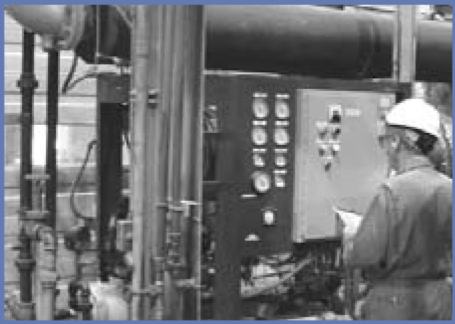

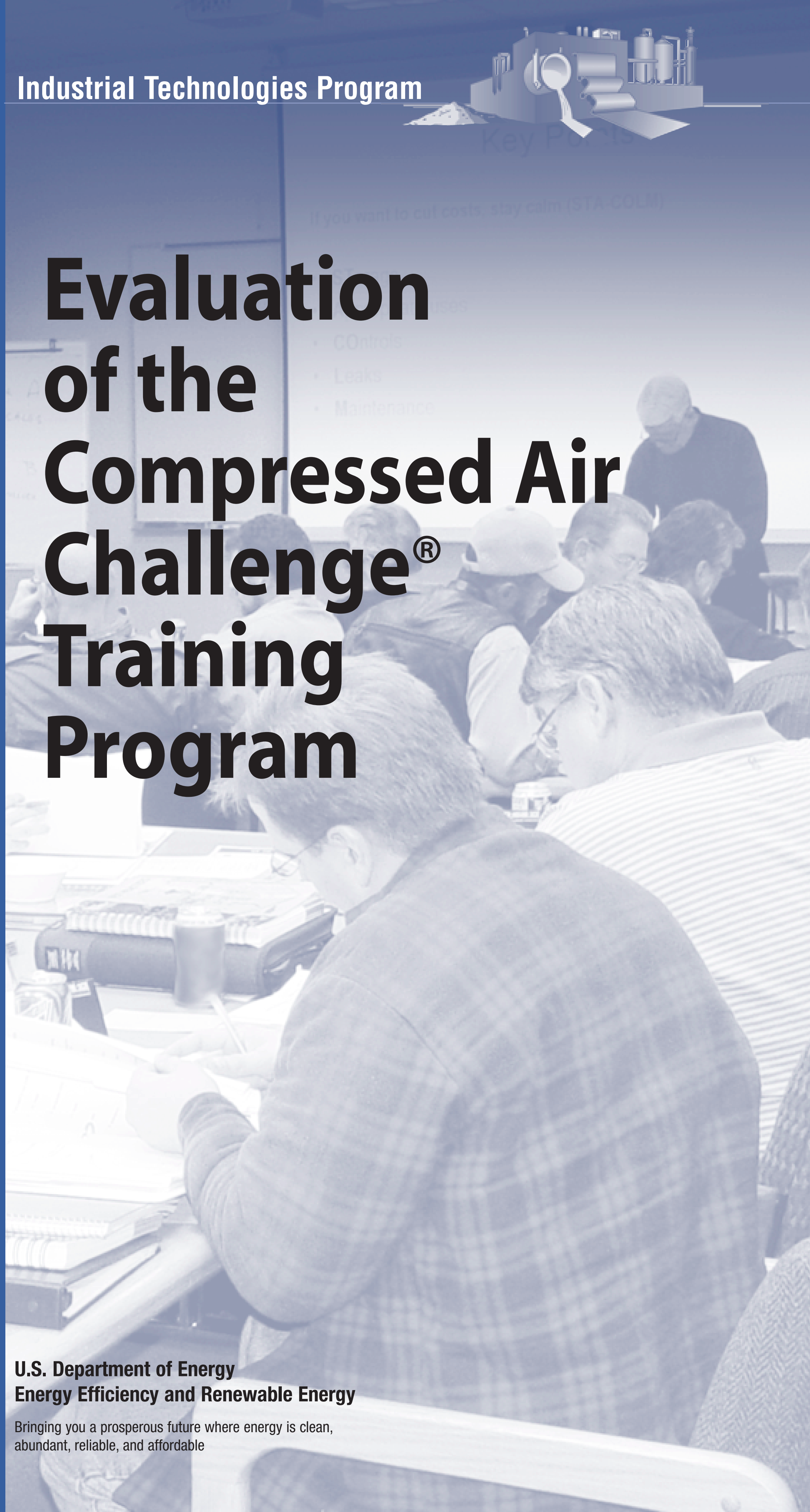

Industrial Technologies Program

Evaluation of the Compressed Air Challenge® Training Program

U.S. Department of Energy
Energy Efficiency and Renewable Energy

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Acknowledgments

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Cover photos courtesy of Compressed Air Challenge®.

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The information listed below can be found in pdf form on the CD attached to the inside back cover of this Executive Summary.

Section 1 Executive Summary

This is the final report of an evaluation of the Compressed Air Challenge (CAC) training program. The training program is designed to provide plant personnel and compressed air system vendors with knowledge and tools required to effect improvements to the energy efficiency and overall performance of plant compressed air systems. As of May 2001, 3,029 individuals had attended the CAC *Fundamentals of Compressed Air Training Systems* and 925 individuals had attended *Advanced Management of Compressed Air Systems*. These individuals represented 1,400–1,500 separate business establishments.

The evaluation is based on three main research tasks: analysis of the CAC registration database, interviews with 100 end-user personnel who attended the CAC training, and interviews with 100 compressed air system vendors and consulting engineers who attended the training sessions.

1.1 Key Findings

Generally, the evaluation found that the program is performing very well. The key findings from this research and analysis are as follows.

- ***The Compressed Air Challenge® Training Program clearly reached its target audiences.*** The CAC Training Program has been very effective in attracting attendance by plant managers and technical staff, as well as by targeted constituencies on the supply side of the market, which consists of compressed air system equipment distributors and consulting engineers. Moreover, the training sessions attracted attendance by more than 500 government officials, engineering faculty, and utility energy efficiency program operators. Many of these individuals play an active role in disseminating information about energy efficiency to end-users and equipment vendors.

