Compressed Air Leak Surveys: Gateway to Industrial Efficiency

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ABSTRACT

Efficiency Nova Scotia (ENS), operated by EfficiencyOne, is Canada's first energy efficiency utility, and the administrator of demand-side management programs in Nova Scotia. ENS offers advice, technical assistance, and financial incentives to help residents and businesses reduce their energy consumption.

ENS typically recommends its complimentary Compressed Air Leak Survey program as a first step for industrial customers. As a free service, facility managers or maintenance staff can often participate without requiring approval from higher management. Leak repairs are inexpensive and fall within maintenance budgets, allowing customers to reduce operating costs without making capital investments. Customers can then use the "free" savings to invest in energy audits or capital upgrades funded in part by ENS.

ENS uses ultrasonic leak detectors to scan compressed air lines and tag leaks, and provides a report listing leak locations and their wasted annual energy and expense. The customer is required to repair a minimum of 50% of identified leaks within six months, after which ENS performs a follow-up survey and provides a final report detailing annual savings.

While on site, ENS technicians have an opportunity to interact with equipment operators, supervisors and managers, gaining insight into the success of other efficiency initiatives, identifying opportunities for future efficiency projects, and generating interest in energy management.

INTRODUCTION

EfficiencyOne is Canada's first energy efficiency utility, and the franchise owner of Efficiency Nova Scotia (ENS), the administrator of electricity demand-side management (DSM) programs in Nova Scotia. ENS offers advice, technical assistance, and financial incentives to help Nova Scotia households and businesses reduce their energy use. For industrial customers, we seek out innovative ways to engage all levels of an organization, and identify electrical energy savings. A service offering that has achieved significant results is the complimentary Compressed Air Leak Survey program.

Using ultrasonic leak detection equipment, an ENS employee scans all compressed air lines in a facility, tagging any identified leaks. Upon completion, the customer receives a detailed report describing all leak locations and their associated annual costs in terms of kWh. A follow up leak survey is performed once the customer has repaired as many leaks as possible, and a post leak survey report is completed to demonstrate energy savings from the leak repairs. In exchange for the complimentary survey, the customer is expected to repair a minimum of 50% of leaks discovered within 6 months of the initial survey.

There are several reasons for the success of the program, and its ability to achieve further energy savings:

1. As a low risk service, the customer often approves of the survey being conducted, allowing entrance to the facility, and providing ENS staff the opportunity to observe other potential efficiency measures.

2. Secondly, the ENS staff member can spend multiple days on site, interacting with equipment operators, supervisors, and management, garnering interest in efficiency measures at all levels.
3. Finally, repairing air leaks in an industrial facility can result in significant energy savings for a very low cost. This often receives positive recognition from senior decision makers who are keen to pursue more projects that result in engaged staff, and lower operating costs.

The aim of this paper is to demonstrate the success of compressed air leak surveys to achieve electrical energy savings, with the further objective of convincing industrial customers of the value of energy efficiency. The paper is separated into three main sections: 1) The cost of air leaks in an industrial compressed air system, 2) The structure of ENS's Compressed Air Leak Survey service, and 3) The success of compressed air leak surveys in terms of electrical savings and conversion to other efficiency projects.

COST OF COMPRESSED AIR LEAKS

Compressed air is used for many different applications in industrial settings, often where it is impractical or hazardous to use electrical energy directly to supply power to tools and equipment. However, it is also one of the most inefficient utilities in an industrial setting. In fact, over the lifetime of a compressor, energy costs will represent approximately 76% of the total cost of running a compressed air system (da Cunha, 2007).

A major opportunity to save energy is in the prevention of leaks in the compressed air system. Leaks frequently occur at air receivers, relief valves, pipe and hose joints, shut off valves, quick release couplings, pressure regulators and lubricators, filters and traps, tools, and equipment. In most cases, these leaks are a result of poor maintenance, and occasionally improper installation. The below figure demonstrates the high annual energy costs that can come from just one leak in a system.

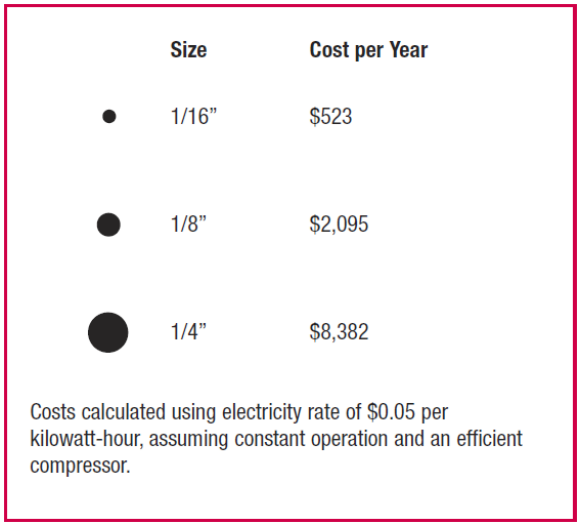

Figure 1. Cost of air leaks by size of orifice. *Source*: USDEERE.

