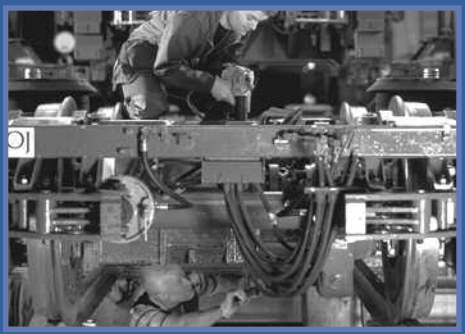

Evaluation of the Compressed Air Challenge® Training Program

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

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Blair Collins, Northwest Energy Efficiency Alliance
Jerry Aue, Energy Center of Wisconsin
Edward McGlynn, NSTAR
Aimee McKane, Lawrence Berkeley National Laboratory, Chair
Tom Mays, Cochrane Compressor
Monica Nevius, Consortium for Energy Efficiency
Colin Odell, Northeast Utilities
Hale Powell, National Grid
Michael Reinhardt, National Grid

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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%).

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.

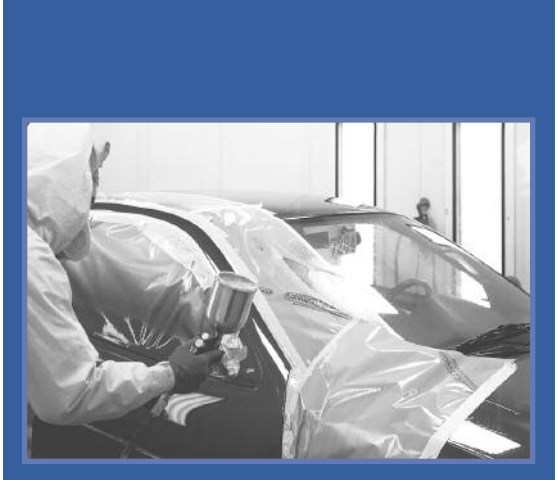
The basic approach to curriculum design, trainee recruitment, and curriculum delivery seem to be working well. In addition to the very intensive use that trainees make of the curriculum, we cite as evidence the fact that trainee suggestions for improvement were widely scattered among many aspects of 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.



Section 2 CAC Evaluation: End-Users

This section presents the results of the end user survey. The survey was administered on a sample of attendants to both the Level I (*Fundamentals*) and Level II (*Advanced*) CAC training courses. A total of 100 end-user surveys were completed. The sample frame and sampling procedures are described in Section 1.

2.1 Respondent Characteristics

2.1.1 Business Activities

The vast majority of respondents to the end-user survey (78%) were located at manufacturing facilities or some other type of industrial facility (12%). The remaining survey participants worked in commercial buildings, schools, or hospitals. (Table 2-1)

Table 2-1 CAC Trainee Facility Type

Type of Facility	Percent of Respondents
Manufacturing	78
Other Industrial—Mine, Water Processing	12
Commercial—Office building, Retailer	8
Other (School, Hospital)	1
Don't Know	1
Number of Respondents to Item	**100**

2.1.2 Respondent Job Title

The end-users were typically plant engineers (25%), electricians (23%), or maintenance managers and staff (17%). There was little representation (5%) among senior company staff members, including company presidents, CEOs, and general managers. Thus, most respondents were not principal management decision makers at their facilities but probably did have direct responsibility for operation and management of compressed air systems. (Table 2-2)

Table 2-2 CAC Trainee Job Titles (End Users)

Reported Job Title	Percent of Respondents
Plant Engineer	25
Chief Electrician	23
Maintenance Manager	17
Plant Manager	5
Maintenance Staff	4
President/CEO	4
Consultant	3
Purchasing Manager	1
General manager	1
Other	17
Number of Respondents to Item	**100**

2.1.3 Primary Business Activity

The end-user participants came from a fairly diverse group of industries as Table 2-3 indicates. Among respondents who specified their industry affiliations, most came from the food, textile, wood/paper, metal, and paper industries. All of these industries are characterized by high levels of compressed air system energy use.

Table 2-3 Attendee Employers by Primary Product/Service

Reported Facility Primary Business	Percent of Respondents
Food Products	11
Textile Products	10
Primary Metals (steel, aluminum)	9
Paper or Allied Products	8
Retail Services (automotive)	5
Stone, Clay, Glass	4
Petroleum	3
Healthcare	3
Lumber or Wood Product	2
Chemicals	2
Metal Fabrication or Machinery	1
Water/Wastewater Processing	1
Manufacturing: Not Otherwise Specified	28
Other	12
Don't Know	1
Number of Respondents to Item	**100**

2.1.4 Firm Size (Number of Employees)

As Table 2-4 shows, end-use participants in CAC training were split roughly evenly among representatives of small (1–100 employees), mid-sized (101–500 employees), and large (> 500 employees) facilities. (Table 2-4)

Table 2-4 Full Time Employees (End Users)

Reported Number of Employees	Percent of Respondents
1–100	30
101–250	16
251–500	12
501–1000	17
101–4000	16
>4000	5
Don't Know	3
Refused	1
Number of Respondents to Item	**100**

2.1.5 Facility Operating Schedules

As Table 2-5 shows, the sample CAC attendees represented very heavily used facilities. More than one-third (35%) worked at facilities that were in full-time, 24/7 operation. An additional 25% worked in facilities that were in three-shift operation (112 – 150 hours per week). The average operating schedule for respondents' facilities was 118 hours per week.

Table 2-5 Distribution of Sample Facilities by Hours of Operation

Weekly Hours of Operation	Percent of Respondents
35–50 (One Shift)	16
51–100 (Two Shifts)	23
112–150 (Three Shifts)	25
168 (Continual Operation)	35
Don't Know	1
Number of Respondents to Item	**100**

The long reported operating schedules have a number of important implications for the CAC program and its potential value to end-users. First, the finding suggests that respondents' facilities are very intensively used and that unplanned down time due to compressed air system (or other production system) failure will be costly. Second, the intensive operating schedules imply high levels of electricity usage, and therefore a substantial pool upon which savings can be realized.

2.1.6 Compressed Air System Description

Of the sample end-user trainees reporting, 6% said that there were no compressed air systems in their facilities. Thus, we have information on compressed air systems in 94 facilities. Tables 2-6 and 2-7 display information on the size of these systems. Most of them can be characterized as small to mid-sized. The respondents provided connected horsepower information for some systems. Of the 94 respondents, more than 40% reported systems in the range of 100 – 500 hp. A majority of systems, 57%, were powered by two, three, or four compressors.

Table 2-6 Number of Compressors at Trainee Facilities

Number of Compressors at Trainee Facility	Percent of Respondents*
1	5
2	27
3	12
4	18
5–10	26
11+	11
Don't Know	2
Number of Respondents to Item	**94**

*Percentages do not add to 100 due to rounding

Table 2-7 Total Connected Horsepower of Compressed Air Systems at Trainee Facilities

Reported Total Horsepower of Compressed Air System	Percent of Respondents
5–100	20
105–500	41
505–1,000	16
1,005–3,600	12
Don't Know	11
Number of Respondents to Item	**94**

Respondents generally reported that their compressed air system load varied by shift or by weekday/weekend operation. Fully 20% of respondents claimed that their compressors only vary their air loads during shutdowns, indicating constant operation. (Table 2-8)

Table 2-8 Reported Pattern of Compressor Load Variance

Time Period for Variation in Load	Percent of Respondents
By Shift	40
Weekday/Weekend	18
Season	2
Only During Shutdowns	20
Don't Know	20
Number of Respondents to Item	**94**

About half (49%) of the respondents' compressed air systems have individual compressor controls, nearly one-third have system level controls (29%), and the remainder have some combination of the two. (Table 2-9)

Table 2-9 Type of Compressor Controls

Type of Controls	Percent of Respondents
System Control	29
Individual Controls	49
Both	16
Don't Know	6
Number of Respondents to Item	**94**

2.2 Program Experience

2.2.1 Sources of Information and/or Motivations for Enrollment

CAC trainees reported that they heard about the program through a wide range of channels including: utility contacts (22%), direct mail ads (18%), compressed air equipment vendors (16%), and their state energy offices (10%). Only 5% of participants noted the CAC Web site as a source of initial information about the program. None of the participants reported learning about the CAC program through DOE representatives or Web sites hosted by that agency. (Table 2-10)

Respondents were asked to identify *the* most important motivation for enrolling in the training, and a follow-up question sought motivations in addition to the one first named. Table 2-11 displays the results of these questions. The three primary motivations identified by a relatively large percentage of respondents as *most* important were: that their company was planning energy efficiency projects at the time of the training (29%); that their company was in the process of making improvements to compressed air systems (23%); or they simply wanted to gain additional knowledge about compressors (20%). Of the respondents, 12% reported that their most important motivation for enrollment was that they were experiencing operating problems with their compressed air systems. The coincidence of the training offering and development of plans for energy efficiency and compressed air system

improvements were most frequently mentioned as secondary reasons for enrollment in the project. These results suggest that attendees are motivated largely by immediate needs for knowledge and advice on how to address current challenges in capital project development and plant operations. This conclusion is reinforced by the finding that only 25% of the respondents sought funding from utilities or other sources to cover the registration fee.

Table 2-10 Sources of Information on the CAC Program

Source of Information (Multiple Sources Accepted)	Percent of Respondents*
Local Electric Utility Representative	22
Direct Mail Advertisement	18
Compressed Air Equipment Vendor	16
State Energy Agency	10
CAC Web Site	5
Advertising/Article in Trade/Industry Publication	5
U.S. DOE Representative	1
U.S. DOE Publication	0
U.S. DOE BestPractices Web Site	0
Other	11
Don't Know	13
Number of Respondents to Item	**100**

* Multiple sources accepted. Percentages do not add to 100. Two respondents mentioned multiple sources of information.

Table 2-11 Most Important Reason to Enroll in Training

Reason for Enrollment	Most Important*	Also Important**
Planning Energy Efficiency Projects in General	29%	15%
Planning to Make Compressed Air System Improvements at the Time	23%	10%
Wanted to Gain Additional Knowledge About Compressors	20%	2%
Experiencing Compressed Air System Operation Problems	12%	7%
Utility Recommendation	3%	6%
Needed to Use Training Budget	2%	2%
Vendor Recommendation	1%	1%
Other	7%	5%
No Reason/No Other Reason	3%	53%
Number of Respondents to Item	**100**	**100**

* One response only accepted
** Multiple answers accepted. Percentages do not add to 100.

2.2.2 Assessment of *Fundamentals* Training

Respondents were asked to identify which elements of the *Fundamentals* training they found most useful and least useful. They were also asked to identify additional useful elements. Table 2-12 displays the results of these questions. Given that not all sample trainees chose to provide responses to these questions, and that they were allowed to identify multiple course elements as "also useful" or "not useful", we found it most straightforward to display the frequency with which the various course elements were mentioned rather than the percentage of respondents who mentioned them.

The end-user training participants generally found the topics covered in the *Fundamentals* course to be interesting and useful in addressing their information needs. The topics that seemed to offer the greatest benefit included "general information on compressed air systems", "methods to calculate compressed air system operating costs", and "the impact of leak management and maintenance practices." Most participants did not identify any course elements as "not useful."

Table 2-12 Elements of *Fundamentals* Training–Useful and Not Useful

	Frequency of Mentions		
Program Element	**Most Useful**	**Also Useful***	**Not Useful***
General Information on Compressed Air Systems, Compressors, Operation	19	13	4
Calculating Cost of Operating a Compressed Air System	18	11	2
Impact of Leak Management/Maintenance Practices	13	9	1
Individual Compressor Control Strategies	5	9	1
Reference Materials in Course Book	5	7	0
Exercises in Diagnosing System Problems	4	6	0
Information on Developing Action Plan	3	6	0
Instructions for Developing Compressed Air System Baseline	2	6	0
Function of Storage in Compressed Air System	2	2	3
How to Develop a System Block Diagram	1	7	1
Other	8	8	9
None/No Other	1	26	54
Don't Know	10	1	17
Number of Respondents to Item	**91**	**81**	**91**

*Multiple sources accepted.

More than three-quarters (78%) of the end-user training participants found the CAC action plan concept useful and 67% of them claimed that they implemented at least some of the action plan steps. However, only six individuals were able to recall actual steps that their company has taken. These included leak identification and repair, ongoing system management, and preventative maintenance walkthroughs.

2.2.3 Assessment of *Advanced* Training

Only 9 of the end-users interviewed for this study had participated in the *Advanced* training course. Among these respondents, the overall rating of the *Advanced* training course was very high. In response to questions about elements they found most and least useful, participants in the *Advanced* course provided a very scattered set of responses, with no single element being mentioned more than twice. This result suggests that enrollees in the *Advanced* course generally come with very specific interests, and that the range of topics addressed by the course generally matches up with the range of interests among enrollees.

2.2.4 Participant Suggestions to Improve the Value of Training

The end-user survey participants provided numerous comments and suggestions to improve the value of the CAC training courses at both the *Fundamentals* and *Advanced* levels.

Advanced Management of Compressed Air Systems

There were only a handful of comments offered about the *Advanced* course. Among this small group, there were appeals to simplify the program, provide greater hands-on training, and a request that program materials be provided in advance of the training date to improve familiarity with topics covered. One of the end-users suggested more content on comparison of costs between piston-based systems and rotary screw or vane-type systems, and another would have liked a section for applicable formulas regarding air systems.

Fundamentals of Compressed Air Systems

A total of 47 end-users contributed comments about the *Fundamentals* course. Of these, 11 participants felt that there was nothing that could be significantly improved about the course, including subject matter and format. This group generally praised the CAC for an interesting and useful course and a job well done.

Several comments addressed the level of difficulty of the *Fundamentals* course. A few of these participants felt the information on compressed air systems was too elementary. They noted that most individuals that attended with them already had a strong working knowledge of compressed air systems. However, about an equal number of individuals thought the concepts presented were too advanced for them. As far as the length of the training session, a few attendees felt that too much information was presented in too short a time, especially on the more technical subjects. A couple of respondents wished that the *Advanced* course was given with the *Fundamentals* course or that they had known which course to take in advance.

Some of the attendees would have preferred a change of locale for the training sessions. A few suggested that CAC bring their training and/or staff members to their own facilities, perhaps for a more hands-on, real-world look at actual systems. One respondent lamented that there was not a training session closer to his home.

The end-users suggested several topics that should be added or emphasized in future *Fundamentals* training sessions. These included:

- Give greater emphasis to compressor systems sizing.
- Address the significance of the air piping in a compressed air system.
- Put greater emphasis on the impact of air loss.
- Provide a compressor comparison. Discuss pros and cons of available compressors.

