Army Research Laboratory Develops Method to Improve Efficiency of Multizone Air Handlers

Approach Reduces Energy Consumption Without HVAC Demolition or Occupant Disturbance

TO IMPROVE ENERGY efficiency throughout the Department of Defense's (DoD) large inventory of aging constant volume multizone air handling units, researchers from the U.S. Army Corps of Engineers Construction Engineering Research Laboratory (CERL) have developed a variable volume retrofit approach that is viable, is readily implemented, and in many circumstances, will be cost-effective when added to a controls retrofit.

The current design practice for most new heating, ventilation, and air-conditioning (HVAC) systems that serve multiple zones is to use variable air volume (VAV) systems with VAV boxes in each zone. The DoD has a large inventory of energy inefficient constant volume multizone air handling units, an older technology also used to serve multiple zones. As these multizone units continue to age, the control systems associated with the units are often upgraded due to obsolescence or replaced due to failure. Due to the common need to perform a controls retrofit on multizone units, CERL researchers wanted to determine if it would make sense to convert the constant volume multizone units to variable volume multizone units as part of the controls retrofit. In other words, would the cost of bolstering the controls retrofit by adding variable frequency drives (VFD), outside air flow stations and some additional programming effort pay for itself in energy savings?

CERL, with funding provided by the DoD's Environmental Security Technology Certification Program (ESTCP), researched this question by retrofitting five multizone air handling units, two of which were located at CERL in Champaign, Illinois and the other three were located at Fort Bragg, North Carolina, and evaluating one year's worth of operational data. The objective of the demonstration was to validate the effectiveness of the retrofit approach in reducing energy consumption, analyze the economics/comfort associated with the upgrade, and develop technical guidance to help installations perform successful retrofits.

CONTINUED ON PAGE 32

Two of the five multizone air handling units retrofitted during this ESTCP-sponsored research effort were located at CERL in Champaign, Illinois.

The Basics About the Army's Construction Engineering Research Laboratory

A CRITICAL COMPONENT of the Army's Engineer Research and Development Center (ERDC), CERL develops innovative technologies to provide suitable facilities and realistic training lands for the DoD. Products and services from CERL research enhance the Army's ability to design, build, operate and maintain its installations and contingency bases and ensure environmental quality at the lowest lifecycle cost. CERL facilities support the Army's training, readiness, mobilization and sustainability missions. An adequate infrastructure and realistic training lands are critical assets to installations in carrying out their military mission.

CERL programs center on military installations, contingency bases and sustainable ranges and lands, additional focus areas include enhancing socio-cultural understanding in theater operations and improving civil works facilities and infrastructure. Specific CERL focus areas include:

- Sustainable Installations
- Military Ranges and Lands
- Resilient Facilities and Infrastructure
- Smart Sustainable Materials
- Installation Decision Support
- Urban and Stability Operations

As the owner of approximately one billion square feet of buildings, the Army must ensure that its facilities are cost-effective, durable, environmentally sustainable and flexible enough to support changing missions. Army facilities must provide quality living, working and training environments for Soldiers and their families. CERL research in military installations focuses on design, materials and delivery of facilities as well as improving the efficiency of business practices and operations, maintenance and repair. These improvements will be achieved by using innovative technologies, expanding automation and streamlining business processes.

DoD uses over 25 million acres of land plus extensive areas of sea and air space in support of military training and testing missions. However, resource degradation and environmental constraints within the fence line and developmental pressures surrounding installations combine to compromise and limit training and testing activities on military lands. CERL research capabilities provide tools for the long-term sustainment of training ranges and lands critical to military readiness. CERL research in sustainable ranges and lands has two goals:

1. Provide knowledge, tools and improved practices to support sustained military use of lands, seas and airspace.
2. Support military stewardship of natural and cultural resources on these lands.

CERL research enhances and expands understanding of the impacts training and testing activities have on resources.

To meet its research challenges, CERL state-of-the-art test facilities include:

- Triaxial Earthquake and Shock Simulator
- Paint Technology Center
- Controlled Archeological Test Site
- Environmental Processes Laboratory
- Microbiology Laboratory
- Structural Load Floor
- Air Pollution Laboratory
- Proton Exchange Membrane Fuel Cell with Electrolyzer
- Environmental Chemistry Laboratory
- Chem-Bio Laboratory
- Materials Laboratory
- Center for the Advancement of Sustainability Innovations
- Synthetic Biology Laboratory
- ERDC Forward Operating Base Laboratory
- Army Facilities Corrosion Prevention and Control Project Management

CERL opened in 1969 in Champaign, Illinois, to be collocated with the University of Illinois at Urbana-Champaign (UIUC) and capitalize on UIUC's own science and engineering programs, experts and facilities. CERL and UIUC collaborate on critical research for DoD under an Educational Partnership Agreement.

For more information, visit www.erdc.usace.army.mil/Locations/CERL or send an email to ERDCinfo@usace.army.mil.

