**Compressed Air Energy Savings: SAV-AIR Monitor and Control System and the PNW Compressed Air Challenge**

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ABSTRACT

This paper presents the results from two compressed air programs supported by the Northwest Energy Efficiency Alliance (Alliance) over the last five years. In 1997 the Alliance funded the Northwest regional version of the Compressed Air Challenge (CAC), a national collaborative that develops and provides resources to educate industrial plant operating staff on ways to increase net profits through compressed air system optimization. CAC has trained about 400 facility people and documented six case studies that saved 4.5 million kWh annually in the PNW.

SAV-AIR, LLC provides integrated compressed air management, including real-time monitoring and control. In 1998 the Alliance partly funded six compressed air systems. These plus seven customer-funded systems averaged a reduction of 35% in electrical energy use. SAV-AIR's system also increased reliability, stabilized pressure control, decreased operating costs, and provided on-going management information to help these facilities avoid capital upgrades. As of the end of 2002 the program has saved 16 million kWh annually and by 2010 the region expects to save 320 million kWh a year.

INTRODUCTION

U.S. Office of Industrial Technologies' 1998 Motor Challenge report estimated that in 1994 industrial motor systems consumed 679 billion kWh per year of which 90 billion kWh were used in compressed air systems (1). Due to frequent modifications, compressed air systems suffer from problems such as improperly installed or leaking distribution lines, outdated or inadequate controls, and excess compressor capacity. But efficiency improvements and speed controls could save over 17%. In the Pacific Northwest (PNW) compressed air systems consumed 4.5 billion kWh/year (11% of all PNW motor energy) and programs funded by the Northwest Energy Efficiency Alliance have typically provided energy savings at over twice the rate predicted by the Motor Challenge report.

COMPRESSED AIR CHALLENGE

The Compressed Air Challenge (CAC) is a national collaborative that develops and provides resources to educate industrial plant operating staff on ways to increase net profits through compressed air system optimization. For more information on the national CAC, see their web-site (2). Over a 10-year period electricity accounts for 76% of a facility's compressed air costs, yet facilities could save 18% to 50% of this energy by using best practices – if they had the proper information. As of July 2002, the national CAC program had trained over 4,000 people in the Fundamentals and Advanced Compressed Air Systems courses (3).

In 1997 the Alliance funded the development of a PNW Compressed Air Advisory group and began offering CAC Fundamentals training (Level 1) in conjunction with local electric utilities and compressed air equipment suppliers. Class attendees have included a wide range of backgrounds; from school maintenance personnel to engineers from large manufacturers with complex systems. To date, CAC has trained about 400 facility people in the PNW and it has documented in case studies 4.5 million kWh/year in savings at six of these facilities.

Evaluation Results

U.S. DOE, in cooperation with Lawrence Berkeley National Laboratory and Oak Ridge National Laboratory conducted a national evaluation and completed phone surveys with 100 CAC participants across the country. 76% of participants reported making significant capital or operating improvements to their compressed air system since attending the training. Participants also reported significant non-energy benefits, including:

- Reduced downtime
- Reduced system moisture and contamination
- More consistent system pressure.

They found the sessions both useful and of high quality and they reported reducing compressed air energy use by 8% and saving about $12 million (3).

In the Pacific Northwest, MetaResource Group and Currents Consulting, two independent evaluation contractors, surveyed regional CAC attendees to understand their actions resulting from the training. These results are included in the evaluation of the two of the Alliance's Initiatives (4) (5).

MetaResource Group conducted a mail survey of 256 participants that had attended one of 12 Level 1 Compressed Air Challenge trainings held in 1999 and 2000 in the Pacific Northwest. The survey respondents included end-users, institutions and vendors. The survey asked respondents if they would be interested in attending a Level 2 training, and also about their application of the Level 1 course materials.

Results of the mail survey indicated that CAC appears to be an effective means to increase the market for compressed air efficiency consulting services and motivate participants to improve their compressed air management practices. Among end-users in the respondent group, 80% said they had applied something they had learned from the Level 1 course.

