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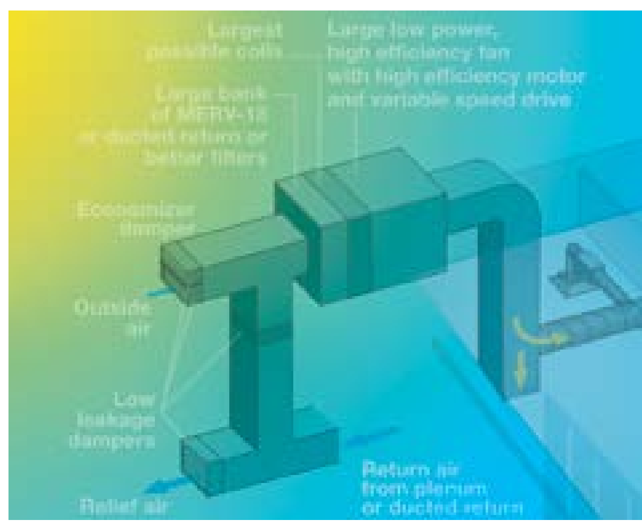

High Performance Air Systems

An AMCA International White Paper

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High Performance Air Systems

Ducted HPASs offer significant benefits over ductless systems

ABSTRACT

This paper will show that ducted high performance air systems (HPASs), when compared to ductless water/refrigerant-based systems, offer the following benefits:

- **Higher efficiency**
- **Lower first and life cycle costs**
- **Minimal refrigerant risk**
- **Better environmental comfort**
- **Better air filtration**
- **Quieter**
- **Easier to adapt to a new layout**
- **Safer and easier to maintain**
- **System component performance third-party certified by AMCA and AHRI**

High performance air systems optimize energy efficiency, comfort and indoor air quality.

INTRODUCTION TO DUCTLESS AND DUCTED SYSTEMS

The following section briefly describes the difference between ducted and ductless systems currently available for installation.

DUCTLESS HVAC: ONE SYSTEM FOR HEATING/COOLING, ANOTHER FOR VENTILATION

Ductless systems use a refrigerant- or water-based piped system for zone heating and cooling. They also have a second ventilation air system to meet outside-air code requirements.

Ductless system heating and cooling technologies include

- Variable refrigerant flow (VRF)
- Ground source heat pumps (GSHPs). Note that GSHP systems also can be connected to ducted systems.
- Water source heat pumps (WSHPs)
- Chilled beams
- Fan coil units (FCUs). Note that an FCU can be used for heating, cooling and/or ventilation.

Ductless system ventilation technologies include

- Dedicated outside air systems (DOASs)
- FCUs
- Active chilled beams with integrated fresh air inlet

Common applications for ductless installations include

- Existing ductless structures, such as masonry buildings, where ducting may be expensive to add
- Multi-family housing, dormitories and hotel applications where a common air return is not permitted
- Mixed-use facilities with different zone requirements (for example, with a ducted system serving common hospital areas and a ductless system serving patient rooms)

