Chapter 10: Installation Considerations / Troubleshooting

Objectives

The objectives for this chapter are as follows:

- Understand the proper method of installing the coil.
- Walk through the steps of the cartridge valve installation, including the seal lubrication and consequences of not lubricating properly.
- Discuss how the tube could be stretched and the consequences of it.
- Become familiar with potential cartridge failures, possible causes and suggested actions.
- Review the concept of back EMF and determine how it affects the circuit and the coil.
- Learn about three surge suppressors to reduce the effects of back EMF; diode, varistor and zener diode.

Introduction

When installed and applied within the guidelines of the catalog, the HydraForce solenoids will work reliably for a minimum of one million cycles. However, as good as the product is, problems may still arise for various reasons. In this chapter we will look at installation considerations that will help prevent failure such as correct tightening of the cartridge and coil. Also, the proper method to protect the customers’ electrical system with a surge suppression device is described. After looking at preventative measures we will explore some troubleshooting techniques to help determine why the valve might fail to operate as expected.
Cartridge Valve Installation

The following section describes the method in which the cartridge valve should be installed. A list of steps as well corresponding diagrams are provided to ensure that the valve is installed properly.

Step 1. Remove cartridge from packing.

Step 2. Inspect o-rings to ensure there is no damage such as cuts or nicks.

Step 3. Check if all back up rings fit tightly within the o-ring groove. They should not stick out further than the o-rings. If they are sticking out further than the o-ring, they must be squeezed back into the groove.

Step 4. Immerse the hydraulic portion of the cartridge in oil to lubricate the seals. It is important to install the cartridge (valve) into the cavities correctly. Before beginning, the o-ring and back up rings should be lubricated with a small amount of oil. The same oil which is used in the application should be used, and the outer surface of the seals should be lubricated. This allows the seals to slide into the cavity easily. Dry seals could cause the back up ring to spin out of the cage groove which could cause damage to or cut the seal. The diagram to the right demonstrates this procedure as well as shows the location of the grooves.
Step 5. Insert the cartridge into the cavity and tighten by hand in a clockwise manner. You should be able to screw it in with little resistance up to the o-ring, below the adapter.

Step 6. Continue to screw in the cartridge with a torque wrench and tighten to the torque specified in the catalog. It is important to use the specified torque for each valve to ensure optimal performance of the cartridge. If the valve is tightened above the specified torque value, this may cause the spool or poppet to stick. This occurs because overtightening the cartridge can deform or collapse the inside of the cage. The diagram to the right shows an example of this. Refer to the catalog for the torque values.
Step 7. Install the waterproof o-ring on the cartridge hex if one is required.

Step 8a. If the valve uses a single coil, install the other waterproof o-ring (if required) and the coil. Install the coil nut and tighten to the torque specified in the catalog.
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It is important to install the 08 and 10 size coils correctly to ensure they operate as they were designed to. If the coil is installed upside down, the magnetic flux path is weak and cannot shift the spool or poppet. The diagram below shows an 08 size coil installed correctly and one installed incorrectly. To ensure the coil is right side up, verify that the HydraForce imprint is facing up.

The installation torque specified for the coil nuts is also important. For example, if the nut is tightened above the specification on the 08, 60, 68, 80 size 2 position actuators, the stainless steel tube could stretch. The stretching causes the inside of the tube around the plunger to collapse, which could cause the plunger to get stuck in the energized or de-energized position. This can be seen in the diagram on the following page.

The installation torque is also important on the cartridges which use o-rings for the waterproof option. If the nut is not tightened to the specification, the o-rings will not be sufficiently compressed. This will allow water to leak past the o-ring and potentially cause the winding to fail.
Step 8b. If the valve requires two coils, install them separately. Install the first coil, the washer and the waterproof o-ring (if required). Then install the second coil, and waterproof o-ring (if required).
Troubleshooting

The following section describes several possible valve failures as well as suggested actions to determine if the problem can be easily solved or if further action is necessary.

