Field Tests of Specially Selected Air Conditioners for Hot Dry Climates

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ABSTRACT

This paper presents the results of three field studies of residential air conditioners in Hot Dry Climates. These air conditioners were production units. The combinations of single speed outdoor condensing units, indoor coils, and furnaces were selected to meet specific performance criteria at hot dry conditions present in the southwestern United States. Eight manufacturers' units were tested in a pre-retrofit, post-retrofit experimental design. Each home was monitored over half a cooling season with a standard SEER 13 unit. The units were replaced with the Hot Dry units and monitoring continued for at least the second half of the summer.

Most of the units performed sufficiently better than the baseline units to meet the goal of 20% energy savings and up to 34% peak reduction at system critical peak times. Characteristics common to the best performing units were brushless DC variable speed fan motors, more efficient heat exchangers, higher sensible heat ratio, and furnace fan control modifications.

Introduction

The southwestern United States is very hot and very dry during the summer. Average daily high temperatures exceed 100 ºF in much of southern California, Nevada and Arizona through the hottest part of the summer, with highs for individual days exceeding 110ºF. Afternoon relative humidity levels are typically less than 30%. Very hot and dry conditions create unique challenges and opportunities for air conditioning.

Air conditioning on hot afternoons causes large peaks in electrical demand, necessitating financially and environmentally costly increases in power generation and transmission infrastructure. The problem is exacerbated by a growing population of refrigerant R-410A machines. It is widely recognized that efficiency degradation at hot temperatures is greater with R-410A compared to R-22 (Domanski & Payne 2002). This is a growing concern as R-22 is phased out and replaced with R-410A over the next 15 years. The peak demand of an R-410A machine in a hot climate is greater than a similarly rated R-22 machine by 5% to over 10%.

Dehumidification is not necessary in dry climates, yet these field tests show standard air conditioners continue to remove moisture from the air. Performance in hot dry climates can be improved through the selection of equipment that produces a higher ratio of sensible capacity (cooling the air) to total capacity (cooling + moisture removal).

Seasonal Energy Efficiency Ratio (SEER) and Energy Efficiency Ratio (EER) are the standard ARI certified air conditioner efficiency metrics. Neither is an adequate predictor of performance at very hot and dry conditions. SEER rates performance at 82ºF, and EER rates performance at 95ºF.

The applicable performance metric for hot dry climates is Peak Energy Efficiency Ratio – Sensible (PEERs) (SCE, PEG, and BKI 2007). PEERs was developed through research sponsored by the California Energy Commission Public Interest Energy Research (PIER) Program to rate the performance of air conditioners at conditions typical for electrical peak in the southwestern United States. A minimum rating to classify a system as a Hot Dry Air Conditioner

(HDAC) was specified (Table 1). Some manufacturers publish extended performance data, and for these units estimated performance at the PEERs conditions can be calculated. Extended performance data is not certified like SEER and EER.

Table 1. PIER Hot Dry Air Conditioner Draft Specification

Condition #1	**115°F outdoor, 80°F indoor with 38.6% RH (63 WB)**
Gross[1] Sensible Capacity (Sensible BTU/h)	75% or greater than the gross total capacity at ARI test A (95/80/67)
Net[1] PEERs	at least 8 BTU/Watt*hr
Condition #2	**115°F outdoor, 80°F indoor with 51.1% RH (67 WB)**
Gross Sensible Capacity (Sensible BTU/h)	65% or greater than the gross total capacity at ARI test A (95/80/67)
Net Sensible PEERs	at least 6.8 BTU/Watt*hr

Two proof of concept HDAC units were constructed and laboratory tested to demonstrate performance potential. One unit was a 3-ton split system and the other was a 5-ton rooftop package unit. The PIER split and packaged prototypes demonstrated 8.22 and 8.60 Net PEERs, respectively, at Condition #1 and 6.91 and 7.08 Net PEERs at Condition #2 (SCE, PEG, and BKI 2007).

Pacific Gas & Electric (PG&E), Southern California Edison (SCE), and Nevada Power (NP) funded side-by-side comparisons of HDAC units to standard SEER 13 units in the field. The field tests were conducted in 2006 and 2007 at eight sites in California and Nevada.

Methods

The field test consisted of site and AC selection, installation and replacement, performance monitoring, and data analysis. Standard (baseline) SEER 13 air conditioners were first monitored and then replaced with HDACs during summer 2006 at all except the Fresno site. In 2007, a HDAC unit selected to demonstrate field performance of a microchannel condenser coil was installed in Fresno. The Fresno site was monitored, and monitoring was continued at the Madera and Yuba sites through summer 2007. Site and air conditioner characteristics are tabulated in tables 2, 3 and 4.

