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Innovative Peak Load Reduction Program CheckMe!® Commercial and Residential AC Tune-Up Project

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EXECUTIVE SUMMARY

In homes and small commercial buildings, the primary cause of electrical peak is central air conditioning. The predominance of older existing air conditioners (not new ones) and their contribution to peak make ensuring highest efficiency operation a prominent priority.

This program addressed excessive electrical peak load due to improperly tuned air conditioners operating below their potential efficiency. Using CheckMe!®, a unique and effective artificial intelligence system developed by Proctor Engineering Group, this program implemented improved repair practices that ensures air conditioners are operating at optimum efficiency.

Program Goals

The primary goal of this program was to reduce peak electrical consumption. The program had a goal of 25.68 MW peak reduction as well as production goals of 12,150 residential air conditioners and 18,865 commercial air conditioners.

Deemed Peak Reduction

The program delivered deemed peak reductions of 30.32 MW or 118% of the goal. It also exceeded the production goals on both residential and commercial units.

Other Program Achievements

The CheckMe!® system provides a very high level of security that program funds are only expended for performance which meets the CheckMe!® standard. Out of over 30,000 air conditioners, Proctor Engineering Group disallowed 1,752 initial tests and 1,202 final tests. The CheckMe!® quality assurance system saved the State $264,415.

This program increased the knowledge and modified the behavior of both the HVAC service technicians and their customers.

A total of 517 technicians employed by 211 different HVAC contractors were trained by PEG under the CheckMe!® program. The training was comprehensive, covering all aspects of the program including customer marketing activities, proper service techniques, interaction with the artificial intelligence system, contractor performance criteria, certification, and decertification. Each technician obtained a full day of hands on training with a student/trainer ratio of 2 or 3 to 1.

For each air conditioner serviced under this program PEG mailed a CheckMe!® certificate to the customer stating the results of the service. Included in each package was a customer satisfaction survey. Customers were asked to rate the service as “Excellent”, “Good”, “Fair”, or “Poor” and to comment on their satisfaction with the service. The results were overwhelmingly positive, with 94% rating the service as “Good” or “Excellent”. Customer satisfaction cards with “fair” or “poor” ratings were investigated through a phone call from Proctor Engineering Group and followed up to ensure customer satisfaction.

Proctor Engineering Group Project Evaluation

Proctor Engineering Group, Ltd. has always been concerned that energy savings and peak reductions occur in reality as well as on paper. In line with this philosophy PEG gathered extensive in-depth information about every air conditioner in the program. In this manner an accurate evaluation of the savings is provided.

The Proctor Engineering Group evaluation of the project showed that while the deemed savings exceeded the goal, the actual savings were less than the goal. Table 1 compares the evaluation results to the goals.

Table E-1. Program Evaluation Results

	Units[1]		
Sector	Goal	Achieved	% of Goal
Residential Air Conditioners	12150	15014	124%
Commercial Air Conditioners 5 tons or less	15797	18360	116%
Commercial Air Conditioners larger than 5 tons	3068	3566	116%
Peak Reduction from Evaluation (kW)			
Total kW	25,689	16,457	64%

The difference between the deemed peak reduction and the achieved peak reduction is primarily due to:

- Air conditioner size and connected loads were smaller than anticipated.
- Over 15% of the units identified as having incorrect charge through the manufacturers' qualification tests were found to need less than a 5% adjustment. Adjustments of less than 5% will produce negligible savings.
- The temperature split method was unable to identify approximately half of the air conditioners likely to have low airflow.

The Challenge

One of the constant challenges for residential and small commercial energy efficiency and peak reduction programs is the diffuse nature of the energy consumption. While the system wide consumption and peak load are substantial, these loads are spread over many buildings and relatively small units.

[1] When capacity was unknown (generally due to illegible model numbers) the units were proportioned based on the known capacity sample.

Recommended Changes

The following items show potential for improving the cost effectiveness of the CheckMe!® system applied to residential and small commercial air conditioners:

1) Target the residential program to sectors of the population where air conditioning is used throughout the day. These would include retires, stay at home parents, and home offices.

2) Improve on the manufacturers' (superheat, subcooling, approach) methods of qualifying a unit for refrigerant adjustment. This would reduce the number of units where refrigerant charge adjustment was less than 5%.

3) Improve on the temperature split method of qualifying a unit for airflow repairs. This would increase the number of units identified in need of airflow repairs.

4) Use the TrueFlow® flow meter to qualify units for airflow repair and to quantify the results.

I. INTRODUCTION

Introduction

This program was funded from Senate Bill 5X, (2001 Extraordinary Session), Section 5 (b)(4), Innovative Program funds. Proctor Engineering Group (PEG) was commissioned by the California Energy Commission (CEC) to reduce peak demand from residential and commercial air conditioners. Air conditioners operate inefficiently due to incorrect refrigerant charge, low airflow across the evaporator coil and inadequate maintenance practices.

The statewide CEC CheckMe!® program took place from August 2001 to June 2003.

The Opportunity

In homes and small commercial buildings, the primary cause of electrical peak is central air conditioning. The average age of the air conditioners is between 8 and 10 years and these units are running below their peak efficiency. The predominance of older existing air conditioners (not new ones) and their contribution to peak make ensuring highest efficiency operation a prominent priority.

