ASHRAE 6 ECM Motors
August 17th CEC Workshop

California Statewide Utility Codes and Standards Program

Taylor Engineering, LLC
Energy Solutions
August 17th, 2011

ASHRAE 6 – Fraction HVAC Motors

Current Code Requirements

- New Energy Policy and Conservation Act (EPCA) requirements for "small motors"
  - Ruling Effective: April 8, 2010
  - New Standards Applied Starting: March 9, 2015
- Sets Efficiency Requirements for Certain Classes of Motors
  - Capacitor-Start Capacitor-Run (CSCR)
  - Capacitor-Start Induction-Run (CSIR)
  - Polyphase
- But Not Others
  - Permanent-Split Capacitor (PSC)
  - Electronically Commutated (EC)
  - Brushless DC motors

ASHRAE 6 – Fraction HVAC Motors

Current Code Requirements

- New Energy Policy and Conservation Act (EPCA) requirements for “small motors”
  - Does not cover motors that are part of equipment that is covered under other efficiency requirements

ASHRAE 6 – Fraction HVAC Motors

Current Code Requirements

- For "fractional" motors below 1 HP there are no California standards in place except for in series fan-powered VAV boxes (T24-2008 144.c.4)

> 4. **Fan motors of series fan-powered terminal units.** Fan motors of series fan-powered terminal units 1 hp or less shall be electronically-commutated motors or shall have a minimum motor efficiency of 70 percent when rated in accordance with NEMA Standard MG 1-2006 at full load rating conditions.

- Refrigerated warehouses require ECM motors (T24-2008 126.c.1)

> (c) **Evaporators.** Fan-powered evaporators used in coolers and freezers shall conform to the following:
>
> 1. Single phase fan motors less than 1 hp and less than 460 Volts shall be electronically commutated motors.
> 2. Evaporator fans shall be variable speed and the speed shall be controlled in response to space conditions.
>
> **EXCEPTION to Section 126(c)2:** Evaporators served by a single compressor without unloading capability.

ASHRAE 6 – Fraction HVAC Motors

Overview

- What is an EC or Brushless DC Motor?
  - Electronically Commutated Motor
  - DC brushless motor with permanent magnet rotor and built-in inverter
  - DC motors more efficient than AC, easier to control
  - Typical HVAC-duty efficiencies: 65% - 85%
  - Low power factors ~40% to 60%
  - Higher harmonic distortion than a PSC.

- What is a PSC Motor?
  - Permanent Split Capacitor induction motor
  - Typical HVAC-duty efficiencies: 12% - 45%