VRF System

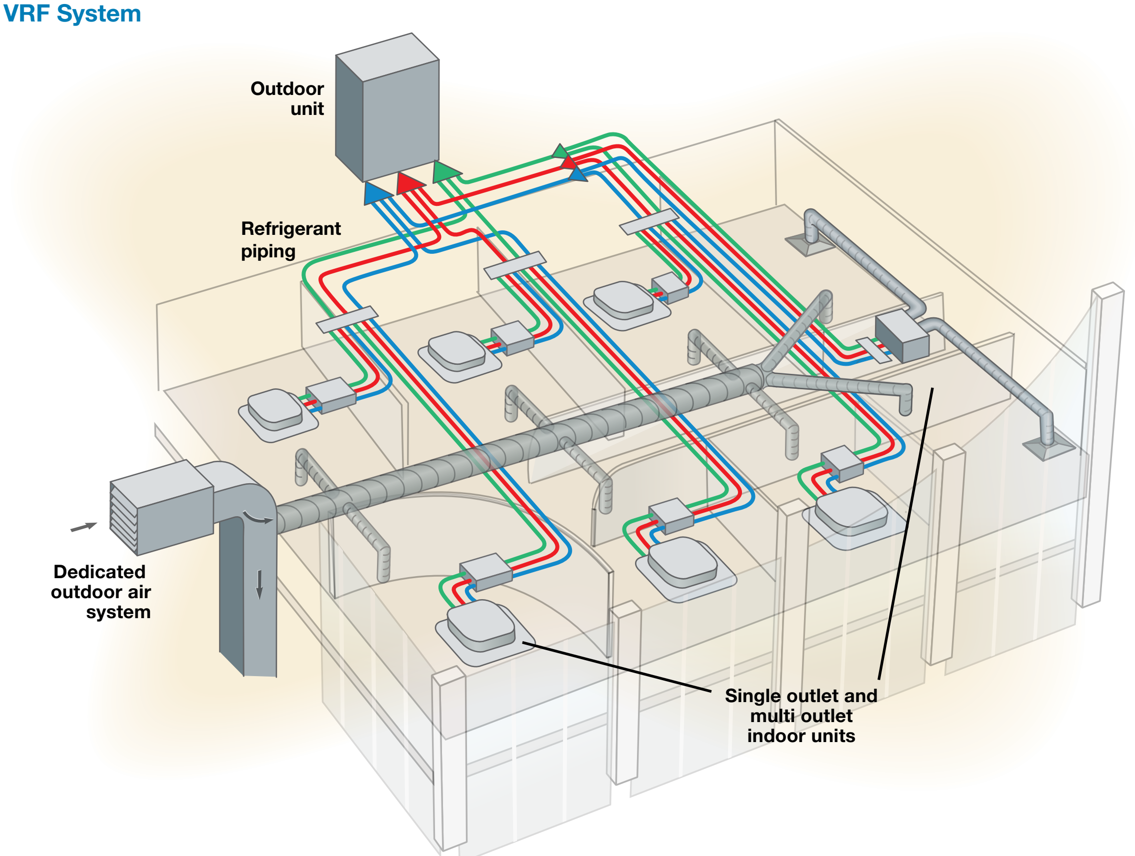

Figure 1: A system using variable refrigerant flow for heating and cooling and a dedicated outdoor air system for ventilation

DUCTED HVAC: ONE INTEGRATED SYSTEM FOR HEATING, COOLING AND VENTILATION

Ducted air-based systems incorporate heating, cooling and ventilation in a single ducted delivery system.

Ducted system heating/cooling/ventilation technologies include

- Constant air volume packaged rooftop units
- Variable air volume systems (VAVs)
- High performance air systems: VAV systems that optimize energy efficiency, comfort and indoor air quality

Common applications for ducted installations include

- Offices, retail, restaurants, theaters, casinos, factories
- Schools, education buildings
- Common areas of mixed-use facilities

WHAT IS A HIGH PERFORMANCE AIR SYSTEM?

HPASs earn their "high performance" name because they perform significantly better than basic VAV systems. HPASs optimize energy efficiency, comfort and indoor air quality, and they eliminate sick building syndrome.

HPAS design integrates the strategies of right-sizing, zone optimization and outside-air-based free cooling. HPASs also minimize static pressure drop, system leakage and system effects.