Site and Air Conditioner Characteristics

Table 2. Site Characteristics

Site	**Madera**	**Yuba**	**Fresno**	**Bakersfield**	**Concord**	**Furnace Creek**	**Victorville**	**Las Vegas**
House Size (square feet)	1650	1600	1700	1200	1400	1230	1600	1225
Year Built	2002	1991	1992	1941	1970s	NA	2004	NA
Air Handler Location	Attic	Attic	Attic	Closet	Closet	Rooftop Package	Attic	Attic
Sponsor	PG&E	PG&E	PG&E	PG&E	PG&E	SCE	SCE	NP

All of the sites except Furnace Creek were occupied homes served by a single air conditioner. The Furnace Creek site was a non-residential modular structure that was also served

[1] Net capacity and efficiency include the effect of the indoor fan energy while gross capacity and efficiency does not include the energy of the indoor fan.

by four small window air conditioners. Furnace Creek is in Death Valley and was chosen for the severity of conditions.

Table 3. Standard Air Conditioner Specifications[2]

Site	Madera	Yuba	Fresno	Bakersfield	Concord	Furnace Creek	Victorville	Las Vegas
Rated SEER	13	13	-	13	13	13	11.3 to 12.3[3]	13[4]
Rated Sensible EER	7.5	8.3	-	8.3	8	8.2	NA	NA
Rated EER	10.8	11.6	-	11.2	11.2	10.9	10 to 10.8	11
Sensible Heat Ratio[5]	0.7	0.72	-	0.74	0.71	0.75	NA	NA
Rated Capacity (BTU/h)	47000	35000	-	34000	34000	54400	55000	35000
Nominal Size (tons)	4	3	-	3	3	5	5	3
Nominal Evaporator Coil Capacity (BTU/h)	48000	36000	-	42000	48000	60000	NA	48000
Refrigerant	R-22	R-22	-	R-22	R-22	R-22	R-22	R-22
Metering Device	Piston	Piston	-	TXV	TXV	NA	NA	NA
Fan Motor Hp	1/2	1/4	-	1/2	1/2	3/4	NA	1/3
Fan Motor Type	PSC	PSC	-	ECM	ECM	PSC	PSC	PSC

The standard ACs were SEER 13 R-22 units either already in place or selected by the contractor and installed for this test. Since sensible heat ratio is the fraction of the capacity that reduces indoor temperature, it is evident that the standard units waste almost a third of their capacity removing water rather than reducing the temperature. Designs capable of sensible heat ratios of 0.80 or higher are possible and the installed HDACs at several sites approached this ratio.

Table 4. Hot Dry Air Conditioner Specifications[2]

Site	Madera	Yuba	Fresno	Bakersfield	Concord	Furnace Creek	Victorville	Las Vegas
Rated SEER	14	14.2	NA	13.25	13.5	14	13 to 13.7[3]	15
Rated Sensible EER	9.4	9.2	9.2	8.5	8.8	8.25	NA	NA
Rated EER	12.3	11.7	12.6	11.2	11.3	11.7	10.7 to 11.2	12.5
Sensible Heat Ratio	0.77	0.79	0.73	0.76	0.78	0.73	NA	NA
Rated Capacity (BTU/h)	50730	35200	35025	36400	44100	59000	52000 to 56000	35600
Nominal Size (tons)	4	3	3	3	3.5	5	5	3
Nominal Evaporator Coil Capacity (BTU/h)	60000	42000	36000	48000	60000	60000	NA	48000
Refrigerant	R-410A	R-410A	R-22	R-410A	R-410A	R-410A	R-410A	R-410A
Metering Device	TXV	TXV	TXV	TXV	TXV	TXV	NA	TXV
Fan Motor Hp	1/2	1/2	1/2	3/4	1/2	3/4	NA	3/4
Fan Motor Type	ECM	ECM	PSC	ECM	ECM	ECM	ECM	ECM

[2] With ARI furnace default assumptions and at standard 95/80/67 conditions
[3] Coil make and model for the Victorville site are unknown.
[4] Estimated. Coil and outdoor unit combination are not ARI listed.
[5] Sensible Heat Ratio is the ratio of sensible capacity to total (sensible + latent) capacity.

The HDAC air conditioners consisted of components (outside unit, inside coil, and furnace) selected because they approached the draft HDAC performance specification. The selections were based on manufacturer supplied performance data on the outside unit and coil combination, the coil air pressure drop, and the furnace blower. The components were standard production equipment that fit into the existing locations with some minor duct system modifications.

Air Conditioner Installation and Replacement

The HDAC specification was approached by the selected air conditioning systems by closely matching the performance of the indoor coil, outdoor unit, and furnace. At most sites, this included replacing the furnace with a new unit listed as providing higher airflow at lower watt draws for the specified external static pressure.

Even with close attention to the work of the HVAC contractors, substitute components were installed at several sites. Substitute coils were installed at some sites, resulting in equipment combinations with no corresponding performance rating. At one site, a larger than specified furnace was installed with airflow set to the highest setting, resulting in significantly higher than expected watt draw. Properly adjusting the airflow setting reduced the furnace watt draw by 50% (350 watts).

