Are You Wasting Money Fixing Compressed Air Leaks?

15 September 2011 Ron Marshall, CET, CEM, and Bill Scales for The Compressed Air Challenge
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If you think finding and repairing leaks is the first step in controlling your compressed air costs, think again.

Much has been written about the significant cost of supplying air leaks—an inevitable part of any compressed air system. Most owners and operators are usually unaware that without a carefully designed and well-maintained compressor control strategy, a leak-repair program may not maximize their savings.

MYTH: Compressed air is free.
FACT: Compressed air is usually your most expensive utility. It takes 8 hp of electricity to produce 1 hp worth of work with compressed air.

MYTH: Leaks don't really amount to much.
FACT: In many plants, compressed air leaks may represent the single largest consumption. Plants with no effective compressed air leak management program lose, on average, 30% to 50% of their compressed air production to leaks.

MYTH: The system may be leaking some air, but it doesn't cost much.
FACT: An air system with 200 hp of air compressor power typically has the equivalent of about 60 hp in leaks. At $.10 per kWh, this costs over $44,000/year in wasted electrical energy.

MYTH: Fixing leaks does not save money.
FACT: Upper management doesn't always recognize the true cost of not repairing air leaks. Knowing the high cost of compressed air, why wouldn't every facility with a compressed air piping system implement continuous leak identification and repair program? Here's one reason why…

A recent meeting was held with the CEO and CFO of a large multi-plant facility to discuss a continuing corporate compressed air support program. The CFO was adamant about not wanting to discuss a leak repair program.

The reason for the CFO's reluctance: 15 years before, he had come away from a workshop on the cost of compressed air, eager to support the repair of all air leaks in his plants. He hired an outside contractor who identified 3600 cfm of leaks in a 7500 cfm system—*leaks with a value of 675 kW.* At the power rate of $.085 kWh, this type of leakage represented a potential cost savings of $500,000/year or $40,000+ per month.

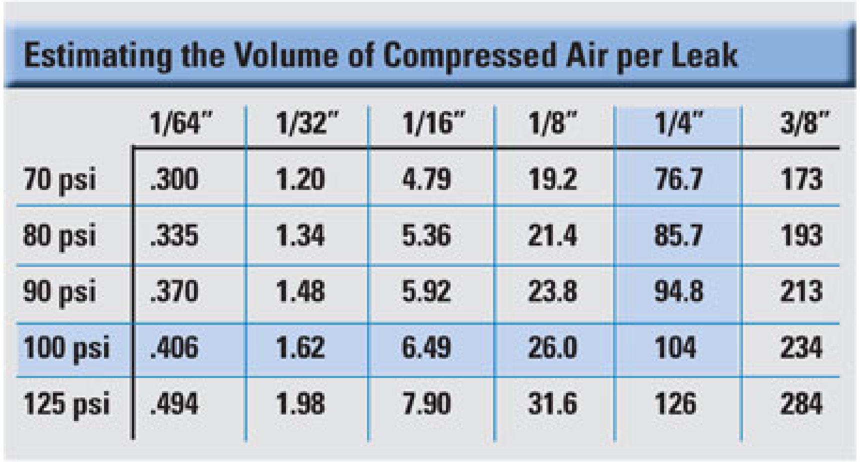
In retrospect, the approximate $25,000 investment in the contractor's fee and required repair work seemed quite reasonable. Yet, after all was said and done, the total reduction in the plants' electric bill came to less than $500 per month. No wonder the CFO concluded that fixing leaks as a continuing program doesn't pay off.

Why this happens

Equivalent flow and cost…

By consulting the orifice chart in Table I—*and knowing a compressed air system uses about 20 kW input per 100 cfm output*—we can estimate that the annual cost of producing the equivalent of a ¼" leak, assuming 8760 operating hours per year, is $18,220 at an energy rate of 10 cents per kWh.

