

# Tips for Extending the Life of a Hydraulic System

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## Introduction

Over the past couple of decades while working in the fluid power industry, I have encountered all kinds of fluid power systems, some better than others. Through my experience I have accumulated a wealth of knowledge in how to get the most out of a hydraulic system, any system. In addition, I have seen those who perform good maintenance and those that take the attitude of; "if it isn't broke, don't fix it". From my experience I have come up with some common tips for getting the most out of a hydraulic system and how to extend its operating life. However before getting into that let's look at some basics about hydraulics.

The first thing that the reader must understand is the reason why the equipment manufacturer decided to use hydraulics in the first place, since there are a number of options open in power design. The knowledge and principles of hydraulics have been around for many millennia, beginning with Archimedes. But it wasn't until the middle of the 19<sup>th</sup> century that fluids were used in directed power transference and transmission. Before the practical use of electricity became available there were only two means to transfer power; 1) mechanical linkage and 2) fluid power. One only has to think about the water powered mill to get the general idea of power generation and transmission. However, with the invention of steam engines power generation took on a whole new meaning. No longer was the power generator tied to a fixed location that had to have an abundance of water. Also, to better utilize the new power generation equipment a more efficient means of power transmission developed. Where transmission over long distances and power density was needed hydraulics provided the answer. At first the only hydraulic fluid available was water. Although water works well as a power transmitter, the nature of water placed limitations on how hydraulic systems could function. Water is a natural corrosive and causes erosion. In addition, water because of its low viscosity easily cavitates. Although water is a good transmitter of power it is difficult to use and get any decent lifetime out of the hydraulic system. In addition, water freezes at a rather high temperature and boils off when subjected to high heat. This problem persisted until the introduction of petroleum based oils, which were cheap and plentiful.

Oil is almost as good as water in the ability to transfer power and it is a great deal friendlier to equipment. The introduction of oil allowed equipment designers to start to design systems that could take full advantage of the potential of hydraulics. One significant advantage of hydraulics and hydraulic actuators, in particular, is the power density of hydraulics. In other words, you can pack a lot more power into a small package. This makes hydraulics an ideal solution for a large number of applications, especially mobile applications. Since

hydraulic systems are self contained they could be used in a wider number of environments. Oil hydraulics also has a wider range of operating conditions and could be used in cold and hot environments. However, oil also has its limitations. Oil is a pollutant; it burns easily and naturally oxidizes with time and temperature. To overcome the problems with petroleum based oils manufacturers began blending additives into the oils to offset some of the less desirable characteristics and also to get fluids that performed better over a wider range of applications. The one disadvantage of oil that the blenders have not been able to overcome with any degree of success is oil's negative environmental impact. In efforts to take advantage of hydraulics desirable characteristics fluid blenders have for over 85 years been blending other fluids in an attempt to find the most desirable fluid for a variety of applications. The current status of hydraulic fluid is that there are a number of alternatives now available. The blending of fluids has reached the level of sophistication that now fluids can be custom blended for specific characteristics and specific applications. Mineral based hydraulic oils still dominate the market, especially in mobile equipment; but even that is beginning to change with the new emphasis on developing environmentally friendly hydraulic fluids. Even pure water has made resurgence for certain environmentally sensitive applications. In any case there is a specific reason why your equipment manufacturer has decided on hydraulics as the best solution for power transmission.

There are many considerations that any equipment designer must take into account when designing equipment. The most important consideration is the work to be accomplished, and what design will best facilitate the task. This includes the history of the particular design and what additional features that the designer wants to incorporate. The designer must also consider what power source is to be employed and how power is to get from the power source to the work to be done. Machine and process control is always an important feature of design. Ease of operation, maintenance and expected machine lifetimes are also considerations. Safety is always an important consideration and now designers must consider the environmental impact of the machine. So, your piece of equipment is a result of a process of choices and in this case the OEM has decided that hydraulics is the best solution. Now let's take a look at what can be done to gain the best operation and lifetime out of your capital investment.

