BEASLEY'S

HYDRAULICS ◇ PNEUMATICS ◇ ENGINEERING

Hints on Hydraulics

Introduction

The application and understanding of Hydraulics is greatly simplified when approached with some key principles kept in mind. The most important of these is undoubtedly the C/C rule. This stands for "Keep it Clean, and Keep it Cool".

It has been proven beyond doubt that the two greatest enemies of hydraulic systems are heat and contamination. By addressing and monitoring these two key elements, system life is increased, maintenance costs are lashed, and downtime becomes a thing of the past.

It is my hope that through the fundamental principles outlined in this booklet your knowledge of hydraulics will be improved, translating to greater savings and improved returns in your business.

Regards,
Peter Beasley

Hints Menu

• Selection of components
• Checking the oil
• Installation of system
• Maintenance
• Heat generation

SELECTION OF COMPONENTS

All hydraulic systems consist in principle of the same basic components, but just as with electronics, the combinations are infinite and the range of components immense.
Which components are the most important in the system?

- is it the cylinder or the motor that is going to perform the work,
- or the liquid (oil) that transfers force to the motor or cylinder,
- or the pipes and hoses that lead oil to motor and cylinder,
- or the valves that control the oil flow paths,
- or the pump that applies energy and movement to the oil,
- or the motor that drives the pump,
- or the filter that removes the dirt from the oil,
- or the oil cooler that ensures a suitable oil temperature,
- or the tank that contains oil for the system... ?

The answer must be that specific demands are made on all these components and since none of them can be allowed to fail, they must all be equally important. Therefore extreme care must be taken in all stages of their creation, selection and application.
Let us look a little closer at an example system, starting with:

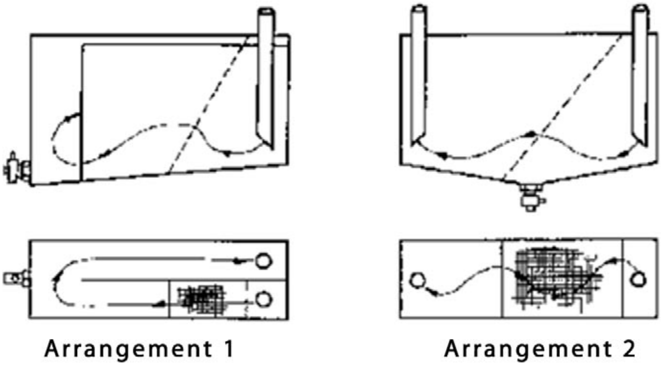
The tank

The tank, which has many functions e.g.

- as a reservoir for the system oil
- as a cooler
- as a "coarse strainer", sedimentation of impurities
- as an air and water separator
- as a foundation for pumps etc.

The dimensions of the tank and its form are important and it should be therefore be designed for its purpose, the same as all other hydraulic components. Its location must also be taken into account so that the sight glass, filters, filling, cap, air filter, drain cock, etc. are easily accessible for daily inspection. If the application is mobile, if there is no cooler built into the system, and provided the tank is located where air circulation is good, the size of the tank can be fixed at approx. 3-4 times the capacity of the pump per minute.

Two arrangements are shown below.



Arrangement 1 is preferred as this increased the cooling effect as much as possible.

To increase the ability of the tank to separate dirt and water, the bottom must be slightly inclined (deepest end opposite the inlet/outlet end). An ordinary cock (without handle) is fitted so that impurities can easily be drained off. Increased separation of the air that is always present in the oil can be obtained by fitting an inclined coarse metal strainer (approx. 25-50 mesh/inch) by the return line.

Both suction and return pipes must be cut diagonally. The ends of the pipes must be located 2-4 times the pipe diameter above the bottom of the tank, partly to avoid foaming at the return line, and partly to prevent air being drawn into the suction line, especially when the vehicle/vessel heels over to one side.

With regard to the annual "spring clean", the tank must have large removable covers, either in the sides, in the top, or in the ends, in order to give easy access for cleaning. If filters are installed, they must be located above that tank oil level and must be easy to replace without significant spillage.

This means it must be possible to place a drip tray under the filter inserts. Since tanks are made of steel plate, rust is inevitable (even below the oil level, because oil contains both water and oxygen) and it is therefore advisable to surface-treat the inside. If the tank is to be painted, thorough cleaning and degreasing is necessary before primer and topcoats are applied. The paint used must, of course, be resistant to hot hydraulic oil.

