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ASHRAE Journal

MARCH 2016

ASHRAE JOURNAL

THE MAGAZINE OF HVAC&R TECHNOLOGY AND APPLICATIONS ASHRAE.ORG

ASHRAE Technology Awards

Best of the Best

Full Range Relative Humidity Definition | DOAS Design Considerations

Making UFAD Systems Work | Geothermal for Science Building

DAIKIN

VRV IV

FEATURES

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- Heat recovery model provides heating down to -13˚F
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Report from Record-Setting AHR Expo

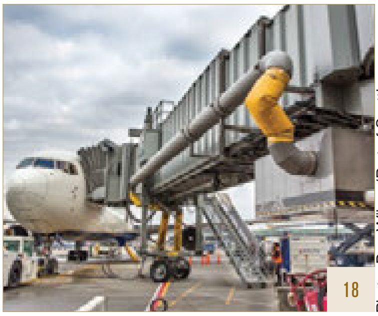

Photo: Don Wilson/Port of Seattle

Photo: Mark Cramer

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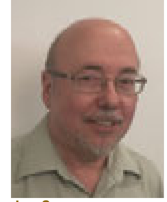
COMMENTARY



Jay Scott

The Road to Innovation

ASHRAE and the built environment community constantly strive for improvement and innovation in our practices and products.

That record of innovation is evident in this month's issue, with articles focused on new products showcased at the 2016 AHR Expo and the projects honored in the 2016 ASHRAE Technology Awards.

THE SHOW IN ORLANDO featured 2,063 exhibitors, including 561 deemed international. Over 80% of the exhibitors introduced new or upgraded products, systems and technologies. Whether an engineer, contractor, wholesaler/distributor, facility manager or owner/operator, all likely saw something new on the Show floor.

"We are impressed by the ingenuity, inventiveness and problem-solving capabilities seen in the incredible variety of the 2016 exhibition line-up," said Clay Stevens, president of International Exposition Company, the Show's organizer.

"It's apparent that manufacturers have been hard at work in redefining the limits of HVAC&R innovation, as well as fine-tuning—and in some cases altogether reinventing—what have already been deemed as bar-raising developments."

That work was apparent in the annual AHR Expo Innovation Awards. Judges considered 196 entries, leading to winners in 10 product categories and the naming of a Product of the Year.

THE ASHRAE TECHNOLOGY AWARDS recognize outstanding achievements by members who have successfully applied innovative building design in the areas of occupant comfort, indoor air quality and energy conservation. Their designs incorporate ASHRAE standards for effective energy management and IAQ.

Five first-place and two second-place awards and seven honorable mentions were given this year. The awards recognize buildings designed for a wide range of occupant types and uses, including drugstores, construction company offices, school buildings and airports.

A series of articles on those honored projects kicks off this month with a look at the Anne-Marie Edward Science Building at John Abbott College in Montreal. More articles about these projects will be published in future issues of *ASHRAE Journal*.

ANNE-MARIE EDWARD was one of the victims of the 1989 shooting at École Polytechnique and a John Abbott science graduate. Edward had been pursuing an engineering degree at Polytechnique. The author writes "the John Abbott community felt that through engineering, the new building demonstrated how humans are essential to environmental sustainability using applied knowledge and technology."

People applying knowledge and technology for a more sustainable world. That's the very essence of innovation.

Enjoy the issue.

Jay Scott

Mission Statement: ASHRAE Journal reviews current HVAC&R technology of broad interest through publication of application-oriented articles. ASHRAE Journal's editorial content ranges from back-to-basics features to reviews of emerging technologies, covering the entire spectrum of professional interest from design and construction practices to commissioning and the service life of HVAC&R environmental systems.

More than 42,000 attended the AHR Expo, with many crowding the entrance as the Show first opened.

FAST FACTS

Total Attendance*	60,374
Visitors*	42,396
International Visitors**	10,103
Exhibiting Companies*	2,063
Percent Increase in Visitor Attendance Over 2010 Orlando Show	51% (42,396 vs. 28,114)
Net Exhibit Space*	469,540 ft^2
International Exhibitors*	561
Countries Represented*	37
Educational Sessions	62
New Product Presentations	88

* Orlando record; ** All-time record

Largest Show in Southeast

First Expo Over 400,000 ft^2 Outside Chicago

ORLANDO, Fla.—Record breaker. And, not just a little record. Orlando is the first non-Chicago Show ever to break 400,000 ft^2 (37 000 m^2) of exhibitor space at 469,540 ft^2 (43 622 m^2). The first Chicago Show to break 400,000 was in 2003 and subsequently in 2006, 2012 and 2015. Traditionally, no southeast Show has even come close to that record. The last Orlando Show was only about 355,000 ft^2 (33 000 m^2).

It's hard to imagine how large this Show really is. Its first edition in 1930 had a mere 45,650 ft^2 (4241 m^2) of space. Eighty-six years later, if an attendee wished to spend five minutes visiting each of the 2,063 booths, he would be walking the Show 24/7 for seven days.

More than 2,000 exhibitors displayed the latest in products and technologies in Orlando's Orange County Convention Center.

Clay Stevens, president of International Exposition Company, the Show manager and producer, says that these numbers indicate the good health of the industry.

"When the industry is challenged, the Show is not as big."

Stevens also said the growth is a bit like the recent Powerball lottery that grew to be about a $1 billion jackpot. "The larger the Show is, the more incentive there is for people to come."

The fact that the 68th edition of the Show is the second-largest in Show history demonstrates the pent-up demand for HVAC&R products, said Stevens.

"The economy has improved enough that companies want to take advantage of that growth," he said.

More than 300 exhibitors are new to the Show this year.

Attendance wasn't affected by the large winter storm that hit the east coast days before the start of the Show. Stevens said he isn't surprised.

"The storm didn't come on us suddenly," said Stevens, whose company is headquartered in Connecticut.

"People were aware that they needed to make special arrangements to avoid the storm."

AHR Expo Global Presence Growing

ORLANDO, Fla.—This year, exhibitors came from 37 different countries, which is an Orlando Expo record-breaking figure that is expected to continue to grow.

Exemplifying the AHR Expo's global appeal and relevance, 561 international exhibitors, and 3,570 in personnel, participated in this year's show in Orlando.

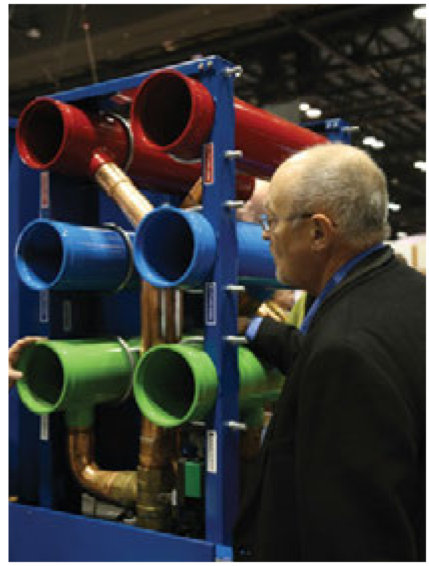
More than 10,000 international visitors came to the show. ■

Dan Berry, executive vice president of TPI, complimented the Show's choice of location.

"Holding the show in Orlando this year is one of the best decisions show management has made. South and Central America are enormous markets, but attendees don't typically come to shows in the Northern U.S. Orlando is the perfect place to draw in that big market of international customers."

Berry added that the benefits that can be gained from the Show make any efforts worth it.

"There is always value in attending this show, and in fact I don't see another show with as much value and expertise as AHR Expo."



John Johannes explores the WC Chiller from WaterFurnace, which has a six-pipe header.

"Based on early feedback, we're already working on several aspects of next year's show to accommodate more attendees and to make the experience even more worthwhile," said Stevens.

Next year's AHR Expo, cosponsored by ASHRAE and AHRI, will be held in Las Vegas from Jan. 30 to Feb. 1, 2017. For additional information, visit www.ahrexpo.com. ■

PULSE OF THE INDUSTRY

According to *ASHRAE Journal's* annual survey of AHR Expo attendees, 83% rate their **business prospects as "good" or "excellent"** for 2016.

Respondents see the **most potential for growth** in the light commercial, office building, residential, and health-care sectors.

The survey shows **reliability, comfort, and first costs** are seen as the most important selling points to customers.

Sixty-five percent of respondents anticipate their **business will grow** 5% or more this year with 27% expecting a 10% or more increase in business. Only 5% think their business will decrease.

Cooling products were the most sought-after technology at this year's show, which took place in a cooling-dominated climate.

What's New From AHR Expo

ORLANDO, Fla.—Here's a sampling of new products shown at the 2016 AHR Expo, organized by category.

Air Conditioning

Mitsubishi Electric U.S. introduces CITY MULTI® L-Generation water source condensing systems—the latest innovation in variable refrigerant flow (VRF) technology. Combining the efficiency of water source with VRF, the next-generation W-Series systems offer enhanced efficiency ratings across all categories. The systems feature single modules up to 20 tons (70 kW), with the ability to combine single modules for systems up to 30 tons (106 kW). W-Series systems can also be integrated into specialized water-side designs, such as geothermal or existing closed water loops.

Fujitsu's 9RLS3H wall-mounted ductless split system offers 33 SEER, a mini-split operating with optimal efficiency at ambient temperatures of –15°F (–26°C). It is an inverter system that requires no modifications for low ambient operation.

White Ryno SINGLE from ***PTubes Inc.*** is pre-insulated copper pipe suitable for air-conditioning applications such as ductless mini-splits, heat-pump units, ducted units and VRF systems.

Todd Burbank (left) and Ron Reppanen (center) learn about Cordless 18 V Fuel tools at the Milwaukee Tool booth.

Air Movement/Fans

VENTUS LUX from ***Titus*** combines air, water and light. This high performance integrated air- and light-distribution system is available in a variety of sizes and styles to accommodate various projects. It is equipped with hydronic-cooled air technology, linear lighting fixtures, and a carriage structure of recycled materials (which serves as the housing).

The dBSilencer from ***DuctSox*** introduces dBSilencer fabric sound attenuator for fabric ductwork systems. The product quiets air-handling unit (AHU) and variable air volume (VAV) box operational and airflow noise in the 500 to 2,000 Hz octave bands by 25 to 35 dB in sound-sensitive areas such as offices, libraries, museums, and classrooms.

Rosenberg offers the new high-efficiency B-Wheel backward curved impeller Spider Module. It features a smaller motor mounting plate and thinner support legs, for use in restrictive environments and 180° discharge applications, such as data center cooling, HVAC, medical systems, power suppliers, air filtration, fan coils and wind or solar energy generation.

ZONEFIRST's By-Pass Eliminator (BPE) is used to eliminate the need for a traditional separate bypass duct and damper directed back into the return duct. The BPE can only be used with ZONEFIRST's Plug-In Zone Dampers and control panels.

ZIEHL-ABEGG presents a new centrifugal fan that sets new records in airflow and compact design. The new ZAvblue impeller is up to 20% more efficient than other standard products in the market. The bionic design requires significantly less space in the customer's device.

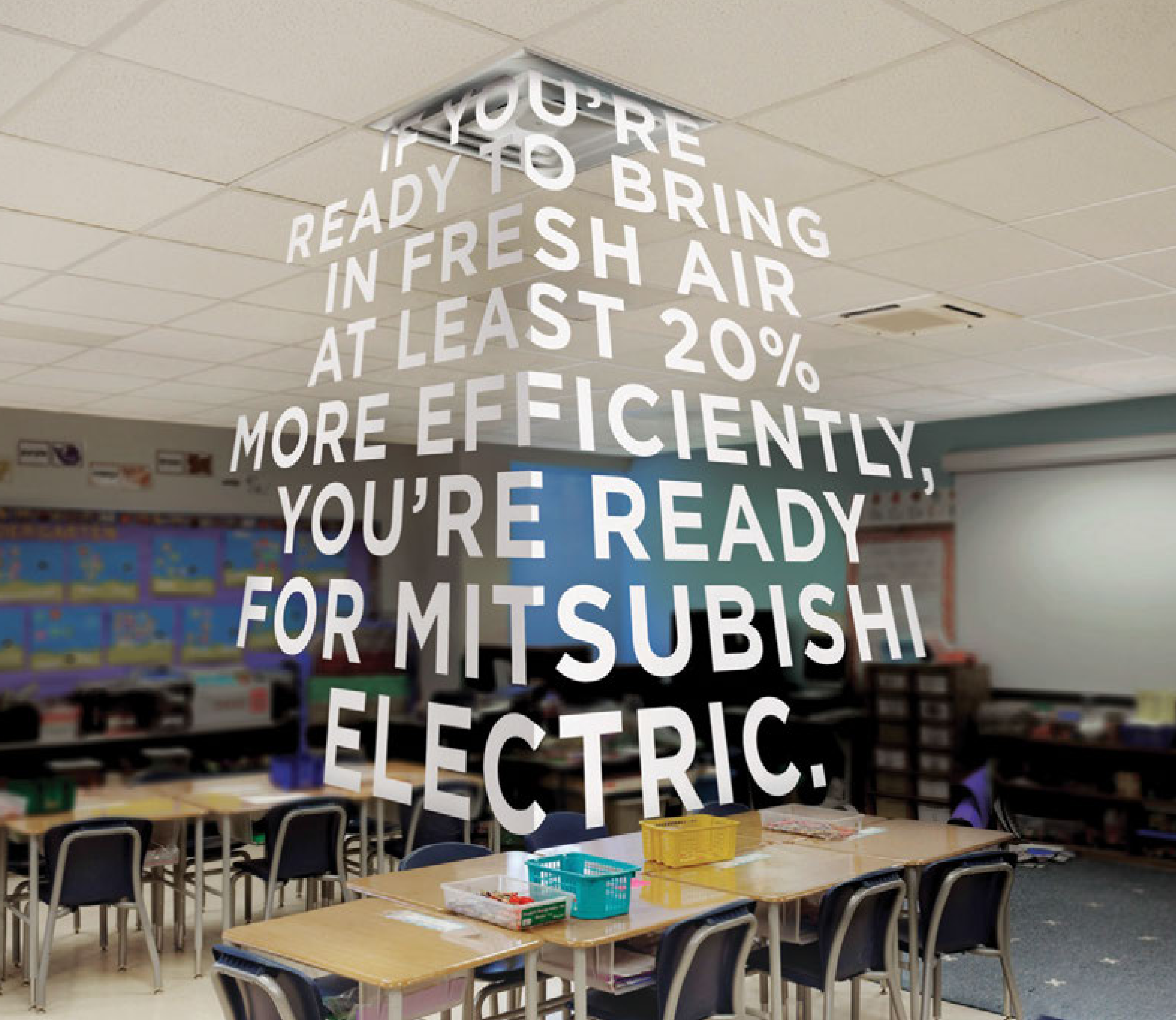
The QuFresh Air Machine (QFAM) from ***Air King*** offers home builders and developers a cost-effective mechanical ventilation solution that helps with humidity and temperature. The QFAM features an independently powered and controlled 120 volt fan that operates separately of air conditioning and heating units.

The ***Hoffman Controls*** Model 759-ECM is a digital variable fan speed controller for ECM evaporator fans for walk-in and reach-in coolers or freezers. It is plug and play with LED indicators for ease of setup and installation. Key features are fault detection, alarm output, status indicators, and ice detection.

SmartAire MZ dampers from ***Tate*** offer automatic balancing by delivering the proper amount of air to equipment to maintain proper inlet temperature. The units adjust cooling independently to four separate zones of a rack to allow for variable loads. Real-time rack level monitoring improves decision-making and reduces operating costs.

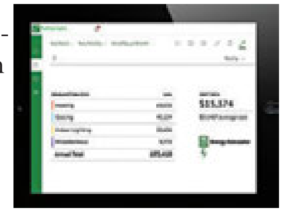
Building Automation

The Proton software-based supervisor/controller from ***Optergy*** combines energy and building management features, uses an intuitive Web interface, and can connect to a companion iOS or Android application. The software can


IF YOU'RE
READY TO BRING
IN FRESH AIR
AT LEAST 20%
MORE EFFICIENTLY,
YOU'RE READY
FOR MITSUBISHI
ELECTRIC.

be installed on simple hardware, manages up to 50 BACnet or Modbus devices, and has built-in programming tools.

Schneider Electric presents Building Insights 9000, a mini-BMS solution for small- to mid-size buildings to monitor HVAC, sensors and meters. Quickly and easily installed with minimal business disruption, it automatically detects devices and data points.



Boilers/Water Heating

The SlimFit commercial condensing gas boiler from ***Weil-McLain*** is designed for fast, easy installation in commercial and institutional settings. Models are designed to deliver up to 96.1% combustion efficiency and up to 95.8% thermal efficiency. Remote modulation is available using Modbus or BACnet.

Tecogen displayed the Ilios high-efficiency water heater, which can operate on either natural gas or propane. Models can be fitted with the company's Ultera emissions control technology.

RBI Water Heaters' Flexcore symmetrical firetube boilers bring hydronic heating products to high levels of operating efficiency. Flexcore combines full modulation and HeatNet 3.0 integrated controls with a perfectly temperature balanced adaptive heat exchanger that provides high efficiencies and durability.

Chillers/Cooling Towers/Chilled Water Systems

WaterFurnace offers the WC screw chiller for commercial and industrial applications. Its modular cabinet design is perfect for multiple chiller bank installations. It features R-134a screw compressors to provide high efficiency and capacity control. The optional six-pipe header rack provides modular application and allows the system to provide simultaneous heating and cooling with efficiencies exceeding 27 EER and 8 COP.

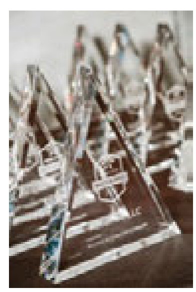
See Products, Page 84

Clay Stevens, president of International Exposition Company, which produces and manages AHR Expo, addresses the audience during the Innovation Awards ceremony. Behind Stevens are (L-R) Doug Young, chair of the Air-Conditioning, Heating, and Refrigeration Institute (AHRI), and David Underwood, P.Eng., president of ASHRAE.

Duct-Sealing Technology Wins AHR Expo Product of the Year

ORLANDO, Fla.—Aeroseal received the 2016 AHR Expo Innovation Awards Product of the Year for the 14th annual competition during a ceremony Jan. 26 at AHR Expo.

The Innovation Awards program honors the most inventive and original products, systems and technologies showcased at each year's Show in 10 categories.

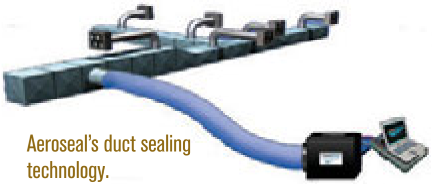


Aeroseal's duct-sealing technology was the Innovation Award winner in the Ventilation category. The technology is an alternative to traditional manual duct sealing, with an aerosol-based duct sealing solution that works from the inside of the ventilation shaft to "seek" and bond-seal targeted leaks.

"We are very proud to win this award," said Aeroseal senior vice president of strategy and commercial sales Neal Walsh, who accepted the Product of the Year Award. "It is testament to the fact that the industry recognizes the importance of ventilation."

The technology, developed by Lawrence Berkeley National Laboratory with funding from the U.S. Department of Energy, EPA and others, works from inside the shaft to find and seal leaks. Aeroseal's solution, which eliminates the need to disrupt or destroy current construction, provides needed assistance to HVAC contractors, for whom accessing exhaust shafts in existing buildings was previously difficult without major demolition. The duct-sealing technology has been used to fix critical ventilation issues in numerous buildings and facilities, including hospitals and multi-story apartment buildings.

"Almost every home in the United States has residential duct leakage that keeps as much as 30% of air in a



Aeroseal's duct sealing technology.

given home out of occupied spaces,” said Walsh during an introductory video played during the ceremony. “This results in a huge loss of energy, but until now solving the problem has typically required major disruption to home interiors. Our technology allows a contractor to seal up ductwork that's already been installed, improving both comfort and energy savings.

While Aeroseal took the top prize, all of the Innovation Awards winners are leaders in their respective categories and in all of HVAC&R.

ASHRAE President David Underwood, P.Eng., said, “These products include the best in creativity, application and energy efficiency, which is very important right now.”

Clay Stevens, president of International Exposition Company, which manages and produces AHR Expo, expanded the praise to the entire Show.

“This is the place where the entire industry gets together in one place to showcase products that push the envelope on innovation.”

Stevens added that the Innovation Awards play an important role for the entire AHR Expo.

“We hope that the awards will inspire other manufacturers and motivate them to build better products.”

The Innovation Awards also contribute to the larger society.

Each year, all of the proceeds from Innovation Awards entry fees are contributed to an organization in the same region as the Show. For 2016, the beneficiary is the Police Athletic League of Jacksonville (Fla.), which aims to create positive relationships between law enforcement officers and the youth of Jacksonville, Fla. ■

Attendance Sets Record For ASHRAE Winter Conference

ORLANDO, Fla.—High attendance was reported for the ASHRAE Winter Conference, as it was for the concurrent AHR Expo.

The Winter Conference had more than 3,000 attendees, which is a record for an Orlando conference. Attendance this year was higher than the past eight Winter Conferences, except Las Vegas in 2011. Attendees came from 67 countries.

Top-attended sessions included Cooling with the Sun: Solar Thermal Cooling; Energy Submetering Fundamentals: Benchmarking, Baselining and Beyond!; and The Impacts of Operable Windows on Building Performance. ■

2016

APRIL

IARW-WFLO Annual Convention and Expo, April 16–20, Las Vegas. Contact the Global Cold Chain Alliance at 703-373-4300, email@gcca.org, or www.gcca.org/events.

NEBB Annual Conference, April 14–16, Albuquerque, N.M. Contact the National Environmental Balancing Bureau at marketing@nebb.org or www.nebb.org/events/2016_nebb_annual_conference.

Lightfair International, April 26–28, San Diego. Contact organizers at 404-220-2220, info@lightfair.com, or www.lightfair.com.

MAY

AHRI Spring Meeting, May 2–4, Reston, Va. Contact the Air-Conditioning, Heating, & Refrigeration Institute at 703-524-8800, ahri@ahrinet.org, or www.ahrinet.org.

Energy Efficiency Global Forum (EE Global 2016), May 10–11, Washington, D.C. Contact Becca Rohrer, Alliance to Save Energy, at 202-530-2206, brohrer@ase.org, or www.eeglobalforum.org.

AIA Convention 2016, May 19–21, Philadelphia. Contact the American Institute of Architects at 800-242-3837, infocentral@aia.org, or www.aia.org/convention.

AIHce 2016, May 21–26, Baltimore. Contact Karen Layser at the American Industrial Hygiene Association at (703) 846-0745, klayser@aiha.org, or www.aihce2016.org.

JUNE

Every Building Conference and Expo, June 25–28, Washington, D.C. Contact the Building Owners and Managers Association at 202-326-6331, meetings@boma.org, or www.bomaconvention.org.

ASHRAE Annual Conference, June 25–29, St. Louis. Contact ASHRAE at 800-527-4723, meetings@ashrae.org, or www.ashrae.org/stlouis.

JULY

SOLAR 2016, July 11–13, San Francisco. Contact the American Solar Energy Society at 303-443-3130, info@ases.org, or www.ases.org/solar-2016.

2016 Purdue Compressor/Refrigeration and Air Conditioning and High Performance Buildings Conferences and Short Courses, July 11–14, West Lafayette, Ind. Contact Kim Stockment at 765-494-6078, kstockme@purdue.edu, or http://tinyurl.com/Purdue2016.

PLEA 2016 Conference, July 11–13, Los Angeles. Contact the Passive and Low Energy Architecture Association at contact@plea2016.org or http://plea2016.uscarch.com/index.php/plea2016/plea2016papers.

AUGUST

ASHRAE and IBPSA-USA SimBuild 2016: Building Performance Modeling Conference, Aug. 10–12, 2016, Salt Lake City. Contact ASHRAE at 800-527-4723, meetings@ashrae.org, or www.ashrae.org/simbuild2016.

SEPTEMBER

ASHRAE IAQ 2016 Conference—Defining Indoor Air Quality: Policy, Standards and Best Practices, Sept. 12–14, Alexandria, Va. Contact ASHRAE at 800-527-4723, meetings@ashrae.org, or www.ashrae.org/IAQ2016.

NAFA Annual Convention, Sept. 14–15, Newport Beach, Calif. Contact the National Air Filtration Association at 608-310-7542, nafa@nafahq.org, or www.nafahq.org.

AHR Expo-Mexico, Sept. 20–22, Monterrey, Mexico. Endorsed by ASHRAE. Contact the International Exposition Company at 203-221-9232, info@ahrexpomexico.com, or www.ahrexpomexico.com.

World Energy Engineering Congress, Sept. 21–23, Washington, D.C. Contact the Association of Energy Engineers at 770-447-5083, info@aeecenter.org, or www.energycongress.com.

