Design Considerations for a More Efficient Power Unit Circuit

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So you’ve determined the power requirement for your next generation series machine and you’re ready to size the cooling circuit for optimum energy efficiency. We all know the general rule of thumb: take the product of your pump flow and your operating pressure then divide by 1714. Then, divide by 0.9 to account for the efficiency of the electric motor. Now, you assume a 1/3 installed horse power removal for cooling and you are good to go, right? Well, maybe. But, did you consider the full extent of your cooling needs? If the operation cycle has extended lulls, then this is likely sufficient. But, what if you are running a constant repetitive cycle?

Heat loads can vary due to small loads such as the excessive warm ambient temperatures on piping and the reservoir. More dramatically, the heat loads of servo systems may double the aforementioned rule of thumb from 1/3 to 2/3 of the installed system horse power. Even while an ideally sized cooling circuit can adequately cool the new machine, are you sure that all conditions will remain constant years down the road? Heat exchanger fouling factors, component retrofits, cycle time changes, variations in water temperature or ambient air temperature swings will all contribute to a skewed range of the original design. Even the individual component degradation of the pump, motors and valves will lead to compounding effects for greater cooling requirements. So what steps can be taken to avoid problems of mis-sizing your main drive unit and heat exchanger circuit? With the right mixture of component selection for the hydraulic unit, much of the heat load removal taxing the heat exchanger can be reduced through more efficient components, circuit configuration and operating modes. Here are 5 quick pointers for a more efficient hydraulic power unit performance:

1. **Don’t oversize the electric motor:**

   Over the past decade, motor manufacturers have standardized on premium efficient motors. Depending on the motor size, this premium efficient design upgrade generally adds about 5% efficiency improvement when compared to its standard efficient predecessor. This represents a significant energy savings over the course of a year. Yet, conservative designers may choose to over size the motor in favor of superfluous safety margins. Ironically, the power generation market tends to be the biggest culprit of this practice. In some cases, we’ve seen motors sized by as much as 20% over the maximum power requirement of the machine cycle. An unloaded motor will still draw about one third the nameplate full-load current. This means that during cycle dwell times, that you could be wasting twice the energy savings gained with the efficiency improvements of the NEMA Premium Efficiency standards.

2. **Select a variable displacement pump in lieu of fixed displacement:**

   Most hydraulic design articles on energy efficiency describe a fixed- displacement gear pump blowing over a direct operated relief valve as the benchmark for
comparison. While seldom put into practice these days, this circuit is analogous to having a variable displacement pump with a compensator set at a value too similar to that of the system relief valve.

With the relief valve set just over its cracking pressure set point, it performs inadvertently as a very effective hydraulic heater. This oversight may go undetected because if the system pressure is only slightly above the relief valve’s cracking pressure, only a marginal flow passes over the valve. The actuators will not display any velocity reduction and the pump does not reach the compensator setting until the system is in a “dead head” status of operation. If the hydraulic system has a cooling circuit designed to remove 1/3 of the installed horsepower, you may be masking this inefficiency by simply running the cooling loop continuously.

For optimized efficiency in high pressure circuits, make sure that the system relief valve has the cracking pressure set at least 200 psi above the pump compensator, or 10% higher than the pump compensator setting, whichever is higher. For lower pressure circuits such as kidney loops, check valves should be used for the bypass safety instead of low pressure relief valves. The will avoid this issue, and also benefit in reduced set-up time and cost of material.

3. **Optimize the pump controller for your application:**

Over the years, variable displacement pumps have diversified their controller options to better match particular modes of operation. These options range from the general pressure controller to the most efficient electronic controllers which closely match the load and speed requirements of the machine cycle.

a. **Constant Pressure Control** (Rexroth’s DR controller) is for pressure regulation. The pump compensator is set so that the pump’s swash plate angle is destroked to 0 degree displacement once the working pressure reaches the regulating pressure setting. The pump supplies the flow necessary to maintain the pressure setting with a small amount of flow lost to pump leakage for lubrication and cooling.

b. **Load sensing** (Rexroth’s DFR controller) is of similar design to the DR controller, but also includes a flow control regulator along with an orifice for a pressure and flow arrangement that will match the speed requirements of the system.

c. **Horse Power Control** (Rexroth’s DFLR controller) further optimizes energy efficiency for applications such as presses or excavators where high flow, low pressure traversing ends with low flow and high pressure transitions. The flow and pressure profile always follows a constant horsepower curve.

d. **Integrated Electronics Control** (Rexroth’s DFEE controller) is the top end for achieving optimum energy efficiency with variable displacement axial piston pumps. A closed loop feedback command utilizes a proportional valve and onboard electronics to swivel the pump’s swash plate angle for optimum following error and the most accurate response to match the machine cycle needs. This solution offers easy control of speed, pressure and power control.
4. Use a rear mount heat exchanger for cooling the leakage line:

All of the previous pump controllers have one common inescapable consequence of physics. In order to lubricate and cool the pumps’ internals, a portion of the pump’s flow efficiency is sacrificed as leakage. This small flow will frequently be the highest temperature fluid source in your whole circuit. Many people tend to overlook this heat source. A preliminary assumption would be that when the system is dead headed, that there is no heat generation. It is tempting to believe that, with no flow to actuators, there should be no pressure drop loss over valves and thus no need to cool through a return line heat exchanger. However, it generally takes less than a couple of hours of idle operation to discover that the high temperature switch in the system has tripped.

This problem can be avoided with a separate filter kidney loop. But, adding either a piggy back pump or a separate motor pump group will increase the energy for cooling by a few horsepower. As an alternative, consider taking advantage of a rear-mount heat exchanger. This unit is a small air-oil cooler that mounts to the back of the main electric motor. It is designed for only small flows of 1 to 2 gpm. And, the air generated by the electric motor fan of the electric motor is enough to cool the leakage line of a variable displacement pump and thus prevent over heating during long deadhead operations. As a result, you have “cool” solution with no additional power draw from an auxiliary pump.

5. Don’t set the thermostat too cold:

All hydraulic fluids will have a temperature range that is ideal for operation. The viscosity grade of a fluid will determine where this temperature range should be maintained for your system cooling parameters. Too often, operators assume that the lower the temperature of fluid, the better. But if you have filled your system with a high quality VG 68 fluid and have the thermostat set at 100 degrees F, you miss the most efficient range of your cooling loop.

For example, let’s assume we have a separate filter cooler circuit with a water-oil heat exchanger with 80 degree cooling water maintaining a 100 degree reservoir temperature. In this case, our approach temperature is a mere 20 degrees. The electric motor and pump will therefore operate three times as long as a conditioning system set to maintain a reservoir temperature of 140 degrees F. This will lead to three times the electric energy usage and three times the cooling water.

By utilizing these design guidelines, it is possible to optimize not only the main system drive power efficiency, but you also your cooling circuit efficiency to perform at its peak levels. So is this the best we can hope for in fluid power efficiency? Is there nothing more we can do to approach an ideal system where we may seem to ask the laws of physics to look the other way during certain modes of operation? Unfortunately, any power input in excess of the work output, inevitably must be addressed by adequate heat
removal process. While we can’t design a perfectly efficient system, there are three application areas that are taking energy efficiencies in fluid power to a new level.

**Rexroth’s Hydraulic Regenerative Braking (HRB)** has been a recent development to establish energy savings on refuse service trucks for New York City. The frequent stop and go transportation of the vehicle is assisted by a hydraulic circuit which converts kinetic energy into potential energy and allows for an approximate 20% energy savings. When the truck is braking, a hydraulic motor turns backwards to act as a pump storing hydraulic fluid as potential energy in an accumulator bank. When the truck starts to accelerate, the motor operates in the forward direction and utilizes the accumulator volume for this power assistance with the engine.

**Rexroth’s Rotary Active Heave System (RAHC)** operates on a similar energy recycling concept. This application is most widely applied on large winch or crane functions on heavy lift rigs for the offshore market. As applications continue to expand into deeper waters, more submersible structures are required which must be positioned on the ocean floor. This is accomplished while compensating for the wave heave motions of the craft on the water’s surface. This constant pay-in, pay-out cycle is a high energy consumer. The winch pulls in the line on the ships decent from the crest of the wave to the trough to keep the load in a uniform motion. This step is followed by large energy dissipation from the subsequent braking function to govern the pay-out speed and acceleration when ascending to the subsequent wave crest. Without implementing a regenerative control circuit, the total energy input requirements and cooling requirements would be massive. Through our secondary control motor circuit and controls, we are able to reduce the input power requirements by up to 65%. Similarly, the cooling circuit is also 65% of the size that would be required on system without secondary control.

**Rexroth’s Variable Frequency Pump Drive (VSP)** focuses on a different concept of energy savings. Instead of recycling energy that is preserved from earlier deceleration motions, the VSP technology is centered around supplying pump flow to machine cycles on an “as needed” basis. Here the electric drive speed is operated via a closed loop PID circuit to adjust the pump speed to match the machine’s flow and pressure requirements. Rexroth refers to this innovative class of products as its Sytronix Variable Speed Pump Drives and its technology incorporates several combinations of frequency converters, electric drives and pump configurations to meet system demands without the energy wastes indicative of constant speed pump/motor drive systems.

For more information on these products, please visit [www.boschrexroth.com](http://www.boschrexroth.com).