Table I. Leak sizing from a standard orifice flow chart (Cv=1.0)



Estimating the Volume of Compressed Air per Leak

	1/64"	1/32"	1/16"	1/8"	1/4"	3/8"
70 psi	.300	1.20	4.79	19.2	76.7	173
80 psi	.335	1.34	5.36	21.4	85.7	193
90 psi	.370	1.48	5.92	23.8	94.8	213
100 psi	.406	1.62	6.49	26.0	104	234
125 psi	.494	1.98	7.90	31.6	126	284

The assumption is often made that by reducing leak flow by the same 104 cfm, savings of over $18,000 can be achieved. This is rarely correct, and depends on how a compressed air system responds in relation to flow change.

Leak estimation

A good approximation of the level of leakage in a plant can be obtained by conducting special testing during a period of non-production in a plant. This type of testing was discussed in last month's "Overcoming The Challenges" column. Instructions on performing these tests can be found in "Fact Sheet 7: Compressed Air Leaks," available for download from the Library section at www.compressedairchallenge.org.

Based on the test, the resulting answer in cfm will equal all the leaks and any processes that were left on. It's important to deduct those processes that have to be left on, if the calculated flow is not to be included in your leak-reduction efforts. The remaining flow is a fair estimate of the total volume of wasted compressed air.

This testing is sometimes supported by additional surveys using ultrasonic leak detection devices. A good test of the validity of this exercise is that any manually compiled leak list that totals more than the number from the previous testing would be suspect.

After accurately identifying the magnitude of the total leaks in a plant, the next significant challenge is to value the potential effect of a leak project on the annual electric bill. To management, this is where "the rubber meets the road" *(i.e., are compressed air leaks worthy fixing?)*. It's important that any estimates done before the work is initiated be achievable and verifiable after the fact. To ensure this works out, we must investigate the compressor control method.

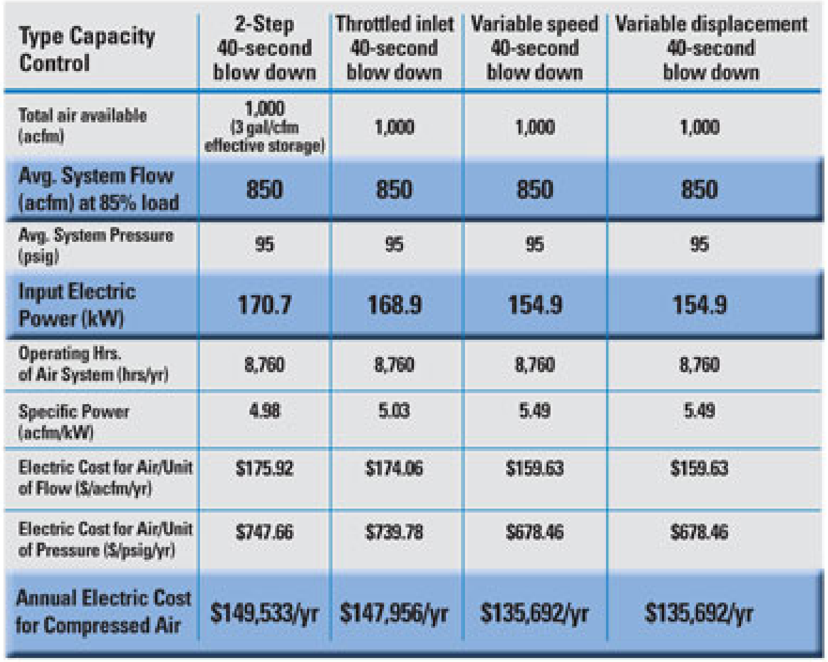
Poor turndown can steal savings

The "turndown" capability of an air compressor—*how effectively the power input turns down in response to lower flows*—often depends on the type of compressors in a system and how they're controlled. This simplified list reflects some common types and how they respond to reduced flows:

- **Rotary screw** – Four different capacity controls with four different results depending on if the compressors are operating in inlet modulation, load/unload, variable displacement capacity control or VSD modes.
- **Centrifugal** – If in "blow-off," fixing leaks just increases the blow-off to atmosphere. Input power and energy consumption stay the same.
- **Reciprocating compressor** – The various load/unload control systems generally have good part-load energy performance, but these systems are becoming less common in larger sizes. Excellent energy reduction is achieved in small systems with start/stop control.

