APPENDIX 7-A. ENERGY USE SCENARIO FOR ELECTRIC MOTORS WITH HIGHER OPERATING SPEEDS

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7-A.1 BACKGROUND

The installation of a higher efficiency motor alone may increase the energy consumption for a particular application, instead of realizing energy savings. A more efficient squirrel-cage induction motor usually has less slip than an older less efficient motor because of a reduction in the resistance of the rotor. This results in higher operating speed and potential overloading of the motor. The U.S. Department of Energy (DOE) acknowledges that the cubic relationship between speed and power requirement in certain fan, pump, and centrifugal compressor applications can affect the benefits gained by efficient motors which have a lower slip. This appendix describes the methodology DOE used to estimate this effect as a sensitivity analysis in the Life-Cycle-Cost spreadsheet at
http://www1.eere.energy.gov/buildings/appliance_standards/commercial/electric_motors.html.

7-A.2 METHOD FOR DETERMINING ENERGY SAVING IN VARIABLE TORQUE APPLICATIONS

DOE based its methodology on a previous publication[i] which states the following:

In the case where there is a cubic relationship between the power and the speed,

$$Po_{EE}(L) = Po_{BE}(L).\frac{\omega_{EE}(L)^3}{\omega_{BE}(L)^3}$$

Where:
L is the load in percentage
$Po_{EE}(L)$ is the output power of the energy efficient motor
$Po_{BE}(L)$ is the output power of the baseline efficiency motor
$\omega_{EE}(L)$ is the operating speed of the energy efficient motor
$\omega_{BE}(L)$ is the operating speed of the baseline efficient motor

When the operating speeds are the same then:

$$Po_{EE}(L) = Po_{BE}(L)$$

If the more efficient motor has a higher speed then it produces more output power then required by the application:

$$Po_{EE}(L) > Po_{BE}(L)$$

If the only useful power is that generated by the baseline motor ($Po_{BE}(L)$), then the "effective" losses[a] of the EE motor are:

$$Losses(L) = Pin_{EE}(L) - Po_{BE}(L)$$

Where:
$Pin_{EE}(L)$ is the input power of the energy efficient motor.

The efficiency of the EE motor is $\eta_{EE}(L)$ and $Pin_{EE}(L)$ is:

$$Pin_{EE}(L) = \frac{Po_{EE}(L)}{\eta_{EE}(L)}$$

And:

$$Pin_{EE}(L) = Po_{BE}(L).\frac{\omega_{EE}(L)^3}{\omega_{BE}(L)^3}.\frac{1}{\eta_{EE}(L)}$$

Then the "effective" losses of the EE motor are:

$$Losses(L) = Po_{BE}(L)(\frac{\omega_{EE}(L)^3}{\omega_{BE}(L)^3}.\frac{1}{\eta_{EE}(L)} - 1) \text{ [Equation 1]}$$

If the end-user does not adjust for the higher speed of the EE motor, then the losses experienced will be greater than if the operating speeds remain constant.

DOE calculated "effective" losses vs. load tables based on Equation 1 and used these values to estimate the energy use of higher efficiency motors in variable torque applications which would not benefit from higher operating speeds.

7-A.3 ASSUMPTIONS TO DETERMINE ENERGY SAVINGS IN VARIABLE TORQUE APPLICATIONS

No sufficient solid data was found to estimate the share of motors which are negatively impacted by higher operating speeds. DOE therefore considered a scenario described by the two following main assumptions: (1) the share of motors which are negatively impacted by higher operating speeds, and (2) the actual operating speed of the motor in the field.

7-A.3.1 Share of motors negatively impacted by higher operating speeds

DOE assumed that 60 percent of pumps, fans and compressor applications are variable torque applications.

[a] The "effective" losses experienced are not losses, they include the increased load imposed by increased speeds associated with variable torque applications.

Of these 60 percent, DOE assumed that all fans and a majority (70 percent) of compressors and pumps would be negatively impacted by higher operating speeds; and that 30 percent of compressors and pumps would not be negatively impacted from higher operating speeds as their time of use would decrease as the flow increases with the speed (e.g. a pump filling a reservoir). DOE assumed this revolutions per minute (RPM) effect did not impact fire pump motors.

When choosing to run the life-cycle cost (LCC) spreadsheet based on the "RPM scenario" the LCC results are based on the "effective" losses for 60 percent of all fans and 42 percent of all compressors and pumps applications. This does not account for the share of users who adjust for increased motor speed.

7-A.4 SENSITIVITY ANALYSIS

The results provided by applying this methodology do not account for motors which are positively impacted for higher operating speeds and rely on two major assumptions: (1) the share of motors which are negatively impacted by higher operating speeds, and (2) the actual operating speed of the motor in the field. DOE believes the data supporting these assumptions is not sufficiently robust to incorporate this effect in the main analysis and therefore incorporated it as a sensitivity scenario in the LCC spreadsheet.

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[i] P. Pillay. *Practical considerations in applying energy efficient motors in the petrochemical industry* . Petroleum and Chemical Industry Conference, 1995. Record of Conference Papers., Industry Applications Society 42nd Annual