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PG&E Appliance Doctor Pre-Production Test

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PG&E Appliance Doctor Pre-Production Test

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The Appliance Doctor Production System (ADPS) is a complete residential air conditioning repair process capable of achieving significant kWh savings. This savings can be obtained by repairing existing electric cooling systems. Repairs focus on reducing duct leakage, correcting low air flow, and insuring proper refrigerant charge.

The Appliance Doctor Pre-Production Test (ADPT) evaluated the ADPS in one community before full-scale replication. This paper discusses the results of the pre-production test on 250 residential air conditioners belonging to Pacific Gas and Electric Company customers in Fresno, California. The effectiveness of all aspects of ADPS is assessed, including marketing, training, quality assurance, and repairs. The program delivery mechanisms are judged for applicability to future large-scale programs. Customer reactions to the program are reported, including both participants' and nonparticipants' attitudes, expectations, and preferences on incentives for the program, and their views on its strengths and weaknesses. Thirty of the homes were submetered and data recorded at fifteen minute intervals. The kWh savings and peak reduction was measured for these homes and is compared to a group of nonparticipants.

Introduction

The 1991 Fresno Appliance Doctor Pre-Production Test is one in a series of pilot projects investigating potential kWh savings in homes. This test determined the savings possible from air conditioning system repair. The Pre-Production test was based on the results of the 1990 Fresno Appliance Doctor Pilot Project conducted by Proctor Engineering Group (PEG) for Pacific Gas and Electric Company (Proctor 1991; Proctor and Pernick 1992).

The 1990 project studied central air conditioners and gas forced-air furnaces. That project indicated a potential annual cooling savings of 24% and a potential coincident peak reduction of approximately 690 watts per unit. It also indicated a heating savings of 12%. These savings could be accomplished by implementing a well-controlled program that diagnosed and repaired duct leakage, air flow, and refrigerant overcharge.

Beyond the problems in the house conditioning system discovered in the 1990 project, there were major HVAC infrastructure problems that could reduce or eliminate the potential benefits of an air conditioner repair program. The 1990 project and the 1989 heat pump study (Proctor et al. 1990) found problems even in homes that were recently serviced. These infrastructure problems called for a systemic solution.

The Appliance Doctor Production System is a complete residential air conditioning system repair process which incorporates program management, training, and quality assurance, as well as repairs to the air conditioning system. This system is an outgrowth of quality assurance processes designed for controlling furnace and air sealing programs (Proctor 1984 and 1988; Proctor and Foster 1986). The Appliance Doctor Pre-Production Test (ADPT) was a comprehensive test of ADPS on a test group of 250 houses in Fresno, California.

Objectives

The objectives of the Fresno Appliance Doctor Pre-Production Test were to:

(1) Evaluate the Appliance Doctor residential air conditioner program in a random sample of houses.

(2) Verify the frequency with which problems identified in the pilot project occurred. Verification took place in both random and high bill complaint/high-use homes.

(3) Test the complete system including marketing, training, quality assurance, and repairs on 250 residential air conditioners.

Test Methodology

The test consisted of attempting to apply the ADPS to 250 houses in the manner proposed for the larger 5,000 unit program planned for the future. This included a functional test of all elements of the system. The 250 test houses were divided into two groups: normal AC customers, and high bill complaint/high-use customers. Study participants were randomly selected Pacific Gas & Electric customers in these two categories. The project occurred in the spring and summer of 1991 in Fresno, California. The submetering, pre-testing, and repairs occurred over a three-month period.

ADM Associates conducted a two-phase study of the ADPT. Phase One included interviews with 80 program Participants and 139 Nonparticipants. Interviews were conducted before any work was performed. Phase Two included telephone interviews with 152 Participants after work was performed (59 were interviewed in both phases).

Initial System Design

The system design was comprised of contracting, marketing, training, diagnosis and repair, and quality assurance components.

Contracting

In order to control cost and assure quality, a fixed-cost performance contract was devised. This contract paid a fixed fee of $375 to the contractor for every unit that met the following criteria after repair: (1) no accessible disconnected ducts, (2) air flow through the unit in excess of 375 cubic feet per minute (cfm) per ton "wet coil," (3) units initially overcharged were properly charged. In addition the contractor was required to meet a "fleet average" duct leakage of less than 150 cfm. at 50 pa. house pressure. Some exceptions to the air flow criteria were included for units with very restrictive duct work to avoid high cost repairs.

