Assembly, start-up and maintenance of Hydraulic Systems

CONTENTS

ASSEMBLY OF HYDRAULIC SYSTEMS IS NOT DIFFICULT - IT'S ONLY A MATTER OF KNOWING HOW

Follow the instructions in this booklet. It will normally pay off.
If you have a problem, contact one of the locations in Servi Group.
Qualified engineers are available to help.

1. INTRODUCTION

Proper layout, management and inspection of hydraulic systems give installations an extended lifetime and reliable operation without interruptions or operational downtime. We therefore recommend careful adherence to the following instructions during assembly and start-up.

These guidelines apply in general to our systems, regardless of the specific equipment used. Information regarding special service details is given as needed.

During installation, start-up and inspections, particular attention must be given to a high degree of cleanliness. All units and parts are inspected carefully before shipping. Nevertheless, we recommend that the system be inspected upon arrival, as it can easily become dirty or damaged during transport. In the event something is not as it should be, please advise us before installation commences. Without being notified in advance, we cannot take responsibility for costs of cleaning and replacement of damaged parts due to foreign particles and dust as it is difficult to diagnose the cause after assembly has begun.
Cleanliness is a prerequisite for problem free operation.

2. ASSEMBLY

During assembly, be careful that tube connections, filling openings, etc... on the unit remain closed until the final installation and filling takes place. Use plastic plugs or caps, never cotton or paper plugs.
NOTE! Remember to remove the plugs before assembly!

2.1 Tubing Selection

On the pressure side of the system, use only seamless precision steel tubes, DIN 2391 c with certification (descaled, annealed, and oiled). For suction and return tubing, use steel tubing of standard NS 582 (DIN 2448). For smaller oil flows, precision tubing could also be used. Galvanized tubing must not be used in hydraulic systems.

Piping systems in corrosive environments, i.e., near salt water, should be composed of stainless and acid-resistant tubing without exception. Acceptable steel qualities are NS 14 450, SIS 2343, AISI 316 (L). It is possible to use couplings of normal carbon steel material, but if so they must be well protected. Couplings of stainless and acid-resistant steel are recommended.

The choice of tube diameter and thickness is dependant on the oil flow, pressure, and environment. Recommended dimensions are indicated on the piping diagram. If no piping diagram is available, the following points should be taken into consideration:

Oil velocities in tubes and hoses:
Suction lines (max. 1-2 meters):

Rising line		0.7-1	m/sec
Descending line		1-1.5	m/sec
Return line		2	m/sec
Pressure line			
Working pressure	5 MPa (50 bar)	3	m/sec
	10 MPa (100 bar)	4	m/sec
	20 MPa (200 bar) and higher	6	m/sec

In longer lines and larger diameter tubes, the velocity shall be reduced. For drain lines from pumps and motors, the pressure drop and oil velocities should be low. Such tubes shall be directly connected to tank and shall not be connected to return lines.

Standard tube dimensions and allowable pressures in industrial systems and marine systems below the deck are listed in Table 1. For shipboard systems on deck and through tanks, the tube dimensions must be evaluated in each individual case.

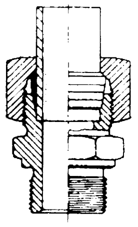
L-Series				**S-Series**			
Out.diam mm.	*Wall thick. mm*	*Press MPa (2).*	*Oil flow l/min (1)*	*Out.diam mm.*	*Wall thick. mm*	*Press MPa (2).*	*Oil flow l/min (1)*
6	1,5	10	(2)	6	1,5	32	(2)
8	1,5	10	5	8	1,5	32	5
10	1,5	10	10	10	1,5	25	10
12	1,5	10	16	12	1,5	20	16
				-	2,0	32	12
15	1,5	10	30	16	2,0	23	30
				-	3,0	41	20
18	1,5	10	45	20	2,0	19	50
				-	3,0	32	30
22	2,0	10	65	25	2,5	20	80
				-	3,5	31	65
28	2,0	10	115	30	3,0	20	115
				-	4,0	30	100
35	2,5	10	180	38	3,5	19	190
				-	5,0	29	160
42	2,5	10	275				

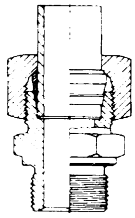
1) For 4m / sec. Table 1
2) 1 MPa = 10 bar

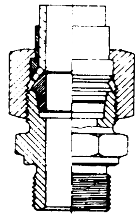
During installation of tubing, all forms of heat treatment should be avoided. All tubes must be bent cold without sand or lead filling. If welding cannot be avoided, the joints should be positioned such that the interior of the tube can be easily smoothed with a hand dressing tool or scraper. See also paragraphs 2.4 and 2.5.

2.2 *Fittings*
In hydraulic systems mechanical (non-welding) couplings are used for tubes with an outside diameter up to approx. 40 mm. A range of couplings is available. The most common types are cutting ring (Figure 1), compression ring (Figure 2), and flare fittings (Figure 3).

The first requirement for ensuring a tight joint is to cut the tube at right angles, preferably in a jig (figure 4). Burrs must be removed both inside and outside, and the lip ground away. Debris from filing within the tube must be completely removed with air pressure, rinsing in a cleaning fluid, or by pulling clean rags through the tube (not paper or polishing cloth).


