TECH NOTE: EFFICIENCY

As the world continues to focus on energy efficiency, the pump industry has too. We have seen progress towards more energy conscious products in both clean water and wastewater. In clean water, it is most prevalent in the 2020 DOE Pump Efficiency requirements. While there has not been any formal requirements for efficiency in the wastewater market, the industry has been moving towards high pump and motor efficiencies as a whole. This tech note focuses on motor efficiency, specifically comparing air filled motors with other technologies, like oil filled submersible motors and standard NEMA motors.

Submersible motor efficiency standards are governed by the International Electrotechnical Commission, through the International Efficiency (IE) Rating. There are currently five levels in IEC60034-30-1, "Rotating electrical machines – Part 30-1: Efficiency classes of line operated AE motors" – IE1, IE2, IE3, IE4 and IE5. These ratings correspond to motor performance curves, where the efficiency requirement increases logarithmically as power (in HP or kW) increases. Any motor that has a curve equal to or above each standard curve meets that efficiency level – similar to how pump efficiency is plotted. IE3 is quickly becoming the industry standard in the wastewater pump market. Figure 1 below details how a typical oil filled submersible motor compares to an IE3 rated air filled submersible motor. At this time, there are only a couple of IE4 rated submersible motors and no IE5 rated motors, yet. There are non-submersible motors on the market that meet both of there standards, so it will not be long before we see the market standard leaning toward IE4 and IE5 rated submersible motors.

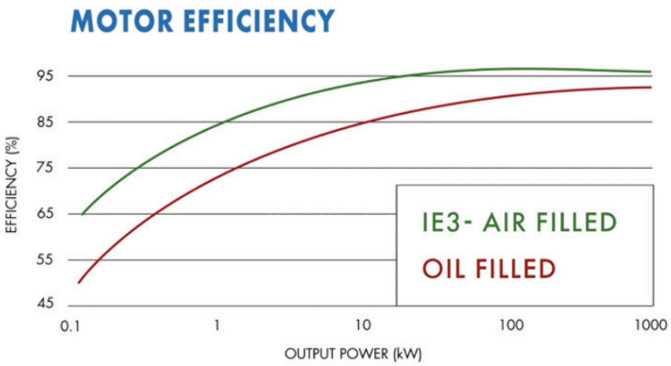

Figure 1: Relation between Efficiency and Electric Motor Performance

It is also useful to relate IE3 rated air filled submersible motors to other motor types and efficiency standards. The majority of IE3 rated submersible motors are air filled designs, equipped with some type of cooling system. The typical oil filled motor is relatively low on efficiency, falling in the "IE0" level – this is not a formal level, but it is below the IE1 rating in most cases. When comparing with NEMA AC motors (T-frame, J-frame, etc.), Table 1 shows how the IE standard and the NEMA standard compare. IE3 is equivalent to NEMA Premium Efficient, which is the current industry standard. However, many installations predate the NEMA Premium level, and are either NEMA Standard or NEMA High Efficiency.

IEC Standard	NEMA Equivalent
IE1	Standard
IE2	High
IE3	Premium
IE4	Super Premium
IE5	Ultra Premium

Table 1: Equivalent IEC and NEMA Efficiency Standards

Installing an IE3 premium efficient motor can result in many benefits for equipment owners. An IE3 Premium Efficient motor will have longer operational life and lower cost of ownership than a less efficient option. IE3 rated motors inherently use less energy, resulting in cost savings that extend over the entire life of the pump. The energy savings can be calculated as per the following equations, and an example of the calculations is included in the appendix. Figure 2 summarizes these examples.

ENERGY COST USING AMPERAGE

$$Annual\ Energy\ Cost\ \left(\$/yr\right) = \left[\frac{I*V*PF*\sqrt{3}}{1000}\right]*\frac{X\ hours}{1\ Day}*\frac{365\ days}{1\ Year}*\frac{\$X}{kwh}$$

Where: $I = Current\ (Amps), V = Voltage\ (Volts), PF = Power\ Factor$

ENERGY COST USING THE DESIGN CONDITION

$$Annual\ Energy\ Cost\ \left(\$/yr\right) = \left[\frac{Flow\ (GPM)*Head\ (ft)}{3960*Wire\ to\ Water\ Efficiency}\right]*\frac{0.7457kW}{HP}*\frac{X\ hours}{1\ Day}*\frac{365\ days}{1\ Year}*\frac{\$X}{kwh}$$

