# DR12.17: Field Testing of Climate Appropriate Air Conditioning Systems

## SIGNIFICANT LOAD SHED POTENTIAL WITH VC-RTU'S

This study examined variable capacity technology as applied within unitary packaged rooftop air-conditioning units. The purpose was to provide a resource for evaluating and potentially implementing a program for variable capacity rooftop units to promote energy efficiency, peak electrical load reduction, and/or increased flexibility (such as for demand response) in commercial space conditioning equipment.

An objective of this project was to document practical challenges associated with installation and operation of this new type of system. With seven distinct modes of operation and a number of variable speed components the VC-RTU is significantly more complex than a conventional rooftop unit. Engineers, contractors, and end users are not familiar with the capabilities and setup requirements for these systems. The lessons learned through this study broaden our understanding of the technology, and should support the evolution of design guidelines, industry standards, and technology function.

Additionally, this project evaluates and demonstrates new potential for otherwise unrealized demand response capability from new-to-market variable capacity commercial HVAC systems in Southern California. Southern California Edison (SCE) and their customers will benefit from this effort by unlocking a new resource for both utility based demand response and customer directed demand management.

The results of this study demonstrate VC-RTU systems achieve superior high energy efficacy at full and part-load conditions. Observations support a 30% reduction in energy usage at peak load. Given additional capabilities to respond to a demand response (DR) signal while optimizing its performance, overall average savings for energy efficiency may be enhanced with the DR functionality, providing a good fit for an integrated EE/DR offering in the future.

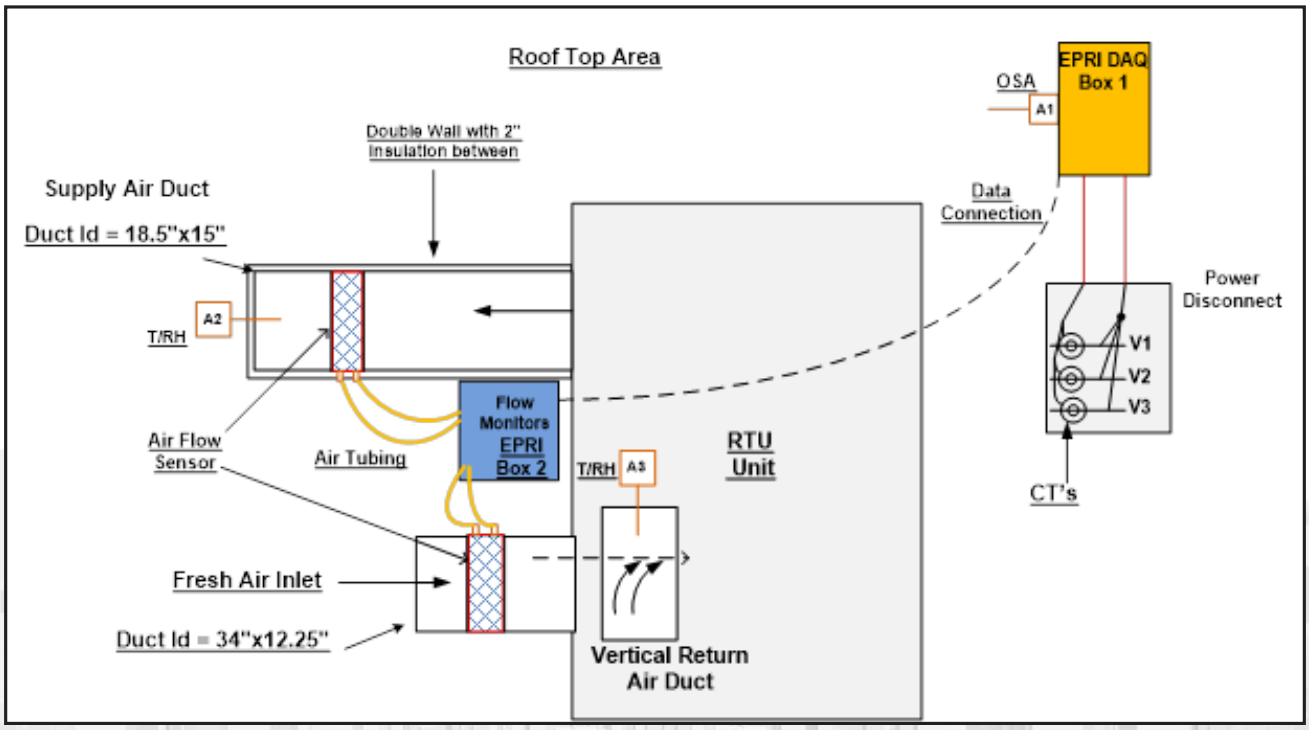


Figure 1: Monitoring Plan, Line Diagram

## EQUIPMENT SPECIFICATIONS VC-RTU

**Model:** Small Cabinet 004

The following specifications were provided:

