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Coils Get Hot

by Damiano Roberti— Sept. 23, 2010
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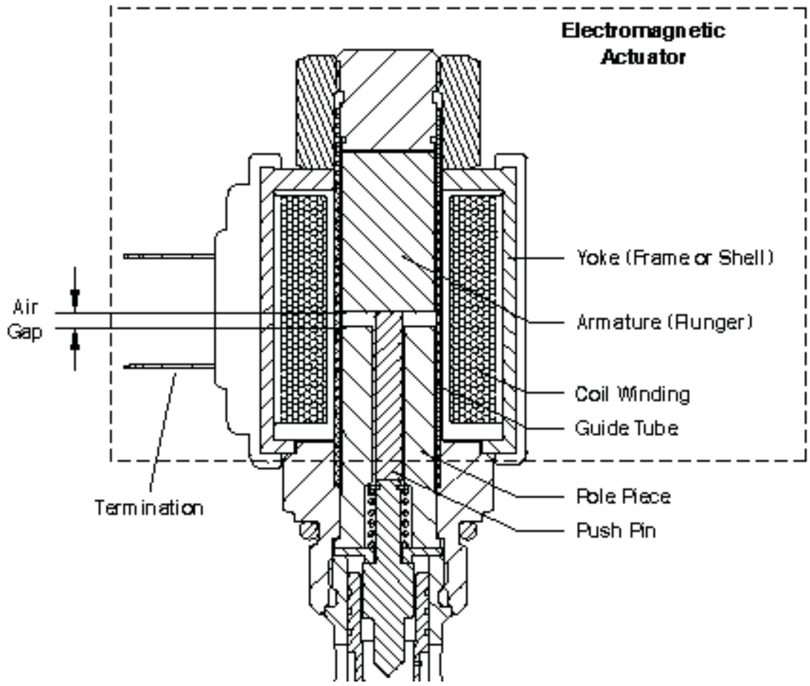
Besides pressure, flow rate and pressure drop considerations, there is another important variable to consider when choosing the proper components to optimize your electro-hydraulic system. This variable is the duty cycle of your coils. If your coil is improperly sized, failure can occur, especially when operating a valve at 100% duty cycle. However, by factoring in coil temperature when you design you machine, you will avoid undesired failures such as degraded solenoid valve performance.

First, a quick description of the relationship a coil has with your valve. A coil is copper wire encapsulated in resin. The coil windings create an electromagnetic field when current is applied across the terminals. This electro-magnetic field actuates the valve by moving the push pin to the appropriate location. The percentage of time the coil is energized is called duty cycle (you can learn more here).



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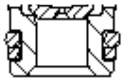


Normally, when your hydraulic system is running, your coils are continuously energized, creating many opportunities for them to get hot or overheat if the ambient temperatures are extreme. Pressure Control Valves (TS Series) and Flow Control Valves (PV Series) typically run at 100% duty cycle. Directional Control Valves (SP Series) typically run at less than 50% duty cycle. This is when working with reliable and robust coils has its advantages. Having more durable coils, like HydraForce's E-series coils, allows you to push the operating limits of your valves and optimize the performance of your machine, especially if your valve is operating simultaneously at maximum flow and pressure rating.

