Making Performance Analysis Business-As-Usual In the Industrial Compressed-Air Market

James B. Hanna, Pacific Gas and Electric Company
Michael Baker, SBW Consulting, Inc.

Abstract

Compressed air is industry's "fourth utility," after electricity, gas and water, and is a major cost in manufacturing plants. Most compressed-air systems do not operate efficiently. PG&E is engaging relevant vendors and many end users in order to find the best approach to transforming the industrial compressed-air market in California, for the purpose of improving the efficiency of these systems. The results of this effort should be valuable to participants in the California market and in other markets where industrial compressed-air systems are an important energy end use.

PG&E conducted market research with compressed-air testing firms throughout the California and national markets and has conducting extensive investigation of compressed-air testing methods and procedures. Data collected is being used to develop successful business models for compressed-air testing services and to determine the best strategy to promote the development of a vibrant and effective market for testing services. Strategies under development include but are not limited to standardized tools for compressed-air testing, training for trade professionals and end users, and development of case studies and other marketing materials. Collectively, these strategies are referred to as CAMP (**C**ompressed-**A**ir **M**arket transformation **P**rogram). As appropriate, PG&E plans to collaborate with the Compressed Air Challenge in implementing CAMP.

This paper describes what has been accomplished to date in the development of CAMP and the next steps needed to expand and enhance the role of performance testing in the identification and implementation of compressed-air efficiency improvements.

Introduction

Compressed air is industry's "fourth utility," after electricity, gas and water, and is a major cost in manufacturing plants. It is used extensively as a source of power for tools, equipment, and industrial processes in the chemicals, plastics, glass, pulp and paper, electricity generation, textiles, petroleum, automobiles, and aircraft industries. Most compressed-air systems do not operate efficiently. They are often modified over time, are frequently oversized, and poorly maintained.

In 1998, PG&E conducted the compressed-air Performance Analysis Testing (PAT Tool) pilot program. This program brought a performance-testing approach to the analysis of compressed-air systems located at 75 industrial facilities. At many of these facilities, the testing program identified O&M (operations and maintenance) and capital measures that could reduce compressed-air energy consumption by 10 to 30 percent. Many of these measures had payback periods less than two years.

The 1998 PAT Tool pilot demonstrated that relative low cost testing services can identify highly cost-effective efficiency opportunities. However, there is little evidence of profitable compressed-air testing services operating in the California industrial market. Is

performance testing an effective way to motivate customers to implement energy efficiency measures? What are the barriers to the development of a market for these testing services? How could these barriers be overcome? These are the three primary questions to be answered in the development of CAMP: **C**ompressed-**A**ir **M**arket transformation **P**rogram. Once these questions are answered, CAMP will implement the best strategies for overcoming market barriers and help performance testing businesses succeed in the California compressed-air market. As appropriate, PG&E plans to collaborate with the Compressed Air Challenge in implementing CAMP.

PG&E's Performance Analysis Testing (PAT Tool) Pilot Program

Objectives of the Pilot Program

In 1998, PG&E developed a new commissioning and market transformation program that provides performance evaluation and efficiency improvement recommendations for commercial and industrial compressed-air systems. PG&E used the PAT Tool, which consists of a data logger (to record compressor operating performance over time) and a compressed-air system audit and analysis system (DOE/BPA's AIRMaster). AIRMaster[1] analyzes compressor performance and calculates energy and cost savings associated with the recommended improvements. Customers and trade allies benefit through reduced energy costs, energy-efficiency information, and quantification of retrofit opportunities. PG&E's program objectives were:

1. To demonstrate the effectiveness of the compressed-air performance PAT Tool.
2. To identify the potential energy savings in compressed-air systems.
3. To provide effective compressed-air system evaluation that facilitates the implementation of significant energy conservation measures that would otherwise not have been consider and installed.
4. To increase the usage of good analysis tools and sound methodologies to achieve credible energy savings estimates and ultimately help to reduce energy consumption in industrial compressed-air systems.
5. To establish equipment and control system performance evaluation as a productive business for our trade allies.

