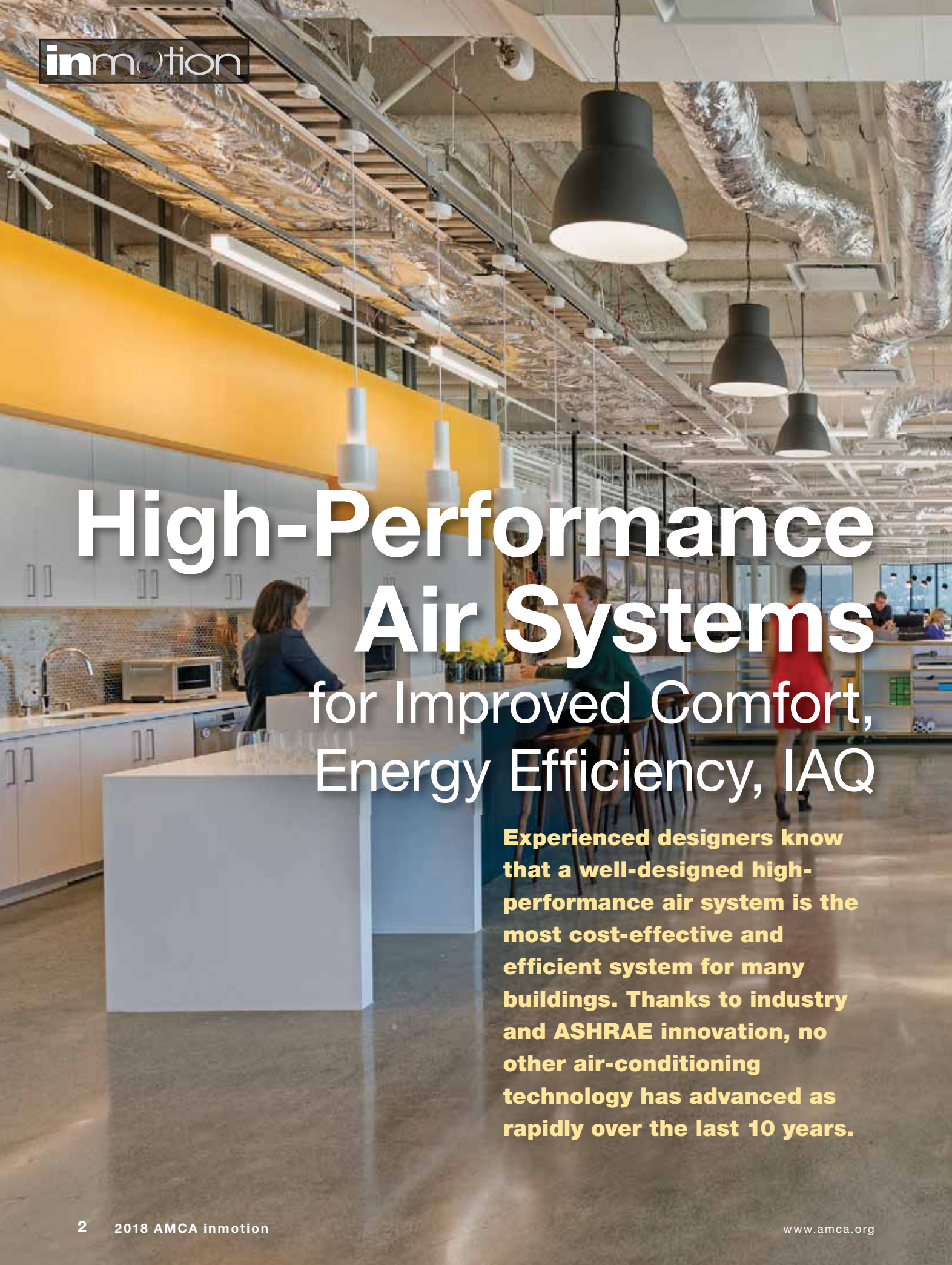


High-Performance Air Systems

for Improved Comfort, Energy Efficiency, IAQ

Experienced designers know that a well-designed high-performance air system is the most cost-effective and efficient system for many buildings. Thanks to industry and ASHRAE innovation, no other air-conditioning technology has advanced as rapidly over the last 10 years.

By **JOHN E. BADE**, Johnson Controls; **GUS FARIS**, Nailor Industries Inc.; **DAN INT-HOUT**, Krueger; and **MARK TERZIGNI**, Sheet Metal and Air Conditioning Contractors' National Association

Over the last decade, perhaps no ventilation-system type has seen more innovation and greater advances than the variable-air-volume (VAV) system. Through application of best practices and the use of modern components, a new generation of VAV system has emerged: the high-performance air system (HPAS), so called because it elevates the already high levels of performance of its technological forebearers.

