C-5: VSD Threshold for Pump Motors (C403.4.3.2.1)

Summary: Variable speed drives (VSD) or other speed control devices are required for pumps in variable flow systems at various thresholds. For this proposal, the various applications were reviewed and the thresholds for VSD requirement were reduced or adjusted where found to be cost-effective. For heating systems, VSDs were added where found to be cost-effective. A VSD saves energy by reducing the motor energy input to provide part load flow when compared to simple throttling with dampers or valves. The cost of VSDs and motors with integral speed control continues to decrease, making them cost-effective for smaller motors.

DOE proposal C-5 was revised on December 18, 2015.

Stakeholder Feedback: There was one public comment received for proposal C-5. The comment is summarized below, followed by a DOE review:

- One comment requested information regarding using future revised motor efficiency standards.
  Review: As for other proposals, DOE used the required efficiencies in the current code. Further, a review of proposed future motor standards indicated there was no change in motor efficiency requirements in the size range of motors included in the proposal.

In response to these comments, there were no revisions made to the proposal; however, DOE revised its proposal to remove supply fan control changes and heat rejection fan control changes, as these areas are expected to be covered by proposals from ASHRAE. Further, DOE will revise its proposal to provide climate zone based requirements as a result of internal and external review of its original proposal.

= = = IECC PROPOSAL:

Modify section C403.4.2.4 and add Table C403.4.2.4 as follows:

C403.4.2.4 Part-load controls. Hydronic systems greater than or equal to 500,000 Btu/h (146.5 kW) in design output capacity supplying heated or chilled water to comfort conditioning systems shall include controls that ~~have the capability~~ <u>are configured</u> to do all of the following:

1. Automatically reset the supply-water temperatures in response to varying building heating and cooling demand using coil valve position, zone-return water temperature, building-return water temperature or outside air temperature. The temperature shall be capable of being reset by not less than 25 percent of the design supply-to-return water temperature difference.
2. Automatically vary fluid flow for hydronic systems with a combined <u>pump</u> motor capacity of ~~10~~ <u>2</u> hp (~~7.5~~ <u>1.5</u> kW) or larger with three or more control valves or other devices by reducing the system design flow rate by not less than 50 percent <u>or as required by the equipment manufacturer for proper operation of equipment</u> by ~~designed~~ valves that modulate or step open and close, or pumps that modulate or turn on and off as a function of load.
3. Automatically vary pump flow on <u>heating-water systems,</u> chilled-water systems and heat rejection loops serving watercooled unitary air conditioners <u>as follows:</u>
   <u>3.1. Where pumps have continuous operation or operation based on a time schedule, pumps with nominal output motor power of 2 hp or more shall have a variable speed drive.</u>
   <u>3.2. Where pumps have automatic direct digital control configured to operate pumps only when zone heating or cooling is required, a variable speed drive shall be provided for pumps with</u>

motors having at least the nominal output power shown in Table C403.4.2.4 based on the climate zone and system served.
~~with a combined motor capacity of 10~~ 2 ~~hp (7.5~~ 1.5 ~~kW) or larger by reducing pump design flow by not less than 50 percent, utilizing adjustable speed drives on pumps, or multiple-staged pumps where not less than one-half of the total pump horsepower is capable of being automatically turned off.~~ Pump motor power input shall be no more than 30% of design wattage at 50% of the design water flow. Pump flow shall be controlled to maintain one control valve nearly wide open or to satisfy the minimum differential pressure.

Exceptions:

1. Supply-water temperature reset is not required for chilled-water systems supplied by off-site district chilled water or chilled water from ice storage systems.
2. ~~Minimum flow rates other than 50 percent as required by the equipment manufacturer for proper operation of equipment where using flow bypass or end-of-line 3-way valves.~~ Variable pump flow is not required on dedicated coil circulation pumps where needed for freeze protection.
3. Variable pump flow is not required on dedicated equipment circulation pumps where configured in primary/secondary design to provide the minimum flow requirements of the equipment manufacturer for proper operation of equipment.
4. Variable speed drives are not required on heating water pumps where more than 50% of annual heat is generated by an electric boiler.

