The Air Conditioning, Heating and Refrigeration NEWS

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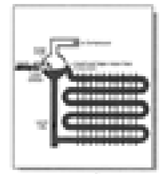

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Variable airflow coming to residential systems

Benefits of variable airflow significantly increase overall system efficiency and improve comfort and indoor air quality of conventional, on-off, constant-volume systems.

BY HOWARD BYRNES, HOFFMAN CONTROLS CORP.

In recent years, there have been efforts to bring variable airflow — commonly known as VAV (variable air volume) in commercial applications — to the residential and light commercial market.

Over the last 25 years, VAV has evolved as one of the preferred methods for delivering variable rates of energy for air-distribution systems. This variable-airflow distribution method was conceived for two basic reasons:

1. To deliver a proportional amount of energy to precisely meet the varying individual space heating and cooling thermal load requirements; and

2. To deliver that energy at the lowest effective cost, while improving the overall comfort level and/or air quality within the conditioned space.

VAV control techniques include the ability to vary flow and control the conditioned air supply to a constant, accurate temperature. This is virtually impossible, certainly impractical, with on-off residential heating-cooling systems that are not designed for and are not intended to operate at a variable flow rate.

During a typical operating cycle, the cooling and heating is at full capacity or off, and the fan is full flow or off.

Current efforts are being directed toward bringing variable-airflow features and benefits to smaller, packaged, unitary equipment and systems. Various technological methods are being explored to accomplish this task. Variable-speed control of single-phase fan or blower motors is at the center of the effort.

Motor Technology

The technology for accomplishing variable–speed control (variable flow) falls into two, distinctly different methods. Of the two, most recent efforts are focused on the development of a specially designed, brushless DC motor that requires a microprocessor and the conversion of AC to DC.

Once converted, speed regulation is a factor of the applied voltage. This method is known in the industry by the term ICM or ECM (Internally or Electrically Commutated Motor).

This method currently has two major obstacles to industry and market acceptance. The first is its high cost; the second is the availability of this special-purpose motor in an industry totally populated with PSC (permanent-split capacitor) type motors.

Microprocessor DC, variable-speed motors can present unique availability and service-related issues. Because of their costs and complexity, replacement variable-speed motors typically are not available for a specific unit model or application through stocking wholesalers. The contractor must special order a replacement motor from his OEM equipment supplier, who will program the specific instruction set into the motor for the specific product application.

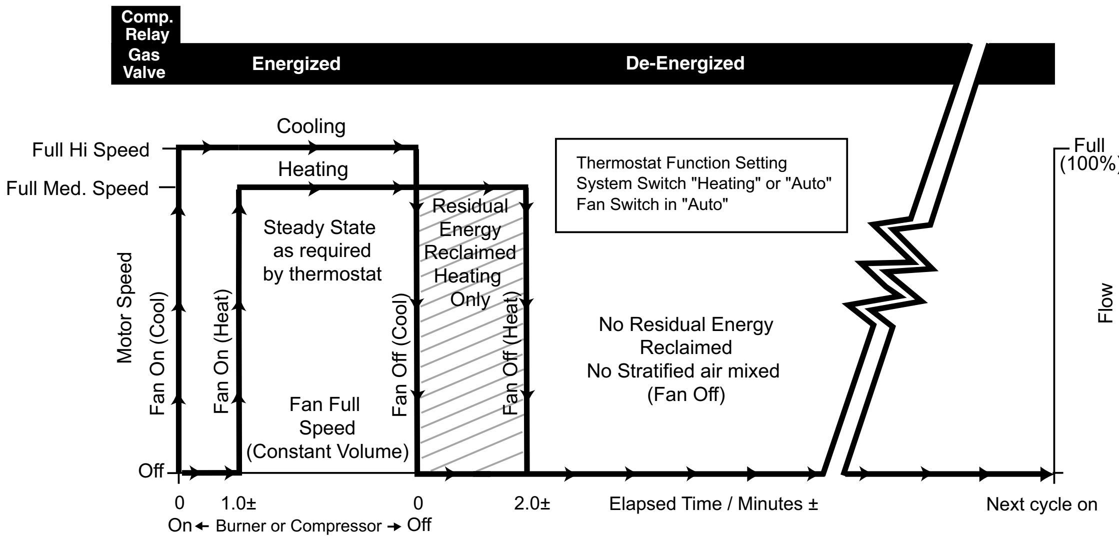
DC motors are inventoried at a national distribution center, where the computer instruction set is downloaded into the microprocessor-controlled motor.