Figur 1


Figur 2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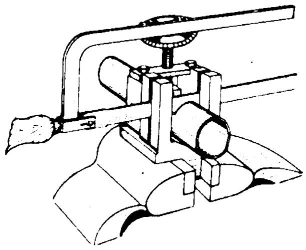
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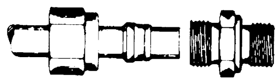
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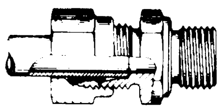

Figur 6 a

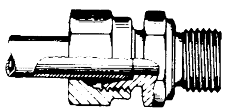

Figur 6 b

Figure 1 shows a cutting ring coupling cross section with all parts. Note the direction the cutting ring faces. The assembly procedure is as follows:

1. The nut and cutting ring are drawn over the tube, Figure 5.
2. The tube is inserted in *the coupling until it seats and then held in place.* Meanwhile the nut is pushed forward and screwed on until the cutting ring contacts the bevel, Figure 6a. Before the nut is screwed on, the threads should be lightly oiled - do not use grease or any other type of lubricant.
3. The nut is now tightened 1.5 to 2 turns, so that the ring cuts into the tube, Figure 6b. Be careful to ensure that the tube is seated the entire time. Loosen the coupling and check that the cutting ring has cut *into* the tube. There should be a distinct lip in front of the ring. If no lip is evident, tighten the nut another ½ to 1 turn and examine the coupling again.

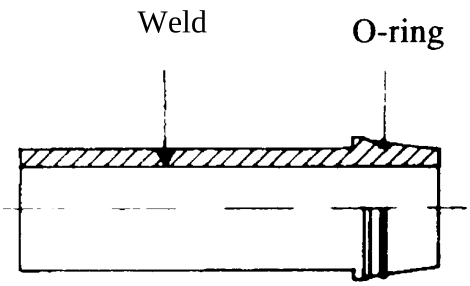
During fitting of tubing, the tubes must be cut to the correct length to match the fittings. The fitting should not be used to pull together two tubes that are too short or to correct a crooked bend. Such problems must be corrected in advance.

Tightening must be carried out with the correct torque. Experience has shown that small fittings are often tightened too much while fittings of larger dimensions are not tightened enough. After the system has been in use for a few days, fittings should be checked and re- tightened as necessary.

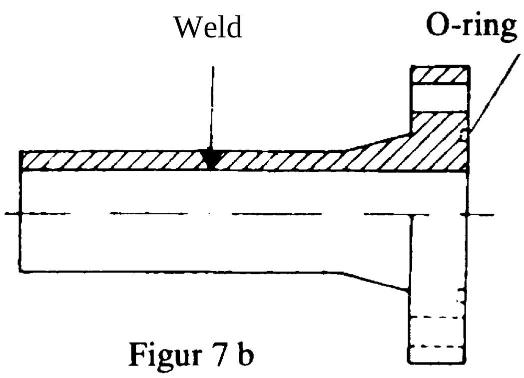
If other types of couplings are used, the assembly instructions for those should be followed.

Piping systems for high pressure and systems which are subject to large pressure variations and mechanical vibration, should be supplied with welded fittings, Figures 7a and 7b. The seal is normally formed by an O-ring. The actual joint should be butt welded, and there must not be differences in the wall thickness between the tube and coupling. The welding groove must be even and free from slag deposits or cracks.

After welding, the tube must be thoroughly cleaned of both loose and fixed impurities. See paragraph 2.4 and 2.5.



Figur 7 a



Figur 7 b

2.3 *Threaded Connections*

None of the threaded connections used in hydraulic systems give full sealing, and additional sealing is required.

Cylindrical threads are combined with a finished sealing surface at right angles to the threads. Certain connections have a cutting edge which is pressed into the base. Others have O-rings. Sealing rings of steel/rubber can also be used. Conical threads are sealed with plastic fluid (i.e. Loctite 69).

Teflon tape is not recommended and should only be used with care. Teflon reduces the friction between threads and grooves and can easily split the threads, especially in cast material. Bits of teflon can easily enter the system and disrupt the operation of valves, etc... Therefore, the first 2 or 3 threads on the connection should be left free of tape when screwing together. Loctite can be used with cylindrical threads to counteract loosening by vibration.

2.4 *Cleaning of Tubes*

All tubes *must* be clean when installed. They *must* be free of fixed and loose grit, welding slag and splatter, mill scale, bits of gaskets and sealing materials, and lint from paper and rags.

We repeat: CLEANLINESS IS NECESSARY.

Precision steel tubing is normally free from fixed impurities as a rule (except for grit from cutting). They have clean rags drawn through them (not polishing cloth or paper). Then they are purged with clean oil and have their ends plugged until assembly. Pneumatically driven cleaning pigs are recommended.

Other tubes must be degreased with a solvent, white spirit, trichloroethylene, or the equivalent, before they are pickled in an acid solution. Welded connections with flanges, bends and branches must be thoroughly mechanically cleaned of foreign particles before degreasing and pickling.

2.5 *Pickling (acid wash)*

All components to be pickled must be degreased in advance.
BE CAREFUL DURING PICKLING
THE FLUID IS CAUSTIC AND ATTACKS EYES, SKIN AND CLOTHES!
The pickling bath consists of:

1 part hydrochloric acid (35%) added to 3 parts water
NOTE! Always add acid to water, never water to acid.

Tubes and components are submersed in the solution for approx. 8 hours at 15°C. Use longer/shorter times with lower/higher temperatures. Tubes which are only to be pickled internally can be filled with solution. It is important to ensure that the tube is completely filled.

To reduce the pickling time, the concentration of the hydrochloric acid can be increased. A bath with the following mixture can be used:

1 part hydrochloric acid
1 part water
1-2 ml hexamine (inhibitor) per liter pickling solution.

Bath temperature: 30-40°C, reduces the pickling time by as much as an hour (maximum time in the bath). After the pickling, the parts are rinsed with large quantities of clean water and submersed for a couple of hours in a neutralizing soda bath which can consist of:

- 1 part calcified soda (sodium carbonate)
- 10-20 parts lukewarm water

After neutralization, the tubes are rinsed in clean water and dried, preferably with warm air, before being purged with oil. Tube ends are sealed with plastic plugs. After cleaning, the parts should be assembled as soon as possible.