Potential Failure #1

If the hydraulic system fails to operate as expected, and the valve is suspected as the cause of failure, the following two actions should be done first to determine if the valve is causing the problem.

Possible Cause

There are several possible causes which are listed on the following pages.

Suggested Action

a. Remove the cartridge from the cavity and push on the spool or poppet to see if it moves easily.

b. Hold the valve outside of the cavity. Energize and de-energize the coil to see if the spool or poppet moves. Listen to hear the plunger hitting the pole piece. On the SVXX-20 and 22 type valves, there is a spring pushing down on the poppet even when the coil is energized, therefore, you may not see the poppet move. To determine if the plunger has moved, push on the poppet. It should be easier to move the poppet when it is energized than when it is de-energized.

If you can see the poppet or spool moving, hear the plunger hitting the pole piece and are able to move the spool or poppet with little effort, the cartridge is most likely not the problem. However, if you still suspect the cartridge, move onto further troubleshooting techniques. If you are unable to do any of the above, contact HydraForce for help.
Potential Failure #2

High internal leakage between ports above catalog specification.

Possible Cause

a. Extruded O-ring  
b. Contamination causes spool or poppet to stick  
c. Fluid viscosity

Suggested Action

a. Remove the cartridge from the cavity and inspect o-rings. If an o-ring is extruded, it can be replaced with a seal kit (consult the catalog for the seal kit). Also, measure the system pressure. If the pressure exceeds the one specified for the o-ring material you are using, contact HydraForce for the correct seal.

b. Remove the cartridge from the cavity and inspect the outside of the cartridge for metal chips and pieces of rubber. If contamination is found, it is recommended that the failed cartridge is sent back to HydraForce. While the external contamination can be cleaned off, internal contamination may still exist.

c. If the fluid viscosity is less than 32 cst, the leakage may be higher than what the catalog specifies.

Potential Failure #3

Cartridge fails to pull in (change from neutral to secondary position).

Possible Cause

a. Contamination causes spool or poppet to stick  
b. Cartridge installation torque is too high  
c. Cavity diameters are not concentric or in line with one another  
d. Stretched tube restricts movement of plunger  
e. System flow and / or pressure above valve rating

Suggested Action

a. Refer to potential failure 2b.

b. (See potential failure #1) After verifying that the spool or poppet shifts, reinstall it into the cavity and tighten to the torque specified in the catalog.
c. (See potential failure #1) After verifying that the spool or poppet shifts, remove all o-rings from the cartridge. Screw the cartridge into the cavity by hand until the adaptor hits the body or manifold. If it feels like the valve is binding or rubbing against the cavity, the cavity diameters may not be concentric. If it is determined that the cavities are not concentric, contact HydraForce for further action.

d. (See potential failure #1) There are two ways to tell if the tube is NOT stretched. The first indication is if the spool or poppet move easily when pushed on. The second is if the current required to shift the valve is less than 70% of the nominal voltage divided by the nominal resistance. (This failure only occurs on the 2 position, 08,60, 68 and 80 cartridges). If the spool or poppet does not move easily or the current to shift the valve is higher than 70%, the tube may be stretched. If you determine that the tube may be stretched, return it to HydraForce for review.

e. After performing the steps in action 1a, determine if the valve is being used beyond its pressure and flow rating. First, measure the pressure. Second, if possible, determine the system flow. This can typically be done by multiplying the pump displacement, which is listed in volume per revolution, by the RPM (revolution per minute), of the motor.

Next, if the valve is controlling a hydraulic cylinder, consider if the flow or pressure is being intensified because of the cylinder. In addition, if an accumulator is part of the system, it may be contributing to the problem. The flow from an accumulator may not be regulated or controlled and could exceed the rating of the valve.

**Potential Failure #4**

Cartridge fails to drop out (change from secondary to neutral position).