It is very common for contractors to substitute alternate components that they judge as comparable to the specified equipment, usually due to cost and availability issues. This is done without thorough analysis of the effects of the substitutions, and can substantially alter the delivered efficiencies from those expected. This is one reason why combinations need to be certified by the manufacturers (including third party manufacturers) at hot dry conditions.

Each air conditioner was commissioned prior to the beginning of the monitoring periods. Commissioning included checking and setting refrigerant levels using manufacturers' recommended methods, determining airflow and adjusting airflow to the degree available, and making sure the duct leakage at 25 Pa (0.10 IWC) was less than 15% of system airflow.

A number of one-time measurements were taken at installation, replacement, and project conclusion. Refrigerant charge was verified to meet manufacturer's specifications. Two methods were used for measuring the evaporator airflows at the PG&E sites, an Energy Conservatory TrueFlow® plate and the pressure matching method as specified in California's Title 24. Airflows, static pressures, and watt draws were recorded at various blower settings.

Equipment and Refrigerant Type Considerations

The field study included evaluation of equipment and refrigerant type impact on system performance. Equipment features identified in the PIER HDAC project for improved sensible efficiency in hot dry climates include microchannel heat exchangers, efficient brushless DC fan motors, and advanced indoor blower control strategies. Conversely, the 'refrigerant of the future', R-410A, is detrimental to air conditioner performance at hot ambient temperatures.

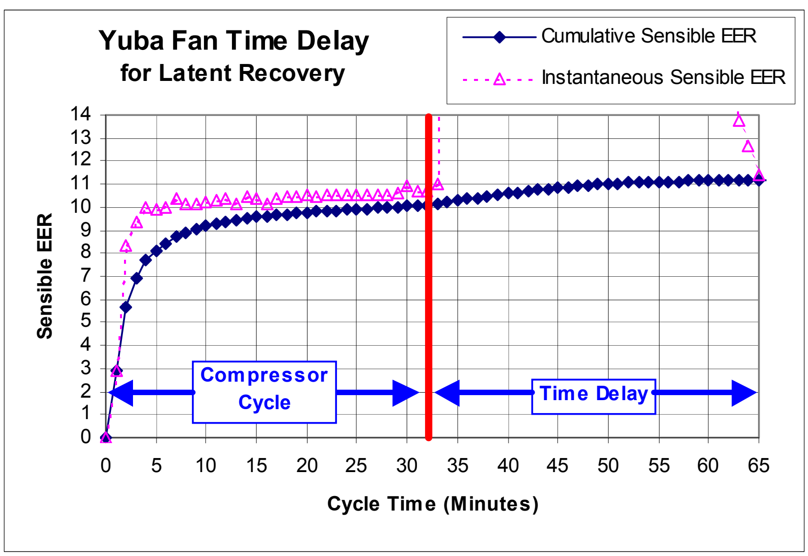
Microchannel coils have greater refrigerant side heat exchanger surface area compared to a standard tube and fin coil of similar dimensions. They are widely used in automotive applications but have only recently become available for residential air conditioners. The Fresno HDAC unit was selected for testing because it has a microchannel condenser coil.

Furnace fan motors can significantly impact the sensible efficiency of air conditioning systems. Inefficient fan motors not only use more energy, the extra energy heats the air that the air conditioner is cooling. The Fresno HDAC unit was installed with an inefficient permanent split capacitor (PSC) fan motor. A similarly sized furnace equipped with an efficient brushless DC fan motor was tested in the laboratory at the same airflow and static pressure measured at Fresno. The watt draw measured in the laboratory was used to calculate performance of the Fresno HDAC unit with an efficient fan motor. Seasonal and peak energy use calculations for the Fresno site assume the higher efficiency motor in order to best represent a system meeting the HDAC PEERs specification. Figure 3 compares sensible efficiency with each motor.

Blower time delay. Many furnaces are capable of running the indoor fan for an extra 30 to 90 seconds after the air conditioner compressor turns off. Manufacturers use an indoor fan off delay to obtain higher ratings on the SEER test. Since the evaporator coil is still cold when the compressor turns off, additional cooling is delivered using only the watt draw of the fan. The manufacturer's standard delays are designed to maximize performance on the SEER test, which is conducted with a dry evaporator coil.

In hot dry climates where dehumidification is not required, a longer delay can be used to take advantage of water retained on the evaporator after the compressor turns off. The system functions as an evaporative cooler during the delay, converting a portion of the unneeded latent capacity into sensible capacity to cool the house. An extended time delay is particularly effective in combination with a brushless DC variable speed motor capable of running at low speed with very low watt draw.

