December 2007 Technical Series 07-120

The Effects of Programmable Fan Controllers on Ventilation, Air Distribution and Energy Use

INTRODUCTION

Recent studies at the Canadian Centre for Housing Technology (CCHT) have demonstrated the effects of energy-efficient, furnace fan-motors on both electricity and natural gas use. While electronically commutated motors (ECMs) reduce electricity consumption year-round (up to 25 per cent in the heating season and 10 per cent in the cooling season), there is an accompanying (roughly 14 per cent) increase in natural gas consumption for heating to compensate for the lower fan-motor heat contribution to internal heat gains. The net effect, however, is still a significant reduction in overall utility bills, with a corresponding reduction in greenhouse gas (GHG) emissions, depending on the electricity generation source mix.

Thus far, ECMs and similar motors are only a practical option to reduce motor fan set energy consumption in new furnaces because retrofitting existing furnaces with ECMs requires significant labour costs and brings into play warranty, certification and liability issues. As a number of existing furnaces far exceed the number of new furnances installed annually, it is general recognized that a viable retrofit technology or strategy is required if fan motor energy consumption is to be addressed in a more comprehensive manner.

This research project assessed a low-cost, commercially available, programmable fan controller in combination with conventional PSC (permanent split capacitor) fan motors as a means of reducing motor energy use in existing appliances.

Without a controller, the fan motor set in most forced-air systems operates in one of two modes. With the fan switch set to "AUTO," the fan runs only when there is a demand for space heating or cooling. With the fan switch set to "ON," the fan runs continuously between the heating or cooling cycles.

When normal (PSC) fan motors are run continuously, they use large amounts of electricity, even at lower speeds. A fan controller would allow for intermittent (on-off) operation. Compared to no circulation, the intermittent modes provide significantly increased air circulation throughout the house, especially during the shoulder seasons. Compared to continuous circulation, the intermittent modes continue to supply some air circulation while saving electricity and increasing the use of natural gas during the heating season. However, this must be balanced against reduced circulation.

RESEARCH PROGRAM

The testing and monitoring for this research took place during one heating and one spring-shoulder season at the Canadian Centre for Housing Technology (CCHT) test houses[1]. This project had many parallels to the previous ECM testing studies[2], with the exception that both furnaces were fitted with PSC furnace motors. The test house had a programmable fan controller that was used to produce four furnace fan operation modes:

- Continuous operation (always running in heating or circulation speed).
- 30/30 (off for 30 minutes, then run in circulation speed for 30 minutes or until there is a demand for heat and the motor runs at the pre-set space heating speed).
- 45/15 (as for 30/30, but up to 45 minutes off, up to 15 minutes on).
- No continuous operation: the fan ran only when there was a demand for heat (similar to how most furnaces are operated).

1 The Canadian Centre for Housing Technology (CCHT) is a partnership. The Centre is jointly operated by the National Research Council (NRC), Natural Resources Canada (NRCan) and Canada Mortgage and Housing Corporation (CMHC). The CCHT research and demonstration facility features two highly instrumented, identical, two-storey houses with full basements. The houses, each 210 m^2 (2,260 sq. ft.), are built to R-2000 standards and use simulated occupancy to evaluate the whole-house performance of new technologies in side-by-side testing. The CCHT also has an Info Centre that includes a demonstration of FlexHousing™. For more information about CCHT, go to http://www.ccht-cctr.gc.ca

2 Manning, M.M.; Swinton, M.C.; Szadkowski, F.; Gusdorf, J.; Ruest, K., The Effects of Thermostat Setting on Seasonal Energy Consumption at the CCHT Research Facility, Research report no. IRC-RR-191, 71 pp., February 14, 2005

FAN CONTROLLER LOGIC

There are two types of fan controllers. The one described above and used for this research project can be described as a "maximum off-time" controller, meaning that it causes the furnace fan to run in circulation speed after it has been off for a user-specified time. That is, if the controller is set to 30 minutes off and 30 minutes on, and there is no demand for heating or cooling from the thermostat, the fan will be off for a maximum of 30 minutes. If the thermostat calls for the furnace to run at least once every 30 minutes, then the fan controller will not run the circulation any further within that period.

The second type can be described as a "minimum on-time" controller, meaning that it causes the fan to run for a minimum time in each period, regardless of heating or cooling draws. That is, if the controller is set for 30 minutes out of 60 and the fan runs in heating or cooling speed for 15 minutes out of an hour, then the controller will cause the fan to run for another 15 minutes in that same hour.