From the above figure, it is evident that leaks can be a significant source of wasted energy in an industrial compressed air system, sometimes wasting 20-30% of a compressor's output (CAC, 1999). A typical plant that has not been well maintained will likely have a leak rate equal to 20% of total compressed air production capacity (CAC, 1999). On the other hand, proactive leak detection and repair can reduce leaks to less than 10% of compressor output (CAC, 1999). Aside from energy waste, leaks can cause several other issues in a system. Leaks cause a drop in system pressure, which can make air tools function less efficiently, adversely affecting production (Marshall, 2010). In addition, by forcing the equipment to cycle more frequently, leaks can reduce the life of almost all system equipment, including the compressor package itself (da Cunha, 2007). Increased running time can also lead to additional maintenance requirements, and increased unscheduled downtime. Finally, leaks can lead to the addition of unnecessary compressor capacity, which induces higher energy costs and waste. Figure 1 shows the scale of inefficiencies on an optimized (low leak rate) 100 HP compressed air system.

Typical Losses in a Compressed Air System

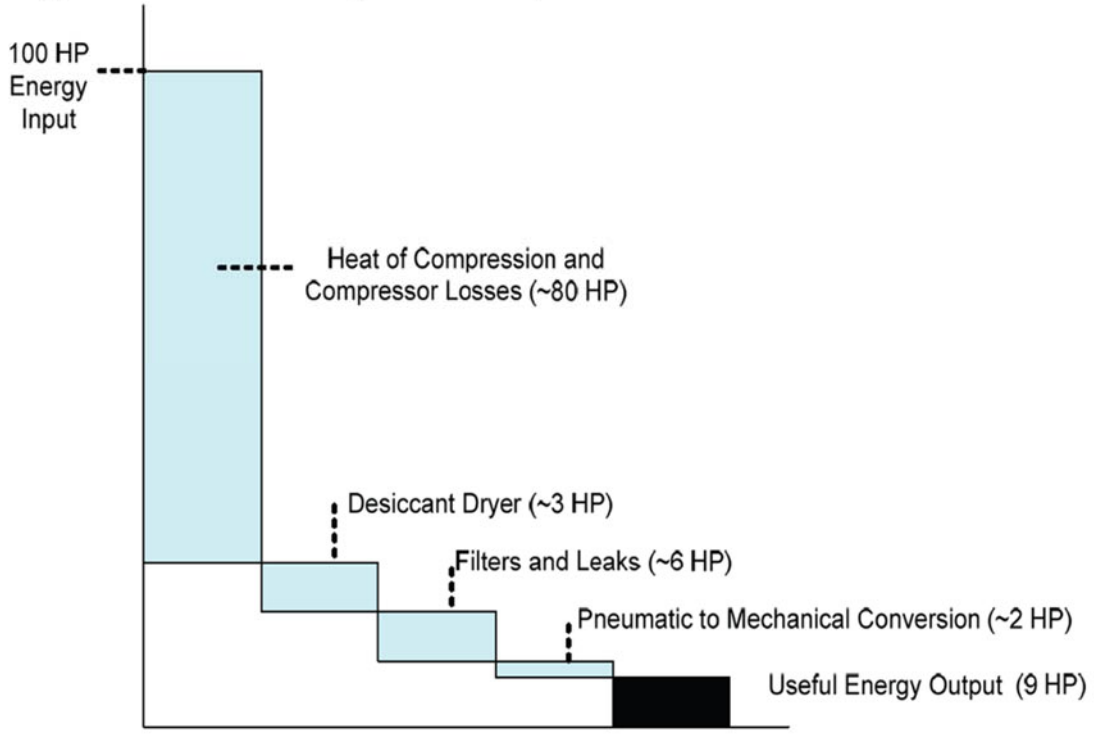

Figure 2. Compressed Air Energy Input and Useful Energy Output (Adapted from Northwest Energy Alliance)**.** *Source*: da Cunha, 2007.