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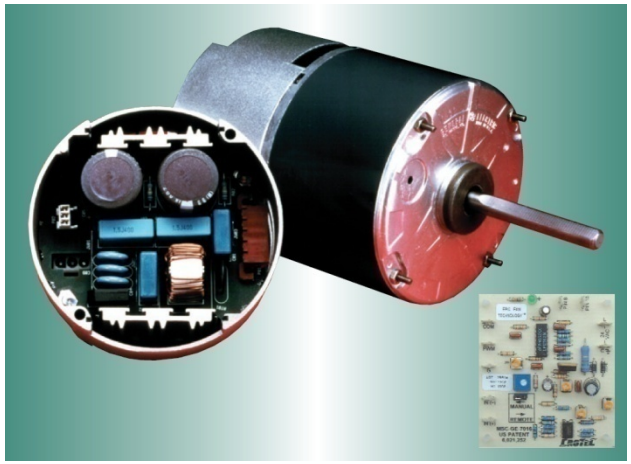
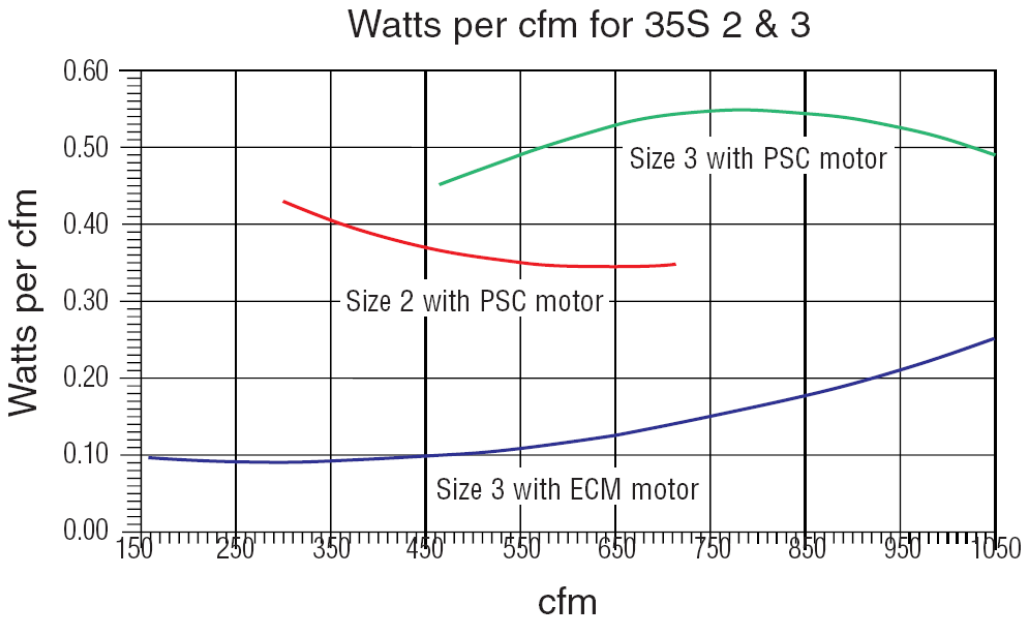
Typical Practice/EC Motor Efficiency

- Small are PSC Class – not covered by new EPCA requirements
- EC or Brushless DC Motors More Efficient for both variable speed and single speed applications





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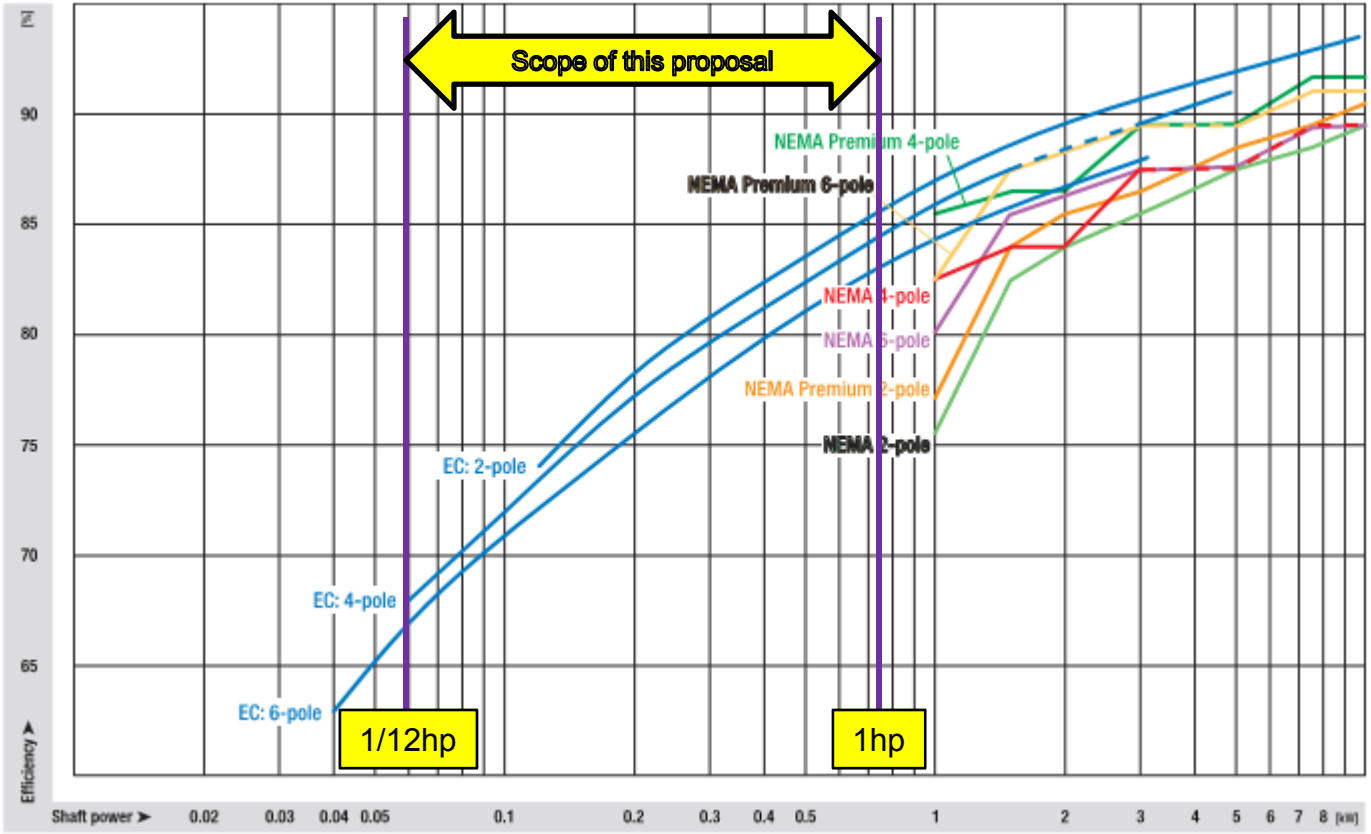
Brushless DC Motor Efficiency