TABLE C403.4.2.4

VARIABLE SPEED DRIVE (VSD) REQUIREMENTS FOR DEMAND-CONTROLLED PUMPS

CHILLED WATER AND HEAT REJECTION LOOP PUMPS IN THESE CLIMATE ZONES	HEATING WATER PUMPS IN THESE CLIMATE ZONES	VSD REQUIRED FOR MOTORS WITH RATED OUTPUT OF AT LEAST
0a, 0b, 1a, 1b, 2b		≥2 HP
2a, 3b		≥3 HP
3a, 3c, 4a, 4b	7, 8	≥5 HP
4c, 5a, 5b, 5c, 6a, 6b	3c, 5a, 5c, 6a, 6b	≥7.5 HP
	4a, 4c, 5b	≥10 HP
7, 8	4b	≥15 HP
	2a, 2b, 3a, 3b	≥25 HP
	1b	≥100 HP
	0a, 0b, 1a	≥200 HP

Note: Climate Zones 0a and 0b to be included in table above only if another proposal introducing these new very hot climate zones is approved.

Reason. This proposal reduces the threshold where variable flow and variable speed drives (VSD) are required for pumping systems. The pump threshold is reduced from 10 to 2 hp for continuous operation and time schedule controlled pumps. Pumps that have operation controlled by direct digital control based on zone demand result in a varied threshold based on climate zone. Requirements for heating pump VSDs are added.

Variable flow systems use less pumping energy than constant flow systems. Variable pumping systems also produce larger system temperature differences that can enhance chiller efficiency and condensing boiler efficiency (although these effects are not included in the savings calculations). Variable flow systems can reduce flow either by throttling flow and then having the pump "ride the pump curve" to reduce flow and energy at higher pressure or by using a VSD. Using a variable speed drive provides similar flow control at a lower energy cost, as pressure differential is reduced.

In addition to threshold reductions, the proposal removes a minimum flow exception, placing the minimum flow in the requirement. An exception for pump flow controls on coils requiring freeze protection is added.

Energy Savings: Operation of variable flow systems is less expensive than constant flow systems and variable speed drives increase the savings compared to throttling control. An analysis of energy impact shows that annual savings from expanding the use of motor speed control in the proposal ranges from $1,303 to $401 for 10 to 3 horsepower heating pumps and from $1821 to $386 for 10 to 2 horsepower cooling pumps in typical HVAC systems. Savings for larger pumps are proportional. More details are found in the cost-effectiveness analysis referenced in the cost impact section.

The U.S. Department of Energy (DOE) develops its proposals through a public process to ensure transparency, objectivity and consistency in DOE-proposed code changes. Energy savings and cost impacts are assessed based on established methods and reported for each proposal, as applicable. More information on the process utilized to develop the DOE proposals for the 2018 IECC can be found at: https://www.energycodes.gov/development/2018IECC.

Cost Impact: The cost of variable frequency drives continues to drop. Incremental cost for VSD and associated controls ranges from $5,101 to $3,920 for 10 to 2 horsepower pumps. Costs for larger pumps are proportional. There is no cost for reducing the threshold where variable flow systems are required, as 2-way valves that vary flow are less costly than 3-way valves used in a constant flow system.

Cost-effectiveness: PNNL performed a cost-effectiveness analysis using the established DOE methodology.[1] Results of the cost-effectiveness analysis showed that the savings-to-investment ratio (SIR) ranged from 1.0 to 3.2 in typical heating HVAC systems and from 1.2 to 4.5 in typical cooling HVAC systems. A proposal is cost-effective when the SIR is greater than or equal to 1.0, indicating that the present value of savings is equal to or greater than the incremental cost. The complete cost-effectiveness analysis is available at: https://www.energycodes.gov/development/2018IECC.

[1] Hart, R., and Liu, B. (2015). *Methodology for Evaluating Cost-effectiveness of Commercial Energy Code Changes.* Pacific Northwest National Laboratories for U.S. Department of Energy; Energy Efficiency & Renewable Energy. PNNL-23923 Rev1. https://www.energycodes.gov/development/commercial/methodology.