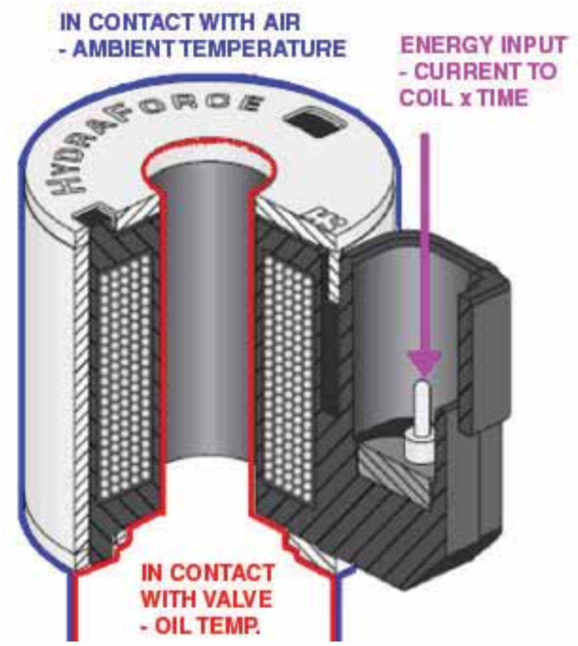
For example, if a valve is energized only a few times during a standard shift of the system, you could use one coil with low nominal voltage (e.g., 10V) and set the supply voltage at 10 to 15% higher (e.g., 12V). This method allows you to produce more magnetic force for the actuation of the pole tube. Consistently generating a higher magnetic force means that you will have more consistent valve performance (e.g., less hysteresis). In addition, when battery voltage becomes low, or when pressure and flow rates are higher than nominal values, you will see no difference in performance.

According to the first and second Ohm's Laws, when you increase the duty cycle of the valve, there is more power dissipated through the coil winding. The resistance of the copper is not constant but it is a function of the coil's temperature.

The change in the resistance of copper due to the change in temperature can be determined by using the following equation:

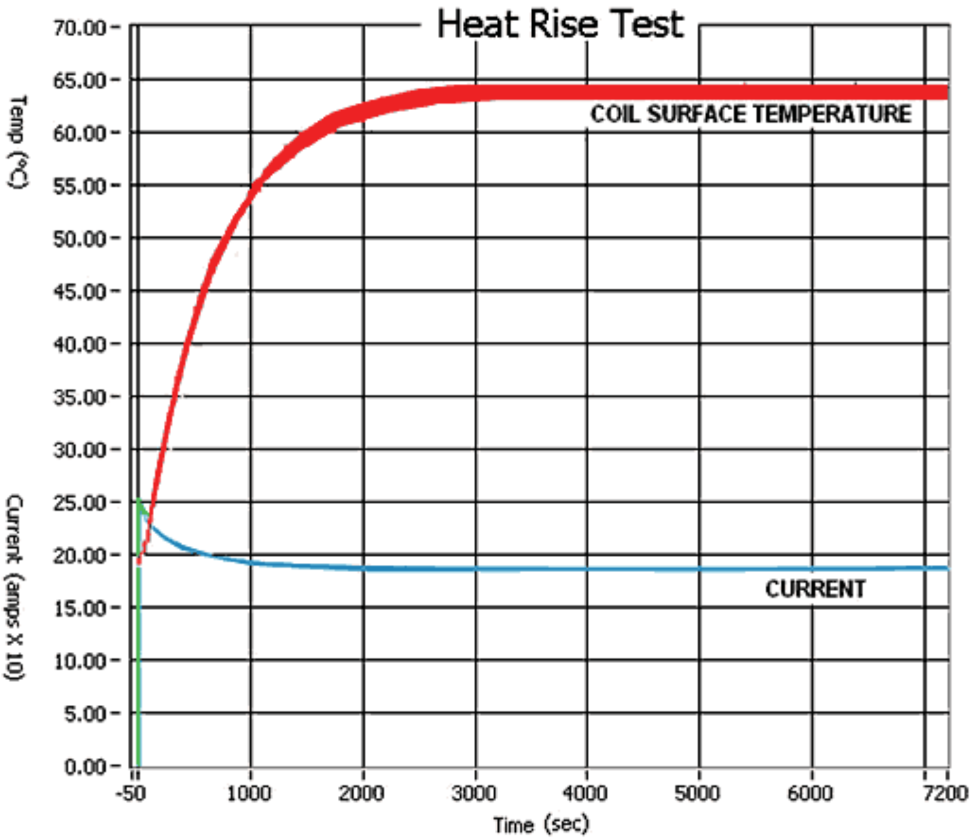
$$R_F = R_{20}[1 + 0.00393(T_F - 20)]$$

where:
R_{20} = resistance of the coil winding at 20°C (Ω)
0.00393 = Physical constant of copper representing the change in resistance due to the change in temperature
T_F = coil winding temperature in °C
R_F = resistance at the coil winding temperature (Ω)