Figure 1. Yuba City Fan Time Delay

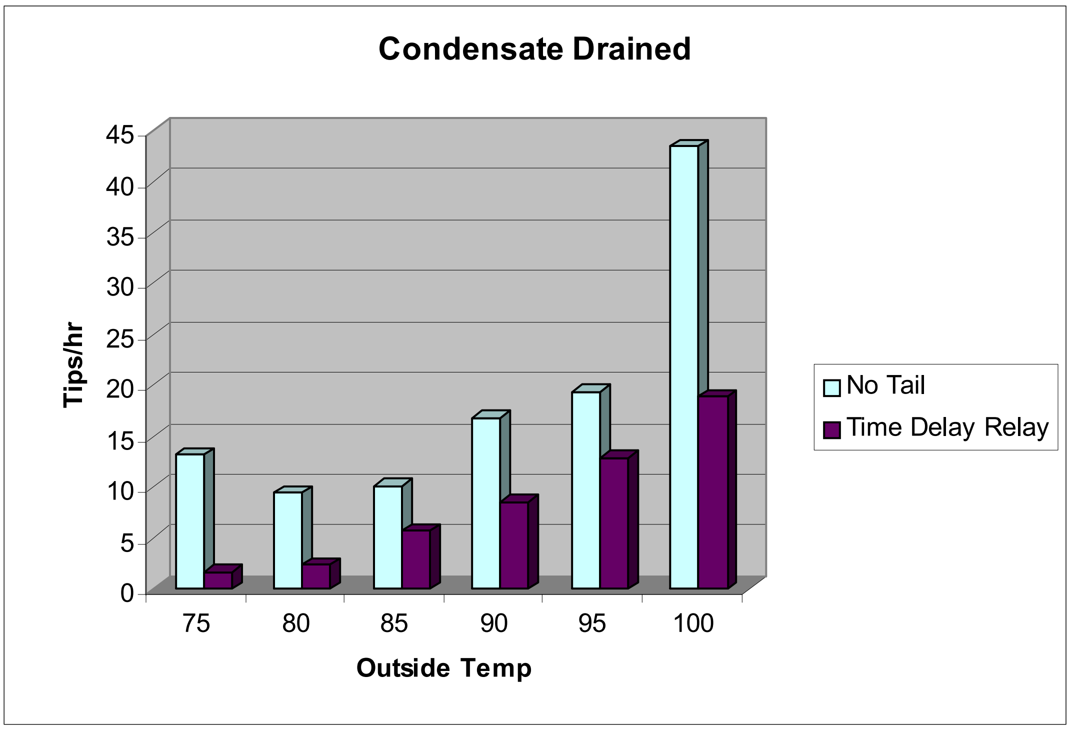


Extended time delays were tested at the Madera, Yuba and Fresno sites. The tests were conducted by configuring the system to run constant fan, and then recording data in 1-minute intervals through a compressor cycle and the subsequent fan-only cycle. The fan was allowed to run until cooling was no longer being delivered. Measured sensible capacity and watt draw during the fan time delay were added to each cycle recorded during monitoring to estimate the efficiency improvement.

Figure 1 shows the time delay improvement measured at the Yuba site with an ECM furnace running at low speed during the delay. Cooling is delivered long after the air conditioner turns off, and sensible EER increases by a full point within 15 minutes.

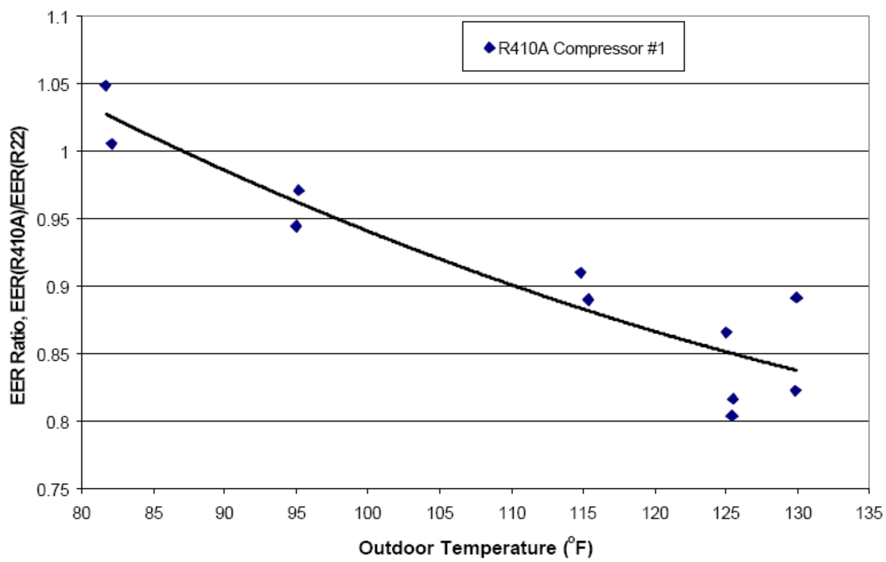
One concern expressed by reviewers was that the inside conditions in these climates would be so dry that the air conditioners would not have any condensate on the coils, negating the potential benefit of a longer time delay. Analysis of the air side data showed latent capacity by all units while the compressors were running. The tipping bucket data from these tests also showed condensate removal at all conditions at all sites except the site with a continuous fan. Figure 2 shows the tipping bucket data with and without a time delay for one site.