**Possible Cause**

a. See potential failure #3
b. Trickle voltage

**Suggested Action**

a. Trickle voltage is a term associated with a low level voltage applied to the coil in the off state. This voltage exists in electrical systems that use a solid state relay to actuate. The trickle voltage is typically not a problem for HydraForce valves because the return spring force ensures that the valve will drop out at a mimimum or 5% of nominal room temperature current draw.
Trickle voltage could cause a problem if the valve were applied in a cold ambient environment. When the temperature decreases, the coil resistance decreases causing the current draw to increase.

In addition, if any of the causes noted in Potential Failure #3 exist, and trickle voltage is present, the valve may hesitate or fail to drop out at all. A valve which hesitates is one in which the switch that controls it has been turned off and the valve waits several seconds before dropping out.

Suggested Action

Unfortunately no action can be taken if trickle voltage is determined to be a problem. Contact HydraForce for assistance.

**Potential Failure #5**

High pressure drop

**Possible Cause**

Contamination causes spool or poppet to stick

**Suggested Action**

(See potential failure #1) If the spool or poppet moves freely, compare the amount of movement to the same type of cartridge (if available). If the movement appears to be less in the suspect valve, there may be contamination in the valve. Return the valve to HydraForce for review and consult for possible solutions.
Potential Failure #6

The coil is stuck on the tube after the nut is removed.

Possible Cause

The tube may have been over pressurized above the proof pressure.

Suggested Action

Pry the coil off. Record the system pressure with a digital pressure transducer. Return the valve to HydraForce and consult for possible solutions.
Electrical Considerations

Back EMF

As noted in chapter three, when a solenoid is powered and the power is turned off, the change in magnetic field creates an induced voltage and current. A term commonly used to describe this induced voltage is *back EMF*. It is given this name because the induced voltage or electromotive force is pushing against the externally applied power supply.

The wiring diagram shown to the left shows a coil, switch and battery. Assume that the voltmeter which is connected across the coil measures and records the following graph.

When the switch is closed, the voltage flows in the positive direction from the battery. When opened, the voltage drops to zero and becomes negative. This indicates that the induced voltage is acting in the direction opposite of the battery. The graph shows that this voltage could be as high as 200 - 400 V. However, this negative voltage exists for only a fraction of a second (10 nanoseconds or 10 seconds/1,000,000,000). Therefore, for a very short time a very high voltage exists.
This induced voltage makes an arc or spark jump across the terminals of a switch when it is opened. The spark could potentially damage the switch. To keep back EMF from damaging a switch, a device known as a surge suppressor is used. A surge suppressor keeps the back EMF from jumping across the switch. Instead, it directs this voltage back into the coil. There are several electronic components which can be used as a surge suppressor. These include the diode, varistor and the zener diode and are described in the following section.

**Diode**

As described in chapter two, a diode is an electronic device which allows voltage and current to flow in one direction only. The diagram below shows a diode connected in parallel with the coil and a graph of the voltage measured when the switch is opened.

![Diode Circuit Diagram]

Notice that the voltage goes to zero when the switch is opened. The voltage does not become negative. Rather, it remains at zero. This indicates that the back EMF was eliminated.

The diode shown in the circuit above can either be molded into the coil as the winding is, or it can be connected across the terminals with dual bolts as shown below. The preferred method of installation is molded into the coil.

*The preferred method of installation is molded into the coil.*
Diode Failure Scenario #1

When connecting power to the coil, care must be taken to connect the positive and negative wires to the correct terminal. If the wires are not correctly connected, damage to the diode could occur. When a diode is damaged it can fail in two ways. The first failure which can occur is that it acts as a piece of wire rather than the diode, and has a much lower resistance than the coil winding. Since the resistance is so low, it draws higher current than the coil would have. This high current draw could be above the electrical rating of the electronics or switch which the diode was supposed to protect. The high current draw could cause these components to fail as well.

Diode Failure Scenario #2

The second type of diode failure is when the diode burns out and is basically no longer part of the circuit. See the diagram to the left. When this occurs, the back EMF creates an arc across the switch, possibly causing it to fail.