OCTOBER

RETA Conference, Oct. 4–7, Las Vegas. Contact the Refrigeration Engineers and Technicians Association at 831-455-8783, info@reta.com, or www.reta.com.

Greenbuild International Conference & Expo, Oct. 5–7, Los Angeles. Contact the U.S. Green Building Council at 866-815-9824, info@greenbuildexpo.com, or www.greenbuildexpo.com.

IFMA World Workplace, Oct. 5–7, San Diego. Contact the International Facility Management Association at 713-623-4362, events@ifma.org, or http://worldworkplace.ifma.org.

SMACNA Annual Convention, Oct. 16–19, Phoenix. Contact the Sheet Metal and Air Conditioning Contractors' National Association at 703-803-2980, info@smacna.org, or www.smacna.org.

ASPE Convention and Exposition, Oct. 27–Nov. 4, Phoenix. Contact the American Society of Plumbing Engineers at 847-296-0002, info@aspe.org, or www.aspe.org.

NOVEMBER

AHRI Annual Meeting, Nov. 13–15, Scottsdale, Ariz. Contact 703-524-8800, ahri@ahrinet.org, or www.ahrinet.org.

DECEMBER

HARDI Annual Conference, Dec. 3–6, Colorado Springs, Colo. Contact the Heating, Air-conditioning & Refrigeration Distributors International at 617-345-4328, hardimail@hardinet.org, or www.hardinet.org.

OUTSIDE NORTH AMERICA

(From April 2016 Forward)

China Refrigeration, April 7–9, Beijing. Contact organizers at penglu@biec.com.cn or www.cr-expo.com/cn/index.asp.

Hannover Messe, April 25–29, Hannover, Germany. Contact 49 511 89 0, fax 49 511 89 32626, or www.hannovermesse.de.

MAY

ISK-SODEX, May 4–7, Istanbul, Turkey. Contact info@sodex.com.tr or www.sodex.com.tr.

CLIMA 2016, May. 22–25, Aalborg, Denmark. Endorsed by ASHRAE. Contact www.clima2016.org.

CIB World Building Congress, May 30–June 3, Tampere, Finland. Contact Kirsti Tikkanen, Finnish Association of Civil Engineers RIL at 358 40 743 3474, kirsti.tikkanen@ril.fi, or www.wbc16.com.

JULY

Indoor Air 2016, July 3–8, Ghent, Belgium. Endorsed by ASHRAE. Contact organizers at IA2016@ugent.be or www.indoorair2016.org.

AUGUST

Gustav Lorentzen Natural Working Fluids Conference, Aug. 21–24, Edinburgh, Scotland. Contact the Institute of Refrigeration at 44 (0)20 86477033 or www.ior.org.uk/GL2016.

SEPTEMBER

2nd International Conference on Efficient Building Design—Materials and HVAC Equipment Technologies, Sept. 22–23, Beirut, Lebanon. Contact ASHRAE at 800-527-4723, meetings@ashrae.org, or www.ashrae.org/Beirut2016.

ISCCBRAZIL2016, Sept. 20–23, São Paulo, Brazil. Contact the Contamination Control Brazilian Society at 55 11 2645-9105, fax 55 11 2645-9205, info@isccbrazil2016.com, or www.isccbrazil2016.com.

OCTOBER

FILTECH 2016, Oct. 11–13, Cologne, Germany. Contact 49 (0)2132 935760 or info@filtech.de.

CTBUH 2016, Oct. 16–21, Shenzhen, Guangzhou, and Hong Kong, China. Contact the Council on Tall Buildings and Urban Habitat at 86-21-23123582, registration@ctbuh2016.com, or www.ctbuh2016.com.

IAQVEC 2016, Oct. 23–26, Seoul. Endorsed by ASHRAE. Contact organizers at info@iaqvec2016.org or www.iaqvec2016.org. ■

CALLS FOR PAPERS

ASHRAE JOURNAL

ASHRAE Journal seeks applications articles of 3,000 or fewer words. Submissions are subject to peer reviews and cannot have been published previously. Submit abstracts before sending articles to Jay Scott, Editor, at jayscott@ashrae.org.

SCIENCE AND TECHNOLOGY FOR THE BUILT ENVIRONMENT

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2016 ASHRAE Technology Awards

ASHRAE Technology Awards recognize outstanding achievements by members who have successfully applied innovative building design in the areas of occupant comfort, indoor air quality and energy conservation. Their designs incorporate ASHRAE standards for effective energy management and IAQ. Performance is proven through one year's actual, verifiable operating data.

This year's awards recognize buildings designed for a range of occupant types and uses, including drugstore shoppers, airplane passengers, and middle school students. The following describes projects from the 2016 ASHRAE Technology Awards winners and honorable mentions. Articles about these projects will be published in future issues of ASHRAE Journal.

FIRST PLACE
BENJAMIN A. SKELTON, P.E., BEMP, MEMBER ASHRAE
WALGREENS NET ZERO STORE

PHOTO: © PADGETT & COMPANY

An Illinois Walgreens is designed to achieve net zero energy use by the National Renewable Energy Laboratory's most stringent definition: "renewable energy generated within the building footprint." Innovative features include 840 roof-mounted solar panels and CO_2 refrigerant for heating, cooling, and refrigeration equipment. The owner's vision is to create a store in which products, materials, systems, and equipment can be tested for incorporation into prototype designs and retrofits in existing stores.

FIRST PLACE
DYLAN T. CONNELLY, ASSOCIATE MEMBER ASHRAE
DPR CONSTRUCTION'S SAN FRANCISCO OFFICE

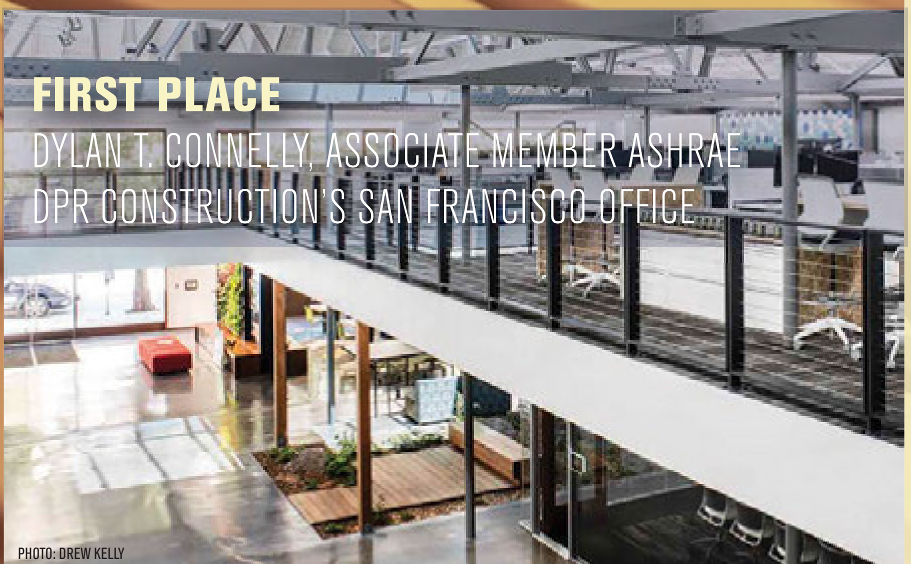

PHOTO: DREW KELLY

This retrofitted San Francisco office building demonstrates the capabilities of integrated, innovative, and replicable design. And, it proves that sustainable buildings can reduce energy use and improve indoor environmental conditions, while being cost effective. The building achieved net positive energy using efficient HVAC and electrical systems, and by installing rooftop PV and solar thermal systems. The building's first year EUI was 20.4 kBtu/ft^2 (231.7 MJ/m^2); its target EUI was 23.6 kBtu/ft^2 (268 MJ/m^2).

FIRST PLACE
NICOLAS LEMIRE, ING., HFDP, MEMBER ASHRAE
ANNE-MARIE EDWARD SCIENCE BUILDING

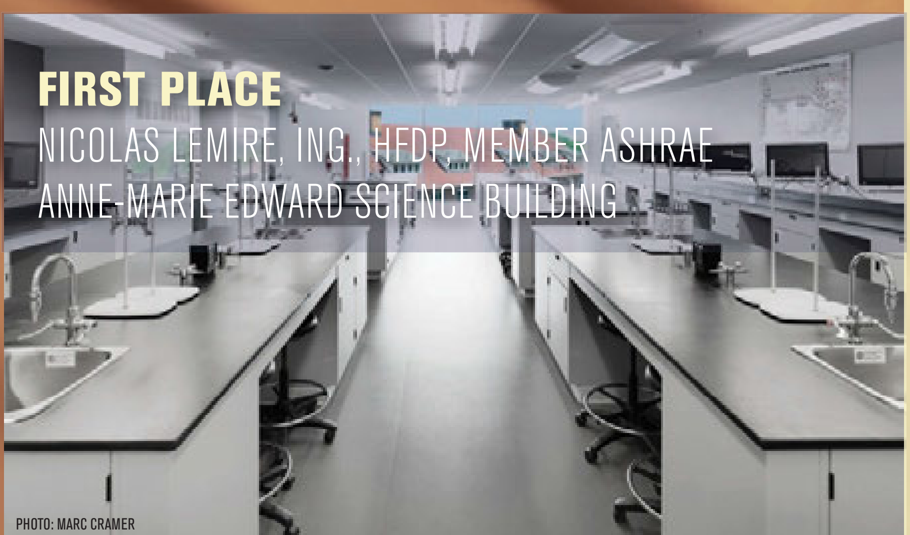

PHOTO: MARC CRAMER

The science and technology building at John Abbott College in Montreal achieves energy diversification with geothermal wells, electrical heating and cooling, natural gas hot water heating, and solar preheating. Resources are maximized through strategies such as reuse of coil condensation water to humidify exhaust air and recuperation of rainwater and fan coil condensation water. **See article on Page 54.**

FIRST PLACE
KEN WARREN, P.E., MEMBER ASHRAE
SEATTLE-TACOMA INTERNATIONAL AIRPORT PRE-CONDITIONED AIR SYSTEM

PHOTO: DON WILSON/PORT OF SEATTLE

The Seattle-Tacoma (Sea-Tac) International Airport Pre-Conditioned Air System provides complete HVAC&R needs during boarding and deplaning for airplanes at all 73 gates. The system includes a preconditioned air plant (PCAP), piping and air handlers. The result is reduced costs for airlines (via reduction of 5 million gallons [19 million L] of fuel annually), improved air quality, reduced noise, and increased energy efficiency.

FIRST PLACE
JONATHAN M. HELLER, P.E., MEMBER ASHRAE
STACK HOUSE APARTMENTS

PHOTO: SPIKE MAFFORD

The apartments in the historic building that make up the Stack House Apartments in Seattle are among the most energy efficient in the Pacific Northwest. The measured EUIs are 19.8 kBtu/ft^2·yr (224.9 MJ/m^2·yr) for one building and 27.1 kBtu/ft^2·yr (307.8 MJ/m^2·yr) for the other. A central heat pump water heating system in the larger of the two buildings and ductless heat pumps for 40% of the apartment units and common spaces are among the innovative features.

SECOND PLACE
STEVE DALEY, P.E., MEMBER ASHRAE, SANDY GROVE MIDDLE SCHOOL

PHOTO: MATTHEW CARBONE

This net positive energy school in North Carolina boasts an EUI of –12.1 kBtu/ft^2·yr (–137.4 MJ/m^2·yr). The design includes solar photovoltaic panels and geothermal heating and cooling. These and other energy conserving practices, combined with a public-private partnership for financing, will save the school district nearly $37.2 million over the next 40 years.

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MRE = latent work / input power (lb / kWh)

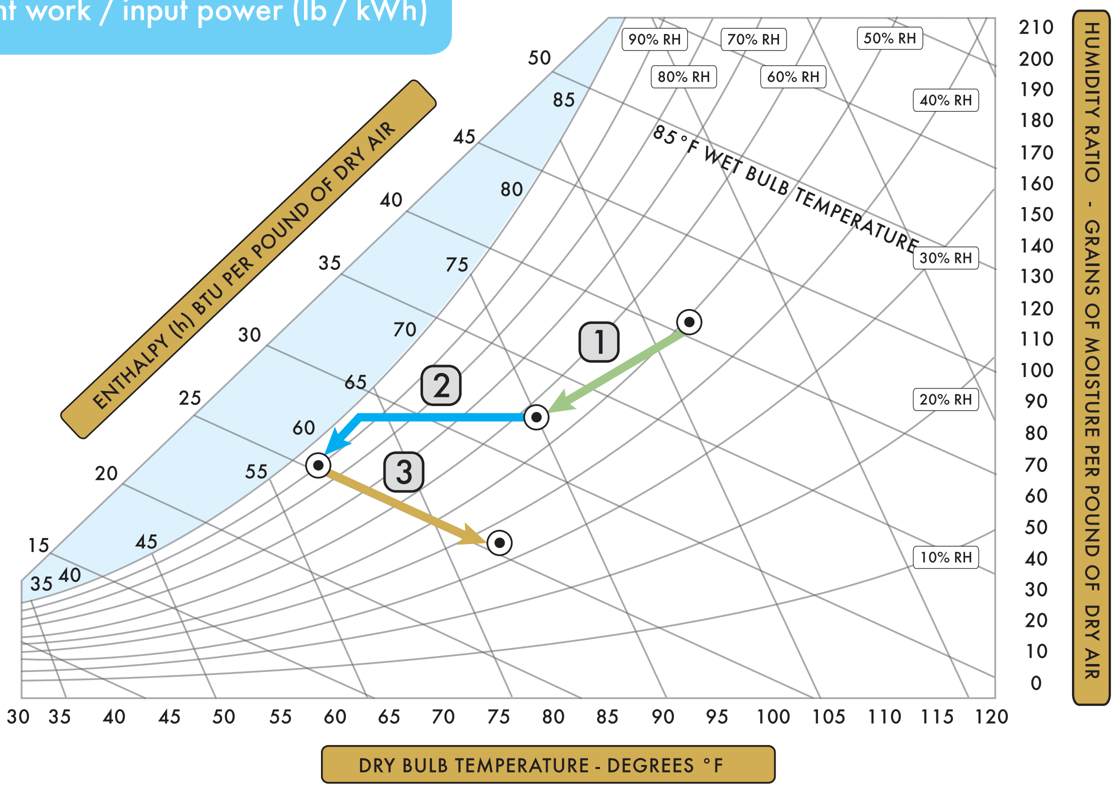

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PHOTO: LAURA SWIMMER

The guiding principle for a Seattle mixed-use campus initially was to choose sensible, sustainable design strategies rather than set specific performance targets. But, the project achieved measured annual EUIs below 2030 Challenge energy baselines. For example, the EUI of the office floors, including the parking garage, was only 14.4 $kBtu/ft^2·yr$ (163.5 $MJ/m^2·yr$), 87% less than the 2030 Challenge baseline.

HONORABLE MENTIONS

SARAH ELIZABETH BERSETH, MEMBER ASHRAE, BISHOP HENRY WHIPPLE FEDERAL BUILDING

After 40 years, systems in the Bishop Henry Whipple government office building in Minnesota needed replacement and modernization. One way designers saved 46% more energy than Standard 90.1-2004 was by installing a geothermal system. Other energy-saving techniques included a solar domestic hot water system and new lighting systems.

ERIC YANG, P.E., BEAP, CPMP, HBDP, MEMBER ASHRAE, STRAWBRIDGE ELEMENTARY SCHOOL

A Virginia school upgraded its heating and cooling systems with a ground-source heat pump system sized for its entire load. In doing so, the EUI dropped 49%, from 91.6 $kBtu/ft^2·yr$ (1040 $MJ/m^2·yr$) to 47.1 $kBtu/ft^2·yr$ (534.9 $MJ/m^2·yr$). Most of the reduction is from using GSHP instead of gas heat during the winter. The school no longer needs a supplemental boiler.

FRANK SHADPOUR, P.E., HFDP, MEMBER ASHRAE, MIRAMAR COLLEGE POLICE SUBSTATION AND PARKING STRUCTURE

Variable refrigerant flow (VRF) systems provide HVAC for a California community college's police substation. The facility uses a photovoltaic system to generate 35,000 kWh of energy annually. The substation's tower serves as a solar chimney to create natural ventilation.

LISA J. SOMBART, P.E., MEMBER ASHRAE, ST. LOUIS PUBLIC LIBRARY – CENTRAL BRANCH RENOVATION

When this 100-year-old St. Louis library was renovated, designers chose variable refrigerant flow (VRF) for the mechanical system. Cost is one reason for selecting VRF—it is 86% less expensive per MBtu (on average) than the previous utility service. Another is that VRF can be concealed in tight quarters within the existing structure.

ABDEL K. DARWICH, P.E., HFDP, MEMBER ASHRAE, JESS S. JACKSON SUSTAINABLE WINERY BUILDING

The goal: a passive net zero energy building able to maintain 50°F to 80°F (10°C to 27°C) internal temperatures with no added heating or cooling. The result: daytime interior temperatures in 2013 around 77°F (25°C), using cool night air and thermal mass, despite outside temperatures of 105°F (41°C). Photovoltaic panels helped generate enough energy to make the California building net positive energy in 2014.

ERIC K. MILLER, HFDP, ASSOCIATE MEMBER ASHRAE, ERIE COUNTY MEDICAL CENTER – CHILLED WATER PLANT IMPROVEMENTS

The Buffalo, N.Y., Erie County Medical Center's chiller components were nearing the end of their useful life in 2009. At the same time, the medical center was planning to add more than 40% more square footage requiring mechanical cooling. The resulting chiller plant increased capacity by 2,400 tons (8440 kW) and reduced annual energy plant use by 6 kWh/ft^2 (65 kWh/m^2), without significant interruption or downtime.

DANIEL ROBERT, P.ENG., ALTORIA/AIMIA TOWER

Heat recovery is prioritized on all wasted heat in both the office and condo towers of this 35-story skyscraper in Montreal. Office spaces are mainly heated and cooled by hybrid heat pumps (HHP) connected to a partial geothermal loop of 15 wells. The office tower's EUI in its first year was 60.3 $kBtu/ft^2$ (684.8 MJ/m^2).

The One-Part Solution

A Proposed Full Range Relative Humidity Definition

BY DONALD P. GATLEY, P.E., FELLOW/LIFE MEMBER ASHRAE

Since the *normal range* of humidity was defined back in 1950, a need has existed for a *one-part, full range* definition of relative humidity* that covers the *normal range*, and the *extended range*. In the extended range, the saturated water vapor pressure equals or exceeds atmospheric pressure. This article provides a one-part "real moist air" full range definition. It also provides a full range approximation suitable for the range of $-80°C \le t \le 40°C$ and $p \le 500$ kPa ($-112°F \le t \le 104°F$ and $p \le 72.5$ psia).

Ranges of ϕ: Normal, Extended and Full

The normal range of relative humidity (ϕ) applies when the saturation pressure of pure water is less than the total pressure, $e_s < p$. The normal range applies to all meteorological conditions at Earth's surface and throughout the troposphere and to most HVAC conditions.

The extended range of ϕ applies when the saturation pressure of pure water is equal to, or greater than, the total pressure, $e_s \ge p$, with the constraint that the actual water vapor saturation pressure (at the dew-point temperature) must be less than the total pressure.† The complete expression representing the extended range is:

$$e_s(t_{db}) \ge p \ge e_s(t_{dp})$$

Applications in the extended range include atmospheric pressure drying operations (lumber kilns) and vacuum drying.

The full range of ϕ is the combined normal and extended range. The primary objective here is to provide a one-part "full range" definition of relative humidity, ϕ_{Real}, applicable for real moist air.‡

* The symbol ϕ replaces the words "relative humidity" throughout. Furthermore, ϕ represents the decimal value of ϕ with the understanding that ϕ% is 100 times the value of decimal ϕ. Numerical psychrometric models normally use decimal ϕ while the general public, including TV meteorologists and weather reporters, use ϕ%.

† Some texts describe the extended range as conditions for which t_{db} is greater than or equal to the normal boiling temperature at standard atmospheric pressure. This description only applies to standard atmospheric pressure (101.325 kPa [14.696 psia]). These limited definitions fail to recognize that extended range applies to system pressures above and below standard atmospheric pressure.

‡ Real moist air includes the non-ideal behavior of water vapor in moist air due to molecular interaction, the total gas pressure and the solution of air in the water condensed phase (liquid or solid water).

RH (Φ) Nomenclature (Note 1)

SYMBOL	PROPERTY NAME	NOTE
$e(t_{db})$	Vapor Pressure of Pure Water at t_{db}	2
$e(t_{db})$	Vapor Pressure of Pure Water at t_{dp}	2
e_s	Saturation Vapor Pressure of Pure Water	2
$f(p, t_{db})$	Enhancement Factor at p and t_{db}	3
$f(p, t_{dp})$	Enhancement Factor at p and t_{dp}	3
p	Atmospheric or Total Pressure of Moist Air	4
p_{wv_enh}	Enhanced Partial Pressure of Water Vapor	5
p_{wvs_enh}	Enhanced Saturated Partial Water Vapor Pressure	5
p_{wvs_ref}	Reference Saturated Water Vapor Pressure	
t_{db}	Dry-Bulb Temperature	
t_{dp}	Dew-Point Temperature	
ϕ	Relative Humidity	
$\phi\%$	Percentage Relative Humidity = 100 ϕ	
ϕ_{IdMix}	Decimal ϕ Ideal Mixture Not Including Enhancement Factors	
ϕ_{Real}	Decimal ϕ With Enhancement Factors	
ψ_{wv}	Mole Fraction of Water Vapor	
ψ_{wvs}	Mole Fraction of Saturated Water Vapor	

Notes

1. In an attempt to contribute to world standardization of psychrometric symbols some of the symbols used here are the same as those of the World Meteorological Organization (WMO). Other symbols are the author's preferences. Standardization of symbols is the purview of others.

2. The symbol e dates from the early 1800s to represent water elasticity or tension (now pressure). It is used here to clearly distinguish pressure of pure water from p_{wvs_enh}.

3. The saturated-water-vapor-pressure enhancement factor was introduced by Goff and Gratch,[4,5] significantly broadened by Wexler and Hyland,[6] and recently updated.[7] The enhancement factor represents the increase of the actual water vapor saturation pressure in moist air from the saturation pressure of pure water with no air present at specified temperature and barometric pressure, $f = p_{wv\_enh}/e_s$. This factor accounts for the non-ideal behavior of the water vapor-air mixture in the saturated state.

The non-ideal behavior arises from: (a) the increase in vapor pressure because of the interaction between different molecular species in the gaseous phase of the mixture (the major contribution); (b) the increase in vapor pressure because of the superimposed pressure of the air on the condensed phase (the Poynting effect); and (c) the decrease in vapor pressure due to the solution of air in the water condensed phase with which the gas mixture is in equilibrium (the Raoult or Henry's law effect). (This is a negligible decrease.)[6–11]

4. The total pressure of real moist air is defined mathematically as $p = p_{da} + p_{wv}$; also $p_{wv\_enh} = \psi_{wv} \times p$.

5. Use of the symbol e' (e prime) is discouraged, and the clearly distinguishing symbol p_{wv_enh} is recommended.

Normal Range Definition

First Equality — Second Equality — Third Equality — Fourth Equality

$$\phi = \psi_{wv}/\psi_{wvs}\,|_{p,t} = (\psi_{wv}\,p)/(\psi_{wvs}\,p)\,|_{p,t} = p_{wv\_enh}/p_{wvs\_enh}\,|_{p,t} = [f(p,t_{dp})\,e(t_{dp})]/[f(p,t_{db})\,e(t_{db})] \quad (1)$$

ASHRAE often uses the first equality, and World Meterological Organization typically uses the third and fourth equalities.

Existing WMO and ASHRAE Normal Range Definitions

The existing rigorous-World Meteorological Organization[1]/*2013 ASHRAE Handbook—Fundamentals*[2] normal-range definitions of ϕ and its equalities (*Equation 1*) are used as a starting point in this article because the equalities provide an easy transition to both a one-part-full-range-real-moist-air definition, ϕ_{Real}, and a one-part-simplified-full-range approximation, ϕ_{IdMix}, having negligible deviation from the ϕ_{Real} definition. The existing "normal range" definition was issued by the International Joint Commission on Psychrometric Data on May 6, 1950.[3]

"In regard to a mixture of air and water vapor under given conditions of barometric pressure and temperature at which (water vapor) saturation of air is possible, relative humidity is the ratio of the mol fraction of water vapor in the mixture to the mol fraction of water vapor in a mass of air saturated

Donald P. Gatley, P.E., is a retired consulting engineer and moisture consultant. He is the author of *Understanding Psychrometrics, 3rd Edition,* published by ASHRAE.