High Performance Air System

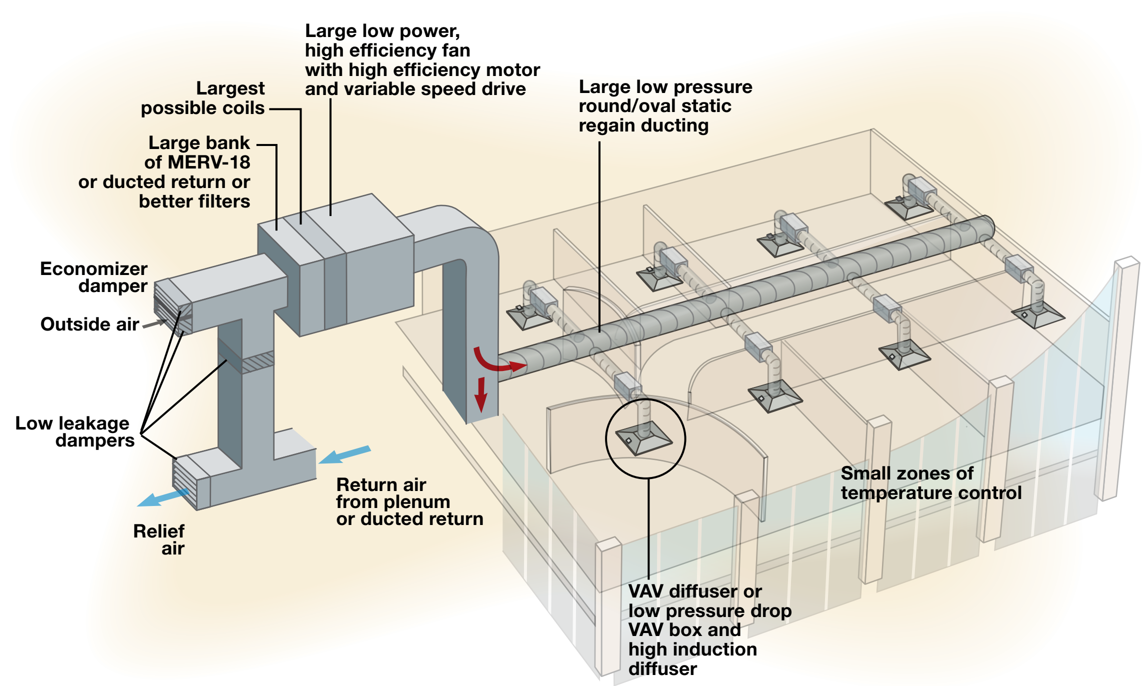

Figure 2: A ducted high performance air system

HPAS technologies and strategies include

- Variable air volume
- Small temperature control zones
- High-efficiency fans
- Outside-air economizers for free cooling
- Air-to-air energy recovery (an important HPAS strategy that is also common to other HVAC system types)
- Low leakage dampers and ducts, spiral/oval static regain ducting
- Low pressure drop components
- Variable flow compressors
- Diagnostic sensors
- Advanced digital controls

BENEFITS OF A HIGH PERFORMANCE AIR SYSTEM

HIGH EFFICIENCY. The most prominent benefit of a high performance air system is efficiency. See the detailed discussion about efficiency on page 7.

LOW LIFE CYCLE COSTS. The largest contributor to low life cycle cost is high efficiency. Cooling energy cost savings are the most significant due to free cooling and lower fan heat, requiring less cooling. Fan energy savings are also significant due to lower total static pressure. Continuous automated monitoring systems can lower life cycle costs by identifying operational events that could affect building performance.

HISTORY OF DUCTED AND DUCTLESS SYSTEMS

DRIVEN BY CONSTRUCTION PRACTICES AND AVAILABLE TECHNOLOGIES

Ducted air systems are used in the majority of comfort cooling applications in North America. In contrast, ductless refrigerant systems in Asia and ductless water systems in Europe dominate their respective HVAC markets. These practices reflect the historical evolution of air conditioning in each location.

EASTERN NORTH AMERICA: COAL-BASED AND WATER-BASED SYSTEMS

Use of coal-fired basement furnaces evolved in the late 19th and early 20th centuries in North America to keep coal dust and storage away from occupied spaces. Coal was used for coal-fired boilers or coal-fired furnaces. Older buildings in the northeastern part of the United States used hydronic heat, distributed by radiators. District steam in New York City and other major cities gave rise to cast-iron components and the pipefitting trade.

With the invention of air conditioning, radiators were replaced with two- to four-pipe fan coil systems, and existing pipe chases were upgraded to handle chilled water as well as hydronic heat. This expertise and preference for water-based systems still exists today in the northeast United States.

WESTERN NORTH AMERICA: DUCTED HEATING AND COOLING

Different factors influenced construction practices during North America's western expansion. Both wood and land were plentiful. Demand for detached, multi-room single family homes grew at a rapid pace.

