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OVERVIEW

Energy efficient homes are inherently airtight and require ventilation for acceptable indoor air quality. Recognizing this fact, two building code jurisdictions, the federal department of Housing and Urban Development and the State of Washington, require mechanical ventilation for homes. The state of Minnesota will soon enact regulations for mechanical ventilation in homes, and it is expected that this trend will continue. Of all the options currently available, the low cost and low maintenance central-fan-integrated ventilation approach is the most acceptable to large production builders and manufactured home producers. In this approach, fresh air is filtered and ducted to the return air side of the central system fan. The central system fan and ducts then distribute the ventilation air throughout the living space. This is a resource and energy efficiency strategy that utilizes the existing air ducts and the normal cycling of the fan, in response to demand from the thermostat, to distribute ventilation air and conditioned air at the same time. The patented AirCycler™ control can be used to automatically operate the fan if the fan has been inactive for a period of time, and to control a motorized outside air damper to limit the intake of ventilation air independent of fan operation.

BACKGROUND

A number of residential mechanical ventilation system types exist. These systems can be generally categorized as follows:

- Supply ventilation, with either central-fan-integrated, or single- or multi-point distribution
- Exhaust ventilation, with either single- or multi-point exhaust, and with or without passive inlet vents
- Balanced ventilation, with either central-fan-integrated, or single- or multi-point supply and exhaust, and with or without heat recovery or energy recovery

Single point ventilation systems of any type suffer from lack of adequate distribution of fresh air, especially to closed rooms. Exhaust only ventilation systems suffer in two ways: 1) potential for creating or adding to pressure conditions conducive to back-drafting of combustion appliances, and; 2) air that replaces exhausted air may not be suitable as fresh ventilation air since the source cannot be controlled (i.e. replacement air may be coming from the garage, crawl space, sub-slab or other undesirable location).

Of the residential ventilation options currently available, central-fan-integrated ventilation is the most acceptable to large production builders. The primary advantages to them are low cost, low maintenance, and improved comfort through full distribution of ventilation air and mixing of indoor air. This system has been demonstrated in over 300 homes as part of the U.S. Department of Energy's Building America Program (http://www.eren.doe.gov/buildings/building_america/).

Central-fan-integrated ventilation systems provide ventilation air through a duct that extends from a known location outdoors to the return air side of a central air distribution fan. This "known location" should be selected to maximize the ventilation air quality. Central-fan-integrated ventilation systems have an advantage in that they achieve full distribution of ventilation air using already existing ducts. A drawback is that these systems only supply ventilation air when the fan is operating, and during mild outdoor conditions, the central fan may not be activated by the thermostat for long periods of time. Until the introduction of the AirCycler™ fan recycling control, there were two available options to remedy this drawback: 1) run the central fan continuously; or, 2) operate the fan in parallel with the thermostat by a separate timer that has no relation to the fan's operation due to thermostat demand, causing overlapping or short-cycling operation. Both of those options create new problems: they are energy inefficient, and resource inefficient, in that the fan consumes more energy than needed and the operational life of the central fan will be shorter. In addition, operating the central system fan continuously can lead to moisture related problems in humid climates. During the cooling season in humid climates, operating the air distribution fan immediately after a cooling cycle is counter-productive, in that, moisture on the wet cooling coil is returned to the interior space by the recirculating air. In addition, immediately after a cooling cycle, depending on the percentage of outdoor air and the outdoor humidity level, moisture could condense inside cool supply ducts.

AirCycler™ CONTROL

The AirCycler control was first developed in 1993 to address the shortcomings of the available technology. The control will automatically cycle the fan only if it has been inactive for a period of time, thus eliminating overlapping or short-cycling operation caused by other timers. The AirCycler control method allows the fan to stay off immediately after a cooling cycle to improve moisture removal. For humid climates, the fan should not operate immediately after a cooling cycle to allow water on the cooling coil to drip off to the condensate drain and to allow cool supply ducts to warm up before introducing humid ventilation air.

The amount of outside air brought in by the central-fan-integrated ventilation system with AirCycler can be limited independent of fan operation. Through the patented control of a standard, inexpensive motorized outside air damper, the AirCycler will stop the flow of ventilation air if the fan has been on long enough to satisfy ventilation needs.

The AirCycler is produced by Lipidex Corporation in Duxbury, Massachusetts. The control is being used by many production home builders who have recognized and demonstrated its effectiveness.

The AirCycler control employs an energy efficiency strategy that utilizes the normal cycling of the fan, as the fan operates to distribute conditioned air in response to calls from the thermostat, to also distribute ventilation air at the same time. Only if the fan has been inactive for a period of time will the fan be operated by the fan recycling control to distribute ventilation air and provide mixing.

In addition to providing effective ventilation, the *AirCycler* control can also provide enhanced temperature and humidity comfort control in conditioned spaces. Thermostats are typically located in a central area and are expected to serve an entire zone that usually includes closed rooms, and often, more than one floor level. Temperature conditions can vary widely between the thermostat location and extremities of the space the thermostat serves. Likewise, for climates where humidity is separately controlled, humidistats are usually located in a central area and suffer the same lack of uniform control. This air stratification problem can be especially pronounced during mild outdoor conditions when long periods elapse between space conditioning demands from the thermostat. Because of this, builders and HVAC contractors lose profit when they are called back to make heating and cooling system adjustments to provide better comfort throughout the house. An inexpensive and effective way to avoid this problem can be to use the *AirCycler* control to intermittently utilize the central air distribution fan to average overall space conditions by mixing. This intermittent fan operation can also improve the performance of air cleaning or special filtration systems that locate the cleaning or filtration media at the return air side of the central fan.