They must not be subjected to humidity or large temperature changes without the external surface being well protected.
There are several preparations on the market that can replace the acid wash.

A good thing cannot be repeated too often: BE EXTREMELY CAREFUL TO OBSERVE CLEANLINESS DURING ASSEMBLY OF HYDRAULIC SYSTEMS!

2.6 *Tubing Layout*

Tubes will transmit large quantities of energy, and the actual layout is extremely important. The runs should be as straight as possible between pumping stations, valves, and cylinders or hydraulic motors. Unnecessary angles and bends should be avoided. The tubes should be securely clamped so that they do not move during load vibrations.

Clamping
Clamping is important - both the types of clamp selected and their use.
A clamp should prevent the tube from movement perpendicular to its length and at the same time leave room for small lengthwise movements. The clamp must be mechanically strong enough to absorb all the strain from the tube, i.e., the weight of the tube, reactions from a pressure pulse, and forces due to expansion in the length of the tube (see below).

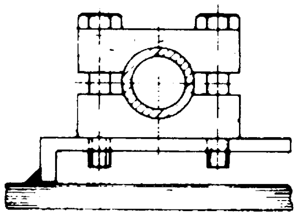
The clamp must not cause wear of the tube or vice versa. Use of noise suppressing materials in the clamp is an advantage.
The clamp must be easy to install, adaptable to deviations in the center-to-center distance between several parallel tubing runs, and allow the tubes to be individually loosened.

Of “home made” varieties of clamps, only the impregnated wooden type clamp shown in Figure 8 is acceptable.
Different varieties of steel clamps - Figure 9 and 10 - with or without an insert do not work as well.

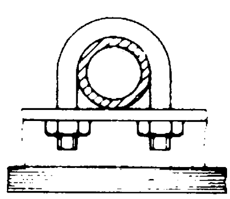
Plastic clamps, as shown in Figure 11, are regulated by Norwegian Standard no. NS 5555.

The plastic reduces the vibration transmission from the tube to the foundation to a degree. A configuration with a rubber ring inserted between the tube and the plastic gives better suppression or it is possible to place (several) clamps on a common rail which hangs from or stands on rubber blocks - Figure 12.

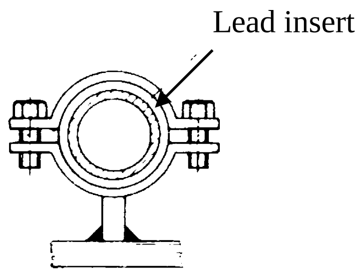
Figur 8



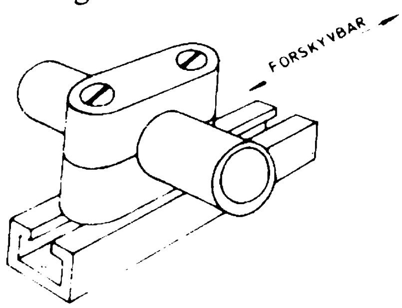
Figur 9



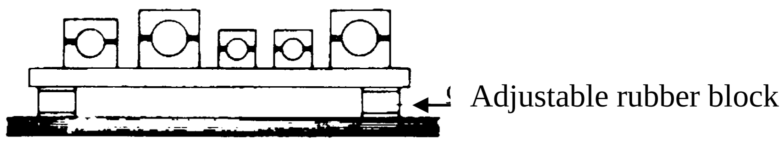
Figur 10



Figur 11



Figur 12



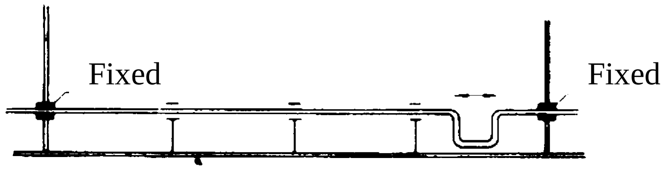
The distance between clamps varies, dependent on the load on the tube (pressure, oil velocity, vibration) and the tube dimensions. It is normally sufficient to place clamps at an interval equal to 25-50 times the tube’s outside diameter. In any case, the distance should be at least 1 meter. It is important to place the clamps so there are no uncontrolled movements of the tube. Increased clamping can be required when the tube is bent. However, tube bends for the purpose of allowing expansion/contraction (see below) must not be “locked.”

Tube Expansion/Contraction
The length of a tube will expand or contract with temperature changes. For systems installed in-house, temperature changes are normally small and do not need to be accounted for in the layout.

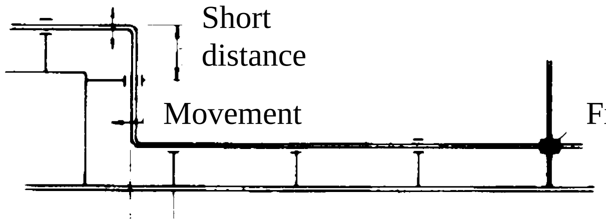
Outdoors and onboard ships, the conditions are more difficult. The foundation for the tubes matches the outside temperature while the temperature of the tubing is dependent on the hydraulic oil and can be quite warm. Temperature differences of up to 80°C between the oil and the surrounding environment are quite common, for example +60°C oil temperature and -20°C in the surroundings.

In such cases it is necessary to insert an expansion joint between fixed points, i.e. bulkhead transits, Figure 13. Necessary bends in the tubing can also be used to compensate for changes in length, Figure 14. It is also possible to use hoses or special compensators.

Figur 13



Figur 14



A 1 meter length of tube will expand 1 mm with a 80°C temperature increase. For long tubing distances, it is obvious that the expansion can be quite large - Table 2.