As rotary screw compressors are the most common type, they are where the remainder of this article will focus. That said, the main reason leak-repair efforts don't gain the expected savings is the poor turndown capabilities of the more common screw compressor control modes.

Table II. Key Air System Characteristics — Current System*



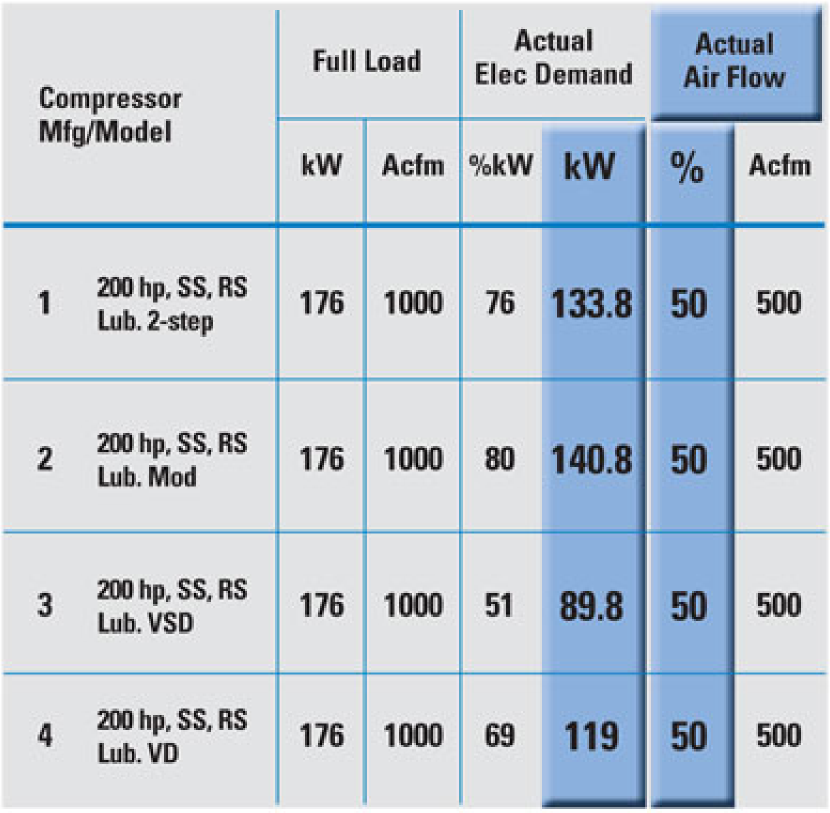
Type Capacity Control	2-Step 40-second blow down	Throttled inlet 40-second blow down	Variable speed 40-second blow down	Variable displacement 40-second blow down
Total air available (acfm)	1,000 (3 gal/cfm effective storage)	1,000	1,000	1,000
Avg. System Flow (acfm) at 85% load	850	850	850	850
Avg. System Pressure (psig)	95	95	95	95
Input Electric Power (kW)	170.7	168.9	154.9	154.9
Operating Hrs. of Air System (hrs/yr)	8,760	8,760	8,760	8,760
Specific Power (acfm/kW)	4.98	5.03	5.49	5.49
Electric Cost for Air/Unit of Flow ($/acfm/yr)	$175.92	$174.06	$159.63	$159.63
Electric Cost for Air/Unit of Pressure ($/psig/yr)	$747.66	$739.78	$678.46	$678.46
Annual Electric Cost for Compressed Air	$149,533/yr	$147,956/yr	$135,692/yr	$135,692/yr

** Based on a blended electric rate of $0.10 kWh and 8760 hrs/yr*

(Click to enlarge.)

One common control method is *modulation mode*, where the compressor's pressure control partially closes a valve to choke off the inlet to control the output flow as pressure rises. Control like this can be compared, for illustration purposes, to driving a car with the engine at full throttle and using the brakes to control the speed. Tables II and III show that a typical modulating screw compressor is fairly efficient at near full load, but at 50% load consumes 80% of its full-load power. In these compressors, a reduction in overall leak levels of 10% would result in a saving of less than 3%.