Studies have shown extensive problems with commercial HVAC equipment installations, maintenance and service. The 1999 study of commercial rooftop units performed by Proctor Engineering Group for the Sacramento Municipal Utility District (Proctor 2000) showed that the majority of the rooftop units had refrigerant charge and air flow problems at least comparable to the problems documented in residential systems. The CEUE study (Hewitt et al. 1992) of commercial rooftop units found that only 28% were correctly charged.

Traditional approaches have failed to address the basic efficiency problems in central air conditioners, low airflow and incorrect refrigerant charge. Refrigerant charge is routinely diagnosed by “checking the pressures”. Regardless of the widespread use of this method, it is not the method approved or recommended by the manufacturers. Airflow across the evaporator coil is not routinely addressed unless it is so bad that the coil is freezing up. In addition, the technician is “on their own” with respect to what they do during maintenance, service, or checkup visits. In short there is no effective feedback loop. The work done is governed by “check lists” that provide insufficient guidance. The major problem is that there is no systematic method, enforced through a feedback loop that ensures the performance of residential or small commercial air conditioners.

The standard AC tune-up is of substantially less value than it could be. Customers are routinely left with air conditioners that have incorrect refrigerant charge, incorrect airflow, low capacity, and low efficiency. Proctor Engineering Group, Ltd. has developed a unique and effective system, CheckMe!®, which examines the critical airflow and refrigerant charge parameters of air conditioners and determines if they are correct. When diagnosis shows one of these problems, the system directs the service technician to correct refrigerant levels and address airflow. It verifies the validity of the tests and reinforces proper procedures with the technician. When the technician leaves the jobsite the air conditioner is tuned to manufacturer’s standards. The customer is integral to the system, becomes informed about the process, and becomes knowledgeable about the results.

Program Goals

The primary goal of this program was to reduce peak electrical consumption. The program established following numeric goals:

Table 1-1. Program Goals

Sector	Units	Deemed Peak Reduction	Total Peak Reduction
Residential Air Conditioners	12150	0.52 kW	6318kW
Commercial Air Conditioners 5 tons or less	15797	0.83 kW	13111 kW
Commercial Air Conditioners larger than 5 tons	3068	2.04 kW	6259 kW
Total kW			25689 kW

Program Objectives

The CheckMe!® program was designed to provide an effective agent to ensure proper operation of residential and commercial air conditioners. The project objectives were to:

- Reduce peak electricity demand from residential and commercial air conditioners by improving system performance and providing quality assurance for maintenance practices.
- Measure the critical airflow and refrigerant charge parameters of air conditioners, determine how well they are operating, as well as to correct refrigerant charge and address airflow when appropriate.
- Motivate contractors to conform to manufacturers' installation and service recommendations.
- Increase consumer demand for effective service work.

The program consisted of a number of coordinated facets surrounding the customer/service contractor interchange. One element of the program was the use of an artificial intelligence (AI) system accessible to the contractor through a toll free phone call. The AI evaluates the service work against attainable goals and makes the results immediately available to the technician and customer.

This program increased the knowledge of customers, making them better consumers. The customer was provided with a free third party verification of the information presented by the technician.

II. PROGRAM HISTORY

Initial Proposal

Proctor Engineering Group, Ltd. initially submitted two proposals for the CEC Innovative Peak Reduction Initiative. One proposal covered small commercial building air conditioners and the other covered residential air conditioners. These two proposals were combined into a single program leading up to the implementation contract.

Peak Reduction

The deemed peak reduction and cost effectiveness calculations in the initial proposals were conservatively stated in the following manner:

1) The savings were based on a 13% overall reduction of energy consumption for both residential and light commercial units. This compares to other sources estimates of 20% for light commercial units and 17% to 24% for residential.

2) The connected loads were based on an average 4 kW diversified peak load for residential air conditioners and an average 8 kW diversified peak load for commercial air conditioners. These are substantially lower than typical CPUC filings.

3) The cost effectiveness was based on a 53% repair rate, with sufficient funds budgeted to provide up to 100% repair (any unused repair incentives would be used to do additional units and increase actual peak reduction).

Revisions During the Program

The CheckMe!® system was modified to track make and model numbers as well as technician reported air conditioner sizes. This information was gathered to check the connected load assumptions in the initial estimates.

In the case of the Commercial units an analysis of reported AC sizes showed that the average commercial unit was 4.4 tons[2] rather than 7.5 tons[3], which gives a significantly reduced connected load and average peak reduction.

[2] with very few large units

[3] PG&E assumes 10 tons per unit (2002 Energy Efficiency Program Selection, Express Efficiency Workpapers, Setback Programmable Thermostat)

Given the significant difference from the initial numbers, Proctor Engineering made the following changes on November 1, 2001:

1) split the commercial units into two categories, large (>5 tons) and small (5 tons or less) and

2) reduced the incentives on commercial systems with a nominal system capacity of 5 tons or less to $35.00 for the initial test and $45.00 for a successful repair.