Performance Testing Tools

The PAT Tool consisted of a data logger and compressed-air performance analysis software. The data logger was Summit Technologies' PowerSight Energy Analyzer (PS), Model PS 3000. The PS data logger measures and stores voltage, current, true power, VA power, true power factor, energy, and frequency. The maximum, minimum, and average values for each parameter are recorded. Up to 59 variables, e.g., max, min., and average voltage, max, min., and average true power) are recorded. The recording interval can vary from 1 second to 99 minutes. At 15-minute intervals, you can store 10 days worth of data.

---

[1]The authors wish to express their appreciation for the help and guidance provided by Eric Bessey in the development of PG&E's program. Mr. Bessey was the developer of AIRMaster 2.0 and is playing a major role in the development of AIRMaster+

We recorded 5-10 days of data with the PS data logger. This data was uploaded from PS's software to an MS Excel™ spreadsheet. Here the data was viewed graphically, analyzed, and combined into day types. Day typing allows the data to be combined based on similar energy usage patterns, e.g., all days with 3 shifts were combined into one day type). Hourly data for each day type was then entered into AIRMaster.

To model compressor performance and calculated energy and cost savings we utilized the AIRMaster 2.0 compressed-air system audit and analysis software. AIRMaster was originally developed by Oregon State University under contract with Bonneville Power Administration.

AIRMaster evaluates potential operation and maintenance (O&M) measures to maximize the performance of existing compressed-air systems. O&M measures are those measures that typically can be carried out by operations and maintenance personnel, and generally entail low capital cost, few operating risks, and quick paybacks. AIRMaster analyzes the following energy efficiency measures: reduce plant leaks, sequencing compressors, installing or adjusting unloading controls, reduce system pressure, and reduce run time.

Lessons Learned

We learned that utilizing a data logger provides an accurate way to record compressor performance. The customers viewed this as a credible way to document compressor performance. In combination with AIRMaster, customers responded that the PAT Tool provided an accurate and credible evaluation of their compressed-air system.

We also determined that the cost saving potential is substantial, among the pilot sites averaging approximately 30% of the compressors' annual usage. These savings can be captured with low cost and short payback investments.

Data loggers and performance analysis software, e.g., AIRMaster can be employed to increase the likelihood that customers will implement the recommendations.

Increased accuracy and credibility that comes from using the PAT Tool, can help vendors and trade allies more effectively assist customers with implementation of AIRMaster's cost saving recommendations.

Market Size Assessment

The PAT Tool pilot demonstrated the potential for a performance testing approach to the California compressed-air market. Next, we needed to know more about the structure and size of that market. A market size assessment was completed to gain a better understanding of the market and to guide the design of additional market research efforts. The market assessment relied on data from the following data sources:

1. PG&E 1997 Customer Billing Records.
2. California Energy Commission 1997 Utility Sales Data.
3. US Bureau of the Census – 1994 Manufacturing Energy Consumption Survey (MECS).
4. US DOE Motor Challenge Market Assessment Inventory (MAI).
5. US DOE Office of Industrial Technology - Industrial Assessment Center (IAC) Audit Database.
6. 1998 PG&E PAT Tool Pilot Results.

Estimates of Compressed Energy Use

Three sources of information were used to estimate the compressed-air end use share in each of the 2-digit SIC manufacturing industries. The two primary sources were the US Motor Challenge Market Assessment Inventory (MAI) and results from PG&E's 1998 PAT Tool pilot. These sources provided average compressed-air end use shares for each manufacturing industry. Both were based on detailed audits of industrial plants. For some industries both studies were based on data from a substantial sample. In these cases an average of the two studies was used. In other industries only a single study provided data from a substantial sample and its end use share was used directly. These shares were multiplied by the share of total electricity use for each industry in the target market. In total, we found that the compressed-air end use accounts for 10.2 % of industrial electric sales in the areas served by California's investor-owned utilities (approximately 75% of the California market)

