General Services Administration
Public Buildings Service

GSA

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HIGH-PERFORMING COMMERCIAL RTUs

Advanced RTU Yields Substantial Savings

Rooftop units (RTUs)—also known as packaged air conditioners—are used to condition nearly half of all commercial floor space in the United States and constitute the most common HVAC equipment found in low-rise commercial structures. RTUs are easy to install and have low first costs but legacy models, built with constant speed drives and without advanced controls, are inherently inefficient. To stimulate the market for higher-performing RTUs, the Department of Energy's (DOE's) Building Technologies Office issued a challenge to manufacturers to build an RTU 50% more efficient than ASHRAE 90.1 standards. The first RTU to meet DOE's "High Performance RTU Challenge"specification was installed in a GSA warehouse in Fort Worth, Texas, and compared, under real-world conditions, with an existing RTU typical of those in the field. Researchers from the Pacific Northwest National Laboratory (PNNL) found that the seasonal energy efficiency ratio (EER) of the "challenge RTU" was 16% higher than the baseline unit, which was already 4% more efficient than ASHRAE 90.1 standards. When ventilation energy from both units, with fans running 24-hours a day, was taken into account, savings increased to 26%. A concurrent study by PNNL of advanced RTUs at two Florida supermarkets demonstrated energy savings of 31% and payback of 3.8 years.[1]

The GPG program enables GSA to make sound investment decisions in next generation building technologies based on their real world performance.

INTRODUCTION

"Because the performance ratings at standard conditions do not necessarily represent the 'true' seasonal energy efficiency, this field test provides a more realistic performance comparison, and demonstrates that savings are still significant compared to standard RTUs."

—Srinivas Katipamula, Ph.D.
Advanced Building Controls,
Energy and Environment Directorate,
Pacific Northwest National Laboratory

5-TON RTU
Specifications

RATED EER

Rheem Model #RLNL-A060CK	**11.4**
Challenge RTU Daikin Model #DPS005A	**12.3**
ASHRAE 90.1 (2010 and 2013)	**11.0**

MEASURED SEASONAL EER

Testbed Standard Rheem Model #RLNL-A060CK	**10.5**
Challenge RTU Daikin Model #DPS005A	**12.2**

MEASURED SEASONAL EER WITH FAN VENTILATION

Testbed Standard Rheem Model #RLNL-A060CK	**7.2**
Challenge RTU Daikin Model #DPS005A	**9.1**

What Is This Technology?

VARIABLE-SPEED VERSUS CONSTANT-SPEED

The challenge RTU, a Daikin Rebel #DPS005A, has one variable-speed inverter-driven compressor, composite condenser fans with variable-speed electronically commutated motors, and controls that can be integrated with optional BACnet or LonMark building automation systems (BASs). Unlike conventional units, the challenge RTU modulates the supply fan in response to zone conditions and controls the compressor speed to maintain supply-air temperature set points. By contrast, the baseline unit, a Rheem #RLNL-A060CK, uses a constant-speed compressor motor and a constant-speed supply fan motor. Eighteen kilowatt (kW) electric-resistance heating coils generate heat, while the challenge RTU operates as a heat-pump, using refrigerant to transport energy from the outside to the inside. The challenge unit also offers a hybrid heat option—18 kW of auxiliary electric heat for use during extremely cold weather. The RTUs compared here are the same size (5-ton), have the same external pressure drop, and are intended for spaces with similar load profiles. The RTU challenge unit comes with an outdoor economizer that introduces outdoor air into the space whereas the baseline unit does not and therefore recirculates indoor air only.

What We Did

STATE-OF-THE-ART RTU COMPARED IN REAL-WORLD SETTING WITH "STANDARD" LEGACY UNIT

In 2011, DOE's Building Technologies Office developed a specification for high-performance RTUs with capacity ranges between 10 and 20 tons. Shortly thereafter, a state-of-the-art RTU from Daikin met this "RTU challenge." A 5-ton version was installed in a General Services Administration (GSA) warehouse in Fort Worth, Texas, to be compared, under real-world conditions, with an existing "standard unit," which had been in operation there for 5 years. Both RTUs had the same rated cooling capacity of 5 tons and served side-by-side office spaces with similar footprints. Once both units were in place, researchers from PNNL monitored them simultaneously for a period of ten months, from December 2015 to September 2016, using sensors to measure dry-bulb temperature and relative humidity for outdoor air, return air, mixed air, and supply air. They also measured total RTU power consumption and ventilation energy. Sensor measurements, together with several control signals, were monitored at 1-minute intervals. The average daily energy efficiency ratio (EER) was computed for each unit, using monitored data, and seasonal cooling efficiency (SEER) was calculated for the entire monitoring period.

FINDINGS

26% REDUCED ENERGY USE The seasonal energy efficiency of the 5-ton challenge RTU was 16% higher than the baseline standard unit. Supply fans in both units ran 24x7, therefore when ventilation energy was taken into account, energy savings in the challenge RTU increased to 26%. Models developed by PNNL[2] predicted that in hot and humid climates, the challenge unit would consume less energy than it actually did—about 40% less than a standard unit with a constant-speed supply fan and single-stage mechanical cooling. That savings were lower than predicted might have been influenced by the following:

- The two units at the test bed served different loads, whereas in the simulation they served the same load.
- The baseline unit at the test bed had higher operating efficiency than the simulation: EER of 11.4 vs 11.
- The baseline unit recirculated 100% of the air, whereas the challenge unit introduced outside air, which creates additional friction and can consume more energy.
- The simulation assumed a 10-ton unit, which was slightly more efficient than the 5-ton unit: EER of 12.5 vs 12.3.