Figure 2. Condensate Removal



Refrigerant type. It is well known that the efficiency of R-410A degrades faster with increasing outdoor temperature compared to R-22. The degradation in one set of laboratory experiments is displayed in Figure 3. The difference in efficiency is less than 5% at the SEER and EER test points. At 115 °F R-410A is 12% less efficient than R-22. The same trend of performance degradation at higher temperatures is evident in the testing by Davis and D'Albora 2000.

Figure 3. Cooling EER of R-410A System Relative to R-22 System



(Domanski & Payne 2002)

This illustrates the importance of performance ratings at hot conditions. As R-22 machines are phased out over the next 15 years, they will be replaced with R-410A machines with significantly worse performance at peak conditions, even if the SEER rating is the same.

Monitoring System[6]

The SCE monitoring system was a multi-channel data logger (DataTrap) that recorded energy, temperature and relative humidity data in 15-minute intervals.

The NP monitoring system used HOBO data loggers to monitor indoor and outdoor temperature and humidity, and temperatures in the return and supply plenums. Dent Instruments Elite PRO poly-phase power meters were used to monitor electrical current, voltage, power and energy for the condensing unit and furnace. Data were recorded in 2-minute intervals.

The PG&E monitoring system was a Campbell Scientific CR10X data logger with an AMT-25 multiplexer and COM210 modem. The temperature probes were bare wire 36 gauge type T thermocouples, RTDs, or thermistors. Indoor, outdoor, and plenum temperature and humidity, and refrigerant line and coil temperatures were monitored. Tipping buckets were used to record condensate removal. Data were gathered every 5 seconds. Instantaneous data were recorded at the beginning and end of all cycles (including compressor, fan, and off cycles). Data were also averaged or summed over each cycle and recorded. Additionally, data were averaged/summed every hour on the hour.

Calculations

Air conditioner energy use for the NP and SCE sites was modeled by regression of total hourly kWh against average hourly outside temperature. Data from days where the thermostat

[6] Monitoring systems for all three studies are described in greater detail in PEG 2007.

setting was constant were included in the analysis. This analysis assumes the loads are adequately represented as a linear function of outdoor temperature when known anomalies are excluded.

For the PG&E sites, air conditioner energy use was modeled in the following manner:

1) The Sensible EER was modeled as a function of outside, return air dry bulb and return air wet bulb temperatures for each air conditioner from the monitored data. The models were used to calculate the sensible EER for each air conditioner in each temperature bin.

$$Sensible\ EER = \frac{Sensible\ Capacity\ with\ Compressor\ On(Btu) + Sensible\ Capacity\ with\ FanOnly\ (Btu)}{Energy\ Used\ with\ Compressor\ On(Wh) + Energy\ Used\ with\ FanOnly\ (Wh)}$$

2) The Sensible load for each site for each hour was calculated from the monitored data.

3) The Sensible loads were grouped by outside temperature bins of 5°F and a function was derived based on hour of the day for each temperature bin. This function is assumed to be the sensible load of the structure at that hour and temperature. The function is of the form:

$$SensibleLoad_{ij} = A_i \times \sin(\frac{2\pi(hour+8)}{24}) + B_i \times \sin(\frac{2\pi(hour+2)}{24}) + C_i$$

Where the independent variable, *hour,* is the hour of the day ranging from 1 to 24 and *i=temperature bin (60°F-110°F)* and *j=hour bin (1-24)*

4) The actual load seen by the air conditioner is dependent on outside temperature, but also on solar position and occupant behavior among other variables. To account for occupant behavior in this analysis the monitored data was analyzed to determine the ratio of the hours in which the air conditioner operated to the total hours in the temperature/hour bin. This ratio is the on fraction.

$$OnFraction_{ij} = \frac{Number\ of\ Monitored\ Hours\ That\ AC\ Was\ Used_{ij}}{Total\ Number\ of\ Monitored\ Hours_{ij}}$$

5) The equivalent sensible load was calculated as the product of the OnFraction and the SensibleLoad for each temperature/hour bin.

$$EquSensibleLoad_{ij} = OnFraction_{ij} \times SensibleLoad_{ij}$$

6) The kWh (annual or average peak[7]) in each temperature bin was compiled.

$$kWh_i = \sum_{j=1}^{24} \frac{EquSensibleLoad_{ij} \times \#of\ Micropas\ Hours_{ij}}{SensibleEER_i}$$

Unit annual energy savings. Unit Annual Energy Savings were determined by applying energy use model results to TMY-2 (SCE and NP) or Micropas (PG&E) temperature bin hours.

Average peak demand. Average Peak Demand was calculated by dividing the total kWh predicted by application of the energy use models to TMY-2 (SCE and NP) or Micropas (PG&E) temperature bin hours occurring at peak times by the total hours occurring at peak times. Peak times were defined as 12 PM to 7 PM, Monday through Friday, June through September.

[7] Where average peak consists of weekday hours between noon and 7PM from June 1 through Sept. 30.