Potential Savings from Efficiency Improvements

A similar approach was used to estimate the fraction of electric sales that could be saved by the adoption of compressed-air efficiency improvements. In this case, we used three sources of data: MAI, the 1998 PAT Tool pilot results, and data from the US DOE Industrial Assessment Center (IAC) database. Again, savings fractions were averaged when the substantial samples were represented by more than one study. In addition, we only used IAC results when no other results were available, as that database represents only small end users. In total, we found that approximately 18.3% of the compressed-air end use in the target market could be saved by these efficiency measures. This translates to savings of approximately 538 GWh per year, which assuming average electricity cost of $.07/kWh is an annual cost savings of $35,000,000.

Survey of End Users and Vendors

The market size assessment helped us target the next stage of CAMP, which involved market research with end users and compressed-air vendors. We selected end users for this survey that fell into the 2-digit SIC industries that account for the largest portions of the compressed-air market in California. Following are the primary conclusions reached as a result of this research.

- Vendors of compressed-air equipment and services collectively believe that customers do not have compressed-air systems that operate efficiently.
- The costs to operate compressed-air systems are perceived as relatively minor compared to the cost of operating an entire facility. Of the 37 customers interviewed, 21 said these costs are "not very important" and most companies (31 of 37) do not track the cost to operate their compressed-air systems. Companies are unaware of the impact compressed-air systems have on energy costs.
- While compressed-air systems are necessary to operate, most systems only receive attention when a performance deficiency affects productivity.
- Most customers (25 of 37) would be willing to pay for a service that enabled them to monitor and evaluate the energy used by their compressed-air systems. The amount they are willing to pay depends on the implementation costs relative to the reduction

in energy costs. System performance data would support proposed compressed-air system improvements.

- Twenty-eight of the thirty-seven compressed-air users we interviewed would find value in a service that illustrates compressed-air system performance and efficiency. A service like this would illustrate the current cost of operating compressed-air systems.
- Compressed-air users and vendor have split opinions about who is best suited to deliver services that monitor and evaluate the energy costs for compressed-air systems. However, respondents do agree that only companies or organizations with personnel experienced in compressed-air applications and systems should offer this service. Two-thirds of the vendors interviewed said results from an energy efficiency service for compressed-air systems need independent verification for credibility.
- Time as well as capital resources are limited. Energy efficiency services offered should be designed to minimize a company's resource investment.
- Companies relying on compressed air for production are concerned about losing productivity by accepting efficiency measures that lower available horsepower or pressure. It may be easier to achieve increased energy efficiency by presenting services targeted at improving compressed-air system productivity, which also reduce energy costs. Customers are uncertain that energy efficiency improvements to the compressed-air systems will deliver the predicted results—significantly reducing energy costs while maintaining productivity.

Survey of PAT Tool Pilot Participants

We allowed some time to pass following completion of the PAT Tool pilot so that participating customers would have an opportunity to take advantage of the recommendation sent to them after the performance testing was completed. Then we drew a sample of these participants to conduct in-depth discussions and determine what impact the testing had on their operations and how we might improve on the business model for the performance testing service. Some of the conclusions from this round of discussions were as follows:

How large are the compressed-air energy costs and the proposed savings?

Data from the PAT Tool test reports and PG&E's billing system were examined to determine the importance of the compressed-air energy costs and the savings associated with the proposed efficiency improvements. In general, the respondents operate relatively large facilities. The median annual electric use was nearly 7,000,000 kWh and demand was over 1,500 kW. The median annual electric bill for these facilities was over $600,000. Median electric use for the compressed-air system (as estimated with AIRMaster) was over 500,000 kWh, and the expense associated with this use was over $40,000 per year. These are relatively large facilities with substantial compressed-air energy bills.

Testing at these facilities uncovered the potential for large savings, ranging from 10 to 70% of the estimated compressed-air electric use. However, when you view this in the context of the overall facility electric bill the savings are a relatively small share, with a median of 1.8%. The median cost of implementing the recommendations was $10,000 with a median simple payback of .7 years. Excluding the cost of the test, it should be possible for these facilities to adopt the proposed measures and pay for them out of their operating

budgets. However, this may not be true once the cost of the test is added. Clearly, many other factors enter into the customer's decision making, beside this simple payback. These factors include the credibility of the test procedure and various operational and organizational barriers to specific recommendations.