  Table 1-1 shows the distribution of training attendees among different groups of actors in the compressed air system market[1].

- ***Training attendees found the sessions to be both useful and of high quality.*** High percentages of both end-users and compressed air professionals reported that they found the training sessions to be useful and of high quality.

- ***A very high portion of end-users reported using materials directly from the training in making efficiency improvements to their compressed air systems.*** In fact, 76% percent of the sample end-user representatives reported that they had made significant

[1] Contact records were available for 2,509 of the training attendees through March 2001. Information about the type of organizations these individuals represented was not recorded in the database. Associations shown in Table 1-1 were inferred from the name of the attendee's organization.

Table 1-1 Distribution of Attendees by Type of Organization

Type of Organization	Percent of Total Attendees
End-User	45
Vendor: Distributor or Consultant	32
Government, Academic, Program Operator	18
Cannot Determine from Organization Name	4
Total	**100***

*Percentages do not add to 100 due to rounding

capital and/or operating improvements to their compressed air system since attending the CAC training. Two-thirds of end-users who made such improvements reported that they had used materials and knowledge gained from the training to guide the improvements they made.

- ***End-users who implemented compressed air system efficiency measures achieved high levels of energy savings.*** Using a conservative approach to the savings analysis, XENERGY estimated that attendees who implemented compressed air system efficiency measures after completing the training saved, on average, 149 megawatt hours (MWh) per year, or roughly 7.5% of pre-project system energy. As a point of reference, compressed air system efficiency experts find that, for the typical compressed air system, 30% of system energy usage can be saved through cost-effective measures.