For this project all testing was done with a fan controller using "maximum off-time" logic.

The objective of both controllers is to ensure that the furnace fan operates just enough to provide reasonable air circulation throughout the house but limits the operation to reduce fan motor set electrical use.

METHODOLOGY

The programmable fan controller was used in the test house, while the fan motor set in the control house was kept in the continuous mode. The airtightness of both houses was decreased to 3.5 air changes per hour (ACH) at 50 Pa (0.01 psi) depressurization to match that of houses built in the 1990s, which is important as this project was looking mainly at retrofit possibilities. For these tests, the heat recovery ventilators (HRVs) in both houses were turned off, and sealed.

Electricity and natural gas use was recorded every five minutes during the testing period. Temperatures at 10 locations in each house were analysed to determine the effects of the different air circulation modes. Equal amounts of carbon dioxide (CO_2) were released in each house at a rate representative of four people and monitored at three points in each house. The testing occurred over one heating and one spring-shoulder season and the results compared to modelling results for a complete heating season.

Analysis of the effects of the four circulation modes compared the following differences between the control house and the test house:

- electricity use by the furnace;
- natural gas use by the furnace;
- daily circulation air volumes;
- temperatures; and
- carbon dioxide levels

FINDINGS

Electricity use by the furnace

As expected, operation modes with longer maximum off-times used less electricity.

Although this project did not examine impacts during the cooling season, it can be surmised that less fan motor operation will also reduce the electrical use by air conditioners due to the decrease in internal heat gains contributed by the fan motor set to the indoor air.

Table 1 Monitored furnace electrical and natural gas use

	Control House	Test House	Difference
	Furnace electricity (kWH/day)		Reduction
Continuous	9.98	9.87	0.11 (1%)
30/30 in Test House	9.41	4.78	4.63 (49%)
45/15 in Test House	9.72	4.03	5.69 (59%)
No circ. in Test House	8.81	1.24	7.57 (86%)
	Furnace natural gas (MJ/day)		Increase
Continuous	292.4	307.9	15.5 (5%)
30/30 in Test House	192.1	220.8	28.7 (15%)
45/15 in Test House	264	316	52.0 (20%)
No circ. in Test House	326.3	373.5	47.2 (14%)

Natural gas use by the furnace

The furnace fan motor set produces heat, which offsets the amount of natural gas required to heat the house. Although the order and amounts of extra gas use were not exactly as anticipated, the differences between continuous circulation and other modes are clear. These differences were not as distinct as the electrical differences because of the effects of varying weather conditions during the days that the four modes were tested.

Table 2 Modelled energy use savings for three intermittent circulation modes

Mode	Electricity use		Natural gas use		Overall savings*
	KWh saved	% Reduction	m^3 increase	% Increase	
30/30	1,117	49	130	7.6	$32.93
45/15	1,488	65	173	10.1	$43.96
No Circ.	1,708	75	199	11.6	$50.24

*Overall savings are based on electricity cost of $0.09/kWh and natural gas cost of $0.52/m^3

Table 2 shows the approximate energy use savings that were modelled over a complete heating season using the "maximum off-time" controller. The model was based on hourly or daily furnace gas consumption recorded during a composite heating season when the same mid-efficiency furnace that was used in this project ran in continuous circulation mode in the test house.

Daily circulation air volumes

The time that the furnace fan spends in each speed multiplied by the airflow rate for that speed gives the total volume of air circulated by the furnace fan each day. The minimum, mean and maximum volumes, as well as the time spent in each speed (heating and circulation) are measures of the effects of each of the circulation modes.

There was a measurable change in the mean percentage of time spent in heating speed with the various operation modes. The total volume of circulated air showed a general decrease with operation mode with longer off times, but the mean for no-circulation mode is slightly larger than the mean for 45/15.

This is due to the fact that the amount of time the furnace fan spends in each speed is a function of heating load as well as the fan controller programs. However, the minimum circulated air volumes in the test house did decrease with circulation modes with longer off times. Some effects of circulation may be more dependent on the minimum volume than they are on the mean.

Temperatures

Circulation is important to help maintain adequate and reasonably constant temperature throughout a dwelling. Temperature differences and deviations between the 10 temperature sensor locations in each house can be taken as an indicator of the amount and adequacy of circulation in each mode, with larger differences indicating less circulation and significant differences indicating possibly inadequate circulation. Analysis of temperatures shows no evidence that any of the circulation modes produce inadequate circulation from a temperature standpoint. The recorded differences between temperature means and maximums are too small to result in occupant discomfort.

