Parker Trilogy Motor Vacuum Compatibility & Sizing Calculations

The Parker Trilogy I-Force Ironless Linear Motors (110, 210, 310, 410 and ML series) are vacuum encapsulated as standard. As a result the I-Force motors have given us a high degree of success in markets such as Semiconductor, Aerospace/Defense, and other research markets requiring vacuum compatibility. The encapsulation, along with small modifications of the motors (listed below), makes them suitable for vacuum environments to pressure of 10e-6 Torr. These motors have been used successfully in 10e-7 vacuum environments; although, they are not rated to this level. Please consult the factory with specific application details for environments with a higher vacuum rating than 10e-6 Torr.

For lower outgassing, Parker can provide special motors that have the following Modifications -

- Mounting holes in the coil are drilled through to eliminate blind holes.
- Cosmetic painting and patching of the coil is omitted to prevent the addition of any air pockets.
- Vent holes are drilled in the magnet track to eliminate air pockets in all blind holes.
- Special cleaning and handling of all parts is used to eliminate any contamination.
- Special packaging is used to prevent contamination during shipping.

When ordering, specify a –V (vacuum compatible option) to receive the modifications mentioned above.

Are the black magnets compatible in a vacuum environment? Don't anodized surfaces need to be nickel coated for vacuum?

The black magnets are not anodized. They are covered in a hardened epoxy material, similar to the epoxy used to encapsulate the Trilogy coils. The black magnets are compatible in vacuum environments.

For higher vacuum levels, the Parker Trilogy tracks and coils can be further customized. Your local Parker ATC can provide custom linear motor product quotes.

Motor Sizing and Selection for Vacuum Environments

First, size the application using Parker MotionSizer or WinTIPS as if the motors were not in a vacuum environment. Note that MotionSizer and WinTIPs are not suitable for selecting motors for vacuum environments. However, they can be used for calculating the continuous force required based upon the load, orientation, move profiles and duty cycle. As an example, let us assume an application requires 4 N continuous force based upon the Parker MotionSizer or WinTIPs sizing software.

Next, calculate the RMS power required using MotionSizer or WinTIPS. Calculating by hand it would be:

$$P = \tfrac{3}{4}\, Isp^2\, R_{hot},$$

where Isp is the current in peak of sine and R_{hot} is the hot resistance of the motor, given by:

$$R_{hot} = R_{25C}\,(1 + .00393\,(T_w - 25))$$

As a conservative estimate, use the maximum winding temperature. For Trilogy motors this is 100 deg C.

In our example, using the 110-1S:

$$I_{sp} = 4\text{N} / 6.8\text{N} / A_{pk} = .588\ A_{pk}$$

$$R_{hot} = 3.8\text{ohm}\,(1 + .00393\,(100 - 25)) = 5.1\text{ohm}$$

$$P = \tfrac{3}{4}\,(.59\ A_{pk})^2\ 5.1\ \text{ohm} = 1.3\text{W}$$

From the Trilogy catalog, we see the 110-1 is capable of 47W power dissipation and the 110-2 of 82W in a standard (non-vacuum) environment. However, there is no convection cooling in a vacuum (non-force cooled).

The motor won't have a problem radiating 5% of its heat; it could be as high as 10%.
When sizing a motor for a vacuum that won’t have forced cooling, 5% I^2R losses would mean selecting a motor with 4-5 times higher continuous current than is needed in the application. This means the I^2R losses are 4% for 5x continuous current and 6.25% for 4x.

In the example, the 110-1S continuous requirement would be $.59A_{pk}$ and the losses 1.3W, which is 2.8% or the motor’s 47W capacity. For the 110-2S, the continuous current required would be .29A and .629W for the I^2R losses which would be .8% of the motor’s capacity. In this application, the 110-1S would be a good choice.

If the motor is force cooled with the liquid option, the heat is removed entirely from the liquid. In this situation, there is no difference with the standard product performance calculations. Trilogy WinTIPs can be used with the liquid cooled to estimate motor performance. The air cooling option is not compatible in vacuum environments as air exits the coil bar blowing over the coil.

The above estimates are good for applications where the vacuum chamber is being pulled down for long periods of time, where the coil temperature would rise slowly over time and reach a thermal equilibrium within the chamber. If the vacuum chamber is not being pulled down for long periods of time, the motor could be convectionally cooled when the chamber is opened by air moving into the chamber. In this situation, a smaller motor could be used. However, we are not able to give a temperature analysis beyond WinTips results without further testing or very specific application details. The vacuum chamber's size and material type (and thus the emissivity) of those surfaces would all affect the motor's ability to dissipate heat via radiation to other parts of the chamber. If the chamber is all stainless steel, the radiant heat would be reflected and not absorbed; however if it was all black coated, then it would absorb the radiant heat. Heat would also be conducted from the coil bar. The tooling mass and thermal conductivity would have a capacitive effect in the rise in temperature.

Because the motor is in close proximity to the magnet track, the black magnets would improve the ability to radiate heat from the coil to the track. The track can then conduct heat to the vacuum chamber. The nickel-coated magnet tracks are also vacuum compatible. Connecting a cooling plate to the outside of the chamber or having a low ambient temperature outside the chamber will improve that heat transfer rate. Please contact the factory with the application details so the best possible solution can be selected.

Please note that the motors include a Thermostat or Thermistor option with the different winding options. This should be connected to the servo amplifier for motor protection.