TABLE 1 Differences – ideal mixture moist air vs. real moist air.

		GREATEST DEVIATION FROM 5,551 RUNS OF ASHRAE'S LIBHUAIRPROP AT EACH PRESSURE			
P	T_{DB}	ϕ_{REAL}	ϕ_{IDMI}	$\Delta\phi_{IDMIX\_REAL}$	$\Delta\phi\%_{IDMIX\_REAL}$
10,000 kPa (1,450.4 psia)	–80°C (–112°F)	0.370000	0.321389	–0.048611	–4.861%
5,000 kPa (725.2 psia)	–80°C (–112°F)	0.360000	0.340678	–0.019322	–1.932%
2,000 kPa (290.1 psia)	–80°C (–112°F)	0.360000	0.353357	–0.006643	–0.664%
1,000 kPa (145.0 psia)	–80°C (–112°F)	0.360000	0.356856	–0.003144	–0.314%
500 kPa (72.5 psia)	–80°C (–112°F)	0.360000	0.358475	–0.001525	–0.153%
200 kPa (29.0 psia)	–80°C (–112°F)	0.360000	0.359406	–0.000594	–0.059%
101 kPa (14.6 psia)	–78°C (–108.4°F)	0.350000	0.349706	–0.000294	–0.029%
70 kPa (10.2 psia)	40°C (104°F)	0.450000	0.450251	0.000251	0.025%
20 kPa (2.9 psia)	30°C (86°F)	0.390000	0.390153	0.000153	0.015%

Note: ϕ for below 0°C (32°F) temperatures in this table was calculated with reference to the saturation vapor pressure over ice in the denominator of *Equation 2*. WMO follows a different practice by calculating ϕ with reference to the vapor pressure of sub-cooled liquid water at temperatures below 0°C. This, in turn, requires a function for the enhancement factor over sub-cooled liquid water at temperatures below 0°C. A special function was created to calculate f over liquid water below 0°C, which was used in a limited comparison of *Table 1* for pressures 500 kPa and lower. The differences were negligible and made no difference in the conclusions (see *Conclusion*).

with water vapor at the given barometric pressure and temperature." (*Equation 1* above.)

Why *Equation 1* First and Second Equalities Do Not Apply in the Extended Range

While the first and second equalities in *Equation 1* are applicable in the normal range of ϕ they are not meaningful in the extended range of ϕ where $p_{wvs}(p,t) > p$ because in this range the equation-denominator "system" is composed entirely of water vapor with no other gases present. Saturation for the denominator system is not possible at p and t and the system is no longer a moist air mixture … it is entirely superheated water vapor with zero dry-air molecules in the system. The mole fraction of water vapor in the extended range system is unity for all possible temperatures in the extended range and as a consequence the first and second equalities using the mole fraction definition are not meaningful in the extended range.

Accurate One-Part Full Range Real Moist Air ϕ Definition

Equation 1 can be modified by removing the first and second equalities and designating the denominator in the third equality as p_{wvs_ref}.[§,#] Note that the p, t constraint in the first, second and third equalities is no longer required in the fourth equality because pressure and temperature are both expressed in the numerator and denominator.

$$\phi_{Real} \overset{\text{Third Equality}}{=} (p_{wv\_enh}/p_{wvs\_ref})\,|_{p,t} = \underset{\text{Fourth Equality}}{[f(p,t_{dp})\,e(t_{dp})]/[f(p,t_{db})\,e(t_{db})]} \quad (2)$$

Converting *Equation 2* to words gives:

ϕ_{Real} *is the ratio of the actual water vapor partial pressure in moist air (at the dewpoint pressure and temperature) to the reference-saturation-water-vapor-partial pressure*[II] *at the dry-bulb pressure and temperature.*

A Simpler One-Part Full Range ϕ Approximation

Equation 2 and its expression in words is the primary thrust of this article. This secondary section introduces a simpler one-part full range ϕ approximation applicable over the range $-80°C \le t \le 40°C$ and $p \le 500$ kPa ($-112°F \le t \le 104°F$ and $p \le 72.5$ psia). The logic behind the simpler equation uses a rearrangement and substitution of the fourth equality in *Equation 2:*

$$\phi_{Real} \overset{\text{Fourth Equality (rearranged)}}{=} [f(p,t_{dp})/f(p,t_{db})] \times [e(t_{dp})/e(t_{db})] \overset{\text{Fourth (Substitution)}}{=} [f(p,t_{dp})/f(p,t_{db})] \times \phi_{IdMix} \quad (3)$$

§ The Verein Deutscher Ingenieure Standard VDI-3514 paragraph 3.4.3[12] "Definition at $t > 100$ °C and standard pressure" uses the term p_{hyp}, which is somewhat similar to the use of p_{wvs_ref}. The VDI term p_{hyp} applies only to the extended range; however p_{wvs_ref} herein applies to the full range of ϕ.

The 1950 International Joint Commission on Psychrometric Data[3] definition of ϕ in the extended range used the single property $e(t_{db})$ in the denominator. This is equivalent to $f(p,t_{db})\,e(t_{db})$ because $f(p,t_{db})$ is unity when using the complete 15-part Hyland[6,10] enhancement factor equation. That is when $p_{wvs} \ge p$ then $f = 1.0$.

II The concept of using a reference saturated water vapor pressure at the dry-bulb temperature in the denominator of *Equation 2* was first suggested by Worrall in 1965.[13]

For the temperature range of −80°C to 40°C (−112°F to 104°F) and pressures of 500 kPa (72.5 psia) and lower, the following simpler full range ϕ_{IdMix} approximation is recommended because the deviation from ϕ_{Real} is much less than the uncertainty of the field measurement of ϕ or dew-point temperature:

$$\phi_{IdMix} \approx e(t_{dp})/e(t_{db}) \text{ applicable in the range } -80°C \le t \le 40°C \text{ and } p \le 500 \text{ kPa} \quad (4)$$

The simpler full range ϕ approximation is possible because the enhancement factors are close, and they appear in both the numerator and denominator as a ratio in the ϕ equation.

For research, accurate experimentation, high accuracy psychrometric modeling and conditions with higher pressures than 500 kPa or outside of the −80°C to 40°C (−112°F to 104°F) range, *Equation 2* is recommended.

Deviation Analysis of $\phi_{IdMix} - \phi_{Real}$

Equation 2 and ASHRAE's LibHuAirProp[14] were used to compute the difference between *Equation 4* and *Equation 2*. *Table 1* summarizes the results for each of nine pressures. At each pressure the temperature was varied in 2°C increments from −80°C to 40°C (−112°F to 104°F) and ϕ_{Real} was varied in 0.01 increments from 0.95 to 0.05. Because ϕ is expressed as a decimal value in most numerical models, but in percentage form in everyday language, the table shows both forms.

Conclusion

For research, accurate experimentation, high-accuracy-real-moist-air-psychrometric modeling, conditions with higher pressures than 500 kPa or outside of the −80°C to 40°C (−112°F to 104°F) range, the one-part "full range" ϕ_{Real} definition is defined as the ratio of the actual water vapor partial pressure in moist air at the dew-point pressure and temperature to the reference-saturation-water-vapor-partial pressure at the dry-bulb pressure and temperature as represented by *Equation 2*.

For meteorological conditions, at Earth's surface and throughout the troposphere, and for a majority of HVAC calculations, the simple ratio $\phi_{IdMix} = e(t_{dp})/e(t_{db})$ is acceptable because the deviation between ϕ_{IdMix} and ϕ_{Real} is less than the uncertainty of the measurement of ϕ.

While the ϕ_{IdMix} approximation equation has little deviation this technique may not apply to the calculation of other psychrometric properties including water vapor pressure, mole and mass fractions of water vapor, mixing ratio or specific enthalpy because the enhancement factor appears only once in the calculation of these properties.

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Design Considerations For Dedicated OA Systems

BY HUGH CROWTHER, P.ENG, MEMBER ASHRAE; YI TENG MA, ASSOCIATE MEMBER ASHRAE

Dedicated outdoor air systems (DOAS) decouple the heating, cooling, dehumidification and humidification of outdoor air from the space air-conditioning system. Common HVAC systems such as water (ground) source heat pumps, variable refrigerant flow (VRF), fan coils and chilled beams require a DOAS to meet ventilation requirements. But DOAS is a system, not a piece of equipment.

In some parts of the world, a DOAS may not be any more complicated than a supply fan and an exhaust louver. For many locations, conditioning (heating, cooling, humidifying and dehumidifying) will be necessary. Often, the DOAS unit performing this work is one of the highest energy consumers in the HVAC system.

DOAS Design

The DOAS's main function is to provide ventilation air to achieve acceptable indoor air quality. One advantage of using a DOAS is that the ventilation air can be directed and balanced to point of use. This is harder to achieve with all air multi-zone systems. The most common way to establish ventilation airflow is to follow ASHRAE Standard 62.1.

In addition to ventilation, the DOAS can also be called upon to deliver outdoor air to offset local exhaust such as bathroom exhaust, provide building pressurization and, with chilled beams or radiant cooling systems, provide dehumidification (latent cooling) and primary air to make the beams function properly.

For a typical office application, the ventilation air will likely be around 0.11 to 0.15 cfm/ft^2 (0.55 to 0.75 L/s·m^2). Centralizing the DOAS to a single unit means connecting every occupied space in the building back to a single location with ductwork. This can be costly but it also impacts fan power requirements and thus energy usage. In Europe, it is far more common to decentralize the DOAS into smaller local systems and thus lower the design external static pressure requirement.

Figure 2 shows the potential energy and cost savings (see sidebar) from decentralizing the DOAS and reducing the required external static pressure. Reducing the external static pressure by 0.75 in. w.c. (187 Pa) reduces the DOAS unit fan energy use by 20%, while also requiring smaller main ducts (smaller ceiling plenum) by using multiple, smaller DOAS units. It does require locations for smaller DOAS units closer to point of use.

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Integrating the psychrometrics of the DOAS with the main HVAC system requires some consideration. Not cooling the outdoor air at all in the Chicago example (in the sidebar at right) will shift 473 kBtu/h (139 kW) of cooling load to the terminal units. If the main HVAC system is made up of WSHPs, then it would increase the model size of all the units by one. Many terminal units are on-off control. During off cycles, outdoor humidity will be directed to the space, resulting in high humidity levels and unsatisfactory space conditions. For most locations, not cooling or dehumidifying the outdoor air in some form is problematic.

At a high level, designing the DOAS for "neutral room air" such as 75°F (24°C) db and 50% RH seems like a good starting point; however, it is not actually an easy condition to achieve. It will likely require reheat in most locations. It also assumes that some other system or piece of equipment is offsetting latent gains from infiltration or zone latent loads.[1] The best designs will integrate the DOAS design conditions into the main HVAC system. This is a topic all by itself; the following are some suggestions.

- Some main HVAC systems (chilled beams, radiant cooling) require the building latent load be decoupled from the zone cooling system. For these systems the DOAS unit must be designed to provide all of the building latent cooling requirements because the zone systems cannot handle condensation.
- Cooling the outdoor air to 75°F (24°C) db makes the outdoor air neutral on dry-bulb temperature but will have removed almost no humidity. This will shift a significant latent load (depending on location) to the terminal units, likely beyond what they are designed to deliver.
- Cooling the outdoor air to 55°F (13°C) db makes the outdoor air neutral on humidity ratio, but much colder than the space condition. This can be advantageous as the primary air can be used to provide space sensible cooling and reduce the size of the terminal units. Care should be taken to make sure the space will not be overcooled by the ventilation air at part-load conditions.
- Using a total energy recovery device such as an enthalpy wheel without additional mechanical cooling may cool and dehumidify the outdoor air enough that when mixed with return air to the terminal units, no other mechanical cooling of the outdoor air is required. For example, using 15% outdoor air, the mixed air condition for the Chicago example is 76°F (24.4°C) db, 64°F (17.8°C) wb, which is well within the cooling capacity of WSHPs, GSHP, fan coils and VRF terminal units. While this approach is (capital) cost effective, there will be part-load conditions (70°F [21.1°C] and raining for example) that can be problematic. Further analysis is warranted before applying.

Chicago DOAS Example

A BIN weather model of a 100,000 ft^2 (9290 m^2), five-story office tower in Chicago is used to help demonstrate the concepts discussed in this article.

The DOAS design is based on 11,000 cfm (5190 L/s) outdoor air and 10,000 cfm (4720 L/s) exhaust air. Summer design conditions are 91.4°F (33°C) db, 74.3°F (23.5°C) wb (Peak dewpoint design is 83.7°F (28.7°C) db, 74.7°F (23.7°C) wb) and winter design is –1.5 °F (–18.6°C). Design space conditions are 75°F (23.9°C) db and 50% RH summer and 72°F (22.2°C) db and 20% RH winter.

Mechanical cooling is provided by a water-cooled chiller plant with variable primary flow and heating is provided by a 90% efficient hot water boiler. The building is occupied 4,015 hours/yr. Electrical costs are based on $0.10/kWh and gas costs are based on $0.50/therm.

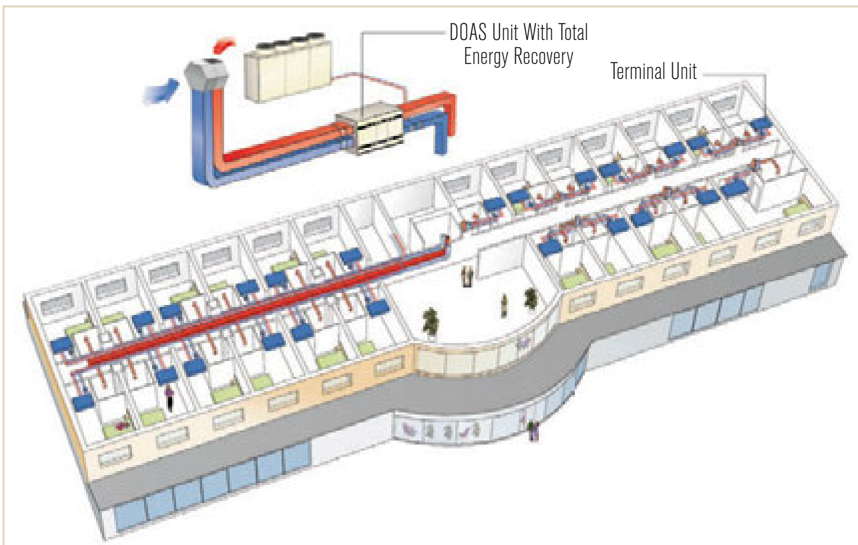

FIGURE 1 Basic DOAS with energy recovery.

- Provide a DOAS unit with passive reheat (hot gas reheat for DX systems, wraparound heat pipe, sensible energy recovery devices such as a wheel or plate) so the outdoor air can achieve 75°F (24°C) db and 50%.

Energy Recovery

For most locations ventilation air represents a significant portion of the total HVAC load. ASHRAE/IES Standard 90.1-2013, Section 6.5.6, covers in detail when exhaust air energy recovery is required. The need for energy recovery is based on location, hours of operation and the size of the system. For many DOAS applications, energy recovery is a requirement and even when it is not mandated, it can be one of the best ways to improve the building's energy efficiency.

When exhaust air energy recovery is required, Standard 90.1 requires 50% total effectiveness*(ASHRAE/USGBC/IES Standard 189.1 requires 60% total effectiveness).

Figure 3 shows the annual savings for the Chicago example vs. enthalpy wheel effectiveness. The operating savings is about $1,000/year between a 50% and 80% wheel. Using a 50% effective recovery device lowered the required design mechanical cooling size by 43% (from 34 tons [120 kW] to 19 tons [67 kW]). Upgrading to an 80% effective device decreases the mechanical cooling load by 73% (34 tons [120 kW] to 12 tons [42 kW]). Considering that the cost difference between a 50% and 80% wheel is relatively small compared to the total DOAS energy recovery system cost (supply and exhaust ducting, dual path AHU, controls, etc.) and the additional savings from reducing the mechanical cooling, a more effective energy recovery device is a good idea.

Not all projects require mechanical humidification. The Chicago example (based on an 80% effective enthalpy wheel) reduced the humidifier size by 45% (capital savings) and annual output by 16,700 lbs (7575 kg). For an electrical humidifier the savings are $489/year and for a gas humidifier the savings are $104/year.

The impact of controls must not be underestimated. In the Chicago example, 25% (1,158 hours) of the operating hours occur where operating the recovery device would actually raise the cooling load, not lower it. It is a Standard 90.1 requirement that the energy recovery device be shut down or bypassed during these operating conditions.

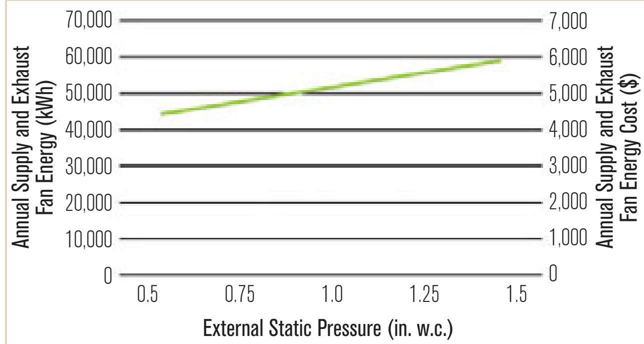

FIGURE 2 Fan energy and cost vs. external static pressure.

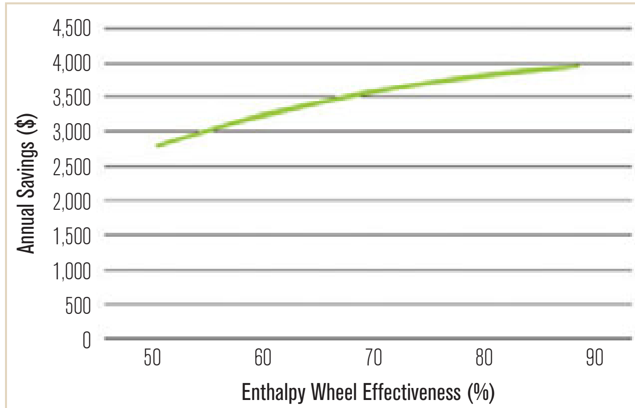

FIGURE 3 Annual cost savings vs. enthalpy wheel effectiveness.

Another example is frost control. A common method to control an enthalpy wheel is to modulate the wheel speed. Most frost control algorithms are based on modulating the wheel speed to maintain the exhaust dry-bulb temperature above freezing (call this dry-bulb control). This effectively flat lines the heat transfer once the exhaust air reaches around 35°F (1.7°C). This is safe and easy to execute. However, an enthalpy wheel lowers the humidity ratio of the exhaust air as it cools it sensibly. For many operating conditions, this means the exhaust air can be cooled below 32°F (0°C) without frost forming. Maximizing the energy transfer by getting the exhaust air as close to the dew-point line as possible (call this dew-point control) will increase the annual energy savings.

In the Chicago example, switching from dry-bulb control to dew-point control increased the annual heat

*ANSI/ASHRAE Standard 84, *Method of Testing Air-to-Air Heat/Energy Exchangers,* defines effectiveness as the actual transfer of moisture or energy/maximum possible transfer between airstreams.

savings by 15.8%. The investment in ducting, DOAS unit, energy recovery devices is identical; how well the DOAS will work will ultimately come down to the controls.

Fan Work

One of the key strengths of decentralized HVAC solutions is that energy is moved throughout the building in water or refrigerant, which have much lower transport costs than air. Now a DOAS unit is, by purpose, an air moving system so close attention to fan system design is warranted, especially with energy recovery, which requires both a supply and exhaust air fan.

Figure 4 shows the annual operating cost for different types of fans. The savings in energy and operating cost is about 20% from worst to best. Permanent magnet synchronous motors (EC motors) offer excellent motor efficiency (93% plus) and can have variable speed, allowing direct drive fans (no belts to service or belt transmission loss).

When the DOAS unit includes fans with speed control (i.e., VFDs), supplemental controls can be included to compensate for air density changes (this can be significant in DOAS units), filter loading, etc. It is also a key building block in designing a demand-controlled ventilation (DCV) DOAS that will be discussed shortly.

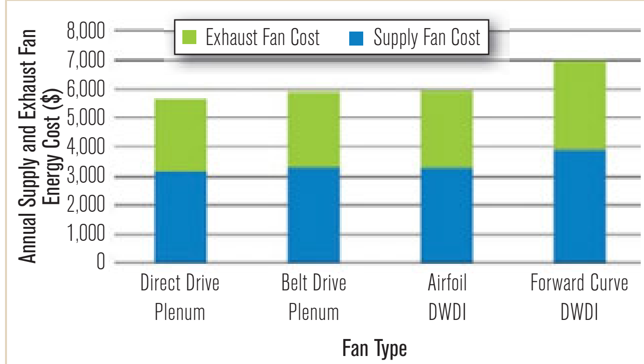

FIGURE 4 DOAS unit fan cost vs. fan type.

Plenum fans are popular because of their small space requirements, particularly in direction of airflow and their real-world versatility regarding system effects. A scrolled fan is more efficient under ideal conditions.

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However, to achieve the additional performance requires the fan, DOAS unit and DOAS duct design be carefully designed and integrated. Introducing an elbow into the duct within 2 ft (610 mm) of the scrolled fan discharge can add 0.7 in. w.c. (174 Pa) static pressure in system effect. That is an additional 20% in fan work.

Demand Control Ventilation

There is no better way to improve energy performance than to not use it in the first place. The DOAS will be sized based on design conditions at full occupancy. Von Neida, et al., and Maiccia, et al.,[2] found daytime occupancy between 6 a.m. and 6 p.m. was 40% for break rooms, 26% for classrooms, 20% for conference rooms, 33% for single person offices and 33% for restrooms.

Figure 5 shows actual ventilation airflow data and energy usage for an office building in Sweden. The system was sampled every hour for a year and never exceeded 76% of design airflow. For 80% of the time it averaged less than 45% of design airflow. Standard 90.1 (6.4.3.8) requires DCV in high density applications such as classrooms. ASHRAE Standard 62.1-2013 (6.2.7) allows DCV providing the minimum ventilation rate is no less than building component (area outdoor air rate, R_a × floor area).

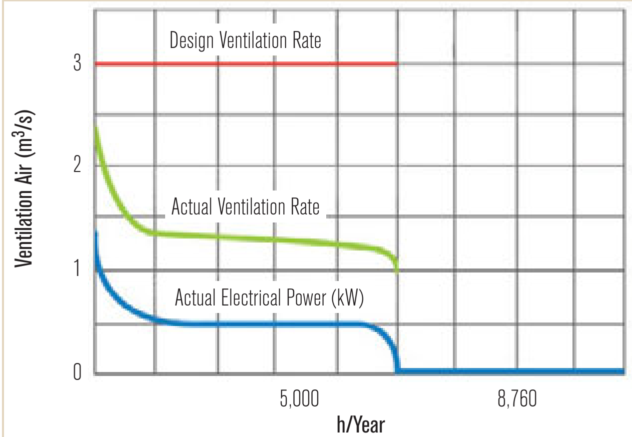


FIGURE 5 Measured airflow log with DCV for one year.[3]

Figure 6 shows a DOAS designed for DCV. In addition to all the components present in a constant airflow (CAV)

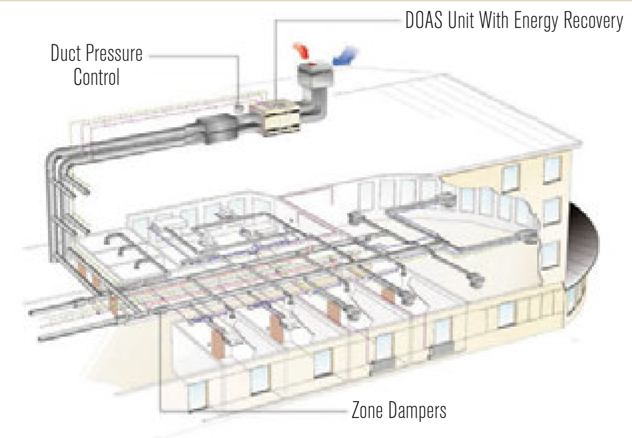


FIGURE 6 DOAS with DCV.

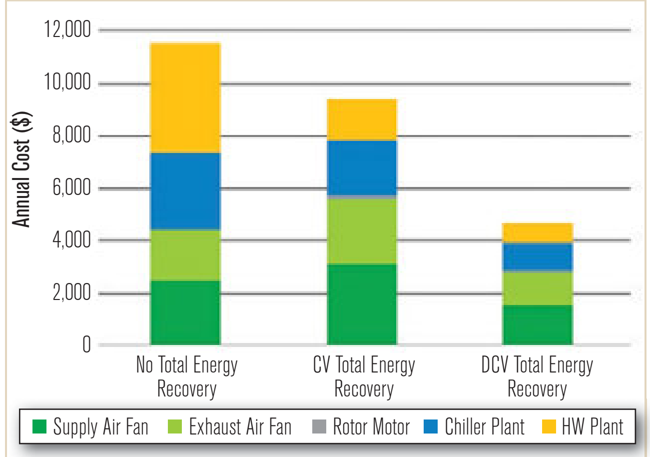


FIGURE 7 Demand control ventilation cost vs. constant volume DOAS cost.

application, the supply and exhaust fans need to be variable flow (add VFDs and controls), and there are now isolation dampers to serve the individual zones.

