



SELECTING FIXED OR VARIABLE PUMP FLOW IN AN OPEN CIRCUIT SYSTEM

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Introduction

The heart of a hydraulic system is the pump. Selecting the heart of a hydraulic system requires a number of important decisions. Where will the pump be mounted, what hydraulic loads should it supply, should it be fixed or variable flow, what technology is most appropriate? All of these choices are critical to the performance of the machine, but none more fundamental than selecting a fixed or variable flow pump. This paper outlines the impact of this choice on the performance of the machine. Specifically, fuel consumption, hydraulic heat load, and the amount of usable power available on the machine are impacted.

Open Circuit Hydraulic Systems: Open Center and Closed Center

Open center valves are used with fixed pump flow systems and have an “open path” for the excess flow to return back to the reservoir via the directional control valve(s). In a variable pump flow system, this path is typically closed. The valve(s) used with a variable pump flow system are closed center, and allow the pump to output only the required amount of flow to do work (no “open path” to the reservoir). The excess return flow in an open center system creates wasted power (called “slip losses”). The “major losses” within an open circuit system include “slip losses” and are shown in Figure 1 and Figure 2, and also Step 1 to Step 4. “Minor losses” are ignored in the diagrams, and are detailed at the end of this article.

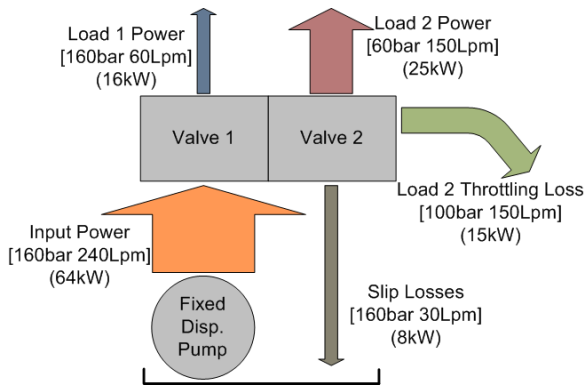


Figure 1. Open Center System

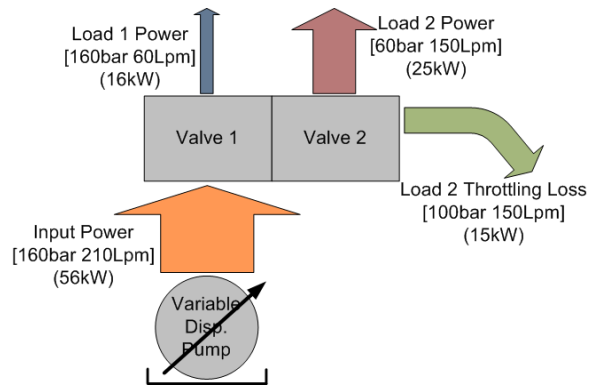


Figure 2. Closed Center System

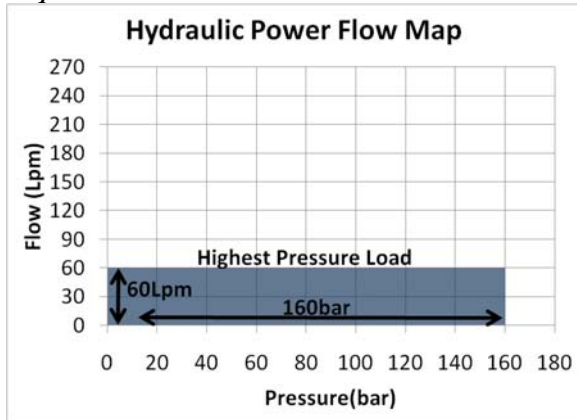
Figure 1 shows an example of the power flow within an open center system. The loads are requiring 60Lpm (Load 1) and 150Lpm (Load 2) while the pump is supplying 240Lpm. This means that 30Lpm of pump flow is unused and is creating slip losses within the system. Another source of loss within the system is based on the difference in load pressures; we’ll call these “throttling losses”. These losses are created inside the valve while supplying oil to the lower pressure load. In this case, “throttling losses” inside the valve are 15kW ($160\text{bar} - 60\text{bar} = 100\text{bar} : 100\text{bar} * 150\text{Lpm} = 15\text{kW}$). The total losses in the system are 15kW (throttling losses) + 8kW (slip losses) = 23kW.

Figure 2 shows the very same power flow, with two exceptions. First, the slip losses are non-existent because the pump flow exactly matches that required by the combination of individual load flow rates. This reduction in loss creates the second difference in the two systems. That is, the hydraulic power input to the closed center system is reduced by 8kw from 64kW (Open Center System) to 56kW (Closed Center System). These numbers represent just one operating scenario, but the process for identifying the losses within a system remains the same independent of the number of loads supplied by one pump, and the operating conditions of those loads.