The type of compressor control can have a large effect on the results of any leak reduction effort. For example, leak repairs that reduce the air consumption by 10% in a system with a single modulating compressor, would only achieve about 3% in energy savings because of the limited turndown capability of the modulating compressor control. (da Cunha, 2007) This same reduction, when applied to a system with a VSD compressor, would result in energy savings of about 10%. (da Cunha, 2007)

In this instance, although the energy savings are significantly lessened from the leak repairs alone, the leak survey provides a demonstration to the customer of the potential savings that can be achieved on a system with more efficient controls. Though capital expenditure is required to upgrade the compressed air system to, for example, a VSD compressor with air storage, the leak survey has provided a well-founded example of a potential reduction in operating costs that can result from such an upgrade. The cost reduction opportunities with compressed air leak repair are significant in and of themselves, however, as the above example reveals, they are often a stepping stone to achieving further energy savings in a compressed air system.

SERVICE DELIVERY

PROGRAM SCOPE

Under the Compressed Air Leak Survey program, ENS offers the opportunity for a participant to receive technical support to identify and repair leaks. An audit is conducted by an ENS program member to determine electrical energy-saving measures associated with compressed air leak repair in one or more qualifying facilities.
To assist in this phase, ENS can:

- Conduct an air leak survey utilizing ENS resources
- Provide documents reporting on survey results
- Provide data logging equipment to measure and verify the savings from repairs

Within two business days after receiving a request for a Compressed Air Leak Survey, ENS notifies the customer of the expected time needed to complete the study, and if any supporting information is required. A site visit may be needed to collect information regarding existing equipment or operating conditions. The eligibility of the customer is determined by the compressor system size, runtime hours, and system pressure. Although there is some flexibility, the compressor should be larger than 40 HP running at a minimum pressure of 70 psi for more than 40 hours per week. A smaller system may yield low energy saving results and prove difficult to justify for the time and resources spent on the survey. Ideally, the system is controlled by a compressor running on load/unload or VSD controls as it is on these systems that the energy savings from leak repair are most fully attained. A compressor operating on modulating controls does not benefit from leak repairs as the motor runs nearly fully loaded regardless of air demand. However, a leak survey on a modulating compressor system can reveal the energy saving potential of a leak reduction program, and the inefficiencies of modulating controls. This can motivate the customer to pursue a more intensive compressed air system retrofit, and has proved successful in 3 customers surveyed.

Once the intake information has been reviewed and deemed suitable for a survey, the customer is asked to complete and sign a Memorandum of Understanding (MOU) prior to ENS staff visiting the site and conducting the survey. The MOU is intended to ensure all safety requirements are met during the survey, and there is a level of commitment required on behalf of the customer to proceed with the service. The MOU confirms the customer understands the following items:

- In exchange for the complimentary compressed air leak survey, (the customer) is expected to repair a minimum of 50% of the number of leaks discovered within 6 months of initial survey
- (the customer) is expected to contact ENS as soon as leaks are repaired to arrange a follow up leak survey
- (the customer) must provide maintenance support while the survey is being conducted to ensure the safe approach of equipment, and to assist in proper labelling of leak locations
- (the customer) must be able to demonstrate adequate in-house technical expertise to repair discovered leaks (or be willing to procure said services at own expense)

The MOU also states that there is a commitment from ENS to provide the following items as part of the leak survey service:

- An Efficiency Nova Scotia employee will conduct a complimentary air leak survey of (the customer's) compressed air system using ultrasonic leak detection equipment
- Tags will be placed as close as possible to any discovered air leaks stating date, location, leak number, and severity
- All leaks will be recorded, and a report will be generated describing all leak locations and their associated annual costs in terms of kWh
- Efficiency Nova Scotia will perform a follow up leak survey once (the customer) has repaired as many leaks as feasibly possible[1]
- A post leak survey report will be completed to demonstrate energy savings from leak repairs
- Efficiency Nova Scotia employees will comply with all OHS policies and necessary protocols required by (the customer)

MEASURING SAVINGS

Each Compressed Air Leak project has a Measurement and Verification (M&V) plan, which is designed to quantify the actual energy and demand savings achieved. M&V activities occur before and after the retrofit. As the survey is being conducted by ENS program staff, the M&V process will involve a follow up leak survey, which will be performed in conjunction with the installation of a data logger on the air compressor for a two week period before, and after the leaks have been repaired. The data logging is completed on a sampling of projects. In comparing the data logger information with the hours provided by the client on the facility's production schedule, a change in the amount of electricity used by the air compressor during downtime hours will indicate a change in the amount of air being supplied to leaks in the system. By analyzing this data, the use of the data logger will allow a comparison of results with the ultrasonic device and verification of ENS auditing equipment accuracy. This assists with the validation of the measured leak results on facilities running 24/7 schedules where it is challenging to obtain leak data through flow monitoring.