**Gross cooling capacity:** 4.0 tons
**Nominal Airflow:** 1500 CFM
**EER:** 12.4
**IEER:** 17.0
**High temp. capacity @ 47°F:** 43 MBh

**COP @ 47°F:** 8.9

**Low temp. capacity @ 17°F:** 24 MBh

**COP @ 17°F:** N/A

Figure 2: Variable Capacity Rooftop Unit

# What Is This Technology?

## EQUIPMENT MODULATES CAPACITY TO MEET ACTUAL CONDITIONS

In cooling operation, variable capacity VC-RTU equipment can adjust system components to accommodate either the sensible or latent cooling loads. In part load operation, variable speed equipment can operate at a reduced capacity and consume less energy while matching the loads of the space.

In humid climates, dehumidification is essential to occupant comfort, and achieving proper dehumidification can result in high energy usage. Both overcooling a supply air and then reheating the air entering the space are approaches used to achieve proper dehumidification which consume high amounts of energy. A variable capacity VC-RTU system modulates system components to achieve a desired latent capacity without consuming extra energy.

In heating operation, some variable capacity VC-RTU systems can provide higher heating capacities at lower outdoor temperatures than similarly sized fixed speed systems by "over-speeding" the compressor of the system. The ability to provide higher heating capacities reduces a system's dependence on backup heat. Reducing the use of electric backup heat can result in high energy savings and potentially peak demand reduction. At part load conditions, variable speed VC-RTU equipment can operate at reduced compressor speeds and higher efficiencies than fixed speed systems in heating operation.

# What We Did

## 4-TON VARIABLE CAPACITY RTU INSTALLED AND MONITORED

The VC-RTU system was installed and commissioned during August and September 2014. Additional adjustments to the thermostat were made past the commissioning date (by the occupants, as the thermostat was not locked). The monitored data for year 2015 is used in this analysis and data from 2014 is not analyzed as data was skewed with the commissioning process.

There were three (3) performance parameters of the VC-RTU that were monitored and recorded:

- Electrical; Power draw (kW), Energy consumption (kWh), Voltage (V), Current (A) and Power Factor (PF)
- Thermal; Temperature (T) and relative humidity (RH) measurement in the class room, as well as
- Air flow: Supply air return air of the system (CFM)

# FINDINGS

**POTENTIAL HVAC EFFICIENCY GAINS:** The reduction at peak is approximately 30% (0.85 kW/ton to 0.6 kW/ton). This is one of the significant advantages of using VC units where system components can be modulated to keep demand in check (although modulation is done primarily for efficiency purposes). A check on supply air temperatures during this same period revealed that on average the VC unit provided 5°F colder air than the fixed-speed unit (55°F versus 60°F). Air flow measurements for VC unit showed reduced volumetric flow rate which resulted in the colder air and potentially contributed to lower power draw. The compressor speed could also have been modulated but the compressor speed (power) wasn't monitored individually.

**IMPLICATIONS FOR DEMAND RESPONSE:** Data seems to suggest that the VC unit is more responsive to load conditions and possibly more adaptable to DR control strategies. Full testing strategies were not conducted at this time, but future program models would inform a recommendation for specific scenarios.

**TECHNOLOGY CHALLENGES:** The contractor responsible for design, installation, and commissioning of the project encountered several challenges with application of the technology. The issues were mostly minor, and can be attributed to the lack of familiarity with the advanced system setup and operation on part of those involved with installation and startup.

**EDUCATION IS VITAL:** While these technologies offer the possibility of significant energy savings, it is very important that the industry develop stronger capabilities surrounding the proper application of these opportunities. The research team recommends that any efforts to advance the broader market adoption of these solutions must be accompanied by strong educational components, and should incorporate mechanisms that actively facilitate proper setup and commissioning. Utilities, manufacturers, regulators and industry associations need to work closely together in this regard because the higher degree of complexity with most advanced rooftop unit introduces more opportunity for failures to obtain its potential energy savings and flexible capacity response.

**LIMITED COST-EFFECTIVENESS:** The baseline FS-RTU equipment cost was $5,731. From the equipment cost alone, the VC system had a premium of $9,056. The cost premium might be slightly higher if a 4-ton VC cost was included but for purposes of the analysis it is assumed that 3-ton system costs equal to the 4-ton system. Using the 4-ton system as a common size the savings in energy found in this study is 582 kWh not enough to make a reasonable economic payback period.