For main HVAC systems where the purpose of the DOAS is ventilation air (WSHP, GSHP, fan coil, VRF), the ventilation airflow control is based on indoor air quality. The most common methods of control are CO_2 sensors or occupancy sensors or both. For small zones, an occupancy sensor is reliable and cost effective. The isolating damper can be an on-off type. For larger zones with a wide range of occupancy, a CO_2 sensor allows for modulating ventilation airflow.

For HVAC systems where the DOAS unit is supplying air for ventilation, latent control and possible zone sensible cooling, the airflow control will need to include sensors and control algorithms for latent and sensible temperature control, as well as IAQ control.

The DOAS unit will require variable airflow, which is typically achieved with VFDs and duct pressure control similar to a conventional VAV system.

Figure 7 shows the annual costs for the Chicago example between a CAV DOAS unit with no energy recovery, a CAV system with energy recovery and a DCV system with energy recovery. It is based on 50% average occupancy during operating hours and 55°F (12.8°C) summer supply air temperature reset to 65°F (18.3°C) in winter. From worst to best is a 72% energy savings and a 59% cost savings.

Economizers and DOAS

Integrating an economizer strategy into a DOAS is worthy of some thought. First step is to determine what is meant by "economizer"? In an all-air HVAC system, economizer means increasing the outdoor airflow (above the minimum required for ventilation) to gain "free cooling" when outdoor air conditions allow. Since a DOAS is a 100% outdoor air unit that is typically sized to deliver the minimum outdoor airflow required for ventilation, it cannot economize by increasing outdoor airflow. (While it is technically possible to oversize a DOAS to provide more airflow for "free cooling," it likely is not a good investment.) But the DOAS unit can provide some level of economizing by not operating cooling or heating components when outdoor conditions allow for the air to be delivered without any conditioning.

For example, if energy recovery is added to the DOAS unit, then ensure its controls will stop the energy transfer by the recovery device when it is counterproductive. For example, allowing the energy recovery device to work when it is 55°F (13°C) outdoors and the exhaust air is 75°F (24°C) will actually add heat to the outdoor air and cooling load to the main HVAC system. To economize, there must be controls to stop energy transfer during economizer opportunities. It is a good idea to rotate wheels periodically during economizer cycles to minimize dust buildup on the wheels.

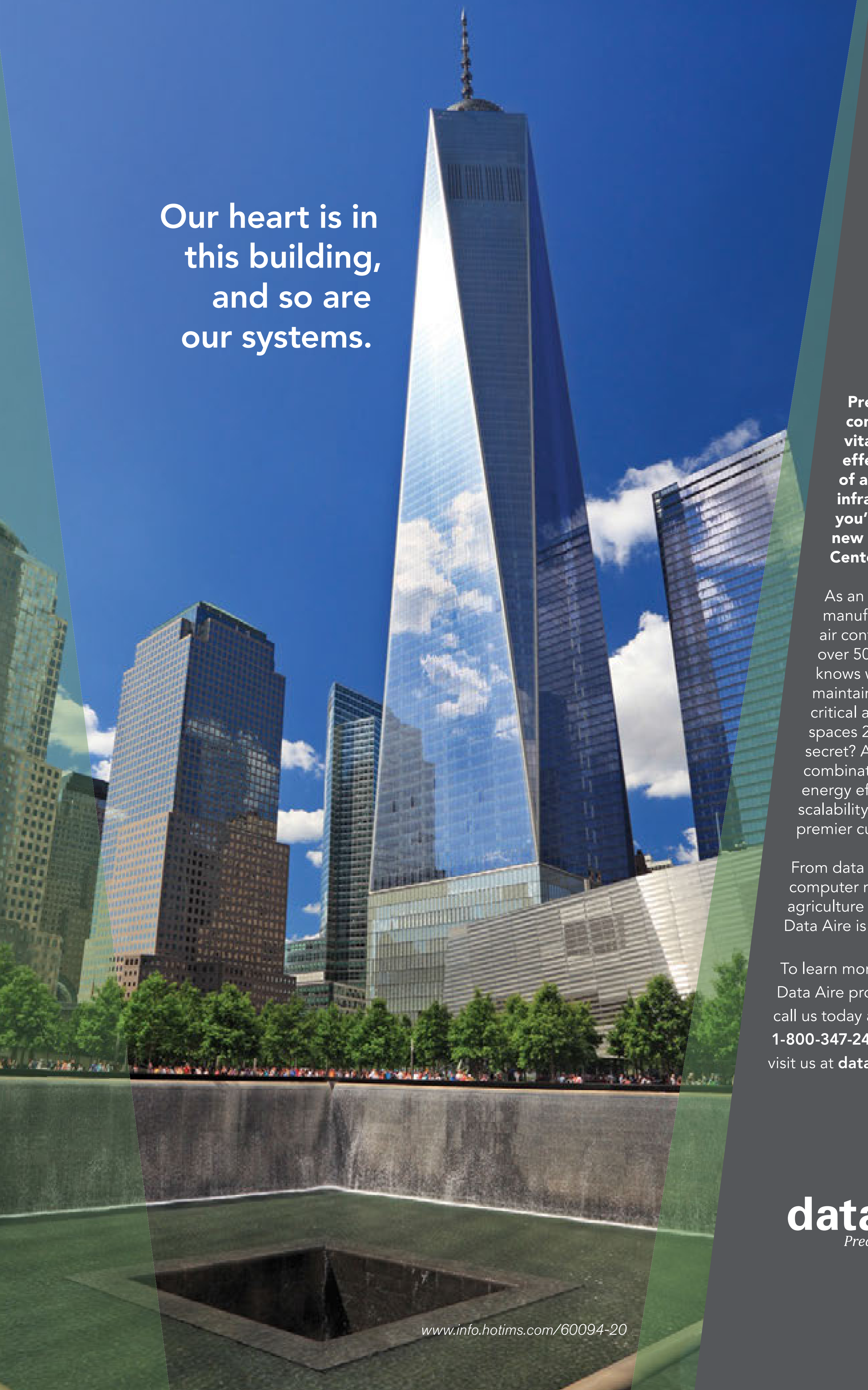
Adding DCV to the DOAS can reduce this economizing benefit. DCV will reduce the outdoor airflow rate during periods of partial occupancy, which greatly reduces the "free cooling" potential of the DOAS during mild weather. During favorable economizer conditions, the controls should "override" DCV and increase outdoor airflow to gain more "free cooling" but this will add fan work.

TABLE 1 DCV economizer performance.

OUTDOOR TEMPERATURE DB (°F)	CHILLER PLANT SAVINGS (KWH)	INCREASED FAN ENERGY (KWH)	TOTAL SAVINGS (KWH)
65 to 70	948	2,886	–1,938
60 to 65	3,094	3,666	–572
55 to 60	3,310	2,661	650
50 to 55	4,510	2,850	1,660
45 to 50	4,537	2,779	1,758
40 to 45	4,051	2,448	1,603
35 to 40	7,603	4,529	3,074
30 to 35	7,318	4,293	3,025

Table 1 compares the cooling plant savings at full DOAS design airflow during favorable outdoor conditions to the increased DOAS fan work. In this example, the additional fan work costs more than the cooling savings until the outdoor air temperature gets close to 55°F (13°C). Compare this to an all-air HVAC system with economizer, which will see energy savings as soon as the enthalpy of the outdoor air is less than the enthalpy of the exhaust air. (Note: the all-air system airflow rates do not change due to economizer operation.)

At ambient air temperatures below 55°F (13°C), the energy recovery device in the DOAS unit can be used to raise the supply air temperature up to 55°F (13°C) and provide zone cooling if required. At these conditions, the cooling energy savings are greater than the additional fan work. However, at some point, supplying outdoor air at 55°F (13°C) to all the zones may not be desirable as it shifts heating load to the terminal device and during zone terminal off cycles may cause drafting. There is energy to be saved here, but the controls can be complex.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Summary

- Many common HVAC systems require a DOAS. Since the DOAS is critical to IAQ and can be a large energy draw (even though the overall HVAC solution can be very efficient), special consideration of the DOAS design, how it integrates with the main HVAC system and the subsequent controls are justified. Here is a summary of the key points:
- It's important to know if the purpose of the DOAS is to provide ventilation air, offset infiltration and local exhaust (WSHPs, GSHPs, fan coils, VRF), or if the DOAS also needs to manage zone latent and sensible loads (chilled beams and radiant cooling).
- Give careful thought to how the DOAS will psychrometrically integrate with the main HVAC system. Consider the cooling capabilities of the terminal units, local design conditions, capital investment and especially control algorithms of both the terminal units and the DOAS unit.
- DOAS units and energy recovery go hand in hand. In many cases it is mandatory. Consider exceeding minimum design efficiencies as it will likely be paid for by the cooling plant savings and will definitely reduce operating cost.
- Energy recovery DOAS unit fans consume 60% of the unit energy input. Pick good fans and motors and consider real-world issues such as system effect.
- DCV is the single best thing to reduce the operating cost of the DOAS unit. It adds complexity and first cost but almost always shows an acceptable payback. In spaces with high ventilation rates due to occupant density, it is mandated by Standard 90.1.
- DOAS units do provide some level of economizing. Make sure the energy recovery control algorithms support free cooling. Integrating economizer logic with DCV logic requires some thought. There is energy to be saved, but the controls can be complex.
- Develop and specify an integrated performance-based control system, detailed steps for commissioning and requirements for operational verification.

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Steven T. Taylor

Making UFAD Systems Work

BY STEVEN T. TAYLOR, P.E., FELLOW ASHRAE

Underfloor air-distribution (UFAD) systems went from "the next best thing" among HVAC systems in the late 1990s and early 2000s to few and far between after 2010, at least in the San Francisco Bay Area. The reason is simple: they have not worked very well! At least that is the case when using the most common U.S. designs. While the convenience of the underfloor plenum for wiring was a real benefit, and surveys show that occupants perceive much better indoor air quality compared to overhead systems, the hype about improved comfort and energy savings has not been realized for most projects.

Comfort problems, in particular, have been worse than with overhead VAV systems in the author's experience. But the reason may be a result of how UFAD system design changed since it was first introduced in the U.S.

Early Days of UFAD

The first UFAD system in the Bay Area was designed for Gap Inc. in San Bruno, Calif., by an English engineering firm based on design concepts drawn from UFAD systems developed in Europe and Southeast Asia. The design included a system to handle envelope heating and cooling loads that was separate from the interior UFAD systems. The initial perimeter system design used underfloor water-source heat pumps, but for various reasons, including high cost, the final design was a variable air volume change-over (aka, variable volume and temperature, VVT) system with an air-handling unit (AHU) serving each exposure as shown in *Figure 1*. The interior zones were served by separate UFAD AHUs supplying 63°F [17°C] supply air. It took a while to debug and tune, as with any new system, but ultimately the design was a success.

But this was a unique building: it had really only two long uniform exposures (the short ends had other building elements served separately) and it was built into a hill that provided a convenient basement area for air handlers as shown in *Figure 1*. The concept could not be replicated on almost any other building.

Development of the UFT Design

The separate perimeter zone heating and cooling system was a problem: it was expensive and hard to accommodate architecturally, requiring extra shafts at the perimeter or equipment, such as fan-coils or heat pumps, crammed under the floor where they could cause noise problems and were difficult to maintain.

In the early 2000s, the author's firm helped develop alternative designs to reduce cost by combining the interior and perimeter systems into one. The design that became the most popular in California was the underfloor terminal UFAD system shown in *Figure 2*. Underfloor terminals (UFTs) are small fan-coils with variable speed fans and modulating electric or hot water heat. Fan-coils that could fit under the floor (typically 14 in. to 18 in. [355 to 460 mm] high) between the

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FIGURE 1 Gap San Bruno UFAD.

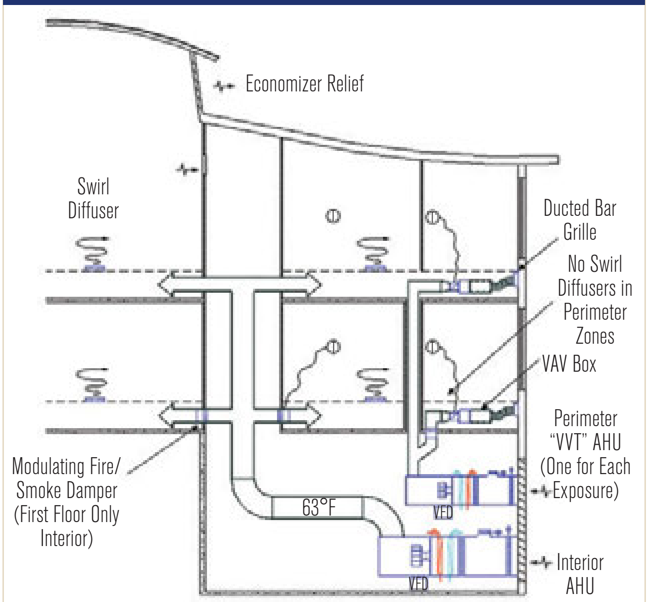


FIGURE 2 Underfloor terminal UFAD.

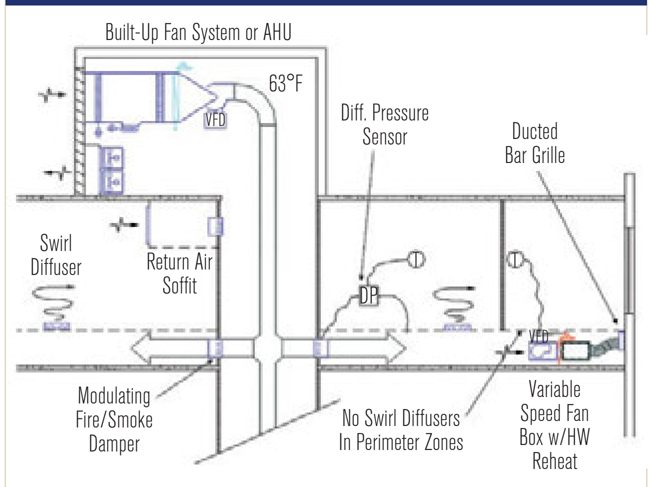
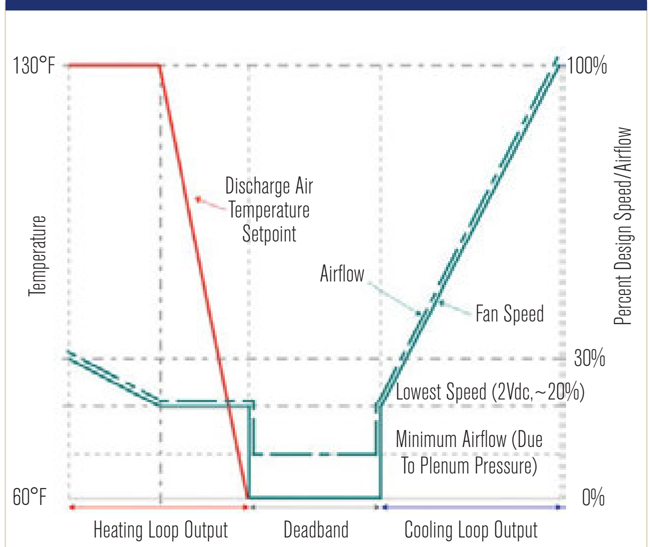


FIGURE 3 UFT control.



pedestals (24 in. [600 mm] on center) did not exist when we first used the system so we used custom fan-coils; now UFTs are standard products available from many manufacturers.

On our projects, UFTs are controlled as shown in *Figure 3*. Initially, we had the UFT fan stay on in the deadband between heating and cooling, but the electronically commutated motors (ECMs) had a minimum speed of 20% (2 vdc to 10 vdc range) and since the fans were direct drive, this often resulted in a much larger percentage of the design flow. This high minimum rate pushed the zone into heating most of the time, causing cold complaints (similar to those caused by high VAV box minimums[1]). So the logic was changed to shut off the fans in the deadband, significantly improving comfort and efficiency. With the fan shut off, the space is still ventilated by leakage through the UFT and the floor due to the pressurized floor. The heating control logic is identical to "Dual Maximum" VAV Reheat logic:[2] the first stage tries to heat the space at the minimum airflow rate; if that is not sufficient, the airflow is increased to 30%, the maximum allowed at the time by ASHRAE/IES Standard 90.1 and California Title 24 Energy Standards. But because the UFT is supplying warm air from the floor at the window, the supply air temperature can be much warmer (e.g., 130°F [55°C]) than an overhead system where stratification can hurt performance.

The supply air rate of cool air from the central AHU to the underfloor plenum was controlled by pressure controllers whose setpoint was reset (typically in the range of 0.01 in. [2.5 Pa] to 0.05 in. [12.5 Pa]) by interior zone space temperature control loops. The low underfloor pressure required with this design minimizes concern with floor leakage that plagues UFAD designs requiring higher pressures.

At the time, we thought the system was ideal: it was reasonably cost efficient, it could be used on almost any building regardless of architectural footprint, and it was energy efficient. The reheat losses were minimal due to the warm central system supply air temperature (63°F [17°C]) and low UFT airflow rates required due to the warm UFT supply air temperatures (130°F [55°C]). But it had a major unanticipated flaw: underfloor supply air temperature degradation (aka, thermal decay). The supply air temperature in the underfloor plenum starts at 63°F [17°C] but by the time supply air crosses the floor from the supply air shafts located in the core out to the UFTs at the perimeter, the air was very warm, 68°F [20°C] and higher, due to heat transfer from the floor served and through the structural slab to the floor below as shown in *Figure 4*.[3] *Figure 5* shows underfloor plenum temperatures for a large project in Sacramento, Calif., our first using UFTs, measured using temporary data loggers placed under the floor. The red squares are the shaft locations and the gray lines are the air-distribution ducts, which had low velocity air outlets every 20 to 30 ft [6 to 9 m]. The temperatures near the injection points that were located near the shafts were close to the 63°F [17°C] AHU supply air temperature, but the temperature quickly decays moving outward from the shafts. On the west side, supply air temperature at UFT inlets was as warm as 72°F (22°C), way too warm to properly cool the offices on that exposure. But if the supply air temperature from the AHU were reduced to compensate, then the interior zones would be overcooled even at zero plenum pressure (no airflow) due to radiation and convection from the cold floor. There was simply no way to satisfy both exterior and perimeter zones at the same time.

Despite the problems seen in our early designs, we did not abandon the UFT concept; instead we tried various kluges to fix it, including:

• More extensive supply air ducts under the floor. Some early designs had almost no ductwork; they were disasters. It soon became apparent that some ductwork is needed to reduce the distance from the point of injection to the UFTs. We at first had the "50 ft rule"—no more than 50 ft from the injection point to the UFT. Better, but not good enough. Soon this morphed into the "40 foot rule," then the "30 foot rule," and then the "20 foot rule." Many designers even went to the "0 foot rule"; they completely ducted the entire perimeter system and converted UFTs to VAV boxes. The perimeter system at that point was simply an overhead VAV system moved under the floor.

• "Rifles" and "shotguns." Initial designs injected air under the floor at relatively low velocities with an airflow spread ("shotgun") to distribute the air evenly and avoid any induction effects from nearby swirl diffusers. But low velocity makes temperature degradation worse. So for exterior zones, we started using higher velocity outlets ("rifles") located directly in line with the UFTs. Because of the Coanda effect from both the structural floor below and raised floor above, the air would rifle with little induction out to the UFT, providing colder inlet air. We included vertically mounted volume dampers at the outlet so we could literally aim the air at the UFT.

FIGURE 4 Heat gain causing supply air temperature degradation.

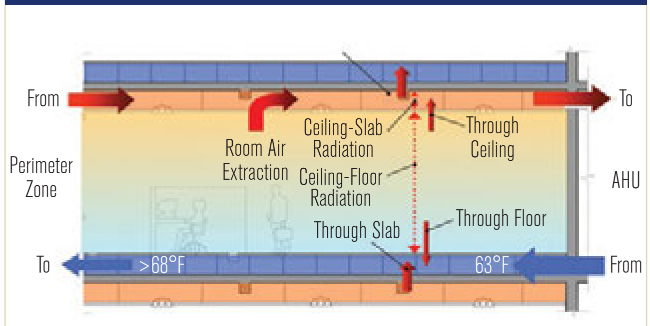
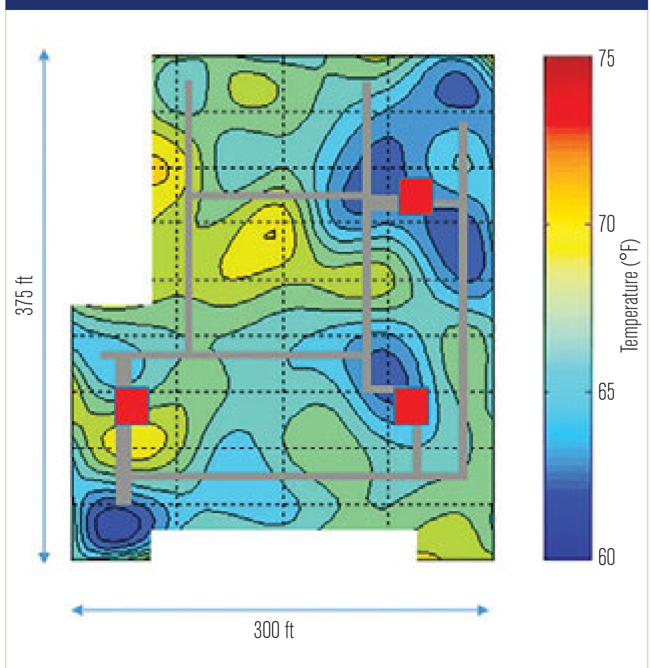


FIGURE 5 Supply air temperature degradation—Capital Area East End Building. (Courtesy of Center for the Built Environment)



These tweaks (and others outlined in the ASHRAE *UFAD Guide*[4]) improved performance, but problems remained. After about our 15^{th} building using the UFT design with less than excellent results, it became clear to us: the Europeans had it right in the first place; the perimeter should be served by separate systems with UFAD only used to condition interior spaces.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Back to the Drawing Board

The author's firm was recently retained to design mechanical systems for two new projects* for which UFAD was deemed a necessity by the owner to attract high tech tenants. Convinced we needed separate perimeter systems, the task then became how to do so efficiently and cost effectively.

The design we developed works well for our two projects because they have these characteristics:

- Relatively regular rectangular shape (no curves, zig-zag, or slanted exposures); and
- Side (rather than center) cores that allow air handlers to be located on each floor with access to the exterior walls for economizer outdoor air intake and relief.

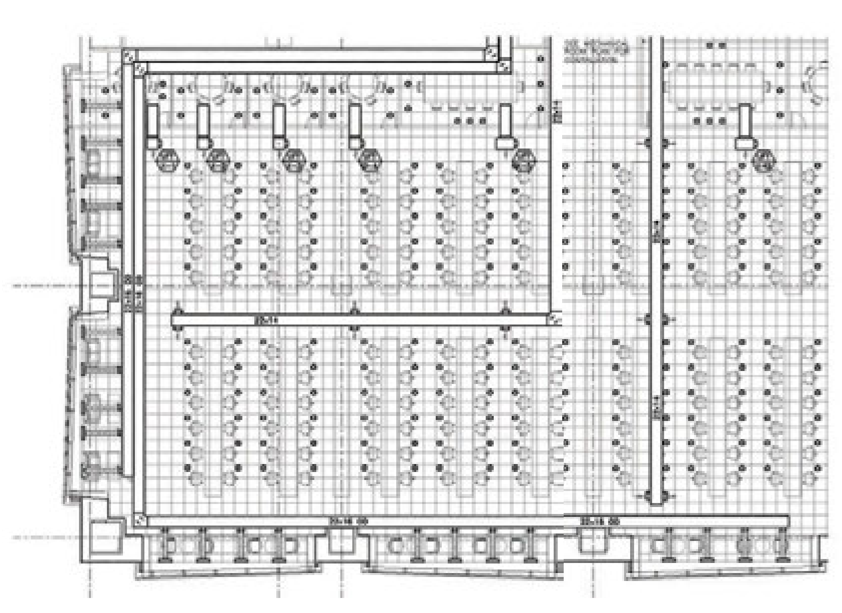


FIGURE 6 South HVAC floor plan.