**Varistor**

The varistor, like the diode is used to protect the switch from the back EMF. The advantage of the varistor over the diode is that it does not matter which way it is connected to the power supply. Current is blocked from flowing through a varistor until the voltage exceeds a certain level. For example (refer to the diagram below), assume the varistor is connected in parallel across the coil. The graph shows the voltage across the coil. When 12V from the battery is applied to the varistor and coil, all of the current is flowing through the coil because the coil has a much lower resistance. After the switch is opened, the voltage drops and becomes negative, indicating the plunger is moving and creating back EMF. At 50V, the voltage begins to return to zero. At the 50V point, the resistance in the varistor suddenly drops to a very low level and the current can flow through it. This limits the back EMF to a maximum voltage within the level the switch can handle. The voltage level at which this occurs is known as the clamping or limiting voltage, because the back EMF is clamped to a certain level.
Bidirectional Zener Diode

The bidirectional zener diode is similar in function to the varistor. When the voltage potential across this diode exceeds the rated clamping or limiting voltage of the zener diode, the diode opens to allow that voltage or current to flow through it. The diagram below shows a schematic of the zener diode in parallel with the coil. The graph beside it shows what is happening with the voltage as the switch opens.

\[ V_S \] is the Battery Voltage
\[ V_C \] is the Clamping Voltage

\[ V_C \] for a 12V or 24V system is typically no greater than 50V. This means that when the switch is opened, back EMF still occurs, but is limited to 50V. Switches can typically handle this level of voltage without damage.

The advantage of using the bidirectional zener diode is that it does not matter how it is wired to the power source. The positive terminal of the power supply can be connected to either terminal of the coil. The disadvantage to having this ability however, is that it is more costly than the standard diode.

The bidirectional zener diode is preferred over the varistor because varistors are easily damaged during the molding process.
Temperature and Pull-in Current

In the previous chapters we mentioned that when the temperature increases, so does the resistance of the coil. This increase in temperature can be from the environment the coil is in, or from power applied to the coil. The resulting resistance determines if the coil will be able to draw sufficient current to operate the valve. Recall the pull in current required for a valve using an 08 size, 10 size or 12 size coil was 840 mAmp, 1140 mAmp or 1850 mAmp, respectively. The graph below shows the voltage required to supply this current at various ambient temperatures, when power is applied continuously. Since the y-axis is given in % of rated voltage, this graph can be applied to any voltage coil. The operating range indicates that at any voltage above the minimum operating voltage line, the coil will draw sufficient current to operate the valve.

If the valves need to be operated with a voltage level lower than the curve in a given ambient temperature, consult HydraForce. The graph shown indicates continuous duty. Many applications power or energize the coil for a short time and de-energize it for at least the same amount of time. If the duty cycle of the solenoid is intermittent, the rule of thumb for the operating voltage is ±15% of the nominal voltage, up to an ambient of 40°C. If the duty cycle is considered light, the valve can be operated in 60°C ambient temperature with a voltage range of -10% to +15%.

If there is any doubt if the valve will operate in a particular environment, HydraForce should be contacted.
Grounding

HydraForce recommends connecting the ground or the negative terminal of the coil to the source. This should be done through a wire, with one end connected to the coil terminal and the other to the source. While HydraForce does offer coils which are internally grounded, this method has potential problems which are not found in the recommended method. An internally grounded coil basically has the negative terminal connected to the coil shell. Also, recall the shell is in contact with the valve, which is screwed into the manifold. The negative end of the source is connected to the manifold. The problem with this method, however, is that all of the boundaries between different materials are potential points for corrosion. The corrosion acts as an insulator. In addition, the anodized manifold is a potential insulator. Each of these factors contribute to a voltage loss in the circuit.

Cartridge Fluid Compatibility

There are times when a customer wants to use HydraForce valves with a non standard fluid. The following section briefly reviews the fluids which can and cannot be used with HydraForce valves.