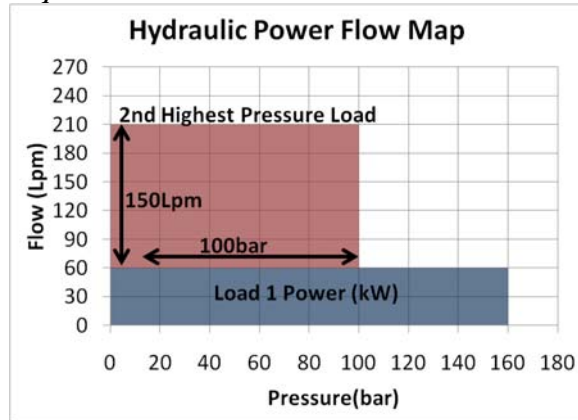


Hydraulic System Power Flow Plot

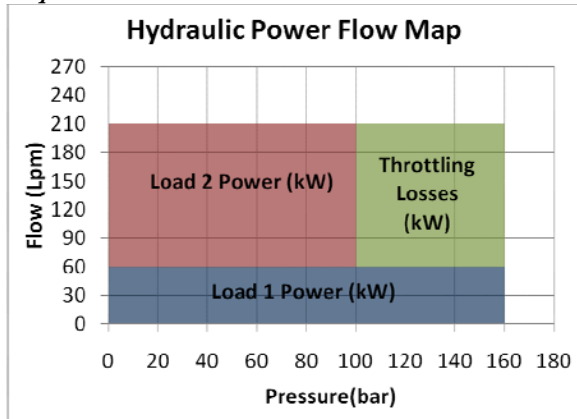
Step 1.



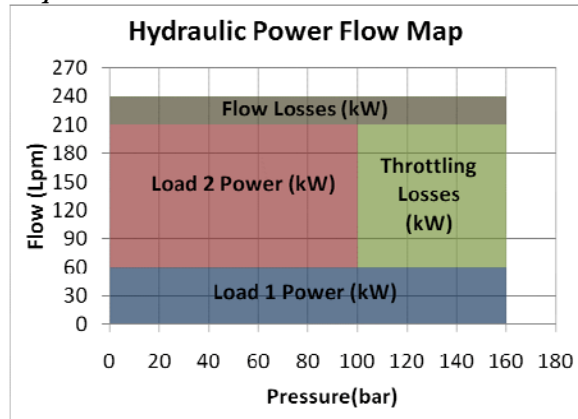
Step 2.



Step 3.



Step 4.



Another way to display power flow is shown in Step 1 through Step 4. Utilizing the scale in Step 1 to Step 4, each shaded box represents 1kW. This power flow map can be constructed as follows:

- **Step 1** – Draw a box representing the operating point of the highest pressure load within the system.
- **Step 2** – “Stack” the next highest pressure load on top of the previous load. New maximum flow rate will be cumulative, but pressure will not be. Repeat Step 2 for all remaining loads.
- **Step 3** – Using the highest flow (sum of all individual load flow rates) and the highest pressure (maximum single load pressure) as boundaries, fill in the remaining area within this envelope. This area represents throttling losses within a Closed Center or an Open Center system. Throttling losses will be equal.
- **Step 4** – If using an open center system, create another box that extends the total box up to the flow rate available from the pump. This box will extend rightward to the highest load pressure. This represents the slip losses, and is the extra power consumed by an open center system relative to a closed center system. Note that if all flow is being applied to provide useful work, this power is zero.

Conclusion

An understanding of machine operating conditions must play a critical role in selecting the heart of a hydraulic system, the pump. A closed center system has the advantage of being able to eliminate slip losses, but at a higher hydraulic system cost. The end user must value the benefits (fuel savings, additional power available for productive work, and a smaller hydraulic heat load) enough to pay the increased initial cost created by a closed center hydraulic system. This choice is the key to overall machine performance, so choose wisely.



Additional Information and Resources

Fuel Savings Quick Guide:

1kW of power savings for 1000 operating hours per year give a fuel savings of 65 gal/year (245 L./year)

With a fuel price of \$2.75 per gallon, 65 gallons per year is \$180 per year **making each 1kW of savings equal to \$180 per year in fuel savings.**

With a fuel price of 1.2€ per liter, 245 liters per year is 294€ per year **making each 1kW of savings equal to 294€ per year in fuel savings.**

NOTE: “Minor Losses” are not considered within this article. Minor losses would include:

- Pump inefficiencies (assumed to be equal – this depends on pump technology)
- Pressure drops in hoses and fittings (higher with open center system)
- Load sense pressure/margin pressure losses (higher with closed center system)
- Pressure drop through the valve to the load (assumed equal between systems)

In total, an open center system will have similar “minor losses” to a closed center system.

Open-Circuit Efficiency Comparison Tool:

Our Open Circuit Efficiency Comparison Tool provides a quick and simple way to compare different open circuit system configurations and the resulting efficiency, power consumption, and fuel usage. This tool calculates peak and average operating conditions over a duty cycle, with inputs supplied by the customer. Contact a Sauer-Danfoss representative to learn more.