Among respondents willing to share information on their application of CAC training, eight success stories were developed. Altogether these stories reported savings of $200,000 per year from actions attributed to the CAC training. The more ambitious respondents installed capital improvements; others focused on operations and maintenance improvements.

Participants liked the Level 1 curriculum and felt that the handouts and presentation materials were excellent and that the instructor was effective. Not all attendees directly benefit from reduced energy cost, but they appreciate improved reliability, avoided capital purchases, improved pressure regulation as well as better air quality.

In January 2003, Currents Consulting conducted a follow-up survey via Internet of participants in three Level 1 Compressed Air Challenge classes in the Pacific Northwest that took place in October 2002. Forty-four participants were compressed air end-users, and among the 34 with viable e-mail addresses, 14 responded to the survey. Although the sample size was small, responses indicated that the trainings had a substantial impact on respondents' compressed air management practices. Findings included the following.

- Respondents were asked to indicate which compressed air management activities they had done as a result of attending the training. Seventy-nine percent of respondents said they had done at lease one activity and fifty-seven percent of respondents said they had done more than one activity.
- Forty-three percent of respondents said they had saved compressed air energy and dollars.
- Fifty percent of respondents said they had achieved one or more non-energy benefits.
- Ninety-three percent of respondents thought there were large reliability benefits (57%) or some reliability benefits (36%) from improving compressed air system management.
- Similarly, ninety-three percent of respondents thought there were large energy or some energy savings cost benefits from improving compressed air system management.

Respondents were also asked about their use of compressed air system operating costs for system management. As an outcome of attending CAC training, sixty-four percent reported either changing the way they looked at compressed air operating costs or were planning to use operating costs in the future for management of their systems.

Case Studies

Thirty-four of 45 survey respondents to the mail survey had applied something that they learned in the CAC course. Table 1 summarizes seven case studies documenting about $200,000 in annual savings. The full case studies are available on the Alliance web-site (6).

Table 1: Compressed Air Challenge Case Studies

| Participant | Compressor Capacity (HP) | Savings (kWh/year and dollars) | Actions taken | Project Cost | Payback |
|---|---|---|---|---|---|
| Medical equipment parts manufacturer | 65 HP plus 40 HP backup | 50,000 ($2,500) | Added storage, reduced leaks and compressor runtime | Labor and nominal cost | NA |
| Automobiles safety restraint manufacturer | 1,100 HP | 1,625,000 ($65,000) Estimated | Improved compressor and dryer controls, pressure reduction | Planned project | NA |
| Hunting equipment manufacturer | 850 HP | 500,000 ($15,500) | Reduced pressure and moved receiver | $10,000 | < 1 year |
| Wood product manufacturer | 75 HP plus a backup compressor | 25,000 ($1,000) Estimated | Cut leaks & compressor operation by 50% | Labor and nominal cost | NA |
| Polymer product manufacturer | 100 HP plus 25 HP backup. Was reduced to 75 HP total. | 200,000 ($12,500) | Leak repair, reduced pressure, new lower capacity compressors | $51,000 | 4 years |
| Dimensional lumber mill | 700 HP. Was reduced to 400 HP | 3,700,000 ($92,600) | Cut 300 HP capacity, air pressure control, better moisture control | $141,000 | 1.5 years |
| Laminated veneer plant | 185 HP | 100,000 ($5,000) | Cut air leaks by 50%, reduced pressure and capacity | Labor and nominal cost | NA |