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LOW FIRST COSTS. Integrated heating/cooling/ventilation systems have lower first costs than ductless systems. Ductless systems combine first costs for two systems: heating/cooling and ventilation. As a result, the installed system cost for a ductless system can be nearly twice that of an HPAS system in some applications.

CENTRALIZED REFRIGERANT SYSTEMS MINIMIZE RISK. Refrigerant leakage in occupied spaces is a safety issue for many ductless technologies, but not for high performance air systems. In HPASs, refrigerant is centralized in an equipment room or rooftop unit. In addition, when any system contains more than 110 lb of refrigerant, fusible plugs must be discharged to the atmosphere at a location not less than 15 ft above adjoining ground level and not less than 20 ft from any window, ventilation opening, or exit (per ANSI/ASHRAE Standards 15 and 34 and local codes). Accomplishing this is easier when the refrigerant system is centralized.

MULTIPLE SMALL ZONES IMPROVE COMFORT, FLEXIBILITY AND EFFICIENCY. An HPAS has small temperature control zones, which can be as small as one office. A refrigerant-based system temperature control zone must be large enough to safely disperse a full system refrigerant charge if there is a leak in that zone (per ANSI/ASHRAE Standards 15 and 34 and local codes). Note that a maximum of 25 lb of R-410A refrigerant per 1000 ft^3 of room volume is allowed for non-institutional spaces. The usual VRF system charge is 3–6 lb of R-410A per ton of refrigeration. When this charge exceeds 25 lb per 1000 ft^3 in any room, multiple rooms typically need to be grouped together to be served safely by a single terminal unit, increasing the temperature control zone size of a ductless system.

Typical Installed System Costs

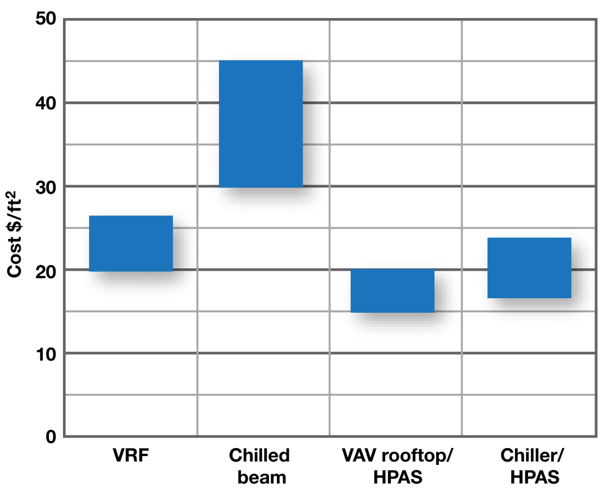

Figure 3: Installed HVAC system cost comparison. Data taken from a Trane nationwide study, 2013.[1]

HISTORY OF DUCTED AND DUCTLESS SYSTEMS (CONTINUED)

It became common practice to duct heated air from the basement furnace to all rooms — first by gravity and then by forced air. Wood construction was common and the space between the wall studs and floor/ceiling joists became the ductwork.

After World War II, contractors invested heavily in duct fabrication to satisfy the new construction demand for housing and quick-build commercial applications. When the market for central air conditioning began during the 1960s and 1970s, it was easy to add an “A” coil (evaporator) to the top of the furnace and add a condensing unit outside.

Because residential and commercial practices influence each other, the use of a common duct for both heating and cooling carried over to all commercial building types as well. DX (direct expansion) rooftop VAV (variable air volume) system use exploded in the 1980s as the demand for cost efficiency and fast installation increased dramatically. CONTINUED ON NEXT PAGE

BETTER AIR FILTRATION. An HPAS uses MERV-13 (or better) filters, UV or photocatalytic air cleaning, which provides higher quality filtration than residential-type filters commonly used in ductless systems.

QUIET. Ductless systems have numerous small room and ceiling fans, which are noisier than centralized fans.

ADAPTABLE. If needed, it is easier to move diffusers and duct takeoff branches than it is to move fan coil units and refrigerant lines.

