The Genteq ECM™ Hi-pot Test

Hi-pot Test Fundamentals: In the design of a motor, a great deal of care is taken in making sure that the coils are completely insulated from the surrounding environment (thus ensuring that the motor is safe to handle and use). This insulation system consists of wire and slot liner insulation, winding varnish, control component insulation, and the stator end-cap. The hi-pot test is performed as a method of evaluating the effectiveness of this system, and determining whether or not it can withstand high levels of voltage without breaking down.

Before proceeding, it is important to establish the meaning of the word "hi-pot." The word is a shortened version of the term "high potential," where potential refers to the input voltage level used in the test. A hi-pot test is performed by applying a high AC or DC voltage between the windings and the shell of the motor. For AC, the minimum potential is 1000+2*rated line voltage. For DC, an additional factor is included, and the minimum becomes 1.414*(1000+2*rated line voltage). The leakage current flowing through the insulation and out to the motor shell is then measured. The motor passes the test only if the amount of leakage current measured is less than the allowed value listed in the specification.

Differences between Induction Motor and ECM Hi-pot Requirements: Leakage current in a motor is created by the capacitance and leakage resistance between the current carrying coils and the motor shell. When a voltage is applied between the windings and the external shell of the motor, the current flowing through the insulation system has two components, capacitive and resistive. The total current can be represented by the following equation:

$$I_L = C*(dV/dt) + V/R_L$$

In this equation, I_L=total leakage current, C=capacitance of insulation, V=input voltage, dV/dt=change in input voltage per unit time, and R_L=leakage resistance of insulation. When using an AC input voltage to perform a hi-pot test, the voltage has a sinusoidal shape, an example of which is shown in Fig. 1(a). Because of the equation above, the resulting leakage current will have a sinusoidal shape as well (see Fig. 1(b)). Please note that the plots are not to scale.

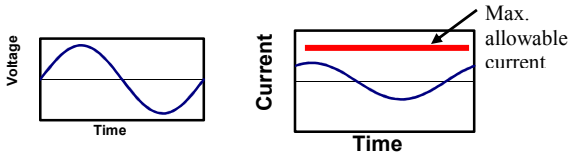

Figure 1. (a) Input voltage and (b) Leakage current

Now let's take a look at the difference in the hi-pot test of an induction motor versus a GENTEQ ECM™ motor. When testing an induction motor using an AC tester, the leakage current will look similar to that shown in Fig. 1(b). In this case, the AC test will provide an accurate measurement of the integrity of the insulation system (since no outside factors in the motor are contributing to the leakage current). As long as the current does not each the maximum level allowed, one may conclude that the motor is indeed safe. However, a major difference in the ECM motor is that the control contains 3 capacitors required for filter

ing out electromagnetic interference. Since these capacitors are connected between the power supply and ground, they also cause an increase in the current detected by the hi-pot tester. Even though this additional current does not reveal anything about the integrity of the insulation system, it *does* show up in an AC hi-pot test.

So although an AC test will not cause any damage to the motor or control, it can lead to a bad insulation system being indistinguishable from a good one (see Fig. 2).

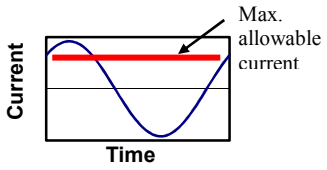

Figure 2. Leakage current plus current due to filter capacitors

Therefore, to eliminate the effect of the filter capacitors, it is necessary to use a DC hi-pot when testing an ECM motor. This procedure involves applying a controlled ramp of voltage until reaching a specified test level, as shown in Fig. 3(a). Going back to the equation for current, we find that such a ramped voltage causes the capacitive component of the leakage current to start out at a finite value, then drop down to zero once the voltage levels off. Furthermore, the resistive component will remain essentially constant throughout the entire test, due to the large resistance of the insulation system. Thus the total current will look like that shown in Fig. 3(b). However, if either the capacitance of the system is too high, or the leakage resistance too low, the maximum leakage current can be exceeded as the voltage ramps up, resulting in a failure.

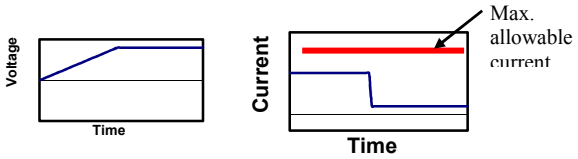

Figure 3. (a) Input voltage and (b) Leakage current

Recommended Test Settings: When performing a hi-pot test on a GENTEQ ECM™ motor, the DC voltage must be applied from both line input terminals to the outer shell of the motor. To meet the specifications, the voltage level should be set at a minimum of 2093 VDC (GENTEQ tests to higher values to assure margin for subsequent tests). It is recommended for motors rated below 460VAC to use a maximum of no more than 2500 VDC for 1 second from both the AC input terminals to the signal input terminals and chassis ground. However, it is very important that this ending voltage be reached at a rate of **no more than 1000 V/sec**. Ramping the voltage up at a continuous rate within this specification will prevent the current from exceeding its maximum (and thus causing a failure) before reaching the desired test conditions. For the ECM motor, the leakage current limit should be set at 0.99 mA. If the current exceeds this maximum at any point during the test, a failure is signaled and a buzzer will sound.
(Note: the exact procedure for completing a hi-pot test will depend on the particular tester you are using. Please see the manufacturer specifications for details.)

If you have further questions concerning the ECM hi-pot test, please contact your GENTEQ account manager.

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