- ***The Compressed Air Challenge® training program was highly cost-effective.*** At current national industrial electricity rates, the average value of savings achieved by program participants who implemented measures was $7,428. Projected to the population of all end-use facilities that sent representatives to the CAC training through May 1, 2001, program savings are estimated to be 144,635 MWh per year or $5.73 million per year.

  Between May 1, 2001 when the initial survey was completed and May 1, 2003, the total number of end-use facilities that received CAC *Fundamentals* training increased from 1,141 to 1,891. Assuming the same implementation rate and similar savings as the surveyed population, the program savings is estimated to be 168,703 MWh per year, or $8.47 million per year. Based on a conservative estimated 5-year project life for these compressed air improvements, the net present value of the cost savings from this training is $37 million[2]. The cost to the CAC sponsors (net of fees) for delivering the compressed air training to all 4,203 training participants, including vendors and others, during this period was approximately $452,000, or $107 per trainee[3]. The value of the energy savings when compared to program costs yields a cost benefit ratio of $82 in energy savings for each training dollar spent.

- These estimates do not include the value of energy savings achieved by vendors who attended the program and incorporated practices they learned into their operating procedures. Nor do they include the value of significant non-energy benefits realized by attendees who implemented compressed air system efficiency measures.

2 Assumes 2% annual increase in electricity process and 6% discount rate.

3 Note: CAC Sponsors may choose to “write down” the cost of the training fee to induce key customers to participate. The net cost figure includes the value of these write downs as reported to the CAC.

- ***End-users who implemented compressed air system efficiency measures experienced significant non-energy benefits.*** A full 76% of end-users who implemented system efficiency measures reported experiencing benefits such as: reduced downtime, reduced moisture and contamination in the system air, more consistent system pressure, and restored delivery of adequate pressure to all system components. This study did not seek an estimate of the dollar value of these benefits. However, some attendees provided dramatic characterizations of the non-energy effects of the projects. For example:

  > "[As a result of the improvements, we] saved time and money in all aspects of production."

  > "[We] gained sufficient air capacity to make quality products that we were previously incapable of producing."

  Additional evidence concerning the value of non-energy benefits of compressed air system efficiency projects can be gleaned from BestPractices case studies. Of 22 facilities that provided case study information on compressed air system improvements to the BestPractices program, 19 reported that they realized benefits such as increased production capacity, avoided capital costs for new compressors, and reduced maintenance costs. The reported value of these benefits ranged from $55,000 to $500,000.

  A recent analysis conducted of 28 compressed air case studies referred by DOE Allied Partners revealed annual energy benefits ranging from 242,000 kilowatt-hours (kWh) to 1 5,000,000 kWh, with an average of 3,440,400 kWh per completed project. The average payback was 1.1 years. Of the 28 completed projects, 15 reported maintenance savings and 17 reported increased productivity as the result of the compressed air improvements[4].

- ***Increased vendor efficiency offerings as a result of training.*** Since participating in the training, 52% of sample vendors reported that their companies have begun to offer new efficiency services. Most have to do with system assessment: analysis of compressed air efficiency (17%), measurements of system flow/pressure and energy consumption (both 11%), and ultrasonic leak detection (11%).

- ***Vendor application of training materials.*** The majority (85%) of vendor participants claimed that they have used training workshop materials or information when they evaluate customer compressed air systems. Among this group, 18% of respondents used them in "all" evaluations, and 40% used them in "many" evaluations. A similarly high percentage of vendors (64%) claimed that they have used the CAC workshop materials in diagnosing their customers' compressed air system operating problems.

1.2 Program Overview

The Compressed Air Challenge® (CAC) is a voluntary collaboration of manufacturers, distributors, and their associations; industrial users; facility operating personnel and their associations; consultants; state research and development agencies; energy efficiency organizations; and utilities. The mission of the CAC is to develop and provide resources that educate industry on the opportunities to increase net profits through compressed air system optimization. To date, the primary activity of the CAC has been to develop, promote, and present training programs in compressed air system efficiency. The programs are targeted to equipment vendors and end-users.