In March of 2002 the peak reduction numbers were revised based on a large unit average 9.5 tons and a small unit average 4.4 tons. This gave a peak reduction of 2.03 kW for larger commercial units and 0.83 kW of smaller commercial units. At that time the commercial incentives were increased to $35 for initial test, $75 for a successful repair on 5 tons or less, and $125 for a successful repair on units larger than 5 tons.

Analysis of data showed the average residential unit being repaired was not 4 tons, but rather 3.4 tons, however the initial percentage of repairs exceeded the proposal estimates, which made up for most of the size differential.

Proctor Engineering implemented changes on June 1, 2002 to reduce the percentage of residential jobs in favor of commercial jobs. The changes:

1) The residential incentives were lowered from $35 for the initial test to $20 and from $45 for the successful repair to $30.

2) The incentive on units less than 2½ tons was eliminated.

This increased the average size of the residential systems repaired and shifted contractor attention to commercial jobs.

Protecting State Money During the Program

The vast majority of technicians and contractors provided services that met the CheckMe!® standards to legitimately earn the incentives offered by the program. In a few cases the services were not delivered or they did not meet the standards.

CheckMe!® is unique in its ability to discern the differences between the two above groups. First, each set of data must pass intensive screens within the artificial intelligence program. Second, all these data from each technician are subjected to robust statistical analysis routines that determine if they contain patterns showing manipulated numbers. These routines are run weekly and monthly for both recent data and for cumulative data from the beginning of the program. Third, random and targeted inspections are used to check on the performance of the technicians. Fourth, the customers are kept informed of the process. Proctor Engineering Group's contact numbers are mailed to every customer, and negative customer satisfaction cards are investigated.

The system decertified 33 technicians and 5 contractors.

This system provides a very high level of security that program funds are only expended for performance which meets the CheckMe!® standard. Out of over 30,000 initial tests, 1,752 were disallowed. In addition 1,202 final tests were disallowed. These disallowed jobs saved the State $264,415.

III. PROGRAM ACTIVITIES

The CheckMe!® program provided a multifaceted approach to the residential and commercial air conditioning service market.

Artificial Intelligence System and Data Protocol

The AI and "hard copy" data entry have been developed and refined over several years of analyzing residential and commercial air conditioning systems. Prior to the CEC program PEG made revisions to both the software and data gathering protocols. The revisions included:

- Revising the AI program to gather the information to one central database. This allowed for shorter phone calls from extensive auto fills on repair calls and on multiple unit buildings.

- Adding new data fields to allow more detailed analysis on each air conditioner serviced.

- Adding a robust statistical analysis of the reported data. This allowed PEG to protect State funds by paying only for verified jobs.

Contractor Recruitment

One of the first tasks was recruiting a large number of contractors to participate. PEG made a concerted effort to include as many of the licensed HVAC contractors within California as possible. The goal was to secure participation of contractors throughout the state.

Air conditioning contractors were identified by purchasing a list of all individuals holding C-20 licenses (Air Conditioning & Heating) from the California Contractors State License Board. The list included the name and address of each contractor. Phone numbers were identified through an Internet search. Over 9000 contractors were identified as potential participants in the CEC CheckMe!® program.

Once contractors were identified, telephone outreach obtained a contact name and confirmed the mailing address. The campaign included two rounds of mailings to all licensed contractors, follow up calls, and personal visits. One full time recruiter was used throughout the program and the effort was supplemented by other personnel.

The recruiting effort resulted in 211 contractor participants. Five of the contractors later decided they could not spare their technicians out of the field for one day of training.

The size of the participating contractors ranged from one or two man operations to large contractors with many technicians. A total of 517 technicians were trained under this program. In addition, 166 previously certified CheckMe!® technicians participated in the program. Table 3-1 details the number of personnel trained per contractor.

Table 3-1 Number of Technicians Trained per Contractor

Number of Technicians Trained	Percentage of Contractors
1	22%
2 - 3	46%
4 - 5	13%
6 - 7	9%
8 - 9	5%
10 - 11	2%
12 - 13	2%
More than 14	1%

Contractor and AC Technician Training

Once the contractors agreed to participate, agreed to perform to CheckMe!® standards, and obtained the proper equipment, their service technicians were trained. The training was comprehensive, covering all aspects of the program including customer marketing activities, proper service techniques, interaction with the artificial intelligence system, contractor performance criteria, certification, and decertification.

Each technician obtained a full day of training with a student/trainer ratio of 2 or 3 to 1. The training included an hour and a half of classroom training and six and a half hours of field training. The hands on training included performing full CheckMe!® service on air conditioners in the contractor’s local service area.

Each technician was given a written examination at the end of the training. To be certified each technician needed to show their proficiency at performing the tests accurately, to have pass the written test.

The average test score for all trainees was 89%.

Contractors completed an anonymous evaluation at the end of the training. Table 3-2 presents the results.

Table 3-2 Contractor Evaluations of Training Program

As a result of the training you attended today can you:

Completely and accurately fill in the required data entry forms?

No 0%	Maybe 1%	Yes with Help 12%	Yes 87%

Assist the customer in understanding the data presented in the data entry forms?

No 1%	Maybe 2%	Yes with Help 12%	Yes 85%

Correctly measure wet bulb and dry bulb temperatures?

No 0%	Maybe 0%	Yes with Help 2%	Yes 98%

Recognize when the temperature measurements you have gotten are correct or incorrect?

