Air-Cooled Unitary Single-Zone VAV Performance Evaluation

Carrier Centurion PD Series Performance Evaluation

Provided by

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Introduction

This paper summarizes the findings of a combined performance monitoring and simulation analysis project designed to assess the potential benefit of new single-zone unitary rooftop VAV equipment. The monitored equipment featured a five ton Carrier single-zone unitary heat pump system equipped with a digital scroll compressor, variable speed drive controlling the indoor fan, and demand control ventilation. While the actual arrival of single-zone unitary VAV to the HVAC market is quite recent, its potential performance advantages has been anticipated through previous detailed simulation analysis[1]. This work reports the results of the first in-field performance measurements and side-by-side comparison of this new system type with two other popular Carrier package rooftop systems.

Background and Methodology

Unitary Equipment represents a majority of the small commercial and school HVAC markets. While high efficiency units are available (SEER 14-15), the majority of this equipment consists of constant volume compressors and fans. Since these units are sized for peak conditions, significant savings are possible by improving part load operations via variable capacity compressors and variable-speed indoor fans.

During the spring of 2009, Russell Sigler Inc. of Arizona approached Quest Energy Group to design and conduct an in-field study to measure the energy performance of Carrier's new Centurion 48/50PD product series, a five ton single-zone unitary VAV heat pump system with demand control ventilation, first offered by Carrier in July 2008. The study also included a side-by-side in-field performance comparison with two other popular Carrier systems, i.e., the Centurion 50PG Series, a high efficiency single-zone unitary constant volume heat pump and the Carrier 50TJQ, a standard efficiency unitary rooftop heat pump. During the summer of 2009, all three systems were installed in identical side-by-side classrooms at a middle school in Anthem Arizona.

Table 1 Carrier heat pump test unit characteristics

	Class Room#	Description	Refrigerant	Indoor Fans	SEER	Compressor Type	CO2
Unit 1	109	PD	R-410A	VSD	14.8	Digital Scroll	Yes
Unit 2	115	PG	R-410A	CV	14.8	Scroll	No
Unit 3	113	TJQ	R-22	CV	10	Scroll	No

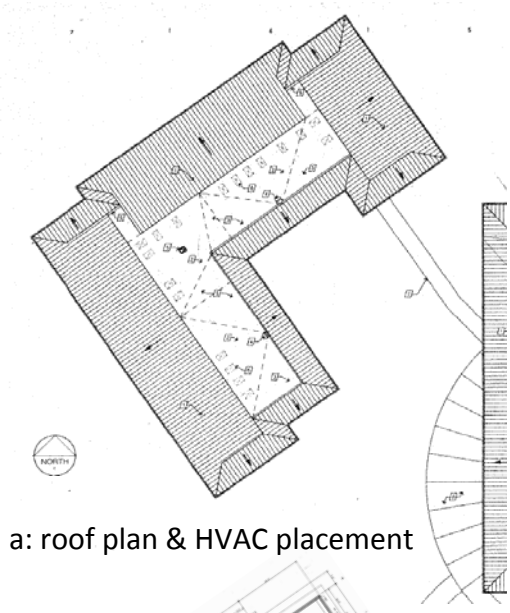
Following an initial test period during the summer of 2009, detailed monitored data were collected during the first few weeks of the 2009-10 school year. A detailed building simulation model of the affected classrooms was prepared using the DOE2.2/eQUEST program and calibrated to the monitored test results from all three classrooms and HVAC systems. The calibrated simulation model was then used to estimate annual performance for the HVAC systems under typical annual operating conditions.

[1] *Single-Zone Staged Volume HVAC Systems.* J.J. Hirsch & Assoc., report of research for Southern California Edison, 2005

Classroom Building Description

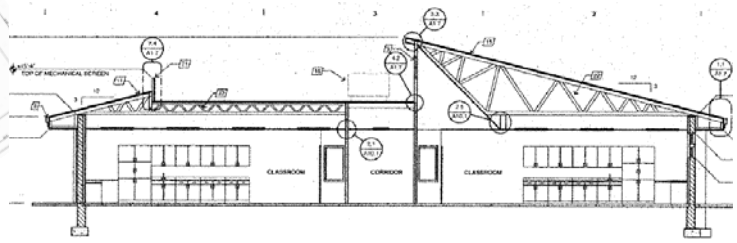
Project Name:	Anthem School, Building 300
Location:	Anthem AZ, 1930 ft elevation
Use:	K-8 School
Architects:	Orcutt / Winslow Partnership, Phoenix, AZ
Mechanical:	Clark Engineers SW, Phoenix, AZ
Constructed:	1998
Square Footage:	31,850 sf (total)