4 Based on an analysis of DOE Allied Partner case studies by Resource Dynamics Corporation, Vienna, VA, July 2003.

CAC currently offers two levels of training: *Fundamentals of Compressed Air Systems* and *Advanced Management of Compressed Air Systems*. CAC recruits local sponsors to market the training sessions to end-users and compressed air system vendors and to provide local logistical support. Attendees are charged a registration fee. The *Fundamentals* session is a 1-day workshop designed to serve as an introduction to compressed air system operation and management. It is oriented to the needs and technical background of plant personnel and compressed air system vendors. The *Advanced* workshop is designed to provide facility engineers, maintenance supervisors, equipment distributors and other key personnel with the most up-to-date, in-depth technical information on how to troubleshoot and implement improvements to industrial compressed air systems.

As of May 2001, 3,029 individuals had attended the CAC *Fundamentals of Compressed Air Systems* and 925 individuals had attended *Advanced Management of Compressed Air Systems*. These individuals represented 1,400–1,500 separate business establishments[5]. As of May 2003, the total number of individuals trained had increased to 4,203[6]. Other program activities include maintenance of an interactive Web site (www.compressedairchallenge.org); provision of additional publications, including *Compressed Air System Performance: A Sourcebook for Industry* and *Best Practices for Compressed Air Systems*; and technical support through the DOE Clearinghouse[7], technical articles, and conference presentations.

1.3 Evaluation Objectives and Methods

The principal objectives of this evaluation were to:

- Identify and characterize the specific energy-saving actions vendor and end-use customers who attended the CAC training programs have taken as a result of their participation in the training
- Determine whether the customers would have undertaken these actions in the absence of the training
- Assess the overall benefits that have resulted from these actions, in terms of reduced system energy consumption, improved system performance, and reduced down-time and maintenance requirements
- Assess the cost-effectiveness of the program.

The research for this report consisted of three primary tasks:

- ***Analysis of Attendee Database***. XENERGY analyzed the database of workshop attendees maintained by CAC. The primary purpose of this task was to develop counts of attendees by type (end-user versus vendor or consultant), level of training, and date of training. These estimates were used to develop samples for the vendor and end-user surveys and to develop estimates of program-level energy savings.
- ***End-user Survey***. XENERGY and its survey research contractor Atlantic Marketing Research Company (AMR) administered a survey to 100 representatives of end-use customers who attended the workshops. The principal objectives of this survey were to characterize the attendees, their companies, and compressed air systems; to determine what actions they had taken to improve the efficiency of their compressed air systems; to assess the influence of the CAC training on those actions; and to estimate energy savings and non-energy benefits arising from those actions.

[5] The estimate of individual establishments was developed by counting unique combinations of firm names and addresses in the workshop attendee database. In some cases, one or both of these fields was missing from the attendee record.

[6] Number of participants reported by ORC/MACRO, Calvert, MD on behalf of the Compressed Air Challenge.

[7] As of January, 2004 the DOE Clearinghouse is now the EERE Information Center.

- ***Vendor Survey***. XENERGY and AMR conducted a survey of 100 representatives of vendors who attended one or another of the CAC training workshops. The principal objectives of this survey were to characterize the vendors who attended; to assess the extent to which they had used knowledge and skills gained through the workshop in their business; and to gauge the effect of the program on their perception of efficiency services as a potential source of revenues and profit.

1.4 Selected Detailed Findings

The following paragraphs present selected details from the findings of the end-user and vendor surveys.

1.4.1 End-Users

Respondent Profiles

The end-user attendees surveyed were primarily plant engineers, chief electricians, and maintenance managers. That is, they were not the principal investment and operating decision makers at their facilities but were likely to have direct supervision over compressed air systems at their facilities.

- Approximately 78% of them were employed at manufacturing facilities and 12% in other kinds of industrial facilities, such as water treatment plants.