On the other hand, there is an existing base of many millions of single-phase, PSC-type motors already embedded in the infrastructure of the HVAC industry. A single-phase, PSC or shaded–pole motor is as common as bread on the shelf at your local supermarket.

Variable-speed regulation or control of AC motors using phase proportioning has been an accepted industry method for decades. This method of speed regulation has been embraced by design engineers by every major manufacturer using single-phase motors.

Phase proportioning can be described as controlling motor speed by varying the amount of energy in each of the 60 cycles of the sine wave.

Phase proportioning can be applied to any typical PSC or shaded pole motor with few exceptions. The resulting controlled



Typical Constant Volume, Warm Air Heating & DX Cooling System
Figure 1

reduction in energy causes the motor to "slip" out of its 60-cycle speed. For single-phase blowers in air-distribution applications, manufacturers have, for the most part, settled on the six-pole, 1050 to 1075 RPM motor.

Phase proportioning is currently being used, and has been used for over three decades, for many variable-airflow applications typically found in venthood, ceiling fans, exhaust fans, VAV fan-terminal blowers, pumps, condenser motors, etc. Using the phase-proportioning method, retrofitting can immediately impact the millions of existing HVAC installations.

Manufacturers' applications of single-phase, PSC motors for conditioned air distribution — new products alone — well exceeds five million a year.

In general, there are some mechanical limitations for the lowest practical speed that may be obtained for a specific application.

Typically, the lowest minimum speed is limited depending on the type of motor bearing design. Sleeve bearing motors usually are limited to 400 to 500 RPM, as recommended by the motor manufacturer. Ball bearing motors do not effectively have a minimum speed limit.

In addition, motors may be limited by the increased rise in motor winding temperature as a result of motor ventilating characteristics. As motor speed slows down, the air over and through the frame of the motor naturally diminishes, and the heat-rejection efficiency of the motor is not always adequately transferred into the airflow. The temperature of the air can also be a factor.

Fortunately, motor design, purposed or not, most often affords satisfactory operation. Thermal overloads, which are almost always found in motors, protect against overheating, should it occur.

As a result of the low first cost and field availability of PSC motors, phase proportioning seems to be the preferred economic choice for varying the speed of fans, blowers, and pumps. It is the only choice for retrofit in existing systems.

The great majority of small, unitary, packaged systems function as a single-stage heating or cooling systems — on or off. Therefore, any variable-flow-control function generally must occur before the next cycle begins, or after a cycle has ended.

This limits the opportunity for variable flow, but innovative methods can drastically impact the efficiency of a simple on-off system and dramatically improve the comfort level and resulting indoor air quality.

Let's look at a graphical depiction of a typical warm-air furnace and DX cooling system that makes up probably more than 50 million existing domestic installations (see Figure 1).