Marketing

Marketing was targeted to customers likely to have problems. It was necessary to identify the customers most in need of this service from information readily available to the utility. For this purpose a calculation from existing revenue meter readings was developed. The amount of summer electricity use in excess of base use was calculated for all summer billing periods. The algorithm used the daily use in the "swing months" (spring and fall) to establish the base. This base was subtracted from the total electrical use in the summer months. The calculation of base use excluded unusual cases caused by extended vacations etc. The resulting indicator of summer cooling load was referred to as "summer swing". The majority of the units in this study were houses in the top quartile of summer swing.

Ducts were repaired in every home. The cost to the customer for this repair was $50. Repairs of low air flow and excess refrigerant charge were made whenever needed and cost the customer $15, and $25 respectively. The complete service cost for each customer was not to exceed $90.

Of the pool of households that met the high-use criteria, 5,000 were contacted through a direct mail piece that stressed:

(1) The monetary value of repair to the customer: "A $400 repair service for $90 or less."

(2) The benefits of an efficiently operating system: "You can cut summer electric bills by 10-15% and make your air conditioner last longer."

(3) The urgency of a quick response from the customer: "We can accept only 250 participants. Participants will be accepted on a first come, first-served basis so return the attached form today."

Telemarketing was initially planned to follow the direct mail piece. However, response was so great that telemarketing was not needed.

Training

Training was provided to three sets of individuals: the contractor, the contractor's AC technicians, and the contractor's duct sealing technicians. The AC technicians were experienced AC service technicians. Training for both sets of technicians lasted three days, with review, inspection and feedback extending for the duration of the project.

All technicians were trained to follow the step-by-step procedures of the program, and to understand and perform the tests and repairs designated for their on-site work. This initial training was the first part of an integrated system of procedures and controls.

Diagnosis and Repair

A two-person crew was utilized to diagnose and repair the ducts and the air conditioner. This crew consisted of the AC technician, responsible for the whole job, and a duct technician who worked exclusively on the ducts.

The duct leakage procedure was based on previous work by this author and the work of other researchers, including John Tooley and Neil Moyer (1989). It tested, sealed, and re-tested the distribution leakage of the air conditioning system. The procedure involved sealing the ductwork beginning with the most critical locations: disconnected ducts, returns open into the attic, crawl space or walls, and large leaks behind the registers. During the procedure insulated joints were unwrapped, sealed with mastic, and re-wrapped. This process was designed to eliminate the largest "catastrophic" leaks and substantially reduce the smaller "diffuse" leaks.

The procedure attempted to eliminate leaks without the use of a blower door or flow hood. Instead, the following combination of methods was employed:

(1) using a micromanometer to measure indoor/outdoor pressure differential with the air handler on;

(2) using a micromanometer to measure pressure differential between the house and the return system with the air handler on and all return grills blocked;

(3) using a micromanometer to measure pressure at each register with the air handler on and the register blocked;

(4) tactilely sensing air flow from each register.

The air conditioning technician procedure is a refinement of the 1989 heat pump study methodology, the work of other researchers including Leon Neal (1990), and criteria developed from manufacturers' data. It tests, modifies, and verifies efficiency improvements on air conditioners.

This procedure guides the technician through the most common and easily solved problems, such as low air flow, to the more time consuming and somewhat less prevalent problems, such as excess charge. Once adequate air flow is obtained by cleaning the coil and opening registers, nonintrusive tests are run. These tests determine charge level, the condition of the compressor, and the efficiency of the unit. The level of charge is corrected by migrating charge out of the unit. The amount removed is measured with a charging cylinder and captured for recycling. Having repaired the unit, the technician retests it to insure that repairs were properly completed.

Quality Assurance

Quality assurance was provided under the ADPS by a system of step-by-step procedures, form review, feedback, inspections, controls, and metering.

All the management processes were closed loop processes. This brought any problems back for final solution. Additionally, any work completed was to be used as an opportunity to improve the quality of future work.

Quality assurance was accomplished primarily through the use of forms, which were completed in the field on every job. These forms were designed to provide adequate information to determine off-site that each job was done properly. Forms were to be reviewed within one week of completion, and the results communicated directly to the technicians performing the task. With timely form review and clear communication, each job improves the competence and confidence of the individual.

In addition to form review, the closed loop system provided feedback to the technicians via post-tests, which were performed on every unit after repairs were made. These tests allowed technicians to immediately see the results of their work. The system also provided long-term feedback through the evaluation process.