- The firms represented were fairly diverse in size (based on number of employees they reported). Their compressed air systems tended to be small- to medium-sized. Of the systems installed, 32% had two or fewer compressors; two-thirds had five or fewer. Connected horsepower for the sample systems clustered in the range from 100–500 horsepower (hp).

Effect of the Program on Capital and Operating Improvements to Compressed Air Systems

Capital and System Improvements

- Overall, 76% of end-users that attended training made some type of capital or operating improvement to their compressed air systems. Among this group, 29% had made compressed air system improvements prior to the training.

- The most common improvements made were the replacement of current compressors with more efficient models (18%), reconfiguring system piping (10%), and adding air storage capacity (8%).

Enhanced Operations and Maintenance Procedures

- About half of end-user respondents said they had implemented changes to their compressed air system maintenance procedures following training.

- Among these individuals, 82% claimed that they had added new procedures to their maintenance routines. The most frequently cited were periodic leak inspection (24%), air filter cleaning (13%) and leak repair (13%.) About 45% of respondents also claimed they increased the frequency of their maintenance procedures.

Measures to Eliminate Inappropriate Uses of Compressed Air

- Most (80%) of the attendees that eliminated inappropriate end-uses reported using CAC materials to identify those measures

- The two most commonly cited processes in which the end-users had ceased using compressed air were open blowing for cleaning machines, finished parts and shop areas (26%); and aerating, agitating, and percolating liquids (20%).

Baseline Development

- The *Fundamentals* course stressed the importance of developing baseline depictions of system operations and estimates of baseline energy use as a foundation for improving system management and design. According to the survey results, 44% of end-users had begun work on their baseline study and roughly 30% had completed them. The majority of end-users who had initiated baseline development used the baseline document to guide component changes (73%) and operations and maintenance improvements (61%).

Training–Facilitated Company Compressed Air Improvements

- Knowledge and skills gained at the CAC training workshops clearly played an important role in enabling attendees to identify, gain management support for, and fund system improvements. About 65% of those that implemented improvements said they used information or analysis from the workshops to support requests for project funding.

  - About 31% of end-users reported that CAC information was "very important" in convincing management to undertake improvements. An additional 43% reported that the workshop material was "important" in that regard.

  - About 22% of vendors thought it "not at all likely" that they would have been able to implement system improvements without attending the workshops. An additional 26% reported that implementation would have been "very unlikely" without training.

Planned Capital Improvements

- A significant portion of attendees (29%) reported that they planned to implement measures in the near future. About 83% of these respondents had already made improvements since attending the workshop. A small group (7%) claimed they had not made any system improvements—either before or after training.

- Approximately 76% of end-users who reported planned system improvements used materials and knowledge gained from CAC training to identify measures to be implemented.

Estimates of Energy Savings and Other Benefits Associated with Projects

XENERGY used information provided by respondents to estimate annual energy consumption of their air compressor systems and energy savings from projects they reported implementing. Estimates were developed for 67 respondents who provided complete information about system configuration, hours of use, and measures implemented. Average annual compressed air system energy consumption for these 67 respondents was 4,590 MWh.

- ***Numbers of efficiency measures implemented***. Managers of 42 of the 67 sample facilities reported that they implemented only one compressed air efficiency measure in the period after the training. Of these 42, relatively complete information on compressed air system configuration and efficiency measures was available. Of the remaining 25 facilities, 19 implemented two measures.

- ***Annual energy savings***. Among those who implemented improvements, average energy savings was estimated at 148,563 kWh per year or 7.5% of system energy use. At the facility level, savings ranged from a few thousand kWh per year up to 1.2 million kWh per year. At an average cost of $0.05/kWh, the mean value of annual savings from compressed air system efficiency projects implemented by the respondents was $7,428, with a range of $1,000 to $58,465[8].

- ***Costs for compressed air system efficiency measures***. Expenditures on compressed air system improvement projects (including engineering and project management) ranged from $500 to $4,000,000, with an average of $150,000. The most expensive projects included replacing compressors (17% of respondents).