No 0%	Maybe 1%	Yes with Help 11%	Yes 88%

Complete airflow testing using the airflow chart provided in training?

No 0%	Maybe 2%	Yes with Help 13%	Yes 86%

Complete charge checks and adjustments using the superheat or subcooling method?

No 0%	Maybe 1%	Yes with Help 10%	Yes 89%

Rate your overall impression of the training you attended today:

This class was helpful in my job

Not at all 0%	A little bit 3%	Quite a bit 25%	Very 73%

This class was interesting

Not at all 0%	A little bit 2%	Quite a bit 24%	Very 74%

As demonstrated in Table 3-2 the contractors felt the training met the stated objectives and would be helpful in the performance of their jobs.

Toll Free Telephone Support

Proctor Engineering Group maintained toll free telephone support for the participating contractors and their technicians. The contractor and service technicians used the telephone support for technical assistance, reporting data and interacting with the CheckMe!® AI system. The activities included:

- Two toll free phone lines (primary line 1-877-CHECKME)
- Staffing the toll free phone lines during normal business hours

- Staffing the technical assistance phone line with technical experts and providing back-up pager service

- Providing voice mail service during non-business hours

Quality Assurance

"Quality comes not from inspection but from improvement of the process."
W. Edwards Deming

Quality Assurance is defined as a system that assures quality through adjustment of the process as opposed to Quality Control typified by end of the process inspections. Quality Assurance uses statistical methods to identify weaknesses in the system and provides feedback and correction to respond to those weaknesses.

The QA system applied in this project was developed over 20 years while working directly with technicians to ensure that their jobs were completed properly.

The system starts with field training in measuring equipment performance parameters in a consistent and accurate manner. The training is followed by immediate feedback and support on every job. The technician relays collected data to PEG using the toll free telephone service. At PEG these data are immediately entered into the AI system by a trained operator. Any out-of-range or suspect values are automatically rejected or questioned. The AI system analyses the interrelationships between the various data points and determines if the test is valid. When necessary or helpful, the operator transfers the call to a field-experienced technical expert who provides immediate technical assistance. These steps ensure the accuracy of the collected and analyzed information. If repairs are required, measurements are taken after the repair and analyzed while the technician is still at the site. This ensures that the equipment has been properly repaired.

Data are post-processed to find incidents where the technicians report inaccurate numbers to generate a false "pass" of the air conditioner. A statistical process looks for patterns in the data. Twelve factors are evaluated in the process and compared against the statistical probability that the patterns will occur randomly. When a technician produces repeated patterns, the technician is decertified and their data are removed from the data set pending further investigation. See "Protecting State Money During the Program" for the outcome of these investigations.

Inspections

Proctor Engineering Group provided inspection services to supply feedback to the service technicians on their work. These examined the quality of the work (compliance with the CheckMe!® standards) and the accuracy of the data reported. The activities included:

- Providing ride-along and post-service inspections of the contractors' work

- Communicating the results of the inspections to the customer, contractor, and technician

- Gathering customer feedback on the program and the contractors' performance

- Analyzing and reporting the inspection results to the CEC

IV. PROGRAM TIMING

The HVAC industry is seasonal. Contractors go through periods where there is an abundance of work, requiring them to add staff (as in the peak of the summer season). On the other hand, they also experience periods where there is little work, requiring them to lay staff off (as in the fall after the summer peak).

In order for any intervention, such as the CheckMe!® program, to be successful, the launch of program activities must be carefully timed. Contractors in California typically perform their residential air conditioner tune-ups in early spring. The optimum time to impact air conditioner tune-ups is when urgent customer demand (no-cool calls) are at a minimum, yet it is warm enough to properly check the air conditioner. This occurs in February, March, April, and May (depending upon the locality).

The launch of the CEC CheckMe!® program provided ample time to meet this deadline for the 2002 season. The launch allowed for recruiting contractors and training technicians prior to the spring tune-up season and the program was very successful. Residential production was extremely high in the early spring and residential CheckMe!® runs exceeded the program target in May 2002, four months ahead of schedule. Residential production resumed in late June at a reduced incentive rate. Following the spring residential maintenance season commercial production ramped up through the summer and into the fall. Figure 4-1 illustrates the monthly production and the progression of the technician training program.