- Present more information on exact cost analysis.
- Give additional training on control systems.
- Provide more coverage on compressed air systems that do not use oil.
- Present more in-depth information on energy usage management, and system designs where the components correlate with each other.
- Furnish more information on and give more focus to smaller compressed air systems, the kind that smaller businesses might have. All of the training materials and machine examples were based on large and multi-system compressors.

Respondents offered relatively few suggestions regarding how to improve course materials or hand-outs. Those they did offer included requests for additional case studies, live examples of compressors running, and a simplification of the calculations portions of the program. One respondent would have liked operating cost hand-outs and another suggested that the CAC provide a list of Internet sites, books, and trade journals at the end of the course or via email updates.

There were only a few strongly negative comments from end-user attendees of the *Fundamentals* course. One respondent was critical of his session instructor who seemed unfamiliar with local utility rates.

Participant Interest in Additional Training

Of the end-users interviewed for this study, 70% reported that they would be interested in additional CAC training. Those who expressed interest in further training listed compressed air system design (17%), control strategies (16%), and diagnosis of operating problems (10%) most frequently as topics they would like to see addressed. System maintenance was also considered an important topic as a second choice by 12% of respondents. Approximately 20 individuals made their own suggestions for future course content (included in "Other" category in Table 2-13). These ideas included information on air dryers, air management, storage, turbo compressors, advanced testing

Table 2-13 Participant Suggestions of Topics for Further Training (Among Those Reporting Interest in Additional Training)

Topics	Frequency of Mentions First Choice**	Frequency of Mentions Other Choices**
System Design	12	25
Control Strategies	11	8
Diagnosis of Operating Problems	7	5
Further Detail on System Measurement	5	4
Maintenance	4	10
Equipment Selection	2	9
Operator Training	1	11
Further Detail on Baselining	1	9
Other	18	7
None/No Other	0	7
Don't Know	10	1
Number of Respondents to Item	**71**	**61**

* One response only accepted.
** Multiple responses accepted.

• Note: Already included in training.

and variable frequency drives. Several trainees simply wanted greater emphasis on topics already covered such as leak detection. Finally, two individuals desired assistance in making their management see the benefits of energy reduction initiatives and later, to convince them to allocate funding towards starting their own programs and system improvements.

2.3 Program Effects

2.3.1 Pre-Training Awareness and Activities

More than two-thirds (69%) of end-users claimed to have been aware of compressed air system efficiency measures prior to attending the CAC training. Of the sample, 41% reported that they had actually implemented capital or operating improvements to their compressed air systems prior to attending training. The most commonly cited system improvements made by these end-users included the replacement of compressors with more efficient units, air dryer improvements, air-filter maintenance, and control upgrades. Only one of the respondents mentioned having made more than one kind of efficiency improvement to his company's compressed air system. Thus, it seems fair to characterize as ad hoc and piecemeal participants' pre-training efforts to improve and maintain the efficiency of their compressed air systems.

Table 2-14 Compressed Air System Improvements Reported Prior to Training

Capital Improvements	Frequency of Mentions
Replace Current Compressor With More Efficient Model	7
Add, Upgrade., or Reconfigure Air Dryers	5
Replace or Repair Air Filters	5
Add, Restore, Upgrade Compressor Controls	4
Reconfigure Piping to Reduce Pressure Loss	3
Add Compressed Air Storage	2
Install or Upgrade Distribution Control System	2
Add Small Compressor for Off-Peak Loads	1
Replace or Upgrade Condensate Drains	1
Rework or Correct Header Piping	1
Modify or Replace Regulators (Controls at the Process)	1
Eliminated Inappropriate Uses	1
Maintenance Improvements	
Leak Inspection and Repair	7
Other Improvements	2
Number of Respondents to Item	**41**

2.3.2 Post-Training Capital Improvements

Fully three-quarters of the sample end-users reported that they had made efficiency improvements to their compressed air systems following their training session. The most common improvements made by these end-users were the replacement of current compressors with more efficient models (18%), reconfiguring system piping (10%), and the addition of air storage (8%). (Table 2-15)

Table 2-15 Post-Training Compressed Air System Improvements Reported

Improvements Made	Percent of Respondents
Replace Current Compressor with More Efficient Model	18
Reconfigure Piping to Reduce Pressure Loss	10
Add Compressor Air Storage	8
Add Small Compressor for Off-Peak Loads	7
Add, Restore, Upgrade Compressor Controls	7
Install or Upgrade Distribution Control System	7
Rework or Correct Header Piping	6
Add, Upgrade, or Reconfigure Air Dryers	6
Replace or Repair Air Filters	4
Replace or Upgrade Condensate Drains	4
Modify or Replace Regulators (Controls at the Process)	4
Improve Compressor Room Ventilation	3
Install or Upgrade (Ball) Valves in Distribution System	2
Other	10
Don't Know	3
Refused	1
Number of Respondents to Item	**76**

As Table 2-16 shows, the end-users that made system improvements were most likely to find the engineering expertise to make these system changes in-house (32%). Nearly half of those making improvements sought engineering assistance from compressed air system consultants, distributors, utility representatives, or engineers. Only one of the respondents who reported using in-house engineering capability also reported seeking help from outside vendors or consultants.

Table 2-16 Sources of Engineering Services for Reported System Improvements

Source of Engineering Services	Percent of Respondents*
Did Engineering Work In-House	32
Compressed Air Equipment Distributor	24
Compressed Air Consultant	14
Utility Representative	10
Consulting Engineer	10
Other	3
Don't Know	7
Number of Respondents to Item	**76**

*Multiple sources accepted.

Roughly two-thirds of the compressed air system improvement projects undertaken by this group of end-users cost $50,000 or less to implement. The remaining projects ranged up to $400,000. Estimates included the costs of engineering and project management. (Table 2-17)

Table 2-17 Estimated Costs of Compressed Air System Measures

Estimated Project Costs	Percent of Respondents
$0-$5,000	21
$6,000-$15,000	14
$16,000-$50,000	14
$51,000-$150,000	11
$151,000-$400,000	12
Don't Know	28
Number of Respondents to Item	**76**

Only 12% of the respondents who made system improvements following attendance at CAC training reported that they received utility rebates to support those projects. This result reinforces the overall importance of the training in prompting attendees to make system efficiency improvements.

2.3.3 Estimates of Energy Savings and Other Benefits Associated with Projects

Information provided by respondents was used to estimate annual energy consumption of their air compressor systems. The survey collected information on the number of compressors in the system, their horsepower, hours of operation (days per week and shifts per day), and type of controls. Energy consumption was estimated using these data combined with assumptions about the efficiency of the compressor motor, the load factor, and service factors of the compressors. Motor efficiency was based on the horsepower of the compressor and used average values taken from the MotorMaster software program. The assumptions used in these calculations were discussed and reviewed extensively with the *Ad Hoc* Evaluation Committee.

Most compressor motors operate at loads greater than their motor nameplate rating and the service factor used for these calculations was 1.1. Compressor load factors vary widely depending on air demand, system efficiency, compressor controls, and other factors. For these calculations the load factor was assumed to be 80% for single compressor systems. For multiple compressor systems, the load factor was assumed to be 90% for the first compressor, and 60% for succeeding compressors that come on line. See Appendix A for more details on the energy use estimating procedure.

The survey collected information on the capital and operating improvements that attendees made in their compressed air systems since attending the workshop. Using the compressed air system energy consumption developed above, savings for each end-user were estimated by applying expert-generated estimates of typical savings for projects they reported implementing. The estimates of typical savings were developed by members of the CAC *Ad Hoc* Evaluation Committee. The basic steps in estimating savings were as follows.

- **Estimate the size of total potential system savings.** The Committee and XENERGY staff compiled and examined the results of a large number of recent case studies of comprehensive compressed air system efficiency projects. These included 22 projects conducted as part of plant assessments sponsored by the BestPractices program and 21 projects undertaken with the support of utility-sponsored custom rebate programs in California. In all cases, savings had been verified using sound pre- and post-measurement methods. Projects undertaken with the support of BestPractices yielded average savings of 28% of pre-project system energy usage. The California projects yielded average savings of 34% of pre-project system energy use. Savings ranged as high as 50% on some projects. We thus set the value of total potential savings available in attendees' compressed air systems at 30% of system energy prior to improvements reported as a result of the training.

- **Estimate savings at individual facilities.** The next step of the process involved estimating what portion of total potential savings individual respondents would be likely to realize as a result of the actions they took. Members of the *Ad Hoc* Evaluation Committee developed estimates of the portion of total potential savings associated with individual measures and sets of measures. XENERGY applied these estimates to the measures reported for each sample facility. We set a limit of 100% on the portion of total potential savings realized at any given facility. Table 2-18 shows the percentage of respondents who reported taking various measures and the portion of potential savings assigned to each.

The individual system savings can vary widely; these estimates provide a means for us to estimate the average savings for participants in the program. Estimates were developed for 67 respondents for which complete information was available.

Table 2-18 Measure Savings Estimates

Measure	Percentage Implementing Measure	Percentage of Potential Savings
Replace Current Compressor with More Efficient Model	18%	2%
Reconfigure Piping to Reduce Pressure Loss	10%	20%
Add Compressed Air Storage	8%	20%
Add Small Compressor for Off-Peak Loads	7%	2%
Add, Restore, Upgrade Compressor Controls	7%	30%
Install or Upgrade Distribution Control System	7%	20%
Rework or Correct Header Piping	6%	20%
Add, Upgrade or Reconfigure Air Dryers	6%	10%
Replace or Repair Air Filters	4%	10%
Replace or Upgrade Condensate Drains	4%	5%
Modify or Replace Regulators (Controls at the Process)	4%	20%
Improve Compressor Room Ventilation	3%	1%
Install or Upgrade (Ball) Valves in Distribution	2%	10%
Other	10%	10%
Number of Respondents to Item	**76**	**N/A**

Table 2-19 shows the distribution of these facilities by the number of measures that the respondents reported implementing. The table also shows the average estimated energy savings for each group of facilities defined by the reported number of measures implemented.

Table 2-19 Distribution of Sample Facilities by Number of Measures Implemented and Average Savings (for 67 Sample Facilities)

		Average Energy Savings from Compressed Air System Measures		
Number of Measures Implemented	Number of Facilities	kWh/Year	Percent of Annual Compressed Air System Use	$/Year
1	42	88,201	5.1%	4,410
2	19	195,518	8.8%	9,776
3	2	66,902	5.4%	3,345
6	1	168,164	21.6%	8,408
10	1	970,938	30.0%	48,547
12	1	92,204	30.0%	4,610
13	1	1,169,293	30.0%	58,465
Weighted Averages		**148,563**	**7.5%**	**7,428**

Findings in regard to energy savings can be summarized as follows.

- **Compressed air system electric use.** Based on respondents' information concerning the number of compressors on site, their horsepower, and hours of operation, XENERGY estimated that the average annual compressed air system electricity use for the 67 facilities was 2,090,000 kilowatt-hours (kWh.) This figure ranged from 14,000 kWh to 23 million kWh, with a median of 890,000. These figures indicate that the participating facilities were clustered in the lower part of the range of annual energy use.

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

- **Annual energy savings.** Among those that implemented improvements, average savings using XENERGY estimates was 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, mean value of annual savings from compressed air system efficiency projects implemented by the respondents was $7,428, with a range of $1,000-$58,465[1].

- **Costs of compressed air system efficiency measure.** 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.

In addition to developing independent estimates of savings for reported compressed air efficiency projects, XENERGY included a question in the survey probing respondents' own estimates of energy savings. Table 2-20 shows the distribution of responses to that question. Only 42 of the interviewees ventured an estimate of how much they had saved through compressed air efficiency programs in terms of percentage of pre-program energy use[2]. Among those who provided an estimate, the average was 17% of system savings—about twice the estimate developed by XENERGY using the methods described above. To probe the reliability of these responses we examined what proportion of respondents who provided a savings estimate had developed a system baseline energy profile. Our hypothesis was that customers who had developed a baseline profile would be in a better position to render a relatively accurate estimate of energy savings than those who had not. Half

[1] 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.

[2] The questionnaire also sought savings estimates in terms of reduced annual energy costs. However, many of the answers provided to this question were far in excess of the total estimated energy consumption for the subject facilities. We therefore decided not to consider these data in analyzing energy savings.

of the customers providing savings estimates had undertaken baseline profiles. This was the proportion for the group of measure implementers as a whole. Thus, this line of inquiry shed little light on the reliability of customers' estimates of energy savings.

While the 17% average savings figure is well within range of savings found in utility program and BestPractices case studies, we believe it is likely to be somewhat high. There are a number of reasons we believe the lower estimate of 7.5% to be more plausible. First, 63% of the end-users who implemented measures implemented one measure only, and another 28% implemented two measures. The projects documented in the case studies generally involved a comprehensive reworking of the compressed air system encompassing a half-dozen or more measures. Second, if we accept the estimate of typical maximum system savings at 30%, then the estimate of realized savings at 7.5% implies that customers captured one-quarter of the potential savings on the basis of knowledge and encouragement gained at a 1- or 2-day training. In light of the mechanical complexity of compressed air systems, the logistical problems of making improvements to critical production machinery, and timing of investment cycles, this is a very good result.

Table 2-20 Respondent Estimates of Compressed Air System Savings (As Percentage of Pre-Project Energy Use)

Respondent Estimate of Savings	Percent of Respondents*
0-5 Percent	14
6-10 Percent	9
11-20 Percent	17
21-40 Percent	11
41-65 Percent	4
Don't Know	45
Number of Respondents to Item	**76**

In addition, although not quantified for this report, the energy savings resulting from improved maintenance practices can be significant. See Section 2.3.7.

2.3.4 Role of CAC Training in Measure Implementation Decisions

The end-user questionnaire contained a number of items designed to probe the extent to which knowledge and materials from the CAC training were used in measure implementation decisions. About two-thirds (65%) of the attendees who implemented measures claimed that they had used information or analysis from the CAC training to justify requests to their management for funds to implement the system improvements. Generally, the CAC information was deemed "important" to "very important" in convincing managers to allocate funds to compressed air system improvements. (Table 2-21)

Table 2-21 Importance of CAC Materials in Convincing Managers to Fund Compressed Air System Improvements

Importance Rating	Percent of Respondents*
Very Important	31
Somewhat Important	43
Neutral	18
Not Very Important	4
Not At All Important	2
Don't Know	2
Number of Respondents to Item	**49**

To develop another measure of the effect of the CAC training on the implementation decision, we asked end-users who reported making improvements how likely their firms would have been to have made those improvements in the absence of training. Nearly half (48%) of the end-users thought it "not very likely" or "very unlikely" that their companies would have made energy efficiency improvements to their compressed air systems had they not attended the CAC training sessions. (Table 2-22)

Table 2-22 Likelihood Improvements Would Have Been Made in the Absence of CAC Training

Likelihood Rating	Percent of Respondents*
Very Likely	13
Somewhat Likely	5
Neutral	32
Not Very Likely	26
Not At All Likely	22
Don't Know	1
Number of Respondents to Item	**76**

*Percentages do not add to 100 due to rounding

Apparently, the *Advanced* CAC training course provided additional benefits beyond those of the *Fundamentals* class. Several end-users claimed that they made certain system improvements that were based solely on the *Advanced* training session. Three respondents noted that they added storage tanks and reduced system pressure 1-5 pounds per the course suggestions.