Inspections were undertaken on 20% of the units. The results of these inspections were communicated to the contractors as a further feedback mechanism. Control over contractor work was to be accomplished by issuing payment authorization only for units that were properly completed.

The final quality assurance mechanism was metering of thirty units in the ADPT.

Results, Conclusions, and Recommendations

The results of this project have important implications for future Appliance Doctor program implementation, quality assurance, and management.

Air Conditioner and Distribution Problems

As with the 1990 Fresno Appliance Doctor Pilot Project, the 1991 Appliance Doctor Pre-Production Test found that

these houses had significant problems with the distribution system and the air conditioner. Despite the fact that sixty-three percent of the units had been serviced in the last two years, the HVAC contractors had neither identified nor solved the problems that were documented in this project.

Table 1 lists the major problems identified at the sites in the ADPT project.

Contracting

It will be necessary to actively recruit contractors for this program. The Appliance Doctor process is too new and unknown to potential contractors to generate sufficient interest in a bid process. Only two contractors attended the pre-bid conference. One contractor had participated in the previous study and had some comfort with the proposed process. The other contractor was not comfortable with the process. Enticing the new contractor to bid involved holding a special meeting to answer his questions. Meetings of this sort will be necessary when the program is first introduced.

Control of the contractor's work was limited by the ability and willingness of all parties to discontinue production with one or more of the contractors and accept the reduced production level. Since only two contractors bid on this project, there was no effective selection of the contractors used.

Table 1. *Problems Identified in Submetered Project Sites*

	Customers with Air Conditioning System Problems	
AC Problems:	Random	High-Use
Air Flow <350 cfm/ton (Wet Coil)	29%	50%
Overcharge	none detected	27%
Undercharge	41%	36%
Distribution Problems:		
Duct Leakage >150 cfm	80%	87%

Paying the contractors a fixed sum per house based on performance criteria worked well under the following conditions. First, form review needed to take place quickly. Second, the technicians needed a blower door to properly determine that they had met the criteria.

Using a two-technician team from the contractors was problematic for two reasons. First, the AC technician's work could not be performed at the same time as the duct technician's work. Second, the AC technicians often had the duct technicians assisting them with air conditioner inspection and repair when in fact, the duct technicians had the more difficult and time-consuming job. The original intent of the program was for the AC technicians to spend half their time assisting the duct technicians. The problem was that the AC technicians had the higher status of the two, and were therefore unwilling to help the duct technicians. The quality of duct repairs and the morale of the duct technicians suffered from this well defined pecking order.

In order to avoid these problems it is recommended that two duct technicians be used to complete the work, that these technicians be employed by a different company than the one supplying the air conditioning technician, and that the AC technician visit the house only after the duct sealing has been completed.

Timing

The project was implemented during the busiest time of the year for the contractors. Administrative and programmatic resources were stretched to the limit in their attempts to add implementation of a large-scale program to an already heavy work-load. A year-round program would be preferable.

The project began with technician training sessions on June 10, 1991. Most of the units were completed by August 15, 1991. Duct and AC unit diagnosis and repairs generally occurred over a period of only two months. This severely limited time period was not a cost- nor time-effective utilization of resources. There was insufficient time to reinforce the training received by the technicians and only a short period of time for them to practice their new skills. The program was over before they reached proficiency.

Management and administration of a short-term project is proportionately more time-intensive than for a long-term project. New information, techniques, and skills are soon forgotten if only used for a few weeks.

Marketing

Utilization of summer swing to predict the high AC use customers proved effective. The submetered units showed that summer swing was highly correlated to AC use. This method of determining high-use AC customers can effectively be used for targeting.

PG&E's marketing campaign for the Appliance Doctor Pre-Production Test was very successful. The direct mail piece used for marketing was sent to 5,000 homes in the hopes of recruiting 250 participants. The allotted 250 spaces were filled by phone in two days. Additional phone calls were directed to a recording indicating that the program was closed. Another 740 customers attempted to join the program by mail. All of this response occurred in spite of the fact that there was no telephone follow-up to the initial offer. In general, this response reflects a great demand for the type of services offered by the program. Also, based on these results, the amount contributed by the customers should be raised. This would lower the per-unit costs and would allow the utility to serve more customers with the program.

The customer satisfaction study showed that 87% of the participants enrolled in the program to lower their AC energy costs, while 49% cited a desire to create a cleaner environment as an important consideration. Most participants read all or most of the letter, thought it easy to understand, and felt that it showed the benefits of the program.