If the cooling effect from the tank and other hydraulic components is insufficient in order to keep oil temperature down to an acceptable maximum an air cooler must be fitted. Most suppliers prescribe 90°C as an absolute maximum partly because of lifetime of rubber parts partly because of alterations of tolerances and possibly bad lubrication.

Today quite often electronic devices are fitted directly onto hot hydraulic components. Inc consideration of the electronics a reduction of the maximum oil temperature to less than 80°C must be aimed at.

Filters

The degree of filtering and filter size are based on so many different criteria, that generalization is seldom possible. The most important factors to be considered are as follows:

Operational environment: How serious would the consequences be if the system failed because of dirt?

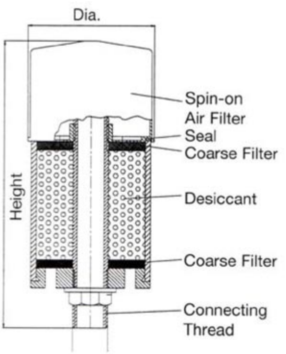
Oil quantity: Would there be a few litres or several hundred litres in the system? Is it expensive or cheap oil?

Operational stop: What would it cost per hour/day if the system came to a standstill? How important is this factor?

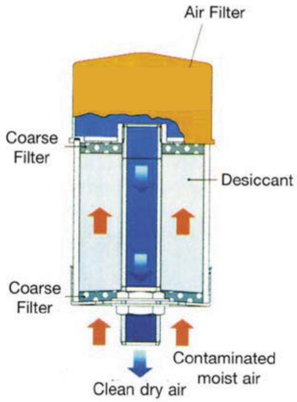
Dirt sensitivity: How dirt-sensitive are the components? What degree of filtering do the component suppliers recommend?

Filter types: Are suction filters, pressure filters or return filters to be used, or a combination of these with or without magnets? Is exclusive full-flow filtering involved, or will there also be by-pass filtering through find filters? Which type of dirt indicators are to be chosen, visual, mechanical or electrical?

Air filtration: Air must be filtered to the same degree as the finest filter in the system. Otherwise too much dirt can enter the tank with the air. If there are large differential or plunger cylinders in the system, the tank breathes in/pushes out large amounts of air. Therefore the size of the air filter must be on the large side. Remember that dirt particles visible to the naked eye (larger then 40mm) are as a rule, less dangerous than those that cannot be seen. It is often hard particles of 5-25mm, corresponding to normal hydraulic component tolerances that are most dangerous.



Operating Principle:



When air enters the Desiccant Breather, large dust particles are trapped by the coarse foam filter.
The air passes through the desiccant where the moisture is removed. The dry air then passes through the 3 micron absolute glass fibre pleated air filter element. The air then enters the reservoir fully dried and clean.

When oil is returned to the reservoir, a surplus of air is created. This air is expelled and leaves the tank through the air conditioner. The air filter gets a little back flush.

The desiccant, foam filters, and the air filter are all replaceable items to keep the unit in top p operating condition.

CHECKING THE OIL

There is evidence that more than 70% of all problems with hydraulic systems can be traced directly to the condition of the oil.

Water in the oil

Is there is water in the oil, the oil must be replaced, as this not only damages the ball and roller bearings but also causes corrosion of all steel surfaces. This especially applies to those surfaces touched by the oil, for in addition to water, oxygen is present and this promotes rust. A further danger is the reduction of the operative area of filters and the consequent increase in the abrasiveness of the oil.

Vane pump damaged by contaminants in fluid.

Oil Oxidation

Normally an oil operating temperature of 30-60°C ought to be aimed at since the life of hydraulic oil is strongly dependent on its operating temperature. The rule-of-thumb is that the useful life of oil is halved for every 8°C the temperature rises above 60°C. That is to say, at 90°C the life of the oil is only about 10% of its life at 60°C.

The reason for this is oxidation. At atmospheric pressure, all oils contain a little less than 01 litres of air per litre of oil. Therefore, in practice, oxygen is always present and it reacts with the hydrocarbons making up the oil gradually, as oxidation increases, the oil becomes darker in colour and its viscosity rises. Finally, the products of oxidation can no longer be dissolved in the oil, but instead settle everywhere in the system as a brown sticky later. This will cause sticking valves and high friction in ball bearings, valve spools and pump pistons. Oxidation also produces corrosive acids. The oxidation process begins gradually, but at a certain stages the oxidation rate suddenly rises and the viscosity rises. The resulting increase in operating temperature accelerates the oxidation process even more and soon the oil becomes quite unusable as hydraulic oil because of deposits, high viscosity and accumulated acids. It therefore pays to take care of the oil. Even without proper laboratory equipment many factors may be checked.