2.3.5 Estimates of Program Energy Savings

Table 2-23 presents XENERGY's estimate of the total annual energy savings attributable to end-user training activities as of May 2001. In expanding the sample results to the population of CAC end-user attendees, we made the following assumptions:

- We used the average estimate of compressed air system energy use for all respondents that provided sufficient information to make the estimate (n = 94) to estimate average energy use for the population of end-users. The average for all respondents was 4,950 MWh, more than double that of the 67 respondents who provided complete information on energy saving measures as well as system configuration.

- All other estimates and assumptions are taken directly from the results of the survey and from the other sources shown in the table.

Based on the approach summarized in Table 2-23, we estimate that energy savings from end-user actions taken in response to the program totaled 114,635 MWh per year, with a value of $5.7 million at current energy prices. Readers should recognize that this estimate is based on self-reported information from end-users concerning compressed air system configuration, operating schedules, maintenance practices, and savings measures. The results should therefore be treated as a general indication of program effects. However, based on personal experience of the evaluators in administering similar programs and verifying compressed air system improvement savings, we believe the savings estimates are plausible.

Table 2-23 Summary of Annual Program Energy Savings Estimate

Variable in Savings Estimate	Estimate	Source/Notes
Total Number of Facilities Represented by Training Attendees	1,500	CAC Attendees Database
Percent of End-User Facilities	45%	Inspection of CAC Database
End-Use Facilities in Training Cohort through 2001	675	N/A
Percent of Facilities Making Compressed Air System Improvements	76%	Survey Analysis
Number of Facilities Making Improvements	513	N/A
Percent of Facilities that Used CAC Training to Guide Improvements	65%	Survey Analysis
Number of Facilities Influenced by Program to Make Improvements	333	N/A
Average Compressed Air System Energy Use (MWh/Year)	4,590	Survey Analysis Advice from Evaluation Committee
Average Energy Savings as Percent of Baseline Energy Use	7.5%	Survey Analysis Advice from Evaluation Committee
Total Annual Savings for Program Cohort (MWh/Year)	114,635	Multiply Previous Three Lines
Average Cost per MWh saved	$50	EIA, Average Revenues
Total Energy Costs Saved/Year	**$5,731,762**	

2.3.6 Non-Energy Benefits from Compressed Air System Improvements

Among the 76 attendees who had implemented compressed air system efficiency measures since attending training, 58 (76%) reported that their facilities derived non-energy benefits from those system improvements. Nearly one-third of respondents reported that they experienced reduced down-time in their systems after the improvements were implemented. Nearly one third noted reductions in moisture and contaminants in the compressed air. Other benefits included improved

consistency of pressure in the system, and restoration of usable pressure to all areas of the plant. See Table 2-24. In some cases, respondents reported that dramatic improvements in production conditions were associated with the improvements. Some examples:

– "[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."

Table 2-24 Reported Non-Energy Benefits from Compressed Air System Improvements

Reported Non-Energy Improvement	Frequency*	Percent of Respondents*
Reduced Down Time	24	32
Reduced Moisture in the System	12	16
Reduced Contamination in the System	9	12
More Consistent Pressure to End-Uses	10	13
Delivery or Restoration of Adequate Pressure to All Areas of the System	11	14
Reduced Maintenance	2	3
Other	9	12
No Non-Energy Benefits Reported	18	24
Number of Respondents to Item	**76**	**N/A**

* Multiple responses accepted. Percentages do not add to 100.

2.3.7 Post-Training Measures to Eliminate Inappropriate Uses of Compressed Air

Both the *Fundamentals* and *Advanced* courses stress the importance and potential benefits of substituting more efficient motive power or devices for certain end-uses that do not require some of the special features of compressed air. The end-user questionnaire contained a number of items that probed the respondents' efforts to eliminate inappropriate uses of compressed air and their use of CAC materials to identify such measures. The key findings from these questions are as follows.

- **Percent of end-users taking action.** Of the sample end-users, 25% reported that they had taken steps to eliminate inappropriate or inefficient uses of compressed air after taking part in the training.

- **Inappropriate end-uses eliminated.** The two most commonly cited processes in which the end-users ceased using compressed air were open blowing for cleaning machines, parts and shop areas (26%), and aerating, agitating, and percolating liquids (20%). The respondents noted numerous other processes including condensation removal from machines and products, drying procedures, and certain wastewater treatment processes. Most of the end-uses addressed through these measures were open blowing to clean machines and parts and aerating or agitating liquids.

- **Use of CAC materials to identify opportunities.** The vast majority (80%) of end-users who eliminated inappropriate end-uses claimed that they had used information from their *Fundamentals* training course to identify which processes could be removed from their compressed air systems.

- **Likelihood of measure implementation in the absence of CAC training.** More than half (52%) of the end-users that eliminated inappropriate end-uses reported that they would have been "unlikely" or "very unlikely" to have undertaken such projects in the absence of guidance and information from CAC.

2.3.8 Post-Training Improvements to Compressed Air System Maintenance Practices

Both the *Fundamentals* and *Advanced* courses stress the importance and potential benefits of systematic and diligent preventive maintenance of compressed air systems. The end-user questionnaire contained a number of items probing the respondents' adoption of operating and maintenance procedures identified and advocated in the training courses. The key findings from these questions are as follows.

- **Percent of end-users adopting new maintenance practices.** About half of the 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 and 43% reported an increase in the frequency of maintenance procedures already in place.

- **New maintenance practices adopted.** Among the 49% of respondents that had made changes to their maintenance procedures, the most frequently cited were periodic leak inspection (24%), air filter cleaning (13%) and leak repair (13%.) One-third of respondents reported other improvements including automated maintenance procedures, 24/7 monitoring, preventive maintenance based on hours of activity rather than the calendar, vibration analysis, addition of an oil-water separator, following manufacturers' recommended maintenance intervals, monthly inspections, more preventive parts replacement, and running compressors under full loads.

- **Likelihood of measure implementation in the absence of CAC training.** As was the case for other types of compressed air system efficiency improvements, many respondents felt that their attendance at the CAC training was very important in bringing about these enhanced maintenance procedures. In fact, 29% of the respondents who made changes to their system O&M procedures reported that they would have been "very unlikely" to have implemented those measures in the absence of training. An additional 20% reported that they would have been "unlikely" to have made the changes without CAC.

2.3.9 Post-Training Efforts to Develop Compressed Air System Baselines

Efforts to prepare baselines. The *Fundamentals* courses stressed the importance of developing baseline depictions of system operations and estimates of baseline energy use as foundation for improving system management and design. Approximately 44% of end-users claimed they had begun developing a baseline description of the configuration and operation of their compressed air systems, and two-thirds of these respondents reported that their baselines were completed at the

time of the interview. The majority of these trainees (81%) found their CAC instruction to be "somewhat useful" to "very useful" as they began the process of developing system baselines for their compressed air systems.

Use of baselines. Nearly three-quarters (73%) of the end-users that had developed baselines reported using them to guide changes to major components of their compressed air systems, and 61% used them to support changes to their compressed air operation and maintenance procedures.

2.3.10 Effect of the Program on Planned Capital Improvements

Of the end-users interviewed, 29 reported that they were planning changes to their compressed air systems at the time of the survey. Among these individuals, 26% are planning compressor replacements. (Table 2-25)

Table 2-25 Capital Improvements Planned

Type of Capital Improvement	Frequency
Replace Current Compressor with More Efficient Model	8
Add Small Compressor for Off-Peak Loads	3
Add Compressed Air Storage	3
Reconfigure Piping to Reduce Presure Loss	3
Rework or Correct Header Piping	2
Add, Upgrade, or Reconfigure Air Dryers	2
Modify or Replace Regulators (Controls at the Process)	2
Add, Restore, Upgrade Compressor Controls	2
Replace or Repair Air Filters	1
Replace or Upgrade Condensate Drains	1
Improve Compressor Room Ventilation	1
Install or Upgrade Distribution Control System	1
Other	3
Don't Know	3
Number of Respondents to Item	**29**

The CAC course materials again received high marks by this group of respondents. More than three-quarters (76%) claimed that they used the CAC course materials when identifying potential system improvements. Approximately 79% of these individuals reported that those materials were "somewhat important" or "very important" when identifying new measures to undertake.

Section 3 CAC Evaluation: Vendors

This section presents the results of the vendor survey. The vendor survey was administered to a sample of attendees at both the Level I (*Fundamentals*) and Level II (*Advanced*) CAC training courses. A total of 100 vendor surveys were completed. The sample frame and sampling procedures are described in Section 1.

3.1 Respondent Characteristics

3.1.1 Business Type:

The majority of survey vendors interviewed (76%) were compressed air system distributors or vendors. The remainder of the participants included equipment manufacturer sales representatives (12%), consultants (7%) or engineering firms (5%). (Table 3-1)

Table 3-1 Distribution of Vendor Attendees by Business Type

Type of Firm	Percent of Respondents
Compressed Air Distributor or Vendor	76
Compressed Air Manufacturer Sales Representative	12
Compressed Air Consultant	7
Compressed Air Engineering Firm	5
Number of Respondents to Item	**100**

3.1.2 Respondent Job Title

The respondents to the vendor survey came from a wide range of positions within the companies they represented. Nearly one-half of the respondents were management staff. Among this group, 26% were product or service managers and 19% were a variety of other management staff. The vendor firms surveyed had more representation among their top-tier decision makers than their end-user counterparts; 17% of respondents listed their position as President/CEO or VP/Senior Director. (Table 3-2)

3.1.3 Service Territory

A large majority (73%) of the respondents served statewide or regional areas. About one-fifth or 21% claimed to have an international sphere of activity. Distributors' and manufacturers representatives accounted for all but three of the establishments with international activities.

Table 3-2 CAC Trainee Job Titles

Reported Job Title	Percent of Respondents
Sales/Product/Service Manager	26
Manager (Customer Service, Energy, Account, Plant Engineering, District, or General	19
President/CEO	12
Sales Engineer	9
Sales Technician/Representative	8
Engineer	8
VP/Senior Director	5
Owner/Proprietor	2
Field Technician	2
Consultant	2
Other	6
Refused	1
Number of Respondents to Item	**100**

Table 3-3 Respondent Service Areas

Reported Service Area	Percent of Respondents
Regional Area	40
Statewide	23
International Area	21
Local/Metropolitan	12
National	4
Number of Respondents to Item	**100**

3.1.4 Firm size (Number of Locations/Employees)

Most respondents (78%) came from companies that have 1-4 office locations. The remainder of the attendees came from larger companies with 5-10 offices (14%) or as many as 50 (8%). In terms of number of employees, most of the firms were quite small. About half, or 51%, employed 15 or fewer individuals. Most of the remaining firms had 40 or fewer people. See Tables 3-4 and 3-5 for details.

3.1.5 Revenues from Various Business Activities

Table 3-6 shows a breakdown of business activities and their corresponding revenues for the respondent companies. Overall, the most prevalent business activities among the group were compressed air equipment and parts sales. This is not surprising because the majority of respondents were vendors, distributors, and manufacturer representatives. Compressed air system efficiency and consulting services represented a very small portion of total business for all attendees,

including consulting and engineering firms. This suggests that the engineering and consulting firms represented by the attendees did not specialize in compressed air systems, but were rather more general mechanical and industrial engineering businesses.

Table 3-4 Number of Business Locations

Reported Number of Locations	Percent of Respondents
1	35
2	18
3	12
4	10
5–10	14
11–50	7
51–100	1
Don't know/Refused	3
Number of Respondents to Item	**100**

Table 3-5 Full-Time Employees

Reported Number of Employees	Percent of Respondents
1–5	15
6–10	16
11–15	21
16–20	11
21–30	10
31–40	8
41–100	10
100+	8
Number of Respondents to Item	**100**

Percentages do not add to 100 due to rounding

Table 3-6 Business Activities–Average Revenues

Activity	Total	Vendor/ Distributor	Manufacturing Sales Representative	Consultant/ Engineer
Compressed Air Equipment Sales	42%	41%	69%	17%
Compressed Air Parts Sales	21%	23%	16%	9%
Compressed Air Equipment Service	18%	22%	7%	3%
Compressed Air System Design	4%	4%	3%	3%
Compressed Air Efficiency Services (leak detection, audits, optimization, controls)	4%	4%	1%	9%
Other	12%	6%	4%	59%
Number of Respondents to Item	**78**	**61**	**9**	**8**

Percentages do not add to 100 due to rounding

3.1.6 Important Industries in Terms of Compressed Air Sales and Services

Nearly half of vendor respondents stated that general manufacturing was their most important industry in terms of sales revenues related to compressed air sales or services. The only other significant industry, mentioned by 11% of respondents, was industrial equipment.

Table 3-7 Important Industries for Compressed Air Sales/Service

Industry	Most Important	Also Important
General Manufacturing	47%	8%
Industrial Equipment	11%	3%
Other	5%	10%
Electronic Equipment	4%	5%
Food Processing	3%	10%
Transportation Equipment	4%	5%
Paper and Allied Products	3%	5%
Chemicals	2%	8%
Rubber and Plastics	1%	7%
Primary Metals	1%	2%
Printing	0%	4%
Fabricated Metals	0%	5%
Petroleum Products	0%	4%
Textile Mill Products	0%	6%
Distributors	2%	0%
Utilities	3%	0%
Don't Know	13%	0%
Refused	1%	0%
No Other Important	N/A	18%
Number of Respondents to Item	**100**	

3.2 Program Experience

3.2.1 Sources of Information/Motivations for Enrollment

The respondents learned about the CAC training programs primarily through their Compressor Distributor Association (19%), other vendors (18%), from "word of mouth" within their company (14%), or directly from CAC personnel (10%). None of the vendors learned of the program through the CAC or DOE websites. (Table 3-8)

Table 3-8 Sources of Information on the CAC Program

Information Source	Percent of Respondents*
Compressor Distributor Association	19
Compressed Air System Vendor	18
Found Out Through My Company	14
Through CAC Personnel/People Involved with CAC	10
Local Electric Utility Representative	7
Direct Mail Advertisement	7
Through ICDA	3
Word of Mouth	3
U.S. DOE Representative	3
State Energy Agency	3
Advertising/Article in Trade/Industry Publication	2
Other	4
Don't Know	7
Number of Respondents to Item	**100**

* Multiple responses accepted. Percentages do not add to 100 due to rounding

Vendors interviewed for this study reported that the single most important reason they enrolled in the CAC training was to increase their overall knowledge of compressed air systems. Improving customer service (29%) and overall service value (14%) were also important considerations. (Table 3-9)

Table 3-9 Most Important Reason to Enroll in Training

	Percent of Respondents	
Reason for Enrollment	Most Important	Also Important*
Wanted to Gain Additional Knowledge about Compressed Air Systems	41	1
Improve Customer Service	29	8
Wanted to Increase Value of Services to Customers	14	16
Develop New Revenue Streams	3	4
Wanted to Retain Equipment/Maintenance Service Customers	2	2
Competitors Offering Similar Services	1	8
Other	8	2
Don't Know	2	0
No Other Reason	N/A	60
Number of Respondents to Item	**100**	

* Multiple responses accepted. Percentages do not add to 100.