Two Detailed CAC Case Studies

Saint-Gobain Performance Plastics

Aaron Houseknecht, Energy Management Analyst at Seattle City Light used his CAC Level 1 training to help his Seattle customer, a plant producing advanced polymer components for aerospace and high tech companies, to save $12,500 a year in compressed air energy costs. Their system included three older oil-flooded screw compressors—two 25-horsepower (HP) and one 75-HP. Although 100-HP of compressor was running continuously, it was having trouble providing enough air for production. Aaron's analysis found that 90% of the time the air requirements could be met with one 25-HP compressor. The remaining 10% could be met by the 75-HP unit. Based on his recommendations, Saint-Gobain replaced the old compressors with one 25-HP and one 50-HP oil-flooded screw machines, they installed updated sequencing controls, added a flow controller. 1,000 gallons of additional receiver capacity, and a new cycling refrigerated air dryer. Maintenance found and removed a major restriction in the air distribution piping and they put in place a plan to detect and repair leaks. These improvements cost $51,000 but the savings will provide a four year simple payback, less if Seattle City Light's utility incentive is considered.

Blount International, Inc.

Dave Scharnhorst, an HVAC mechanic, used his CAC Level 1 training to help Blount International's Lewiston, Idaho ammunition plant to save $15,000 in energy costs. Blount's compressed air system used 14 compressors with a combined capacity of 850-HP. He first upgraded the size of one of the air receivers to reduce pressure variation and stop over-modulation of the largest compressor. He moved the smaller receiver to another system that also needed more capacity. These improvements cut electrical use by 400,000 kWh/year. Then Dave reduced the plant's main air pressure by 15 psig saving an additional 77,000 kWh/year and cutting 35% off the operating hours of the 250-HP compressor. The total cost of these improvements was recovered in less than one year. Dave's next projects are to install load/unload controls, increase the distribution manifold size, and to continue repairing leaks in Blount's miles of air distribution piping. Dave's major lesson from the CAC course, "I want to correct the unfortunate and untrue belief that air is free."

The Alliance learned that facilities people who had attended CAC training were much more likely to seek additional support from a consulting firm specializing in compressed air systems. One consultant used by PNW CAC graduates is SAV-AIR, LLC, a Portland, Oregon firm that was also supported by the Alliance.

SAV-AIR: INTEGRATED COMPRESSED AIR MANAGEMENT SYSTEMS AND ENGINEERING SERVICES

SAV-AIR's management systems include integrated compressor control and monitoring that:

- Provide significant product quality and productivity benefits due to reliable compressed air; and
- Reduce production costs through direct energy savings.

SAV-AIR's compressed air solutions eliminate pressure fluctuations and reduce system downtime that often hinders productivity and product quality. After implementing their recommendations, customers have seen 17% to 60% energy savings in compressor energy consumption and consistent, reliable compressed air on the factory floor.

SAV-AIR has achieved a proven and significant technological breakthrough designed to improve the reliability of the entire compressed air system and provide financial justification through energy cost savings and productivity benefits. Just considering those projects where monetary value could be assigned to the non-energy benefits, the average productivity savings have been 60% of the energy cost savings achieved.

Other productivity benefits include:

- Consistent processing which provides a more safe and profitable operation,
- Product damage or loss avoidance due to compressed air quality and pressure fluctuations,
- Compressed air system reliability, and
- Reduced downtime through preventative maintenance practices.

Distinctive features of SAV-AIR's PL-2000 compressed air management system include:

- Response to production demand in real time
- Stabile system pressure
- Verified energy cost savings

- System monitoring and trending including:
  - Power (kW)
  - Flow (scfm)
  - Pressure (psig)
  - Temperature (°F)
  - Dewpoint (°F)
- SCADA ready for plant-wide network display and control
- Compressor manufacturers' native controls for offline operation always available.

As the initial step for making decisions about the best approaches for reducing compressed air costs, SAV-AIR first installs a temporary monitoring and reporting system to establish flow, power and pressure baselines. They also complete a detailed characterization of plant demand, distribution dynamics, and equipment performance by running simulations to determine which control strategies and system modifications will optimize system performance and efficiency. The results from this monitoring and modeling are an objective recommendation for compressed air system performance improvements – SAV-AIR does not always recommend their own controls as the best solution for a customer.

SAV-AIR's PL-2000 is an innovative measurement and reporting system that makes compressed air a "visible," measured utility—like water, gas and electricity—this system provides the information and control capability for an integrated approach to identifying, implementing and monitoring efficiency measures in industrial compressed air systems. SAV-AIR's progress toward market transformation in the PNW has been documented by MetaResource Group, an independent evaluation contractor (7).