- ***Project payback periods***. Payback periods on projects for which estimates of cost and savings were available ranged from 3 months to more than 10 years, with a median of 5 years. Projects with the longest paybacks were compressor replacements. This suggests that respondents had reasons other than energy savings to undertake compressor replacements. The median payback period for measures other than compressor replacements was 1.8 years, which is in keeping with the experience of members of the Ad Hoc Evaluation Committee[9].

- ***Non-energy benefits***. 76% of end-users who made significant capital or operating improvements to their compressed air systems reported experiencing benefits in addition to energy savings. These included reduced down-time, reduced moisture and contamination in the system air, more consistent system pressure, and restored delivery of adequate pressure to all system components.

End-user Response to the Workshops

- Both *Fundamentals* and *Advanced* workshops were very well received by the end-users. The attendees generally could not name any subjects discussed that were not beneficial.

- Among *Fundamentals* attendees, the topics that were deemed most useful included general principles of compressed air systems (21%), methods to calculate operating costs (20%), and the impact of leak management and maintenance practices (14%).

- Among *Advanced* workshop attendees, there was strong interest in a broad range of topics covered, especially diagnosis of common system operation problems (22%), measurement of operating parameters (11%), control strategies (11%), and development of system pressure profiles (11%).

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8 XENERGY used the national average revenue per kWh of industrial electricity sales, estimated by the U. S. Department of Energy, Energy Information Administration as the value of energy savings. This figure has hovered around $0.05 for the past several years.

9 Members of the Evaluation Committee are acknowledged on the inside front cover of this report.

1.4.2 Vendors

Respondent Profiles

- The majority of survey respondents (76%) were compressed air system distributors or vendors. Most of the remainder were equipment manufacturer sales representatives (12%).
- Although most vendor training participants performed a variety of functions within their respective companies, there was greater representation from the top tier decision makers as compared to the end-users. Of these respondents, 17% listed their position as President/CEO or VP/Senior Director.
- Approximately 40% of businesses represented served a regional area, 23% a statewide territory, and 21% claimed an international service area.
- The primary business activities for the vendor respondents were compressed air equipment and parts sales. Compressed air system design and efficiency services only accounted for a very small part of overall revenue (8%).

Effect of the Program on Vendor Service Offerings

- Although 86% of vendors reported delivering some kind of efficiency-related service prior to training, more detailed results show that this was a very small-scale and infrequent business activity. Most firms apparently only offered a few services apiece. In fact, no more than 14% of the vendors reported delivering any one of eight specific efficiency services listed in the survey.

  This finding suggests that vendors lacked a comprehensive suite of efficiency services designed to address a well-defined set of customer needs. Most likely, the few services that each vendor mentioned were offered as a convenience to customers.
- More than half of the vendors, 52%, reported that their companies had begun to offer new efficiency services after they attended the training. Most of the new services mentioned involved system assessment: analysis of compressed air efficiency (17%), measurements of system flow/pressure and energy consumption (both 11%), and ultrasonic leak detection (11%).

Effect of Training on Improving Customer Service

- The majority (85%) of vendor participants claimed that they had used training workshop materials or information when they evaluated customer compressed air systems. Among this group, 18% of respondents used them in “all” evaluations, and 40% used them in “many” evaluations.
- A similarly high percentage of vendors (64%) claimed that they had used the CAC workshop materials in diagnosing their customers’ compressed air system operating problems.
- Most sample vendors (72%) had also made use of training materials and information when they made specified improvements to their customers’ systems. Among those respondents, 21% reported using the course materials in “all” relevant projects, and 38% used them in “most” projects.

- About 46% of vendors claimed that they had undertaken new compressed air marketing initiatives following their training. The most common initiatives were direct consumer mail (26%), and marketing packaged with maintenance service sales (22%), and equipment sales (16%).