It is interesting to note that only about 20% of the sample vendors mentioned reasons having to do with the potential commercial value of efficiency-related services as their primary motivation for attendance. These results suggest that, prior to the training, vendors may not have had 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.

3.2.2 Assessment of *Fundamentals* Training

The vendor training participants generally found the topics covered in the *Fundamentals* course to be useful in addressing their information needs. The respondents saw the greatest benefit in the course discussions on general compressed air system information, instructions to develop system baselines, exercises to diagnose system problems, and the course book reference materials. The participants were generally unable to list any program topics that were not useful to them. (Table 3-10)

Table 3-10 Elements of *Fundamentals* Training–Useful and Not Useful

	Frequency of Mentions		
Program Element	**Most Useful**	**Also Useful***	**Not Useful***
General Information on Compressed Air Systems, Compressors, Operation	14	7	2
Instructions for Developing a Compressed Air System Baseline	13	4	1
Exercises in Diagnosing System Problems	13	13	1
Reference Materials in Course Book	9	8	0
Description of Potential Capital Improvements	4	8	1
Description of Potential Maintenance Improvements	3	6	1
Other	6	1	10
Don't Know	3	0	8
None/No Other (Column 2)(Column 1)	8	28	48
Number of Respondents to Item	**73**	**59**	**71**

* Multiple sources accepted.

3.2.3 Assessment of *Advanced* Training

There were 29 sample vendors who attended the *Advanced* training sessions. The *Advanced* training participants reported that they derived the most benefit from the exercises in diagnosing systems problems, general compressed air system information, the course book reference materials, and the system baselining instructions. (Table 3-11)

Table 3-11 Elements of *Advanced* Training–Useful and Not Useful

Program Element	Frequency of Mention: Most Useful	Also Useful*	Not Useful*
Exercises in Diagnosing System Problems	7	3	2
General Information on Compressed Air Systems, Comps, Operation	6	4	4
Reference Materials in Course Book	5	3	2
Instructions for Developing a Compressed Air System Baseline	3	1	1
Description of Potential Capital Improvements	1	2	2
Description of Potential Maintenance Improvements	1	4	1
Case Studies	1		2
Compressor Efficiency Ratings	1		2
Opportunities to Save Energy		1	
Storage Tank Sizing		1	
Other	2	2	1
Don't Know	2		14
Refused			1
None (Column 1)		10	1
Number of Respondents to Item	**29**	**27**	**29**

*Multiple sources accepted.

3.2.4 Participant Suggestions to Improve the Value of Training

The vendor participants provided numerous suggestions on how to improve the value of both levels of the CAC training courses. Although there were many *Fundamentals* and *Advanced* attendees that thought the course should be left unmodified, there were dozens of suggestions to improve future training sessions with changes in content and format.

Fundamentals of Compressed Air Systems

A fair number of comments focused on the technical level of the *Fundamentals* course. Several vendors thought the course material was simply too basic to be useful to them. This response was to be expected given that the *Fundamentals* course was designed specifically to meet the needs of end users. One of the vendors in this group wished that he could have skipped the course and taken the *Advanced* course only. Another participant criticized the decision to include vendors and end-users in the same class because the two groups differ substantially in their grasp of compressed air system management. On the other hand, a few vendors thought that too much information was covered in too short a time period and suggested extending the training over additional days. This would provide greater opportunities for more trainees to voice their perspectives on the subject[1].

[1] XENERGY's experience in running similar types of training programs suggests that it is nearly impossible to attract vendors to training seminars that last more than 2 days.

The vendors suggested several topics that should be added or emphasized in future training sessions. These included:

- Offer more information on the costs related to making improvements (e.g. sealing leaks, system improvements).
- Provide more information on air dryer technology.
- Give greater emphasis to the demand side. Look at artificial demand and how it is applied.
- Present more specifics on variable speed drives.
- Put greater emphasis on smaller projects and smaller systems when using examples.

Many vendors also wanted to change the layout of the course as well. Some suggestions included:

- Provide group activities with mock set-ups where participants may troubleshoot various problems.
- Make the class generally more "hands-on" and less classroom based.
- Explain the math portion with more hands-on examples, specifically concerning velocity, pressure drop, storage and sizing tanks.
- Gear the training less toward end-user, and more toward the distributor.
- Add a field trip to demonstrate some of the techniques referred to in the course.
- Provide more case studies.
- Get engineers and power companies more involved in the program.
- Market the program better. Many additional customers may benefit.

Although overall vendor ratings for the *Fundamentals* course were high, many voiced specific criticisms. Several comments centered on perceived deficiencies with the course instructors. One vendor thought the instructors were not well prepared and two others suggested that the instructors were biased towards certain products that their own companies produced. One trainee recalled that his instructor made what amounted to a sales presentation for his own company, which he felt was a "conflict of interest." Another respondent felt that the technology utilized in the course was not the most up-to-date. Two respondents noted that the course material was "too generic" or "not specific", perhaps attributable to the large numbers of different instructors involved in the training and the breadth of the audience addressed. Finally, one vendor seemed rather irate: "People should be indoctrinated into other modes of compressing air, such as natural gas, engine-driven, and steam driven compressors."

Advanced Management of Compressed Air Systems

As was the case for the *Fundamentals* course above, several vendors commented on the level of difficulty of the *Advanced* course and how quickly the course subjects were covered. These vendors thought the training should have focused on even more complex concepts. One respondent noted that the CAC could have been more selective with the audience participants, because beginners in the class tended to slow down the instruction process. A few vendors also thought the course covered too much material in the time allowed and would add additional days to the training. One participant thought the course should be spread out over 5 days.

The vendors that attended the *Advanced* training offered these suggestions for topics that should be added or emphasized in future training sessions:

- Give more in-depth information on variable speed drives.
- Provide more in-depth system review and less information on general equipment.
- Address more real-world applications, specifically for small to mid-sized end-users.

There were also several suggestions regarding course layout and format:

- Furnish additional group leaders in the room to guide people through projects.
- Provide models to look at for reference.
- Give more in-depth views on case studies.

The vendors made very few outright criticisms of the *Advanced* training course. One vendor's comment seemed to mirror those of his counterparts in the *Fundamentals* course. He suggested that the instructors were biased towards certain products and could possibly be better trained or selected for future trainings. Another vendor felt unprepared for the course and suggested that the course materials be provided in advance.

Overall, the CAC trainings were very well received by the majority of vendors and the vast majority (86%) of participants said they would be interested in attending future CAC training events. These vendors were asked which topics they would most like to see in future CAC training sessions. The top choices were system controls, system measurement, diagnosis of operating problems, baselining, maintenance, and equipment selection. (Table 3-12)

Among the vendors who were interested in future CAC trainings, about half of them (48%) felt that it was "somewhat likely" or "very likely" that the training they received may be useful for their customers. Furthermore, one-half of these vendors were receptive to hosting a training event or referring their customers to one. In fact, 23% said it was "very likely" that they would do so if given the opportunity.

Table 3-12 Participant Suggestions of Topics for Further Training (Among Those Reporting Interest in Additional Training)

Topics	Frequency of Mention First Choice	Frequency of Mention Other Choices*
Controls	19	11
Further Detail on System Measurement	9	13
Diagnosis of Operating Problems	8	11
Further Detail on Baselining	5	17
Maintenance	5	15
Equipment Selection	3	13
Compressor Types/Compressor Efficiency	3	
Energy Savings and Conservation	2	
Further Details on All Topics	3	
Variable Speed Drives	3	
Power Cost Efficiency	1	
System Dynamics/Installation/General Compressor System Usage	5	
Dryers and Operating Costs	1	
Air Master/Air Tanks	2	
Other	7	7
No Other	N/A	25
Don't Know	10	
Number of Respondents to Item	**86**	**76**

* Multiple responses accepted.

3.3 Program Effects

3.3.1 Pre-Training Awareness and Activities

Prior to training participation, 86% of the vendors claimed their companies offered services specifically designed to reduce energy costs in plant compressed air systems. Table 3-13 shows a breakdown of the types of compressed air efficiency services that were mentioned by this group of respondents. The scattered response pattern seems to indicate that most firms only offered a few of these services each, as opposed to a comprehensive, integrated package to meet customer needs.

Prior to training, 80% of vendor respondents that claimed to offer compressed air efficiency services (or 69% of all vendors surveyed) stated that their companies actively promoted these services to their customers. The most common means were to market them in conjunction with equipment sales, through direct mail, as part of their maintenance services, or through customer efficiency training. (Table 3-14)

Table 3-13 Compressed Air Services Offered Prior to Training

Service	Percent of Respondents
No Compressed Air System Efficiency Services Offered	14
Measurement of Pressure Dynamics in a System	13
Measurement of System Flow and Pressure	15
Measurement of System Energy Consumption	15
Analysis of Compressed Air System Efficiency	16
Leak Prevention Services	14
Ultrasonic Leak Detection	14
ID of Supply-Side Efficiency Opportunities	14
Analysis of End-Use Reduction Opportunities	14
Other	1
Don't Know	0
Number of Respondents to Item	**100**

* Multiple responses accepted.

Table 3-14 Actions To Promote Compressed Air Efficiency Services Prior to Training

Marketing Approach	Percent of Respondents*
Did Not Actively Market Services Prior to Training	31
Sold in Connection with Equipment Sales	38
Direct Mail to Consumers	35
Sold in Connection with/or as Part of Maintenance Service/Sales	29
Sponsored/Delivered Training for Customers in Compressed Air Efficiency	25
Telemarketing	4
Literature and System Guides for Customers	3
Face-to-Face Customer Marketing	3
Other	4
Don't Know	3
Number of Respondents to Item	**100**

* Multiple responses accepted.

3.3.2 Post-Training Services Offered

The vendor questionnaire included several questions that sought to determine how useful the CAC workshop materials and information were in addressing the needs of their compressed air service customers, and in helping to create new service offerings. Apparently, the training participants found the CAC workshop materials and information to be very useful in their service to customers. The key findings from these questions are as follows.

- **Use of CAC materials to evaluate customer systems**. The vast majority (85%) of vendor participants claimed that they have used training workshop materials or information when they evaluate their customers' compressed air systems. Among this group of vendors, 18% of respondents used them in "all" customer system evaluations, and 40% used them in "many" system evaluations.

- **Use of CAC materials to diagnose system operating problems.** 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. Among this group, 9% used them in "all" diagnostic situations, and about one-third used them in "many" situations (30%).

- **Use of CAC materials to specify customer system improvements**. The majority of vendors (72%) made use of CAC workshop materials and information to specify improvements to their customers' compressed air systems. Among those respondents, 21% used the course materials in "all" relevant projects, and 38% used them in "many" projects.

- **New compressed air services.** Since participating in the training, about half (52%) of respondents said that their companies have begun to offer new services to increase the energy efficiency of compressed air systems at their customers' facilities. Among this group of vendors, the most common services added are listed in Table 3-15. These include analysis of compressed air system efficiency (9% overall), measurements of system flow/pressure and energy consumption (both 6% overall), and ultrasonic leak detection (6% overall).

- **Likelihood of enhancement to service offerings in the absence of CAC training.** For the 52% of vendors that began to offer new efficiency services after attending training, the majority claimed that they would have been offered anyway. Approximately 60% of these vendors (or 31% overall) said that it was "somewhat likely" or "very likely" that their companies would have offered them without the benefit of CAC training (Table 3-16)

- **Percentage of vendors adding/enhancing services based on *Advanced* course.** Among the 29 vendors that attended the *Advanced* training course, most (79%) said that there were no new service offerings or enhancements made specifically on the basis of information or techniques gained through that course over the *Fundamentals* course.

Table 3-15 New Compressed Air Efficiency Services Offered After Training

New Services	Percent of Respondents*
Analysis of Compressed Air System Efficiency	9
Ultrasonic Leak Detection	6
Measurement of System Flow and Pressure	6
Measurement of System Energy Consumption	6
Analysis of End-Use Reduction Opportunities	4
Leak Prevention Services	4
ID of Supply-Side Efficiency Opportunities	3
Data Logging	3
Compressed Air System Auditing/Improved Auditing Capability	3
Other	6
No New Services Offered	48
Don't Know	3
Number of Respondents to Item	**100**

* Multiple responses accepted. Percentages do not add to 100.

Table 3-16 LIkelihood New Services Would Be Offered Without CAC Training

Likelihood Rating	Percent of Respondents
Not at All Likely	6
Not Very Likely	13
Neutral	21
Somewhat Likely	17
Very Likely	43
Number of Respondents to Item	**100**

3.3.3 Post-Training Marketing Activities

Nearly half (46%) of vendor respondents claimed that they had undertaken new compressed air marketing initiatives following their participation in the CAC training.

- **New marketing initiatives adopted.** The most common marketing techniques added by this group of vendors were direct consumer mail (26%), marketing in conjunction with maintenance service sales (22%), and equipment sales (16%). (Table 3-17)

Table 3-17 New Activities Added to Market Compressed Air Efficiency Services After Training

Marketing Approach	Percent of Respondents*
Direct Mail to Consumers	26
Marketed in Connection or as Part of Maintenance Service Sales	22
Marketed in Connection with Equipment Sales	16
Sponsored or Delivered Training for Customers in Compressed Air Efficiency	10
Radio/Newspaper Ads	3
Faxes	3
Added Additional Personnel/Better Training	3
Money Back Guarantee	3
Phone Sales	3
Compressed Air System Audits	1
Lobbied with Utility Companies	1
Other	4
Don't Know	4
Number of Respondents to Item	**46**

* Multiple responses accepted. Percentages do not add to 100.

- **Importance of the availability of utility rebates.** The majority of vendor trainees perceived an important role for utility rebates in their marketing of compressed air efficiency services. Nearly 60% of participants thought they were "very important" or "somewhat important."