Table III. Compressor Use Profile — Current System



Compressor Mfg/Model		Full Load		Actual Elec Demand		Actual Air Flow	
		kW	Acfm	%kW	kW	%	Acfm
1	200 hp, SS, RS Lub. 2-step	176	1000	76	133.8	50	500
2	200 hp, SS, RS Lub. Mod	176	1000	80	140.8	50	500
3	200 hp, SS, RS Lub. VSD	176	1000	51	89.8	50	500
4	200 hp, SS, RS Lub. VD	176	1000	69	119	50	500

Another common mode is *two-step control* (a.k.a. load/unload or online/offline). This type of control is like stop-and-go driving, but allowing the car engine to rev at full speed all the time. With minimal storage, two-step control also is fairly efficient at full load, but consumes about 76% of its full-load power at 50% load. Larger air receiver sizes can be installed, however, to capture additional savings.

A third type, *variable displacement mode*, opens up ports in the compressor screw element and saves power in the top 50% of the control range. This system is not unlike a gas-saving 8/4 cylinder-unloading system in a modern automobile engine. Variable displacement mode is quite efficient at higher flows, but the compressor still consumes 69% of its power at 50% loading.

A fourth method of compressor control, *use of a variable speed drive (VSD)*, has the best turndown with good efficiency at higher load. At 50% loading, it consumes about 51% of its full load power. Continuing the analogy, the VSD mode is like an automobile in cruise control, with the motor speed adjusting to exactly match the power needed to maintain constant speed (pressure). This type of control has an almost direct savings relationship with leak reduction—*with an almost 10% reduction achieved with a 10% leak reduction.* At or near full load, however, the VSD control method will consume slightly more power than an equivalent fixed-speed compressor.

These, of course, are simple examples. They're based on the assumption that only one compressor is running in a system. Complex systems with multiple compressors can have efficiencies and turndowns much better or much worse than these examples illustrate. Automatic shutdown of unnecessary compressors is common with well-controlled systems, so, even if your compressors are running using an inefficient mode, the control system might still be able to shed compressors for good savings gains. The results usually depend on the combination of compressor sizes, control types and what central control method is used to coordinate the operation of the complete system.

The size of your savings

How much you save in your leak-reduction efforts depends on how well your compressed air system turns down in response to the change in flow. Before you run out and adjust your compressors, though, you should be aware that gaining this increased efficiency is not as simple as just changing the operating mode. Proper system design is required to ensure this new operating mode does not adversely affect your compressors or interrupt production activities.

Fortunately, most newer air compressors running in inefficient operating modes have the ability to run in more efficient modes with better turndown efficiencies—*i.e., in the load/unload or start/stop modes, or even variable speed drive (VSD) mode, if the unit is so equipped.* With the help of a qualified air-system expert and some affordable modifications to your system, it's possible to optimize your existing system for better leak-reduction savings. **MT**

Acknowledgements

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Ron Marshall, CET, CEM, is industrial systems officer with Manitoba Hydro's Customer Engineering Services (Winnipeg, MB). Bill Scales is CEO of Scales Industrial Technologies, Inc. (Carle Place, NY). Both are active members of the Compressed Air Challenge® (CAC). A partner organization of USDOE's Industrial Technology Program, the CAC is a voluntary col-laboration of North American industrial users, manufacturers, distributors (and their associations), consultants, state research and development agencies, energy-efficiency organizations and utilities working together to provide resources that educate industry on optimizing compressed air systems. The CAC has trained over 13,000 compressed air users since 1999. To learn how you can get involved in this important initiative, email: rcmarshall@hydro.mb.ca.

New Web-Based Training Offering Lets You Upgrade Your Compressed Air Knowledge

Join the CAC on November 9 for an especially cost-effective session of Fundamentals of Compressed Air Systems WE (Web edition). Led by experienced CAC instructors, this online version of the organization's popular live program offering uses an interactive format that lets the instructor diagram examples, give pop quizzes and answer students' questions in real time. Enrollment is limited to 25 participants. Visit www.compressedairchallenge.org to access online registration or find more details about the training.

If you have additional questions about this November Web-based session and/or other CAC training, please email info@compressedairchallenge.org.