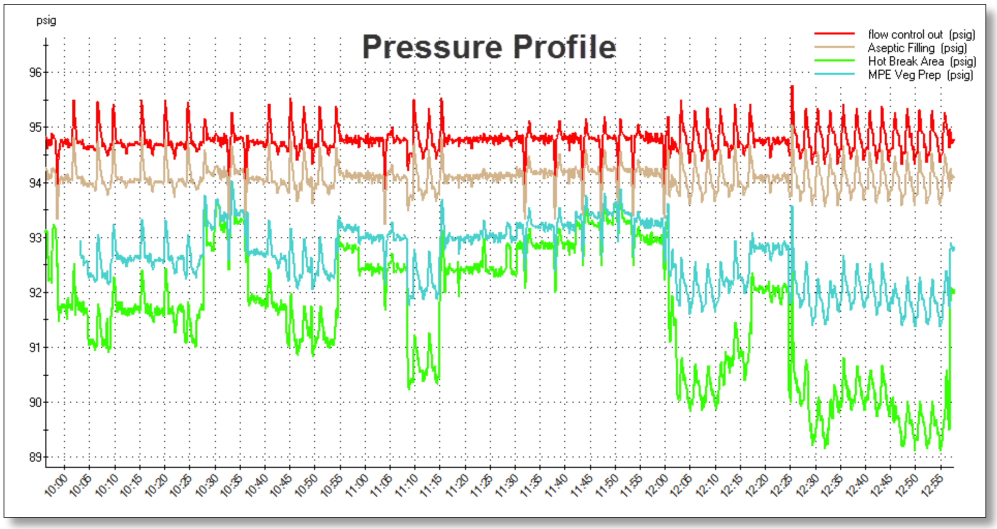


Figure 2. Pressure Profile Diagram

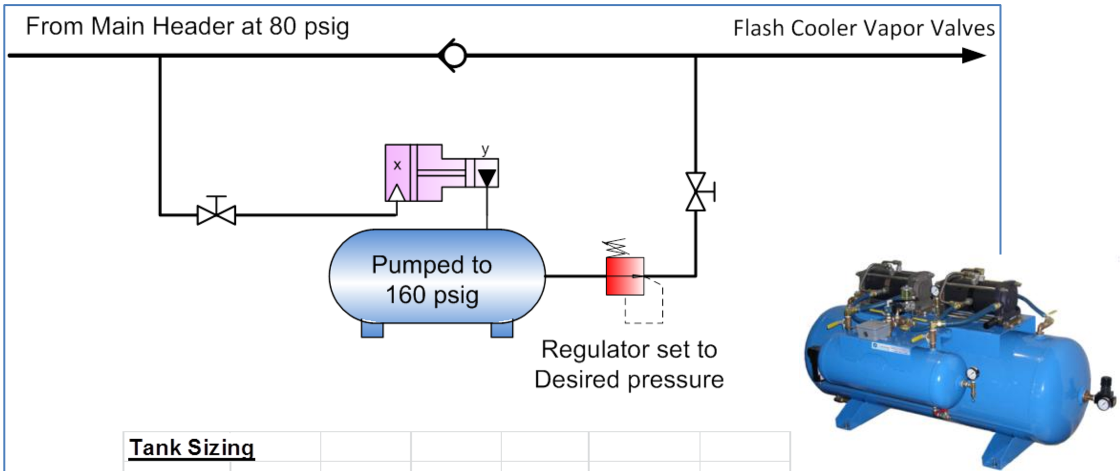
Peak demands such as flow from an air operated diaphragm pump or any open blowing can create large pressure drops that will disrupt production and cause possible product interruptions.

Point of Use Storage and Pressure

Point of use storage and pressure requirements are very site-specific conditions. To understand these subtle conditions, the ESA invests additional time understanding the demand-side of the compressed air system. The following example is taken from one of the participating facilities where the vast majority of valves and controls do not require more than 25 psig to operate.

There are those few points of use that require 80 psig. Such an area would be at the "Flash Cooler Vapor Valves" in the Aseptic area. These valves are critical for maintaining sterility on the flash coolers after a power outage. The valves take 18 seconds to close with 80 psig. What is not known is the flow during actuation. Both valves are 24-36" butterfly type. Based on discussions at the facility about air storage capacity and a review of technical bulletins of large pneumatic butterfly valves, there seems to be a good chance that there **would not be** enough pressure available in the time required to shut these critical valves during a power emergency.