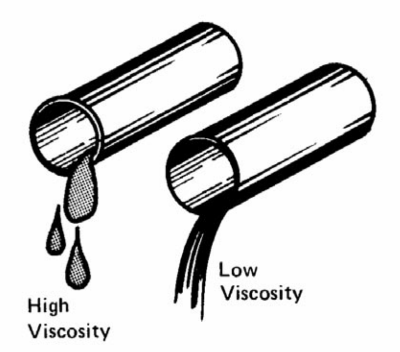
It is possible to make the following checks:

The presence of water

The presence of water can be detected as follows. Drain two of three cm2 of oil into a test tube and allow it to stand for a few minutes until any air bubbles have disappeared. Then heat up the oil, with a gas lighter, for example, and at the same time listen (at the top of the test tube) for small "explosions" in the oil. This sound comes from the creation of water vapour when the small particles in the oil are shock-boiled.

Viscosity

Viscosity can be established with sufficient accuracy using homemade equipment consisting of a small container (e.g. a can) able to hold 3-4 litres. The bottom of the can must be pushed slightly outwards and a burr-free hole of 4-5 mm drilled. Put water which has been heated to 40-50°C into the can whilst keeping a finger over the hold. Remove the finger and record in seconds how long it takes for the water to run out. Repeat the process, but this time use oil. The viscosity of the oil can be calculated in degrees Engler (E°). If the viscosity is too high or too low then the oil needs changing.



$$\text{Engler viscosity} = \frac{\text{drain time for oil}}{\text{drain time for water}} = E^{\circ}$$

The smell and the appearance

The smell and the appearance of an oil sample also reveals much about its condition, especially if its is compared with a sample of clean unused oil at the same temperature and in the same kind of glass container. By allowing two such samples to stand overnight, the bottom of the glass contained the used oil might reveal a deposit. If it does the oil in the system must be fine-filtered and the tank cleaned.

If these relatively crude tests indicate that the oil might be bad, small systems should scrap the oil. For larger systems an oil sample of approx. 1/2 – 1 litre should be sent to a laboratory for a thorough check. Remember it Is important that the bottles used for the samples are completely clean.

INSTALLATION OF SYSTEM

After the designer has made calculations and selected the correct components, a number of questions have to be considered.

Where and how are the components to be placed?

This must be in strict accordance with, amongst others, the following factors:

- suitability in relation to the work the motor or cylinder must perform
- Easily accessible for installation and inspection, and not least for repair or replacement. There is no such thing as a system that never needs to be repaired.
- Maximum heat emission is obtained by locating individual components, tanks, pipes, hoses and filters at the outer boundaries of the system. If pipes are bracketed to the machine frame or vehicle chassis, large amounts of heat will be given off.
- Noise suppression is the subject of environmental legislation and much can be achieved by installing pumps and their motors on dampers and by using hoses between all moving/vibrating components and rigid parts.

Remember to follow catalogue instructions on pipes, hoses and fittings.

Remember that pies which are welded or hot-bent must be thoroughly cleaned. Scale etc. must be cleaned by wire brushing, WAD cleaning or by pickling followed by thorough flushing and drying.

Remember that it is very advisable to read the supplier's directions and meet the requirements contained in the installation instructions which nearly always accompany components.

Remember the three most important rules to be followed when working with hydraulics are:

1. **Clean Installation**
2. **Clean Operation**
3. **Clean Inspection and Repair**

Rule 1: Clean Installation

Hoses, pipes and fittings are never clean after being worked on and must therefore always be cleaned immediately prior to installation. Pipes, including pipe bends, should preferably be cleaned with a plug of crepe paper of lint-free coth soaked in paraffin and blown through the pipe with compressed air. This process must be repeated with several plugs until a completely clean plug emerges. If pipes have been hot-bent or welded they must be cleaned by pickling in hydrochloric acid, flushed with cold water and then hot water and dried. If the pipes are not to be fitted immediately, they must be lubricated with clean hydraulic oil and plugged, otherwise they will rust. The blanking plugs fitted in all pumps, motors, valves, etc. must not be removed until just before the components are installed.

Workshops, work stations, tools and clothing must also be clean as possible. Then there is smoking! Apart from the fire risk, tobacco ash is harmful, it acts as an abrasive. Smoking should therefore be prohibited.