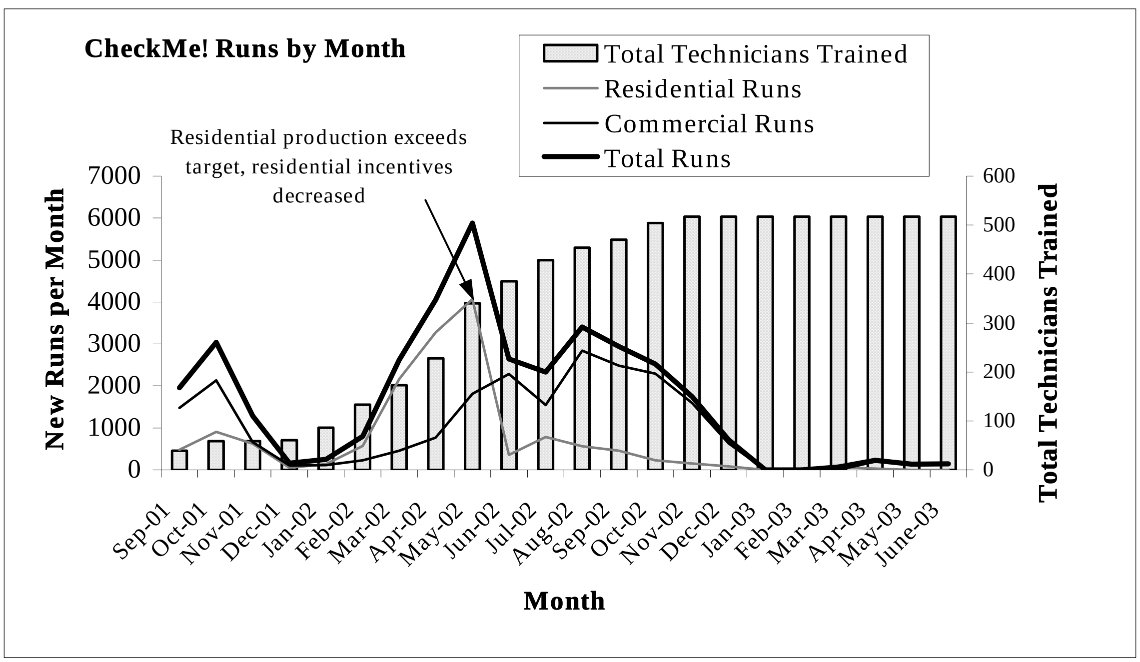

Figure 4-1 Monthly CheckMe!® Production and Training

Program Timing

Proctor Engineering Group recommends that the CheckMe!® program, or any program trying to cost effectively intervene in the residential or commercial air conditioner retrocommissioning process be initiated prior to February and be continued at least through November.

V. ARTIFICIAL INTELLIGENCE SYSTEM, DATA COLLECTION, MEASURE QUALIFICATION AND QUANTIFICATION

Artificial Intelligence System

A key to the success of the CheckMe!® program was having an artificial intelligence system that was quick and user friendly. The contractors and service technicians needed a mechanism that did not require them to spend extraordinary amounts of time gathering or reporting data. The service technician needed swift, definitive, and comprehensible answers concerning the air conditioner's performance and applicable repairs.

With the system, the program knows what actually happens at the job site. The data provided by the technician provides a clear record of the condition of each system at the time of initial diagnosis and after repair. The CheckMe!® AI system does error checking on every number and the interrelationships between numbers to determine the validity of the test. If the test data is good, the condition of the air conditioner's charge and airflow are determined and reported to the technician. Every datum and result is stored in the comprehensive database.

CheckMe!® assesses the air conditioner's performance in accordance with the manufacturer's recommended airflow and charge specifications then delivers the results in plain English (or Spanish).

Field Data

Within the CheckMe!® system field data is used for multiple purposes.

- Field data are used to qualify the air conditioner for a repair attempt.
- Field data are used to quantify the effectiveness of the repair attempt.
- Field data are used to quantify the magnitude of the initial problem and the savings effect of the repair.
- Field data are used to improve the system to ensure high-level technician performance.

Qualifying for Repairs

The initial test on an air conditioner in the program determined whether it was qualified for repair and the incentives for repair. Qualification controls the cost of the program by determining which units require sufficient repair to warrant repair costs. This program used the manufacturers' methods to qualify units for refrigerant charge repair and airflow repair.

Quantifying the Results of Repairs

The percentage savings from repairs are directly related to the amount of refrigerant adjustment and airflow adjustment achieved by the technician. The quantification of the savings is explained in Section VI. RESULTS / Evaluation.

Charge Analysis

CheckMe!® analyzes charge based on superheat, subcooling, or approach, following the manufacturers' recommendations. These procedures require the following information:

- Refrigerant metering device
- Condenser air entering temperature
- Return plenum dry bulb and wet bulb temperatures
- Supply plenum dry bulb temperature
- Refrigerant suction line and liquid line temperature
- Refrigerant system suction and discharge pressures as well as associated temperatures

The manufacturers' approved methods of diagnosing refrigerant levels are rarely used. Less than 5% of the technicians trained in the CheckMe!® system even claimed to use superheat, subcooling or approach prior to the training. Unfortunately, most technicians have gotten into the habit of looking at the refrigerant gauge and using a "rule of thumb" to estimate proper charge (e.g. "You should have 70 PSIG on the low side and less than 275 PSIG on the high side.").

Airflow Analysis

Airflow is rarely tested in either residential or small-commercial AC systems. CheckMe!® uses two alternative evaporator airflow analyses. The most common is the temperature split method as promulgated by Carrier Corporation (Carrier Corporation 1994). The better alternative is the TrueFlow® airflow meter manufactured by the Energy Conservatory.

When the temperature split is used the refrigerant level must be corrected at the same time and the mixed air temperature in the plenums must be measured.