Coincident peak demand. Coincident peak demand was derived from the hourly data set. The days with highest watt draws during peak hours were examined to determine whether the unit was cycling or running continuously. For units that were cycling, the connected load was calculated as the recorded outside unit kWh/hr divided by the compressor duty cycle plus the recorded fan kWh/hr divided by the fan duty cycle. The recorded kWh/hr is reported for the hours ending in 4PM, 5PM, and 6PM for matched peak days.

Refrigerant type normalization. Analysis for the PG&E sites included refrigerant type normalization. The measured efficiency of R-22 units was adjusted to estimate performance with refrigerant R-410A. The adjustment was calculated by multiplying the measured EER by the R-410A/R-22 EER ratio documented by Domanski and Payne, 2002 (Figure 2). Refrigerant normalized results are presented in tables 9 and 10, following the measured results.

Results

Results were obtained for seasonal cooling energy consumption (kWh) as well as coincident and average peak power draw (average kWh per hr). These results are presented for standard operation, with advanced furnace fan controls, and normalized to refrigerant R-410A.

Seasonal Cooling Energy Consumption

Table 5. Weather Normalized Seasonal Cooling Energy Consumption

Location	Madera	Yuba	Fresno[8]	Bakersfield	Concord	Las Vegas	Furnace Creek	Victorville
R-22 Standard Unit Annual Energy Usage (kWh)	1490	1385	1298	3059	420	2770	11086	3534
R-410A HDAC Unit Annual Energy Usage (kWh)	1329	1111	847	3262	443	2291	9232	2498
Energy Savings vs. R-22 Standard Unit (kWh)	161	274	451	-203	-23	478	1854	1036
Annual Energy Savings vs. R-22 Standard Unit (%)	**11%**	**20%**	**35%**	**-7%**	**-5%**	**17%**	**17%**	**29%**

Las Vegas, Furnace Creek, Madera, and Yuba all showed substantial Annual Cooling Energy savings of 11% to 29%. Bakersfield and Concord showed increases in Annual Cooling Energy Use of 7% and 5% respectively. The units in Bakersfield and Concord were similar models produced by the same manufacturer. Both units were intensively monitored and it was determined that they performed well below the manufacturers' published data.

The occupant at the Madera site operated the AC with a continuous fan. The sensible EER used to calculate annual and peak energy usage is the sensible EER measured during the compressor cycle only. After the changeout, measured temperature gain between the return and supply plenums relative to attic temperature during long fan only periods indicates leakage into the furnace cabinet or connection to the plenum estimated to be 7% of the cooling airflow. Without the leak, Madera annual energy savings would increase to 257 kWh, or 17%.

[8] No Standard Unit was tested in Fresno. Standard Unit annual and peak energy use was calculated by assuming a unit operating with the average sensible EER of the Standard Units at the Madera and Yuba sites, for the cooling load measured at the Fresno site.

Peak Demand

The peak demand of major importance occurs on hot afternoons and is driven by the diversified air conditioner demand. The diversified peak demand of air conditioners is generally coincident with the peak demand of the system. The hours from 3PM to 6PM are of particular significance. The coincident peak demand for matched peak days are shown in Table 6.

Table 6. Standard vs. HDAC 4PM to 6PM Coincident Peak Demand Summary

	Madera	Yuba	Fresno	Bakersfield	Concord	Las Vegas	Furnace Creek	Victorville
3PM to 4PM								
R-22 Standard Unit Peak Demand (W)	1657	2047	1802	3156	2751	1849	6245	4102
R-410A HDAC Unit Peak Demand (W)	1610	1722	1253	NA	NA	1612	6025	3040
Peak Demand Reduction (W)	47	325	549	Est. 0	Est. 0	237	220	1062
4PM to 5PM								
R-22 Standard Unit Peak Demand (W)	1792	1878	2337	3159	2624	1934	6098	3935
R-410A HDAC Unit Peak Demand (W)	1749	1577	1650	NA	NA	1416	5935	2910
Peak Demand Reduction (W)	43	301	687	Est. 0	Est. 0	518	163	1025
5PM to 6PM								
R-22 Standard Unit Peak Demand (W)	1734	1897	2065	2902	2859	1872	5962	3768
R-410A HDAC Unit Peak Demand (W)	1682	1582	1465	NA	NA	1541	5977	2780
Peak Demand Reduction (W)	52	315	600	Est. 0	Est. 0	331	-15	988

Five of the eight HDAC units demonstrated significant peak demand reduction compared to the standard unit. The Bakersfield and Concord HDAC units performed well below the manufacturers' specification and were no better than the standard units they replaced. At Furnace Creek both the standard and HDAC units were undersized and had the same connected load. The HDAC had more cooling capacity but it was still operating continuously at peak.

