ME/ECE 4710 Motion and Control  
Lab #2: Hydraulic Cylinder Circuits

Introduction  
The purpose of this experiment is to gain some experience using directional control valves and double-acting, single-rod hydraulic cylinders. Two simple circuits are built. The first measures flow from both ends of a cylinder at various pressures. The second is a metering-out circuit used to keep loads from having unwanted acceleration while the cylinder is extending. If a load has uncontrolled acceleration, it is called a runaway load. One example is a heavy load that is being lowered to the ground.

Part 1: Measuring Flow Exiting a Cylinder

Introduction  
Double-acting, single-rod hydraulic cylinders have different areas and volumes on either side of the piston. As a result, different flow rates and pressures are generated during extension and retraction. In this exercise, you will measure the flow rates of the fluid exiting a cylinder at various supply pressures, calculate the corresponding rod speeds, and explain the results you find.

Components  
1. Motor and Pump  
2. Relief valve  
3. Flow meter  
4. Pressure gage  
5. Solenoid-operated directional control valve  
6. Horizontal hydraulic cylinder (1.5 inch diameter bore, 1.0 inch diameter rod)  
7. Loose components: hoses

Procedure  
a) Complete steps 1-3 of the Procedure for Connecting a Hydraulic Circuit, setting the relief valve to 100 PSI.  
b) Complete steps 4-8 of the Procedure for Connecting a Hydraulic Circuit:  
   • Connect a hose from a second pressure port on the supply/return manifold to the “P” port on the solenoid-operated directional control valve.  
   • Connect the “T” port of the directional control valve to the inlet of the flow meter.  
   • Connect the outlet of the flow meter to a return port on the supply/return manifold.  
   • Connect the “A” port of the directional control valve to the cap end of the horizontal cylinder.  
   • Connect the “B” port of the directional control valve to the rod end of the horizontal cylinder.  
c) After the instructor has inspected your circuit, complete steps 9-10 of the Procedure for Connecting a Hydraulic Circuit. Observe and record the flow rates for the cylinder during extension and retraction. Also observe and record how the supply pressure changes during extension and retraction. Increase the supply pressure in 50 PSI increments from 100-300 PSI, observing the flow rates for extension and retraction at each pressure.  
d) Follow the Shutdown Procedure. After opening the vent valve, sequence the directional control valve from left to right to relieve any built up pressure in the valve body.
<table>
<thead>
<tr>
<th>Supply Pressure (PSI)</th>
<th>100</th>
<th>150</th>
<th>200</th>
<th>250</th>
<th>300</th>
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</thead>
<tbody>
<tr>
<td>Exit Flow Rate during Extension (LPM or GPM)</td>
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<tr>
<td>Exit Flow Rate during Return (LPM or GPM)</td>
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<tr>
<td>Change in Supply Pressure (Ext/Ret) (PSI)</td>
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</tbody>
</table>

Questions
1. How do you explain the trends in the flow rates as you move from 100 to 300 PSI? Which flow rate is larger at each pressure setting? Why? When is the system flow limited? When is it pressure limited?
2. What are the extension and retraction velocities at each pressure?
3. How much flow comes out of the cap end of the cylinder when the cylinder retracts? Is it possible for this flow to be greater than the maximum pump flow? Why?
4. How does the supply pressure change when the cylinder extends? Retracts? Is there any indication that the relief valve is opening during extension or retraction?

Part 2: Metering-Out Circuit

Introduction
When using a hydraulic cylinder to lower a heavy load, a metering-out circuit is required. In this type of circuit, a restriction is placed on the outflow of the cylinder to control the flow rate, and hence, the velocity of the load. Check valves are used to ensure unrestricted flow in the opposite direction. A metering-out circuit is used whenever the load wants to accelerate in the direction of the motion of the cylinder.

Components
1. Motor and Pump
2. Relief valve
3. Flow meter and pressure gage
4. Solenoid-operated directional control valve
5. Flow control valve with built-in check valve
6. Horizontal hydraulic cylinder (1.5 inch diameter bore, 1.0 inch diameter rod)
7. Loose components: hoses
Procedure

a) Complete steps 1-3 of the *Procedure for Connecting a Hydraulic Circuit*, setting the relief valve to **100 PSI**.

b) Complete steps 4-8 of the *Procedure for Connecting a Hydraulic Circuit*:

- Connect a hose from a *second pressure port* on the supply/return manifold to the “P” port on the *solenoid-operated directional control valve*.
- Connect the “A” port of the directional control valve to the *cap end* of the horizontal cylinder.
- Place a *tee on the rod end of the cylinder*. Connect a hose from this tee to the *inlet* of one of the *flow control valves* that has a *check-valve bypass*. From the other branch of the tee, connect a hose to one of the *pressure gages*.
- Connect the *outlet* of the *flow control valve* to the “B” port of the directional control valve.
- Connect the “T” port of the directional control valve to the *inlet of the flow meter*.
- Connect the *outlet* of the *flow meter* to a *return port* on the supply/return manifold.

c) After the instructor has inspected your circuit, complete steps 9-10 of the *Procedure for Connecting a Hydraulic Circuit*. Adjust the flow control valve to provide **3 LPM** flow rate at **100 PSI**. Using this setting for the flow control valve, complete the table below.

d) Follow the *Shutdown Procedure*. After opening the vent valve, *sequence the directional control valve* from left to right to relieve any built up pressure.

<table>
<thead>
<tr>
<th>Supply Pressure (PSI)</th>
<th>Flow Rate Extension (GPM/LPM)</th>
<th>Flow Rate Retraction (GPM/LPM)</th>
<th>Extension: Max Cylinder Pressure/ Supply Pressure Change (PSI)</th>
<th>Retraction: Max Cylinder Pressure/ Supply Pressure Change (PSI)</th>
<th>Time to Extend (sec)</th>
<th>Time to Retract (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>0.8 / 3</td>
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<td>150</td>
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Questions
1. How do your rates of cylinder extension and retraction compare with those you found in Part 1? How can you explain the differences?
2. Is your measured flow rate on extension consistent with your times to extend? How might you explain any differences in these values?
3. Based on your timing data, what are your estimated flow rates during retraction?
4. How do you explain your timing results at various pressures?
5. Is this system ever flow limited? Is it ever pressure limited?
6. What is the maximum pressure on the rod end of the cylinder during extension? How does this pressure compare with the supply pressure?
7. What is the maximum possible pressure on the rod end of the cylinder assuming the flow restrictor is completely closed and the relief valve is set to 300PSI?