The temperature split method is a qualitative airflow indicator that fits easily into technicians' standard diagnostic tests. Temperature split is the difference between the supply plenum dry bulb temperature and the return plenum dry bulb temperature. This temperature difference is a strong indicator of the correct operation of the air conditioner. For any given set of conditions (return plenum wet and dry bulb temperature and outside coil inlet temperature), there is an expected temperature split for a proper operating unit. The expected temperature split is the "Target Split". A measured temperature split within 3°F of the Target Split is considered acceptable. A measured temperature split outside that range is a strong indication that there is a problem with the machine. When the temperature split is too large it is an indication of low airflow through the inside coil. When the temperature split is too low it usually indicates low cooling capacity which can be associated with a number of problems including: dirty outside coil, low airflow through the outside coil, compressor problems, contaminated refrigerant, restrictions in lines, orifice problems, and others.

AI System and Data Collection

The TrueFlow® method is independent of refrigerant charge levels and accurate mixed air temperatures. It measures the flow based on pressures measured through specially designed flow plate. This method provides a measured airflow as opposed to just indications from the temperature split method.

VI. RESULTS

During this program PEG collected CheckMe!® data from 36,940 air conditioners. 15,014 of those were residential air conditioners and 21,926 were commercial. The program exceeded all the goals. Table 6-1 compares the results to the goals.

Table 6-1. Program Results

	Units[4]		
Sector	Goal	Achieved	% of Goal
Residential Air Conditioners	12150	15014	124%
Commercial Air Conditioners 5 tons or less	15797	18360	116%
Commercial Air Conditioners larger than 5 tons	3068	3566	116%
	Deemed Peak Reduction (kW)		
Total kW	25,689	30,321	118%

Deemed Savings and Cost per kW

The deemed savings from the program was 30.3 MW, which was 118% of the goal. The cost was $171 per kW.

Deemed Savings and Missing Information

Deemed savings has many administrative advantages over in-depth evaluations. The results generally require little information (typically the number of units) and are simple to calculate. The weaknesses of deemed savings calculations are unknown or untracked variables that result in actual savings or peak reductions being different from the deemed savings of peak reductions. These variables are often hidden in the assumptions behind the deemed savings. They may be as simple as assuming that the program will be delivered to the same type of population or in the same way as it was in the previous in-depth evaluated program.

Proctor Engineering Group, Ltd. has always been concerned that the energy savings and peak reductions occur in reality as well as on paper. In line with this philosophy PEG gathers extensive in-depth information about every air conditioner in the program. In this manner at the end of the program an accurate evaluation of the savings can be provided.

[4] When capacity was unknown (generally due to illegible model numbers) the units were proportioned based on the known capacity sample.

Evaluation Methodology

As previously described the CheckMe!® system checks data as it is reported from the field. These data are subsequently checked through statistical programs and open communication with all parties. When analysis indicates that additional information is necessary, collection of these data is added during the project.

Air Conditioner Tonnage

Average air conditioner sizing in residential and commercial buildings has been assumed for many calculations. From the beginning of the program PEG was concerned that the average tonnage might be different from the assumed tonnage in the deemed savings. This project collected the tonnage data via two methods.

- First the technician reported the unit capacity from the field when it was available from the nameplate or the model number.
- Second the technician reported the make and model number of the unit when they were legible.

Early in the program the technician reported capacities did not support the assumed tonnages in the deemed savings. This information inspired a change in the structure of the program to give higher incentives to larger commercial units and smaller incentives to smaller units.

In the final evaluation of the program the technician reported capacities were compared to a listing of capacities based on model numbers. Approximately 20% of the technician reported capacities were corrected in that process.

The figure of interest is the average tonnage of units that were repaired. Table 6-1 compares the initial tonnage estimates with the final evaluation results.

Table 6-2. AC Tonnage

Sector	Initial Estimate	Repaired Average	n
Residential Air Conditioners	4 tons	2.93 tons	6547
Commercial Air Conditioners	7.5 tons	4.67 tons	
Commercial Air Conditioners 5 tons or less		3.63 tons	8366
Commercial Air Conditioners larger than 5 tons		10.03 tons	1625

Diversified Connected Load

The deemed diversified connected load was based on the initial estimates of tonnage and a conservative peak EER of 8. The diversity factors were taken as .70 for the residential units and .80 for the commercial units.

Based on the final tonnage figures, the final diversified connected loads are compared to the initial estimates in Table 6-3.

Table 6-3. Diversified AC Peak Load

Sector	Initial Estimate	Evaluation
Residential Air Conditioners	4 kW[5]	3.51 kW
Commercial Air Conditioners	8 kW[6]	
Commercial Air Conditioners 5 tons or less		6.07 kW
Commercial Air Conditioners larger than 5 tons		11.86 kW

Refrigerant Charge

During this project information was gathered on the amount of refrigerant charge added or removed from systems as well as their nameplate refrigerant capacity. This was the first time that both of these variables were gathered on any significant population. The air conditioner efficiency is directly related to the percentage adjustment of the refrigerant charge by the following equation for fixed metering devices:

EERnorm1 =5.082403 - 4.100056 * perchg + 4.619659 * LN(perchg)

Where:

EERnorm1 is EER at measured charge / EER at correct charge

perchg is the fraction of correct charge (1=correct charge)

EER is the btu / watt hour of the unit when running at 95°F condenser air entering temperature

With:

perchg between .6 and 1.8

The information gathered on refrigerant charge adjustments and factory refrigerant capacity results in distributions of pre-repair refrigerant charge (perchg) and normalized efficiency (EERnorm1). When the refrigerant charge is corrected to perchg = 1 the savings from the adjustment is calculated as follows:

Savings = 1-EERnorm1

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[5] 4 kW was used as a more conservative estimate than the 4.2 derived from 48,000 btuh / 8EER * .7

[6] 8 kW was used as a more conservative estimate than the 9 derived from 90,000 btuh / 8EER * .8

The distributions and savings by charge category are shown in Table 6-4.