Rule 2: Clean Operation

Here, the main objective is to prevent the oil from becoming dirty. That is to say, filters (including air filters) must be clean - especially piston rods, shafts and shaft seals. It has been proven that on every square centimetre of piston rod area, one dirt particle of more that 10mm penetrates the cylinder. Imagine a piston rod of 50mm diameter, a length of just 100mm, and a velocity of 12m/min. This means about 20,000 particles larger than 10mm per minute! The tools used for filling must of course be perfectly clean and the oil filled in to the system must be filtered through filters of the same fineness as the finest in the system, normally 5mm, but in any event no coarser than 10mm nominal. Oil in large drums is not normally clean enough and, depending on the storage, often contains water. Therefore drums should be laid down during storage, or better still, should stand on a slant if kept outdoors that that water cannot collect around the plugs.

Rule 3: Clean Inspection and Repair

Here also it goes without saying that everything should be kept as clean as possible. Before a hydraulic component is removed, both of the component itself and the immediate surroundings must be clean.

All loose paint scale must be removed before screwed connections are dismantled and all open parts, pipes, hoses, etc. must be blanked off with, for example, plastic bags bound on so that dirt and dust cannot enter the system when it is in standstill.

A hydraulic component must never be dismantled outdoors, but always in a closed workshop equipped with necessary facilities, special equipment and trained personnel.

MAINTENANCE

Nearly all hydraulic systems, stationary as well as mobile, are accompanied by operating instructions, but the issue of maintenance instructions is just as important. To be able to correctly maintain a hydraulic system, the customer (end user) must know what has to be done. The transfer of this knowledge is the responsibility of the manufacturer.

Periodic inspection

The regular inspection of a hydraulic system is more economical than making repairs when a fault occurs. If a fault does occur, the whole system ought to be checked rather than just the defective component. Regular planned preventative maintenance of the system after a certain number of operating hours and the scheduled replacement of important seals ensures the avoidance of costly operational stops.

To avoid forgetting something, a routine following the direction of oil flow should be adopted, beginning with:

The tank

The oil level must be correct and the oil must be of the prescribed type and viscosity. On large systems it pays to send oil samples for analysis at regular intervals. Factors of special importance in deciding g whether the oil can continue to be used are the rise in oil viscosity, the acidity number and the content of impurities. If there is no special equipment available, a lot can still be learned about the condition of the oil by looking at its colour. Poor oil can be dark, it can smell rancid or burnt; or it can be yellow, unclear or milky, which indicates the presence of air of emulsified water. And of course the oil might contain microscopic metal particles and other foreign substances.

The suction line

The suction line must be inspected for damage and sharp bends that reduce the bore of the pipe and create noisy cavitation. Screwed connections must be inspected for leaks and tightened if necessary. Rubber or plastic hoses are suspect because they often become contracted by vacuum when the oil is hot. Such items should be replaced with pipes or armoured hoses.

The pump

The pump must be inspected for shaft seal and other leakage. If the pump is driven by V-belt, this should be examined to ensure that it is not worn and is correctly tensioned. The different circuits on the pressure side must be examined individually, following the direction of oil flow. There must be no leaks. Look on the floor under the vehicle for oil patches. The fingertips are good instruments for sensing faults, the ears too - by using a screwdriver or similar tool as a stethoscope, irregularities which might later cause breakdown can often be heard.

The return line and return filter

The return line and return filter must be inspected for leaks, etc. and the filter must be checked. If the filter has a dirt indicator, the filter has to be taken out to see whether it needs cleaning or replacement.

Fig. 8—The Machine Will Respond to the Proper Lubrication

HEAT GENERATION

Heat is generated in a hydraulic system whenever oil dumps from a higher to a lower pressure without doing mechanical work. Typical examples are oil venting across a relief valve, pressure losses from oil flowing through piping, valving, etc.. At the point where mechanical work is being done, such as in the cylinder, fluid motor, etc., most of the energy is going into work, and very little heat is being generated.

When designing any hydraulic system, an estimate must be made of the heat which will be generated. An oil reservoir of suitable size must be added to the system. Oil Temperature should be kept to the lowest practical temperature for top efficiency and service life. At high temperatures, oxidation of the oil is accelerated, shortening its useful life by producing acids and sludge which corrode metal parts, clog valve orifices, and cause rapid wear of moving parts.

Oil reservoir temperature should be checked occasionally, since overheating tends to get worse as the system ages. Oil leaking past cylinder pistons and slippage in the pump and valves, produces a quite appreciable amount of heat which accumulates in the oil tank. And, of course, the danger of overheating is much greater in hot weather.

A high oil temperature may cause many problems in the system.