Relevance of CAC to SAV-AIR

There has been one consistent attribute of customers that have selected SAV-AIR's compressed air management system – the firms' commitment to compressed air training for their staff--through the Compressed Air Challenge training or other course work and vendor education. Awareness of the costs and opportunities for compressed air optimization have lead to a full range of solutions – from simple leak repair to sophisticated monitoring and control options.

SAV-AIR Case Studies

SAV-AIR is now working toward business independence after working with the Northwest Energy Efficiency Alliance to develop and test its services and management system approach in about a dozen facilities. Six projects are documented in case studies available on the Alliance web-site (8) and additional case studies are available on SAV-AIR's web-site (9).

Table 2 summarizes eleven of the SAV-AIR projects. In each case, a PL-2000 control and monitoring system was installed. The measured savings percentage is of compressed air energy costs and the simple payback in the table is based on energy savings alone and does not include utility incentives or the value of non-energy (productivity) benefits.

Table 2: Pacific Northwest SAV-AIR Project Summary

| | ANNUAL CA ENERGY COSTS | | | PROJECT | | |
|---|---|---|---|---|---|---|
| | **Before** | **After** | **Measured Savings** | **Included Measures** | **Cost** | **Payback*** |
| **MINERAL PROCESSING** | $175,000 | $77,000 | $98,000 (56%) | Controls, 3 compressors, new dryer, receiver & building piping | $395,000 ** | 4.0 |
| **WOOD PRODUCTS A** | $175,000 | $120,000 | $55,000 (31%) | Controls, receiver, dryer repair | $110,000 | 2.0 |
| **METALS CASTING** | $193,000 | $118,000 | $75,000 (39%) | Controls | $30,000 | 0.4 |
| **CABLE MANUFACTURER (PLANT CLOSED)** | $53,300 | $28,200 | $25,100 (47%) | Controls, one compressor | $52,000 | 2.1 |
| **PLYWOOD PLANT A** | $120,000 | $99,600 | $20,400 (17%) | Controls, valve upgrades | $123,000 | 6.0 |
| **PARTICLE BOARD PLANT** | $85,000 Estimated | $64,000 | $21,000 (25%) | Controls and system design for Greenfield plant | $21,000 | 1.0 |
| **WOOD PRODUCTS B** | $118,000 | $76,700 | $41,300 (35%) | Controls, piping, receiver | $175,000 | 4.2 |
| **TRANSPORTATION MANUFACTURER** | $82,500 | $55,000 | $27,500 (33%) Estimated | Controls, piping, receiver | $101,000 | 3.7 |
| **WOOD PRODUCTS C** | $74,500 | $30,000 | $44,500 (60%) | Controls, dryer, piping, receiver | $138,000 | 3.1 |
| **WOOD PRODUCTS D** | $104,400 | $68,200 | $36,200 (35%) | Controls, receiver | $122,500 | 3.4 |
| **PLYWOOD PLANT B** | $120,700 | $86,400 | $34,300 (28%) | Controls, piping, dryer, receiver, move compressor | $103,000 | 3.0 |
| **WOOD PRODUCTS E (PLANT CLOSED) *** ** | $143,500 | $114,200 | $29,300 (20%) | Controls, receiver, two compressors | $80,000 | 2.7 |

* All project paybacks are from energy savings alone.

** Project costs were for a complete new compressed air system and a building that would have been needed, regardless of the efficiency project.

*** Project costs do not include two new replacement compressors.

Luzenac America Talc Mill

Luzenac America's Talc grinding plant in Three Forks, Montana (Figure 1) approached SAV-AIR to help them provide a more reliable compressed air system that would consume less energy.

