Chapter 1 Overview of hydraulics and objective of the notes

1.1 Introduction

In these notes, we shall not be using a lot of detailed written text or explanations except where we feel it is absolutely necessary. We shall, in many cases, present equations without proof as the derivations are done in great detail in the cited references.

1.2 Advantages and disadvantages

Hydraulic systems have many well defined advantages over their mechanical or electrical counterparts.

- They have a very good power to weight ratio; that is they can deliver a significant power to a load with a relatively small mass. This makes them very appealing for aircraft applications where weight is all important.
- The components are self lubricating which helps assist in prolonging the life of the components (for a clean fluid that is) and for smooth positioning applications.
- The movement of the fluid helps to draw away heat from “hot spots”.
- The systems can operate in a very wide range of operating environments such as those found in extreme temperature variations (performance can degrade though).
- Sudden starts, stops and especially, reversal of motion can readily be accommodated by hydraulic systems
- Hydraulic systems can readily be interfaced with electronic or microprocessor based controllers.

However, hydraulic systems suck when it comes to efficiency. They are most certainly less efficient than both mechanical and electrical transmission systems. Overall efficiencies in the order of 60-70% are not uncommon in individual components and this efficiency can be cut in half depending on the type of circuit they are used in. Inefficiencies can lead to higher temperature systems that can have a negative effect on the surroundings. Thus, it is important to know what is happening in any circuit that you design and this efficiency situation was one of the motivations for the approach to design introduced in these notes.

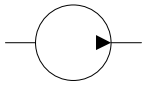
It is interesting to note that in the past, hydraulic components and circuits have been “king” in large power, off highway type of applications; however, recent advances in electrical high power systems have certainly changed this royal position of hydraulics. It is essential that hydraulic researchers continue to examine how to improve component and circuit efficiencies using all type of approaches from individual component design to integration of servo-based systems with electronics (beat them at their own game with their own equipment approach).

1.3 Layout of a Simple Hydraulic Circuit and Components (Introduction to some important components)

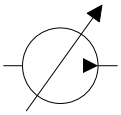
What we want to show in this next section is a circuit of typical components. No details of the components will be given here; it is just an objective to provide an overview of a very basic hydraulic circuit, what components are in them and why they are there.

The first thing you need is a device to "pump" fluid to the system. Obviously this is called a pump and it can be a "fixed displacement" (constant flow output) or a "variable displacement" type (where you can change the output flow). Hydraulic symbols for these components are shown below.

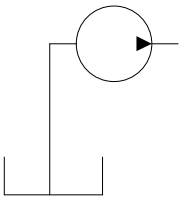
Fixed displacement pump



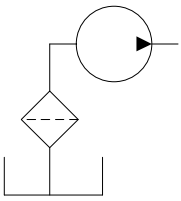
Variable displacement pump



Now, we have the pumps sucking air. This is all right if you want a "pneumatic" system that uses air, but we are interested in hydraulics that use fluids. Air is a no-no for hydraulics!!! So let's add a reservoir to the inlet of the fixed displacement pump (note the symbol).



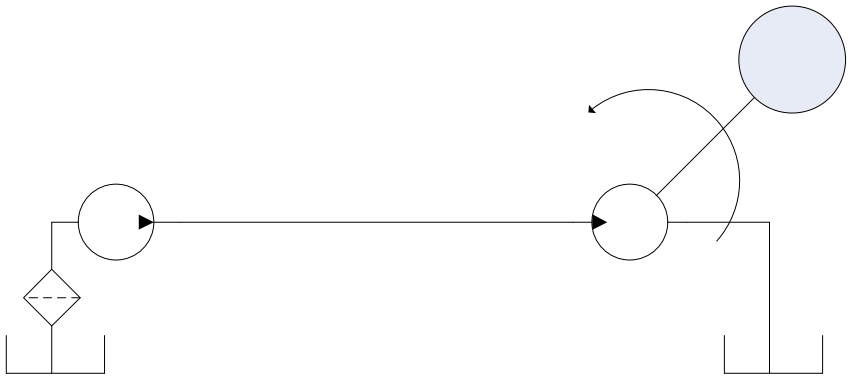
We don't want dirty fluid going through the pump, so let's add a filter between the pump and inlet to prevent wear particles and wrenches (yes I did say wrenches!!! But that's another story) from getting into the pump.



Hydraulic systems drive a load whether it is a rotary system (motor) or a linear system (actuator or ram). Let us use a hydraulic motor in this example. Note that the motor symbol is the same as the pump symbol, except that the arrow is at the inlet. Connect the pump to the motor with a hydraulic hose of some form.