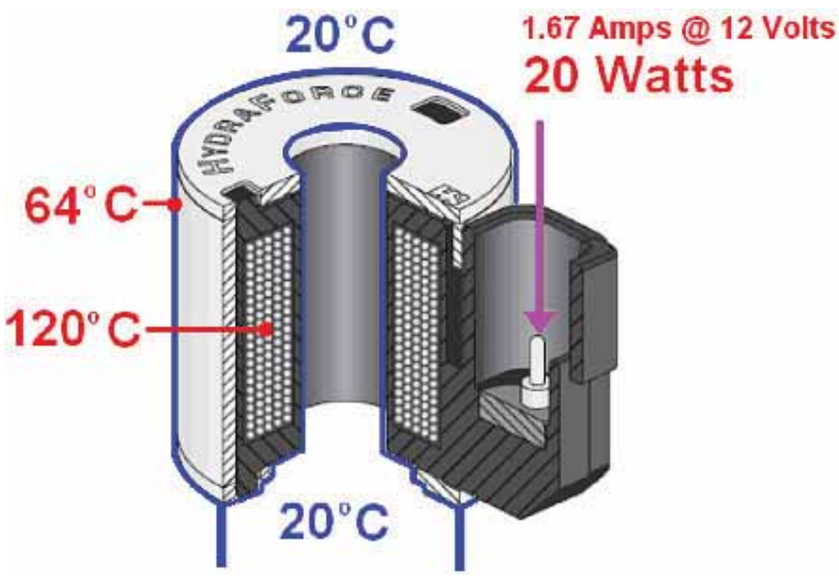
For example, assume that a 10V, 10-size E-Coil is energized for 1 hour at 100% Duty Cycle:
R_{20} = 4.8Ω at 20°C
V_{SUPPLY} = 12V (power supply)
Ambient temperaure of 20°C

Under these conditions, the coil surface temperature and current (amp) values would be:
T_S = 64°C; I = 1.8 amps



Applying the first of Ohm's Laws, we can evaluate the resistance of the coil winding (**R_F**) in that condition:
$R_F = V_{SUPPLY}/I = 12/1.8 = 6.67\Omega$

Using the equation
$$R_F = R_{20}[1 + 0.00393(T_F - 20)]$$
we can calculate the coil winding temperature inside the core of the coil:
$$6.67\Omega = 4.8\Omega[1 + 0.00393(T_F - 20)]$$
so, $T_F = 120°C$



Looking at the diagram above, you can see that the temperature inside the coil winding is higher than the temperature on the coil surface, and much higher than the ambient temperature. Therefore, we can expect the following correlation to be true:

The temperature inside the core of the coil is generally greater than ambient temperature. Around 5°C / 41° F more for each watt provided to coil.
$T_F = T_{AMB} + 5(P_{SUPPLY})$

As you now know, coil damage will occur if the temperature of the core is too high for an extended period. By design, HydraForce coils can withstand these adverse conditions and provide a consistent duty cycle of 100%, all while simultaneously applying a power supply voltage greater then the nominal value. Refer to our E-Coil bulletin for more information on coils and the relationship between ambient temperature and voltage supply that you can apply to HydraForce coils.

In Summary:

- The temperature inside the coil increases when coil is energized.
- Temperature increase is a function of the supply voltage and ambient temperature.
- HydraForce coils can withstand high temperature without degradation of the coil.
- If the duty cycle of a valve is below 50%, you can use a lower voltage coil to get more magnetic force in all work conditions.
- Higher magnetic force means performance that is more consistent during low voltage conditions. Working pressure and flow rate can be higher than nominal values.
- HydraForce Controller's are designed to compensate for changes in coil resistance.

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