The design is summarized as follows:

- Each building exposure is served by a separate AHU, one per exposure. These are ducted to bar grilles in the floor directly under the windows. These AHUs have heating and cooling capability and are designed to condition just the envelope loads.
- Internal loads (lights, people, and equipment) are conditioned by cooling-only AHUs discharging air under the floor with occupant-adjustable swirl diffuser outlets located at each work station—the classic UFAD design.
- Each AHU has its own outdoor air economizer section, but they all draw through a common outdoor air plenum with a single airflow measuring station (AFMS) to measure and control overall outdoor airflow.
- The AHUs are 24 in. [600 mm] wide to match the width of the raised floor tiles and capable of supplying about 3000 cfm [1400 L/s]. The depth (30 in. [760 mm]) could be increased to increase airflow capacity, but the airflow is limited by the size of the supply air ducts, which, in turn, are limited by the pedestal dimension and raised floor height. Access is only required from one short side of the AHUs (optional for the opposite side) and not required on the long sides so the AHUs can be racked side by side, allowing for a very compact mechanical equipment room (MER). The supply fans are upside down plug fans that extend below the floor and discharge into 22 in. [560 mm] wide ducts that just fit between the floor pedestals. The fans are variable speed, either specialty plug fans paired with ECMs (EC fans) or standard plug fans and motors with variable frequency drives. (The design borrowed features from both downflow computer room air handlers and in-row computer room cooling units.) These AHUs are currently semi-custom but very simple and easily manufactured by almost any air handler manufacturer.
- The perimeter AHU ducts are 22 in. [560 mm] × 16 in. [380 mm] OD ducts with slip-&-drive flat seams that lay flat on the floor between the floor pedestals and under the 18 in. [460 mm] raised floor. They are internally lined with 1 in. [25 mm] duct liner to minimize any heat gain to the floor when supplying warm air in heating mode. Interior AHU ducts are 14 in. [355 mm] high and uninsulated; they are raised off the floor 1.5 in. [38 mm] to allow wiring to pass below. Duct size is maintained the same the entire length to reduce pressure drop, compensating for higher than normal initial friction rates.

A floor plan of the air-distribution system for the south half of the building is shown in *Figure 6*. The south MER plan is shown in *Figure 7;* no piping is shown for clarity. *Figure 8* shows side and front elevations of the AHU.† The

*In association with Foster Partners on one project and ACCO Engineered Systems on the other.

†For humid climates, a return air coil bypass damper could be added below the cooling coil to allow the coil to cool supply air to 53°F [12°C] then blended with return air and supplied at 63°F [17°C].

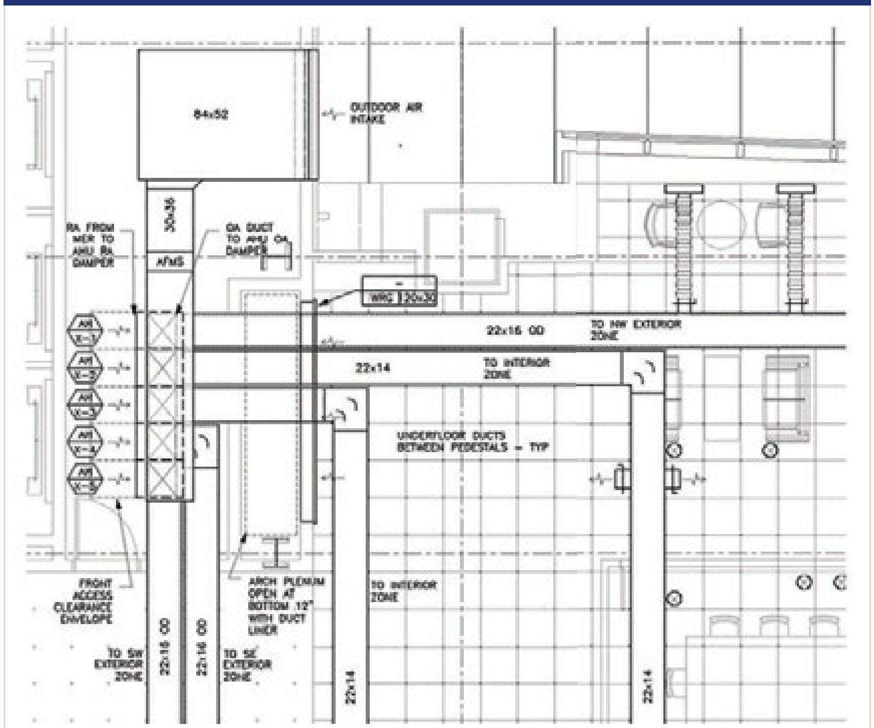

THIS YEAR, WE'RE INTRODUCING SOMETHING SMALL.
YOUR FUTURE ENERGY BILLS.

AHUs will be controlled using single zone VAV (SZVAV) logic from pending Guideline 36P;[5] the logic, which balances fan energy with outdoor air economizer energy savings, will be the subject of a future column.

This system has many advantages and should solve issues experienced with other UFAD designs:

- The fully ducted perimeter system substantially eliminates concerns about supply air temperature degradation; envelope cooling loads can be handled without any risk of overcooling the interior.
- All cooling AHUs have outdoor air economizers whose performance is enhanced by the relatively warm 63°F [17°C] supply air temperature, which reduces mechanical cooling operation by more than 2,000 hours per year in this climate compared to overhead systems supplying 55°F [13°C].[II] Hydronic perimeter systems (e.g., chilled beams, radiant slab) might have lower transport energy but would require more mechanical cooling, which makes them less efficient than systems with air economizers in Bay Area climates. This is true even when the chilled water system has a water economizer. Water economizers are not as efficient as air economizers,[6] particularly in this climate.
- There is no simultaneous heating and cooling at all. All systems that have a central AHU serving multiple zones experience some simultaneous heating and cooling. This is certainly true of UFTs (*Figure 3*) and standard overhead VAV systems. But it is also true of dedicated outdoor air systems (DOAS) serving zonal coils if the DOAS AHU has any heating or cooling capability—at some point it will either heat air that is then supplied to a zone that is in cooling mode (and would have benefited from unheated air) or it will cool air that is then supplied to a zone that is in heating mode.
- Because our design has a bank of AHUs serving the floor with common outdoor air and return air paths, outdoor air can be supplied by the interior units in economizer mode while the perimeter AHUs can supply zero outdoor air in heating mode when the weather is cool, most of the year in this climate. Basically the interior cooling loads will effectively heat the minimum ventilation air for less than free –free cooling and free outdoor air preheating are provided at the same time. When outdoor air temperatures are cold enough that the interior AHUs would be overcooled supplying minimum ventilation outdoor air, non-zero minimum damper position setpoints would be maintained on the outdoor air dampers on the perimeter AHUs so they also can supply the outdoor air. They have heating capability so the air can be heated.
- The system has no VAV dampers so there are no associated pressure drop losses. Using an automobile analogy, VAV dampers (and two-way control valves on hydronic systems) act as brakes while fans (and pumps in hydronic systems) act as the motors/accelerators. In a car we avoid stepping on the brake and accelerator pedals at the same time, but typical variable flow air and hydronic systems do it all the time. With the SZVAV design, there are only variable speed accelerators and no brakes so fan energy is minimized.

FIGURE 7 South HVAC mechanical equipment room plan.



[II]Supplying air this warm without dehumidification is possible in the Bay Area because of the very mild weather. For humid climates, return air coil bypass dampers must be provided to reduce space humidity. This negates the economizer advantage of UFAD systems vs. overhead systems.

• If a perimeter exposure has a very large solar gain such that a 22 in. [560 mm] × 16 in. [380 mm] OD duct would be too small at the typical 63°F [17°C] UFAD supply air temperature, the AHU supply air temperature can be lowered down to as low as 55°F [13°C] during peak load periods. Colder air will not result in discomfort from drafts because it is supplied right at, and upward along, the glass line, not near workstations.

• All coils and all piping are in the MER. No piping is under the raised floor so there is little risk of a leak causing underfloor water damage.

• All maintenance can be done in the MER; there are no dampers, control valves, or terminal units under the raised floor at all. This is a significant advantage over typical UFAD designs, in particular UFTs, which require regular filter maintenance. Devices under the raised floor are often difficult to access, e.g., a desk or filing cabinet must first be moved, then the carpet tiles, and then the floor tiles.

• Enclosed conference rooms can be provided with individual temperature control using cooling-only UFTs supplying sub-plenums created by full height walls or plenum dividers. Examples are shown in *Figure 6*.

• Costs are similar to and can be lower than the UFT design; duct runs are a bit longer but hot water distribution and the UFTs themselves are eliminated.

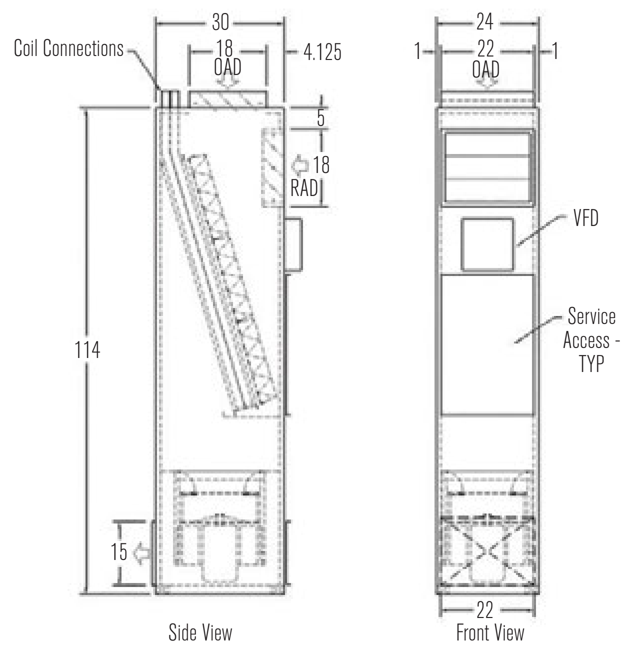
But, as with all HVAC systems, there are some disadvantages:

• The exterior zone ducts can block access for wiring from the underfloor plenum to perimeter columns and electrical boxes and swirl diffusers cannot be located where the ducts are located. The wiring issue can be mitigated by providing notches on the bottom of the duct at regular intervals to allow wiring to pass under.

• The exterior systems can "fight" with interior systems. While fighting is possible with all systems that have perimeter zones open to interior zones, the "skin" system concept can result in swirl diffusers that are located close to the temperature sensors controlling the perimeter AHUs, typically located on an exterior column. Mild fighting can also occur in perimeter conference rooms also served with UFTs.

• The design cannot be practically applied to all buildings; it applies only to architectural layouts like those on our two projects, i.e., floor-by-floor air handlers and largely rectangular floor plans.

FIGURE 8 AHU elevations. (Courtesy of BASX Solutions)



Conclusions

Our UFAD designs have come full circle, starting with a European concept that worked well, morphing into the UFT concept that seldom worked well, and then back to a design that once again has separate perimeter and interior systems. Note that neither of the buildings using our new design has been built; perhaps I'll write another column a year from now about unexpected problems we encountered.

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2016 ASHRAE TECHNOLOGY AWARD CASE STUDIES

The Anne-Marie Edward Science Building at John Abbott College serves as a steward of sustainable practices through education, diligent site management, reduction and recuperation of energy and water, and the use of multiple energy sources.

FIRST PLACE
EDUCATIONAL FACILITIES, NEW

Dedicated *To Efficiency*


Photo: Mark Cramer

BY NICOLAS LEMIRE, P.E., MEMBER ASHRAE; PIERRE-LUC BARIL, P.E.; ROSELLE O. FREDERICKS, P.E., ASSOCIATE MEMBER ASHRAE; CHRISTELLE PROULX, P.E.

BUILDING AT A GLANCE

Anne-Marie Edward
Science Building

Location: Montreal, Canada

Owner: John Abbott College

Principal Use: Teaching facility

Includes: Laboratories, classrooms, learning center, offices, public spaces

Gross Square Footage: 121,600

Conditioned Space Square Footage: 121,600

Substantial Completion/Occupancy: Summer 2012

Occupancy: 100%

National Distinctions/Awards: 2014 Énergia Award (AQME)–New Building, All sectors (First Place); 2014 Contech Trophy–Innovative Practices (First Place)

Architects: Saucier + Perrotte Architectes

Structural Engineers: SDK et associés inc.

The Anne-Marie Edward Science Building at John Abbott College in Montreal folds itself around a century-old Ginkgo tree. The new 121,600 ft^2 (11 297 m^2) building has large glazing surfaces that reflect the surrounding architecture and a large atrium with an imposing staircase designed to emulate the majestic Ginkgo tree.

The contemporary six-story building, located on an historic campus, is dedicated to teaching physics, biology and chemistry. It contains classrooms, teaching laboratories with chemical hoods, faculty offices, student spaces as well as central areas including a spacious entrance foyer and a 12,900 ft^2 (1198 m^2) atrium.

Nicolas Lemire, P.E., is president and principal, Pierre-Luc Baril, P.E., is an associate, and Roselle O. Fredericks, P.E., and Christelle Proulx, P.E., are project engineers at Pageau Morel and Associates in Montreal.

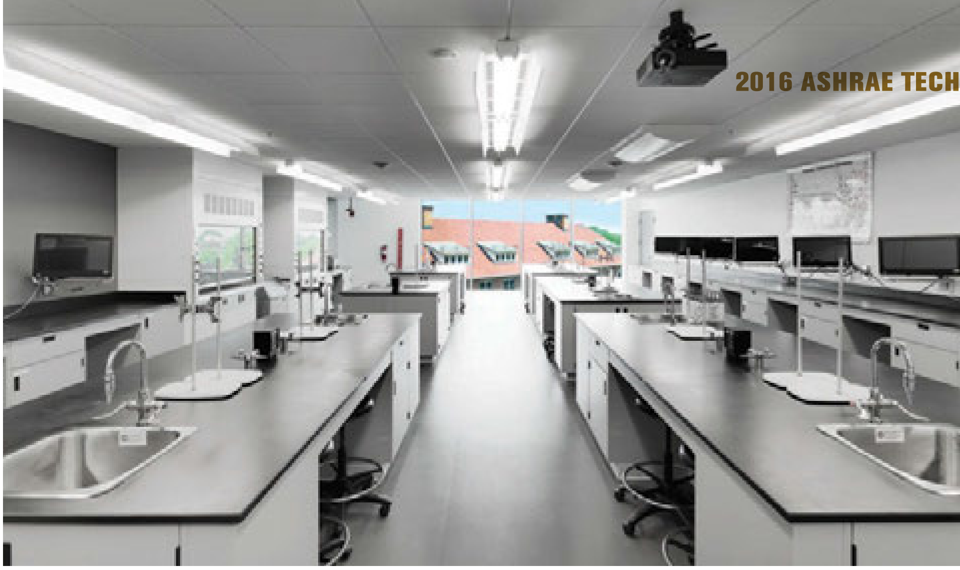

Photo: Mark Cramer

ABOVE Interactive dashboard in the main foyer presents data in an easy to understand format.

LEFT Required laboratory conditions provide the right circumstances for DOAS and dual energy recovery.

John Abbott College named the new science building after Anne-Marie Edward, one of the victims of the 1989 shooting at École Polytechnique and a John Abbott science graduate. Edward had been pursuing an engineering degree at Polytechnique, and the John Abbott community felt that through engineering, the new building demonstrated how humans are essential to environmental sustainability using applied knowledge and technology.

Integration of sustainable design principles were key to the success of the project aiming for a LEED Gold certification. Early on, it was decided that geothermal wells, thermal storage, radiant heating and cooling, a primary dedicated outdoor air system and energy recovery on both general and chemical hood exhausts would set the foundations for the building's energy efficiency, indoor air quality and thermal comfort.

Energy Efficiency

A full building energy model was simulated in Canmet ENERGY's EE4 software, which uses DOE-2.1e. The reference case for EE4 is based on the Canadian Model National Energy Code for Buildings (MNECB – 1997). The simulation predicted that the building was to consume 39% less energy than the baseline case, which, according to LEED Canada NC 2009, is equivalent to a 28% reduction when compared to ASHRAE/IESNA Standard 90.1-2007. These results include an appreciable amount of exhausted laboratory process air: 24 chemical and canopy hoods, extraction arms, solvent and acid cabinets, specialized equipment, etc. The simulation's energy consumption is much lower than the baseline case due to the extensive use of geothermal energy.

Energy metering data from February 2014 to January 2015 is provided in *Figure 1*. Actual energy use is 10% lower than the simulation and 45% lower than the baseline case. Site energy intensity is currently 48 kBtu/ft^2·yr (545 MJ/m^2·yr) whereas the baseline case is 87.2 kBtu/ft·yr (990 MJ/m^2·yr).

Hydronic Systems

The presence of a geothermal network combined with heat pumps and stratified hot and cold thermal storage tanks enable the distribution network to operate simultaneously in cooling and heating modes. The two 800 gallons (3028 L) thermal storage tanks are connected to five two-stage heat pumps which maintain stratification by feeding hot fluid to the upper part of the hot tank and cold fluid to the lower part of the cold tank. The 45 geothermal wells, each around 400 ft (122 m) deep, are used to reactivate the storage tanks. This system responds to 50% to 70% of the heating and cooling energy demands of the building. Two 150 tons (528 kW) air-cooled rooftop chillers and two 288 kW (983 MBH) electric boilers are used to cover the remaining loads. Variable speed pumps are used on the hot and cold sides of the distribution network to respond to real-time load conditions.

A solar heating system is used to preheat domestic hot water. The solar flat plate collectors can preheat a portion of the total daily demand for domestic hot water and yearly natural gas energy savings are evaluated at 0.149 kBtu/ft^2·yr (1.7 MJ/m^2·yr).

Air Systems

The dedicated outdoor air system (DOAS), combined with secondary air systems, fan-coil units and radiant floor and ceiling slabs, provide the means to decouple fresh air treatment and distribution from zone temperature control and laboratory pressurization and air changes per hour (ACH) requirements. The fresh air system incorporates two energy recovery methods. The more efficient accumulation type exchanger (using aluminium energy absorbing cassettes) is applied to the general exhaust (10,800 cfm [5097 L/s]) and the less efficient runaround glycol loop is applied to the laboratory exhaust (25,000 cfm [11 799 L/s]) to prevent any type of cross-contamination. Based on Montreal BIN temperatures, the accumulation type exchanger has estimated yearly efficiencies of 82% for sensible energy and 70% for latent energy. The runaround glycol loop has a winter efficiency evaluated at 40%. Summer efficiency is typically lower because of smaller temperature differentials between indoors and outdoors. This temperature differential is increased in the summertime with indirect evaporative cooling (the water being collected from cooling coil pans). The increase is estimated at 20% based on comparative calculations with and without the humidification process. All air-handling unit fans are equipped with variable speed drives to respond to real-time ventilation requirements including input from CO_2 sensors.

To cut down on the amount of fresh air treated for laboratory purposes, a double duct secondary system is used to recirculate return air from common zones. Based on need, this warmer air can be recirculated to interior zones, used as compensation air for laboratory process exhaust or exhausted through the accumulation-type exchanger.

Indoor Air Quality and Thermal Comfort

Learning centers, classrooms, conference rooms and other high density spaces have CO_2 sensors within the breathing zone, which allow ventilation to be modulated according to actual need. Laboratories require 4 ach of air to be exhausted, which means that 4 ach of air needs to be supplied. To limit waste, only the minimum ventilation rate is supplied and compensation air completes the ACH requirement.

Laboratories also require 10 ach of mixing which is accomplished with the use of fan-coils, as with most other non-laboratory spaces. Although laboratories are negatively pressurized, the building in general has a positive pressurization to reduce outdoor air infiltration. During suitable weather conditions(between 53.6°F and 68°F [12°C and 20°C]), natural ventilation through main circulation areas is automatically controlled (operating windows near the end of hallways open to encourage stack effect through the atrium which has operable skylight windows). Manually operable windows allow for individual control of natural ventilation in non-laboratory perimeter spaces.

Because natural lighting was an important design factor, most spaces are largely glazed. To satisfy resulting envelope loads, a heating and cooling radiant floor and ceiling system is installed in concrete slabs at the perimeter of the building. In addition to having a DOAS that dehumidifies air by supplying it saturated at 53.6°F (12°C) special attention was brought to controlling the dew point during the cooling season to prevent condensation on the slabs. Condensation was also a concern in the entrance foyer and central atrium during the heating season. Foyer loads are mostly dealt with radiant floors whereas floor diffusers air wash windows to prevent condensation.

Atrium staircase is designed to emulate the saved Ginkgo tree.

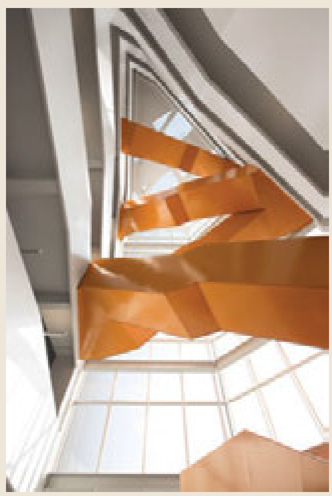

Photo: Olivier Blouin

Innovation

The new building is heavily glazed and contains many laboratories yet manages to be energy efficient thanks to the particular combination of technologies in its water- and air-based systems.

The hydronic network, which supplies the cooling and heating water to all fan-coils and radiant slabs, is uniquely conceived. First, the same network simultaneously supplies cold and hot water. This is possible because of two large stratified storage tanks and five heat pumps. The heat pumps continuously extract heat from the cold storage for transfer to the hot storage and the geothermal network adds or removes energy from the system. All components work together to maintain the tanks balanced and stratified for simultaneous supply of hot and cold water.

Laboratories are large energy consumers because of their requirements for ACH, pressurization relationships and contaminants control. These conditions actually provide the right circumstances for a DOAS and dual energy recovery. The DOAS decouples fresh air treatment from zone control by providing fresh air to secondary air treatment systems

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LEADING EFFICIENCY
& CAPACITY
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and zone fan-coils. Zone fresh air, ACH and temperature requirements are individually fulfilled and consequently provide energy savings. Also, the double duct system further reduces energy consumption by supplying warm return air to laboratories that require additional air to compensate for that which is exhausted through hoods and extraction arms. Air extracted by such equipment must be exhausted separately from the general exhaust to prevent cross-contamination in energy recovery devices. A runaround glycol loop could be applied to a combined exhaust, but provides the lowest sensible efficiency and no latent energy exchange. Therefore, this solution is retained only for the laboratory exhaust, whereas an accumulation-type exchanger is applied to the general exhaust. Since all air is returned to the double duct system, the idea is that it is either recycled as compensation air or its energy is recuperated through the general exhaust system.

FIGURE 1 Total energy consumption.

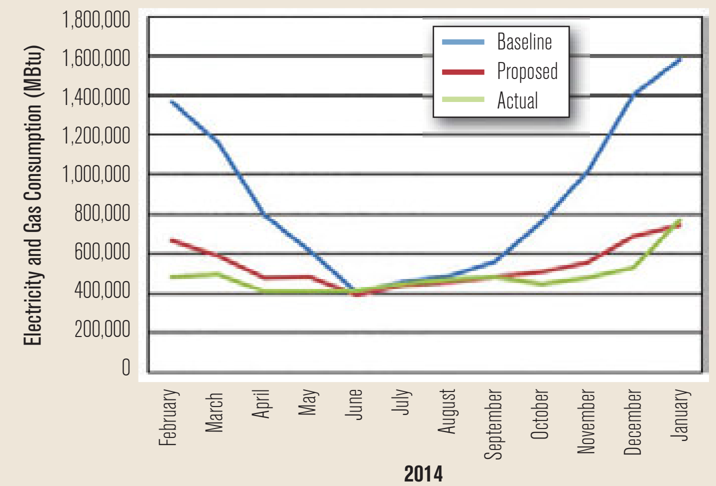
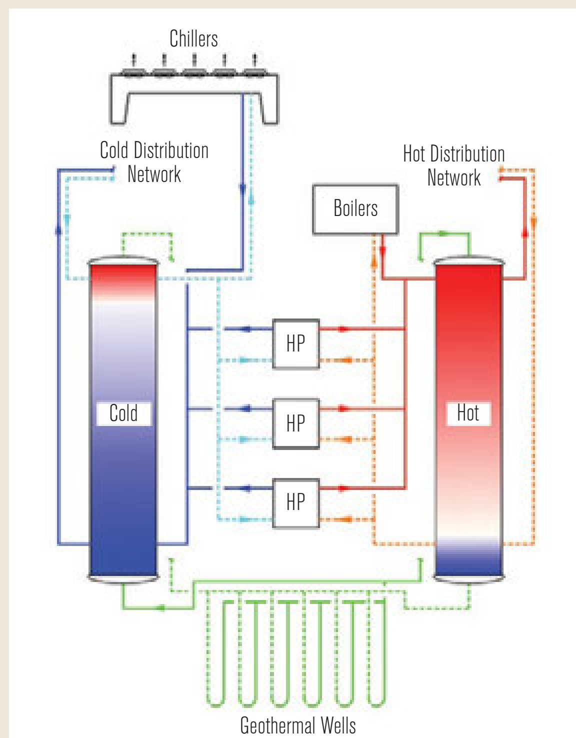


FIGURE 2 Hydronic network.