# LESSONS LEARNED

- Anticipate essential equipment setup issues: The unit was initially setup so that the supply fan would run at full speed during all hours, regardless of cooling load, and whether the space was occupied. Before this issue was resolved, the setup had basically eliminated one of the greatest opportunities for energy savings with advanced rooftop units, and had added a number of unnecessary operation hours.
- Configuration needs to be optimized: The modulating damper was not properly configured, and was setup to remain in a fixed position for all fan speeds. This resulted in excess ventilation at high fan speeds, and inadequate ventilation at lower fan speeds.
- Proper controls that comply with EE standards: The VC-RTU is delivered with a custom thermostat that controls the system's unique features in the appropriate way and allows for seven-day scheduling of occupancy and set points. Initially, the contractor did not utilize this thermostat because it used an unfamiliar digital control interface. Instead, a series of timers and override switches were installed to control the unit. Incidentally, this arrangement is not allowed by Title 24 – California's Building Energy Efficiency Standards require the use of programmable thermostats
- Industry education and training needed: Identified issues highlight the fact that many industry practitioners are not familiar with the unique needs for advanced rooftop air conditioners and heat pump systems

# CONCLUSIONS

## LESSONS LEARNED (Cont.)

- Availability of small-capacity units: The rooftop unit prior to installing the VC-RTU was a 2.5-ton unit; the minimum capacity for this unit stated at 4 tons, which was installed in its place.

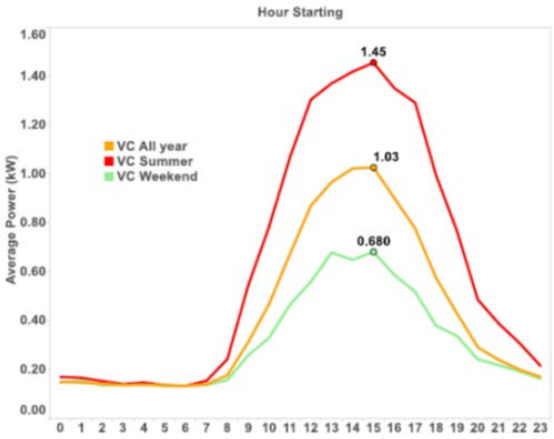


*Figure 4: Load Shapes for VC-RTU*
*Based on the load shape it can be deduced that the system was set in occupied mode in between 8am and 6pm. The lower average power draw in between 6pm and 8am indicate that the fan was running all the time which provides an opportunity to save energy.*

These Findings are based on the report, "Field Testing of Climate Appropriate Air Conditioning Systems" which is available from the ETCC-CA website, www.etcc-ca.com

Footnotes
[i]Field Testing of Climate Appropriate Air Conditioning Systems. Emerging Products (SCE), December 2017.

# What We Concluded

## VC UNITS OFFER STRONG ENERGY SAVINGS POTENTIAL BUT INDUSTRY EDUCATION IS KEY

The VC-RTU has a number differentiating features that offer significant energy savings. The most important of these are the variable speed compressor and supply fan, which allow the unit to fluidly match capacity to cooling load. At part speed the VC-RTU can achieve exceptional efficiency – the system averaged around EER SENS = 17.5 for operation below 50% capacity, and reached as high as EER SENS = 40 for some periods.

In January, the unit spent a significant amount of time at part speed. In April and July, part capacity modes accounted for a much smaller number of operating hours, and the unit mostly operated continuously. This study confirms that the VC-RTU can achieve very high efficiency at certain part load conditions and achieves good savings at peak cooling conditions compared to the standard alternative. The measurements recorded in this study indicate that the unit uses 30% less electricity at peak than a minimum standard unit would in the same scenario.

Full speed operation accounted for nearly 50% of all operating hours in April and practically 100% of operating hours in July. As a result, the unit had little opportunity to gain from some of its advanced features. Moreover, since the VC-RTU achieves much higher efficiency at part capacity, a system that is oversized for the application should generally use less energy than a system that is "right sized".

This field installation offered many lessons for future application of advanced rooftop unit technologies. The experience highlights the need for increased education and training for industry practitioners. Initially, there were many problems with the equipment setup that caused the system to use substantially more energy than it should have. None of the problems resulted from technical failure for the unit, but the complexity for setup compared to a conventional rooftop air conditioner was a significant challenge for the installing contractor.[i]