Carbon dioxide levels

Higher CO_2 levels were observed in intermittent circulation modes, but in no case did the levels approach the Health Canada limits, nor were they higher compared to previously observed levels in Canadian homes.

Fan Controller Logic

Although testing was carried out using only "maximum off-time" controllers, a comparison was simulated between the two types of fan controller in a shoulder-season scenario and a mid-winter scenario. In the shoulder-season simulation, the two types of controllers are very similar.

Table 3 Total circulated air volumes (m^3/day), and difference between means

Condition in Test House	Control House (Continuous Circulation)			Test House			Mean Test/Control
	Min	Mean	Max	Min	Mean	Max	
Continuous	46,177	46,177	46,177	46,697	46,697	46,697	101.1%
30/30	42,851	43,574	44,194	18,485	19,427	20,648	44.6%
45/15	40,905	43,447	47,815	10,338	14,257	27,826	32.8%
No Circulation	42,048	44, 744	48,001	3,696	14,617	27,798	32.7%

However, in the mid-winter case, the "minimum on-time" controller produces significantly higher circulated volumes and uses significantly more electricity. Based on this limited modelling, it seems that the "maximum off-time" controller does a better job of maintaining a constant amount of circulation regardless of season, and would also result in more gas use and less electricity consumption resulting in more total savings.

LIMITATIONS TO THIS STUDY

There were problems with the CO_2 flowmeters and calibration of some of the CO_2 sensors, leaving only one benchmarking day with both the correct rate of CO_2 release in both houses and properly calibrated CO_2 sensors, and only seven days of testing with the 30/30 mode. Nevertheless, the valid CO_2 data yielded useful results.

The fan controllers were modelled for one particular type of house and furnace and for only two of the very large number of possible circulation modes that fan controllers can produce.

CONCLUSIONS AND IMPLICATIONS FOR THE HOUSING INDUSTRY

Programmable fan controllers are an inexpensive, practical way of achieving energy savings while ensuring good air circulation for houses built since 1990 that have furnaces equipped with conventional PSC fan motors. Fan controllers are easy to use with existing furnaces.

For households that currently use continuous circulation, the controller will continue to provide some circulation and use less electricity and more gas, resulting in a net decrease in utility bills. Higher CO_2 levels as a result of intermittent circulation may be associated with odours, or with high levels of humidity that could cause condensation or mold growth. These conditions are easily observed and can be dealt with by occupants by increasing the fan-motor operating time.For households that now operate in no-circulation mode and would like to have better circulation, a programmable fan controller can be recommended. The controller will provide better circulation but use more electricity and save some natural gas. The net effect will be a slight increase in utility bills because electricity is more expensive than gas on an energy content basis. Since the current norm in Canadian houses is not to operate the furnace fan continuously, operating the furnace fan intermittently with a fan controller will provide better indoor air circulation than the current norm.

The Canadian Centre for Housing Technology (CCHT)

Canada Mortgage and Housing Corporation (CMHC), The National Research Council (NRC) and Natural Resources (NRCan) jointly operate the Canadian Centre for Housing Technology (CCHT). CCHT is a unique research, testing and demonstration resource for innovative technology in housing. CCHT's mission is to accelerate the development of new housing technologies and their acceptance in the marketplace. CCHT operates a Twin-House Research Facility, which offers an intensively monitored, real-world environment. Each of the two identical, two-storey houses has a full basement. The houses, 210 m^2 (2,260 sq. ft.) each, are built to R-2000 standards. For more information about the CCHT Twin-House Research Facility and other CCHT capabilities, visit http://www.ccht-cctr.gc.ca

Project Manager: John Gusdorf, Natural Resources Canada
CMHC representative on the CCHT Technical Research Committee:
Ken Ruest

Consultant: John Gusdorf, Craig Simpson, Mike Swinton, Tracey Forrest, Frank Szadkowski, T.J. Hwang

Housing Research at CMHC

Under Part IX of the ***National Housing Act***, the Government of Canada provides funds to CMHC to conduct research into the social, economic and technical aspects of housing and related fields, and to undertake the publishing and distribution of the results of this research.

This fact sheet is one of a series intended to inform you of the nature and scope of CMHC's research.

To find more ***Research Highlights*** plus a wide variety of information products, visit our website at

www.cmhc.ca

or contact:

Canada Mortgage and Housing Corporation
700 Montreal Road
Ottawa, Ontario
K1A 0P7

Phone: 1-800-668-2642
Fax: 1-800-245-9274

Printed in Canada
Produced by CMHC 30-11-07

65834