Operation and Maintenance

A building's optimal performance goes hand in hand with optimal operations, which directly depends on existing and experienced staff. During the design phase, the design team advocated for the involvement of the operation and maintenance personnel on campus to discuss the proposed principles and obtain feedback.

Mechanical rooms and air-handling units are set up to provide the required access and space for maintenance. Laboratories don't have ceilings and most fan-coils are installed either in hallway cabinets or local mechanical rooms to facilitate access to equipment.

A building automation system (BAS) is implemented to automatically control the various building systems and provide operation and maintenance alarms. The building went through a commissioning process that began long before start-up (December 2012) to improve systems even before construction. After start-up, seasonal reports were provided over a one-year span with comments and corrective actions that have all been resolved.

One of the objectives recommended by the designers and supported by John Abbott College was to ensure the building would be used as a sustainability awareness tool. Information about geothermal and solar energy use as well as grey water recuperation is presented in an easy to understand format on an interactive dashboard in the main foyer for consultation by students, teachers and visitors. Additionally, mechanical rooms are designed to showcase the various equipment as their use is explained through a training program overseen

by operations personnel in collaboration with teachers from the engineering technology department. Scale mock-up air and hydronic systems are also being prepared for use as teaching setups.

Cost Effectiveness

Total construction costs are of $35 million of which $10.8 million are for electromechanical services. A total of $1.1 million ($9.1/ft^2 [98 m^2]) is associated specifically to energy efficient measures with a payback period estimated at 7.6 years. The payback is reduced to 6.1 years when Hydro-Quebec ($216,647) and Gaz Metro ($8,250) grants are included. Continuous measurement has substantiated annual energy savings, which are currently evaluated at $144,783. Natural gas savings account for $1,970 (domestic and laboratory hot water), $730 of which are estimated as savings from the solar thermal system.

Electrical savings are calculated based on both energy and power usage: energy is charged $0.0441/kWh up to 210,000 kWh and then $0.0391 per additional kWh, whereas power is charged a monthly base rate of $7,541, plus $13.44 per kW over the first 561 kW.

The building uses a combination of water and air based systems for energy efficiency.

Photo: Marc Cramer

Environmental Impact

The design team adapted the building to the site and not the other way around. Indeed, a century-old Ginkgo tree inspired the design team and explains the unusual shape of the building. The inflection point in the middle of the structure is uniquely due to the safeguarding of the tree. During construction, 75% of waste was diverted from landfill sites and construction materials contain 15% recycled content.

The 45 geothermal wells located within the grassy central courtyard and the solar domestic hot water preheat system offer sustainable forms of energy sources. The dedicated outdoor air system's two energy recovery systems as well as natural ventilation during balmy weather offer significant energy savings. According to the simulation, the building is 39% more efficient than the baseline case which is estimated to be equivalent to 359 tons of CO_2 per year (as per Environment Canada). This value is actually larger considering that the building surpassed the simulation results by 10%. Additionally, the geothermal heat pumps and chillers, the only equipment with refrigerant, do not use any CFCs.

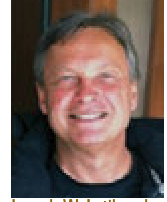
In terms of water use, the building limits potable water consumption and recuperates rainwater and coil condensation. Potable water consumption is reduced by 60% relative to the baseline case with the use of low flow plumbing fixtures such as infrared-controlled faucets and low flow toilets and urinals. Also, rainwater and cooling coil condensate is recuperated and redistributed to the building's sanitary fixtures. The grey water installation consists of a large underground tank to store the collected water and of a smaller indoor tank to treat the water before its distribution. The condensation from the cooling coil in the fresh air system is also recovered. It is then pumped to the humidifiers in the chemical exhaust system to improve the summertime efficiency of the runaround glycol loop.

Conclusion

The new Anne-Marie Edward Science Building at John Abbott College accomplishes energy diversification with the use of geothermal wells, electrical heating and cooling, natural gas hot water heating and solar preheating. Potable water consumption is reduced with the use of low flow plumbing fixtures and resources are maximized through reuse and recuperation:

- Reuse of return air as compensation air in laboratories;
- Reuse of coil condensation water to humidify exhaust air;
- Recuperation on both general and laboratory exhausts;
- Recuperation through heat pump extraction and storage in stratified tanks; and
- Recovery of rainwater and fan-coil condensation water.

Laboratory ventilation requirements and large glazing surfaces can have devastating effects on energy efficiency. Nonetheless, the building's actual energy use is 45% lower than the baseline case and 10% lower than the proposed simulation. ■



Joseph W. Lstiburek

All Decked Out*

BY JOSEPH W. LSTIBUREK, PH.D., P.ENG., FELLOW ASHRAE

"If you want to save cash. . .flash." "Don't be a dope. . .slope."

We are adding balconies to everything and people are forgetting that balconies are more than decoration but also have to function. And when we get it wrong it can be catastrophic.†

We are going to be dealing with wood balconies due to their popularity and because they tend to get done wrong more often than concrete and steel balconies.

Aside from the obvious structural engineering issues dealing with water is the number one issue.

With any balcony, getting the water off of it is a big deal. You need to drain the rain. Let me repeat, you need to drain the rain. Balconies need to slope to provide drainage. How much? A quarter inch per foot works. When you slope the balcony deck the water goes over the balcony edge and the edge needs a drip function. And where the edge meets a wall it needs to terminate in a gutter or a "kick out." If you do not provide a drip edge, water stains the surface of the balcony face. Not a very good aesthetic result. It can also allow the water to wick inward.

It gets interesting‡ when the balcony "traffic surface" is a concrete toping or tile set in concrete. There are two fundamental approaches to "waterproofing" a balcony deck. The first is where the waterproofing layer is exposed and also is the traffic surface. The second

* "Decked out," to be decorated with something, or dressed in something special, from the Cambridge Dictionary.

† Balcony collapse in Berkeley, Calif., June 16, 2015, resulting in six deaths and seven serious injuries.

‡ As an engineer I try to avoid "interesting" details as much as possible. "May you live in interesting times" is purported to be a Chinese curse and means "may you experience much disorder and trouble in your life." I am pretty sure a Chinese engineer coined the phrase. OK, not true, no engineer, Chinese or otherwise, had anything to do with the coining of the phrase. But all engineers get it. The phrase's popularization is attributed to Bobby Kennedy from a speech in Cape Town in the mid 1960s—a time and place that was apparently interesting.

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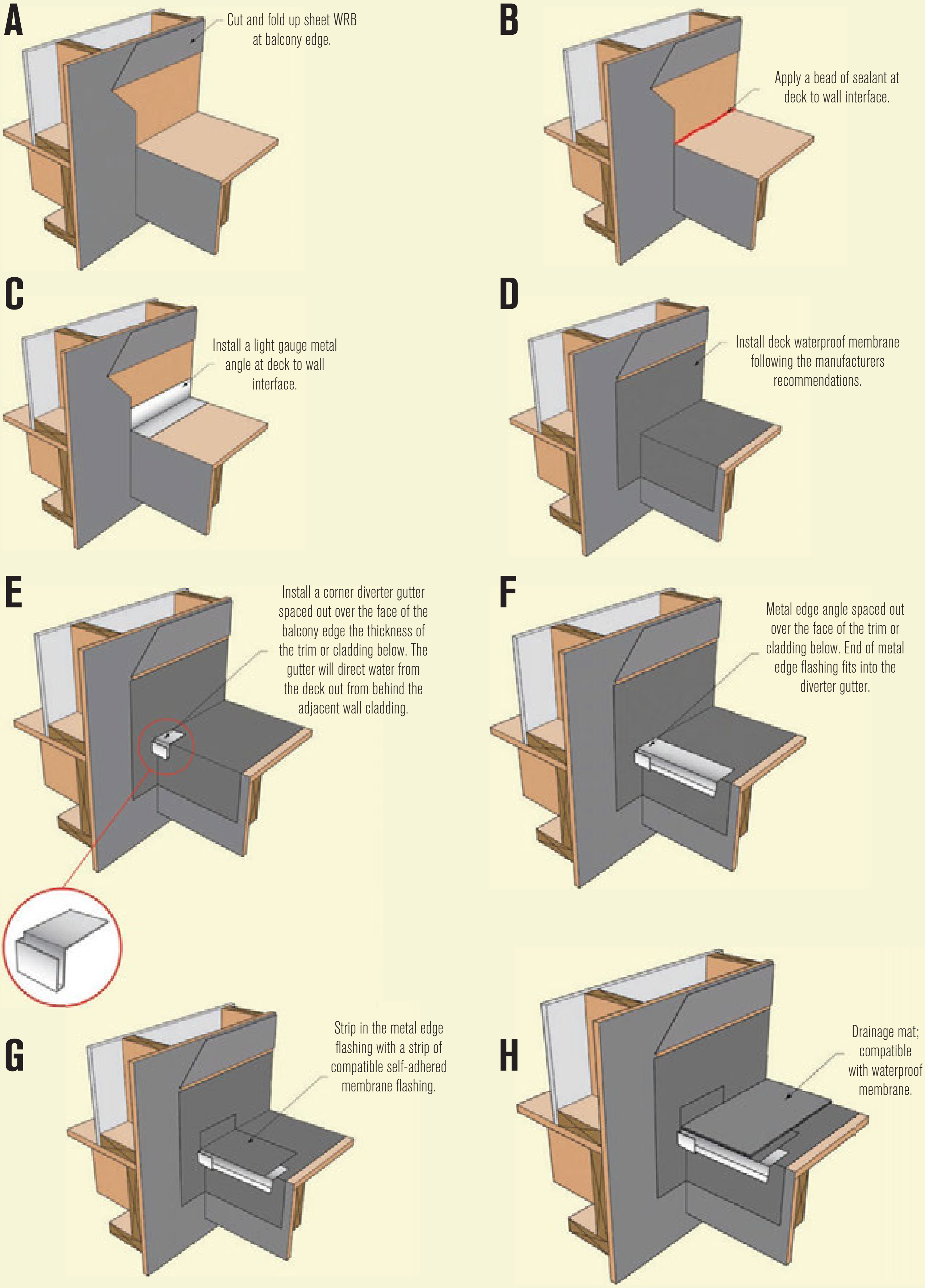
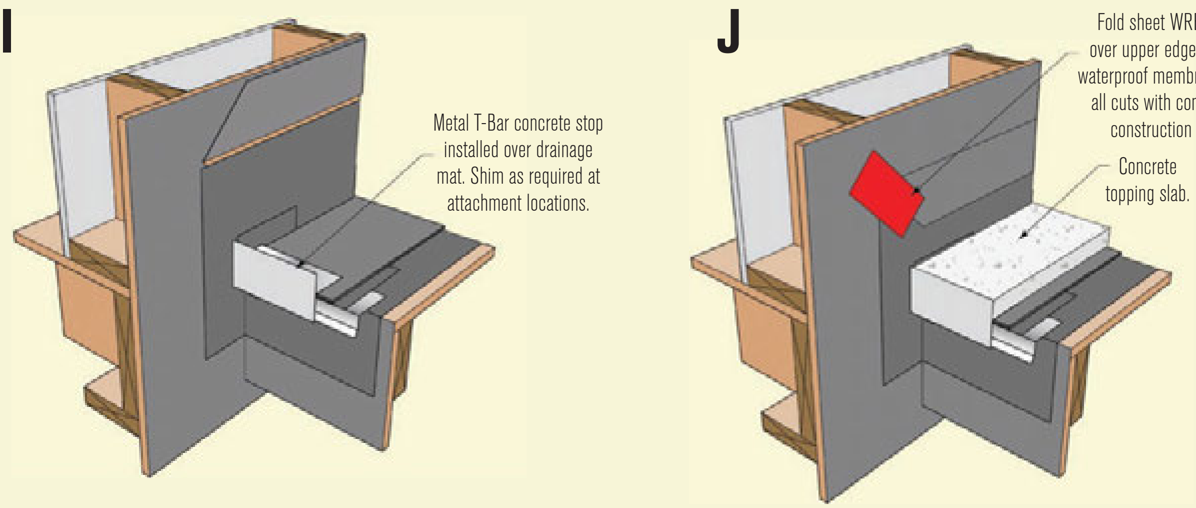
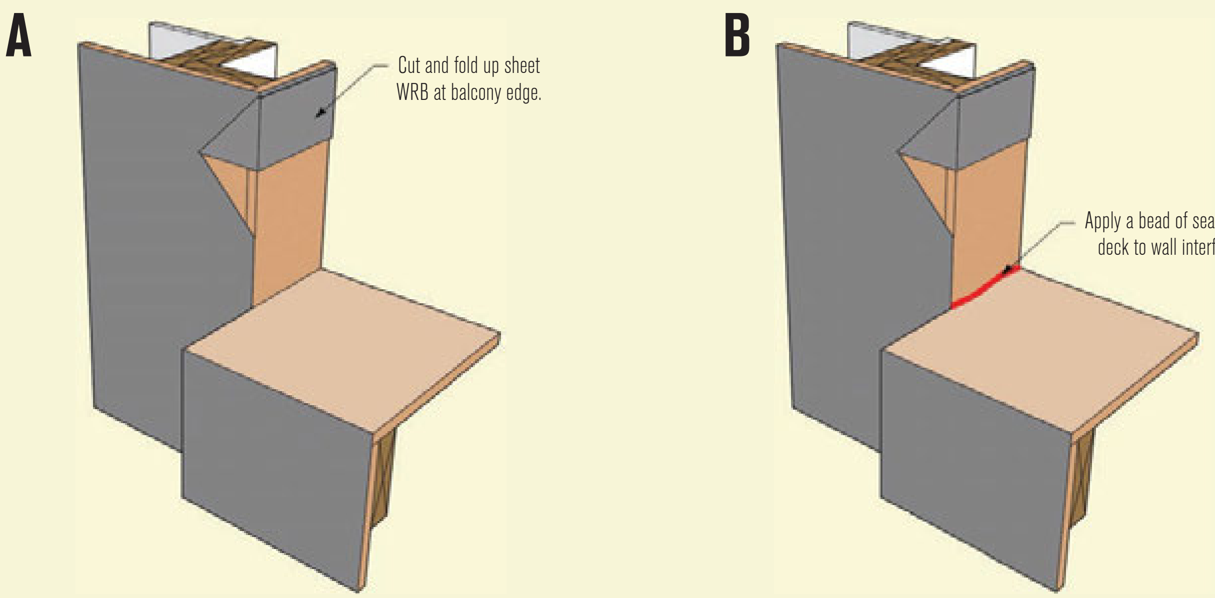
FIGURES 1A – 1J Intersection of a Balcony Edge Perpendicular to a Wall. The details remain substantially the same if a fluid-applied water control layer is used or a fully adhered sheet membrane water control layer is used.



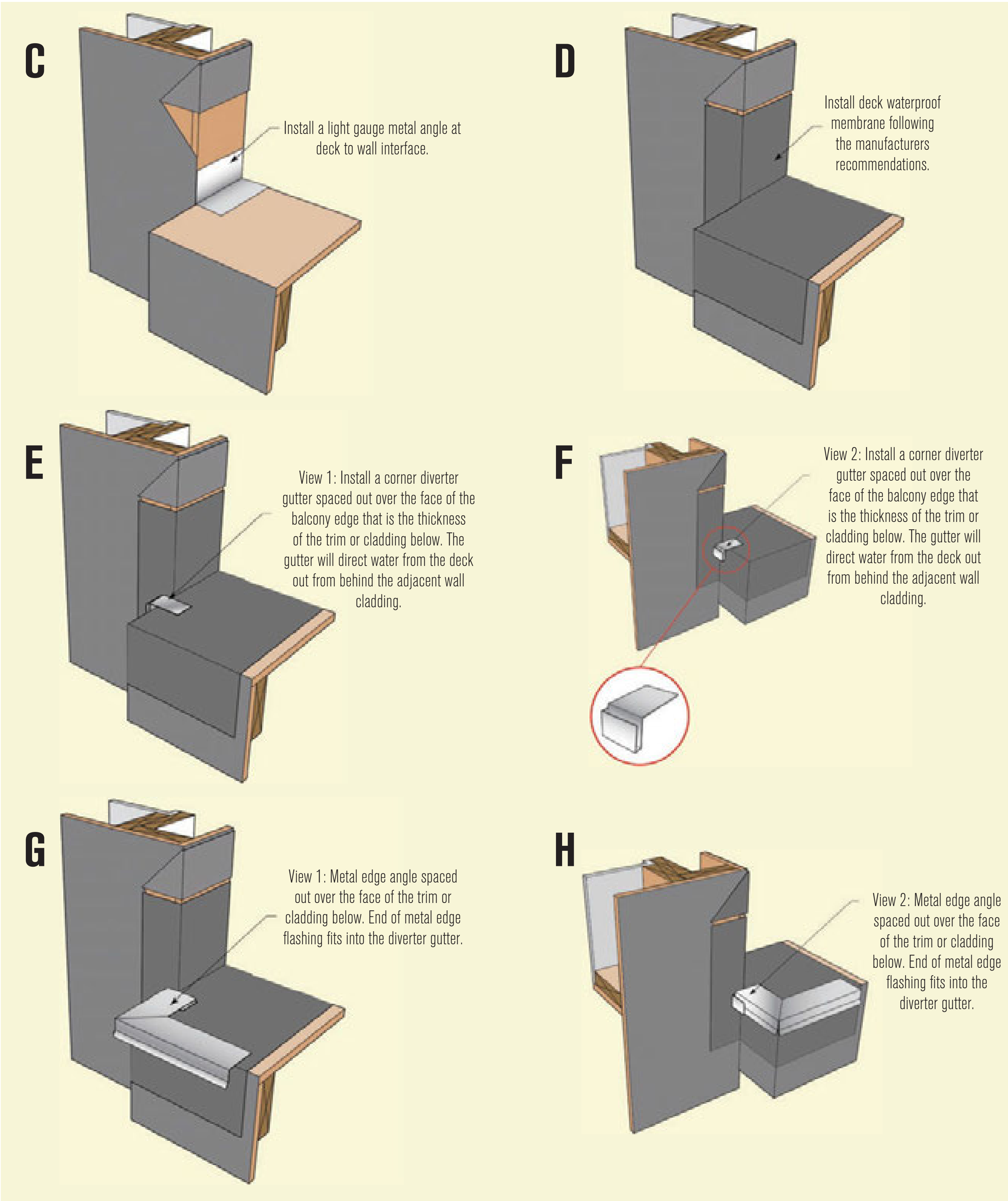


FIGURES 2A – 2L Intersection of a Balcony Edge Proud of a Wall. The details remain substantially the same if a fluid-applied water control layer is used or a fully adhered sheet membrane water control layer is used.



is where the waterproofing layer is covered over by a traffic surface. Wherever the waterproofing layer is covered it is critical that a drainage layer or space is provided immediately above the waterproofing layer. I do not use the word "critical" lightly. How big/deep/thick this drainage layer of space should be is open to debate. I typically recommend 3/8 inch. Note that concrete toppings are not waterproofing layers. And coating them with sealers does not turn them into waterproofing layers.

It gets even more interesting when architects push the balconies outwards and inwards and locate them in corners. The waterproofing of the balcony deck needs to connect to the waterproofing of the walls. Remember the first principle of building enclosures? Connect the water control layer of the wall to the water control layer of the roof and to the water control layer of the foundation? Well, a balcony is a roof that you walk on. The aesthetic complexity results in construction complexity. The detailing and execution of the detailing is a big deal.



It is probably the most difficult thing to get right and probably the most important thing to get right.

Two of the most common—and most problematic—balcony detailing geometries are presented in *Figure 1* and *Figure 2.* The figures are drawn with a concrete traffic surface installed over a waterproofing layer and drainage mat.

The figures are also drawn with a standard sheet water resistive barrier (WRB) such as building paper. The

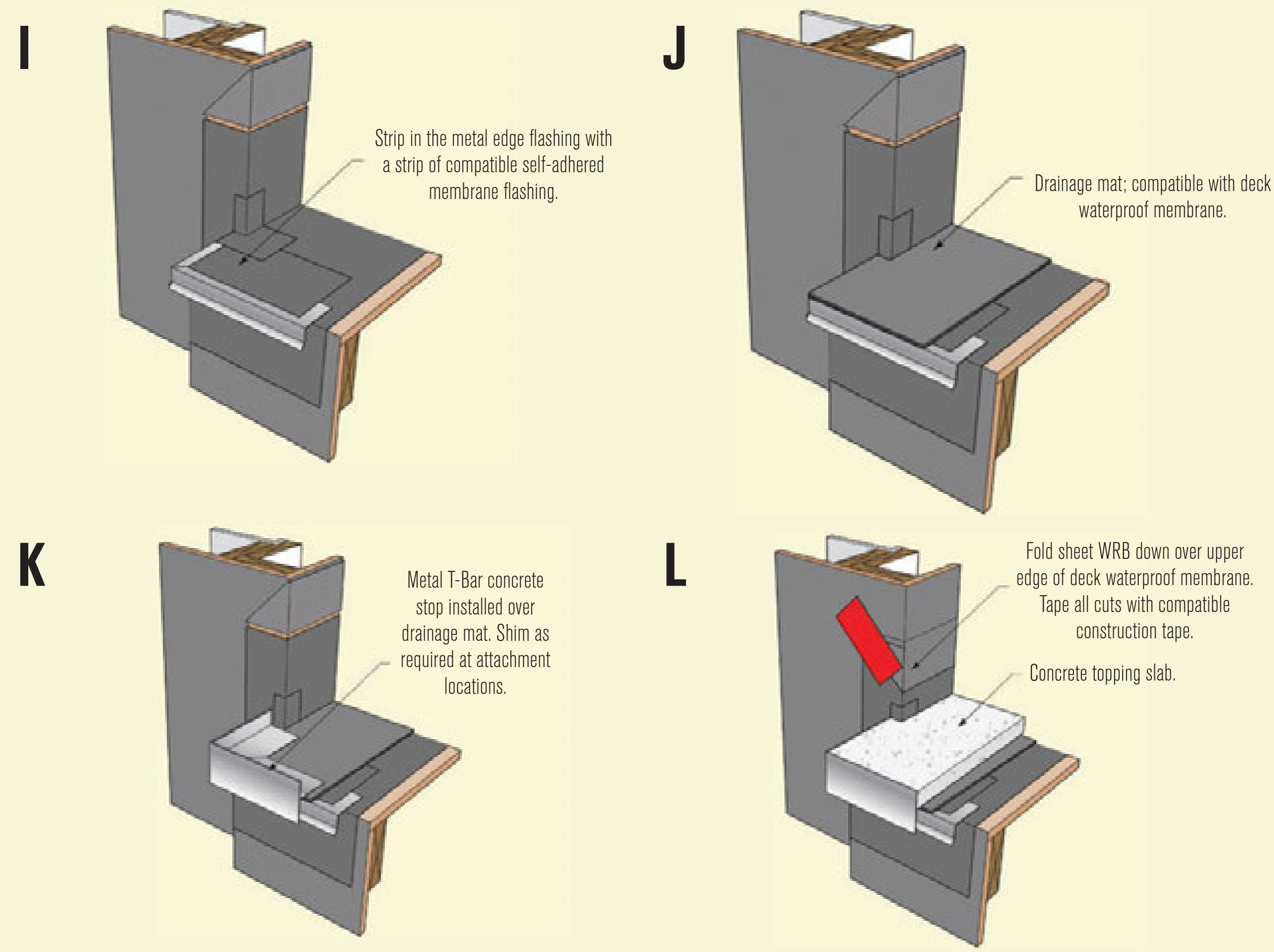


PHOTO 1 Sealant Joint. A sealant joint is installed at the perimeter of the balcony deck where it intersects the exterior wall. Note the primer application on engineered wood deck sheathing and the OSB wall sheathing. The primer's function is to facilitate adhesion of the waterproofing membrane. Also note the back dam support for the yet to be installed pan flashing in the rough opening for the balcony door.

details remain substantially the same if a fluid-applied water control layer is used or a fully adhered sheet membrane water control layer is used.

The details in *Figure 1* show the intersection of a balcony edge perpendicular to a wall.

The details in *Figure 2* show the intersection of a balcony edge proud of a wall.