Who would be the best testing agent?

None of the options discussed with respondents received unanimous support. The highest positive ratings were given to independent testing agents. Although a majority thought they could work with equipment vendors. Respondents were concerned with credentials, e.g., do they know compressed-air systems, for all types other than equipment vendors. The most negative opinions were recorded for engineering consulting firms and maintenance contractors.

How could we increase the value of the testing service?

None of the respondents knew how their system's energy use compared to systems in other plants. Four thought this might help motivate them to act. The testing service could provide benchmark comparisons, appropriately normalized, for system energy use and energy costs. Five thought that training should be included in the testing service, particularly with respect to the recommended measures. Some measures require design work prior to implementation. Four thought this could be a valuable addition to a testing service. The majority of respondents require performance verification for project acceptance. Three thought that it might be appropriate to include this in a testing service. This seems like a reasonable addition, if the testing has identified equipment upgrades, e.g., controls, the testing agent could easily become the commissioning agent for the measure.

Survey of Similar Testing Services

We also felt that much could be learned by talking with firms that deliver other types of testing services to industrial customers. We contacted a sample of six firms in following types of businesses.

- Boiler Equipment Vendor
- Building Commissioning
- Electric Systems Testing
- Building Systems Consulting Engineers
- Testing Services -Specialized Production
- Building Controls Vendor

Some of these businesses obtain all of their revenues from testing services. Others provide testing in conjunction with the sales of other equipment and services. Their existence proves that testing-based services can be profitable for the industrial market. Our major conclusions from these discussions were as follows:

1. The most effective marketing tools for a testing services company are a good reputation and a satisfied customer base willing to tout the firm's services by word-of-mouth.

2. The most important factors in closing sales for testing services are quality, flexibility and timeliness
3. While there are some basic requirements that must be met by potential employees, the most important employee attributes are good character and good work habits. Most of the required technical knowledge can be gained through training and experience.
4. Support services (such as design, specification writing, construction management or commissioning) for implementing recommended measures are seldom used
5. There is little customer demand for financing of recommended measures

Survey of Compressed Air Testing Firms

Another step in our pursuit of CAMP has been to examine the business and technical practices of firms who are currently delivering performance testing services to the industrial compressed-air market. By examining the pros and cons of their various business models we can further refine our notions of what type of testing service would be most successful.

Of the seven firms interviewed, four indicated their business was solely involved with providing energy audits, while three firms indicated they were primarily in the business of selling compressed-air equipment or services other than energy audits. One of the firms that does not sell compressed-air system-related equipment sells equipment to monitor compressed-air systems.

The following comments summarize the important findings of these interviews:

1. There are a wide variety of approaches that are practiced in performing compressed-air audits.
2. There is a great deal of disagreement among the auditors as to what are and what are not appropriate and meaningful methods of determining compressed-air system performance.
3. Customer's perceptions of the operation of their systems are often erroneous.
4. There is agreement among the auditors that many opportunities exist for substantial energy saving projects in compressed-air systems.
5. It is possible to support a business that performs only compressed-air audits and testing, although it is helpful to establish a relationship with an ESCO or utility that will "feed" the auditor projects.
6. Firms in this business rely on referrals for most of their sales. These firms undertake little proactive marketing.