Tubing lenght(m)	Temperature change (°C)						
	10	20	40	60	80	100	120
1	-	0,25	0,5	0,75	1	1,25	1,5
2	0,25	0,5	1	1,5	2	2,5	3
5	0,6	1,25	2,5	3,75	5	6,5	7,5
10	1,25	2,5	5	7,5	10	12,5	15
20	2,5	5	10	15	20	25	30

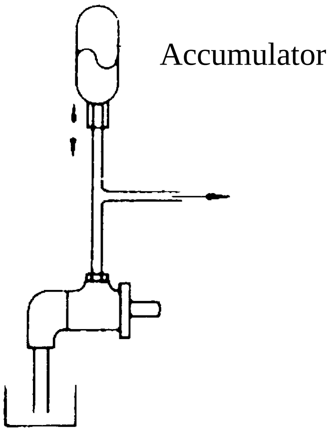
Expansion in mm Table 2

<u>Noise</u>

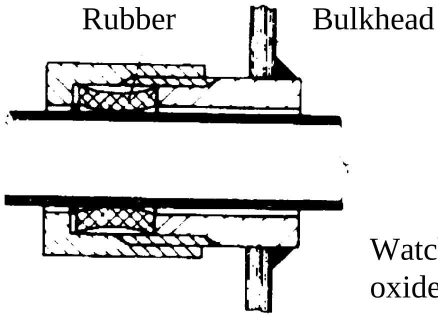
Noise in connection with hydraulic systems is often a problem. It is difficult to eliminate, but with a proper design it can be greatly reduced. An unrestricted flow of oil to the pump must be ensured. Flexible suction lines (hose) can be an advantage. Suction lines must be tightly sealed to ensure no air is sucked into the oil. Pressure lines can also be made flexible (high pressure hoses). A noise suppressor will absorb vibrations from the pump - Figure 15.

In the system, hoses can be used both as noise suppressors and expansion compensators. Metallic contact between the tubing and foundation should be avoided. This applies to both normal clamps and to transits through bulkheads, decks, walls, and floors. Clamps should be placed on vibration dampers, Figure 12, and transits should be completed as shown in Figure 16 and 17.

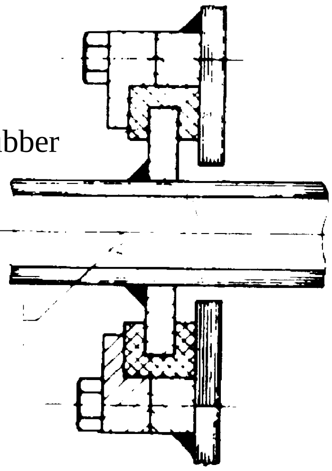
For the best possible noise suppression, it is of course important for the power pack to be mounted on vibration dampers and that valves in the system be carefully positioned.