1.5 Recommendations

Overall, the results of the evaluation demonstrate that the CAC training program has been successful in meeting its objectives. The stated objective of the CAC *Fundamentals* course is to teach facility engineers, operators, and maintenance staff how to achieve energy and cost savings through more effective production and use of compressed air. *Fundamentals* uses a systems approach, which seeks to verify the demand or uses for compressed air in a facility and balance it with the supply.

The basic approach to curriculum design, trainee recruitment, and curriculum delivery seem to be working well. In addition to the very intensive use that trainees make of the curriculum, we cite as evidence the fact that trainee suggestions for improvement were widely scattered among many aspects of course substance and presentation. The relatively small number of attendees who found the curriculum too technical and demanding was balanced by a small number who found that the curriculum was not intensive enough. This suggests that the curriculum is well-positioned in terms of needs and capabilities of the intended participants.

However, a number of consistent themes did come through in participant response to the program. These suggest that some adjustments to the curriculum might enhance the value of the program to participants. These suggestions are as follows.

- ***Develop a unit in the*** **Advanced** ***course presenting the business case for vendors to become more active in promoting and delivering efficiency-oriented services.*** The results of the vendor survey suggest that, prior to the training, vendors did not have a clear understanding as to how the materials covered in the CAC training would be applied in creating new business opportunities or in retaining existing customers. They also suggest that vendors continue to be unclear on the commercial value of the training even after participation. If this is indeed the case, perhaps future CAC training sessions should incorporate a compelling business case in favor of these services. The discussion should also include information on successful marketing techniques and how to work with consultants who have expertise in providing these services. Perhaps some of the *Advanced* sessions could be marketed exclusively to vendors.

- ***Develop case studies and examples that use experience on small and medium-sized systems.*** Several vendors and end-users mentioned that they would find examples and case studies based on smaller systems useful, given that they rarely deal with some of the larger kinds of systems discussed in the instructional materials.

- ***Include information on the cost of improvements as well as energy savings.*** Both users and vendors mentioned that it would be easier to evaluate compressed air system opportunities and to sell them to management if they had a sense of the range of costs associated with common measures. We acknowledge that this item may be hard to implement given the extreme variation in system design and operation from one plant to another.

About Compressed Air Challenge®

A national collaborative, the Compressed Air Challenge®, was formed in October of 1997 to assemble state-of-the-art information on compressed air system design, performance, and assessment procedures. This collaborative is delivering best-practice compressed air system information to the plant floor, creating a consistent national market message that supports the application of these best practices, providing a technically sound and professionally delivered training program for plant operating personnel, and will, through a certification program, recognize plant personnel's skills in operating compressed air systems. Participants include: large industrial users of compressed air, manufacturers and distributors of compressed air equipment and their associations, facility engineers and their associations, compressed air system consultants, state research and development agencies, energy efficiency organizations, and utilities. The goals of the Compressed Air Challenge® are to:

- Increase the reliability and quality of industrial production processes
- Reduce plant operating costs
- Expand the market for high quality compressed air services
- Save energy; a 10 percent improvement over current usage, resulting in annual savings of approximately 3 billion kilowatt hours of electricity nationwide.

The purpose of the Compressed Air Challenge® is to initiate a national collaborative that develops materials, a training curriculum, a certification program, and other information that can be used by the project sponsors in cooperation with others to:

- Raise awareness of the importance of efficient, effective plant air systems
- Train industrial plant operating personnel on best practices for plant air systems
- Expand the market for expert plant air assessment services
- Help build the local market infrastructure to deliver these services.

The Compressed Air Challenge® includes:

- A Board of Directors comprised of the project sponsors
- A Project Development Committee, which includes a representative from each key stakeholder group and is responsible for overall project coordination
- Working Groups, which provide essential technical input to the project.

The Compressed Air Challenge® is seeking additional participants interested in sponsorship or contributing to materials development. For general information, call the Compressed Air Challenge® at (800) 862-2086. If you would like to join the Challenge, see ***www.compressedairchallenge.org***.

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