Barriers to Improved Compressed-Air Efficiency

Based on all of the efforts described above and our review of the literature, we have identified a number of barriers that must be overcome before improvements can be made in the typical efficiency of compressed-air systems. We have also identified barriers to the development of a vibrant compressed-air performance testing market in California. These barriers are as follows:

Barriers to Adopting Compressed-Air Efficiency Improvements

1. **Lack of Compressed-Air Cost Information**. Operations, maintenance and financial managers lack information on the cost of operating their compressed-air system, and thus do not recognize it as a source of potential cost savings.
2. **Lack of Understanding of Compressed-Air System**. Operations and maintenance managers do not understand how the compressed-air system works as a whole and the factors that affect its efficiency. Therefore, they turn to simple solutions like buying more horsepower rather than optimizing the system.
3. **Compressed Air is a Low-Priority Auxiliary System**. Operations and financial managers consider the compressed-air system to be an auxiliary system; thus it gets low budget priority and little management attention. Systems only get attention when performance degrades to the point that production is threatened.
4. **Decision-making Lacks Life Cycle Costing**. Financial managers do not consider life cycle costs when deciding whether to invest in compressed-air system improvements.
5. **Lack of Cost/Benefit Data on Compressed-Air Improvements**. There is a lack of credible information (costs, benefits, risks and applicability) about strategies for reducing compressed-air costs. Information is needed that satisfies the needs of operations, maintenance and financial managers.
6. **Lack of Skills to Implement Compressed-Air Improvements**. Plant operations and maintenance staff lacks the skills needed to implement and maintain cost saving improvements.
7. **O&M Staff can not Internally Sell Compressed-Air Improvements**. Operations and maintenance staff do not have the time, skills or organizational standing needed to convince financial managers that investments should be made in cost saving improvements.
8. **Lack of Standards for Rating Efficient Equipment**. There is a lack of generally available standardized efficiency and performance ratings to guide the selection of new or replacement equipment, *e.g.*, compressors, dryers, and end use devices.
9. **Conditioned to Expect Rebates for Equipment**. Plant managers in California are accustomed to receiving utility rebates for new energy efficient equipment, which may address only part of the energy cost saving opportunities in a system. They are less receptive to unsubsidized efficiency projects that only involve changes to operations and maintenance practices.

Barriers to Purchasing Performance Testing Services

1. **Too Few Credible Testing Firms**. There are too few credible testing firms operating in the California market. Credible firms are knowledgeable about compressed-air systems and the requirements of the customer's end uses and should not be motivated by the sale of new equipment.
2. **Little Experience Buying Testing Services**. Operations and Maintenance managers have little experience working with compressed-air testing firms.
3. **Little Credible Data on Cost/Benefit of Testing**. There is little credible information about the cost-effectiveness of the services provided by compressed-air testing firms.

4. **Concern about Impact of Testing on Production**. Operations and Maintenance managers are influenced by the Production managers' concerns about the impact of testing on production.
5. **Existing Testing Firms are Not Visible**. Testing firms only market by referral, thus the existing pool of firms are not generally visible to operations and maintenance managers.
6. **Limited Time to Devote to Testing**. Operations and maintenance managers do not have the time required to work with a testing firm and to understand and apply the test results.

Market Barriers Originating with Testing Firms

1. **Lack of Compressed-Air Testing Experience**. New firms who want to enter this market may lack experience evaluating compressed-air systems.
2. **Lack of Credible Market Potential Data**. New firms who want to enter this market may lack credible information about sales and profit potential associated with selling performance-testing services.
3. **Lack of Working Capital**. New firms who want to enter this market may lack working capital needed to establish a successful performance testing service (equipment, labor and overhead costs).
4. **Lack of Marketing Materials/Methods**. Both new and existing firms may lack materials and methods needed for marketing the testing services, i.e., to generate good sales leads.
5. **Lack of Qualified Sales Staff**. Both new and existing firms may lack staff who can sell performance-testing services, *i.e.*, good at converting a good lead to a firm sale.
6. **Lack of Qualified Testing Staff**. New firms may lack the staff needed to deliver high quality performance testing services. This may also be a barrier for existing firms if they attempt to substantially expand their testing business.
7. **Lack of Testing Tools and Procedures**. Both new and existing firms may lack the tools and procedures (audit, measurement and analysis) needed to efficiently and reliably deliver the testing service.

