AML D-Series Motor Vacuum Performance

APPLICATION NOTES

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1. D-Series Stepper Motor Vacuum Performance

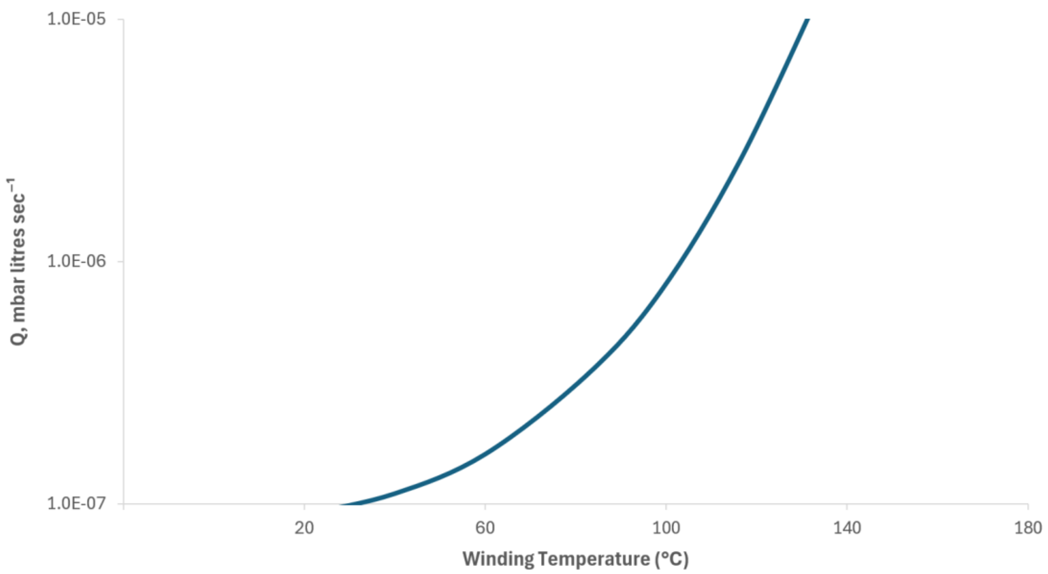
1.1. Outgassing rate and vacuum system sizing guide

This guide provides an engineering estimate of the gas load produced by an AML D-series stepper motor as a function of winding temperature. The curve can be used to estimate the pumping speed required for a target pressure, or the pressure contribution expected with a known effective pumping speed.

1.2. Results

Gas load, Q, increases strongly as winding temperature rises. Where vacuum performance is important, the motor should therefore be operated at the lowest practical winding temperature consistent with the required torque, speed and duty cycle. Selection of the minimum suitable phase current, reduction of unnecessary holding current and provision of suitable heat sinking can help reduce winding temperature and therefore reduce the gas load presented to the vacuum system.

The curve should be used as an engineering estimate. Actual system pressure will also depend on the vacuum chamber, pumped conductance, other components within the system and their individual gas loads.



1.3. Using the Outgassing Rate Curve

a) **Determine the expected winding temperature.** Use the intended operating current, speed, duty cycle and installation conditions to establish the approximate winding temperature of the motor.

b) **Read the motor gas load, Q, from the graph.** At the expected winding temperature, read the corresponding gas load from the vertical axis in $mbar \cdot L \cdot s^{-1}$.

c) **Use Q to estimate the required vacuum performance.** The relationship between gas load, effective pumping speed and pressure is:

$$Q = S \times P$$

Symbol	Unit	Meaning
Q	$mbar \cdot L \cdot s^{-1}$	Gas load produced by the motor
S	$L \cdot s^{-1}$	Effective pumping speed available at the motor / chamber
P	mbar	Pressure contribution associated with the motor gas load

1.3.1. Estimating the required pumping speed

If the maximum acceptable motor pressure contribution is known, estimate the effective pumping speed required from:

$$S = Q / P$$

1.3.2. Estimating the resulting pressure

If the effective pumping speed of the vacuum system is known, estimate the motor pressure contribution from the following formula:

$$P = Q / S$$

2. Improving the vacuum performance

In practical situations, the temperature rise is somewhat smaller than predicted, giving a substantially smaller gas load. An appreciation of the factors affecting temperature rise allows users to tailor their applications for minimum outgassing. The relative importance of these factors depends on the type of application: those which require continuous operation of the motor being the most challenging.

Since the curves of motor temperature were derived with no heat-sinking, they are conservative in predicting temperature rise in real applications. It is very easy to reduce equilibrium temperatures of 100°C and over by 30°C to 40°C by relatively simple means, such as mounting the motor on a plate or mechanism. Additional heat-sinking has little effect on the curves before some tens of minutes of heating because the transient thermal impedance of the motor is not reduced.

The temperature curves were obtained with both motor phases being driven with a steady direct current, which is only representative of low-frequency stepping. Since the motor windings are inductive, it takes a finite time to establish a current in them and this delay begins to become significant at stepping rates of a few hundred Hz. The effect is that the average winding current is progressively less than the set current at increasing speeds. This means that a motor running at faster than a few hundred steps per second reaches a lower final temperature than predicted. Beyond about 2 kHz, the reduction is dramatic; however, the available torque is much reduced.

Wherever possible, applications should be designed so that the load may be held in position by the detent torque of the motor, so that power may be removed between periods of motion.

The power output of the motor is proportional to the product of the output torque and the step frequency. At low step frequencies, each step is taken in a few milliseconds, after which no useful work is done, although power continues to be dissipated. The effect of this is that the electromechanical efficiency of the motor increases with speed until other factors reduce it, reaching a peak from about 500 Hz to 1 kHz. Operation in this range of speeds will, therefore, minimise the temperature rise for a given power output. Where gearing is involved, as in most mechanisms, this is, in any case, the optimum range of speeds for mechanical reasons.

For many applications motion is intermittent, with relatively short periods of motion and long periods of rest (low duty cycle). Provided the temperature rise during each cycle is small, it is valid to multiply the phase current by the duty cycle to estimate an effective phase current. If interpolation between the curves is required, it should be remembered that the heat dissipated in the motor is proportional to the square of the phase current.

Typical temperature rise of AML UHV motors at 1000 Hz step frequency