[1] Some compressed air leaks are inaccessible or capital intensive to repair, therefore, it is understood that not all leaks can be fixed within a reasonable time frame and budget.

After the Compressed Air Leak Survey has been completed by the ENS program staff, a report will be generated that covers the following:

- Overview of facility and air compressor system
- Summary of air leaks found
- Savings as calculated using auditing equipment software
- Recommendations for repairs
- Other efficiency opportunities identified on site

The figure on the following page provides an overview of the program path that ENS and participants take when engaging in the Compressed Air Leak Survey service. The benefit of this figure is it demonstrates the 'Shared Task' portion of the program that can often be absent from other DSM programs. The shared tasks offer an opportunity for prolonged engagement between ENS and the customer, allowing time to explore all equipment and areas of an industrial facility, discuss problem areas and solutions with equipment operators, and build a rapport with site staff.

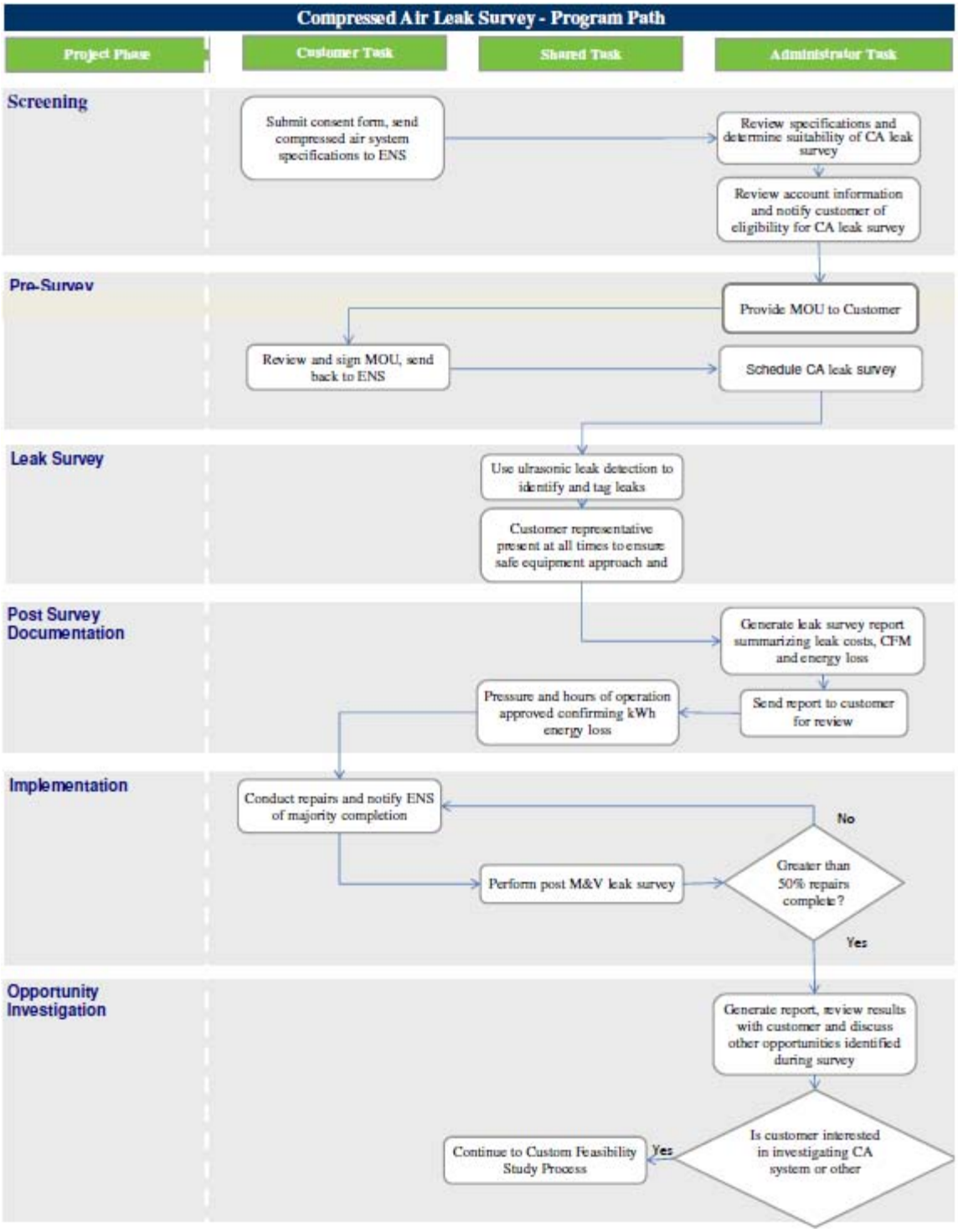

Figure 1. Compressed Air Leak Survey program path. *Source*: Efficiency Nova Scotia.