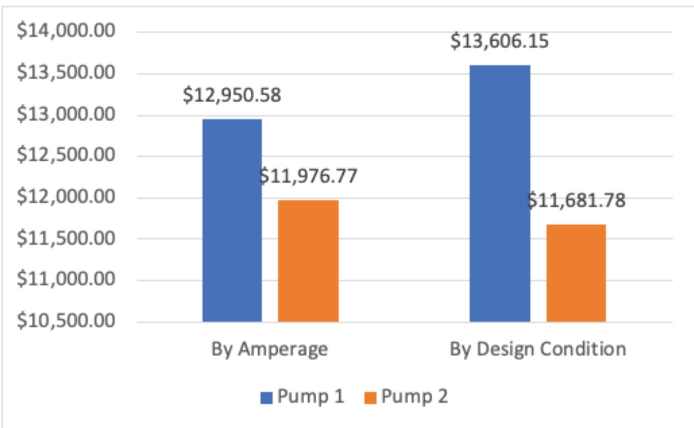

Figure 2: Summary of Examples 1 & 2 in Appendix

The IE3 rating also means that the pump can convert more of the energy consumed into pump energy, and less energy is lost in other ways – like heat. Premium efficient motors run cooler than lower efficiency motors, especially when they have a cooling jacket. A motor that operates cooler will also operate longer – the US Department of Energy states "Higher temperatures shorten motor life. For every 10°C (50°F) rise in operating temperature, the insulation life is reduced by half." Upgrading an installation an IE3 rated submersible motor can save money and provide excellent performance.

Efficiency calculation demonstration at Crane Pumps & Systems

APPENDIX

Example 1 – Energy Calculations by Amperage

Pump 1: 46 Amps, 460 volts, 80.5% Power Factor

Pump 2: 40 Amps, 460 volts, 85.8% Power Factor

Constants: Operating 10 hours per day, Energy is $0.12 per kilowatt-hour

$$Annual\ Energy\ Cost\ \left(\$/yr\right) = \left[\frac{I*V*PF*\sqrt{3}}{1000}\right]*\frac{X\ hours}{1\ Day}*\frac{365\ days}{1\ Year}*\frac{\$X}{kwh}$$

$$Pump\ 1: Annual\ Energy\ Cost\ \left(\$/yr\right) = \left[\frac{46*460*0.805*\sqrt{3}}{1000}\right]*\frac{10\ hours}{1\ Day}*\frac{365\ days}{1\ Year}*\frac{\$0.12}{kwh}$$
$$= \$12{,}950.58$$

$$Pump\ 2: Annual\ Energy\ Cost\ \left(\$/yr\right) = \left[\frac{40*460*0.858*\sqrt{3}}{1000}\right]*\frac{10\ hours}{1\ Day}*\frac{365\ days}{1\ Year}*\frac{\$0.12}{kwh} = \$11{,}976.77$$

$$Energy\ Cost\ Savings = Pump\ 1\ Energy\ Cost - Pump\ 2\ Energy\ Cost$$

$$\underline{Energy\ Cost\ Savings = \$12{,}950.58 - \$11{,}976.77 = \$973.81\ Annually}$$

Example 2 – Energy Calculations by Design Condition

Pump 1: 43.1% Wire to Water Efficiency

Pump 2: 50.2% Wire to Water Efficiency

Constants: 1580 GPM at 45 ft, Operating for 10 hours per day, Energy is $0.12 per kilowatt-hour

$$Annual\ Energy\ Cost\ \left(\$/yr\right) = \left[\frac{Flow\ (GPM)*Head\ (ft)}{3960*Wire\ to\ Water\ Efficiency}\right]*\frac{0.7457kW}{HP}*\frac{X\ hours}{1\ Day}*\frac{365\ days}{1\ Year}*\frac{\$X}{kwh}$$

$$Pump\ 1\ Annual\ Energy\ Cost\ \left(\$/yr\right) = \left[\frac{1580*45}{3960*0.431}\right]*\frac{0.7457kW}{HP}*\frac{10\ hours}{1\ Day}*\frac{365\ days}{1\ Year}*\frac{\$0.12}{kwh} = \$13{,}606.15$$

$$Pump\ 2\ Annual\ Energy\ Cost\ \left(\$/yr\right) = \left[\frac{1580*45}{3960*0.502}\right]*\frac{0.7457kW}{HP}*\frac{10\ hours}{1\ Day}*\frac{365\ days}{1\ Year}*\frac{\$0.12}{kwh} = \$11{,}681.78$$

$$Energy\ Cost\ Savings = Pump\ 1\ Energy\ Cost - Pump\ 2\ Energy\ Cost$$

$$\underline{Energy\ Cost\ Savings = \$13{,}606.15 - \$11{,}681.78 = \$1{,}924.38\ Annually}$$

Sources: US Department of Energy, Advanced Manufacturing Office, Energy Efficiency and Renewable Energy, "Extend the Operating Life of Your Motor", Report No. DOE/GO-102012-3735, https://www.energy.gov/sites/prod/files/2014/04/f15/extend_motor_operlife_motor_systemts3.pdf