The key to designing an amplified storage vessel dedicated to the valves would be to know how many cubic feet of air a valve needs to actuate. A call to the manufacturer might reveal this number. Pictured below is a typical amplifier setup showing how the valves can have their own source of compressed air using an amplifier that is mounted on a tank. Assuming a flow of 50 scfm for 30 seconds (way more than these valves would ever need) and the tank size is only 33.89 gallons. The reason for the small size is that the tank can be pumped up to 160 psig. The amplifiers are a 2:1 ratio. So if the header is only at 80 psig, we can pump the tank to 160 psig. That differential pressure will allow us to flow 50 scfm for 30 seconds if needed. That's how you can supply air to the valves when power fails.



Tank Sizing

gallons =	33.89	gallons
V =	4.53	cubic feet
T =	0.5	minutes
C =	50	cfm
S=	0	cfm
Pa =	14.5	psia atm pressure
P1 =	160	Initial tank psi
p2 =	80	minimum pressure to operate

$$V_{cf} = \frac{T(C-S)(P_a)}{(P_1-P_2)}$$

Figure 3. Typical Air Amplifier System

There are other causes for the loss of air pressure from the use of systems like the Wilden Pumps or other control systems. The easiest way to be sure that air pressure and volume is available to close the vapor valve is to install the amplifier and storage tank.

Air Leaks[7]

To conduct a leak test, first pressurize the plant during a non-working day. Then shut off the compressor. If the plant is at pressure and allowed to bleed down with no production running, the loss of air would be considered leakage. Pressure reduction is timed from start to 50% of start. Using the equation below will offer some view of the flow rate.

$$\text{Leakage (cfm free air)} = \left[\frac{V \times (P_1 - P_2)}{T \times P_a}\right] \times 1.25$$

Where:
V = system volume in cubic feet
$P_1 - P_2$ = Starting and Ending Pressure of Bleed Down
T = Time for bleed down in minutes
P_a = Local barometric pressure in psia

[7] DOE Energy Tips: Minimize Compressed Air Leaks. http://www.energystar.gov/ia/business/industry/compressed_air3.pdf. See Apendix X for copy of brochure.

Benefits of Leak Detection and Repair

- Air leakage: can be defined as consumed air that contributes nothing to production.
- A typical plant that has not been well maintained will likely have a leak rate equal to 30% of total compressed air production capacity.
- On the other hand, proactive leak detection and repair can reduce leaks to less than 10% of compressor output.
- If you can't feel it or hear it, that's about $ 500 per year
- If you can feel it and hear it, that's about $ 2,000 per year
- Leaks cause a drop in system pressure, which can make air tools function less efficiently, adversely affecting production.
- By forcing the equipment to cycle more frequently, leaks shorten the life of almost all system equipment (including the compressor package itself).
- Increased running time can also lead to additional maintenance requirements and increased unscheduled downtime.
- Finally, leaks can lead to adding unnecessary compressor capacity.
- The best way to detect leaks is to use an ultrasonic acoustic detector, which can recognize the high frequency hissing sounds associated with air leaks.

The most important recommendation for all food industry facilities using compressed air systems is to establish continuous leak detection and repair BPs.

Inappropriate Uses of Air

Any end use requiring compressed air that can be performed by something other than compressed air is considered an inappropriate use. Air Operated Diaphragm Pumps are a necessary end use if required. However with no controls, they can consume hundreds of scfm. Air-operated diaphragm pumps use compressed air to drive diaphragms to force liquid out of a pumping chamber. An air shifter typically is used to alternate between two opposing diaphragms and check valves prevent the backflow of liquid. These pumps are typically easy to install and have a relatively low purchase price making them popular in a wide range of applications.

Unfortunately, this also drives users to misapplication of these pumps and higher overall costs due to the hidden costs of electrical energy. There are many electrical motor operated replacement pumps that can equal or outperform any air operated diaphragm pump. These pumps are driven by electric motors and are designed to handle fluids containing large solids (up to the full diameter of the discharge); fragile solids, such as crystals, carbon and even live shellfish; abrasives; as well as long fibrous and stringy materials. Readers of this report are encouraged to obtain a copy of the Compressed Air Challenge's "Best Practices for Compressed Air Systems"[8].

[8] Best Practices for Compressed Air Systems. http://www.compressedairchallenge.org/bookstore/bpm/

Summary

System assessments are preferred to properly understand the performance of compressed air systems. General compressor audit services are often incomplete by not conducting a comprehensive demand-side system characteristics analysis. Most of the industrial BP recommendations offered by Air ESAs are identified by understanding the demand –side and how its performance impacts the supply-side.