Figure 1 Classrooms location, plans and details



a: roof plan & HVAC placement

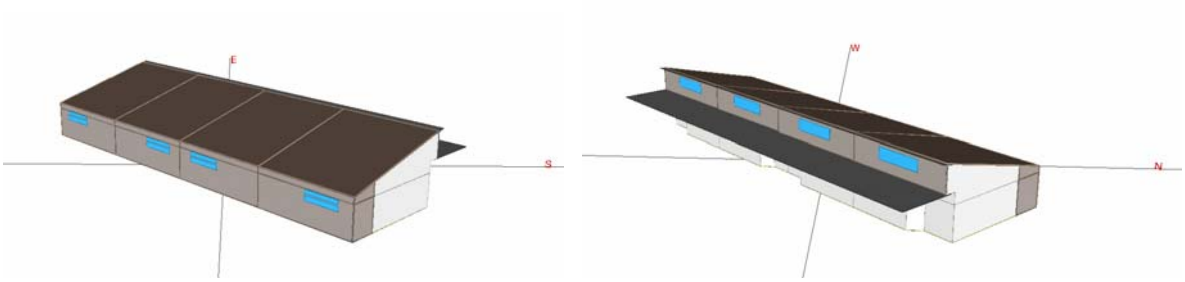
b: aerial photo showing classroom Building 300



c: classroom section (see section line at left)

d: classroom locations (hatched area) & section line (see above)

Figure 2 Three-Dimensional classrooms simulation model



Classroom 3-D simulation model, NW elevation and SE elevation; light-colored surfaces are interior surfaces adjacent to other conditioned spaces (modeled as adiabatic); darker surfaces are exterior surfaces; compare Figure 1c and 1d above.

Field Test Data

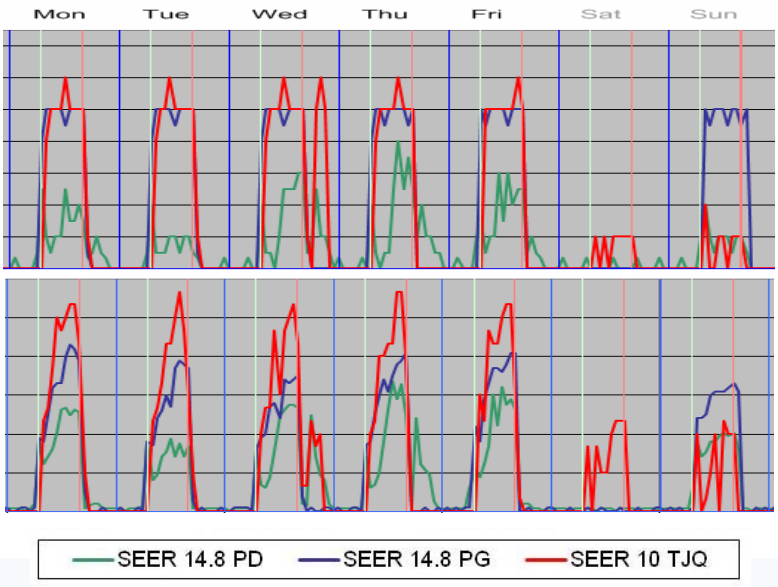
The following data were recorded every 15 minutes:

Unit kW demand:	Zone temperature (°F)
Total Unit Power	Zone humidity (% RH)
Indoor Fan Power	Zone dew point (°F)
Outdoor air temp (°F)	CO_2 levels

Figure 3 Monitored Test Data

a: total unit power

b: indoor fan power



Field Test Results

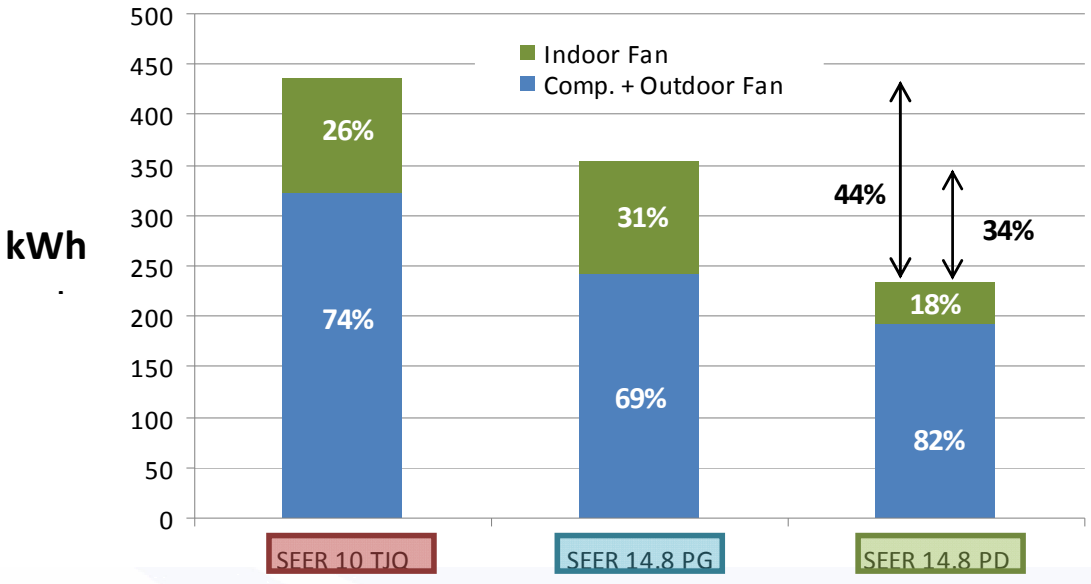
Table 2 and Figure 4 below summarize the measured energy use and savings for the period September 15, 2009 through October 2, 2009.