Static-pressure and supply-air-temperature reset, along with significant improvements in economizer control and reliability, have slashed energy consumption. Chiller and rooftop-unit part-load efficiencies, meanwhile, have increased 50 percent with the addition of variable-speed technology for fans and compressors and now often are used with geothermal fields, further enhancing efficiency. Fan arrays, direct-drive fans, and advanced motors have reduced air-handler maintenance and unit size and driven up efficiency, while pretreatment, series energy recovery, bypass, and heat recovery have cut the amount of primary energy used for reheat to nearly zero.

ASHRAE research has driven changes in ANSI/ASHRAE Standard 62.1, *Ventilation for Acceptable Indoor Air Quality*, that will allow a HPAS to bring in less outside air than a typical dedicated outdoor-air system (DOAS) and have provided a standardized sequence of operations that make HPAS the easiest systems to specify controls for.

For more evidence, look at the list of winning projects in virtually any building-design awards program from the last five years, and you will see HPAS are well-represented. In fact, from 2016 to 2018, every hospital and every large office building but one recognized in the ASHRAE Technology Awards program utilized a HPAS.

COMFORT AND IEQ

No issue is more important in the design of a commercial building than occupant comfort. To a leaseholder, employee-compensation costs are by far the largest expense—more than 130 times the cost of providing HVAC.[1] That is why dissatisfaction with indoor environmental quality (IEQ) is the top reason owners cite for why leases do not get renewed.[1]

The zoning capability of HPAS enhances comfort. As with zonal cooling systems, indoor equipment can be sized for any zone, with most zones able to be served with one VAV terminal; even very large open areas rarely require more than two VAV terminals. HPAS achieve this level of zone control much more cost-effectively than do zonal systems—a central system requires only a VAV terminal, while a zonal system requires an additional fan coil, ventilation air distribution, piping controls, and, often, condensate collection for each new zone. And if a building needs to be reconfigured, changing the capacity of a VAV terminal often is as simple as updating a few parameters in the building automation system.

Comfort involves more than air temperature; it also encompasses drafts, noise, and humidity. With high-efficiency fans located far from occupants and

compressors located even farther, HPAS operate at Noise Criterion (NC) levels lower than those of any competing system. Modern HPAS humidity control largely happens at the air handler or rooftop unit. Designers are using methods such as coil bypass, outside-air pretreatment, and series energy recovery to circulate cool, dry air throughout buildings at temperatures that minimize reheat well below the maximum level in ANSI/ASHRAE/IES 90.1, *Energy Standard for Buildings Except Low-Rise Residential Buildings*. With widespread use of heat-recovery chillers, many buildings use almost zero primary energy for reheat.

For designers using ANSI/ASHRAE 55, *Thermal Environmental Conditions for Human Occupancy*, HPAS solve a lot of problems. Achieving and maintaining comfort involves much more than the control of air temperature; how air is distributed also is critical. The correct setting on a thermostat is of no value if occupants are in the path of a draft. With a HPAS and data provided by suppliers, designers can set the location of grilles, registers, and diffusers to ensure proper air distribution and eliminate drafts. Not only are many zonal devices, particularly those in occupied spaces, not designed to ensure proper throws, their manufacturers do not supply the data required by ANSI/ASHRAE 55, making it difficult for designers to show compliance.

Right behind comfort, indoor-air quality (IAQ) is a top concern of building owners. HPAS ensure clean air is provided to every part of a building. Zone air-conditioning systems, on the other hand, struggle to provide high-efficiency filtration and often provide no filtration at all; when they attempt to provide MERV (Minimum Efficiency Reporting Value) 13 performance, for example, their 1-in. and 2-in. filters clog rapidly, wasting energy and necessitating more frequent maintenance. With a rooftop unit or air handler, high-efficiency filters have a barely noticeable effect on performance and reduce maintenance requirements, according to the U.S. General Services Administration.[2] For this reason, the U.S. Environmental Protection Agency recommends the use of an HPAS-type system in schools.[3]

In addition to ensuring clean air, air handlers are easy to keep clean, meeting the accessibility requirements of ANSI/ASHRAE Standard 62.1. Most direct-expansion (DX) fan coils, on the other hand, require nearly complete disassembly for cleaning. For owners wanting to cover all of the bases, ultraviolet lights, which are difficult and often unsafe to add to small DX fan coils but are a standard option in HPAS products, nearly eliminate any risk of biological contaminants.