Figur 15



Figur 16

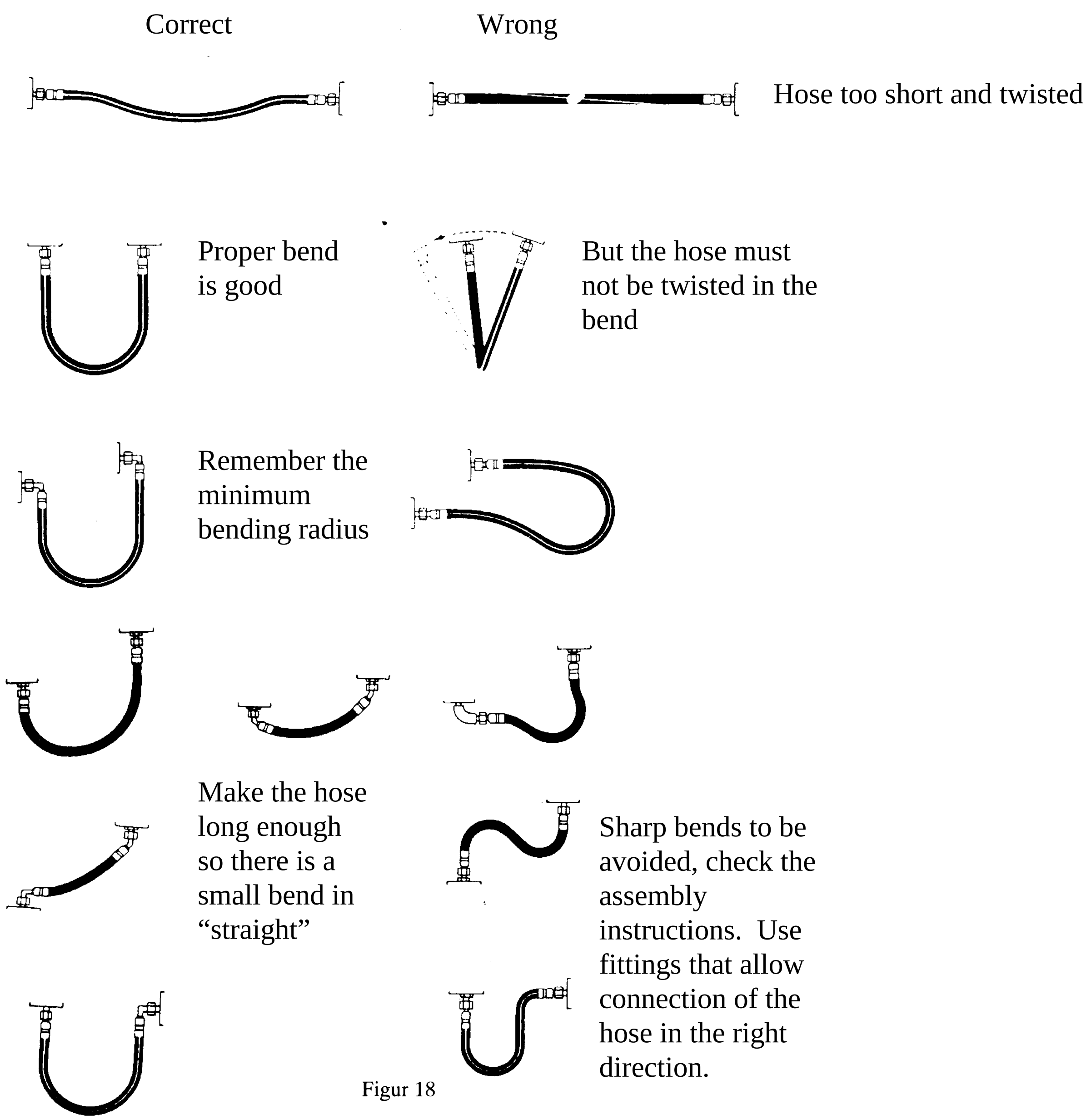


Figur 17

2.7 *Assembly of Hoses*

For hoses, the guidelines in paragraph 2.2 apply in regards to dimensions.
It is best to use fitted with crimped-on couplings.

Requirements for high pressure hoses vary widely, dependent on where they are used. Before the quality and application is chosen, get advice from us.
When installing flexible hoses, recommendations from the manufacturer should be adhered to with regards to the bending radius. Crimping, squeezing, and twisting must be avoided. Figure 18 shows proper and improper examples of hose installations.



Figur 18

2. HYDRAULIC FLUID (OIL)

Oil is the blood of the system. It conveys energy from pumps to cylinders and motors and lubricates all moving parts to reduce wear, prevents corrosion, transfers heat, and conveys particles due to wear and contamination back to the filter and out of circulation.

3.1 *Oil Selection*

The choice of oil is decisive for the system's lifetime and operational reliability.
In hydraulic systems, only fluids designed for such use from competent suppliers should be used. It must also be appropriate for all pump types in the system. The most important additional criteria are:

a. Viscosity
b. Viscosity Index
c. Low temperature characteristics
d. Flammability

Viscosity
If no other information is given, the following table can be used as a basis for choice of viscosity (mm^2/s = cSt). It is also important to check the upper and lower limits for the actual components used in a system.

Type of pump	Viscosity at (°C)	Min. visc. 1)	Max. visc. 2)	Max. visc. at start-up
Gear pump	20-60	15	250	1000
Vane pump	30-60	20	100	800
Axial piston pump	25-50	15	80	600
Radial piston pump	15-60	12	100	400

Table 3

1) Allowed for short periods of time at reduced pressure
2) Start-up with cold (thick) oil should be carried out slowly without load and, if possible, at low rpm.

It is important to note that the recommended viscosities apply to conditions during operation at normal operating temperatures and not at any alternate reference temperatures.

NOTE! In systems with radial piston motors and ORBIT motors, the viscosity should not be lower than 40 mm^2/s at operating temperatures.

Viscosity Index
The viscosity index (VI) is an expression of an oil's viscosity stability. A low VI indicates that an oil's viscosity changes rapidly with temperature while a high VI indicates the oil is less affected by temperature changes.

Low Temperature Characteristics
Outdoor systems in cold climates must use an oil for which the pump can obtain suction under the most extreme conditions expected. This can result in a viscosity near the lower limit at normal operating temperatures. In such cases, the systems should not be heavily loaded.

Flammability
Mineral oils have most of the properties which provide the basis for a good hydraulic fluid. An unfortunate property is flammability which in certain cases is unacceptable. There are, however, several types of replacement fluids which are not very flammable (do not support combustion) and which provide excellent fire safety.

These fluids are primarily water/oil emulsions, water/glycol mixtures, and synthetic fluids (i.e. phosphate esters). Properties of the different fluids vary greatly, both with regards to lubricating properties, viscosity, and interaction with certain metals, paint, gasket materials, and the environment.

It is beyond the scope of this short orientation to discuss this subject in detail, but Servi's engineers can give further advice.

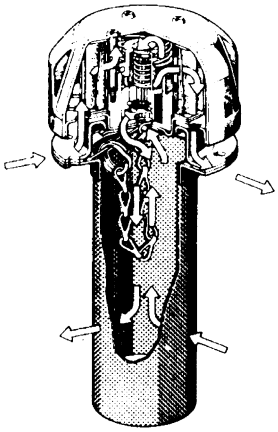
3.2 Oil Filling

During the initial and subsequent fillings, it is always important to avoid introducing more dirt into the system than necessary. The area around the filling opening should be cleaned from loose impurities before filling begins.

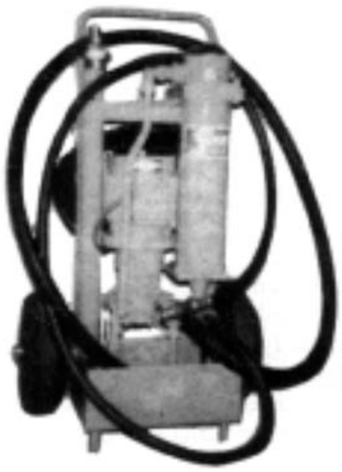
It is important to be aware that new oil, delivered in cans or barrels, contains a considerable amount of particles. Even if the oil appears clear to the naked eye, it is not clean enough, especially for certain applications.

As a minimum protection, a system should have a filling strainer with a mesh size no greater than 100 m m - Figure 19.

A better arrangement is to pour the oil through the return filter if there is one. Most return filters that are sufficiently fine have a limited flow capacity, and it can be tempting to fill directly, bypassing the filter. To enable ease of filling while ensuring clean oil in the tank, a filter cart (Figure 20) should be used. The cart supports a motor driven self priming pump which sucks the oil from its container and through a fine filter (with indicator) before flowing through a hose into the tank. Such a filter cart can also be used for circulatory cleansing of the oil in a tank by putting the suction line into the same tank and letting the pump run.