Table 6-3. Diversified AC Peak Load

Percent	Charge Category	Average perchg	EERnorm1	Savings
3.41%	<0.60		[7]	
1.47%	0.65	0.63	0.36	0.64
1.83%	0.7	0.68	0.50	0.50
2.83%	0.75	0.73	0.63	0.37
3.67%	0.8	0.78	0.73	0.27
6.85%	0.85	0.83	0.81	0.19
12.54%	0.9	0.88	0.88	0.12
17.86%	0.95	0.93	0.93	0.07
7.62%	1	0.96	0.96	0.04
7.75%	1.05	1.04	1.00	0.00
15.43%	1.1	1.07	1.01	-0.01
9.28%	1.15	1.12	1.01	-0.01
4.26%	1.2	1.17	1.01	-0.01
2.08%	1.25	1.22	1.00	0.00
1.04%	1.3	1.27	0.98	0.02
0.61%	1.35	1.32	0.95	0.05
0.42%	1.4	1.37	0.92	0.08
0.19%	1.45	1.42	0.88	0.12
0.19%	1.5	1.47	0.83	0.17
0.10%	1.55	1.53	0.78	0.22
0.13%	1.6	1.57	0.73	0.27
0.06%	1.65	1.63	0.66	0.34
0.05%	1.7	1.68	0.59	0.41
0.11%	1.75	1.73	0.52	0.48
0.06%	1.8	1.78	0.50	0.50
0.15%	1.85	1.83	[8]	

The sample for this table consisted of the 12,547 units where charge was added or removed and the nameplate refrigerant level was known. This does not include units that were too low on refrigerant to test in the initial diagnostic test.

[7] EERnorm1 is taken as 0.36 for all units with less than .65 of correct charge.

[8] EERnorm1 is taken as 0.50 for all units with more than 1.8 of correct charge.

The table shows that 15.37% of the units identified as incorrectly charged using the manufacturer's diagnostic procedures were within 5% of correct charge. The adjustment and retesting of these units is a financial burden without sufficient subsequent benefit.

The reader will also notice that there are a number of situations (between 5% and 20% overcharge) where negative savings are indicated. This indication is due to the efficiency formula having been developed at 95°F. At higher temperatures (as at peak in many California locations) the efficiency curve shifts and savings does occur when these overcharged units are corrected. It is also of importance to the building owner and AC manufacturer that units are not overcharged. Overcharged units are prone to failure at high temperatures.

Refrigerant Charge Savings

The average savings for air conditioner units initially diagnosed with incorrect charge and with the charge corrected is 10.5%.

Airflow Across the Evaporator Coil

The air conditioner efficiency is directly related to the airflow across the evaporator coil. Laboratory tests indicate that the efficiency is related to airflow in the following manner:

$$EERnorm2 = 0.65 + 0.35 * flowratio$$

Where:

EERnorm2 is the ratio of the EER and the maximum EER at those outdoor and charge conditions

flowratio is the ratio of the actual airflow to 400 cfm per ton

The temperature split method provides an airflow indicator (qualitative) as opposed to a quantification of airflow across the evaporator coil. Airflow repairs consisted of opening registers, changing and cleaning filters, cleaning evaporator coils, cleaning blowers, opening dampers, adjusting blower speed, etc. The savings estimate is based on a 75 cfm per ton improvement and a normally distributed airflow with a mean of 325 cfm per ton and a standard deviation of 80 cfm per ton.

There are at least two sources of uncertainty in this calculation. Since the temperature split is qualitative there is not absolute certainty about either the initial amount of airflow or the amount of airflow correction.

Our analysis shows that only 35% of the air conditioners were identified as having low airflow. This directly contradicts field studies where the airflow was measured directly using the TrueFlow® grid or the Duct Blaster®. In the studies with direct measurement, approximately 67% of the units were found to have low airflow. The temperature split method appears to miss almost half of the air conditioners with low airflow.

Results

An ideal qualifying test for airflow would identify 90+% of the units with low airflow. It would identify the low flow units regardless of the test conditions. The temperature split method as it is currently used shows a bias[9] in the results. This bias is related to the return plenum wet bulb temperature as shown in Figure 6-1.