ECONOMIZING

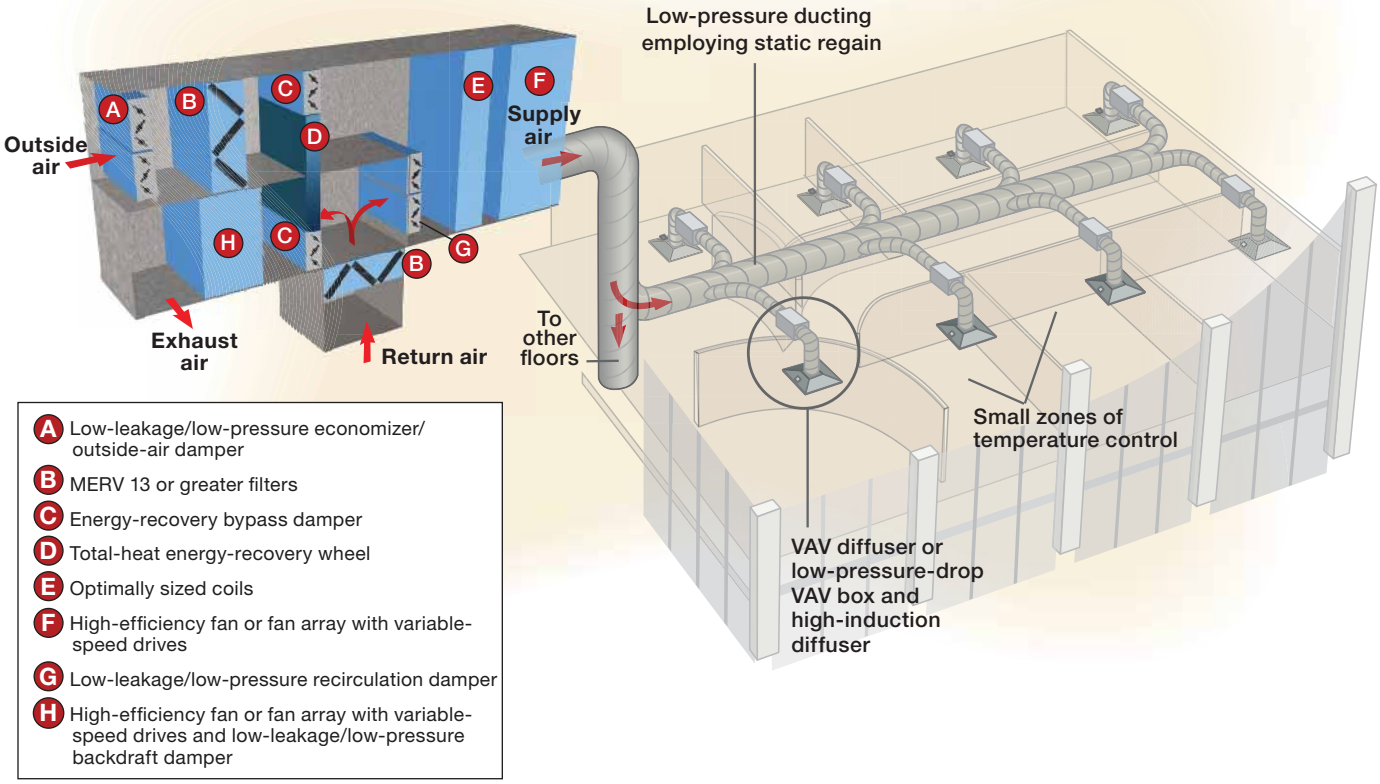
Of course, energy never is far from owners' minds, either. It is easy to convince a layperson a zoned system will use less fan energy, but when you "look under the hood," the advantages of a central system quickly reveal themselves.

Experienced designers know compressor energy exceeds fan energy by a factor of five or more in any system, and the surest way to reduce HVAC energy consumption is to turn off, or at least reduce the load on, compressors. This means economizing, bringing in 100 percent outdoor air when outdoor air has less energy than indoor air—like opening windows at exactly the right times. Of course, this makes IAQ advocates happy, as buildings can operate with 100 percent outdoor air much of the time in most climates.

ANSI/ASHRAE/IES 90.1 and the International Energy Conservation Code (IECC) recognize the value of economizing, requiring it in all but the warmest climate zones. Zonal systems are exempt from this requirement because the cost of adding economizing makes the systems economically unfeasible. With a HPAS, economizing is practically free. The duct system and VAV devices already are designed for the airflow; the only required additions are a fan, a damper, and controls. California standardized requirements for economizer-control operation and quality in Title 24 of its Code of Regulations. ANSI/ASHRAE/IES 90.1 and the IECC have followed suit, and now controls vendors provide systems that are robust and ensure building managers are notified immediately if the system is not working properly.