- Source ebm-papst



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Cost Data

- Cook (Brushless DC Motors)
  - ¾ hp motor add: $170
  - ½ hp motor add: $160
  - ¼ hp motor add: $130
  - 1/8 hp motor add: $170
- Greenheck (EC Motors)
  - 1/12 hp motor add: $185
  - 1/8 hp motor add: $ 185
  - 1/4 HP motor add: $140

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Preliminary Analysis

- Proposed Case A:
  - Direct drive with no balancing (adjusting speed) in the field
  - No start-up cost
  - BHP = MHP for EC/brushless DC
- Proposed Case B:
  - Direct drive with balancing in the field
  - $100 start-up/commissioning cost
  - BHP = 80% of MHP for EC/brushless DC

ASHRAE 6 – Fraction HVAC Motors

Preliminary Analysis

	1/12 HP			*1/8 HP*			*1/4 HP*		
	Basecase	**Proposed A**	**Proposed B**	**Basecase**	**Proposed A**	**Proposed B**	**Basecase**	**Proposed A**	**Proposed B**
Energy									
MHP	1/12	1/12	1/12	1/8	1/8	1/8	1/4	1/4	1/4
Motor	Standard	ECM	ECM	Standard	ECM	ECM	Standard	ECM	ECM
motor efficiency	29%	69%	69%	29%	69%	69%	29%	69%	69%
% of MHP for BHP	100%	100%	80%	100%	100%	80%	100%	100%	80%
MHP	0.083	0.083	0.067	0.125	0.125	0.100	0.250	0.250	0.200
Fan kW	0.218	0.091	0.073	0.327	0.136	0.109	0.654	0.272	0.218
Delta Fan kW		**0.127**	**0.145**		**0.191**	**0.218**		**0.382**	**0.436**
Incremental Cost									
ECM incremental cost		$185	$185		$185	$185		$140	$140
Contractor markup		30%	30%		30%	30%		30%	30%
Add for start-up/Cx		$0	$100		$0	$100		$0	$100
Total incremental cost		**$241**	**$341**		**$241**	**$341**		**$182**	**$282**