Table 7. Standard vs. HDAC Average Peak Demand Summary

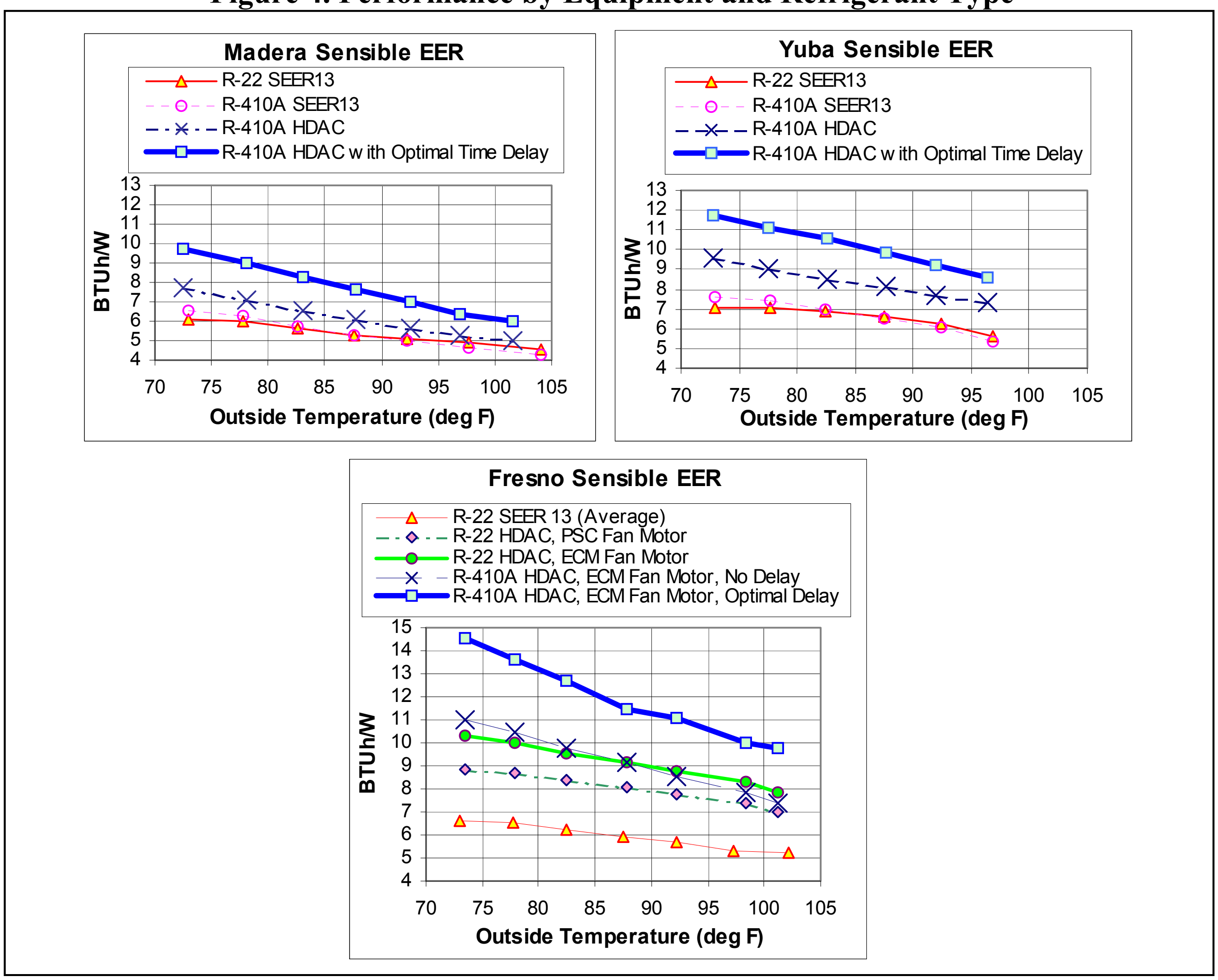
	Madera	Yuba	Fresno	Bakersfield	Concord	Las Vegas	Furnace Creek	Victorville
Standard Unit Average Peak Demand (W)	706	676	625	1888	297	1630	4125	2633
HDAC Unit Average Peak Demand (W)	639	548	414	2073	312	1292	3632	1903
Average Peak Demand Reduction (W)	67	128	211	-186	-16	339	493	729
Average Peak Demand Reduction (%)	9%	19%	34%	-10%	-5%	21%	12%	28%

Average peak demand occurs over a longer period of time and includes days with cooler temperatures. All except the under performing Bakersfield and Concord HDAC units provided significant reductions in average peak demand.

Equipment and Refrigerant Type

Figure 4 displays performance relative to outside temperature with R-22 and R-410A, and with a blower time delay. Performance with an ECM vs. PSC motor is displayed for Fresno.

Figure 4. Performance by Equipment and Refrigerant Type



Fan motor. The Fresno HDAC unit was installed with a permanent split capacitor (PSC) fan motor that drew 616 watts at cooling speed. A similarly sized furnace equipped with an efficient brushless DC fan motor was tested in the laboratory and drew 350 watts at the same airflow and static pressure measured at Fresno. The more efficient motor would decrease watt draw by 266 W, and increase sensible capacity by 908 BTU/hour. The average improvement in steady state sensible EER from using a high efficiency fan motor in the Fresno unit is 13.5%.