Half of the nonparticipants did not completely read the direct mail piece and 49% could not distinguish the service offered in the marketing piece from standard service that they had recently purchased. The $90 cost of the program was considered a barrier for only 20% of the nonparticipants.

The participants were satisfied with the program, rating it at 4.4 on a 5 point scale. More than half (55%) of the participants believe their AC system is operating more efficiently and should reduce energy consumption. Eleven percent of the customers said their AC was not working any better after the work. Some (15%) of the participants were not prepared for the extensive nature of the service, reporting that they were inconvenienced by the service.

The variable customer cost caused some confusion on the part of the customer and on the part of the technician. It would be better to fix the customer cost at a single price for any particular period. The fee could be lower in the off-season to attract customers and higher in the peak season when interest is higher.

A high number of the air conditioners in the program had refrigerant leaks known to the customer. Some units were not operational when the customers signed up for the program. It is very easy for efficiency programs to become an alternative method for customers to get their broken air conditioners repaired. To maintain the effectiveness of the program, it is essential that only operational air conditioners be included. Marketing needs to stress that refrigerant leaks in coils and lines will not be repaired in the program, and that refrigerant will not be added to units with these problems. Marketing must also stress that this program will only be applied to operational units. Almost 9 out of 10 of the participants in the customer survey would like the program to provide additional follow-up work as needed.

Diagnosis and Repair

As an attempt to lower the cost of the program, duct sealing was attempted without the use of the blower door and flow hood for initial and final testing by the team. Since the technicians did not have the immediate feedback of the blower door, their competency never reached an adequate level. This resulted in less than adequate diagnosis and sealing of duct leaks. Once it became clear that this method was unacceptable, the submetered units were repaired using two duct technicians equipped with a blower door and flow hood. This method should be used when the program is applied to a larger population.

When equipped with the necessary tools and guided by the step-by-step procedure, the duct technicians were able to do a creditable job of sealing the ducts.

Quality Assurance

The specialized training of the technicians was very successful. Concentrating on a limited number of specialized test procedures greatly improved the technicians' understanding of the air conditioning system. The use of fixed step-by-step procedures provided a means of insuring quality work while the pre-/post- testing protocol increased the technicians enthusiasm for the job. When the on-site forms were reviewed and discussed with the technicians within one week after the date of service, their performance improved. However, when feedback was delayed, control over the contractors' performance decreased significantly. In order to provide that form review and feedback on a timely basis the program manager should be assisted by an expert computer system. Without such a system the form review process on large numbers of units would be very time consuming.

Initial training should be revised to include more customer interaction training. Nearly one-fourth of the respondents in the customer survey expressed dissatisfaction with some element of the technician's work. The biggest problem was technicians not arriving on schedule (11% of the respondents). Other inconsiderate behavior such as poor clean-up was also noted.

Metering

The cooling energy use was lowered by 21.5% on high-use customers with systems that were not leaking refrigerant. Table 2, from Proctor and Pernick (1992), shows energy savings by customer group. The cited paper discusses methods used to calculate energy savings and peak reduction, and provides further analysis of the submetering data.

Table 2. Energy Savings

Test Group	Net Cooling Savings
High-Use/High Bill Complaint (n=15)	16.18%
High-Use/High Bill Complaint excluding undercharged units (n=11)	21.63%
Random Units (n=11)	9.25%
Top Quartile of Random Units (n=3)	23.46%
Second Quartile of Random Units (n=4)	5.76%
Bottom Two Quartiles of Random Units (n=4)	2.08%

Program Costs

The total estimated cost per unit for the new program design is $785. With a customer contribution of $90, the total utility cost will be $695. This includes all known costs, direct and indirect, including HVAC infrastructure-building costs such as training and certification. These calculations depend on economies of scale that are achieved only at 1250 or more units per year in one location.

Summary

The Pre-Production Test was valuable. It helped avoid costly errors in applying the ADPS to large numbers of customers. During the upcoming three years, PG&E intends to apply the system to 4,000 residential heat pump systems per year, and 6,000 residential air conditioning systems per year pending approval from the California Public Utilities Commission. As a result of the test, significant changes in procedure have taken place.

The ADPT demonstrated that substantial energy savings are available by repairing existing cooling systems. Along with these savings came improved customer relations and a substantive response to high bill complaints.

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