Figur 19



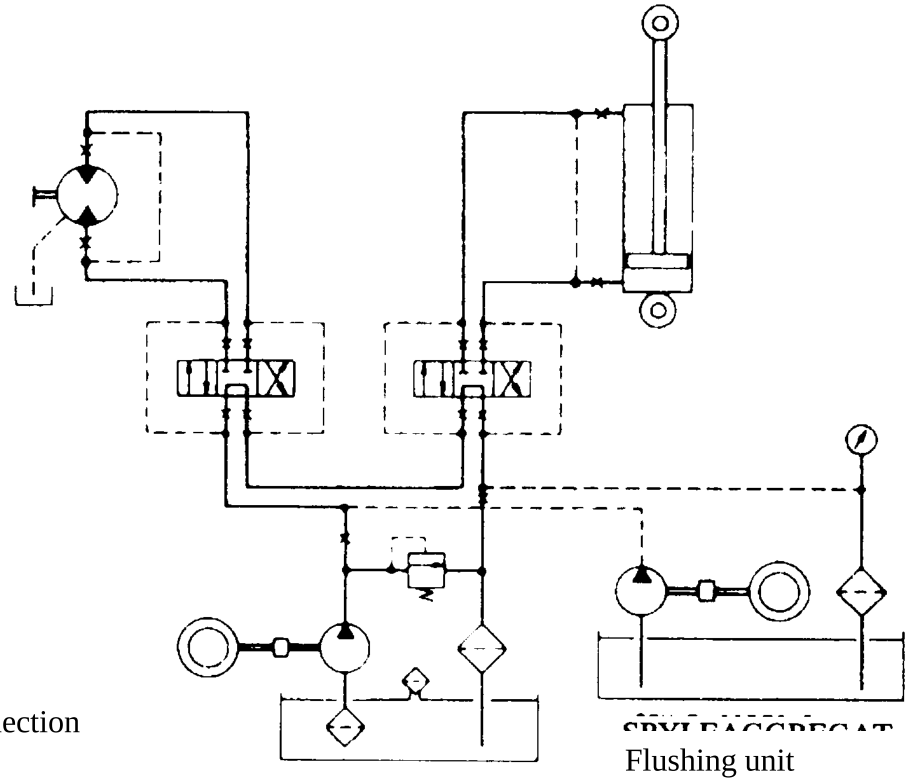
Figur 20

3. FILLING OF ACCUMULATORS
4.

Filling of a pressure accumulator must be carried out in accordance with the manufacturer's guidelines. Before we deliver a system, the accumulator is pressurized to 0.5 - 1 MPa (5-10) bar unless otherwise agreed. Accumulators should be pressurized with nitrogen. Use of air or oxygen is hazardous and can cause an explosion.

5. SYSTEM

After assembly, a tubing system will never be completely clean. Before the system is used, the tubing system must be flushed. Flushing can be carried out with a dedicated flushing unit with high oil flow or with the power pack which will later be used. Cylinders and motors in the system should not be connected. In order to flush lines completely to these units, tube ends can be connected with a bypass hose (Figure 21).



Figur 21

----- Bypass connection
x Blocked

Flushing should continue as long as time allows, preferably several hours. During the process, the oil filters must be carefully monitored and filter cartridges replaced as necessary. During flushing, filters should be used which have the same filtration rating (or finer) as the filters used in the system. After flushing, all filter cartridges must be replaced. The oil is normally not changed.
In addition, see the booklet on flushing of pipes and piping systems in hydraulic installations, reference E0530.

6. PREPARATION FOR START-UP

After assembly and filling of oil, the following points should be checked before the system is put into operation:

1. Oil level
2. Mains and control voltage
3. Rotation direction of pumps and motors
4. Pressure relief valves, throttle valves, and flow control valves are open
5. Valves in the suction line are open
6. Fittings are properly tightened

7. START-UP

After the points in paragraph six are checked, trial operation can commence. The pump shaft should be turned by hand to confirm oil flow. Afterwards, the air bleed plug on the pressure side of the pump can be loosened, and the pump started momentarily several times to ensure proper pump suction. For axial piston pumps with a drain line, the pump must be filled with hydraulic oil before the electric motor is started.

After the suction condition is tested, the system is pressurized to a low pressure to bleed off air. This is done by carefully opening air cocks and bleed plugs. Large systems should be bled at several locations, beginning with those closest to the pump and ending with those furthest away - motors and cylinders. Single-acting cylinders normally have air bleed plugs. For double-acting cylinders which normally do not have plugs, the piston should be moved back and forth from one end position to the other several times. Bleed plugs should not be closed until oil free of air bubbles comes out. Afterwards the various functions of the power pack should be tested individually - still at low pressure. If all tests are satisfactory, the system should be slowly brought up to operating pressure through regulation of the pressure relief valve.

Now check:

1. All lines are free from leaks
2. The oil level in the tank is correct
3. The operating temperature remains at a reasonable level

If leaks are found in the tubing, couplings must be tightened after first reducing the pressure. Once all lines are free of leaks, throttle valves, safety valves, and flow control valves, etc... should be adjusted to their proper settings. The system can now be pressure tested and afterwards is ready for normal operation. During initial operation, filter cartridges should be changed at short intervals. The first inspections of filters should be carried out after 1, 10 and 25 hours operation. These initial checks can be expanded into a normal inspection schedule, whose format is dependent on operational conditions, i.e. running hours for the system and other factors. During the initial running-in period the working temperature must be monitored. It should normally be approx. 40-50°C. In some exceptions, higher temperatures are acceptable. In such cases, our company should be notified.