INFRASTRUCTURE REINFORCEMENT AND OTHER ADJUSTMENTS NEEDED TO ACCOMMODATE CHALLENGE UNIT The challenge unit had a different footprint from the legacy RTU and was considerably heavier, requiring roof infrastructure reinforcement. Commissioning required the manufacturer's distributor to make minor changes to the initial startup configuration and the local GSA building automation system support team also had to modify the Tridium network and the power sensors to correct issues related to trending and power meter accuracy.

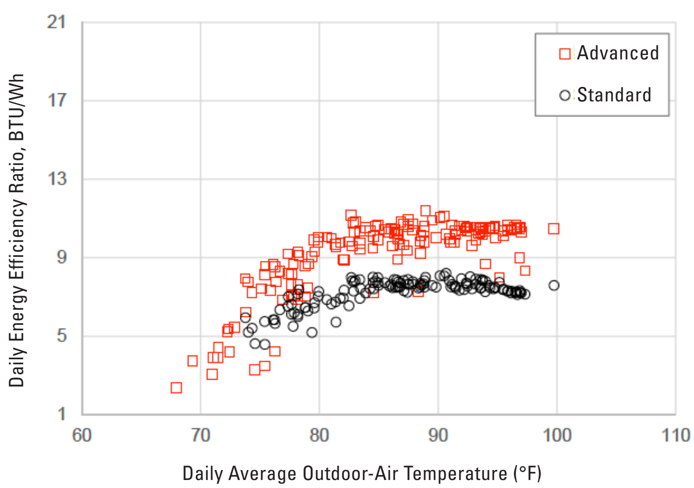
EQUIVALENT OPERATIONS AND MAINTENANCE Over a 12-month period, maintenance requirements for the challenge unit were similar to that of the baseline standard unit.

CONCURRENT PNNL STUDY DEMONSTRATED 3.8 YEAR PAYBACK Although cost data was unavailable for the GSA demonstration, a concurrent PNNL study of high-performance RTUs at two Florida supermarkets found payback of 3.8 years.[1] PNNL has developed an interactive cost calculator[4] to estimate payback periods for RTUs based on energy use and incremental costs.

CONSIDER FOR NEW CONSTRUCTION AND END-OF-LIFE RETROFITS High-performance RTUs should be considered for new-construction and end-of-life retrofits. Modeling conducted by PNNL indicates that savings will be greatest in hot, humid climates. Installation costs for an advanced RTU will vary by site, and installation may be more expensive in retrofits, where infrastructure reinforcement or duct changes may be needed.

Energy Efficiency Ratio as a Function of Outdoor Air Temperature

Advanced RTU exceeds baseline efficiency, particularly at higher outdoor air temperatures



CONCLUSIONS

These Findings are based on the reports, "Field Evaluation of the Performance of the RTU Challenge Unit: Daikin Rebel" which is available from the GPG program website, www.gsa.gov/gpg

For more information, contact GSA's GPG program gpg@gsa.gov

What We Concluded

RELATIVELY LIMITED DEPLOYMENT POTENTIAL FOR GSA

Though 80% of GSA floor space is in large buildings that are cooled by central plants, RTUs are still found throughout the portfolio in low-rise buildings, such as warehouses and land ports of entry (LPOEs). As is common with many technologies, the RTU market has favored low first costs and ease of installation over long-term cost-effectiveness. DOE's RTU challenge has stimulated the market and produced a more cost-effective and efficient RTU. The challenge unit deployed in Texas had energy savings of 26%; the Florida units saved 31% and achieved a 3.8 year payback. High-performance RTU's should be considered for all end-of-life retrofits and new construction.

For RTUs that have not yet reached end of life, advanced rooftop control (ARC) retrofits that have integrated air-side economizers, supply-fan speed controls, and demand-controlled ventilation should be considered. A PNNL field study[4] of 66 RTUs retrofitted with advanced controls found energy savings ranging from 22% to 90%, with an average 57% savings and 3 year payback (@ $0.10/kWh).

Reference to any specific commercial product, process or service does not constitute or imply its endorsement, recommendation or favoring by the United States Government or any agency thereof.

Footnotes

[1]Field Evaluation of the Performance of the RTU Challenge Unit: Daikin Rebel, S Katipamula, W Wang, H Ngo, RM Underhill, Pacific Northwest National Laboratory, PNNL-23672, March, 2015

[2]Part-load Performance and Characterization and Energy Savings Potential of the RTU Challenge Unit, W Wang, S Katipamula, Pacific Northwest National Laboratory, PNNL-22720, September 2013

[3]RTU Comparison Calculator, Pacific Northwest National Laboratory, https://www.pnnl.gov/uac/costestimator/main.stm

[4]Advanced Rooftop Control Retrofit: Field Test Results, S Katipamula, W Wang, H Ngo, RM Underhill, D Taasevigen, R Lutes Pacific Northwest National Laboratory, PNNL-22656, July, 2013

Technology for test-bed measurement and verification provided by Daikin Applied