SAFE AND EASY MAINTENANCE. High performance air systems require no scheduled maintenance in occupied spaces. Ductless systems require indoor unit filter replacement, coil cleaning and visual condensate drain inspection for every indoor fan coil on a scheduled basis. Above-ceiling maintenance, condensate pan overflow risk and refrigerant leaks can result in ceiling damage, inconvenience and health hazards for occupants.

COMPONENT PERFORMANCE IS THIRD-PARTY CERTIFIED BY AMCA AND AHRI. Most HPAS components are certified by the Air Movement and Control Association (AMCA) and the Air-Conditioning, Heating and Refrigeration Institute (AHRI), assuring owners that performance meets specified levels. AMCA-certified air performance covers fan efficiency grades, sound levels, ducted air system performance and leakage and damper performance and leakage. AHRI-certified thermal performance covers refrigeration system efficiency.

HOW HIGH PERFORMANCE AIR SYSTEMS BOOST EFFICIENCY

Several energy-reducing features distinguish high performance air systems.

OPTIMIZED FANS, REDUCED PRESSURE DROP. To lower fan energy consumption, system designers achieve the best airflow performance by selecting the fan with the lowest power (which is not always the lowest cost or the smallest fan). Manufacturers of air handling units, rooftops, and fans have selection programs that help designers meet airflow and system pressure requirements. Further optimization results from lowering design supply air temperature, specifying low leak spiral/oval ducting and not oversizing design loads.

HISTORY OF DUCTED AND DUCTLESS SYSTEMS (CONTINUED)

EUROPE AND ASIA: SOLID WALLS, DUCTLESS SYSTEMS

Europe and Asia's HVAC evolution was driven by their construction practices and constraints. Europe's path was similar to that of the northeast United States. Older buildings, which are plentiful in Europe, allowed no provision for ductwork — masonry construction had no hollow walls. These buildings were heated using piped radiation systems. Contractors developed a strong pipefitting culture and engineers built a substantial knowledge base of water-centric systems. As a result, ductless water-based systems are still preferred in Europe and Asia.

Past and present Asian apartments are typically one or two rooms constructed of poured concrete or concrete block with no hollow walls. Through the 1950s, many were heated by a single kerosene heater. Central heating, using hydronic radiators, was rare.

In the 1960s and 1970s, the window unit boom provided cooling and safer electric-strip heating in one device to satisfy the needs of these small living quarters that had no provision for piping or ductwork. In the late 1970s and 1980s, the evaporator/heating and compressor/condenser were separated into indoor and outdoor components (called "the mini split"). This was not only a quieter alternative to the "window-shaker;" it also gave owners back their outdoor view. The next logical evolution was multiple direct expansion (DX) fan coils from a single condensing unit for commercial and multi-family applications. Variable refrigerant flow (VRF) split systems with multiple indoor units were introduced for multi-room applications.

Other high performance features include design of lower pressure drop air systems using large coils, large filter banks, static-regain duct design and aerodynamic ducts (large radius elbows and fewer transitions and joints), low pressure drop terminals and plenum returns.

Further optimization includes selecting efficient motors and drives or efficient variable speed motors and drives for part load energy savings. A fan running at one-half the design airflow with optimized control can operate with nearly one-eighth the power consumption.

FREE COOLING. Today's tight building envelopes with high occupant densities and internal loads require year-round cooling in interior zones. High performance air systems bring in free, cool air when outside temperatures are low. Compare this to the energy use of ductless systems that must always run compressors to satisfy cooling demand.

SOPHISTICATED CONTROL. HPAS advanced control technologies increase energy savings further through

- Ventilation optimization based on fresh air demand by zone
- Comparative enthalpy economizers with remote indication
- Supply air temperature reset tied to measured system demand
- Optimum start/stop
- Static pressure set point reset based on zone demand
- VAV terminal reheat strategy
- Reduced VAV terminal minimum airflows
- Variable-speed compressors and fans
- Low cost efficient gas heating systems
- Trending and automated reporting of total system diagnostics
- User-specific building automation control strategies
- Airflow measurement and control
- Ice and chilled water thermal energy storage in the building (pre-cooling with economizer flush at night) that reduces peak demand and shifts the cooling load to times of cooler outside air

HPAS ENERGY SAVINGS DEMONSTRATED

There are two ways to demonstrate system energy savings: through computer modeling and by analyzing actual installations. The table that follows models the energy use of three HVAC systems in four cities.