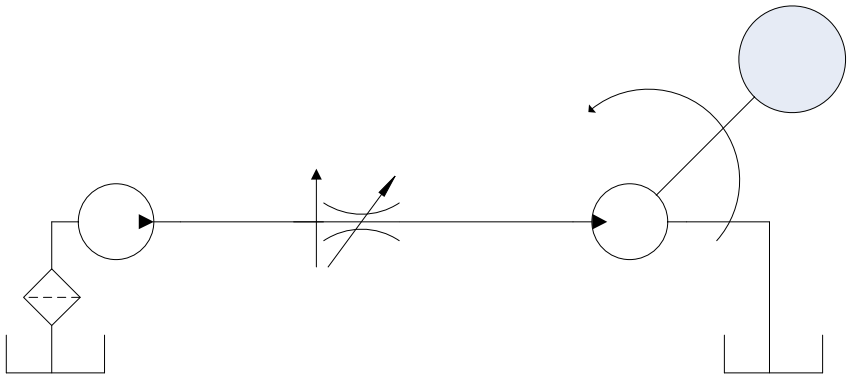
This is not a great idea because you forgot to take the fluid that passes through the motor and sent it somewhere. Right now it is spilling on the floor and you have a mess to clean up. Let us send the exiting fluid from the motor back to the reservoir to recirculate it and cool it down.

Hey, we need a load on the motor so let's add one.



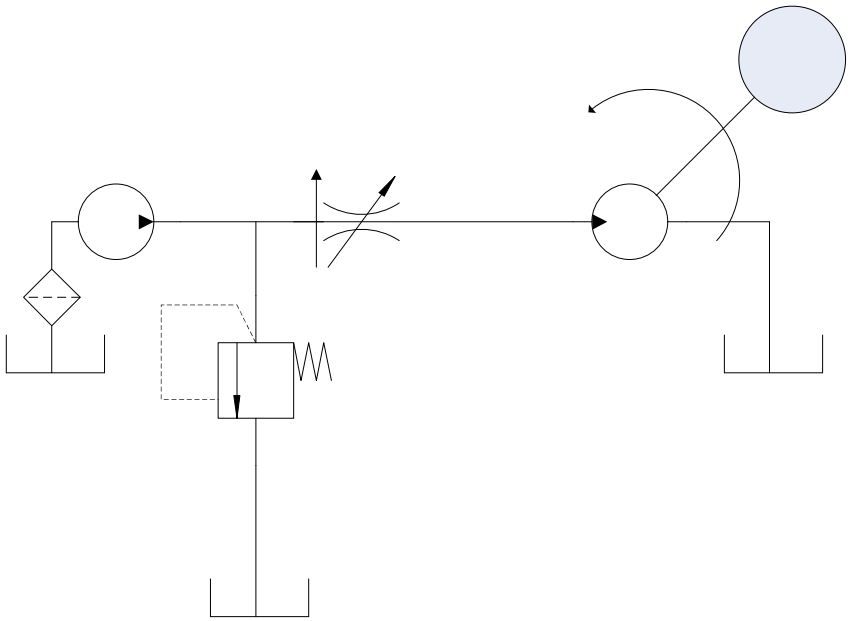
We have shown a simple inertial load that applies some external torque.

Quite frankly, this is a boring circuit, so let's change the flow rate. If you go back to the beginning of this section, we could have used a variable displacement pump to change the flow rate. But in our example, we can use a flow control valve which is a special valve used to control (or vary) flow:

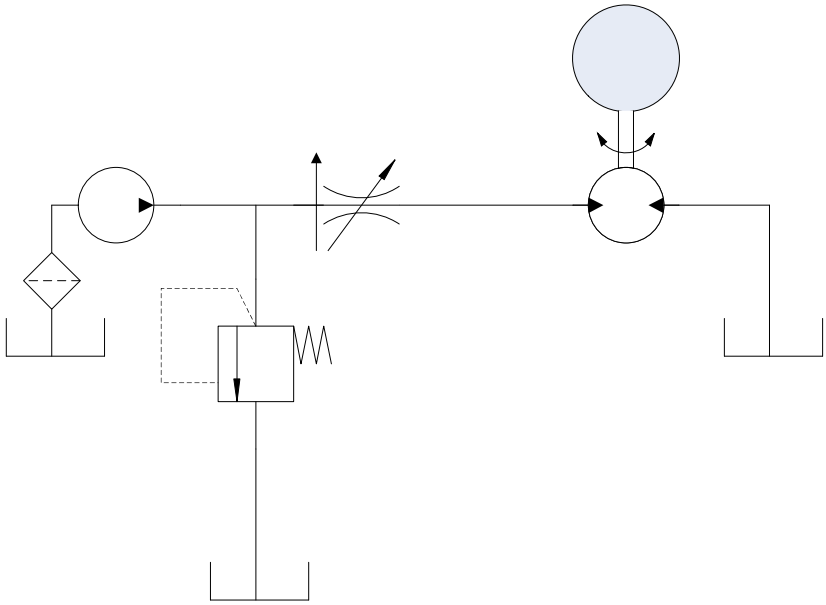


Note the two arrows on this valve symbol; the vertical arrow is an indication that the valve is pressure compensated; that is, the flow rate will not change with changes in pressure upstream or down stream, and the slanted arrow states that the valve flow rate can be varied by some means.