Photo 1 shows a sealant joint at the perimeter of the balcony deck where it intersects the exterior wall. Note the primer application on engineered wood deck sheathing and the OSB wall sheathing. The primer's function is to facilitate adhesion of the waterproofing membrane. Also note the back dam support for the yet to be installed pan flashing in the rough opening for the balcony door.

Photo 2 shows the installation of a light gauge metal angle at the deck to wall interface. Note the use of plywood as the balcony deck surface. Plywood and engineered wood deck sheathing are typically both used interchangeably. However, adhesion of membrane waterproofing to engineered wood deck sheathing tends to be more difficult and primers become key to successful adhesion.

Photo 3 shows the pan flashing of the rough opening of the balcony door. Note the back dam and end dam of the flashing for the balcony door. The back dam support for the pan flashing has not yet been installed. The back dam support protects the upstand of the back dam during the construction process.

Photo 4 shows the installation of the membrane waterproofing. In this balcony installation an additional metal flashing is installed over the waterproofing that is stripped into the pan flashed balcony door opening. This additional metal flashing protects the membrane waterproofing at the door opening.

Photo 5 shows the installation of membrane waterproofing stripped into the pan flashed balcony door opening. Note the drainage mat installed over the top of the membrane waterproofing. Also note the mastic application sealing the waterproofing membrane to the wall sheathing.

Photo 6 shows the lapping of the water resistive barrier (WRB) over the vertical portions of the membrane waterproofing. Also note the installation of the balcony door. A drainage mat is yet to be installed.

Photo 7 also shows the lapping of the water resistive barrier (WRB) over the membrane waterproofing. A drainage mat is in place as is the drip edge at the balcony edge.

PHOTO 2 Metal Angle. Note the use of plywood as the balcony deck surface. Plywood and engineered wood deck sheathing are typically both used interchangeably. However, adhesion of membrane waterproofing to engineered wood deck sheathing tends to be more difficult and primers become key to successful adhesion. **PHOTO 3** Pan Flashing of Balcony Door. Note the back dam and end dam of the flashing for the balcony door. The back dam support for the pan flashing has not yet been installed. The back dam support protects the upstand of the back dam during the construction process.

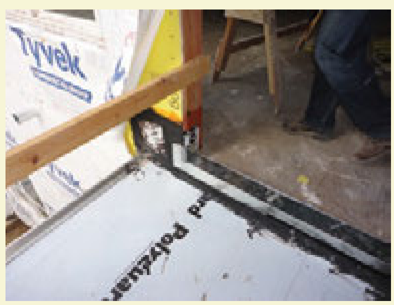


PHOTO 4 Membrane Waterproofing. Additional metal flashing is installed over the waterproofing that is stripped into the pan flashed balcony door opening. This additional metal flashing protects the membrane waterproofing at the door opening. **PHOTO 5** Drainage Mat. Membrane waterproofing is stripped into the pan flashed balcony door opening. Note the drainage mat installed over the top of the membrane waterproofing. Also note the mastic application sealing the vertical portion of the balcony deck waterproofing membrane to the wall sheathing. **PHOTO 6** Shingle Lapping. The water resistive barrier (WRB) is shingle lapped over the vertical portions of the membrane waterproofing. Also note the installation of the balcony door. A drainage mat is yet to be installed.



PHOTO 7 Drip Edge and Drainage Mat. The water resistive barrier (WRB) is lapped over the membrane waterproofing. A drainage mat is in place as is the drip edge at the balcony edge. **PHOTO 8** More Drainage Mat. The vertical top edge of the perimeter balcony deck waterproofing membrane is yet to be stripped into the exterior wall sheathing with mastic. **PHOTO 9** Two Drip Edges. The upper drip edge sheds water flowing over the edge of the concrete topping. The lower drip edge sheds water from the drainage mat gap on the top of the waterproofing membrane under the concrete topping. This two-stage drip edge approach is recommended to deal with any minerals carried in solution in drain water exiting the drainage mat gap.

Photo 8 shows the installation of a drainage mat. The vertical top edge of the perimeter balcony deck waterproofing membrane is yet to be stripped into the exterior wall sheathing with mastic.

Photo 9 shows two drip edges at the balcony perimeter edge. The upper drip edge sheds water flowing over the edge of the concrete topping. The lower drip edge sheds water from the drainage mat gap on the top of the waterproofing membrane under the concrete topping. This two stage drip edge approach is recommended to deal with any minerals carried in solution in drain water exiting the drainage mat gap. ■

De-Risking Data Center Temperature Increases, Part 2

BY DONALD L. BEATY, P.E., FELLOW ASHRAE; DAVID QUIRK, P.E., MEMBER ASHRAE

De-risking the process of raising temperatures in the data center involves many steps. In this column, we address the remaining steps of the process we began in January's column.

To this point, we've covered the following steps toward raising temperatures:

- Reviewed the air management approaches;
- Possibly determined the bypass and recirculation airflow metrics (temperature conditions);
- Reviewed the existing thermal conditions and possibly the type of IT hardware class;
- Measured the inlet temperature conditions on the IT hardware;
- Reviewed and defined the boundary conditions on the HVAC system and IT hardware;
- Determined which temperatures to raise to save HVAC energy; and

Possibly evaluated the order of magnitude of energy that could be saved and potential ROI of a more thorough review.

Each data center is unique. The combinations of their air management approach, the HVAC systems used, their operating boundary conditions, types of IT hardware, and geographic areas make for unique conditions.

These unique conditions need to be evaluated for each data center to determine *if,* and what magnitudes of, energy savings are possible through the increase in the temperatures.

Unlike normal commercial HVAC systems, data center systems require a more thorough approach when change is involved to avoid any unplanned failures of the cooling to the information and technology equipment (ITE). While many of the steps can be considered HVAC 101, it's the combination of steps applied to data center applications that removes the barriers in data center operator's minds for raising temperatures in the data center and doing so reliably.

In this column, we'll explore the remaining steps for *how* to raise the temperatures in the data center.

Identify Objectives

Raising temperatures in the data center usually starts with some discussion by management, the chief financial officer (CFO), or the sustainability management looking to save money and/or reduce the company's carbon footprint.

To save the energy and associated money, it's necessary to identify the changes to specific systems that will result in savings. For data centers, this comes from a couple of primary means:

- Raising supply temperatures from the HVAC to the data center information technology equipment (ITE);
- Raising the return temperatures coming back to the HVAC; or
- Both.

If the HVAC systems are chilled water based, they will benefit the most by raising the chilled water supply temperature, because of the thermodynamic efficiency gain of the chiller (*Figure 1*). If the system has a water-side economizer, this will also be a significant increase in economizer hours for almost all climate zones.

If the HVAC systems are DX or have airside economizers, they will benefit most through raising the HVAC return temperatures (*Figures 2* and *3*).

The temperature difference across the coils may or may not remain the same based on the strategies employed. Strategies such as aisle containment can result in increases to the return temperatures and an increase in the ΔT. This means that the supply

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FIGURE 1 Sample chiller efficiency as a function of leaving chilled water temperature (with chilled water differential temperature constant).

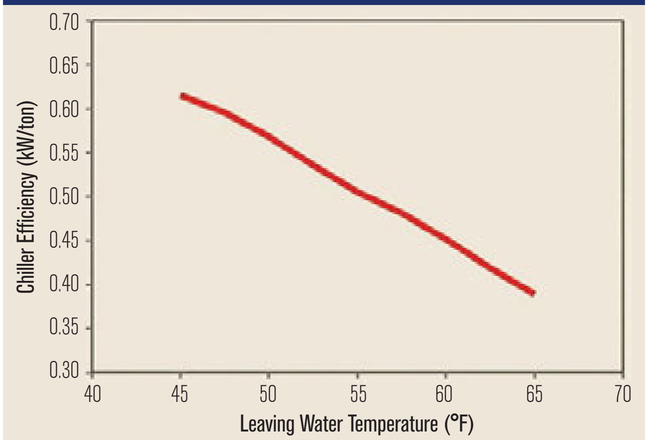
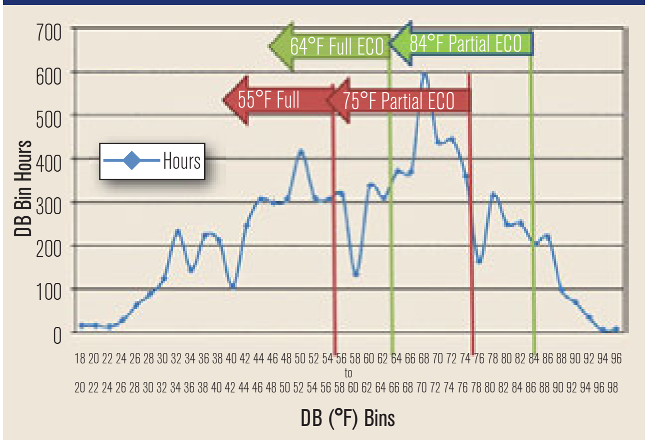


FIGURE 2 Example bin hours versus economizer operation. DB bin hours, Charlotte, N.C.



temperatures may not have changed at all unless steps have been taken to do so.

This is why it's important to identify the objectives upfront and ensure the strategies used align with those objectives to saving energy in the data center.

Identify System Limits

Once objectives are identified, the next important step is to determine *if* the systems are capable of achieving those objectives, safely and reliably. Not all systems can perform as desired. Each type of HVAC system has inherited limitations via its original design and internal safeties, settings, and controls.

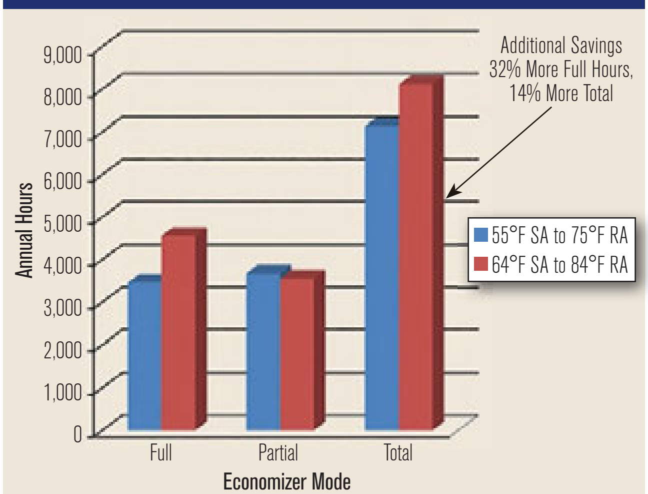
Beginning with the type of HVAC equipment, a thorough evaluation of the equipment limitations is necessary. For example, is there an economizer on the HVAC system? If yes, what type? What is the form of high-limit control?

For the existing ITE hardware, at what entering temperatures does the ITE power increase based on higher fan speeds? Many existing ITE installations will increase their power consumption above 75°F (24°C) to 77°F (25°C) entering air temperatures.

Is the equipment direct expansion (DX) refrigerant based or chilled water? Is the system air-cooled or water-cooled? What is the existing temperature difference on the coils and what temperature difference are they capable of? What humidity range (either dew point, RH, or both) is desired in the facility, and will the facility be able to adequately dehumidify to this range if the cooling coil temperature is increased?

What safeties are installed on the equipment to prevent damage to compressors? Typical refrigerant compressors

FIGURE 3 Example full versus partial economizer hours. Charlotte, N.C., air economizer.



will include low suction switches, high discharge pressure switches, and motor overload protection.

Additional questions that need answered included:

• What do the equipment efficiency curves look like and are they available?

• What's the potential savings per degree change in return air temperature on DX equipment performance?

• What's the return air temperature limit on the equipment (often limited to 100°F (38°C) to 105°F (41°C) on DX equipment as an example)?

• What were the original design assumptions?

• Do the changes involve a temperature difference on the chilled water or condenser water, which may affect piping, pumps, and towers? Both the temperature difference and temperature limits need evaluated.

Once the equipment limitations are known, the controls systems (temperature, pressure, humidity) need review.

For temperature controls, the difference between the temperature control setpoint and the actual entering conditions on the ITE should be evaluated. The Temperature Control Index (TCI) is the difference between the set point on the temperature controls and the average intake temperature to the Datacom equipment. This can be evaluated as follows:

$$\text{TCI} = \text{Average Temp Controls Reading} - \text{Average ITE Intake Temperature}$$

Example,

- T-stat on wall, or at CRAC, return reading 77°F (25°C), and the average ITE intake temperature is 66°F (19°C), the TCI = 11°F (6°C), and
- Ideally, TCI would equal zero.

In the example above, the adjustments to the temperature controls need to account for the TCI gap. If the goal is to set the ITE intakes at 80°F (27°C), then the temperature controls needs to be adjusted up by the value of TCI. In this example, the temperature controls need to be adjusted up to 14°F (8°C), which means it would be set at 91°F (33°C),

For spaces characterized as Case A2, B2, C2, or D2, with a highly variable inlet temperature across the ITE inlets, greater care must be taken. The highest temperature in the inlet range needs to be assessed. The temperature controls setting should be low enough to keep the percentage of the distribution of inlet temperatures below the upper limit of the ASHRAE "recommended" range *or* whatever objective has been set for the data center by the owner.

Next is the review of pressure and humidity controls, if present. If HVAC fans are being controlled by some form of pressure controls, then the location, type, and settings of the sensors needs evaluated. Questions for evaluation include:

- Where are the reference points?
- Location of sensors?
  - Underfloor
  - Cold aisles or containment
  - Ductwork
  - Room
- How many sensors?
- Are they monitoring, control, averaged, or other?

Finally, if humidity controls exist, there are several questions to evaluate for them as well as follows:

- What type exists?
  - Absolute (specific humidity, humidity ratio)
  - Relative Humidity
    1. Dependent upon temperature at the sensors
    2. Offsets necessary?
- How many sensors?
- Are they monitoring, control, averaged, other?

After the systems and controls have been evaluated, any containment strategies that exist or proposed should also be evaluated (See the September 2015 column, "Complying with NFPA's Aisle Containment Requirements").

The above steps are important, particularly in data centers, because they are significant contributors to system failures if not properly verified prior to system changes.

Implement and Review Tradeoffs

Perhaps the most important consideration with the proposed implementation of raising temperatures is to perform it slowly and with iterative measurements. The performance of systems, temperatures, airflows, etc., is not linear. Therefore, a slow and iterative process is necessary when raising temperatures in the data center.

This implementation process should be planned out very carefully to maximize the efforts commonly performed during "maintenance windows" in the middle of the night. Data center work is almost always accompanied with Methods of Procedures (MOPs) for any work involving changes in the data center systems and operations. Everything described in this column ultimately must find itself mapped into a detailed MOP for review and approval prior to implementation.

The implementation process will reveal surprises and unexpected results. This will often lead to the review of various trade-offs.

Measure, Monitor, and Adjust

Implementation is often considered the final step in obtaining the energy savings; however, this can lead to a lack of obtaining the estimated savings.

Data center systems are complex systems with many

tradeoffs in performance with the slightest of adjustments.

This is where post measurement, monitoring, and additional adjustments come into play. These are critically important steps because each data center is unique and can have differing results with each adjustment.

The measurement process can be conducted through an existing building automation system (BAS), but may oftentimes require some further adjustment to do so. Additional means of measurement may be required and includes the continued use of temporary monitoring systems such as data loggers, portable handheld devices, or related equipment. Caution should be exercised in evaluating the accuracy of the equipment, locations of measurement, baselines used, etc.

Final Thoughts

In this column we've covered Part 2 of raising temperatures in the data center. Raising temperatures is rarely as simple as adjusting the thermostat or temperature controls setting on the building automation system.

The process to raise the temperatures involves many steps to do it properly, safely, reliably, and with accountable results. This is particularly true in data centers where even small changes can result in system failures (a large reason many data center operators are so fearful to raise temperatures in the first place).

It requires a systemic engineering and commissioning approach because each data center, it's information & technology equipment (ITE), HVAC systems, etc., are unique.

The process for raising the temperatures begins with characterizing the temperatures, airflow management, boundary conditions, and determining method and order of magnitude of energy to be saved. With that data in hand, it's possible to identify the objectives, identify system limits to meeting those objectives, and implementing and reviewing tradeoffs. Once implemented, it's time to measure, monitor, and adjust as necessary to sustain the results.

In this month's column we completed the remaining steps necessary to de-risk the process of raising temperatures in the data center.

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1. Quirk, D., Patterson, M. 2010. "The right temperature in datacom environments." *ASHRAE Transactions.*

2. ASHRAE. 2012. *Thermal Guidelines for Data Processing Environments, 3rd edition*. ■


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Andy Pearson

Business, as Usual?

BY ANDY PEARSON, PH.D., C.ENG., FELLOW ASHRAE

I stuck my neck out recently. Not in a radical, adventurous way, but as more of a naysaying churl. However, the past is littered with elder statesmen who confidently decried new ways of thinking, from powered flight, to X-rays, to quantum mechanics, so I'd like to put my negativity into a positive context, because I believe that there are very valuable and economically precious lessons to be learned.

What I said was in most forms of refrigeration, from domestic to industrial and encompassing chillers and air-conditioning along the way, the vapor compression cycle will continue to dominate all types of systems to the almost complete exclusion of all other novel, "not-in-kind" technologies. This is not a very exciting message, and it is not intended to diminish the efforts and achievements of the many researchers and developers who are making progress with new systems, but it is based on simple observations and sound logic.

New, improved wheel, now with added corners.

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Vapor compression is the familiar system where a liquid is boiled at a lower pressure to make something cold and the resulting gas is compressed to a higher pressure and then cooled to turn it back to liquid at a higher temperature. The high pressure liquid can then be lowered in pressure, usually by squirting it through a small hole or a narrow pipe. This is sometimes called "The Perkins System" after Jacob Perkins who patented the idea in 1834. There is a wide range of "not-in-kind" alternatives; I don't intend to name any of them here because I don't want to suggest that I am picking on a specific few. I think these observations apply to pretty much all of them: if the cap fits, wear it.

The obvious advantages of the Perkins cycle are that it is simple and well understood. It is so simple that it has been built into equipment ranging from personal cooling suits up to multi-megawatt industrial complexes. Operation of these systems is relatively easy and compared to most other technologies we use daily they are also incredibly reliable. The service interval on a typical Perkins cycle compressor is the equivalent of driving a car 750,000 miles (1.2 million km) and many compressors go two or three times that distance without an overhaul. There are some less obvious advantages, too. Pretty much every "not-in-kind" device creates a warm zone and a cold zone within a single machine. To deliver the cooling to a remote location, like an office, classroom or operating theater, or over a wide area, like a refrigerated warehouse, a secondary heat transfer liquid would be required; usually water or a glycol solution. Similarly to take the heat away from the device a secondary fluid (perhaps water or glycol, but sometimes also ducted air) is required. Big not-in-kind systems need, I think, more fans and pumps than a direct Perkins cycle. Now many medium-sized Perkins cycles, such as chillers, are indirect systems but the majority of small and large systems are direct. The cold end delivers cooling directly to the people or process or stuff that needs to be cooled and the warm end releases the extracted heat directly to the outdoors. The addition of secondary heat transfer is expensive and inefficient, but these disadvantages rarely seem to feature when a "not-in-kind" technology is being promoted as the next greatest thing.

Perkins cycles also have disadvantages. Most Perkins cycle compressors require a lubricant—what I have previously described as a "necessary evil" (*ASHRAE Journal,* November 2012). The majority of maintenance activity, with the subsequent breakdown and repair, is related to lubricant issues. The expansion process is also quite inefficient, although cheap. Perhaps more of our research effort should recognize that Perkins is here to stay and should be directed toward tackling these disadvantages, not reconfiguring the wheel by adding corners to it. ■

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Residential IAQ Guide

BY LAWRENCE J. SCHOEN, P.E., FELLOW ASHRAE

Have you been asked by a friend or relative for advice about duct cleaning, mold or the best air purifier for their home? Would you know what to say? Would you know where to get the best answers? Can ASHRAE resources help? These questions and more will be answered in the *Residential Indoor Air Quality Guide* coming from ASHRAE next year (early 2017).

Does ASHRAE Do Residential?

ASHRAE publications don't yet cover homes, right? Wrong. Homes and residences are extensively covered in *ASHRAE Journal,* Handbook (see the index and table of contents per volume) and papers presented at ASHRAE conferences.

Historically, there were 10 residential space types in the first published version of ASHRAE Standard 62-1973, *Standards for Natural and Mechanical Ventilation,* which replaced the 1946 version of the ventilation section of ASA Standard A53.1, *Light and Ventilation.*[1]

ASHRAE Standard 62.2, *Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings,* was first published in 2003, is reviewed and revised every three years and the most current version is ANSI/ASHRAE Standard 62.2-2013. The 2016 version will cover all dwelling units in residential occupancies in which the occupants are nontransient.[2]

Why Have IAQ Guides?

If ASHRAE already has so much published information, why does it need more? The answer is to be found in the focus of the current documents. While standards provide only minimal requirements for new construction, guides can go beyond the minimum, provide helpful advice not suitable for standards and address problem solving in existing buildings.

The new guide will be a companion to the affordable *Indoor Air Quality Guide: Best Practices for Design, Construction and Commissioning* that ASHRAE published in 2009, which focused primarily on non-residential indoor air quality.[3] It provides summary guidance for best practice building design, commissioning construction and operation, through 40 strategies for achieving eight critical IAQ objectives. Furthermore, hundreds of internal and external links provide access to a wide variety of in-depth external resources.

Why Have a Separate Guide for Residential?

If there is so much information and so many references in the 2009 publication, why is a new one focused on residential needed? The answer can be found partly in the target audience and also in some of the unique issues faced in residential.

The 2009 *Guide* is designed for architects, design engineers, contractors, commissioning agents, and all other professionals concerned with IAQ, but it really focused on such professionals in the non-residential world.

The professionals and firms who work on residences are often from those who work on stores, offices, education, industrial and laboratories. Furthermore, even within the residential construction world, the groups of professionals who concentrate on single family are distinct from those who work on multi-family homes. The guide needs to address all of these audiences.

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On the occupant side, the residential world is very different from other building types since the occupant often has more control over indoor activities and is the ultimate "end user." However, even that level of control varies depending on other factors.

The owner may live in the house (single family or condominium) or may rent. Operational relationships also vary, depending on the owner/renter distinction, but also on whether the occupant or a separate entity manages the common area, the units themselves and the HVAC systems. One of the tasks will be to cover actions that homeowners and residents themselves can take. The new guide needs to address all of these audiences.

In covering residential IAQ, there are some unique characteristics and issues to include:

- Cooking that is not fully vented like it is in commercial;
- Greater use of appliances such as clothes dryers;
- Less commissioning and quality control;
- Single family homes often do not have designers independent of the installer;
- Less distribution of ventilation air;
- Smoking, burning of candles, incense and other substances;
- Large variations in maintenance quality and regularity;
- Proximity to subgrade and unconditioned areas such as crawl spaces, attics and basements;
- Absence of outdoor air economizers;
- Presence of operable windows and doors; and
- Bedding and sleeping.

What Are the Challenges and Opportunities?

Residential IAQ is vital because of the amount of time people spend indoors and in their homes in particular.

To cover the broad range of audiences and purposes, this publication will rely on many useful resources already provided by other industry partners. There is a wealth of information in existing programs and publications. Here is a list of some of them:

- Environmental Protection Agency (EPA) Indoor airPLUS and its other programs, publications and guidance;
- Guides from Canada Mortgage and Housing Corporation (CMHC);
- Centers for Disease Control and Prevention (CDC)/ Housing and Urban Development (HUD) Healthy Housing Manual;
- National Institute of Standards and Technology (NIST) IAQ Guidance for Net Zero Energy Homes;
- National Renewable Energy Laboratory (NREL) Guidelines and Specifications for Energy Retrofits;
- Privately published best practices guides to residential construction; and
- Periodicals including *Indoor Air* from International Society of Indoor Air and Climate (ISIAQ).

ASHRAE is a respected voice in the field of IAQ. Given the time people spend in their homes we have an important role to play in increasing the healthfulness of the residential indoor environment.

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1. Stanke, D. 2009. "Ventilation through the years: a perspective." *ASHRAE Journal* (8).