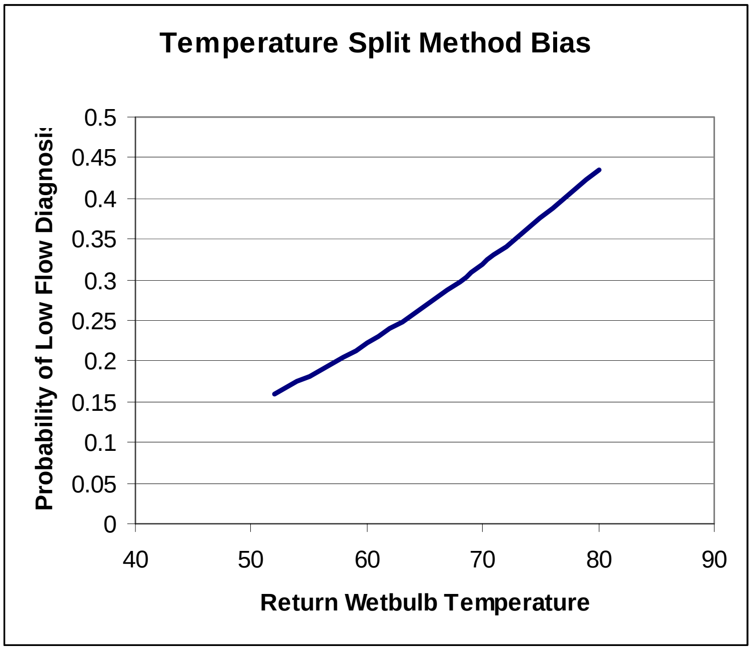

Figure 6-1 Temperature Split Test Bias

Investigating temperature split as a qualifying measurement for repairs confirms that it is better than standard practice, but falls short of an ideal qualifying test.

Airflow Repair Savings

The average savings for air conditioner units initially diagnosed with low airflow and with correcting measures taken is 7.0%.

Customer Satisfaction

For each air conditioner serviced under this program PEG mailed a CheckMe!® certificate to the customer stating the results of the service. Included in each certificate package was a customer satisfaction survey requesting feedback from the customer's perspective on the CheckMe!® service. Customers were asked to rate the service as "Excellent", "Good", "Fair", or "Poor" and to comment on their satisfaction with the service.

A total of 740 survey cards were returned. The results were overwhelmingly positive, with 74% rating the service as "Excellent", 20% as "Good", 4% as "Fair" and 3% as "Poor". The following comments attest to the high level of customer satisfaction achieved with the CheckMe!® program:

> "Demonstrated how efficient the new system was compared to the old one"
>
> "Good idea. Make sure air-conditioners work as efficiently as possible."
>
> "Efficient and thorough professional, courteous."
>
> "I didn't know that my unit was not properly installed, but now I know"

[9] A bias is noted when different test conditions change whether the unit qualifies for a repair.

Evaluation Results

The Proctor Engineering Group evaluation of the project showed that while the deemed savings exceeded the goal, the actual savings were less than the goal. Table 6-4 compares the evaluation results to the goals.

Table 6-4. Program Evaluation Results

	Units[10]		
Sector	Goal	Achieved	% of Goal
Residential Air Conditioners	12150	15014	124%
Commercial Air Conditioners 5 tons or less	15797	18360	116%
Commercial Air Conditioners larger than 5 tons	3068	3566	116%
Peak Reduction from Evaluation (kW)			
Total kW	25,689	16,457	64%

Features that Worked Well

The program was able to deliver significant AC tune up volume for a number of reasons:

- The program was able to "piggyback" and use technicians that were previously trained in the CheckMe!® system.
- The program was paperless. It required no paperwork from the customer, contractor, or the technician.
- The program paid the contractor by the tenth working day of the following month based on the electronic data stored in the central computer.
- The program was able to respond quickly to new information and adjust the system to compensate.
- The program was able to determine units that did not meet the standards of the program and saved the State over $250,000.
- Having a contract in place from the previous year made it possible for the program to deliver during the early spring season.
- The keystone to the interaction between the service technician and the consumer is trust. Any project targeted at this interaction must build the consumer's trust in the technician. Otherwise, it will be rejected by the contractor.
- While many customers did not understand the technical side of the process, they liked the additional information and openness of the technician in providing the information.

[10] When capacity was unknown (generally due to illegible model numbers) the units were proportioned based on the known capacity sample.

VII. POTENTIAL FOR IMPROVEMENT

One of the constant challenges for residential and small commercial energy efficiency and peak reduction programs is the diffuse nature of the energy consumption. While the total consumption and peak load are substantial, these loads are spread over many buildings and relatively small units.

Recommended Changes

The following items show potential for improving the cost effectiveness of the CheckMe!® system applied to residential and small commercial air conditioners:

1) Target the residential program to sectors of the population where air conditioning is used throughout the day. These would include retires, stay at home parents, and home offices.

2) Improve on the manufacturers' (superheat, subcooling, approach) methods of qualifying a unit for refrigerant adjustment. This would reduce the number of units where refrigerant charge adjustment was ineffective in improving efficiency.

3) Improve on the temperature split method of qualifying a unit for airflow repairs.

4) Use the TrueFlow® flow meter to qualify units for airflow repair and to quantify the results.

5) Provide error checking on technician reported air conditioner capacity in real time (based on model numbers).

Other Potential Changes

The following potential changes would increase the cost effectiveness of the program, however, they would have other deleterious effects.

1) Target the program to larger units (over 5 tons) on commercial structures. This targeting has the downside of isolating the small commercial buildings, a continuing problem.

2) Target the program to larger residential units. This targeting has the downside of isolating renters in apartments, another continuing problem.