## Tips

### **Tip #1: Select the right hydraulic fluid for the job.**

It is true that synthetic hydraulic fluids can provide an extended lifetime for a number of applications. Just as in cars; synthetic oils, when properly maintained, will provide better lubrication, thus leading to less wear on the engine parts. This is also true in the case of most fluid power systems. Not only does the fluid function as a power transmitter but it also functions as a lubricant to the many moving parts in the system. Typical wear occurs between mating surfaces such as bearings, vanes, pistons and gears. By providing a better lubrication film those surfaces just

wear less. Pumps, motors, cylinders and valves all have moving parts that must be lubricated. Those system components are the ones that usually wear out and need replacement. By providing better lubrication, they just last longer. However, hydraulic components are not designed around the use of synthetic fluids.

Most equipment, unless otherwise stated is designed around standard mineral based hydraulic oil. The operation parameters of the machine are designed to utilize the characteristics of mineral based hydraulic oil; including pressure, flow, fire resistance, operating temperatures, controllability and a number of other characteristics. However, just because the machine is designed around mineral based hydraulic fluid doesn't mean that you can't enhance the equipment's lifetime expectancy, the operating efficiency and safety by utilizing an alternative synthetic hydraulic fluid. Generally speaking, properly applied and maintained synthetic hydraulic fluids will extend the operating lifetime of the equipment.

There are a number of criteria that must be considered before finalizing your fluid selection.

1. What kind of lifetime are you expecting from your equipment? Standard hydraulic pumps and motors are designed to operate, on average, between 8,000 to 10,000 hours. Cylinders and valves will last millions of operations. As pumps and motors wear they begin to lose efficiency, while cylinders will typically begin to develop internal leakage around the piston and will not move or hold the load, and valves either begin to leak internally or just quit operating. The design goal is to maintain the highest level of efficiency over the longest period of time. Therefore; pumps, motors, cylinders, and valves are all expensive components and extending their respective lifetimes will provide the best economy.
2. Where is the equipment to be used? Is it a particularly environmentally sensitive area? Does it need to be food grade? Is fire resistance an important need? Are operating temperatures an important consideration? Is it to be operated in a wet or dry environment? Is the operating environment clean or dirty? The better you can determine the exact operating environment and conditions the easier it is to make the right choice in fluid the first time.
3. How will the equipment be maintained? Will the equipment be maintained on a Planned Preventative Maintenance program or will it be repaired as needed? Proper maintenance is the secret to extending equipment lifetimes. This includes keeping the fluids clean and balanced.
4. Who will maintain the equipment? Will the equipment be maintained by experienced professionals or will it be maintained by general maintenance personnel? Not everyone can afford the on site fluid power professional. However, that does not mean that general maintenance personnel can't do good maintenance. They

generally need some specific training. A good fluid supplier can help with fluid maintenance training. It is in his best interest to make sure the fluid performs as expected.

5. How much are you willing to invest to get the most out of your equipment? Typically synthetic hydraulic fluids are more expensive than standard mineral oil base fluids. However, the extended lifetime gained through properly maintained synthetics, higher safety, and, in some cases, better environmental impact characteristics; makes it worth it over the entire lifetime of the equipment.

By considering these questions it sets the limits of your fluid selection. A good resource is always the Original Equipment Manufacturer (OEM) to check on their fluid standards for synthetic fluids. Another good resource is the fluid manufacturer. By utilizing these two resources it can prevent costly mistakes.

Before selecting a fluid always discuss your particular application needs with the supplier. In general, the more information that you can provide the better the recommendations he can make for fluid selection. Whatever the recommended hydraulic fluid is, ask about operating experience in similar applications. Ask for contact information of other users to verify their experience with this particular fluid. It is probably wise to not be the "first guy on the block" to try something new that doesn't have an established track record. Finally, if it sounds too good to be true, it probably is.