ASHRAE 6 – Fraction HVAC Motors

Preliminary Analysis

- Case A: Direct Drive with no field balancing

		1/12 HP			1/8 HP			1/4 HP		
Climate Zone	Average cost [PV$/kWh]	Fan hours for various payback periods			Fan hours for various payback periods			Fan hours for various payback periods		
		5 years	10 years	15 years	5 years	10 years	15 years	5 years	10 years	15 years
CZ01	0.1612	2344	1172	781	1563	781	521	591	296	197
CZ02	0.1596	2367	1184	789	1578	789	526	597	299	199
CZ03	0.1598	2363	1182	788	1576	788	525	596	298	199
CZ04	0.1597	2366	1183	789	1577	789	526	597	298	199
CZ05	0.1602	2358	1179	786	1572	786	524	595	297	198
CZ06	0.1582	2387	1194	796	1592	796	531	602	301	201
CZ07	0.1611	2344	1172	781	1563	781	521	591	296	197
CZ08	0.1589	2377	1189	792	1585	792	528	600	300	200
CZ09	0.1581	2389	1195	796	1593	796	531	603	301	201
CZ10	0.1581	2390	1195	797	1593	797	531	603	301	201
CZ11	0.1605	2353	1177	784	1569	784	523	594	297	198
CZ12	0.1605	2354	1177	785	1569	785	523	594	297	198
CZ13	0.1609	2348	1174	783	1565	783	522	592	296	197
CZ14	0.1586	2382	1191	794	1588	794	529	601	300	200
CZ15	0.1590	2376	1188	792	1584	792	528	599	300	200
CZ16	0.1593	2371	1185	790	1581	790	527	598	299	199
	Avg	**2367**	**1183**	**789**	**1578**	**789**	**526**	**597**	**299**	**199**
	StDev	**15.8**	**7.9**	**5.3**	**10.5**	**5.3**	**3.5**	**4.0**	**2.0**	**1.3**

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Preliminary Analysis

- Case B: Direct Drive with field balancing

		1/12 HP			*1/8 HP*			*1/4 HP*		
Climate Zone	Average cost [PV$/kWh]	Fan hours for various payback periods			Fan hours for various payback periods			Fan hours for various payback periods		
		5 years	*10 years*	*15 years*	*5 years*	*10 years*	*15 years*	*5 years*	*10 years*	*15 years*
CZ01	0.1612	2905	1453	968	1937	968	646	802	401	267
CZ02	0.1596	2933	1467	978	1956	978	652	810	405	270
CZ03	0.1598	2929	1464	976	1953	976	651	809	404	270
CZ04	0.1597	2932	1466	977	1955	977	652	809	405	270
CZ05	0.1602	2922	1461	974	1948	974	649	807	403	269
CZ06	0.1582	2958	1479	986	1972	986	657	817	408	272
CZ07	0.1611	2905	1453	968	1937	968	646	802	401	267
CZ08	0.1589	2946	1473	982	1964	982	655	813	407	271
CZ09	0.1581	2961	1480	987	1974	987	658	817	409	272
CZ10	0.1581	2962	1481	987	1975	987	658	818	409	273
CZ11	0.1605	2916	1458	972	1944	972	648	805	403	268
CZ12	0.1605	2917	1458	972	1945	972	648	805	403	268
CZ13	0.1609	2910	1455	970	1940	970	647	803	402	268
CZ14	0.1586	2952	1476	984	1968	984	656	815	407	272
CZ15	0.1590	2945	1472	982	1963	982	654	813	406	271
CZ16	0.1593	2938	1469	979	1959	979	653	811	406	270
	Avg	**2933**	**1467**	**978**	**1955**	**978**	**652**	**810**	**405**	**270**
	StDev	**19.6**	**9.8**	**6.5**	**13.0**	**6.5**	**4.3**	**5.4**	**2.7**	**1.8**