- **Likelihood of new marketing initiatives in the absence of CAC training.** The majority (60%) of this group of vendors claimed that they would have undertaken these activities even if they had not attended the training. Only 20% reported that they would have been unlikely to offer such services in the absence of the program. Less than one-third (29%) of these vendors claimed that they had based the new initiatives on information and techniques that they learned during the CAC trainings. The majority (65%) apparently had prior knowledge or techniques in place for these efforts.

3.3.4 Changes in Demand for Compressed Air Efficiency Services

The respondents were asked if the number of customers to whom they provide compressed air system efficiency services increased or decreased after they attended the CAC training. As Table 3-18 indicates, about half of respondents thought their business in this area had increased (50%) and the remainder witnessed little change (45%).

Table 3-18 Post-Training Change in Compressed Air Efficiency Service Customers

Number of Compressed Air Service Customers	Percent of Respondents
Increased	50
Decreased	1
Stayed the Same	45
Don't Know	4
Number of Respondents to Item	**100**

Among the 50 vendor respondents that witnessed an increase in customer demand for compressed air system efficiency services, nearly half estimated the rate of increase at 25% or less. This is still a substantial level of growth in a service field such as engineering. We should also note that 60% of those reporting growth in compressed air system efficiency services claimed to have initiated new services in the period since the training. Among those with increased efficiency business, 50% reported undertaking new marketing initiatives since the training.

According to the 50 vendors who reported an increase in demand for efficiency services, the most important contributing factors were greater customer awareness of compressed air efficiency opportunities (33%), higher electricity prices (16%), and strengthened vendor and consultant marketing efforts (14%). (Table 3-19)

Table 3-19 Important Factors that Contributed to Increase

Factor	Most Important*	Also Important*
Greater Customer Awareness of Compressed Air Efficiency Opportunities	33%	13%
Increase in Electricity Prices	16%	13%
Increased Marketing Efforts by Vendors, Consultants	14%	5%
Economic Downturn; Reduced Funds for Investment	8%	2%
Increased Cost Competition in Industry	6%	5%
Utility Programs	6%	2%
Government Programs	2%	2%
Other	16%	5%
Don't Know	N/A	4%
No Other Factors	N/A	49%
Number of Respondents to Item	50	43

* Multiple responses accepted. Percentages do not add to 100.

3.4 Selected Details of Current Efficiency Services

Size of Typical Systems Serviced

According to the survey data, the vendors perform efficiency services on customer compressed air systems that occupy a broad range of capacities (in terms of connected horsepower). As Table 3-20 shows, customer systems were typically sized from 100 hp up to 750 hp.

Table 3-20 Typical Customer Compressed Air System Size (Connected Horsepower)

System Connected Horsepower	Percent of Respondents
5–99	23
100–199	34
200–299	16
300-499	10
500-750	7
Don't Know	10
Number of Respondents to Item	**100**

Most Frequent Compressed Air System Efficiency Measures Recommended

Vendors were asked to name the three compressed air efficiency measures they recommended most frequently to customers. The objective of this set of questions was to elicit information that might suggest an emerging pattern of standard practices or approaches currently in use by vendors and

consultants in the field. The four compressed air system efficiency measures that the vendor firms most frequently recommend to their customers are the addition of compressed air storage (18%), compressor controls (14%), the reconfiguration of piping to reduce pressure loss (14%), and compressor replacement (11%). (Table 3-21) Members of the CAC's Ad Hoc Evaluation Committee identified adding storage, reworking controls, and reconfiguring piping to reduce pressure loss as the most productive energy efficiency measures. It appears that the vendors who attended the training at least shared that perception, although it is not clear to what extent this perception was shaped by the training. We should note that end- users who attended the training sessions reported that the improvements they made most frequently were upgrades to compressor efficiency, leak reduction, upgrade of air dryers, and replacement of air filters.

Table 3-21 Compressed Air System Efficiency Measures Most Frequently Recommended to Customers

	Percent of Respondents	
Efficiency Measures	**Three Most Frequent**	**Other Measures***
Add Compressed Air Storage	18	9
Add, Restore, Upgrade Compressor Controls	14	4
Reconfigure Piping to Reduce Pressure Loss	13	14
Replace Current Compressor with More Efficient Model	11	9
Add Small Compressor for Off-Peak Loads	9	9
Add, Upgrade or Reconfigure Air Dryers	6	13
Install or Upgrade Distribution Control System	4	11
Modify or Replace Regulators (Controls at the Process)	4	9
Rework or Correct Header Piping	3	11
Replace or Repair Air Filters	3	11
Replace or Upgrade Condensate Drains	0	11
Improve Compressor Room Ventilation	0	11
Install or Upgrade (Ball) Valves in Distribution System	0	9
Other	10	23
No Other Measures		50
Don't Know	2	7
Number of Respondents to Item	**100**	**100**

* Multiple responses accepted. Percentages do not add to 100.

Targeted Levels of Compressed Air System Energy Savings

Vendors were asked to estimate the minimum level of energy savings they seek to achieve (in terms of reduction of baseline energy usage) when they undertake compressed air system efficiency projects. They were then asked what level of savings they thought they typically achieved. The objective of these questions was to probe how realistic the vendors' expectations were when compared to

the experience of members of the CAC Ad Hoc Evaluation Committee, most of whom are active in the field. The minimum level of energy savings, in terms of baseline system consumption, that the vendors reported targeting through their compressed air efficiency projects ranged from 5 to more than 40%, clustering in the 15 – 30% range. This estimate corresponds fairly well to the experience of the Ad Hoc Evaluation Committee members, who estimated maximum achievable savings at 30 – 40%. The typical level of energy savings that respondents reported actually achieving followed the same pattern. (Table 3-22) The majority of vendors (69%) claimed that they measure changes in energy consumption or demand for the compressed air efficiency projects they have implemented.

Table 3-22 Minimum/Typical Energy Savings Targeted In Compressed Air Efficiency Projects

	Percent of Respondents	
Savings (% of baseline system use)	**Targeted**	**Achieved**
0-5%	4	2
7-10%	9	6
15%	11	10
18-20%	19	17
22-27%	9	14
30-35%	5	14
40+%	2	7
Don't Know	38	29
Refused	3	1
Number of Respondents to Item	**100**	**100**

Appendix A
Energy Use and Savings Calculations

We estimated air compressor energy consumption using information collected through the end-user survey. This appendix contains the details of the calculations.

Energy consumption is calculated using the equation:

Energy Consumption=hp x .746 x hours x service factor x load factor / efficiency

The definition of each factor and the source of the data are given in the following table.

Factor	Definition	Source/Value
hp	Nameplate horsepower of compressor	Question SD2a of the end-user survey for up to 6 compressors.
0.746	hp to kW conversion factor	
Hours	Annual hours of operation of the compressor	The product of: daily hours of operation X operating days per week X weeks per year. • Daily hours of operation for each compressor are taken from questions SD1b of end-user survey. • Days per week–from question SC5. • Weeks per year–from question SD2 (based on interpretation of response to question on seasonal use)
Service Factor	Compressor service factor	1.1 used in all calculations based on the assumption that most compressors operate at loads greater than the hp rating.
Load Factor	Compressor load factor	Load factors are set based on the number of compressors in the facility. • End-users with 1 compressor: Load factor is 80%. • End-users with 2 or more compressors: Load factor is 90% for first compressor, and 60% for the remaining compressors.
Efficiency	Motor efficiency	Baseline efficiency tables from MotorMaster+ based on the hp of the compressor.

The motor efficiencies from MotorMaster+ are listed in the following table.

Horsepower Range	Efficiency
<1	0.776
1-1.5	0.793
1.5–2	0.805
2–3	0.824
3–5	0.838
5–7.5	0.852
7.5–10	0.861
10–15	0.878
15–20	0.883
20–25	0.889
25–30	0.889
30–40	0.900
40–50	0.907
50–60	0.913
60–75	0.919
75–100	0.921
100–125	0.922
125–150	0.928
150–200	0.930
200–250	0.930
250–300	0.930
300–350	0.930
350–400	0.930
400–450	0.930
>450	0.930

Question C2 of the survey asks about the energy efficiency measures implemented since attending the workshop. The annual energy savings from the measures mentioned in question C2 were estimated by applying savings fractions to the estimated energy consumption of all compressors at the facility. Savings fractions are based on communications from the CAC Ad Hoc Evaluation Committee. The percentage savings for each site was limited to a maximum of 30% of estimated compressor energy. Thus any one site that may have had multiple measures could save a maximum of 30%. The savings fractions are listed in the following table.

Measure	Percentage of Potential Savings
Replace Current Compressor with More Efficient Model	2
Reconfigure Piping to Reduce Pressure Loss	20
Add Compressed Air Storage	20
Add Small Compressor for Off-Peak Loads	2
Add, Restore, Upgrade Compressor Controls	30
Install or Upgrade Distribution Control System	20
Rework or Correct Header Piping	20
Add, Upgrade, or Reconfigure Air Dryers	1
Replace or Repair Air Filters	10
Replace or Upgrade Condensate Drains	5
Modify or Replace Regulators (Controls at the Process)	20
Improve Compressor Room Ventilation	1
Install or Upgrade (Ball) Valves in Distribution System	10
Other	10

The annual cost savings are calculated from the annual energy savings using $0.05/kWh as the unit cost. The unit cost is based on information contained in the table: "Electric Utility Average Revenue per Kilowatthour to Ultimate Consumers by Sector, Census Division, and State" prepared monthly by the Energy Information Administration, U. S. Department of Energy. The cost of the capital improvements is asked in question C4 of the survey. The payback of the energy savings is calculated as the ratio of the capital cost (C4) to the energy cost savings from the measures.

Appendix B: Questionnaires on the Compressed Air Challenge® Training Evaluation

End-User Survey

CUSTOMER IDENTIFICATION
Contact Name: [from sample] _____
Company: [from sample] _____
Address: [from sample] _____
City, State, Zip [from sample] _____
Telephone: [from sample] _____
Registration site [from sample] _____
Session Date [from Sample] _____
Survey ID Number: _____

Introduction and Respondent ID

Hello, my name is _____ and I'm calling from _____. We're conducting a study for the Compressed Air Challenge training program.

SCA. May I speak with [CONTACT NAME]

[IF CONTACT IS NOT AVAILABLE, ASCERTAIN BEST TIME TO CALL.]
[IF CONTACT NO LONGER WORKS AT THE LOCATION, CODE 1 AND TERMINATE THE CALL.]

Lead in for respondent. Hello, this is _____ calling from _____. We're conducting a study to assess the results of the Compressed Air Challenge training programs. Do you have 10-15 minutes to discuss your participation in the training program and your firm's experience with compressed air systems?

IF PROGRAM RECORDS INDICATE THAT THE RESPONDENT ATTENDED THE FUNDAMENTALS (LEVEL =1) ASK SCB. ELSE SKIP TO INSTRUCTIONS AT SCE.

SCB. According to our records you attended a training session on *Fundamentals of Compressed Air Systems* in [REGISTRATION SITE] in [MONTH AND YEAR OF SESSION DATE]. Is our information about your attendance at the training session correct?
Yes [GO TO INSTRUCTIONS AT SCE]..... 1
NO [GO TO SCC]..... 2

SCC. Did you attend any session of the *Fundamentals of Compressed Air Systems* training offered by the Compressed Air Challenge Program?

Yes..... 1
No [GO TO INSTRUCTIONS AT SCE]..... 2

SCD. Can you tell me in which city that training took place?
ENTER CITY_____

CHECK CITY AGAINST LIST OF TRAINING SITES. IF CITY IS NOT ON THE LIST SEEK FURTHER INFORMATION/CLARIFICATION TO ASCERTAIN CORRECT TRAINING LOCATION. IF LOCATION CANNOT BE CONFIRMED, TERMINATE CALL.

IF CITY IS ON THE LIST, CONTINUE WITH THE LEAD-IN.

IF CUSTOMER DOES NOT REMEMBER ATTENDING TRAINING OR DOES NOT REMEMBER ATTENDING TRAINING AT A VERIFIED SITE AND DOES NOT HAVE INDICATION OF ATTENDING LEVEL 2, THANK AND TERMINATE.

IF PROGRAM RECORDS INDICATE CUSTOMER ATTENDED ADVANCE TRAINING (LEVEL = 2), ASK SCE. ELSE GO TO "LEAD IN CONTINUED".

SCE. According to our records you attended a training session on *Advanced Management of Compressed Air Systems* in [REGISTRATION SITE] in [MONTH AND YEAR OF SESSION DATE]. Is our information about your attendance at the *Advanced* training session correct?

Yes [GO TO "LEAD IN CONTINUED".]..... 1
NO [GO TO SCC]..... 2

SCF. Did you attend any session of the *Advanced Management of Compressed Air Systems* training offered by the Compressed Air Challenge Program?

Yes..... 1
No [GO TO INSTRUCTIONS AT PRIOR TO "LEAD IN CONTINUED".]..... 2

SCG. Can you tell me in which city that training took place?
ENTER CITY_____

CHECK CITY AGAINST LIST OF TRAINING SITES. IF CITY IS NOT ON THE LIST SEEK FURTHER INFORMATION/CLARIFICATION TO ASCERTAIN CORRECT TRAINING LOCATION. IF LOCATION CANNOT BE CONFIRMED AND CUSTOMER DID NOT ATTEND FUNDAMENTALS, THANK AND TERMINATE.

IF CITY IS ON THE LIST, CONTINUE WITH THE LEAD-IN.
IF CITY IS NOT ON THE LIST, TREAT CUSTOMER AS ATTENDEE OF FUNDAMENTALS (LEVEL = 1) ONLY.

Lead-in Continued. We are conducting a study on behalf of the sponsors of the Compressed Air Challenge program to determine how information gained at its training programs are being used by those who attend. The results of this study will be used to assess and develop improvements for the program. REASSURE: Your responses to our questions will be entirely confidential. Again, this interview will only take about 10-15 minutes of your time…

First, I'd like to get a little information about you and your firm.

SC1 Which of the following 6 choices best describes your company? Is it [READ CHOICES]…

A manufacturing facility..... 1
Another type of industrial facility, such as
a mine or water processing plant..... 2
A commercial facility such as an office building or retailer..... 3
Other facility, such as a school or hospital..... 4
A compressed air equipment manufacturer or vendor..... 5
Consulting firm..... 6

IF SC1 = 1-4 OR IS OTHERWISE AN END-USER OF COMPRESSED AIR SYSTEMS GO TO SC2.
IF SC1 = 5 GO TO THE VENDOR SURVEY.
IF SC1 = 6, ASK RESPONDENT IF HIS COMPANY IS ASSOCIATED WITH AN EQUIPMENT PROVIDER. IF YES, GO TO VENDOR SURVEY. IF NOT, GO TO SC2.