Furnace blower control modification. The efficiency improvement from the use of an extended blower off time delay is dependant upon the operating mode of the air conditioner. Units that are operating continuously at peak will see no improvement. The units at Madera, Yuba, and Fresno were cycling at peak and the improvement ranged from 9% to 17% (Table 8).

Table 8. Extended Furnace Fan Time Delay Efficiency Improvement Potential

	Madera		**Yuba**		**Fresno**	
Control Mode	Standard Delay	Optimum Delay	Standard Delay	Optimum Delay	Standard Delay	Optimum Delay
HDAC Unit Delay Length (minutes)	1.5	7	0	20	0.75	5
R-410A Standard Unit Annual Energy Usage (kWh)	1510		1387		1323	
R-410A HDAC Unit Annual Energy Usage (kWh)	1329	1068	1111	926	847	720
Energy Savings (kWh)	181	442	276	461	476	603
R-410A Standard Unit Annual Average Sensible EER	5.2		6.5		5.8	
R-410A HDAC Unit Annual Average Sensible EER	5.9	7.3	8.1	9.7	9.1	10.7
Annual Energy Savings based on Sensible EER (%)	12%	29%	20%	33%	36%	46%
Average Peak Demand Reduction (%)	12%	29%	20%	34%	36%	45%

Refrigerant type. Tables 9 and 10 display refrigerant normalized average and coincident peak demand for the PG&E sites. The HDAC units demonstrate 9% to 34% lower coincident, and 12% to 36% lower average peak demand compared to R-410A Standard units.

Table 9. Refrigerant Normalized Average Peak Demand Summary

	Madera	**Yuba**	**Fresno**
R-22 Standard Unit Average Peak Demand (W)	706	676	625
R-410A Standard Unit Average Peak Demand (W)	723	689	646
Average Peak Demand Increase due to R410A (W)	**17**	**13**	**21**
R-410A HDAC Unit Average Peak Demand (W)	639	548	414
Average Peak Demand Reduction vs. R-410A Standard Unit (W **[%]**)	84 **[12%]**	141 **[20%]**	232 **[36%]**

Table 10. Refrigerant Normalized Coincident Peak Demand Summary

	Madera	Yuba	Fresno
3PM to 4PM			
R-22 Standard Unit Peak Demand (W)	1657	2047	1802
R-410A Standard Unit Peak Demand (W)	1767	2160	1912
Peak Demand Increase due to R410A (W)	**111**	**112**	**110**
R-410A HDAC Unit Peak Demand (W)	1610	1722	1253
Peak Demand Reduction vs. R-410A Standard Unit (W **[%]**)	157 **[9%]**	438 **[20%]**	659 **[34%]**
4PM to 5PM			
R-22 Standard Unit Peak Demand (W)	1792	1878	2337
R-410A Standard Unit Peak Demand (W)	1916	1986	2491
Peak Demand Increase due to R410A (W)	**124**	**108**	**154**
R-410A HDAC Unit Peak Demand (W)	1749	1577	1650
Peak Demand Reduction vs. R-410A Standard Unit (W **[%]**)	167 **[9%]**	409 **[21%]**	842 **[34%]**
5PM to 6PM			
R-22 Standard Unit Peak Demand (W)	1734	1897	2065
R-410A Standard Unit Peak Demand (W)	1849	2004	2201
Peak Demand Increase due to R410A (W)	**115**	**107**	**136**
R-410A HDAC Unit Peak Demand (W)	1682	1582	1465
Peak Demand Reduction vs. R-410A Standard Unit (W **[%]**)	167 **[9%]**	421 **[21%]**	736 **[33%]**

Conclusions

- Existing single speed air conditioners that meet the HDAC Peak Energy Efficiency – Sensible (PEERs) specifications can reduce annual cooling energy use and peak demand by 20% or more in hot dry climates.
- Control modifications to the furnace fan timing can reduce annual cooling energy use and peak demand an additional 9% to 17%. The highest savings are accomplished on units with variable speed brushless DC fan motors.
- Migration from refrigerant R-22 to R-410A over the next 15 years will increase average peak demand by 5% to 10% in hot climates unless offset by higher efficiency equipment. The HDAC PEERs standard provides a specification for performance at peak regardless of refrigerant type.
- Efficient performance is obtained by carefully matching the condensing unit, evaporator coil and furnace. Equipment features common to units that perform well are more efficient heat exchangers and brushless DC fan motors.
- Equipment selection and fan timing control modifications can significantly increase the Sensible Heat Ratio.
- The best performing unit in the PG&E study contained a microchannel condenser coil. This supports conclusions from the CEC PIER HDAC study (SCE, PEG, and BKI 2007), which found improved performance with microchannel condenser and evaporator coils.
- The HDAC units in the PG&E study performed at 20% to 30% below the manufacturers' published data for sensible EER. Manufacturers' published data is not the result of laboratory testing, but rather is modeled performance and limited testing. An additional test point should be created to certify performance at peak conditions.

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