**Tip #2: Keep it clean.**

There is a saying that has been around forever which states: "cleanliness is next to godliness". This holds true for hydraulic systems as well. A hydraulic system that runs on clean fluid just lasts longer. Dirty fluid is the single largest contributor to wear and premature failure. The OEM has built into the system a series of filters and devices to prevent damage to the components. This may include suction strainers, high pressure filters and return filters. In addition, in the equipment Operating and Maintenance Manual will be the requirements that the OEM expects to be performed in order to prevent premature wear. This normally includes information on filters and filter maintenance. The changing of a filter is one of the simplest and least expensive things that one can do to extend the lifetime of their system. However, filters are fluid specific. Some types of filter media react with certain types of fluids and are unacceptable for use. It is best to check with the fluid supplier and filter supply as to acceptability.

The place to start is with a clean system. Just because the system is new you can't assume that it is clean. If it is filled with fluid from the OEM follow the start up procedures. After running the system for several hours change the return filters. If you are converting an existing system over to a synthetic fluid it is important to thoroughly clean the system prior to filling it with new fluid. This includes not only draining and cleaning the reservoir but also changing all of the system filters prior to refilling with the new

fluids. Fill the system with the new fluid by running it through a filter cart. Run the system for ½ an hour, shut it down and replace the return filters. Also visually check the reservoir to see if there is an accumulation of old oil. Since most of the synthetics are heavier than oil, then the oil will be seen floating on the top of the reservoir fluid. Do not agitate the fluid because it may cause it to emulsify. Then carefully skim the oil off the top. This can be done by the use of an industrial wet/dry vacuum.

Maintaining a clean system is fairly simple. It will normally require only changing the return filters when they are full of dirt.<sup>1</sup> The best way to determine when a filter needs to be changed is to install, if it is not already installed, a dirt indicator. This is usually a visual indicator that can be checked. Some systems have an electronic switch built into the filter that will signal when the filter needs to be changed. When it is indicated change the filter. Do not run the system with dirty filters, this cuts the lifetime. Also, never bypass filters when they become dirty and clogged. That is a sure prescription for disaster. If there is no dirt indicator in the filters and you don't wish to install them, then put filter changes on a time schedule. Heavy use equipment should have the filters changed more frequently whereas light use equipment must have them changed less frequently. If a system has set for some time, run it for ½ hour and then change the return filters.

Let's do a little filter 101. The best policy is to follow the OEM's filter recommendations. However, filters are classified by a number of designations. First, they come in a range of configurations and sizes. There are three basic types; strainers, self contained such as "spin on" and replaceable element, which is a filter housing that is an integral part of the system and can be accessed for element replacement. Second, they will be designated as either high or low pressure filters. High pressure filters are placed between two components in the high pressure side of the system and are always a replaceable element filter or mesh strainer. They are used to protect components from contamination. For example it is common to place a high pressure filter between the hydraulic pump and proportional or servo valves. If the pump should have a catastrophic failure, the high pressure filter would prevent the ingress of debris into the rest of the system, thus limiting the damage. Low pressure filters are used in the return side of the system and strainers are usually placed in the tank on the suction inlet of the pump. Third, the filter will be classified by filter media type such as steel mesh, paper media, fiberglass, polypropylene, etc. Paying attention to the filter media is critical to avoid placing the wrong filter into the system. Fourth, they will be rated as either Nominal or Absolute. Nominal rated filters do not filter out as many particles as do the Absolute rated filters. Fifth, the filter will have a micron rating. This is an indication of how small a particle that will be allowed to pass through the media. One important note, the higher the micron ratings means that they will pass through particles smaller than the rating. Finally, most industrial filters now have a  $\beta$  (beta) rating. This is an indication of the percentage of particles that will be filtered out. High  $\beta$  ratings indicate a high percentage of filtered particles above

the micron rating. When it comes to filters you get what you pay for. Better filters cost more but can also do a better job.