2. ASHRAE Standard 62.2-2013, *Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings*, Addendum g.

3. ASHRAE. 2009. *Indoor Air Quality Guide: Best Practices for Design, Construction and Commissioning.* Atlanta: ASHRAE. ■

CHILLERS, VALVES, PUMPS

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A Scroll Compressors

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Chillers

LF Series chillers from *AAON*, Tulsa, Okla., are engineered for performance and serviceability. They feature high-efficiency microchannel air-cooled condenser coils to maximize performance, as well as 10% to 100% variable-capacity scroll compressors to maximize part-load efficiency.
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B Control Valve/Flow Limiter

NEUTON from *SEMCO*, Columbia, Mo., is a plug-and-play controlled chilled beam pump module (CCBPM) designed to reduce chilled beam system installation and operational costs. The proactive condensation control device is designed to eliminate the expense of separate chiller/boiler and secondary water distribution systems.
www.info.hotims.com/60094-203

Pump

Toronto-based *Armstrong Fluid Technology* announces 33 models of the Generation Three Design Envelope pump. Design Envelope technology integrates selection, control and hydronic tools into heat-transfer solutions that accommodate changes in building design and demand to ensure that system performance is at an optimum at any given time.
www.info.hotims.com/60094-204

Control Valve/Flow Limiter

Dynamic from *Nexus Valve*, Fishers, Ind., is a combined pressure-independent flow limiter and control valve (PICV) in one device. It can operate as an externally adjustable automatic flow limiting valve or as a pressure independent control valve by adding the appropriate actuator.
www.info.hotims.com/60094-205

A Scroll Compressor
By Danfoss

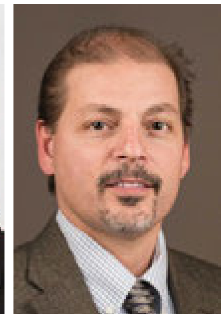
B Control Valve/Flow Limiter
By SEMCO

AIRAH Names Gleeson New CEO


Gleeson


Pearson


Vallort


Alduino

The Australian Institute of Refrigeration, Air Conditioning and Heating (AIRAH) has appointed **Tony Gleeson** as its new CEO after a nationwide search. Gleeson started Feb. 1. Former CEO **Phil Wilkinson**, Member ASHRAE, assumes the new role of executive manager – government relations and technical services. Former COO **Neil Cox** becomes executive manager – business development.

Andy Pearson, **Ph.D., C.Eng.,** Fellow ASHRAE, has been promoted to group managing director for Star Refrigeration, Glasgow, Scotland.

The North American Technician Excellence (NATE) Board of Trustees renamed **Wade Mayfield**, president of Thermal Services, Inc. of Omaha, Neb., as the 2015-2016 chairman of the board. **Gary Bedard** of Lennox Industries will continue to serve as secretary/treasurer for the 2015–2016 term. **Donald Frendberg** continues in the role of immediate past chairman. **David McIlwaine**, president, CEO and founder of HVAC Distributors in Mount Joy, Pa., and **Laura DiFilippo**, Vice President and co-owner of DiFilippo's Service Company in Paoli, Pa., were elected new vice-chairmen for the NATE Board.

Maik Bohlmann is now chief sales officer and top strategist at DencoHappel, formerly GEA Air Treatment, Herne, Germany.

James K. Vallort, Member ASHRAE, Environmental Systems Design, Inc.'s executive vice president and chief of services, discussed processes of energy efficiency as they relate to chilled water systems at the Conference on Chilled Water Systems hosted by the Brazilian Ministry of Environment and United Nations Development Programme (UNDP), in Rio de Janeiro, Brazil, on Feb. 24 to 25.

Anthony Alduino, **P.E.,** Member ASHRAE, and **Alex Melgar**, **P.E.,** are now senior project managers in Dewberry's New York office.

Dave Binz, Associate Member ASHRAE, is now Applications Engineering Manager for Cambridge Engineering, Chesterfield, Mo.

David Sinz, **P.E.,** Member ASHRAE, is promoted to senior vice president, and **Adam Kyle**, Member ASHRAE, to vice president at WSP Parsons Brinckerhoff. ■

Attendees crowded around exhibitors' booths all day to explore the thousands of new products on display.

Products, From Page 12

ClimaCool offers the Simultaneous Heating and Cooling (SHC) on Demand modular chiller systems for use in building applications that demand coinciding heating and cooling loads, SHC on Demand produces heating, cooling, and hot water from a single unit, minimizing the operating footprint. The chiller system delivers cooling to areas with a sizable cooling load, such as surgery suites or computer rooms, and transfers the captured heat via the condenser or heat recovery loop to areas requiring heat.

MTA-USA presents the enhanced range of the former TAEevo industrial water chillers with added features such as R-410A, user friendly controller with dynamic dew-point control, and more standard options.

MAC (Multi Advance Cooling Cells) is a dry, air-cooled, closed-loop liquid cooling system from ***RADICON***. Designed to replace traditional cooling towers, it offers no water loss, very low water footprint, no requirement of chemical, ozone treatment, etc., and low maintenance cost.

EVAPCO's Pulse~Pure Water Treatment System offers an environmentally responsible, nonchemical alternative for treating cooling water. The system is designed for open evaporative cooling systems and can be factory mounted on new closed-circuit coolers and evaporative condensers.

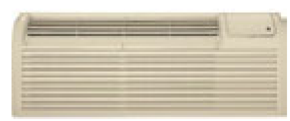
Coils, Piping

Victaulic has developed the world's first grooved piping system for saturated steam and condensate piping. Designed for use on commercial and industrial steam applications, the system features the Style 870 rigid coupling, a full line of fittings, and pipe preparation tool roll sets to process the new OGS-200 groove profile. The Victaulic grooved steam system eliminates the need to weld steam piping.

Perma-Pipe's 4010 Multi-Therm 750 Supreme is a pre-insulated piping system fortified with Aerogel nanotechnology, making it an advanced and thermally efficient steam and hot water transportation piping system. Aerogel's Pyrogel XT® reduces cross-sectional size, which provides cost savings, reduces insulation thickness, and improves thermal efficiency.

The WRX Vertical Stack Fan Coil from ***Whalen*** is the first fan coil on the market with a slide-out chassis, which greatly minimizes the time associated with maintenance and repair in occupied spaces. Having the ability to slide out a chassis and not have to remove multiple fasteners and replace it with a spare allows maintenance personnel to get a unit up and running within minutes.

Combined Heating/Cooling/ Chilled Beams



GE Appliances displayed GE Zoneline, a through-the-wall heating and air conditioning unit mainly used in the hotel/motel industry. The new Zoneline is engineered to be more reliable, quiet, energy efficient, and easier to install and maintain, all features that are critical to hotel/motel customers.

The ***Panasonic Heating & Air Conditioning Group*** expands its EXTERIOS series with the ENERGY STAR®- certified EXTERIOS XE Low Ambient series. The all-in-one ductless heat pump and air conditioner range for cooling is 9,000 Btu/h to 15,000 Btu/h (2638 W to 4396 W). And,

TOP TRENDS FOR 2016

ORLANDO, Fla.—Notable trends emerged from recent online surveys of AHR Expo exhibitors and attendees conducted by *ASHRAE Journal* and International Exposition Company. As in the 2015 surveys, energy efficiency was mentioned often by both exhibitors and attendees. Here are some of the top trends gleaned from responses to an open-ended survey question. Individual responses that can be seen as exemplary of thoughts on the trends are replicated verbatim.

EXHIBITORS

Energy Efficiency. "Energy savings and ultra low emissions (Low NO_x)."

Government Regulations. "Governmental red tape and requirements. Almost all governmental requirements in our industry equates to increased costs and reduced performance."

Sustainability. "Alignment of sustainability activities."

Skills of HVAC Technicians. "Skills gap."

Industry Education. "The most important issue is to [distribute] the knowledge of HVAC&R to all users and buyers."

Staying Competitive in the Future. "How to stay competitive in the the most challenging and industry changing times."

New Products/Technologies. "Moving from copper tubes to aluminum tubes for heat exchange coils. Expansion of microchannel (flat tubes). Inner-grooved copper tubes improvement on heat transfer coefficients/efficiency."

Economic/Political Landscape. "Presidential elections."

ATTENDEES

Energy Efficiency. "The increased willingness to look past first cost, and adopt a longer-sighted view when it comes to energy-efficient tech (including solar), which pays off in the long run. Incentives really sweeten this pot, and encourage adoption of efficient tech."

Energy Conservation. "Energy savings across the system versus at the component level."

"Green" Building. "Products at AHR Expo that are promoted as 'green.'"

Reliability/Quality. "Reliable products. Too many warranty issues with new products today."

Government Regulations. "Reduction of government encroachment that unnecessarily magnifies the cost of our products, while achieving marginal benefit to anyone."

Costs. "Pressure to reduce cost, forcing down operational margins."

Refrigerants. "Right now, I see a trend toward lower GWP refrigerants, many of which create flammability hazards. With much work in medium-temperature being done in the USA with R-410A, a shift away from R-410A would be very dramatic (similar to R-22 phaseout)."

Hiring Qualified Employees. "Shrinking qualified workforce."

Building Automation. "Affordable home automation."

Business Operations. "The biggest issue in our part of the industry is customers compromising potential safety in order to save upfront costs." ■

they feature Panasonic's inverter compressors.

500XR from ***Gilsulate International*** is a patented controlled density insulation and corrosion protection system. It is engineered to provide direct-buried district heating and cooling systems an economical, thermally efficient, dry and stable environment in which to perform in operating temperatures from 35°F to 800°F (1.7°C to 427°C).

Fantech/Systemair's ERVs are designed to reduce the energy required to heat or cool outdoor air by up to 80%. This allows users to effectively and economically accommodate the increase in outdoor air quantities.

Energy Recovery

AERCO International introduces the OriGen, an energy recovery system that converts waste heat into clean, renewable power. Capturing and turning low- to medium-temperature waste heat into usable electricity, The OriGen can be used across a broad range of applications, including biomass, geothermal/solar, and heat recovery in such places as manufacturing and industrial plants, office buildings, landfills, power plants, and refineries. By allowing facilities to consume supplemental, non-grid power locally, the OriGen helps decrease both peak and overall power demand on the utility grid, while reducing utility rates.

Airxchange introduces a line of expanded capacity energy recovery wheels with airflow capacities from 15,000 to 60,000 cfm (7080 to 28 314 L/s). The largest, ERC-156, can provide more than 150 tons (538 kW) of cooling at AHRI test conditions.

Heating

LG's Multi V S is a compact, efficient, heat pump outdoor unit that supports up to nine individual indoor units with a two-pipe refrigeration circuit. And, it allows individual control of room temperatures while offering overall increased flexibility and efficiency for commercial installations. The Multi V S only requires single-phase power rather than the traditional three-phase required for most VRF systems. The system requires little to no ductwork.

The new B35TDW brazed plate heat exchanger (BPHE) from ***SWEP*** offers higher capacities by combining the brazed plate heat exchanger with double-wall technology. Double-wall technology enhances safety by ensuring that liquids in the BPHE cannot mix and any internal leaks are easily detectable. SWEP provides BPHEs certified by the Air-Conditioning, Heating, and Refrigeration Institute (AHRI).

VAU Thermotech's fully welded plate heat exchangers feature a unique plate pattern and a flexible custom design. The hybrid heat exchanger unites conventional tubular, plate and spiral heat exchangers, and can be made to fit almost all thermal conditions.

The MSEV USHC Retrofit Kit from ***DunAn Microstaq*** consists of the modular silicon expansion valve (MSEV) and universal superheat controller (USHC). The MSEV is compact and refrigerant agnostic. It is connected to a stand-alone USHC that controls superheat precisely at varying load conditions.

Daikin North America announces the May launch of the VRV IV-S Series heat pump—the next generation "Mini-VRV" for residential and light commercial applications. The product is a single-phase, air-cooled, outdoor unit that operates up to 10 indoor units and accommodates extensive piping networks up to 984 ft (300 m).

Eichenauer offers in-stock slip-in duct heaters featuring Eichenauer's Zig Zag heater technology. The technology features enhanced heat transfer, low pressure drop, dynamic heating behavior with quick heat up and cool down, higher power outputs possible vs. conventional round wire, enhanced efficiency, lower watt densities for long life, and no brittle ceramics.

Humidification/ Dehumidification

Dectron International's air-cooled DX indoor pool dehumidifier requires no remote condenser. It features increased energy efficiency and reliability; a 65% reduction of refrigerant valves/piping/welds compared to conventional units; lower refrigerant charge; a simplified user-friendly refrigerant circuit; a new head pressure control; a compact footprint; and indoor or outdoor installation capability.

DriSteem offers an all-in-one, near-zero maintenance steam humidification system that integrates two of the company's products—the Vapormist electric humidifier and the 200 Series reverse-osmosis system—on a single skid mount with a single power supply and user interface controller.

Carel's humiSonic direct humidifier encompasses the control panel/power supply and air humidity probe in a single solution. It is, therefore, a fully stand-alone unit, suitable for both new applications and retrofit installations. In addition, master/slave mode can be used to quadruple humidification system capacity.

Indoor Air Quality

CLARCOR Air Filtration Products introduces the LoadTech line of filters. The MERV 14 filters are manufactured with the company's proprietary E-pleat technology. They feature media designed to hold twice as much dust as conventional air filters.

The new Bypass Blocking System for ***Air Filters Incorporated***'s Pockit Loc pleated filters locks filters together with a new innovative patented flap and insert on the filters. It stops premature changing of second- and third-stage filters. Equipment stays clean longer and reduces energy and labor cost.

Motors, Drives, Compressors

The second generation of ***Emerson Climate Technologies'*** Copeland Scroll variable speed ZPV2 compressor features intermediate discharge valves to boost efficiency, optimized scroll elements for variable speed performance, and positive displacement oil pump for enhanced reliability in low-speed operation.

Embraco introduces the EM3 Series compressor.

Beata Swiecicka learns about Hangzhou Shenshi's portable hot and cold compression therapy product.

The compressor features a smaller platform with an extended capacity level that can replace some larger compressors inside warehouses and stores, creating more internal space. Additionally, with the new shock-loop technology, the EM3 compressor delivers low pulsation on the system's tubes, minimizing total noise level.

The Marathon Motors brand from ***Regal Beloit*** offers the SyMax-i 56 permanent magnet ac motor with integrated electronic control for use in applications such as commercial HVAC, fans and blowers, and commercial refrigeration direct-drive and belt fans. It features the company's Radial Flux technology and an interior permanent magnet rotor.

Nidec Motor offers the U.S. MOTORS brand EC IE4-rated motor and VFD for use with variable torque pumps, fans, blowers, farm vents and hydronic pumps. The integrated motor and drive was designed with ferrite magnets rather than rare earths for more consistent pricing and cost structure.

BITZER showcased the CKH reciprocating compressors for transcritical CO_2 applications. They feature modern cylinder heads to work with low-pressure pulsation. The compressors are designed for standstill pressures of up to 1,450 psi (10 000 kPa) low pressure and 2,320 psi (16 000 kPa) high pressure.

Yaskawa's Z1000U HVAC Matrix drive brings a synergy of innovation and green technology to the forefront of building automation. Featuring direct ac-to-ac design, the unit delivers improved harmonic performance, network compatibility, reliability, reduced overall footprint, improved efficiency, and low cost of ownership.

IBYSS 2.0 is the newest, patented version of ***Advance Controls Inc.***'s (ACI) full isolation VFD bypass switch. Using a four-position switch, the devices adds early break auxilliary contacts to protect a VFD by signalling the drive's processor to start a controlled shutdown should the switch be activated to "Off" or "Bypass" positions abruptly.

Plumbing

The N-Series negative-pressure waterless trap from ***Des Champs Technologies*** allows liquid condensate to drain from HVAC equipment and simultaneously prevents air from entering or escaping. It operates in a horizontal position, which eliminates dry trap syndrome or burst pipes from freezing.

Rovanco Piping Systems pre-insulated piping systems are manufactured to exact standards with patented methods, resulting in high-quality, unique products.

Pumps

Armstrong Fluid Technology announces two new series of Horizontal End Suction Design Envelope (DE) Pumps They feature Sensorless integrated controls for greater energy savings. Both the DE 4200H and DE 4280 Series include Armstrong Design Envelope technology, with easy-to-use Sensorless control and enhanced connectivity to BAS to achieve significant efficiency improvements.

The TechnoForce e-HV by ***Bell & Gossett***, a Xylem brand, is a pre-engineered pressure booster package, and the newest addition to B&G's POWER OF e portfolio. These compact, multi-pump packages offer highly efficient variable speed solutions and hydraulic performance when additional potable water pressure and flow is required. The e-HV is designed for new or retrofit commercial applications.

New SCI close-coupled end suction pumps, and SFI frame-mounted end suction pumps from ***Taco*** provide superior reliability and ease in installation for heating, air conditioning, pressure boosting, cooling water transfer and water supply applications.

Lawrence Longo examines one of Taco's line of regulators for the plumbing industry.

Refrigeration/Process Cooling

A-Gas Americas offers a line of refrigerants for the automotive, HVAC and transport refrigeration industry.

Mexichem's KLEA 407A is an energy-efficient, low-GWP refrigerant designed for use in medium- and low-temperature supermarket applications. It is suitable for both new installations and retrofits, making it a suitable replacement for use in existing R-404A units affected by SNAP delisting.

MSA's Chillgard VRF detector is a safe, reliable solution to detect refrigerant leaks. Using photoacoustic infrared (PAIR) sensing technology, the Chillgard VRF operates over time without adjustment or zero drift, providing a stable zero baseline while achieving low levels of detection at 20 ppm minimum detection.

Sensors, Instruments

The LX205T Touch Thermostat from ***Danfoss*** is designed to control the company's LX Floor Warming Mats, LX Floor Warming Cables, or TX Thermal Trace electric heating products. The thermostat is programmable and can switch on and off an underfloor heating system at predetermined times. It is suitable for use with tile, stone, laminate, concrete, and wooden floor system applications.

Honeywell unveils the second generation Lyric Round thermostat and Lyric Wi-Fi Water Leak and Freeze Detector. The thermostat, with Apple HomeKit™, Samsung SmartThings and IFTTT compatibility, features smart alerts regarding extreme temperatures and humidity inside the home, customizable geofencing, and much more.


Ken Beebe and Phil Nehring (left) learn about the features of the Powermaster Boiler's industrial boiler.

White-Rodgers, part of Emerson Climate Technologies, introduces a new line of 80 Series thermostats. The thermostat options are designed to help HVAC professionals select the right application for each customer. The Sensi Wi-Fi Universal Thermostat requires no c-wire.

Bacharach's MGS-550 Gas Detector can use any combination of sensor technologies, including electrochemical, semiconductor (MOS), catalytic bead or infrared, in a single platform. It also features one or two sensor configurations with remote sensor options to detect refrigerant or toxic gas leaks.

General Tools & Instruments' DAF3009 is a one-piece vane anemometer/psychrometer that can measure all parameters needed to install, test and fine-tune the performance of an HVAC&R system.

SenseAir offers a low power consumption CO_2 sensor for use in battery-powered wireless transmitters. It has an accuracy of ±35 ppm ±3% of reading and will run multiple years on AA or Lithium Ion battery power.

ECOM America presents the ecom-D Portable Emissions Analyzer. Its modular design allows it to be configured to individual needs. Up to six sensors, including IR technology, provide flexibility.

The ***TRERICE*** SX9 Solar-Therm digital thermometer replaces mercury thermometers in boiler, chiller and other HVAC applications. The company's Capsule-Tite sealing technology ensures that electronics stay dry in a range of applications.

Software

With the free ***Berner*** Air Curtain Savings Calculator, users can input data and

Scott Krahn (left) and Kyle Richards (right) discuss with Abe Majors the commercial burners and boilers offered at Johnson Burners.

receive potential energy savings and ROI on Berner air curtains in just minutes.

iControl PLC from ***Innovative Air Technologies*** (IAT) is designed to give users information about their desiccant dehumidification system in one convenient place while offering superior energy savings during non-peak times. The iPad-compatible software provides remote access control data logging.

Sierra Monitor offers the

IIoT On-Ramp Suite for original equipment manufacturers (OEMs). The IIoT On-Ramp Suite comprises four products: FieldPoP™ device cloud; FieldPoP integration with leading analytics platforms, starting with Salesforce; ProtoAir™ wireless gateway; and an Application Engine with prepackaged applications.

CMD and iSqFt offers its comprehensive planning, bidding and post-bid information system, which marries CMD's Insight platform and iSqFt's proprietary network and software. The platform provides detailed views of construction activity, including historical data, projections and forecasts.

Dexen Industries' Internet of HVAC Things is designed to monitor the performance of HVAC equipment. It collects and transmits data to process and analyze in the cloud.

Tools and Accessories

The ***Trimble*** TX8 scanner for building construction can measure one million points per second while capturing precise data over its full measurement range of 360 degrees × 317 degrees.

Southwire introduces EZ-In, a cable designed with a protective outer coating that makes it suitable for both inside and outside use. EZ-In™ cable makes mini-split installation easier and more efficient by eliminating the use of conduit or cable trays. It also saves users the hassle of running two wires through a junction box.

REHAU introduces the RAUPEX® SPEED fastening system. Used in floors to efficiently and evenly distribute heat/cold from RAUPEX®SPEED pipe into the room, the hook-and-loop system can be installed in a normal concrete slab-on-grade, suspended slab or thin slab overpour.

Troy Davis (left) demonstrates to Charles Teplin the self-powered switches and sensors at EnOcean Alliance's ecosystem wall featured at their booth. The wall represents a complete automation system based on EnOcean's energy harvesting wireless standard.

RectorSeal introduces the Big Foot Stands to its product line of HVAC equipment mounts. The square, tubular galvanized metal stands have nylon footings that distribute weight evenly and absorb vibration. They can support all brands/models of ductless mini-split systems and variable refrigerant volume (VRF) condenser units.

ClimaSkinz's products protect air conditioners, heat pumps, and package units from harmful outdoor elements and debris that cause premature failure and higher electric bills. ClimaSkinz provides year-round protection against rain, snow, leaves, UV rays, and other outdoor elements.

Heresite Protective Coatings offers the P-413px baked phenolic coating for use in finned tube coils, radiators, heat pipes, air-to-air heat exchangers, and refrigeration coils.

Electro Static Technology – ITW/AEGIS High-Frequency Ground Straps ensure a low impedance path to ground for the high-frequency currents generated by VFD-driven motors and systems.

Mastercool offers its hydraulic line of tubing tools. The Hydraulic Flaring and Expanding kits make fabricating copper, aluminum and soft steel tubing simple.

Valves, Actuators

Sporlan Division of Parker Hannifin introduces two sizes of the Modulating 3-Way Valve (MTW) for use with conventional direct expansion air-conditioning and refrigeration systems.

Triatek introduces its new smart actuator for Venturi air valves. The ACT-FA-9001 includes a quiet, brushless motor that will improve the user experience, and cycle count tracking that will provide predictive analytics about the actuator and valve to facility managers.

Bray's new BV and BVM industrial ball valves feature carbon steel bodies, stainless steel balls and stems and advanced packing materials. The valves are suited for high-temperature and high-pressure water and steam applications.

Ventilation

Spinnaker Industries' RERV Series rotary energy recovery ventilators range in standard sizes from 250 to 20,000 cfm (118 and 9439 L/s) and custom sizes even larger.

Accents' new Bronze Series of decorative HVAC products is specifically designed for projects where budget is a concern. Products include supply registers, return grilles, and return-air filter frames.

ECCO Manufacturing offers the 3787 UL S636 vent system for type BH gas venting that is long lasting, lightweight and easy to install. ECCO Polypropylene Vent is resistant to aggressive condensed water, reducing contaminant pollution of the boiler.

The new ***American Coolair*** motor outside kit transforms the JBC upblast power roof ventilator into a more versatile and practical unit by mounting the motor outside of the airstream to allow ease of access for simple maintenance. ■

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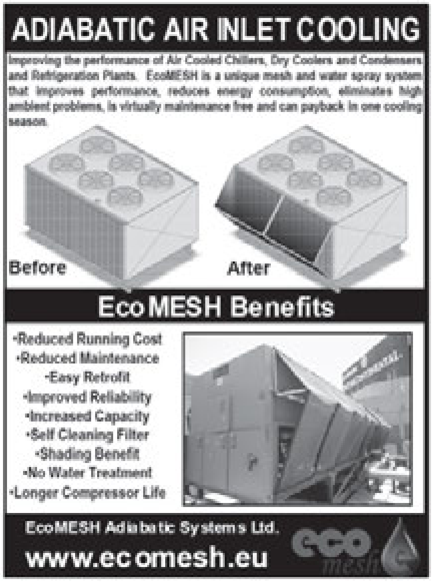

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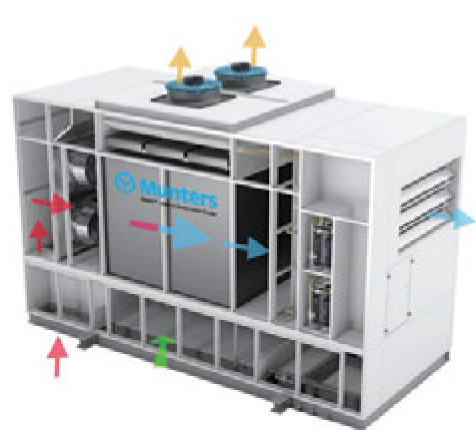

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