CONTINUED FROM PAGE 30

Multizone Units

In a traditional multizone system, the air handling unit contains a hot deck and a cold deck with associated heating and cooling coils. Constant volume multizone air handlers tend to be inefficient because they cannot reduce the supply fan speed when zones in the building do not need full heating or full cooling. To deal with the lack of fan speed control, multizone systems blend conditioned air from the hot and cold decks to create a zone air supply temperature to meet the demands of the zone, which leads to simultaneous heating and cooling.

Converting a constant volume multizone air handling unit to a variable air volume unit will reduce heating, cooling and fan energy.

Neutral deck units have a deck for unconditioned air to mix with either hot or cold deck supply air to maintain zone temperature set points. Though both traditional and neutral deck multizone units operate fan systems at a constant speed, neutral deck units are more energy efficient since they can take advantage of the "neutral air" both to avoid mixing heated and cooled air and to provide "free heating" to zones with minimal heating requirements.

The CERL Retrofit Approach

Converting a constant volume multizone system to a variable air volume system ordinarily requires re-ducting and re-zoning to accommodate VAV box terminal units. This conversion requires a major renovation that can be very costly, time consuming, and disruptive to building occupants. This complete overhaul renovation approach is seldom considered attractive; therefore, multizone systems are usually operated as constant volume systems until they fail or otherwise warrant replacement (e.g. due to a building renovation).

The Basics About the Environmental Security Technology Certification Program

ESTCP IS THE DoD's environmental technology demonstration and validation program. The program was established in 1995 to promote the transfer of innovative technologies that have successfully established proof of concept to field or production use. ESTCP demonstrations collect cost and performance data to overcome the barriers to employ an innovative technology because of concerns regarding technical or programmatic risk.

The program's goal is to identify and demonstrate the most promising innovative and cost-effective technologies and methods that address DoD's high-priority environmental requirements. Projects conduct formal demonstrations at DoD facilities and sites in operational settings to document and validate improved performance and cost savings. To ensure the demonstrated technologies have a real impact, ESTCP collaborates with end users and regulators throughout the development and execution of each demonstration. Transition challenges are overcome with rigorous and well-documented demonstrations that provide the information needed by all stakeholders for acceptance of the technology.

ESTCP issues an annual solicitation for proposals from the Federal government, academia and industry and employs a competitive selection process to ensure that ESTCP funds high-quality demonstrations. ESTCP requires each project to develop a formal test and evaluation plan. Demonstration results are subject to rigorous technical reviews to ensure that the conclusions are accurate and well supported by data.

ESTCP is managed by a Director and Deputy Director, five Program Managers, and a Financial Officer. The ESTCP office is co-located with the Strategic Environmental Research and Development Program in Alexandria, Virginia. In this joint program structure, the management staff has insight into the entire range of scientific and technical issues associated with an environmental problem, from basic research questions through implementation. ESTCP relies on the technical skills offered by the participating Services serving on its technical committees to assist in the technical aspects of program development, project selection, program monitoring and technology transfer.

ESTCP projects are managed within the following five program areas:

1. Energy and Water
2. Environmental Restoration
3. Munitions Response
4. Resource Conservation and Climate Change
5. Weapons Systems and Platforms

For more information, visit the program's web site at www.serdp-estcp.org.

The retrofit technique developed and studied by CERL, which is intended to be applied as part of a planned HVAC controls upgrade, retains HVAC infrastructure and leverages simple controls changes to achieve variable airflow. The approach includes the installation of VFDs for the system fans and a flow station for the outside air intake. Since air handlers can be operated based on a set schedule or based on occupancy sensors the CERL team implemented and tested both options. Because the approach avoids tampering with ductwork and terminal units it can be accomplished for a lower first cost with less system down time and less disturbance to building occupants than a full system retrofit.

CERL engineers developed standard controls drawings that define the sequence of operation changes required for both traditional multizone air handlers, which were studied at CERL, and neutral deck multizone air handlers, which were studied at Fort Bragg. The CERL control drawings include sequences for the modulating fan speed based on critical zone damper position and an optional sequence for demand controlled zone ventilation through room carbon dioxide or occupancy sensors. These control drawings can be used to help implement the CERL retrofit approach when multizone units are selected for controls upgrades.