8. PRESSURE TESTING

Pressure testing of the piping system must be carried out before the system is put into operation. If nothing else is specified, a test pressure 50% higher than the normal working pressure, (limited to 70 bar «over-pressure») can be used as a basis.

NOTE! It is the piping system that is to be tested, not the power pack and other hydraulic components (pumps, motors, and cylinders).

It is not normal to use the operational power pack for the pressure test. In the event that it is, authorization must first be obtained from a responsible and named person in our company.
In addition the test pressure and length of time (in minutes) must be agreed. Otherwise no guarantee against damages incurred during testing will be given.

If the test pressure is higher than the operational power pack is designed for, a separate power pack or hand pump must be used.

9. INSPECTION AND MAINTENANCE

The first time the system is operated. It must be monitored constantly. Inspection and maintenance should be carried out in accordance with a maintenance plan determined by the type and conditions of operation.

The goal of regular inspection and maintenance is to maximize the operational security and ensure stable operation. Surprises can be exciting, but are never welcome.

Regular maintenance can be divided into three primary areas with relative sub-topics.

1. Inspection
    a. Measurement of oil level and temperature, pressure, oil flow, running hours, pressure drop over the filters, etc...
    b. Check that all functions work
    c. Be alert for irregular noises, changes in the appearance of the oil, leaks, etc.
    d. Measure the contamination level of the oil.

2. Maintenance Tasks
    a. Keep the system clean, especially around breathing filters.
    b. Replace filter cartridges.
    c. Top up/change oil.
    d. Adjust valve settings.
    e. Lubricate moving parts.

3. Repair
    a. Repair damaged parts
    b. Replace worn parts and components
    c. Run-in repaired/replaced parts and adjust related valves, etc...

An ongoing maintenance program is so critical that some of the points are further detailed below.

9.1 Inspection Routines

The following items should be regularly controlled:

Item	Period
Oil level	Daily
Oil temperature	
External leakage	
Pressure	
Noise, vibration	Weekly / monthly
Oil filters (pressure drop)	
Mechanical fasteners	
Tube and hose connections, gaskets	
Protective caps, bellows	
Measuring equipment (gauges, etc.)	Monthly / quarterly
Air filter	
General external condition, dust, damage	
Flow volume/pressure	
Oil condition	2-4 times/year
Oil tank/internal system	Yearly

Table 4

Oil level
If the oil level is too low, the pump can begin to suck air. Initially this will result in air mixing with the oil and foaming. The noise level will increase, the load on the pump will increase drastically from cavitation, and it can be ruined in a matter of minutes. A low oil level can also cause the oil temperature to increase. It is especially important to monitor the oil level in the tank while a system with tubes, cylinders and motors is filled with oil from the power pack. Filling the system with oil cannot be considered complete until the oil level is checked.

The temperature of the oil will also change in accordance with the surrounding temperature and the load on the system.

As a general rule, mineral oil should not be used with temperatures above 60-65°C; that is, the temperature at which it is possible to lay one's hand on a tank surface or tube without it being unbearably hot.

The temperature is also closely related to the oil's viscosity to such a degree that temperature has a direct influence on the components of the system (pumps, motors, etc.).

Oil Condition

The oil's physical and chemical condition can be determined from oil samples taken from the system. It is important that oil in the sample is representative of the oil in the system. It is therefore important that the sample oil should be drained from the system while in operation and at normal operating temperature. The sampling should be taken through a valve or a Minimess® test point that can be opened during operation. The valve should be located in the return line before the return filter. To obtain a representative sample, the valve should be opened and oil run out until it is certain any residual oil or deposits in the valve are washed out, before a sample bottle is put under the stream.

It should not be necessary to note that the sample bottle must be extremely clean and dry. Screw caps give a secure seal. A convenient volume is 0.2 liters. The bottle should not be filled to more than 2/3 full. When not possible to drain the oil from an operational system, oil can be taken from the middle of the tank with a siphon. The oil must run out for approx. one minute before the sample is taken. It is important in this case to take the sample immediately after shutting down the system, so that particles suspended in the oil do not settle to the bottom.

Oil samples for analysis must never be taken from the bottom of the tank or from a bleed hole in the tank. Silt that has settled and possibly water will be included and make the sample unrepresentative. A sample from the tank bottom can, however, determine the need for cleaning the tank.

To get a reliable analysis, the oil sample must be sent to a lab with a particle counter. We have particle counters and can provide sample bottles and equipment for sample taking.

There is no easy way to give an exact answer regarding the condition of the oil. A rough idea of some typical conditions can likewise be ascertained from viewing and smelling the sample. Table 5 gives some guidelines.

Impression	Contamination	Possible Causes
Dark colouring	Oxidation products	High temperature, old oil, mix of oil types
Pale, cloudy	Water or foam	Water contamination (condensate) Suction of air, air whipped into foam
Water separation	Water	Water contamination, for example, from a cooler
Air bubbles	Solid contaminants	Wear particles, dirt, products of aging
Burnt smell	Products of aging	Overheating, burning, oxidation (In cylinders - check gaskets)

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9.2 *Maintenance*

The extent of maintenance required is determined by the system's function and location of operation and by the results of the daily/weekly/monthly, etc... inspections.

It goes without saying that there must necessarily be different maintenance routines for a system running continuously in a primary function and systems that have intermittent use in secondary functions. On the other hand, emergency systems must be kept under strict inspection and carefully maintained, even though they may never be used. They must work perfectly if the need does arise. Regardless of the operational conditions, a maintenance plan will make maintenance easier and will contribute to better operational reliability of a system.

In Table 6 a number of relative points are listed.