Developing a Successful Market Transformation Strategy

If a vibrant market for performance testing services can be created in California, we believe that many market barriers can be overcome and substantial improvements in compressed-air system efficiency will result. However, it will take a many pronged strategy to create this market for testing services. Attitudes will have to change on both the supply (vendors) and demand side (end users) of this market. We will also have to tightly integrate testing with other strategies, such as improved procurement practices and training for system auditors, system operators and financial decision-makers.

We have begun the process of developing the needed strategies. We have also learned that the only successful strategies are those that many market actors help create. We have begun a series of on-going dialogues with trade allies and have presented the following possible strategies that could be support by PG&E's CAMP:

1. **Offer a Toolkit for Performance Testing**. A toolkit for testing compressed-air systems will be developed and offered to testing agents ("Testing agent" refers to

firms that sell testing services. These firms may also offer other products and services such as compressed-air equipment and components.) The toolkit will consist of AirMaster+, a family of popular data loggers (available from the Pacific Energy Center Tool Lending Library), and software for analyzing performance measurements taken with these loggers.

2. **On-Going Dialogue with Local Partners**. The results from PG&E market research and the critical components of this market transformation plan will be presented to a number of firms that either currently offer or might be interested in offering compressed-air testing services. These presentations will promote the opportunity present in the California market to expand revenues from testing services and will allow PG&E's market transformation team to gather specific suggestions for improving this market transformation plan.
3. **Create and Promote "Best Practice" Guidelines**. PG&E's market transformation team, with the assistance of a group of compressed-air testing experts and other market actors will create a "best practice" guideline for compressed-air performance testing and analysis. Other best practice guidelines will also be developed to help end users "shop smart" when selecting a testing agent and when investing in new compressed-air equipment.
4. **Sales Support**. PG&E' will help recruit interested end users and assist testing agents in providing performance testing services. Testing agents interested in the California market will use the performance testing toolkit and the best practice guidelines in providing these services.
5. **Provide Marketing, Advertising and Sales Support**. Materials such as case studies and management presentations will be developed and made available to testing agents to be used in marketing and selling testing services.
6. **CFO/Decision Maker Training** Instructional materials and systems will be developed and deployed to advance the skills of key decision makers, who determine whether testing would be a valuable service and who are authorize the purchase of testing services.
7. **Testing Agent/Operator Training**. Instructional materials and systems will be developed and deployed to advance the skills of end users (operators and technicians) and testing agents.
8. **Provide Internet Resources for Performance Testing and Analysis**. Information, documents and tools will be made available via the web to assist end users in purchasing quality testing services and assist testing agents in marketing and delivering these services.

These strategies were presented in half-day workshops held with four groups of trade allies (distributors, consulting engineers and manufacturer representatives). In general, the strategies were well received although many specific improvements were identified. This kind of interaction with local trade allies will be continued as we develop and pursue each of these strategies. In addition, PG&E plans to collaborate with the Compressed Air Challenge in implementing CAMP.

References

US Department of Energy, Compressed-Air Challenge. 1998. *Compressed-Air Challenge Source Book.*

Compressed Air and Gas Institute, Rollins, John P., Editor. 1989. *Compressed Air and Gas Handbook, Fifth Edition.* Prentice Hall PTR.

Pacific Gas and Electric Company. 1998. Portions of the site reports from PG&E's 1998 Compressed-Air Performance Analysis Pilot Program.

Pacific Gas and Electric Company, Application Note. 1997. *Efficiency Improvements in Industrial Compressed Air Systems.*

Pacific Gas and Electric Company. 1999. *Potential Energy Savings in the California Compressed Air Market .*

Pacific Gas and Electric Company. 1998. *User Documentation for the Operations and Maintenance Automated Tool.*

Bonneville Power Administration. 1997. *Case Studies: Compressed Air System Audits Using AIRMaster.*

Aimee T. MCKANE . 1999. *Collaborative Intervention: Working With Market Forces to Effect Lasting Change.* Lawrence Berkeley National Laboratory, Washington, DC.

US Department of Energy, Motor Challenge. 1998. *National Market Transformation Strategies for Industrial Electric Motor Systems, Volume II: Market Assessment.*