ULTRASONIC LEAK DETECTION

Leaks can be identified by many methods, but, as described above, the tool used by ENS is an ultrasonic acoustic leak detector. Ultrasonic leak detection is said to be the most versatile

form of leak detection. Due to its capabilities, it is readily adapted to a variety of leak detection situations. In the Compressed Air Challenge's *Advanced Management of Compressed Air*, the principle behind ultrasonic leak detection is described as follows: "In a pressure or vacuum leak, the leak flows from a high pressure laminar flow to a low pressure turbulence. The turbulence generates a white noise which contains a broad spectrum of sound ranging from audible to inaudible frequencies. An ultrasonic sensor focuses in on the ultrasonic elements in the noise. Since ultrasound is a short wave signal, the sound level will be loudest at the leak site. Ultrasonic detectors are generally unaffected by background noises in the audible range because these signals are filtered out." The advantages of ultrasonic leak detection include speed, accuracy, ease of use, the ability to perform tests while equipment is running, and the ability to find a wide variety of leaks ranging from very small to large (Bhatia, 2015).

Using the ultrasonic leak detector, ENS documents the location of leak, type of leak, size of leak, pressure at nearest regulator, and the estimated cost of each leak. The system pressure and nameplate information is noted at the compressor, and any pressure increases or decreases are noted at pressure regulators throughout the system. The customer is encouraged to prioritize leak repair, fixing the largest leaks first to achieve the most significant savings. The follow-up leak survey and report demonstrates the fixed leaks and associated cost savings, which validates the effectiveness of the program and strengthens the support for compressed air efficiency. Furthermore, documenting the repairs and the type of leaks can also indicate equipment that is a reoccurring problem for the customer. This provides clear maintenance benefits to the program participant, in addition to significant achievements in compressed air efficiency.

PROGRAM SUCCESS

LEAK SURVEYS AS EDUCATION

In their chapter in *Energy Efficiency in Motor Drive Systems* (2003), McKane and Medaris state that "optimization of compressed air systems represents one of the largest non-process industrial energy efficiency opportunities, with improvements of 20-50% readily achievable through the introduction of a best-practices approach. Lack of information has been a primary barrier to realizing substantial improvement in the efficiency, reliability, and productivity of industrial compressed air systems." Their reference to the interviews conducted with industrial compressed air users, as part of the USDOE *Assessment of the Market for Compressed Air Efficiency Services* (2001), indicated that most are unaware of the benefits of improving compressed air system efficiency, and are reluctant to purchase or pursue efficient compressed air system upgrades as they do not understand why they are beneficial (McKane and Medaris, 2003). These findings show the need for a low-risk, ease-of-entry program to both inform industrial customers, and achieve low-cost energy savings. The Compressed Air leak survey service offered through ENS is therefore seen as an educational tool that can offer a direct example of the benefits of efficiency measures, and the costs of taking no action.

To recap, when performing a compressed air leak survey, ENS staff spend the day on site with dedicated personnel from the facility, scanning all compressed air lines, inspecting most equipment, and interacting with managers and operators. This allows ENS staff the opportunity to gain insight into the operations of the equipment, learn of any ongoing issues that the operators have noticed, and may not have passed on to management, and listen to potential solutions or ideas from personnel. This builds trust among the operators and technicians, and

relaying this information to senior management demonstrates an understanding of the facility's processes, building further rapport. After the survey has taken place, and the report summarizing the leak costs has been sent, the customer is often interested in the energy-saving potential of the leaks, and is motivated to enquire further about other energy efficiency measures.