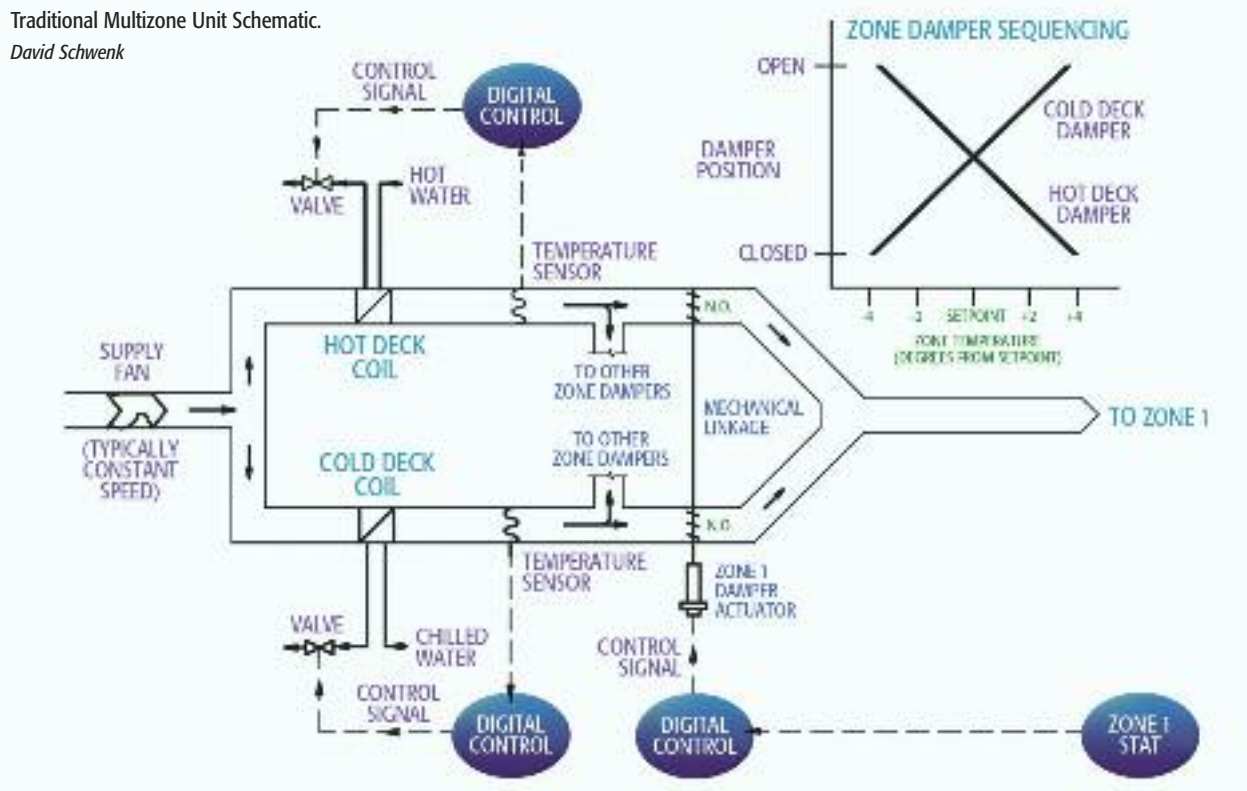
Results

Historical weather data and the performance of the system at various temperatures during the demonstration year were used to determine expected annual energy savings for each system. Analysts determined that retrofitting traditional (hot deck/cold deck) units at CERL and neutral deck units at Fort Bragg resulted in a 26 to 64 percent reduction in energy consumption using either scheduled or demand controlled ventilation. Considering only the additional costs associated with implementing the variable volume conversion as part of an HVAC controls retrofit project, four of the five multizone units had a simple payback within the 15-year lifecycle period. The larger the unit, the faster the payback tended to be due to energy savings being proportional to multizone unit size but with only incremental implementation cost increases; however, retrofits for traditional multizone units as small as three horsepower (HP) were lifecycle cost-effective.

Along with all of the relevant energy usage data (i.e., fan, chilled water and hot water) researchers also collected zone temperature and relative humidity data to determine

CERL researchers wanted to determine if it would make sense to convert the constant volume multizone units to variable volume multizone units as part of a retrofit of system controls.

Traditional Multizone Unit Schematic.
David Schwenk



RETROFIT ENERGY REDUCTION COMPARED TO A CONSTANT VOLUME MULTIZONE

Air Handling Unit	Unit Type	HP	Scheduled Ventilation Energy Reduction (in %/year)	Demand Controlled Ventilation Energy Reduction (in %/year)	Demand Controlled Ventilation Payback (in years)
1	2-Deck	8	28	42	7
2	2-Deck	3	60	64	3
3	3-Deck	3	63	57	10
4	3-Deck	3	30	26	never
5	3-Deck	3	40	39	13

how effectively the retrofitted units were able to maintain occupant thermal comfort. This was important because the retrofit technique was judged based on its ability to pay for itself in energy savings while maintaining occupant comfort. Researchers used American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) Standard 55 metrics to gauge and assess comfort.

The demonstration showed that this retrofit technique is viable, readily implemented, and in many circumstances, will be cost-effective when added to a controls renovation. Contact Brian Clark for more details about this study or to receive technical support for your own multizone retrofit project. ⚓

Sean Wallace
U.S. Army Corps of Engineers Construction Engineering Research Laboratory
217-398-5567
DSN: 314-524-9922
sean.m.wallace@usace.army.mil

Brian Clark
U.S. Army Corps of Engineers Construction Engineering Research Laboratory
217-373-3338
DSN: 314-524-9922
brian.c.clark@usace.army.mil

Joseph Bush
U.S. Army Corps of Engineers Construction Engineering Research Laboratory
217-373-4433
DSN: 314-524-9922
joseph.bush@usace.army.mil