Whenever repairs that open the internal integrity of the system are made to the hydraulic system the return filters should be replaced. This also holds true for small things such as hose and fittings replacement. Return filters need to be replaced whenever the hydraulic system is drained and recharged with new fluid. As a matter of course, the return filters should be replaced twice; once when the system is refilled and then after a couple of hours operation.

#### **Tip #3: Repair leaks as they occur.**

Leakage normally occurs around connections and seals. The repair of leaks prevents the accumulation of fluid, which can provide a safety hazard for both equipment and personnel. Quickly getting on top of the leaks also prevents the loss of fluid. Leaks on the high pressure side can lead to overall reduced system efficiency. Fluid loss, if left unchecked, can lead to over heating of the system and premature wear of the components. In addition, fluid leaks are the leading cause of environmental pollution. I have read estimates that somewhere between 10 to 20 percent of all hydraulic fluid are lost through leakage. I have no way of verifying the validity of these statements, but even 10% represents tens of millions of liters every year.

#### **Tip #4: Keep it cool.**

All mechanical systems produce heat of some kind. The more efficient the system the less of the energy goes into heat and the more that goes into work. A sizable percentage of the heat comes from the friction generated just from pushing the fluid through the pipes and hoses. Additional heat producers are pumps, motors, cylinders, valves, high pressure filters, and high pressure bypasses. Poorly designed systems produce more heat than do well designed systems, and mobile systems usually run hotter than fixed site systems. In any case heat represents a serious threat to system efficiencies and lifetime.

Prolonged excessive heat increases the wear on hydraulic systems. Traditionally systems work best between 40° C to 80° C. Operating in temperatures above this range begin to break down the chemistry of the fluids. When running mineral oils the heat breaks down the molecular chains and the oils lose some of their lubricity and also deposit varnishes on the mating surfaces. Excessive heat can also cause synthetic fluids to break down but they tend to be more resistant to the high temperatures. Synthetic fluids with high water content tend to do much better in hotter environments because of the better heat transfer capability of the water. However, even with water based fluids prolonged heat can have the affect of causing some evaporation of the water, thus reducing the water content and making the fluid unbalanced chemically.

There are three primary methods for taking the heat out of a system; radiation heat exchange, air/fluid heat exchange, and fluid/fluid heat exchange. Radiation heat exchange normally uses the hydraulic reservoir as the main heat exchanger. The sides and top of the tank provide a surface

area for the heat exchange to take place. However for this to work well there must be a sufficient  $\Delta T$  between the ambient temperature and the fluid temperature. If the ambient temperature is either equal to or greater than the fluid temperature then the fluid will not be cooled. The second most common means for cooling the hydraulic system is through the use of an air/fluid heat exchanger or commonly known as a radiator. This method utilizes air movement over fluid coils to carry off the excess heat. Mobile equipment utilizes this method and attaches the cooling fan to the main power plant. Again there needs to be a sufficient  $\Delta T$  between the ambient temperature and the fluid temperature. It works more efficiently than simple radiation but it also requires a power source to drive the air fan. Of the three means of cooling the most efficient is that of fluid/fluid heat exchange. The heat exchanger is of tube and shell construction where the hydraulic fluid tubing passes through a shell filled with normally water or some other fluid and the heat is exchanged from the hydraulic fluid to the cooling fluid. This type of system is not dependent on sufficient  $\Delta T$  between the ambient temperature and the fluid temperature since the cooling fluid temperature can be controlled to provide a great enough differential.

If the hydraulic system is installed in high ambient heat environments, a heat exchanger may well be in order if the OEM has not designed one into the system. Heat exchangers are available from a number of sources including your local fluid power distributor. Good control of operating temperatures can literally add years of life to the system.