SC2 What is your title?

Plant Manager..... 1
Maintenance Manager..... 2
Purchasing Manager..... 3
Plant Engineer..... 4
Chief Electrician..... 5
Maintenance Staff..... 6
President/CEO..... 7
General Manager..... 8
Consultant..... 9
Other(Specify)_____..... 10

SC3 What is the principal product produced or service provided at your facility?

Food product..... 1
Textile product..... 2
Lumber or wood product..... 3
Paper or allied product..... 4
Chemicals..... 5
Petroleum..... 6
Stone, Clay, Glass..... 7
Primary metals (e.g. Steel, aluminum)..... 8
Metal fabrication or machinery..... 9
Water/Wastewater Processing..... 10
General Manufacturing.....11
Other (Specify _____)..... 12

SC4 How many full-time employees work at this location? This includes clerical and professional employees as well as production workers.
ENTER NUMBER OF EMPLOYEES.....____

SC5 How many days per week are your production facilities currently operating?
ENTER NUMBER OF DAYS PER WEEK.....____

SC6 And how many hours per day, on average?
ENTER NUMBER OF HOURS PER DAY.....____

Compressed Air Description

SC7 Do you have a compressed air system in your facility?

Yes..... 1
No..... 2
Don't know.....97

IF SC7 = NO OR DON'T KNOW, SKIP TO PE1.

SD1 How many compressors are there in your compressed air system?
ENTER NUMBER OF COMPRESSORS; 97 FOR DON'T KNOW…____

IF SD1 = 1, ASK SD1a-b FOR 1 ONLY.
IF SD1 > 1 ANSWER QUESTION SD1a-b FOR ALL COMPRESSORS.
USE TABLE BELOW TO RECORD ANSWERS TO SD1a and SD1b

SD1a. What is the horsepower of the [first, second, third…] compressor?
SD1b. How many hours a day does the [first, second, third…] compressor typically run?

Compressor Number	SD1a (Horsepower)	SD1b (Hours per day)
1		
2		
3		
4		
5		
6		

SD2 Does your compressor use vary by:

Shift..... 1
Weekday/weekend..... 2
Season..... 3
Only during shutdowns..... 4
Don't know..... 97

SD4 Do you have a system control or individual controls for your compressors?

System control..... 1
Individual controls..... 2
Don't know..... 97

Program Experience

PE1 First, how did you find out about the Compressed Air Challenge training program? DO NOT READ. CIRCLE ALL THAT APPLY.

From compressed air equipment vendor..... 1
From local electric utility representative..... 2
From a U.S. Department of Energy publication..... 3
From a U.S. Department of Energy representative..... 4
From advertisement or article in a trade or industry publication..... 5
From direct mail advertisement..... 6
Other (Specify: _____)..... 7
Don't know.....97

PE2a What was the most important reason you decided to enroll in the training?
USE TABLE BELOW. MARK ONE ANSWER ONLY.

PE2b Were there other reasons?
USE TABLE BELOW. CIRCLE ALL THAT APPLY.

	PE2a	PE2b
Was experiencing problems with compressed air system operation at the time.	1	1
Was planning to make improvements to the compressed air system at the time.	2	2
Recommended by vendor	3	3
Recommended by utility	4	4
Needed to use training budget	5	5
Was planning energy efficiency projects in general	6	6
Other (Specify):	7	7

PE3 The fee for the "Fundamentals of Compressed Air Systems" is $495, and "Advanced Management" is $495. Did you or your firm receive a subsidy or cost reduction to attend?

Yes..... 1
No..... 2
Don't know.....97

IF LEVEL = 1 OR 2, ASK PE4a.

PE4a What element of the *Fundamentals* program did you find most useful?
USE TABLE BELOW. CIRCLE ONE ONLY.

PE4b What other elements of the *Fundamentals* program were also useful?
USE TABLE BELOW. CIRCLE ALL THAT APPLY.

PE4c What elements of the *Fundamentals* program did you find were not useful?
USE TABLE BELOW. CIRCLE ALL THAT APPLY.

IF LEVEL = 2, ASK PE4d. ELSE SKIP TO PE5.

	PE4a	PE4b	PE4c
General information on compressed air system components and operation.	1	1	1
Instructions for developing a compressed air system baseline.	2	2	2
Description of potential capital improvements	3	3	3
Description of potential maintenance improvements	4	4	4
Exercises in diagnosing system problems	5	5	5
Reference materials in the course book	6	6	6
Other (Specify):	7	7	7

PE4d What element of the *Advanced* program did you find most useful?
USE TABLE BELOW. CIRCLE ONE ONLY.

PE4e What other elements of the *Advanced* program were also useful?
USE TABLE BELOW. CIRCLE ALL THAT APPLY.

PE4f What elements of the *Advanced* program did you find were not useful?
USE TABLE BELOW. CIRCLE ALL THAT APPLY.

	PE4d	PE4e	PE4f
General information on compressed air system components and operation.	1	1	1
Instructions for developing a compressed air system baseline.	2	2	2
Description of potential capital improvements	3	3	3
Description of potential maintenance improvements	4	4	4
Exercises in diagnosing system problems	5	5	5
Reference materials in the course book	6	6	6
Other (Specify):	7	7	7

PE5 What steps do you think the Compressed Air Challenge program could have taken to improve the usefulness and value of the training for you?

_____

_____

PE6 Would you be interested in additional training from Compressed Air Challenge?

Yes..... 1
No..... 2
Don't know..... 97

IF PE6 = 1, GO TO PE7a,
IF PE6 = 2 OR 97, GO TO G1.

PE7a What topic would you most like to see addressed in additional training sessions?
USE TABLE BELOW. CIRCLE ONE RESPONSE ONLY.

PE7b What other topics would be of interest?
READ CHOICES IF NECESSARY FROM TABLE BELOW.
ACCEPT MULTIPLE RESPONSES.

	PE7a	PE7b
Further detail on system measurement	1	1
Further detail on baselining	2	2
Equipment selection	3	3
Controls	4	4
Diagnosis of operating problems	5	5
Maintenance	6	6
Other (Specify):	7	7
Don't know	97	97

General Program Effects

G1 Prior to participating in the Compressed Air Challenge training, were you aware of specific actions you could take to reduce electric use and costs associated with your compressed air system?

Yes..... 1
No..... 2
Don't know..... 97

IF G1 = 1, GO TO G2.
IF G1 = 2 OR 3, SKIP TO G4

G2 During the year prior to the training, had you implemented any capital or operating improvements to your compressed air system to reduce energy consumption?

Yes..... 1
No..... 2
Don't know..... 97

IF G2 = 1, ASK G3.
IF G2 = 2 OR 3, SKIP TO G4

G3 What specific improvements did you make?

Capital Improvements

Replace current compressor with more efficient model.... 1
Add small compressor for off-peak loads..... 2
Add, restore, upgrade compressor controls..... 3
Add compressed air storage..... 4
Reconfigure piping to reduce pressure loss..... 5
Add, upgrade, or reconfigure air dryers..... 6
Replace or repair air filters..... 7
Replace or upgrade condensate drains..... 8

Improve compressor room ventilation..... 9
Rework or correct header piping..... 10
Install or upgrade distribution control system..... 11
Install or upgrade (ball) valves in distribution system..... 12
Modify or replace regulators (controls at the process)..... 13
Other Capital 1 (Specify _____)..... 14
Other Capital 2 (Specify _____)..... 15
Eliminated inappropriate uses..... 16

Maintenance Improvements
Leak inspection and repair..... 17
Other maintenance improvements..... 18
Don't know..... 97

Capital Improvements Made

C1. Since participating in the training course, have you completed any changes to the components of your compressed air system or its configuration with the objective of reducing energy consumption or improving general system performance?

Yes..... 1
No..... 2
Don't know.....97

IF C1 = 1, GO TO QUESTION C2.
IF C1 = 2 OR 97, SKIP TO QUESTION PC1.

C2. What changes to system components or configuration have you made?
PROMPT WITH EXAMPLES IF NECESSARY. CHECK ALL MENTIONED.

Replace current compressor with more efficient model..... 1
Add small compressor for off-peak loads..... 2
Add, restore, upgrade compressor controls..... 3
Add compressed air storage..... 4
Reconfigure piping to reduce pressure loss..... 5
Add, upgrade, or reconfigure air dryers..... 6
Replace or repair air filters..... 7
Replace or upgrade condensate drains..... 8
Improve compressor room ventilation..... 9
Rework or correct header piping..... 10
Install or upgrade distribution control system..... 11
Install or upgrade (ball) valves in distribution system..... 12
Modify or replace regulators (controls at the process)..... 13
Other 1 (Specify _____)....14
Other 2 (Specify _____)....14
Don't know..... 97

C3. What kind of firms did you work with to identify and engineer these changes?
CHECK ALL THAT APPLY.

Compressed air system consultant..... 1
Compressed air equipment distributor..... 2
Consulting engineer..... 3
Did engineering work in-house..... 4
Utility representative..... 5
Other..... 6
Don't know..... 97

C4. Roughly how much did these systems changes cost to implement? Please include the costs of engineering and project management services in your estimate.
ENTER COST OF PROJECT IN $1000's
ENTER 9997 FOR DON'T KNOW.....$_____,000

C5. Did the availability of rebates from a utility-sponsored energy efficiency program affect your decision to implement these changes to your compressed air system?
Yes..... 1
No..... 2
Don't know..... 3

C6. Roughly how much electricity do you expect to save through these changes, in terms of dollars or kilowatt-hours per year? CODE 97 FOR DON'T KNOW.
1. ENTER DOLLARS/YEAR.....$_____
2. ENTER KWH/YEAR....._____KWH

C6a What is your estimate of savings in terms of a percentage of initial system electric use?
ENTER PERCENT, 997 FOR DON'T KNOW....._____

C7. Have the system changes led to benefits to your company other than reduced energy costs? PROMPT FROM C7a LIST IF NEEDED.

Yes..... 1
No..... 2
Don't know..... 97

IF C7 = 1, ASK C7a.
IF C7 = 2 OR 97, SKIP TO QUESTION C8.

C7a. What specific benefits have resulted from the compressed air system measures? DO NOT READ. CIRCLE ALL THAT APPLY.

Reduced down time..... 1
Reduced moisture in the system..... 2
Reduced contamination in the system..... 3
More consistent pressure to end-uses..... 4
Delivery or restoration of adequate pressure to all areas of the system..... 5
Other (Specify: _____)..... 6
Don't know..... 97

C8. Did you use information or analysis approaches contained in the Compressed Air Challenge training to support a request to your management for funds to implement the improvements you made?

Yes..... 1
No..... 2
Don't know..... 97

IF C8 = 1 ASK C8a.
IF C8 = 2 OR 97, SKIP TO QUESTION C9.

C8a. On a scale of 1 to 5, where 1 means not at all important and 5 means very important, how important was that information in convincing your managers to fund the compressed air system improvement measures?

ENTER RATING 1-5, CODE 97 FOR DON'T KNOW _____

C9. On a scale of 1 to 5, where 1 means not at all likely and 5 means very likely, how likely is it that your company would have made improvements to the energy efficiency of its compressed air system if you had not attended the training?

ENTER RATING 1-5, CODE 97 FOR DON'T KNOW _____

IF LEVEL = 2, ASK C10. ELSE SKIP TO PC1.

C10. Were there any improvements that you made specifically on the basis of information or analysis techniques you gained through the *Advanced* training workshop, as opposed to the *Fundamentals* workshop?

Yes..... 1
No..... 2
Don't know..... 97

IF C10 = 1 ASK C10a.
IF C10 = 2 OR 97, SKIP TO QUESTION PC1.

C10a Which improvements did you undertake based on the *Advanced* training workshop?

_____

_____

Planned Capital Improvements

PC1. Are you planning to make any (additional) changes to your compressed air system or its components?

Yes..... 1
No..... 2
Don't know..... 97

IF PC1 = 1, GO TO PC2.
IF PC1 = 2 OR 97, SKIP TO EU1.

.

PC2. What changes to system components or configuration are you planning to make? PROMPT WITH EXAMPLES IF NECESSARY. CHECK ALL MENTIONED.

Replace current compressor with more efficient mode..... 1
Add small compressor for off-peak loads..... 2
Add, restore, upgrade compressor controls..... 3
Add compressed air storage..... 4
Reconfigure piping to reduce pressure loss..... 5
Add, upgrade, or reconfigure air dryers..... 6
Replace or repair air filters..... 7
Replace or upgrade condensate drains..... 8
Improve compressor room ventilation..... 9
Rework or correct header piping..... 10
Install or upgrade distribution control system..... 11
Install or upgrade (ball) valves in distribution system..... 12
Modify or replace regulators (controls at the process)..... 13
Other 1 (Specify _____)..... 14
Other 2 (Specify _____)..... 15
Don't know..... 97

PC2a. Is the availability of rebates from a utility-sponsored energy efficiency program a factor in your decision to implement these changes to your compressed air system?

Yes..... 1
No..... 2
Don't know..... 3

PC3. When do you plan to implement these changes?
ENTER MONTH (01 – 12) AND YEAR (01, 02…).
9997 FOR DON'T KNOW....._____

PC4. Did you refer to your Compressed Air Challenge training material in identifying the kinds of improvements to undertake?
Yes..... 1
No..... 2
Don't know..... 3

PC5. On a scale of 1 to 5, where 1 means not at all important and 5 means very important, how would you rate the usefulness of the Compressed Air Challenge course materials in identifying measures to undertake?
ENTER RATING 1-5, CODE 97 FOR DON'T KNOW....._____

IF LEVEL = 2, ASK C10. ELSE SKIP TO PC1.

PC10. Are there any potential system improvements that you have identified specifically on the basis of information or analysis techniques you gained through the *Advanced* training workshop, as opposed to the *Fundamentals* workshop?
Yes..... 1
No..... 2
Don't know..... 97

IF PC10 = 1 ASK C10a.
IF PC10 = 2 OR 97, SKIP TO QUESTION PC1.

PC10a Which improvements did you identify based on the *Advanced* training workshop?
_____
_____

Eliminating Inappropriate Uses of Compressed Air

EU1. Since attending the *Fundamentals* training, have you substituted low-pressure blowers or other technologies to perform tasks that previously used compressed air from your plant's system?
Yes..... 1
No..... 2
Don't know..... 97

IF EU1 = YES, GO TO EU2.
IF EU1 = NO (2) OR DON'T KNOW (97), SKIP TO M1.

EU2. In which processes have you stopped using compressed air from your plant system? CIRCLE ALL THAT APPLY.

