

### ABSTRACT

HOMA Submersible Motors will operate successfully with all three lines of the supply voltage within +/- 10% of the nameplate rating. However, the slightest (1%) imbalance in voltage between any of the three supply lines (phases) will cause a significantly higher percentage of current imbalance within the motor. This current imbalance is in the order of 6 to 10 times the measured voltage imbalance. Further to the problem, some of this excessively high current is in the form of circulating currents within the stator, and therefore is not readable at the control box. The generation of these circulating current is best defined as follows:

*From NEMA MG-1 part14, Page 11*

*“The effect of imbalanced voltages on polyphase induction motors is equivalent to the introduction of a “negative sequence voltage” having a rotation opposite to that occurring with the balanced voltages. This negative sequence voltage produces in the air gap a flux rotating against the rotation of the rotor, tending to produce high currents. A small negative sequence voltage may produce in the windings currents considerably in excess of those present under balanced conditions.”*

Temperature rise within the stator windings will be proportional to the actual (not measured) current imbalance. The increased heat should cause the winding thermal sensors to react and shutdown the motor, provided the thermal sensors are properly wired and the alarm is not overridden. However, continued operation of the motor at elevated temperatures will lead to a breakdown of the winding insulation. In addition, continued cyclic operation of thermal switches will cause a decay of their set temperature, and may ultimately lead to their failure.

While the voltage imbalance has considerable effect on the stator winding, problems will also arise within the shaft/rotor assembly. Induced circulating current will cause the rotor to heat up. This may cause the rotor to expand, and excessive heat will be directly transferred to the motor bearings and mechanical seals through the shaft.

This document will provide the calculations necessary to determine if voltage imbalance is present, as well as how to identify possible causes.

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## PROCEDURE

The percentage of voltage imbalance is commonly defined as:

$$\text{Voltage Imbalance \%} = 100 \times \frac{Vp}{Va}$$

Where  $Va$  is the average measured voltage, and  $Vp$  is the peak deviation from the average voltage.

EX: If the measured voltages are  $L_1 = 452$ ,  $L_2 = 461$ , and  $L_3 = 466$ , then the average voltage ( $Va$ ) is 460. The peak deviation from average  $Vp$  is 8 ( $460 - 452 = 8$ ). Therefore, the percent voltage imbalance is

$$\text{Voltage Imbalance \%} = 100 \times \frac{8}{460} = 1.74\%$$

The percentage of current imbalance is commonly defined as:

$$\text{Current Imbalance \%} = 100 \times \frac{Ip}{Ia}$$

Where  $Ia$  is the average measured current, and  $Ip$  is the peak deviation from the average current.

EX: If the measured currents are  $L_1 = 56.3$  amps,  $L_2 = 51.1$  amps, and  $L_3 = 58.7$  amps, then the average current ( $Ip$ ) is 55.36 amps. The peak deviation from average ( $Ia$ ) is 4.26 amps ( $55.36 - 51.1 = 4.26$ ). Therefore the percent current imbalance is

$$\text{Current Imbalance \%} = 100 \times \frac{4.26}{55.36} = 7.69\%$$

Measured current imbalance should not exceed (5%), and is generally due to voltage imbalance in the supply. To determine if imbalance is coming from the load or the source, use the following procedure.

1. Measure and record voltage on each power lead. ( $L_1$ ,  $L_2$ ,  $L_3$ )
2. Change all three power leads as follows:  $L_1$  to  $L_2$ ,  $L_2$  to  $L_3$ ,  $L_3$  to  $L_1$ .

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3. Measure and record voltage on each lead again. (L<sub>1</sub>, L<sub>2</sub>, L<sub>3</sub>)
  4. If the imbalanced leg follows the motor lead, then a problem exists somewhere within the pump cable, connections, or stator winding.
  5. If the imbalanced leg stays on the same control box terminal, and jumps to a different pump lead number, then the problem is with the supply or control box.

If the voltage imbalance is found to be with the supply, then it must be:

1. Corrected by inspection and repair control box wiring or components.
2. Corrected by working with the power company.
3. Reduced by decreasing the load on the motor.
4. Compensated for with an oversized motor to handle the additional heat energy.

**IMPORTANT: ANY VOLTAGE IMBALANCE WILL CAUSE ADDITIONAL HEAT BUILDUP WITHIN THE MOTOR. THE DEGREE OF PROBLEMS AND/OR DAMAGE WILL BE A FUNCTION OF THE VOLTAGE IMBALANCE AND THE LOAD FACTOR OF THE MOTOR.**

As a minimum, nuisance thermal tripping will occur. If this goes unchecked, the following mechanical damage may occur.

**Bearings** - Grease will be melted out of upper bearing. Bearing will often look dry.

**Stator** - Winding insulation will breakdown, ultimately causing a short in the winding.

**Rotor** – May expand enough to contact the stator assembly. Will often be blue in color due to the heat.

**Upper Mechanical Seal** – Elastomers will be hard and brittle from heat exposure. Seal faces will often have heat checking them.

Continued operation of any pump with a significant (over 1%) voltage imbalance will make the above list of damage a certainty at some point in the motors life.