ASHRAE 6 – Fraction HVAC Motors

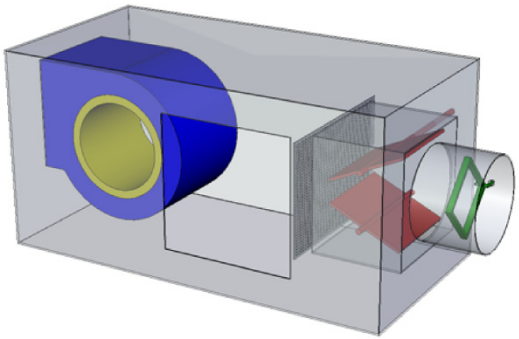
Preliminary Conclusions

- It appears that EC or brushless DC motors are cost effective for systems ≥1/12 hp that run during normal occupied hours
  - Typical office occupancies have run hours >2,500 hrs/yr
  - Both cases are <5 year paybacks in all climates
- Analysis is conservative
  - No credit provided for reduced cooling energy (albeit there is an offsetting credit for heating)
  - Most systems in conditioned spaces are balanced (PSC, EC, or brushless DC). The $100 balance fee in case B is probably $0
  - Title 24 uses 15 year lives for HVAC measures
- Parallel fan-powered VAV boxes should be exempt
  - They benefit from reduced heating with PSC motors

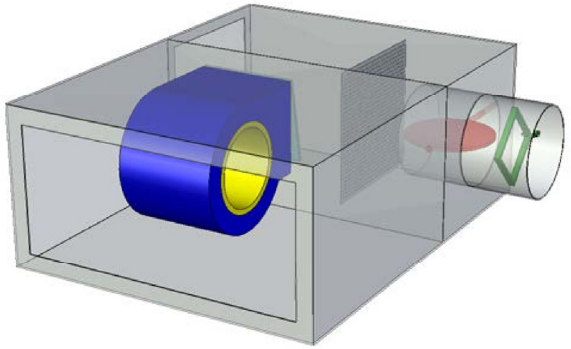
ASHRAE 6 – Fraction HVAC Motors

Fan-Powered VAV Box Configurations

- **Series Fan**
  - Fan runs in heating and cooling.
  - More run hours
  - Increases cooling load
  - Decreases heating load



- **Parallel Fan**
  - Fan runs only in heating.
  - Fewer run hours
  - No impact on cooling load
  - Decreases heating load



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Power Factors and THD

- EC motors have lower power factors and higher THD than PSC motors.
- There is no electrical premium for EC motors as they also have higher efficiency. At 50% PF and 69% efficiency an EC motor has a lower current drawn than a PSC motor at 100% PF and 29% efficiency
- There is no transformer penalty for EC motors as fractional motors only represent only a small fraction of the total building load ~1% to 2%

ASHRAE 6 – Fraction HVAC Motors

Proposal

- **Modify Section 144(c)4 as follows**
  - **144(c)4 Fractional HVAC Motors for Pumps and Fans. ~~Fan motors of series fan-powered terminal units.~~** ~~Fan motors of series fan-powered terminal units~~ HVAC motors for pumps or fans that are 1 hp or less shall be electronically-commutated motors or shall have a minimum motor efficiency of 70 percent when rated in accordance with NEMA Standard MG 1-2006 at full load rating conditions. These motors shall also have the means to adjust motor speed for either balancing or remote control in the field.
  - **EXCEPTION 1 to Section 144(c)4:** Motors in parallel fan-powered terminal units.
  - **EXCEPTION 2 to Section 144(c)4:** Motors installed in space conditioning equipment certified under Section 111 or 112.

ASHRAE 6 – Fraction HVAC Motors

Proposal

- **Delete an existing definition in Section 101**
  - ~~**SERIES FAN-POWERED TERMINAL UNIT is** a terminal unit that combines a VAV damper in series with a downstream fan which runs at all times that the terminal unit is supplying air to the space.~~
- **Add a new definition to Section 101**
  - **PARALLEL FAN-POWERED TERMINAL UNIT** is a terminal unit that combines a VAV damper in parallel with a fan that only runs when the terminal unit is providing heating to the space.

ASHRAE 6 – Fraction HVAC Motors

Proposal

- **Modify Section 126(c)1 as follows**
  - **126(c)1 (c) Evaporators.** Fan-powered evaporators used in coolers and freezers shall conform to the following:
  - 1. Single phase fan motors less than 1 hp and less than 460 Volts shall be ~~electronically commutated motors~~meet the requirements of 144(c)4.
  - 2. Evaporator fans shall be variable speed and the speed shall be controlled in response to space conditions.

ASHRAE 6 – Small EC or Brushless DC Motors

QUESTIONS & COMMENTS