Aerating, agitating, or percolating liquids (sparging)..... 1
Inducing flows of other gases (aspirating)..... 2
Atomizing..... 3
Transport of solids and liquids through pipes (padding)..... 4
Open blowing for cleaning machines, finished parts, shop areas. 5
Vacuum generators..... 6
Other (Specify: _____)..... 7
Don't know..... 97

EU3. Did you use information from the *Fundamentals* training to identify which processes could be taken off the compressed air system?
Yes..... 1
No..... 2
Don't know..... 97

EU4. On a scale of 1 to 5, where 1 means not at all likely and 5 means very likely, how likely is it that you would have eliminated these end-uses from your compressed air system if you had not attended the training?
ENTER RATING 1-5, CODE 97 FOR DON'T KNOW _____

Maintenance Practices

M1. Have you made any changes to your compressed air system maintenance procedures since participating in the Compressed Air Challenge training?
Yes..... 1
No..... 2
Don't know..... 97

IF M1 = 1, GO TO M2.
IF M1 = 2 OR 97, SKIP TO PR1.

M2. Have you added new procedures to your maintenance routine since participating in the training? PROMPT WITH EXAMPLES FROM M3 RESPONSE LIST IF NEEDED.
Yes..... 1
No..... 2
Don't know..... 97

IF M2 = 1, GO TO M3.
IF M2 = 2 OR 97, SKIP TO M4.

M3. Which procedures have you added? DO NOT READ. CIRCLE ALL THAT APPLY.
Lubricate compressor motor..... 1
Clean compressor motor..... 2
Adjust belts..... 3

Inspect automatic drain traps..... 4
Clean air filters..... 5
Check tool lubrication..... 6
Periodic inspection for leaks..... 7
Repair leaks..... 8
Other (Specify: _____)..... 9
Don't know.....97

M4. Have you increased the frequency of procedures you had followed prior to the training?
Yes..... 1
No..... 2
Don't know.....97

IF M4 = 1, GO TO M5.
IF M4 = 2 OR 97, SKIP TO M6.

M5. Which procedures do you now perform more frequently?
DO NOT READ. CIRCLE ALL THAT APPLY.

Lubricate compressor motor..... 1
Clean compressor motor..... 2
Adjust belts..... 3
Inspect automatic drain traps..... 4
Clean air filters..... 5
Check tool lubrication..... 6
Periodic inspection for leaks..... 7
Repair leaks..... 8
Other (Specify: _____)... 9
Don't know.....97

M6. On a scale of 1 to 5, where 1 means not at all likely and 5 means very likely, how likely is it that you would have made these changes to your compressed air system maintenance procedures if you had not attended the training?
ENTER RATING 1-5, CODE 97 FOR DON'T KNOW....._____

M7. Does your company have an ongoing leak detection program or do you usually repair leaks on an ad hoc basis?
Yes..... 1
No..... 2
Don't know.....97

IF LEVEL = 2, ASK M10. ELSE SKIP TO PR1.

M10. Are there any changes in O&M procedures that you undertook specifically on the basis of information or analysis techniques you gained through the *Advanced* training workshop, as opposed to the *Fundamentals* workshop?
Yes..... 1
No..... 2
Don't know.....97

IF M10 = 1 ASK M10a.
IF PC10 = 2 OR 97, SKIP TO QUESTION PR1.
M10a Which O&M procedures did you undertake based on the *Advanced* training workshop?
_____

Program Effects-Baselining

PR1. Have you worked on developing a baseline description of the configuration and operation of your compressed air system?
Yes..... 1
No..... 2

IF PR1 = YES, CONTINUE TO PR2.
IF PR1 = NO, GO TO G4.

PR2 Is the baseline complete at this time?
Yes..... 1
No 2
Don't know..... 97

PR3. On a scale of 1 to 5, where 1 means not at all useful and 5 means very useful, how would you rate the usefulness of the course materials in developing the baseline?
ENTER RATING 1-5, CODE 97 FOR DON'T KNOW....._____

PR4. Have you used the baseline to guide decisions regarding changes to the major components of your compressed air system or to the configuration of those components?
Yes..... 1
No 2
Don't know..... 97

PR5. Have you used the baseline to guide changes to operation and maintenance procedures for your compressed air system?
Yes..... 1
No 2
Don't know..... 97

G4. Does your company or organization operate other than the one in which you work?
Yes..... 1
No 2
Don't know..... 97

IF G4 = 1, GO TO G5.
IF G4 = 2 OR 97, SKIP TO C1.

G5. Have you worked with colleagues in other facilities to identify and capture compressed air system efficiency opportunities?

Yes..... 1
No 2
Don't know.....97

Conclusion-Terminate Message

THANK YOU VERY MUCH FOR YOUR TIME TODAY. YOUR INPUT WILL BE VERY HELPFUL TO US IN ENHANCING THE COMPRESSED AIR CHALLENGE PROGRAM SO THAT IT WILL BE MORE USEFUL TO YOU AND OTHER INDUSTRY PARTICIPANTS, ETC.

VENDOR SURVEY

CUSTOMER IDENTIFICATION
Contact Name: [from sample] _____
Company: [from sample] _____
Address: [from sample] _____
City, State, Zip [from sample] _____
Telephone: [from sample]_____
Registration site [from sample] _____
Session Date [from Sample]_____
Survey ID Number: _____

Introduction and Respondent ID

Hello, my name is _____ and I'm calling from _____. We're conducting a study for the Compressed Air Challenge training program.

SCA. May I speak with [CONTACT NAME]

[IF CONTACT IS NOT AVAILABLE, ASCERTAIN BEST TIME TO CALL.]
[IF CONTACT NO LONGER WORKS AT THE LOCATION, CODE 1 AND TERMINATE THE CALL.]

Lead in for respondent. Hello, this is _____ calling from _____. We're conducting a study to assess the results of the Compressed Air Challenge training programs. Do you have 10-15 minutes to discuss your participation in the training program and your firm's experience with compressed air system sales and services?

IF PROGRAM RECORDS INDICATE THAT THE RESPONDENT ATTENDED THE FUNDAMENTALS ONLY (LEVEL = 1) ASK SCB. ELSE SKIP TO INSTRUCTIONS AT SCE.

SCB. According to our records you attended a training session on *Fundamentals of Compressed Air Systems* in [REGISTRATION SITE] in [MONTH AND YEAR OF SESSION DATE]. Is our information about your attendance at the training session correct?
Yes [GO TO INSTRUCTIONS AT SCE] 1
NO [GO TO SCC] 2

SCC. Did you attend any session of the *Fundamentals of Compressed Air Systems* training offered by the Compressed Air Challenge Program?
Yes 1
No [GO TO INSTRUCTIONS AT SCE] 2

SCD. Can you tell me in which city that training took place?
ENTER CITY_____

CHECK CITY AGAINST LIST OF TRAINING SITES. IF CITY IS NOT ON THE LIST SEEK FURTHER INFORMATION/CLARIFICATION TO ASCERTAIN CORRECT TRAINING LOCATION. IF LOCATION CANNOT BE CONFIRMED, TERMINATE CALL

IF CITY IS ON THE LIST, CONTINUE WITH THE LEAD-IN.

IF CUSTOMER DOES NOT REMEMBER ATTENDING TRAINING OR DOES NOT REMEMBER ATTENDING TRAINING AT A VERIFIED SITE AND DOES NOT HAVE INDICATION OF ATTENDING LEVEL 2, THANK AND TERMINATE.

IF PROGRAM RECORDS INDICATE CUSTOMER ATTENDED ADVANCED TRAINING (LEVEL = 2), ASK SCE. ELSE GO TO "LEAD IN CONTINUED".

SCE. According to our records you attended a training session on *Advanced Management* of *Compressed Air Systems* in [REGISTRATION SITE] in [MONTH AND YEAR OF SESSION DATE]. Is our information about your attendance at the *Advanced* training session correct?
Yes [GO TO "LEAD IN CONTINUED".] 1
NO [GO TO SCC] 2

SCF. Did you attend any session of the *Advanced Management of Compressed Air Systems* training offered by the Compressed Air Challenge Program?
Yes 1
No [GO TO INSTRUCTIONS AT PRIOR TO "LEAD IN CONTINUED".] .. 2

SCG. Can you tell me in which city that training took place?
ENTER CITY_____

CHECK CITY AGAINST LIST OF TRAINING SITES. IF CITY IS NOT ON THE LIST SEEK FURTHER INFORMATION/CLARIFICATION TO ASCERTAIN CORRECT TRAINING LOCATION. IF LOCATION CANNOT BE CONFIRMED AND CUSTOMER DID NOT ATTEND FUNDAMENTALS, THANK AND TERMINATE.

IF CITY IS ON THE LIST, CONTINUE WITH THE LEAD-IN.
IF CITY IS NOT ON THE LIST, TREAT CUSTOMER AS ATTENDEE OF FUNDAMENTALS (LEVEL = 1) ONLY.

Lead-in Continued. We are conducting a study on behalf of the sponsors of the Compressed Air Challenge program to determine how information gained at its training programs is being used by those who attend. The results of this study will be used to assess and develop improvements for the program. REASSURE: Your responses to our questions will be entirely confidential. Again, this interview will only take about 10-15 minutes of your time.

First, I'd like to get a little information about you and your firm.

SC1 Which of the following four choices best describes your company? Is it [READ CHOICES]…

A compressed air system equipment distributor or vendor..... 1
An engineering firm..... 2
A compressed air system consultant..... 3
Equipment manufacturer sales representative..... 4
Other (specify _____)..... 6

IF SC1 = 1, 2, 3, OR 4, OR IS OTHERWISE A COMPANY ENGAGED IN THE DESIGN, SALE, OR MAINTENANCE OF COMPRESSED AIR EQUIPMENT, GO TO QUESTION SC2.
IF NOT, ASCERTAIN WHETHER THEY ARE AN END USER AND IF SO, USE END USER SURVEY.

SC2 What is your title?

Owner/proprietor..... 1
President/CEO..... 2
Sales Engineer..... 3
Sales Manager..... 4
Field Technician..... 5
Engineer..... 6
Other(Specify)_____)..... 7

SC3 What geographic area does your company serve? Would you say it is:
PLEASE CIRCLE ONE ANSWER ONLY.

Local or metropolitan area..... 1
State..... 2
Regional..... 3
National..... 4
International..... 5
Don't know..... 97

SC3a. How many offices does your company have (in this country)?
ENTER NUMBER OF DOMESTIC OFFICES....._____
ENTER 9997 FOR DON'T KNOW
ENTER 9998 IF THE RESPONDENT REFUSES TO ANSWER

SC4 How many full-time employees work in your office? This includes clerical as well as professional and technical staff.
ENTER NUMBER OF EMPLOYEES....._____
ENTER 9997 FOR DON'T KNOW
ENTER 9998 IF THE RESPONDENT REFUSES TO ANSWER

SC5 Roughly what percentage of your company's total revenues the last fiscal year came from the following activities? Your best estimate will be fine.
USE TABLE BELOW TO RECORD ANSWERS TO QUESTION SC5
ENTER 9997 FOR DON'T KNOW
ENTER 9998 IF THE RESPONDENT REFUSES TO ANSWER

Activity	Percent of Revenues
Compressed air equipment sales	
Compressed air parts sales	
Compressed air equipment service	
Compressed air system design	
Compressed air efficiency services (leak detection, compressed air system audits, system optimization, controls)	
Other compressed air related services (Specify)	

SC6a Which industry accounts for the largest portion of your sales revenues related to compressed air system sales or services?
PLEASE CIRCLE ONE ANSWER ONLY.
USE TABLE BELOW TO RECORD ANSWER.

SC6b What other industries are important customers for these products and services?
CIRCLE ALL THAT APPLY.
USE TABLE BELOW TO RECORD ANSWER.

	SC6a	SC6b
Food Processing	1	1
Petroleum Products	2	2
Electronic Equipment	3	3
Textile Mill Products	4	4
Rubber and Plastics	5	5
Transportation Equipment	6	6
Paper and Allied Products	7	7
Primary Metals	8	8
Printing	9	9
Fabricated Metals	10	10
Chemicals	11	11
Industrial Equipment	12	12
General Manufacturing	13	13
Other 1 (Specify)	14	14
Other 2 (Specify)	15	15
Don't know	97	97

Program Experience

Now I would like to ask a few questions about your experience with the training program itself.

PE1 First, how did you find out about the Compressed Air Challenge training program? DO NOT READ. CIRCLE ALL THAT APPLY.

From compressed air equipment vendor..... 1
From local electric utility representative..... 2
From a US Department of Energy publication..... 3
From a US Department of Energy representative..... 4
From advertisement or article in a trade or industry publication.. 5
From direct mail advertisement..... 6
From a customer..... 7
Other (Specify: _____)..... 8
Don't know.....97

PE2a What was the most important reason you decided to enroll in the training?
USE TABLE BELOW.
CIRCLE ONE ANSWER ONLY.

PE2b Were there other reasons?
USE TABLE BELOW. CIRCLE ALL THAT APPLY.

	PE2a	PE2b
Wanted to improve services to customers	1	1
Wanted to develop new revenue streams	2	2
Competitors were offering similar services	3	3
Wanted to retain equipment and maintenance service customers	4	4
Wanted to increase value of services to customers	5	5
Other (Specify):	7	7

PE3 Since taking part in the training, have you used information from the course or referred to the course materials when evaluating a customers' compressed air system?
Yes..... 1
No 2
Don't know.....97

IF PE3 = YES(1), GO TO QUESTION PE4.
IF PE3 = NO(2) OR DON'T KNOW (97) SKIP TO PE5.

PE4 How often have you used the course materials in evaluating customers' systems? Would you say it is…
For all customer evaluations..... 1
For many customer evaluations..... 2
For some customer evaluations.....97

PE5 Since taking part in the training, have you used information from the course or referred to the course materials when diagnosing operating problems in a customers' compressed air system?
Yes..... 1
No 2
Don't know.....97

IF PE5 = YES(1), GO TO QUESTION PE6.
IF PE5 = NO(2) OR DON'T KNOW(97), SKIP TO PE7.

PE6 How often have you used the course materials in diagnosing system operating problems? Would you say it is…
In all diagnostic situations 1
In most diagnostic situations..... 2
In some diagnostic situations..... 3

PE7 Since taking part in the training, have you used information from the course or referred to the course materials when specifying compressed air system efficiency improvements?
Yes..... 1
No 2
Don't know.....97

IF PE7 = YES(1), GO TO QUESTION PE8.
IF PE7 = NO(2) OR DON'T KNOW(97), SKIP TO PE9a.

PE8 How often have you used the course materials in specifying compressed air system efficiency improvements? Would you say it is…
In all relevant projects..... 1
In most relevant projects..... 2
In some relevant projects..... 3

IF LEVEL = 1 OR 2, ASK PE4a.