The standard HydraForce cartridge valves were designed to be used with petroleum based oils and synthetic oils with lubricating additives. As mentioned in Chapter 9, other seals are available for different fluids, such as brake fluid. HydraForce should also be consulted if the viscosity seems extremely high or low.

In addition to the fluids mentioned above, HydraForce valves have been used in the following fluids:

- water glycol
- diesel fuel
- cutting fluids (used in machining operations)
- biodegradables (used in machining operations)

Consult HydraForce before applying the valves in any of these fluids.

HydraForce valves are NOT compatible with several fluids. These include:

- water
- gasoline
- kerosene
- alcohol
Fluid Resistance

In many applications, the outer surfaces of the cartridge and coil are subjected to a harsh environment. We have already discussed water intrusion. However, some customers are concerned that the product will fail if it comes in contact with various fluids. To determine if there are any concerns, HydraForce cartridges and coils have been subjected to a splash test with the following fluids:

- battery acid
- antifreeze
- screen washer fluid
- Texaco Cold Climate PSF (TL-14315)
- Pentosin
- Dexron III
- Dexron IID
- Chlorinated solvents
- Body and Underbody wax
- Diesel Fuel (BS 2869)
- Distillate
- Wiping fluid
- Brake Fluid
- Grease (lithium soap based)
- Hypoid oil
- Engine oil
- Gasoline

The coils were immersed in each chemical for 30 seconds. After the coils were removed from the chemicals, they were baked for four hours at 50°C. This procedure was repeated for a total of three trails.

When the test was completed, the coils still actuated the valves. The only fluid which caused any material degradation was battery acid.
EMI/RFI Issues

Electromagnetic Interference (EMI) and Radio Frequency Interference (RFI) are becoming more common as technology becomes more sophisticated. The use of electronics is a normal occurrence on a large variety of systems. These electronic systems can, and often do interfere with one another. Electronic engines, computers, relay switches, solenoids, cell phones, radios and a great deal of magnetic field producing wire, are all among the systems which can interfere with one another on mobile equipment alone. Thousands more exist in other environments. The challenge now is to determine how these systems can coexist and function as intended.

Electromagnetic Interference is a form of environmental pollution which can be generated from low-power digital circuits to high-power radio antennae. Electronic malfunctions can cause a number of problems including malfunctions in safety equipment, navigation equipment and protective equipment. Radiated emissions can be solved by shielding critical parts and using line filters. This should be done while keeping in mind the effects of harmonics, voltage fluctuations, electrostatic discharge and other factors.

The European community is taking a proactive approach to this problem. The European Commission has ruled that all electrical devices should function effectively despite the existence of electromagnetic interference. Standards and shielding techniques against the interference are being developed. These standards will include rules on the acceptable levels of electrical emissions from low and high voltage industrial equipment as well as noise emissions. However, there is considerable difficulty in creating these standards, since they must apply to such a large variety of products.

At this time, HydraForce has not specifically qualified its product against any general EMI or RFI specification. This issue needs to be addressed at this time on a customer by customer basis.
Summary

In this chapter the following concepts were presented:

• The proper method of installing a coil.
• The proper method of installing the cartridge valve into the cavity.
• The importance of lubricating the seals (or consequences of not).
• Five methods of troubleshooting the cartridge valve operation.
• Review of back EMF and why it occurs.
• Surge supersession methods to avoid damage from EMF.
• How the diode, varistor and zener diode provide surge suppression.
• What EMI is.
Review Questions

Use the following review questions as a measure of your understanding of the chapter material. Answers are provided in the appendix.

1. What term is commonly used to describe the induced voltage when power is turned on and off? ________________

2. What type of device is used to prevent damage from EMF? ________________

3. Name the three types of surge suppression methods described. ________________

4. What is the advantage of the varistor over the diode? ________________

5. Which surge suppressor is the zener diode similar to in function? ________________

6. When installing the coil, in which direction should the lettering face? ________________

7. What step must be taken before inserting the cartridge valve into the cavity? ________________

8. What could happen to an 08 size cartridge if the nut is overtightened? ________________
Notes