The *AirCycler* creates more uniform temperature and humidity conditions throughout the conditioned space that may cause occupants to use more moderate temperature and humidity setpoints rather than exaggerating setpoints to overcome comfort problems in isolated locations. The result can be reduced energy cost.

As a prerequisite for energy efficiency in any forced air system, the entire air distribution system must be substantially airtight, including all ducts, dampers, fittings, and the air handler cabinet itself. If the air distribution system is leaky to unconditioned space, this will defeat the purpose of intentionally sizing an outside air duct to provide a controlled amount of ventilation air. A reference leakage rate for "substantially airtight" could be defined as leakage to outdoors of less than five percent of the rated fan flow. The best solution to duct leakage is to locate the entire air distribution system inside conditioned space, however, many production builders are reluctant to do so because of space allocation and aesthetic concerns.

Supply ventilation will tend to pressurize an interior space relative to the outdoors, causing inside air to be forced out through leak sites (cracks, holes, etc.) located randomly in the building envelope. This strategy is advantageous in warm, humid climates to minimize moisture entry into the building structure from outdoors. However, care should be taken with building envelope design and workmanship when using supply ventilation that could pressure buildings in climates with cold winters. To avoid potential problems with supply ventilation in cold climate buildings: 1) the building envelope must be constructed to avoid air leakage that will transport interior moisture into the building envelope; 2) interior humidity must be controlled such that surfaces inside wall and unvented ceiling cavities remain above the interior air dewpoint temperature; 3) surfaces inside wall and unvented ceiling cavities can be elevated through use of exterior insulating sheathing.

ENERGY AND ECONOMIC BENEFIT

Since October 1994, all manufactured homes constructed under the Code of Federal Regulations, Housing and Urban Development (HUD), Manufactured Home Construction and Safety Standards have included a whole house ventilation system. Most of these HUD Code homes have central-fan-integrated ventilation systems installed. To achieve ventilation during mild outdoor conditions, the central fan must be operated continuously. Use of the *AirCycler* control could have a large impact on reducing fan energy use and space conditioning energy use by eliminating the need to operate the central fan continuously to provide ventilation.

Based on hourly computer simulations for four U.S. climate zones, 28% savings in total heating, cooling, and fan energy could be realized, per year per house, by operating the fan intermittently with the *AirCycler* control compared to operating the fan continuously. This is equivalent to an average of 4459 kW-h or 2.6 barrels of oil per house per year. The building energy simulations were conducted using DOE2.1E and a reference 1500 ft^2 house. Table 1 shows the results for the four U.S. cities chosen to represent each climate zone (cold, mixed, hot-dry, hot-humid).

	Chicago		Charlotte		Las Vegas		Orlando	
	kW-h	$ @.11	kW-h	$ @.07	kW-h	$ @.07	kW-h	$ @.08
Fan Energy								
Central fan, 60 cfm @ 33%	1019	112	1284	90	1486	104	1216	97
Central fan, 60 cfm @ 100%	2460	271	3066	215	3679	258	3066	245
Difference	1441	159	1782	125	2193	154	1850	148
Cooling Energy	kW-h	$ @.11	kW-h	$ @.07	kW-h	$ @.07	kW-h	$ @.08
Central fan, 60 cfm @ 33%	2290	252	2813	197	4728	331	5321	426
Central fan, 60 cfm @ 100%	2197	242	2805	196	4814	337	5759	461
Difference	-93	-10	-8	-1	86	6	438	35
Heating Energy	kW-h	$ @.02	kW-h	$ @.03	kW-h	$ @.02	kW-h	$ @.08
Central fan, 60 cfm @ 33%	13553	271	7807	234	5594	112	258	21
Central fan, 60 cfm @ 100%	18119	362	10786	324	8009	160	443	35
Difference	4566	91	2979	89	2415	48	185	15
Net Annual Energy	kW-h		kW-h		kW-h		kW-h	
Central fan, 60 cfm @ 33%	16862		11904		11808		6795	
Central fan, 60 cfm @ 100%	22776		16657		16502		9268	
Difference	5914		4753		4694		2473	
Net Annual Cost	$		$		$		$	
Central fan, 60 cfm @ 33%	635		521		547		544	
Central fan, 60 cfm @ 100%	875		735		755		741	
Difference	240		214		208		198	
Central Fan Operational Hours	hours		hours		hours		hours	
Central fan, 60 cfm @ 33%	3639		3668		3538		3474	
Central fan, 60 cfm @ 100%	8760		8760		8760		8760	
Difference	5121		5092		5222		5286	
Central Fan Average Hourly Duty Cycle	avg duty cycle		avg duty cycle		avg duty cycle		avg duty cycle	
Central fan, 60 cfm @ 33%	42%		42%		40%		40%	
Central fan, 60 cfm @ 100%	100%		100%		100%		100.0%	

Table 1 Summary of hourly simulations for central-fan-integrated ventilation with 33% fan duty cycle versus constant fan operation

It was estimated that available motor timer controls, that operate the fan in parallel with the thermostat, would cause the central fan to operate at least 20% more than needed due to overlapping and short-cycling operation. This inefficient fan control method occurs because the ventilation timer control has no relation to the fan's operation due to thermostat demand. For example, the central system may have just completed ten minutes of operation to meet a thermostat demand when the ventilation timer re-initiates central fan operation to meet the ventilation demand. The *AirCycler* control automatically and efficiently allows the occurrence of thermostat demand to simultaneously meet ventilation demand.