PE9a What element of the *Fundamentals* program did you find most useful?
USE TABLE BELOW. CIRCLE ONE ONLY.

PE9b What other elements of the *Fundamentals* program were also useful?
USE TABLE BELOW. CIRCLE ALL THAT APPLY.

PE9c What elements of the *Fundamentals* program did you find were not useful?
USE TABLE BELOW. CIRCLE ALL THAT APPLY.

	PE9a	PE9b	PE9c
General information on compressed air system components and operation.	1	1	1
Instructions for developing a compressed air system baseline.	2	2	2
Description of potential capital improvements	3	3	3
Description of potential maintenance improvements	4	4	4
Exercises in diagnosing system problems	5	5	5
Reference materials in the course book	6	6	6
Other (Specify):	7	7	7

IF LEVEL = 2, ASK PE4d. ELSE SKIP TO PE5.

PE9d What element of the *Advanced* program did you find most useful?
USE TABLE BELOW. CIRCLE ONE ONLY.

PE9e What other elements of the *Advanced* program were also useful?
USE TABLE BELOW. CIRCLE ALL THAT APPLY.

PE9f What elements of the *Advanced* program did you find were not useful?
USE TABLE BELOW. CIRCLE ALL THAT APPLY.

	PE9d	PE9e	PE9f
General information on compressed air system components and operation.	1	1	1
Instructions for developing a compressed air system baseline.	2	2	2
Description of potential capital improvements	3	3	3
Description of potential maintenance improvements	4	4	4
Exercises in diagnosing system problems	5	5	5
Reference materials in the course book	6	6	6
Other (Specify):	7	7	7

PE10 What steps do you think the Compressed Air Challenge program could have taken to improve the usefulness and value of the training for you?

_____

_____

PE11 Would you be interested in additional training from Compressed Air Challenge?
Yes..... 1
No 2
Don't know..... 97

IF PE11 = YES (1), GO TO PE12a,
IF PE11 = NO (2) OR 3, SKIP TO CS1.

PE12a What topic would you most like to see addressed in additional training sessions?
USE TABLE BELOW. CIRCLE ONE RESPONSE ONLY.

PE12b What other topics would be of interest?
READ CHOICES IF NECESSARY FROM TABLE BELOW.
ACCEPT MULTIPLE RESPONSES.

	PE12a	PE12b
Further detail on system measurement	1	1
Further detail on baselining	2	2
Equipment selection	3	3
Controls	4	4
Diagnosis of operating problems	5	5
Maintenance	6	6
Other (Specify):	7	7
Don't know	97	97

PE13. How likely is it that you would either host a CAC training session for your customers or refer your customers to a CAC training session in the future?

Very likely..... 1
Somewhat likely..... 2
Not very likely..... 3
Don't know..... 97

Compressed Air Efficiency Services: Pre-Training

CS1 Prior to participating in the Compressed Air Challenge training program, did your company offer services specifically designed to reduce energy costs in plant compressed air systems?

Yes..... 1
No 2
Don't know.....97

IF CS1 = YES(1) GO TO QUESTION CS2a
IF CS1 = NO(2) OR DON'T KNOW(97), SKIP TO QUESTION PT1

CS2a Which of the following compressed air system efficiency services did you offer?
CHECK ALL THAT APPLY.
USE TABLE BELOW TO RECORD ANSWERS.

CS2b FOR ALL SERVICES CHECKED: Roughly how many facilities purchased [SERVICE] from your company in the year prior to attending the Compressed Air Challenge Training?
ENTER 997 FOR DON'T KNOW
ENTER 998 IF RESPONDENT REFUSES TO ANSWER
USE TABLE BELOW TO RECORD ANSWERS.

	CS2a	CS2b
Measurement of system flow and pressure		
Measurement of system energy consumption		
Analysis of compressed air system energy efficiency		
Leak prevention services		
Ultrasonic leak detection		
Identification of supply-side efficiency opportunities		
Analysis of end-use reduction opportunities		
Other (Specify):		

CS3 Prior to taking the training course did you actively promote your compressed air system efficiency services to your customers?

Yes..... 1
No 2
Don't know..... 97

IF CS3 = YES(1) GO TO CS4
IF CS3 = NO(2) OR DON'T KNOW(97), SKIP TO QUESTION PT1.

CS4 What actions did you take to promote compressed air efficiency services?
CIRCLE ALL THAT APPLY

Direct mail to customers..... 1
Sponsored or delivered training for customers in compressed air efficiency..... 2
Sold in connection with equipment sales..... 3
Sold in connection with/or as part of maintenance service sales..... 4
Other (Specify) _____..... 5

Compressed Air Efficiency Services: Post-Training

PT1 Since participating in the Compressed Air Challenge training program, has your company begun to offer new services to increase the energy efficiency of compressed air systems in your customers' facilities?

Yes..... 1
No 2
Don't know..... 97

IF PT1 = YES(1), GO TO PT2
IF PT1 = NO(2) OR DON'T KNOW(97), GOTO PT3

PT2 What NEW services have you added?
PROMPT WITH EXAMPLES FROM TABLE BELOW IF NECESSARY.
CHECK ALL THAT APPLY IN TABLE BELOW.

	PT2
Measurement of system flow and pressure	
Measurement of system energy consumption	
Analysis of compressed air system energy efficiency	
Leak prevention services	
Ultrasonic leak detection	
Identification of supply-side efficiency opportunities	
Analysis of end-use reduction opportunities	
Other (Specify)	

PT2a On a scale of 1 to 5, where 1 means "not at all likely" and 5 means "very likely", how likely is it that you would have begun offering these new services in the past year if you had not attended the training?
ENTER RATING 1-5, ENTER 97 FOR DON'T KNOW....._____

IF LEVEL = 2, ASK PT3. ELSE SKIP TO PT4.

PT3. Are there any services that you started providing or improved specifically on the basis of information or analysis techniques you gained through the *Advanced* training workshop, as opposed to the Fundamentals workshop?
Yes..... 1
No 2
Don't know..... 97

IF PT3 = 1 ASK PT3a.
IF PT3 = 2 OR 97, SKIP TO QUESTION PT4.

PT3a Which services did you start providing or improve based on the *Advanced* training workshop?

_____

_____

PT4 How important are utility rebates to your marketing of compressed air efficiency services?
Very important..... 1
Somewhat important..... 2
Not important at all..... 3
Don't know..... 97

PT5 Since participating in the training, has the number of customers to whom you provide compressed air system efficiency services increased, decreased, or stayed about the same?
PLEASE CIRCLE ONE ANSWER ONLY

Increased..... 1
Decreased..... 2
Stayed about the same..... 4
DK..... 97

IF PT5 = INCREASED(1) OR DECREASED(2), GO TO QUESTION PT6
IF PT5 = STAYED ABOUT THE SAME(4) OR DON'T KNOW(97), SKIP TO QUESTION PT7

PT6 By what percent would you say the number of customers purchasing compressed air efficiency services has INCREASED or DECREASED?

ENTER PERCENTAGE
USE NEGATIVE FOR DECREASE
ENTER 997 FOR DON'T KNOW....._____

PT6a In your opinion, what is the most important factor that has contributed to this increase/decrease?
PROMPT WITH EXAMPLES FROM TABLE BELOW IF NECESSARY.
PLEASE CIRCLE ONE ANSWER ONLY.

PT6b Are there other important factors contributing to this change?
PROMPT WITH EXAMPLES FROM TABLE BELOW IF NECESSARY.
CIRCLE ALL THAT APPLY.

	PT4a	PT4b
Increase in electricity prices	1	1
Increased cost competition in industry	2	2
Greater customer awareness of compressed air efficiency opportunities	3	3
Utility programs	4	4
Government programs	5	5
Increased marketing efforts by vendors, consultants	6	6
Economic downturn; reduced funds for investment	7	7
Other (Specify)	13	13

PT9a Which industry accounts for the largest percent of your company's compressed air efficiency projects? PLEASE CIRCLE ONE ANSWER ONLY.
USE TABLE BELOW TO RECORD ANSWER.

PT9b Which other industries are purchasing these services from your company?
CIRCLE ALL THAT APPLY.
USE TABLE BELOW TO RECORD ANSWERS.

	PT9a	PT9b
Food Processing	1	1
Petroleum Products	2	2
Electronic Equipment	3	3
Textile Mill Products	4	4
Rubber and Plastics	5	5
Transportation Equipment	6	6
Paper and Allied Products	7	7
Primary Metals	8	8
Printing	9	9
Fabricated Metals	10	10
Chemicals	11	11
Industrial Equipment	12	12
General Manufacturing	13	13
Other 1 (Specify)	14	14
Other 2 (Specify)	15	15
Don't know	97	97

PT10. What is the typical connected compressor horsepower among customers who have purchased compressed air efficiency services?
ENTER NUMBER OF HORSEPOWER....._____
ENTER 997 FOR DON'T KNOW

PT11a What are the three compressed air system efficiency measures you recommend most often to your customers?
CIRCLE UP TO 3 ANSWERS.
USE TABLE BELOW TO RECORD ANSWERS.

	PT11a	PT11b
Replace current compressor with more efficient model	1	1
Add small compressor for off-peak loads	2	2
Add, restore, upgrade compressor controls	3	3
Add compressed air storage	4	4
Reconfigure piping to reduce pressure loss	5	5
Add, upgrade, or reconfigure air dryers	6	6
Replace or repair air filters	7	7
Replace or upgrade condensate drains	8	8
Improve compressor room ventilation	9	9
Rework or correct header piping	10	10
Install or upgrade distribution control system	11	11
Install or upgrade (ball) valves in distribution system	12	12
Modify or replace regulators (controls at the process)	13	13
Eliminated inappropriate uses	14	14
Leak inspection and repair	15	15
Other maintenance improvements	16	16
Other 1 (specify)	17	17
Other 2 (specify)	18	18
Don't know	97	97

PT11b What other measures do you frequently recommend?
CIRCLE ALL THAT APPLY.
USE TABLE BELOW TO RECORD ANSWERS.

PT12 In terms of percent of baseline system consumption, what is the minimum level of energy savings you target through these projects?
ENTER PERCENT....._____%

PT13 Again, in terms of percent of baseline system consumption, what is the typical level of energy savings you estimate for the compressed air system efficiency projects your company does?
ENTER PERCENT....._____%

PT14 Have you measured changes in energy consumption or demand for compressed air system efficiency projects you have implemented?

Yes..... 1
No 2
Don't know..... 3

Marketing of Compressed Air System Efficiency Services Post-Training

PT15 Since participating in the training have you undertaken any new initiatives to market compressed air system efficiency services?
Yes..... 1
No 2
Don't know..... 3

IF PT15 = YES(1), GO TO QUESTION PT16.
IF PT15 = NO(2) OR DON'T KNOW(97), GO TO CONCLUSION MESSAGE AND TERMINATE CALL.

PT16 What new activities have you initiated to market compressed air efficiency services?
CIRCLE ALL THAT APPLY.
PROMPT WITH EXAMPLES FROM LIST BELOW.
Direct mail to customers..... 1
Sponsored or delivered training for customers in
compressed air efficiency..... 2
Marketed in connection with equipment sales..... 3
Marketed in connection or as part of maintenance service sales..... 4
Other (Specify) _____..... 5

PT17 On a scale of 1 to 5, where 1 means "not at all likely" and 5 means "very likely", how likely is it that you would have undertaken these promotional activities if you had not attended the training?
ENTER RATING 1-5,....._____
ENTER 97 FOR DON'T KNOW

IF LEVEL = 2, ASK PT18. ELSE SKIP TO END.

PT18. Are there any marketing initiatives you undertook specifically on the basis of information or analysis techniques you gained through the *Advanced* training workshop, as opposed to the *Fundamentals* workshop?

Yes..... 1
No 2
Don't know.....97

IF PT18 = 1 ASK PT18a.
IF PT3 = 2 OR 97, SKIP TO END.

PT18a Which marketing initiatives did you undertake based on the *Advanced* training workshop?

_____

_____

Conclusion-Termination Message

THANK YOU VERY MUCH FOR YOUR TIME TODAY. YOUR INPUT WILL BE VERY HELPFUL TO US IN ENHANCING THE COMPRESSED AIR CHALLENGE PROGRAM SO THAT IT WILL BE MORE USEFUL TO YOU AND OTHER INDUSTRY PARTICIPANTS, ETC.

About the Office of Energy Efficiency and Renewable Energy

A Strong Energy Portfolio for a Strong America

Energy efficiency and clean, renewable energy will mean a stronger economy, a cleaner environment, and greater energy independence for America. By investing in technology breakthroughs today, our nation can look forward to a more resilient economy and secure future.

Far-reaching technology changes will be essential to America's energy future. Working with a wide array of state, community, industry, and university partners, the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy invests in a diverse portfolio of energy technologies that will:

- Conserve energy in the residential, commercial, industrial, government, and transportation sectors
- Increase and diversify energy supply, with a focus on renewable domestic sources
- Upgrade our national energy infrastructure
- Facilitate the emergence of hydrogen technologies as a vital new "energy carrier."

The opportunities

Biomass Program
Using domestic, plant-derived resources to meet our fuel, power, and chemical needs

Building Technologies Program
Homes, schools, and businesses that use less energy, cost less to operate, and ultimately, generate as much power as they use

Distributed Energy & Electric Reliability Program
Expanding clean on-site energy choices for greater efficiency, reliability, and security

Federal Energy Management Program
Leading by example, saving energy and taxpayer dollars in federal facilities

FreedomCAR & Vehicle Technologies Program
Less dependence on foreign oil, and eventual transition to an emisions-free, petroleum-free vehicle

Geothermal Technologies Program
Tapping the earth's energy to meet our heat and power needs

Hydrogen, Fuel Cells & Infrastructure Technologies Program
Paving the way toward a hydrogen economy and net-zero carbon energy future

Industrial Technologies Program
Boosting the productivity and competitiveness of U.S. industry through improvements in energy and environmental performance

Solar Energy Technology Program
Utilizing the sun's natural energy to generate electricity and provide water and space heating

Weatherization & Intergovernmental Program
Accelerating the use of today's best energy-efficient and renewable technologies in homes, communities, and businesses

Wind & Hydropower Technologies Program
Harnessing America's abundant natural resources for clean power generation

To learn more, visit ***www.eere.energy.gov.***

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***.

Contact Information:

U.S. Department of Energy
Energy Efficiency and Renewable Energy
Industrial Technologies Program
www.eere.energy.gov/industry

Compressed Air Challenge®
www.compressedairchallenge.org

Prepared for:
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Prepared by:
Lawrence Berkeley National Laboratory
Washington, D.C.

XENERGY Inc.
Burlington, MS

Industrial Technologies Program

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