PROGRAM ENERGY SAVINGS

To date, ENS has conducted leak surveys at 39 different customer sites, achieving a total of 7,082,227 kWh saved since 2013. The surveys were performed at industrial facilities ranging from small to large, and with a diverse range of processes and compressed air system specifications. In each case, the customer repaired greater than the requisite 50% of leaks as verified by follow-up leak surveys. The average savings achieved at the facilities were 262,669 kWh. Of these survey participants, 53% went on to complete full-scale Feasibility Studies on their compressed air systems, or other large energy consuming equipment in their facility, which lead to the installation of more energy efficient equipment or upgrades. Of the 39 customers, 6 large industrials moved on to participate in ENS's Strategic Energy Management cohort program.

Once a compressed air leak project has been completed, funding is available to the customer at the Feasibility Study stage, with up to 100% of the costs covered by ENS. Further incentives to assist in the implementation of energy efficient equipment are also available. Despite these program benefits, and cost offsets, there can still be reluctance on the part of senior management to move forward with energy efficiency measures, due to a lack of understanding of the benefits, and higher priority capital expenditure items. However, after the leak survey has been completed, there is greater interest among participants in the other programs available to industrial customers. Of the 39 customers surveyed, 41% had not participated in any ENS program prior to the compressed air leak survey, despite prior communications and outreach. Due to the accessibility of the Compressed Air Leak Survey service, ENS was able to demonstrate the value of both DMS programming, and energy efficiency to the maintenance and operation departments, as well as senior decision makers.

CASE STUDY

A large industrial manufacturing facility with production facilities in Nova Scotia has a sprawling complex of production lines throughout several buildings. One of the largest uses of electricity in the facility is compressed air, and due to the amount of equipment, air lines, and pneumatics, compressed air leaks can be a major source of energy waste.

Beginning in 2014, ENS conducted periodic compressed air leak surveys using ultrasonic leak detection equipment to identify, measure, and tag leaks. During each visit, a different area of production was targeted, and a report was provided to the customer, summarizing the CFM and kWh loss of each leak, and its annual cost to the company. The facility's Energy Manager used this data to run a competition among the various departments to see how many leaks could be repaired on a weekly basis. This led to increased employee engagement on compressed air energy waste, and many of the leaks were fixed within a reasonable timeframe. ENS performed follow up leaks surveys to verify that leaks had been repaired. The project resulted in 1.8 GWh

in electricity savings, and permitted the customer to take 400 HP of compressors offline. With no cost to the customer, aside from some in-house labour to repair the leaks, the total financial savings are in the range of $130,000 annually.

Due to the facility-wide, multi-level engagement of staff, and enhanced awareness of energy issues in production, the customer went on to install numerous lighting retrofits, efficiency motor control upgrades, and achieved energy savings through participation in ENS's Strategic Energy Management program.

DSM PROGRAM BENEFITS

Compressed air leak management was identified as a specific low unit cost custom measure. The increase in volume of low unit cost programs offered the program greater budgetary flexibility. Originally, business development targeted this measure when discussing opportunities with industrial participants. As internal staff developed knowledge on compressed air leak management auditing practices, it was determined that a streamlined auditing approach would greatly benefit the programs results, and thus increase the volume of these projects. As a service offered by ENS, there has been great success on many levels with the Compressed Air Leak Survey program, both in terms of electrical energy savings, and increasing customer engagement.

CONCLUSION

In conclusion, compressed air leak surveys are an effective means of educating industrial customers on the costs of compressed air systems and the benefits of efficiency, engaging with multiple levels of an industrial organization, and achieving significant kWh at a low cost.

The high costs of compressed air are often hidden to industrial customers, as are many inefficiencies that exist in industrial equipment. Compressed air leak surveys demonstrate to maintenance staff, plant managers, and senior management, the costs associated with leaks in a compressed air system, and how low-cost improvements can achieve significant electrical energy savings. This engages all levels of the organization to seek out other opportunities to save energy and money in processes and equipment.

The structure of ENS's Compressed Air Leak Survey service offers a simple and cost-effective program that is appealing for industrial customers. By offering a complimentary service, senior management is more likely to permit the energy audit to be conducted due to the low risk of participation, and small dedication of resources required. The quality of the study and reporting provided to the customer builds a rapport on multiple levels of the organization from which to build on for further efficiency projects. The exploratory structure of the leak survey ensures ENS staff are investigating all areas of an industrial facility, and are able to identify other areas of improvement. This information is passed on during the review of the leak survey results, and encourages further implementation of efficiency measures.

The lessons from this program should be applied to other energy intensive industrial processes and equipment, focusing on no-cost, or low-cost solutions that are easily achieved by facility staff and equipment operators. Providing a simple and effective means to make the cost of electricity visible to all levels of an organization encourages engagement in energy efficiency measures, and leads to deeper energy retrofits.

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