Figure 1. Luzenac Talc Mill

SAV-AIR established flow, pressure, power and electrical energy costs for the existing compressed air system. SAV-AIR and Discovery Energy Solutions, a Montana Power Company, helped Luzenac to replace their old system with one 250-HP variable speed and two 250-HP standard oil-flooded air compressors as well a new receiver and a heated regenerative air dryer as well as new piping. To optimize performance, flow, power and pressure sensors were installed and connected to a PL2000™ (Figures 2 and 3).

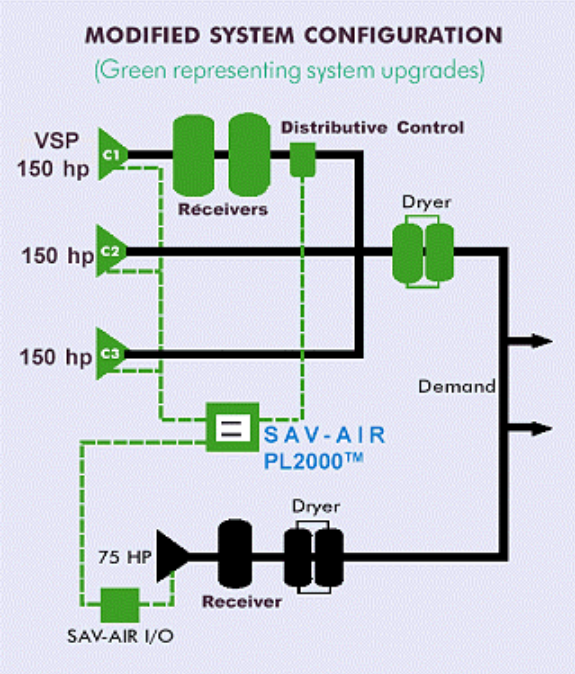

Figure 2. Luzenac SAV-AIR Control Schematic


Figure 3. Luzenac Compressor Room

John Campbell of Discovery Energy Solutions feels that, "The average system is usually over-pressurized, and it fluctuates a lot. SAV-AIR's PL2000™ actually makes decisions about what the system is requiring at any given time and provides just that much pressure. This ability to stabilize pressure is of tremendous value to industries." This can be seen in Figure 4 where the upper plot shows wide fluctuations in pressure before compared to the much tighter control shown in the after plot below.

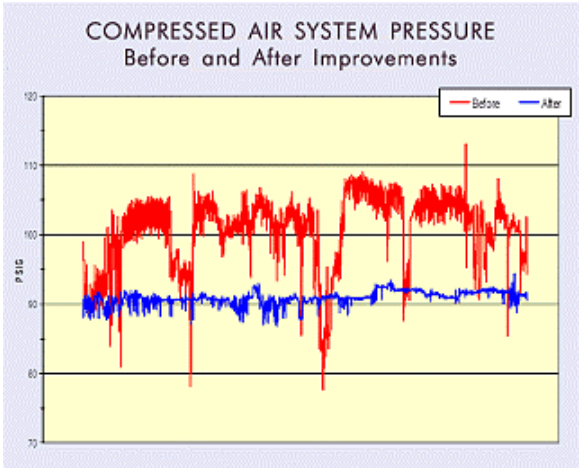

Figure 4. Compressed Air System Pressure

Results:

- Annual energy savings of **$92,000** ($.04/kWh)
- Fully automated compressed air controls
- Compressed air system monitoring
- Reliable system performance
- Stable pressure (+/- 3 psi)
- Clean dry air
- Reduced maintenance costs

Weyerhaeuser Sawmill and Veneer Drying Plant.

The Emerald Public Utility District teamed with SAV-AIR to help Weyerhaeuser's Coburg, Oregon sawmill (Figure 5) to save over 1.3 million kWh annually by fixing leaks, optimizing the compressor configuration and monitoring and managing their compressed air system.

Figure 5. Weyerhaeuser's Coburg Sawmill and Veneer

These improvements avoided the purchase of additional compressors and stabilized pressure to within +/- 5 psi. The sawmill and veneer drying plants each had separate systems but they were combined and the 300-HP sawmill compressor met "base-load" while the two smaller veneer compressors now serve as "trim" machines (Figure 6).