Beginning with a call for heating:

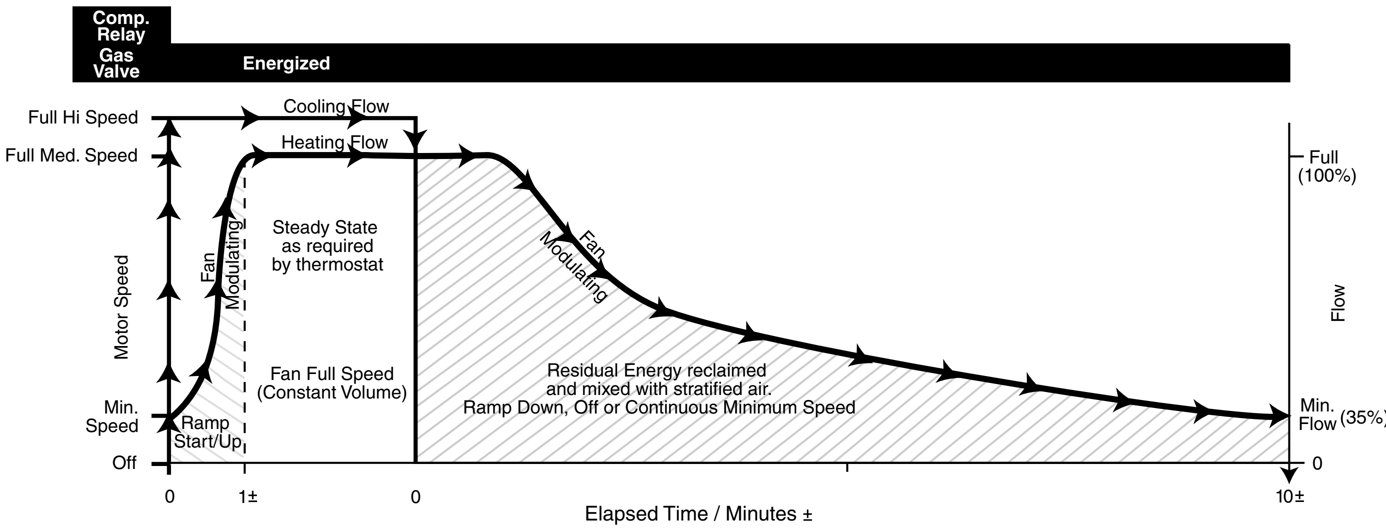
1. Burner ignites after proof of safety controls; fan remains off.

2. Fan energizes
   - After time delay, or
   - After a temperature rise of conditioned air.

3. Fan operates at medium speed (medium-speed winding of multi-tap motor).

4. Medium speed continues until burner de-energizes and remains at medium speed until
   - Predetermined time delay elapses, or
   - Temperature of conditioned air reaches a predetermined temperature.

5. Fan remains off until next cycle, calling for heating.



VariFlow Variable Volume, Warm Air Heating & DX Cooling System
Figure 2

Beginning with a call for cooling:

1. Compressor and fan energize simultaneously.
2. Fan operates at high speed (high-speed winding of multi-tap motor).
3. Remains at high speed until thermostat de-energizes compressor and fan.
4. Compressor and fan remain off until next cycle, calling for cooling.

The fan in either cooling or heating mode operates at full flow as required for cooling capacity requirements (400 cfm/ton) or heating capacity requirements (40° to 70°F temperature rise). Cooling and heating are typically single-stage, on-off functions of two different flow rates, at constant volume.

Presently, a new special-purpose, variable-flow controller is being made available for factory or field (retrofit) installation on PSC motors for HVAC equipment. The new controller incorporates the phase-proportioning design and regulates variable flow of fans and blowers in warm-air furnaces, heat pumps, and DX/chilled and hot water fancoil units.

Two independent, preprogrammed, variable-speed control ramps initiate flow at a predetermined, selectable minimum flow and increase to full flow, subsequently decrease to minimum flow, before and after each typical heating and/or cooling cycle.

This variable-flow function will be offered factory-installed on warm-air furnaces, with or without DX cooling, by OEMs. It is currently available for retrofit on existing systems. This new, variable-flow function-control method is graphically depicted in Figure 2.