Table 2 Measured energy use and savings for period Sep 15 – Oct 2

Unit	Comp. + Outdoor Fan		Indoor Fan		Total	
	kWh	% of Total	kWh	% of Total	kWh	% of Total
SEER 10 TJQ	321	74%	114	26%	436	100%
SEER 14.8 PG	242	69%	111	31%	353	100%
SEER 14.8 PD	192	82%	41	18%	233	100%

SEER 14.8 PD Savings						
	Compressor + Outdoor Fan		Indoor Fan		Total	
	kWh	%	kWh	%	kWh	%
vs SEER 10 TJQ	129	40%	73	64%	203	47%
vs SEER 14.8 PG	50	21%	70	63%	120	34%

Figure 4 Measured energy use and savings for period Sep 15 – Oct 2



Calibrated Energy Simulation Model Results

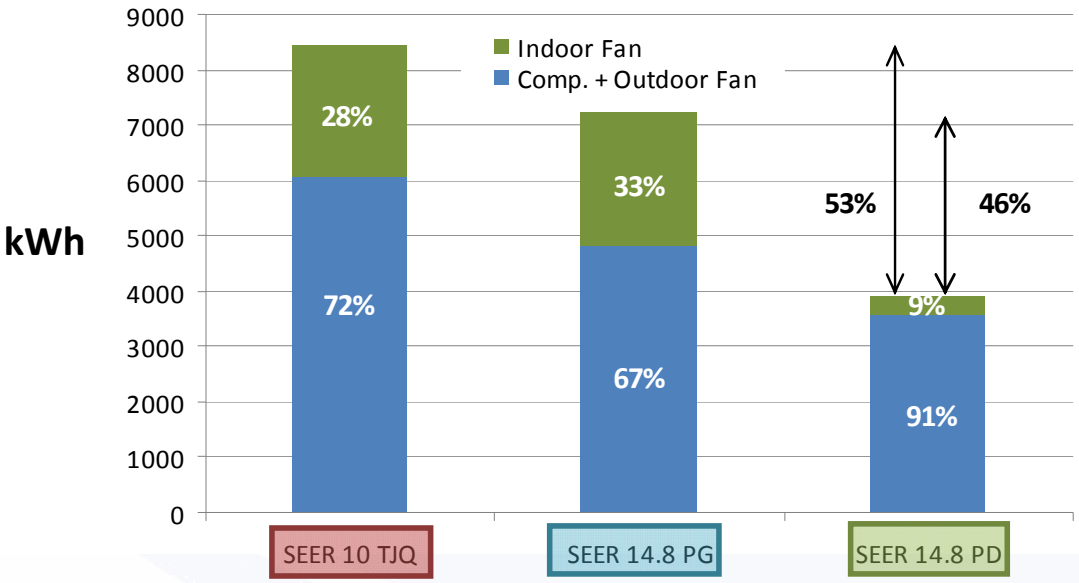
Tables 3 and 4 and Figure 5 below summarize the simulation-predicted annual energy use and savings based on an assumed 1800 occupied hours during a nine month school year.

Table 3 Simulation-predicted annual energy use and savings

Unit	Comp. + Outdoor Fan		Indoor Fan		Total	
	kWh	% of Total	kWh	% of Total	kWh	% of Total
SEER 10 TJQ	6047	72%	2395	28%	8442	100%
SEER 14.8 PG	4835	67%	2402	33%	7237	100%
SEER 14.8 PD	3591	91%	338	9%	3929	100%

SEER 14.8 PD Savings						
	Compressor + Outdoor Fan		Indoor Fan		Total	
	kWh	%	kWh	%	kWh	%
vs SEER 10 TJQ	2456	41%	2057	86%	4513	53%
vs SEER 14.8 PG	1244	26%	2064	86%	3308	46%

Figure 5 Simulation-predicted annual energy use and savings



The following simple payback periods are estimated assuming 1800 annual occupied hours (2400 HVAC operating hours) which is representative of a typical nine-month school schedule and 5800 annual occupied hours (6000 HVAC operating hours) which is representative of many retail facilities and 10 to 15 cents per kWh average electric cost.

Table 4, Estimated simple payback* based on annual simulation

	School Schedule	Retail Schedule
	1800 (2400) hrs (6a-4p, 5dys, 9mo)	5800 (6000) hrs (6a-9p, 7dys, 12mo)
10¢/kWh	5.3 yrs	2.3 yrs
15¢/kWh	3.5 yrs	1.5 yrs

** assumes $350/ton incremental cost, no future utility price escalation and no utility sales tax*