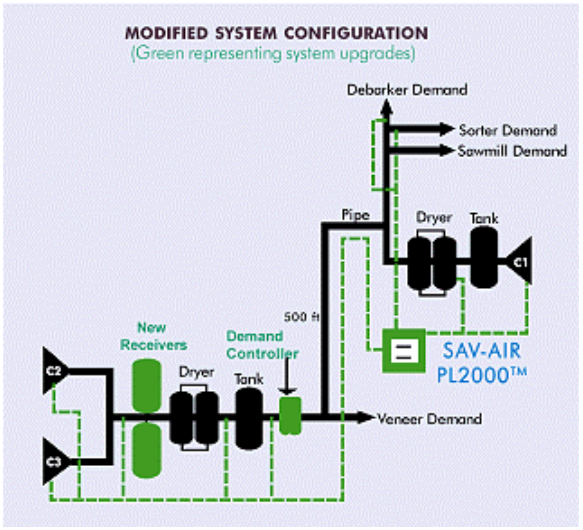


Figure 6. Weyerhaeuser SAV-AIR Control Schematic

To stabilize and control pressure in the system, a SAV-AIR Demand Controller was installed along with a PL2000™ monitoring and control system.

Figure 7 shows the average compressor power draw reduction from about 530 kW to 400 kW.

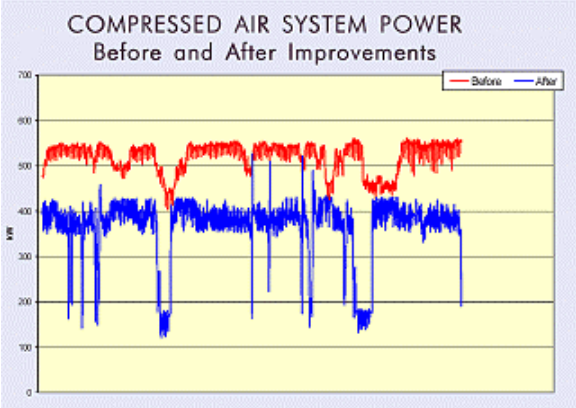


Figure 7. Compressed Air System Power

Results:

- Annual energy savings of **$55,000** ($.04/kWh)
- Fully automated compressed air controls
- Compressed air system monitoring
- Reliable system performance
- Stable pressure (+/- 5 psi)
- Access to real-time data
- Reduced maintenance costs

REFERENCES

1. XENERGY Inc., "United States Industrial Motor Systems Market Opportunities Assessment," prepared for the U.S. Department of Energy, Office of Industrial Technologies, Washington, DC (1998).

2. Compressed Air Challenge web site, www.compressedairchallenge.org.

3. Dan Greenberg, "Leveraging the Compressed Air Challenge to Deliver Increased Productivity and Customer Satisfaction, An Exclusive Report for E Source Members," Platts Research & Consulting, ER-03-1, January 2003.

4. MetaResource Group, "SAV-AIR Initiative Market Progress Evaluation Report #3," prepared for Northwest Energy Efficiency Alliance, Portland, OR (2001).

5. Currents Consulting, "Drive Power Initiative Market Progress Evaluation Report #4," prepared for Northwest Energy Efficiency Alliance, Portland, OR (2002).

http://www.nwalliance.org/projects/projectdetail.asp?PID=57

6. Northwest Energy Efficiency Alliance, Compressed Air Challenge Success Stories, http://www.nwalliance.org/projects/projectdetail.asp?PID=27

7. MetaResource Group, "SAV-AIR Initiative Market Progress Evaluation Report #4," prepared for Northwest Energy Efficiency Alliance, Portland, OR (2002).

8. Northwest Energy Efficiency Alliance, SAV-AIR Case studies web-site http://www.nwalliance.org/projects/projectdetail.asp?PID=22

9. SAV-AIR web site and case studies, http://www.savair.com/resources/cases.htm

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