It is evident that the food industry facilities that have participated in the California Compressed Air Challenge have benefited by the results of these comprehensive ESAs. The experience of attending BP training workshops and participating in ESA efforts has enhanced the knowledge and the abilities of facility operators to better manage their compressed air systems.   The ESAs have identified significant opportunities to reduce the cost of operating compressed air systems by properly understanding the supply and demand side characteristics of these systems.

We encourage food industry managers to ask their utility companies to deliver comprehensive system assessment methodologies using ASME Certified Practitioners.   Ask your utility company to meet the national Compressed Air Challenge and ensure that their service providers meet this highest of standards.

Additional Case Studies and other resource materials are available as Appendixes.

Appendix A

Energy Management Best Practices Food & Beverage Industries

Compressed Air Challenge

Modesto California Fruit Processing Facility Achieves $81,000 Electric Savings Adopting ESA Measures

The Modesto Del Monte Foods facility operates at full capacity from late May to mid-September producing fruit cocktails. Off-season activities include management of cold storage facilities, packing and distribution services. Del Monte Foods received, an Air Energy System Assessment (ESA) in August, 2006. A DOE Qualified Specialist evaluated the system to identify cost effective recommendations.

Plant managers and operators have adopted these measures:

Reconfigure Primary Air Storage System. Capacitance calculations determined that at least 4,125 gallons is required to reduce the rate of pressure decay during compressor unloading, absorb short duration plant peak air demands, and support air demand requirements during compressor permissive startup. ESA recommended to allow approximately 1,000 gallons of wet storage, or 25% of the total 4,125 gallons of receiver capacity, to address water carryover that caused undesirable pressure drop to certain buildings; because of the need for extra filtration and a dedicated point-of-use drier in those locations.

Install Automatic Central Sequencer Master Control and Reduce Artificial Demand. To obtain optimal energy efficiency, operating compressors should run at full load, rather than multiple partly-loaded compressors, with only one compressor functioning at part load possibly via a variable speed drive to provide trim. Although the target system supply pressure should be 86 psig, the plant was supplying pressure at 100 psig to overcome pressure drops caused by insufficient storage volume, extra filtration and drying issues related to water carryover.

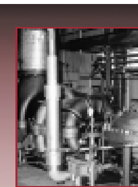
Reduce Leakage and Inappropriate Uses of Air. Conducted a leak survey and implemented management program to identify and correct sources of leaks, provided training to plant personnel on inappropriate uses of compressed air.

Appendix B

Energy Tips

Steam

Motors



Compressed Air

Minimize Compressed Air Leaks

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, which 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, FRLs (filter, regulator, and lubricator), condensate traps, valves, flanges, packings, 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 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	0.3	1.2	4.8	19.2	76.7	173
80	0.33	1.3	5.4	21.4	85.7	193
90	0.37	1.5	5.9	23.8	94.8	213
100	0.41	1.6	6.5	26.0	104	234
125	0.49	2.0	7.9	31.6	126	284

[a] For well-rounded orifices, multiply the values by 0.97, and for sharp-edged orifices, multiply the values by 0.61.

[b] Used with permission from *Fundamentals of Compressed Air Systems Training* offered by the Compressed Air Challenge™.

Leak Detection

The best way to detect leaks is to use an ultrasonic acoustic detector, which can recognize high frequency hissing sounds associated with air leaks. These portable units are very easy to use. Costs and sensitivities vary, so test before you buy. A simpler method is to apply soapy water with a paintbrush to suspect areas. Although reliable, this method can be time consuming and messy.

Suggested Actions

- Fixing leaks once is not enough. Incorporate a leak prevention program into your facility's operations. It should include identification and tagging, tracking, repair, verification, and employee involvement. Set a reasonable target for cost-effective leak reduction—5-10% of total system flow is typical for industrial facilities.
- Once leaks are repaired, re-evaluate your compressed air system supply. Work with a compressed air systems specialist to adjust compressor controls. Also look at alternatives to some compressed air uses. If a compressor can be turned off, benefits include cost savings and a system backup.

References

Improving Compressed Air System Performance: A Sourcebook for the Industry, Motor Challenge and Compressed Air Challenge, April 1998.

Training

- *Fundamentals of Compressed Air Systems* - 1 day
- *Advanced Management of Compressed Air Systems* - 2 days

Offered by the Compressed Air Challenge. Call the OIT Clearinghouse or visit the BestPractices Web site (www.oit.doe.gov/bestpractices) for the latest schedule and locations.

For additional information on industrial energy efficiency measures, contact the OIT Clearinghouse at (800) 862-2086.

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