Maintenance task	Period
Repair/adjustment of irregularities found during periodic inspection	As needed
Drain and check sediment and mud from the tank	As needed
Clean dirt from exterior surfaces	Weekly/monthly
Exchange cartridges in oil and air filters	As needed (pressure drop indicator), after 200-300 running hours or at least once a year
Change oil	After 1000 to 5000 operational hours or as needed
Change gaskets and hoses	According to maintenance plan or when indications of damage
Lubricate mechanical connections	According to maintenance program
Clean secondary components (heating coils, coolers, etc.)	Yearly

Table 6

NOTE! During testing and overhauling of pumps and control equipment, service instructions for the individual parts must be carefully followed. Be aware that ignorant handling during maintenance can negate guarantees. For difficult maintenance case, it is preferable to send the parts in, or if that is not possible, contact one of the locations in Servi Group.

10. PARTICLE REMOVAL (FILTER)

A very essential part of all hydraulic systems is the control of foreign particles in the system. This includes hindering particles from entering the system as well as removing particles that develop in the system's components during operation.

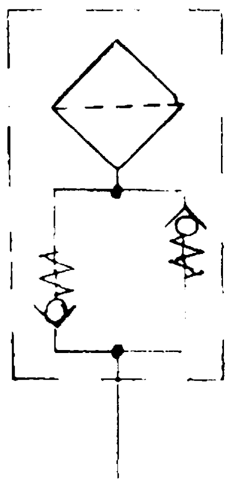
Particles can enter the system:

a. during oil filling
b. through the air filter
c. attached to piston rods in hydraulic cylinders
d. during repairs

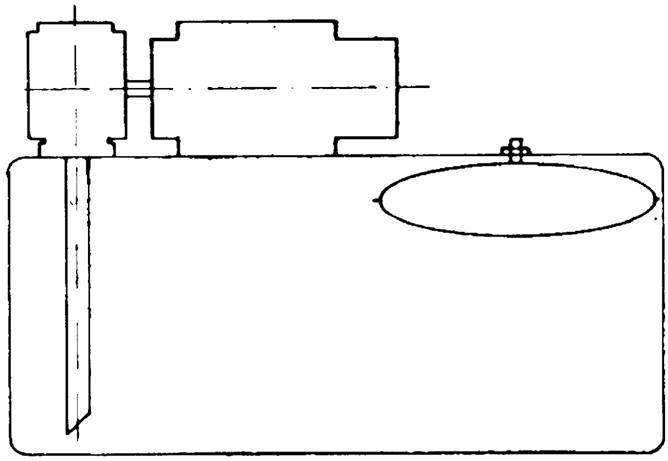
Particles are created by

a. component wear
b. chemical changes in the oil

To prevent particles entering the system, an effective air filter is necessary. To limit the air exchange in a tank, it can be an advantage to use a sealed tank and air filter with a built in pressure valve - Figure 22 (see also Figure 19). Power packs that are located in a dust filled environment must be ventilated to a cleaner location through a properly dimensioned air hose.



Figur 22



Figur 23

One alternative is to use a flexible bellows which separates the oil and atmosphere. The bellows follows changes in the oil volume and prevents contact between the surrounding air and the oil (Figure 23). To prevent the bellows from filling with dust, it should also be fitted with an air filter, but one of a lower standard.

Tests have shown that a significant amount of dust can enter a system as it adheres to a piston rod that is pulled into the system where the dust is subsequently washed off.

Protective bellows around piston rods can reduce this problem, but such bellows have disadvantages that make their use undesirable except in very special cases.

Particles that enter the system can only be trapped by an oil filter with a fine enough mesh. The following filter locations are suitable:

a. Suction filter before the tank or line mounting
b. Pressure filter before the line or manifold mounting
c. Return filter before the line or tank mounting

The suction filter is only recommended for closed-loop hydraulic transmission charge pumps and is ideally built into the tank with access from outside for changing the cartridges without emptying the tank. The filter should have a mesh size not significantly less than 25 um abs. The opening pressure for the bypass valve must be low, not over approx. 0.1 bar. A pressure drop indicator must be mounted.

Pure suction strainers are not recommended for use except in special cases, and then must have a large mesh width - at least 250 μm.

Pressure filters should be built into the piping system between the feed pump and the primary pump, or directly in the main system. The filter cartridge should not be coarser than 25 um abs. for general systems with moderate pressure , and 10 um abs. for more highly loaded systems with piston pumps installed.

Without exception, all filters should be fitted with pressure drop indicators, either electrical or visual.

Filters that are not coarser than 5-8 um abs. should be mounted ahead of servo valves. Such filters must not be fitted with bypass valves. The actual filter cartridge must therefore be pressure rated to system pressure. A pressure drop indicator is required.

Return filters built into the tank normally provide the simplest solution for general systems. The return filter can serve as a filling filter. A return filter should also have a pressure drop indicator. Requirements for the filtration rating are in principle the same as for pressure filters.

Active use of oil filters and replacement of cartridges when the pressure drop is too large (revealed by the pressure drop indicator) is a prerequisite for problem free operation of a system.

By far the majority of disruptions, shut-downs, and breakdowns in hydraulic systems are caused by insufficient filtration of the oil. Excessive filtration is difficult to imagine, and would have no other effect then to prolong the life of the equipment beyond that considered normal.

11. EXTENDED SHUTDOWNS AND RENEWED START-UP

When shutting down a system for a longer period of time, the oil tank must be filled with oil to just under the lid in order to protect the inside of the tank against corrosion. For the same reason, running through the entire system from time to time to lubricate all internal parts is recommended. When restarting, the same procedure should be used as when starting up the system for the first time. In addition, the following points should be considered.

1. Check that the oil does not contain water (tank bottom).
   Remove impurities.
   If necessary, change the oil
2. Check the oil level.
3. Examine filters and filter cartridges.
   Clean parts, and replace if necessary

12. FAULTFINDING AND REPAIR

To determine the cause of faults and to repair them, contact Servi Group.