**Tip #5: Don't over or undersize your system.**

Sizing the hydraulic system to meet the work requirements is vitally important. Systems that are undersized will work the hydraulic components too hard and cut system lifetime. Key hydraulic components will have to be changed more often, creating higher maintenance costs. Over sizing the system will extend the system lifetime but whatever savings are achieved will be eaten up unnecessarily with higher energy costs. The only time that I would recommend over sizing a system is if there are plans to immediately expand. For example, many plants use a ring style hydraulic system with one large reservoir. If there are firm plans for expansion then it makes economic sense to put in a large enough reservoir to accommodate the expansion. If you are controlling the design for a custom system, then it would probably be wise to oversize it no more than 10%. The 10% will provide enough of a safety margin that as the system ages and loses efficiency the system can be adjusted to accommodate the change.

**Tip #6: Put your equipment on a preventative maintenance schedule.**

So far we have discussed using the right fluid, keeping the system clean, repairing leaks, keeping the system cool and correctly sizing the system for the work to be done. A critical element of extending the lifetime of any hydraulic system is to perform preventative maintenance. This includes monitoring system function, changing the hydraulic fluid when it is worn out, and changing filters.

To perform proper maintenance it doesn't necessarily require a fluid power specialist. General maintenance personnel can perform most of the preventative maintenance functions. This includes monitoring the system. Part of any preventative maintenance program is, on a scheduled basis, monitor and record basic system data. The most basic reading is pressure. When the machine was new a base line pressure should have been made and recorded. As pumps wear they will produce less pressure for the same amount of input energy. The pump is literally the heart of the system. It converts the electrical or mechanical energy into fluid energy and flow. In fluid power pressure = force and flow = speed. Therefore the monitoring of pressure will indicate pump wear. It is more difficult to monitor flow unless a flow meter is installed into the system. However, as motors wear they will not be able to produce the same speed at the same level of force. Also as cylinders wear they will lose speed, lifting force and holding force. Simple tests require a pressure reading and stop watch. Motor speeds and cylinder speeds can be checked this way.

Also part of the monitoring process is taking hydraulic fluid samples and sending them off for analysis. The fluid sample will tell a great deal about system health. As systems wear the worn material will appear in the fluid as contamination. Most of it will be caught in the return filters therefore the sample should be taken prior to the return filter. Besides particle contamination from wearing components, a fluid sample can tell a great deal about the fluid chemistry. It will indicate if the fluid is still capable of providing lubrication, fire resistance, oxidizing and rust resistance, biocide levels, demulsifying content, and a number of other factors. For some systems the manufacturer of the fluid will indicate lifetime expectancies. This is especially prevalent in vegetable oils used in hydraulics and food grade water glycols. These fluids typically having shorter operating lives and must be changed more often.

Water based fluids must have their water content monitored. This can be done by the use of a viscometer. This will give an accurate reading by measuring the viscosity of the fluid. The manufacturer of the fluid will provide an acceptable range for the fluid viscosity. If there is not enough water content the ph will be too high and it will not retain its fire resistance. If the water content is too high the ph will be lower and it will not provide the lubricity that is needed. Water based fluids that are out of range must be changed. Do not under any circumstance add water to a system to attempt to bring the water content back into the acceptable range.

If proper preventative maintenance is performed, then most catastrophic failures can be avoided. As the old saying goes; "an ounce of prevention is worth a pound of cure".

**Tip #7: Don't be afraid to ask for advice.**

It is prudent to utilize the resources available. They include the OEM, the fluid supplier and other equipment manufacturers. Most are happy to assist.

By asking for expert advice many of the common problems can be avoided.

By following the simple tips contained herein, one can extend the lifetime of their system and provide for continuing satisfying performance.

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<sup>1</sup> Indicators will sometimes malfunction leaving the filter clogged while it indicates it is satisfactory. Periodically check filters manually. Clogged filters will sometimes go into bypass causing dirt and other debris to get downstream of the filter.

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