Beginning with a call for heating:

1. Fan-blower is initiated immediately at minimum flow (no delay) when the burner ignites.
2. Flow increases to full flow by the time the blower normally would have energized at full flow.
3. Fan operates at medium speed until burner is de-energized.
4. Fan decreases in speed over an extended ramp-down cycle until minimum speed is obtained.
5. Installer or customer may select
   - Off fan operation once minimum speed (flow) is obtained, or
   - Continuous minimum speed (flow) until next heating cycle.

Beginning with a call for cooling:

1. Compressor and fan energize immediately at cooling cfm flow.
2. Fan functions at high speed (high-speed winding of multi-tap motor).
3. Remains at high speed until thermostat de-energizes.
4. Fan speed immediately drops to medium speed (flow) and decreases in speed over an extended ramp-down cycle until minimum speed is obtained.
5. Installer or customer may select
   - Off fan operation once minimum speed (flow) is obtained, or
   - Continuous minimum speed (flow) until next cooling cycle.

This pre- and post-variable-flow regulation of fan-blower speed increases system efficiency. It purges all of the residual energy remaining in the heat exchanger, DX coil (if installed), and the unit-system at the end of each cycle at a decreasing flow rate. This minimizes cold drafts, air stratification, and noise.

In addition to delivering air at an optimum temperature and flow rate (before and after the normal functioning cycle), this variable-flow system improves comfort and indoor air quality by minimizing air stratification during the period that the fan-flow would not have operated, or would have operated at full flow.

Reducing air stratification in the space "homogenizes" the air from floor to ceiling, and *increases or decreases the mean effective temperature in the space. This precludes the requirement for an earlier call for heating or cooling.*

Filter efficiency is greatly increased as a result of increased entrapment of airborne particles, due to the lower air velocity through the filter media. This simple phenomenon can increase filter absorption of airborne particles that enhances efficiencies in passive filters, and can increase efficiencies in electronic filter types up to 98%.

Features and benefits of variable airflow significantly increase overall system efficiency and improve comfort and indoor air quality of conventional, on-off, constant-volume systems.

The new series of variable-airflow products generally fall into two control theory methods. These methods basically accomplish the same result, but vary in their approach.

A *time–based* or *temperature-sensed* method is used to automatically vary the flow of air from full to minimum, or minimum to full. This is accomplished by varying fan–blower motor speed.

The *time-based* (TB) method regulates, or ramps, motor speed (RPM) from the unit's designed minimum flow to a predetermined maximum flow, and back again. This increasing–decreasing flow occurs before and after the normal operating "on" cycle, as controlled by the thermostat.

The TB method is generally preferred by OEMs of unitary equipment and can be selected from the known performance characteristics of the manufacturers' equipment. Two separate TB ramps are selected to match the type of equipment and the residual energy value for that unit.

On the other hand, the *temperature–sensed* (TS) method may be the preferred choice for field retrofit of an existing installation, as a result of the wide variety of product design found in the vast quantity of existing, installed systems.

The TS method also regulates, or ramps, motor speed (RPM) from minimum flow to the predetermined full flow, and back again, based on the temperature difference (delta °F) between the entering air and the conditioned supply air temperature. This differential drives motor speed, increasing and decreasing flow as monitored by the two sensors in the entering and supply air of the unit.

This method independently sets the time for increasing and decreasing flow at the beginning and end of each cycle. It could be simply described as a "self-sizing" method for ramping motor speed. This customizes the control of flow to equipment type, size, capacity, and installation variables.

In either method, the *abnormalities* typically found in an on-off system *are minimized or eliminated.* Overall noise level at minimum flow is reduced to an inaudible level.

Filtration is significantly increased, and all of the *residual energy (heating or cooling)* remaining at the end of each cycle *is delivered to the space* at the *decreasing flow rate.* Drafts and stratification of air in the space are minimized as well.

As a result, variable flow can be an integral part of an on-off, constant-volume, unitary package, central air conditioning system.

This variable air flow enhancement effectively eliminates or minimizes most of the undesirable abnormalities typically found in our yet primitively controlled on-off, full- or noflow, central A/C systems.

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