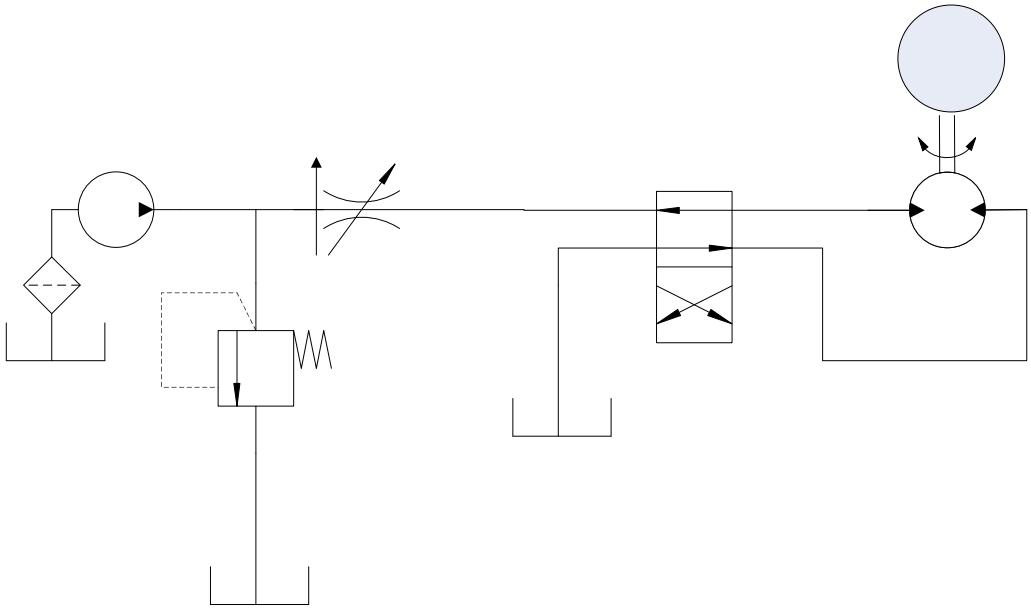
But we have a big problem. The pump is fixed displacement which means that it outputs a fixed amount of flow. But if we set the flow rate through the valve to be less than the pump output, then we are in big doo-doo!!! Where does the excess flow go? Well, it cannot go anywhere and as a result, the pressure in the line builds up rapidly until the pump torques out (stalls), the pump seals blow, or the line blows (in which case you have another oil spill to clean up on the floor). So we have to put in some kind of pressure limiting device in the line that will bypass the excess flow between the pump and that of the flow control valve. This is called a relief valve.



Let us do a few more things to this circuit before we finish. It would be nice to make the hydraulic motor and load reversible. So we can put in a reversible motor as indicated below. Note the addition of the second arrow head on the motor symbol. I have also changed the load symbol to be comparable with the symbol software I am using.



But we still cannot change directions. We need to add a valve that will allow us to reverse the flow to the motor. This is called a directional control valve and one such valve is shown as follows (we will discuss how the valve and symbol work later).



Thus we have now created a hydraulic circuit that can drive a rotary load in either direction and its speed can also be changed. This is a typical type of an application that a hydraulic circuit can be designed for. However, this will be the last time we design from the pump to the motor. The philosophy of circuit design is based on Russ Henke's approach (Henke, 1996) and which will be expanded upon in these notes. Russ has stressed the importance of defining the load profile (the job to be done) first and then used good design practices to configure the circuit. Thus we will always consider the job to be done first and then work backwards from the motor (actuator) to the pump. We will also spend considerable time doing some very simple circuit analysis (easy for me to say). If you can model the basic circuit and understand why the pressure and flow do what they do in the system, then you will able to understand how to trouble shoot for problems should they arise.

Onward!!

Exercise #1 (Objective: to assist you in becoming familiar with verbal descriptors and using component schematics to describe a circuit)

Using the symbols shown above, draw a schematic of the following circuit. One pump is to provide flow to two rotary load circuits. The system pressure is limited by a relief valve at the pump. The first circuit has a flow control valve to change the flow rate to a hydraulic motor which is driving an inertial load. The motor is uni-directional. The second load does not have a flow control valve in it, but it is driving a bidirectional motor (simple resistive load) and hence the flow must be able to be reversed.

References:

R.W. Henke, 1983. Fluid Power Systems and Circuits, Edited by T Goldoftas, Hydraulics and Pneumatics Magazine, publishers.