FAN POWER

When applied with static-pressure reset, HPAS use much less fan energy than in the past. While they may use more fan energy than a zonal system at the building design point, 99 percent of the time, the fans are running at much lower loads. In fact, for the vast majority of operating hours over the course of a year, HPAS fan motors consume 30 percent or less power than they do at full speed.



Ducted high-performance air system.

With buildings often operated at minimum ventilation airflows, HPAS use less fan power than DOAS much of the time. While both system types circulate the same amount of air, HPAS do it with more efficient fans and lower pressure drop. HPAS can circulate less ventilation air than DOAS for two reasons:

- Demand-controlled ventilation is easy and nearly cost-free to implement with a HPAS. With a DOAS, it significantly increases equipment and controls costs.
- Since publication of the 2016 version of ANSI/ASHRAE Standard 62.1, outside air to many zones can be turned off while the zones are unoccupied, which can reduce outside-air requirements by up to 15 percent.

FIRST AND LIFETIME COSTS

In almost all cases, a HPAS will have the lowest installed first cost of systems commonly considered. Following are typical expected first costs of various systems:

- Variable refrigerant flow (VRF): $20 to $27 per square foot
- Chilled beam: $30 to $45 per square foot
- VAV rooftop HPAS: $15 to $20 per square foot
- Chiller HPAS: $17 to $24 per square foot

What may be even more important to building owners are lifetime maintenance costs. A central air-handling unit or a rooftop unit requires only periodic maintenance at one location. Compare that to 30 or more fan coils or heat pumps, each in an occupied space and, in many cases, requiring a ladder for access, making it a two-person job.

When repairs are needed, if a terminal fan-coil system is proprietary, as in the case of VRF, there is only a single source for replacement parts and expert service personnel with the equipment to diagnose problems. On the other hand, parts and expert service for rooftop and air-handler systems are widely available from competing sources in every market.

RECENT DEVELOPMENTS

For years, design of HPAS was complicated by two issues:

- Difficulty in the design of controls for central systems.
- The multiple-spaces equation in ANSI/ASHRAE Standard

62.1 requiring considerably more outdoor air than it did for DOAS.

In 2018, ASHRAE demolished both of those barriers. The controls issue was resolved with the publication of Guideline 36, *High Performance Sequences of Operation for HVAC Systems*, which gives designers a simple way to specify controls for an efficient and robust VAV system meeting the requirements of ANSI/ASHRAE/IES 90.1, ANSI/ASHRAE Standard 62.1, and Title 24. It includes sequences for single-duct and fan-powered VAV systems, static-pressure and temperate reset, economizer operation, and robust alarm requirements.

The multiple-spaces equation was eliminated with the approval of Addendum *F* to ANSI/ASHRAE Standard 62.1, which will be included in the 2019 version of the standard. Going forward, the outdoor-air-intake calculation for HPAS will be the same as that for DOAS: the sum of the zone requirements. Designers no longer will have to take lengthy classes to learn how to use the equation or spend hours struggling with spreadsheets.

For more on these developments, read "Making VAV Great Again" by Steven T. Taylor, PE, in the August 2018 issue of *ASHRAE Journal* (*http://bit.ly/VAV_Great*).

TRANSPARENT AND CERTIFIED PERFORMANCE

Part of the beauty of a HPAS is there is no mystery to it; every important component has a widely accepted performance-certification program. Air Movement and Control Association International programs for fan, damper, and louver performance, combined with Air-Conditioning, Heating, and Refrigeration Institute programs for coil, air-handler, chiller, and VAV-terminal performance, ensure manufacturers are providing what is promised. In contrast, there is no performance certification for any DOAS unit.

Unlike zonal systems that come with proprietary controls and sequences carefully hidden from view, HPAS are completely open. Designers understand the critical components and have complete control over how the systems operate. While minimum requirements for operation are laid out in ANSI/ASHRAE/IES 90.1, there are plenty of tools, such as Guideline 36, that allow designers to easily specify peak performance.

CONCLUSION

The new emphasis on system part-load operation has been a boon for central-station air handlers and VAV rooftop systems. Engineers have come to realize accurate modeling of real part-load performance is necessary to achieve meaningful energy savings. This involves use of best practices, including all of those discussed here. Do not make the mistake of using ANSI/ASHRAE/IES 90.1 Appendix G, which, by design, incorporates only the bare-minimum standards. When models reflect real-world, best-practice operation, HPAS always show an energy savings compared with systems originally intended for small buildings. When first cost, IEQ, and maintenance benefits are considered, the choice becomes clear.

To learn more, read "ASHRAE Design Guide for Air Terminal Units: Selection, Application, Control, and Commissioning," published by ASHRAE in 2017.

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