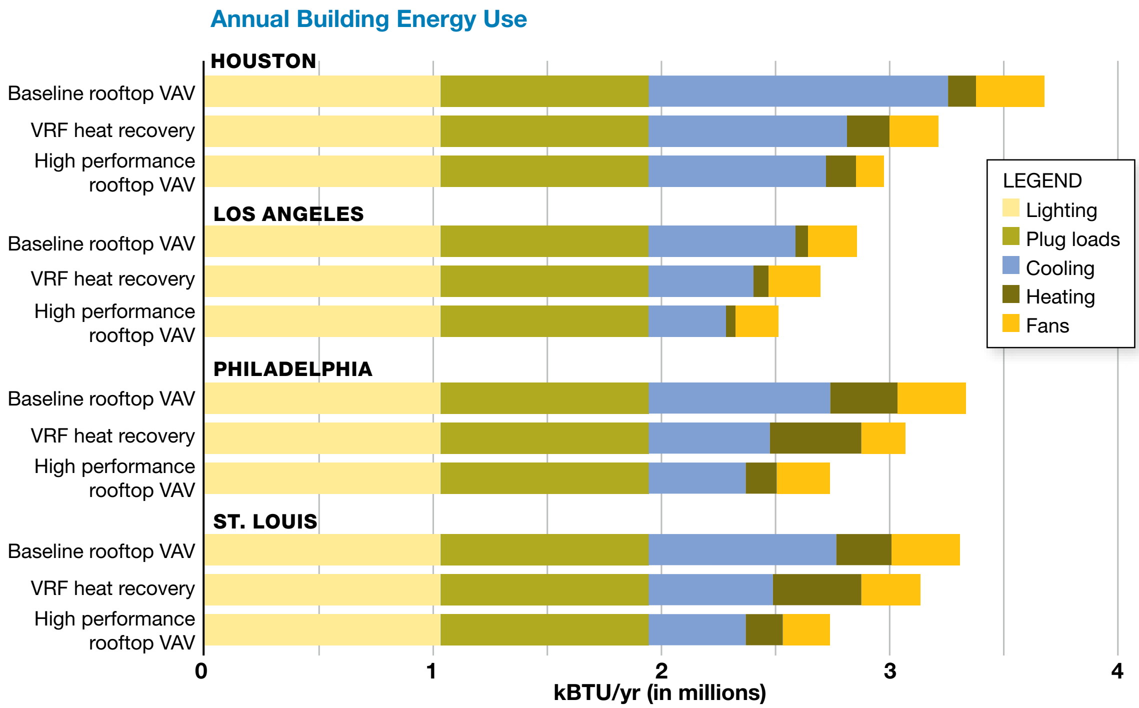

Figure 4: A TRACE Energy model of four cities representing different climate zones and HVAC system approaches. Energy use data from 2013 national averages.[1] Courtesy Trane/ Ingersoll Rand.

SUMMARY

While ductless systems are appropriate for certain applications, there are many applications for which a ducted high performance air system is a better choice. When compared to ductless systems, high performance air systems have been proven to be more efficient, have lower first and life cycle costs and deliver better occupant comfort.

RESOURCES

AMCA high performance air systems
www.amca.org/adovacy/hpairsystems.php

AMCA International headquarters and laboratory
www.amca.org

Asia AMCA offices and testing lab
www.asiaamca.org

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Air-Conditioning, Heating, and Refrigeration Institute (AHRI)
www.ahrinet.org

ASHRAE Standards 15, 34, and 62.1
Available for download at **www.ashrae.org**

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1 Trane. "Intelligent Variable Air: An EarthWise™ System from Trane for packaged DX applications." APP-PRC003-EN. La Crosse, WI: Trane, 2013.

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